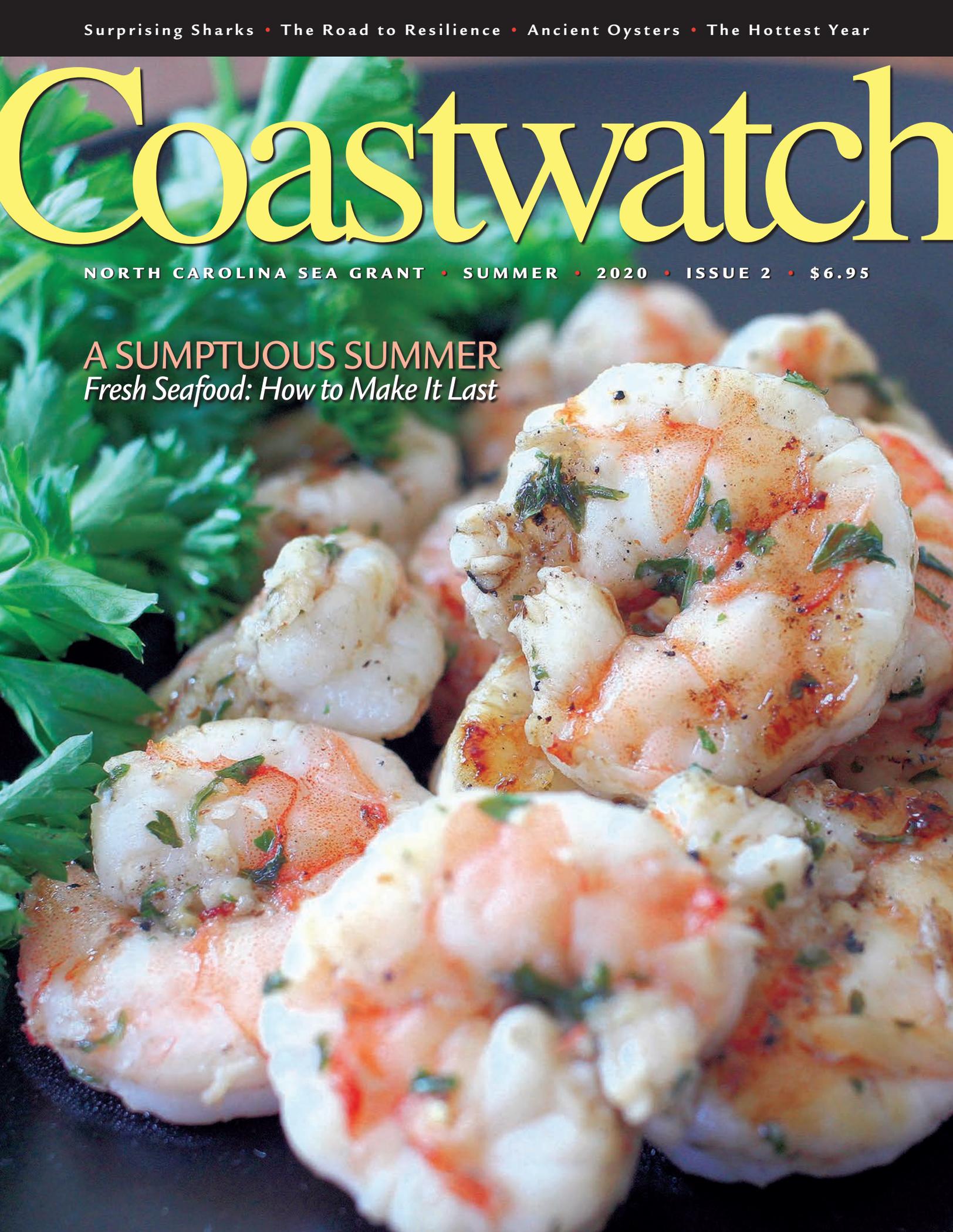


Surprising Sharks • The Road to Resilience • Ancient Oysters • The Hottest Year

Coastwatch

NORTH CAROLINA SEA GRANT • SUMMER • 2020 • ISSUE 2 • \$6.95

A SUMPTUOUS SUMMER
Fresh Seafood: How to Make It Last



Responding to Urgent Challenges

As this issue of *Coastwatch* goes to press, a pandemic and long-standing injustice and racism are colliding, resulting in protests and great unrest across our nation and in our communities. Many North Carolinians have experienced individual and community anxiety, anger, and sorrow. In grieving for the families of George Floyd, Ahmaud Arbery, Breonna Taylor — among too many others — we see persistent discrimination in our own state.

Our team continues to strive to contribute to an equitable and inclusive community. Through the work of our Diversity, Equity, and Inclusion workgroup we try to embed these values in our expectations and daily operations. Action and education are critical for long-term success, and all of us can play important roles. The time is always — not just now — to show by example, to recognize inequalities and to find opportunities to build a just society that respects and values all people.

We also want to recognize the significant contributions of health care providers, teachers, grocery clerks, and many other frontline workers and community members who have continued to support North Carolinians' needs throughout the spring. We are grateful for your service and hope your workload eases. Thank you.

I often discuss North Carolina Sea Grant's leading role to increase the environmental and economic resilience of our communities. Resilience often is defined as the ability of a community to recover after a significant disruption. We are all too familiar with recovery from hurricanes and inland flooding. Recent challenges have brought collaborations to strengthen the resilience of individual properties and businesses, as well as ecosystems and communities.

Our ongoing experiences with COVID-19 offer parallels to extreme weather impacts. Significant short-term impacts already have been identified in terms of health, economies, and community infrastructure — with the understanding that longer-term impacts are yet to come. A successful framework for community resilience requires long-term engagement and investments, along with current empowerment to bring change, and new resources to lead the response.

Through our long-term extension expertise and presence across the coast and inland, we continue to advance community resilience. In this new 2020 context, our program rapidly developed online portals to support educators, parents, businesses, and communities during the state's early stay-at-home orders, as well as into phased returns. Our efforts included coastal-focused educational resources for K-12 classwork at home and resources for seafood consumers and industry professionals. Visit North Carolina Sea Grant's COVID-19 Resource Hub here: go.ncsu.edu/COVID-resource-hub.

Many kudos to our team and partners for their innovation and ingenuity to provide critical information during these rapidly changing times. In this issue of *Coastwatch*, you will even find tips for freezing fish and shellfish if you are limiting your shopping trips, along with always-popular recipes from our Mariner's Menu blog: MarinersMenu.org.

Good news includes ongoing and newly funded research. These opportunities to share the latest science and its applications across our coast and throughout our coastal watersheds provide a window on our support for resilient coasts and communities. We are particularly proud of contributions from our student researchers, who are becoming the change leaders we need to move forward.

This summer season undoubtedly will look, and feel, a lot different than past years for your family and community. Some things, however, do not change — including the need to be as prepared as possible. For example, our beach safety efforts have a new theme: "Rip Currents: Know Your Options." Clip out the poster inside the back cover, take it with you when you head to the coast, and share it broadly. The hurricane season also is upon us. Review plans and preparations for your family and community at readync.org.

We always appreciate your support. Many thanks to our numerous community heroes, known and unknown, as we continue to work together through these changing and challenging times.

And, as always, feel free to send me a note: smwhite3@ncsu.edu.
— Susan White, Executive Director, North Carolina Sea Grant

IN THIS ISSUE

CONTRIBUTING WRITERS:

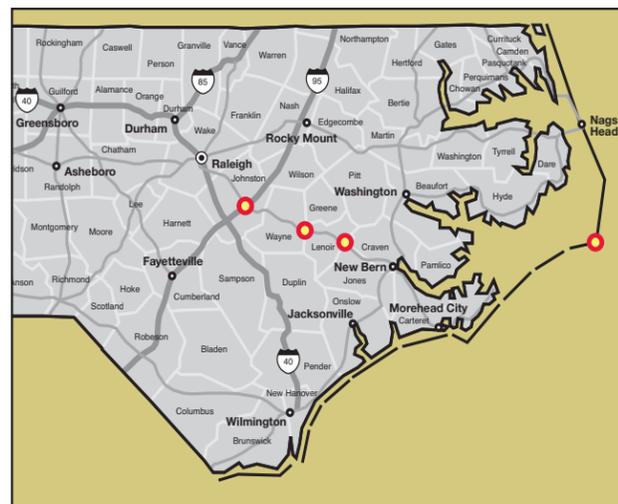
Scott Baker ■ Julia Byrd ■ Corey Davis ■ Kathie Dello ■ Evan Ferguson
Maya Hoon ■ Allie Iberle ■ Julie Leibach ■ Vanda Lewis
Sara Mirabilio ■ Katie Mosher ■ Barry Nash ■ Dave Shaw
Joyce Taylor ■ Chloe Tenn ■ Katelyn Vause ■ Susan White

CONTRIBUTING PHOTOGRAPHERS:

Mark Conlin ■ Sam Dean ■ Patrick Doll ■ Evan Ferguson
Kelvin Gorospe ■ Rusty Hudson & the Hudson, Timmons, & Stone families
Jared Kay ■ Vanda Lewis ■ Baxter Miller ■ Sara Mirabilio
Ilana Nimz ■ Yasin Ramirez ■ Paul Stephen ■ Jhonny Terrazas
Robert Tucker ■ Benjamin Wilson

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The story settings in this issue include the Neuse River communities Smithfield, Goldsboro, and Kinston, as well as Hatteras Island and other places.



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■ Front Cover: Photograph by Vanda Lewis. ■ Table of Contents: Photograph by Baxter Miller/VisitNC.com.

Communications Director
North Carolina Sea Grant
Katie Mosher

Editor
Dave Shaw

Science Editor
Julie Leibach

Contributing Editors
Lee Cannon
Katelyn Vause

Assistant Editor
Chloe Tenn

Designer
Linda Noble

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.

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NC State University Box 8605
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North Carolina Sea Grant Coastal Offices:

Coastal Studies Institute
Wanchese, NC ☐ 252-475-3663

Center for Marine Sciences & Technology
Morehead City, NC ☐ 252-222-6307

Center for Marine Science
Wilmington, NC ☐ 910-962-2491



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COASTAL TIDINGS

NINE CORE RESEARCH PROJECTS LAUNCH THIS YEAR

North Carolina Sea Grant's core research projects for 2020 to 2022 include innovative new studies on coastal resilience, climate change, flooding, shellfish and aquaculture, environmental literacy, and more.

"Our core research examines real-world needs of our coastal communities and ecosystems," says Susan White, executive director of North Carolina Sea Grant. "We are pleased to have so many multidisciplinary collaborations that address our program's strategic focus areas."

The new projects include lead researchers from five schools in the state: North Carolina State University, the University of North Carolina at Chapel Hill, East Carolina University, the University of North Carolina Wilmington, and Carteret Community College.

The following new studies will run through early 2022:

- **Can Strategic Riparian Buffers Improve Coastal Resilience to Changing Conditions in the Cape Fear River Watershed?**

Katherine Martin (lead), Georgina Sanchez, and Ross Meentemeyer, NC State; Ana Garcia, U.S. Geological Survey; Danica Schaffer-Smith, The Nature Conservancy and Arizona State University; and Julie DeMeester, The Nature Conservancy

- **Changing SAV Communities and Impacts on Blue Crabs: Potential Ecosystem and Fisheries Impacts of Climate Change**

Jessie Jarvis (lead), Troy Alphin, and Martin Posey, UNCW; Whitney Jenkins, N.C. National Estuarine Research Reserve; Dean Carpenter, Albemarle-Pamlico National Estuary Program

- **A Process-Based Model of Wind-Wave and Boat-Wake Attenuation to Aid Evaluation and Design of Living Shorelines**

Johanna Rosman (lead) and Richard Luettich, UNC-CH

- **Improving Predictions of Estuarine Flooding and Circulation During Storms**

J. Casey Dietrich (lead), NC State; John McCord, ECU's Coastal Studies Institute; Terri Kirby Hathaway, North Carolina Sea Grant

- **Mitigating the Effects of Storm Water Flooding in Coastal Regions Using Machine Learning Techniques**
Alex Manda (lead) and Rui Wu, ECU

- **Evaluating the Reproductive Cycle and Development of Spawning Methods for Native North Carolina Sunray Venus Clams — A Candidate Species for Crop Diversification**

David Cerino (lead), Carteret Community College; Ami Wilbur, UNCW; Jimmy Morris, Morris Family Shellfish Farms

- **Increased Commercial Aquaculture Production of U.S. Bay Scallops *Argopecten irradians* in North Carolina**

Ami Wilbur (lead) and Robin Vamey, UNCW

- **Impacts of Culture Technique and Position in the Estuary on the Nutrient Removal Potential of Oyster Aquaculture**

Michael Piehler (lead) and Joel Fodrie, UNC-CH; James Morley, ECU

- **Development of a Tool to Forecast Closure of Shellfish Aquaculture Harvest Areas**

Natalie Nelson (lead), NC State; Shannon Jenkins and Andrew Haines, N.C. Division of Marine Fisheries; Chris Matteo, N.C. Shellfish Growers Association and Chadwick Creek Oyster Company; David Glenn, National Weather Service; Ken Riley, NOAA's National Centers for Coastal Ocean Science

- **Strengthening Community Networks for Environmental Learning and Resilience through Children**

Kathryn Stevenson (lead), K.C. Busch, Nils Peterson, Sarah Carrier and Danielle Lawson, NC State; Elizabeth DeMattia, Duke

These projects receive funding from NOAA through the National Sea Grant College Program, as well as state funding through the University of North Carolina System. Each project also receives matching funds from its respective university.

- North Carolina Sea Grant's Core Research Projects: go.ncsu.edu/core-funding

— Chloe Tenn



CZ Photography/VisitNC.com

SEA GRANT AND PARTNERS JOIN FORCES ON COASTAL RESILIENCY

Rachel Carson Reserve on Carrot Island

The North Carolina Division of Coastal Management has received more than \$1.1 million from the National Fish and Wildlife Foundation's Emergency Coastal Resilience Fund. The funds will enhance the resilience of North Carolina's coastal communities and natural resources by supporting local planning and pre-construction activities.

Overcoming Local Barriers to Implementation and Getting to Shovel Readiness is a collaborative project with partners that include the N.C. Office of Recovery and Resiliency, North Carolina Sea Grant, and The Nature Conservancy. Funding also will support the development of a habitat resilience plan for the

Rachel Carson Reserve, as well as engineering for two projects that will protect the reserve and the Town of Beaufort.

Frank Lopez, extension director for North Carolina Sea Grant and North Carolina's Water Resources Research Institute, says his team is pleased to be working with the diverse group of partners.

"This critical project will help participating coastal communities plan to increase their resilience to natural hazards and prepare priority projects to reduce risk," Lopez says.

• go.ncsu.edu/resiliency-project — Chloe Tenn



Aaron Ramus, 2020 Coastal Research Fellow

HOW DOES SEAWEED AFFECT ESTUARIES?

