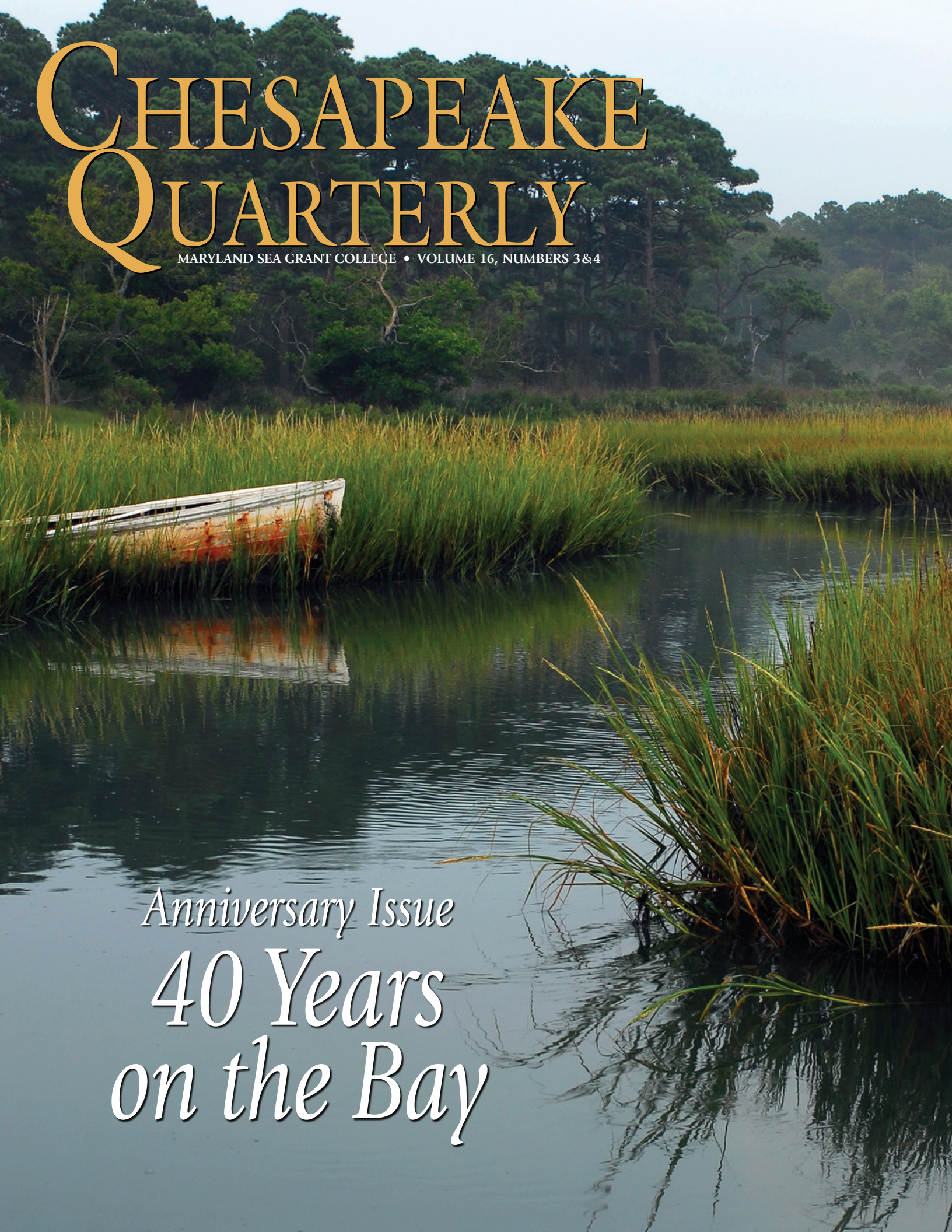

Chesapeake Quarterly

MARYLAND SEA GRANT COLLEGE • VOLUME 16, NUMBERS 3&4

Anniversary Issue

40 Years on the Bay

contents

Volume 16, Numbers 3 & 4

CHESAPEAKE QUARTERLY *December 2017*

Chesapeake Quarterly explores scientific, environmental, and cultural issues relevant to the Chesapeake Bay and its watershed. The magazine is produced and funded by the Maryland Sea Grant College. The college receives support from the National Oceanic and Atmospheric Administration and the state of Maryland.

