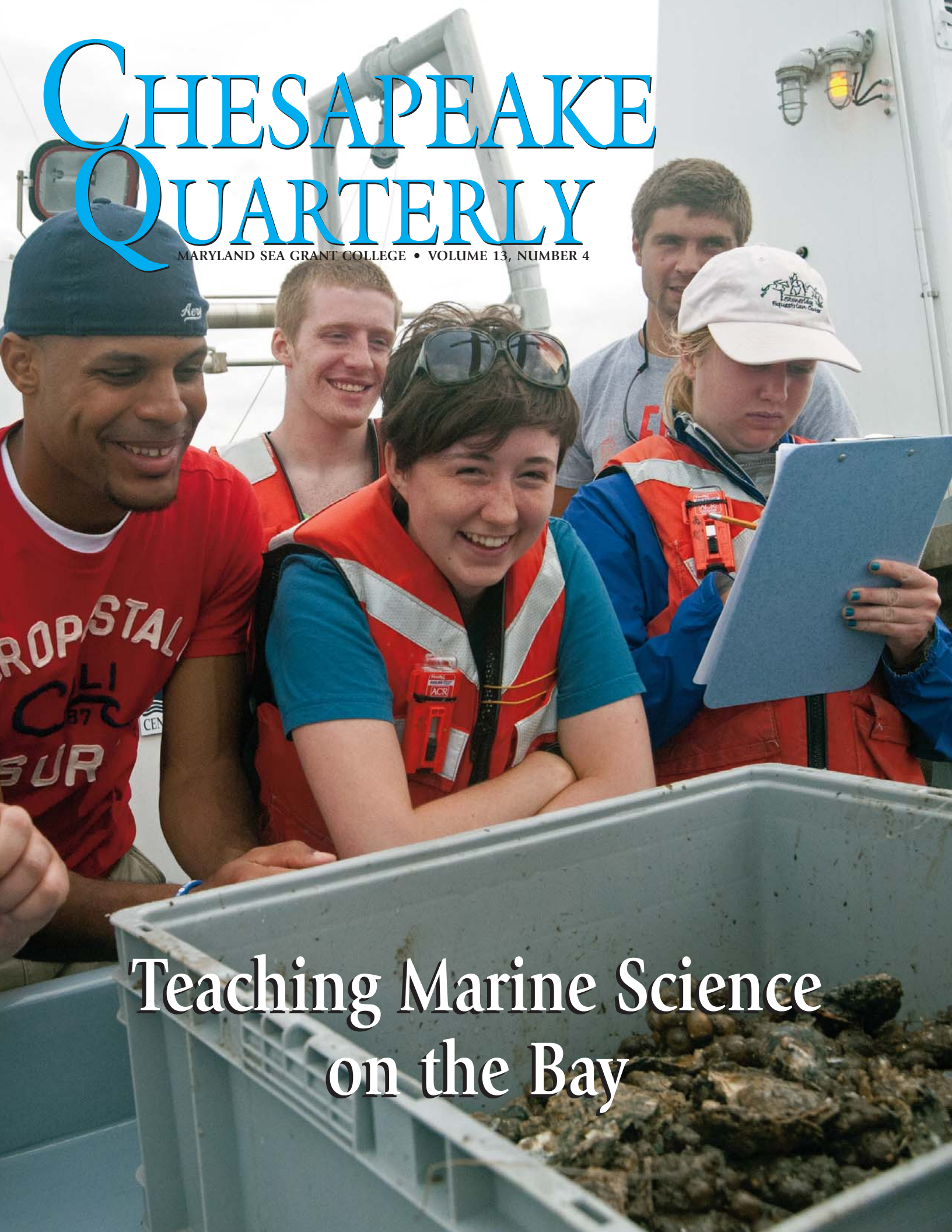

Chesapeake Quarterly

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Teaching Marine Science on the Bay

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CHESAPEAKE QUARTERLY *December 2014*

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Cover photo: *Student fellows on their orientation cruise for Maryland Sea Grant's Research Experiences for Undergraduates program in summer 2013 pore over a bucket filled with oysters: (from left to right) Arthur Williams, Zachary Watkins, Jenessa Duncombe, Nicholas Taylor, Christine Schalkoff.* ***Page 3:*** *Katie Kramlick, a senior at Francis Scott Key High School in Union Bridge, Maryland, sees a different slice of Bay life as a painted turtle tries to nip her hand. The turtle is being kept in the high school's aquaculture lab, which is also home to fish, crabs, and other swimming life.*
PHOTOGRAPHS: COVER,, SANDY RODGERS; P. 3, DANIEL STRAIN

The Bay as Teaching Tool

Science teachers in Maryland are facing several problems. And the Chesapeake Bay may offer some solutions. One problem: finding a better way of teaching science, whether in grade school, high school, or college. According to many education experts, the way most students learn science is outdated. It relies too much on memorizing facts and not enough on thinking like a scientist. In 2013 the Maryland State Board of Education adopted a new set of science education standards for the state's 24 school districts. They go by the name Next Generation Science Standards and they tell teachers to provide students some "inquiry-based" experiences in the classroom.

A second problem teachers face: raising environmental literacy levels. Since 2011 the state has told them to focus more on environmental issues in their science and social science classes.

Making big changes is easier said than done, but a number of Maryland teachers are already pioneering new approaches to these problems. They are giving students hands-on research projects that require them to investigate a question, absorb basic concepts, and follow the scientific method. And they are putting students to work on "inquiry projects" that examine aspects of the Chesapeake Bay ecosystem. The Bay, it turns out, offers workable options for drawing students into science, a field that seems daunting to many.

So daunting that most adults in the current generation of Americans have a poor grasp of basic facts about the environment. In 2010 the Yale Project on Climate Change Communication quizzed 2,000 Americans about their knowledge of climate change — and the results were troubling. Fewer than one in 10 would earn an "A" or "B," and only one in four had even heard of coral bleaching or ocean acidification, two side effects of rising greenhouse gases.

Will the next generation do better? Perhaps, but only if teachers find better ways of drawing students into the challenges, rigor, and rewards of doing good science. In recent years, giving students a hands-on research experience is emerging as one of the key tools in science education. To work well, however, a hands-on project needs a question, a question interesting enough to stir students' interests and energies and commitment to finding an answer. The Bay, with its seagrasses and striped bass, its crabs and oysters, and its far-reaching watershed, poses plenty of interesting questions.

In this issue, "Bringing the Bay into the Classroom" (p. 3) examines the progress and pitfalls of bringing marine science into the science curricula of our state schools. Science education, of course, doesn't end with high school. For college students ready to plunge deeper into marine science, Maryland Sea Grant offers select undergraduates the chance to spend a summer at a working marine laboratory on the Chesapeake Bay. "Living the Life of a Marine Scientist" (p. 11) explores how students respond to submerging themselves in a summer-long science inquiry project

Programs like these are important not just for training scientists, but for educating citizens. Students who study the Bay learn to understand environmental issues such as declining fisheries and deteriorating water quality. And marine education becomes a critical step in creating a next generation of Marylanders who could make decisions in their day-to-day lives to help preserve an ecosystem they've learned to understand.

— *The Editors*

Bringing the Bay into the Classroom

Daniel Strain

Maryland schools face challenges to educate all students about the Chesapeake Bay

The goldfish regains consciousness in the basement classroom at Francis Scott Key High School. First the fish, floating on its side in a plastic bucket filled with water, starts to twitch its pectoral fins. Then over a period of minutes, it rolls back to an alert, upright position.

