

North Carolina Oyster Sanctuaries

Growing Coastal Communities 2013–2023

SEPTEMBER 2024

RTI PROJECT NUMBER 0219440.000



North Carolina
Coastal Federation
Working Together for a Healthy Coast

RTI
INTERNATIONAL

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North Carolina
Coastal Federation
Working Together for a Healthy Coast



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Glossary of Terms

TERM	UNITS	DEFINITION
Benefit-to-cost ratio (BCR)	<i>Ratio</i>	A ratio formed by setting the numerator as the present value (PV) of benefits resulting from an investment, and the denominator as the PV of investment costs, where discounting is performed at a 2% real discount rate.
Discount rate	<i>Percent</i>	A discount rate is the interest rate used in discounted cash flow (DCF) analysis to determine the PV of future cash flows. Investors and businesses use the discount rate to evaluate potential investments. The current discount rate recommended by the federal Office of Management and Budget (OMB) for use in benefit-cost analyses is 2%.
Internal rate of return (IRR)	<i>Percent</i>	The percentage yield on an investment calculated as the interest rate that, when used in appropriate discount formulas, equates the PV of benefits with the PV of costs for an investment, resulting in a net present value of zero and a BCR of one. The IRR can be compared with the OMB-specified real discount rate, currently set at 2% for benefit-cost analysis.
Net present value (NPV)	<i>Dollars</i>	The PV benefits from an investment, less the PV of the investment cost, where discounting is performed at a 2% real discount rate.
Payback period	<i>Years</i>	Amount of time that it is estimated to take for the PV of benefits from an investment to outweigh the PV of costs of that investment, applying a discount rate of 2%.

Director's letter



The North Carolina Coastal Federation is proud to work together with our partners for a healthy coast, including the N.C. Division of Marine Fisheries, the state legislature, National Oceanic and Atmospheric Administration and many others who have joined together to support the Senator Jean Preston Oyster Sanctuary Network.

The oyster sanctuary program has resulted in tremendous benefits to the oyster population and our coast, from both an environmental and economic perspective. We can be proud of this network that protects nearly 350 million oysters and covers almost 400 acres of Pamlico Sound. These protected reefs serve as an insurance policy to our oyster populations - safeguarding adult oysters that spawn and support the

sound's oyster population while creating new fish habitats and improving water clarity and quality. Furthermore, the construction of these reefs creates jobs and supports our coastal culture.

As we are on the cusp of reaching our goal to build 500 acres of oyster sanctuary in the Pamlico Sound, and with over \$20 million of state and federal investments being made in this program during the last decade, this is an important time to take a step back and critically evaluate the quantifiable benefits of this program. Benefits that include new oyster habitat built, jobs created, improved recreational and commercial fishing opportunities, and water quality benefits. This report helps us understand that the investments made are seeing a true return.

As we continue to invest in environmental restoration projects along the coast of North Carolina, we will seek to maximize the social and economic co-benefits of this work, as we have seen in the Senator Jean Preston Oyster Sanctuary Network.

For the coast and the oysters!

Erin Fleckenstein

Oyster Program Director
North Carolina Coastal Federation

Executive Summary

In the 1990s, North Carolina’s leadership committed to an ambitious plan to protect and enhance the state’s oyster habitats to sustain the oyster industry and maintain water quality. During the last 28 years, the state has made noteworthy progress toward oyster habitat enhancement through two different programs: the Oyster Sanctuary Program and the Shellfish Rehabilitation Program.

This report focuses exclusively on the last 10 years (2013–2023) of the Oyster Sanctuary Program. The sanctuary program’s primary objective is to establish a network of no-harvest oyster reefs, which serve as reef habitat and provide oyster larvae to reseed the wild population and support harvested oyster reefs in Pamlico Sound. The North Carolina Department of Environmental Quality’s Division of Marine Fisheries implements the Oyster Sanctuary Program. **As of 2023, North Carolina has developed 15 oyster sanctuaries with 389 acres of habitat in the Senator Jean Preston Oyster Sanctuary Network.**

The North Carolina Coastal Federation is a member-supported nonprofit organization that focuses on protecting and restoring the North Carolina coast. Since 1982, the Coastal Federation has been in the field restoring miles of coastline and training and educating students, adults, and communities to take actions that result in cleaner coastal waters and advocating for an accessible, healthy, productive coast. The Coastal Federation, along with federal, state, and community partners, has been instrumental in developing and leading the implementation of the “Oyster Restoration and Protection Plan for North Carolina: A Blueprint for Action” and facilitating grant funding for sanctuary development.

To better document how sanctuaries contribute to the coastal economy and environment, the Coastal Federation contracted with RTI International to assess the benefits and costs of the Oyster Sanctuary Program and to measure the impacts of program spending on the coastal region. By comparing the costs to the benefits, we can develop an understanding of how these investments can lead to community benefits. This study focuses on sanctuary construction between 2013 and 2023.

Key findings include the following:

- In the last decade, North Carolina invested just over \$20 million of government and private funds in sanctuary construction. Approximately \$13 million in state funds matched an additional \$7 million in federal and private funds. These resources created 159 acres of oyster sanctuary.
- The sanctuaries provide key market and non-market benefits, including:
 - Recreational fishing
 - Commercial fishing
 - Water quality services such as nitrogen removal and improved water clarity for submerged aquatic vegetation (SAV) habitat.

- **Combined oyster sanctuary benefits are expected to be worth \$38 million between 2014 and 2048.**
 - Every \$1.00 invested in oyster sanctuaries provides North Carolina with \$1.71 in expected benefits.
 - Expected benefits include recreational fishing (38%), water quality (33%), and commercial fishing (29%).
- **Oyster Sanctuary Program spending resulted in the following impacts:**
 - Supported 143 total jobs
 - Generated \$34 million in revenue to North Carolina businesses
 - Provided \$8.7 million in employee wages and benefits.

Program funding amounts included salaries and benefits, supplies such as limestone and granite, and transportation of materials and deployment into the Pamlico Sound. Local businesses, including quarries, transportation firms, construction groups, and equipment rental companies benefited directly from this spending.

The benefits resulting from sanctuary program funding are concentrated in the coastal counties of Carteret, Chowan, Craven, and Dare mainly due to the location of program partners and resources. These four counties experience less poverty and unemployment when compared to the coastal region overall, but future program funding can potentially extend the benefits to reach more disadvantaged populations by expanding into neighboring counties such as Hyde and Washington. These two counties have higher proportions of minority and impoverished individuals.

While the water filtration benefit associated with oyster restoration is experienced broadly within the coastal region, harvesting benefits mostly provide opportunities to commercial and recreational fishers of the sound. These individuals accumulate food and income by harvesting the fish and crustaceans that become more abundant as more habitats are supported by oyster reefs. Most fishers experiencing these benefits are white males over the age of 40, but the activities likely generate indirect benefits to others through their participation in the seafood industry.

This study was unable to model the potential impacts of oyster sanctuaries on oyster harvest levels due to a lack of baseline information on the oyster population level or the maximum sustainable yield of oysters along the North Carolina coast. A comprehensive stock assessment of oysters in North Carolina has not been possible in the past due to a lack of data (NCDMF, 2023). The Division of Marine Fisheries is in the process of developing a methodology for a future oyster stock assessment. This assessment will provide valuable information to inform management and conservation practices.

1. Introduction

Oyster sanctuaries provide a wide range of environmental and economic benefits for North Carolina. First developed in the 1990s, the state's oyster sanctuaries now cover almost 400 acres in the Pamlico Sound. This report was commissioned by the North Carolina Coastal Federation to better understand the amount of state and federal funding that has been used to create and maintain the sanctuaries and the resulting benefits of this funding. By comparing these costs to the benefits, we can develop an understanding of how these investments can lead to community benefits.

RTI first assessed the costs and benefits associated with oyster sanctuaries in the 2016 report, "Economic Analysis of the Costs and Benefits of Restoration and Enhancement of Shellfish Habitat and Oyster Propagation in North Carolina," which was prepared for the Albemarle-Pamlico National Estuary Partnership. This research sought to assess the benefits and costs of three different state programs—the Oyster Sanctuary Program, the Shellfish Rehabilitation Program, and the Inshore Artificial Reef Program. In contrast, this current effort exclusively focuses on the Oyster Sanctuary Program.

The specific research questions that this report attempts to answer are the following.

- How much has been invested by different entities to construct the Senator Jean Preston Oyster Sanctuary Network from 2013 to 2023?
- What is the return on investment for state funding that is directed toward the Senator Jean Preston Oyster Sanctuary Network and how do these state funds leverage other investments?
- What are the total (direct, indirect [business to business spending], and induced [worker spending]) economic benefits associated with investment in construction and maintenance of the Senator Jean Preston Oyster Sanctuary Network?

- What is the profile of people who benefit from oyster sanctuaries and what share of the benefits from oyster sanctuaries are realized by underserved or disadvantaged communities?

1.1 Report Background

This report was prepared by RTI on behalf of the North Carolina Coastal Federation (the Coastal Federation).

North Carolina Coastal Federation is a member-supported nonprofit organization that focuses on protecting and restoring the North Carolina coast. Since 1982, the Coastal Federation has been in the field restoring miles of coastline and training and educating students, adults, and communities to take actions that result in cleaner coastal waters and advocating for an accessible, healthy, productive coast.

Created to give a united voice to the need for long-term coastal management, the Coastal Federation remains a collaborative, grassroots organization at its heart and brings together traditional and nontraditional organizations, government agencies, and businesses to achieve what is best for the North Carolina coast and to leave a legacy of clean water for future generations.

The Coastal Federation has 16,000 supporters and reaches almost 300,000 people directly each year through various engagement activities like local school partnerships, social media, online and traditional media outlets, as well as events.

The North Carolina Division of Marine Fisheries (NCDMF) is responsible for the stewardship of the state's marine and estuarine resources. NCDMF's jurisdiction encompasses all coastal waters and extends to three miles offshore. Agency policies are established by the nine-member Marine Fisheries Commission and the Secretary of the Department of Environmental Quality. North Carolina is a member of the Atlantic States Marine

Fisheries Commission, the Mid-Atlantic Fishery Management Council, and the South Atlantic Fishery Management Council.

RTI International is an independent, nonprofit research institute dedicated to improving the human condition. Our vision is to address the world's most critical problems with science-based solutions in pursuit of a better future. Clients rely on us to answer questions that demand an objective and multidisciplinary approach—one that integrates expertise across the social and laboratory sciences, engineering, and international development.

1.2 Analysis Scope and Objectives

The objectives of this research are to examine the benefits of oyster sanctuaries relative to the costs, consider how these benefits are distributed through the community, and determine how state funding has been used to leverage federal investment. To complete this work, RTI performed the following tasks:

- Identified the amount of federal, state, and private funds that were used to create oyster sanctuaries between 2013 and 2023
- Specified an IMPLAN model to estimate the economic impacts associated with oyster sanctuary creation and monitoring
- Reviewed current literature for estimates for oyster sanctuary benefits that could be applied to North Carolina's sanctuaries
- Created a benefit-cost analysis to determine the return on investment associated with creating and maintaining oyster sanctuaries
- Considered methods to determine how benefits are distributed across populations in the coastal region.

