Ghost Hunters • Sea Stars • The Catch • Ricky Moore

Coastwatch

NORTH CAROLINA SEA GRANT • WINTER • 2019 • ISSUE 4 • $6.95

A BRIEF HISTORY OF SEA LEVEL RISE IN NORTH CAROLINA

Our Moving Coastline

FROM THE EXECUTIVE DIRECTOR

Groundwork for Grand Challenges

Autumn flew past. Now come the holidays, which arrive more quickly every year.

It is also elementary science experiment season for 2nd and 4th graders. I have fond memories of my own requisite volcanoes, bug collections, and plant dissections. I'm not as sure how my parents recall those weeks of brainstorming with a final few days to execute and deliver a poster board. Although, I've got a pretty good idea now. Perhaps, it was not as rosy for them throughout the process. On the upside, I'm learning a lot about rabies (and also pumpkin decomposition after Halloween) in the company of family. That's something to be thankful for!

Paths to accessing and enjoying science — and seeing applications in one's own life — take many forms, come along at different times, and use varied avenues. North Carolina Sea Grant continues to engage students, faculty, and communities through *science*, *technology*, *engineering*, and *mathematics* (STEM) research and educational opportunities. Now we are expanding to a STEAM focus, as we strive to provide engaging efforts to integrate *the arts* into our programming.

In 2020, our Sea Grant program and the N.C. Water Resources Research Institute are among the cosponsors of *Water/Ways*, in partnership with the North Carolina Humanities Council. This Smithsonian touring exhibit dives into water — as a key component of life on our planet, environmentally, culturally, and historically.

Water/Ways clearly adds the A in STEAM. The series is part of the Humanities Council's "Museums on Main Street" program that offered small-town museums, libraries, and cultural organizations a chance to catalyze community conversations about water's impact on American culture. The exhibit explores water as an essential natural resource that allows us to travel, determines where we live, controls what we eat and drink, and inspires culture.

Six host sites, from the mountains to the coast, will showcase the exhibit in their respective communities, and will add local information and programming to highlight the topic. The tour begins in Burnsville in May 2020, then travels through 2021 with stops in Franklin, Wake Forest, Washington, Wrightsville Beach, and Graham.

I encourage you to attend one of these events, and bring your family and friends. Early and consistent access to and enjoyment of science, and seeing its local applications, is a critical factor for future engagement. Those early steps build an understanding of how, collectively, we can address grand challenges facing us here in North Carolina and elsewhere.

You'll learn about a few of these current challenges in this issue. Communities are coming together to address repetitive storm-flooding impacts. Teams are working towards improving water quality conditions. Partners, including Sea Grant specialists, are enhancing aquaculture and fisheries economies here in North Carolina. Engaging science and culinary arts, our Sea Grant partner and New Bern native Ricky Moore shares his cultural culinary expertise, inviting those new to cooking seafood to join him in a new adventure.

Additional challenges and potential solutions were highlighted at our N.C. Coastal Conference in Wilmington in November. We were grateful to engage and learn from the nearly 200 attendees. I was especially pleased to see so many students and young professionals join us, and I look forward to learning how their opportunities to network and to present their own research will open new doors for their careers.

Strengthening science literacy requires work on many levels to encourage folks to interact with and see science impacts as relevant to our communities and our lives. I'll keep you posted on our family's science fair projects. I also welcome you to share your thoughts with me at *snwhite3@ncsu.edu*. Tell us how North Carolina Sea Grant can continue to expand our STEM and STEAM efforts.

— Susan White, Executive Director, North Carolina Sea Grant

IN THIS ISSUE

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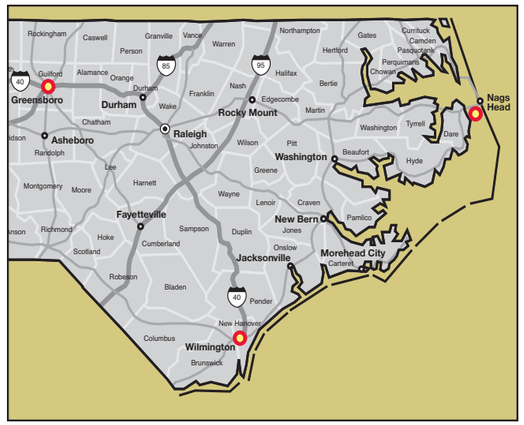
North Carolina's diverse coast and inland terrain offer countless interesting subjects. The story settings in this issue include Guilford County, Croatan Sound, and the Cape Fear River, as well as much of the North Carolina coast.



Coastwatch

FEATURES

▫ *Front Cover: Sunrise on the Atlantic; photo by James K. via CCO/public domain.*
▫ *Table of Contents: A Ricky Moore delicacy; photo by Baxter Miller.*

Coastwatch

North Carolina Sea Grant • Winter • 2019 • Issue 4

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North Carolina Sea Grant is a federal/state partnership that promotes stewardship of marine, coastal and watershed resources through research and outreach. It joined the National Sea Grant College Network in 1970 as an institutional program. In 1976, it was designated a full Sea Grant College program. Today, North Carolina Sea Grant supports research projects, along with extension and communications teams. Susan White is executive director. The program is funded by the National Oceanic and Atmospheric Administration in the U.S. Department of Commerce, and by the state through the University of North Carolina.

Coastwatch (ISSN: 1068-784X; USPS Periodical # 010464) is published quarterly (Spring, Summer, Autumn, Winter) by:

North Carolina Sea Grant

NC State University Box 8605
Raleigh, NC 27695-8605
Telephone: 919-515-2454.

Subscriptions are $15 per year.
Email: *dmshaw@ncsu.edu*
URL: *ncseagrant.org*
Periodical Postage paid at Raleigh, NC

POSTMASTER: Send address changes to:

COASTWATCH
North Carolina Sea Grant
NC State University Box 8605
Raleigh, NC 27695-8605

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Printed on recycled paper.

Research to Focus on Algae Toxins

Haley Plaas, the recipient of the 2020 joint fellowship from North Carolina Sea Grant and the Albemarle-Pamlico National Estuary Partnership

Haley Plaas, a doctoral student in environmental science and engineering at the University of North Carolina at Chapel Hill, will conduct new research on algal blooms as the recipient of the 2020 joint fellowship from North Carolina Sea Grant and the Albemarle-Pamlico National Estuary Partnership (APNEP). The fellowship, now in its fifth year, supports graduate students at institutions in North Carolina who conduct applied research within the state's portion of the APNEP region.

John Fear, deputy director of North Carolina Sea Grant and the state's Water Resources Research Institute, says Plass will explore multiple issues related to cyanobacteria toxins in the Chowan River and Albemarle Sound.

"This is a very timely project, as the water quality issues in this region are re-emerging after decades of calm," says Fear. "This work will help us understand how the algae toxins in the water respond to nutrient inputs and are translated into airborne molecules."

Wind currents can transport airborne toxins inland from the waterfront, Fear explains. "This work also can be rapidly utilized by the state's working group on nutrient criteria, which is now focusing on the Albemarle Sound area."

Bill Crowell, director of APNEP, says harmful algal blooms are a water quality and environmental health concern in the Chowan River-Albemarle Sound region.

"Ms. Plaas' research will increase our understanding of the threat that cyanotoxins produced by these blooms pose to human communities," Crowell says.

Plaas will announce and explain her findings through educational videos and a short film.

Fellowships and funding opportunities: *ncseagrant.ncsu.edu/funding-opps/*

— Katelyn Vause & Dave Shaw

Scientists and Communities Meet about Algal Blooms

Scientists and community leaders discussed harmful algal blooms in northeastern North Carolina during an information session that North Carolina Sea Grant led earlier this year in Edenton. State officials had issued multiple warnings over the summer for residents and visitors to avoid contact with algae on waters in the region.

Held at the College of the Albemarle, the session included presentations and input from partners at universities and community organizations, as well as federal, state and local agencies.

"Over 80 people attended, from many different sectors, including farming and the U.S. Coast Guard, with some traveling from as far away as Southern Shores and Wake County," says Gloria Putnam, coastal resources and communities specialist at North Carolina Sea Grant. "It was clear from the questions and comments there is a strong interest to learn and engage on this regionally important issue."

With Community Collaborative Research Grant funding, partners on the outreach program included scientists from NC State University and the University of North Carolina at Chapel Hill, as well as Chowan Edenton Environmental Group.

Additional partners included the N.C. Department of Environmental Quality, Water Resources Research Institute, National Oceanic and Atmospheric Administration's Beaufort Laboratory, N.C. Department of Health and Human Services' Division of Public Health, Albemarle-Pamlico National Estuary Partnership and Town of Edenton.

In advance of the Edenton meeting, Putnam led development of a research-based, two-page fact sheet, *Algal Blooms: Things to Know*.

Read the fact sheet: *go.ncsu.edu/algal-blooms*

Access presentations from the forum: *go.ncsu.edu/bloom-talks*

— Katie Mosher

Baxter Miller

Innovation Key to Fisheries Projects

Economics, fishing industry training, and oyster harvests are the primary focuses of three new initiatives.

North Carolina Sea Grant extension specialists are heading three new research projects, thanks to grants from the N.C. Commercial Fishing Resource Fund. The projects cover economics, fishing industry training, and oyster harvest enhancements.

"We are pleased that the funding reflects the strength of the research proposals and the project teams assembled," says Frank Lopez, North Carolina Sea Grant's extension director.

Lopez will lead a team looking to confirm "spat on shell" demonstration sites to enhance wild oyster stocks and potential harvests. The N.C. Farm Bureau is a key partner on the project, along with the N.C. Fisheries Association.

Jane Harrison, North Carolina Sea Grant's coastal economist, will lead a study of the economic impacts of wild-caught commercial fisheries' harvests. The team includes Barry Nash, Sea Grant's seafood technology and marketing specialist, as well as economists Chris Dumas at UNC Wilmington, Eric Edwards and Sara Sutherland at NC State University, and John Whitehead at Appalachian State University.

In addition, North Carolina Sea Grant fisheries specialists Sara Mirabilio and Scott Baker will host a networking and skill-building workshop for a rising generation of men and women involved in commercial fishing. The project builds on previous North Carolina Sea Grant workshops — "Fish Camps" — that looked at aging in the fishing fleet as younger people seek jobs outside the industry.

Workshops kick off in January 2020 and cover business management, fisheries science, North Carolina seafood in the global marketplace, and more. Partners include UNC-TV, Barbara Garrity-Blake at Duke University Marine Laboratory, and freelance journalist Susan West.

— Katie Mosher

New Projects Boost NC Aquaculture

Several North Carolina efforts are among 43 research projects and collaborative programs that the National Sea Grant College Program has funded to advance sustainable aquaculture.

Susan White, executive director of North Carolina Sea Grant, says that seafood consumption continues to rise, which means that wild-caught fisheries alone cannot meet the demand for seafood in the United States.

"Aquaculture's role in the Blue Economy is becoming more and more important," White says. "Along with North Carolina Sea Grant's ongoing initiatives in support of aquaculture, these new efforts will help enhance and expand the industry in our state."

The new projects include collaborations among North Carolina Sea Grant experts with researchers at a host of institutions and organizations along the East Coast and beyond.

Frank Lopez, North Carolina Sea Grant's extension director, leads a tri-state project to expand comprehensive shellfish aquaculture training opportunities. In addition, NC State's Whitney Knollenberg heads a team that works to advance shellfish mariculture tourism.

Luke Fairbanks at Duke University and his team are exploring the social dimensions of aquaculture in Florida, Maine and North Carolina. The N.C. Shellfish Growers Association and the East Coast Shellfish Growers Association also are partnering, researching development of a crop insurance product for oyster growers from Georgia to Maine.

"Our country imports 85% of its seafood," White says. "There's tremendous potential for the aquaculture industry to increase its share of the market in North Carolina and more broadly across the United States. These projects take steps toward that goal."

Read more: *go.ncsu.edu/boost*

— Katie Mosher & Dave Shaw

Marae Lindquist, with a mist net extraction of a seaside sparrow on Masonboro Island

Will Changing Sea Levels Affect Sparrow Habitat?

North Carolina Sea Grant and the NC Sentinel Site Cooperative have announced Marae Lindquist as their 2019 joint fellow. Her research focuses on modeling sea level rise in order to determine how changes in habitat will affect winter populations of saltmarsh and seaside sparrows.

The NC Sentinel Site is one of five cooperatives under the National Oceanic and Atmospheric Administration's Sentinel Site program. These cooperatives bring together science, management and technology to address the impacts of sea level changes on coastal communities.

"The NC Sentinel Site Cooperative is very excited to fund Marae to study the impacts of changing sea levels on marsh bird populations and habitats in one of the newly expanded regions of the cooperative," says Sarah Spiegler, cooperative coordinator and marine education specialist for North Carolina Sea Grant. "Marae is our second joint graduate fellow. Her research will contribute to a better understanding of how sea level rise will affect NC coastal ecosystems."

John Fear, deputy director of North Carolina Sea Grant, says Lindquist's work helps mark the cooperative's next phase in a wider coastal region. "This is the first year that the research results will be from within that new geography," Fear says.

Learn more about the North Carolina Sea Grant/NC Sentinel Site Cooperative Joint Graduate Fellowship: *go.ncsu.edu/joint-fellowships.*

— Katelyn Vause

A forensic science class at the University of North Carolina at Chapel Hill found 35% of shrimp samples were mislabeled as North Carolina products.

How Prevalent Is Seafood Fraud?

Cases of seafood fraud have made news recently. A North Carolina crabmeat processor pleaded guilty in federal court in New Bern on charges the company falsely labeled millions of dollars' worth of cooked crabmeat from Asia and South America as "Product of the USA."

In addition, a forensic science class at the University of North Carolina at Chapel Hill found 35% of shrimp samples obtained from 60 grocery stores and seafood markets across the state were mislabeled as North Carolina products. The mislabeled shrimp actually was a farmed species imported from the eastern Pacific.

Numerous investigations have shown several kinds of fraud can occur as seafood moves from fishermen to consumers. These deceptions range from flagrant attempts to increase profits to simple misunderstandings or a lack of information.

The UNC-Chapel Hill study, for instance, noted the average price for mislabeled shrimp was $11.00 per pound compared to $13.20 per pound for correctly-labeled shrimp, which suggests the mislabeling likely was unintentional rather than economically driven.

But just how widespread is seafood fraud?

Estimates vary, but in 2012 the U.S. Food and Drug Administration started an investigation into seafood mislabeling. The investigation found 85% of the seafood they tested was properly identified.

More information, including how consumers can verify seafood authenticity: *go.ncsu.edu/fraud* — *Barry Nash*

Scientists Test Device to Deter Sharks

North Carolina Sea Grant is collaborating on a new project to keep sharks away from commercial fishing gear. Researchers are partnering with the private sector to pilot test a state-of-the-art electronic device that deters the predators.

"Several sharks are overfished or are experiencing overfishing on the U.S. East Coast," says Sara Mirabilio, a fisheries extension specialist with North Carolina Sea Grant. "Populations of scalloped hammerhead, dusky, sandbar and blacknose sharks all could benefit from an effective deterrent from commercial fishing gear."

Most often, sharks are caught unintentionally, Mirabilio explains. That's why she and her colleagues, including Richard Brill at the Virginia Institute of Marine Science and Peter Bushnell at Indiana University-South Bend, plan to test a device that produces a small electric field around a baited hook.