Seniors Bree Malebranche and Alyssa Klein are keeping a close eye on this process. "We put it into — this is called a recovery bucket — and basically wait for it to regain equilibrium," says Klein, who is attending her first class of the day at this high school in Union Bridge in Maryland's Carroll County.

That class is called Science Research. Unlike a lot of traditional science courses, the students in Science Research get a hands-on introduction to what it takes to be a scientist. Here, high schoolers learn how to design scientific studies, collect data, and analyze their results.

Malebranche and Klein, for instance, are exploring the best methods for anesthetizing aquarium fish like their goldfish. They're using an agent popular with some researchers called clove oil, an extract that you can buy in drug stores. Add a few drops of this spicy-smelling liquid to a fish's water supply, and in a few minutes, the swimmer goes from awake to fully knocked out.

But getting to practice real research methods isn't the only thing that sets this class apart from ordinary high school courses. Like the two fishy anesthesiologists, all of the students in Science Research also conduct their studies on aquatic, not land-based organisms. There is a menagerie of animals stored in more than a dozen tanks at Francis Scott Key to choose from: goldfish, yes, but also tilapia, bluegill, hybrid sunfish, flounder, corals, turtles, crayfish, a blue crab, and even a four-foot-long sturgeon.

The course is one of a growing number of educational programs across Maryland that seek to introduce young students to key concepts about the watery world. Like what organisms live below the water's surface, and how do aquatic ecosystems work?

In many cases, these programs revolve around the Chesapeake Bay and the rivers and creeks that spill into it. Proponents

say that by bringing the Bay to classrooms, or by bringing classrooms to the Bay, teachers give students real and often wiggling reasons to care about science. These sorts of learning experiences also help to foster informed citizens — Marylanders who can make smart decisions about how to help preserve the Bay and its watershed.

But some educators who focus on the Chesapeake Bay argue that Maryland has a long way to go: opportunities to learn about aquatic environments, and the Bay watershed in particular, still don't reach all public school students in the state. Many education leaders in the region are hopeful that developments in education policy, both at the state and national level, could put new pressure on schools to meet that need.

The goal of marine educators working around the Bay is to make learning about the estuary a requirement in K-12 schools, says Tom Ackerman, an educator who works with the Chesapeake Bay Foundation, a prominent nonprofit environmental organization in the Bay region: "So it's not just students at some very high-flying suburban schools that get this opportunity, but all students."

Death and Oddities

School teachers are notoriously busy people, but Emily Fair's life seems to run at a whole other level of crazy. She's a teacher at Francis Scott Key and is Malebranche and Klein's instructor in spring 2014 in Science Research.

Right now, she's bouncing between teams of students in the high school's aquaculture lab, which isn't much bigger than a two-car garage. The noise of chugging water pumps and gurgling filters floods the room. There are all sorts of tanks here: they range in size from the kind of aquaria that you can find at pet stores to two 1,000 gallon drums that together could hold the water from four standard hot tubs.

And all of them contain some sort of animal. The roughly 30 students in the Science Research class are studying these critters to learn, for example, how flounder camouflage themselves to escape predators, why crayfish cannibalize one another, and how loud noises affect the growth of young fish. There's always something interesting to see here. When the lab's one blue crab, a male that's almost big enough to be on the menu at a seafood restaurant, molted, Fair collected the exoskeleton that it left behind.

"This is going on my table of death and oddities," she says, referring to a countertop where she keeps biological artifacts that she thinks will capture the attention of teenagers.

The Science Research program was launched more than two decades ago at South Carroll High School in Sykesville, which like Francis Scott Key is part of the Carroll County School District. Since then, aquaculture labs like Fair's have spread to all nine high schools in the county and in a reduced form to some middle schools. The county is the only district in the state that has made aquaculture labs a permanent fixture in so many schools. All of these schools are permitted through Maryland's Department of Natural Resources to keep these animals for aquaculture education purposes.

The district receives funding and technical support for these labs from Maryland Sea Grant, the publisher of *Chesapeake Quarterly*. The program also benefits from assistance and surplus equipment donated by staff at the Institute of Marine and Environmental Technology in Baltimore and grants from other organizations.

Fair has only been teaching Science Research since the 2011-2012 school year, but she fits right into this environment. She's quick to smile and joke with her students and has seemingly endless supplies of energy.

Her lessons about the scientific method include reminders that research projects don't always go as planned. Early in the semester, all of the tilapia in one of the lab's 1,000 gallon tanks came down with a weird infection and died within a

"It's always a zoo," *says science teacher Emily Fair (above) about her Science Research class. On the opposite page, students like senior Mitchel Agate (top), junior Halle Fogle (second from bottom), and senior Patrick Mojica (bottom) conduct diverse studies on a menagerie of animals, including the class's star crab (opposite page, second from top). Fair is helping senior Nick Amoss (above) to fix the plumbing on one of the many tanks in this aquaculture lab.* PHOTOGRAPHS, DANIEL STRAIN

few weeks. "Students need to be able to embrace failure," Fair says, "because then they learn from that."

She also takes the time to connect what students are studying in this lab setting back to the natural world. Her pupils, for instance, learn that fish in a tank can only survive under a certain range of environmental conditions. If ammonia levels in the water get too high, or oxygen levels too low, the fish can become sick or die. Fish living in the Chesapeake Bay face similar restrictions: as humans dump nutrients such as nitrogen and phosphorus into the estuary, the water quality in the Bay deteriorates, with real-world consequences for many animal populations.

The course seems to be paying off, too. Lauren Cheeks is a senior at Francis Scott Key who's taking Science Research for a third semester. (Students are allowed to enroll in up to four semesters of the course.) In the 2014-2015 school year, she'll be a freshman at Shepherd University in Shepherdstown, West Virginia. "Everyone who takes this class changes what they want to be when they grow up," Cheeks says. "I wanted to be a large animal vet. Now, I want to work in marine studies."

She isn't the only person who sees the value in these sorts of classes.

Sturgeon Experiences

Learning about the marine world isn't just a potentially life-changing experience. It's also a necessary part of a student's education.

That's the argument made by Craig Strang, associate director of the Lawrence Hall of Science, a museum and education center that's part of the University of California, Berkeley. Strang is also one of roughly 1,100 members of the National Marine Educators Association, an organization that draws representatives from schools as well as aquariums. For decades, he says, marine science has largely been squashed out of school curricula in favor of other subjects — cell biology, inorganic chemistry, particle physics, and other textbook topics. But Strang argues that science teachers should make room at the table for the watery world.

Aquatic ecosystems are central to the workings of our planet, notes Michael Wysession, a seismologist at Washington University in St. Louis. Wysession has helped to write a number of reports on national science education policy and pushes for science teachers to focus on "earth systems." In other words, the earth has many parts — like its atmosphere and crust — that interact with each other to drive the climate and other natural processes. Think of them like the cogs and gears that underlie the ticking of a watch. And aquatic environments are a critical component of that timepiece.

"Oceans dominate the Earth's surface. You can't avoid having the oceans play a dominant role" in topics related to how the planet works, Wysession says. "Whether it's transferring energy, heat around the planet, or whether it's controlling the water cycle."

But for Marylanders, there's another reason to include marine and aquatic science in a child's education. Young learners often jump at the chance to get outside and see living plants and animals up close. Such excitement can, in turn, help interest kids in learning more about science — a subject that can seem intimidating at first to many students.

"The formal education community has known for a long time that if the student has some emotional connection to [educational] content, they're going to be excited about it. They're going to learn more," says Marc Stern, a social scientist at Virginia Tech who studies the efficacy of education programs that focus on the environment. "And it just so happens… they're likely to take action" to protect local habitats.