1.3 Report Organization

Chapter 2 provides background about the formation and operation of North Carolina's Senator Jean Preston Oyster Sanctuary Network. Here we provide information about the benefits associated with the eastern oyster, detail North Carolina's policies and funding to support the network, and depicts the location and size of sanctuaries. We describe how NCDMF constructs and maintains sanctuaries and how the Coastal Federation supports these efforts. The last portion of this chapter provides demographic information for the coastal counties most directly impacted by oyster sanctuary activity.

Chapter 3 contains an accounting of spending from various sources that has been used to create the sanctuaries. Costs are broken into specific categories to depict composition of spending. An IMPLAN input-output (I-O) model estimates the economic impacts, such as jobs and labor income, supported by spending on sanctuary construction and maintenance between 2013 and 2023.

I-O models cannot account for non-market benefits, or benefits for which traditional markets do not exist, produced by oyster sanctuaries. To measure these more comprehensive benefits, Chapter 4 contains estimates of oyster sanctuary benefits taken from other studies and applies them to North Carolina's sanctuaries. These estimates of benefits are used in conjunction with the costs estimated in Chapter 3 to produce a benefit-to-cost analysis and return on investment for the state's oyster sanctuaries. The sensitivity of these results is tested using varied discount rates¹ and benefit amounts.

Chapter 5 summarizes key findings from previous chapters, compares the results of this research with past efforts, and presents information about new activities the Coastal Federation and NCDMF will be undertaking in the coming years with support from the National Oceanic and Atmospheric Administration (NOAA) and the state of North Carolina. In addition, this chapter presents some ideas for future research.

¹ A discount rate is the interest rate used in discounted cash flow (DCF) analysis to determine the present value of future cash flows. Investors and businesses use the discount rate to evaluate potential investments.

2. Oyster Sanctuaries in Eastern North Carolina



Source: North Carolina Coastal Federation; photo by Daniel Pullen

Throughout history, oysters have been an important source of sustenance for people and aquatic organisms. But the benefits provided by oysters and oyster reefs extend well beyond being a food source. As sedentary filter feeders, oysters remove sediment and nitrogen from water, improving water quality and clarity (Grabowski and Peterson, 2007). Oyster reefs, which consist of successive layers of oysters clustered together to form solid masses, provide an ideal habitat for fish and aquatic animals to spawn and grow, increasing fish populations and biodiversity (Lotze et al., 2006). Furthermore, high water quality supports recreational activities such as boating and associated tourism (Lipton, 2004).

The type of oyster found in North Carolina is the eastern oyster or *Crassostrea virginica*, a bivalve mollusk that thrives in brackish estuarine habitat. The eastern oyster can grow up to eight inches long and live up to twenty years (NOAA, 2023). During the last century, oyster stocks have declined globally, with an estimated 85% of all oyster reefs lost. In North Carolina, more than 90% of oyster reef area has been lost (Beck et al., 2011). The causes of this decline include overharvesting, disease, declines in water quality, and natural disasters. A comprehensive oyster stock assessment has not been completed in North

Carolina due to data limitations, meaning scientists have little information on changes in oyster populations relative to the past nor the level of maximum sustainable yield (NCDMF, 2023).

2.1 Oyster Sanctuaries

The oyster sanctuaries in Pamlico Sound are areas where the harvest of oysters is prohibited (NCDMF, n.d.a). This protection allow oysters to grow into adulthood and provide larvae to help sustain and grow populations in other parts of the sound. A single adult oyster produces millions of eggs each year and currents carry them until they find a suitable structure to settle on (NOAA, 2024).

Examples of fish and shellfish found on oyster sanctuaries

Sheepshead	Blue crab
Oyster toadfish	Clams
Red drum	Atlantic croaker
Southern flounder	Black sea bass
Shrimp	Blue fish

The primary objective of the North Carolina Oyster Sanctuary Program is to establish a network of no-harvest oyster reefs that serve as habitat and provide larvae to reseed the wild population; thereby supporting harvested oyster reefs. Having protected oyster reefs as a source of brood stock ensures a dedicated source of larval oysters in the sound. Sanctuaries are developed in areas most conducive to oyster growth and proliferation (i.e., optimum salinity and oxygen levels, ample water flow and depth, available substrate for continued larval settlement) (Callihan et al., 2016). For their relative footprint, oyster sanctuaries contribute disproportionately to the oyster population and larval output in the sound. Sanctuaries cover only about 6% of the oyster reef footprint in the Pamlico

Sound, but account for more than 19% of the oyster population and provide 25% of all the oyster larvae that settle within the sound (Theuerkauf et al., 2021).

Oyster sanctuaries are open to commercial and recreational hook-and-line fishing. Commercial finfish and crustacean fishers directly benefit from oyster sanctuaries via the natural recruitment and use of the reef by commercially valuable species. Commercial shellfish harvesters benefit from protected oysters providing larvae to natural reefs and cultch planted sites, thereby growing the number of oysters available for harvest. Recreational fishers also benefit from the increased opportunity to target and catch reef-associated species (Callihan et al., 2016). The list in the sidebar contains a few of the relatively common oyster sanctuary-associated species in North Carolina that have an existing commercial or recreational fishing value (NCDMF, n.d.b, Settlage, 2012).

2.2 State Policy and Investment

The North Carolina General Assembly convened the Blue Ribbon Advisory Council on Oysters during the 1994 session to consider the issue of oyster declines and make recommendations to restore and manage the state's oyster resources. The formation of the Council was driven by commercial fishers who were concerned about the dwindling oyster harvest. Based on the Council's findings, the first oyster sanctuary was established in 1996 in Pamlico Sound. In subsequent years, the number of sanctuaries has grown to 15.

The General Assembly has continued to provide strong policy support for oyster sanctuaries. Session Law 2015-241 established the Senator Jean Preston Oyster Sanctuary Network. This session law stipulates sanctuary areas are, "to enhance shellfish habitats within the Albemarle and Pamlico Sound and their tributaries to benefit fisheries, water quality, and the economy."

From 2013 to 2023, approximately \$13.4 million of state funds were used to support oyster sanctuaries. State funding for oyster sanctuaries also attracts additional federal and private funding,

magnifying the impact of these funds. The Coastal Federation has received three different grants from NOAA in the past 15 years to help construct oyster sanctuaries. These federal funds represent 35% of all oyster sanctuary funding. In addition, early in the program, NCDMF received financial support from groups like the Nature Conservancy, the Albemarle-Pamlico National Estuary Partnership, and the U.S. Army Corps of Engineers. The agency also applies for funds from the Coastal Recreational Fishing License (CRFL) Grant Program, which supports projects that manage, protect, restore, and enhance the marine resources of the state (NCDEQ, 2023).

Organizational Cooperation

Beginning in 2003, the Coastal Federation worked with other state, federal, nonprofit and university partners, to build upon and reinvigorate the work of the Council's findings to develop the Oyster Restoration and Protection Plan for North Carolina: A Blueprint for Action. This document is now on its fourth edition and serves as a road map for actions that can be undertaken to preserve and restore oyster populations. The plan, which is referred to as the Blueprint, fosters partnership and collaboration by creating a common set of goals and actions along with a delineation of responsibilities and roles needed to build and protect oyster resources in the state. The Coastal Federation provides staffing for the Blueprint effort and develops communications materials for education and outreach to provide the public with insights on program activities and progress.

Blueprint partners include more than two dozen state and federal agencies, other nonprofits, university and research partners, private companies, and oyster farmers and harvesters. The list of partners includes North Carolina Division of Marine Fisheries, National Oceanic and Atmospheric Administration, North Carolina Sea Grant, NC Shellfish Growers Association, the Nature Conservancy, North Carolina Aquariums, North Carolina Division of Coastal Management, Albemarle-Pamlico National Estuary Partnership, Carteret Community College, East Carolina University, North Carolina State University,

University of North Carolina at Wilmington, North Carolina Central University, and the University of North Carolina Chapel Hill, Institute of Marine Sciences, among others.

One of the main goals outlined in the Blueprint is to build 500 acres of oyster sanctuary in Pamlico Sound by 2025. The breadth of responsibilities that come with sustaining North Carolina’s Oyster Sanctuary Program requires an equally broad set of skills and expertise, which has been established through strategic partnerships. The NCDMF is the state agency responsible for constructing and maintaining oyster sanctuaries. Strong partnerships among NCDMF, the Coastal Federation, and other partners has provided greater resources and

management tools that support the aims of the Oyster Sanctuary Program.

To support the growth of the oyster sanctuaries, the Coastal Federation was awarded a \$5 million grant entitled “Putting Private Industry to Work Rebuilding North Carolina’s Oyster Habitat” as part of the American Reinvestment and Recovery Act in 2009. This funding allowed NCDMF and the Coastal Federation’s contractors to construct 47 acres of sanctuary (NCCF, 2009). Since 2017, the Coastal Federation and NCDMF have had a partner agreement and more recently a Memorandum of Understanding that outlines responsibilities between the two entities for oyster sanctuary efforts. The Coastal Federation provides grant

Table 1. Division of Oyster Sanctuary Responsibilities

Responsibility	Coastal Federation	Division of Marine Fisheries	Project Partners/Vendors
Project Management			
Administration and coordination	•	•	
Contracting	•	•	•
Financial support	•	•	
Reporting, outreach, and communication	•	•	
Reef Materials			
Mining and quarrying			•
Stockpiling		•	•
Purchasing	•	•	
Transport			•
Reef Construction and Restoration			
Site selection		•	
Permitting		•	
Construction		•	•
Monitoring		•	

Source: RTI based on information from the Coastal Federation and NCDMF.

writing and financial support for construction activities, coordinates regular planning meetings with NCDMF staff and outside advisors, partners to bid and contract with vendors to purchase materials and construction services, and communicates project activities and results via social media, website, and other media outlets. NCDMF is responsible for selecting sanctuary sites, acquiring needed permits, designing sanctuaries, and developing plans for distribution of materials within reef boundaries. NCDMF also purchases materials, stockpiles them at their facility, and coordinates with the Coastal Federation's vendor on construction activities. NCDMF monitors sanctuary sites and regularly reports details on the status of each site. **Table 1** depicts program responsibilities by organization.

The Coastal Federation and the NCDMF are aided by North Carolina's strong marine sciences research institutions. Researchers at North Carolina State University's Center for Marine Science and Technology, the North Carolina Coastal Reserve and

National Estuarine Research Reserve developed a habitat suitability index to guide siting of sanctuaries. By using the habitat suitability index model, sanctuaries are developed in areas that provide the best possible environment for oyster growth and reproduction (Puckett et al., 2018). Other research is being done to examine the long-term viability of the reefs and factors, such as larval connectivity, that contribute to oyster restoration.

2.3 Oyster Sanctuary Location and Size Growth

North Carolina's Jean Preston Oyster Sanctuary Network consists of 15 individual sites spread across Pamlico Sound and its tributaries. Although the Blue Ribbon Advisory Council on Oysters specifically indicated that sanctuaries be established in both the Albemarle and Pamlico Sounds, the Pamlico Sound has better environmental conditions for oyster production and was once a highly productive oyster habitat. NCDMF has chosen to locate sanctuaries in the

Pamlico Sound where they will have the best potential for success. **Figure 1** presents the locations of North Carolina's oyster sanctuaries.

