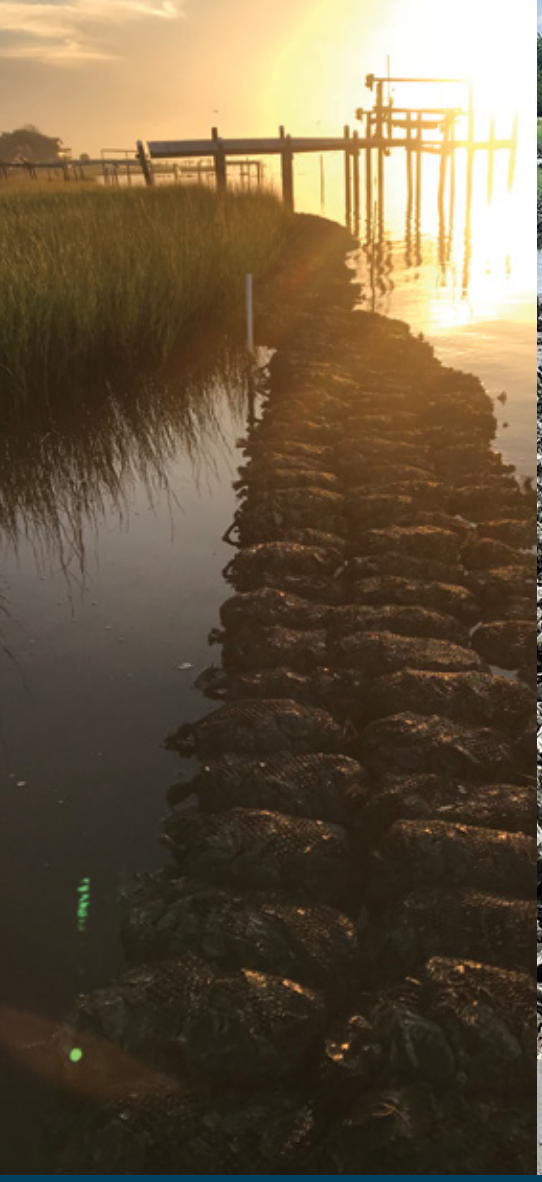

Oyster Restoration and Protection Plan for North Carolina

A Blueprint for Action **2021-2025**

[FOURTH EDITION]

Recommendations contained in the 2021-2025 Oyster Restoration and Protection Plan for North Carolina: A Blueprint for Action (the Blueprint) collectively reflect the expertise and valuable input of the Oyster Steering Committee, as well as workgroups developing strategies relevant to oyster protection, restoration, harvest and education about oysters. These recommendations are made by the North Carolina Coastal Federation, which facilitated the workgroup process with support from The Pew Charitable Trusts. Every effort has been made to reflect the philosophies, knowledge and expertise contributed by the Oyster Steering Committee and Strategy Workgroup participants.

Special Thanks to the following organizations, agencies and businesses that actively participated in guiding the development of the Blueprint's fourth edition.

A complete list of Strategy Workgroup Members and 2015-2020 Oyster Steering Committee members is found in Appendix D.

Executive Summary

The vision of the Blueprint is that North Carolina oysters contribute to a healthy coastal environment and a robust coastal economy. This vision is shared among the many partners who developed the Blueprint, which fosters collaboration and ensures partnership and commitment toward its fulfillment.

A diverse group of volunteers involved in growing, harvesting, studying, managing and conserving oysters has worked together since 2003 to protect and restore North Carolina's oyster habitats and fishery. They did this because the eastern oyster, Crassostrea virginica, is an ecological and economic treasure for the state. Dramatic declines in oyster abundance, reflected in declining commercial landings over the past century, have been attributed to overharvest and exacerbated by habitat disturbance, pollution, and biological and environmental stressors. Due to the multiple factors that negatively impact oyster survival, the North Carolina Division of Marine Fisheries views this stock as particularly vulnerable to overfishing (NCDEQ, Oyster FMP Amendment 4, 2017).

The 2021-2025 Oyster Restoration and Protection Plan for North Carolina: A Blueprint for Action (the Blueprint) focuses on ways to enhance native oyster populations and promote sustainable aquaculture in the state, addressing specific stakeholder concerns or documented threats to support healthy and productive coastal waters and habitats. The plan recognizes the essential role each partner plays in implementing the efforts outlined and encourages adaptive management of the strategies employed by making necessary adjustments to improve them going forward.

This fourth edition of the Blueprint identifies eight strategies and corresponding actions needed to rebuild the state's oyster resources. The work outlined advances strategies toward a shared vision that fosters collaboration among partners, ensuring oysters in North Carolina perpetuate a healthy and robust environment and economy.

Led by a statewide Oyster Steering Committee, the Blueprint effort parallels and augments the state's Fishery Management Plan for Oysters, Basinwide Planning efforts and Strategic Mariculture Plan; enhances the efforts of the state's Coastal Habitat Protection Plan and regional Albemarle-Pamlico National Estuary Partnership's 2012 Comprehensive Conservation Management Plan; and elements of the Blueprint are elevated through the state's participation in the National Oceanic and Atmospheric Administration's National Shellfish Initiative.

This Blueprint was developed in 2020, when North Carolina - and indeed, the world - experienced unprecedented challenges associated with the COVID-19 pandemic. In addition to the personal and community impacts on the many stakeholders involved in this effort, the state and other resources for implementing the strategies it contains may be strained. Yet the threats to North Carolina's unique ecology, economy and way of life are no less diminished. If anything, the need for oyster protection and restoration – and creative, collaborative management strategies – is more urgent than ever. As we look to the next five years, we are renewed in our commitment to conserve and manage North Carolina oyster resources toward a brighter future for all stakeholder communities.

The first three editions of the Blueprint resulted in:

- **Restoring nearly 450 acres of oyster habitat for environmental benefits and harvest opportunities.**
- **Increasing funds for oyster related programs by a factor of 10.**
- **Documenting the economic benefits of oyster restoration; for each $1 invested, at least $4.05 in benefit are realized.**
- **Maintaining a viable and dynamic level of wild harvest, with a peak of 186,000 bushels in 2010.**
- **Developing the North Carolina Strategic Plan for Mariculture.**
- **Growing the shellfish aquaculture industry from $250,000 to $5 million and increasing the number of farms in the state tenfold.**
- **Developing a nationally recognized shell recycling program that collected nearly 250,000 bushels of shell from 2003-2015.**
- **North Carolina joining NOAA's National Shellfish Initiative.**
- **Building and strengthening a coalition of more than 25 partners dedicated to the restoration and protection of oysters in the state.**

One major change to the Blueprint for this edition is identifying living shorelines that include oysters as a distinct strategy to restore and protect oyster habitat. Similarly, oyster shell recycling has been elevated to a strategy unto itself with key actions. Both of these strategies previously were incorporated as part of the sanctuary and cultch planting strategies, respectively. They were elevated to distinct strategies to bring timely attention to them and also because of the level of action that should be taken to advance the work identified.

As the fourth edition of the Blueprint is implemented, a key area of focus will be to consider the ecosystem services provided by oysters as future plans are made. Ecosystem services are defined as the benefits people gain from thriving coastal habitats and clean waters.

There are eight strategies of the Blueprint, which include measures to improve water quality in critical shellfish waters where harvest occurs, restore and manage oyster habitat, recycle oyster shell to build new habitat, improve sustainable wild harvest opportunities, sustainably grow the oyster aquaculture industry and encourage engagement and outreach around oysters in North Carolina.

The eight major strategies of the Blueprint fall into four themes: Protect, Restore, Harvest and Educate. These strategies should not be thought of as independent from one another but instead work in a cohesive fashion to comprehensively support and perpetuate healthy oyster populations in our coastal waters.

Strategies to PROTECT oysters include water quality protection and oyster sanctuaries.

Strategies to RESTORE oysters include living shorelines and shell recycling for reefs.

Strategies to HARVEST oysters include cultch planting, sustainable wild harvest and shellfish aquaculture.

Strategies to EDUCATE about oysters include outreach and engagement.

These strategies and many of the 45 action steps detailed in this Blueprint are already being implemented. In the next five years, significant progress can and will be taken to advance oyster restoration, protection and harvest goals in North Carolina.

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Introduction

Background and Need

Oyster populations are declining globally, with an estimated 85 percent of oyster reefs lost (Beck et. al 2011). The story is no different in North Carolina. The decline in our state's eastern oyster (*Crassostrea virginica*) population is largely attributed to historic over harvest, subsequently followed by impacts from natural disasters, predation, disease and declines in water quality. There is no current stock assessment of the oyster population in North Carolina but due to the multiple factors that negatively impact oyster survival, the North Carolina Division of Marine Fisheries (DMF) views this stock as particularly vulnerable to overfishing (NCDEQ, Oyster FMP Amendment 4, 2017).

Actions have been taken in North Carolina to manage and rebuild the depleted oyster population for over a century. For example, in 1915, the state began actively restoring harvested reefs by deploying cultch material. Limestone marl, recycled shell or other suitable material collectively referred to as cultch, are used as a base material for rebuilding oyster reefs. Prompted by historic low harvest, the North Carolina General Assembly in the 1990s convened a Blue Ribbon Advisory Council on Oysters (BRACO) that made recommendations related to the best methods for rebuilding the state's oyster industry. Many of the recommendations of the BRACO report have guided restoration and management efforts for the past 25 years and are reflected today in DMF's Oyster Fishery Management Plan (FMP), North Carolina Division of Water Resources Basinwide Water Quality Plans, the North Carolina Strategic Plan for Shellfish Mariculture, and the Department of Environmental Quality's Coastal Habitat Protection Plan (CHPP).

In 2003, the North Carolina Coastal Federation, along with partners from North Carolina Sea Grant, North Carolina Aquariums, North Carolina Coastal Reserve and National Estuarine Research Reserve, Albemarle-Pamlico National Estuary Partnership, Duke University Marine Lab, Environmental Defense, The Nature Conservancy, the North Carolina Division of Marine Fisheries, and others joined together to host a series of meetings known as the Oyster Forum. The Oyster Forum yielded a compilation of suggested actions to restore oysters in North Carolina. The Forum found synergies between the BRACO report, the Fisheries Reform Act, FMP for Oysters, CHPP and Basinwide Water Quality Plans. In looking at the synergies, a common set of goals and actions was compiled, known as the Oyster Restoration and Protection Plan for North Carolina: A Blueprint for Action, commonly referred to as The Blueprint. This effort worked to break down agency and organizational

silos, to foster partnership and collaboration, working together for a common purpose. To date, three Blueprints have been released, each building on the successes, actions and lessons learned of the previous edition.

Accomplishments to Date

Successes from the Blueprint have been documented and tracked. Notable accomplishments of the first three editions of the Blueprint (2003-2020) include the following:

- Restored nearly 450 acres of oyster habitat for environmental benefits and harvest opportunities.
- Documented the economic benefits of oyster restoration; for each $1 invested, at least $4.05 in benefit are realized.
- Increased and maintained funding for oyster related programs by a factor of 10 through legislation and appropriations by the North Carolina General Assembly
- Supported fishery management efforts to maintain a viable and dynamic level of harvest, with a peak of 186,000 bushels in 2010.
- Expanded and supported sustainable development of the shellfish aquaculture industry, guided by the North Carolina Strategic Plan for Mariculture.
- Grew the shellfish aquaculture industry from $250,000 to $5 million and increased the number of farms in the state tenfold.
- Established and expanded the University of North Carolina Wilmington Shellfish Research Hatchery to support

development of the state's shellfish aquaculture program.

- Planned for future restoration, habitat and oyster fisheries management activities by engaging numerous research institutions and stakeholders while using new tools and resources.
- Fostered the protection and restoration of the state's shellfish waters through rulemaking, advancing low impact development with local governments and engaging stakeholders in watershed restoration planning and implementation.
- Developed and distributed education materials and resources linking the state's water quality to the safe growing and harvesting of oysters, as well as the continued recreational enjoyment of our coast.
- Developed a nationally recognized shell recycling program that collected nearly 250,000 bushels of valuable shell from 2003-2015.
- Gained national support and international recognition for North Carolina's oyster work.
- Engaged thousands of volunteers in hands-on oyster restoration and water quality protection projects.
- Provided education opportunities for tens of thousands of people through workshops, activities, publications, curriculum and hands-on training.
- Launched new communications tools to build on the growing public support for oysters and advance the work of the Blueprint and its stakeholders.
- Supported the collaboration of more than 25 partners to ensure the implementation of the Blueprint and alignment with the Coastal Habitat Protection Plan, Fishery Management Plan and other critical planning and management efforts.

Of significant national importance, during the implementation of the third edition of the Blueprint, in 2018, North Carolina became the sixth state to join the National Shellfish Initiative. The National Oceanic and Atmospheric Administration established the Initiative in 2011 with the goal to increase populations of bivalve shellfish in our nation's coastal waters — including oysters, clams, and mussels — through both sustainable commercial production and restoration activities. By joining the Initiative, the state recognized the value and importance of shellfish to its economy, cultural heritage, and environmental health. In launching a state initiative, North Carolina galvanized the support of local, state and federal leadership in promoting sustainable seafood, shellfish restoration and clean water.

The Initiative will help create new jobs in the state's coastal communities while protecting and restoring its environment, protect and restore water quality to allow natural reefs to thrive, use the pristine and unique water quality of North Carolina to grow shellfish markets, and ensure shellfish aquaculture growth occurs in a sustainable and socially acceptable manner.

Process for Updating the Fourth Edition of the Blueprint

Timeline to Update

Throughout its 18-month development, hundreds of people were engaged to outline new goals and actions for the next five years. The full update process is described in detail as Appendix B.

Building on the success of the previous Blueprint, the following timeline was used to update the Blueprint to the fourth edition:

- **September 2019:** Oyster Steering Committee met to review the plan update, timeline and next steps.
- **October 2019:** Developed an outline of work for Strategy Workgroups to review oyster restoration and management strategies in North Carolina.
- **October 2019-May 2020:** Strategy Workgroups convened to develop a list of draft issues and recommendations for consideration related to their specific strategies.
- **December 2019:** Began to compile information on accomplishments realized during the Third Edition of the Blueprint.
- **January 2020:** Issued a stakeholder survey to identify what stakeholders value about oysters, what ecosystem services of oysters are priorities, what are perceived threats to the oyster population. In addition, the survey solicited suggestions for actions that should be considered in next edition of the Blueprint.
- **March 2020:** Drafted strategy recommendations provided from the workgroups.
- **April-June 2020:** Conducted a series of six virtual workshops to review results of the stakeholder survey, discuss draft recommendations from the workgroups, and seek input on the top three actions for each strategy.
- **May-June 2020:** Strategy workgroups incorporated feedback from virtual meetings to revise the suite of Blueprint recommendations.
- **June 2020:** Convened the Oyster Steering Committee to review feedback from the virtual workshops and prioritized actions for consideration.
- **July 2020:** Stakeholder Survey Summary completed and released online. (Appendix C)
- **November 2020:** Draft of Blueprint released to the Oyster Steering Committee.
- **December 2020:** Oyster Steering Committee convened to review the compiled recommendations.
- **January 2021:** Revised Blueprint circulated for final edits.

- **March 2021:** Oyster Steering Committee reviewed final recommendations.
- **April 2021:** Final 2021-2025 Blueprint released.

New to the Blueprint

In this edition of the Blueprint, two strategies were elevated. Distinct goals and actions were identified for the Living Shoreline and Shell Recycling for Reefs strategies. Previously, the actions associated with these strategies were captured in the Sanctuary and Cultch Planting strategies respectively. By elevating these to stand alone strategies, it reflects the need to bring timely attention to the strategies and actions identified. In addition, the level of action that should be taken to advance the work warrants these strategies being identified as distinct strategies in the Blueprint. Both of these strategies contribute to the overarching themes of restoration and protection of oyster habitat.

Ecosystem Services

Also new to this edition of the Blueprint is the consideration of oyster ecosystem services. Ecosystem services are defined as benefits people gain from thriving coastal habitats and clean waters. These include provisioning services (such as providing food), regulating services (such as flood protection and filtering water), cultural services (such as recreational opportunities, spiritual and aesthetic opportunities) and supporting services (such as nitrogen cycling).

As the fourth edition of the Blueprint is implemented, a key area of focus will be to define future goals based on ecosystem services and outcomes.

Eight Major Strategies Recommended

Working with information collected throughout the Blueprint update process, **eight major strategies and 45 actions are recommended for the next edition of the Blueprint**. Each strategy, the rationale for its inclusion in the fourth edition of the Blueprint, and major accomplishments to date are explained in detail in this report. The top three recommended actions, as prioritized during virtual workshops held as part of the update process, for each strategy are also listed. A complete table of all actions and sub-actions included in this edition of the Blueprint is provided as Appendix D. These actions are not intended to be implemented by any one organization or entity but instead are collectively considered important to advance oyster protection, restoration, harvest and education efforts in the state of North Carolina.

The recommended actions described here will advance each strategy toward a shared vision where oysters contribute to a healthy coastal environment and a robust coastal economy. This vision is shared among the many partners who developed the Blueprint, which fosters collaboration and ensures partnership and commitment toward its fulfillment.

The eight major strategies of the Blueprint can be broadly categorized in four themes: protect, restore, harvest and educate. These strategies should not be thought of as independent from one another but rather work in a cohesive fashion to comprehensively support the perpetuation of healthy oyster populations in our coastal waters.

- Strategies to ***Protect*** oysters include: water quality protection and oyster sanctuary efforts.
- Strategies to ***Restore*** oysters include: living shorelines and shell recycling for reefs.
- Strategies to ***Harvest*** oysters include: sustainable wild harvest, cultch planting, and shellfish aquaculture.
- Strategies to ***Educate*** about oysters include: outreach and engagement.

Strategies to Protect Oysters

Protect: Water Quality

Overarching goal of the water quality strategy: Protect and restore water quality in shellfish growing waters that are both critically important and endangered.

Respondents to the 2020 Oyster Stakeholder Survey identified water quality as the single greatest threat to oysters in the next 5-10 years (Appendix C). Pristine waters are key to oyster success, both as critical estuarine habitat and to ensure they are safe for human consumption. In many areas where the landscape has been modified by development, shellfish waters are closed after moderate and severe rains due to runoff that contains high-bacteria levels. About 34 percent of all North Carolina's coastal waters are permanently closed to shellfish harvest because of pollution and a lack of monitoring capacity. Many more areas are temporarily closed as a result of polluted runoff after moderate to severe storm events (Figure 1). In our prime shellfish growing waters, it's imperative that the volume and rate of runoff resemble levels that occurred naturally before land use changes occurred.

Over the past decade, multiple coastal communities have developed watershed management and restoration plans that determine the extent of hydrologic modifications that have occurred, and identified cost-effective practices that can help to restore or replicate more natural runoff patterns. In this updated Blueprint, lessons learned from these watershed management and restoration efforts are being used to develop a systematic approach to restoring or replicating natural hydrology in our most important and endangered shellfish growing waters in North Carolina. This effort will result in effective, targeted and collaborative measures to ensure a healthy future for oysters in these watersheds. This work will also demonstrate a strategy that can be replicated in additional future priority watersheds.

Links to other Plans

One of the goals of the Coastal Habitat Protection Plan (CHPP) is to protect and enhance water quality. The CHPP recommends strategies to address water quality impacts that will help improve shellfish growing waters in conjunction with the Oyster Blueprint, including maintaining rule compliance through inspections, local government incentives, and developing new technology to reduce point and nonpoint pollution through voluntary actions. Maintaining the water quality necessary to support vital coastal fisheries will benefit not only the oyster fishery but also a large sector of the entire coastal economy built around travel, tourism, recreational fishing, and other outdoor activities.

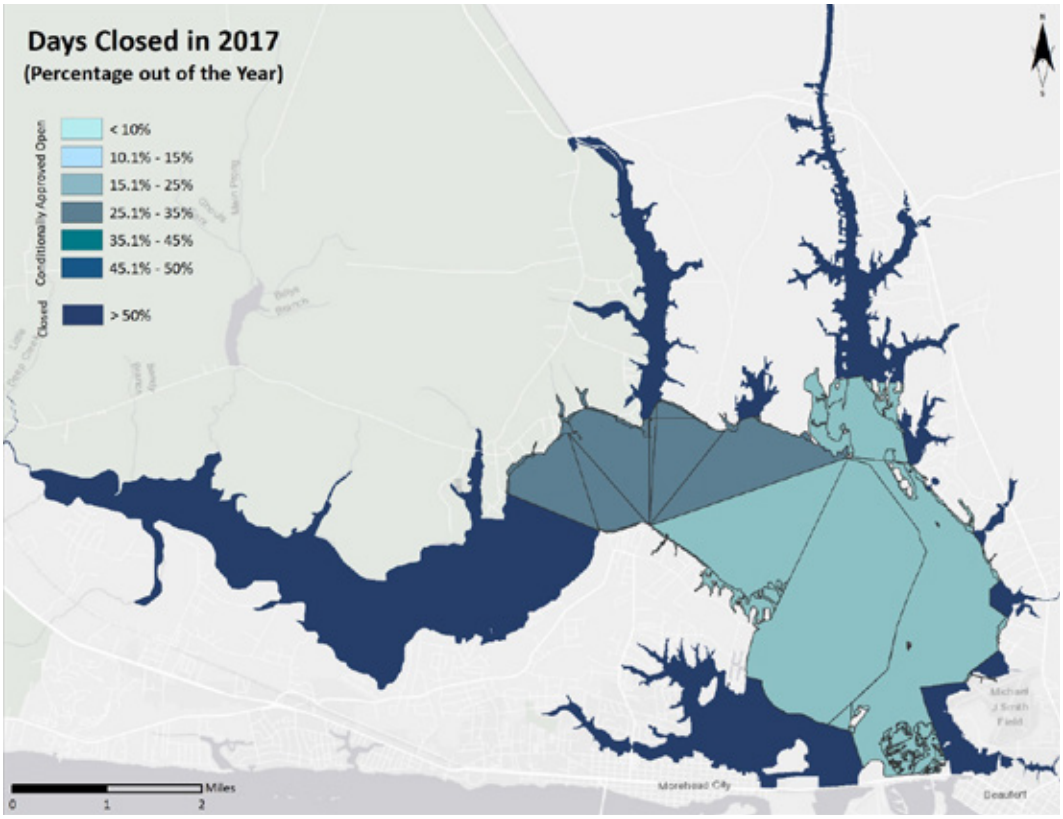


Figure 1. *A map of the Newport River near Morehead City and Beaufort, N.C. Areas in dark blue are permanently closed to shellfish harvest due to poor water quality. Areas in shades of teal and green indicate areas that are often closed due to rainfall events. Portions of the river are temporarily closed for more than 50% of the year, but are listed as "open" in the state's water quality monitoring results. The increasing frequency and duration of these temporary closures pose a threat to shellfish restoration and harvest efforts. This same pattern of temporary closures is seen in many North Carolina coastal watersheds. Map created by North Carolina Coastal Federation with data provided by DMF's Shellfish Sanitation Section monitoring data.*

Accomplishments

In 2019, a series of stormwater retrofit projects reduced stormwater runoff that would be caused by one-year, 24-hour rainfall events by 7,700,000 gallons throughout coastal North Carolina. This work was accomplished through partnerships between the North Carolina Coastal Federation, Beaufort, Pine Knoll Shores, Swansboro, New Hanover County, Wilmington, University of North Carolina Wilmington, North Carolina Wildlife Resources Commission, and North Carolina Soil and Water Conservation Districts.