And in a state with nearly 3,200 miles of coastline, the local environment in Maryland revolves around water. That's true even in land-locked areas like Carroll County, where small streams feed into

bigger rivers that eventually empty into the Bay. About 70 percent of Maryland's population and land lies in the state's coastal zone.

"I'm just struck with the incredible, incredible resources that the Chesapeake Bay provides to a very large and dense population on the East Coast," Strang says.

In school districts like those in Montgomery, Prince Georges, and Anne Arundel counties, those rich teaching resources include the districts' own environmental education centers. These are at off-campus sites where students can go on hikes or other field adventures to learn about the local environment.

In other cases, non-profit groups have designed educational opportunities that school districts can take advantage of, usually for a fee. Teachers can arrange for their classes to take a boat ride down the Potomac River with educators from the Chesapeake Bay Foundation (CBF). Students can raise terrapin turtles in their own classrooms with assistance from staff at the National Aquarium in Baltimore. Kids from southeast Washington, D.C., can learn about marsh plants on Kingman and Heritage islands on the Anacostia River as part of programs organized by the Living Classrooms Foundation, a non-profit group based in Baltimore.

The list goes on and on. "I think we're a little bit spoiled in this region," says Tom Ackerman, the educator at CBF.

In many cases, these programs are popular with parents and other community members, too. Twice a year, they flock to high schools in the Carroll County district to open house nights that feature Science Research students, says Brad Yohe, who helped start the program. He served as a science supervisor in the district before retiring in 2012. Students present their research projects at these events. During one at Francis Scott Key three years ago, he remembers seeing a student of Emily Fair's lift a sturgeon out of its tank to show the audience, which included her family.

"The student brought up this four-foot-long sturgeon and put it in the lap of her grandmother who was in a wheelchair and explained her project," Yohe says. "The looks on their faces — it was a photographic moment."

But it's a type of photographic moment that thousands of students in Maryland still never get to see. No statewide assessment has been undertaken to gauge how many students get the opportunity to learn about the Bay in a hands-on manner every year. But it's clear that the number is less than the more than 800,000 students who enroll in Maryland public schools.

Many educators in the state are looking for ways to provide even more students with access to a Bay education. To that end, teachers and others have their eyes on some big changes in the educational world that might help that to happen.

The Next Generation

Over the next several years, Emily Fair and other teachers like her in Maryland could see big shifts in the way science is taught in the state — not just when it comes to marine science but also physics, chemistry, biology, and a host of other subjects. These changes come down to one thing: standards.

Think of educational standards like the map you take on a long road trip. They detail, in a step-by-step fashion, how students should reach certain education goals and by what grade. Young learners start by absorbing basic concepts, then move onto more complex ones. School districts, like the one in Carroll County, use these maps to shape their curricula. They choose lessons that they think will help students to meet the requirements set out in standards.

So when the Maryland State Board of Education voted in June 2013 to adopt a new set of science education standards for the state's 24 school districts, big changes seemed to be afoot for local classrooms.

The new requirements are dubbed the Next Generation Science Standards (NGSS). They're based on the work of a team of education leaders and researchers assembled by the U.S. National Research Council and were released in their final form earlier that same year.

Under the NGSS, second graders, for example, are supposed to gain an understanding that "wind and water can change the shape of the land." By the time a student reaches middle school, they're onto a more sophisticated elaboration on this idea: "global movements of water and its changes in form are propelled by sunlight and gravity."

But the new Next Generation standards also represent a relatively new focus in science education. They rely heavily on a particular teaching tool, something that educators call "inquiry," says Gary Hedges, who oversees science education policy at the Maryland State Department of Education.

Inquiry-based approaches to education shy away from having students memorize long lists of facts, instead encouraging them to learn for themselves through hands-on activities. That can include running experiments, drawing diagrams, or completing other classroom projects. The NGSS, for instance, requires high schoolers to "design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity."

"It takes the teacher off the stage and really puts them in a facilitating role," Hedges says.

As of December 2014, 12 other states plus the District of Columbia had joined Maryland in adopting the Next Generation standards. The state plans to have all school districts come up with curricula that meet the requirements set out in the new standards by the 2017-2018 school year. But some science educators in Maryland are already looking forward to the shift, with expectations that the new standards may foster learning opportunities that address the Chesapeake Bay.

The NGSS could encourage the teaching of more marine science content than most schools are used to providing, says Craig Strang of the Lawrence Hall of Science. That might be hard to grasp just by picking up the new standards and flip-

ping through them. Read the text, and there are few direct mentions of aquatic ecosystems.

But the standards embrace an "earth systems" approach to learning about the planet — the same approach championed by Michael Wysession of Washington University. In fact, the seismologist served on the team that wrote the NGSS. Because students need to know how the oceans work to understand complex topics like climate change or the water cycle, "ocean systems can come into a huge number of those performance expectations" under the NGSS, Wysession says.

Despite this potential sea change, the NGSS are just one example of a potentially promising new approach to science education in Maryland.

The Story of Cocktown Creek

To see another one, head south from the green farms and rolling hills of Carroll County to the marshes and cliffs bordering the Chesapeake Bay in Calvert County.

There, at the edge of Cocktown Creek, Tom Harten sits in the middle of a flotilla of canoes. They are lined up along a grassy bank of the creek, a small waterway that empties into the Patuxent River. Harten, a veteran science teacher, is vying for the attention of 15 adolescents and a handful of adults all wearing brightly-colored life preservers. "Dad, I found a snake," one student shouts.

Harten's audience today are seventh graders from John Pellock's science class at Plum Point Middle School in Huntingtown, Maryland. They're taking part in a program called CHESPAX, which gets its name from a mash up of the words "Chesapeake" and "Patuxent." This series of educational activities has been a mainstay of the Calvert County School District since 1988. Students in kindergarten through seventh grade get the chance to learn about the Chesapeake once a year — digging, sometimes literally, into the estuary's history and ecology.

All fourth graders in the county, for instance, visit Calvert Marine Museum in Solomons, where they handle fossils that have been found along the Bay. All fifth graders travel to the county's Fishing Creek or Flag Ponds Nature Park to learn about oysters and their influence on water quality in the region. So far, Calvert County is the only school district in the state that sends students in all these grades on such excursions every year.

Today, the seventh graders jostling around in the canoes will use small rakes that look like back-scratchers to collect submerged aquatic vegetation, or SAV, from Cocktown Creek.

These grasses sit just below the surface of the water, and this year, they're growing in clumps so thick that you can barely push your oar through them. This underwater grassland — made up of plants like hydrilla, coontail, and naiads — is prime habitat for small crabs and other swimming life.

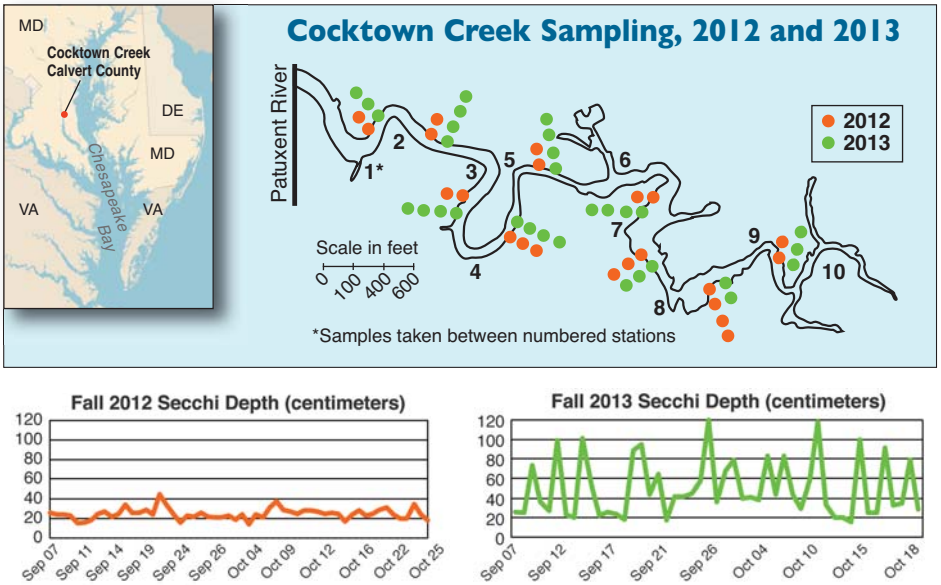
The students will help to map out where you can find SAV in the creek and what species are most common. That information is relevant to the day-to-day lives of these students, says Harten, who's been a teacher with CHESPAX for more than two decades. Human activities, such as building houses or roads, can flush sediment into streams like this one, turning the water muddy. When that happens, those grasses struggle to soak up sunlight and may eventually die off.