Between the end of 2012 and 2023, the total area in the Pamlico Sound devoted to oyster sanctuaries increased by 159 developed acres. By the end of 2023, oyster sanctuaries were established on a total of 389 developed acres (**Table 2**).

Whereas most of this growth occurred in steady increments, there was one year, 2021, in which the oyster sanctuary area declined. This decline is due to the NCDMF engaging in rulemaking to remove Clam Shoal and Ocracoke from the designated list of oyster sanctuaries. The agency sought this change after long-term biological evaluation determined that these sites no longer functioned as biologically productive oyster sanctuaries (Luck, 2019).

Figure 1. Location of Oyster Sanctuaries in the Pamlico Sound



Source: The North Carolina Coastal Federation, 2022.

Table 2. Oyster Sanctuary Build Out by Year

REGION	COVERING COSTS	
2012		187.4
2013	28.05	215.45
2014	5.87	221.32
2015	26.8	248.12
2016	12.4	260.52
2017	12.52	273.04
2018	22.63	295.67
2019	12.52	308.19
2020	30.1	338.29
2021	-26.7	311.59
2022	17.58	329.17
2023	59.58*	388.75

Source: NCDMF, 2024.

Notes: The developed acreage numbers are not comparable to figures reported in the 2016 study as those represent the approximate footprint area rather than developed acres. In 2021, the number of sanctuary acres declined due to removal of sanctuary status from the Clam Shoal and Ocracoke sites. * 42 of these acres were transferred from the Division of Mitigation Services and are not included in this analysis.

2.4 Coastal North Carolina Demographics

Understanding who benefits and how benefits are distributed from oyster sanctuaries is a major question this report is trying to answer. This section of the report strives to provide background information about which coastal counties benefit and their population demographics. About 10% of North Carolina's total population resides within one of 20 counties that form the state's coastal region where oyster sanctuary activities occur. More than 220-thousand coastal residents live in the four counties that directly benefit from oyster sanctuary network activities, based on the location of project sites and partners. These four focus counties are: Carteret, Chowan, Craven, and Dare. [Table 3](#)

compares the demographics of these four focus counties with the coastal region and the rest of the state. A comprehensive summary of coastal county demographics is presented in [Appendix A](#).

The median age in three of the four focus counties is older than the state average of 43 years, but Craven County has a younger population than the other three counties, with a median age of 39 years. The ratio of males to females in most coastal counties falls near the state average of 98 males per 100 females, but Chowan County's ratio is 91.3 - the 8th lowest ratio in the state. Chowan County additionally has a relatively high minority population proportion and higher rates of poverty when compared to both coastal and state averages. Higher rates of poverty and higher minority population proportions are often linked to increased rates of social and economic vulnerability, so benefits impacting counties like Chowan are especially important because they are more likely to impact the state's most vulnerable populations.

Counties within the coastal region have a higher-than-average unemployment rate when compared to the state, but all four of the focus counties experience lower than average rates of unemployment. Three of the four focus counties also have relatively high median income values, but Chowan County's median income is more than 10% lower than the state average. Chowan County falls within the bottom one-third of counties across the state based on median income.

The age-dependency ratio for three of the four focus counties lands at or near the state average of about 70%, but Carteret County has a much higher age dependency ratio of nearly 83%, likely due to the county's higher than average median age. Carteret's higher age dependency ratio implies that its workforce carries a larger relative economic burden due to higher proportions of dependent populations aged below 16 and above 65. [Table 4](#) compares the workforce metrics for the four focus counties with the coastal region and the state.

Table 3. Coastal North Carolina Demographics

Geography	Median Age (years)	Sex Ratio (Males per 100 Females)	Percent, %		
			Non-White Population	Income Below Poverty Level, Last 12 Months	25+ Population with a Bachelor's Degree
North Carolina*	43	98	30.6	15.0	15.7
Rest of NC*	43	97	30.2	15.4	15.8
Coastal NC*	45	102	32.5	13.7	15.3
Carteret	50	97	11.9	9.5	19.8
Chowan	49	91.3	39.6	20.5	15.1
Craven	39	100.1	31.6	13.4	15.1
Dare	48	99.7	12.1	6.5	28.0

* Mean value; Source: U.S. Census Bureau. 2018–2022 American Community Survey 5-Year Estimates. Table B02001, S0101, B17001, and S1501.

Table 4. Coastal North Carolina Workforce

Geography	Median Income (2022\$)	Civilian Employed Population (16+)	Percent, %	
			Unemployment Rate	Age-Dependency Ratio
North Carolina	\$58,261*	4,925,500	5.7*	69.8*
Rest of NC	\$57,714*	4,469,528	5.6*	69.3*
Coastal NC	\$60,453*	455,972	6.0*	78.6*
Carteret	\$66,965	30,029	4.9	82.6
Chowan	\$51,188	5,922	4.3	71
Craven	\$61,676	40,158	5.1	63.7
Dare	\$79,742	19,041	5.1	69

* Mean value; Source: U.S. Census Bureau. 2018–2022 American Community Survey 5-Year Estimates. Table S2301 and S1903.

3. Economic Impacts of Spending on Sanctuaries



Source: North Carolina Coastal Federation

Figure 2 depicts some of the leading organizations and businesses that are involved in oyster sanctuary construction. When money is spent to create oyster sanctuaries, it has a ripple effect on the surrounding communities and region. Because the source of these funds is usually a federal grant or state appropriation, this spending is in addition to existing economic activity in the region with many local businesses directly benefiting. Still more receive additional business and sales due to indirect and induced spending in the community. As depicted in the image, oyster sanctuary partners, like the North Carolina Aquariums and the North Carolina Division of Marine Fisheries, line the state's coast while other partners such as Martin Marietta and Stevens Towing, are located further inland.

Figure 2. Senator Jean Preston Oyster Sanctuary Network Partners and Services



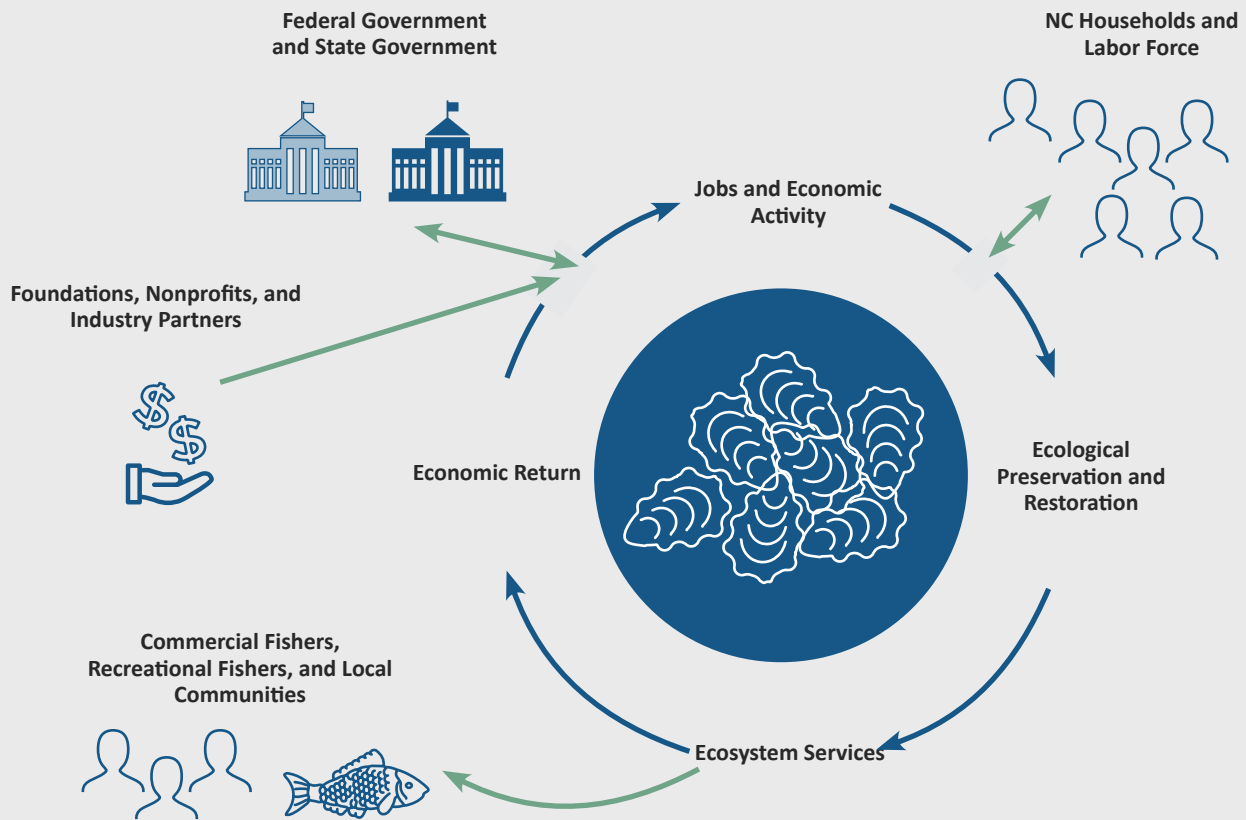
Source: RTI International, 2024.

Figure 3 depicts the ties between oyster sanctuary activities and the regional economy. Although sanctuary construction takes place in the Pamlico Sound, construction spending supports jobs and companies across the entire coastal region. Companies in Chowan, Dare, Craven, and Carteret provide goods and services for sanctuary construction. The sanctuaries provide ecosystem services that provide benefits to recreational and commercial fishers, tourists, residents, and communities. These benefits result in financial gains for local communities and the state by making coastal counties desirable tourism spots and sustaining the commercial fishing industry.



Source: North Carolina Coastal Federation

Figure 3. Oyster Sanctuary Spending Flows Through Economy



Source: RTI International, 2024.

Martin Marietta Materials

NCDMF uses limestone marl, granite, basalt, and recycled concrete materials to construct sanctuaries. These materials are cost effective and can be provided by local companies.

For example, Martin Marietta is a leading supplier of building materials, including aggregates, cement, ready mixed concrete, and asphalt. Through a network of operations spanning more than 500 facilities in 28 states, Canada and The Bahamas, Martin Marietta supplies building materials for a variety of industries and uses. Martin Marietta's marl has played a major role in the creation of North Carolina's oyster sanctuaries with class B rip rap (bowling ball-sized limestone rock) from Clarks Quarry, near New Bern, being used as the primary material for reefs. Since 2018, more than 150,000 tons of Martin Marietta limestone has been used for oyster reef creation. Other materials, such as granite and basalt, are sourced from Martin Marietta's Fountain Quarry, located in Pitt County. Martin Marietta also supplies oyster sanctuary efforts in other states such as Maryland and Florida.

The Clarks Quarry employs 28 people in skilled occupations such as equipment operators, team supervisors, and office staff. In addition, the facility subcontracts with local trucking firms to haul materials to clients and with a specialty firm that does rock splitting at the quarry. The company's Fountain location employs an additional 30 workers. Matt Waligora, General District Manager for Martin Marietta, believes that use of local stone products benefits their company and the Oyster Sanctuary Program:

Martin Marietta Facility in New Bern, NC



Source: Martin Marietta

"This is yet another example of how our aggregates can be used for countless applications for the betterment of our communities. Most people think of aggregates as solely an end use for construction purposes. While this makes up most of the primary business, projects like oyster sanctuaries underscore the wide breadth of unique opportunities for our aggregates to partner with the local environmental communities. Additionally, by having the source quarry close to the project allows for these projects to be completed by the most economical means possible."