The North Carolina Division of Energy, Mineral and Land Resources assembled a Post-construction Program Review committee to evaluate and recommend solutions to improve compliance with existing and often failing permitted coastal stormwater systems. This includes reviewing permit transfer procedures and long-term compliance for low density developments. The Division of Energy, Mineral and Land Resources has also secured a new Permittee Outreach Coordinator to assist.

Partnering with The Pew Charitable Trusts, the North Carolina Coastal Federation engaged in a collaborative project to advance nature-based stormwater strategies to reduce flooding and protect water quality. This statewide effort resulted in a comprehensive plan for reducing stormwater plaguing North Carolina surface waters. Four work groups focused on strategies to address stormwater in new development, stormwater retrofits, roadways and working lands. The statewide Nature-Based Stormwater Strategies plan was released in 2020.

Nature-based stormwater strategies are effective stormwater management methods to reduce flooding and surface runoff while accommodating existing and future land uses, both urban and rural. The key principal of nature-based stormwater strategies is to maintain or mimic a site's natural hydrology and capacity to collect, infiltrate and filter stormwater runoff. Nature-based stormwater strategies include bioretention, disconnected impervious surfaces, permeable pavers and large-scale watershed restoration that attempts to protect and restore a site's natural hydrology.

Top three actions for water quality

Action 1: Demonstrate success in protecting and restoring Newport River and Stump Sound, two of the state's most important and endangered shellfish growing waters.

Organizations involved in this action include Albemarle-Pamlico National Estuary Partnership, Division of Marine Fisheries, North Carolina Coastal Federation, The Pew Charitable Trusts, shellfish growers and harvesters in the targeted watersheds, researchers and local governments and others.

Specific action steps include the following:

- Engage key stakeholders such as fishers, farmers, landowners, government agencies, academia and experts in teams to tackle the water quality threats facing Newport River and Stump Sound.
- Prepare a comprehensive and easily identifiable and understood watershed management and restoration plan that includes strategies for reducing the volume of runoff and other strategies to maintain, protect and replicate natural watershed hydrology for each of these growing waters and meets the EPA's nine minimum elements for plan development.
- Implement and monitor the top five cost-effective measures identified in the plans in each watershed. Implementation should continue after year five.

Action 2: Create and heavily publicize a prioritized list of additional endangered shellfish growing waters for targeted management and restoration planning.

Organizations involved in this action include Albemarle-Pamlico National Estuary Partnership, Division of Marine Fisheries, North Carolina Coastal Federation, North Carolina State University-Center for Marine Science and Technology, The Nature Conservancy, University of North Carolina Wilmington and others.

Specific action steps include the following:

- Develop maps with ranking criteria based on waters that have existing or potential oyster harvest, as well as waters that have the greatest threats for current and future shellfish closures as indicated by rainfall thresholds that cause closures.
- Present priority list to Oyster Steering Committee during year one and refine with their input.
- Update the priority waters list every five years.

Action 3: Adopt state policy for application of stormwater volume matching criteria using Low-Impact Development practices when feasible and practical for state funded construction projects and showcase projects located in priority shellfish growing waters.

Organizations involved in this action include Brooks-Pierce, Department of Environmental Quality, Department of Transportation, North Carolina Coastal Federation, The Pew Charitable Trusts and others.

Specific action step includes the following:

- Encourage government agencies to serve as role models by ensuring that state construction projects consider low-impact design or nature-based stormwater strategies in state-funded construction projects where practical and feasible throughout the coast. This recommendation is consistent with an approved recommendation in the North Carolina Strategic Plan for Shellfish Mariculture adopted in 2018 and should at a minimum be applied in priority shellfish growing waters.

Protect: Oyster Sanctuaries

Overarching goal for the oyster sanctuary strategy: Establish sufficient acreage of protected oyster reefs to support desired ecosystem services by building fish habitat, supplementing wild oyster stock and filtering water.

Oyster sanctuaries are a major pillar of the oyster protection and restoration efforts in North Carolina. Stemming from recommendations in the BRACO report, DMF began constructing oyster sanctuaries in 1996. Building on the successes and lessons learned of this effort, the recommendation to construct oyster sanctuaries holds true 25 years later.

Oyster sanctuaries are a strategy that restores oyster habitat in key areas throughout Pamlico Sound to serve as reef habitat and to provide a subsidy of oyster larvae to reseed the wild population on harvested oyster reefs. Sanctuaries are built to function as broodstock, providing larvae to nearby oyster reefs, thereby serving as an insurance policy for the oyster population. In an oyster sanctuary, oysters cannot be harvested, but hook-and-line fishing is allowed.

To date, 15 oyster sanctuaries have been established in Pamlico Sound. By providing high-quality restored habitat and limiting harvest of oysters from sanctuaries, oyster sanctuaries help

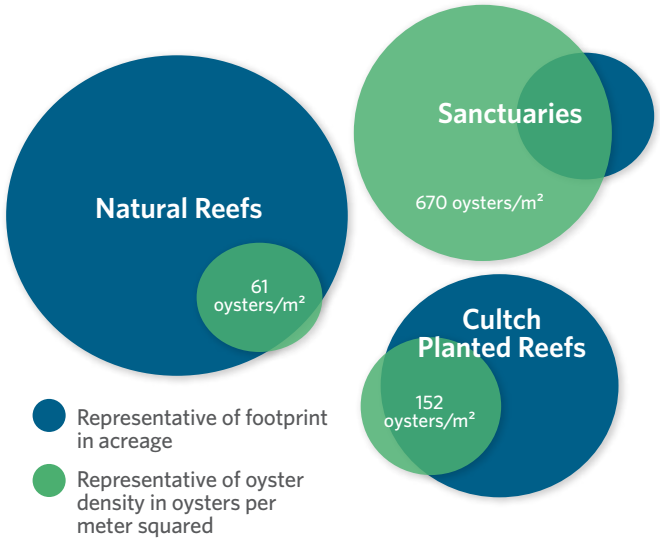


Figure 2. *Average oyster densities (oysters/m2) at three different reef types relative to their aerial extent in Pamlico Sound. Adopted from Puckett et al. 2012, Peters et al. 2017, and Theuerkauf et al. 2017.*

to improve the demographics of oyster populations in Pamlico Sound. Reefs within the sanctuaries support a high density of sexually mature oysters relative to other reef types in the sound. In fact, estimates suggest that oyster sanctuaries can boast up to 5-10 times more oysters per area than natural subtidal or cultch-planted reefs currently or historically harbored (Puckett and Eggleston 2012; Peters et al. 2017; Theuerkauf et al. 2017; Figure 2). Monitoring showed that oyster sanctuaries supported, on average, 670 oysters per square meter, whereas average oyster density on natural subtidal reefs, subtidal cultch-planted

reefs, and intertidal reefs were 61 oysters per square meter, 152 oysters per square meter, and 121 oysters per square meter, respectively.

In addition to higher densities overall, oyster sanctuaries generally have a better distribution of size classes with higher densities of juveniles, sub-legal oysters and legal-sized oysters compared to natural and cultch planted reefs (Figure 3). Higher densities of larger oysters result in increased reproductive output of oyster larvae from sanctuaries (Peters et al. 2017). To harness the reproductive output of sanctuaries, they are located in areas of the sound where their larvae can be broadcast to subsidize and support the wild population, as well as other sanctuaries (Haase et al. 2012, Puckett and Eggleston 2016, Puckett et al. 2018, Theuerkauf et al. in press).

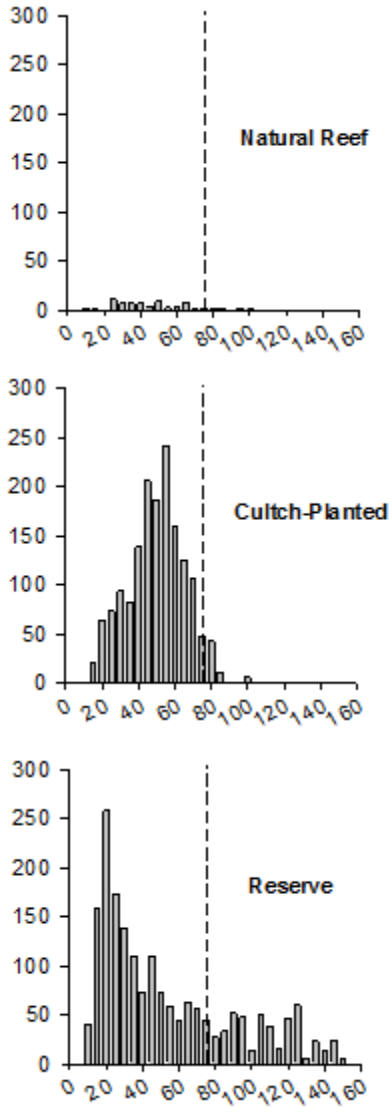


Figure 3. *Comparison of oyster densities (per meter square, on the y-axis) and size class (length of left valve in mm, on the x-axis) on three different reef types. Dotted line indicates 75 mm (3 inches), the legal size for oyster harvest in North Carolina. Courtesy Peters et al. 2017.*

The demographic benefits of sanctuaries appear to be long-lasting in many cases. High oyster densities in oyster sanctuaries persist for well over a decade with average densities of approximately 400 oysters per square meter, and in some cases, for nearly two decades with oyster densities of approximately 200 oysters per square meter (Puckett et al 2018; Figure 4). Two notable exceptions occurred at the Ocracoke and Clam Shoal sanctuaries (blue and red lines in Figure 4). After initial oyster recruitment success, these two sanctuaries saw complete loss of oysters within five years of construction, potentially due to oyster pests such as boring sponge and drills.

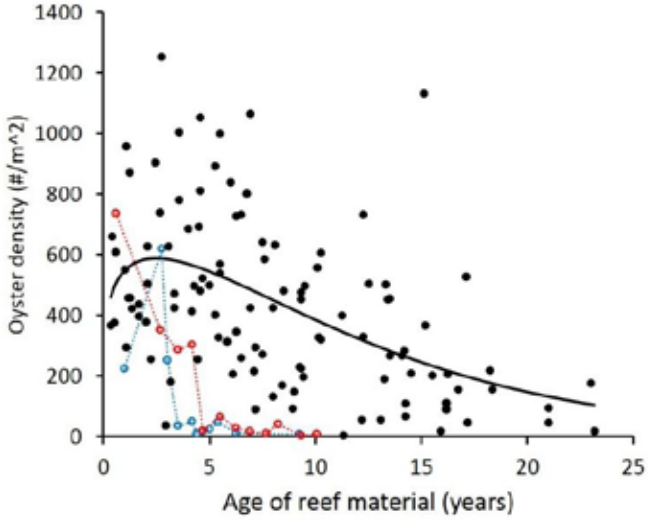


Figure 4. *Mean oyster density in sanctuaries over time, showing oyster sanctuaries maintain high (>100/m2) densities of oysters for more than two decades. The solid curve depicts best fitting trend and closed black circles are actual observations. Open circle lines represent two sanctuaries (Ocracoke = blue and Clam Shoal = red) where oyster densities collapsed within five years. Courtesy Puckett et al. 2018. Updated in 2020 with data provided by DMF.*

For their relative footprint, oyster sanctuaries contribute disproportionately to the oyster population and larval output in the sound. They cover only about 6 percent of the oyster reef footprint in the sound, but account for over 19 percent of the oyster population and provide nearly 25 percent of all the oyster larvae that settle within the sound (Theuerkauf et al. in press).

DMF continues to refine the sanctuary program based on scientific literature, guidance from researchers and advisory groups and DMF-led monitoring of sanctuary reefs. Siting the location of sanctuaries and material used in sanctuary construction are two main areas where the program continues to evolve.

A habitat suitability model developed by researchers at North Carolina State University's Center for Marine Science

and Technology and the North Carolina Coastal Reserve and National Estuarine Research Reserve helps to guide siting of sanctuaries. This model continues to be updated and refined. Most recently, the researchers have started to consider long-term persistence of the reefs (Puckett et al. 2018) and water filtration capacity (Theuerkauf et al. 2019) in addition to the larval connectivity and other environmental parameters that contribute to oyster restoration success (Figure 5).

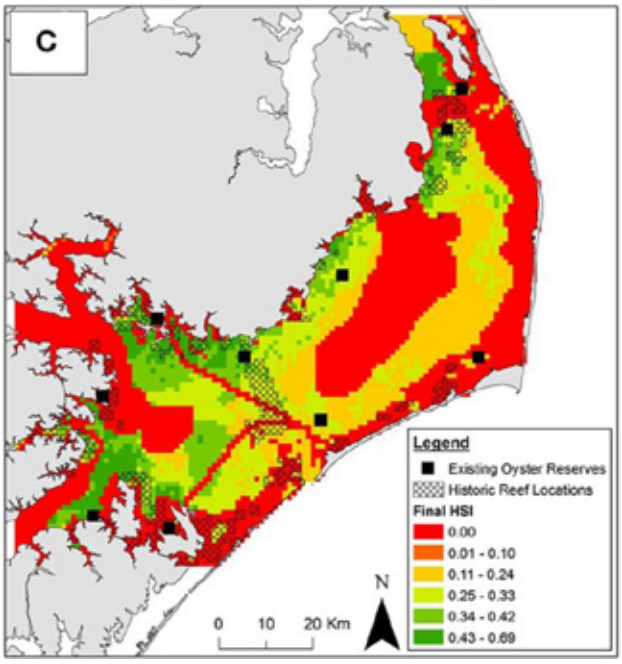


Figure 5. *Habitat suitability index for siting sanctuaries in locations to maximize oyster persistence. Suitability increases from low (red) to high (green). Existing oyster sanctuaries are depicted by black squares (not to scale) and location of historic oyster reefs (c. 1890) depicted by black crosshatch. Puckett et al. 2018.*

The material used in construction of the sanctuaries can include limestone marl, granite, crushed concrete or other suitable substrate. Limestone is often used in construction of sanctuaries but DMF considers salinity, cost and availability of material before proceeding. Sanctuary sites with moderate to low salinity can be suitable for limestone marl reef construction. There is substantial cost savings when using marl over alternate materials such as granite. For example, in constructing the first two phases of the recent Swan Island, a sanctuary, DMF estimated that building 10 acres of reef would cost $1,325,000 if constructed with granite, versus $855,000 when constructed with marl, a cost increase of nearly 50 percent.

In general, the oyster sanctuary program is thought to be very successful in restoring oysters to the sound. Recent research and monitoring bears this out. Currently, oyster sanctuaries are only in Pamlico Sound. They are designated by proclamation until they can be defined in rule.

Other Protected Reef Designations

The closed shellfish waters in the southern region of the state have long been considered de facto sanctuaries because harvest is prohibited. However, research from the UNC-Wilmington shows that these closed waters may exhibit a shell budget deficit, skewed sex ratios and possibly low larval output and may not in fact be serving in a sanctuary capacity. In addition, the shellfish relay program occurs in some of these closed areas, further effecting their capacity to serve as a protected source of spawning oyster stock.

Designating a management area is strategy that can afford DMF and its partners more flexibility to implement and manage oyster protection and restoration projects. Managed areas can serve to protect oyster habitat, support broodstock growth and provide oysters additional time to develop increased disease resistance. Shellfish Management Areas for example have been used to protect restoration projects, produce oysters for transplanting as seed and manage other oyster enhancement projects. Larger, older oysters protected in managed areas serve as spawning bloodstock that produce larvae capable of seeding nearby reefs. The reefs in managed areas also filter and improve water quality in the sounds and tidal creeks, a vital role in smaller estuaries with more urbanized watersheds. Oyster reefs in managed areas also create habitat that support recreational fishing opportunities.

Some type of managed area designation is a suitable tool and strategy for use in all shellfish growing areas, but in particular in the shallow, narrow estuaries in the central and southern areas of the state where large sanctuaries, as defined by rule, are not as feasible. In these estuaries south of Pamlico Sound, the percentage of polluted shellfish water increases significantly -- 48 percent of waters are closed to shellfish harvest. These same waters also contribute between 40-50 percent of the annual wild oyster landings. This is a significant factor because the area only encompasses 6 percent of the total coastal water body area of the state, and only 5 percent of the total area open to shellfishing.

Accomplishments

The first sanctuary was built in 1996 in Croatan Sound. As of 2020, there are 15 sanctuaries strategically located in Pamlico Sound (Figure 6). DMF has permitted 395.44 acres and with partners, such as the North Carolina Coastal Federation, developed oyster habitat on 357.76 acres.

In 2008 and 2015, the North Carolina Oyster Steering Committee released the second and third editions of the Blueprint. The Blueprint outlined a goal of building 500 acres

of oyster sanctuary in Pamlico Sound. This goal was set based on the potential construction capabilities of DMF working at full potential and with consistent, full funding. This goal was reiterated in 2016 when DMF provided a report to the General Assembly outlining their future needs to build the Senator Jean Preston Oyster Sanctuary Network by 2026. The plan called for an investment of $30 million to the sanctuary program made up of state appropriations and federal grants, which would result in the completion of 500 acres of sanctuary reef in Pamlico Sound by 2026. From 2015-2020, nearly $8 million has been invested in the sanctuary program, building 40 acres of new oyster sanctuary habitat.

The fourth edition of the Blueprint builds off of the goals stated in the previous Blueprints and the Senator Jean Preston Oyster Sanctuary Network recommendations. It also considers whether or not 500 acres of oyster sanctuary is enough to reach ecosystem service goals for the coast. For reference, The Chesapeake Bay 2000 Agreement was developed in cooperation by scientists, managers, watermen and environmentalists to determine an appropriate acreage for oyster sanctuary designation in the Chesapeake Bay. The agreement called for setting aside at least 10 percent of traditional oyster reef acreage as sanctuaries (Keiner 2009).

Applying this model to North Carolina would yield a recommendation of at least 2,170 acres of restored and/or healthy oyster reefs that should be protected. This is based on the 21,736 acres of oyster reef/ shell bottom habitat mapped in the state.

To achieve this goal, existing and planned protected areas could be included and additional areas could be identified and evaluated.

Figure 6. *The current Senator Jean Preston Oyster Sanctuary Network, 2020. The network consists of fifteen sanctuaries and 357.76 developed acres of reef throughout Pamlico Sound. Courtesy DMF.*

A number of additional considerations should be evaluated as well, including the following:

- Protected oyster habitat areas could include existing and future sanctuaries.
- Protected areas could also include areas that restrict mechanical bottom disturbing gear, military protected zones, or waters closed to harvest containing viable or restored oyster reef habitat. However, the oyster habitat in these areas will need to be evaluated to ensure that they are healthy or have the potential for successful restoration.
- The CHPP Strategic Habitat Area identification and designation process can be used to evaluate and designate areas for oyster habitat protection and restoration.
- These protected areas should be evenly distributed throughout the coast.
- In addition, these areas should be protected from habitat losses from shellfish relay, water-dependent development and water quality degradation.
- In the waters south of Pamlico Sound, the percent of polluted shellfish water increases significantly (48 percent), and these closed areas have been previously viewed as de facto sanctuaries and a protected source of spawning oyster stocks. However, not all polluted closed areas function as broodstock reserves. These areas are affected by stressors associated with urbanized drainage which may lead to altered sex ratios, burial of reefs, lower populations and higher incidence of disease (Ravit et al. 2014; UNCW Tidal Creek Studies). In addition, the southern region -- New River to Little River Inlet -- generates significant landings even though the area only encompasses 6 percent of the total coastal water body area of the state, and only 5 percent of the total area is open to shellfishing.

In addition, this Blueprint considers the need for protection of oyster reefs in areas outside of Pamlico Sound. The Blueprint recommends that a workgroup be formed to consider the intent and need for protected reefs in the southern region of the state. The workgroup will look at available data to determine locations within waters that are both open and closed to harvest where populations of oysters appear to be depressed, and whereby enhancement and/or protection through a managed area or sanctuary designation can meet the assigned goals for the area. The recommendations from this workgroup would be shared for consideration during the next Oyster Fisheries Management Plan update.