Mirabilio says their approach has shown promise in the laboratory. The team is partnering on the project with Ocean Guardian, the company that pioneered "Shark Shield®" technology, to manufacture the first field-ready prototype.

Electrical impulses can keep fishing gear free of sharks like this juvenile dusky, caught at Ocean Isle.

"To an approaching shark, even a weak electrical impulse can be disorientating or physically painful," Brill explains.

Mirabilio says reducing shark-gear interactions will bring savings to commercial fishing operations.

"Sharks eat the fishing boat's intended catch before it can be brought aboard," explains the team's industry partner, Captain Charlie Locke, who owns the F/V *Salvation*. "Also, when sharks are going for the tuna or other fish, they often damage, or even destroy, fishing gear." Locke adds that sharks can increase the amount of time it takes to retrieve gear, as well as the time to sort the catch on-deck.

More on sustainable fisheries and aquaculture: *go.ncsu.edu/Fish*

— *Katie Mosher & Dave Shaw*

Wetland Chemical Compositions Change Hourly

Nitrate levels in wetlands fluctuate throughout the day, according to a new study from researchers at NC State University. The findings have implications for how to measure and account for nitrate, which can originate from fertilizers and sometimes can act as a pollutant.

Michael Burchell from NC State's Department of Biological and Agricultural Engineering says the findings provide new insights about nitrate concentrations in wetlands constructed for pollutant removal.

"Agricultural drainage water can be pumped from farms into constructed wetlands as a way to remove pollutants from the water," Burchell explains. "It's important we gain an understanding of how nitrate levels change in these systems over time."

New sensor technology allowed Burchell and his team to make hourly measurements, which revealed that nitrate levels in wetlands fluctuate during certain times of the day, even though overall the levels tend to decrease.

Burchell says microorganisms and utltraviolet light break down organic matter, releasing internal sources of nitrogen that likely cause the hourly fluctuations that his team identified.

"This research overall helps practitioners predict how much agricultural drainage water they can pump into a wetland," Burchell says.

North Carolina Sea Grant, the North Carolina Water Resources Research Institute, and other groups funded the study.

Read the full study in *Ecological Engineering: go.ncsu.edu/wetlands-study* — *Katelyn Vause*

An albino alligator at the North Carolina Aquarium at Fort Fisher

Aquarium Provides Sensory Inclusive Experiences

The North Carolina Aquarium at Fort Fisher wanted to make exploring a little easier for visitors with sensory sensitivities, including people on the autism spectrum, as well as people with sensory processing disorders, post-traumatic stress disorder, and other needs.

The aquarium recently earned its Sensory Inclusive Certification in partnership with KultureCity, a national nonprofit that focuses on sensory-inclusive technology and spaces. Aquarium staff from all departments, as well as many volunteers, completed training to better understand and interact with guests with differing sensory characteristics.

"This illustrates our team's commitment to making the aquarium a place all people can experience and enjoy," says educator Erin Gross, who led the certification initiative and training.

Where possible, the N.C. Department of Natural and Cultural Resources offers assistive listening devices, Braille signage, wheelchairs, accessible facilities, and other features at museums, parks, and attractions.

Read more: *www.ncdcr.gov* — *Katelyn Vause*

Study Explores Climate Adaptation

Rural communities already have seen the chaos hurricane flooding can bring when septic systems overflow into nearby land and water. The National Oceanic and Atmospheric Administration is supporting a new project looking at impacts of climate change for onsite wastewater treatment systems in North and South Carolina.

"Ultimately, we want to help coastal communities prioritize climate adaptation investments," says Jane Harrison, North Carolina Sea Grant's coastal economist, who will lead the study.

The mulitcampus and interdisciplinary team also includes Charles Humphrey and Michael O'Driscoll of East Carolina University; Eric Edwards and Jared Bowden of North Carolina State University; and Katie Hill of the University of Georgia.

"High-tide flooding and extreme precipitation events, as well as sea level rise, can bring immediate and long-term losses of system functionality," says Humphrey. "If septic systems and other onsite technologies fail to process contaminants, results may include human illness, ecosystem damage, and ultimately the un-livability of communities that depend on them."

The study will focus on fecal bacteria, phosphorus, and nitrogen in partnership with the Town of Nags Head and City of Folly Beach.

"The effort builds on existing understanding of decentralized wastewater infrastructure functionality by wastewater facility operators, private septic experts, and coastal community decision makers," Harrison explains. "The team will develop protocols that coastal decision makers and adaptation professionals can use to plan and prepare for climate change with regards to decentralized wastewater infrastructure."

More about Nags Head's pioneering town planning: *go.ncsu.edu/TheLongView* — *Katie Mosher*

Flooded maintenance buildings at Cape Lookout

Dorian Brings 9-Foot Storm Surge to Cape Lookout

Earlier this year, *The Guardian* reported that when Hurricane Dorian struck the Bahamas as a Category 5 hurricane, it was the strongest storm on record to hit the country and caused the worst natural disaster in the islands' history.

Dorian made landfall on Cape Hatteras a few days later as a Category 1 hurricane, but the storm's impact on some parts of coastal North Carolina also was severe. Ocracoke Island, for instance, received devastating storm surge, damaging homes, businesses, roads and infrastructure such that access remained limited for more than a month.

At Cape Lookout National Seashore, superintendent Jeff West says Dorian's damage was unlike anything he had experienced while with the park. The 7-foot storm surge that came across Portsmouth wrought havoc on the village's historic and modern maintenance structures.

"I have not seen total building impact like this to a historic district anywhere or anytime in my career," says West. "All of the infrastructure for the cabin camp was completely destroyed."

An even greater storm surge — 9 feet — washed over most of North Core Island from the sound side and left over 54 inlets that cut through the Island from sound to ocean. At the end of September, some of the larger ones still had remained active.

"This is personally hard, professionally difficult," says West, who lives on Harkers Island. "At the same time, it is an opportunity to inject sustainable design and operations into the process of learning to live within new weather patterns, rather than fighting it."

Within a week, Dorian had sped up the East Coast, into Canada, and out to sea, dissipating near Greenland.

— *Sarah Spiegler & Dave Shaw*

The story of accelerating sea level rise and its human impact unfolds on the most recent edge of a 200-million-year-old timeline. The longer tale begins with the birth of the Atlantic ocean, and it includes a record of how people have responded to the encroaching water for centuries.

A Brief History of Sea Level Rise in North Carolina

STANLEY R. RIGGS

Continued

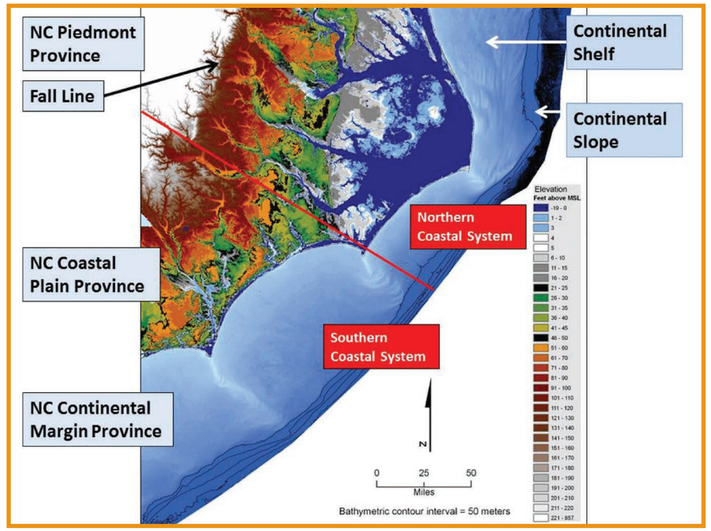
BillRuss/VisitNC.com

Northeastern North Carolina's coastal system embodies the best of water, wildlife, and wildness — an energetic, complex, and diverse waterscape superimposed on the geologic and biologic landscape. This landscape also is overlain with a rich but conflicted human history. The many different human groups inhabiting this world-class coastal system for millennia have witnessed the natural dynamics of change and left a cultural history based on these dynamics.

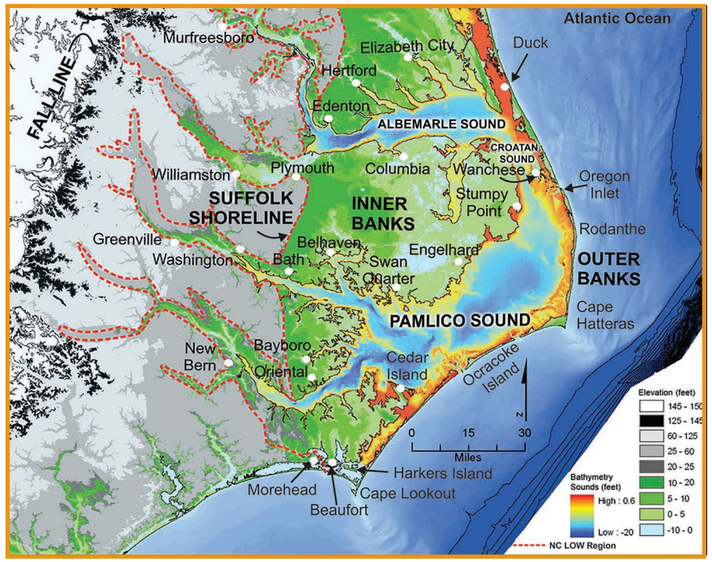
Where the western boundary of the vast Atlantic Ocean intersects the irregular topography of the North Carolina landmass today, a broad and shallow coastal system occurs (*Figure 1*). This land-water interface forms the modern North Carolina coastal system that is still dominated by and the product of energetic storms that build, maintain, and obliterate it; these are the forces that drive coastal evolution. The result is a complex network of diverse geomorphic features and associated aquatic ecosystems in which change is the only constant.

The wild and beautiful coastal system of North Carolina (*Figure 2*) has always had a magical draw for human occupation and, most recently, has become an essential component for ever increasing economic growth and development. However, continued expansion in a dynamic coastal system dominated by high-energy storms and change has set economic growth and community development on a collision course with natural processes.

A new vision must emerge, one in which society adapts to and lives with the ongoing processes of dynamic change. This can only happen if society integrates scientific understanding with our cultural needs into a new paradigm for the "North Carolina Land of Water."[1]



2015 NC Floodplain Mapping Program & D. Ames



Riggs et al., 2011

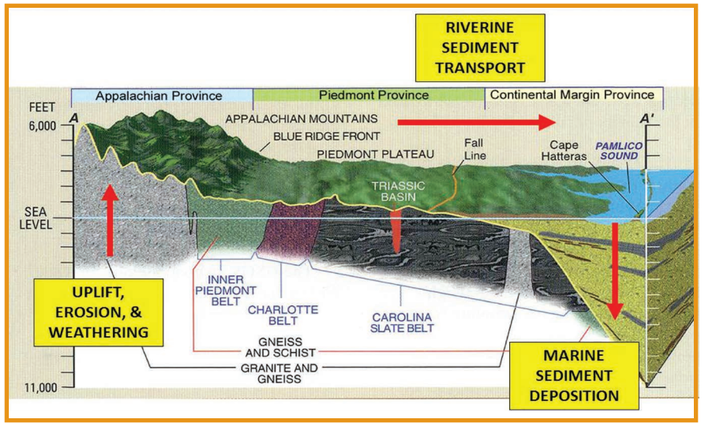
• Figure 1 (Top): If the ice on Greenland and Antarctica were to melt entirely, the sea level would rise, flooding the coastal plain to the "Fall Line" at the edge of the Piedmont Province and Interstate 95 — where the ocean was before. Today, riverine drainage systems flow off the Piedmont across the Coastal Plain Province (dark red-brown to light blue). The vast estuarine system forms as rivers reach sea level and mix with the Atlantic. • Figure 2 (Bottom): The Land of Water coastal system extends westward to the Paleo-Suffolk shoreline and associated river systems (the red dashed line). Yellow to red areas represent shallow shoals slightly below sea level; blue areas increasingly are below sea level.

• Building North Carolina's "Coastal Margin"

The North Carolina Coastal Plain is bordered on the Atlantic Ocean side by its drowned partner, the submarine continental margin, and on the inland side by the "Fall Line" that separates the Coastal Plain from the Piedmont and Appalachian Provinces (*Figure 1*).

The Piedmont and Appalachians are ancient landforms resulting from severe mountain-building processes more than 250 million years ago. They have substantial elevation above modern sea level and are composed of ancient metamorphosed sedimentary rocks and crystalline granitic and basaltic rock types. The Atlantic Ocean started to form about 200 million years ago and accumulated vast thicknesses of marine sediments, which range from a few feet at the Fall Line to 10,000 feet at Cape Hatteras, and to about 40,000 feet on the outer continental margin about 50 miles off the present barrier island system (*Figure 3*). This sediment wedge is composed of marine deposits and associated fossils (such as oysters, clams, mussels, corals, crabs, and shrimp) that today extend inland to form the Coastal Plain and that occur in part above modern sea level.

The topography of North Carolina's modern Coastal Plain is the direct product of previous coastal systems as sea level rose and fell, causing the coastal system to migrate back and forth across the continental margin. The processes of climate change — fluctuations in sea level, ocean dynamics, and frequency and intensity of storms — dictated when coastal waters flooded or drained the river valleys,



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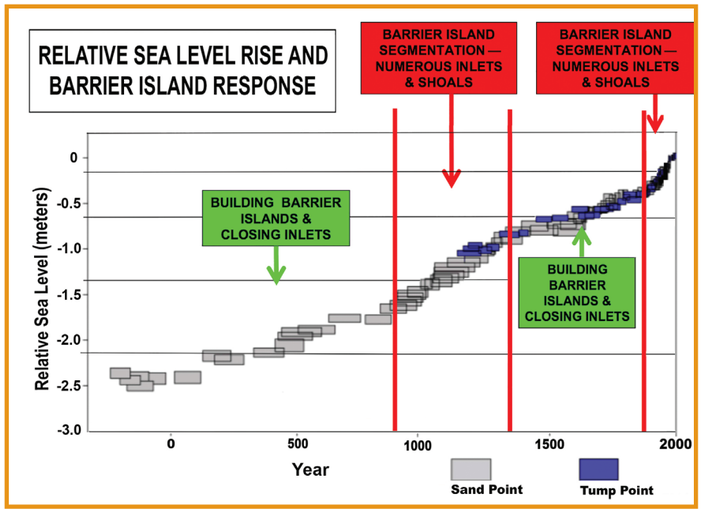


Kemp et al., 2011 & 2017; Mallinson et al., 2005, 2010 & 2018; Riggs et al., 2011

• Figure 3 (Top): Mountain-building processes formed the Appalachian and Piedmont Provinces, and weathering and erosion then produced river systems that delivered sediment to the coast. The deposits accumulated, creating the Coastal Plain and Continental Margin, and by about 3,000 years ago portions of the modern barrier islands had begun to form near their present location. • Figure 4 (Bottom): Analyses of microscopic organisms and isotopic dating at saltwater marshes on Roanoke Island (Sand Point) and Cedar Island (Tump Point) provide a record of gradual sea level rise more than 2,000 years long.

when shorelines advanced or receded, when ecosystems evolved or migrated, and when barrier islands moved landward or seaward.