3.1 Estimate of Total Spending

To estimate total funding used to plan, construct, and maintain oyster sanctuaries, we relied on annual spending data from the Coastal Federation and NCDMF records. In many cases, these records were detailed enough to know which companies benefited from spending, and to separate the cost of materials such as limestone out from transportation expenses. Construction of oyster mitigation projects by the Division of Mitigation Services are not included in this analysis.

Between 2013 and 2016, all oyster sanctuary construction was managed by NCDMF. The agency estimated staff hours and associated costs for these projects based on the number of oyster sanctuary deployments. The primary vessel for these deployments was the state-owned MV West Bay (crew of four NCDMF staff). For every deployment day, there are two estimated days of loading and transit (four NCDMF staff). For every four deployments, there is one estimated day of stockpiling materials (two NCDMF staff). The total number of days was multiplied by eight hours and subsequently by an average of \$20/hour cost to the state. Equipment rates for a front-end loader are based on 2019 day rates from the North Carolina Department of Transportation multiplied by the number of days stockpiling, loading/transiting, and deploying.²

Project costs between 2017 and 2023 were taken from cost matching letters sent from NCDMF to the Coastal Federation, which depict the amount of state resources used to create sanctuaries. The amount of federal grant funding used to construct sanctuaries was provided by the Coastal Federation and verified by Stevens Towing.

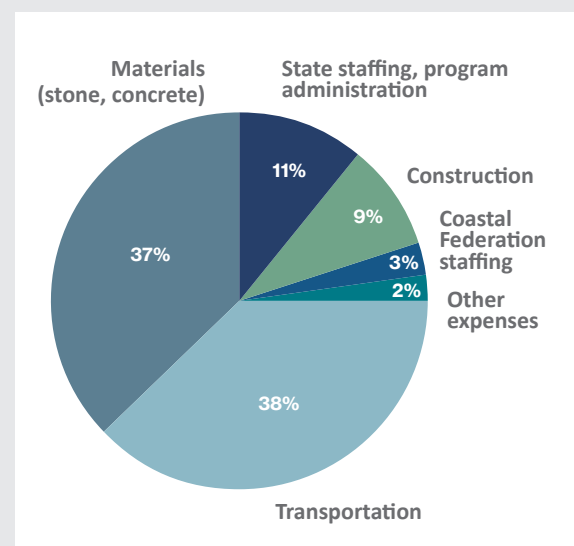
Using this methodology, total sanctuary spending was approximately \$20.3 million from 2013 to 2023. Major expenses include material purchase (limestone, granite, and concrete), truck and water transportation, construction, and project management. The distribution of total spending on

Organizations with Increased Sales

Martin Marietta Materials
Cape Dredging
North Carolina Division of Marine Fisheries
Sunland Development and Construction
North Carolina Coastal Federation
Stevens Towing Company
Multiple Independent Trucking Firms
Local Equipment Rental Companies

oyster sanctuaries is presented in **Figure 4**. Most funding was used to purchase oyster sanctuary materials and place this material within the sanctuary boundaries. Three percent of resources were devoted toward Federation activities that supported and promoted oyster sanctuaries such as grant administration, educating the public about benefits, dealing with contractors, and advocating for state and federal support. Another 11% of funding was used by NCDMF to support planning, oversee deployment, and maintenance of sanctuaries.

Figure 4. Oyster Sanctuary Creation Activities, 2013–2023



Source: RTI based on data from the Coastal Federation, NCDMF, and Stevens Towing.

² Methodology provided by the Division of Marine Fisheries

3.2 Methodology

To examine total economic impacts of this spending, we developed a customized regional/state IMPLAN input-output (I-O) model. Input-output analysis is a well-known and reliable methodology for estimating these expansive spill-over effects. The framework and methodological basis for the IMPLAN model is derived from the U.S. Department of Commerce's Benchmark Input-Output Accounts. The I-O accounts provide detailed information on the flows of the goods and services that make up the production processes of industries. The benchmark tables show how spending in one industry affects others. These relationships determine how regional economies may respond to specific economic events.

Four common measures of economic impact can be used to describe impacts:

- **Employment:** Consists of all full-time, part-time, and temporary positions.
- **Labor Income:** Represents multiple forms of employee compensation, including wages and benefits.
- **Value Added:** Provides an indicator of the labor, capital, and tax income generated from production activities. Also referred to as "State GDP." States use value added to describe the size of specific industries and the economy as a whole.
- **Output:** Represents the value of industry production. For manufacturers, output is equal to sales plus/minus the change in inventory. For service sectors, output equates to sales. Output is also used to describe the size of specific industries and the economy as a whole.



Source: North Carolina Coastal Federation

These measures are further broken down into direct, indirect, and induced effects. The total impact is the sum of all direct, indirect, and induced effects. For the Oyster Sanctuary Program, the effects are considered as follows:

- **Direct Effects:** Spending on oyster sanctuary creation.
- **Indirect Effects:** Oyster sanctuary suppliers' spending.
- **Induced Effects:** Direct and indirect effects of the Coastal Federation/NCDMF and suppliers' employees' spending.

Stevens Towing Company, Inc.

Stevens Towing Company, Inc. is one local business that assists with oyster sanctuary construction. Stevens is a midsize freight transportation company based on Yorges Island, South Carolina just south of Charleston with a Mid-Atlantic operation based in Edenton, North Carolina. The company was founded in 1913 and remains a family-owned business. Since 2009, the Coastal Federation and NCDMF have contracted with Stevens Towing to transport and deploy limestone, granite, recycled concrete, and other materials at designated oyster sanctuary locations. These contracts provide several months of work for 10 to 15 skilled employees.

Will Hollowell, Operations Manager at Stevens Towing, described their participation in the Oyster Sanctuary Program in the following way: *“Stevens Towing of NC considers our role in oyster sanctuary construction as a privilege to be a part of. I myself, as well as many members of our Stevens Towing family, grew up on the coast of eastern North Carolina so we look at this as an honor to be able to give back to the environment and be part of something bigger. We value our relationship with Coastal Federation and Marine Fisheries and take a team approach to these projects and I think our efforts are shown in the way we have grown oyster reef construction over the years with this year being the largest amount of tonnage to date. It helps that we all share the same vision and accept the responsibility to do our part to take care of our local waters and preserve our local waters hoping to make a difference not just today but for future generations.”*

Stevens Towing’s Special Projects Team Deploying Material



Source: Stevens Towing

\$20 million
invested generated
\$33.9 million
in revenue

143 jobs
supported oyster
sanctuary work

3.3 Summary of Results

As depicted in [Table 5](#), the total economic impacts associated with oyster sanctuaries were much greater than the initial spending. We estimate that between 2013 and 2023, spending on oyster sanctuaries generated more than \$33 million in total business revenue, supporting jobs in numerous industries.

A total of 61 jobs were needed to directly support oyster sanctuary work. These jobs were created in industries such as transportation, mining, construction, and state government services. Workers and business owners received more than \$4.4 million in wages and benefits. Subsequent rounds of spending (or indirect effects) include the money spent upstream on items such as financial services, employment services, and transportation equipment maintenance. This indirect activity supported 52 jobs and \$2.9 million in earnings.

The induced effect includes all money spent by the employees who receive salaries and benefits from jobs created by the Coastal Federation and NCDMF and local businesses on purchases such as those

from retail stores, restaurants, health care services, and other local businesses. Oyster sanctuary spending helped support an additional 30 jobs through spending in industries such as restaurants, doctors' offices, and retail stores.

The Oyster Sanctuary Program has contributed \$16.2 million of value added to North Carolina's economy since 2013. This value is in the form of wages and benefits (\$8.7 million), returns to business owners such as equipment vendors, and in the form of state and local taxes. North Carolina has raised more than \$700,000 of tax revenue from the Oyster Sanctuary Program in the form of sales taxes, business taxes, and personal income tax. Local governments also benefit from the Oyster Sanctuary Program through more property tax and sales tax revenue. Since 2013, program activities have provided more than \$300,000 in local taxes.

Approximately 94% of total economic impacts have occurred within the 20-county coastal region of the state. Investment in oyster sanctuary construction and maintenance brings jobs and economic opportunity to a region of the state with higher-than-average unemployment.

Table 5. Economic Impact of Oyster Sanctuaries in North Carolina, 2013–2023

Impact	Jobs	Labor Income (million \$)	Value Added (million \$)	Output (million \$)
Direct	61	\$4.4	\$9.0	\$20.3
Indirect	52	\$2.9	\$4.4	\$8.7
Induced	30	\$1.4	\$2.8	\$4.8
Total	143	\$8.7	\$16.2	\$33.9

Source: RTI International, 2024.

4. Benefit-Cost Analysis



Source: North Carolina Coastal Federation

4.1 Introduction

In this chapter, we present the benefits and costs of oyster sanctuary construction and monitoring. With the present value of investment at \$22.3 million between 2013 and 2023, we estimate that oyster sanctuaries produced expected benefits valued at \$45.7 million. Every \$1 invested in sanctuaries provides North Carolina residents and visitors with \$1.71 in benefits. This section presents the assumptions, values, and methodology used to estimate benefits and the benefit-to-cost ratio.

4.2 Establishing a Baseline and Time Horizon

The first step of a benefit-cost analysis is to establish a “baseline” scenario. The baseline scenario describes what the sanctuary sites would look like without human intervention. Without the actions of the General Assembly, the Coastal Federation, and the NCDMF, we assumed that oyster sanctuaries would not have been constructed. It is possible that some natural recovery of the wild oyster stock may still have occurred in these areas. However, it is unlikely that natural events would provide noticeable results in such a short period because natural oyster reefs take tens to hundreds of years to form. Anecdotal

information indicates spatfall counts on cultch sites were declining prior to the establishment of oyster sanctuaries in Pamlico Sound (Callihan et al., 2016). This pattern may have continued without construction of the sanctuaries.

This analysis begins in 2013 and considers how many acres of sanctuary were developed during the ten-year activity interval (2013 through 2023). This interval is long enough to consider fluctuations in funding and unusual circumstances that may have affected activity in a single year. By selecting this period, we avoid under- or overstating actual net benefits of sanctuary construction. This time horizon also covers two distinctly different approaches toward oyster sanctuary creation. In years 2013 through 2016, oyster sanctuaries were constructed using reef balls and relied on NCDMF staff for construction. In later years, construction materials consisted of limestone marl, granite, and recycled concrete and water transportation and construction activities were performed by Stevens Towing and Cape Dredging.

The endpoint of the analysis is 2048, or 25 years after the last year of construction, because the sanctuaries will provide benefits well beyond the initial year of deployment. This endpoint allows the research team to capture the stream of post-deployment benefits. Research on existing reefs indicates that NCDMF incurs minimal maintenance costs once a sanctuary is established. For this reason, maintenance costs are not included in this analysis.