Top three actions for oyster sanctuaries

Action 1: Build an additional 100 acres of oyster sanctuary in Pamlico Sound by 2025.

Organizations involved in this action include Albemarle-Pamlico National Estuary Partnership, Division of Marine Fisheries, North Carolina Coastal Federation, The Nature Conservancy, The Pew Charitable Trusts and others.

Specific action steps include the following:

- Secure funding and staff to build 100 acres of sanctuary reef.
  - Maintain current state appropriations of $850,000 to build 3 to 5 acres of sanctuary reef annually.
  - Match with federal grants whenever possible so that 6 to 10 acres can be constructed each year.
  - Target a total of $3.5 million in state and federal grants annually to construct oyster sanctuaries at a rate of 20 acres per year.
- Determine best method to allow DMF to issue reef material acquisition and construction contracts over multiple fiscal years.

Action 2: Monitor and use the best science available to inform restoration activities.

Organizations involved in this action include Albemarle-Pamlico National Estuary Partnership, Division of Marine Fisheries, Division of Coastal Management/National Estuarine Research Reserve, East Carolina University/ Coastal Studies Institute, North Carolina Coastal Federation, North Carolina Sea Grant, North Carolina State University-Center for Marine Science and Technology, The Nature Conservancy, The Pew Charitable Trusts, University of North Carolina Chapel Hill- Institute of Marine Science, University of North Carolina Wilmington and others.

Specific action steps include the following:

- Identify the ideal locations of sanctuaries and ensure they are well distributed, and there's an understanding of sediment transport dynamics to avoid areas that will be buried during storm events such as nor-easters and hurricanes.
- Select appropriate substrate material, not all materials are suitable in all locations.
- Design of each sanctuary should be appropriate for its location including size, architecture and amount of relief.
- Determine the metrics of success that would allow sanctuaries to sustain a positive return on investment. Consider the following:
  - How much water filtration and nitrogen removal should oyster sanctuaries contribute to Pamlico Sound? What is the wastewater treatment equivalent value?
  - How many oyster larvae should oyster sanctuaries contribute to commercial harvest?
  - How much fish production should be attributed to oyster sanctuaries?
  - How many recreational fishing opportunities should oyster sanctuaries provide?
  - How many people should be employed in the construction of oyster sanctuaries?
- Monitor reefs for success metrics identified above and practice adaptive management of sanctuaries as needed.

Action 3: Determine the need for and feasibility of a protected reef designation in the southern region of the state.

Organizations involved in this action include Division of Marine Fisheries, North Carolina Coastal Federation, The Pew Charitable Trusts, University of North Carolina Wilmington and others.

Specific action steps include the following:

- Define the need and intent of this management action, for example ecosystem service-based versus larval connectivity versus coastal resiliency.
- Determine the best and most appropriate designation of protected or created reef.
- Enact rule change and/or legislation to allow new designation as needed.
- Conduct research and modeling to inform the location, material and architecture of reefs based on intent.
- Use existing science to inform success of proposed reefs.
- Establish a plan for future reefs including a plan for funding development.

Strategies to Restore Oysters

Restore: Living Shorelines

Overarching goal for the living shoreline strategy: Expand the use of living shorelines to become the most commonly used shoreline stabilization method in estuaries that support oyster habitats.

Living shorelines, as a strategy for building oyster resources in the state, is a new stand-alone strategy in this fourth edition of the Blueprint.

Shoreline hardening, such as the installation of bulkheads and riprap revetments, has destroyed a considerable amount of North Carolina's estuarine habitats. These habitats are vital to commercially and recreationally important species as well as coastal water quality. Shoreline hardening has been the de facto approach for addressing shoreline erosion for many years. It is recognized by the state Living Shoreline Steering Committee and partners that the remaining natural shorelines in the state should be sustainably managed through the promotion and expanded use of living shorelines. Living shorelines are environmentally friendly shoreline stabilization techniques that help reduce shoreline erosion while simultaneously protecting and restoring valuable coastal marsh and oyster habitat. For the purposes of the Blueprint, actions related to living shorelines are directly referring to sill-based structures made of materials that recruit or support oyster growth.

There is ample scientific evidence and demonstration that living shorelines built with varying materials in areas conducive to oyster growth provide new hard substrate for oyster growth and develop into productive oyster reefs that are an important source of oyster larvae for surrounding areas (Meyer et al. 1997, Piazza et al. 2005, La Peyre et al. 2014 a, La Peyre et al. 2014 b, La Peyre et al. 2015, Ridge et al. 2015, Colden et al. 2017, Graham et al. 2017).

Living shoreline oyster reefs also provide ecosystem services comparable to natural oyster reefs such as coastal marsh and shoreline protection, sediment stabilization, enhancement of fish and shellfish habitat and improvement of water quality through the filtering capabilities of the salt marsh grasses and oysters (Gittman et al. 2016, DEQ 2016). In addition, living shorelines have proven to fare better than hardened structures following the passage of hurricanes and strong storms (Gittman et al. 2014, Smith et al. 2018), as well as higher than normal water levels.

These multiple benefits of living shorelines can increase public and private support for oyster restoration and stress the importance of including living shorelines as a tool in the toolbox for restoring oysters. Lessons learned from decades of intertidal oyster restoration and research on salinity and tidal regime in North Carolina and elsewhere have been and should be applied to the siting and design of living shorelines to promote oyster growth and development, as well as to support the numerous other ecosystem services that living shorelines provide. Implementing living shorelines along waterfront properties where oysters grow and where erosion is occurring, is a sound strategy for expanding oyster habitats, reducing shoreline erosion and protecting and improving water quality.

The 2016 CHPP also recognized the value of living shorelines and made them a priority habitat issue. Implementation actions in that plan complement the Blueprint in areas of demonstration projects, as well as education and outreach to homeowners and contractors to increase their use of living shorelines to restore shorelines and improve water quality.

Accomplishments

The use of living shorelines in North Carolina has steadily increased over the past two decades. The recent simplification of the Division of Coastal Management's Coastal Area Management Act (CAMA) General Permit for the construction of marsh sills has helped to remove permitting as a barrier to living shoreline implementation. CAMA Major Development permits for larger-scale, more complex living shorelines have also been increasingly quicker to obtain as agency familiarity with these projects has increased. Advancements in the science of living shorelines have shown they are a viable shoreline stabilization option that can withstand hurricanes, storms and rising water levels. Living shorelines built with varying materials in areas conducive to oyster growth have also created productive oyster reefs. Currently one cumulative mile of living shorelines exists in oyster growing waters of the state. Despite the increased use of living shorelines in the state, there is still a long way to go in making living shorelines the preferred method for shoreline stabilization.

Top three actions for living shorelines

Action 1: Implement living shorelines to continue to demonstrate their benefits to oysters and soundfront property owners.

Organizations involved in this action include Albemarle-Pamlico National Estuary Partnership, Brooks-Pierce, Division of Coastal Management, Division of Marine Fisheries, Duke University Marine Lab, East Carolina University, North Carolina Aquariums, North Carolina Coastal Federation, North Carolina Sea Grant, The Nature Conservancy, University of North Carolina Chapel Hill-Institute of Marine Sciences, University of North Carolina Wilmington and others.

Specific action steps to take include the following:

- Build at least 3 miles of living shorelines coastwide on public and private lands where oysters grow by 2025, an increase of 15 percent over the last five years.
- Secure protection for sills that support oyster growth so they cannot be harvested.
- Identify locations to use as stockpile sites for materials used in living shoreline construction.
- Continue to site and design living shorelines based on current research and lessons learned from decades of intertidal oyster restoration to promote oyster growth and adaptation to sea level rise, as well as support other ecosystem services.
- Implement a communication and education strategy around highly visible projects to publicize the benefits and gain more public and agency demand for these projects.
- Engage volunteers and contractors in building living shorelines to help increase public awareness of their benefits.
- Document the success of living shoreline projects each year, both new and old, including their oyster recruitment potential, cost-benefits and resilience compared to other types of shoreline stabilization.

Action 2: Create and promote consumer demand for living shorelines by property owners with a special focus on shorelines that support oyster growth.

Organizations involved in this action step include Albemarle-Pamlico National Estuary Partnership, Division of Coastal Management, Duke University Marine Lab, East Carolina University, North Carolina Coastal Federation, North Carolina Sea Grant, University of North Carolina Chapel Hill-Institute of Marine Sciences, University of North Carolina Wilmington and others.

Specific action steps to take include the following:

- Educate waterfront property owners, realtors, homeowners associations, Community Association Management Services, local governments and the general public on the value and benefits of living shorelines.
- Develop educational outreach materials in electronic and printed form to be distributed to these audiences.
- Conduct one-on-one living shoreline consultations with 50 waterfront property owners per year.
- Market the use of living shorelines by property managers and owners at three outreach events in three regions of the coast.

Action 3: Test alternative living shoreline construction materials and methods that increase oyster recruitment.

Organizations involved in this action include Division of Coastal Management, Duke University Marine Lab, East Carolina University/Coastal Studies Institute, North Carolina Aquariums, North Carolina Coastal Federation, North Carolina Coastal Reserve and National Estuarine Research Reserve, North Carolina Sea Grant, The Nature Conservancy, University of North Carolina Chapel Hill-Institute of Marine Sciences, University of North Carolina Wilmington and others.

Specific action steps to take include the following:

- Test nonplastic, alternative materials for living shoreline construction at five demonstration project sites.
- Monitor and report the performance of alternative materials.

Living shoreline materials that promote oyster growth and recruitment include but are not limited to rock such as granite, limestone marl, recycled oyster shells, Oyster CatcherTM, Atlantic Reefmaker, oyster castles, oyster domes, etc.

Restore: Shell Recycling for Reefs

Overarching goal for the shell recycling for reefs strategy: Create a coordinated oyster shell recycling program to provide 5 percent of the material needed to support oyster restoration.

Oyster shell is a valuable resource in the state of North Carolina. It is used by the North Carolina Coastal Federation, DMF and others to build new oyster reefs. Recycled oyster shells, when used to build reefs, becomes habitat for subsequent generations of oysters. In a few years, mature oysters, grown on recycled shell, can be harvested. To get the material that is needed to build reefs, shells are often bought from shucking houses and delivered to project sites for $2-3 per bushel. A recycling program provides an alternative way to collect the shells that may otherwise be discarded. This type of program gives both restaurants and consumers a chance to return their shells to the water, thereby contributing to the perpetuation of oysters.

Accomplishments

From 2003 to 2013, the state of North Carolina ran a state-funded shell recycling program. When the program first started in 2003, DMF partnered with several nonprofit and community groups to establish public drop-off sites and collect shells from restaurants, festivals and oyster roasts. DMF also provided maintenance of shell collection dumpsters.

In 2006, appropriations were available to hire a coordinator designated for the program, more public sites, restaurants and volunteers were added to the program, which increased the volume of shells.

In 2006 and 2007 the state General Assembly passed the following statutes to promote participation in the recycling program:

- General Statute 105-130.48: For every bushel of oyster shell donated to the program, the taxpayer will receive $1 per bushel tax credit.
- General Statute 130A-309.10(f)(l): Jan. 1, 2007, oyster shells are banned in landfills.
- General Statute 136-123 (b): No landscaping or highway beautification project undertaken by the department or any other unit of government may use oyster shells as a ground cover.

By the end of 2007, the program recycled 32,188 bushels. At the height of the program, DMF and its partners maintained 113 public drop-off sites and picked up shell from 52 restaurants

statewide. Over the 10 years of program, 165,769 bushel of oyster shell were recycled (Figure 7).

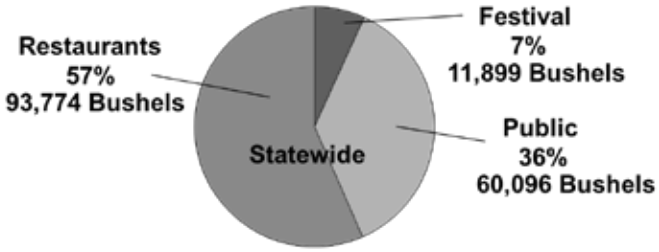


Figure 7. *Percent of recycled shell by source from 2003-2012. During the program's full run, 2002-2015, nearly 250,000 bushels were recycled. Courtesy DMF*

In 2013, funding from the General Assembly for the Oyster Shell Recycling Program was discontinued and the program became defunct. In addition, the tax credit for donating recycled shell was repealed. However, some recycling responsibilities were absorbed by other programs within DMF's Habitat & Enhancement and Fisheries Management section. Historically high-yield recycling sites were maintained, while low-yield collections sites were closed. From 2013 to 2018, DMF ran a scaled-down program with limited grant funding that provided drop-off locations for collecting the shell. While operating, the program provided 6-15 percent of the needed material for restoration activities. Unfortunately, due to budget cuts and a reduction in staff, as of 2018, all state-run oyster shell recycling centers have been removed in North Carolina. A few counties, municipalities and organizations have stepped up to fill the void. Shells can be brought to a limited number of collection points along the coast. The most up-to-date listing of shell collection points can be found at nccoast.org/shellrecycling.

Putting the Shell to Work

Restoration of oyster habitat can be enhanced through reef building. This type of restoration is designed to address the decline in oyster population and suitable habitat. Building reefs for restoration is carried out in a management area such as Shellfish Management Areas, Research Sanctuary and/or in prohibited waters with limited to no harvest. The reefs are sited and designed through a collaborative stakeholder process to meet the identified oyster population needs in that area. The constructed reefs can provide oyster habitat, produce broodstock, support oyster populations and provide other ecosystem services. This restoration effort is often the result of a collaborative effort among conservation organizations, researchers and DMF.

Since 2004, oyster restoration stakeholders, have worked with DMF to site, design and construct over 30 acres of oyster reef habitat in the central and southern regions (Figure 8). From Williston Creek in the Down East area of Carteret County to the Lockwood Folly River in Brunswick County, these projects have created oyster reef habitat in areas experiencing high-harvest pressure. The reefs have been placed in both prohibited and approved harvest waters, but a significant majority have been in polluted shellfish waters closed to harvest to reduce user conflict. The sites have been managed as Shellfish Management Areas, Research Sanctuaries or through no designation at all.

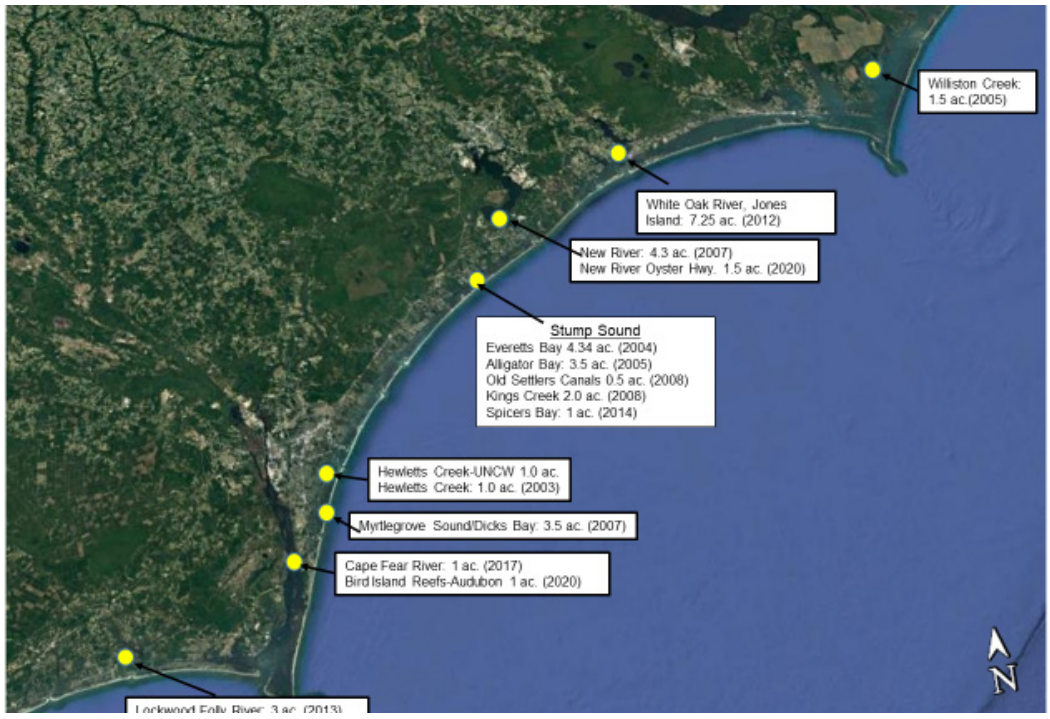


Figure 8. *Over 30 acres of oyster habitat have been created and restored by Blueprint stakeholders through patch reef creation at various sites throughout the state's central and southern coastal waters. Courtesy North Carolina Coastal Federation*

These projects were selected, designed and constructed through an informal collaborative process engaging stakeholders from the Blueprint's regional workgroups and the community. As described in the Sanctuary strategy, further reef-building efforts will be greatly enhanced and aided through the consideration of a management area strategy for these regions.

Top three actions for shell recycling for reefs

Action 1: Collect shell through a partnership and volunteer led shell collection effort.

Organizations involved in this action include North Carolina Coastal Federation, North Carolina Restaurant Association, local municipalities, restaurants, businesses and others.

Specific action steps include the following:

- Assess opportunities and build partnerships with the following:
  - Towns and counties to provide shell drop-off locations.
  - Restaurants and fish houses/seafood dealers for volunteer pick-ups where possible.
  - Private waste hauling/recycling companies to service restaurants.
- Collect 15,000 bushels of shell annually by 2025.
- Grow the Restaurant to Reef Program.
  - Engage 50-75 percent of all oyster selling restaurants on the Outer Banks in the program.
  - Determine ability to expand the Restaurant to Reef Program to Carteret County and the Cape Fear region by 2025.
- Secure funding and seek ways for businesses to participate in an economically feasible way.
  - Determine funding sources, which may include:
    - Federal, state, private restoration grants.
    - NCDWM: county tax break to companies hauling recyclable products and is available to assist when needed. This tax credit can be applied to equipment purchases.
    - NCDEQ Recycling Business Assistance Center: possible grants and staff can provide assistance/guidance to participants, such as restaurants and businesses.
- Determine funding needs, which may include:
  - Dumpsters and other collection drop-off point needs.
  - Pilot projects/startup funds with private haulers and restaurants.
  - Promotion/education of program.
  - Volunteer supplies.

Action 2. Improve shell collection and storage logistics.

Organizations involved in this action include Albemarle-Pamlico National Estuary Partnership, North Carolina Coastal Federation, as well as local and county waste management, key businesses and others.

Specific action steps include the following:

- Create at least two drop-off locations in each coastal county by 2025.
- Create at least two new stockpile sites for shell along the coast.

Action 3. Use recycled shell in reef building activities.

Organizations involved in this action include Albemarle-Pamlico National Estuary Partnership, Division of Marine Fisheries, North Carolina Coastal Federation and others.

Specific action steps include the following:

- Restore 20 acres of oyster reef in the southern region of the state.
  - Regional stakeholders will collaborate with the Managed Areas Workgroup to prioritize growing areas for reef building for restoration.
  - Stakeholders will develop a list of sites, restoration goal for each area and design recommendations for the restoration projects.
  - Recommendations will be used to seek grant and other funding to implement the projects and support monitoring of the sites.
- Restore at least 5 acres of oyster reef using recycled shell in the northern region of the state.

Strategies to Harvest Oysters

Harvest: Sustainable Wild Harvest

Overarching goal for the sustainable wild harvest strategy: Sustainably manage natural oyster habitats within public trust areas to perpetuate ecosystem services and wild harvest.

Arguably the longest-standing strategy related to oysters in North Carolina is wild harvest management. Initial management efforts by DMF focused on regulating harvest methods and amounts. From 1889 to 1908, yearly harvests of oyster typically exceeded 500,000 bushels. Around 1910, harvest levels dropped significantly to less than 263,000 bushels, resulting in a new initiative by the state's Fisheries Commission Board to incorporate restoration of oyster habitat.

For the greater part of the 20th century, oyster landings generally declined. In response to the decline in oyster landings, the North Carolina Blue Ribbon Advisory Council on Oysters was formed in 1992 by the state General Assembly. In its final report, the council stated, "The health of North Carolina's oyster population is a good indicator of the overall health of our estuaries, and all prudent measures should be taken to ensure a viable oyster resource." The council concluded that there is no single explanation for the progressive loss of oysters over the preceding century. It found that habitat destroyed by oyster harvesting has never been adequately replaced by oyster enhancement programs; public trust waters have not been effectively developed for oyster aquaculture; coastal lands have been developed for agriculture, forestry and residences with little regard for impact on oysters or other aquatic resources. In addition, it found that the decline of the eastern oyster (*Crassostrea virginica*) throughout its range in the U.S. can be attributed to outbreaks of oyster diseases; failure to preserve oyster reef habitat against degradation; overharvest; and substantial deterioration of coastal water quality.

This strategy focuses on what additional management actions should be taken in the next five years so that oyster populations in the state increase, and that the increased population is managed in a way that supports a sustainable fishery and important ecosystem services for generations to come.

Accomplishments

Since 2001, oysters have been managed by DMF following a Fisheries Management Plan (FMP) adopted by the North Carolina Marine Fisheries Commission. The original goal of the FMP was to restore the state's oyster population so that it might produce the optimum yield and regain its role in providing ecosystem services to North Carolina's estuaries. That goal was amended in 2017 to read: Manage the state's oyster population so that it achieves sustainable harvest and maximizes its role in providing ecological benefits (aka ecosystem services) to North Carolina's estuaries.