"This creek basically drains the town where a lot of you live," Harten says from his perch on the seat of his canoe.

The students, many turning pink from the sun, also seem excited to see some of the concepts they've been studying in Pellock's class up close. "It's cool that we're learning about SAV," says seventh-grader Josh Hancock, who sits in the front of one of the canoes, "actually seeing it in the wild rather than just learning about it in the classroom."

His response shows why marine educators in the state would like to see more

Seventh grader Ariana Smith *(above, black t-shirt) and Madeline Freck (above, red t-shirt) are visiting Cocktown Creek in Calvert County, Maryland, as part of the county's CHESPAX program. First the two classmates use a device called a transparency tube to measure Secchi depth (clarity of water) in samples collected from the creek. Later, Smith and Freck drag a seine net along the beach (above, right) to see what sort of swimming animals live in this waterway. Tom Harten (below and above left with Smith and Freck) is a science teacher who has been leading CHESPAX trips for more than two decades.* PHOTOGRAPHS, DANIEL STRAIN



The more than 15 years of observations *made by seventh graders from Calvert County on Cocktown Creek have tracked changes in the waterway over time. The map above compares the number of diverse species of submerged aquatic vegetation (SAV) the students found in the creek in the fall of 2012 and 2013. In the first year (orange dots), the numbers plummeted after a series of storms hit the region. By fall 2013, SAV populations had begun to increase (green dots). The loss of SAV diversity may may have been caused by the cloudiness of the creek water, which the students measured as "Secchi depth" (graphs, below). The greater the Secchi depth, the clearer the water — allowing more sunlight to reach growing plants.* MAP OF COCKTOWN CREEK AND GRAPHS, ADAPTED FROM FIGURE AND DATA USED COURTESY OF THE CHESPAX PROGRAM; MAP OF CHESAPEAKE BAY, ISTOCKPHOTO.COM/TEXAS UNIVERSITY MAP LIBRARY

of this type of educational opportunity in Maryland. But there are huge challenges to making that happen.

That's largely because launching an educational program like CHESPAX or Carroll County's Science Research courses takes a lot of work — on the part of school districts, principals, teachers, and others. Maryland is also a "home rule" state when it comes to education. That means that each and every county in the state draws up its own curriculum, based on standards, and would have to create its own version of CHESPAX.

The end result is that if schools don't have to develop these sorts of programs, many won't, says Brad Yohe, the former science supervisor from Carroll County. He explains that he tried during his tenure to get other school districts interested in setting up their own aquaculture labs. He had few takers.

"You can be a science supervisor and do all the things you have to do for the county and never do" a program like Science Research, Yohe says. "And you'll be fine and successful, and you'll save yourself a lot of work."

One solution to that problem is for the state of Maryland to make teaching students about the Bay mandatory, says Tom Ackerman, the educator from the Chesapeake Bay Foundation.

Maryland is getting closer to that goal. In 2011, the state's Board of Education passed a new set of standards called environmental literacy standards. The aim of these requirements is to ensure that all students in the state get access to quality educational experiences that focus on the environment.

In practice, the environmental literacy standards require schools to provide their students with yearly opportunities to learn about using science to solve various problems. Aquatic habitats are called out in the regulations that put the standards into place: under the requirements, students need to understand how they can "preserve and protect the unique natural resources of Maryland, particularly those of the Chesapeake Bay and its watershed." Before they graduate from high school, all Marylanders will receive chances to explore environmental issues and come up with ways to address them.

These standards went into effect in the 2011-2012 school year. They put Maryland on a short list of states that have made education about the environment such an important part of school curricula — something that educators who were already teaching students about the Bay saw as a victory.

"It definitely validates what they do," says Melanie Parker. She coordinates the environmental literacy programs at the Arlington Echo Outdoor Education Center in Millersville, Maryland. The center is part of the Anne Arundel County School District.

Like other school districts in the state, Anne Arundel County is taking steps to adapt its curricula to meet these requirements, Parker says.

Arlington Echo, for instance, runs an educational program called Chesapeake Connections that helps students to explore the Bay through a variety of hands-on activities. That might include raising yellow perch in the classroom or learning about monarch butterflies outside. Before the new standards went into effect, that program was optional. If elementary and middle school teachers wanted their classes to take part, they would have to sign up through the center. Now, it's part of the school year for all fourth graders. That ensures that "we hit every single student in the county," Parker says.

In 2015, the Maryland State Department of Education will conduct its first evaluation of the progress that counties have made toward meeting the new standards.

Making the Commitment

As with any education push, schools in Maryland will need a lot of resources in order to meet the requirements laid out in the state's environmental literacy standards and the Next Generation Science Standards.

Or, as Brad Yohe puts it, "what we need are more lessons."

Many science teachers, for instance, have little experience with helping their students carry out investigations of environmental issues. What sort of experiments can students reasonably conduct in a classroom setting? And how do teachers evaluate this work?

That's where lesson plans come into play: lists of classroom activities like experiments or art projects that have been designed to touch various objectives in education standards. School districts can pick and choose from among these activities and add them to their curricula. When it comes to the NGSS, there are a lot to choose from. Because these standards will reach so many students, large numbers of education groups have already put together lesson plans on an array of topics that align with the NGSS.

But because Maryland's separate standards for environmental literacy are only statewide, not national, fewer resources exist to help school districts meet these requirements.

Luckily, that's something that marine and environmental educators in the state are keenly aware of. The need for better environmental lesson plans in the state, for instance, drove the formation of the Maryland Environmental Literacy Partnership. This collaboration includes the state's Department of Education, the Chesapeake Bay Foundation, and the University of Maryland Center for Environmental Science. During the 2014-2015 school year, the partnership is working with nine school districts in the state to test out a series of lessons, or "modules," that focus on the workings of the Bay watershed.

These new modules include one that asks high schoolers to answer the question "how do humans impact the water quality of your local region of the Chesapeake watershed." Requiring around 14 to 17 hours of class time, this module allows educators not only to check off several boxes under the environmental literacy standards but also hit six points in the NGSS — "evaluate or refine a technological solution that reduces impacts of

A Slice of Raspberry Pi

High schoolers program small computers to keep an eye on fish tanks

Ricky Catron, Tim Bowersox, and Emily Keith spend many mornings in a science lab tucked into a corner of North Carroll High School. Here, you can find a diverse array of equipment: computer monitors, an electronic device called a "breadboard" that's bursting with wires, and a fish tank complete with a toy tiki hut and a spotted goldfish named Bessie.

"This is our little lair," Catron says.