4.3 Oyster Sanctuary Benefits

Oyster sanctuaries generate significant economic and environmental benefits, including direct economic benefits from the reef construction activities and commercial harvest of oysters outside the sanctuaries and indirect benefits through habitat provision for commercial and recreational fisheries, such as finfish and shellfish (Peterson et al., 2003; Sharma, et al., 2016). They also deliver a wide range of ecosystem services, such as nitrogen

removal through denitrification, phytoplankton removal, and seagrass enhancement (Beseres et al., 2013; Sharma et al., 2016). Furthermore, oyster reefs sequester carbon by converting oceanic carbon into calcium carbonate shells, thereby reducing greenhouse gas concentrations (Fodrie et al., 2017). Additionally, oyster reefs serve as natural shoreline stabilization structures, functioning like breakwaters while supporting diverse aquatic communities (Scyphers et al., 2011).

To quantify the indirect environmental and economic benefits of oyster sanctuaries, one must use non-market valuation methods, such as travel cost methods³ or estimates of people’s willingness to pay for associated improvements like increased recreational opportunities, water quality services, and greater biodiversity protection. Applying these methods is costly and time-consuming and falls outside the scope of this project; therefore, we employ a benefit transfer approach using research results from existing primary research at an original study site (referred to as the “study site”) to predict estimates for other sites of interest (referred to as “policy sites”) where direct non-market valuation methods are not available (Johnston and Rosenberger, 2010). While benefit transfer methods are commonly used in Benefit-Cost Analysis, several shortcomings are well-known as the contexts, ecosystems, or population preferences at the original study site may differ significantly from those at the policy site (Barton, 2002; Costanza et al., 1997; Boutwell and Westra, 2013).

Our benefit transfer approach relies on using unit values reported by Grabowski et al. (2012) and Grabowski, Piehler, and Peterson (2011), which estimate the economic value derived from oyster harvests, commercial and recreational values, and water quality service values provided by oyster reefs located in North Carolina. The validity of our approach hinges on the similarity of the commodity valued at the study site (oyster reef sanctuaries) to that at the individual oyster

sanctuary sites in the Pamlico Sound. Additionally, the populations affected by oyster reef sanctuaries at both the study site and the oyster sanctuary sites share similar characteristics, as all are in the same study area, North Carolina. However, we acknowledge that one limitation is that the values we use were estimated more than a decade ago, and the literature has asserted that non-market values are temporally robust only over a short time span, suggesting that the validity of transfers over longer time horizons may be less certain (Downing and Ozuna, 1996; McConnell et al., 1998).

To apply the benefit transfer approach, we used original values estimated in 2011 dollars by Grabowski et al. (2012) and Grabowski et al. (2011) and adjusted them to 2023 dollars to account for inflation using the Consumer Price Index⁴. Additionally, we converted the values from dollars per hectare to dollars per acre using a conversion factor of 2.47105 acres per hectare. **Table 6** presents the annual benefits from oyster sanctuaries.

As mentioned in Section 2, little is known about the population level of oysters along the North Carolina coast or the maximum sustainable yield for oyster harvests due to a lack of stock assessments (NCDME, 2023). Thus, to be conservative in our estimates, we did not include any values for commercial and recreational oyster harvest increases that may be attributable to the sanctuaries. Furthermore, we did not include any value for shoreline protection, which could be applied to reefs that are located close to shore. Because oyster sanctuaries are submerged reefs up to two miles offshore, they provide little wave attenuation and therefore minimal shoreline protection (Gittman, 2024; Grabowski, 2024). It is worth noting that larval oysters from sanctuary reefs may contribute to the health of natural shoreline reefs, however, determining their connection and true benefit was outside the scope of this current effort.

³ Travel cost methods are based on the premise that the time and travel expenses that people incur to visit a site represent the price of access to the site. Peoples’ willingness to pay to visit the site can be estimated based on the number of trips that they make at different travel costs. This is similar to estimating peoples’ willingness to pay for a marketed good based on the quantity demanded at different prices.

⁴ To adjust for inflation, we converted the 2011 dollars to 2023 dollars using the Consumer Price Index for All Urban Consumers (CPI-U) from the U.S. Department of Labor Bureau of Labor Statistics, available at <https://www.bls.gov/cpi/data.htm>.

Table 6. Total Annual Value of Ecosystem Services Provided by Oyster Reefs in 2023 Dollars per Acre Per Year

Ecosystem Service Values	Minimum	Maximum	Average
Finfish and Mobile Crustacean Value			
Recreational	NA	NA	\$3,546
Commercial	NA	NA	\$2,260
Water Quality Services			
Nitrogen removal ^a	\$759	\$3,682	\$2,768
SAV enhancement ^b	0	\$1,417	\$708
Non-Oyster Harvest Service Total	\$6,566	\$58,048	\$9,283

Sources: All original values were, except for recreational fisheries, obtained from Grabowski et al. (2012).

Recreational values come from Grabowski et al. (2011).

a: We estimated the value of nitrogen removal by quantifying the value of enhanced denitrification rates on oyster reefs.

b: We valued the average submerged aquatic vegetation (SAV) enhancement assuming that 1% of the linear length of reefs perform this function.

4.4 Sanctuary Costs

As presented in Chapter 1, both state resources and federal grant funding from NOAA, which is administered by the Coastal Federation, are used to support the planning, construction, and maintenance of oyster sanctuaries. **Table 7** presents the total amount of spending on oyster sanctuaries by year. This table accounts for resources regardless of funding source and presents the nominal, real, and discounted values. Nominal values are adjusted into 2023

values using the Consumer Price Index Ratio, which represents the amount values in other years must be increased to reach 2023 price levels. The discount rate is used to calculate the present value of these costs.

\$1.71
in benefits
realized from
every dollar
invested

4.5 Comparison of Benefits and Costs: Benefit-Cost Ratio

Our study focused on the value of the ecosystem services provided by oyster reefs described in **Table 6** in Section 4.3. These benefits include positive externalities related to improved commercial and recreational fishing for finfish and mobile crustaceans, water quality improvements in the form of nitrogen removal, and submerged aquatic vegetation (SAV) enhancement.

The ecosystem services benefits provided by improved oyster sanctuaries in North Carolina from 2014 through 2048 strongly outweigh investment in these sanctuaries from 2013 through 2023 (see **Table 8**). The estimated benefit-to-cost ratio (BCR) is 1.71, meaning that for every dollar invested in oyster sanctuaries in North Carolina, \$1.71 in ecosystem services benefits will accrue. Accrued benefits will outweigh total investment in North Carolina oyster sanctuaries by 2026. By 2048, the net present value (NPV) will be \$15.8 million, and the internal rate of return (IRR) will be 7.04%.

Table 7. Total Spending on Oyster Sanctuaries in North Carolina, 2013–2023

Year	Total Costs (Nominal)	Consumer Price Index Ratio	Total Costs (2023 Dollars)	Present Value @ 2% Discount Rate
2013	\$1,420,217	1.308	\$1,857,609	\$2,398,402
2014	\$554,735	1.287	\$713,997	\$853,292
2015	\$462,381	1.286	\$594,423	\$696,461
2016	\$844,674	1.270	\$1,072,359	\$1,231,804
2017	\$2,549,933	1.243	\$3,169,752	\$3,569,656
2018	\$2,531,996	1.213	\$3,072,412	\$3,392,191
2019	\$2,093,998	1.192	\$2,495,709	\$2,701,435
2020	\$825,623	1.177	\$972,018	\$1,031,513
2021	\$1,820,053	1.124	\$2,046,624	\$2,129,308
2022	\$1,854,372	1.041	\$1,930,706	\$1,969,321
2023	\$2,398,402	1	\$2,398,402	\$2,398,402
Total	\$17,356,383		\$20,324,012	\$22,371,785

Source: RTI calculations based on data from the Coastal Federation and NCDMF, 2024.

Table 8. Return on Investment in Total Spending on Oyster Sanctuaries in North Carolina, 2013–2048

Measure	Description/Units	Units	Value
Present Value (PV) of Benefits	Sum of annual values adjusted for inflation and discounted at 2%	2023\$M	\$38.1
Present Value (PV) of Costs	Sum of annual values adjusted for inflation and discounted at 2%	2023\$M	\$22.2
Benefit-Cost Ratio (BCR)	PV Benefits / PV Costs	Ratio:1	1.71
Net Present Value (NPV)	PV Benefits – PV Costs	2023\$M	\$15.8
Payback Period	Year when PV Benefits = PV Costs at 2% discount rate	Calendar Year	2033
Internal Rate of Return (IRR)	Interest rate at which PV Benefits = PV Costs by 2048	%	7.04

Source: RTI calculations using data from the Coastal Federation and Grabowski, 2024.

4.6 Sensitivity Analysis

As can be seen in [Table 6](#) in Section 4.3, the values reported by Grabowski et al. (2012) include a range of estimates for the economic value derived from water quality improvements in the form of nitrogen removal and SAV enhancement. These ranges in benefits generate a range of return-on-investment figures, displayed in [Table 9](#). Importantly, returns are positive under even the most conservative scenario, with a BCR of 1.21 indicating that \$1.21 in benefits are returned for each dollar invested. Under this conservative scenario, the payback period is 2042 and by 2048, the NPV will be \$4.7 million and the IRR will be 3.60%. Returns are quite large under the most optimistic scenario, with a BCR of 12.85 indicating that \$10.71 in benefits are returned for each dollar invested. Under the most optimistic scenario, the payback period is 2015 and by 2048, the NPV will be \$215.9 million and the IRR will be 81.32%.

4.7 Distribution of Benefits

Oyster sanctuary benefits accrue to different groups of individuals based on their use of and

proximity to Pamlico Sound. The most valuable benefit is provided by increasing the abundance and variety of fish and crustaceans for recreational harvest. Between 2017 and 2022, North Carolina averaged more than 470,000 Coastal Recreational Fishing Licenses (CRFLs) sold each year and an annual average of over 18,600,000 angler trips (Newman, 2023). According to the NCDMF, in 2022, approximately 300,000 North Carolinians purchased a CRFL and non-residents purchased 172,000 licenses. The most recent NCDMF survey of active seawater anglers found that 90% of respondents were White and had fished, on average, for 28 years. Half were college graduates and almost 80% were married (Stemle and Condon, 2017).

Out-of-state recreational anglers contribute a significant amount of economic impact to the coastal economy. One estimate placed the economic impact attributed to recreational fishing trip expenditures at \$802 million for the coastal region (Lovell et al., 2013). However, this estimate is from 2013 and may be higher at this time (Stemle and Condon, 2017).

Table 9. Range of Return-on-Investment Estimates for Total Spending on Oyster Sanctuaries in North Carolina, 2013–2048

Measure	Description/Units	Units	Min	Max
Present Value (PV) of Benefits	Sum of annual values adjusted for inflation and discounted at 2%	2024\$M	\$26.93	\$238.09
Present Value (PV) of Costs	Sum of annual values adjusted for inflation and discounted at 2%	2024\$M	\$22.24	\$22.24
Benefit-Cost Ratio (BCR)	PV Benefits / PV Costs	Ratio:1	1.21	10.71
Net Present Value (NPV)	PV Benefits – PV Costs	2024\$M	\$4.69	\$215.86
Payback Period	Year when PV Benefits = PV Costs at 2% discount rate	Calendar Year	2042	2015
Internal Rate of Return (IRR)	Interest rate at which PV Benefits = PV Costs by 2048	%	3.60%	81.32%

Source: RTI calculations using data from the Coastal Federation and Grabowski, 2024.