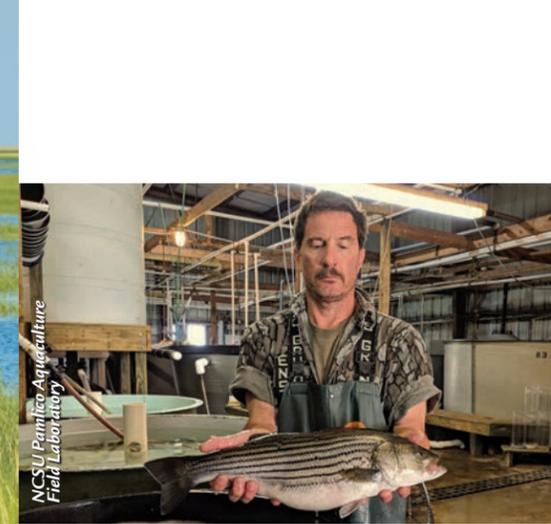
A new study is exploring the impact of non-native seaweed in the North Carolina Coastal Reserve and National Estuarine Research Reserve. Aaron Ramus, recipient of the 2020 Coastal Research Fellowship, is investigating the effects of *Gracilaria vermiculophylla* on estuarine lagoons.

North Carolina Sea Grant and the N.C. Coastal Reserve and National Estuarine Research Reserve Program sponsor the fellowship, which supports work in the state's reserve system. Ramus, a doctoral student in marine biology at the University of North Carolina Wilmington, says he hopes to better understand how *Gracilaria vermiculophylla* affects the food chain, including the hard clam fishery.

"I'm very excited about receiving this award," Ramus says. "Hard clams constitute the basis for a popular recreational and major commercial shellfishery in North Carolina."

Ramus plans to develop a web-based interactive map of the seaweed's distribution and abundance. He also will share his results through an open access journal, conferences, and other avenues.

• The Coastal Research Fellowship: go.ncsu.edu/CRF
— Katelyn Vause



NCSU Pamlico Aquaculture Field Laboratory

Hatchery manager Robert Clark with a striped bass

STRIPERHUB TO BOOST THE EAST COAST SEAFOOD INDUSTRY

StriperHub, among the National Sea Grant Office's recently funded initiatives on sustainable aquaculture, is advancing the commercialization of marine striped bass.

NC State University's Benjamin Reading says the project, which also includes North Carolina Sea Grant, will help address a \$16 billion seafood trade deficit.

"Nine out of 10 seafood products that Americans consume are imported," says Reading, StriperHub's program coordinator. "But there's a significant untapped demand for marine striped bass — and this project can help to satisfy those consumers."

Frank Lopez, North Carolina Sea Grant's extension director, serves as StriperHub's principal investigator and director. The program has a long history of funding striped bass aquaculture research and extension.

NC State's Russell Borski, StriperHub's southeast regional coordinator, says taste is part of what makes striped bass a prized species for aquaculture — and a rarity.

"A candidate species has a premium price, high consumer demand, and adapts well to localized production," Borski says. "Among white-fleshed marine fishes in the U.S., there aren't many of these. But striped bass meets all the criteria."

• go.ncsu.edu/striper-hub
— Katie Mosher



Volunteers removing stream debris

HOW DOES PLASTIC LITTER REACH PAMLICO SOUND?

New research will investigate how much plastic travels from the upper areas of the Neuse River watershed into the Pamlico Sound. The North Carolina Sea Grant study is one of eight initiatives set to launch in collaboration with the NOAA Marine Debris Program.

“We hope to increase our understanding of plastic contamination in North Carolina waters,” says Barbara Doll, water protection and restoration specialist for North Carolina Sea Grant. “We also plan to increase public awareness of the problem.”

Plastics and other human-created litter threaten the environment and safe navigation of waterways – with potential implications for the economy and human health in our state and beyond.

Doll will partner with several universities and environmental programs, including NC State University, the University of North Carolina Wilmington, Plastics Ocean Project, and Sound Rivers, Inc.

Jack Kurki-Fox, research associate from the Department of Biological and Agricultural Engineering at NC State, will coordinate the collection of samples of visible and microscopic plastics from the Neuse River and its feeder streams. These samples will enable the team to estimate the total amount of plastic litter coming from the upper reaches of the watershed.

North Carolina Sea Grant’s Gloria Putnam, coastal resources and communities specialist, says the project implements priorities that the new North Carolina Marine Debris Action Plan identifies.

“The practical solutions that this project will inform are right in line with the plan,” Putnam explains. “In the long run, prevention will be the key to success.”

• NOAA’s Marine Debris Program: go.ncsu.edu/NOAA-Marine-Debris

— Katelyn Vause



COASTAL TIDINGS

Benjamin Wilson/CC BY-SA 2.0

NEW PROJECTS STUDY OYSTER, SHRIMP, AND CRAB POPULATIONS

Three new North Carolina Sea Grant projects are studying impacts on the state’s oyster, brown shrimp, and blue crab populations. The projects meet key needs identified by state agencies that manage natural resources.

John Fear, North Carolina Sea Grant’s deputy director, says discussions with directors of various agencies, along with review of the state’s Coastal Habitat Protection Plan, informed the design of these projects.

“Additional needs identified in our recent discussions will continue to feed into our future research funding opportunities,” Fear says.

Nathan Hall of the University of North Carolina at Chapel Hill will examine the impacts of water quality on oyster recovery and restoration. In particular, his team will study how raphidophyte, a harmful algal bloom

species, affects oyster recruitment to the New River Estuary.

James Morley of East Carolina University will study the influence of environmental factors on brown shrimp recruitment. Morley will examine differences in the effects of climate on shrimp in the Pamlico Sound, as well as in 13 North Carolina tidal creeks.

Jim Cao of NC State will study blue crab populations, a keystone species in our coastal system. He will focus on how water temperature, salinity, dissolved oxygen, and chemical contaminants affect the blue crab population over the long term.

• Funding opportunities from North Carolina Sea Grant: ncseagrant.ncsu.edu/funding-opps

— Katie Mosher & Chloe Tenn

COASTAL LANDSCAPES INITIATIVE OFFERS FREE RESOURCES

The Coastal Landscapes Initiative recently took center stage at the North Carolina Museum of Natural Science’s *Science Café* series. “Landscaping Inspired by Nature” includes tips on creating green spaces filled with native species. Video from the virtual café is available online.

A collaborative effort among North Carolina Sea Grant and partners, CLI fosters the design, implementation, and management of coastal landscapes that balance beauty and cost-effectiveness with eco-friendliness.

In addition to appearing on *Science Café*, the CLI team also recently completed new templates for landscaping sites that primarily use native plants and that homeowners and businesses can replicate on residential, commercial, and government properties.

“Deciding which plants to use can be a challenging task and can be even more daunting in harsh coastal environments,” says Gloria Putnam, North Carolina Sea Grant’s coastal resources and communities specialist. Putnam coordinated development of the templates.

“These designs will help property owners and landscapers with choosing and arranging native plants suitable for their sites’ conditions and needs. Each design can be modified to meet lot configurations, and alternative plant choices are provided for flexibility.”

• go.ncsu.edu/coastal-landscaping

— Katelyn Vause



Baxter Miller/VisitNC.com

ENJOY THE BOUNTY OF NC LOCAL FOODS

Consumers everywhere have been gravitating to the familiar to cope with the COVID-19 pandemic.

“Nothing is more comforting than making family recipes and memories using ingredients from local farms, fisheries, and food businesses,” says Barry Nash, North Carolina Sea Grant’s seafood safety and technology specialist.

Nash also currently leads the N.C. Local Food Council, which supports collaborations to improve supply chains, as well as consumer education on the variety and value of local foods.

Nash suggests heading to farmers markets and other local options. To find locations, contacts, and details, visit:

• **Got to Be NC** gottoenc.com

There, you can locate hundreds of local products and producers in a searchable database. Look for the “Find Local” option.

• **Visit NC Farms** visitncfarmstoday.com

This app quickly helps users find places to purchase from local growers.

• **Mariner’s Menu** marinersmenu.org

This North Carolina Sea Grant blog has hundreds of seafood recipes. You also can find more *Mariner’s Menu* selections in each issue of *Coastwatch*, as well as our special guide on page 36 in this issue, “How to Freeze Your Fresh North Carolina Seafood,” which includes links to find seafood suppliers near you.

“North Carolina’s home cooks have one of the greatest bounties of local foods available anywhere,” says N.C. Farm Bureau’s Debbie Hamrick, who also serves on the food council. “Consider inviting a North Carolina farmer or fisherman to dinner by sharing a meal made with locally sourced ingredients.”

— Katie Mosher

STUDY FINDS PFAS IN CAPE FEAR RIVER’S STRIPED BASS

New research from NC State University has found elevated levels of perfluoroalkyl and polyfluoroalkyl substances (PFAS) in striped bass living in the Cape Fear River. T.C. Guillette, a postdoctoral researcher working with Scott Belcher at NC State, led the study.

Common household items, such as nonstick coatings and plastics, contain PFAS. Their unique properties make them useful, but the chemicals also remain in the environment for extended periods of time.

Scientists are investigating how these substances affect the environment, as well as

potential impacts when humans ingest PFAS-contaminated animals, such as fish. For this study, researchers examined PFAS concentrations in striped bass by taking blood samples of the wild fish and comparing them with fish in an aquaculture facility.

The findings revealed that striped bass in the Cape Fear River are contaminated with PFAS, affecting their liver and immune system functions.

• T.C. Guillette on her team’s work:

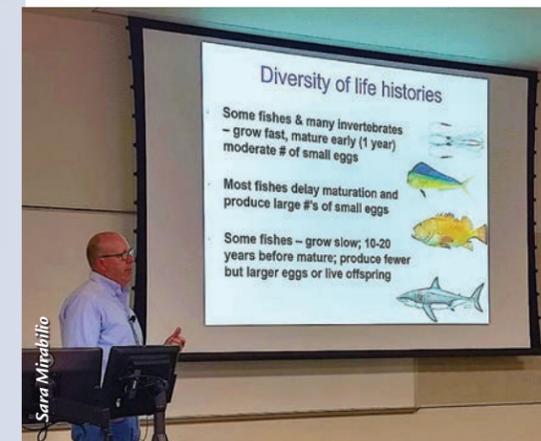
go.ncsu.edu/PFAS-in-fish

• full study: go.ncsu.edu/striped-bass-study

— Katelyn Vause

FISHERIES SCIENCE COURSE EARNS HIGH MARKS

Scott Baker and Sara Mirabilio, fisheries specialists at North Carolina Sea Grant, offered their popular class on fisheries science again this past February and March. The “Introductory Fisheries Science for Fishermen” course included four weekly classes online and at UNC Wilmington.



Fisheries Science Course guest lecturer Fred Scharf

These classes focused on renewable fishery management, research, stock assessment, and evaluation. Guest speakers from UNCW, NC State, and the N.C. Division of Marine Fisheries, as well as other fishery professionals, offered their expertise.

An anonymous survey netted positive feedback from participants.

“I hoped to gain better knowledge of how regulations on fishing are set by the state and how they oversee marine fisheries,” reported one participant, “and my expectations were exceeded.”

Another sought to better understand management of fish stocks, especially what factors led to limits and closures.

“And the classes provided me with that,” said the participant. “I can see both sides a little more clearly now.”

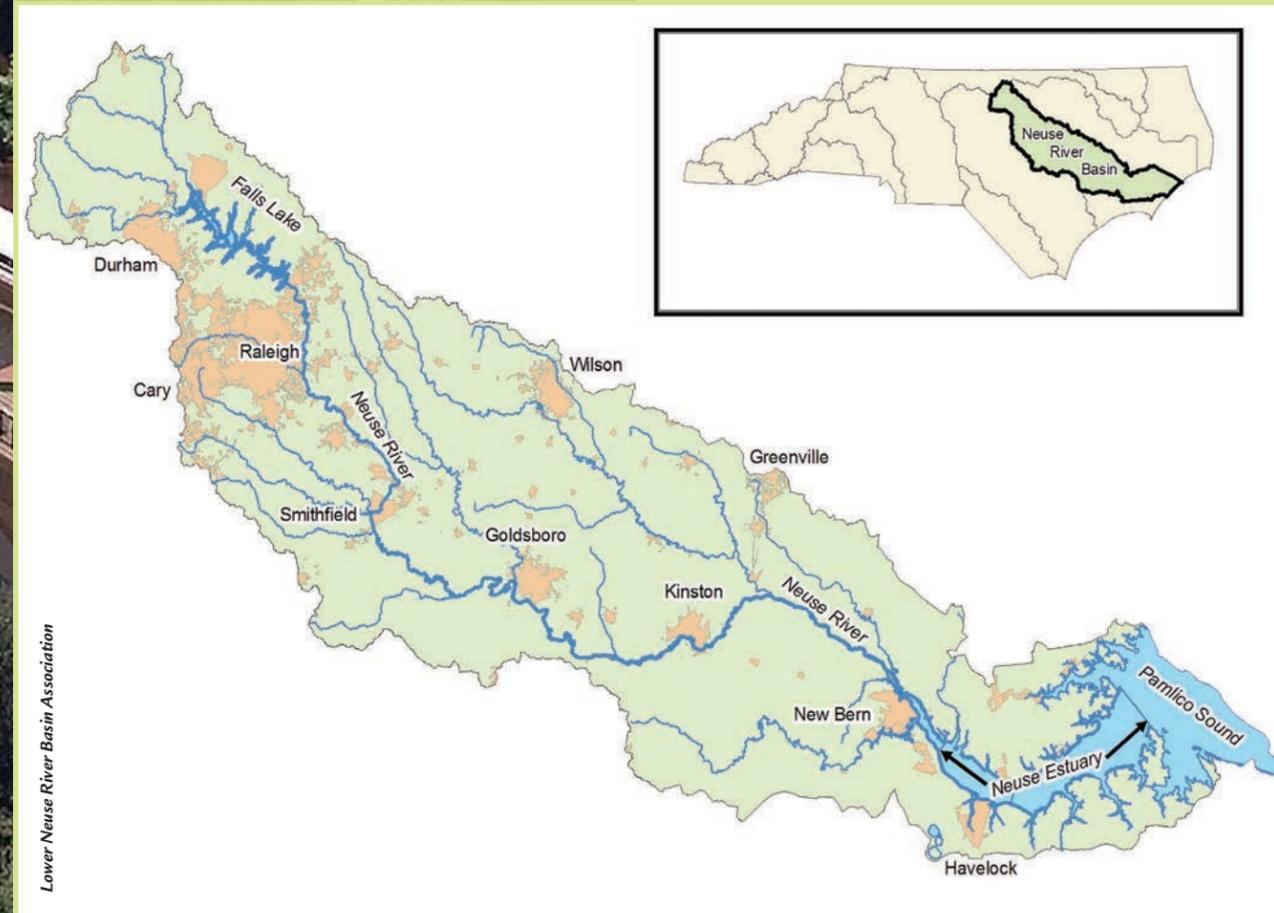
— Chloe Tenn

BY JULIE LEIBACH

THE ROAD TO RESILIENCE

**A LARGE TRANSPORTATION STUDY ON FLOODING IN
EASTERN NORTH CAROLINA COMMUNITIES SUGGESTS
THAT THOUGHTFUL PLANNING AND TARGETED
ROUTE IMPROVEMENTS ARE KEY.**

THE NEUSE RIVER IN KINSTON



HURRICANES FLOYD, MATTHEW, AND FLORENCE TOGETHER COST THE STATE TENS OF BILLIONS OF DOLLARS, MAINLY BECAUSE OF DAMAGES FROM MAJOR FLOODING IN THE NEUSE, CAPE FEAR, LUMBER, CASHIE, AND TAR-PAMLICO RIVER BASINS OF THE COASTAL PLAIN.