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Cover photo: *A wooden boat finds a final resting place in a wetlands along a Virgina creek.* PHOTOGRAPH, JAY FLEMING

Harnessing the Power of Science to Improve Maryland's Coasts

By Fredrika Moser

It is a pleasure to bring this issue of *Chesapeake Quarterly* to our readers in celebration of our 40th anniversary. As the current director of Maryland Sea Grant, I am grateful to work every day with wonderful colleagues and collaborators who care as deeply as I do about restoring the rivers, bays, and coasts of Maryland.

Marine microbiologist Rita Colwell, *first director of Maryland Sea Grant, set the program's early goal as finding and funding excellent research focused on the Chesapeake Bay's deteriorating water quality and declining fisheries. She later served as the first woman director of the National Science Foundation.* PHOTOGRAPH, MICHAEL W. FINCHAM

Maryland Sea Grant supports a special mix of programming that employs science to address serious challenges confronting the Bay's ecology and the people who enjoy and make a living from its natural resources. We support research to better understand how we can restore and sustain the health of the estuary. Our portfolio includes supporting educational activities to foster an informed citizenry and the next generation of coastal scientists. We provide technical expertise that helps Maryland's seafood industry create and sustain jobs. And we assist a variety of community organizations to improve the Chesapeake Bay's water quality and coastal land use. In 1966, Congress presciently established the National Sea Grant College Program, of which Maryland Sea Grant is a part, because legislators recognized the need for science-based policy for our coastal and estuarine ecosystems to benefit a variety of constituents including resource managers, decision makers, businesses, and citizen volunteers.

The growth of our program's capabilities is a result of the collective vision and commitment of a series of talented individuals who led our program before my tenure as director began in 2012. Their efforts helped to shape strengths of Maryland Sea Grant that persist today.

In 1977, Rita Colwell, an internationally renowned microbiologist, and colleagues at the University of Maryland designed and launched the Maryland Sea Grant Program. In 1978, Rita became our first director. Her vision guided Maryland Sea Grant's early years researching Chesapeake Bay's natural resources and supporting the state's fishing industry. Maryland Sea Grant's focus then and now linked research and public outreach.

Our partnership with the University of Maryland Extension service has been integral to our program's success from the beginning. The first Sea Grant employee was Don Webster, an Extension agent who works directly with fishers and processors (see "Seeding an Industry," page 11). Additional Sea Grant Extension specialists in shellfish and fisheries soon joined the program. Their early and continuing support of oyster farmers has played an important role in fostering the growth of Maryland's nascent aquaculture industry.

Rita also perceived a critical need for a first-rate communications program that would explain for many audiences how research was illuminating in detail the ecological processes of the Bay and coastal waters. She recruited Michael W. Fincham, a writer and filmmaker, who organized a multi-level approach to science communication that continues today. Since 2002, *Chesapeake Quarterly* has brought science-rich analysis to understanding environmental issues throughout the watershed. In 2007, we published a comprehensive reference work, *The Blue Crab: Callinectes sapidus,* complementing our 1996 seminal oyster book, *The Eastern Oyster: Crassostrea virginica.* We've produced television documentaries, online videos, reports, and infographics about submerged aquatic vegetation, oysters, fisheries, invasive species, climate change, and watersheds, all of which have provided Marylanders with engaging and useful information about the Chesapeake and our coasts.

When Rita became director of the newly established University of Maryland Biotechnology Institute (UMBI) in 1985, she continued to administer the Maryland Sea Grant Program. In 1998, she moved on to become director (and the first woman leader) of the National Science Foundation, one of the largest funders of academic research. In a White House ceremony in 2007, Rita was awarded the U.S. National Medal of Science.