The historical evolution of the ancient to modern coastal systems has been extensively analyzed and mapped, such that now these processes of change can be projected into the short-term future with a certain level of confidence.[1,2]

• The Scientific Record of Sea Level Rise

Sea level rise by itself is a fairly slow and gentle process that is like filling a bathtub. The scientific record of sea level change in coastal North Carolina has been well established over the last 50 years by a vast array of coastal marine scientists of many different disciplines dissecting the North Carolina coastal system (*Figure 4*).

Sea levels have risen and fallen for as long as there has been an Atlantic Ocean along North Carolina's eastern shore. Today, fossil beds of marine shells in our estuarine bluffs occur well above modern sea level. For instance, one such bed — full of finger corals, oysters, and articulated clams — is located about 10 to 15 feet above present sea level in the west banks of the Chowan River Estuary.[3,4] To produce this deposit, the relative level of the sea in the recent past must have been substantially higher than at present.

However, frequent coastal storms superimposed upon rising sea level contain the energy to build, modify, and migrate coastal systems. These storms are drivers of change that erode shorelines, move barrier islands, and cause ecosystems to evolve. For many millennia, before the first English explorers landed on Roanoke Island in 1584, extra-tropical storms, tropical storms, and hurricanes played substantial roles in changing and rearranging the natural coastal system. About 1,500 tropical storms have occurred in the North Atlantic in the last 160 years alone, with many inpacting the North Carolina coastal system (*Figure 5*).

During the late 1960s and early 1970s, my colleagues and I began studying the dynamics and evolutionary history of the Albemarle-Croatan-Pamlico region.[5] This initial research project was largely funded by the newly founded North Carolina Sea Grant Program in 1970 through 1974. The project involved running subsurface surveys, drilling deep core holes, and analyzing age-dated sediments. We developed a summary of the physical dynamics operating

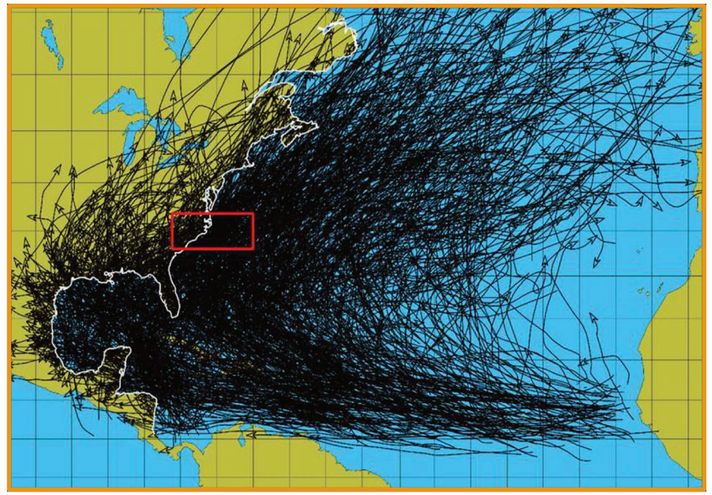
Continued

within this coastal system and a preliminary map documenting the evolutionary history of Croatan Sound.[6,7] Subsequent research established the details of how Croatan Sound evolved from a drowning creek, surrounded by vast coastal marshes, to a relatively wide and deep estuary 200 years after closure of the northern Outer Banks inlets — dynamic change that had significant human consequences.[8,9]

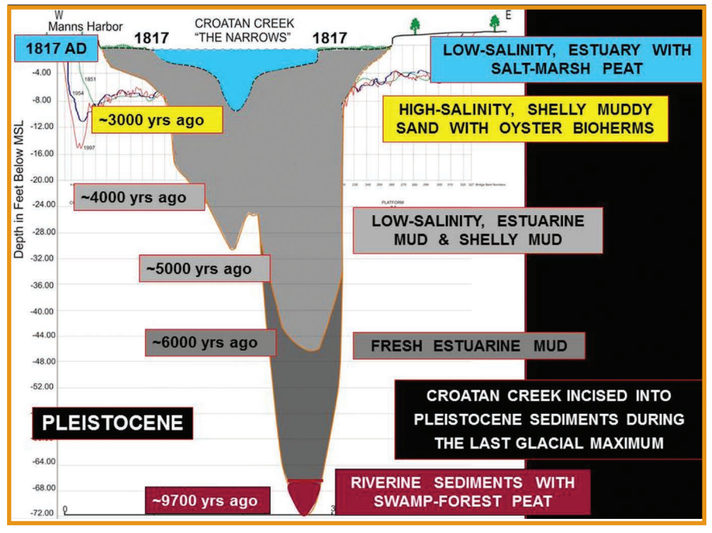
Additional research by numerous scientists over the next 45 years has further documented the formation of the entire North Carolina coastal system — including the inner continental shelf, barrier island-estuarine system, and associated riverine and adjacent Coastal Plain uplands.[5] The origin and evolution of Croatan Sound (*Figures 6 and 7*), for instance, clearly demonstrate the details of sea level rise and resulting change in coastal ecosystems through time. The scientific result provided the first detailed 10,000-year history of sea level rise in North Carolina's coastal system and supplied initial data for subsequent sea level studies within the scientific community.[10, 11, 12, 13, 14, 15]

• The Natural and Cultural Response to Sea Level Rise

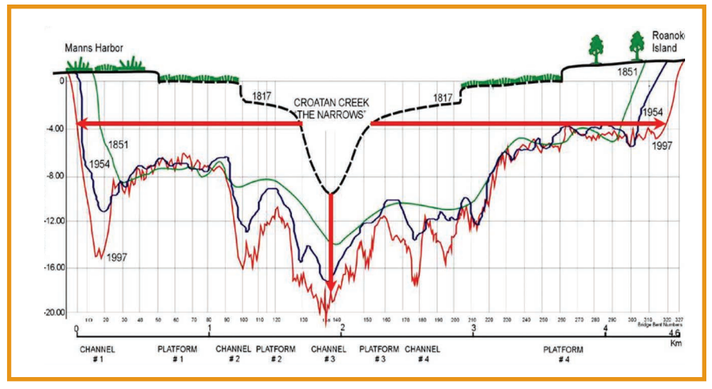
Although the record of sea level change is scientifically well known, this phenomenon is not well understood by the public. Nonetheless, sea level change has left a major record of its overwhelming impact upon the history of coastal cultures, especially in northeastern North Carolina. (See "A Timeline of Natural Changes and Human Responses to Sea Level Rise, 1706-1867" on page 12.)



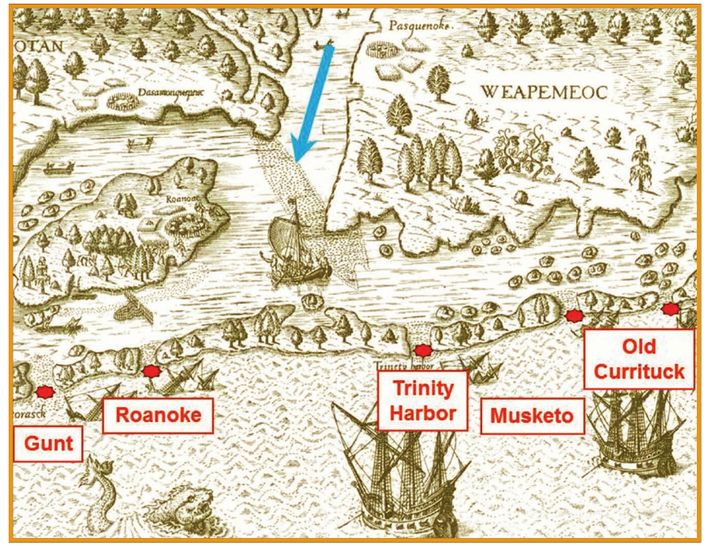
NOAA's National Hurricane Center



Riggs, Rudolph & Ames, 2000; Culver et al., 2011 & 2016; Mallinson et al., 2005



Riggs, Rudolph & Ames, 2000



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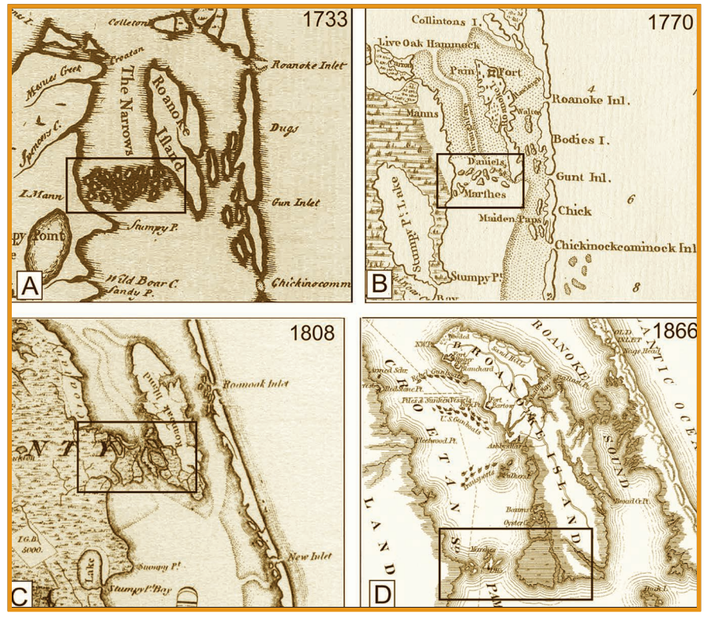


A–Moseley, 1733; B–Collet, 1770; C–Price and Strother, 1808; D–Union and Confederate Navies, 1866

• Figure 8 (top): This 1590 map shows the five inlets and outlets (in red) for the Roanoke-Albemarle drainage system (blue arrow) in the region north of Roanoke Island. These passages were transient — opening, migrating, and closing at different times in response to storms. • Figure 9 (Bottom): The black boxes mark the Roanoke Marshes inter-stream divide, which eroded away and opened Croatan Sound to connect Albemarle and Pamlico sounds.

From 1584 to 1587, Sir Walter Raleigh and his English settlers sailed into the salty estuarine waters of Currituck, Roanoke, and Albemarle sounds looking for the "New World." There were at least five ephemeral inlets through the Outer Banks barrier islands north of Roanoke Island at the time, as indicated on a 1590 map by John White and Theodor de Bry (*Figure 8*). These fickle openings through the barrier islands were inlets for the settlers and outlets for the Roanoke-Albemarle drainage discharge and the shipping industry.

The English ships probably came through the "Roanoke Inlet," which at that time was located just south of Jockey's Ridge in Nags Head and followed a deep channel to the northwest, passing adjacent to the high bluffs and overlying dune field along the north shore of Roanoke Island. The Roanoke Island shoreline then extended well over one-half mile farther north than today's shoreline, which is still severely eroding.[4]

During the first three centuries of European settlement, the riverine and estuarine waterways were highways and inlets through the barrier islands crucial for shipping between the newfound colonies and the old world. Early maps demonstrate the dynamic changes that were taking place to the waterways during this time period. The ephemeral inlets through the highly mobile barrier islands routinely opened, migrated, and closed in response to individual storm events.[16, 17, 18, 19]

When the colonists were exploring coastal North Carolina in the late 16th century, sea level was at least 3 feet lower than today but rising (*Figure 4*). The Pamlico and Albemarle Sounds were saltwater estuaries, and the two sounds were barely connected to each other by only a few tidal channels for small boats (*Figure 9A*).

Croatan Sound, which today connects the two drainage systems, did not yet exist (*Figure 11*). Rather, it was a drowning Croatan Creek that occupied the "Croatan Narrows," flowing off the shallow-water marshes on the inter-stream divide known as the "Roanoke Marshes" — which still connected Roanoke Island to the mainland (*Figures 9A, 9B, and 9C*). The detailed geologic history of the evolution of Croatan Sound is supported by the historic maps and oral traditions of early

Continued

• Figure 5 (top): From 1851 to 2017, about 1,500 tropical storms occurred in the North Atlantic, including many that directly affected the N.C. coastal system. • Figure 6 (middle): Seismic and drill core data, as well as radiocarbon dating, show how Croatan Creek evolved from a freshwater creek to an estuarine sound over 10,000 years. • Figure 7 (bottom): With closure of all northern inlets in the early 1800s, the Roanoke-Albemarle discharge flowed through the Croatan Narrows and flooded the Roanoke Marsh interstream divide. Bathymetric surveys have revealed the subsequent increase in erosion, the process that formed the modern Croatan Sound. *Figure 7*'s dashed black line, within today's much broader and deeper sound, marks the bed of the old Croatan Creek, which *Figure 6* represents in blue.

A TIMELINE OF NATURAL CHANGES AND HUMAN RESPONSES TO SEA LEVEL RISE, 1705–1867

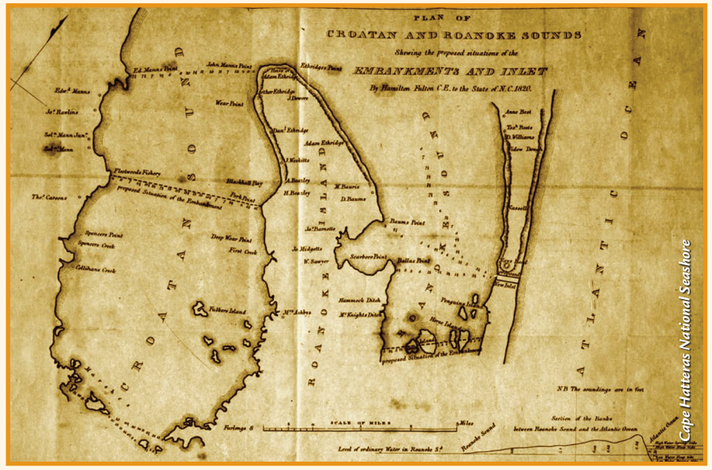
As the natural dynamics of sea level rise and storms brought evolutionary changes to the coastal system, it severely impacted the course of human settlement in the region. The scientific record of sea level change in coastal North Carolina is underscored by the state legislature's relentless efforts to prevent coastal change and control the dynamics of water. The historical record of the North Carolina Colonial Assembly and State Legislature document long and unending efforts to tame the wilderness and contain the ongoing processes of natural climate change, such as sea level rise and storm dynamics.

In 1705 to 1706, Bath, located on the Pamlico River estuary with access to the Atlantic Ocean via Ocracoke Inlet, was incorporated as North Carolina's oldest town.

In 1722, the North Carolina Colonial Assembly established Edenton as North Carolina's first capital due to availability of shipping through the northern inlets and because of its proximity to Jamestown, Virginia, and Chesapeake Bay.

By the MID-1700S, changing coastal storm activity caused the northern inlets to become increasingly unreliable for shipping, rapidly jeopardizing Edenton's access to the ocean. The North Carolina Colonial Assembly determined that the more stable Ocracoke Inlet would be established as the major port for northeastern North Carolina.

In 1753, the North Carolina Colonial Assembly established the town of Portsmouth on North Core Banks (southwest side of Ocracoke Inlet) and platted it for development.



• FIGURE 10: HAMILTON FULTON'S 1820 ENGINEERING MAP DETAILS WATER DEPTHS, PROPOSED ROCK DAMS OR EMBANKMENTS ACROSS THE SHALLOW WATERS OF CROATAN SOUND AND ROANOKE SOUND, AND THE PROPOSED NEW ROANOKE INLET THROUGH THE OUTER BANKS OPPOSITE ROANOKE ISLAND.

In 1766, Governor Tryon moved the capital of colonial North Carolina from Edenton, which was rapidly becoming landlocked, to the new port city of New Bern on the Neuse River with direct access to shipping through Ocracoke Inlet.