To achieve the goal of the plan, the original FMP and its later amendments have consistently included the following objectives, if achieved, would result in regaining some of the oyster habitat, ecosystem services and harvest that have been lost during the past centuries:

- Identify, restore and protect oyster populations as important estuarine habitat.
- Manage and restore oyster populations to levels capable of maintaining sustained production through judicious use of natural oyster resources, enhancement of oyster habitats, and development and improvement of oyster production on shellfish leases and franchises.
- Minimize the impacts of oyster parasites and other biological stressors through better understanding of oyster disease, better utilization of affected stocks, and use of disease and other biological stress resistant oysters.
- Consider the socioeconomic concerns of all oyster resource user groups, including market factors.
- Recommend improvements to coastal water quality to reduce bacteriological-based harvest closures and to limit other pollutants to provide a suitable environment for healthy oyster populations.
- Identify and encourage research to improve understanding of oyster population ecology and dynamics, habitat restoration needs, and oyster aquaculture practices.
- Identify, develop, and promote efficient oyster harvesting practices that minimize damage to the habitat.
- Initiate, enhance, and continue studies to collect and analyze economic, social, and fisheries data needed to effectively monitor and manage the oyster resource.
- Promote public awareness regarding the ecological value of oysters and encourage public involvement in management and enhancement activities.

Since 2001, there have been four amendments to the FMP that have changed some of the management rules that were adopted to implement these objectives. None of these amendments have changed the objectives, and still provide the framework used by the state to devise actions needed to restore oyster stocks,

improve the sustainability of oyster harvest of wild stocks, and improve oyster production on shellfish leases and franchises.

- 2001 Original Oyster FMP:
  - Set up process for designation of additional areas limited to hand harvest methods around Pamlico Sound.
  - Recommended several statutory changes to the shellfish lease program including higher fees, training requirements and modified lease production requirements.
- 2003 Amendment 1:
  - Changed one of the criteria for designation of hand harvest areas from waters generally less than 10 feet deep to waters less than 6 feet deep.
- 2008 Amendment 2:
  - Adopted 15-bushel harvest limit in Pamlico Sound and 10-bushel harvest limit for all gears (hand and mechanical) in designated areas around the sound.
  - Reduced available harvest season.
  - Changed method for lease production averages calculations.
  - Limited lease applications to 5 acres.
  - Recommended expansion of oyster sanctuary construction efforts.
  - 2010 Supplement A raised the potential harvest limit in Pamlico Sound to 20 bushels and created a monitoring system for determining when to close mechanical harvest in that area.
- 2014 Amendment 3:
  - Created two seed oyster management areas in Onslow County.
- 2017 Amendment 4:
  - Continuation of the monitoring system for when to close mechanical harvest in public harvest areas. If sampling by DMF indicates that oysters of legal size have been reduced to below 26 percent of the live oysters.

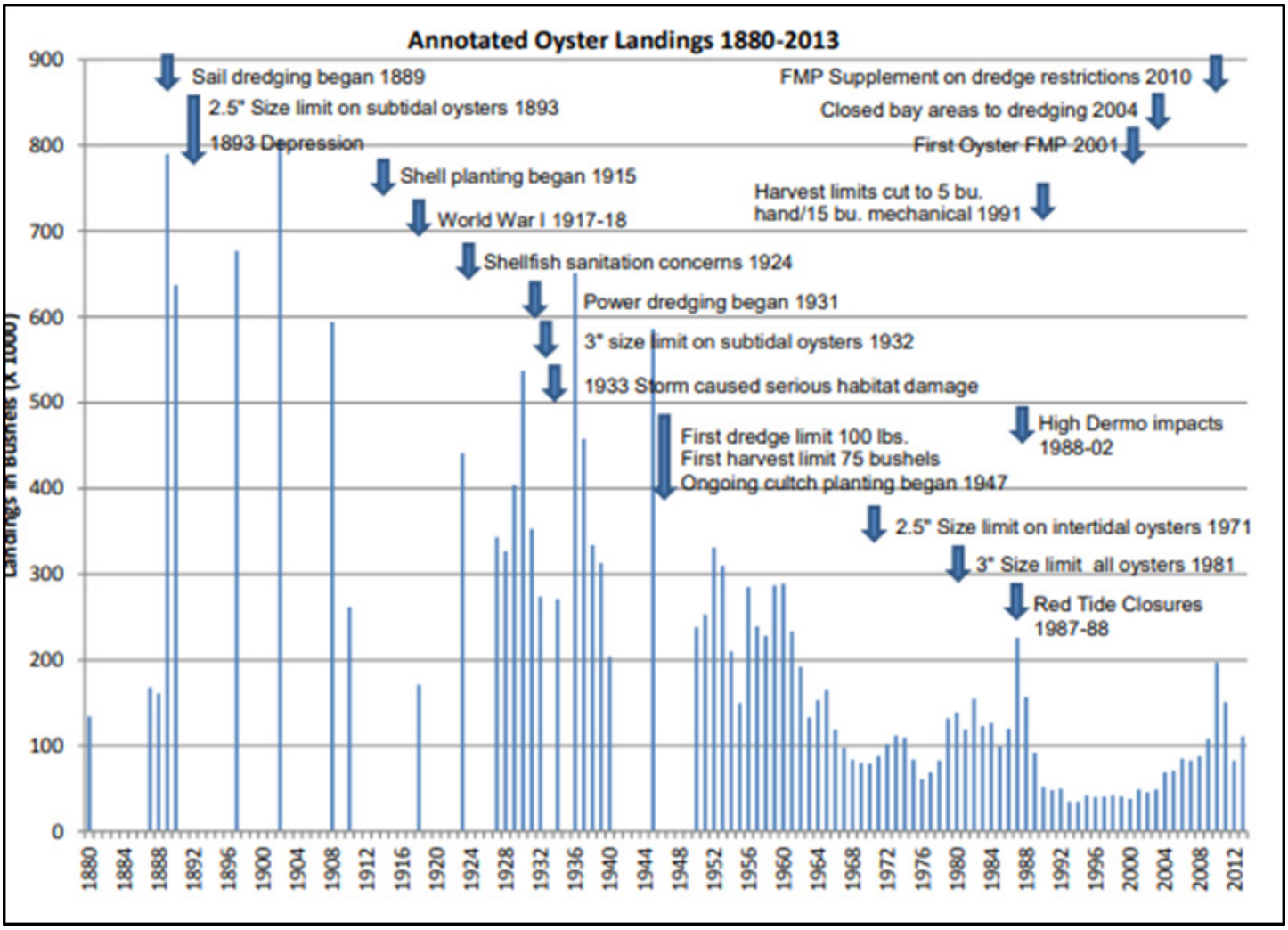


Figure 9. *Statewide annual landings of oysters (in bushels) from 1880 to 2013. Landings peaked in 1902 at 800,000 bushels. Since that time, landings have generally declined. Arrows indicate factors affecting the North Carolina oyster fishery and associated landings over time. NCDEQ, Oyster FMP Amendment 4, 2017.*

- Reduction of the culling tolerance from 10 to 5 percent in the commercial fisheries off public harvest areas.
- Reduction of the daily harvest limit for holders of the shellfish license off public harvest areas to two bushels per person, per day maximums, four bushels per vessel.
- Continuation of the six-week open season to mechanical harvest in public harvest areas of the bays with changes in the timing of the six-week opening.
- Modifications to shellfish lease provisions.
- Adding convictions of theft on shellfish leases and franchises to the types of violations that could result in license suspension or revocation.

Status and Trends

North Carolina commercial oyster landings have been in decline for most of the past century (Figure 9). This decline was likely initiated by overharvest and compounded by habitat disturbance, pollution, and biological and environmental stressors. After 1991, oyster stocks and harvests experienced additional significant declines from disease mortalities, toxic algae blooms and low spawning stock biomass. Harvests amounts began to rise again around 2002, and have fluctuated annually near or above about 100,000 bushels since then.

It is important to note that landings are impacted by harvest effort. In North Carolina harvest effort can come from hand harvest or mechanical (i.e., dredge) harvest. DMF reports that hand harvest effort has remained relatively constant over the last decade while mechanical harvest effort fluctuates annually. In addition, the last decade has seen an increase in landings from private leases versus publicly harvested areas (Figure 10). In 2017, the volume of oysters harvested from private leases exceeded that which was harvested from publicly harvested areas.

Stock Assessment

A stock assessment is a scientific study that uses available data to estimate: the abundance of wild oysters in North Carolina; the fraction of oysters that die each year from natural causes including disease; and the fraction of oysters that are harvested each year by fishing. Stock assessments develop biological reference points, which serve as benchmarks used to determine if abundance and removals are at sustainable levels and the overall condition of the oyster population.

An oyster stock assessment has been attempted by DMF, but data are not available to perform a traditional assessment. It has not been possible to estimate population size, demographic rates, or removals from the population of oysters in the state.

To address this issue, a pilot project led by The Nature Conservancy and North Carolina State University-Center for Marine Science and Technology, with guidance from DMF, is being conducted from 2020-2023 to develop a subtidal oyster population survey with the potential to become a long-term biological sampling program in DMF.

Concurrent with these efforts and outside the scope of this pilot project, The Nature Conservancy is collaborating with DMF and commercial oystermen to refine the collection of harvest data to gather more accurate information on harvest levels and effort, as well as discard mortality from dredges. DMF is developing a biological sampling program for intertidal oysters using existing bottom mapping sampling program data to delineate oyster reefs and evaluate changes over time for intertidal oysters in the southern region of the state.

Results from these projects will be used to form a methodology for a stock assessment for oysters in North Carolina. However, due to the necessary extensive sampling, data collection

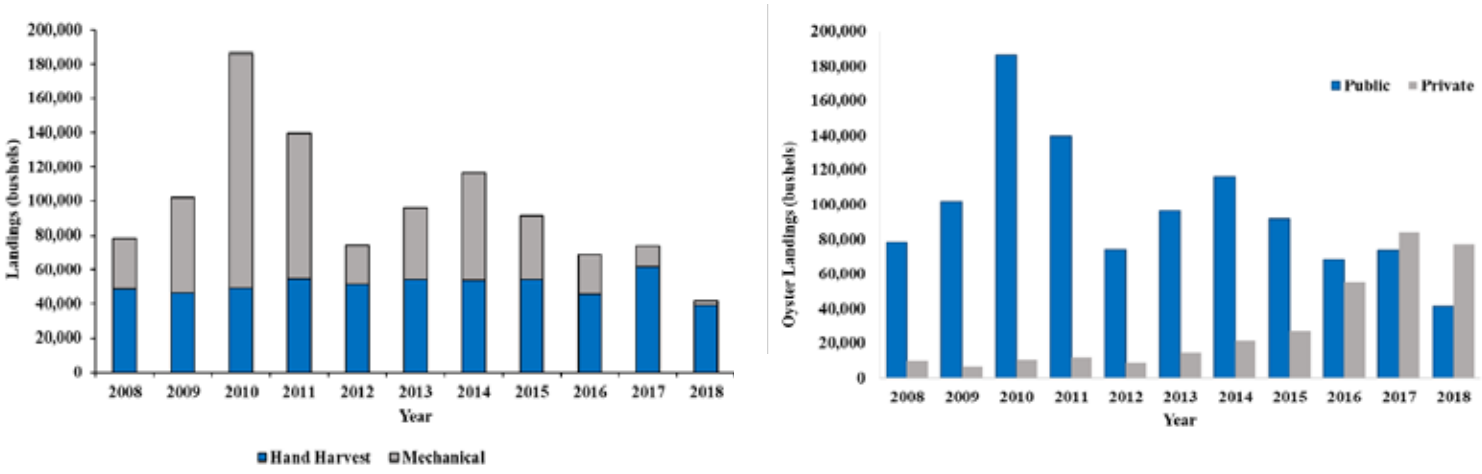


Figure 10. *Annual commercial oyster landings (bushels) from: A) public bottom separated by mechanical and hand harvest methods 2008-2018; B) separated by private and public bottom in North Carolina, 2008-2018 (DMF Trip Ticket Program). Fishery Management Plan Update, Eastern Oyster, August 2019.*

and analysis, the stock assessment will most likely not be operational for the entire coast during the next five years of the Blueprint and the next FMP. Therefore, management actions taken will still need to be based upon existing knowledge and professional expertise.

Shellfish Mapping

To support the stock assessment and aid in oyster management, up-to-date and reliable maps of oyster reefs/shell bottom are critical. As of October 2020, all shellfish waters less than 12 feet deep had undergone shell bottom habitat mapping within CHPP Management Units. This program defines shell habitat, or shell bottom, as significant cover, less than 30% of bottom, of living or dead shells.

DMF's Estuarine Bottom Mapping Program indicated the existing extent of mapped shell bottom in North Carolina as 16,551 acres Subtidal Shell Bottom, 5,185 acres of Intertidal Shell Bottom, totaling 21,736 acres.

The southern estuaries have the greatest relative area of shell bottom, mostly intertidal. The Cape Fear River had the greatest relative area of subtidal shell bottom. The largest area of subtidal shell bottom was in Core and Bogue Sounds, followed by Pamlico Sound areas, New and White Oak rivers, followed by the southern estuaries (NCDEQ, Oyster FMP Amendment 4, 2017). An example of the estuarine bottom mapping products is included in Figure 11.

Oyster Relay

Oyster relay is the practice of moving oysters from polluted, or closed due to high bacteria count, portions of sounds and tributaries to shellfish leases that have open water designations. The oysters remain on the lease for a period of time to allow for cleansing or purging themselves by continuing their normal, filter-feeding and digestive processes. Relay from closed areas is a highly managed program where oysters can be removed out of specific polluted areas to shellfish leases with Marine Patrol coordination, occurring weekdays between April 1 and May 15. Shellfish leases with relayed oysters must remain closed until reopened by proclamation, about 21 days. Relay effort is declining in North Carolina as more intensive cultivation methods on shellfish leases replace traditional bottom gardens. The 2020 relay season was more limited, only having two days per week available for relay due to National Shellfish Sanitation Program guidelines and resources accessibility. There is a lack of monitoring to determine if relay methods cause any long-term harm to the population of oysters growing in closed areas where relay occurs, and if relay practices reduce the ecosystem services previously provided by these oysters in a significant way.

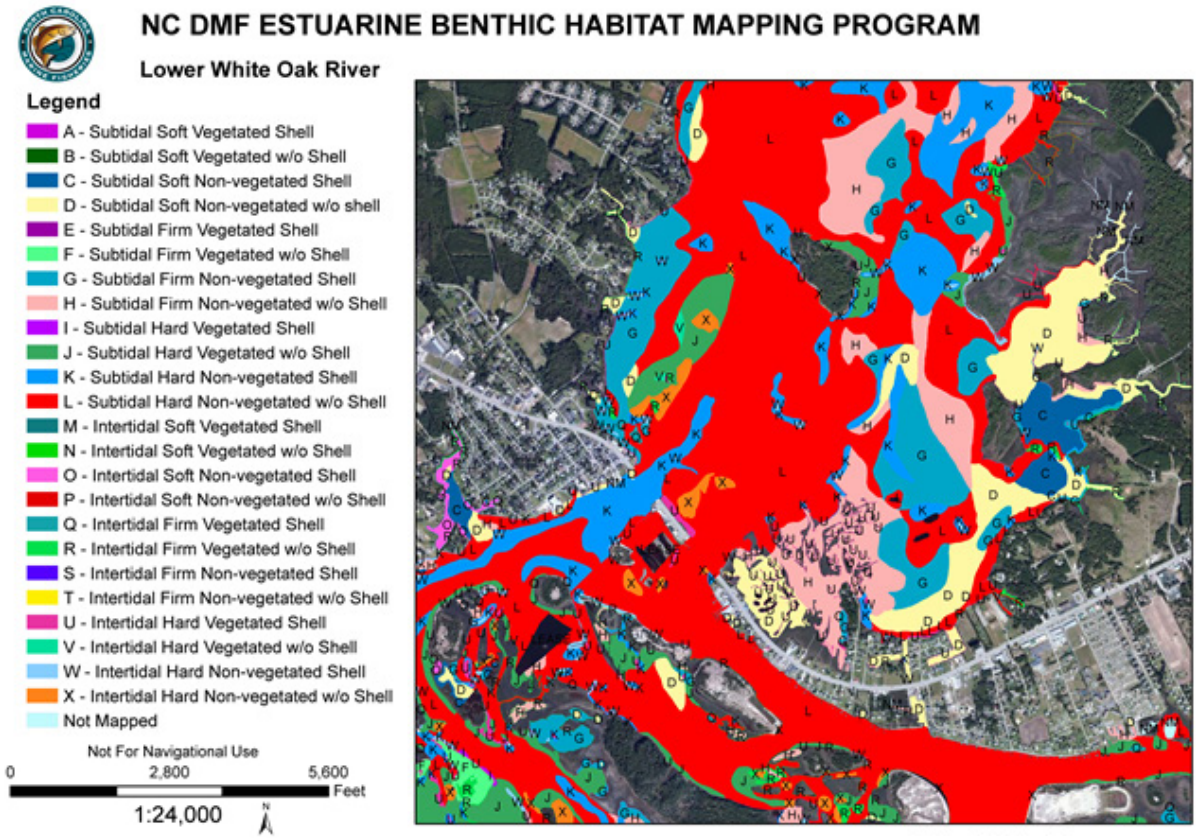


Figure 11. *Estuarine benthic habitat mapping product of the Lower White Oak River. An interactive mapping tool is available on DMF's website and shows the results of their active estuarine benthic mapping activities.*

Top four actions for sustainable wild harvest

Action 1. Conduct sampling, analyze data and implement the methodology to establish a stock assessment of the oyster population in North Carolina.

Organizations involved in this action include Albemarle-Pamlico National Estuary Partnership, Division of Marine Fisheries, North Carolina State University-Center for Marine Science and Technology, The Nature Conservancy, University of North Carolina Wilmington and others.

Specific action steps include the following:

- Collaborate among stakeholders to develop a fisheries independent stock assessment methodology.
- Support and secure needed resources for DMF by the Oyster Steering Committee. Conduct research to establish the assessment methodology, complete sampling and analyze data to create a stock assessment.
- Develop a stock assessment methodology.
- Ensure that any resulting recommendations from the methodology and assessment are considered in the next update of the oyster FMP and CHPP.

Action 2. Develop a fishery-independent oyster abundance index to assist with oyster management decisions.

Organizations involved in this action include Albemarle-Pamlico National Estuary Partnership, Division of Marine Fisheries, North Carolina State University-Center for Marine Science and Technology, The Nature Conservancy, University of North Carolina Wilmington and others.

Specific action steps include the following:

- Create a stakeholder working group to determine the methodology, entities and resources needed to develop an oyster abundance index.
- Establish sentinel sites, or standardized sampling stations, to serve as the foundation of a fishery independent index of oyster abundance. Sentinel sites should be located in both open and closed shellfishing waters to assess the impacts of harvest on the regions oyster resources. Careful consideration must be given to abundance index sampling strategies, and to the scale to which any management action is applied. Two superficially similar and adjacent oyster reefs may vary greatly in the percent of legal oysters. Interpreting local size distributions as representative of entire regions can be erroneous.
- Develop the oyster abundance index, coordinated with the stock assessment development.
- Use trends from this independent abundance index, as well as input from harvesters and dealers to inform and enact management actions.

Action 3. Refine oyster landing data collection to provide more information to assist with management.

Organizations involved in this action include Division of Marine Fisheries, North Carolina Coastal Federation, The Nature Conservancy and others.

Specific action steps include the following:

- Create a working group in 2022 to examine how landing estimates can be obtained to improve data collection and reporting.
- Consider new data tracking procedures to support the stock assessment.
- Collect information specific to determine if harvest landings are coming from wild stocks for commercial purposes, wild stocks in prohibited areas through the relay program; cultch planted reefs created by DMF; recreational harvest estimates (through surveys); and farm-raised oysters from shellfish leases.

Action 4: Enhance, maintain and link habitat mapping efforts to develop a substrate budget, guide restoration efforts and support the stock assessment development.

Organizations involved in this action include Albemarle-Pamlico National Estuary Partnership, Division of Marine Fisheries, The Nature Conservancy and others.

Specific steps include the following:

- Establish a workgroup to look at the need to establish a substrate budget for areas where wild harvest is occurring.
- Update and maintain the baseline shellfish habitat mapping using the most appropriate technology.
- Consider the use of selected sites being remapped more frequently using rapid analysis technology such as drones or sonar.
- Selectively monitor the condition and status of habitat to guide oyster restoration and management.
- Link mapping needs to CHPP Strategic Habitat Areas.
- Ground truth mapping efforts in partnership with university researchers and others.
- Use data to support the development of a balanced shellfish budget and change analysis for the state's 21,000 acres of oyster habitat along the coast.
- Use data to identify and support restoration and management goals.

Harvest: Cultch Planting

Overarching goal for the cultch planting strategy: Use cultch planting to replenish and enhance oyster habitat for commercial harvest and ecosystem services.

North Carolina has worked to increase oyster production in the estuarine waters for more than a century. Prompted by low harvest in the beginning of the 20th century, the state's Fisheries Commission Board began to rebuild oyster stocks by planting shell, or cultch, for substrate and seed oysters, now commonly referred to as cultch planting. Cultch planting is the longest running strategy that has been employed to enhance oyster resources in North Carolina.

Historical Cultch Planting Program: 1915-1998

The state planted between 10,000 and 12,000 bushels of shell each year from 1915 to 1920. Additional funding then allowed the state to plant around 100,000 bushels of seed oysters and substrate in the early 1920s. Harvest statistics show a rebound in landings from 1923 to around 1931 with landings ranging between a high of 441,307 bushels to a low of 326,659 bushels. Then from 1932 to 1934 landings dropped again, reaching a low of 271,192 bushels.

In 1934, the state conducted the largest annual oyster enhancement project in North Carolina by planting 825,000 bushels of seed oysters and 78,567 bushels of shells. These planted areas were closed to harvest until 1936. Oyster landings more than doubled from 271,192 bushels in 1934 to 651,050 bushels in 1936. In this case, the 1934 enhancement efforts likely provided for substantially increased harvest landings.