Durwood Stephenson’s cell phone lit up with calls when Hurricane Matthew battered North Carolina in October 2016. As the director of the U.S. Highway 70 Corridor Commission, he was a go-to for eastern North Carolinians worried about road conditions.

For example, a caller in New Bern who had encountered flooding on U.S. 70 lamented, “I don’t know where to go or how to go. What do I do?” The driver was en route to Goldsboro to pick up his mother and take her to the hospital. “I suggested he call 911 in Wayne County,” Stephenson says.

Matthew caused more than 1,760 road closures in the state, according to the North Carolina Department of Transportation Statewide Operations Center. A section of Interstate 40 in Johnston County was shut down for a week, while portions of Interstate 95 in Robeson and Cumberland counties were closed for 10 days.

The storm’s costliest impacts stemmed from river flooding in eastern North Carolina, according to the National Oceanic and Atmospheric Administration’s National Centers for Environmental Information. The state hadn’t seen such devastation from inland flooding since 1999, with Hurricane Floyd.

“Matthew made it popular again in eastern North Carolina to start thinking about flood mitigation,” Stephenson says. “It flooded everything east of Raleigh, all the way to the coast. Smithfield was not passable; I couldn’t get to my office, and I don’t live but five or six miles away.”

North Carolina was still recovering from Matthew when Hurricane Florence arrived in 2018. Its drenching rains caused rivers to overtop their banks, crushing many previous record flood heights. The storm caused more than 2,500 road closures, again including sections of Interstates 95 and 40.

LEFT: In 1999, Hurricane Floyd caused flooding in many areas of southeast Kinston near the Adkin Branch of the Neuse River. **ABOVE:** The Neuse River flows from the Piedmont to the Coastal Plain, where it empties into Pamlico Sound.

Short-term closures occurred because of standing water and overtopping from streams. Meanwhile, road washouts that required repairs or complete reconstruction forced long-term closures.

Hurricanes Floyd, Matthew, and Florence together cost the state tens of billions of dollars, mainly because of damages from major flooding in the Neuse, Cape Fear, Lumber, Cashie, and Tar-Pamlico river basins of the Coastal Plain.

As the climate warms, North Carolinians can likely expect more frequent and severe inland flooding, fueled by more frequent, intense precipitation, according to the North Carolina Climate Science Report, released this past March by the North Carolina Institute for Climate Studies.

Continued

To better understand transportation-related impacts and other problems associated with Coastal Plain flooding, North Carolina Sea Grant and NC State University's Biological & Agricultural Engineering Department collaborated with the N.C. Department of Transportation (NCDOT), N.C. Emergency Management (NCEM), and local governments on a multifaceted study now wrapping up. The team also investigated potential mitigation strategies.

Their research centered on three municipalities in the Neuse River basin: Smithfield, Goldsboro, and Kinston. "They had suffered a lot in the last couple floods," says NCDOT's LeiLani Paugh of the communities. "They had reached out to DOT, they had reached out to other officials."

Stephenson, a self-described "eastern North Carolina boy," is an active community member. "I've been interested in and concerned about the flood issue for a long time," he says. "It is a major problem for eastern North Carolina."

LAY OF THE LAND

The Neuse River begins at Falls Lake Reservoir Dam in the Piedmont and empties more than 200 miles later into Pamlico Sound. Its course traces rolling hills and eroded valleys that transition to sand hills and more level land at a geographic feature known as the fall line, or fall zone.

"As soon as you get in the Coastal Plain, there's really not a lot of relief to speak of," says Jonathan Page, a hydraulic engineer who was part of the study team.

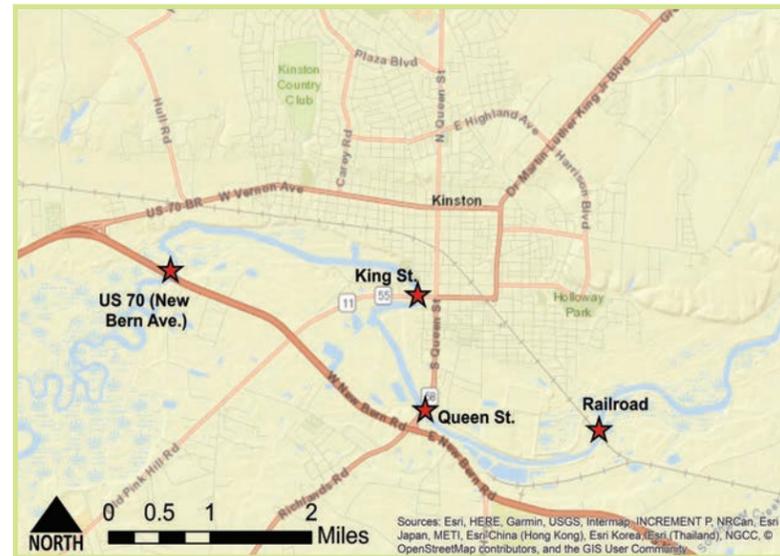
In rivers, the fall line manifests as rapids, which prevent boats from navigating farther upstream. As North Carolina developed, the fall line significantly affected where people settled, according to the *Encyclopedia of North Carolina*.

"The fall line was a first frontier," wrote the journalist T. Edward Nickens for *Our State* in 2016. "The river shallows made for convenient crossings — first for Native Americans, and then for settlers, and later for bridges that carried cars across the rivers. It was the place where towns were planted."

As it flows eastward from the fall line, the Neuse flattens, and the floodplain significantly widens. By virtue of their location, parts



Wilson Library/UNC-Chapel Hill



N.C. Sea Grant/NC State University Department of Biological and Agricultural Engineering

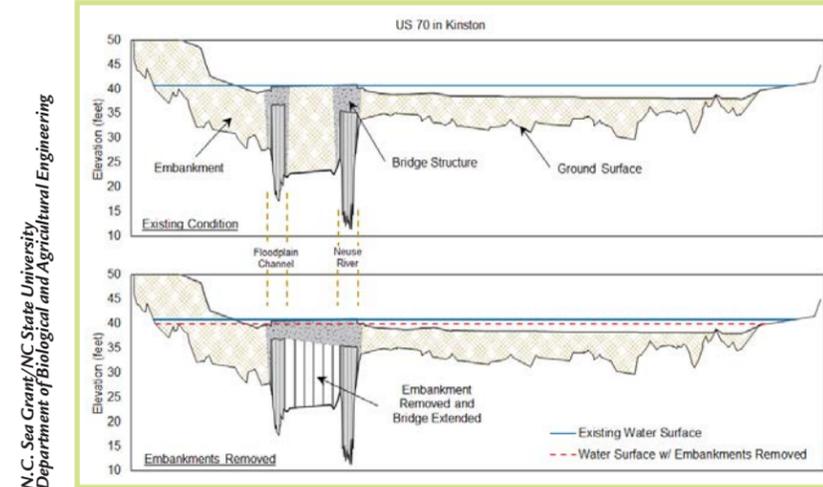
ABOVE: A postcard circa 1915-1930 depicts a downtown intersection in Kinston.

BOTTOM: In Kinston, researchers modeled how modifications to three road bridges and a railroad bridge would affect upstream flooding.

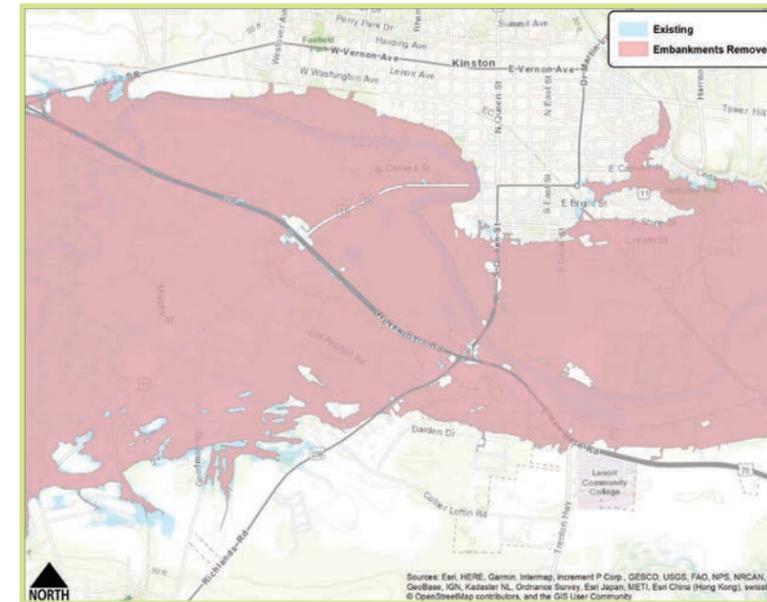
of Smithfield, Goldsboro, and Kinston exist in that floodplain.

As many North Carolinians know all too well, flooding imperils life, health, and livelihoods, in part because it can debilitate transportation infrastructure.

"Road closures — especially extended road closures, when the road is completely washed away — have big impacts," says Barbara Doll, an extension specialist with North Carolina Sea Grant and NC State faculty member, who led the study.



N.C. Sea Grant/NC State University Department of Biological and Agricultural Engineering



N.C. Sea Grant/NC State University Department of Biological and Agricultural Engineering

TOP: A cross section of the Neuse River at U.S. Highway 70 in Kinston. The bridge consists of two sections separated by an embankment. The blue line indicates the level of flooding at the bridge during Hurricane Matthew. If this crossing and the King Street and Queen Street bridges were substantially modified, water surface elevation upstream of U.S. 70 would decrease by an estimated 1.2 feet during a Matthew-scale event. Water would still overtop the bridge, as indicated by the red dashed line. BOTTOM: Pink indicates flooding during a Matthew-scale event if the U.S. 70, King Street and Queen Street bridges were modified. The extent is only slightly less than the flooding that would occur under existing conditions, highlighted in blue.

To kick off their project in 2018, Doll's team first needed to familiarize themselves with how land use and land cover have evolved over time in each study area. They asked questions such as, What's the soil like? How have rainfall patterns changed? To develop a detailed picture, the researchers used geospatial data;

historical precipitation and discharge records; satellite imagery; soil surveys; and topographic data.

Then they hosted stakeholder meetings in Smithfield, Goldsboro, and Kinston. At each workshop, they invited local officials, emergency responders, utility operators, and other specialists to identify locations where they were concerned about flooding, with a focus on the transportation network. Doll's team also shared what they had learned in their background research.

"It really provided a unique opportunity to say, 'Hey, here's what we're seeing from all of the information, data, that we've gathered; give us your thoughts and feedback,'" Page says.

That stakeholder feedback informed the scope of the study. "We really let what they said in those meetings drive a lot of what we did," Doll says.

OVER THE RIVER

During the workshops, stakeholders expressed concerns that various bridges were contributing to flooding in their municipalities.

More than 10 road, highway, and railroad bridges straddle the Neuse River between Smithfield and Kinston. Those bridges have embankments to elevate the road surface across the floodplain leading up to the river channel.

Embankments obstruct water flow on the floodplain. During an extreme event such as a hurricane, it's possible that embankments create a backwater effect that potentially exacerbates upstream flooding.

Doll's team decided to investigate the influence of bridges on water surface elevation using hydraulic modeling, a computational way of predicting flooding based on different scenarios. What if bridge span or elevation were increased, or an embankment were removed?

In Smithfield, they studied U.S. 301 and I-95 bridges and a railroad bridge. Near Goldsboro, they focused on the Arrington Bridge Road crossing. And in Kinston, they examined bridges along U.S. 70 (also called New Bern Avenue), King Street, Queen Street, and a railroad southeast of town.

Continued



ABOVE: A postcard from 1925 features a view of downtown Smithfield. **RIGHT:** Hurricane Matthew led to more than 1,760 road closures in North Carolina.

Through modeling, they experimented with modifying one bridge or multiple in tandem. In Goldsboro and Kinston, they also tried removing bridges entirely.

Overall, modeling suggested that substantially altering bridges would have minimal impact on upstream flooding. For most of the bridge modification scenarios, the change in water surface upstream was less than a foot, and often less than half of a foot for a storm like Matthew.

“We saw that investing millions and millions of dollars in increasing the spans of those bridges provided limited flood reduction benefits upstream,” says Jack Kurki-Fox, a team member who worked on the hydraulic modeling. “This money could be better spent on strategic transportation infrastructure upgrades and moving people out of flood-prone areas through buyouts, especially given the likelihood of more extreme events in the future.”

In many of the modeling scenarios, the primary reason bridge modification had limited advantages appears to stem from the very nature of the surrounding environment. Because the Coastal Plain gradually slopes toward the sea, rising floodwaters move sluggishly eastward. The resulting backwater eclipses any limited relief on upstream flooding from bridge modification, according to Doll.

“In many areas, the river itself is a relatively small channel when compared to its wide floodplain,” Doll says. “During these huge flows, the water is already spread way out onto the floodplain downstream of the bridges. So, even if the bridges were modified, the flow is blocked by all the water that is pooled downstream.”



BEYOND BRIDGES

Smithfield, Goldsboro, and Kinston also reported severe flash flooding along tributary creeks to the Neuse River.

In many cases the flooding — which often occurs much earlier than when the river crests — forces road closures and restricts access to important areas of town. As the river discharge peaks, it creates backwater that floods the creeks again.

Doll’s team inventoried culverts and bridges along all tributaries that experience flash flooding that had been identified by stakeholders. Their aim was to determine if any updates could alleviate flooding.

They found that most structures were in decent condition. To have

EMBANKMENTS OBSTRUCT WATER FLOW ON THE FLOODPLAIN. DURING AN EXTREME EVENT SUCH AS A HURRICANE, IT’S POSSIBLE THAT EMBANKMENTS CREATE A BACKWATER EFFECT THAT POTENTIALLY EXACERBATES UPSTREAM FLOODING.

any effect on flood mitigation, costly modifications — namely, raising roads — would be necessary.

Another common concern in all three municipalities was that development upstream in and around Raleigh has worsened flooding in their communities during large rain events. As the thinking goes, more impervious surfaces cause greater amounts of runoff that eventually wends its way downstream.

The team found through modeling that development near the state capital isn’t a major culprit. A large rain event in the Neuse River basin will create runoff regardless of where the precipitation falls.

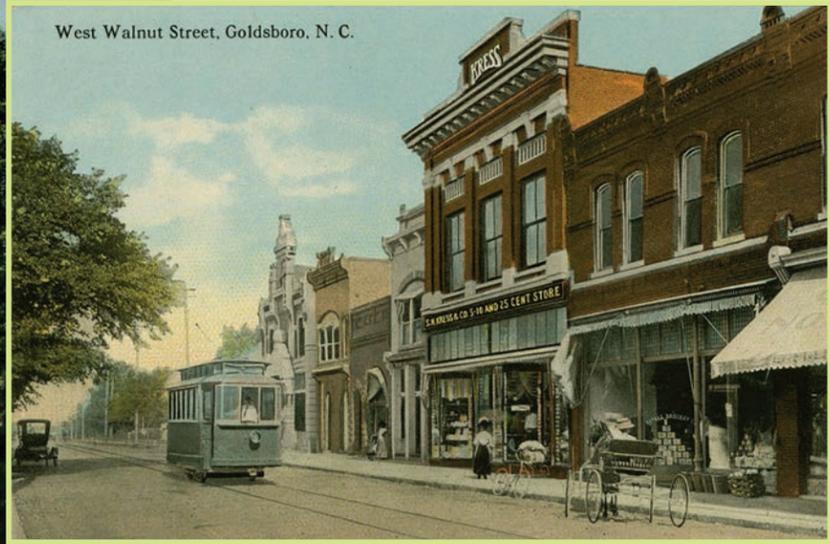
“If you get 10 to 15 inches of rain covering a large portion of the watershed, it runs off of everything, especially when the ground is already wet. It doesn’t have to fall on the pavement and developed

areas of Raleigh,” says Dan Line, who modeled watershed hydrology for the study. “In fact, much of the rain during Hurricane Matthew fell on Johnston County and areas southeast of Raleigh.”

