

COVID-19 and Hurricanes • Overheating Turtle Eggs • Shark Bait • When Science Needs You

Coastwatch

NORTH CAROLINA SEA GRANT • AUTUMN • 2020 • ISSUE 3 • \$6.95



THE HORSESHOE CRAB CONNECTION
An Ancient Sea Creature and a Safe COVID-19 Vaccine

Shifting Seasons, Ongoing Challenges, New Opportunities

I hope that you and your families continue to stay healthy during these difficult times. Our continuing thanks go out to health care and teacher heroes — including those in health care facilities, schools, and homes. There are countless other heroes that ensure our communities continue to thrive. We thank all of you as well.

While there is no “new normal” yet that I can find with my 3rd and 5th graders’ schooling from home, I certainly am reminded daily to appreciate the time with family — and I look forward to days when we can all get back together with our extended families, as well as friends and colleagues. I also am reminded daily to practice patience and grace within our home and within our communities, as dealing with continuing uncertainties brings enormous stress for everyone.

It is clear that our great North Carolina Sea Grant team members and partners continue to help meet the needs of our communities with new updates for direct seafood sale opportunities and strong resources on seasonal safety and hurricane preparedness, as well as continuing to provide subject matter and support for online learning. This issue of *Coastwatch*, in fact, will include supplementary online material for educators to use alongside magazine content in their virtual classrooms.

In this issue, you also will learn of new projects we have funded with support from the William R. Kenan Jr. Institute for Engineering, Technology and Science and the N.C. Water Resources Research Institute. These exciting new partnerships include one with North Carolina Health News and Working Narratives/Coastal Youth Media that allows our program to incorporate new audiences and needs related to coastal communities. We welcome these opportunities to continue to strengthen our program’s engagement with, and understanding of, diverse North Carolina communities throughout the coastal regions and related watersheds.

One of the happy constants for us is the ongoing excellence of

student fellows, who are pursuing their research passions and providing actionable information for individuals and communities to improve their environmental and personal health. Our fellows bring significant breadth and depth of subject areas — and Sea Grant benefits from their engagement and commitment. Often these students graduate and become leaders in their field, sometimes even within Sea Grant programs across the nation. It is a pleasure to see their professional growth during and after their time with our program.

I am excited to welcome Eric Herbst, our new coastal aquaculture specialist, as well as congratulate Sarah Spiegler, who will continue with our program and provide her expertise as our new coastal resilience specialist. It is exciting to have Eric and Sarah bring new perspectives and experiences that will strengthen our community service.

In continuing good news, North Carolina Sea Grant hosted an external panel of reviewers in September 2018 to meet federal requirements. We recently were notified that our program not only meets but exceeds required standards of excellence for state programs. Thus, we are federally recertified as a state Sea Grant College Program.

Notably, the panel was very impressed with engagement of our advisory board and their impactful role in providing input to help prioritize needs, make informed decisions, evaluate initiatives, and advocate for the program. The reviewers noted our Sea Grant advisory board as an asset to be recognized as a best management practice. The panel also noted that our program is a trusted partner of an impressive number of stakeholders, with our extension staff involved in numerous leadership roles at state and national levels.

We look forward to the autumn season and wish the best to all of you in this most unusual year. If you have topics of interest, please send me an email at snwhite3@ncsu.edu.

— Susan White, Executive Director, North Carolina Sea Grant

IN THIS ISSUE

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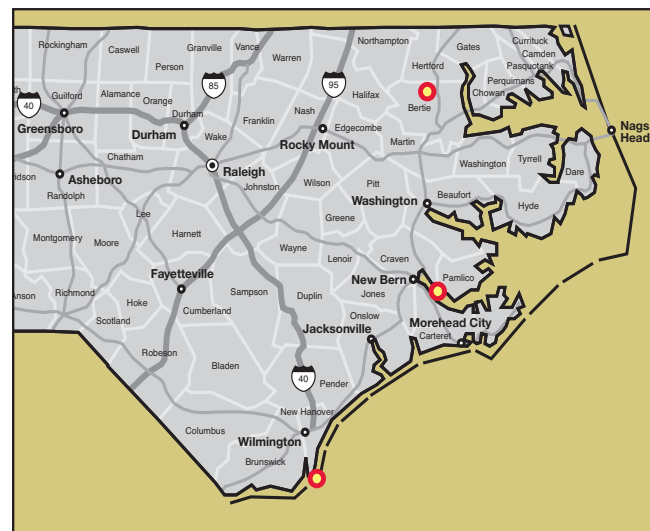
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Settings for the stories in this issue include the Neuse River Estuary, Bald Head Island, Bertie County, and many other locations.



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□ Front Cover: Photograph courtesy of University of Georgia Marine Extension and Georgia Sea Grant □ Table of Contents: Photograph courtesy of NOAA

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Since 1970, North Carolina Sea Grant has aligned our goals with the National Sea Grant College Program. We provide research, education, and outreach to serve our state's coast and its communities.

Under executive director Susan White, our primary areas of emphasis include healthy coastal ecosystems, resilient communities and economies, sustainable fisheries and aquaculture, and environmental literacy and workforce development.

NOAA and the State of North Carolina fund our work. By forging enduring collaborations that bridge North Carolina's public and private universities with critical coastal needs, our program fuels discovery, learning, and real-world solutions.

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COASTAL TIDINGS

ONLINE LESSON OFFERS WATERSHED WISDOM

A new Watershed Wisdom lesson plan includes activities for elementary school students at home and in class. As schools move to alternate forms of instruction due to the spread of COVID-19, Watershed Wisdom is the latest of many educational resources available through North Carolina Sea Grant's online portal for at-home learning.

Christy Perrin, sustainable waters and communities coordinator for North Carolina Sea Grant and the North Carolina Water Resources Research Institute, says that she and her colleagues wanted to support teachers by providing them with a free and easily accessible lesson plan on watersheds that meets required N.C. Essential Standards.

"We wanted to creatively engage students in learning about their local watersheds and empower students to take action," says Perrin. "We created it to get students outdoors, teach them about their local watersheds, and prompt student-parent interaction with the concepts at home."

North Carolina Sea Grant partnered for the project with UNC-TV, the North Carolina Watershed Stewardship Network's K-12 team — which includes NC Project WET, WRRRI, Town of Hillsborough, and City of Raleigh stormwater staff — and the Albemarle-Pamlico National Estuary Partnership. GSK also provided funding for the project.

- Watershed Wisdom Lesson Plan: go.ncsu.edu/Watershed-Wisdom
- Watershed Wisdom "Learning from Home Guide": go.ncsu.edu/Home-Guide
- Portal of Resources for At-Home Learning: go.ncsu.edu/Ed-Portal

— Katelyn Vause

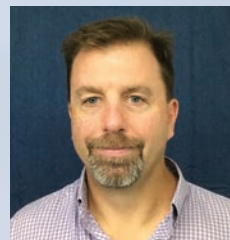
SEA GRANT ADDS KEY SPECIALISTS

This summer, North Carolina Sea Grant brought aboard specialists to address urgent needs at the coast.

Eric Herbst joined the program in June, serving as coastal aquaculture specialist out of NC State University's Center for Marine Sciences and Technology in Morehead City. Herbst supports the development, expansion, and diversification of the state's coastal aquaculture industries, including shellfish, finfish, and algal species.

"I am very excited about returning to North Carolina and am honored to be joining the North Carolina Sea Grant team in support of the promotion of responsible and sustainable aquaculture," Herbst says. "I look forward to working closely with growers and farmers, and the diverse group of aquaculture stakeholders and partners to develop solutions to challenges and help grow the state's aquaculture industry."

Frank López, North Carolina Sea Grant's extension director, describes Herbst as a skilled and experienced scientist with excellent problem-solving skills. "He will bring a fresh perspective," adds López.



Eric Herbst



Sarah Spiegler

Sarah Spiegler began her new responsibilities in August as coastal resilience specialist. Since 2018, she had served as the N.C. Sentinel Site Cooperative coordinator and marine education specialist for Sea Grant, after several years in prior roles with the cooperative.

"I am thrilled to continue working on pressing coastal issues, including adapting to climate change and increasing the resilience of North Carolina's coastal communities and habitats," Spiegler says.

Susan White, North Carolina Sea Grant's executive director, says Spiegler's previous roles brought productive partnerships and projects to the North Carolina coast.

"As global climate change fuels new challenges, especially along North Carolina's coastlines, we're fortunate to have Sarah's expertise and experience," says White. "Developing resilience in our coastal communities remains an urgent priority in our state and a cornerstone of our strategic planning."

— Katelyn Vause & Dave Shaw



Gray Whitley/Sun Journal

SEA GRANT ANALYZES FLOOD IMPACTS

Storm surge from Florence in New Bern

North Carolina coastal scientists and officials are key partners for a Sea Grant research project in which experts from four South Atlantic states are analyzing the impacts of flooding and the associated economic costs to coastal communities.

With funding from the Sea Grant programs and the National Oceanic and Atmospheric Administration Office for Coastal Management in the South Atlantic Region, the interdisciplinary research grant supporting the project honors the late Karl Havens, former director of Florida Sea Grant.

The N.C. team will include North Carolina Sea Grant, N.C. Department of Transportation, N.C. Division of Coastal Management, N.C. Division of Emergency Management, and the N.C. Coastal Reserve and National Estuarine Research Reserve.

"This project is especially interesting as it includes a broad range of data sources and also brings together coastal communities, state agencies, and our next generation of researchers to address real-world issues," says Narcisa Pricope from the University of North Carolina Wilmington, the lead N.C. researcher.

"Working with collaborators at the City of New Bern and New Hanover County," she explains, "we will develop community-relevant green infrastructure interventions — like natural land conservation and restoration of coastal wetlands, oyster reefs, and beach dunes — that may provide cost-effective flood-mitigation strategies within essential transportation networks throughout the coastal regions of our state."

- Read more: go.ncsu.edu/flood-costs

— Katie Mosher

CCRG PROGRAM LAUNCHES NEW PROJECTS

With support from the Community Collaborative Research Grant Program (CCRG), new projects on student leadership, the safety of shellfish harvests, and efficient shoreline restoration are underway.

"Each of these projects involves community partners to tackle important topics in our coastal region, with results that will include recommendations that can be used by other organizations and businesses," says John Fear, deputy director for North Carolina Sea Grant.

Rose Hoban of North Carolina Health News and Nick Szuberla of Working Narratives/Coastal Youth Media are building on prior leadership development initiatives to train students in coastal communities to consider coastal culture and history.

In addition, Joel Fodrie at the University of North Carolina at Chapel Hill, Stevenson Weeks of Crab Point Seafood, and two UNC-CH grad students are evaluating the

environmental impacts of moving oysters from polluted habitats to cleaner waters.

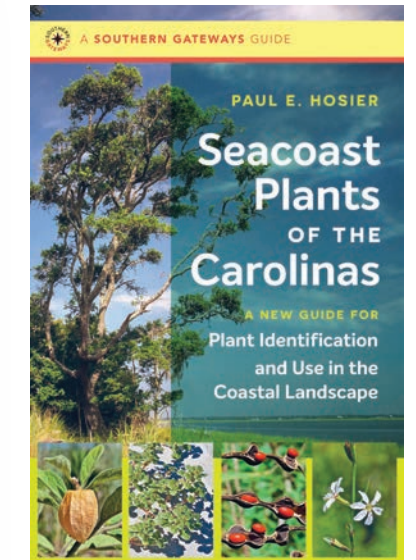
Also, on Taylor's Creek in Beaufort, Rachel Gittman at East Carolina University and Brandon Puckett of the N.C. Coastal Reserve and National Estuarine Research Reserve are partnering with David Cessna and Niels Lindquist of Sandbar Oyster Company to study whether restoring oyster reefs can alleviate the effects of boat wakes on marsh shoreline.

North Carolina Sea Grant administers the CCRG Program with the William R. Kenan Jr. Institute for Engineering, Technology, and Science (KIETS) and the N.C. Water Resources Research Institute.

"These projects will engage scientists, businesses, and community stakeholders, as well as young leaders, in thoughtful collaborations that will enable innovative solutions," says Raj Narayan, associate director at KIETS.

- The CCRG Program: go.ncsu.edu/CCRGprogram

— Katie Mosher



SEA GRANT WINS NATIONAL HONORS

Over the summer, Lessons in Mariculture and *Seacoast Plants of the Carolinas* each earned national recognition.

Lessons in Mariculture, 10 free resources for high school teachers, has won an APEX Award for Excellence in Campaigns, Programs & Plans – Education & Training. The lesson plans cover a variety of topics, such as aquaculture's origins and production methods, and align with North Carolina science standards and Career and Technical Education programs.

"We wanted to create easy-to-use resources that educators in science and agriculture could seamlessly integrate into their curriculum," says North Carolina Sea Grant coastal economist Jane Harrison, who led the project.

Seacoast Plants of the Carolinas: A New Guide for Plant Identification and Use in the Coastal Landscape has earned two national awards. The American Library Association recognized Paul E. Hosier's full-color authoritative guide as a 2019 Notable Government Document. *Choice* magazine also honored it as a 2019 Outstanding Academic Title.

North Carolina Sea Grant published *Seacoast Plants* in partnership with the University of North Carolina Press. The guidebook features over 200 profiles of plants in the coastal zone of the Carolinas.

- Lessons in Mariculture go.ncsu.edu/MaricultureLessons
- *Seacoast Plants of the Carolinas* go.ncsu.edu/SeacoastPlants

— Julie Leibach & Katie Mosher



Danielle Costantini (above) and James Withrow (below)

FIRST STEM POLICY FELLOWS SERVE NC

North Carolina's inaugural STEM Policy Fellows began yearlong assignments in August in two high-level state government offices.

"This new fellowship — focusing on science, technology, engineering, and mathematics — provides unique, in-state, non-academic career opportunities for recent graduate students," says Susan White, North Carolina Sea Grant's executive director. "It is clear from the outstanding applications we received that there is a desire among multi-talented graduate students to help our state consider key policy challenges."

James Withrow, a doctoral candidate at NC State University, serves at the N.C. Department of Commerce's Office of Science, Technology, and Innovation. Danielle Costantini, who recently completed her master's at NC State, is working in the N.C. Department of Environmental Quality's State Energy Office.

The prestigious STEM Policy Fellowship also includes professional development sessions in science policy in partnership with Sigma Xi. North Carolina Sea Grant administers the fellowship.

Russ Campbell with the Burroughs Wellcome Fund, which provided a generous matching grant for the fellowship, says the program is a hit even amidst the pandemic.

"Despite the challenges of COVID-19 restrictions," Campbell says, "this pilot year already has shown great success, including strong host offices, outstanding applicants, and the professional development to help fellows bridge the science and policy arenas."

• More about the STEM Policy Fellows go.ncsu.edu/STEM-Fellows — Katie Mosher

COASTAL TIDINGS

NC STUDENTS EARN TOP FELLOWSHIPS

North Carolina continues to supply prestigious fellowships with talented graduate students. In addition to the inaugural North Carolina STEM Policy Fellowships, several programs are providing recent winners with seminal opportunities for early career development.

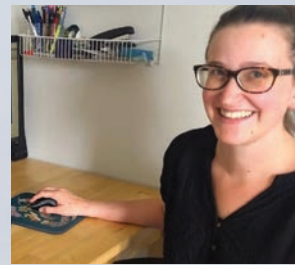
North Carolina Sea Grant and North Carolina Space Grant selected **Shannon Ricci**, a Ph.D. student at NC State University, for their joint fellowship program. The fellowship supports interdisciplinary approaches that address research needs for nearshore environments, coastal areas, and coastal watersheds.