Records do not indicate that any significant investments were made to rebuild oyster stocks for the next decade, and during this period, landings declined significantly, except for one bump in landings at the end of World War II in 1945. Then Gov. Cherry created a special oyster commission in 1946. The legislation resulting from the oyster commission's recommendations contained landmark changes in oyster management. The renewed enhancement effort was known as

the Oyster Rehabilitation Program. Provisions were made for an ongoing, large-scale shell and seed oyster planting program on natural oyster rocks, an oyster tax to support the program, a requirement that 50 percent of the shell from shucking operations be contributed to the program, a 50 cents per bushel tax on shell stock shipped out-of-state, and a $100,000 appropriation to initiate the program.

Plantings during the first 10 years of the program totaled 838,000 bushels of shell and 350,734 bushels of seed oysters. By the mid-1950s, appropriations were exhausted, landings and oyster tax collection had not increased. Landings during this period fluctuated between 149,489 and 331,472 bushels.

Prior to 1954, fishermen were employed to carry out enhancement activities. In 1954, the state purchased a 40-foot wooden barge and began to deploy material on its own.

In 1956, a request for an $80,000 annual appropriation was presented to the state General Assembly to increase oyster enhancement efforts to 500,000 bushels per year. This request was approved. The state reported that repeated severe hurricane activity negated most of the oyster rehabilitation efforts conducted since 1947 (Munden, 1981). Oyster landings remained above 200,000 bushels each year until 1962. To date they have not reached that level of harvest again.

In 1972, the program transitioned from employing fishermen, to carry out cultch planting deployments, to a program fully implemented by the state. The state acquired barges, support equipment and staff to run the program itself. The fleet of vessels used by the program continued to expand and get larger for the next couple of decades. New attempts to enhance oyster stocks were undertaken with increased appropriations in 1972, 1977, and 1979. The rehabilitation program received a grant from the Coastal Plains Regional Commission in 1980 along with state appropriations that allowed it to pay for its operations. These funds allowed the state to buy two large surplus military landing crafts that it put into service to deploy shells. In 1980, 257,900 bushels of substrate were planted, and that total was increased to 456,710 bushels of substrate in 1981. The program continued with state appropriations deploying around 250,000 bushels of substrate each year until it was revised by the legislature in 1997. Landings during this period peaked in 1987 at 226,283 bushels. From then they dropped significantly, reaching a low point in 1994 of 34,420 bushels. Landings never went above 100,000 bushels after 1988 through 2008.

Modern Cultch Planting Program: 1998 – to date

The revised Shellfish Rehabilitation Program began in 1998 with an annual budget of approximately $268,650. Until fiscal year 2015-2016, annual funding was limited to approximately $300,000 to purchase and transport cultch material. This funding allowed for annual enhancement of 30-40 acres of harvestable reef. In fiscal year 2015-2016, funds for cultch planting were increased to approximately $600,000, with another increase to a total of approximately $900,000 in fiscal year 2016-2017. In subsequent years, annual appropriations for the program have increased substantially to over $1 million in some years to cover the cost of substrate, staffing and vessels. Increases in appropriations have resulted in substantial increases in annual deployments and investments in much needed modernization of fleet equipment.

Methods of oyster rehabilitation through cultch planting has remained quite consistent since 1998. Planting sites are selected based on criteria including bottom type, salinity, currents,

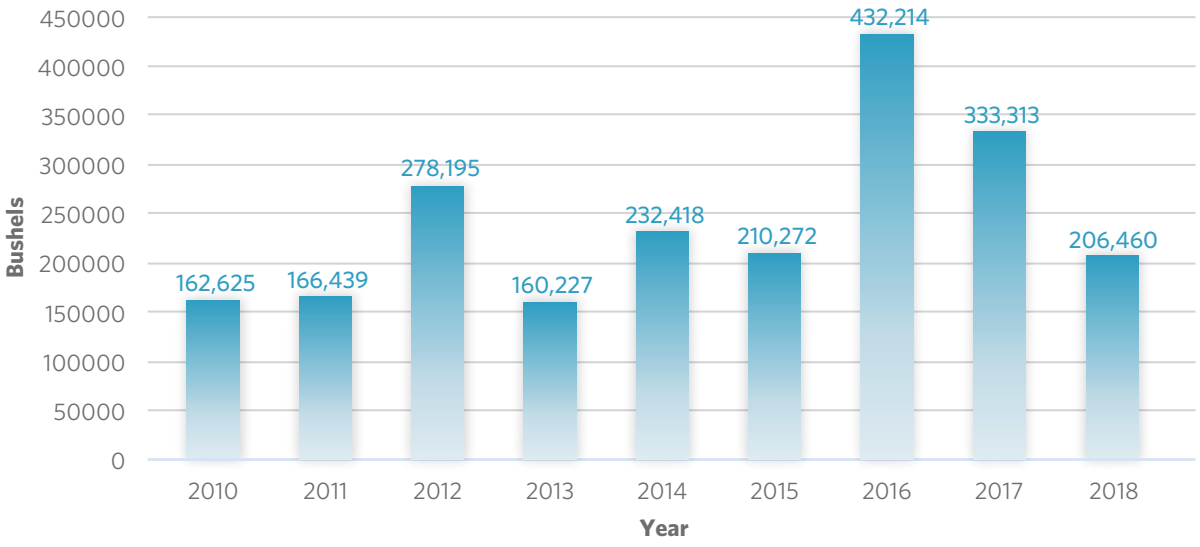


Figure 12. *Amount of cultch deployed annually by DMF from 2010-2018. 2018 State of the Oyster Report*

historical production, input from local fishermen and effects of fishing operations in the area. DMF continues to successfully use shell and marl, nearly all of which is deployed by DMF Cultch Planting Program vessel crews and heavy equipment operators. However, other methods have been explored with varying levels of success. These alternate methods include hiring fishermen to gather and transplant seed oysters and hiring marine contractors to supplement deployments. Efforts to increase the size of planting sites in recent years have reduced the total number of sites planted per year, but the integrity and effectiveness of the sites seem to have improved. Today, cultch sites range in size from 0.1 to 10 acres and include annual deployments of up to 400,000 bushels of material (Figure 12).

Monitoring

For a period of three years post-construction, DMF monitors each cultch planting site to observe trends in annual recruitment, size frequency and population density. Long-term monitoring of cultch planting sites is not conducted due to funding and staffing limitations, though long-term datasets are always more desirable for evaluating trends. Despite limited resources, DMF has recruited and funded university partners to provide analysis of cultch site performance. Recently published literature from North Carolina State University-Center for Marine Science and Technology provides the most detailed evaluation of population demographics at cultch planting reefs in North Carolina, as compared to naturally occurring reefs and sanctuary reefs, which are protected from harvest. In that report, researchers found that total mean population density for cultch-planted sites is 247 oysters per square meter (Figure 2). Some sites are exceptions, presumably due to low spat fall, catastrophic events or depletion. Size structure at harvested reef sites like cultch planting reefs is truncated compared to sanctuaries with harvested reefs hosting fewer legal-sized oysters. Cultch reefs successfully host nearly 5 times more legal oysters than natural reefs where no enhancement effort has occurred. On average at cultch sites, 11 percent of oysters are large enough at 3 inches or larger to legally harvest (Peters et al. 2017, Figure 3).

Using an estimate of 27 legal oysters per square meter, a conservative estimate is that cultch sites host approximately one bushel of harvestable product for every 11 square meters of surface area, about 300 oysters per bushel. Based on that estimate, one acre of harvestable cultch reef should yield approximately 368 bushels of oysters, which is about 110,369 individual legal oysters. Estimating the number of oysters produced over the lifespan of a cultch reef proves difficult, as reefs take several years for oysters to mature. Harvested in the third year, for example, may only last approximately five years, and may be harvested multiple times during their lifespan. Under those assumptions, and in an oversimplified example, five years of planting 40 acres annually will make 200 acres of habitat but 240 acres of area available for harvest. Again, this is considering reefs may be harvested multiple times.

The following is an example of this scheme:

	Planted Acres	Acres with Harvestable Oysters
Year 1	40	0
Year 2	40	0
Year 3	40	40
Year 4	40	80
Year 5	40	120
Year 6	40	120

In the above example, oysters from year one sites are not large enough for harvest until year three. In year four, both year one and two sites are producing legal-sized oysters. In year five, sites from years one to three are producing oysters for harvest (120 acres). In year six, sites from year one may no longer exist, but sites from year two to four are producing. In this simplified scheme, the total habitat area available for annual harvest never exceeds 120 acres, but since habitats are available for harvest in years' prior, the harvested acreage is cumulative. Year six is not included in the oyster production estimates below.

Return on Investment

At a cumulative 240 acres of harvested area, 88,320 bushels of oysters are estimated to be available to the fishery for harvest over the five-year period, given 27 legal oysters per square meter. Not considering the fish production value, water filtration value, or other ecosystem service value of the habitat, the market value of oysters provided by 200 acres of constructed habitat over five years is estimated to be $6,624,000 at $75 per bushel. Typical investment for DMF to construct 40 acres using 250,000 bushels is approximately $795,000, or about $1.90 per bushel for limestone marl and $1.25 per bushel to deploy. Based on reef demographics in published literature and construction cost estimates, the five-year investment cost of $3,975,000 is met with a direct return potential of $6,624,000; an about 167% return in harvest value alone.

It is important to recognize that this return on investment is only realized if the reefs are entirely exploited during the five-year period. History has taught us that harvest trends more closely follow patterns of socioeconomics and can be correlated to market, regulatory and environmental factors, more so than biological productivity. Therefore, it is important to draw a clear

distinction between annual harvest levels and reef productivity or success. Regardless of harvest levels and subsequent annual market value, oyster reefs developed by cultch planting have indirect and likely immeasurable monetary value, providing water filtration, fish production, both recreational and commercial, and other ecosystem services which positively impact tourism and overall environmental health.

Cultch Planting Studies

DMF is currently undertaking an internal review of the Shellfish Rehabilitation Program to assist in: drafting new strategies for cultch site management; determining the net benefit of cultch sites, dollar value and biological value, and quantifying the effect of mechanical harvest on oyster resources at cultch sites. This review will also examine potential additional methods to traditional cultch planting including fewer but large reef sites in mechanical harvest areas such as Pamlico Sound; as well as management measures to monitor, maintain, and regulate mechanical harvest reefs over time.

In 2016 RTI International released a report, commissioned by the Albemarle Pamlico National Estuary Partnership, "Economic Analysis of the Costs and Benefits of Restoration and Enhancement of Shellfish Habitat and Oyster Propagation in North Carolina."

The report found that for small cultch planting projects, it is more time and cost-effective for DMF to complete them instead of contractors, based on DMF vessel operational costs and contractor willingness. Large-scale projects are also considerably more cost-effective, but may require considerably more time to construct. For example, deploying 30,000 tons of material, which is equivalent to 668,000 – 1.1 million bushels, would create around 145 acres, and will take contractors four months to complete. DMF could complete the same work in approximately three years, but at a considerably lower cost due to the availability of equipment and resources. The report recommended that DMF hire contractors to complete large-scale projects when time is an important consideration. However, DMF oversight of deployment, timelines, and the cost of monitoring contractors should all be considered when estimating costs and working with contractors. More analysis should be completed to determine the breakpoint at which it becomes more effective to hire contractors.

Complementary Plans

The Blueprint and CHPP overlap on a number of issues, goals and management options. In the 2016 CHPP, oyster rehabilitation and habitat enhancement was one of the main focus areas of that edition. Cultch planting was an important part of that focus. The CHPP and the Blueprint both recognize a number of initiatives that are significant in the effort to rehabilitate and manage the state's oyster production. Included in those initiatives is the need to develop a cooperative public/private, self-sustaining shell recycling program by providing financial incentives in exchange for recycled shell. Also of importance to both plans is the need to identify alternative substrates for larval settlement in intertidal and subtidal reefs. Both plans also seek to establish long-term monitoring programs to support future decision making and to use new siting tools and monitoring protocols to maximize reef success.

Top three actions for cultch planting

Action 1: Conduct a cultch planting program study.

Organizations involved in this action include Division of Marine Fisheries, North Carolina Coastal Federation and key stakeholders including contractors, commercial fishers and others.

Specific action steps include the following:

- Analyze the strengths and weaknesses of existing procedures, policies, rules and laws that govern or affect the existing cultch planting program in North Carolina.
- Analyze quantitatively existing programmatic data.
- Summarize cultch planting programs in other states and countries, including a comparison of how these entities fund their programs; types, volume and density of substrate deployed; how substrate is deployed and managed; and benefits documented, as well as an estimated cost-benefit analysis of each program studied.
- Analyze how to expand federal funding to help pay for deploying cultch in North Carolina.
- Examine environmental policies and permits that govern deployment of cultch in North Carolina and how they can be improved; i.e., incorporating the use of crushed concrete into DMF's permit.
- Identify strategies, resources and statutory changes needed to incorporate the use of private contractors to support and expand cultch planting efforts.
- Incorporate substrate budget and enhancement plans from the sustainable wild harvest strategy to ensure cultch planting efforts reflect regional habitat needs and regional harvest pressure to maintain oyster population.
- Identify the statutory amendments and appropriations that will be needed to implement the report's recommendations.
    - Ability to establish longer-term contracts and purchasing agreements for appropriate reef building materials and work with contractors.
    - Ability to carry over funding from multiple fiscal years.

- Resources required to implement and maintain long-term monitoring.

Action 2: Incorporate cultch planting program evaluation recommendations into program development and implementation.

Organizations involved in this action include Division of Marine Fisheries with the Marine Fisheries Commission, North Carolina Coastal Federation, North Carolina State University-Center for Marine Science and Technology, the legislature, key stakeholder support and others.

Specific action steps include the following:

- Ensure cultch planting efforts reflect regional habitat needs and regional harvest pressure to maintain oyster population.
- Establish and maintain siting and monitoring parameters at long-term sentinel sites for cultch sites similar to the oyster sanctuary program. Maintaining long-term monitoring will be dependent upon available resources.
- Continue to test and evaluate cultch planting strategies of larger sites; rotational harvest on cultch sites; varying reef heights and thickness; volume of material in the right locations on a regional scale; remote setting spat on shell for seeding of cultch sites; and creating metrics for appropriate sites, acreage, size, type, and amount of materials required.
- Continue to document, disseminate and highlight ecosystem services provided by the cultch planting sites.

Action 3: Plant cultch to build 200 acres of harvestable oyster habitat over 5 years.

Organizations involved in this action include: Division of Marine Fisheries, North Carolina Coastal Federation, North Carolina Coastal Reserve and National Estuarine Research Reserve, North Carolina State University-Center for Marine Science and Technology, as well as contractors, commercial fishers and others.

Specific action steps include the following:

- Maximize DMF's current cultch planting capacity to build an average of 40 acres of cultch reefs annually over five years. This comes with a goal to increase internal and external DMF capacity to eventually be able to build 100 acres of cultch reefs annually.
- Test and evaluate rotationally harvested oyster areas by DMF using a portion of the 200 acres of cultch reefs in the Pamlico Sound while maintaining cultch planting efforts in other high harvest areas of the coast.
- Plan and implement reefs that maximize harvest and ecosystem services.
- Use science to inform siting and management for long-term maintenance and oyster productivity.
- Consider needed management and enforcement of closed area.
- Select sentinel sites for long-term monitoring.

Harvest: Shellfish Aquaculture

Overarching goal for the shellfish aquaculture strategy: Build the shellfish aquaculture industry to create a $45 million industry by 2025.

In a display of bipartisanship, the state General Assembly recognized that shellfish aquaculture offers a unique economic opportunity to coastal North Carolina. Following the legislative mandate to study and recommend a shellfish aquaculture strategy for the state, the General Assembly unanimously adopted many of the key recommendations of that Strategy in 2019. The Strategy set out an ambitious goal for the shellfish aquaculture industry includes to achieve $100 million in value and create 1,000 jobs by 2030. The Blueprint reflects an interim goal of $45 million in value by 2025.

The state government and other partners have shown a strong commitment in supporting the rapidly growing shellfish aquaculture industry. A wide array of regulatory, scientific and legal support has contributed to the industry's expansion.

In 2016 the General Assembly mandated a multi-stakeholder project to study and advance efforts to ecologically restore and achieve economic stability of the shellfish industry. In partnership with the North Carolina Policy Collaboratory, the North Carolina Coastal Federation led the two-year multi-stakeholder endeavor that resulted in the state's first Shellfish Aquaculture Strategic Plan (Strategy, 2018). The Plan sets out an ambitious goal to sustainably grow the industry to $33 million in landings generating 1,000 jobs by 2030. This will make shellfish farming worth approximately $100 million to the coastal economy of North Carolina.

In addition, national recognition for North Carolina's aquaculture efforts was given when, in 2018, North Carolina became the sixth of eight states to join the National Shellfish Initiative. The National Oceanic and Atmospheric Administration established the Initiative in 2011 with the goal to increase populations of bivalve shellfish in our nation's coastal waters, including oysters, clams and mussels, through both sustainable commercial production and restoration activities. By joining the Initiative, the state recognized the value and importance of shellfish to its economy, cultural heritage, and environmental health. In launching a state initiative, North Carolina galvanized the support of local, state, and federal leadership in promoting sustainable seafood, shellfish restoration, and clean water.

Accomplishments

In 2019, the General Assembly showed further support for advancing the shellfish aquaculture industry by ratifying Shellfish Legislation (SL 2019-37; SB 648). This legislation implemented many of the Strategy's recommendations. The legislation:

- Allowed establishment of Shellfish Aquaculture Enterprise Areas that will group shellfish leases in large prior-designated leases. This will speed up the permitting of leases and potentially reduce user conflicts.
- Established a pilot project for large leases allowing up to three 50-acres leases in Pamlico Sound. This would attract large aquaculture operations.
- Increased production requirements for shellfish leases ensuring efficient use of public trust resources.
- Allowed transplanting seed oysters or seed clams from certain prohibited growing waters to private beds in open waters increasing the areas available for aquaculture.
- Established a Shellfish Cultivation Lease Review Committee within the Marine Fisheries Commission with the goal of reducing third party lawsuits.
- Mandated a number of studies, including how to reduce user conflicts around shellfish aquaculture; how to implement proper measures for theft of aquaculture gear and products; and how to set up a successful shellfish crop insurance program.

The North Carolina Coastal Federation, in 2020, finalized a feasibility study with the support from the U.S. Economic Development Administration to develop a network of shellfish aquaculture hubs, which are startup incubators, that support the shellfish aquaculture industry with land-based facilities. The study has identified a major industry limitation to be lack of storage, refrigeration and processing of the product. The study also identified three locations that could host these hubs. These facilities will be constructed in the next several years as funding is secured.

Mandated by the General Assembly, the North Carolina Coastal Federation finalized a Low-Interest Loan Program study in March 2020. The North Carolina Coastal Federation recommended a two-phased program. The study also recognized and emphasized the intricate relationship between the low-interest loan program and comprehensive crop insurance for shellfish. Without federal crop insurance for shellfish, a meaningful loan program will be difficult to achieve. Thus, the North Carolina Coastal Federation recommended the General Assembly to appropriate $1 million for the establishment of the two-phased loan program.

Summary table of the proposed loan program structure for the state:

Characteristics	PHASE I*	PHASE II**
Target Audience	New and existing small shellfish growers	Mid and large size shellfish growers
Loan Size	Up to $50,000	Over $50,000
Interest Rate	5.5%	TBD
Lender	Thread Capital & NCI Fund	Thread Capital & Other Lenders

**First five years of the loan program.*
***Contingent upon Phase I evaluation and development of comprehensive federal crop insurance program for shellfish aquaculture crops.*

Top three actions for shellfish aquaculture

Action 1: Support and assist the shellfish growers.

Organizations involved in this action include Carteret Community College, Division of Marine Fisheries, North Carolina Coastal Federation, North Carolina Sea Grant, North Carolina State University-Center for Marine Science and Technology, The Pew Charitable Trusts, University of North Carolina Institute of Marine Sciences, University of North Carolina Wilmington and others.

Specific action steps include the following:

- Economically support growers
  - Develop low-interest loan program for shellfish growers. (Year 1)
  - Include farmed shellfish products into Federal Crop Insurance. (Year 2)
  - Achieve eligibility of farmed shellfish products for future disaster relief funds. (Year 2)
  - Explore the opportunities that exist for the state Department of Agriculture to support shellfish growers.
  - Enable use of farmed oysters, seed or larger, for restoration purposes. (Year 2)
  - Implement findings of the study of penalties associated with theft of shellfish aquaculture gear and product. (Year 3)
  - Develop a nutrient reduction mitigation payment program. (Year 4)
  - Establish an Aquaculture Resource Grant Program administered by North Carolina Sea Grant. (Year 5)
  - Establish an Aquaculture Business Agent at North Carolina Sea Grant to aid the existing Marine Aquaculture Extension Specialist. (Year 5)
- Educationally support growers
  - Promote educational opportunities for shellfish growers through the North Carolina Shellfish Farming Academy and Aquaculture curriculum program offered at Carteret Community College.

Action 2: Modernize regulatory scheme and reduce user conflicts.

Organizations involved in this action include Brooks-Pierce, Division of Marine Fisheries, East Carolina University/Coastal Studies Institute, North Carolina Coastal Federation, North Carolina Sea Grant, University of North Carolina Institute of Marine Sciences and others.