Water quality services that oyster sanctuaries provide, including nitrogen removal and SAV habitat, reduce the number of public resources, both state and local, that must be devoted toward maintaining water quality. These benefits are broadly shared by all residents of coastal communities and state taxpayers. Maintaining water quality is essential to preserving fish and crustacean habitats and for sustaining recreational amenities like boating and water sports. These activities draw millions of tourists to North Carolina's coastal region each year and help sustain a significant portion of the region's economy (Visit North Carolina, 2022).

The third most valuable benefit attributed to oyster sanctuaries is sustaining fish and crustacean stock for commercial harvesting. A 2021 survey of commercial fishers determined that 91% were white and 95% were male, with an average age of 54. Ninety-four percent of North Carolina's commercial fishers lived within the coastal region. These individuals derived an average of 48% of their total income from fishing and had been commercially fishing for an average of 28 years (Dumas, 2021). These commercial fishers support the entire North Carolina seafood industry, from seafood processing and preparation to fish markets and seafood restaurants. A companion study by North Carolina State University placed the economic impact of the state's seafood industry at \$300 million in 2019 (Edwards, 2021).

Direct spending on the Jean Preston Oyster Sanctuary Program is concentrated in Carteret, Craven, Chowan, and Dare Counties. This is due in large part to the location of the limestone mine and to firm locations. In general, these counties experience less poverty and unemployment than other coastal counties (see Tables 3 and 4). If the Coastal Federation desires to direct a portion of program resources to support businesses in less advantaged parts of the coast, it could consider

new ways to attract and contract with companies that are registered as historically underutilized businesses or those that are certified with the Small Business Administration as women- or minority-owned small businesses. Underutilized businesses may need to partner with larger firms to support these large-scale restoration projects or may benefit from additional training or resource opportunities to be competitive. Another option would be to shift project activities to adjacent counties such as Hyde County, which is directly on the Pamlico Sound but has higher rates of unemployment and poverty than nearby counties.



Source: North Carolina Coastal Federation

5. Findings and Future Activity



Source: North Carolina Coastal Federation

This chapter summarizes key findings from previous chapters, compares the results of this research with past efforts, and presents information about new activities the Coastal Federation will be undertaking in the coming years with support from NOAA and the state of North Carolina. This chapter also presents ideas for future research to improve estimates of oyster reef benefits.

5.1 Summary of Research Findings

This study had two main components: an economic impact assessment for Oyster Sanctuary Program spending and a benefit-to-cost analysis.

As presented in Chapter 3, the total economic impacts associated with oyster sanctuaries were much greater than the initial spending. We estimate that between 2013 and 2023, spending on oyster sanctuaries, which was approximately \$20.3 million, generated more than \$33 million in total business revenue.

A total of 143 jobs were supported by oyster sanctuary work. These jobs were created in a variety of industries such as transportation, mining, state government services, and retail stores. Workers and business owners received more than \$8.7 million in wages and benefits. North Carolina

has raised more than \$700,000 of tax revenue from the Oyster Sanctuary Program in the form of sales taxes, business taxes, and personal income tax. Local governments also benefit from the Oyster Sanctuary Program through more property tax and sales tax revenue. Since 2013, program activities have provided more than \$300,000 in local taxes. Approximately 94% of total economic impacts have occurred within the 20-county coastal region of the state.

The benefit-to-cost analysis presented in Chapter 4 determined that for every dollar invested in the Oyster Sanctuary Program, \$1.71 of ecosystem benefits will have accrued by 2048. Benefits provided by the program will exceed program costs in 2033. Program costs were incurred between 2013 and 2023. Major costs included purchasing sanctuary materials, transportation, program administration, and construction, totaling \$20.3 million. Program benefits were estimated at \$38.1 million for the years 2014 to 2048. These benefits are in the form of water quality services such as nitrogen removal and SAV enhancements. Further, by providing more fish and crustacean habitat, oyster sanctuaries promote diverse aquatic life and overall abundance. Recreational and commercial fishers thus directly benefit from sanctuaries via greater catch and fish diversity. Water quality benefits are experienced by all who use the Pamlico Sound for recreational and commercial purposes.

5.2 Comparison of Study Results with Past Work

To compare the findings of this study with those described by RTI in 2016, we adjusted the oyster sanctuary figures from using a discount rate of 3% to 2% so they would match the current methodology. Based on this change, the 2016 BCR for oyster sanctuaries was 2.45, about 43% higher than the 1.71 ratio presented in this report for 2023.

The types, sources, and values of benefits used in the two studies were identical. This indicates that the change in the BCR is due to an increase in program costs. The average cost to construct an acre of sanctuary was estimated to be about \$71,000 during the 2010–2015 timeframe of the first study and has risen to about \$128,000 per acre in 2023. The 2016 report relied on estimates of anticipated fiscal year spending,⁵ whereas this report uses actual spending by calendar year, and actual costs were greater than the estimates. Some of these cost differences are likely due to typical discrepancies in estimated versus actual values. However, actual costs also outpaced estimates because of changes in the types of materials used for sanctuary construction and increases in the cost of goods and services relied on for reef construction beyond that of inflation overall.

Although the BCR in this current study is lower than in the past, the ecosystem benefits provided by oyster sanctuaries are still projected to outweigh the actual costs of the initiative. Federal, state, and private funding sources that support sanctuary construction are preserving water quality in the Pamlico Sound, promoting healthy aquatic resources such as oysters, fish, and mobile crustaceans, and sustaining recreation and tourism industries that are dependent on clean water.

5.3 Research Needs

Our findings rely on the estimated ecosystem services benefits from an oyster sanctuary, using a benefit transfer approach based on studies published in 2011 and 2012. Both studies used data collected before their publication to estimate ecosystem service values. Specifically, the authors calculated recreational benefits using data from a 1992 survey conducted by Easley and Smith (1992). In the case of commercial fishing, the value attributed to oyster reefs depended on estimates of increased fish production from oyster reefs that Peterson et al. published in 2003. For nitrogen removal, the authors applied hourly

nitrogen removal rates from 2012 combined with the average trading price per kilogram of nitrogen removed for estuarine sites in the 2012 North Carolina Nutrient Offset Credit Program. The economic valuation of SAV enhancement relied on a willingness-to-pay survey for the Penobscot River Estuary's eelgrass habitat, initially conducted in 1995.

To address the noted shortcoming, further research is needed to update the valuation of ecosystem services provided by oyster reefs and to incorporate innovations in ecosystem services assessment, methods, and data availability. For example, there is a need for contemporary surveys to reassess recreational benefits, focusing on changes in fishermen's willingness to pay due to potential shifts in recreational fishing behaviors and other activities enhanced by habitat restoration and water quality improvements, such as boating or tourism. Regarding commercial fishing, it is necessary to estimate yield improvements from oyster reefs for species targeted within the Senator Jean Preston Oyster Sanctuary Network (e.g., red drum, southern flounder, shrimp, blue crab, clams, black sea bass). Moreover, future research should combine updated market values with observed nitrogen removal rates (calculated using advanced analysis techniques) and current shoreline stabilization methods.

Future valuation studies should consider estimates of other ecosystem services not included in our estimates, such as carbon sequestration. Another point of research interest is the ability, if any, for submerged oyster sanctuaries to provide wave attenuation, or the ability to scatter or absorb the force of waves, thereby protecting the shoreline from erosion. At present, much research is being done to determine the wave attenuation and economic benefits associated with living shorelines, but less focus has been on submerged reefs that may be some distance from shore. More research in this area would help determine if oyster sanctuaries provide shoreline protection benefits.

⁵ Provided in NCDMF reports to the General Assembly.

New funding in 2023 brings
sanctuary investments to
\$36.2 million

\$14 million
invested by state leverages
\$22 million
in federal and private funds

120 acres
of new sanctuary to be built

Finally, we were unable to model the potential impacts of oyster sanctuaries on oyster harvest levels due to a lack of baseline information on the population level or the maximum sustainable yield of oysters along the North Carolina coast. While previous research suggests that oyster sanctuaries contribute disproportionately

to the oyster population and larval output in the sound (Theuerkauf et al., 2021), this effect cannot be modelled without baseline population data to which growth estimates could be applied. Further, potential impacts of sanctuaries on oyster population growth cannot be converted into potential impacts on oyster harvest without data on the maximum sustainable yield of oyster harvests relative to population levels. The needed population and maximum sustainable yield levels cannot be determined without a comprehensive stock assessment of oysters along the North Carolina coast (NCDMF, 2023).

5.4 Current and Future Federation Activities

In 2023, the Coastal Federation received a \$14.9 million grant from the NOAA Transformational Habitat Grant program funded by the Bipartisan Infrastructure Law and Inflation Reduction Act. This grant was matched by a \$1 million state appropriation. This investment changes the narrative that 65% of sanctuary construction is paid for by state appropriations and 35% by federal grants, to a narrative that shows more equal shares in the sanctuary effort. With the \$14.9 million investment from the federal grant and \$1 million from the state appropriation, total investment from 2013 to present equals nearly \$36.2 million with \$14 million invested by the state and \$22 million invested by the federal government. For every state

dollar invested, 1.6 federal and private dollars have been invested. And for every dollar, regardless of its source, invested, \$1.71 benefits have been realized. These funds are being used to create 120 acres of new sanctuary habitat in Pamlico Sound. Adding to the existing 389 acres, this will bring the total sanctuary habitat acreage to 509 acres, reaching the stated goal of building 500 acres of oyster sanctuary in the sound.

Achieving this milestone is a huge accomplishment to celebrate. And while it is being reached, it is also causing the Coastal Federation, NCDMF, and Blueprint partners to begin discussions about reevaluating the acreage goal for sanctuaries. Is 500 acres of protected reef in Pamlico Sound enough? How many acres are needed to meet habitat, population, and ecosystem service goals? What should the habitat, oyster population, and ecosystem service goals be for Pamlico Sound? Several tools exist such as the Oyster Calculator—a tool developed by the Nature Conservancy to estimate the filtering capacity and fish production of oyster reefs—that can start to answer these questions. The Oyster Calculator provides a rough estimate of the rate at which the existing oyster population in the sound filters water to improve clarity. It could, in theory, also be used to determine what size population is needed in the sound to achieve desired filtering, helping predict how many acres of protected oyster reef are needed.

Partners like NC State University and NOAA are also working to update and refine the habitat suitability index model that is currently used to predict where good oyster sanctuary locations might be in the sound. With an updated acreage goal, and proposed updates and new layers added to this model, NCDMF, the Coastal Federation, and partners could evaluate the potential for an oyster sanctuary to not only provide oyster brood stock and filter water in the sound but could also evaluate the potential for a sanctuary to create habitat for important and desirable finfish species, including both commercially and recreationally important species. The updated model could thus help predict how many acres of oyster sanctuary are needed to support a certain number of finfish.

Additional questions that are being explored include:

- Is any management needed on the existing sanctuary network to maximize the success and persistence of the sanctuaries?
- What types of management activities would achieve the best results for the sanctuary, sound, and oyster population overall?