Ricci will use remote-sensing technology and satellite images to study how frequently boats visit sites that the N.C. Division of Marine Fisheries (DMF) maintains through its artificial reef program.

"Rapid advances in technology — including widening access to satellite and remote-sensing data — are opening new avenues to study our state's coastal region," says John Fear, deputy director of North Carolina Sea Grant. "Such novel research approaches ultimately will benefit the state's ecology and economy."

B Stevens holds the N.C. Marine Fisheries Fellowship, which includes North Carolina Sea Grant as partner. Stevens holds a masters in coastal environmental management from Duke University and serves at DMF and NC State's Center for Marine Sciences and Technology.

"This program helps develop future leaders by giving scientists early-on, real-world experience considering complex questions," says



Shannon Ricci



B Stevens



Matthew Damiano



Anna Jane Jones

Susan White, North Carolina Sea Grant's executive director. "In turn, they bring to the agency new tools for fisheries management, including data analysis methods and visualizations."

Matthew Damiano, a doctoral student at NC State, received a NOAA Fisheries-Sea Grant Joint Fellowship, which supports students pursuing degrees in population and ecosystem dynamics and in marine resource economics. Damiano will develop a stock assessment and management strategy evaluation tool for common dolphinfish.

"While dolphinfish is popular on restaurant menus, often under the name mahi mahi, the species' stock status and fishing mortality rate are not well identified," Fear says.

Another national program, NOAA's Coastal Management and Digital Coast Fellowship, offers on-the-job training for postgraduate students in coastal resource management and policy.

Anna Jane Jones, among this year's select group, earned her master's in city and regional planning from the University of North Carolina at Chapel Hill and will work with The Nature Conservancy to plan and implement nature-based solutions to reduce risk.

"We are extremely thrilled that Anna Jane will bring her planning skills to The Nature Conservancy in support of their risk reduction and recovery efforts," Fear says.

In addition, four new finalists for the John A. Knauss Marine Policy Fellowship from our state are about to learn in which federal offices they will serve. You can read their stories in the next issue.

• Sea Grant fellowships: go.ncsu.edu/fellowships — Lee Cannon, Katie Mosher, and Dave Shaw



John Lambeth/NCFBF

PROJECT DEPLOYS SPAT ON SHELL

Spat on shell, the juvenile oysters (small brown ovals) on an old oyster shell

North Carolina Sea Grant, the North Carolina Farm Bureau Federation, N.C. Division of Marine Fisheries, and industry collaborators have joined forces to produce "spat on shell" in order to restore wild oyster populations for future harvest.

Frank López, extension director for North Carolina Sea Grant, says the project will bring economic and environmental benefits.

"Recent storms like Hurricane Florence have impacted wild oyster populations," he explains. "Spat-on-shell culturing allows oysters to be started as larvae in a nursery setting. As the larvae permanently attach to oyster shell in climate-controlled tanks, they are known as 'spat.' The spat-on-shell then can be deployed in sounds. The spat grow into adult oysters in this natural setting — and can form dense oyster beds over time."

This summer the project completed deployments in Jarrett Bay off the Core Sound and a site in North River, with another scheduled for Newport River in the spring.

Support from the North Carolina Commercial Fishing Resource Fund was invaluable, López says, and he credits Debbie Hamrick, director of specialty crops for the N.C. Farm Bureau Federation and an advisory board member for Sea Grant, with helping to initiate the project.

"Oysters are an important fishery for North Carolina's working watermen," says Hamrick. "During winter months, wild-harvested oysters provide needed income to support coastal fishing families, while providing tasty, healthy local food to seafood markets."

• Read more: go.ncsu.edu/spat-on-shell — Katie Mosher & Dave Shaw

FLOOD MITIGATION RESOURCES NOW ONLINE

N.C. Coastal Rivers Flood Mitigation, North Carolina Sea Grant's new online informational portal, offers strategies and resources for improving flood mitigation and transportation resilience in eastern N.C. communities.

As the global climate warms, North Carolinians likely can expect more severe inland flooding from more frequent, intense precipitation, according to the recent *North Carolina Climate Science Report*.

"The infrastructure of many small Coastal Plain communities won't be able to handle the flooding that we'll likely see with climate change," says Barbara Doll, North Carolina Sea Grant's water protection and restoration specialist and a faculty member in the Department of Biological and Agricultural Engineering at NC State University. "A big question is, how can they make

cost-effective improvements?"

The N.C. Coastal Rivers Flood Mitigation portal builds on research from Doll and her team, as well as partners that include the N.C. Department of Transportation.

Reader-friendly content covers major floods in North Carolina, their impacts on transportation, and future flooding risks. Additional sections describe methods to improve resilience, offer online tools that communities can use for forecasting and planning, and provide case studies and links to relevant research.

"The idea is to provide science-based information to decision-makers who want to improve resilience in their communities but may not know where or how to start," Doll says.

• N.C. Coastal Rivers Flood Mitigation go.ncsu.edu/flood-mitigation — Julie Leibach



Austin Gray in the field

STUDY REVEALS ANTIBIOTICS IN STREAMS AND WELLS

Austin Gray and his colleagues have published results of research assessing the presence, quantity, and seasonality of antibiotics in the Piedmont of North Carolina, a region with a large farm animal population and high prevalence of private wells. Their study sampled 16 private wells and 16 streams across three counties in the fall, winter, and spring.


Gray's team conducted targeted and non-targeted spectrometry to evaluate antibiotics. Analyses revealed the widespread occurrence of antibiotics in surface water, groundwater, and sediment. Veterinary antibiotics accounted for 33% of all antibiotics the team detected and occurred at the highest concentrations, highlighting the potential ecological and human health risks associated with animal husbandry.

Results also showed considerable seasonality in antibiotic concentrations. Surface water and sediment concentrations were highest in the fall, and groundwater concentrations were highest in the winter.

Gray received a joint North Carolina Sea Grant and N.C. Water Resources Research Institute Graduate Student Research Fellowship to study antibiotic pollution, as well as subsequent North Carolina Sea Grant funding for related research.

Findings from his fellowship have resulted in invited presentations in the United States and abroad. He also has written for *Coastwatch* about his research.

• Full study go.ncsu.edu/Austin-Gray
• Austin Gray on his research go.ncsu.edu/Gray-in-Coastwatch
• Sea Grant funding opportunities go.ncsu.edu/Sea-Grant-funding — adapted from an article by Julia Guimond

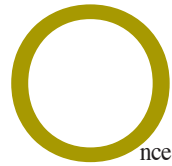
A group of horseshoe crabs are shown in the ocean at twilight. The water is dark blue with some ripples. The crabs are dark in color, and their shells are wet, reflecting the light. One crab in the foreground is particularly prominent, showing its large, rounded shell and long, thin legs. The background shows several other crabs, some partially obscured by the water's surface.

BLOOD DRAW AT THE HORSESHOE CORRAL

An essential medical safety test used globally depends on blood from wild horseshoe crabs. Could aquaculture provide a more sustainable source?

BY JULIE LEIBACH

A FEMALE HORSESHOE CRAB APPEARS WITH SEVERAL MALES AT TWILIGHT IN NEW JERSEY'S CAPE MAY NATIONAL WILDLIFE REFUGE.



nce researchers develop a COVID-19 vaccine that receives approval from the U.S. Food and Drug Administration, we undoubtedly will celebrate the news. Those scientists will deserve our gratitude. But we might also appreciate another important player: the American horseshoe crab (*Limulus polyphemus*), a rugged coastal creature found along the eastern seaboard and portions of the Gulf of Mexico.

Horseshoe crab blood is the basis for a gold-standard safety test used worldwide on vaccines and other injectable medicines, intravenous fluids, and implantable medical devices. Specifically, the test, or assay, identifies whether certain bacterial contaminants called endotoxins are present, and to what extent. Endotoxins can be detrimental to human health if they appear in high concentrations in the blood.

In essence, the assay consists of a series of enzymes from the horseshoe crab's only blood cell, the amebocyte. Known as LAL, for *Limulus amebocyte lysate*, the extract reacts when it comes into contact with endotoxins, forming a telltale clot.

In 2019, the researchers who developed the LAL assay — Jack Levin and Frederik Bang — won a Golden Goose Award, which honors seemingly obscure research that ultimately has a significant impact on society.

“The ability to measure in a precise way the amount of endotoxin in things we are exposed to every day has a societal benefit that I think few people recognize,” said Brad Fenwick, a senior vice president at the science-focused publisher Elsevier, in a video published by the Golden Goose Awards.

Presently, there are four U.S.-based LAL manufacturers, three of which serve the U.S. market. Horseshoe crabs are gathered from Atlantic waters up and down the East Coast and transported to facilities for blood collection, then returned to the location they came from.

Those companies have stated that they're committed to horseshoe crab welfare and conservation. “Overall it's a sustainable industry if it's done properly,” says Jennifer Mattei, a biologist who studies horseshoe crabs at Sacred Heart University in Connecticut.

Still, the reliance on wild organisms — whose numbers have ranged from plentiful

TOP: Horseshoe crabs come ashore on sandy beaches en masse to lay their eggs.
BOTTOM: One female horseshoe crab may lay a few egg clusters each evening over the course of several nights.



Spawning female horseshoe crabs usually come ashore with a male attached.

to precarious — has led researchers to pursue alternative strategies for endotoxin testing.

One company in particular is taking a page out of the oyster grower's book: Greensboro-based Kepley Biosystems Inc., which received initial funding from North Carolina Sea Grant, aspires to build a network of horseshoe crab aquaculture facilities for the express purpose of blood collection.

“There was an opportunity to benefit a species both critical to the ecosystem and to human health,” says Kepley Biosystems Inc. founder and president Anthony Dellinger. “This aligns with our company philosophy to focus on projects that provide a net good to the public and the planet while addressing massive global markets.”

ANCIENT MARINERS

Despite what their name suggests, horseshoe crabs aren't actually crabs. More

closely related to spiders and scorpions, they hail from an ancient lineage predating the oldest dinosaurs by a couple hundred millennia. Based on fossil evidence, horseshoe crab physique has remained relatively unchanged for nearly 450 million years.

“They're amazing to look at, because they have a very unique body plan that we don't see in other organisms,” says Mattei, who runs a horseshoe crab tracking program called Project *Limulus*.

The creature's tank-like structure consists of a front shell hinged to a back shell, where a pointy tail called a telson pokes out. Despite its menacing appearance, “it's not a weapon,” says North Carolina Sea Grant marine education specialist Terri Kirby Hathaway. “If the animal gets turned upside down, it uses that tail to push into the sand and turn itself back over.” The telson also functions as a rudder in the water and

has patches of specialized cells that detect light.

A glance under the carapace reveals six pairs of appendages for locomotion and foraging and so-called book gills — thin sheets of tissue with a leathery cover — used for breathing and propulsion.

American horseshoe crabs are coastal species from Maine to northeast Gulf of Mexico states, as well as along Mexico's Yucatán Peninsula. While the animals have different habitat requirements at different stages of their life cycle, spawning adults depend on sandy beaches where they come ashore annually, typically during spring high tides. Females dig pits in the sand where they deposit tens of thousands of eggs, which males then fertilize.

It takes 10 years for a horseshoe crab to mature to an adult, which can reach at least

Continued



Gregory Breese/USFWS



Timothy Furek



Courtesy of Jack Levin

Red knots are migrating shorebirds that feast on horseshoe crab eggs.

20 years of age, according to Mattei. These long-lived arthropods are integral to their ecosystems. For starters, loggerhead turtles eat them, and a host of organisms such as barnacles, marine snails called slipper shells, and anemones reside on horseshoe crab shells.

Their eggs, meanwhile, nourish various invertebrates, finfish, and migrating shorebirds. For example, during a 9,000-mile migration from the tip of South America to the Canadian Arctic, Atlantic Coast red knots touch down on eastern beaches to refuel. It's no coincidence that Delaware Bay, the second-largest staging area for migrating shorebirds in North America, is also a horseshoe crab spawning hotspot.

"There're some organisms that are really important when they're abundant, and the horseshoe crab is one of them," Mattei says.

LUCK OF THE DRAW

Never in his life had Jack Levin seen a horseshoe crab when he arrived at the Marine Biological Laboratory in Woods Hole,

Massachusetts, during the summer of 1963 to study the organism's blood.

At the time, Levin was a research fellow in hematology at the Johns Hopkins University (JHU) School of Medicine and Hospital, where he was studying blood clotting in rabbits. Levin's advisor had suggested he collaborate with a JHU colleague named Frederik Bang, who spent summers at Woods Hole. Bang was "a pioneer in applying marine biology to medical research," the *New York Times* noted after his death in 1981.

Bang had done earlier research on horseshoe crab blood clotting. Levin was to continue in that vein, conducting basic research into similarities between the horseshoe crab's blood cell — the amebocyte — and human platelets, which help blood clot.

Bang acquainted Levin with his study subject by pointing to a tank containing horseshoe crabs and instructing him to, "Pick one out," recalls Levin, now on the faculty at the University of California School of Medicine, San Francisco. "Of course, I was

absolutely thunderstruck, sure that my fingers would either be crushed by one of their claws or stuck by their tail." (Neither happened.)

As Levin pursued his research, he noticed that samples of liquid horseshoe crab blood left in the lab overnight had coagulated by the next morning, despite the addition of standard anticoagulants. He wondered: Could his glassware be contaminated? From his studies at JHU, he knew that bacterial endotoxins caused rabbit blood to clot. Maybe endotoxins were responsible for horseshoe crab blood clotting as well.

Further experiments supported Levin's hunch — endotoxins prompted blood coagulation. He also learned that clotting was the result of an enzymatic reaction. Once a clot forms, the amebocyte unleashes other factors that work to destroy the source of infection, Levin explains.

The adaptation is phenomenal if you consider the horseshoe crab's habitat, he says. "An animal like *Limulus* is crawling around the bottom, getting bumped, damaged, and they

have to have a mechanism that immediately controls bacterial infection," Levin says. "The amebocyte is an all-purpose cell. It aggregates, traps the bacteria, produces clots around them, and then is capable of releasing substances that will kill or immobilize the bacteria. It's a much more effective all-purpose cell than anything we humans have."

Levin went on to develop a way to extract the clotting factors from the amebocyte. In 1987, the LAL assay became the standard method of screening for bacterial endotoxins. Until that point, a test that required the use of live rabbits had been used.

"Not only was the *Limulus* test more sensitive, but it was relatively easy to do," as well as practical, Levin says. Overall, "it was clearly enormously better."

OUT OF THE WILD

The collection of horseshoe crabs for the biomedical industry ranks second to their commercial use as bait in the eel and whelk fisheries, according to the Atlantic States Marine Fisheries Commission, or ASMFC, which oversees the management of horseshoe crabs from Maine south through Florida's East Coast.

The ASMFC assumed that role in 1998, following several years of dramatic growth in horseshoe crab bait landings. Since then,

landings have declined and become fairly stable. In 2018, close to 660,000 horseshoe crabs were harvested for use as bait. Whereas 100% of bait crabs die, the ASMFC estimates a 15% mortality rate from bleeding the animals for LAL production.

Although the collection of horseshoe crabs for biomedical purposes has increased since reporting began in 2004, the number has remained relatively consistent over the past several years, hovering around 500,000.

Yet, these pandemic times beg the question: Will COVID-19 vaccine production have a measurable impact on the demand for horseshoe crab blood?

"It was estimated that the production of 5 billion doses of vaccine will require less than a day's production from three U.S.-based LAL manufacturers," according to Allen Burgenson, who chairs the ASMFC's horseshoe crab advisory panel and works for Lonza Walkersville Inc., which produces LAL in Maryland.