Specific action steps include the following:

- Implement the findings of the study on how to reduce user conflicts related to shellfish cultivation. (Begin implementing by Year 2)
- Ensure re-opening of moratoria imposed by the shellfish aquaculture legislation. (Year 3)
- Develop criteria for Shellfish Enterprise Areas. (Year 2)
- Reevaluate Strategic Plan's Recommendation #10 in light of the findings of the user conflict study ("Amend North Carolina General Statute §113-202 to afford the Secretary of the Department of Environmental Quality substantial discretion in balancing public trust uses"). (Year 2)
- Establish Shellfish Enterprise Areas in compliance with existing shellfish lease statutes. (Years 3-5)
- Amend the statute to increase the duration of leases from 10 to 20 years. (by Year 5)

Action 3: Support aquaculture-related research.

Organizations involved in this action include Albemarle-Pamlico National Estuary Partnership, East Carolina University/Coastal Studies Institute, North Carolina Sea Grant, North Carolina State University-Center for Marine Science and Technology, University of North Carolina Chapel Hill-Institute of Marine Sciences, University of North Carolina Wilmington and others.

Specific action steps include the following:

- Develop a list of research needs and progress for the annual report. (Year 2)
- Fund a Shellfish Aquaculture Grant Program administered by North Carolina Sea Grant. (Year 4)
- Provide guidance and support efforts for the UNCW Shellfish Research Hatchery and other possible/future hatcheries. (Year 4)
- Research environmental, economic and social impacts of oyster aquaculture. (Year 4)

Strategies to Educate about Oysters

Educate: Outreach and Engagement

Overarching goal of the outreach and engagement strategy: Create communication and outreach strategies that engage stakeholders and the general public to actively support the goals, strategies and actions outlined in the Blueprint.

For nearly two decades, the North Carolina Oyster Steering Committee has developed a variety of outreach and communication strategies that have engaged thousands of stakeholders and informed the public about the Blueprint efforts. It has developed a website for the Blueprint (ncoysters.org), produced an annual progress report, organized workshops and conferences, and engaged the media in press events and through press releases. Organizations that participate in the Oyster Steering Committee have also organized educational volunteer activities and sessions to help the general public better understand and support Blueprint actions. These efforts have provided meaningful and engaging communication content to a variety of targeted audiences.

The messaging has been that oysters are vital to North Carolina's coastal ecology and economy. They filter water, provide food and create reefs that are habitat for fish and crabs. These ecosystem services, in turn, support jobs and provide economic opportunities for coastal communities. Stakeholders range from individuals and entities directly involved with oyster work including federal, state and local government agencies, as well as oyster growers, commercial fishers, academics, conservation organizations, and others. Outreach has targeted tourists in the state who contribute to the coastal economy. There has also been active engagement of students in volunteer activities and learning field trips. With widespread visible stakeholder and public support, the Oyster Steering Committee has been successful in engaging lawmakers to garner their enthusiasm and appropriations for future oyster work.

Accomplishments

A comprehensive annual report, the State of the Oyster Report, accompanied by quarterly newsletters have been distributed targeting a relatively small audience of about 1,100 email subscribers, primarily consisting of stakeholder organizations participating in the Oyster Steering Committee. Biannual Oyster Summits have drawn great numbers of participants throughout the state and have served as an effective method for communicating accomplishments associated with the plan. Multiple stakeholder groups are present at the summits, including professionals from the shellfish aquaculture industry, representatives from state and federal agencies, state legislators across the political spectrum, staff from nonprofit organizations, researchers, university partners and passionate individuals. The North Carolina Coastal Federation-run website, ncoysters.org, serves as a clearinghouse for all things related to North Carolina oysters, successfully highlighting accomplishments from a variety of stakeholders. In 2019, social media accounts were launched in conjunction with this website.

The entities represented in this strategy workgroup all have oyster focused information available on their respective websites that includes educational materials, information on their projects, and more. Communication strategies have engaged legislators and the General Assembly in a manner that has successfully secured funding for a variety of projects. There remains a need to communicate progress in achieving goals and recommended actions in a way that relates to stakeholder interests. In specific, the economic benefits of achieving oyster restoration goals need to be demonstrated in meaningful and compelling ways. Opportunities for improvement in communications include engaging more diverse audiences in a way that invites people to participate or take action associated with the desired Blueprint outcomes.

Top three actions for outreach and engagement

Action 1: Engage the Oyster Steering Committee and members' corresponding organizations to convey the work being done through the Blueprint.

Organizations involved in this action include Albemarle-Pamlico National Estuary Partnership, Brooks-Pierce, Carteret Community College, Crystal Coast Ecotours, Department of Commerce, Department of Cultural and Natural Resources, Department of Environmental Quality, Department of Transportation, Division of Coastal Management, Division of Marine Fisheries, Duke University Marine Lab, East Carolina University/Coastal Studies Institute, LDSI, Inc., Middle Sound Mariculture, National Oceanic and Atmospheric Administration, North Carolina Aquariums, North Carolina Coastal Federation, North Carolina Coastal Reserve and National Estuarine Research Reserve, North Carolina Sea Grant, North Carolina Shellfish Growers Association, North Carolina State University Center for Marine Science and Technology, North Carolina State University College of Veterinary Medicine, Restoration Systems, The Nature Conservancy, The Pew Charitable Trusts, University of North Carolina Wilmington, U.S. Department of Agriculture-Natural Resources Conservation Service, oyster harvesters, local government, contractors and businesses

Specific action steps include the following:

- Review target audiences reached by past Blueprint communication efforts and identify any new or changed priorities regarding audiences to reach with new Blueprint.
- Continue to engage a steering committee and continue the work of the two regional workgroups to identify, select, monitor, implement and evaluate restoration and communication strategies with key stakeholders. Annually review successes and failures of the communications strategy with steering committee.
- Create an editorial calendar that the steering committee and other stakeholders can review and contribute to monthly in order to properly encapsulate the work of all stakeholders in the Blueprint.
- Convene at least three steering committee meeting each year to coordinate the work of workgroups and other stakeholders.
- Hold at least two strategy workgroup meetings each year to guide restoration efforts.
- Hold technical workshops as needed, targeting one per year, to encourage communication and partnership opportunities.
- Organize at least one major public oyster summit every two years.
- Maintain and update annually a list of research needs and questions, and report annually on findings and answers related to that list.
- Devise a strategy to be reviewed by the Steering Committee for building broader public awareness that engages adults and students in actions of the Blueprint. This strategy needs to help broaden the level of community understanding and support to help advance this work. Parts of the strategy may include student engagement (i.e., develop premade modules for educators to use in the classroom, share existing modules with educators via ncoysters.org, create with interactive activities for children to be distributed at schools) or could seek to reach families and members of coastal communities through activities such as existing festivals, or special events accessible with low cost of admission and activities appealing to a wide range of audiences and age groups.

Action 2: Use digital and online media to expand the reach of the Blueprint.

Organizations involved in this action include: Albemarle-Pamlico National Estuary Partnership, East Carolina University, North Carolina Aquariums and Department of Cultural and Natural Resources, North Carolina Coastal Federation, North Carolina Sea Grant, North Carolina State University-Center for Marine Science and Technology and others.

Specific action steps include the following:

- Supply content to keep website updated to include historic and current data on Blueprint goals and actions.
- Make website more visually appealing and organized, so that it reflects work accomplished by all stakeholders involved.
- Make content relevant and up-to-date on a monthly basis, including publishing updated links to shellfish maps on Blueprint website.
- Create a database of educational resources to be listed on the ncoysters.org website. Create quarterly Grower Profiles for website.
- Create social media accounts corresponding to the Blueprint and website.
- Evaluate the benefit of creating a quarterly On the Half Shell digital newsletter. If maintained, increase subscriber list to On the Half Shell by 50 percent at the end of 2025.
- Analyze monthly metrics on website, social media activity and digital newsletter visitation, and report findings to the steering committee at its meetings.
- Create monthly, incremental goals for viewership and engagement across platforms including: three posts per month with at least 150 likes; three interactive social media days per month like polls and Q&A; and Increase website and newsletter traffic by 5 percent per month.
- Provide action steps for audiences in each post, event, newsletter, website update – for example, "learn more here" or "donate here."

Action 3: Engage stakeholders beyond the Oyster Steering Committee to help advance the work of the Blueprint.

Organizations involved in this action step include Albemarle-Pamlico National Estuary Partnership, East Carolina University/Coastal Studies Institute, North Carolina Aquariums, North Carolina Coastal Federation, North Carolina Sea Grant, North Carolina State University-Center for Marine Science and Technology, University of North Carolina Wilmington and others.

Specific action steps include the following:

- Expand the use of the Oyster Trail as a communications tool to highlight the work of the Blueprint.
- Invite and engage lawmakers in activities related to the goals and actions in the Blueprint so they can see firsthand the results of their support.
- Assist growers and other private sector stakeholders in engaging with policy makers to demonstrate support for relevant policy and appropriation's requests.
- Highlight the Blueprint in working watermen publications, both print and online. Identify communications potentials with working watermen.
- Conduct periodic survey of stakeholders to help direct communications strategies so that they reflect the priority of target audiences and contain appropriate content and messaging.
- Identify nonstakeholder interest in Blueprint and Steering Committee efforts.
- Work with stakeholders to create effective and consistent messaging campaigns that help advance the work of the Blueprint.

Next Steps and Funding

The implementation of the Blueprint will be overseen by the Oyster Steering Committee. The committee members provide guidance and recommendations on actions necessary to comprehensively support and perpetuate healthy oyster populations in our coastal waters through the implementation of the Blueprint; set the agenda for regional and focus area workgroup work products; provide guidance and review of the workgroup work products; review and approve revisions to the Blueprint as it evolves; review and approve the annual State of the Oyster Report.

More than 30 stakeholders regularly participate in the Oyster Steering Committee with representation from: Albemarle-Pamlico National Estuary Partnership, Brooks-Pierce, Carteret Community College, Crystal Coast Ecotours, Department of Commerce, Department of Cultural and Natural Resources, Department of Environmental Quality, Department of Transportation, Division of Coastal Management, Division of Marine Fisheries, Duke University Marine Lab, East Carolina University/Coastal Studies Institute, LDSI, Inc., Middle Sound Mariculture, National Oceanic and Atmospheric Administration, North Carolina Aquariums, North Carolina Coastal Federation, North Carolina Coastal Reserve and National Estuarine Research Reserve, North Carolina Sea Grant, North Carolina Shellfish Growers Association, North Carolina State University Center for Marine Science and Technology, North Carolina State University College of Veterinary Medicine, Restoration Systems, The Nature Conservancy, The Pew Charitable Trusts, University of North Carolina Wilmington, U.S. Department of Agriculture-Natural Resources Conservation Service, oyster harvesters, local government, contractors and businesses.

The leadership team is a subset of the Steering Committee that meet between steering committee meetings to review progress; develop agendas for the steering committee to review; and provide strategic guidance on the next steps in the Blueprint implementation. The 2021-2025 leadership team includes: Jacob Boyd, DMF; Eric Herbst, North Carolina Sea Grant; Katherine McGlade, North Carolina Shellfish Growers Association; Dr. Ken Riley, National Oceanic and Atmospheric Administration; as well as Todd Miller, Erin Fleckenstein, Lauren Kolodij, Leslie Vegas, Dr. Lexia Weaver, Ted Wilgis, and Ana Zivanovic-Nenadovic, of the North Carolina Coastal Federation.

The first steps that will be taken to secure support for the Fourth Edition of the Blueprint are to conduct a series of outreach and engagement measures including a press event around the release of the Blueprint and briefings to key commissions and leadership teams.

Ideally the secretaries of several state departments and leaders in the Oyster Steering Committee will converge to announce the release of the Fourth Edition of the Blueprint. This should include the secretary of the state's Department of Cultural and Natural Resources, Department of Environmental Quality and Department of Commerce and key coastal legislators as well as leaders from North Carolina Shellfish Growers Association, North Carolina Sea Grant, North Carolina Coastal Federation, Albemarle-Pamlico National Estuary Partnership and federal leaders such as National Oceanic and Atmospheric Administration among others. In addition to the press event, the North Carolina Coastal Federation will plan to brief key commissions such as the Coastal Resources Commission, Environmental Management Commission, Marine Fisheries Commission, the Coastal Habitat and Protection Plan Steering Committee as well as the Albemarle-Pamlico National Estuary Partnership's Leadership Council and Scientific and Technical Advisory Committees, among others.

While some state appropriations as well as state and federal grant funds are secured to advance the actions laid out in the Blueprint, additional funds and staff will be necessary to see the full scope of actions laid out in the Blueprint come to fruition.

Future Climate Considerations

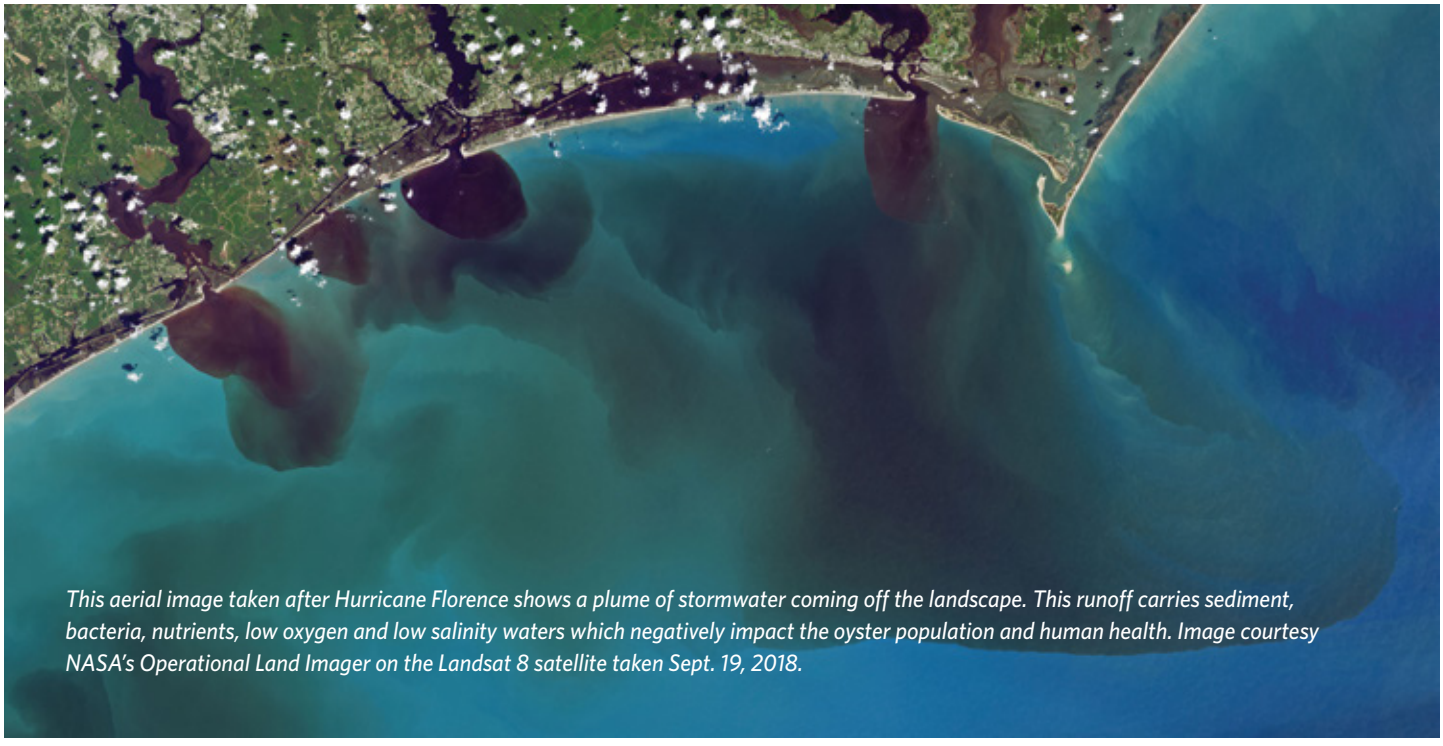
Much of North Carolina is already experiencing a number of impacts related to climate change that will have to be accounted for in oyster management, conservation and restoration plans to support reef resilience and coastal adaptability. These include a number of first-order effects from warming waters, sea level rise, saltwater intrusion and increased storms. Additional potential secondary and indirect effects of climate change include changes in primary productivity, ocean acidification, altered phenology and species invasions with poleward range shifts. Developing plans that anticipate these changes will require broad stakeholder engagement, increased research and long-term planning to account for the natural history, ecosystem benefits, socioeconomics and restoration efficacy of subtidal reefs, intertidal reefs and farm-raised oysters.

The suite of likely effects of climate change on oysters is daunting. Temperature and salinity are a fundamental drivers of ecosystem dynamics in estuaries. Rising water temperatures will affect individual oyster metabolism, growth rate and survivorship (Casas et al. 2018), and will also decrease the concentrations of dissolved oxygen in coastal waters (Breitburg et al. 2018). This will likely exacerbate hypoxic/anoxic conditions that negatively impact the fitness of subtidal oysters in broad areas of western Pamlico Sound and adjacent river

mouths, (Lenihan and Peterson 1998). Changes in salinity due to sea level rise and predicted increases in major storm events such as saltwater intrusion, new inlets along Outer Banks, increased rainfall will alter, and potentially reduce, suitable habitat for subtidal oyster reefs. Because oysters are heavily preyed upon, susceptible to infestation from pests, and fouled by macroalgae or tunicates in high salinity waters, reefs can only persist in the intertidal zone in high-salinity waters, largely south of Core Sound in North Carolina. In lower salinity waters, such as Pamlico Sound and lower parts of adjacent rivers, reefs can persist in the subtidal zone (Walles et al. 2016). Thus, changes in salinity, combined with existing water quality issues may result in a form of "coastal squeeze" for harvestable, subtidal oyster reefs, whereby sea level rise induced saltwater intrusion may lead to the up-estuary retreat of subtidal reefs, while water quality concerns force harvest of oysters further downstream. Ultimately, this may result in significant losses of suitable subtidal oyster habitat and harvest in areas such as Pamlico Sound (Tice-Lewis et al. submitted). Increasing frequency, intensity, and rainfall associated with major storms will impact reefs and mariculture operations. These strong pulse events can damage intertidal reefs via intensive physical stress, and also degrade subtidal reefs via extended periods of extremely low salinity, dissolved oxygen, and/or burial from sedimentation (Hogan et al. 2020). As the September 2018 Hurricane Florence demonstrated, shellfish farms can suffer catastrophic losses of product and gears as these storms impact our coast, and current insurance and recovery plans are not well-structured to account for these damages in support of this industry (Baillie et al. submitted).

While southeast waters are defined by relatively high alkalinity that buffers our region from the worst effects of global-scale ocean acidification, event-specific changes in pH may impact natural oyster settlement, or oyster hatcheries/nurseries in ways that are currently poorly understood (Waldbusser et al. 2011). Relatively small changes in survivorship of oyster larvae and settlement can have profound impacts on the dynamics of oyster populations (Theuerkauf et al. in press). The ecosystem-level effects of reef-associated species that are expanding their ranges and becoming more common in North Carolina estuaries in response to regional warming, such as bonnethead sharks (Byers et al. 2017) and stone crabs (Rindone and Eggleston 2011), may also profoundly impact the oyster population.

These dynamics represent notable challenges for maximizing oyster function and productivity, yet there are also a number of opportunities for promoting resilience and adaptability if we plan aggressively for anticipated changes. For instance, intertidal reefs, when restored at appropriate elevations within the tidal frame, demonstrate the ability to grow vertically at rates that exceed sea-level rise (Rodriguez et al. 2014), and therefore may provide a mechanism for shoreline protection and incentive for reef enhancement. As these issues -- and associated solutions – continue to emerge, the Blueprint will be adapted to leverage novel approaches for promoting the ecological and economic health of oysters in an era of change.



This aerial image taken after Hurricane Florence shows a plume of stormwater coming off the landscape. This runoff carries sediment, bacteria, nutrients, low oxygen and low salinity waters which negatively impact the oyster population and human health. Image courtesy NASA's Operational Land Imager on the Landsat 8 satellite taken Sept. 19, 2018.

Appendices

Appendix A: Strategy Summary: A Summary of the Blueprint's Strategies and Actions 2021-20215

Read a summary of the strategies and recommended actions for 2021-2025 **here**.

Appendix B: Process to Update the Fourth Edition of the Blueprint

Timeline to Update

Building on the success of the previous Blueprint, the process to update the Blueprint to the fourth edition is described in detail below. This process engaged hundreds of people over eighteen months to outline new goals and actions for the next five years.

- **September 2019:** Oyster Steering Committee met to review plan update, timeline and next steps
- **October 2019:** Developed outline of work for strategy workgroups to review oyster restoration and management strategies in North Carolina.
- **October 2019-May 2020:** Strategy workgroups convened to develop a list of draft issues and recommendations for consideration related to their specific strategies.
- **December 2019:** Began to compile information on the Third Edition Blueprint accomplishments.
- **January 2020:** Issued a stakeholder survey to identify what stakeholders value about oysters, what benefits of oysters are priorities, what are perceived threats to the oyster population and solicited suggestions for consideration in next edition of the Blueprint.
- **March 2020:** Drafted strategy recommendations provided from the workgroups.
- **April-June 2020:** Conducted a series of six virtual workshops to review results of the stakeholder survey, discuss draft recommendations, and seek input on top three actions for each strategy
- **May-June 2020:** Strategy workgroups incorporated feedback from virtual meetings to revise the suite of Blueprint recommendations.
- **June 2020:** Convened the Oyster Steering Committee to review feedback from the virtual workshops and prioritized actions for consideration.
- **July 2020:** Stakeholder Survey Summary completed and released online (Appendix C)
- **November 2020:** Draft of Blueprint released to the Oyster Steering Committee.
- **December 2020:** Oyster Steering Committee convened to review the compiled recommendations.
- **January 2021:** Revised Blueprint circulated for final edits.
- **March 2021:** Oyster Steering Committee reviewed final recommendations.
- **April 2021:** Final 2021-2025 Blueprint released.