In 1784, construction began on the 22-mile Dismal Swamp Canal, built by enslaved Africans to open up shipping from Albemarle Sound to Chesapeake Bay and beyond. This canal was completed for small boats in 1805 and enlarged by 1820S for larger vessels.

From 1787 to 1789, the Raleigh Company was established by the state legislature to re-open the deteriorating Roanoke Inlet from Roanoke Sound to the Atlantic Ocean.

By 1808 only Roanoke Inlet remained open from Roanoke Sound (*Figure 9C*).

By 1815, Roanoke Inlet was in its final stages of closing, and Archibald Murphey, a North Carolina politician known as the state's "Father of Education," developed a plan to re-establish ocean-going navigation for the Albemarle Sound region.

The ephemeral Roanoke Inlet, the last inlet to allow discharge of the Roanoke-Albemarle drainage basin into the ocean, finally closed by 1817 in the vicinity of Whalebone Junction (*Figure 9C*). As a result:

- Without any inlets, the Albemarle and Currituck Sounds and their tributary estuaries became freshwater along with major shifts in both the flora and fauna.
- Without a direct outlet to the ocean, the freshwater discharge from the Roanoke-Albemarle drainage system was forced to flow through the Croatan Narrows, flooding across the inter-stream divide into the Pamlico Sound drainage system with its outlets to the ocean (*Figures 6* and *7*).
- The human response was that the coastal system could be engineered and managed to benefit society without regard to the ongoing natural dynamics of a high energy coastal system. Murphey developed plans for doing so by maintaining a system of canals.

In 1820, English engineer Hamilton Fulton was employed by the legislature to produce a map (*Figure 10*) and a plan to re-open Roanoke Inlet permanently. His plan required building rock dams across the shallows of both the newly forming Croatan Sound and Roanoke Sound to force the Roanoke River discharge through the proposed Roanoke Inlet with its rock hardened shorelines. Fulton believed the fickle waterways could be engineered.

In 1821, the legislature authorized the Roanoke Inlet Co. to build the dam structures and inlet as laid out on the 1820 Fulton engineering map. The effort failed.

Five more detailed surveys were authorized by the state legislature in 1828-29, 1840, 1843, 1852, and in 1853, all based on Fulton's 1820 map, but with new depth survey data, slight project modifications, and new dates. All efforts failed.

In 1846, a storm opened the present Oregon Inlet south of Roanoke Island. The ongoing rise of the sea level had flooded over the top of the "Croatan Narrows" and "Roanoke Marshes," which allowed the Roanoke-Albemarle drainage discharge to flow through Croatan Sound and connect the Albemarle and Pamlico drainage basins. This increased flow rapidly amplified the erosion rates of the Croatan Sound shorelines and its bottom depth (*Figures 6* and *7*).

In 1857, the U.S. Congress made $50,000 available to dredge a new Roanoke Inlet, but the project ended later that year when the inlet filled faster than it could be dredged.

By the start of the Civil War in 1861, Croatan Sound was already a major body of water with established navigation channels that allowed General Ambrose Burnside to bring 13,000 troops and 67 ships through Roanoke Marshes to carry out the largest naval battle in North Carolina on the north shore of Roanoke Island (*Figure 9D*).

In 1867, Congress built two screw-pile lighthouses at Roanoke Marshes and Colington Shoals, the south-channel and north-channel entrances to Croatan Sound, respectively, as it became a major navigational waterway to the southern Outer Banks inlets (*Figure 9D*).

The historic freshwater Croatan Creek evolved into a saltwater tidal creek, occupying "The Narrows" on maps from 1590 to 1808 maps (*Figures 8* and *9*) before becoming today's relatively wide and deep Croatan Sound, now a major waterway in North Carolina (*Figure 2*). This 200-year old body of water is a dramatic example of coastal system change in response to persistent storm activity and the ongoing rise of sea level.


Outer Banks History Center

• ABOVE: THE ROANOKE MARSHES SCREW-PILE LIGHTHOUSE STOOD AT THE SOUTH ENTRANCE TO CROATAN SOUND ON AN ERODING MARSH ISLAND FROM 1867 TO 1955.

• THIS TIMELINE RELIES ON DATA SUMMARIZED FROM THE AUTHOR'S RESEARCH AND TEACHING CAREER IN COASTAL NORTH CAROLINA FOR OVER A HALF CENTURY.

Wanchese residents, which chronicle how they walked the Roanoke Marshes to the mainland with only a few planks to cross small tidal channels.

As mentioned earlier, the evolution of Croatan Creek into Croatan Sound over 200 years is a direct product of ongoing sea level rise and subsequent flooding across the Roanoke Marshes inter-stream divide that separated the Albemarle and Pamlico drainage basins[20, 8] (*Figure 11*). In addition to the rising sea level, this drowning process was enhanced by the final closure by 1817 of all five ephemeral inlets that had cut through the Outer Banks north of Roanoke Island (*Figure 8*). These inlets were the primary discharge points for the Roanoke-Albemarle drainage system into the Atlantic Ocean.

The final closure of these northern inlets forced the full power of the Roanoke-Albemarle discharge, the state's largest river, through Croatan Creek and Roanoke Marshes into Pamlico Sound and out through southern inlets. In the process, the large flow dramatically eroded Croatan Sound both laterally and downward to produce the wide and deep estuary that exists today (*Figures 6* and *7*).

Total closure of inlets north of Roanoke Island had other major consequences. Prior to 1817, Albemarle Sound was a brackish-water estuary, much like Pamlico Sound is today. However, no barrier island outlets for the continuous seaward flow of fresh Roanoke River and brackish Albemarle basin waters also meant no inlets for inflowing ocean water. Thus, Albemarle Sound and associated tributary estuaries became freshwater estuaries.

Because salty water is toxic to all land-based trees in the mid-Atlantic climate zone, prior to two centuries ago there were no submerged trees *living* in the water along the shorelines, not even bald cypress. However, with the rising sea level and the closing of the outlets, the coastal swamp forests slowly drowned — all trees, that is, except the bald cypress. Although this tree must germinate on land, after a certain young age the bald cypress can continue to live, although stressed, under permanently flooded, freshwater conditions.

This evolutionary change put a critical data point on the reality of ongoing sea level rise that is dramatically documented by the hundreds of thousands of bald cypress trees

Continued

permanently under water and rimming the entire Albemarle estuarine system. Thus, the closing of all inlets north of Roanoke Island by 1817, along with the ongoing upward march of rising sea level, created massive changes in the physical and chemical dynamics of the Albemarle Sound water bodies, causing major shifts in plant and animal life of the associated coastal ecosystems.

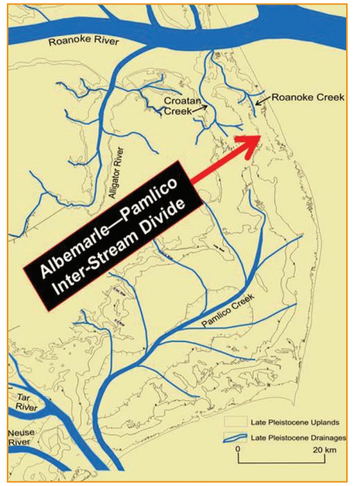
This is absolute evidence of coastal change in response to ongoing sea level rise. When Albemarle and Currituck Sounds became freshwater estuaries, the surrounding coastal region experienced the emergence of new bass fishing and wildfowl hunting industries.

• Conclusion

Both historical and recent economic development in North Carolina's coastal system have largely ignored the dynamics of natural change. Centuries of engineering the low swamplands and the more recent introduction of an upland style of business economy — including highways, mega-houses, hotels, and condominiums — on mobile piles of barrier sands has created the potential for a catastrophic failure in response to a large-scale hurricane. Escalating urbanization within this dynamic system almost guarantees massive economic losses in the case of every major storm event.

North Carolina's coastal economy is largely dependent upon a mixed commerce of agriculture, forestry, and tourism that is perched on a dynamic system of low wetlands and mobile barrier islands. Large portions of these ecosystems are overwhelmed by storms in a period with a rising sea level as the coastal population has boomed in the 21st century. North Carolina finds itself in the throes of a "Perfect Conflict": an escalating battle between alteration of landscape-waterscape resources and the natural dynamics of coastal change.

North Carolina's unique coastal system has challenged the engineering prowess of many great minds through the centuries: Thomas Harriot and John White, who mapped northeastern North Carolina for Sir Walter Raleigh in 1585; George Washington, who initially tried to drain the great Dismal Swamp in the latter half of the 18th century; Archibald Murphey's antebellum efforts to reopen inlets through the Outer Banks; and the U.S. Army Corps of Engineers, who have fought the dynamics of nature from the 19th to the 21st century. With a fuller understanding of the science behind the state's coastal region, North Carolina's future challenge is to devise a coastal management and development system that can advance in harmony with the realities of change within this magnificent natural resource system.



Riggs et al., 1995 & 2000

• Figure 11: This map shows the major inter-stream divide about 9,000 years ago, when sea level was substantially lower. Pamlico Creek, Croatan Creek, and Roanoke River were pre-cursers of Pamlico Sound, Croatan Sound, and Albemarle Sound respectively. For reference only, the figure includes the Outer Banks, which did not then exist.

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• Above: Bald cypress trees within the Albemarle-Chowan estuaries germinated in swamp forests on land and subsequently survived permanent flooding in response to ongoing sea level rise.

• Notes

1 Riggs, S.R., Ames, D.V., Culver, S.J., and Mallinson, D.J. 2011. *The Battle for North Carolina's Coast: Evolutionary History, Present Crisis, and Vision for the Future*. University of North Carolina Press.

2 Riggs, S.R., Ames, D.V., Culver, S.J., Mallinson, D.J., Corbett, D.R., and Walsh, J.P. 2009. "Eye of a Human Hurricane: Pea Island, Oregon Inlet, and Bodie Island, Northern Outer Banks, North Carolina" in *Identifying America's Most Vulnerable Oceanfront Communities: A Geological Perspective*, Geological Society of America, Special Paper 460, p. 43-72.

3 Bellis, V., O'Connor, M.P., and Riggs, S.R. 1975. *Estuarine Shoreline Erosion in the Albemarle-Pamlico Region of North Carolina*. University of North Carolina Sea Grant, Pub. No. UNCSG7529.

4 Riggs, S.R. and Ames, D.V. 2003. *Drowning of North Carolina: Sea-Level Rise and Estuarine Dynamics*. NC Sea Grant Program, Pub. No. UNC-SG-03-04.

5 Miller, W. 2019. "New Model of Pleistocene Stratigraphy, Outer Coastal Plain, Northeastern North Carolina: Patterns and Problems," *Southeastern Geology, v. 53, no. 3*, p. 181-189.

6 O'Connor, M.P., Riggs, S.R., and Winston, D. 1973. "Recent Estuarine Sediment History of the Roanoke Island Area, North Carolina," in *Environmental Framework of Coastal Plain Estuaries*, Geological Society of America Memoir 133, p. 453-464.

7 Riggs, S.R. and O'Connor, M.P. 1974. *Relict Sediment Deposits in a Major Transgressive Coastal System*. University of North Carolina Sea Grant, Pub. No. UNCSG7404.

8 Riggs, S.R., Rudolph, G.L. and Ames, D.V. 2000. *Erosional Scour and Geologic Evolution of Croatan Sound, Northeastern North Carolina*. N.C. Department of Transportation, No. FHWA/NC/2000-002.

9 Riggs, S.R. and Ames, D.V. 2017. "An Uncompromising Environment: North Carolina's 'Land of Water' Coastal System," in *New Voyages to Carolina*, University of North Carolina Press, p. 14-40.

10 Culver, S.J., Grand Pre, C.A., Mallinson, D.J., Riggs, S.R., Corbett, D.R., Foley, J., Hale, M., Metger, L., Ricardo, J., Rosenberger, J., Smith, D.G., Smith, C. W., Snyder, S.W., Twamley, D., Farrell, K. and Horton, B.P. 2007. "Late Holocene Barrier Island Collapse: Outer Banks, North Carolina, USA," *The Sedimentary Record, v. 5*, p. 4-8

11 Culver, S.J., Farrell, K., Mallinson, D.J., Willard, D., Horton, B., Riggs, S.R., Thieler, R., Wehmiller, J., Parham, P., Snyder, S.W., Hillier, C. 2011. "Micropaleontological Record of Quaternary Paleoenvironments in the Central Albemarle Embayment, North Carolina, USA," *Palaeogeography, Palaeoclimatology, Palaeoecology. v. 305*, p. 227-249.

12 Kemp, A.C., Horton, B.P., Donnelly, J.P., Mann, M.E., Vermeer, M., and Rahmstorf, S. 2011. "Climate Related Sea-Level Variations over the Past Two Millennia," *www.pnas.org/cgi/doi/10.1073/pnas.1015619110*

13 Kemp, A.C., Kegel, J.J., Culver, S.J., Barber, D.C., Mallinson, D.J., Leorri, E., Bernhardt, C.E., Cahill, N., Riggs, S.R., Woodson, A.L., Mulligan, R.P., and Horton, B.P. 2017. "An Extended Late Holocene Relative Sea-Level History for North Carolina, USA," *Quaternary Science Reviews, v. 160*, p. 13-30.

14 Mallinson, D.J., Riggs, S.R., Thieler, E., Culver, S.J., Foster, D., Corbett, D.R., Farrell, K., and Wehmiller, J. J. 2005. "Late Neogene and Quaternary Evolution of the Northern Albemarle Embayment (Mid-Atlantic Continental Margin, U.S.)," *Marine Geology, v. 217*, p. 97-117.

15 Mallinson, D.J., Culver, S.J., Leorri, E., Mitra, S., Mulligan, R.P., and Riggs, S.R. 2018. "Barrier Island and Estuary Co-Evolution in Response to Holocene Climate and Sea-Level Change: Pamlico Sound and the Outer Banks Barrier Islands, North Carolina, USA," in *Barrier Dynamics and Response to Changing Climate*, Springer International Publishing AG, *https://org/10.1007/078-3-319-68086-63*.

16 Cumming, W.P. 1966. *North Carolina in Maps*. North Carolina Department of Cultural Resources, Division of Archives and History.

17 Cumming, W.P. 1988. *Mapping the North Carolina Coast: Sixteenth-Century Cartography and the Roanoke Voyages*. North Carolina Department of Cultural Resources, Division of Archives and History.

18 Everts, C.H., Battlet, J.P., and Gibson, P.N. 1983. *Shoreline Movements: Cape Henry, Virginia to Cape Hatteras, North Carolina, 1849-1980*. US Army Corps of Engineers Technical Report CERC-83-1.

19 Mallinson, D.J., Smith, C., Culver, S.J., Riggs, S.R., and Ames, D.V. 2010. "Geological Characteristics and Spatial Distribution of Paleo-Inlet Channels Beneath the Outer Banks Barrier Islands, North Carolina, USA," *Estuarine, Coastal and Shelf Science, v. 88*, p. 175-189.

20 Riggs, S.R., Cleary, W.J., and Snyder, S.W. 1995. "Influence of Inherited Geologic Framework upon Barrier Beach Morphology and Shoreface Dynamics," *Marine Geology, v. 126*, p. 213-234.