The three students, all seniors, are enrolled in Science Research. That's the name for a series of courses offered through all nine high schools in Maryland's Carroll County, including North Carroll. In these classes, students learn about science while raising populations of fish, turtles, crayfish, and other aquatic animals in a variety of fish tanks (see Bringing the Bay to the Classroom, p. 3).

In the fall of 2014, Catron's group began a project to change how students collect water quality data from these fish tanks. The project blends engineering, computer programming, and marine biology. It's an excellent example of the diverse opportunities for students working in an aquaculture setting to learn about science, says James Peters, the science supervisor for Carroll County's high and middle schools.

One of the big problems with running a lab filled with fish tanks, Catron explains, is that aquaculture is finicky: if the oxygen levels in a tank's water supply get too low, or the temperature gets too hot, the fish inside can go belly up.

A team of students — *Ricky Catron, Emily Keith, and Tim Bowersox (above, from left) — looks over code that they've written to program a Raspberry Pi, a small computer that can fit in the palm of your hand (above, right) but has versatile uses.* PHOTOGRAPHS, DANIEL STRAIN

So he and his partners in crime are designing a system to monitor conditions in these tanks automatically. The key to their project is a small computer about the size of a drink coaster called a Raspberry Pi. This device shares its pastry-like name with its developer, a non-profit group called the Raspberry Pi Foundation that specializes in education. The students chose this computer because it's versatile — unlike a desktop computer, it's relatively easy to program a Raspberry Pi to complete various tasks.

Here's how the setup works: Catron, Bowersox, and Keith will connect a Raspberry Pi computer to sensors installed in a tank of their choosing. Then the students will program the Pi device to collect data streaming in from the aquarium and post it to a website at regular intervals. That way, if the water quality in the tank goes south, its keepers will know right away.

"We could send a text alert to their phone and say, 'Hey, this is going really bad, you need to get to your tank now before everything dies,'" Catron says.

In 2014 Catron, Bowersox, and Keith received $1,000 to complete their project as part of a workshop organized by Maryland Sea Grant to train teachers in the state about aquaculture education. They used those funds plus $200 of their own money to buy five Raspberry Pis and an assortment of temperature and oxygen sensors.

Once they've finished setting up all of the equipment, the group will be the first in Maryland to do this sort of water monitoring in a K-12 classroom setting, says Hannah McNett, who teaches Science Research at North Carroll. She says that the project shows what teenagers are capable of if they're allowed to take charge of their own educations. She's barely helped them at all this year. "It's all them," McNett says. "I'm just here."

— *D.S.*

human activities on natural systems," for one. Among other activities, students taking these modules learn how to make a topographical map using cardstock and create a budget for how much water they use at home and school.

In the end, however, new standards or lesson plans alone can't drive schools to create programs like CHESPAX or Science Research, Yohe says. That takes something more intangible: a culture shift in the school district. In other words, teachers, principals, and other administrators need to lend their full support to a new educational approach. And be willing to put in the extra time and money that it takes to set up something like an aquaculture lab.

Still, once Yohe got the Science Research program off the ground, "the rewards were worth all the effort," he says.

Emily Fair is one of the motivated educators who keep the Science Research program afloat. It's July and she is back in the aquaculture lab. With school on summer break, the room is a lot quieter. But Fair and a handful of student volunteers are still coming in about once a week to clean the tanks and do other upkeep tasks.

Today, Fair's main task is to figure out what's gone wrong with one of the lab's pumps, which stopped working recently, requiring her to "don my electrician's hat."

In the end, she says, it's all worth it. She still remembers the first time she saw this aquaculture lab years ago. She was getting her bachelor's degree at McDaniel College, which is also in Carroll County, and was working as a student intern for a biology teacher at Francis Scott Key. One day, her mentor told her that she needed to check out the school's lab down the hall. "I walked in," Fair says, "and I knew then and there that I wanted to be a part of this."

— *strain@mdsg.umd.edu*

Marine Environmental Education Resources

Do you want to help young learners explore the Chesapeake Bay and other marine environments? It can be tricky to know where to start, so we've put together this list of selected Bay and marine education resources that can be found online.

Maryland Sea Grant. Education specialists offer training and technical assistance for using aquaculture in Maryland and Washington, D.C. schools; lesson plans for teaching about Chesapeake Bay ecosystems.
www.mdsg.umd.edu/our-education-programs

Outdoor and Environmental Education Centers. Specializing in environmental and outdoor education; located in all 24 Maryland counties.
www.marylandpublicschools.org/msde/programs/environment/envorg/index.html

Chesapeake Bay Education Providers. Educational opportunities for students to explore the Bay watershed, outdoors and in the classroom; teacher training programs.
Chesapeake Bay Foundation:
www.cbf.org/education-program
Living Classrooms Foundation:
www.livingclassrooms.org
National Aquarium in Baltimore:
www.aqua.org/learn

Maryland Association for Environmental and Outdoor Education. Non-profit organization that oversees the certification of Maryland's "Green Schools" — schools building sustainable school environments and helping their students reduce their impacts on the natural world.
maeoe.org

MADE-CLEAR. Maryland and Delaware Climate Change Education Assessment, a partnership between the University System of Maryland and the University of Delaware to support education and communication efforts surrounding climate change; teacher training and resources.
www.madeclear.org

NMEA. National Marine Educators Association, a membership group that organizes events; resources for educators who specialize in marine and aquatic education, both in and outside of formal school settings. The Mid-Atlantic Marine Education Association (MAMEA), a regional chapter of NMEA; resources specific to Mid-Atlantic states. NMEA's administrative office is housed at Maryland Sea Grant.
NMEA: www.marine-ed.org
MAMEA: www.mamea.org

COSEE. Centers for Ocean Sciences and Education Excellence, a group of regional centers formerly funded by the National Science Foundation; education resources including online activities and presentations from marine scientists.
http://www.cosee.net/

The Ocean Literacy Framework. Written by researchers and marine educators, the framework is a set of new education standards that aim to capture the most important things that students need to learn about the aquatic world.
http://oceanliteracy.wp2.coexploration.org/