Four directors have led Maryland Sea Grant *since Rita Colwell founded the program. Clockwise from upper left: Jack Greer was acting director for Maryland Sea Grant for one year in 1988; Chris D'Elia served as director for ten years, Jon Kramer for 12 years, and Fredrika Moser has led the program since 2012.* PHOTOGRAPHS, SKIP BROWN (GREER); MICHAEL W. FINCHAM (D'ELIA, KRAMER, MOSER)

During the UMBI transition, Rick Jarman served briefly as an executive director, followed by Jack Greer, then assistant director of communications and public affairs, who took over as acting director in 1987. Both these successors built on the strong foundation of Rita's vision and scientific expertise. Under Jack's leadership, Maryland Sea Grant developed a specialty as a convener of key players in Chesapeake Bay restoration and an integrator of scientific findings for them. A talented writer, Jack was also a gifted facilitator. One of my favorite examples of his success as an integrator and communicator was when he worked with academics, the Chesapeake Bay Commission, watermen, fisheries regulators, and environmentalists to address the challenge of setting harvest limits for Chesapeake Bay blue crabs. New management ideas were needed for ensuring a sustainable crab population. The trust and understanding that Jack helped develop among these diverse individuals over months of work led to a compromise approach recommended by a government body, the Bi-state Blue Crab Advisory Committee, that is still driving harvest policy today.

Following Jack as director was Chris D'Elia, a scientist with deep knowledge of the Chesapeake Bay's ecology. He came from the Chesapeake Biological Laboratory (CBL) where he was among a group of determined scientists whose research began detailing the effects of excess nutrients in the Bay, especially the creation of hypoxia, the near absence of dissolved oxygen in bottom waters, and the resulting creation of "dead zones" devoid of estuarine life. Early in his career, Chris worked closely with Walter Boynton, also at CBL, Jim Sanders (now at the University of Georgia), and other scientists to establish the Patuxent River as a national model for understanding estuarine nutrient dynamics and for reducing nutrient inputs to a river. Chris never failed to credit the late Donald R. Heinle, another CBL scientist, who helped pioneer the view that nitrogen, not phosphorus, was the nutrient that needed to be curtailed in many estuaries. Their scientific insight drove innovations in nutrient management.

Chris's scientific interests and expertise led Maryland Sea Grant to produce a number of important synthesis documents that organized key findings in environmental science and their implications for policy. These included reports on contaminants in the Chesapeake and, notably, a book that has been a major contribution to understanding the dynamics of oxygen in estuarine systems, *Dissolved Oxygen in the Chesapeake Bay.*

In addition, Chris also deepened Sea Grant's support for both graduate and undergraduate education. Awarded a grant from the National Science Foundation in 1989, he established our Research Experiences for Undergraduates program. It continues bringing students to the Chesapeake Bay region each summer to conduct

environmental research. Building on this program, Maryland Sea Grant has recruited students from underrepresented groups into the program and introduced them to research and careers in marine science.

Chris left in 1999 for another position in administration and later became dean of Louisiana State University's College of the Coast and Environment.

His successor, Jon Kramer, took over as Maryland Sea Grant moved its association from the University of Maryland Biotechnology Institute to its current home under the University of Maryland Center for Environmental Science.

In Sea Grant tradition, Jon was skilled at harnessing science to change conversations about the Bay. He convened teams of researchers to develop consensus on the science of complex coastal issues and provide research-based advice on emerging issues in the estuary. Highlights of this work include analyses of the efficacy of dredging in Baltimore Harbor and of oyster restoration in the Chesapeake; Jon also helped develop a framework for how to conduct ecosystem-based fisheries management (EBFM) in the Bay. These reports were useful and influential. Significantly, the Chesapeake Bay fisheries management discussion shifted forever as a result of Sea Grant's EBFM effort.

Sea Grant's work has been molded not only by the vision and leadership of its directors but also its many talented staff members. Among them is J. Adam Frederick, assistant director for education, who has developed and helped Maryland science teachers use innovative, experiential pedagogy based on principles in coastal science. (See "Living Micro-Reefs Bring Excitement to the Classroom," page 15). Another is Doug Lipton, an economist and former director of Maryland Sea Grant Extension, who was instrumental in developing a cadre of Extension watershed restoration specialists (see "Partners in Stormwater Control," page 18). Peer-reviewed scientific research remains foundational to Maryland Sea Grant, but with Adam's and Doug's work, we greatly expanded our educational and outreach programs to meet the needs of Maryland residents.