The “Best Chef in the Triangle” Talks Carolina Cooking

The Story of Ricky Moore

Baxter Miller

Continued

Baxter Miller

"When I opened up Saltbox, I wasn't trying to be trendy," says Ricky Moore.

His small walk-up counter, Saltbox Seafood Joint, quickly has become recognized as one of the top places to get fresh seafood in the Triangle. Moore has gained local and national acclaim for his use of North Carolina seafood and traditional recipes — but with modern twists.

Raised in New Bern, Moore thrives on local flavors that he now brings to his customers. "I grew up eating seafood," he says. "I felt like if I was going to do a seafood concept, and in the context that I wanted to do it, I didn't want it to be in a fine-dining setting."

His food, served on trays and in paper baskets, is reminiscent of a fish-fry or road-side stand — and that's how he wants it.

"It's an everyday thing for these fishermen to get fish and provide this food," he says. "I want to make it an everyday occasion to eat their food."

Saltbox highlights the bounty of the North Carolina coast, cuisine that customers traditionally have found difficult to enjoy inland.

"Seeing that we have all of this coastline and all of these wonderful natural resources, why are they not showcased on menus?" Moore says, adding that he draws inspiration from his time in France, where globally-known recipes, like bouillabaisse, rely on locally caught seafood.

He spotlights North Carolina's catch, even when the species are not as well-known as some frequently appearing on menus. "Flounder, shrimp, and oyster," he says of common public perceptions and options. "Done. That is seafood."

But by including other N.C. species on his menu — like triggerfish, mullet, or sheepshead — Moore is changing the narrative around local seafood.

"I want to diminish the terminology and reputation of 'trash fish,'" Moore says. "Just because it isn't mainstream doesn't make it lesser."

To him, "native fish" is the more appropriate term.

"I understood and knew that it was going to take time to inspire and influence people to try some different things," Moore says. "I have a standard menu, but also a try-me kind of dish, which is literally, 'Try this fish!'"

His small, personable locations allow more interaction with consumers, including opportunities to answer their questions about unfamiliar species and seasonality.

In response, *IndyWeek* readers named Moore "Best Chef in the Triangle" last June.

And what are the best chef's personal favorites?

"I grew up eating bonefish, like croaker, spot, and star butterfish," he says, adding that one of his beloved preparations is "fried hard." This eastern-North Carolina cooking style includes a whole or butterflied fish, seasoned in cornmeal batter and fried in a cast iron skillet, bones and all.

"When you fry it so crispy," he says, "it almost becomes like bacon."

To bring coastal Carolina cooking to the broader public, Moore recently published the *Saltbox Seafood Joint Cookbook*. Written with K.C. Hysmith, the book explains the basics of preparing seafood and how to make classic North Carolina recipes.

In these excerpts from *Saltbox Seafood Joint Cookbook*, Moore discusses North Carolina's foodways and how they have shaped his career.

— Danielle Costantini

Left: *Moore, a New Bern native, brings southern cooking to his customers.*

Growing Up in New Bern

Local seafood is my gospel and always has been. My mother's side of the family came from a community called Riverdale, situated between New Bern and Havelock. My father was from Harlowe, halfway between Beaufort and New Bern. You crossed waters whichever way you went.

I grew up along the Neuse and Trent Rivers and spent plenty of my childhood fishing those waters, but I don't want this to sound as though we were eating fish all the time. We ate it whenever we could get it, whenever it was available, or whenever somebody went out fishing. This was real life, so we ate standard eastern North Carolina stuff, too, like greens with white cornmeal dumplings and salted pig tails, collard sandwiches, tender flat biscuits, fried chicken, and iceberg lettuce covered with thick salad dressing. It was never all fish.

A lot of people in my area didn't have traditional families or upbringings where the mother or grandmother stayed home and cooked everything from scratch. They had jobs, too. My mother worked at the local hospital for a long time. She was incredibly busy, but when she had time to cook she always did it in a very organized way. At no point in her process was the kitchen ever a mess. She kept things clean and neat, and made things like "priddy fried chicken," clean fried fish, and meatloaf with a tight and tidy ketchup glaze on top. My maternal grandmother, Bernice, worked in a Havelock school cafeteria and would bring home all sorts of extras from work. Hot, scratch-made dishes like lasagna, chicken tetrazzini, yeast rolls, and hamburger steak and gravy. Bernice had a close companion named James — we called him Tick — who learned to cook when he was stationed at Cherry Point. He was a kind of grandfather figure to me (and later married my grandmother Bernice) and was always cooking good food. Tick was known for his big breakfasts. They weren't anything fancy — standard eggs

Continued

and potatoes, fresh sausage, boiled and pan-fried ham, and bacon with a thick rind on it — but they were always done with precision.

Food and work were always tied up together. In the summertime, when we wanted some pocket money, all of us kids would get on our bikes and ride across the Bridgeton Bridge to go pick blueberries at Morris Blueberry Farm. The earlier you got there, the sooner you could finish before it got too hot. The farm paid in crisp, clean dollars that stuck together when you first got them.

My first official job was in a barbershop where I ran errands, shined shoes, and swept up the hair from the floor. My aunt got me the job. Down the street from the shop, a lady would cook food and sell plates heaped high with fried chicken, roast beef, chitlins, barbecue ribs, macaroni and cheese, collards, corn pudding, and such. I took orders, ran to collect the plates, and brought them back to the barbershop. At the end of the day, I spent the tips on a plate just for myself. Later, I ran a paper route, but I spent all my money on candy, so my mother made me quit. In high school, I worked at the Piggly Wiggly as a bagger, cashier, and produce stocker. Then I took another job as a dishwasher at a local seafood restaurant called "Friday's 1890." They never made the kind of fish you ate at home; instead, they made popcorn shrimp, fried flounder, hushpuppies, all the normal sides, and classic North Carolina pulled pork barbecue. A lot of restaurants did pork and seafood, like an eastern North Carolina surf and turf, and served it all on the same plate. I've always wondered why barbecue took the lead.

Life was busy, and everybody had work to do, so we didn't always gather at the table together to eat, but the food we had was always nurturing. Whatever I was fed, whichever friend or family made it, it was good to me. And, thankfully, we still found time for fishing.

During the summer all the cousins would gather at my other grandmother Lottie Mae's house. Once a week or so we'd set off on very informal fishing excursions with bamboo fishing poles fitted with standard bits of bait. Whenever you did go fishing, everybody caught enough for everybody — at least, that was the plan anyways. We'd haul our catch home for our aunts and grandmother to do the extra-messy job of scaling, gutting, and cleaning. They never trusted us kids to do it. When we couldn't make it out to the water, there was a gentleman who drove around selling freshly caught fish in his pickup truck that he had outfitted with a wood and galvanized tin storage setup and a big metal scale. All the fish was stored on ice — it seemed so special. You made your selection and he would weigh it out and wrap it up for you to take back into the house. Fish was either fried or stewed, depending on the size of the catch, and always very simply prepared. It was served with boiled potatoes or other some vegetable. Everybody, even us kids, ate the same thing.

Above and Right: *Moore has gained experience in domestic and international culinary settings.*

Launching a Career

It was part of my personal practice to further my culinary education and experience by working abroad whenever I had the opportunity. I wanted to work in specific restaurants just to define for myself what, exactly, a Michelin-starred kitchen was and what made it so special. Through this work abroad, I found a shared sense of tradition, culture, behavior, and, most important, discipline when it came to food and dining.

I was the only person of color in these European kitchens, which made me even more intense about learning as much as possible. Back then, the only African American chef I knew of was Patrick Clark, who ran famous restaurants like Odeon and Tavern on the Green and was on *Iron Chef* back before the show was big in the United States. Being black automatically pigeonholed you. By focusing on the classical cuisines of France and Italy,

Continued

Clark was never perceived as a typical African American chef. Not wanting to be recognized as just a southern cook, I thought that I should follow a similar path.

After some time and additional stages in European restaurants, I realized that the rustic roots of these culinary mainstays weren't that different from the food of my childhood. I began to see that southern food is not a lesser cuisine, and I shed many of the insecurities I had held about my own food culture. It was time to head back to the States.

Doing One Thing Really Well

I wanted a little shop, to do one thing really well, and to control every aspect of it. This was ultimately the base of my business model...during my search and was my first thought when I finally found a small building, a little walkup with the right bones, that wouldn't require a lot of staff and would allow me to be in a place where I was there every day doing it all myself. A place where I wanted to be all the time. Seafood just made sense.

Unfortunately, this little shop was not for rent and was occupied by a burger and hot dog joint, so I decided to observe this operation's routine. For about a week, I went there in the morning, at noontime, and late at night. I observed the traffic patterns, the local activities, the types of customers on foot and in cars, and the neighborhood vibe. I also watched the business. The owners weren't working the place as I thought they should have been. They were always late, glued to the loud television in the restaurant kitchen, and seemed to have no interest in serving food. So, I thought I would ask them, "You must be tired of this?"

They were a little offended.

I talked to the building's owner, an elderly lady whose family had owned the place for a long time, and I told her about what I wanted to do and what the place could be. Thankfully, the timing was right, the old business left, we drew up a new lease, and I found myself with a small restaurant without bells and whistles and in need of a thorough cleaning and complete reorganization.

Then came the naysayers. "You going to go to that little building over there?" "We've seen so many different things in there... " "You're coming in here with seafood, okay... you'll be gone in three months." But they were all missing the boat. I had driven around this neighborhood and seen firsthand the changes that were coming. I knew, five years from now, this would be a success. I could get it done. This was a practical opportunity to go into business for myself, do something creative and thoughtful, without big loans or investors. I could work this little thing.

Soon the questions changed. "Where did you find this space? It's so cool!" Seeing the success, the people who ran the burger stand before me even came back and wanted to take over my lease. People were really excited about what I was doing, and it seemed as if every chef in Durham came by to eat. As a chef, I feel that I know what chefs like: goodness, simple goodness, and to taste the care in what we're eating.

My original plan was to have a food truck (it was all the rage at the time). Instead, I got a stationary concession stand with two small fryers and a four-burner range. I was cooking everything to order. And I found I could do everything I wanted all for myself. I had Saltbox.

For me, Saltbox means hometown, and I kept this in mind as I created the menu. I wanted to bring that hometown food forward. I did my research and asked, "What was your hometown food in Durham?" The default answer was always pulled pork. Growing up in New Bern, it was fried hard crabs or fried chicken from Melvin's Chicken Shack, where they cooked chicken to order and you'd wait a while but never complain. In

Continued

Baxter Miller

Above and Left: *Saltbox Seafood Joint highlights North Carolina's catch and offers customers traditional and novel meals.*

Baxter Miller

Chapel Hill there was the Rathskeller, where you could get the best spaghetti dinner, and Hector's, which was known far and wide for its wraps before wraps were cool. I wanted Saltbox to be a place like this, a place folks would consider part of their hometown and the fabric of the community. A place that would make folks say, "You ain't been to Durham if you haven't been to Saltbox." I opened the doors in October 2012, just in time for the first fish running of the fall.

Four years on, after staying steady, preaching the gospel about local seafood, and having confidence in my work, I decided to expand. As I drove back and forth between my home in Chapel Hill and my work in Durham, I kept passing the old Shrimp Boat restaurant. I thought, "If this space ever comes available, it would be ideal for a sit-down Saltbox." Through word of mouth, I found out that the Shrimp Boat's owners wanted to leave, so I jumped. Norma and I went through the bank process, cleaned up the space together, and turned the restaurant into a seamless second version of Saltbox. We painted the bricks the signature Saltbox colors that always remind me of the beach: the light green of seagrass, the orange of life preservers and fishermen's jumpsuits, and a light blue to represent North Carolina. Everything needed to be authentic. For inspiration, I visited the Core Sound Waterfowl Museum on Harkers Island, noting all the natural wood and the purposeful lack of mermaids, pirates, and anchors.

Locals Seafood sent over cleaned oyster shells that we spread under the picnic tables situated beneath our giant vintage 1969 marquee. The marquee is how I communicate with my customers, building a space of awareness about local seafood and letting folks know what fish is in season. Although I use social media, I like this old-fashioned version, too. I'll spell out "Croaker Season" or "Butterfish is here" and watch as the cars pull in with curiosity. As a final touch, two vintage boat clocks hang over the door, so customers and cooks can see the time and understand the importance of how this process of slow, local food works.

Victoria Bouloubasis/The Hook

Moore has drawn acclaim, including recognition as IndyWeek*'s "Best Chef in the Triangle" and owner of one of the* News and Observer*'s "Best New Restaurants." He also now has a new UNC-TV show (above) called* The Hook.

Saltbox quickly became a platform for me to advocate for good cooking, evangelize local North Carolina seafood, and give back to the community. It's important to give back and give back genuinely, not just because you're supposed to, but because you are connected to it all.

I've had the great fortune to partner with many meaningful events from fundraising dinners for homeless organizations to working with Durham Independent School District kitchen managers to create recipes for school cafeteria menus. Recent events I have held with Adrian Lindsay and the Green Book Supper Club, a pop-up dinner series showcasing African American chefs in North Carolina, have even inspired much of the historic and cultural research for this cookbook. *The Green Book* was an annual guidebook for African Americans during the Jim Crow era that pointed out shops, hotels, and restaurants that were friendly to the black community. Back then there were two places in Durham where you could stop and grab a bite to eat. Ultimately these places were a way to bring folks together.

Change seems to happen if you put good food in front of people.

- *From* Saltbox Seafood Joint Cookbook *by Ricky Moore. © 2019 Ricky Moore. Used by permission of the University of North Carolina Press,* www.uncpress.org.
- *Order the cookbook here:* go.ncsu.edu/Saltbox
- *Watch The Hook, Ricky Moore's new television show with UNC-TV:* go.ncsu.edu/Ricky-TV

Baxter Miller

THE GHOST HUNTERS

Using remote sensing technology, Melinda Martinez and Emily Ury are investigating the mysteries underlying coastal ghost forests.

LEE CANNON

Continued

In the Alligator River basin, North Carolina.

Emily Ury

WHAT HAPPENED?

"When you're driving to the coast or the Outer Banks, you'll see dead trunks and stumps that have no branches and leaves," says Emily Ury, a Ph.D. student at Duke University. "When you're seeing not one but hundreds of dead trees, it's alarming. It raises the question, 'What happened here?'"

North Carolina's coastal region is home to many healthy, thriving, forested wetlands. In the past, only the occasional severe weather event could threaten these ecosystems with saltwater pushed inland. In more recent years, however, the soil in many of these wetlands is becoming saltier, killing plants and leaving stands of skeletal trees. Eventually these forests turn over into brackish marshland, driving out the plant and animal species that had called them home.

"There is this unique system of forested wetlands close to the coast," Ury explains, "but in some areas, we're seeing that ecosystem turning over in fewer than 10 years. That's jarring."

The resulting marsh eventually will become a sanctuary for myriad other plant and animal species. However, less is known about what happens during the transition, this ghost forest phase, or about the long-term impacts of wetland turnover.

Ury and NC State University's Melinda Martinez, also a Ph.D. student, are North Carolina Sea Grant-Space Grant graduate fellows who are looking at how and why wetlands are turning into ghost forests. To do so, Ury and Martinez — along with their advisors, lab mates and a small but growing cadre of other labs and researchers — are using remote sensing data from several sources, including NASA, which funds Space Grant. Ultimately, they hope to understand how ecosystem turnover impacts the coastal region of North Carolina and beyond.