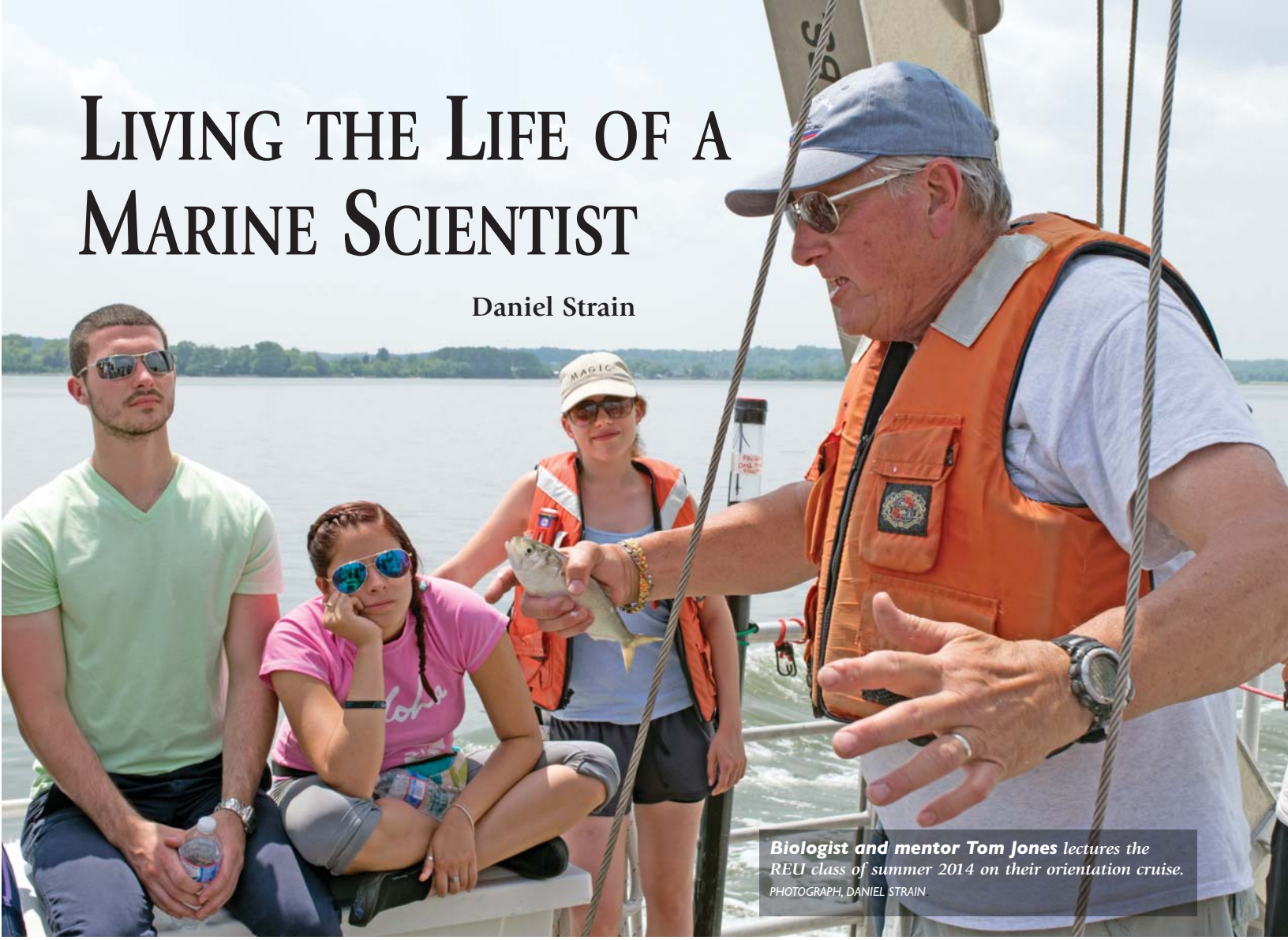
NOAA Ocean Explorer. The National Oceanic and Atmospheric Administration's Ocean Exploration and Research website; engaging information on scientific missions to explore the marine realm, marine education lesson plans, and webinars developed by scientists and educators.
oceanexplorer.noaa.gov

The Bridge, Ocean Education Teacher Resource Center. Sponsored by NOAA Sea Grant and the National Marine Educators Association, the Bridge provides links to a collection of online marine education resources.
web.vims.edu/bridge

National Science Teachers Association NGSS Hub. A wealth of information, including books and web seminars designed to help K-12 educators implement Next Generation Science Standards.
ngss.nsta.org

Living the Life of a Marine Scientist

Daniel Strain



Biologist and mentor Tom Jones *lectures the REU class of summer 2014 on their orientation cruise.*
PHOTOGRAPH, DANIEL STRAIN

Each summer, college students get an introduction to Chesapeake Bay science through the Research Experiences for Undergraduates program.

Barret Wessel is a student of goop. Right now, he's standing by a narrow stream in Rock Creek Park in Washington, D.C. The waterway, too small to merit a name, "flows into, I think it's Bingham Run and then Rock Creek," Wessel says, referring to the park's namesake. The creek curves through the city before emptying into the Potomac River.

It's July, and Wessel is about a month away from starting his final year of college at the University of Maryland, College Park. This afternoon, he's on the hunt. A fringe of marshy plants borders the stream, and flying insects flit just above the surface of the water. But Wessel, wearing a denim shirt and rubber boots for wading, is looking for something else. He calls it "goop."

"Let's see if we can find some iron flocculate," Wessel says. "There's a little bit right here."

He steps onto wet river rocks and points to an orange film that is growing in a shallow ripple in the stream. This gelatinous material, which looks like someone poured pudding into the creek, is iron flocculate, Wessel explains. It's produced by a certain class of microbes called iron-oxidizing bacteria. You can find these microbes in any stream, but they're particularly common in environments that are rich in iron.

The college student is spending his summer exploring this goop. He's paid regular visits to nine streams in Maryland and the District of Columbia, collecting dozens of water samples and measuring the amount of flocculate growing in the currents. Wessel hopes that his research project will help to answer a few questions about the growth of these bacteria: why, for instance, are iron-oxidizing bacteria more abundant in some creeks than others? His results could inform ongoing research into how scientists and others can restore the health of urban streams that trickle into the Chesapeake Bay.

Wessel is one of 18 students partici-

***A day onboard the* R/V Rachel Carson** *gives REU students a sneak peek of the sorts of research activities they may be doing during their summer fellowship. Here, 2014 students Isabel Sanchez (left) and Megan Bock measure the salinity level of water near the mouth of the Choptank River using a device called a refractometer while Anastasia Maydanov watches. Opposite page: 18 students including Sanchez, Barret Wessel, and Jeffrey Rice were selected for the REU program in 2014.* PHOTOGRAPHS, DANIEL STRAIN

pating during the summer of 2014 in Maryland Sea Grant's Research Experiences for Undergraduates (REU) program. This educational opportunity aims to give undergraduates from across the country an introduction to scientific research: like Wessel, these REU students will spend 12 weeks embedded in a marine science lab in Maryland, learning how to design and conduct their own research study.

Such forays into research can be an important step in a college undergraduate's education. Through this REU program, students like Wessel produce high-quality scientific reports, and gain experience working in a lab — experience that can help to give them an edge when they apply for jobs or graduate schools. But maybe more important, they also receive a first-hand glimpse into what it's like to be a marine scientist.

"It's all part of training the next generation" of scientists, says Jamie Pierson, a biological oceanographer at the Horn Point Laboratory of the University of Maryland Center for Environmental Science (UMCES), who has mentored several REU students over the years. "The rewarding part is seeing them be successful and get excited about science and stay in science."

Wet and Muddy

The students who join this educational experience hail from diverse backgrounds. Wessel, for instance, came to science from a roundabout path. The Maryland native, now 28, signed enlistment papers to join the U.S. Navy when he was still in high school.

After leaving military service because of a knee injury, Wessel worked odd jobs for several years. Then, in his mid-20s, he had an epiphany of sorts. He was working at a used bookstore at the time that took in a big donation of books from the library of a science buff.

"It was just a huge personal collection of math, physics, science books. I read a bunch of them and ended up getting my hands on Carl Sagan's 'Cosmos,' " he says, referring to a TV show that aired in 1980 and a book of the same name that delved into the workings of the universe. "And I was sold."

Soon after, Wessel enrolled in classes at the Howard Community College in Columbia, Maryland, and later transferred to the University of Maryland. During his REU summer, he interned in the lab of Michael Williams, a biochemist at the Chesapeake Biological Laboratory, which is also part of UMCES.

Wessel says he applied to the Maryland Sea Grant REU program because he plans to go to graduate school, either in environmental science or environmental engineering.

It was also just exciting to get outside and do field work, he says. "You get wet and muddy," he says. "You work like a 16- or 20-hour day just to get the samples in the fridge so you can look at them the next day." But, he adds, "It's a lot of fun."

Encouraging Future Scientists

He's not the only student getting in on that fun, either. Maryland Sea Grant's REU program is one of nearly 650 sim-

ilar educational experiences spread across the United States and funded by the National Science Foundation (NSF). In the Chesapeake Bay region alone, you can find four REU programs in addition to Maryland Sea Grant's that focus on marine research.