I find the variety and impacts of Maryland Sea Grant's work heartening. It is encouraging to see our state's aquaculture industry expand. Introducing students to marine science and watching them become new champions for environmental science inspires me. Our collaborations with great colleagues and partners strengthen our resolve to solve hard problems. As I like to say, "If it was easy, everyone would do it."

The National Sea Grant College Program has faced budget challenges in past years and new ones in 2017. But we remain optimistic that Maryland's future will be one in which our bays and watersheds are cleaner and our coastal communities remain vibrant. We are excited about working with our colleagues, our *Chesapeake Quarterly* readers, and our many friends and supporters in the state and beyond to solve challenging environmental problems and help make that future vision a reality during Maryland Sea Grant's next 40 years.

40 YEARS OF COMMUNICATING BAY SCIENCE

From its beginning, Maryland Sea Grant Communications has been reaching out to our many audiences in the Chesapeake Bay and coastal regions by creating products that address issues important to the region. Topics we've covered include oyster biology and disease, sustainable blue crab populations, fisheries management, sea level rise, and declining seagrasses. Below are selected highlights of our efforts.

Documentary Films

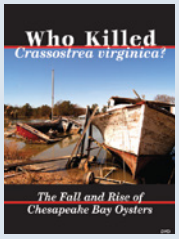
1. Who Killed *Crassostrea virginica?* The Fall and Rise of Chesapeake Bay Oysters

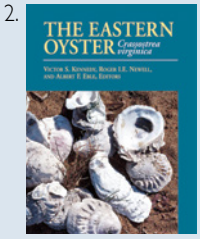
Books

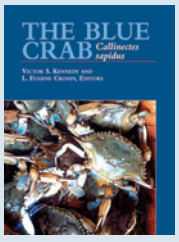
2. The Eastern Oyster: *Crassostrea virginica* (reference book)
3. The Blue Crab: *Callinectes sapidus* (reference book)
4. Decoding the Deep Sediments: The Ecological History of Chesapeake Bay (monograph series)
5. Underwater Grasses in Chesapeake Bay and Mid-Atlantic Coastal Waters (field guide)
6. Working the Chesapeake: Watermen on the Bay (general interest)

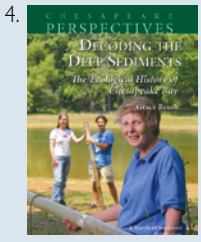
Chesapeake Quarterly magazine and website

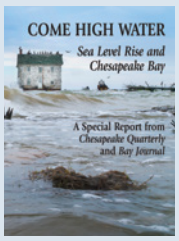
7. Come High Water: Sea Level Rise and Chesapeake Bay — A Special Report from *Chesapeake Quarterly* and *Bay Journal*
8. *Chesapeake Quarterly* — The Ups and Downs of Bay Stripers