"These fellows are making important contributions," says John Fear, deputy director of North Carolina Sea Grant. "Sea level rise and saltwater intrusion are important drivers of change in our coastal zone. Both of these studies will help us better understand how large areas of our coastal plain may transition due to these increasing threats."

EYES IN THE SKY

Martinez and Ury are utilizing an enormous compilation of over 30 years of photos and data collected through the Landsat Program, a network of Earth-observing satellites jointly administered by NASA and the U.S. Geological Survey. This remote sensing information is helping the two researchers scale up their findings to make inferences about entire regions.

Remote sensing technologies look at Earth from near or far and include radiometers, spectroradiometers, satellite sensors, LiDAR (Light Detection and Ranging), aerial imagery and other data collected from airplanes or various types of drones, such as unmanned aerial vehicles or unpiloted submersibles.

Jobi Cook, associate director at NC Space Grant, says that using

Continued

Courtesy of Melinda Martinez

"When you're driving to the coast or the Outer Banks, you'll see dead trunks and stumps that have no branches and leaves. When you're seeing not one but hundreds of dead trees, it's alarming. It raises the question, 'What happened here?'"

— EMILY URY, PH.D. STUDENT, DUKE UNIVERSITY

Courtesy of Emily Ury

INSET: *Melinda Martinez combines remote sensing data and ground-level observations to uncover the impacts of ghost forests on the larger environment.* RIGHT: *Emily Ury focuses on vegetation change to understand patterns of sea level rise.*

"eyes in the sky" is integral for coastal research.

"Through programs like Landsat and other remote sensing data collection efforts, we have access to a treasure trove of information about every corner of our planet and can track trends and changes over time," Cook explains. "North Carolina has a big chunk of coastal plain that's essential for the environment and the economy of the state, so it makes great sense to use the datasets available through NASA and others to help researchers study the health of our coast."

THE VIEW FROM SPACE

Emily Ury is not a native of the Alligator River basin in eastern North Carolina, where she conducts her research, so she has not watched these ghost forests form over the years with her own eyes. She is, instead, relying on decades of satellite data and images to show her the progression of the forests, snapshot by snapshot, a story of 35 years of change on the Alligator River.

"The end result will be a case study of how to use remote sensing to observe the effects of sea level rise," Ury says.

Ury has a background in biogeochemistry, looking at how chemicals, such as carbon, nutrients, and salt, move through the environment. As an undergraduate at Williams College in Massachusetts, she was interested in environmental contaminants in river ecosystems. For her master's degree at Yale School of Forestry and Environmental Studies, she studied nutrient cycling in rivers heavily polluted from intensive agriculture in the Mississippi River Basin.

For her Ph.D. work, Ury was planning to study how salinity affects the capture or release of nutrients and carbon in soil, but she found herself drawn to figuring out where this phenomenon was even happening. Now, she uses vegetation change to understand spatial patterns of sea level rise and saltwater intrusion.

In doing so, Ury has dug deeply into the NASA/USGS Landsat Program's satellite data to answer key questions: *Why did this patch of trees die and not another one? Can we predict what's next? Is saltwater intrusion caused by sea-level rise, inundation stress from flooding events, or is it from acute events, such as hurricanes?*

She says ghost forests appear at the places most vulnerable to saltwater intrusion, and they highlight the risks posed to all coastal forested wetlands.

"Now," Ury explains, "we can create a time series to show the slow but steady decline of forests as they continue to convert to marshes. Every year, a little bit more of the forest is lost, with the occasional disaster year that catalyzes large declines in forested wetlands."

Ury sees the potential for further research projects to take the current work to the next level through field experiments — experimental manipulation of wetlands to prevent or restore damage from saltwater intrusion events.

Continued

INSET: *A tree chamber collects measurements of greenhouse gases from a dead tree in Alligator River National Wildlife Refuge.*
RIGHT: *In a transitioned marsh in Swanquarter National Wildlife Refuge, a standing dead tree wears a research identification tag.*


Courtesy of Melinda Martinez

"Through programs like Landsat and other remote sensing data collection efforts, we have access to a treasure trove of information about every corner of our planet and can track trends and changes over time. North Carolina has a big chunk of coastal plain that's essential for the environment and the economy of the state, so it makes great sense to use the datasets available through NASA and others to help researchers study the health of our coast."

— JOBI COOK, ASSOCIATE DIRECTOR, NC SPACE GRANT

Courtesy of Melinda Martinez

Eventually, she hopes to use her data to help predict how long it takes for forested wetlands to turn into ghost forests and then into marshes, as well as to determine under what conditions they may be able to change back.

"Some areas do recover," she says. "But it's not the overall trend."

ABOVE: *Martinez rescued a turtle who found one of the soil chambers that she uses to measure greenhouse gases in the ground.*

TREE BY TREE

"I've been studying wetlands for so long, I've really started to appreciate this field," says Melinda Martinez. But forested wetlands haven't always been on her radar.

Growing up in Dallas, she was environmentally conscious and had a passion for the coast, but admits she had limited exposure to wetlands. That changed when, as an undergraduate at the University of Texas at Austin, she took an opportunity to study seagrass ecology in the Yucatán Peninsula.

That experience was her introduction to research into coastal issues. Later, she studied Texas' barrier islands while at the Texas A&M University-Corpus Christi for her first master's degree, leading her deeper into the coastal and wetland ecology field. She sought a second master's at Northeastern University before studying in the Ph.D. program at NC State.

According to Martinez, there are only a handful of other researchers and labs studying ghost forests, which was a draw for her. There's plenty of room for new discoveries — and from many different angles.

These researchers at the cutting-edge include Emily Bernhardt and Justin Wright, Ury's advisors at Duke, as well as Marcelo Ardón, Martinez's advisor at NC State, and Ryan Emanuel, also at NC State. All participate in a large research project the National Science Foundation supports on saltwater intrusion and are deep into their research at a time when ghost forests are gaining national attention.

Martinez also uses the NASA/USGS Landsat Program's satellite photo compilation to detect the progression of ghost forests, as Ury does, but she zooms in to view ghost forests on a granular level: tree by tree. While Ury is trying to understand how, where, and why ghost forests form, Martinez combines remote sensing data and ground-level observations to uncover the impacts ghost forests make on the larger environment *here and now*.

Martinez spent the past summer not only sifting through satellite data, but also going into the field, attaching gas chambers to trees and measuring the outputs of carbon dioxide, methane and, the most potent, nitrous oxide.

Her data set already suggests a few trends. For instance, she sees evidence of much higher greenhouse gas emissions inside stands of dead trees compared to the levels expected in a normal forested wetland. Now, she hopes to tease out why.

"Wetland plants act as straws and naturally suck greenhouse gases from soil and emit them into the air," Martinez says. She emphasizes that photosynthesis, the process of plants converting carbon dioxide into oxygen, is not the only gas exchange involved.

Anaerobic bacteria living in the soil of wetlands, ghost forests, and marshes are the originators of those gases in the soil, she explains, and they produce methane as a part of their life cycle, which the trees and plants then absorb and emit. When the trees die, however, they remain standing and continue to emit soil-produced gases. The decaying wood itself can also emit methane, carbon dioxide, and nitrous oxide, complicating Martinez's efforts to measure them.

Martinez says she hopes she can begin to parse out the quantities from each source and find the fluctuations in methane and nitrous oxide emitted by landforms as they change. Someday, these measurements will help her and other researchers better calculate the quantity of greenhouse gases the landscape emits naturally.

"The next step," she says, "will be to create a regional greenhouse gas emissions estimate." In this way, her data will add a new tool to wetland managers' toolkits, helping to inform decisions by accounting for the amount of various greenhouse gases the terrain is absorbing or emitting.

The information Ury and Martinez are compiling from their time as North Carolina Sea Grant-Space Grant graduate research fellows is certain to impact a field ripe for new discoveries. Ultimately, they may also help people the world over become more aware of our impacts on ecosystems — and provide important guidance for wetland managers and conservationists about the lands under their care.

Watch a *Science Friday* video about the research labs that Ury and Martinez work with: *go.ncsu.edu/Ghost-tv.*

Last year, the total recreational catch declined for North Carolina anglers — but they still pulled in nearly 79 million fish.

The Money, the Catch, and the Cape Fear

BY SCOTT BAKER AND SARA MIRABILIO

from the popular blog series on the latest research for anglers

WHAT DO THEY SPEND YOUR FISHING LICENSE FEE ON?

North Carolina's inquiring anglers want to know.

What happens to proceeds from Coastal Recreational Fishing Licenses?

It costs money to manage living marine resources, create and enhance fisheries habitat, and provide access and educational programs for the angling public. Officials rolled out the North Carolina Coastal Recreational Fishing License (CRFL) in 2007, in part, to assist in funding such tasks. The state requires that most saltwater anglers purchase a license in order to fish legally in the state.

Once an angler purchases a CRFL, proceeds from the sale go into the Marine Resources Fund. (New lifetime licenses go into a separate fund.) The North Carolina General Assembly created the Marine Resources Fund to manage, protect, restore, develop, cultivate and enhance the marine resources of the state.

But what happens to the money after it reaches the fund? More than a few times anglers have asked, "Where does my license fee go — and what do they spend it on?"

Long story short: a portion of the fund supports the everyday activities of the North Carolina Division of Marine Fisheries (NCDMF), and a portion underwrites new or temporary expenditures that vary from year to year.

Because this is such a popular question, here's a look at how the state has used the Marine Resource Fund for these new or temporary expenditures from 2009 to 2017. The grants that the program supports cover three focus areas.

People: projects that include public education and public water access.

Habitat: projects that enhance, protect, or research fisheries habitat.

Fish: projects that conduct fisheries research.

Publically available information includes news releases, which list titles of projects funded, sometimes with descriptions, for each year by category

Continued

(fish, habitat, people) and recipient (e.g., town, university, agency, nonprofit).

From 2009 to 2017, the Marine Resources Fund supported "Fish, Habitat and People" through 146 grants amounting to $18,481,378. Recipients included NCDMF, the N.C. Wildlife Resources Commission, universities, cities and towns, and nonprofits, among others. More funding has gone to "People" (54%) than Fish (21%) and Habitat (25%) combined.

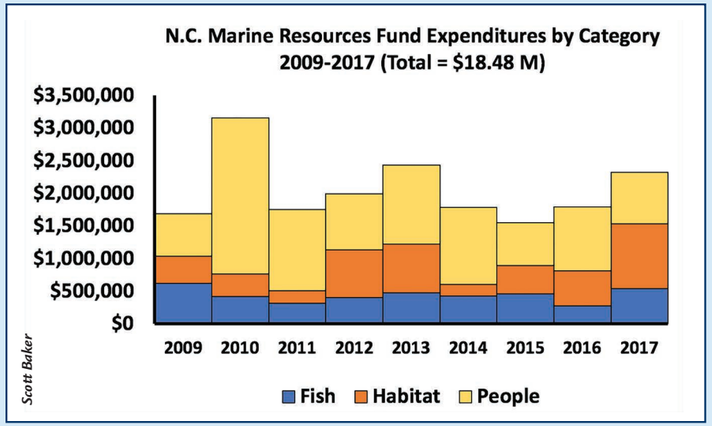
The "People" category includes expensive waterfront access projects, such as new or improved boat ramps and the purchase of property for those accesses, as well as public education projects, which, on average, are much less expensive. In fact, the state allocated 37 of 59 of the projects and 92% of the funding under this category to enhancing public access.

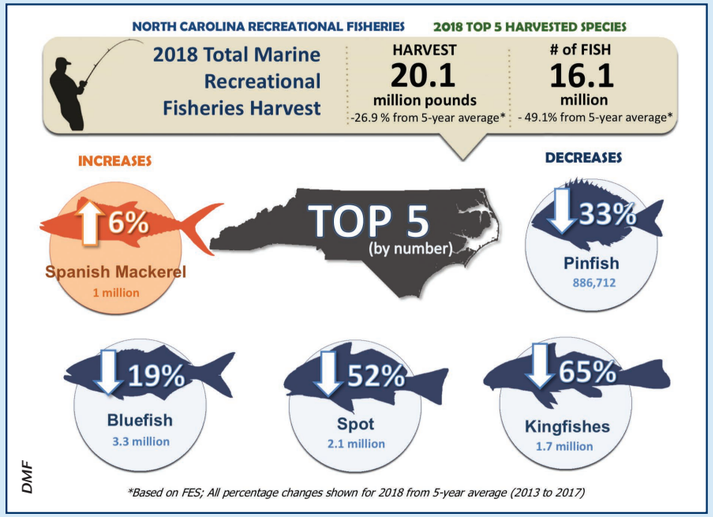
Some people would argue that the most needed public water access projects have been completed, which, in turn, might suggest that more funding should be available for other categories of projects now and in the years to come. On the other hand, many people in southeastern North Carolina, the most crowded portion of the coast, likely will see a need for more access.

Also of note, the "Habitat" category of funding has fluctuated year to year, because it occasionally has included research projects and efforts to create inshore and offshore artificial reefs. The "Fish" category, however, has remained the lowest and the most consistent, because these projects only focused on fisheries research and monitoring.

You can access the final reports of all the projects that the Marine Resources Fund supports: *go.ncsu.edu/The-Money*

— Summary compiled by Scott Baker





ABOVE: *From 2009 to 2017, the Marine Resources Fund supported 146 grants totaling over $18 million.* BELOW: *N.C. Anglers harvested 20.1 million pounds of fish in 2018, down almost 27% from the five-year average.*

DID 2018'S HURRICANES CURTAIL NC SALTWATER ANGLING?

Last year, the total recreational catch declined for North Carolina anglers — but they still pulled in nearly 79 million fish.

All this recent bad weather have you gazing out the window, longing to wet a hook?

Looks like you're not alone, especially if you felt this way last fall, too. Similar to the data on last year's commercial fishery, 2018 saltwater angler data shows a decline in recreational catch, likely due to hurricanes and other extreme weather events.

At the August business meeting of the N.C. Marine Fisheries Commission, N.C. Division of Marine Fisheries (NCDMF) staff reported that in 2018 the total recreational catch — the amount of harvested fish and the amount of released fish — numbered 78.6 million.

Recreational harvest was 49% lower than the previous average from 2013 to 2017 by number of fish and 28% lower by pounds of fish. Still, in 2018 North Carolina coastal recreational fishing license holders kept an estimated 16.2 million fish that weighed in at over 20 million pounds total.

The top five harvested recreational species by weight were dolphin, bluefish, spot, yellowfin tuna, and red drum. The top five harvested species by number were bluefish, spot, kingfishes, Spanish mackerel, and pinfish.

More of these numbers might surprise you. For instance, on 41% of fishing trips, saltwater anglers wet a hook off a beach or bank. In addition, anglers released 62.4 million fish, around four times as many as they kept last year. In fact, since 2013, the proportion of released fish to the total catch has been increasing.

The NCDMF Coastal Angling Program, which collects and maintains data for a variety of different recreational fishing surveys, provides estimates of recreational fishing catch and effort. The program interviews around 23,000 anglers and sends out an additional 24,000 surveys per year. The data helps researchers understand the wide range of saltwater angling efforts, including, as mentioned above, numbers of fish harvested and released, as well as the number of angler trips. Scientists even can use these data in population models to determine statewide stock assessments and fishery management plans.