Line also investigated how future urban sprawl south and east of Raleigh might contribute to downstream flooding. His modeling showed that continued buildout would result in only a moderate rise in peak flow. Indeed, most of that area is farmland, which already generates substantial runoff when fully saturated.

Falls Lake Reservoir, which in part provides drinking water to the City of Raleigh, was a hot topic as well. The team confirmed that the water body doesn’t contribute to downstream flooding, however. In fact, says hydraulic engineer Jonathan Page, “the primary purpose and overwhelming majority of the storage within the lake is used for flood control!”

Continued



Wilson Library/UNC-Chapel Hill

RESILIENT ROUTES WOULD MAINTAIN ACCESS TO IMPORTANT AREAS, SUCH AS HOSPITALS, DURING EXTREME FLOODING, AS WELL AS ENABLE EMERGENCY RESPONSE, EVACUATIONS, AND SUPPLY DELIVERY.

Robert Tucker/CC BY-SA 2.0

ABOVE: A postcard circa 1905-1915 shows a business district in Goldsboro. **LEFT:** A view of the Neuse River from N.C. Highway 581 in Goldsboro, after heavy rains.

an earlier study commissioned by NCEM found that from 2001 to 2016, development in the 100-year floodplain increased by an average of 17% in Smithfield, Goldsboro, and Kinston.

To help those communities plan better, Doll's team enlisted researchers at the University of North Carolina at Chapel Hill to review floodplain ordinances across the country in order to make recommendations to the municipalities on how to modify their own language.

Ultimately, Doll's study is one element of a larger, ongoing effort by partners such as NC DOT to address resilience in the face of climate change. "It's not just an engineering issue, it's not just an environmental or a natural resource issue. The impacts, the problems, and the solutions all have multidisciplinary components," Paugh says.

"That study is not necessarily the end — it's maybe the beginning of additional studies and collaboration," adds Stephen Morgan, the state hydraulics engineer for NC DOT. "I think through that process we will continue being a leader in forward-thinking approaches to our most challenging problems." 

For more information on the Neuse River flood mitigation study, and for details on improving resilience to flooding, go to go.ncsu.edu/flood-mitigation.

EDITOR'S NOTE: This article relies in large part on summaries and reports written by Jack Kurki-Fox, Dan Line, and Barbara Doll.

ALTERNATE ROUTES

The very fact that Smithfield, Goldsboro, and Kinston lie along a floodplain makes a degree of flooding inevitable. And the problem will likely get worse.

For example, Doll's team also looked at the effect of future storms on Neuse River flooding. Using climate data from the United States Environmental Protection Agency and assistance from the Southeast Climate Adaptation Science Center, they found that, under warmer conditions, another hurricane like Matthew would produce more rainfall, resulting in flooding of greater extent and depth along the river.

As Doll's study suggests, certain infrastructure updates, such as modifying bridges, would have virtually no effect on alleviating

flooding, while other upgrades, like raising roads, are cost- and technically prohibitive. Short of moving whole communities to higher ground, what other options exist?

"We can't just leave people hanging," Paugh of NC DOT says.

There are various strategies to consider. For instance, early warning systems that indicate when important routes will flood could prove vital to steering people away from dangerous streets. For their part, Doll's team investigated locations where new stream gauges could be installed as part of an early-warning network.

In response to prolonged closures of important thoroughfares, the concept of "resilient routes" also has emerged. Instead of attempting to fix all roads, so the idea goes, attention should

be on identifying critical transportation routes that experience minimal flooding, and then upgrading them to withstand extreme events, such as 500-year or 1,000-year floods.

"We can't pick every road up out of the floodway," Paugh says. "What are those safe routes, and can we make those more resilient?" Such a network would provide access to important areas, such as hospitals, during extreme flooding, as well as enable emergency response, evacuations, and supply delivery.

"It's not going to prevent flooding," Page says, "but it is going to maintain access and continue to allow those emergency services to occur."

Finally, one relatively simple approach to minimize damage from flooding is to curb development in susceptible areas. For example,

WHAT'S IN YOUR WATER?

Predicting Contaminated Drinking Supplies

MAYA HOON

RILEY MULHERN IS DEVELOPING A MODEL THAT CALCULATES THE CHARACTERISTICS OF HOUSEHOLDS AND LOCATIONS WITH A HIGHER CHANCE OF LEAD CONTAMINATION IN DRINKING WATER.

Riley Mulhern, using a field-based filtration test kit in Oruro, Bolivia.

Continued

Yasín Ramírez

AS HOUSEHOLD PLUMBING AND WATER PIPES AGE, LEAD — AN INFAMOUSLY POTENT NEUROTOXIN — CONTAMINATES DRINKING WATER. WITH SUPPORT FROM HIS NORTH CAROLINA SEA GRANT — WATER RESOURCES RESEARCH INSTITUTE GRADUATE RESEARCH FELLOWSHIP, RILEY MULHERN HOPES TO PREDICT WHERE SUCH CONTAMINATED WATERS ARE MORE LIKELY TO OCCUR.

Mulhern, a Ph.D. candidate in the Gillings School of Global Public Health at the University of North Carolina at Chapel Hill, uses machine learning software, feeding large data sets into computers with the help of two undergraduate students. These data sets pair drinking water quality and characteristics of water utility infrastructure with child blood-lead measurements. Mulhern’s team then can identify patterns between blood-lead occurrences in children and characteristics of their water system.

LOW INCOME AND AFRICAN-AMERICAN NEIGHBORHOODS — AND HIGHER LEVELS OF LEAD

Mulhern’s team has found a strong association between higher levels of lead in children in Wake County and low-income and predominantly African-American neighborhoods. These results do not necessarily mean water is the only or primary source of lead exposure, because many other mediums also introduce lead to humans. However, Mulhern explains, “drinking water may be associated with low levels of chronic lead exposure that might not be detected otherwise.”

Essentially, such a scenario fails to trigger appropriate steps to remove the lead, because levels are below official detection or required action. Nonetheless, lead may accumulate in people who drink contaminated water, placing them at risk for health problems.

Ideally, when alerted, water utilities will work to improve infrastructure if necessary to reduce the risks of harmful water contaminants. However, Mulhern says, the process can be slow, and some utilities lack the finances to make necessary improvements.

Mulhern plans to use his model in other counties, such as water utilities in southern parts of North Carolina, to understand how well the model can predict risk in other areas.

Above and Right: Riley Mulhern in the lab and in the field.

ARE PRIVATE WELLS SAFER?

Jacqueline MacDonald Gibson, Mulhern’s advisor, has conducted research showing that people who rely on private well water are at an even higher risk.

As a result, private well owners also are a focus of Mulhern’s research. Mulhern has installed water filters in 18 homes on private wells in Robeson and Orange County and has been collecting water samples from these homes regularly.

“I kind of had to learn how to become a plumber,” Mulhern says. “I had to learn how to install all of these filters in people’s homes, which is fairly simple, but every home is different. I had to learn a lot about different plumbing fixtures, which was a challenge.”



After collecting his samples, he tests for metals, organic chemicals, and microbes, such as *E. coli*, and viruses. Mulhern then explains his findings to his study participants.

“I do try and be very intentional in my research, with communication with every study participant to understand their water quality data,” Mulhern says. “I don’t think I do it perfectly, but to do it perfectly, I would need a whole team, because it takes a lot of time. But it’s worth it.”

Although time constraints can create pressure and stress, Mulhern finds all his field work to be a rewarding experience.

Continued



“I often get back from those field days pretty exhausted,” he says. “But somehow energized too, and that’s why I do this. I get to establish a rapport with study participants and be someone they feel they can trust, and I feel like that’s an important part of doing public health work — that people involved in the study are able to trust the researcher.”

His current data suggest water filters show promise as effective tools for lead removal. However, Mulhern also hopes to learn to what extent and for how long filters might be effective in order to identify the most cost-effective solution — especially because lower-income communities are at higher risk for lead contamination. With more evidence of effectiveness, water filters could better provide protection to vulnerable communities.

ARSENIC, MINING, AND WATER CONTAMINATION AROUND THE GLOBE

For six months as an undergraduate intern in Nicaragua, Mulhern worked with communities struggling with arsenic-contaminated well water, which ultimately compelled him to pursue a master’s degree in environmental engineering and water treatment at the University of Colorado Boulder.

He and his wife later lived in Bolivia for two years, and during that time, he interacted with indigenous communities whose water was contaminated from mining activities.

“There was a lot of debate and confusion about the full impacts of mining in the area and the health effects,” he says. “And so, those communities really wanted researchers to come alongside them and support them. That was another instance that really compelled me to want to do a Ph.D., in particular, because I saw the value of research as a means to accompany communities in some of these difficult circumstances.”

Mulhern also realized many of the same issues existed in America, where he felt drinking water disparity by income or race was an ongoing issue of social justice.

“It’s just satisfying being able to provide these filters to people,” Mulhern says. “It feels like a service to the community, at the same time as it is an academic pursuit. I enjoy that. Now I just need to find a way to make them sustainable, so that people continue to be provided with the service.”

Mulhern plans to continue his focus on lead contamination in water supplies, as well as on other potentially harmful chemicals that require more research and attention.

Wherever his work takes him, he says, he’s sure to continue serving vulnerable communities. 🌍

Left and Right: From Nicaragua to Colorado to Bolivia to North Carolina, Riley Mulhern has tested and researched how to keep contaminated water from vulnerable communities.

The North Carolina Sea Grant - Water Resources Research Institute Graduate Research Fellowship:
go.ncsu.edu/NCSEG-WRRI-fellows

Maya Hoon graduated from NC State University with a B.S. in environmental sciences. Last summer, she conducted mercury cycling research as a research assistant for Clarkson University’s ASSETs to Serve Humanity REU program. This fall, she will be pursuing her M.S. in environmental sciences & engineering at UNC Chapel Hill’s Gillings School of Public Health.



INSIDE THE GREENHOUSE

NORTH CAROLINA'S HOTTEST YEAR ON RECORD

COREY DAVIS AND KATHIE DELLO

WE'RE MOVING RAPIDLY INTO A DIFFERENT NORTH CAROLINA THAN THE ONE WE USED TO KNOW. WILL 2020 SURPASS LAST YEAR AND BRING EVEN MORE RECORD HEAT?

Continued

CLIMATE CHANGE LIKELY WILL CREATE MORE FREQUENT CONDITIONS FOR WILDFIRES LIKE THIS ONE IN WHIPPING CREEK.



Jared Kay/visitNC.com

• IN THE PAST 30 YEARS, NORTH CAROLINA HAS RECORDED EACH OF ITS FIVE WARMEST YEARS ON RECORD — ALONG WITH 10 OF ITS TOP 30 WARMEST YEARS.

THOSE WARM DAYS LAST DECEMBER WHEN TEMPERATURES TOUCHED THE 70S DIDN'T JUST MAKE YOU PULL OUT THE SANDALS FOR HOLIDAY BREAK. THEY ALSO HELPED 2019 SECURE THE TITLE OF NORTH CAROLINA'S WARMEST YEAR ON RECORD.

Earlier this year, our colleagues in Asheville at NOAA's National Centers for Environmental Information confirmed 2019's record-breaking status. They calculated national, state-level, and local average temperatures and precipitation using quality-controlled weather station observations. These data date back to 1895.

It's our best and most accurate measure

of surface weather conditions using on-the-ground monitoring sites, which is a fancy way of saying good old-fashioned thermometers and rain gauges. This tried-and-true equipment tells us that 2019 consistently moved the mercury higher than any other year observed.

To break down this record and what it means — and where we're headed in 2020 — here are the answers to some common questions about climate change in North Carolina.

HOW DID IT HAPPEN?

In short, our temperatures were generally temperate, and our prevailing air masses were typically tropical. Just two months all year — March and November — had below-normal statewide average temperatures, while three

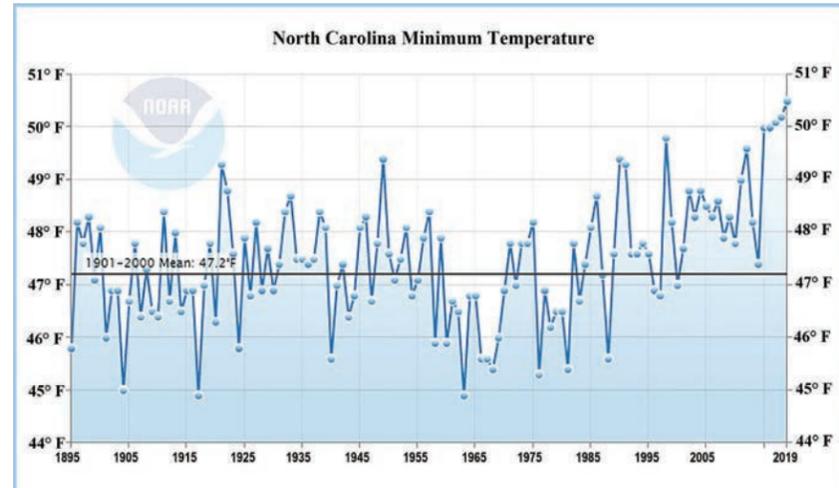
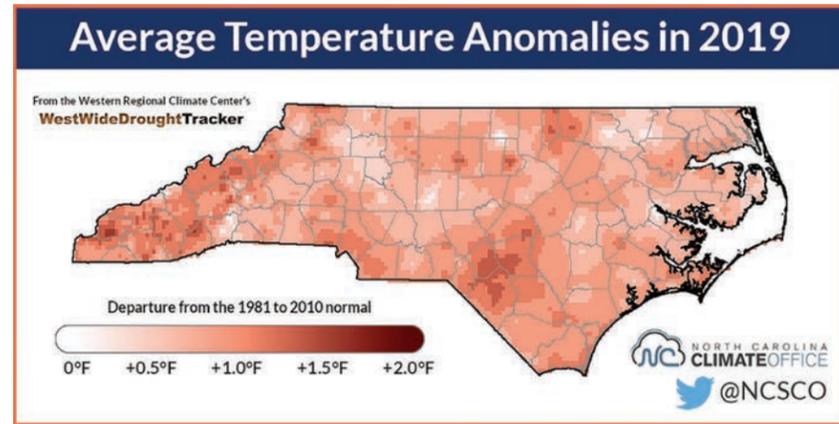
others — May, September, and October — all ranked among the top-five warmest.

That early-summer onset and early-fall persistence of heat and humidity were ultimately among the most memorable parts of the year, and they helped make it such a warm one.

A stubborn subtropical high-pressure system made our weather so hot and humid during that time, but much earlier similar weather systems also had set up off our coast and given us a warm finish to the winter.