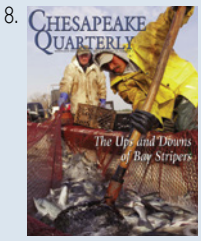


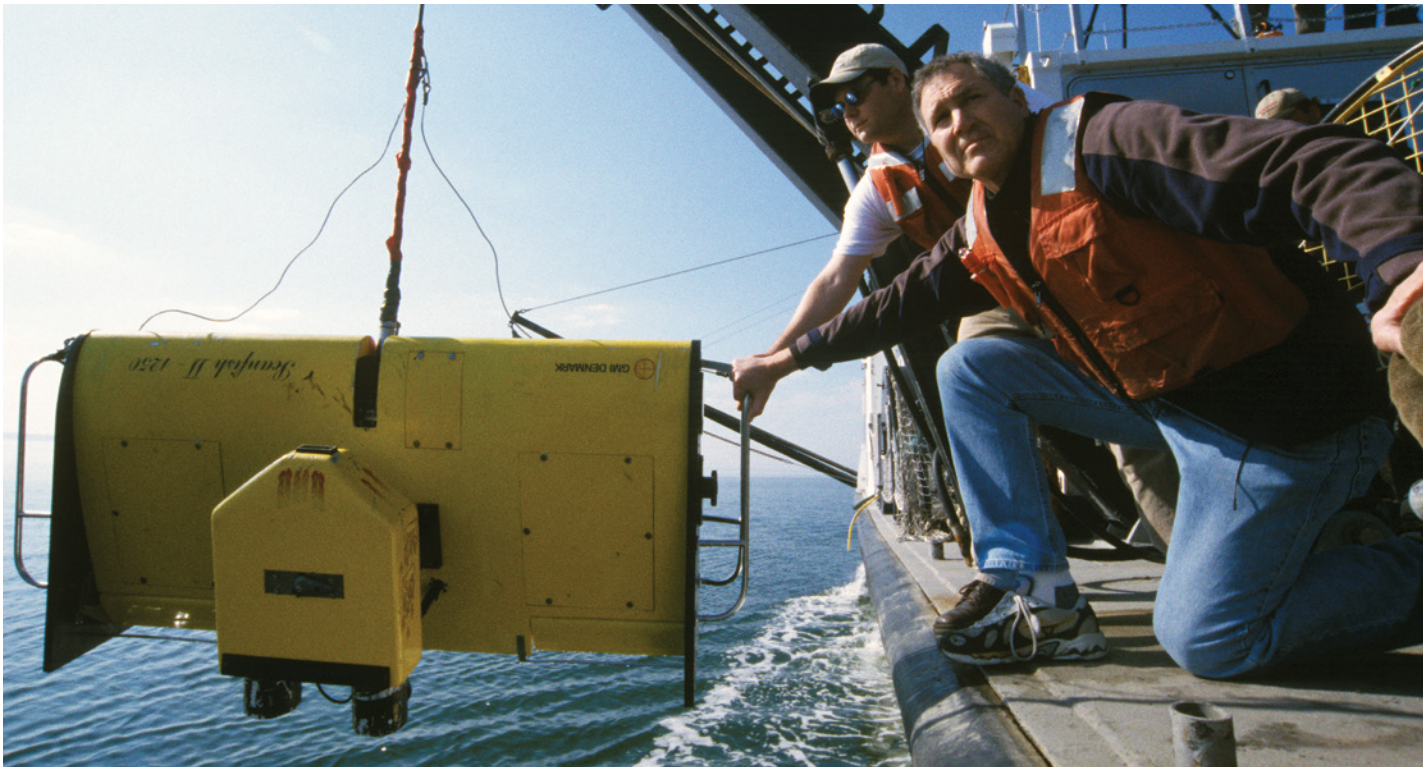












Overture for a New Estuary

A generation changes the Chesapeake

By Michael W. Fincham

Life has lately turned more hectic for lab directors on both sides of the Chesapeake Bay. At this key moment in the multi-state campaign to restore the estuary, they have a new problem on their hands: a lot of well-known scientists were leaving.

On the western shore, Tom Miller was losing two of the Bay's best-known scientists from the Chesapeake Biological Laboratory (CBL), the historic, 92-year-old research center stationed at the mouth of the Patuxent River. Biologist Ed Houde was retiring after 37 years studying the Chesapeake's fisheries, and Walter Boynton was finishing up 42 years of research in systems ecology.

But even more scientists were retiring on the Eastern Shore of Maryland, where Mike Roman is director for the Horn Point Laboratory (HPL), a 40-year old research center located along the Choptank River. On May 5th, 2017, Roman and his staff threw a party to mark the departures of not one but seven well-known researchers. The exiting scientists were Bill Boicourt, Mike Kemp, Vic Kennedy, Laura Murray, Roger Newell, Court Stevenson, and Diane Stoecker. In the last two years, says Roman, "Thirty percent of our faculty retired."

Both labs are part of the University of Maryland Center for Environmental Science (UMCES), and in August its president, Don Boesch, also retired after 27 years coordinating these research labs and advising state agencies on the benefits of science-based management.

That makes ten scientists from two labs in just two years. If you do the math, the Bay restoration effort was losing a total of 330 years of science expertise in fields as diverse as marine biology, natural history, quantitative ecology, fisheries science, systems ecology, wetlands ecology, plankton ecology, and physical and estuarine oceanography.

Other Bay labs are seeing a similar surge of retirements. In the next three years the Smithsonian Environmental Research Center (SERC) on the Rhode River will watch 33 percent of their principal scientists retire.