Over the next few years, while construction of the 120 acres takes place, these questions will be explored and evaluated.

5.5 Conclusions

North Carolina's Oyster Sanctuary Program benefits the state by increasing the stock and diversity of fish and shellfish, by filtering nitrogen out of the water, and by enhancing SAV habitat. This research has established that investments in oyster sanctuary development result in a 100% return on investment via ecosystem service provision over the life of the sanctuary network. Furthermore, oyster sanctuary spending supports local economies across the coastal counties. The \$20.3 million spent on sanctuaries between 2013 and 2023 resulted in \$34 million in total business revenue.

Our estimate of sanctuary benefits only considers ecosystem services and economic activities that have been specifically linked to oyster sanctuaries in research publications. Future research findings can potentially expand upon the known suite of ecosystem services provided by oyster sanctuaries and the economic valuations for these services. For example, future valuation studies should consider estimates of oyster benefits such as carbon sequestration, which are not included in this study.

The partnership between the Coastal Federation and NCDMF has yielded tremendous benefit to the state. Over the past decade, this effort has built an impressive 159 acres of protected oyster sanctuary with plans to construct 120 more acres over the next three years. The partnership has successfully attracted funding from federal, private, and state sources that make this work possible, bringing \$22 million in federal and private dollars to match the state's investment of \$14 million. This work has created jobs, supports a robust population of oysters within the sanctuary network and requires little to no maintenance. As the partnership considers next steps and future work, the success of the program to-date rests squarely with these benefits.



Source: North Carolina Coastal Federation

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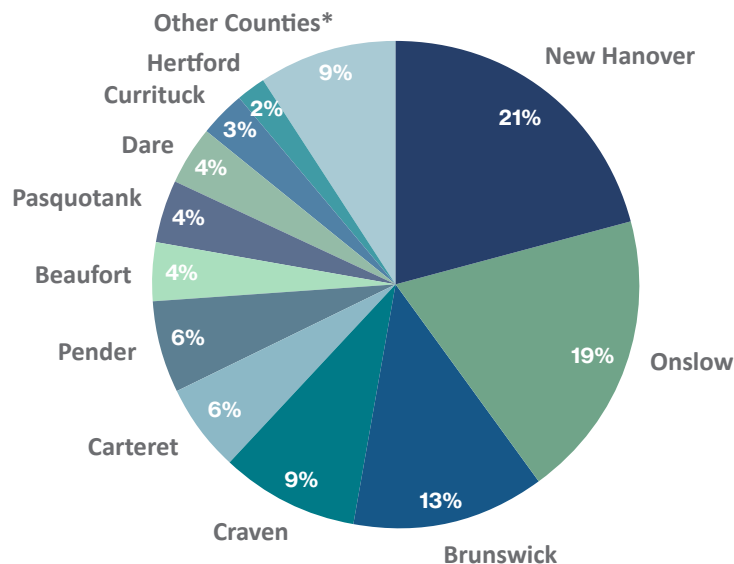
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Appendix

A-1: Coastal North Carolina Demographics

About 10% of North Carolina’s total population resides within one of 20 counties that form the state’s coastal region. There are more than 1.07 million people living in coastal North Carolina and half of that population is in the three southernmost counties, which is home to both the Wilmington and Jacksonville metropolitan areas, as well as Marine Corps Base Camp Lejeune. As depicted in **Figure A1**, the counties with the highest populations include New Hanover (Wilmington), Onslow (Jacksonville), and Brunswick.

Figure A1. Each Coastal County’s Share of Coastal Population



*Other counties make up less than 2% of the coastal North Carolina population each.

Source: U.S. Census Bureau. 2018–2022 American Community Survey 5-Year Estimates. Table B02001.

Overall, the population of coastal North Carolina has a similar composition to the state average; however, there are some notable differences that make coastal North Carolina unique, as seen in **Table A1**. The median age across coastal counties is two years older than the state average (43 years). Two coastal counties, Brunswick, and Pamlico, both have a population with a median age that exceeds 54. The coastal population is also more male than the state average, with an average county-level sex ratio of 102 males per 100 females versus an average ratio of 97 males per 100 females in the rest of North Carolina.

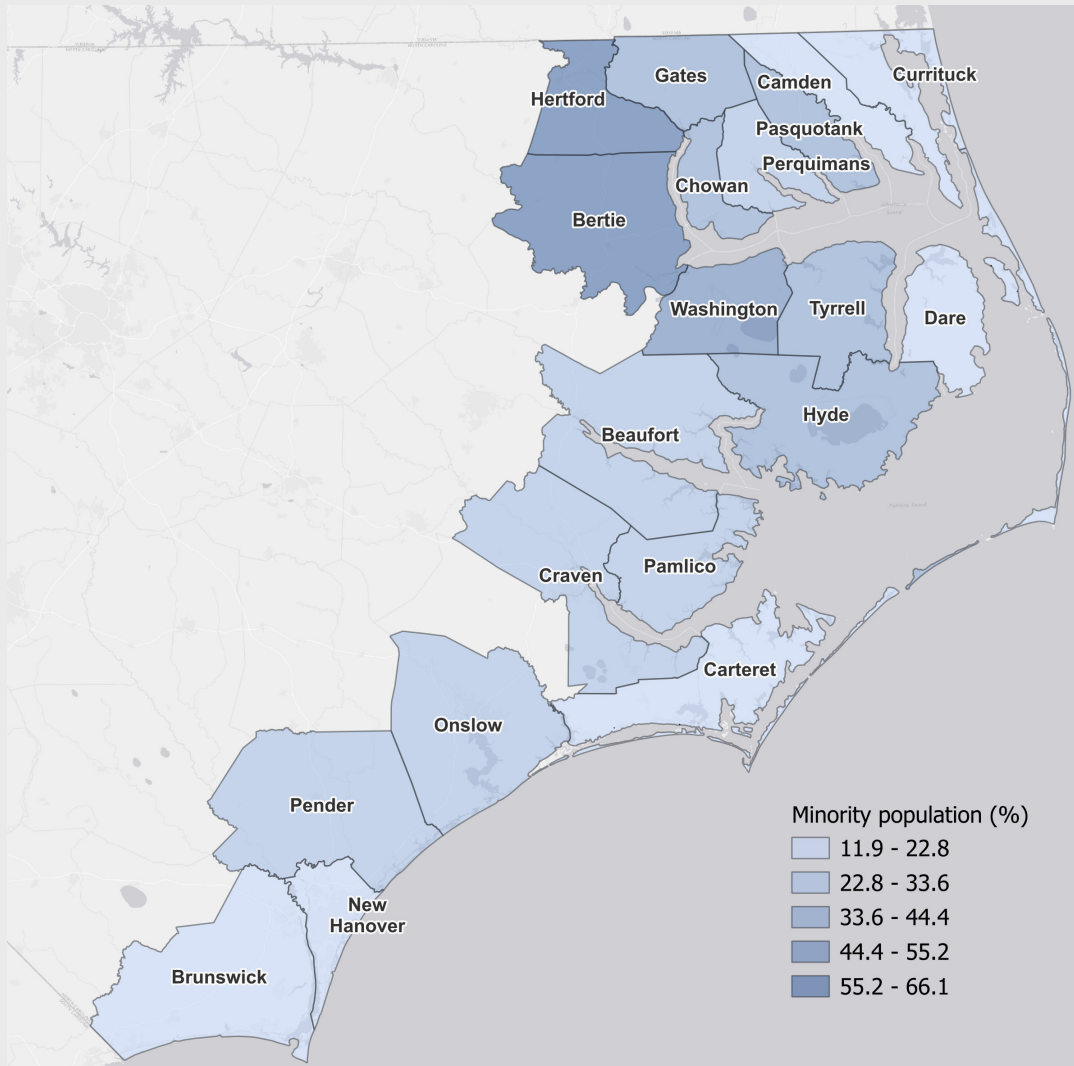
Table A1. Coastal North Carolina Demographics

Geography	Median Age (years)	Sex Ratio (Males per 100 Females)	Percent, %		
			Non-White Population	Income Below Poverty Level, Last 12 Months	25+ Population with a Bachelor's Degree
North Carolina*	43	98	30.6	15.0	15.7
Rest of NC*	43	97	30.2	15.4	15.8
Coastal NC*	45	102	32.5	13.7	15.3
Beaufort	47	92.5	29.5	16.8	12.2
Bertie	46	107.4	65.3	19.6	10.9
Brunswick	56	93.2	17.0	9.0	20.4
Camden	41	108.7	18.9	5.9	16.4
Carteret	50	97	11.9	9.5	19.8
Chowan	49	91.3	39.6	20.5	15.1
Craven	39	100.1	31.6	13.4	15.1
Currituck	43	102.8	13.2	8.4	18.6
Dare	48	99.7	12.1	6.5	28.0
Gates	47	98.4	36.8	14.1	5.3
Hertford	42	101.7	66.1	18.3	9.4
Hyde	47	106.8	41.3	26.1	11.5
New Hanover	40	91.9	20.9	12.4	28.3
Onslow	27	125.5	29.5	11.4	17.6
Pamlico	54	106	24.3	12.9	12.4
Pasquotank	39	98.5	43.5	10.8	17.2
Pender	43	103	24.2	11.4	19.2
Perquimans	50	91.4	28.2	13.2	10.9
Tyrrell	45	119.8	41.0	12.7	7.8
Washington	48	105	54.2	21.3	10.7

* Mean value; Source: U.S. Census Bureau. 2018-2022 American Community Survey 5-Year Estimates. Table B02001, S0101, B17001, and S1501.