Even so, the global bacterial endotoxin testing market is expected to double by 2024 based on growth in the pharmaceutical, medical device, and healthcare facility industries, says Glenn Gauvry, founder and president of the Ecological Research & Development Group Inc., a nonprofit horseshoe crab conservation organization.

The American horseshoe crab population as a whole appears to be generally stable, according to the ASMFC, aside from the New York region, where it's declining. In North Carolina, the population also looks healthy. "It does seem like, over time, it has been increasing" in the state based on the available data, says Kristen Anstead, a stock assessment scientist with the ASMFC.

In Asia, however, the future is bleaker. There, a version of the assay is made with blood from the two horseshoe crab species of the genus *Tachyplesus*. One of those species has been listed as endangered by the International Union for Conservation of Nature, or IUCN. There is insufficient data on the other to determine its conservation status.

If it turns out that Gauvry is right and demand for bacterial endotoxin testing spikes in coming years, the industry might have to lean more heavily on American horseshoe

Continued

crabs. “Whether *Limulus* can handle that is in question,” Gauvry says. “Right now, it seems that it can, but it’s something that we’re going to have to keep an eye on.”

CORRALLING CRABS

Like Jack Levin, Anthony Dellinger of Kepley Biosystems Inc. had never seen a horseshoe crab until 2018, when he began a *Limulus* research project, supported by a North Carolina Sea Grant minigrant.

He had worked with LAL as a student in biology labs and in other research posts, but he was unaware of its origin in horseshoe crabs. “I didn’t even know that the animal existed,” Dellinger says.

Eventually he learned about the organism — and saw an opportunity. He and his team could raise horseshoe crabs through aquaculture and bleed them in-house for LAL. That way, they could help curb wild collection. If they bled crabs at regular intervals, they could potentially increase exponentially the amount of LAL that can be produced per crab each year.

The N.C. Sea Grant minigrant enabled the Kepley team to acquire several horseshoe crabs, construct an aquaculture apparatus, and generate preliminary data.

“One role of our minigrant program is to stimulate innovation, and Kepley’s horseshoe crab aquaculture idea struck us as a unique concept worth supporting,” says John Fear, North Carolina Sea Grant’s deputy director.

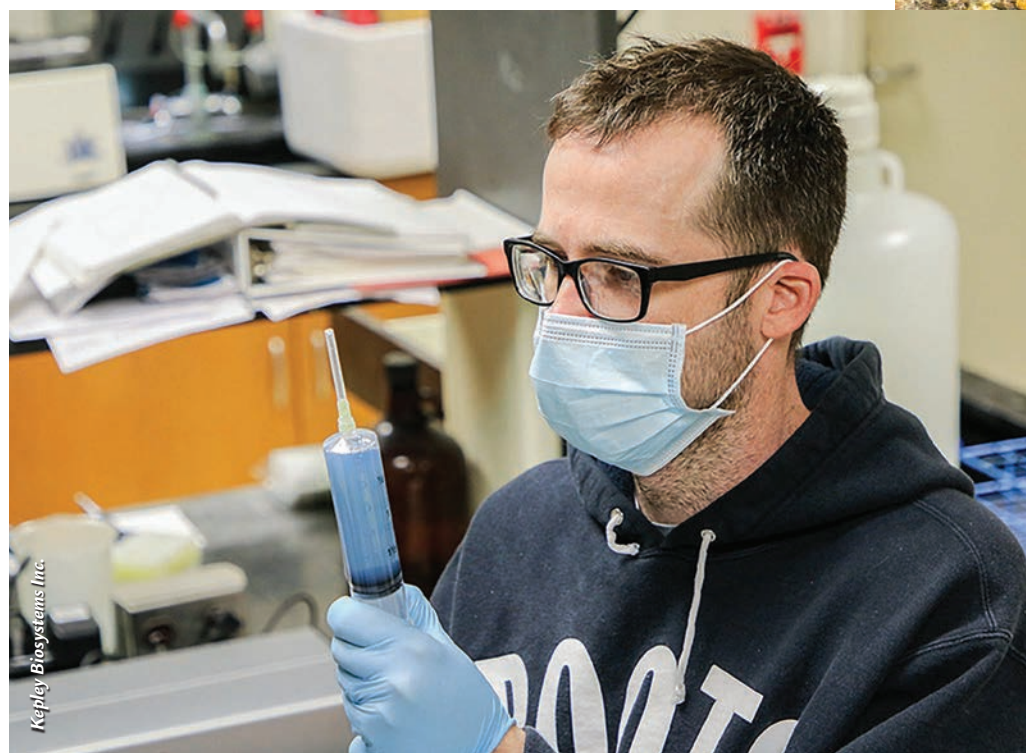
Dellinger adds that the minigrant “allowed us to get to a serious stage.” Indeed, after their initial project, his team received funding from the National Science Foundation to continue their husbandry research.

Working with University of Georgia Marine Extension and Georgia Sea Grant, Dellinger and his collaborators constructed four outdoor pens from PVC pipe and crab trap wire in a pond located at the 4-H Tideland Nature Center on Jekyll Island.

The team monitored 40 crabs over the course of several months. “This was something totally different than I’ve ever worked with,” says marine resource specialist Lisa Gentit, who assisted with the fieldwork.

For comparison, Dellinger’s team also investigated crabs raised indoors in a recirculating aquaculture system.

Their results indicated that the indoor



TOP: Working with the University of Georgia Marine Extension and Georgia Sea Grant, the Kepley Biosystems Inc. team built outdoor aquaculture pens for horseshoe crabs.

BOTTOM: Anthony Dellinger, founder of Kepley Biosystems Inc., envisions creating a network of horseshoe crab aquaculture facilities for blood collection.



A host of organisms, such as barnacles, marine snails, and anemones, reside on horseshoe crab shells.

system was superior to the outdoor pens. For one, 100% of the 24 indoor crabs survived. Meanwhile, seven of the crabs raised outside died, likely because water temperatures got too warm and dissolved oxygen got too low, according to Gentit.

Outdoor aquaculture also posed logistical challenges. “It was really difficult to find [the crabs] in the pens, because they will bury up into the mud and sand,” Gentit explains. “So, you had to basically dive under and feel around in the dirt, in the sediment, to find them.”

Dellinger maintains that outdoor aquaculture has advantages, but it “introduces uncontrollable variables, like weather and temp,” he says. In indoor systems, crabs can be closely monitored and their diets controlled.

As Gauvry of ERDG sees it, raising crabs and bleeding them all in the same facility could help preserve their well-being.

“Anytime that you take a wild animal out of its natural habitat, you’ve interjected stress,” says Gauvry, who serves with Dellinger on an IUCN work group focused on the horseshoe crab trade. “Anthony’s approach eliminates that. These animals become acclimated to the environment that they’re in,” at least theoretically, he says.

Dellinger’s team has also been developing a nutritional regimen that has so far proven to ensure horseshoe crab vitality and LAL quality. At this article’s writing, the journal *Frontiers in Marine Science* was reviewing a paper on that work.

Dellinger envisions ultimately building multiple horseshoe crab aquaculture facilities for LAL production. Growers could be trained to raise the animals, while traveling phlebotomists could circulate around the facilities to bleed them on a rotating basis, he explains.

Achieving that goal would require substantial investment, Dellinger acknowledges. And it’s possible that, in the meantime, an alternative assay that already exists — one that negates the need for horseshoe crabs altogether — will become more widely adopted. That assay uses material called recombinant Factor C, or rFC, but its use in endotoxin testing is not standard in the U.S.

For his part, Dellinger says that demand for LAL “is likely going to increase” and thinks Kepley could satisfy that market. “We’ve always been of the opinion that if you could do it very thoughtfully and consciously and optimize the aquaculture, then there’s not necessarily a need to transition away from LAL, especially if you can use a fraction of the crabs,” he says. “You would still have this perfect end product, just in a more sustainable form.”



SCIENCE

Monitoring and Assessing Water Quality Across the Neuse River Estuary-Pamlico Sound Continuum

Paerl Lab technician Jeremy Braddy

UNC Institute of Marine Sciences



UNC Research

Just north of Durham, the Eno River and the Flat River join to form the Neuse River, one of the oldest rivers in the country at approximately 2 million years old. It runs rapidly for about 150 miles before slowing to a crawl and spreading out to form the brackish, tea-colored Neuse River Estuary, which then empties into the Pamlico Sound.

Archaeologists have shown that human settlements have existed around the river and estuary for the past 14,000 years. The name “Neuse” means “peace” and was taken from the Neusiok tribe with

whom early European explorers connected in the 16th century.

Today, the ModMon and FerryMon programs monitor water quality trends throughout the Neuse River Estuary and Pamlico Sound, and you can help. For that matter, you can assess any body of water that you believe may need monitoring for the health and safety of the environment.

Read on to learn how you can be involved in measuring water quality and aid researchers in their efforts to monitor the health of our coastal waters.

Continued

NEEDS YOU

FOR DECADES, RESEARCHERS HAVE BEEN TRACKING THE HEALTH OF THE SECOND LARGEST ESTUARINE COMPLEX IN THE UNITED STATES — AND YOU CAN HELP, TOO.

HANS W. PAERL, ALAN R. JOYNER, BENJAMIN L. PEIERLS, AND KAREN L. ROSSIGNOL

Adapted from *30 Great North Carolina Science Adventures: From Underground Wonderlands to Islands in the Sky and Everything in Between*, edited by April C. Smith. Copyright © 2020 by the University of North Carolina Press. Used by permission of the publisher. www.uncpress.org



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FerryMon (above) and ModMon sample water quality at sites stretching from the Neuse River upstream from New Bern into the Pamlico Sound.

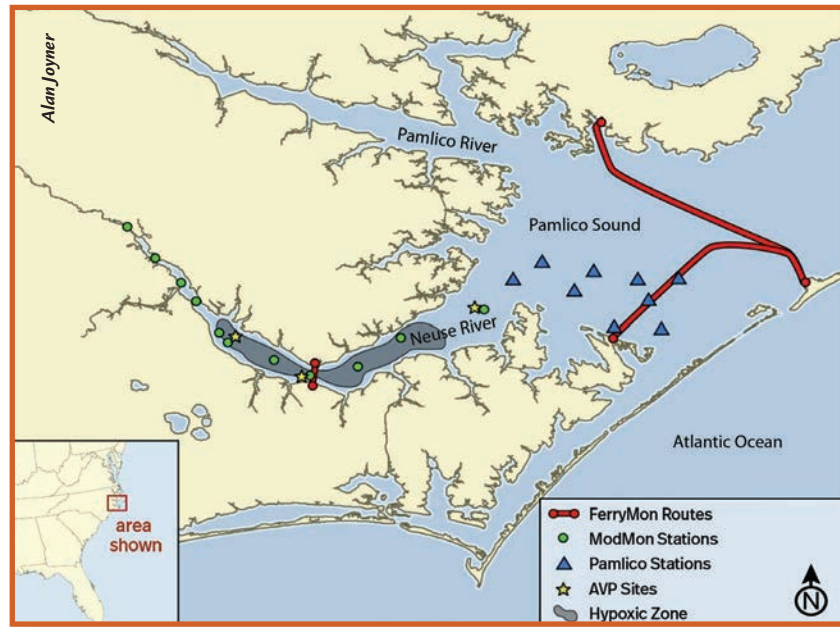
Why the Neuse River Estuary Is Important

An estuary is a semi-enclosed, transitional body of water where fresh water from a river mixes with saltwater derived from the ocean. Estuaries are impacted by tides but are often shielded from powerful ocean waves by barrier islands or reefs that border them. They are critical zones of environmental importance.

Estuaries are highly productive and beneficial habitats for many types of finfish and shellfish. In the United States, approximately 90% of recreationally caught fish and 75% of commercially caught fish spend part of their lives in estuaries.

The Neuse River Estuary is a major tributary of the second largest estuarine complex in the United States and North Carolina's most important water body, the Albemarle-Pamlico Sound. This is a very important fisheries nursery, meaning that, for marine organisms living here, the estuary provides a hospitable and protective habitat, as well as a food source for their young while they mature. In North Carolina, businesses or activities that deal with fish and shellfish — including harvesting, buying, and selling — contribute about \$1.7 billion per year to the state's economy.

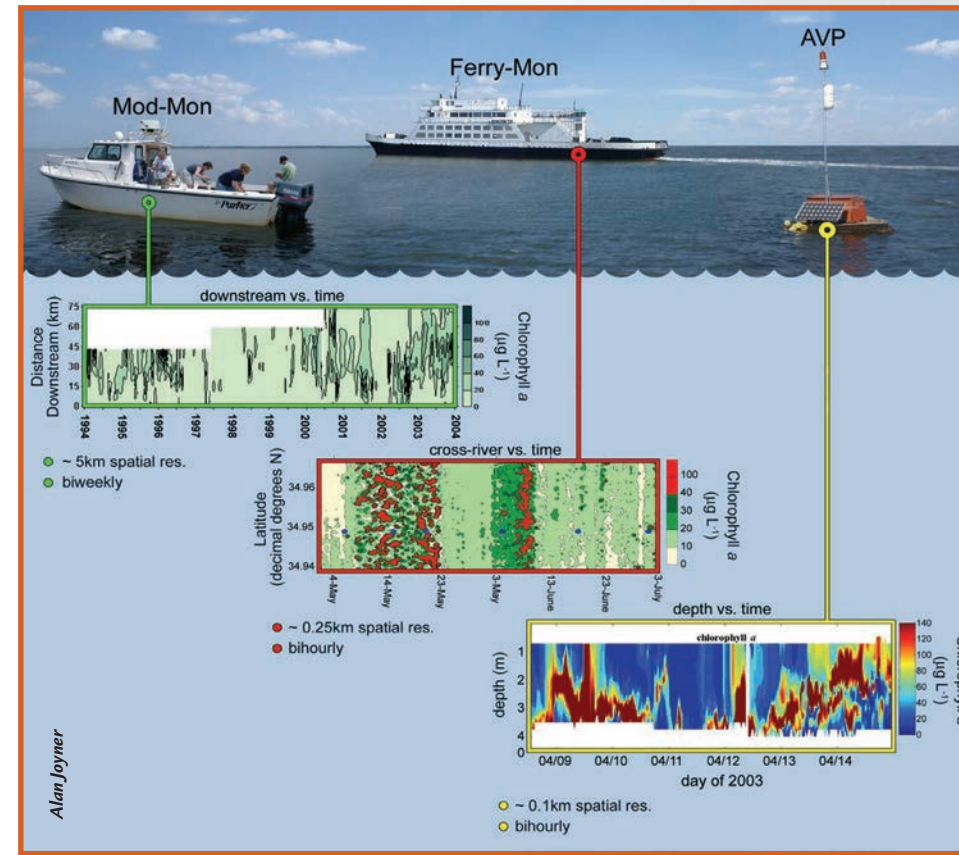
There are currently about 3.9 million people living within the Albemarle-Pamlico Sound Watershed area. In addition to the human population, this region also contains 16,000 farms and 4.8 million acres of farmland, including swine and poultry operations. With a large number of people building homes and businesses and managing farms



in this watershed, it is very important that this estuarine system be closely monitored to ensure it is productive, healthy, and safe for future generations.

Ongoing Water Quality Monitoring

Researchers at the University of North Carolina's Institute of Marine Sciences (UNC-IMS) continuously sample and evaluate the water in order to monitor the health of these important estuarine ecosystems using several long-term projects: the Neuse River Estuary Modeling and Monitoring Program ("ModMon"), since 1994; a ferry-based water quality monitoring program ("FerryMon"), since 2000; several autonomous vertical profilers ("AVPs"); and a set of monitoring stations on the Pamlico Sound. (See Figure 1.)