The statewide average mean temperature of 61.22°F last year edged out the 61.08°F average from 1990, but crucially, it was 2.7 degrees warmer than the 1901 to 2000 average temperature of 58.5°F.

And it wasn't just our mean



• **TOP:** THE STATEWIDE AVERAGE MEAN TEMPERATURE IN 2019 WAS 2.7 DEGREES WARMER THAN THE 1901-TO-2000 AVERAGE TEMPERATURE. • **BOTTOM:** THE CLIMATE SYSTEM IS MORE SENSITIVE TO WARMING NIGHTTIME TEMPERATURES, AND N.C.'S LOWS HAVE CLIMBED IN RECENT YEARS.

temperatures. 2019 was also our record warmest year based on *average minimum temperatures* — each of *those* warmest years coming in the past five years — and 2019 also was our fifth-warmest year based on *average maximum temperatures*.

IS THERE A WARMING TREND IN NORTH CAROLINA?

In the past 30 years, North Carolina has recorded each of its five warmest years on record — along with 10 of its top 30 warmest years.

Over that same time, we have recorded *zero* of our 30 coolest years on record. The last year that cold was 1988 — our 15th-coolest year — when Phil Collins was on top of the Billboard pop charts and the elder George Bush had just won the White House.

The '80s also was a decade with several extreme cold events, including the state's infamous "Coldest Day" in January of 1985, when many sites set their all-time record lows, and the Christmas blizzard in 1989 at the coast, which blew through with sub-zero temperatures following it.

Similar atmospheric setups have brought

some cold weather since then, but we haven't approached those record lows. In fact, record lows are getting harder to come by. In 2019, 881 daily maximum temperatures broke or tied records across North Carolina, which was almost four times the number of daily minimum temperatures that broke or tied records in the state.

That's another way of showing that it's been more warm than cool recently, and it's one sign that North Carolina is experiencing the consequences of a warming planet. Essentially, the climate system is more sensitive to warming nighttime temps, and we see the dominant trend in our nighttime lows — readings that have consistently pushed some of our recent warm years into the top 10.

WHAT DO WE KNOW ABOUT 2020 SO FAR?

We began this year the same way we ended last year — with overall warm weather. January and February were each the 11th-warmest out of the past 126 years, and March was our fifth-warmest on record statewide.

The same large-scale, high-pressure system that made for so many warm months in 2019 was also at play this winter and early spring. However, that pattern relaxed in April, which had near-normal temperatures on average.

When comparing the first four months of the year *only*, 2020 ranks as the fourth-warmest on record — trailing 2017, the warmest year at the one-third mark, by a little less than a degree. Our average temperature so far this year is also a full 1.7°F warmer than at the same point last year.

Of course, that's no guarantee that 2020 will top the list of our warmest years as well, especially with several months still to go. But we're off to a warm start, and many of the same trends we've observed in recent years — including the warmth in our nighttime lows — are holding true so far this year.

Continued on page 27

WHAT TO EXPECT FROM CLIMATE CHANGE

PROJECTIONS FROM THE NORTH CAROLINA CLIMATE SCIENCE REPORT

In March, the North Carolina Institute for Climate Studies released the *North Carolina Climate Science Report*, an independent assessment of observed and projected climate. The report provides crucial information about the past, present, and future of climate change.

NC State University's Kenneth Kunkel assembled the team that wrote the report and the Climate Science Advisory Panel that provided scientific oversight. The panel included scientists with national and international reputations.

The panel based its projections for climate change on what the report calls “the *virtual certainty* that greenhouse gas concentrations” will continue to rise. As a result, the panel’s overarching conclusion is that “large changes in North Carolina’s climate, much larger than at any time in the state’s history, are *very likely* by the end of this century.”

KEY CONCLUSIONS

• TEMPERATURE

The most recent 10 years represent the warmest 10-year period on record in North Carolina.

It is *very likely* that North Carolina temperatures will increase substantially in all seasons. Annual average temperature increases relative to the recent climate for North Carolina are projected to be 2°F to 5°F by the middle of this century.

It is *very likely* that the number of warm and very warm nights will increase.

It is *very likely* that summer heat index values will increase because of increases in absolute humidity.

It is *likely* that the number of hot and very hot days will increase.

It is *likely* that the number of cold days (with daytime maximum temperatures below 32°F) will decrease.

• PRECIPITATION

There is no long-term trend in annual total precipitation averaged across the state. However, there is an upward trend in the number of heavy rainfall events (3 inches or more in a day), with 2015 to 2018 having seen the greatest number of events since 1900.

It is *likely* that annual total precipitation for North Carolina will increase.

It is *very likely* that extreme precipitation frequency and intensity in North Carolina will increase due to increases in atmospheric water vapor content.

• SEA LEVEL

Sea level along the northeastern coast of North Carolina has risen about twice as fast as along the southeastern coast, averaging 1.8 inches per decade since 1978 at Duck and 0.9 inches per decade since 1935 at Wilmington.

It is *virtually certain* that sea level along the North Carolina coast will continue to rise due to expansion of ocean water from warming and melting of ice on land, such as the Greenland and Antarctic ice sheets. High-tide flooding is projected to become a nearly daily occurrence by 2100.

• HURRICANES

The intensity of the strongest hurricanes is *likely* to increase with warming, and this could result in stronger hurricanes impacting North Carolina. Confidence in this result is *high* for global hurricane changes but lower for North Carolina specifically.

Heavy precipitation accompanying hurricanes that pass near or over North Carolina is *very likely* to increase, which would in turn increase the potential for freshwater flooding in the state.

There is *low confidence* in predicting future changes in the number of landfalling hurricanes in North Carolina.

• STORMS

It is *likely* that the frequency of severe thunderstorms in North Carolina will increase.

It is *likely* that total snowfall and the number of heavy snowstorms in North Carolina will decrease, but there is *low confidence* in predicting both future changes in the number of winter coastal storms and the number of ice storms in North Carolina.

• FLOODS, DROUGHTS, AND WILDFIRE

It is *virtually certain* that rising sea level and increasing intensity of coastal storms, especially hurricanes, will lead to an increase in storm surge flooding in coastal North Carolina.

It is *likely* that increases in extreme precipitation will lead to increases in inland flooding in North Carolina.

It is *likely* that future severe droughts in North Carolina will be more intense due to higher temperatures leading to increased

evaporation. As a result, it is *likely* that the frequency of climate conditions conducive to wildfires in North Carolina will increase.

• URBAN GROWTH

It is *likely* that future urban growth will increase the magnitude of the urban heat island effect, with stronger warming in North Carolina urban centers.

The full *North Carolina Climate Science Report*: go.ncsu.edu/climate-science-full

The North Carolina Institute for Climate Studies: ncics.org

• WILL SCENES LIKE THIS ONE AT BEECH MOUNTAIN BECOME RARER IF TOTAL SNOWFALL AND THE NUMBER OF HEAVY SNOWSTORMS IN THE STATE DECREASE?

WHAT WILL THIS MEAN FOR FUTURE YEARS?

Even on a warming planet, North Carolina's climate isn't a staircase. There's no guarantee that going forward we will see day-to-day, month-to-month, and year-to-year variability in our weather, and not every year will be warmer than the ones before it. But if you're a gambler, we're stacking the deck with more warm daily temperature records than cool ones. And those warm days and nights add up to warm months, which make for warm years.

There almost certainly will be more record-breakers, based on future global temperature projections. In North Carolina, the climate will warm anywhere from 4°F

to 10°F by the end of the century. The addition of heat-trapping greenhouse gases to the atmosphere over a relatively short time means that warmer years are more likely than cooler ones, which is exactly what we've already seen over the past three decades.

Small changes in these annual averages mean big shifts in our extremes. Our hottest days and nights are getting hotter.

Not every October will feel like August, as it did in 2019, but that's likely to become a more common occurrence, especially as the warmer climate creates more evaporation from the oceans, more condensation in the air, and, overall, a more tropical environment that could infiltrate our springs and falls.

Continued



• BENCHMARKS LIKE “THE WARMEST YEAR ON RECORD” ARE EVIDENCE OF A GLOBAL PHENOMENON THAT ALREADY AFFECTS OUR STATE. NORTH CAROLINA IS MORE PRONE TO EXTREMES OF INTENSE HEAT, HOT NIGHTS, AND HEAVY DOWNPOURS.

Jared Kay/VisitNC.com

Likewise, locations like Raleigh — which is already having more intense and longer heatwaves, according to the *National Climate Assessment* — may see a transition to a warmer climate more similar to Savannah’s than its historically moderate one.

WHY DOES IT MATTER?
First and foremost, heat is a human

health issue. According to the National Weather Service, it is the #1 weather-related killer. And with more extreme temperatures, longer heatwaves, and general socioeconomic disparity, the risks only increase.
More people will be exposed to lethal temperatures. Some of our most sensitive populations in North Carolina lack access to sufficient cooling or live in urban areas

covered in asphalt without access to shade. We also have outdoor laborers on our farms and in construction, who face extreme heat during the day and little relief at night.
Although milder winters and faster-emerging springs could extend the growing season and make our climate more hospitable to crops such as citrus fruits, more intense summer heat will also increase the stress

on crops and make year-to-year yields more unpredictable.
Stone fruits will lack the chilling hours, or cooler temperatures, required for their development. That’s not speculation; it’s a phenomenon that peach farmers in Georgia are already facing. Likewise, the things we grow in North Carolina are accustomed to a specific climate. In addition, with those longer growing

seasons and extended warm periods, we could see the emergence of things we don’t want: more weeds, pests, and invasive species. Warmer weather also provides a more hospitable climate for the bugs that carry vector-borne diseases.

We’re moving rapidly into a different North Carolina than the one we used to know. It is warmer, wetter, and generally more prone to extremes of intense daytime heat, hot nights, and heavy downpours.

Yet, drought and wildfire are also part of North Carolina’s climate, and our state remains susceptible to the same growing extreme we’ve seen on the West Coast.

Benchmarks like “the warmest year on record” don’t just make for coffee-shop small talk. They’re evidence in the case pointing to a global phenomenon that already affects us here, in our own backyard.

READ MORE

For a broad look at what scientists are forecasting for our state’s climate, see “**What to Expect from Climate Change**” on page 26, a selection of key conclusions and projections from the new *North Carolina Climate Science Report*.

- *Coastwatch* on climate change go.ncsu.edu/Coastwatch-climate
- The NC Climate Divisions Dataset go.ncsu.edu/climate-data
- “The Coldest Day Redefined Records” go.ncsu.edu/coldest-day
- “A Coastal White Christmas: Revisiting the 1989 Winter Storm” go.ncsu.edu/1989storm
- “Emission Levels Determine Temperature Rises” go.ncsu.edu/future-climate
- National Climate Assessment go.ncsu.edu/national-climate
- “Chill Hours for Peaches and Other Fruit Even Lower than Last Year” go.ncsu.edu/peaches 📌

COREY DAVIS IS AN APPLIED CLIMATOLOGIST AT THE NORTH CAROLINA STATE CLIMATE OFFICE AND AN NC STATE GRADUATE WITH A BACHELOR’S DEGREE IN METEOROLOGY AND A MASTER’S IN ATMOSPHERIC SCIENCE. BORN IN THE TRIAD AND NOW BASED IN THE TRIANGLE, COREY HAS SPENT HIS LIFE OBSERVING NORTH CAROLINA’S WEATHER — FROM HURRICANES TO HUMIDITY TO THOSE FICKLE SNOW AND ICE STORMS — AND HE NOW WRITES ABOUT IT FOR THE STATE CLIMATE OFFICE’S CLIMATE BLOG: CLIMATE.NCSU.EDU/CLIMATEBLOG.

KATHIE DELLO IS THE STATE CLIMATOLOGIST OF NORTH CAROLINA AND THE DIRECTOR OF THE NORTH CAROLINA STATE CLIMATE OFFICE AT NC STATE UNIVERSITY. SHE IS ORIGINALLY FROM NEW YORK STATE AND MOST RECENTLY SPENT A DECADE IN OREGON, WHERE SHE EARNED HER PH.D. IN ENVIRONMENTAL SCIENCE FROM OREGON STATE UNIVERSITY. KATHIE MOVED TO NORTH CAROLINA LAST YEAR AND LOVES ALL THAT IT HAS TO OFFER: GOOD FOOD, GREEN SPACE, MOUNTAINS, AND THE BEACH.



Shortfin mako, Condor Bank, Azores

Patrick Doll & Kurzflüssen/CC BY-SA 3.0



Iana Nimz/NOAA

Tiger shark versus albatross

SHARK FACTS THAT MIGHT SURPRISE YOU

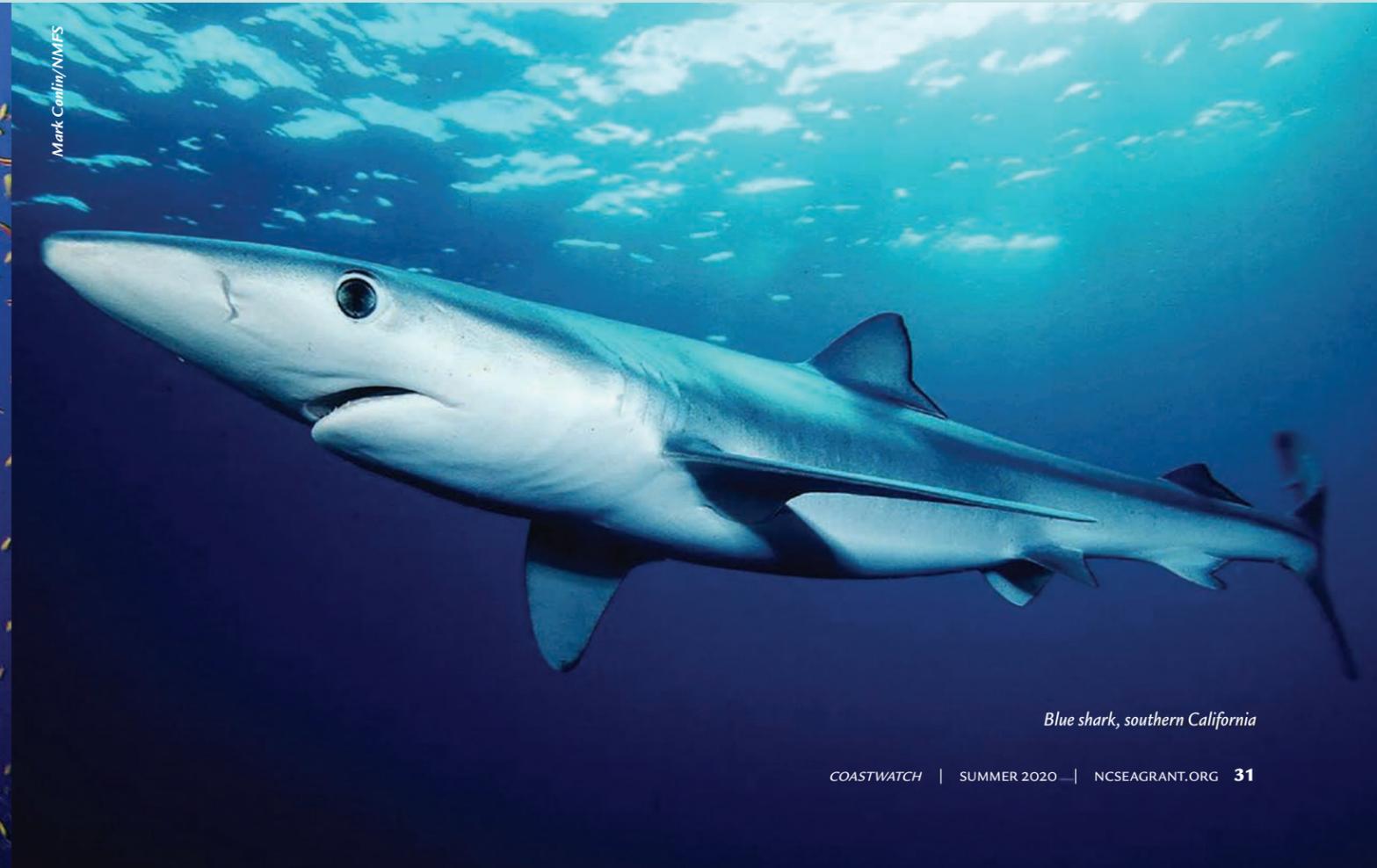
FOR DECADES, READERS OF COASTWATCH HAVE BEEN HERE'S A COLLECTION OF TIDBITS FROM OUR PARTNERS AT NOAA

DEVOURING CONTENT ABOUT NORTH CAROLINA'S SHARKS. THAT INCLUDES INFORMATION ABOUT SHARKS AROUND THE GLOBE.