They're affiliated with the University of Maryland Eastern Shore in Princess Anne, Maryland, the Smithsonian Environmental Research Center in Edgewater, and the Virginia Institute of Marine Science and Old Dominion University, both in Virginia.

The REU program run by Maryland Sea Grant accepted its first students in 1989 and has operated every year since then. It's selective: Wessel and the 17 other REU students enrolled in the program in 2014 were chosen from around 350 applicants, a typical number for this program.

One of the goals of the national REU program is to spur more women and members of minority groups to pursue careers in science, says Elizabeth Rom, who oversees the NSF's ocean education programs. That's been a constant struggle both in the sciences in general and in ocean science in particular, Rom explains. In 2012, for instance, around 10 percent of the science Ph.D.'s awarded to U.S. citizens or permanent residents went to minority students, according to data collected by the NSF.

Maryland Sea Grant's REU program has worked to increase those numbers. Between 2009 and 2014, 20 out of the 75 participating students came from minority backgrounds. From the start, women have made up around half or more of the program's participants every year. That's a ratio that the field of ocean science as a whole has only recently caught up to.

Other kinds of diversity are also advanced by the program. Some of the undergraduates come from institutions like Elmhurst College in Illinois that are far from America's coasts and whose students otherwise would have little opportunity to experience marine research firsthand. (See map, page 14.) And the program draws most of its participants from small colleges where faculty members do little scientific research of any kind, says Mike Allen, assistant director for research at Maryland Sea Grant.

"I think the REU program is really important for those students," says Hali Kilbourne, a paleoclimatologist at the Chesapeake Biological Lab, who has also mentored REU students.

That's because getting hands-on exposure to real research is a crucial step in an undergraduate's education, says Tom Jones, an estuarine ecologist at Salisbury University in Maryland. Jones has been a mainstay of the Maryland Sea Grant REU program since its start and leads the program's annual orientation program that includes a day-long cruise. During this boat trip on the Chesapeake Bay and Patuxent River, REU students get a crash course in the ecology and history of the estuary — while collecting data relevant to local ecosystems.

Jones notes that too often students in higher education only have the opportunity to learn about science through lectures or staged lab experiments. Without the opportunity to get wet and muddy as Wessel did, many students get turned off by the sciences, switching their majors to other fields. And that's of concern because numerous national reports have argued that America's economy would benefit if its workforce were more scientifically literate.

When it comes to conducting research, "if students don't have the responsibility to do it and get it right in the lab for real," Jones says, they never gain "the confidence that they can do it. They just lean on other people."

From the Class of 2014

Barret Wessel, *University of Maryland, College Park, MD*

Jeffrey Rice, *Florida Gulf Coast University, FL*

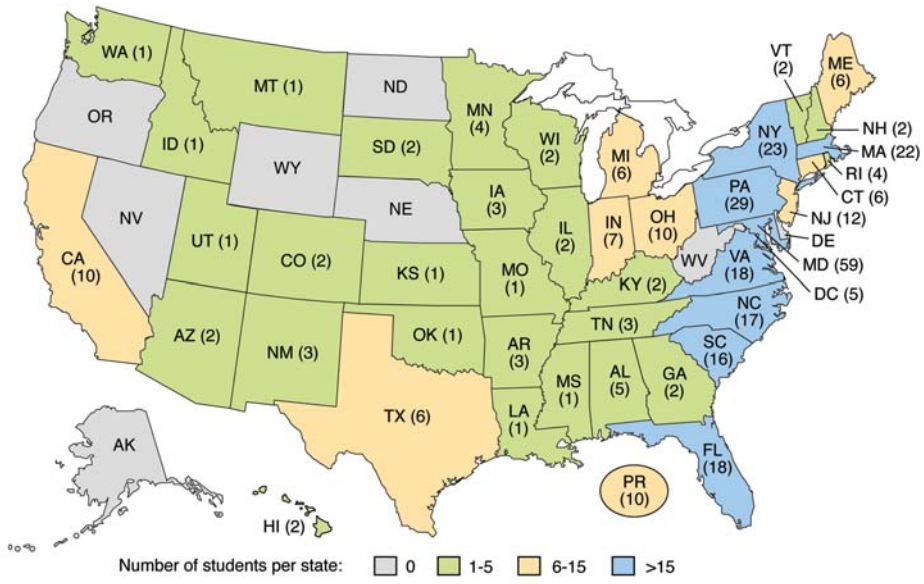
Isabel Sanchez, *Universidad Metropolitana, PR*

What's in a Crab's Shell?

To offer these helpful doses of confidence and experience, the Maryland Sea Grant REU program pairs each participating undergraduate with a mentor at one of two marine labs: the Chesapeake Biological Laboratory in Solomons, Maryland, and the Horn Point Laboratory in Cambridge. The students live in dorms on those campuses and receive stipends of $6,000 each. They work with their mentors to pick a topic that they want to study, then carry out a complete research project from start to finish. At the end of the summer, the students write up their research results in a final paper and speak about their work in a talk that's open to the public.

Over the years, Maryland Sea Grant's REU students have spent their summers exploring a wide array of topics that have spanned the entire Chesapeake Bay ecosystem. Some students have dug into the lives of important Bay organisms, like oysters and wetland reeds. Other undergraduates have researched issues that affect the health of the estuary like nutri-

Maryland Sea Grant REU Fellowship Program, 1989-2014
Number of Fellows by State/Territory



Traveling to the Chesapeake from across the country, *Maryland Sea Grant REU fellows have come from 42 states and the territory of Puerto Rico. This map shows how many of the alumni are from each state/territory. (Data represent the state where the undergraduate institution attended by the fellow is located, not the fellow's home state.)* MAP, JENNA CLARK USING MARYLAND SEA GRANT DATA

Maryland Sea Grant REU by the Numbers

345 students have taken part in the REU program since 1989

34 papers have been published in scientific journals with REU students as coauthors

52 out of 177 REU alumni surveyed later enrolled in Ph.D. programs

⅓ of all REU students between 2009 and 2014 were first generation college students

¼ were members of minority groups

ent runoff from cities and farms and blooms of harmful algae.

Maryland Sea Grant also introduces its interns to some of the less obvious aspects of being a scientist. REU students learn how to write research grants and funding proposals, and they attend a workshop on scientific ethics — topics that take up a lot of a researcher's time but rarely get mentioned in the classroom.

All of these activities make for a busy summer for REU students like Jeffrey Rice. He's an undergrad at Florida Gulf Coast University in Fort Meyers and is interning with Thomas Miller, a fisheries scientist and director of the Chesapeake Biological Laboratory.

Rice is doing his daily rounds in a laboratory that houses dozens of scuttling blue crabs. The crustaceans are young, only a few inches long at this point, and are stored individually in small tanks the size of shoeboxes. If you keep two crabs in the same tank, Rice explains, they'll start to fight — sometimes to the death. "They're jerks," he says, laughing.

This summer, he's learning a lot about these crustacean jerks. In particular, he's trying to unravel the chemical composition of the blue crab exoskeleton.

It may sound like a simple question — what is a crab's shell made of? But it's not one that scientists know the answer to. Crustacean researchers assumed that the shells were built mostly out of calcium carbonate, the main mineral in chalk. Lobsters and some other close cousins of crabs have shells that are 95 percent calcium carbonate by weight. But no one knew whether blue crabs shared that exact make up.

It's a question that's relevant to the Chesapeake Bay. That's because the estuary, like other water bodies around the world, is growing more acidic as a result of increasing levels of carbon dioxide in the atmosphere. This chemical change, called ocean acidification, may affect how some shelled animals build their exoskeletons. Knowing the exact ingredients in a crab's exoskeleton could give scientists clues as to how acidification might alter how crabs form their shells.