The ModMon program provides researchers with continuous information about the health of the estuary. ModMon has 11 sampling stations for assessing water quality that are located down the main channel of the Neuse River, from upstream above New Bern to the mouth, where it discharges into the Pamlico Sound. Twice a month, researchers visit each station by boat. Water quality conditions are first measured using

Continued

Figure 1 (left): ModMon stations, FerryMon routes, and AVP sites collect water quality data at different depths. Haley Plaas (below), the 2020 North Carolina Sea Grant and Albemarle-Pamlico National Estuary Partnership joint fellow, processes algal bloom samples for her research with the Paerl Lab at the University of North Carolina's Institute of Marine Sciences.



M. May/UNC Research



Scientist Hans Pearl (center) and colleagues on a FerryMon route to collect vital water quality data from the Neuse River Estuary and Pamlico Sound.

a multisensor probe, or “sonde,” that is lowered down through the water column. Water samples are then collected near the surface and near the bottom from each station and brought back to the lab.

The ModMon program also uses AVPs to monitor strategic locations in the Neuse River. While the ModMon stations require a boat-based crew to perform the sampling, these buoy-based profilers are floating platforms that are continually on the water, automatically taking measurements of different parameters. This information is sent wirelessly from the AVPs to UNC-IMS in Morehead City.

FerryMon also operates on the Neuse River and Pamlico Sound, enabling researchers to continually collect surface water quality data along the routes that the ferries travel. Data are linked to a GPS location, logged to an onboard computer, and sent via wireless connection to computer servers at UNC-IMS.

ModMon, FerryMon, and the AVPs all record water depth, light, temperature, dissolved oxygen, salinity, turbidity, chlorophyll fluorescence (as a measure of the amount of algae), and pH. Water samples are also collected from Pamlico and ModMon stations.

How We Use the Data

After the data are collected and processed, we can visualize the results as graphs and tables, which we then share with many different organizations, including state and federal governments, environmental and fisheries agencies, schools and universities, and other public and private groups. These include the North Carolina Department of Environmental Quality, the Division of Marine Fisheries, NOAA and the EPA, university researchers, stakeholder groups (such as the

Neuse Basin Association and Neuse River Compliance Association), riverkeepers, and K-12 educators, as well as the public at large through the ModMon and FerryMon websites. (See the links to online information at the end of the article.)

This information is vitally important for determining and evaluating the health of our estuarine water today and to evaluate changes in water quality over time, going back to the early 1990s.

ModMon’s data are used to evaluate the amount of nitrogen discharged into the water, which is essential to understand in order to control eutrophication (the unfettered growth of algae) and harmful algal blooms, as well as hypoxia (excessive oxygen consumption).

These data also are used to evaluate alternatives for reducing nitrogen loading as specified by the North Carolina legislature and to calibrate and validate several predictive water quality models that then help test the effectiveness of limits on nitrogen discharge to our local waters.

In addition, ModMon and FerryMon data are used to calibrate various satellite-based and aircraft-based remote-sensing systems, enabling us to scale up views of water quality conditions across the entire Albemarle-Pamlico Sound system.

Last, data from ModMon and FerryMon also allow us to observe the effects of storms, hurricanes, and nutrient and pollution discharges on the environment, as well as to create a means to monitor water quality over a longer period of time. Most importantly, data collected from this network of monitoring programs help scientists learn what affects water quality on the coast of North Carolina. These are essential ingredients for long-term environmental management and protection of the Albemarle-Pamlico Sound’s precious resources.

What We Measure and Why

To determine water quality, we collect data on physical, chemical, and biological factors.

- **Nutrients**

Nutrients like nitrogen and phosphorus are essential for supporting the growth of phytoplankton, the floating microscopic algae that form the base of estuarine and coastal food chains. We can measure nutrient concentrations either directly with sensors or through laboratory chemical techniques.

High nutrient concentrations can at times cause uncontrolled growth of algae, seen as distinct greening of the water column. These algae “blooms” sometimes even become toxic to many organisms, including fish and humans. When blooms sink and die, the water at the bottom of the estuary starts to run out of oxygen, which severely stresses and kills shellfish and finfish trapped in those zones.

What causes high nutrient concentrations? Human activities create nutrient sources that either discharge directly or wash into the estuary when it rains: fertilizer runoff from farmland, waste from animal operations, discharge from septic systems, urban stormwater runoff, sediment loss from exposed and eroded soils, and discharge from industries and wastewater treatment plants. All of these contribute to excessive algae growth.

- **Chlorophyll**

Plants, including algae, use the green pigment chlorophyll to trap energy from the sun and convert it to chemical energy for growth in the process of photosynthesis. Chlorophyll is measured by fluorescence, using sensors in the water or by extracting the pigments from samples. Chlorophyll tells us how much algae is in the water.

Continued



To capture water quality, the Modmon and FerryMon programs rely on hands-on technology and data collection, as well as pre-programmed information gathering from autonomous vertical profilers (AVPs), like the one below.





Hans Paerl in the lab, algae bloom in hand.

UNC

• **Temperature and Dissolved Oxygen**

All plants, animals, bacteria, and algae prefer specific temperature ranges, and most grow faster in warmer waters. The temperatures in the Neuse River and Pamlico Sound usually range from about 43°F to 86°F. Warm water holds less oxygen than cold water, so waters are more likely to have dangerously low levels of oxygen during the summer months. If oxygen concentrations get too low, some of the animals and plants in the water can die.

• **pH**

Parts hydrogen, or “pH,” is a measure of how acidic or basic the water is. On a scale of 0 to 14, the majority of aquatic animals need a range of 6.5 to 8.5 to survive. Low pH can make toxic compounds in the water, like heavy metals, more available to marine organisms, creating harmful conditions for aquatic life. Some mollusks have trouble making their shells under such acidic conditions.

pH can be affected by pollutants entering the water from acid rainfall, runoff, and surface and groundwater discharge. Also, increasing atmospheric levels of the greenhouse gas carbon dioxide (CO₂) in turn can lead to more CO₂ in fresh and marine waters, which then lowers their pH. Rising CO₂ emissions from the burning of fossil fuels, therefore, contributes both to global warming and ocean acidification.

• **Salinity**

Plants, animals, bacteria, and algae have certain salinity ranges in which they can grow and survive best, and, thus, sudden changes in salt content can kill an organism. The salinity in the Neuse River and Pamlico Sound can range from 0 to 30 parts per thousand. Fresh water is less dense than salty sea water, so when a surge of fresh water from the Neuse River enters the saltier Pamlico Sound, the lighter fresh water sits on the surface, while the denser, heavier salt water stays on the bottom.

• **Turbidity**

Turbidity is a measure of water transparency. Organic and inorganic solid matter can become suspended in the water, causing the water to look cloudy. This can prevent sunlight from reaching aquatic plants that need light for growth. In the Neuse River, high turbidity is often caused by high wind, high flow rate, stormwater runoff that contains floating sediment, and algal blooms. Colored, dissolved organic matter — like when fallen leaves from trees turn river water brown — may also block sunlight.

How You Can Help

You can participate in water quality monitoring for the Neuse River Estuary and Pamlico Sound. We would love to include your data to help monitor the health of the estuary.

To begin, order a test kit: monitorwater.org/order-kits. You can find kit instructions and video tutorials at monitorwater.org/tools/event-resources.

With this kit, you will be able to collect data on temperature, dissolved oxygen, pH, and turbidity. If possible, return periodically to sample and monitor how the water quality changes over time at any of a series of shore-based sites along the Neuse River complementing our ModMon sampling sites.

Public access locations along the Neuse River, starting upstream in

New Bern and ending downstream in Oriental, include:

- Boat Ramp dock at Glenburnie Park in New Bern (N 35°8.383, W 77°3.592)
- Boat Ramp dock at Union Point Park in New Bern (N 35°6.292, W 77°2.084)
- Neuse River/Flanners Beach Recreation Area (N 34°59.065, W 76°56.931)
- Pine Cliff Recreation Area in Havelock (N 34°56.361, W 76°49.322)
Note: When exiting Pine Cliff Recreation Area, take a left onto Ferry Road. Drive to the end of the road to take the ferry across the Neuse River to Minnesott Beach to continue to the next sampling location.
- Janiero Road in Arapahoe (N 34°59.572, W 76°45.403)
- South Avenue in Oriental (N 35°1.479, W 76°41.509)

As a reward for your hard work, be sure to sample some ice cream at The Bean in Oriental before you return home.

Once you have collected data, you can upload the information at monitorwater.org.

You also can compare your data to ModMon and FerryMon data at the project websites (below).

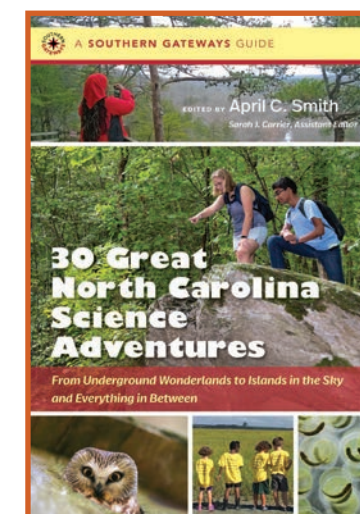
And consider monitoring other bodies of water for which you have an interest or concern.

- FerryMon: paerllab.web.unc.edu/projects/ferrymon/
- ModMon: paerllab.web.unc.edu/projects/modmon/
- The Paerl Lab: paerllab.web.unc.edu/

FerryMon started with support from North Carolina Sea Grant and the N.C. Hurricane Floyd Relief Fund. The N.C. General Assembly, the National Fish and Wildlife Foundation, the Duke Energy Water Resources Fund, The Reynolds Foundation, the National Science Foundation, and the N.C. Water Resources Research Institute have funded it since then. Over the years, several North Carolina Sea Grant projects also have relied on data from ModMon.

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IF COVID-19 AND A MAJOR HURRICANE COLLIDE

BY GREG BARNES

HURRICANE ISAIAS ALREADY LEFT DAMAGE THAT SPANNED THE EAST COAST, AND THE CORONAVIRUS CONTINUES TO CAUSE CHAOS. WITH FORECASTERS HAVING PREDICTED AN ABOVE-NORMAL HURRICANE SEASON, CAN NORTH CAROLINA'S MOST VULNERABLE COMMUNITIES FACE BOTH A SERIOUS STORM AND A PANDEMIC?

Continued

THE EYE OF FLORENCE



NWS Wakefield

HURRICANE ISAIAS BROUGHT TORNADOES TO THE EAST COAST EARLIER THIS YEAR, INCLUDING ONE THAT OBLITERATED A BERTIE COUNTY MOBILE HOME COMMUNITY.

Traffic snarled in Wilmington on July 11 as hundreds of vehicles lined up to receive free hurricane preparedness toolkits.

After three major hurricanes in 36 months, officials say the tremendous response to the toolkits shows that people are taking the threat of another hurricane seriously.

The National Oceanic and Atmospheric Administration predicts a 70% chance that this hurricane season will bring 19 to 25 named storms, with seven to 11 of those becoming hurricanes — including three to six major hurricanes. As *Coastwatch* went to press in early September, 15 storms already had been named this season.

In less turbulent times — those with cooler oceans and without the dampening effects of an El Niño — the typical prediction would be 12 named storms, with six becoming hurricanes.

North Carolina, like other states, has struggled to recover from the aftermath of one hurricane after another. Now it faces a much bigger challenge: the likelihood that a

hurricane will hit the coast during a pandemic of the highly contagious coronavirus.

NORTH CAROLINA, LIKE OTHER STATES, HAS STRUGGLED TO RECOVER FROM THE AFTERMATH OF ONE HURRICANE AFTER ANOTHER. NOW IT FACES A MUCH BIGGER CHALLENGE: THE LIKELIHOOD THAT A HURRICANE WILL HIT THE COAST DURING A PANDEMIC OF THE HIGHLY CONTAGIOUS CORONAVIRUS.

Mike Sprayberry, director of the state Department of Public Safety's Emergency Management, said COVID-19 adds many new and unwanted challenges, especially with shelters.

He said his agency has "a good, solid plan" to deal with a hurricane during these troubling times, but he didn't downplay the seriousness of the additional problems a major storm could create this year.

"It's important to be concerned,"

Sprayberry said. "Not worried, just concerned."

In July, he said, Emergency Management and other state agencies held a virtual teleconference to update and hear concerns from about 300 people — including local emergency management officials, first responders, National Guardsmen, volunteers, and many others — on executing the plans for hurricane preparedness and recovery.

Normally, Sprayberry and officials from other state agencies would take their show on the road, making in-person visits before representatives from counties, cities, and towns in hurricane-prone areas.

WHAT SOCIAL DISTANCING MEANS TO SHELTERS

Virtual conferencing is just one way that the pandemic has influenced the state's hurricane preparedness planning. Others include maintaining safe distancing in shelters, a potential reduction in disaster relief from other states, preparing to deal with already

crowded hospitals and exhausted medical personnel, and ensuring that people have places other than shelters to ride out the storm.

Perhaps the biggest challenge should a hurricane strike is safely operating and maintaining evacuation shelters, Sprayberry said. To provide adequate social distancing, the state has limited the shelters to 115 square feet per person.

Natosha Vincent, Wilmington's emergency services coordinator, said that means the four shelters designated for her city cannot hold a total of more than 235 people. During Hurricane Florence, Vincent said, those same shelters had a capacity of about 600 people.

Although no one would be turned away, Vincent said, the city is encouraging people who might have even a remote chance of having to evacuate to a shelter to make arrangements now to stay with family or friends who live inland.

Sprayberry said the state has plans in place to open more shelters if needed, a difficult task even without the pandemic because it is usually done with little advance warning.

Because of the coronavirus, Sprayberry said, shelters are being viewed as "a last resort," to be used primarily for people with nowhere else to go. Unlike in the past, cots won't be provided to maximize space, and people will have to bring their own bedding, Vincent said.

Sprayberry called shelters — and the possibility that such close living quarters will lead to a spread of the coronavirus — his "greatest concern."

As an alternative to shelters, Sprayberry said the state has identified more than 30,000 non-congregate living quarters for people forced to evacuate, including rooms in motels and dormitories farther inland.

Although still awaiting approval from the Federal Emergency Management Agency,

Sprayberry said, the state plans to establish reception areas where low-income people in high-risk areas could go before evacuating to learn which motel or dormitory would accommodate them.

THE STATE HAS ALSO CREATED EVACUATION ZONES IN AN EFFORT TO MAKE EVACUATING FASTER, MORE ORGANIZED, AND EFFICIENT. THE ZONES CAN BE FOUND ON A NEW INTERACTIVE WEBSITE, WHICH WILL ALSO UPDATE EVACUATION ORDERS FOR THE ZONES. IN ADDITION, READYNC HAS A COMPREHENSIVE WEBSITE THAT PROVIDES INFORMATION ABOUT STORM PREPAREDNESS, EVACUATIONS, SHELTERS, RECOVERY, AND THE CORONAVIRUS.

Continued on page 27

NORTH CAROLINA, LIKE OTHER STATES, HAS STRUGGLED TO RECOVER FROM THE AFTERMATH OF ONE HURRICANE AFTER ANOTHER. THE MONTH AFTER FLORENCE (HERE) MADE LANDFALL IN 2018, MICHAEL MOVED THROUGH THE STATE.



KNOW YOUR ZONE A NEW EVACUATION SYSTEM FOR COASTAL NC

BY DABNEY WEEMS

Know Your Zone, North Carolina's new system of coastal evacuation zones, launched earlier this summer. This tiered evacuation system focuses on areas most vulnerable to impacts from hurricanes, tropical storms, and other hazards.