Stakeholder Survey

A stakeholder survey was sent to 731 contacts including fishers, scientists, resource managers, nonprofit agencies and interested stakeholders in January 2020. Responses were received from 166 stakeholders, about 22 percent. The survey was designed to solicit input on the perceived benefits of oysters, threats to oysters in the next 5 to 10 years and suggestions for protection, management or restoration of oysters in North Carolina.

The stakeholder survey proved to be a useful tool. The results indicated that respondents were most concerned about the impact that degraded water quality will have on the oyster population in North Carolina and, overwhelmingly, suggested additional actions be taken to rebuild oyster reefs through various habitat restoration activities. Additional concerns and threats to the oyster population included overharvest, physical destruction to reefs and land based activities that impact oysters. The eight strategies identified in the fourth edition of the Blueprint were designed to address these stakeholder concerns. The complete summary of survey responses is included as Appendix C.

Strategy Workgroups

During the process to update the Blueprint, eight workgroups were created to review each of the strategies of the Blueprint. The workgroups were formed around the strategies of water quality protection and restoration, oyster sanctuaries, living shorelines, recycling for reefs, oyster cultch planting, sustainable wild harvest, shellfish aquaculture, and outreach and education. These workgroups summarized information about their strategy, including why it was an important component of the Blueprint, past accomplishments as well as suggested actions that should be prioritized for the coming Blueprint. Workgroups consisted of six to 20 members that were considered experts or had a key interest in the strategy at hand. Each workgroup met at least twice during the update process to review their respective strategy and propose priority actions to be considered for the

updated edition of the Blueprint. A full listing of the workgroups and their members is available in Appendix D.

Recommendations from the workgroups were presented at a series of Virtual Stakeholder Workshops in the spring of 2020 and provided to the Oyster Steering Committee for their summer meeting.

Virtual Workshops

Originally envisioned to be a two-day, in-person workshop, a series of six, two-hour virtual meetings were held in April, May and early June to review the draft recommendations from the strategy workgroup members. The workgroup recommendations were posted in advance on the ncoyster.org website. As part of the virtual meetings, the presenters moved through the recommendations and meeting facilitators made use of the chat box, virtual polling and email feedback to solicit input on the recommendations.

From each workshop the top three actions of each strategy were prioritized. Nearly one hundred fifty unique individuals participated in the workshops, with 25 participating in all six workshops.

Oyster Steering Committee Review

The Steering Committee reviewed the workgroup recommendations and prioritized results from the virtual workshop. They also identified which organizations/entities would be most critically involved in advancing the suggested actions moving forward.

The North Carolina Coastal Federation worked to compile all of the information collected and summarized in a draft Blueprint Document which was circulated in November 2020. The Oyster Steering Committee reviewed and provided edits to the draft before reconvening in early December 2020. Edits from the full Steering Committee were accepted through the end of December 2020. Many suggestions for improvement were provided by the Steering Committee and incorporated into the Blueprint. A final round of edits was made by a smaller, six-person, proofing committee in the spring of 2020. The document was released to the public in April 2020.

Appendix C: Stakeholder Survey Summary

Read the full stakeholder survey summary **here**.

Appendix D: Strategy Workgroup Members

The North Carolina Coastal Federation extends deep gratitude to all of the volunteers, stakeholders, steering committee members and strategy workgroup members for the tireless hours they contributed to the review and update of the Blueprint.

Strategy workgroups were charged with reviewing the current status and trends of their topic and providing an assessment of key actions and work that needs to be implemented in the coming five years. Below is a listing of the strategy workgroups and their members. All workgroups were facilitated by North Carolina Coastal Federation staff. Workgroup facilitator is **bolded**.

Water Quality Workgroup Members

Anne Deaton (DMF), Erin Fleckenstein (North Carolina Coastal Federation), James Hargrove (Middle Sound Mariculture), Jonathan Hinkle (LDSI, Inc.), Shannon Jenkins (Shellfish Sanitation, DMF), Casey Knight (DMF), **Lauren Kolodij (North Carolina Coastal Federation),** Frank Lopez (North Carolina Sea Grant), Andy McDaniel (Department of Transportation), Todd Miller (North Carolina Coastal Federation), Dr. Natalie Nelson (North Carolina State University), Matthew Stuart (Onslow County), Keith Walls (Falling Tide Oyster Co.), Ted Wilgis (North Carolina Coastal Federation), Ana Zivanovic-Nenadovic (North Carolina Coastal Federation)

Oyster Sanctuary Workgroup Members

Dr. Brian Boutin (The Nature Conservancy); Daniel Brinn (Hyde County); Dr. Dave Eggleston (North Carolina State University, Center for Marine Science and Technology); **Erin Fleckenstein (North Carolina Coastal Federation)**; Jimmy Johnson (Albemarle-Pamlico National Estuary Partnership); Dr. Niels Lindquist (University of North Carolina Institute of Marine Sciences); Todd Miller (North Carolina Coastal Federation); Jason Peters (DMF); Dr. Brandon Puckett (North Carolina Coastal Reserve and National Estuarine Research Reserve); Simon Rich (Stevens Towing); Ted Wilgis (North Carolina Coastal Federation)

Living Shoreline Workgroup Members

Jacob Boyd (DMF), Bill Cary (Brooks-Pierce), Dr. Carolyn Currin (National Oceanic and Atmospheric Administration), Dr. Jenny Davis (National Oceanic and Atmospheric Administration), Anne Deaton (DMF), Rebecca Ellin (North Carolina Coastal Reserve and National Estuarine Research Reserve), Dr.

Devon Eulie (University of North Carolina Wilmington), Erin Fleckenstein (North Carolina Coastal Federation), Dr. Rachel Gittman (East Carolina University), Dr. Niels Lindquist (University of North Carolina, Institute of Marine Science), Todd Miller (North Carolina Coastal Federation), Trish Murphey (Albemarle-Pamlico National Estuary Partnership), Dr. Martin Posey (University of North Carolina Wilmington), Dr. Brandon Puckett (North Carolina Coastal Reserve and National Estuarine Research Reserve), Dr. Tony Rodriguez (University of North Carolina, Institute of Marine Science), Dr. Brian Silliman (Duke University Marine Lab), Carter Smith (Duke University Marine Lab), Dr. Seth Theuerkauf (The Nature Conservancy), Leslie Vegas, (North Carolina Coastal Federation), Curt Weychert (DMF), **Dr. Lexia Weaver (North Carolina Coastal Federation),** Ted Wilgis (North Carolina Coastal Federation)

Shell Recycling for Reefs Workgroup Members

Sarah Bodin (North Carolina Coastal Federation); Erin Fleckenstein (North Carolina Coastal Federation); Todd Miller (North Carolina Coastal Federation); **Leslie Vegas (North Carolina Coastal Federation);** Ted Wilgis (North Carolina Coastal Federation)

Sustainable Wild Harvest and Cultch Planting Workgroup Members

Troy Alphin (University of North Carolina Wilmington); Jacob Boyd (DMF); Dr. Brian Boutin (The Nature Conservancy); Anne Deaton (DMF); Jeffrey Dobbs (DMF); Dr. Dave Eggleston (North Carolina State University, Center for Marine Science and Technology); Joe Facendola (DMF); Erin Fleckenstein (North Carolina Coastal Federation); Dr. Niels Lindquist (University of North Carolina, Institute of Marine Science); Todd Miller (North Carolina Coastal Federation); Tina Moore (DMF); Jason Peters (DMF); Dr. Martin Posey (University of North Carolina Wilmington); Dr. Brandon Puckett (North Carolina Coastal Reserve and National Estuarine Research Reserve); **Ted Wilgis (North Carolina Coastal Federation)**

Shellfish Aquaculture Workgroup Members

Jacob Boyd (DMF), Bill Cary (Brooks Pierce), Eric Herbst (North Carolina Sea Grant), Susan Hill (Downeast Mariculture Supply), Tom Looney (North Carolina Coastal Federation), Katherine McGlade (North Carolina Shellfish Growers Association), Todd Miller (North Carolina Coastal Federation), Dr. Ken Riley (National Oceanic and Atmospheric Administration), Jay Styron (Carolina Mariculture), Dr. Ami Wilbur (University of North Carolina Wilmington), **Ana Zivanovic-Nenadovic (North Carolina Coastal Federation)**

Outreach and Engagement Workgroup Members

Dr. Linda D'Anna (Coastal Studies Institute), Stacey Feken (Albemarle-Pamlico National Estuarine Partnership), Dr. Jane Harrison (North Carolina Sea Grant), Whitney Jenkins (North Carolina Coastal Reserve and National Estuarine Research Reserve), Dr. Carol Price (North Carolina Aquariums), **Leslie Vegas (North Carolina Coastal Federation)**

Appendix E: Complete Table of Strategy Recommendations with Action Steps.

Protect Strategy: **Water Quality**

Overarching goal: Protect and restore water quality in shellfish growing waters that are both critically important and endangered.

Action 1: Demonstrate success in protecting and restoring two of the state's most important and endangered shellfish growing waters (Newport River and Stump Sound).

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, Division of Marine Fisheries, North Carolina Coastal Federation, The Pew Charitable Trusts*

Specific action steps include the following:

- Engage key stakeholders such as fishers, farmers, landowners, government agencies, academia and experts in teams to tackle the water quality threats facing Newport River and Stump Sound.
- Prepare a comprehensive and easily identifiable and understood watershed management and restoration plan that includes strategies for reducing the volume of runoff and other strategies to maintain, protect and replicate natural watershed hydrology for each of these growing waters and meets the EPA's nine minimum elements for plan development.
- Implement and monitor the top five cost-effective measures identified in the plans in each watershed. Implementation should continue after year five.

Action 2: Create and heavily publicize a prioritized list of additional endangered shellfish growing waters for targeted management and restoration planning.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, Division of Marine Fisheries, North Carolina Coastal Federation, North Carolina State University-Center for Marine Science and Technology, The Nature Conservancy, University of North Carolina Wilmington*

Specific action steps include the following:

- Develop maps with ranking criteria based on waters that have existing or potential oyster harvest, as well as waters that have the greatest threats for current and future shellfish closures as indicated by rainfall thresholds that cause closures.
- Present priority list to Oyster Steering Committee during year one and refine with their input.
- Update the priority waters list every five years.

Action 3: Adopt state policy for application of stormwater volume matching criteria using Low Impact Development practices when feasible and practical for state funded construction projects and showcase projects located in priority shellfish growing waters.

Involved Parties: *Brooks-Pierce, Department of Environmental Quality, Department of Transportation, North Carolina Coastal Federation, The Pew Charitable Trusts*

Specific action steps include the following:

- Encourage government agencies to serve as role models by ensuring that state construction projects consider low-impact design or nature-based stormwater strategies in state-funded construction projects where practical and feasible throughout the coast. This recommendation is consistent with an approved recommendation in the North Carolina Strategic Plan for Shellfish Mariculture adopted in 2018 and should at a minimum be applied in priority shellfish growing waters.

Action 4: Recruit decision makers to help implement strategies to protect and restore water quality in shellfish growing waters

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, Division of Marine Fisheries, North Carolina Coastal Federation, The Pew Charitable Trusts, University of North Carolina Wilmington, as well as members of: Coastal Resources Commission, Environmental Management Commission, Marine Fisheries Commission, and Wildlife Resources Commission, leadership of numerous federal and state agencies including the state Departments of Commerce, Environmental Quality, Cultural and Natural Resources, Transportation and Administration.*

Specific action steps include the following:

- Reach out to key decision-makers to encourage their active participation in efforts to protect and restore water quality in the watersheds of priority shellfish growing waters.
- Specifically engage members of the Coastal Resources Commission, Environmental Management Commission, Marine Fisheries Commission, and Wildlife Resources Commission, as well as leadership of numerous federal and state agencies including the N.C. Departments of Environment, Natural and Cultural Resources, Transportation, and Administration and programs such as the Albemarle-Pamlico Estuary Partnership and Coastal Habitat Protection Plan
- Engage locally elected and appointed officials that represent high priority target watersheds.
- Identify local government leaders who should be invited to join the Oyster Steering Committee.

Action 5: Encourage government programs to adopt and implement protection and restoration strategies for priority shellfish growing waters.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, Brooks-Pierce, Division of Marine Fisheries, North Carolina Coastal Federation*

Specific action steps include the following:

- Work in partnership with state and federal government programs to incorporate water quality protection and restoration strategies for priority shellfish growing waters into their ongoing management activities.
- Seek statutory authority, appropriations and grants to implement recommended watershed management actions including but not limited to land acquisition, wetland restoration, stormwater retrofits, and programs that encourage good operation and maintenance of permitted coastal stormwater systems.
- Report, annually, on any of the successes or failures of management measures implemented via watershed plans for priority shellfish growing waters.

Action 6: Revise scoring criteria for state-administered grant funding programs.

Involved Parties: *Brooks-Pierce, North Carolina Coastal Federation*

Specific action steps include the following:

- Elevate scoring of projects that protect and/or restore priority shellfish growing waters identified by the Oyster Steering Committee.
- Specifically target the Parks and Recreation Trust Fund, Clean Water Management Trust Fund, access grants from the N.C. Division of Coastal Management, Section 319 grants, and the N.C. Division of Water Resource grants.

Action 7: Report progress achieving action strategies in annual State of the Oyster Report.

Involved Parties: *Division of Marine Fisheries, North Carolina Coastal Federation, University of North Carolina Wilmington*

Specific action steps include the following:

- Use quantifiable metrics to report on progress towards these actions in the annual State of the Oyster Report.

Protect Strategy: Oyster Sanctuaries

Overarching goal: Establish sufficient acreage of protected oyster reefs to support desired ecosystem services by building fish habitat, supplementing wild oyster stock and filtering water.

Action 1: Build an additional 100 acres of oyster sanctuary in Pamlico Sound by 2025.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, Division of Marine Fisheries, North Carolina Coastal Federation, The Nature Conservancy, The Pew Charitable Trusts*

Specific action steps include the following:

- Secure funding and staff to build 100 acres of sanctuary reef.
- Maintain current state appropriations of $850,000 to build 3 to 5 acres of sanctuary reef annually.
- Match with federal grants whenever possible so that 6 to 10 acres can be constructed each year.
- Target a total of $3.5 million in state and federal grants annually to construct oyster sanctuaries at a rate of 20 acres per year.
- Determine best method to allow DMF to issue reef material acquisition and construction contracts over multiple fiscal years.

Action 2: Monitor and use the best science available to inform restoration activities.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, Division of Coastal Management, East Carolina University/Coastal Studies Institute, Division of Marine Fisheries, North Carolina Coastal Federation, North Carolina Coastal Reserve and National Estuarine Research Reserve, North Carolina Sea Grant, North Carolina State University Center for Marine Sciences and Technology, The Nature Conservancy, The Pew Charitable Trusts, University of North Carolina Chapel Hill-Institute of Marine Sciences, University of North Carolina Wilmington*

Specific action steps include the following:

- Identify the ideal locations of sanctuaries and ensure they are well distributed, and there's an understanding of sediment transport dynamics to avoid areas that will be buried during storm events such as nor-easters and hurricanes.
- Select appropriate substrate material, not all materials are suitable in all locations.
- Design of each sanctuary should be appropriate for its location including size, architecture and amount of relief.
- Determine the metrics of success that would allow sanctuaries to sustain a positive return on investment. Consider the following:
  - How much water filtration and nitrogen removal should oyster sanctuaries contribute to Pamlico Sound? What is the wastewater treatment equivalent value?
  - How many oyster larvae should oyster sanctuaries contribute to commercial harvest?
  - How much fish production should be attributed to oyster sanctuaries?
  - How many recreational fishing opportunities should oyster sanctuaries provide?
  - How many people should be employed in the construction of oyster sanctuaries?
- Monitor reefs for success metrics identified above and practice adaptive management of sanctuaries as needed.

Action 3: Determine the need for and feasibility of a protected reef designation in the southern region of the state.

Involved Parties: *Division of Marine Fisheries, North Carolina Coastal Federation, The Pew Charitable Trusts, University of North Carolina Wilmington*

Specific action steps include the following:

- Define the need and intent of this management action, for example ecosystem service-based versus larval connectivity versus coastal resiliency.
- Determine the best and most appropriate designation of protected or created reef.
- Enact rule change and/or legislation to allow new designation as needed.
- Conduct research and modeling to inform the location, material and architecture of reefs based on intent.
- Use existing science to inform success of proposed reefs.
- Establish a plan for future reefs including a plan for funding development.

Action 4: Make restoration of oyster habitat a state mandated activity, building off the state shellfish initiative.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, North Carolina Coastal Federation, The Nature Conservancy, The Pew Charitable Trusts*

Specific action steps include the following:

- Define restoration and enhancement activities in rule as an activity of the Division of Marine Fisheries.

Action 5: Report out and publicize the results of the sanctuary program in the annual State of the Oyster Report.

Involved Parties: *Division of Marine Fisheries, North Carolina Coastal Federation*

Specific action steps include the following:

- Report, annually, on the number of acres created, the success of the program, understanding that the success of the reefs changes over time, the estimated fish production, estimated water filtration improvements and the economic impact, specifically the number of people employed in the reef construction.

Action 6: Continue to refine and improve the oyster sanctuary acreage goal through the next five-year Blueprint period.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, Division of Marine Fisheries, North Carolina Coastal Federation, The Nature Conservancy, The Pew Charitable Trusts*

Specific action steps include the following:

- Determine the highest priority ecosystem service that more oyster reefs would achieve.
- Based on the priority ecosystem services of the sanctuary network, determine how many sanctuaries are needed to achieve this goal.
- Communicate sanctuary accomplishments, additional needs and goals through a coordinated outreach strategy.
- Clearly communicate economic benefits of sanctuaries.
- Develop recommendations for sampling methods and survey design for a statewide oyster stock assessment of subtidal and intertidal populations.
- Maintain shell bottom mapping effort.
- Assess oyster health.
- Further considerations described in the Natural Habitat Management Strategy.

Action 7: Determine the feasibility of closing existing natural reefs for protections as sentinel sites.

Involved Parties: *Division of Marine Fisheries, North Carolina Coastal Federation, The Nature Conservancy, The Pew Charitable Trusts, University of North Carolina Wilmington*

Specific action steps include the following:

- Identify characteristics of a sentinel reef.
- Identify existing reefs that exhibit desired characteristics.
- Develop monitoring protocols to track reef health over time.
- Determine feasibility of closing reefs to serve as sentinel sites.

Restore Strategy: Living Shorelines

Overarching goal: Expand the use of living shorelines to become the most commonly used shoreline stabilization method in estuaries that support oyster habitats.

Action 1: Implement living shorelines to continue to demonstrate their benefits to oysters and soundfront property owners.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, Brooks- Pierce, Division of Coastal Management, Duke University Marine Lab, East Carolina University, North Carolina Aquariums, North Carolina Coastal Federation, North Carolina Sea Grant, The Nature Conservancy, University of North Carolina Chapel Hill Institute of Marine Sciences, University of North Carolina Wilmington*

Specific action steps include the following:

- Build at least 3 miles of living shorelines coastwide on public and private lands where oysters grow by 2025, an increase of 15 percent over the last five years.
- Secure protection for sills that support oyster growth so they cannot be harvested.
- Identify locations to use as stockpile sites for materials used in living shoreline construction.
- Continue to site and design living shorelines based on current research and lessons learned from decades of intertidal oyster restoration to promote oyster growth and adaptation to sea level rise, as well as support other ecosystem services.
- Implement a communication and education strategy around highly visible projects to publicize the benefits and gain more public and agency demand for these projects.
- Engage volunteers and contractors in building living shorelines to help increase public awareness of their benefits.
- Document the success of living shoreline projects each year, both new and old, including their oyster recruitment potential, cost-benefits and resilience compared to other types of shoreline stabilization.

Action 2: Create and promote consumer demand for living shorelines by property owners with a special focus on shorelines that support oyster growth.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, Division of Coastal Management, Duke University Marine Lab, East Carolina University, North Carolina Coastal Federation, North Carolina Sea Grant, University of North Carolina Chapel Hill-Institute of Marine Sciences, University of North Carolina Wilmington*

Specific action steps include the following:

- Educate waterfront property owners, realtors, homeowners associations, Community Association Management Services, local governments and the general public on the value and benefits of living shorelines.
- Develop educational outreach materials in electronic and printed form to be distributed to these audiences.
- Conduct one-on-one living shoreline consultations with 50 waterfront property owners per year.
- Market the use of living shorelines by property managers and owners at three outreach events in three regions of the coast.

Action 3: Test alternative living shoreline construction materials and methods that increase oyster recruitment.

Involved Parties: *Division of Coastal Management, Duke University Marine Lab, East Carolina University/ Coastal Studies Institute, North Carolina Aquariums, North Carolina Coastal Federation, North Carolina Coastal Reserve and National Estuarine Research Reserve, North Carolina Sea Grant, The Nature Conservancy, University of North Carolina Chapel Hill-Institute of Marine Sciences, University of North Carolina Wilmington*

Specific action steps include the following:

- Test nonplastic, alternative materials for living shoreline construction at five demonstration project sites.
- Monitor and report the performance of alternative materials.

Action 4: Protect regulated and permitted living shorelines that grow harvestable oysters.

Involved Parties: *Brooks-Pierce, Division of Marine Fisheries, Duke University Marine Lab, East Carolina University, North Carolina Aquariums, North Carolina Coastal Federation, The Pew Charitable Trusts, University of North Carolina Chapel Hill-Institute of Marine Sciences*

Specific action steps include the following:

- Explore the protection of living shorelines from oyster harvest in the next update to the N.C. Coastal Habitat Protection Plan (CHPP).
- Experiment with the use of stronger living shoreline materials that would not be damaged if oysters are harvested from them.