Sustainable fishing begins and ends with fishermen. Saltwater anglers support the long-term health of coastal fisheries by serving as eyes and ears on the water and sharing information on their fishing activities.

More commercial and recreational fisheries infographics: *go.ncsu.edu/NC-Infographics*

— Summary compiled by Sara Mirabilio

The Cape Fear River serves as critical habitat for several fishes, including the striped bass.

WHY SHOULD WE RESTORE RIVERS?

The Cape Fear River Partnership has been a collaborative success, benefiting fish and people.

Healthy coastal ecosystems are the foundation for life along the coast. However, coastal development, current land-use practices, and other human activities are contributing to lower water quality, as well as to the degradation of aquatic and terrestrial habitat for fish and other species.

As a fisheries specialist, I forge partnerships between university researchers, natural resource managers, and the fishing public — commercial and recreational — to generate information and guide habitat restoration for fish. This, in turn, supports the local communities that rely on those habitats for clean drinking water, flood and storm protection, and industries like boating, fishing and tourism.

One great example of this type of collaboration is NOAA's restoration of the Cape Fear River by establishing the Cape Fear River Partnership.

- *What was the challenge?*

Some fish species (called "anadromous") travel considerable distances between distinct habitats for spawning purposes. Man-made barriers — such as dam and culvert construction, water withdrawal, channelization and stream bank modification, and shoreline erosion — can obstruct fish movements and affect water flow and quality.

Here in North Carolina, the Cape Fear River serves as critical habitat for several anadromous fishes. American shad, river herring, Atlantic sturgeon, shortnose sturgeon and striped bass spend most of their lives in the ocean but return to the river's freshwater streams to spawn.

The Cape Fear River's once-thriving populations of migratory fish have sharply declined. Pollution from agriculture and development has led to unhealthy water quality, and dams and other barriers block fish from migrating to the upstream areas where they reproduce.

Declining fish populations have resulted in moratoriums and fishing restrictions for river herring, striped bass, and American shad. Both Atlantic and shortnose sturgeon are endangered species.

- *How did they address the problem?*

In 2011, NOAA's Office of Habitat Conservation formed the Cape Fear River Partnership. The project aimed to eliminate fish passage barriers, reconnect freshwater streams and wetlands, and restore the native plant community.

- *What were the results?*

Eight years later, the Cape Fear River Partnership's efforts have resulted in nursery habitat for migrating fish, as well as resting and dabbling habitat for waterfowl. The partnership also has created opportunities for passive wildlife-oriented recreation and education for the community.

More: *go.ncsu.edu/Cape-Fear*

— Summary compiled by Sara Mirabilio

Many more blogposts for anglers are available at *HookLineScience.com*.

Rural Economic Development in the Coastal Region

Why are some coastal rural counties thriving while others struggle?

BY JANE HARRISON

North Carolina's Blue Economy information series provides updates related to the state's ocean economy and underlying natural resources. Jane Harrison, North Carolina Sea Grant's coastal economist, has published four editions online, including this issue on rural economic development. go.ncsu.edu/Blue-Economy

RURAL COMMUNITIES NEAR NORTH CAROLINA'S COASTS ARE NEITHER CONSISTENTLY PROSPERING NOR UNIFORMLY IN DECLINE. ALTHOUGH RURAL AREAS HAVE SOME DISTINCT ECONOMIC ATTRIBUTES, THEY ALSO INCREASINGLY MIRROR DEVELOPMENT PATTERNS IN MORE POPULATED LOCALES.

A far distance to markets, low population density, and an abundance of natural resources are distinguishing features of rural places. Typically, a rural community is part of a non-metropolitan statistical area that contains cities with populations under 50,000 and that have a high degree of economic and social integration.

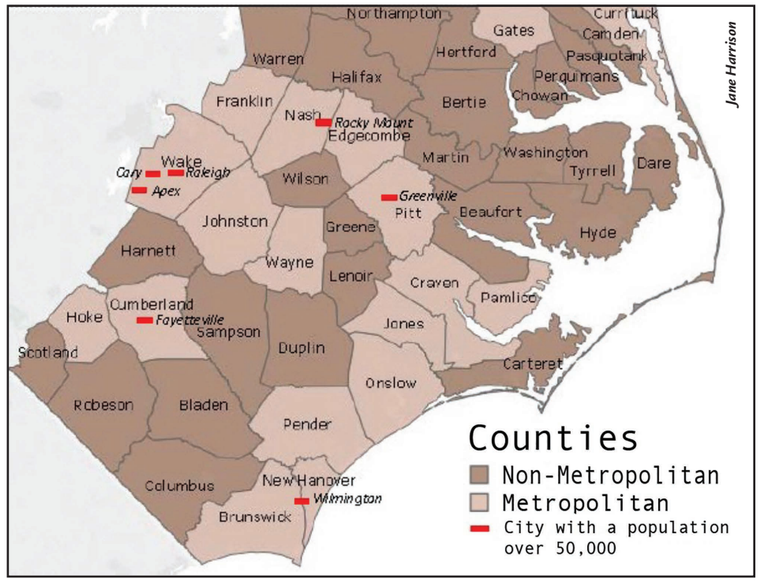


FIGURE 1. *Non-Metropolitan and Metropolitan Counties in Eastern North Carolina*

There are two rural areas in the coastal plain, as defined by U.S. Census Bureau statistics. The Northeast Coastal non-metropolitan area includes Bertie, Camden, Chowan, Dare, Halifax, Hertford, Hyde, Martin, Northampton, Pasquotank, Perquimans, Tyrrell, Warren, and Washington counties. The Southeast Coastal non-metropolitan area includes Beaufort, Bladen, Carteret, Columbus, Duplin, Greene, Harnett, Lenoir, Robeson, Sampson, Scotland, and Wilson counties. (*See the dark brown counties in Figure 1.)*

RURAL POPULATION TRENDS

Migration patterns — the movement of people from one place to another — are one indicator of the economic health of rural areas. Population growth is generally associated with economic growth but comes with its own challenges, such as new infrastructure needs and increased demand for public services. In addition, high levels of migration, whether into or out of an area, can lead to unemployment, depending on how businesses grow or adapt to change.

Retirement destinations like metropolitan Brunswick and Pender counties are some of the fastest-growing areas in the state, while the least populated counties continue to experience population loss. In fact, the majority of the nonmetropolitan counties in the coastal region have lost residents since 2010. *(See the counties in orange in Figure 2).* Eight of those counties lost more than 5% of their population during this time: Northampton (-10.1%), Washington (-9.1%), Bertie (-9.7%), Tyrrell (-8.1%), Hyde (-7.8%), Martin (-7.0%), Halifax (-6.1%) and Warren (-5.4%).[1]

The composition of the rural workforce is evolving, with new demographic groups seeking out employment opportunities. Latino migration to the rural coastal region increased significantly between 2000 and 2010, resulting in a doubling, on average, of the Latino population. Although the total population of Latinos is often smaller in rural areas than urban areas, the proportion of Latinos is often greater in rural places. For example, as of 2010, Latinos made up 20.6% of the population in Duplin County, 16.5% in Sampson, and 14.3% in Greene, whereas they made up 10.2% of the population in metropolitan Wake County.

THREE TYPES OF RURAL AMERICA

Prosperity in the coastal region is uneven, with some communities still struggling to make economic gains since the Great Recession of the late 2000s. Rural America is comprised of three distinct areas: (1) "high-amenity" rural regions, (2) "urban-adjacent" rural places, and (3) remote rural communities.[2] It is the last that has typically struggled, while rural areas with high amenities and access to urban labor markets generally experience greater population and economic growth than their remote counterparts.

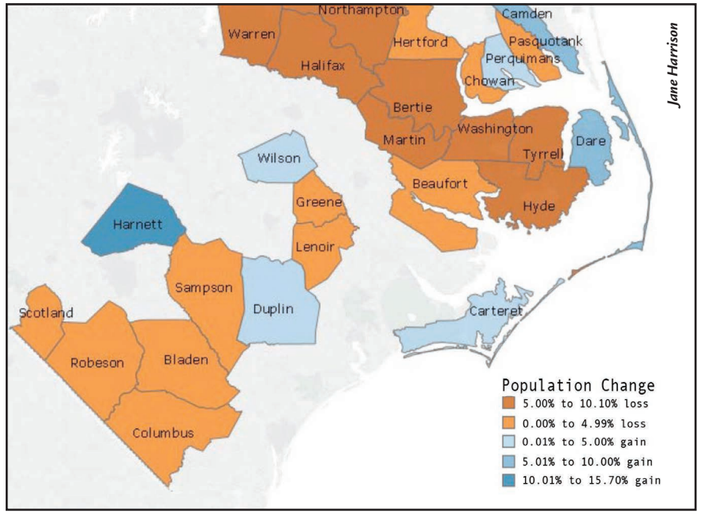


FIGURE 2. *Percentage Change in Population of Non-Metropolitan Coastal Counties, 2010-2017*

• *High-Amenity Rural Areas*

Amenities and quality-of-life increasingly influence rural migration flows and business development. Natural amenities, like attractive scenery and recreational opportunities, draw people to rural areas and have boosted the wealth of many waterfront communities. As a result, median household income in the rural counties closest to the coast — Camden ($60,714), Dare ($54,787) and Carteret ($50,599) — are all higher than the state average of $48,256.[1]

High-amenity rural areas typically have experienced substantial economic and population growth. In the 1990s, in-migration began to outpace natural population growth — the number of births minus the number of deaths.[3] In addition to wealth transfer, which can serve as financial capital to invest in new and existing businesses, population growth in these communities is generally associated with new jobs in construction and higher demand for employees in retail and commercial services.

Downsides of this population gain include higher costs of living — driven by increased demand for housing — and greater traffic congestion.

• *Urban-Adjacent Rural Areas*

Rural communities have benefited from the proliferation of automobiles and improvements in transportation infrastructure, which allow for more rural-to-urban commuting. For rural areas located near metropolitan areas, access to urban employment is an important cause of population retention and growth. For example, non-metropolitan Harnett County sits between metropolitan Wake County to the north and Cumberland County to the south, making work possible in cities from Raleigh and Fayetteville.

Continued

Over time, the population growth rates of metropolitan counties have increased in comparison with non-metropolitan counties. However, this trend in part reflects how rural communities that experience significant population growth often get reclassified as metropolitan themselves.

- ***Remote Rural Areas***

Remote rural communities in the coastal area face fewer employment opportunities and longer distances to urban areas. Traditionally their economies are resource-based, dependent on harvesting or extracting natural resources with little or no processing. Generally, more remote places have the lowest median household incomes. *(See the counties shaded in lightest teal in Figure 3.)*

Lower-income communities also usually have lower costs of living, which can help to offset this deficit. That said, lagging rural regions are likely to be geographically remote, with poor infrastructure, low population density, and limited employment opportunities.

Remote regions in the coastal plain traditionally have depended economically on agriculture and manufacturing. Labor-saving technologies in both industries have reduced the need for workers. In Lenoir County, for example, manufacturing employs 25% of the workforce, whereas statewide this sector only employs 12% of the labor force[1], and the county's population declined by 4.4% from 2010 to 2017. Employment in manufacturing bottomed out nationally in 2010, and recovery after the Great Recession has been slow in places that depend on either of these industries.

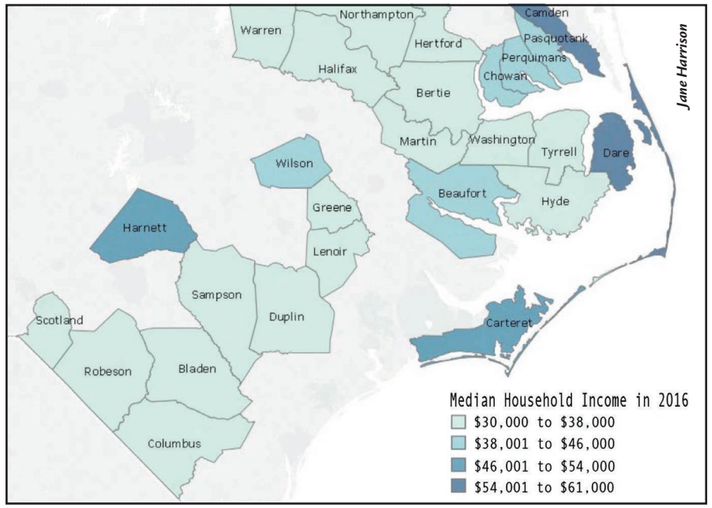


FIGURE 3. *Median Household Income of Non-Metro Coastal Counties, 2012-2016*

Remote regions in the Coastal Plain traditionally have depended economically on agriculture and manufacturing. Halifax County, 1938.

REGIONAL DEVELOPMENT DRIVERS

Understanding why businesses locate where they do helps to explain why some rural regions prosper while others languish. Businesses locate where they can maximize profit, which often depends on regional uniqueness and comparative advantage.

A region's uniqueness is based on the availability and productive use of essential assets for production, such as land, labor, and capital. Land is related to climate, growing season, and soil types. Labor pertains to the workforce and its skillsets. Capital consists of the monetary resources available to invest in a business or to purchase goods. The assets in a community affect its development path.

Some assets, such as land or natural resources, are unique to a place and influence the types of businesses that can succeed. For example, oyster farmers must locate their operations in waters with appropriate salinity levels, but this coastal environment cannot easily be replicated artificially.

Other assets, like labor, are more productive when used in combination with certain technologies or physical infrastructure. Consider a single shrimper with a 20-foot boat who can haul in 2,000 pounds of shrimp in a night. If he adds one additional crew member, he won't increase his landings. He needs a bigger boat to productively use that additional labor.

The size of a business operation and the markets it can sell to impact its effectiveness and efficiency. The cost savings from an increased level of production — "economies of scale" — mean, for instance, that a seafood processor with sizable business volume can bulk-purchase supplies at a lower rate than a smaller-scale competitor.

"Clustered development" — the close proximity of multiple businesses — facilitate economies of scale, as well as spillovers in knowledge that result in innovation. Clustering stems from private sector leadership and government partnerships that drive such outcomes as business and industrial parks. Important industrial clusters in the rural coastal region include aerospace and defense, food processing and manufacturing, and energy, among others.

In pursuing economic development, some communities have a local focus. For example, a rural municipality can increase tax rates to benefit local schools. A town can implement zoning policies that encourage manufacturing firms to locate there.

How a place relates to surrounding areas, though, is also a vital component of its economic success. Rural communities do not develop in a vacuum. Rural areas are, more than ever, integrated into a regional economy and tied to nearby urban centers.

In fact, the economic structures of rural places increasingly mirror their urban counterparts. Most of the rural population does not depend on natural resources for their livelihoods. Today, even rural residents who engage in farming earn most of their incomes from off-farm employment.

Like urban centers, rural areas with significant manufacturing bases develop commerce hubs and advanced supply chains in specific industries to compete with producers globally. Even the most remote rural areas are less isolated than in the past, with ever stronger ties to international markets and labor. Much of the coastal region is located near Interstate 95, facilitating transport of goods to large markets in other states. Deep-water ports in Morehead City and Wilmington provide rural regions with additional market access.

Solar farms, such as this one in Greene County, are part of a growing energy industry cluster in the rural coastal region.