The campaign was implemented to simplify the evacuation process by assigning lettered evacuation zones in each county, based on areas of higher and lower risk of flooding.

HOW DOES IT WORK?

Local governments in 20 North Carolina coastal counties have drawn pre-determined evacuation zones. As storms approach, local officials will determine which zones need to be evacuated and will order evacuations using the lettered zones.

North Carolinians can learn their zone by entering their address into an interactive map. You can find the zone for your workplace, children's school, and/or your loved ones, too. Visit KnowYourZone.NC.gov.

DURING AN EMERGENCY

Local officials will determine which zones should be evacuated. Areas in Zone A will typically be evacuated first, followed by areas in Zone B, etc.

While all zones won't be evacuated in every event, emergency managers will work with local media and use other outreach tools to notify residents and visitors of impacted zones and evacuation instructions. Residents should look and listen for their county name and zone when evacuations are ordered.

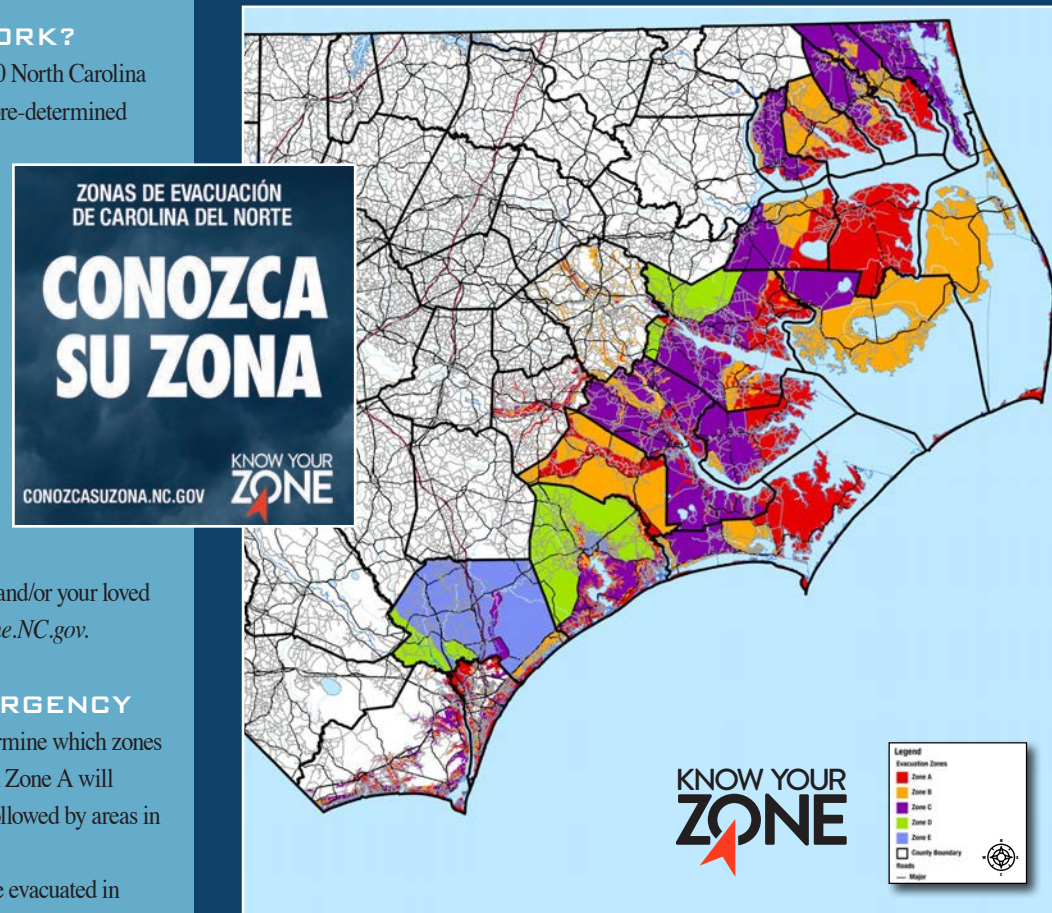
TELL YOUR NEIGHBORS

Once you learn your zone, the website has plenty of resources to share with your community. Social media graphics, posters, and even a children's activity packet are available to download here. Use them to help spread the word about *Know Your Zone*.

The more people who know their zone, the smoother the evacuation process becomes.

- North Carolina Hurricane Guides KnowYourZone.NC.gov
- ReadyNC.org
- *Know Your Zone* en español go.ncsu.edu/Conozca-Su-Zona

NORTH CAROLINA EVACUATION ZONES



KNOWYOURZONE.NC.GOV



Jorge Intrigoso/U.S. Army National Guard

TYPICALLY, JUST AFTER A HURRICANE HITS, HELP COMES POURING IN FROM OTHER STATES, INCLUDING SWIFT WATER RESCUE BOATS AND PERSONNEL, MEDICAL PROFESSIONALS, CHURCH ORGANIZATIONS, AND UTILITY CREWS — BUT WILL THE PANDEMIC AFFECT THIS RESPONSE?

The state has also created evacuation zones in an effort to make evacuating faster, more organized, and efficient. (See *Know Your Zone* on page 26.) The zones can be found on a new interactive website, which will also update evacuation orders for the zones. In addition, ReadyNC has a comprehensive website that provides information about storm preparedness, evacuations, shelters, recovery, and the coronavirus.

DOES NORTH CAROLINA HAVE ENOUGH PPE?

Sprayberry said he is less concerned about the availability of face masks and other personal protective equipment should a hurricane strike. The state now has a significant amount of PPE in its warehouses, compared with the shortage that happened in March and April, Sprayberry said.

"I'm not going to say comfortable, I'm going to say I'm not alarmed right now and I think it's something that we need to monitor closely and to make sure that we have a good plan in place," he reported in July. "Right now,

we have a significant amount of PPE in stock, but we can't take our eyes off the ball."

Sprayberry said local government officials can order more personal protective equipment from the state with no questions asked.

"We're not stopping ordering because we know that we're going to need it for building our strategic state stockpile for PPE."

HIGH RISKS FOR MARGINALIZED COMMUNITIES

People living in marginalized communities — typically poor minorities in low-lying, flood-prone areas — are the most susceptible to the coronavirus and to major storms. Many of those people lack transportation or friends and family living inland where they could go to seek shelter from a hurricane.

"One of the things that stands out to me about North Carolina, specifically, is that the risks and the vulnerabilities of those folks who are least able to manage those risks are so high," said Elena Craft, senior director of

climate and health for the Environmental Defense Fund. "For example, the low-income minority populations, especially in eastern North Carolina, and the impact of the underlying disease factors that also contribute to the risk for coronavirus infections.

"We think of it as a double or triple whammy, where they're at increased risk for having a severe coronavirus infection. They are more likely to have jobs where they're potentially exposed to coronavirus, less likely to have access to health care. It's just a tsunami of different variables that all contribute to sort of higher risk," she said. "Then you obviously add the impact from hurricanes."

Sprayberry is aware of those concerns.

"We always make plans for transportation," he said. "We can get buses. We have to put less people on the buses than normal. So what would be critical during a time like this is to ensure that if an evacuation order is going to be made, that it's done timely enough so that we have an orderly response that helps us maintain social distancing."

Continued

Betsy Albright, chairwoman of the Environmental Economics & Policy Program at Duke University's Nicholas School of the Environment, said the issue goes far beyond ensuring that people living in marginalized communities can safely evacuate. Albright spoke during a July 1 webinar hosted by the university, titled "Perfect Storms: Responding to Hurricanes While Addressing COVID-19."

"We know that low-wealth communities and communities of color are disproportionately affected by COVID-19, both in health and economic impacts," Albright said. "The impacts of hurricanes are amplified disproportionately across race, due to centuries of institutional and systemic racism. Further studies have documented inequitable access to resources for hurricane recovery across race."

"So all this taken together, the risk of hurricanes will magnify risks of COVID, and vice versa, with more significant impacts on communities of color, under-resourced

communities, and people who are living or working in congregate facilities, nursing homes and correctional facilities, meat processing facilities, etc."

THE FEET ON THE GROUND

Dawn Baldwin Gibson has worked in disaster relief efforts since Hurricane Irene struck the North Carolina coast in 2011. She now heads a task force for N.C. Voluntary Organizations Active in Disasters, is the administrator for a 5,657-member Facebook group called Eastern NC Disaster Resources, and is a superintendent at Peletah Ministries in New Bern.

In short, she is among the leading voices on the ground in eastern North Carolina taking charge of efforts to provide information, resources, and disaster recovery to impoverished minority communities.

Baldwin Gibson tells a story that begins shortly after Hurricane Irene, while she was

helping to hand out food in hard-hit areas. She said she came upon a man who thanked her for the food and then asked, "What about my dog?" With no food left in his home, the man had resorted to eating dog food.

Baldwin Gibson said hurricane preparedness and relief efforts have improved markedly since then.

"We've taken this community approach that it has to happen in communities," she said. "We need government. We need emergency management. We need these state agencies. But we also have to have communities that are at the table."

Baldwin Gibson noted an event scheduled for late July for hundreds of people to receive free healthy food, hurricane preparedness toolkits, and information on how to prepare for a storm.

"What we need is for this information that we're getting from the governor's office, from Director Sprayberry's office ... to make

CAN WE FOCUS ON A PANDEMIC AND STAY PREPARED FOR HURRICANE SEASON? COVID-19 TESTING IN SANFORD.



North Carolina National Guard/CC-BY-ND 2.0



North Carolina National Guard/CC-BY-ND 2.0

THE NATIONAL GUARD TRANSPORTED COTS AND BLANKETS TO THE AMERICAN RED CROSS SHELTERS IN FAYETTEVILLE IN THE AFTERMATH OF HURRICANE FLORENCE. THE NEED FOR SOCIAL DISTANCING NOW BRINGS ADDITIONAL CONSIDERATIONS WHEN PLANNING FOR SHELTER USE.

sure that it's getting to everyone that needs to be getting it," Baldwin Gibson said.

WILL THE CAVALRY COME?

Typically, just after a hurricane hits in North Carolina, help will come pouring in from other states, and sometimes even before the storm. That assistance includes swift water rescue boats and personnel, medical professionals, church organizations, utility crews, and the like.

Because of the pandemic, Sprayberry said, that may not happen with the same intensity as in the past, especially when it comes to medical workers. Other states now have their own problems to deal with, he said.

Baldwin Gibson said one of her biggest concerns is a lack of linemen from other states to help restore power.

"If that doesn't happen then we're talking about how we may be without electricity for much longer periods of time," she said. "What does that look like in marginalized communities?"

Baldwin Gibson said her biggest worry is that people become so focused on dealing with the pandemic that they forget just how important it is to prepare for a hurricane.

"MY GREATEST CONCERN IS THAT WE ARE SO FOCUSED ON THE DISASTER OF COVID-19 THAT WE DON'T UNDERSTAND HOW WE MUST STAY PREPARED FOR HURRICANE SEASON. THAT IS MY OVERWHELMING CONCERN, AND I AM APPRECIATIVE THAT THE INFORMATION IS BEING PUSHED OUT, BUT THIS IS REALLY GOING TO HAVE TO BE SOMETHING THAT WE'RE DOING AT A COMMUNITY LEVEL, THAT WE ARE WORKING WITH OUR LOCAL AGENCIES AND OUR LOCAL OFFICIALS TO MAKE SURE THAT EVERYONE UNDERSTANDS THE SERIOUSNESS OF WHAT WE ARE FACING."

— DAWN BALDWIN GIBSON

"My greatest concern is that we are so focused on the disaster of COVID-19 that we don't understand how we must stay prepared for hurricane season," Baldwin Gibson said. "That is my overwhelming concern, and I am appreciative that the information is being pushed out, but this is really going to have to be something that we're doing at a community level, that we are working with our local agencies and our local officials to make sure that everyone understands the seriousness of what we are facing." 📱

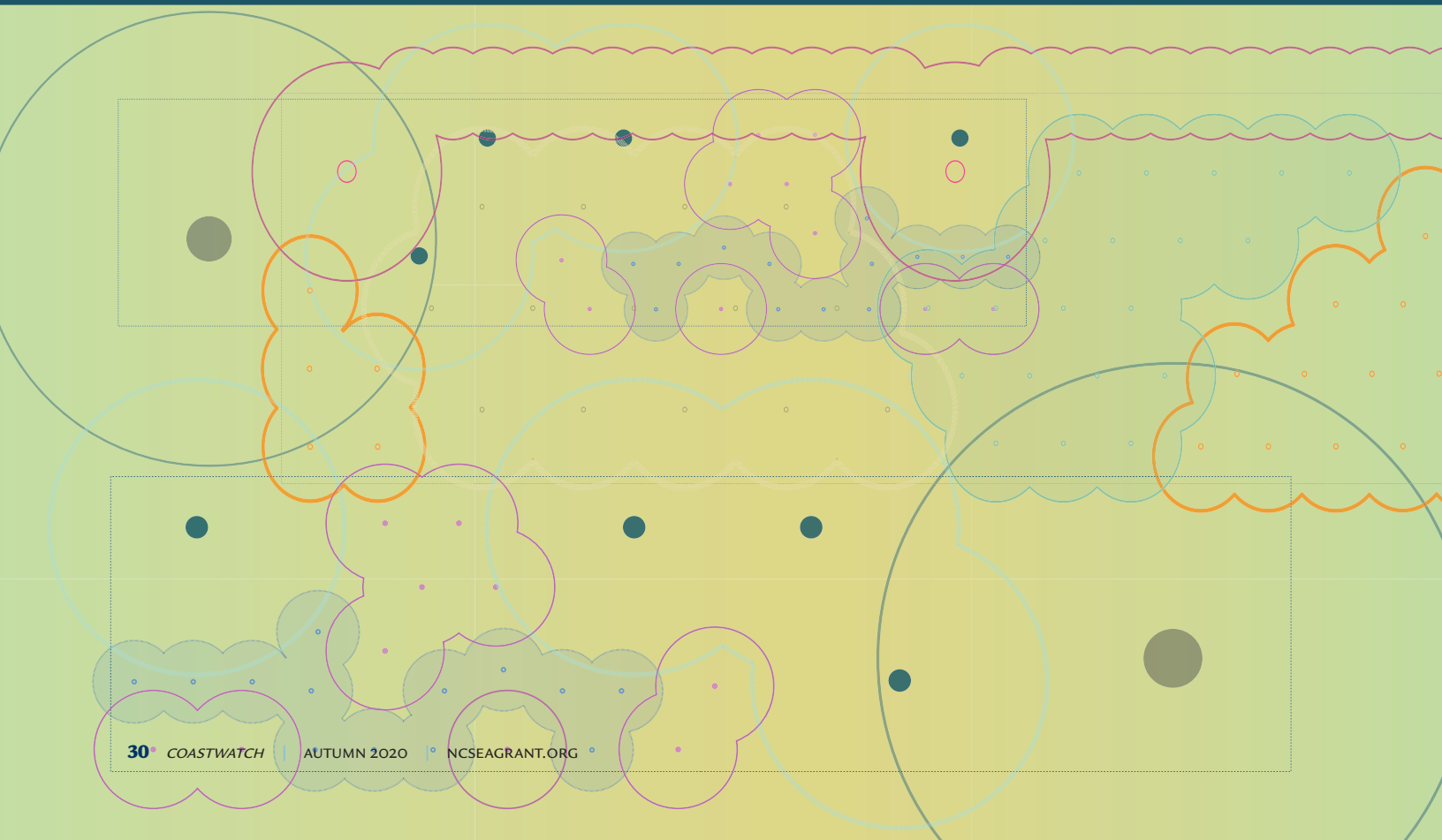
- More about hurricanes go.ncsu.edu/Coastwatch-hurricanes
- North Carolina Sea Grant's COVID-19 Resource Hub go.ncsu.edu/Covid-Resource-Hub
- More about climate change go.ncsu.edu/Coastwatch-climate

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NC COASTAL LANDSCAPING DESIGNS

NATIVE PLANTING TEMPLATES FROM THE COASTAL LANDSCAPES INITIATIVE



LANDSCAPING FOR THE COAST

The following pages contain landscaping design templates intended for anyone interested in growing native North Carolina plants in their yards. The templates are part of a larger series produced by the Coastal Landscapes Initiative and include two types of designs: borders and screens. Borders define edges and organize spaces in your yard but also can work as stand-alone gardens. Ideal locations are along walkways, driveways, fences, or road frontage. Screening designs block unwanted views and increase privacy. Ideal locations are along the street front, between houses, or in front of fences, air conditioning units, trash cans, and gas tanks.