Action 5: Increase the use of living shorelines instead of bulkheads.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, Duke University Marine Lab, East Carolina University, North Carolina Coastal Federation, University of North Carolina Chapel Hill-Institute of Marine Sciences, University of North Carolina Wilmington*

Specific action steps include the following:

- Quantify the extent of living shorelines implemented to date that also serve as oyster habitat.
- Increase the percentage of living shorelines permitted for shoreline stabilization along shorelines that support oyster growth by 15 percent a year. The more living shorelines, the more oysters in the water.
- Track the number and type of shoreline stabilization projects authorized each year.
- Educate marine contractors, engineers, consultants and regulators through technical trainings to encourage the use of living shorelines. Conduct three regional 2-day trainings for marine contractors, consultants, engineers, agency staff, beginning in Wilmington in February 2021.
- Conduct living shoreline consultations with five marine contractors per year.

Action 6: Collaborate through the Living Shorelines Steering Committee.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, Brooks-Pierce, Division of Marine Fisheries, Duke University Marine Lab, East Carolina University, North Carolina Aquariums, North Carolina Coastal Federation, The Nature Conservancy, University of North Carolina Chapel Hill- Institute of Marine Sciences, University of North Carolina Wilmington*

Specific action steps include the following:

- Identify and bring together the multiple efforts focused on promoting the use of living shorelines.
- Provide the leadership necessary to reach the goal for living shorelines within this blueprint.

Action 7: Summarize living shoreline research accomplishments and major findings to date related to oysters.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership Duke University Marine Lab, East Carolina University/Coastal Studies Institute, North Carolina Coastal Federation, North Carolina Sea Grant, University of North Carolina Chapel Hill-Institute of Marine Sciences, University of North Carolina Wilmington*

Specific action steps include the following:

- Provide information on how to site and design living shorelines to promote oysters based on research to date.

Action 8: Identify and answer living shoreline research questions and gaps as they pertain to oysters.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, Duke University Marine Lab, East Carolina University/Coastal Studies Institute, North Carolina Coastal Federation, North Carolina Sea Grant, University of North Carolina Chapel Hill-Institute of Marine Sciences, University of North Carolina Wilmington*

Specific action steps include the following:

- Continue quantifying the role of living shorelines in supporting oyster populations.
- Document the degree to which living shorelines using oysters can adjust to sea level rise.
- Study the impact of legally harvesting oysters on the structural integrity of living shorelines and their habitat and stabilization functions.
- Research the nutrient (nitrogen, phosphorus) reduction benefits provided by living shorelines and use that information to provide incentives for living shoreline projects if warranted.
- Determine why is oyster recruitment on living shoreline materials more abundant on the seaward edge of the sill. How can they be designed differently to increase oyster recruitment?
- On average, how many oysters per ft. can be generated from a living shoreline? On average, how much water can be filtered by oysters on a living shoreline per ft. or other unit?

Action 9: Qualify living shorelines for mitigation credits.

Involved Parties: *Brooks-Pierce, North Carolina Coastal Federation*

Specific action steps include the following:

- Determine if living shoreline projects can be built to qualify for salt marsh ($560,000 an acre value) or nutrient mitigation credits.
- Issue formal policy recommendations.
- Inform mitigation bankers about this opportunity.

Restore Strategy: Shell Recycling for Reefs

Overarching goal: Create a coordinated oyster shell recycling program to provide 5 percent of the material needed to support oyster restoration.

Action 1: Collect shell through a partnership and volunteer led shell collection effort.

Involved Parties: *North Carolina Coastal Federation, Coastal Conservation Association*

Specific action steps include the following:

- Assess opportunities and build partnerships with the following:
- Towns and counties to provide shell drop-off locations.
- Restaurants and fish houses/seafood dealers for volunteer pick-ups where possible.
- Private waste hauling/recycling companies to service restaurants.
- Collect 15,000 bushels of shell annually by 2025.
- Grow the Restaurant to Reef Program.
- Engage 50-75 percent of all oyster selling restaurants on the Outer Banks in the program.
- Determine ability to expand the Restaurant to Reef Program to Carteret County and the Cape Fear region by 2025.
- Secure funding and seek ways for businesses to participate in an economically feasible way.
- Determine funding sources
- Determine funding needs

Action 2: Improve shell collection and storage logistics.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, North Carolina Coastal Federation*

Specific action steps include the following:

- Create at least two drop-off locations in each coastal county by 2025.
- Create at least two new stockpile sites for shell along the coast.

Action 3: Use recycled shell in reef building activities.

Involved Parties: *Audubon North Carolina, Coastal Conservation Association, City of Jacksonville, Division of Marine Fisheries, North Carolina Coastal Federation, North Carolina State University- Center for Marine Science and Technology, The Nature Conservancy, University of North Carolina Chapel Hill-Institute of Marine Science, University of North Carolina Wilmington and others.*

Specific action steps include the following:

- Restore 20 acres of oyster reef in the southern region of the state.
- Regional stakeholders will collaborate with the Managed Areas Workgroup to prioritize growing areas for reef building for restoration.
- Stakeholders will develop a list of sites, restoration goal for each area and design recommendations for the restoration projects.
- Recommendations will be used to seek grant and other funding to implement the projects and support monitoring of the sites.
- Restore at least 5 acres of oyster reef using recycled shell in the northern region of the state.

Harvest Strategy: Sustainable Wild Harvest

Overarching goal: Sustainably manage natural oyster habitats within public trust areas to perpetuate ecosystem services and wild harvest.

Action 1: Conduct sampling, analyze data and implement the methodology to establish a stock assessment of the oyster population in North Carolina.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, Division of Marine Fisheries, North Carolina State University-Center for Marine Science and Technology, The Nature Conservancy, University of North Carolina Wilmington*

Specific action steps include the following:

- Collaborate among stakeholders to develop a fisheries independent stock assessment methodology.
- Support and secure needed resources for DMF by the Oyster Steering Committee. Conduct research to establish the assessment methodology, complete sampling and analyze data to create a stock assessment.
- Develop a stock assessment methodology.
- Ensure that any resulting recommendations from the methodology and assessment are considered in the next update of the oyster FMP and CHPP.

Action 2: Develop a fishery independent oyster abundance index to assist with oyster management decisions.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, Division of Marine Fisheries, North Carolina State University-Center for Marine Science and Technology, The Nature Conservancy, University of North Carolina Wilmington*

Specific action steps include the following:

- Create a stakeholder working group to determine the methodology, entities and resources needed to develop an oyster abundance index.
- Establish sentinel sites, or standardized sampling stations, to serve as the foundation of a fishery independent index of oyster abundance. Sentinel sites should be located in both open and closed shellfishing waters to assess the impacts of harvest on the regions oyster resources. Careful consideration must be given to abundance index sampling strategies, and to the scale to which any management action is applied. Two superficially similar and adjacent oyster reefs may vary greatly in the percent of legal oysters. Interpreting local size distributions as representative of entire regions can be erroneous.
- Develop the oyster abundance index, coordinated with the stock assessment development.
- Use trends from this independent abundance index, as well as input from harvesters and dealers to inform and enact management actions.

Action 3: Refine oyster landing data collection to provide more information to assist with management.

Involved Parties: *Division of Marine Fisheries, North Carolina Coastal Federation, The Nature Conservancy*

Specific action steps include the following:

- Create a working group in 2022 to examine how landing estimates can be obtained to improve data collection and reporting.
- Consider new data tracking procedures to support the stock assessment.
- Collect information specific to determine if harvest landings are coming from wild stocks for commercial purposes, wild stocks in prohibited areas through the relay program; cultch planted reefs created by DMF; recreational harvest estimates (through surveys); and farm-raised oysters from shellfish leases.

Action 4: Enhance, maintain and link habitat mapping efforts to develop a substrate budget, guide restoration efforts and support the stock assessment development.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, Division of Marine Fisheries, The Nature Conservancy*

Specific action steps include the following:

- Establish a workgroup to look at the need to establish a substrate budget for areas where wild harvest is occurring.
- Update and maintain the baseline shellfish habitat mapping using the most appropriate technology.
- Consider the use of selected sites being remapped more frequently using rapid analysis technology such as drones or sonar.
- Selectively monitor the condition and status of habitat to guide oyster restoration and management.
- Link mapping needs to CHPP Strategic Habitat Areas.
- Ground truth mapping efforts in partnership with university researchers and others.
- Use data to support the development of a balanced shellfish budget and change analysis for the state's 21,000 acres of oyster habitat along the coast.
- Use data to identify and support restoration and management goals.

Action 5: Examine North Carolina oyster relay practices.

Involved Parties: *Division of Marine Fisheries, Coastal Conservation Association, North Carolina Coastal Federation, fishers who make use of the relay program and others*

Specific action steps include the following:

- Convene a stakeholder team to
- Review current shell relay practices
- Assess impacts and benefits of the program
- Make recommendations to improve or discontinue program based on results of stakeholder team findings

Action 6: Incorporate Blueprint recommendations and actions into the Oyster Fishery Management Plan and Coastal Habitat Protection Plan.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, East Carolina University, Division of Marine Fisheries, North Carolina Coastal Federation, The Pew Charitable Trusts*

Specific action steps include the following:

- Submit the actions listed within this goal to the plan development teams and advisory committees for both the FMP and CHPP. The next update to the Oyster Fisheries Management Plan is scheduled to occur in 2022 through 2024. The CHPP is to be updated in 2021.

Harvest Strategy: Cultch Planting

Overarching goal: Use cultch planting to replenish and enhance oyster habitat for commercial harvest and ecosystem services.

Action 1: Conduct cultch planting program study.

Involved Parties: *Division of Marine Fisheries, North Carolina Coastal Federation*

Specific action steps include the following:

- Analyze the strengths and weaknesses of existing procedures, policies, rules and laws that govern or affect the existing cultch planting program in North Carolina.
- Analyze quantitatively existing programmatic data.
- Summarize cultch planting programs in other states and countries, including a comparison of how these entities fund their programs; types, volume and density of substrate deployed; how substrate is deployed and managed; and benefits documented, as well as an estimated cost-benefit analysis of each program studied.
- Analyze how to expand federal funding to help pay for deploying cultch in North Carolina.
- Examine environmental policies and permits that govern deployment of cultch in North Carolina and how they can be improved; i.e., incorporating the use of crushed concrete into DMF's permit.
- Identify strategies, resources and statutory changes needed to incorporate the use of private contractors to support and expand cultch planting efforts.
- Incorporate substrate budget and enhancement plans from the sustainable wild harvest strategy to ensure cultch planting efforts reflect regional habitat needs and regional harvest pressure to maintain oyster population.
- Identify the statutory amendments and appropriations that will be needed to implement the report's recommendations.
- Ability to establish longer-term contracts and purchasing agreements for appropriate reef building materials and work with contractors.
- Ability to carry over funding from multiple fiscal years.
- Resources required to implement and maintain long-term monitoring.

Action 2: Incorporate cultch planting program evaluation recommendations into program development and implementation.

Involved Parties: *Division of Marine Fisheries with Marine Fisheries Commission, North Carolina Coastal Federation, North Carolina State University-Center for Marine Science and Technology*

Specific action steps include the following:

- Ensure cultch planting efforts reflect regional habitat needs and regional harvest pressure to maintain oyster population.
- Establish and maintain siting and monitoring parameters at long-term sentinel sites for cultch sites similar to the oyster sanctuary program. Maintaining long-term monitoring will be dependent upon available resources.
- Continue to test and evaluate cultch planting strategies of larger sites; rotational harvest on cultch sites; varying reef heights and thickness; volume of material in the right locations on a regional scale; remote setting spat on shell for seeding of cultch sites; and creating metrics for appropriate sites, acreage, size, type, and amount of materials required.
- Continue to document, disseminate and highlight ecosystem services provided by the cultch planting sites.

Action 3: Plant cultch to build 200 acres of harvestable oyster habitat over five years.

Involved Parties: *Division of Marine Fisheries, North Carolina Coastal Federation, North Carolina Coastal Reserve and National Estuarine Research Reserve, North Carolina State University-Center for Marine Science and Technology*

Specific action steps include the following:

- Maximize DMF's current cultch planting capacity to build an average of 40 acres of cultch reefs annually over five years. This comes with a goal to increase internal and external DMF capacity to eventually be able to build 100 acres of cultch reefs annually.
- Test and evaluate rotationally harvested oyster areas by DMF using a portion of the 200 acres of cultch reefs in the Pamlico Sound while maintaining cultch planting efforts in other high harvest areas of the coast.
- Plan and implement reefs that maximize harvest and ecosystem services.
- Use science to inform siting and management for long-term maintenance and oyster productivity.
- Consider needed management and enforcement of closed area.
- Select sentinel sites for long-term monitoring.

Harvest Strategy: Shellfish Aquaculture

Overarching goal: Build the shellfish aquaculture industry to create a $45 million industry by 2025.

Action 1: Support and assist the shellfish growers.

Involved Parties: *Carteret Community College, Division of Marine Fisheries, North Carolina Coastal Federation, North Carolina Sea Grant, North Carolina State University-Center for Marine Science and Technology, The Pew Charitable Trusts, University of North Carolina Institute of Marine Sciences, University of North Carolina Wilmington*

Specific action steps include the following:

- Economically support growers
  - Develop low-interest loan program for shellfish growers.
  - Include farmed shellfish products into Federal Crop Insurance.
  - Achieve eligibility of farmed shellfish products for future disaster relief funds.
- Explore the opportunities that exist for the state Department of Agriculture to support shellfish growers.
  - Enable use of farmed oysters, seed or larger, for restoration purposes.
  - Implement findings of the study of penalties associated with theft of shellfish aquaculture gear and product.
  - Develop a nutrient reduction mitigation payment program.
  - Establish an Aquaculture Resource Grant Program administered by North Carolina Sea Grant.
  - Establish an Aquaculture Business Agent at North Carolina Sea Grant to aid the existing Marine Aquaculture Extension Specialist.
- Educationally support growers
  - Promote educational opportunities for shellfish growers through the North Carolina Shellfish Farming Academy and Aquaculture curriculum program offered at Carteret Community College.

Action 2: Modernize regulatory scheme and reduce user conflicts.

Involved Parties: *Brooks Pierce, East Carolina University- Coastal Studies Institute, Division of Marine Fisheries, North Carolina Coastal Federation, North Carolina Sea Grant, University of North Carolina Institute of Marine Sciences*

Specific action steps include the following:

- Implement the findings of the study on how to reduce user conflicts related to shellfish cultivation.
- Ensure re-opening of moratoria imposed by the shellfish aquaculture legislation.
- Develop criteria for Shellfish Enterprise Areas.
- Reevaluate Strategic Plan's Recommendation #10 in light of the findings of the user conflict study ("Amend North Carolina General Statute §113-202 to afford the Secretary of the Department of Environmental Quality substantial discretion in balancing public trust uses").
- Establish Shellfish Enterprise Areas in compliance with existing shellfish lease statutes.
- Amend the statute to increase the duration of leases from 10 to 20 years.

Action 3: Support aquaculture related research.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, East Carolina University- Coastal Studies Institute, North Carolina Sea Grant, North Carolina State University- Center for Marine Science and Technology, University of North Carolina Institute of Marine Sciences, University of North Carolina Wilmington*

Specific action steps include the following:

- Develop a list of research needs and progress for the annual report.
- Fund a Shellfish Aquaculture Grant Program administered by North Carolina Sea Grant.
- Provide guidance and support efforts for the UNCW Shellfish Research Hatchery and other possible/future hatcheries.
- Research environmental, economic and social impacts of oyster aquaculture.

Action 4: Monitor and report on industry growth.

Involved Parties: *Division of Marine Fisheries, North Carolina Coastal Federation, North Carolina Sea Grant*

Specific action steps include the following:

- **Ensure the 2030 goal**. Report shellfish aquaculture landings each year and report progress in State of the Oyster Report.

Year	Estimated Landings Range (in millions)
Year 1 - 2021	$6.2 - $7
Year 2 – 2022	$7 - $8.6
Year 3 – 2023	$8.6 - $10.4
Year 4 - 2024	$10.4 - $12.5
Year 5 - 2025	$12.5 - $15

- Evaluate Data Used to Monitor and Report Industry Growth
- Organize a multistakeholder working group to evaluate data collection methods and type of data used to track progress and other relevant actions. The group should develop recommendations for any possible changes.

Action 5: Improve marketing, promotion and distribution of shellfish products.

Involved Parties: *North Carolina Sea Grant, North Carolina Coastal Federation, North Carolina Shellfish Growers Association*

Specific action steps include the following:

- Develop a network of aquaculture incubator hubs along the coast to support the industry.
- Perform a market study analysis for N.C shellfish aquaculture products, both in and out of state.
- Establish a Shellfish Aquaculture Advisory Panel at the N.C. Department of Agriculture and Consumer Services with the following roles: fulfill mandate to promote the industry; develop an annual assessment report to guide adaptive management.
- Appropriate funding to develop NC Oyster Trail.
- Develop a public awareness program to
- build knowledge of the business
- explain the value oysters contribute both environmentally and economically
- eliminate misconceptions (R months, southern oysters, etc.)
- Develop alternative routes to market and value-added offerings.
- Processing opportunities in conjunction with the EDPNC, N.C. State Food Processing Innovation Center and retail channels
- Leverage and build channels of distribution in N.C. and beyond.

Educate Strategy: Outreach and Engagement

Overarching goal: Create communication and outreach strategies that engages stakeholders and the general public to actively support the goals, strategies and actions outlined in the Blueprint.

Action 1: Engage the Oyster Steering Committee and members' corresponding organizations to convey the work being done through the Blueprint.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, East Carolina University, North Carolina Aquariums, Division of Marine Fisheries, North Carolina Coastal Federation, North Carolina Sea Grant, North Carolina University-Center for Marine Science and Technology*

Specific action steps include the following:

- Review target audiences reached by past Blueprint communication efforts and identify any new or changed priorities regarding audiences to reach with new Blueprint.
- Continue to engage a steering committee and continue the work of the two regional workgroups to identify, select, monitor, implement and evaluate restoration and communication strategies with key stakeholders. Annually review successes and failures of the communications strategy with steering committee.
- Create an editorial calendar that the steering committee and other stakeholders can review and contribute to monthly in order to properly encapsulate the work of all stakeholders in the Blueprint.
- Convene at least three steering committee meeting each year to coordinate the work of workgroups and other stakeholders.
- Hold at least two strategy workgroup meetings each year to guide restoration efforts.
- Hold technical workshops as needed, targeting one per year, to encourage communication and partnership opportunities.
- Organize at least one major public oyster summit every two years.
- Maintain and update annually a list of research needs and questions, and report annually on findings and answers related to that list.
- Devise a strategy to be reviewed by the Steering Committee for building broader public awareness that engages adults and students in actions of the Blueprint.

Action 2: Use digital and online media to expand the reach of the Blueprint.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, Department of Cultural and Natural Resources, East Carolina University, North Carolina Aquariums, North Carolina Coastal Federation, North Carolina Sea Grant, North Carolina State University-Center for Marine Science and Technology*

Specific action steps include the following:

- Supply content to keep website updated to include historic and current data on Blueprint goals and actions.
- Make website more visually appealing and organized, so that it reflects work accomplished by all stakeholders involved.
- Make content relevant and up-to-date on a monthly basis, including publishing updated links to shellfish maps on Blueprint website.
- Create a database of educational resources to be listed on the ncoysters.org website. Create quarterly Grower Profiles for website.
- Create social media accounts corresponding to the Blueprint and website.
- Evaluate the benefit of creating a quarterly On the Half Shell digital newsletter. If maintained, increase subscriber list to On the Half Shell by 50 percent at the end of 2025.
- Analyze monthly metrics on website, social media activity and digital newsletter visitation, and report findings to the steering committee at its meetings.
- Create monthly, incremental goals for viewership and engagement across platforms including: three posts per month with at least 150 likes; three interactive social media days per month like polls and Q&A; and Increase website and newsletter traffic by 5 percent per month.
- Provide action steps for audiences in each post, event, newsletter, website update – for example, "learn more here" or "donate here."

Action 3: Engage stakeholders beyond the Oyster Steering Committee to help advance the work of the Blueprint.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, East Carolina University- Coastal Studies Institute, North Carolina Aquariums, North Carolina Coastal Federation, North Carolina Sea Grant, North Carolina State University-Center for Marine Science and Technology, University of North Carolina Wilmington*

Specific action steps include the following:

- Expand the use of the Oyster Trail as a communications tool to highlight the work of the Blueprint.
- Invite and engage lawmakers in activities related to the goals and actions in the Blueprint so they can see firsthand the results of their support.
- Assist growers and other private sector stakeholders in engaging with policy makers to demonstrate support for relevant policy and appropriation's requests.
- Highlight the Blueprint in working watermen publications, both print and online. Identify communications potentials with working watermen.
- Conduct periodic survey of stakeholders to help direct communications strategies so that they reflect the priority of target audiences and contain appropriate content and messaging.
- Identify nonstakeholder interest in Blueprint and Steering Committee efforts.
- Work with stakeholders to create effective and consistent messaging campaigns that help advance the work of the Blueprint.

Action 4: Use traditional and print media to expand the reach of the Blueprint.

Involved Parties: *Albemarle-Pamlico National Estuary Partnership, East Carolina University, North Carolina Aquariums, North Carolina Coastal Federation*

Specific action steps include the following:

- Produce an annual report on actions taken to carry-out the Blueprint recommendations. Aim to have report ready prior to sessions of the N.C. General Assembly. Report on work accomplished in a way so that successes and failures can be identified and evaluated to help communicate lessons learned.
- Develop and distribute flyers and other appropriate published materials about the Blueprint to restaurants, town centers (specifically coastal), public spaces and event.

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