Regional economic integration depends upon robust market relationships and communications between rural and urban areas. Decreasing costs of transport and communication have been a boon to rural areas, yet the quality of these infrastructures continues to be inconsistent. For example, broadband access is still limited in some rural areas, curtailing the types of businesses that can locate there. In the non-metropolitan counties in the coastal region, approximately 60% of households have broadband internet service subscriptions. In metropolitan counties like Wake, Durham, and Mecklenburg, 80% or more rely on broadband.[4]

CONTINUED RURAL INVESTMENT

To sustain economic well-being, rural communities must continue to invest in the productivity of unique assets that support economic development. Increased access to high-quality education and workforce development programs can strengthen the labor force. In addition, land and water resources in the coastal region will support further development as long as economic activity is in balance with the capacity of these natural systems. Financial capital will follow where labor and land quality are high.

In coming years, high-amenity and urban-adjacent rural areas that comprise North Carolina's coastal region are likely to continue to be competitive in a global economy, while more remote rural places may require additional investment to thrive.

References

1. U.S. Census Bureau. 2018. American Fact Finder. *https://factfinder.census.gov.*
2. Goetz, Stephan J., Partridge, Mark D., and Heather M. Stephens. 2018. The economic status of rural America in the President Trump era and beyond. *Applied Economic Perspectives and Policy 40 (1)*: 97-118.
3. Fulton, John A., Fuguitt, Glenn V., and Richard M. Gibson. 1997. Recent changes in metropolitan-nonmetropolitan migration streams. *Rural Sociology 62 (3)*: 363-384.
4. North Carolina Broadband Infrastructure Office. 2019. Broadband adoption recommendations. *https://www.ncbroadband.gov/connectingnc/broadband-adoption.*

• *Trout with Parmesan Stuffing (top)* • *Mini Crab Cakes (bottom)*

Seasonal Specialties

BY VANDA LEWIS
AND JOYCE TAYLOR

FROM TIME TO TIME, WE'VE BROUGHT YOU RECIPES FROM MARINER'S MENU, ONE OF THE FASTEST GROWING SITES FOR SEAFOOD RECIPES ON THE WEB. BLOGGER AND PHOTOGRAPHER VANDA LEWIS HAS WORKED WITH NORTH CAROLINA SEA GRANT FOR MORE THAN THREE DECADES. HER POSTS FEATURE RECIPES DEVELOPED BY THE LATE JOYCE TAYLOR, AUTHOR OF THE POPULAR RESOURCE BOOK, *MARINER'S MENU: 30 YEARS OF FRESH SEAFOOD IDEAS*. LEWIS SELECTED THESE FIVE FAVORITES JUST FOR THE HOLIDAY SEASON.

A QUICK REMINDER: IF THE TYPE OF FISH THE RECIPE RECOMMENDS ISN'T AVAILABLE AT THE MARKET, YOU CAN ALWAYS SUBSTITUTE A SIMILAR FISH.

TROUT WITH PARMESAN STUFFING

- 4 trout, butterflied
- 2 tablespoons butter
- 1/2 cup chopped onion
- 1/2 cup chopped celery
- 1 cup fresh bread crumbs
- 1/2 cup freshly grated Parmesan cheese
- 1/4 teaspoon salt
- 1/4 teaspoon freshly ground black pepper
- 3/4 teaspoon chopped fresh basil
- 1 1/2 tablespoons melted butter
- salt
- freshly ground black pepper

Melt 2 tablespoons butter in medium saucepan. Sauté onion and celery until tender. Remove from heat. Stir in crumbs, Parmesan, salt, pepper and basil.

Stuff fish loosely. Brush with 1 1/2 tablespoons melted butter. Lightly salt and pepper. Bake at 400° for about 20 minutes or until done.

MINI CRAB CAKES

- 1 pound backfin crab meat
- 3 tablespoons margarine or butter
- 1/2 cup chopped red onion
- 1/4 cup chopped fresh parsley
- 1/4 teaspoon Tabasco sauce
- 2 teaspoons fresh lemon juice
- 1/8 teaspoon cayenne pepper
- 1/2 teaspoon salt
- 1/2 cup mayonnaise
- 1 egg, beaten
- 2 tablespoons canola oil for frying
- 1 cup French bread crumbs
- 2 cups French bread crumbs for coating
- Lemon wedges

Remove any shell or cartilage from crabmeat. Place meat in medium bowl.

Melt margarine or butter in medium saucepan. Sauté onion until tender. Remove from heat. Stir in parsley, Tabasco, lemon juice, cayenne and salt.

Blend in mayonnaise, egg, and 1 cup bread crumbs. Gently blend into crabmeat, being careful not to break meat apart.

Shape into silver dollar size cakes. Dredge lightly in remaining 2 cups bread crumbs.

Fry in 3 tablespoons of hot oil until golden brown on one side, about 2 to 3 minutes. Turn and repeat on other side. Drain on paper towels. Garnish with lemon wedges.

Visit the *Mariner's Menu* archive of free recipes: *MarinersMenu.org.*

PARMESAN TRIGGERFISH

- 1 1/2 pounds triggerfish fillets, cut into serving size pieces
- 1 tablespoon melted margarine or butter
- 2 tablespoons fresh lemon juice
- 1/4 cup margarine or butter, softened
- 1 tablespoon mayonnaise
- 1 tablespoon Dijon mustard
- 1/2 cup freshly grated Parmesan cheese
- salt
- freshly ground white pepper

In small bowl, combine 1 tablespoon melted margarine or butter and 2 tablespoons fresh lemon juice.

In another small bowl, combine softened margarine or butter, mayonnaise, mustard and Parmesan.

Lightly salt and pepper fish and place on a greased broiler pan. Brush with butter-lemon juice mixture. Broil about 4 inches from heat for about 5 minutes.

Remove fish from oven. Spread with Parmesan mixture. Return to oven and cook until done, about 6 to 8 more minutes.

PECAN ENCRUSTED GROUPER WITH FRESH CILANTRO

- 1 1/2 pound grouper fillet
- 3 tablespoons melted margarine or butter
- 1/2 teaspoon salt
- 1/4 teaspoon freshly ground white pepper
- 1/2 teaspoon minced garlic
- 1/3 cup finely chopped fresh cilantro
- 1/2 cup finely chopped pecans

In small bowl, combine margarine, salt, pepper, garlic and cilantro. Brush over fish.

Sprinkle pecans over fish, pressing lightly.

Place in lightly greased baking dish and bake at 425° until fish flakes easily with a fork, about 10 to 15 minutes.

STUFFED CLAMS

- 2 cups chopped clams
- 1/2 cup clam liquid
- 4 tablespoons margarine or butter
- 2 tablespoons minced onion
- 2 tablespoons minced green pepper
- 2 tablespoons minced celery leaves
- 1/4 cup chopped celery
- 1/8 teaspoon freshly ground black pepper
- 1/4 teaspoon salt
- 1/2 teaspoon prepared mustard
- 3/4 cup fresh cracker crumbs
- paprika

Place clams and liquid in medium saucepan and simmer 5 minutes.

• *Parmesan Triggerfish (top)* • *Pecan Encrusted Grouper with Fresh Cilantro (middle)* • *Stuffed Clams (bottom)*

Melt margarine in small saucepan over medium heat. Add onion, green pepper, celery leaves, celery, black pepper, salt, and mustard. Cook until vegetables are tender-crisp. Add to clam mixture. Stir in crumbs and mix well.

Place in shells or ramekins. Sprinkle lightly with paprika. Bake at 450° until nicely browned and bubbly, about 15-20 minutes.

Order the book, *Mariner's Menu: 30 Years of Fresh Seafood Ideas: go.ncsu.edu/Recipe-Book.*

Courtesy of Austin Gray

Austin Gray's findings have garnered awards and invitations to give presentations in the United States and abroad.

Research Explores Implications of Antibiotic Pollution

Antibiotic pollution in Piedmont North Carolina is widespread.

BY AUSTIN GRAY

Austin Gray received a joint North Carolina Sea Grant and Water Resources Research Institute Graduate Student Research Fellowship to study antibiotic pollution, as well as a subsequent minigrant for related research. He has studied in Anne Hershey's lab at the University of North Carolina at Greensboro, where he is completing his Ph.D. in biology. Findings from his fellowship resulted in invited presentations in the United States and abroad — as well as university and regional honors that included a Society of Environmental Toxicology and Chemistry Student Exchange Award, which supports his ongoing research at Duke University's Bernhardt Lab.

POLLUTION IS A GROWING ENVIRONMENTAL THREAT THAT IS IMPORTANT TO ME AS A SCIENTIST — AND AS A CITIZEN.

Human medications and animal feed operations make use of antibiotics. While the benefits of antibiotics are well understood, therein lies a mystery: the environmental implications of antibiotics pollution. When I designed my dissertation project, I focused on developing research that would allow me to investigate antibiotic pollution and its ecological impact.

Before I could assess the implications of antibiotics on the environment, I first needed to evaluate what antibiotics were present and at what concentrations. The North Carolina Sea Grant and Water Resources Research Institute fellowship supported my investigation of antibiotic pollution in rural streams and drinking wells in North Carolina's Piedmont region. This funding opportunity allowed me to interact with residents in Guilford, Alamance, and Randolph County to talk about my research. I also was able to discuss antibiotic pollution and its relevance in the state.

In these ways, this project was critical in helping bridge the gap between the public and scientist. Outreach is essential. As scientists, we are servants to the world we live in — and that includes all people, not just those in our respective disciplines.

Courtesy of Austin Gray

Austin Gray records data on site.

"In these ways, this project was critical in helping bridge the gap between the public and scientist. Outreach is essential. As scientists, we are servants to the world we live in — and that includes all people, not just those in our respective disciplines."

In addition, the findings from this project were quite shocking. Thanks to Daniel Todd, who heads the Triad Mass Spec Facility on the UNCG campus, we were able to determine the presence of 15 antibiotics in streams and drinking wells. The antibiotics we detected were from human and veterinary applications at concentrations of up to 1.2 micrograms per liter in surface water and up to 1.8 micrograms per liter in well water.

The main take away: Antibiotic pollution in Piedmont North Carolina is widespread — and thus is a relevant water-quality issue that requires greater monitoring.

These results led me to develop additional studies regarding antibiotics in streams, focusing on those antibiotics most commonly detected.

When I researched the bioavailability of antibiotics, for instance, I assessed the uptake of antibiotics by Asian clams to determine if the clams retain specific antibiotics differently from others. This study provided insight into the potential mitigating role these invasive bivalves may play in antibiotics pollution and possible antibiotic transfer through the food web.

My advisor, Anne Hershey, and I also received a minigrant from North Carolina Sea Grant to investigate how antibiotics are transported following introduction into a stream.

Currently, thanks to my SETAC Exchange Award, I have a visiting scholar appointment where I work under Emily Bernhardt at Duke University. This research focuses on how antibiotics detected in Piedmont streams may impact specific sediment biogeochemical processes — in other words, how antibiotics in streams may affect the transfer of chemical substances among living systems and the surrounding environment.

More about the joint North Carolina Sea Grant and North Carolina Water Resources Research Institute Graduate Student Research Fellowship: *go.ncsu.edu/NCSG-WRRI-fellows*.

More about the Minigrant Program: *go.ncsu.edu/Minigrants*.

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A star by any name: Asterias forbesi.

You Say Starfish, I Say Sea Star

BY TERRI KIRBY HATHAWAY

HOPEFULLY, YOUR VACATION PLANS WILL TAKE YOU TO A NORTH CAROLINA SEASHORE, WHERE YOU CAN SPEND TIME WANDERING ALONG THE WATER'S EDGE, CONTEMPLATING THE NEARSHORE OCEAN UNIVERSE.

If you're lucky, maybe you'll find something special. Keep an eye out for starfish, sea stars, or asteroids — all common names for the star-shaped animals that are fun beachcombing finds.

These creatures belong to the phylum *Echinodermata*, whose name stems from the Latin words *echinos*, for spiny (or hedgehog), and *derma*, for skin. Echinoderms are spiny-skinned animals that also include brittle stars, sand dollars, sea urchins, and sea cucumbers.

Echinoderms exhibit radial symmetry, meaning that they have a central part, with other parts arranged around that central axis. For a clearer idea of radial symmetry, think of a daisy — the white petals are arranged around the yellow center. Most sea stars have five arms, although some have seven, and some have 10 or more. The sunflower star, for example, may have up to 24 arms!

The bottom of the sea star is called the oral surface, because that's where the mouth is. If you look at that side, you'll see tiny tube feet with suction cups that line each arm. Those sticky tube feet help the animal hold onto its prey — usually bivalves, like clams and scallops.

The feet pull the mollusk's two shells apart just enough so that the sea star can extend its stomach from its mouth, located in a structure called the central disc, where all the arms meet. Digestive juices from the stomach dissolve the prey's body, which is then absorbed by the stomach's lining.

Examine the sea star's central disc and you'll notice a structure called the madreporite, or sieve plate, which pulls water into the sea star's water vascular system. This hydraulic system channels water to the tube feet through canals. The combination of muscular contractions and changes in water pressure causes the tube feet to extend and contract, moving the sea star's body along the sandy bottom.

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The top side of the sea star is called the aboral side, because it's opposite the oral side. The bumpy-skinned aboral side is covered with loads of tiny pinchers called pedicellariae that help clean the rough surface.

Although sea stars cannot see images, eyespots on the end of each arm enable them to see light, dark, and shadows.

Sea stars have a pretty cool ability called regeneration. If a sea star loses one of its arms, it can regenerate, or regrow, that appendage, as long as part of the central disc is still attached. It may take a year to get back to full size.

Most scientists, naturalists, and aquarium educators now refer to these echinoderms as "sea stars" rather than starfish, since they do not have scales, they do not swim, and they are not "fish," even though they live in water. Common names can differ from region to region, and from state to state.

If you want to know the scientific name of an animal, you must check the binomial, or two name, classification system developed in the early 1700s by Carolus Linnaeus.

According to Linnaeus, our common sea star, also called Forbes' sea star, is classified this way:

Kingdom: Animalia
Phylum: Echinodermata
Class: Asteroidea
Order: Forcipulatida
Family: Asteriidae
Genus: *Asterias*
Species: *Asterias forbesi*

But remember: Scientific names also change from time to time, as in the case of a well-known smooth cordgrass found in North Carolina.

Read the smooth cordgrass story: *go.ncsu.edu/Goodbye-Spartina.*

Terri Kirby Hathaway is a marine education specialist at North Carolina Sea Grant. Three times a year she publishes *Scotch Bonnet*, a compilation of professional development workshops and resources for North Carolina educators. The latest issue is always available here: *NCseagrant.ncsu.edu/ScotchBonnet.*

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Scientists, naturalists, and educators now call these echinoderms "sea stars" rather than starfish, because they lack scales, don't swim, and aren't actually fish.

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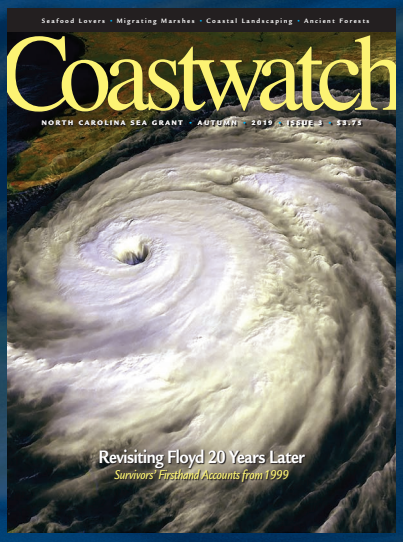

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