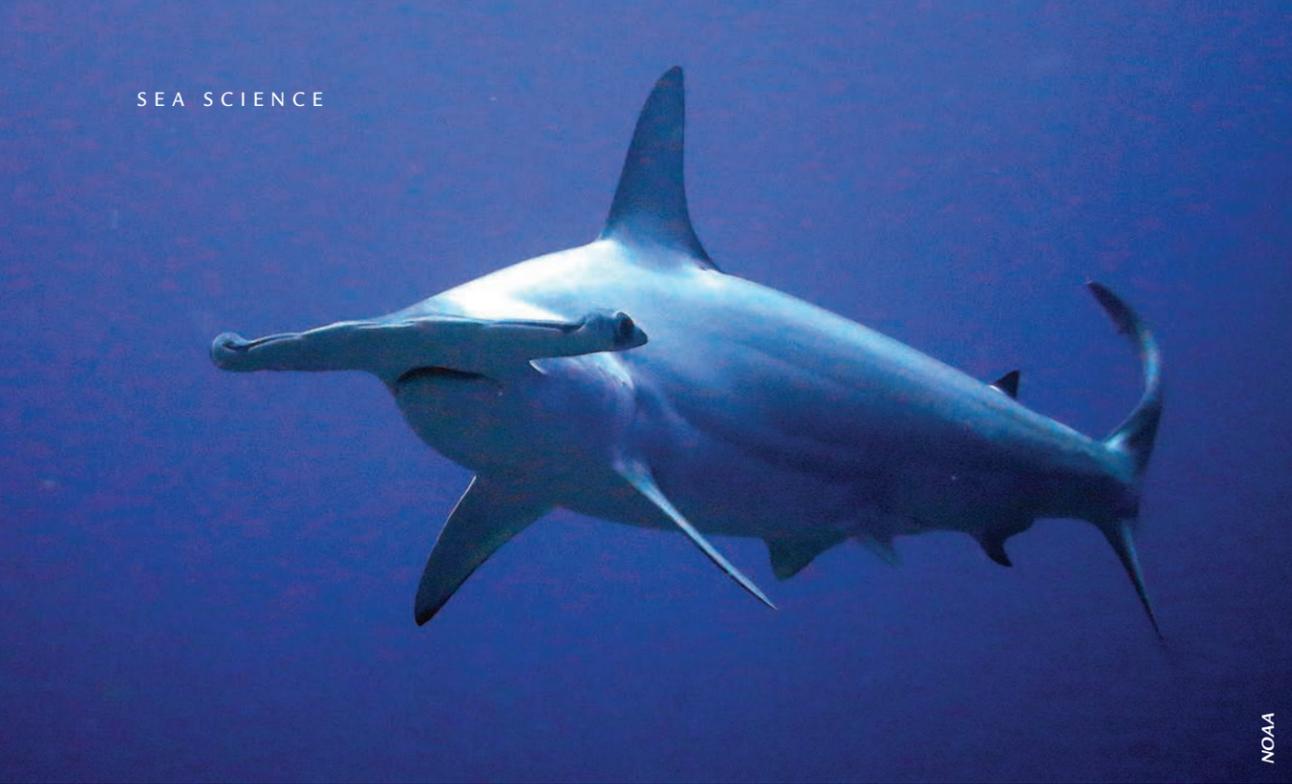
Kelvin Corospe/NOAA

Grey reef sharks near Jarvis Island, Pacific Remote Island Areas Marine National Monument



Mark Conlin/NMFS

Blue shark, southern California



NOAA



NOAA/NEFSC



NOAA

TOP ROW: • A scalloped hammerhead (left), the green eye of a night shark (middle), and the sandpaper skin of a sandbar shark. • BOTTOM ROW: A blacknose shark (left) and the largest fish in the ocean, the whale shark (right).

1. Sharks don't have bones. Sharks use their gills to filter oxygen from the water. They are a special type of fish known "elasmobranch," which translates as "fish made of cartilaginous tissues" — the clear gristly stuff that your ears and nose tip are made of. This category of fish also includes rays, sawfish, and skates. Their cartilaginous skeletons are much lighter than true bone, and their large livers are full of low-density oils, helping them to be buoyant.

Even though sharks don't have bones, they still can fossilize. As most sharks age, they deposit calcium salts in their skeletal cartilage to strengthen it. The dried jaws of a shark feel heavy and solid, much like bone. These same minerals allow most shark skeletal systems to fossilize quite nicely. The teeth have enamel, so they fossilize, too.

2. Most sharks have good eyesight. Most sharks have fantastic night vision, and they can see colors. The back of sharks' eyeballs have a reflective layer of tissue called a tapetum, which helps sharks see extremely well with little light.

3. Sharks have special electroreceptor organs. Sharks have small black spots near the nose, eyes, and mouth. These spots are the ampullae of Lorenzini — special electroreceptor organs that allow the shark to sense electromagnetic fields and temperature shifts in the ocean.

4. Shark skin feels like sandpaper. Shark skin feels exactly like sandpaper, because it is made up of tiny teeth-like structures called placoid scales, also known as dermal denticles. These scales point towards the tail and help reduce friction from surrounding water as sharks swim.

5. Sharks can go into a trance. When you flip a shark upside down, it enters a trance-like state called "tonic immobility." This is why you often see sawfish flipped over while NOAA scientists are working on them in the water.

6. Sharks have been around a very long time. Based on fossil scales found in Australia and the United States, scientists hypothesize sharks first appeared in the ocean around 455 million years ago.

7. Scientists age sharks by counting the rings on their vertebrae. Shark vertebrae contain concentric pairs of opaque and translucent bands. Scientists can count band pairs like rings on a tree and assign ages to sharks based on the count. However, researchers must study each species and size class to determine how often the band pairs are deposited, because the deposition rate may change over time.

8. Blue sharks are really blue. The blue shark



NOAA



NOAA

displays a brilliant blue on the upper portion of its body and is normally snowy white beneath. The mako and porbeagle sharks also exhibit a blue coloration, but not nearly as strikingly as a blue shark. Most sharks are brown, olive, or gray.

9. Each whale shark's spot pattern is as unique as a fingerprint. Whale sharks are the biggest fish in the ocean. They can grow to 40 feet — and weigh as much as 40 tons, by some estimates. Basking sharks are the world's second largest

fish, growing to as long as 32 feet and weighing in at more than five tons.

10. Some species of shark have a spiracle that allows them to pull water into their respiratory system while at rest. Most sharks have to keep swimming to pump water over their gills. A shark's spiracle is located just behind the eyes and supplies oxygen directly to the eyes and brain. Bottom dwelling sharks, like angel sharks and nurse sharks, use this extra respiratory organ to breathe while at rest on the seafloor. Sharks

also use the spiracle for respiration when eating.

11. Not all sharks have the same teeth. Mako sharks have very pointed teeth, while white sharks have triangular, serrated teeth. Each leave a unique, tell-tale mark on their prey. A sandbar shark will have around 35,000 teeth over the course of its lifetime.

12. Different shark species reproduce in different ways. Sharks exhibit a great diversity in how they reproduce. There are oviparous

(egg-laying) and viviparous (live-bearing) species of shark. Oviparous species lay eggs that develop and hatch outside the mother's body with no parental care after the eggs are laid. 🐠

• [Want more on sharks?](https://www.noaa.gov/education/outreach-and-communication/12-shark-facts-that-may-surprise-you)
[go.ncsu.edu/Coastwatch-sharks](https://www.noaa.gov/education/outreach-and-communication/12-shark-facts-that-may-surprise-you)

Adapted from NOAA's "12 Shark Facts that May Surprise You"

Hatteras Island Students Tackle Coastal Change

BY EVAN FERGUSON

Evan Ferguson is a 30-year resident of Cape Hatteras, where she teaches at Cape Hatteras Secondary School. She is a mother of two boys who love to fish, surf, and hunt with their father, a tugboat engineer. She worked with North Carolina Sea Grant on the Cape Shark Project and celebrates the state's coast, fisheries, and unique culture. Before the COVID-19 outbreak, her students conducted the "Student Perspectives on Coastal Change" study, which she discussed at the North Carolina Coastal Conference and writes about here.

HATTERAS ISLAND'S YOUTH ARE STRONG AND RESILIENT. "SALTY," SOME MIGHT SAY. THEY HAVE GROWN UP ON A 70-MILE-LONG BARRIER ISLAND ON THE OUTER BANKS WITH FLOODING, WIND, POWER OUTAGES, AND WEATHER WOES.

Students at Cape Hatteras Secondary School of Coastal Studies are noticing, in particular, that storms and weather are becoming more frequent and more intense. Hurricane Dorian, which hit in September 2019, severely damaged parts of our island and one-third of our school. Students and staff missed nine days of instruction and then had to adapt to shared classrooms and no gymnasiums for months.

Two additional unnamed storms battered our coast in October and November, stranding residents on and off the island, due to Highway 12's closure from ocean tide overwash. Subsequently, students and staff were also unable to attend school during those weather events.

Students at CHSSCS are organizing to understand these more frequent weather events and advocate for change. A group of 11th and 12th graders in Career and Technical Education Advanced Studies decided to conduct a study called "Student Perspectives on Coastal Change."

The group concluded that a paper survey and focus groups would be the most effective way to collect data from the student body — 358 students in grades 6 through 12. Almost 70% of the student body completed and returned the survey.

From the survey, the group set out to learn general opinions on several topics regarding coastal change.

What They Found

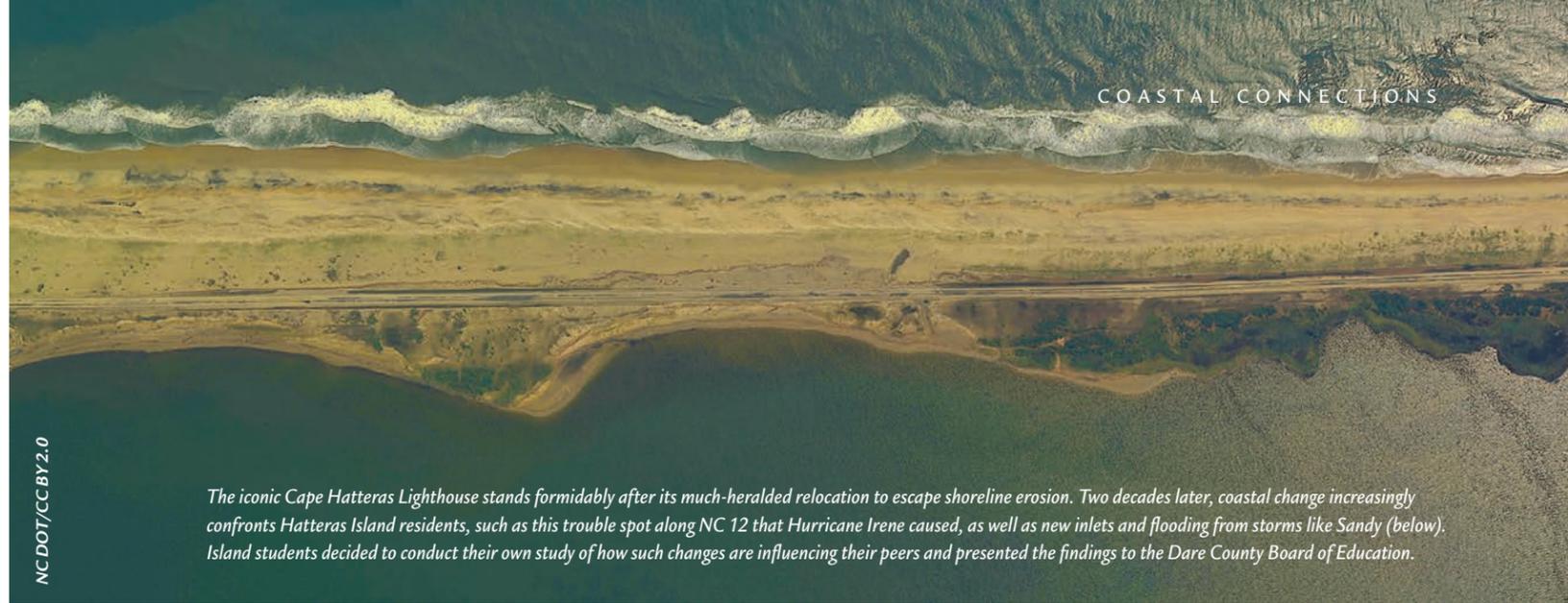
Do students believe in climate change, and do they believe climate change is to blame for our increased storm activity and floods? Ninety-five percent of CHSSCS students surveyed said they believe in climate change, and 89% said that climate change was to blame for increased flooding on our island.

How has increased flooding affected our students? Forty-two percent of those surveyed said that they had experienced flooding in their homes, and 24% had been displaced from their homes due to flooding.

Perhaps most importantly, students stated *that storms and weather events cause them significant stress, and they worry about loss of home, money, or having to move away.* Ninety-five percent of students believe that roads, bridges, and buildings will have to change in order for them to continue living here.



Division of Tourism/VisitNC.com



NC DOT/CC BY 2.0

The iconic Cape Hatteras Lighthouse stands formidably after its much-heralded relocation to escape shoreline erosion. Two decades later, coastal change increasingly confronts Hatteras Island residents, such as this trouble spot along NC 12 that Hurricane Irene caused, as well as new inlets and flooding from storms like Sandy (below). Island students decided to conduct their own study of how such changes are influencing their peers and presented the findings to the Dare County Board of Education.



NC DOT/CC BY 2.0



Evan Ferguson

It is critical to understand how these weather events affect our students, because such concerns and stressors can impact attendance, behavior, and academic performance.

Diving Deeper

The group administering the survey asked students who had responded whether they would be willing to participate in a focus group, and 28% agreed to do so. Using a variety of criteria, 15 students were chosen from grades 6 to 8 and grades 9 to 12 to participate.