WHY PLANT NATIVE?

Native plants play important roles in the coastal ecosystem. Incorporating them into developed landscapes is key to sustaining our coastal communities. These plants are attractive, versatile, and resilient. Native shrubs and trees are more likely to withstand the effects of storms because they are adapted to harsh coastal conditions. Wildlife also relies on native plants for nourishment and shelter.

USING THESE DESIGNS

Each template provides the design intent, ideal site conditions, an illustration of the design at maturity, a detailed planting guide, plant quantities, spacing, and seasonal bloom or berry color (gray indicates inconspicuous blooms or berries). Alternative plant suggestions and maintenance tips are included as well.

All designs have the same dimensions and can be modified or combined, such as by adding curves. When combining designs, you may need to move or rearrange plants to address crowding along edges. Also, the suggested number of perennials creates maximum density and effect from the start. If you are comfortable with less dense gardens, use fewer perennials.

When considering planting locations, do not place tall-growing plants below electrical power lines or where they pose hazards to built structures. Also avoid installing trees or shrubs above or near septic fields and close to mature trees. At least three days before you start digging, call 811 or 1-800-632-4949 for a free service that will mark your buried publicly managed utility lines.

SYMBOL KEY

SUN EXPOSURE

- 6+ hours of sun per day
- 3-6 hours of sun per day
- < 3 hours of sun per day

SOIL MOISTURE

- Areas that are dry and drain quickly
- Areas that retain moisture but drain well
- Areas that are typically wet

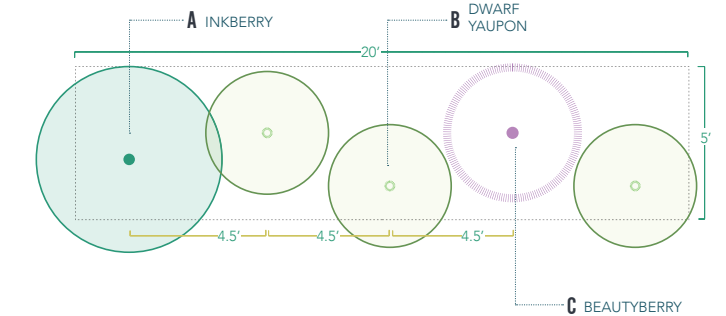
Elevation View

- Illustrates plant heights, horizontal spacing, and visual appearance such as shape, texture, and color.
- Shows the garden at maturity. It will take a year or more before a newly planted garden starts filling out.



Plan View

- Depicts plants, layout, and spacing for a 20-foot-by-5-foot area.
- Plants are color-coded and labeled with dimensions at maturity. Plants will be smaller when installed.
- Spacing is given "on center" (O.C.), indicating the planting distance between the center of one plant to the center of the next, regardless of plant size at installation.



Plant Selection

KEY	QTY	COMMON NAME	BOTANICAL NAME	PLANT TYPE	SPACING	SEASONAL COLOR																	
						J	F	M	A	M	J	J	A	S	O	N	D						
A	3	Sweetbay magnolia	Magnolia virginiana	TREE	10' O.C.																		
B	31	'Fireworks' goldenrod	Solidago rugosa 'Fireworks'	PERENNIAL	18" O.C.																		
C	14	Orange coneflower	Rudbeckia fulgida	PERENNIAL	18" O.C.																		

Worksheet and Other Resources

Gridded worksheets can help you determine where the designs best fit on your property. A printable worksheet, plant guides, and other resources on native plants are available online: go.ncsu.edu/CoastalLandscapes.

FILTER STRIP

FOR SUNNY AREAS WITH DRY TO MOIST SOIL

SUN: ☀️ ☁️
 SOIL MOISTURE: 💧 💧
 SEASONAL COLOR: SPRING & FALL



ELEVATION VIEW

DESCRIPTION

This simple, naturalistic design works well along roads, driveways, ditches, swales, pond shores, or bulkheads. The plants filter out sediment, nutrients, and other pollutants from stormwater and also attract native pollinators and birds.

ALTERNATIVE

Grass substitutes: Elliott's lovegrass (*Eragrostis elliottii*) and the perennial goldenrod cultivar *Solidago rugosa* 'Fireworks,' which blooms in autumn.

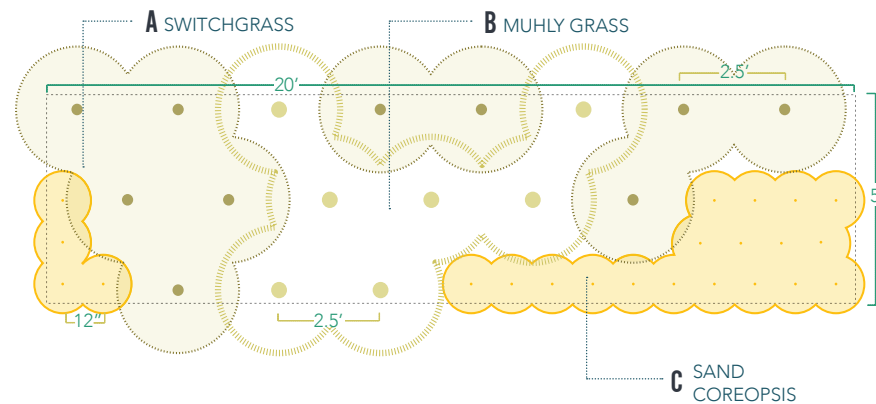
Perennial substitutes: For autumn interest and pollinator support, use calico aster (*Symphotrichum lateriflorum*) and *Solidago rugosa* 'Fireworks.'

For early season color, use blue wild indigo (*Baptisia australis*) or bluestar (*Amsonia tabernaemontana*).

MAINTENANCE

Cut back grasses in late winter or early March. Leave an 8-to-12-inch crown on the muhly grass.

PLAN VIEW 5' x 20'



PLANT SELECTION

KEY	QTY	COMMON NAME	BOTANICAL NAME	PLANT TYPE	SPACING	SEASONAL COLOR														
						J	F	M	A	M	J	J	A	S	O	N	D			
A	10	Switchgrass	<i>Panicum virgatum</i>	GRASS	2.5' O.C.															
B	7	Muhly grass	<i>Muhlenbergia capillaris</i>	GRASS	2.5' O.C.															
C	22	Sand coreopsis	<i>Coreopsis lanceolata</i>	PERENNIAL	12" O.C.															

EVERGREEN SCREEN

FOR DRY AREAS WITH SUN TO PART-SHADE

SUN: ☀️ ☁️
 WATER: 💧
 SEASONAL COLOR: OCT-FEB



ELEVATION VIEW

DESCRIPTION

The dense, bushy habit of these large shrubs provides separation and privacy, making this screening garden ideal for along roads or between houses. When placing this design, avoid blocking long views of the landscape for you and your neighbors.

Wax myrtle has a fast growth rate, yaupon has a moderate rate, and inkberry grows slowly.

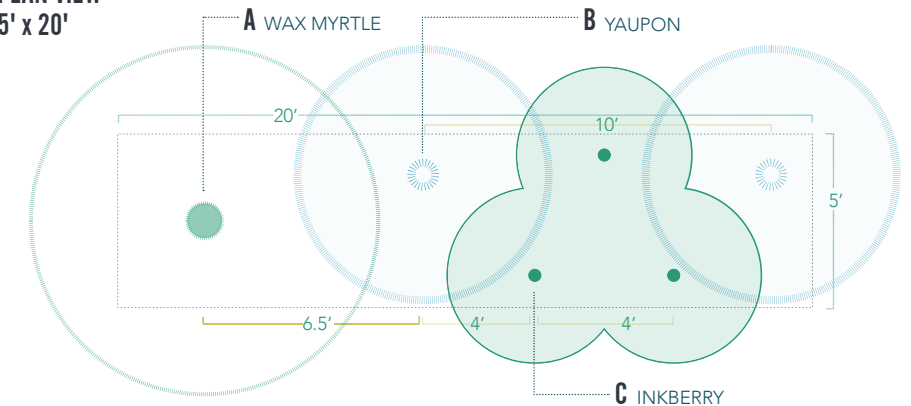
ALTERNATIVE

The eco-regional anise shrub (*Illicium parviflorum*) is an additional shrub option. If you prefer less height, dwarf varieties also are available for most plants in this design. Dwarf palmetto (*Sabal minor*) would be appropriate for drier sites.

MAINTENANCE

If needed, prune shrubs in late autumn or winter.

PLAN VIEW 5' x 20'



PLANT SELECTION

KEY	QTY	COMMON NAME	BOTANICAL NAME	PLANT TYPE	SPACING	SEASONAL COLOR														
						J	F	M	A	M	J	J	A	S	O	N	D			
A	1	Wax myrtle	<i>Morella cerifera</i>	SHRUB	6.5' O.C. TO YAUPON															
B	2	Yaupon	<i>Ilex vomitoria</i>	SHRUB	10' O.C.															
C	3	Inkberry	<i>Ilex glabra</i>	SHRUB	4' O.C.															

BIRD-FRIENDLY SCREEN

FOR DRY TO MOIST AREAS WITH SUN TO PART-SHADE

SUN: ☀️
 SOIL MOISTURE: 💧-💧
 SEASONAL COLOR: MAY-DEC



Wax myrtle



American beautyberry



Inkberry



Orange coneflower

DESCRIPTION

All plants in this design attract birds to the yard. Wax myrtle, inkberry, and beautyberry produce abundant berries in late summer and fall that are irresistible to birds and other backyard wildlife. Many birds also eat the seeds of the orange coneflower.

This design provides a screen to increase privacy or block unwanted views. It also creates a stand-alone garden area for observing wildlife. Only female plants of wax myrtle and inkberry produce berries, so try to select a female plant at the nursery and ensure there are male plants nearby for pollination (in a neighbor's yard or a natural area). This approach is also true for the alternates below.

Wax myrtle and beautyberry are fast-growing while inkberry is slow-growing.

ALTERNATIVE

All of these plants should be readily available. If you need less height, dwarf varieties exist for most of the shrubs.

Shrub substitutes: For wax myrtle, try yaupon holly (*Ilex vomitoria*). For beautyberry, choose winterberry holly (*Ilex verticillata*) or black chokeberry (*Aronia melanocarpa*). For inkberry, try dwarf palmetto (*Sabal minor*) or deciduous coralberry (*Symphoricarpos orbiculatus*).

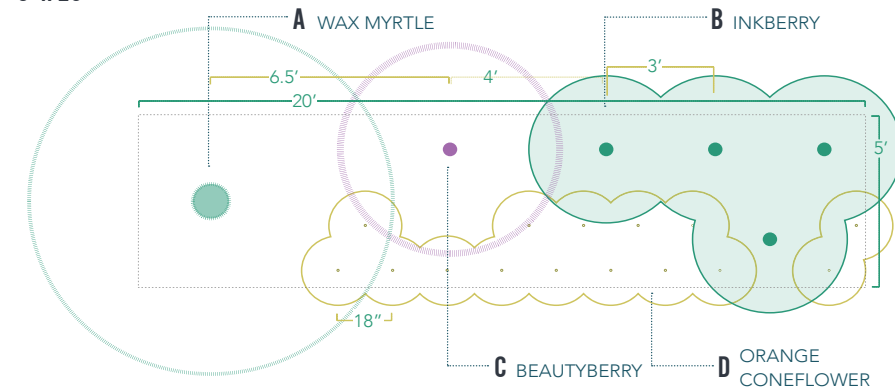
MAINTENANCE

If needed, shrubs can be pruned in late autumn or winter. Beautyberry can be pruned more than other shrubs if a smaller size is desired, but it also thrives if left to grow. Wax myrtle recovers quickly from minor storm damage, but broken branches or damaged bark should be removed.



ELEVATION VIEW

PLAN VIEW
5' x 20'



PLANT SELECTION

KEY	QTY	COMMON NAME	BOTANICAL NAME	PLANT TYPE	SPACING	SEASONAL COLOR																
						J	F	M	A	M	J	J	A	S	O	N	D					
A	1	Wax myrtle	Morella cerifera	SHRUB	6.5' O.C. TO INKERRY																	
B	4	Inkberry	Ilex glabra	SHRUB	6.5' O.C.																	
C	1	American beautyberry	Callicarpa americana	SHRUB	3' O.C. TO WAX MYRTLE																	
D	15	Orange coneflower	Rudbeckia fuligida	PERENNIAL	18" O.C.																	

POLLINATOR-FRIENDLY BORDER

FOR SUNNY AREAS WITH DRY TO MOIST SOIL

SUN: ☀️
 SOIL MOISTURE: 💧-💧
 SEASONAL COLOR: APR-DEC



Sweet pepperbush



Butterfly weed



Wild blue indigo



Purple coneflower



Pink muhly grass



ELEVATION VIEW

DESCRIPTION

The combination of flowering perennials, native ornamental grass, and shrubs add year-round interest with texture and color. This design also provides important foraging grounds and habitat for birds, bees, and butterflies. Butterfly weed (or milk-weed) is a host plant for monarch butterflies. It also readily seeds, so patient gardeners can plant less, letting it naturally colonize over time. If exposure to salt spray is a concern, search for more salt-tolerant plants.

ALTERNATIVE

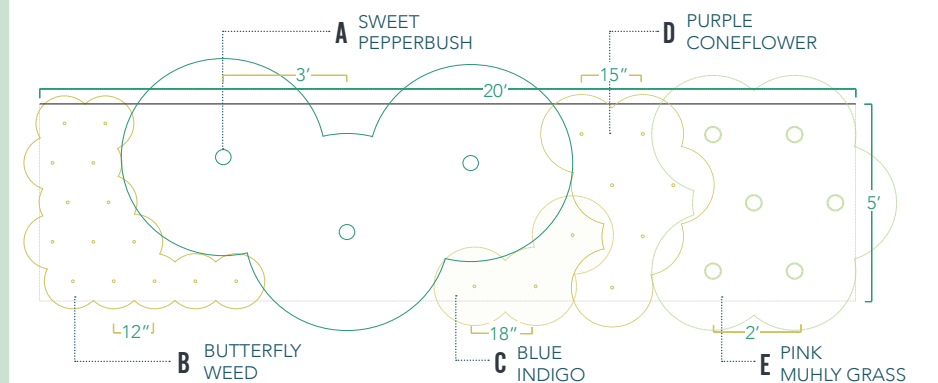
Shrub substitutes: For dry soils, Adam's needle (*Yucca filamentosa*) is a good choice. Otherwise, opt for inkberry (*Ilex glabra*).