The non-White population proportion is 2% higher on average in coastal counties when compared to the rest of the state. **Figure A2** shows the non-White proportion for each coastal county. In the coastal counties of Bertie, Hertford, and Washington the proportion of non-White individuals accounts for more than half of the total population, while there are five coastal counties with a proportion of non-White individuals below 20%. Many coastal counties

Figure A2. Non-White Population Share in Coastal North Carolina Counties (2022)

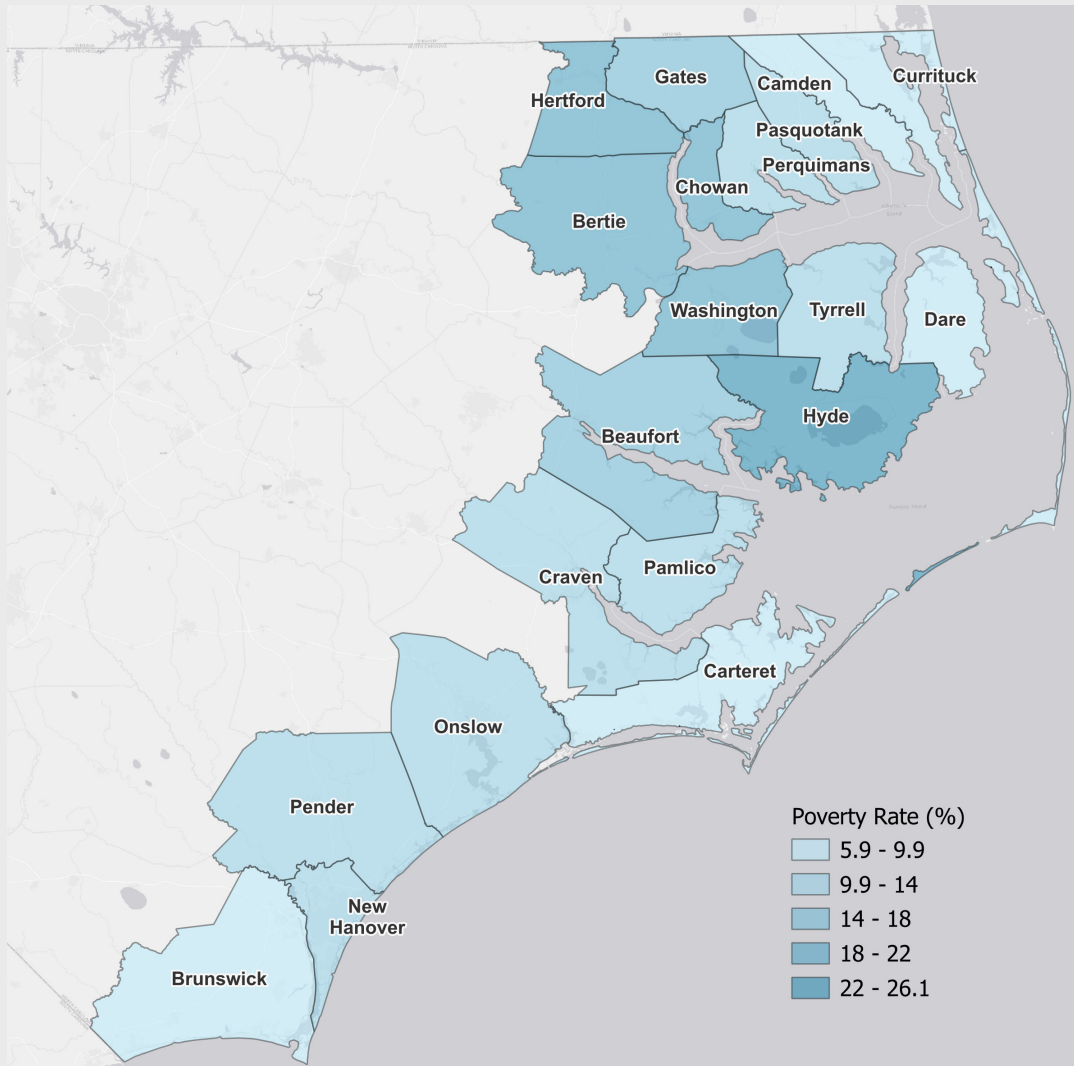


Source: U.S. Census Bureau. 2018-2022 American Community Survey 5-Year Estimates. Table B02001.

experience lower-than-average proportions of poverty, and the coastal region's average poverty rate is almost 2% lower than both the state and non-coastal averages. However, the coastal counties of Chowan, Hyde, and Washington have each had more than one-fifth of their respective populations experiencing poverty as of 2022. **Figure A3** depicts the prevalence of poverty across the coastal counties.

Coastal region counties have a higher-than-average unemployment rate when compared to both the state average and the average of non-coastal counties. The average of the coastal county median income is slightly higher than that of the non-coastal counties and the state as a whole. The average age-dependency ratio among coastal counties also is higher than both the state and non-coastal average, meaning that the workforce within the coastal region

Figure A3. Poverty Rates in Coastal North Carolina Counties (2022)



Source: U.S. Census Bureau. 2018-2022 American Community Survey 5-Year Estimates. Table B17001.

carries a larger economic burden compared to the rest of the state, due to higher proportions of dependent populations aged below 16 and above 65. **Table A2** presents this information for the state, coastal region counties, and the rest of the state.

Table A2. Workforce/Employment in Coastal North Carolina

Geography	Median Income (2022\$)	Civilian Employed Population (16+)	Percent, %	
			Unemployment Rate	Age-Dependency Ratio
North Carolina	\$58,261*	4,925,500	5.7*	69.8*
Rest of NC	\$57,714*	4,469,528	5.6*	69.3*
Coastal NC	\$60,453*	455,972	6.0*	78.6*
Beaufort	\$56,081	19,319	5.6	69.3
Bertie	\$41,652	6,308	6.4	89.5
Brunswick	\$71,193	56,463	5.0	65.4
Camden	\$79,120	4,793	5.7	75.2
Carteret	\$66,965	30,029	4.9	82.6
Chowan	\$51,188	5,922	4.3	71
Craven	\$61,676	40,158	5.1	63.7
Currituck	\$82,793	14,123	3.2	70.7
Dare	\$79,742	19,041	5.1	69
Gates	\$55,750	4,560	9.3	62.2
Hertford	\$46,196	8,643	7.2	75.7
Hyde	\$43,724	1,410	8.7	57.6
New Hanover	\$67,515	117,011	4.8	51.3
Onslow	\$59,976	67,951	6.4	81.2
Pamlico	\$55,867	4,494	4.6	64.6
Pasquotank	\$61,411	17,817	5.8	66.9
Pender	\$74,538	27,737	6.4	87.5
Perquimans	\$59,401	5,120	5.0	65.3
Tyrrell	\$55,341	1,180	3.9	85.7
Washington	\$38,927	3,893	12.7	78.6

*Mean value; Source: U.S. Census Bureau. 2018–2022 American Community Survey 5-Year Estimates. Table S2301 and S1903.

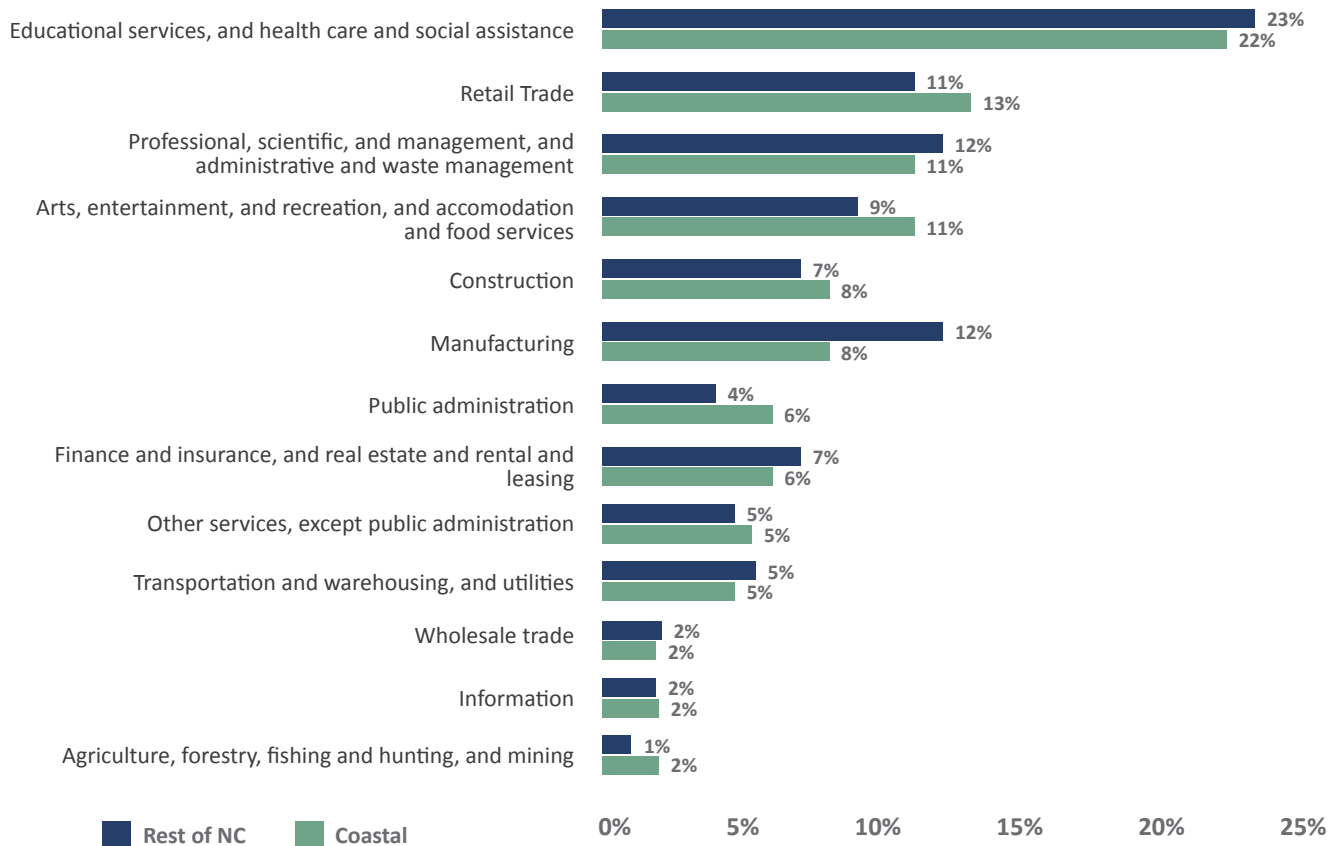
In terms of industry, the health care and assistance industry has the highest share (22%) of civilian workers in coastal North Carolina, which is consistent with the rest of the state. Eleven percent of civilian workers were employed in the retail sector, which is slightly greater than the rest of the state.

Coastal counties have a higher percentage of employees working in the construction, public administration, and arts, entertainment, and recreation, and accommodation and food service industries compared with other portions of the state. Agriculture, forestry, fishing, hunting, and mining industries also employ a higher proportion of workers than in other regions of the state.

Figure A4 presents the share of workers by industry for the coastal and non-coastal regions of the state.

Construction, retail trades, tourism/entertainment, and agriculture/fishing are all industries that are seasonal or have more activity in certain times of the year. This seasonality may be based on holidays, the weather, fishing regulations, or the primary school year. Workers in seasonal industries may work significantly more than 40 hours per week in the peak periods and much less, if at all, during the low seasons (Hayes, 2022).

Figure A4. Each Coastal County's Share of Coastal Population



Source: U.S. Census Bureau. 2018-2022 American Community Survey 5-Year Estimates. Table S2403.

When considering the educational attainment of individuals aged 25 years and older, coastal North Carolina is fairly aligned with the state average (15.7%), but there are some notable outliers. In the coastal counties of Dare, Brunswick, and New Hanover, the respective proportions of 25+ individuals with a bachelor’s degree are more than 25%. These counties also have the lowest average unemployment rate at 5%.

Conversely, in the three coastal counties of Gates, Hertford, and Tyrrell less than 10% of individuals 25 years or older hold a bachelor’s degree. As shown in **Table A3**, the unemployment rate in these three counties is 6.8%.

Table A3. Educational Attainment and Unemployment in Coastal Counties, 2022

Percent of 25+ Population with a Bachelor’s Degree	Counties	Average Unemployment Rate, %
Less than 10%	Gates, Hertford, Tyrrell	6.8
10% to 19.9%	Beaufort, Bertie, Camden, Carteret, Chowan, Craven, Currituck, Hyde, Onslow, Pamlico, Pasquotank, Pender, Perquimans, Washington	6.1
20% or more	Brunswick, Dare, New Hanover	5.0

Source: U.S. Census Bureau. 2018-2022 American Community Survey 5-Year Estimates. Table S2301 and Table S1501.