In the focus group, students talked about how to combat problems resulting from the increase in flooding. They mentioned stricter building codes, including hurricane-proof dwellings, and added that they did not believe

that anyone should be allowed to build on the ocean or sound fronts.

The group discussed Highway 12 and how it seems like lost dunes are constantly being pushed into place by heavy machinery. Students asked why sea oats were not being planted on the dunes anymore, since sea oats act as a stabilizing force.

During the conversation, students indicated certain thin strips of the island that frequently wash over and passionately advocated for allowing the ocean and sound to flow over such places on the island. They appreciated the value of natural inlets, which permit this water flow and presumably relieve stress on other parts of the island, where land would thicken and grow. Over natural inlets, the state could build small bridges or causeways, similar to the Florida Keys.

Students also discussed federal and state storm assistance, as well as insurance claims for locals and non-resident homeowners.

How Long Will the Community Survive?

The final question: *How long do you think our community has left to live on this island?*

The middle school group had a bleak outlook, replying 20 years or less.

High school students did not think they would live to see the end of our island, responding *not in my lifetime or around 100 years.*

Students also said these views would influence their decisions on where to settle after high school. Most planned to move away from the island.

How does this impact the future workforce of Hatteras Island? What will happen

to our community's unique culture, traditions, and resilient spirit if those who were born and grew up here move away?

Questions remain. However, students also realized that they have the power to advocate as the next generation of change-makers on our island. They met up with a local county commissioner to address concerns and brainstorm solutions, and they already presented their findings to the Dare County Board of Education in February.

The impacts of climate change on our coast continue to be important for all those involved, and students may indeed be the driving force for adapting to climate change on Hatteras Island. 📍

• [more from Coastwatch on climate change: go.ncsu.edu/Coastwatch-climate](https://go.ncsu.edu/Coastwatch-climate)



Spicy Crab Cakes



Broiled Sea Bass with Dill Sauce



Shrimp-and-Crab-Stuffed Potatoes

How to Freeze Your Fresh North Carolina Seafood

BY VANDA LEWIS AND BARRY NASH

Seafood is an excellent source of flavorful, nutritious protein any time of the year.

If you're limiting shopping trips during the COVID-19 pandemic, consider freezing some of your fresh seafood purchases for later enjoyment.

"I often use fresh North Carolina seafood immediately to test recipes for our Mariner's Menu blog, but I also freeze some that same day to test more recipes later," says North Carolina Sea Grant's Vanda Lewis.

FINFISH

Fish have varying amounts of fat content depending on the species. The leanest fish, such as flounder, have a white- or light-colored flesh, while fattier fish, such as salmon or mackerel, usually have a darker hue.

The list below shows the average total fat content in a three-ounce serving of common finfish:

- **High Fat** (10 grams or greater)
Herring, mackerel, salmon (Atlantic, coho, sockeye, chinook)
- **Medium Fat** (5 to 10 grams)
Bluefish, catfish, swordfish
- **Low Fat** (2 to 5 grams)
Halibut, mussels, oysters, ocean perch, salmon (chum, pink)
- **Very Low Fat** (less than 2 grams)
Crab, clams, flounder, mahi mahi, scallops, shrimp, tuna

The fat in finfish tends to be polyunsaturated. When they react with oxygen, these fats will degrade and create off-odors and flavors. This process can happen even in frozen storage.

To maintain quality, finfish can be pretreated before freezing and frozen storage. We recommend a lemon-gelatin glaze that was developed by extension specialists with the NC State University Seafood Laboratory.

Just measure 1/4 cup of bottled lemon juice into a pint container and fill the rest of the container with water. Dissolve one packet of unflavored gelatin in 1/2 cup of this mixture. Heat the remaining liquid to boiling, and then stir the dissolved gelatin mixture into the boiling liquid. Cool to room temperature.

Dip the fillet or steak in the liquid. Lift it out and allow to drain for a few seconds.

Wrap the fish tightly in a heavy, protective plastic film, such as Saran Wrap or similar heavy film. Freeze quickly.

Fish frozen with a gelatin glaze will remain fresh longer than those with no glaze.

SHELLFISH

Clams and oysters are best if frozen in their shells, which makes them easier to shuck with no loss of juice. Thoroughly wash the shells and place live shellfish in moisture-vapor-resistant bags if you have plenty of freezer space to accommodate them.

If you're tight on freezer space, however, you can shuck the shellfish. First, wash clams and oysters, discarding any shellfish that have died. These you can identify by gently tapping shells that are open slightly. If they do not close when tapped, they are likely dead. Shuck the shellfish into a strainer (save the liquid, known as liquor) and remove any pieces of shell.

If necessary, the clams and oysters can be rinsed to remove any sand. Place clams and oysters and their liquor in a plastic container or freezer bag (leaving 1/2-inch headspace), seal, and freeze. If there is not enough liquor to fill the container, use ice water.

SHRIMP

Remove the head from whole shrimp, but leave the shell on. Place the shrimp in a freezer container and cover them with ice water.

Leave enough headspace for the water to expand when frozen. Use small or medium-size containers so the shrimp will freeze more quickly.

Avoid using freezer bags, because the shrimp tails can puncture them, causing leaks.

PICKED CRABMEAT

You should freeze cooked, picked crabmeat in covered, airtight containers or in heavy-duty freezer bags. Massage the bag to force as much air out of it before placing the meat in a freezer. Another way to extend the shelf life of cooked crabmeat is to freeze it in preparations, such as crab cakes or casseroles. Blending cooked crabmeat with non-seafood ingredients tends to protect its tender texture by keeping it from becoming stringy.

NEW RECIPES

Many consumers love seafood, but they tend to enjoy it at restaurants.

North Carolina Sea Grant's research shows that consumers would purchase

more local seafood to eat at home if they were confident in their cooking skills. Survey respondents indicated that *recipes* would enrich their experience cooking with fresh seafood at home.

To that end, Sea Grant has been adding new recipes online to MarinersMenu.org. You can now choose from more than 200 recipes, including appetizers and entrees that feature crab, clams, finfish, oysters, scallops, and shrimp.

These recipes were developed and crafted by a former Sea Grant extension educator and her hand-picked volunteers using seafood harvested by North Carolina fishermen. Preparations that did not score a four or five on a five-point scale were reformulated to correct problems with flavor, texture, and appearance.

Where can I buy fresh North Carolina seafood?

- Brunswick County:
BrunswickCatch.com/retailers-and-dealers
- Carteret County:
CarteretCatch.com/retail-markets
- Inland areas:
NCcatch.org/pages/market-lists

For amazing seafood recipes...turn the page. 📖

Summertime Sumptuousness

VANDA LEWIS AND JOYCE TAYLOR

MARINER'S MENU, ONE OF THE FASTEST GROWING SITES FOR SEAFOOD RECIPES ON THE WEB, FEATURES BLOGGER AND PHOTOGRAPHER VANDA LEWIS'S POSTS OF RECIPES THE LATE JOYCE TAYLOR DEVELOPED. LEWIS SELECTED THESE SUMMERTIME FAVORITES. MarinersMenu.org



Fresh Mahi-Mahi Bisque

Vanda Lewis



Honey-Glazed Shrimp

Vanda Lewis



Walnut-Encrusted Snapper

Vanda Lewis

WALNUT-ENCRUSTED SNAPPER

- 1 1/2 pound snapper fillets
- 1/2 cup flour
- 3/4 teaspoon salt

- 1/4 teaspoon freshly ground black pepper
- 1/2 cup milk
- 1 cup toasted French bread crumbs
- 1 cup walnuts, finely chopped
- 2 tablespoons butter, melted

Place flour, salt and pepper in shallow dish (or on wax paper). Place milk in shallow dish. Combine crumbs and walnuts in another dish.

Dredge fish lightly in flour, then dip in milk. Dredge in crumb-walnut mixture.

Place fish in a lightly greased baking dish and brush lightly with butter, so that nuts are not moved.

Bake at 450°F until outside is lightly browned and crispy, about 15 minutes.

FRESH MAHI-MAHI BISQUE

- 1 pound flaked mahi-mahi (begin with 1 1/2 pounds raw)
- 3 tablespoons butter
- 2 tablespoons onion, finely chopped
- 2 tablespoons celery, finely chopped
- 3 tablespoons flour
- 1 teaspoon salt
- 1/2 teaspoon freshly ground white pepper
- 1 tablespoon tomato paste
- 2 1/2 cups whole milk
- 1 cup heavy whipping cream
- 2 tablespoons sherry wine
- 3 tablespoons fresh parsley, finely chopped

Poach fish in lightly salted water. Flake and set aside.

In medium saucepan, melt butter. Add onion and celery and sauté lightly. Blend in flour, salt, pepper, and tomato paste and cook for 2 minutes.

Gradually whisk in milk and cook, stirring constantly, until it thickens.

Add heavy cream, sherry wine, and flaked fish, and heat thoroughly. Do not boil and do not overcook fish. Garnish with fresh parsley.

HONEY-GLAZED SHRIMP

- 1 pound large shrimp, peeled and deveined
- 3 tablespoons honey
- 1/4 cup vegetable oil
- 1/2 tablespoon Dijon mustard
- 1 teaspoon pressed garlic
- 1/4 teaspoon red pepper flakes
- 1/4 teaspoon salt
- 2 tablespoons fresh parsley, chopped
- 1 tablespoon fresh ginger root, minced
- 1 tablespoon fresh lemon juice

In small bowl, combine honey, oil, mustard, garlic, pepper flakes, salt, parsley, and ginger root.

Place shrimp in mixture and marinate in refrigerator 10 minutes.

Broil or grill

about 4 inches

from heat until

done, about 5 to

6 minutes, turning

once. 🍴



EASY GRILLED SOFT-SHELL CRABS

INGREDIENTS:
8 soft-shell crabs
1/2 cup butter, melted
1/2 teaspoon salt
1/2 teaspoon freshly ground black pepper
1/2 teaspoon Tabasco sauce

Combine melted butter, salt, pepper and Tabasco. Let cool.

Brush both sides of crabs with mixture. Place crabs, topside down, over hot coals. Close grill and cook until shell turns bright red on one side, about 2 1/2 to 3 minutes. Turn and repeat on other side.

Serve with tartar sauce, if desired.

Check out our new Mariner's Menu recipe posters!

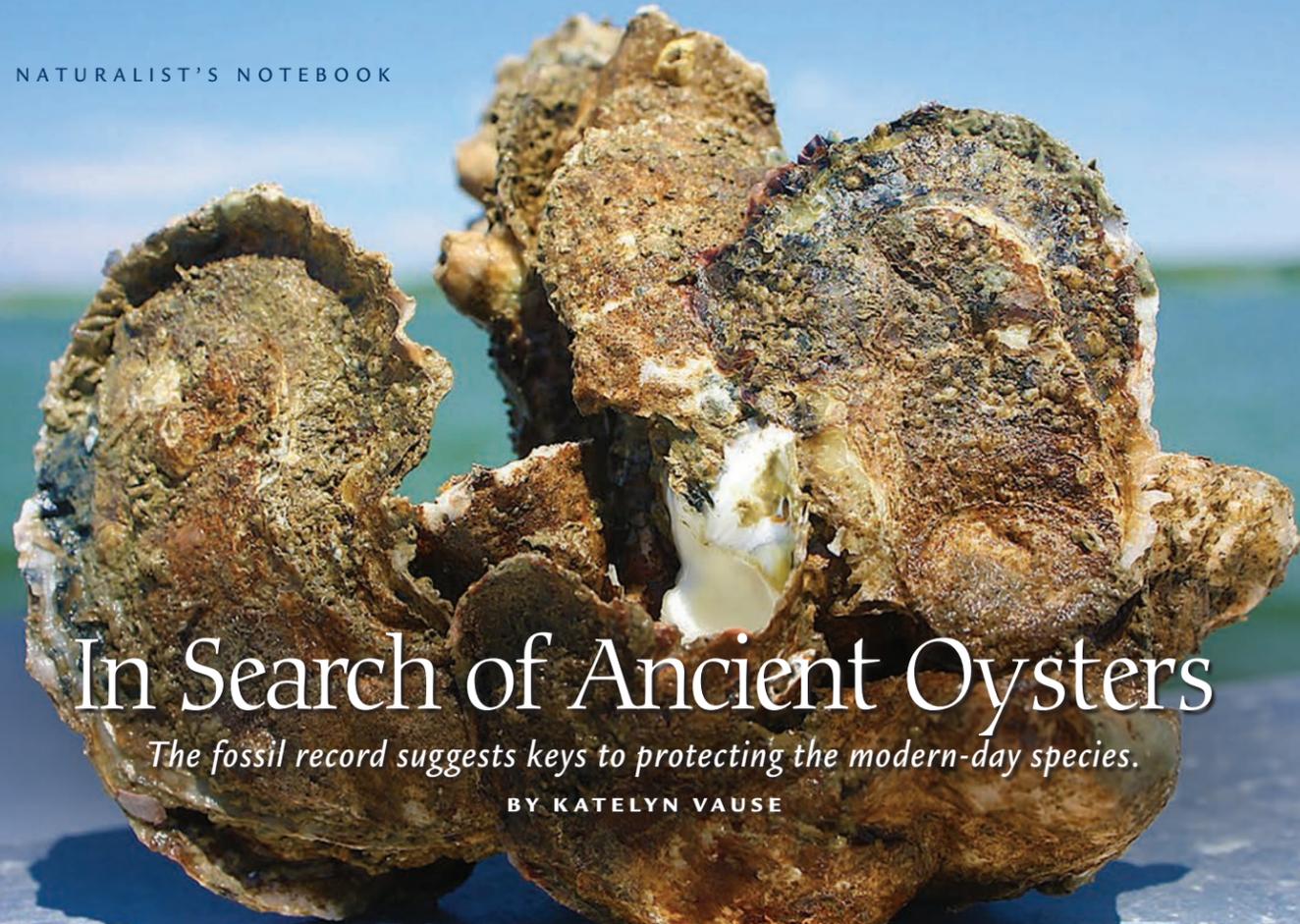
go.ncsu.edu/yummy

Poster design by Hayden Stephens



MarinersMenu.org
#SeaGrantNC
#MarinersMenu





In Search of Ancient Oysters

The fossil record suggests keys to protecting the modern-day species.

BY KATELYN VAUSE

NOAA

Oysters from a feeder stream to the Chesapeake Bay

RESTORED OYSTER REEFS PROVIDE HEALTHY HABITATS AND GREAT PLACES FOR FISHING. ONGOING THREATS TO OYSTERS, SUCH AS DISEASE AND HARVESTING, MEAN THAT UNLESS WE MAKE DELIBERATE EFFORTS TO RESTORE THEM, WE ARE IN DANGER OF LOSING THE BENEFITS OYSTER REEFS PROVIDE.

Oysters are a valuable seafood product, and restoration and conservation efforts have historically focused on protecting juvenile oysters. Mature oysters devote more energy to reproduction than shell growth, and they could be a valuable asset that currently receives inadequate levels of protection. Learning more about oysters of the past, which might have faced fewer challenges, could inform how we think about both juvenile and mature oysters when conceiving new strategies for oyster management.

What They Found and What It Means

Kristopher M. Kusnerik at the University of Florida, Rowan Lockwood at the College of William & Mary, and Amanda N. Grant at

the University of Northern Arizona teamed to gather data from five sites in North Carolina, Maryland, and Virginia. They collected oyster shells from the Ice Age, the colonial era, and today. Then, they analyzed salinity and temperature from all three time periods, as well as oyster-shell height, age, and growth rates.