Perennial substitutes: eastern smooth beardtongue (*Penstemon laevigatus*), sand coreopsis (*Coreopsis lanceolata*), or more butterfly weed. Also, add a tall (6-foot) semi-evergreen bush like zenobia (*Zenobia pulverulanta*) on the back of the border for year-round structure.

MAINTENANCE

Prune clethra in winter or early spring, if needed. Cut back grasses in late winter or early spring. Leave an 8-to-12-inch crown on muhly grass.

PLAN VIEW
5' x 20'



PLANT SELECTION

KEY	QTY	COMMON NAME	BOTANICAL NAME	PLANT TYPE	SPACING	SEASONAL COLOR																
						J	F	M	A	M	J	J	A	S	O	N	D					
A	3	Sweet pepperbush	Clethra alnifolia	SHRUB	3' O.C.																	
B	14	Butterfly weed	Asclepias tuberosa	PERENNIAL	12" O.C.																	
C	3	Blue wild indigo	Baptisia australis	PERENNIAL	18" O.C.																	
D	6	Purple coneflower	Echinacea purpurea	PERENNIAL	15" O.C.																	
E	6	Muhly grass	Muhlenbergia capillaris	GRASS	2' O.C.																	



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Sharks, Shrimp, and Computerized Fish IDs

The Latest Science for Anglers

BY SCOTT BAKER AND SARA MIRABILIO

ARE CATCH-AND-RELEASE DEEPWATER FISH AN EASY MEAL FOR SHARKS?

Research suggests that using descending devices doesn't serve up dinner.

I confess to binge watching National Geographic's SHARKFEST. Five weeks of episodes highlighted the varying behaviors and life strategies of the ocean's greatest predators.

Back in July, just before SHARKFEST began, new regulations went into effect requiring use of a descending device in South Atlantic federal waters to help improve survival of released deepwater fish. But can shark appetites undermine this conservation strategy?

A research team led by one of the

scientists who appeared on SHARKFEST, Marcus Drymon of Mississippi-Alabama Sea Grant, decided to find out.

• Research Need

Reducing mortality after catch-and-release in offshore recreational fisheries remains an important component of stock rebuilding for many reef fish. Mortality for these species can be high, due in part to injuries sustained during capture, coupled with high catch rates and various regulations.

Possible causes of mortality also include plundering sharks and other predators.

Anglers and regulatory agencies alike want to know more about such opportunistic feeding, especially during the use of descending devices, which help released fish reacclimate to water pressure and return to deep waters.

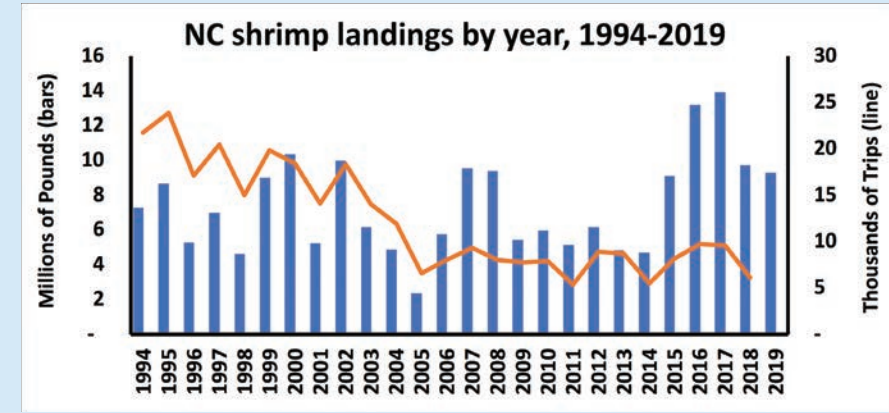
• What did they study?

To understand whether use of descending devices increases opportunities for predators to have a quick meal, researchers examined two GoPro camera data sets of red snapper from the Alabama Artificial Reef Zone in the northern Gulf of Mexico. This area is the largest artificial reef network in the United States, supporting avid catch-and-release fishing for red snapper. Anglers in this region say sharks often partially or completely chomp offhooked fish.

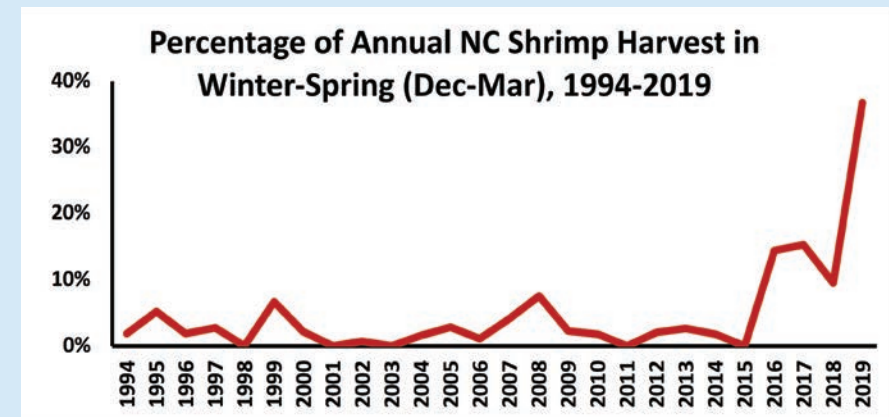
Scientists reviewed video footage for fish caught and ascended on commercial longline gear and also for descender releases from hook-and-line-caught fish.

• What did they find?

From 2016 to 2018, scientists collected a total of 1,483 videos from longline catches



Scott Baker



Scott Baker

Shrimp landings vary a lot year by year, but more recently the percentage of annual shrimp harvest has jumped for wintertime, December through March.

and 1,096 from descender releases. Sharks feasted on 54 longline catches but not on any fish released with a descending device. Videos also showed dolphins stealing from longlines 15 times, but, as with sharks, never from descender-released fish. Incidentally, 11 of those 15 instances of dolphins feeding off longlines occurred within a single two-day period.

• Anything else?

Scientists believe red snapper resist the ascending longline hook and, thus, swim erratically, which attracts sharks. Conversely, red snapper attached to descenders are nearly motionless and, therefore, likely do not attract attention from predators.

• So what?

Angler concerns about pillaging sharks have slowed the adoption of descending devices as a conservation strategy. However, results from this study show that descending devices aren't actually baiting sharks or other predatory thieves, allowing released fish to live another day and help rebuild the population.

—by Sara Mirabilio

WHAT'S UP WITH NORTH CAROLINA SHRIMP?

Are we catching more shrimp offshore during the winter and spring?

While it seems like a lifetime ago now, in early March I was invited to give a presentation at the annual North Carolina Catch Summit in Raleigh to discuss North Carolina marine fisheries and seafood trends. I had received several requests for topics to discuss beforehand, one being to provide more information about anecdotal reports of an increase in N.C. shrimp during the winter and spring months the past few years.

• Research Need

In North Carolina, wild-caught shrimp is one of the most important seafoods to the coastal economy, providing the livelihood for many commercial fishermen, a popular seafood for residents and tourists, and the bait-of-choice for many saltwater anglers.

Unlike most marine finfish, shrimp species are an annual crop, with fluctuations in their numbers closely linked to environmental drivers and biotic conditions. As a rule of thumb,

historically 75% of N.C. shrimp are harvested in internal waters, with 25% coming from the Atlantic Ocean, predominantly off our southern coast.

The last few years, however, fishermen have reported catching more shrimp in the ocean during the winter and spring. Are the numbers really up? And, if so, how would it compare to historic levels of shrimp harvest by waterbody and season?

• What did we study?

N.C. Division of Marine Fisheries (NCDMF) provided shrimp landings data by month, year, and waterbody for 1994 through 2019. Comparing shrimp harvest by season during this period can show if and how the December through March periods are changing in relation to the rest of the year.

• What did we find?

First, from a historical perspective, it is important to see that shrimp landings and the number of trips by year are highly variable. Over the last 26 years, annual shrimp landings have ranged from 2.3 million to 13.9 million pounds.

Next, during this same 26-year period, most of the N.C. shrimp harvest (76% of total landings) occurred in July through October.

It gets more interesting when we look at shrimp landings by waterbody and season.

It is easy to see the relative stability of the ocean landings in comparison with the estuarine landings until 2015. At that point, the nearshore ocean landings begin to spike – followed by an increase in offshore ocean landings later in 2019. Estuarine landings during this time remain highly variable.

Finally, when we look at shrimp landings by season, we really start to see some changes.

Between the years 1994 and 2015, the percentage of annual shrimp harvest during December through March each year ranged from 0% to 8%. However, during the same months in the years 2015 to 2019, the percentage of annual shrimp harvest ranged from 10% to 37%.

Again, it's important to reiterate that very few shrimping trips typically occur during these months, because shrimp are usually not abundant in our waters then.

By the way, the predominant species associated with the December to March time period is white shrimp.

Continued

• *Anything else?*

Since 2017, one year after North Carolina's first uptick in December to March Atlantic Ocean landings, Virginia has consistently seen an increasing abundance of white shrimp in its nearshore ocean waters. This is highly unusual. North Carolina historically has been the northernmost boundary on the East Coast for commercial quantities of Penaeid shrimp species, which don't do well in cold water. An experimental shrimp trawl fishery has expanded each year in Virginia since 2017, where six permitted vessels collectively harvested 65,000 pounds of shrimp in 2019.

• *So what?*

It's too early to tell whether changes in shrimp harvest by waterbody and season will be a consistent, long-term trend or simply a multi-year anomaly. These changes can at least partially be attributed to the global rise in sea surface temperatures, which is causing similar shifts for other marine finfish. Regardless, it has extended the shrimp season for N.C. fishermen and consumers requesting N.C. shrimp, a trend certainly worth watching.

— by Scott Baker

CAN COMPUTERS ACCURATELY IDENTIFY FISH BY SPECIES?

Research suggests that state-of-the-art modeling is the key to the automated identification of fish.

• *Research Need*

Fisheries managers need to correctly count and identify fish by species to estimate fish abundance and monitor ecosystem health. Traditionally, scientists have relied on lethal sampling practices to gather this information. However, whenever possible, scientists are increasingly relying on underwater video-based fish monitoring to observe and document fish populations.

Sounds perfect, right? But what's the catch with this type of technique?

The challenge is that fish identification through video typically requires the use of skilled human video reviewers. Attempts to use computers alone have produced widely mixed results. But what if researchers could develop an algorithm that would allow computers alone to identify fish by species from video footage?

• *What did they study?*

Scientists collected underwater stereo-video footage from other researchers leading fish-trap sampling programs in the marine waters of Western Australia. They obtained footage for 16 different marine species from native shallow waters and habitats (kelp, seagrass, sand, and coral reefs).

Whereas most previous automated fish identification systems used only the images to develop a computer algorithm, researchers in this study also incorporated many of the unique features of each fish species — such as body shape, color, and shading — into the process. Then, by using many different layers of data and decision steps, researchers developed and evaluated a “deep-learning neural network.”

• *What did they find?*

This method was accurate 89% to 94% for fish species examined in typical underwater imagery. The higher range of classification accuracy is competitive with how well human experts identify fish by species.

This research indicates that further development of computer-based, automated fish identification classification systems from



Emma Hickerson/NOAA

Fishery managers can use study results to predict areas of fish biodiversity at large and small scales.

underwater imagery is warranted, and that these systems can be feasible and cost-effective alternatives to identification by humans.

• *What's Next?*

The authors admit that fish observed in underwater videos outside of these tests will likely be recorded under a wide range of resolutions, swimming orientations (e.g., towards the camera), speeds, and background clutter (like other fish) — criteria that will make classification success more challenging. However, this study provides important progress on a path to further advance this field of study.

— by Scott Baker

HOW DIVERSE ARE TEMPERATE REEF FISHES ON THE SOUTHEAST COAST?

Over a three-year period, scientists observed 138 species of fish.

• *Research Need*

Temperate waters off the coast of North Carolina support a diverse reef-fish community. Saltwater fishing is wildly popular due to the accessibility of thriving reefs and wrecks in nearshore waters.

But unlike coral reef fishes in tropical environments, scientists have not studied

temperate reefs to great extent. Fishery managers need data to document gradual changes in reef fish communities over time and to properly manage them for long-term viability.

• *What did they study?*

Scientists wanted to know more about broad patterns and numbers of fish species inhabiting temperate reefs of the U.S. Southeast Atlantic. Using a fish trap mounted with a video camera, they collected underwater videos and fish samples at depths from 15 to 115 meters (49.2 to 377.3 feet) from Cape Hatteras, North Carolina, to St. Lucie Inlet, Florida.

Sampling occurred from spring through fall of each year. Scientists reviewed the videos to determine which fish species and families were most and least often observed on naturally occurring hardbottom reefs throughout the region. They then compared those observations to the number of species collected from fish trap sampling. Finally, the scientists examined how these observations changed with space, time, environmental conditions, and habitats.

• *What did they find?*

From 2015 to 2017, scientists sampled 4,130 stations. Overall, they observed 138 species of fish.

Just over half of all species observed were seen on less than 1% of videos, and 23 species appeared just once in a single video. Video

most often captured gray triggerfish (45.6%), tomate (42.7%), red porgy (39.4%), almaco jack (36.6%), sand perch (35.8%), vermilion snapper (34.9%), and black sea bass (32.2%).

Some species were observed much more frequently in North and South Carolina compared to Georgia and Florida, including black sea bass, bandtail puffer, white grunt, scamp, and gag.

Generally, fishes occurred at consistent rates across the three study years. The biggest decline occurred with black sea bass, from 38.3% in 2015 to 29.0% in 2016. The largest increase occurred with red snapper, from 24.7% in 2016 to 34.3% in 2017.

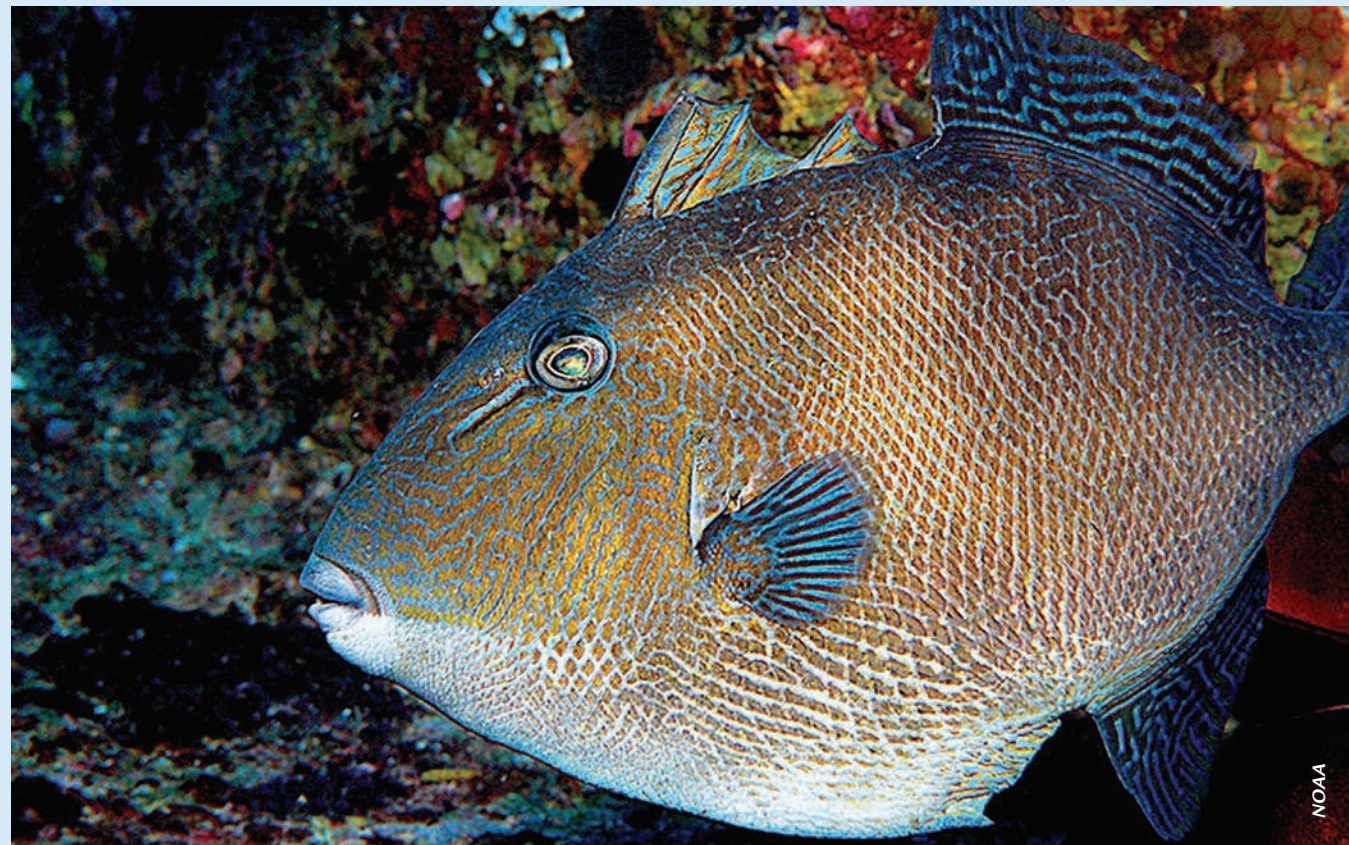
Models suggested that the number of different fish species represented on a reef was highest at sites characterized by moderate depths, a high proportion of hardbottom, high elevation and slope of the hardbottom, and warm water.