***Oceanographer Bill Boicourt** and research assistant Tom Wazniak lower a sampling device called a ScanFish into the water where it will undulate through the Bay, measuring temperature, salinity, dissolved oxygen, chlorophyll, and plankton. Technologies like the ScanFish and high-resolution satellites have dramatically expanded data gathering during recent decades.* PHOTOGRAPH, MICHAEL W. FINCHAM

Pioneering work *in the fields of paleoecology and system ecology helped change our understanding of the Chesapeake. Paleoecologist Grace Brush (above with Angie Sowers and Holly Bowers) was able to uncover alterations in the Bay ecosystem caused by historic changes in land use like colonization, deforestation and large-scale farming. And systems ecologists Walter Boynton (top right) and Mike Kemp (bottom right) teamed up with Virginia scientists to identify nutrient and sediment inputs as the major threats to ecosystem health.* PHOTOGRAPHS, SKIP BROWN (ABOVE AND TOP RIGHT); DEBBIE HINKLE (BOTTOM RIGHT)

And down at the southern end of the Chesapeake, lab director John Wells says the Virginia Institute of Marine Science (VIMS) will lose 25 percent of its faculty in a four-year period. "If we look over the last decade," says Wells, "it's been about 40 percent."

A generation of Bay scientists is leaving. What defines them as a generation is their arrival almost en masse during the mid-1970s and their departure en masse some 40 years later. "It's just the actuarial nature of this thing," says Boesch. Scientists arrive, time passes, they retire. And in the normal flow of science, of course, new researchers arrive to replace the retirees.

But this current wave of departures is not a normal flow — for the marine labs in the Chesapeake, this looks like the largest turnover in research talent they've ever experienced.

Turnovers can be times of evolution. In looking for new hires, lab directors have the chance to recruit scientists in emerging fields such as molecular biology, advanced statistics, and coastal synthesis science. And these new researchers will have their chance to apply their approaches to solving issues now facing the Chesapeake Bay ecosystem.

But those issues will not be the same ones scientists faced 40 years ago. The starting point for these incoming scientists will build on the foundational work of those outgoing scientists.

Chesapeake Bay 2.0

So what did the work of that departing generation achieve?

The short answer: a new estuary. Not a restored estuary, but a restorable estuary.

The longer answer: the last 40 years of research — with its discoveries and debates and occasional dead ends — helped create a new way of thinking about the Bay, a new narrative of the Chesapeake.

To anyone paying attention, the Chesapeake Bay of 1977 looked like an ecosystem in decline: the waters were growing murky, the bottom of the estuary was losing seagrasses and oyster reefs, the deeper waters seemed to be

showing more zones and larger zones of low oxygen, striped bass reproduction was dropping, and blue crab harvests were wildly and mysteriously erratic.

To help people pay attention, the Chesapeake Bay Foundation was sounding the warning with its terse slogan, "Save the Bay," a call to action that sounded simultaneously hopeful and fearful. Was the Chesapeake already a lost cause? Newspapers were even more alarmist, with headlines asking bluntly "Is the Bay Dying?"

What was behind all these problems? In the case of oysters, the causes seemed clear: overfishing and disease. But with nearly every other stress symptom, the causes seemed as murky as the darkening waters of the estuary. And nobody had a road map for restoration.

Forty years later the Chesapeake Bay of 2017 faces a different future. There's a moderate but growing optimism about restoration among many key players, including scientists and citizens and environmentalists. That optimism is based in part on a shared perception that scientists have been able to discover many of the causes for declines, that they are figuring out how the ecosystem works, that they are outlining options for restoration. And state and federal agencies, as a result, seem to be trying more often than in the past to apply science-based policies to address the Bay's problems.

The year 2017 could even be called "the Year of Bay Optimism," says Tuck Hines, lab director at the Smithsonian Environmental Research Center. The Chesapeake by now seemed to be an estuary that could be understood — not completely, but in greater depth and detail than ever before. And an understandable estuary could be a restorable estuary.

After all, science-based recovery seems to be working in other ecosystems, according to Hines. If recovery can happen in places such as Monterey Bay in California and the Willamette watershed around Portland, Oregon, then it can happen in the Chesapeake, says Hines. "It can be done."