Of particular note, they found that oysters in the Chesapeake Bay area from the Ice Age grew slower — but they also were larger and lived longer than their colonial-era or modern-day counterparts. The study also revealed that water-nutrient levels were likely lower during the Ice Age, suggesting that the increased rates of oyster growth today by comparison could result from higher nutrient levels.

Other studies have shown that traditionally undisturbed oysters at the Tangier Sound and Elizabeth River in Virginia are larger and more disease resistant. This suggests that, if given the opportunity, Chesapeake Bay oysters also could evolve disease resistance and grow larger.

Kusnerik's team also concluded that although modern oysters in North Carolina's Pamlico Sound grow six to seven times faster than ancient oysters, the short life spans of both ancient and modern oysters in North

Carolina resulted in little to no difference in the parameters of these populations over time. The reasons behind the differences between the Chesapeake Bay oysters and North Carolina's oysters remain unknown.

It's also clear that overharvesting and disease particularly challenge mature female oysters, which, in turn, negatively affects reproduction rates and the overall oyster population.

Based on their findings, Kusnerik, Lockwood, and Grant recommend new harvesting restrictions on mature oysters. Possible solutions include decreasing the harvest total, establishing a maximum size limit, and creating oyster-specific marine protected areas. 📍

- full study: go.ncsu.edu/oyster-study
- the "Oyster Culture" issue of *Coastwatch*: go.ncsu.edu/oyster-culture

HookLineScience.com originally published this story.

Katelyn Vause is a contributing editor for *Coastwatch*. She recently graduated with a master's degree in English from NC State University.

Rusty Hudson & the Hudson, Timmons, & Stone families



Blacktip Sharks, Historic Dock Photos, and Hand-Crank Electrofishing

BY SCOTT BAKER AND SARA MIRABILIO

from the popular blog series on the latest science for anglers

WHAT ATTRACTS BLACKTIP SHARKS TO FISHING PIERS?

Research shows the number of anglers makes a difference.

Prime angling from fishing piers is upon us. But, spring and summer also usher in the

increased presence of larger sharks off North Carolina's beaches. Among them: blacktips. For those who would rather not mess with catching a shark — and who would rather keep their bait — some factors could influence the probability of encountering one.

• Research Need

Fishing piers and other manmade coastal structures often become a hotspot for various species of fish. The blacktip shark is one of the most common shark species people spot at fishing piers on the North Carolina and South Carolina coasts. *Continued*

Atlantic blacktip sharks

NOAA

Anglers often have seen blacktip sharks feeding off their fish scraps, but researchers have believed these sharks frequent piers based on additional factors, notably tides and temperatures, as well as other environmental cues.

However, can the presence of anglers also affect where and why blacktip sharks gather?

If such patterns exist, revealing them could help to clarify the shark's behaviors and help to design measures to minimize chances of incidental capture and injury at piers, especially since the current population trend for blacktip sharks is unknown.

• *What did they study?*

Researchers from Coastal Carolina University and the University of Miami collected data on the presence of blacktip sharks along the northeast coast of South Carolina. They captured and tagged 12 of the species with transmitters and monitored their movements between five different piers from July to November in 2016. They repeated the process with four of the five piers from May to November of the following year.

• *What did they find?*

The team detected 9 of the 12 tagged sharks post-release but detected a majority of the sharks only infrequently at piers.

The presence of blacktip sharks at fishing piers increased during the day with increasing

tidal height, barometric pressure, and angler count.

Wind speed and water turbidity did not appear to affect the presence of blacktip sharks.

Most of the blacktip sharks remained at the same pier where researchers originally had tagged them. The sharks made a higher number of visits and showed more movement around South Carolina's Pier 14, 2nd Avenue Pier, and MBSP Pier.

• *So what?*

Although this study drew on a very small sample size, it suggests that the availability of food and prey may be influencing the behavior of blacktip sharks at piers. Fish scraps and bait from anglers provide food sources for these sharks and attract other fish, which in turn also become prey for blacktip sharks. Such considerations can help inform management of coastal fish populations and fisheries.

full study: go.ncsu.edu/blacktips

— Summary compiled by Chloe Tenn

WHAT WILL HISTORIC DOCK PHOTOS REVEAL ABOUT FISHERIES?

Citizen scientists will help to fill in the gaps.

FISHstory (rhymes with "history"), the South Atlantic Fishery Management Council's citizen science project, will take participants

back in time to the docks of Daytona Beach. The project plans to train volunteers to identify and count fish in historic fishing photos.

• *Research Need*

Knowing the species, number, and size of fish caught over time is critical in order to understand the health of a fish population. In particular, the diversity and length of these fish can be important for estimates of stock productivity.

However, there is little information prior to the 1970s available in the South Atlantic, from North Carolina through the Florida Keys, on overall catch or size composition in the charter and head boat fisheries. Historic dock photos, an untapped source of this important biological data, might help to recreate this data.

• *What are they studying?*

The FISHstory team is collaborating with Rusty Hudson, a retired fisherman, who has provided over 1,300 historic dock photos from his family's head boat fleet in Daytona Beach from the 1940s to 1970s. Due to the large number of photos, the South Atlantic Fishery Management Council is turning to citizen scientists to help gather data.

FISHstory will gather information on species composition and length. Using Zooniverse, a crowdsourcing platform that

hosts citizen science projects, volunteers will identify and count the fish and anglers in the photos. Tutorials and training materials are available, so even people unfamiliar with fish can help collect data.

The FISHstory team also will develop a method to estimate fish lengths from the historic photos. The method will be tested on king mackerel, and, if successful, can be adapted to determine the lengths of other species, too.

• *What could they find?*

The project will help us better understand if there were changes in overall catches or seasonality of catches from the docks in Daytona during the 40s, 50s, 60s, and 70s that we can compare with data from modern catch monitoring programs.

Additionally, counting the anglers in these photos could provide a rough estimate of

fishing effort, and estimating fish lengths also might provide insight on changes in the size of fish caught over time.

• *So what?*

Data gathered from this citizen science project exploring fisheries of the past could help us better understand the health of fish stocks today and in the future. If the FISHstory pilot project is successful, it could lead to the study of other fishing fleets throughout the South Atlantic and elsewhere.

• *Anything else?*

The project needs citizen scientists. Do you want to test your fish identification knowledge? Reach out to us at allie.iberle@safmc.net or julia.byrd@safmc.net to learn more.

safmc.net/Citizen-Science-Program/

— Summary compiled by Allie Iberle and Julia Byrd

DOES HAND-CRANK ELECTROFISHING HELP BATTLE INVASIVE CATFISH?

Research suggests environmental factors play a larger role.

In February, in conjunction with the American Fisheries Society's Southern Division Annual Meeting in Little Rock, the third International Catfish Symposium focused on communicating catfish science. The symposium included research on "hand-crank electrofishing" and its impact on nonnative catfish.

Hand-crank electrofishing (HCE) — or telephoning — is a recreational fishing technique that has been legal in North Carolina since 1985. As the name suggests, HCE involves using a telephone generator to produce low-voltage alternating current by turning a hand crank, which stuns catfish.

Continued



Rusty Hudson & the Hudson, Timmons, & Stone families

What can we learn from historic dock photos, like this one from Daytona Beach in 1967?

Nonnative catfish are voracious eaters and can cause harm to food webs. As they have with many invasive fish, resource managers have been trying to get anglers to keep them and eat them.

• **Research Need**

Flathead catfish, blue catfish, and channel catfish have invaded North Carolina's rivers, and catfish anglers have enjoyed fishing these species for their trophy sizes. However, the decline of populations of native fish species in our rivers, in fact, is partially due to the invasion of nonnative species of catfish.

North Carolina remains the only state to allow HCE as a method for dealing with the catfish invasion. Anglers are concerned, though, that HCE might remove too many trophy-sized catches and disrupt the biting patterns of catfish.

• **What did they study?**

Researchers focused on three nonnative catfish species to understand better whether they displayed differences from other fish populations when anglers used HCE.

Scientists studied established catfish populations in the Cape Fear, Black, Lumber, and Waccamaw rivers of southeastern North Carolina, and they compared abundance, size, weight, age, growth, and mortality of nonnative catfish. The research team used a combination of low- and high-frequency electrofishing to collect catfish.

• **What did they find?**

Researchers did find differences in several aspects of the populations of flathead catfish, blue catfish, and channel catfish in river reaches where HCE was allowed. These differences, however, were likely attributable to the variety and numbers of nonnative catfish, as well as other fishes in the river, in addition to environmental factors that include water depth and bottom structures.

With data from the project, researchers and policymakers can develop alternative techniques to limit the population growth of invasive catfish. In particular, the findings could shed light on *if* and *how* to modify and use HCE for ecological reasons.

• **What else did they find?**

The team found that hand-crank electrofishing does not significantly affect catfish populations. However, overall



The formidable blue catfish

U.S. Fish & Wildlife Service

angler harvests *do* make an impact. A better understanding of the catfish sizes and species that anglers target and harvest would inform the management of nonnative catfish.

full study: go.ncsu.edu/electrofish

— Summary compiled by Chloe Tenn

WHO DO ANGLERS TRUST?

It depends on whether they want information about fisheries — or about what they should buy.

• **Research Need**

Today, we are squarely in the Information Age. I know because I Googled it to confirm. Never before has so much information been available to the public. Recently, I was astounded to read that 90% of the world's information has been created in the last two years!

But with this much information available, people obviously are often asking similar questions and getting different answers from various sources.

If you recall, this is a subject of great interest to us — and one of the reasons we conducted our survey with anglers in 2017. It turns out, many other organizations and businesses that provide goods, services, and information to anglers are also interested in angler opinions about which sources they trust.

With the constant barrage of information about fisheries newly available to anglers — from stock assessments to online fishing forums — how do anglers actually prefer to get their information?

• **What did they study?**

Research and marketing firms often use voluntary surveys to gauge public opinion and glean information about consumer habits and trends. Southwick Associates, for instance, specializes in the hunting, shooting, sportfishing, and outdoor recreation markets. The firm runs *anglersurvey.com*, a survey distributed every two months to anglers across the country to collect information about fishing behavior and purchases.

The March-April 2019 edition of the survey included two additional questions to determine who anglers trust for information about fisheries and for advice on fishing purchases.

• **What did they find?**

According to the survey results, anglers in the United States consider state or federal wildlife agencies, fisheries scientists, and other fishermen (through personal communications, forums, social media, and other avenues) to be the most credible sources of information related to fisheries. Speaking as a fisheries scientist who works for a university program, I am happy to see that anglers include state and federal agency information as among the most credible sources for fisheries information.

Those same anglers consider other fishermen, guides and outfitters, and professional and competitive tournament anglers to be the top sources of information when considering their next fishing purchases.

Interestingly, the only group to make the top three for both questions was “other fishermen.”

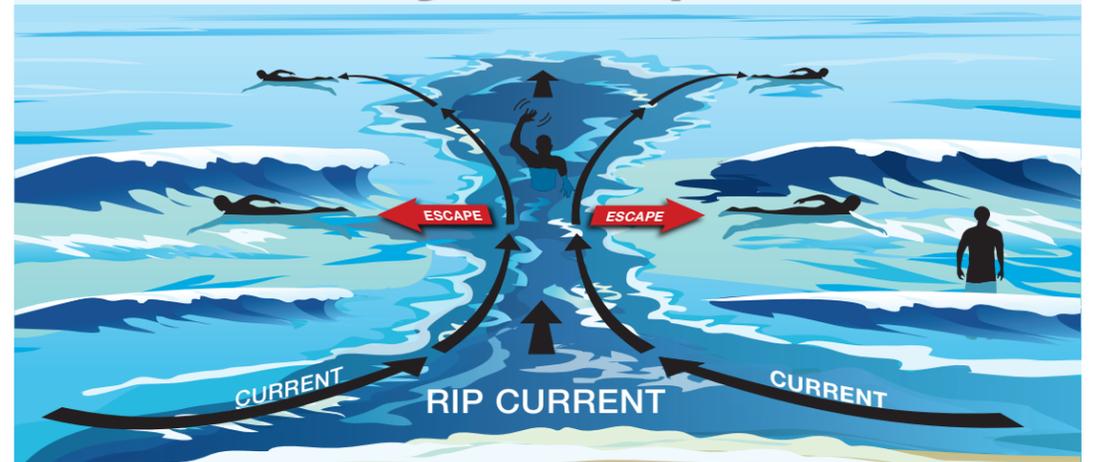
AnglerSurvey.com

— Summary by Scott Baker

HookLineScience.com

Detach this page and stick it to your refrigerator at the beach house, post it on the back door of your coastal rental cottage, pack it in your beach bag, use it as a bookmark, or stow it with the suntan lotion and umbrellas.

RIP CURRENTS
Know your options



Rip currents are powerful currents of water moving away from shore. They can sweep even the strongest swimmer away from shore. If at all possible, swim near a lifeguard.

IF CAUGHT IN A RIP CURRENT

- ◆ Relax, rip currents don't pull you under.
- ◆ Don't swim against the current.
- ◆ Swim out of the current, then to shore.
- ◆ If you can't escape, float or tread water.
- ◆ If you need help, yell or wave for assistance.

SAFETY

- ◆ Know how to swim.
- ◆ Never swim alone.
- ◆ If in doubt, don't go out.
- ◆ Swim near a lifeguard.

More information about rip currents can be found at the following websites:

weather.gov/safety/ripcurrent/
usla.org



RIP CURRENTS: KNOW YOUR OPTIONS

North Carolina Sea Grant joins the National Weather Service, oceanfront communities, and other partners to highlight surf-zone safety throughout the year. Learn more, and find links to order signs and magnets at ncseagrant.ncsu.edu/ripcurrents



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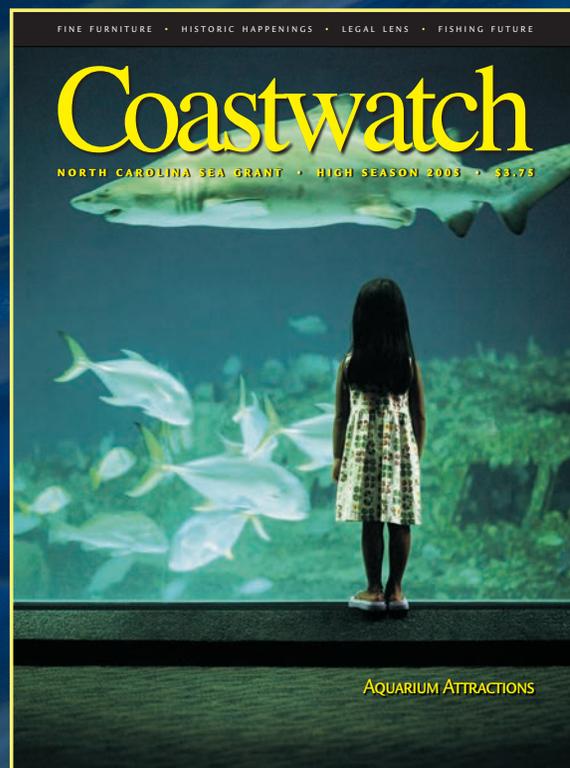
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