To discover this recipe, Rice crushed up bits of shell from both adult and juvenile blue crabs. Then he ran the resulting mash through a machine called a spectrometer that analyzed its chemical ingredients.

The results were surprising. Rice discovered that the exoskeletons of adult blue crabs were only 65 percent calcium carbonate by weight — much less than lobsters.

Why the exoskeletons of blue crabs are so different from those of other crustaceans isn't clear, Rice says. But his findings will inform further research and understanding about the effect of ocean acidification on the Bay's crab populations.

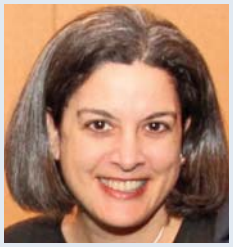
He's not the only REU student whose work has advanced science about the Chesapeake Bay. In many cases, these undergrads have helped to produce research findings that were later published in scientific journals. Maryland Sea Grant's REU students have coauthored 34 scholarly papers with their mentors. More than 70 students, and counting, also presented their research at science conferences both in the United States and abroad.

One of the papers was coauthored by Katharine Smith, an REU student in 2005. She helped to show that breakwaters made from oyster reefs can benefit

A Good Start to Their Careers

Maryland Sea Grant's REU students have gone on to contribute to the field of marine science, following diverse career paths both nationally and on the Chesapeake Bay. Here are some of the program's talented alumni from over the years.

Cynthia Suchman (Class of '89)
Undergraduate at: Amherst College, Massachusetts; REU advisor/institution: Denise Breitburg, Academy of Natural Sciences Research Center



Where is she now: Suchman served as assistant director for Virginia Sea Grant from 2004 to 2007. She is a program director in the division of Ocean Sciences within the Geosciences Directorate at the National Science Foundation.

Carlos Lozano (Class of '05)
Undergraduate at: University of Texas at San Antonio; REU advisor/institution: Edward Houde, Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science (UMCES)

Where is he now: Lozano received his master's degree from the University of Maryland's Marine Estuarine Environmental Science program. He is now a faculty research assistant in Houde's lab where he studies, among other things, the early lives of fish in the Bay.

Jeanette Davis (Class of '06)
Undergraduate at: Hampton University, Virginia; REU advisor-/institution: Judy O'Neil, Horn Point Laboratory, University of Maryland Center for Environmental Science

Where is she now: Jeanette Davis is completing her Ph.D. from the Institute of Marine and Environmental Technology (UMCES), in Baltimore, where she studies the bacterial communities associated with tropical sea slugs. In February 2015, Davis will begin a Knauss Marine Policy Fellowship, serving as a sea turtle science coordinator for the National Oceanic and Atmospheric Administration.

nearby clumps of underwater grasses in the Chesapeake. The reefs block waves, keeping the water around the plants from getting choppy and cloudy. That was an important finding because these grasses have largely disappeared around the estuary in recent decades. Smith and her mentor, Elizabeth North of the Horn Point Laboratory, published their research in 2009 in the journal *Estuaries and Coasts*.

Jamie Pierson, the biological oceanographer at Horn Point Laboratory, says that when he takes on an intern, his goal from the start is to give the student a great learning experience. But he also wants them to do something with real results.

"We try to set up a project that will be successful for them and that will move the lab forward," he says.

Decision Time

There are less tangible benefits of REU programs that can't be boiled down to a scientific paper or a resume point. That's because the end of college for students like Rice brings a lot of choices.

"At the undergraduate level, it's really critical for them as juniors and seniors to figure out, first off, 'Am I going to go to grad school, and…do I want to do it in marine science?'" says Tom Jones, the estuarine scientist at Salisbury University.

And many REU students say that the program has helped them to make those exact kinds of decisions.

Here on the Chesapeake Bay, dozens of Maryland Sea Grant's former REU students have gone on to obtain graduate degrees in science fields, according to an ongoing survey of alumni. Of the 177 students who responded to Maryland Sea Grant's queries over the years, 52 had already received or were in the process of getting their Ph.D.s in various fields. A total of 121 were enrolled in or had finished a master's degree program.

The same is true on the national level. In 2007, researchers surveyed thousands of students who had taken part in an REU or another similar educational program about their experiences. About two-thirds of the respondents said that their time doing research increased their interest in going to grad school or working in a science-related field. Simply put, once they whetted their appetite for research, they wanted more.

At the same time, these programs only go so far: about 4,000 students attend one of the NSF-funded REU programs per year. That's a sliver of America's total undergraduate population of 18 million.

Maryland Sea Grant REU students who spent the summer of 2014 on the Bay say the program helped to open their eyes to a variety of possible careers. That includes Isabel Sanchez, one of two students from Puerto Rico who joined the program. She will graduate in 2015 from the Universidad Metropolitana, a four-year university in San Juan. In Maryland, she interned for Pat Glibert, a plankton ecologist at the Horn Point Laboratory.

Sanchez's research focused on the population booms and busts of microscopic algae that live in lagoons off the coast of mainland Virginia. Her research is important for understanding how the runoff from farm fertilizers, which are rich in nutrients like nitrogen, might help to trigger explosive blooms of algae in

Continued on the next page

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Life of a Scientist, *cont.*

these ecosystems. Such blooms can pose health risks to people and fish.

She says that because of her experiences in Maryland, she's hoping to attend graduate school in environmental science in the continental United States. Her ultimate plan is to take what she's learned back to Puerto Rico, helping to preserve marine ecosystems on the island.

"All the stuff that I've been learning and doing here has never been done back in Puerto Rico," Sanchez says.

Emily Maung-Douglass made a lot of decisions, both professional and personal, while she was an REU student. She spent the summer of 2003 at the Chesapeake Biological Laboratory studying marine bacterial diversity. She said she was taken by the adventure of living at a marine lab tucked away from most of the world and working odd hours as needed to complete research.

"It was kind of a romantic thing to be the scientist in the middle of the night coming into the lab," Maung-Douglass says.

So she earned her Ph.D. in marine biosciences at another quiet marine lab — this one at the Lewes campus of the University of Delaware. Now at Louisiana Sea Grant, which is based in Baton Rouge, Emily is an outreach specialist helping to educate the public about new research findings regarding the Deepwater Horizon oil spill.

Maung-Douglass met her future husband, Keith Douglass, in Solomons that summer, too. He was an REU student that same year. For a recent anniversary, the couple traveled back to Solomons and strolled past the buildings where they lived and worked years before.

Her REU internship "was just one of the best experiences of my life," Maung-Douglass says. "It really made me grow creatively as a scientist. And it made me brave enough to try to live at other marine labs."

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REU Program Summer 2015

Maryland Sea Grant (MDSG) is now accepting applications for its summer 2015 Research Experiences for Undergraduates (REU) program. The deadline for applying is February 20. For more information, or to access the online application, click on the QR code above, or visit MDSG's REU web page at: www.mdsg.umd.edu/reu.

Maryland Sea Grant Welcomes New Watershed Specialist

Eric Buehl is Maryland Sea Grant Extension's new watershed restoration specialist for the state's mid and upper Eastern Shore. He is working with communities, citizen groups, and governments to help improve water quality in the rivers and creeks that feed into the Chesapeake Bay. Buehl, who has lived on the Eastern Shore since 1989, will serve Maryland's Talbot, Caroline, Queen Anne's, Kent, and Cecil counties.

He joins the Extension program's team of five watershed restoration specialists, succeeding Dr. Amy Scaroni in the position. The specialists work to secure funding to install and monitor measures like rain gardens that capture nutrients from stormwater runoff. Read more about Eric and the other specialists' work at:

http://bit.ly/mdsg-buehl.