• *So what?*

Fishery managers can use these research results to predict areas of highest reef fish biodiversity at large (regional) and small (“microhabitat”) scales to improve marine-protected area design, delineate essential fish habitats, and refine ecosystem models.

— by Sara Mirabilio

HookLineScience.com



NOAA

Gray triggerfish were prominent in a study of Southeast reef fish diversity.



Baked Spotted Trout with Bacon Stuffing



Crab Cake Appetizers with Fresh Tarragon



Oyster Dressing with Thyme



Sautéed Black Sea Bass with Lemon-Thyme Sauce

FALL FAVORITES

BY 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 PICTURES WITH RECIPES THE LATE JOYCE TAYLOR DEVELOPED. LEWIS SELECTED THESE SAVORY DELIGHTS TO ENJOY THIS AUTUMN. MARINERSMENU.ORG

BAKED SPOTTED TROUT WITH BACON STUFFING

- 4 spotted trout fillets
- 6 bacon slices
- 1/4 cup onion, finely chopped
- 2 cups soft breadcrumbs
- 1/4 cup chicken broth
- 1/4 teaspoon salt
- 1/4 teaspoon freshly ground black pepper
- 1/4 teaspoon sage
- 1/4 teaspoon thyme leaves
- 1 1/2 tablespoons butter, melted salt
- freshly ground black pepper

In a medium saucepan, cook the bacon. Remove the bacon and dice. Discard all but 1 tablespoon of bacon drippings. Add onion and

cook until tender. Stir in crumbs, broth, 1/4 teaspoon salt, 1/4 teaspoon pepper, sage, thyme, and bacon.

Lay out the fillets on a work surface, skin side up. Spoon stuffing onto the fillets. Roll up each fillet and place the seam side down on a parchment-lined baking sheet. Brush with 1 1/2 tablespoons of melted butter. Lightly salt and pepper. Bake at 375°F until done, about 10 to 12 minutes.

CRAB CAKE APPETIZERS WITH FRESH TARRAGON

- 1 pound backfin crab meat
- 3 tablespoons butter
- 1/4 cup red pepper, chopped
- 1/4 cup celery, chopped
- 1/4 cup onion, chopped
- 3 tablespoons fresh tarragon, chopped
- 1/4 teaspoon Tabasco sauce
- 1/8 teaspoon cayenne pepper
- 1/2 teaspoon salt
- 1/2 cup mayonnaise
- 1 egg, beaten
- 1 cup French breadcrumbs
- 1 cup French breadcrumbs for coating

Melt the butter in a medium saucepan. Sauté red pepper, celery, and onion until tender.

Remove it from heat. Stir in tarragon, Tabasco, cayenne, and salt. Blend in mayonnaise, egg, and breadcrumbs. Gently blend in crab meat, taking care not to break the meat apart.

Shape into bite-size balls, about 1 inch in diameter. Dredge lightly in the remaining 1 cup of breadcrumbs.

Deep fry in hot oil until golden brown, about 3 minutes. Be sure the oil is hot before putting in the second batch.

You also can prepare these as regular crab cakes.

OYSTER DRESSING WITH THYME

- 2 cups oysters, drained, coarsely chopped, liquid reserved
- 2 sleeves saltine crackers, crushed
- 1/2 cup butter
- 1/2 cup onion, chopped
- 1/2 cup green onions, including tops, chopped
- 1/2 cup celery, chopped
- 1/2 cup heavy cream
- 1 teaspoon dried thyme
- 1/4 teaspoon salt
- 1/2 teaspoon freshly ground black pepper

Melt the butter, and add onion, green onions, and celery. Lightly sauté it. Remove it from heat. Add cream, thyme, salt, and pepper.

In a large bowl, combine the crushed crackers and vegetable mix.

Add oysters and toss lightly. Add the reserved oyster liquid until stuffing is moist, about 1/4 cup.

Place in a shallow greased baking pan. Bake, uncovered, at 400° F until done through and crusty on top, about 30 to 40 minutes.

SAUTÉED BLACK SEA BASS WITH LEMON-THYME SAUCE

- 4 black sea bass fillets
- salt
- freshly ground black pepper
- flour
- 2 tablespoons vegetable oil
- 2 tablespoons butter

Lemon-Thyme Sauce

- 4 tablespoons butter
- 2 tablespoons fresh lemon juice
- 1/2 teaspoon lemon zest
- 1/4 teaspoon freshly ground white pepper
- 2 teaspoons fresh thyme, minced

Prepare lemon-thyme sauce and keep warm. In a small saucepan over low heat, melt the butter. Remove from heat and add juice, zest, pepper, and thyme. Mix well.

Lightly salt and pepper the fillets. Dredge lightly in flour. Heat oil in a large skillet, and then add butter. Cook the fish until just golden brown on one side, about 3 to 4 minutes. Turn and repeat on the other side. Serve with lemon-thyme sauce over the black sea bass. 🍴

MARINERSMENU.ORG

Is Climate Change Affecting Sea Turtle Hatchlings?



T. Moore/NOAA

As cold-blooded creatures, loggerhead sea turtles remain vulnerable to global warming.

BY SARA MIRABILIO

Research shows that warming temperatures cause loggerheads to give birth mostly to female offspring.

AT THE N.C. AQUARIUM ON ROANOKE ISLAND, A JANUARY COLD SNAP RESULTED IN ABOUT 180 SEA TURTLE “PATIENTS” AT THE FACILITY FOR REHAB, ALMOST ALL SUFFERING FROM A CONDITION CALLED COLD STUN – THE HYPOTHERMIA THAT OCCURS WHEN SEA TURTLES ARE EXPOSED TO QUICK ONSET OR PROLONGED COLD-WATER TEMPERATURES.

As cold-blooded animals, sea turtles are vulnerable to climate change, because their life history and reproduction are tied to

environmental temperatures. High temperatures in the nest increase hatchling mortality, as well as the proportion of female hatchlings produced. This, in turn, affects long-term viability of sea turtle populations. Worldwide, six of the seven sea turtle species are classified as threatened or endangered, which is why sea turtles are a high priority for natural resource managers.

In North Carolina, scientists wanted to know a little more about the risk to sea turtle populations from environmental changes.

• **WHAT THEY STUDIED**

Studies have shown that when sea turtle eggs incubate below 81.8°F, the hatchlings will

be male. When the eggs incubate above 87.8°F, the hatchlings will be female. Temperatures that fluctuate between the two extremes will produce a mix of male and female baby turtles. Given that global temperatures are predicted to increase by as much as 7.2°F over the next century, widespread “feminization” of sea turtle hatchlings is a significant concern.

Scientists at the University of North Carolina Wilmington wanted to see whether changes in climate over the past 25 years have affected incubation times or the proportions of male and female offspring of loggerhead sea turtles, a protected species.

The study location was a high-density nesting beach on Bald Head Island, where the

Bald Head Island Conservancy has tracked loggerhead nests each year since 1991. Over a 25-year period, the Conservancy has monitored 1,347 nests from the first nights when the turtles deposited eggs up until the emergence of hatchlings.

Long incubation times often correspond to lower incubation temperatures (and, in turn, more male hatchlings). As a result, armed with information from NOAA’s weather station in nearby Southport and the Conservancy’s

dataset of incubation times, the research team could calculate the percentage of male and female hatchlings for each nest.

• **THE KEY FINDINGS**

Over the 25-year study period, the mean temperatures during the peak nesting season from June to August significantly increased, while incubation times significantly decreased. As a result, researchers calculated that the proportion of female hatchlings produced on

the island significantly increased.

The research team did not find evidence of significant changes over time in either hatching success — the portion of eggs from a nest that hatched — or in the dates of initial nesting. They did find that precipitation has a small effect on hatching success.

The journal *Ecology* published the full study: go.ncsu.edu/hot-eggs.

From HookLineScience.com

A nesting loggerhead mother (left), a mature loggerhead sea turtle at home in the water (right), and the very first steps of a loggerhead hatchling (below).

Jean-Lou Justine/CC-BY-SA 4.0



NOAA



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MORE THAN SAND DOLLARS

BY JEFF HAMPTON

Beachcombers prize the iconic skeletons, but these creatures were masters of their environment when they were alive.

THE BRIGHT WHITE SAND DOLLARS PRIZED BY BEACHCOMBERS AND COVETED BY CRAFT MAKERS WERE ONCE MASTERS OF THEIR SEA-BOTTOM HABITAT.

The elements that make a sand dollar so attractive served vital functions for the living creature: the five-pointed star in the center, the five flower petals radiating out from the star, and the five oblong holes.

Sand dollars found on the Outer Banks

are the skeletons of “keyhole urchins,” says Terri Kirby Hathaway, marine education specialist for North Carolina Sea Grant.

Hathaway speaks with school groups, museums, and civic organizations about marine life. Sand dollars — related to starfish

and sea urchins — are among the favorite topics.

Many species of sand dollars live in tropical waters of the Atlantic and Pacific oceans and are known by names such as sea cookies and sand cakes. They are built like Frisbees to allow food-filled ocean currents to pass over them easily.

When alive, sand dollars are brown or purple instead of white. They are covered in thousands of tiny spines that catch larvae, plankton, and algae and pass them along like a bucket brigade to their mouth in the center.

“If they’re brown and still have spines on them, throw them back into the water,” Hathaway says. “They’re probably still alive.”

The star on the skeleton was part of the food grooves that channel morsels to the mouth. The five-petal pattern around the star were sets of pores that extended to tube feet which allow for respiration, Hathaway says.

These sea creatures are 2 to 4 inches in diameter and live in groups by the hundreds on the sea floor, partially burrowing themselves into the sand to remain in place as they catch

food. They don’t have many predators, but if threatened, they bury themselves entirely.

The creatures’ five oblong holes, known as “lunules,” let water pass through them to reduce the lifting pressure of the current. The holes also let sand pass through and the animals disappear more quickly into the sea bottom.

When they die and wash ashore, their skeletons become works of art.

Designs and jewelry made from them, and in their likeness, are among the most desired pieces of beach art, says Laura Parks, a manager at Seagreen Gallery in Nags Head.

“I think they are one of those things that are classic beach,” she adds.

As small, round, well-decorated objects lying on the beach, they look like coins. Legends say they are mermaid money or currency used in Atlantis, the mythical undersea city.

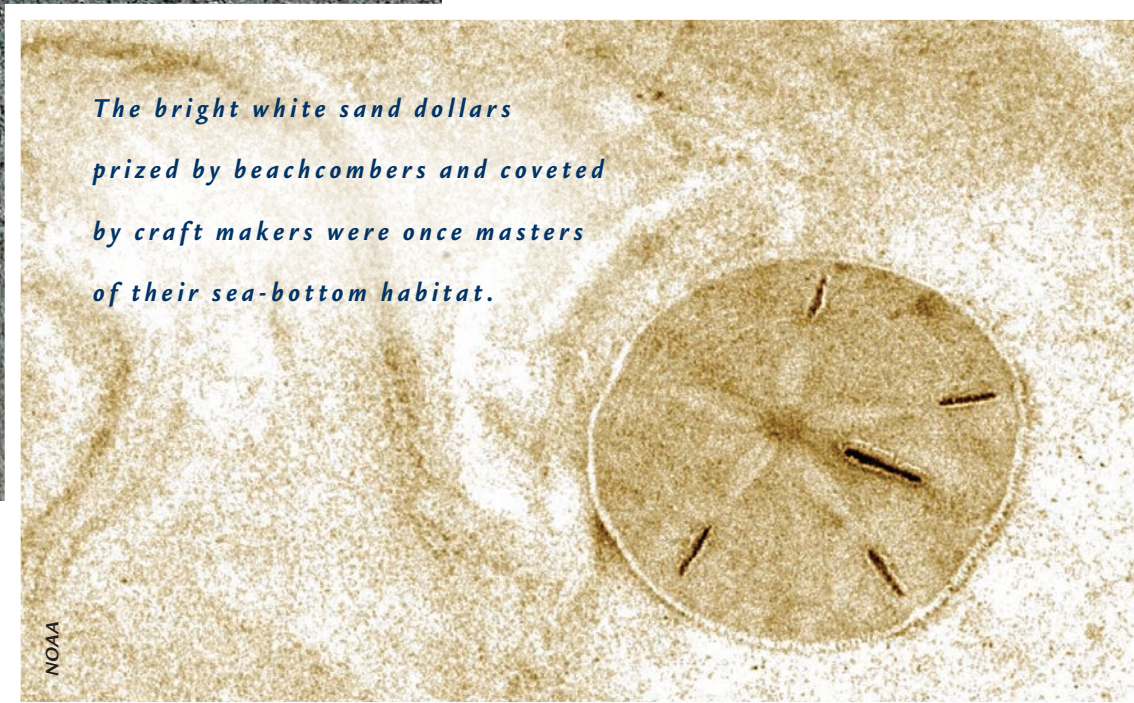
A well-circulated poem about sand dollars based on Christian lore tells of the flower shape representing the poinsettia and the holes depicting the wounds in Jesus. The star in the center of the petals suggests the star over

Bethlehem. When broken apart, the five parts of the mouth each look like tiny white doves, a symbol of peace on earth.

Ocracoke and Portsmouth Island are among the best places on the Outer Banks to find sand dollars, but they can be found all the way to Corolla, Hathaway says.

The best times are after storms and early in the morning before other collectors get there.

“One of the most frequent questions I get from tourists,” she says, “is ‘Where can I find sand dollars?’”



*The bright white sand dollars
prized by beachcombers and coveted
by craft makers were once masters
of their sea-bottom habitat.*

- Terri Kirby Hathaway on Sea Stars: go.ncsu.edu/sea-stars
- and on Naked Sea Butterflies: go.ncsu.edu/sea-butterflies
- Critters of all kinds in *Coastwatch*: go.ncsu.edu/critters

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