Learning to Love the Chesapeake

The scientists who helped spur this optimism about restoration did not come here to save the Chesapeake Bay. Arriving in the mid-1970s most of them came with graduate degrees acquired elsewhere and brought little personal connection with the estuary and little historical background about the problems facing this ecosystem. "My sense of scientists being concerned about the health of the Bay — that didn't occur until very late," says Bill Boicourt, one of the few scientists of this generation who had already spent years working on the Bay as a student and scientist at the Johns Hopkins Chesapeake Bay Institute.

Most of the new scientists came for other reasons: to get a job and to try out their advanced training on the country's largest estuary. Those fresh out of graduate school were primarily interested in exploring questions deemed interesting or important during their graduate-school training. In a speech several years ago, Mike Kemp, a systems ecologist trained in Florida, spelled out a typical mindset. The Chesapeake Bay with its beauty and bounty certainly struck him as "a cool place," but what attracted researchers to the region was something else. "There are all kinds of interesting problems," he said. "A question, a big question to try to solve and resolve. That's what's exciting."

And the most exciting question to be answered — what was happening to the health of the estuary — was a question that had seldom been publicly acknowledged by the previous generation of Bay scientists. The methodological reason: earlier scientists tended to study Bay conditions as they found them. They worked with very little long-term data about Bay conditions in the past.

The political reason: speaking out about an estuary in decline was not a good career move for a young scientist. When plankton specialist Don Heinle dug up earlier records showing long-term declines in water clarity and oxygen levels in the Patuxent River, he spoke up publicly about his findings. Worse yet, he also allied himself with a local environmental leader who was pushing a campaign to clean up the river. The result: state officials were soon calling for his dismissal from CBL. And the lab later denied his promotion request.

As a result, it was mostly private citizens — not state-paid scientists — who began raising the alarm about the health of the Bay. In 1973 U.S. Senator Charles "Mac" Mathias organized a "fact-finding" tour of the Maryland part of the Chesapeake, and he spent most of his time listening to local environmental leaders, commercial watermen and sports fishermen, bird hunters, and Bayshore residents. From them he heard eyewitness accounts of darkening waters, disappearing seagrasses, and declining numbers of waterfowl and oysters and striped bass.

The senator also spoke with a number of scientists, only to discover "there was really no one," he later said, "who had any total solution to the problems." After listening to so many citizen complaints, Mathias pushed through a federal funding bill that directed the EPA to organize a five-year scientific study of this damaged estuary.

The study began in 1977 when the EPA — with its new funding — asked scientists to investigate the question that was troubling so many citizens: was the health of the Bay in decline? The question, however, seemed to surprise many in the established science community, according to Boicourt, then a researcher at Johns Hopkins University. "I think EPA was the shocker," he says. "They came to town and said the Bay was dying."

A Restorable Estuary?

How then did an incoming generation, arriving from elsewhere, begin to rewrite this "dying Bay" narrative?

By uncovering the key causes of ecosystem decline. When researchers in Maryland and Virginia, working

with EPA funding, investigated the causes of the great seagrass die-off, their unexpected findings began to revise popular and scientific thinking about the estuary's pollution problems. They pinpointed nutrient inputs and sediment runoff as the most damaging, system-wide threats to the health of the Bay.

By discarding or reworking faulty paradigms. On several issues, says Boesch, "scientists were just flat wrong." It wasn't farm chemicals that were killing off seagrasses. It wasn't acid rain that was depressing striped bass recruitments.

By speaking out about science findings. In the late 1970s, four university scientists from CBL and Rita Colwell from Maryland Sea Grant signed on a historic environmental lawsuit brought against the EPA and against their employer, the state of Maryland. Court-orders would lead to reduced sewage discharges into the Patuxent River and new requirements that treatment plants begin removing nitrogen from wastewater.

By engaging with stakeholder groups. Researchers worked with the Patuxent Charette that set a water quality plan for the river, the Bi-State Blue Crab Advisory Committee that set harvest targets for the fishery, and with the Oyster Advisory Commission that revived oyster aquaculture in Maryland. UMCES president Don Boesch served as science adviser for the Governor's Bay Panel.

By focusing research on the Bay's watershed. "We realized that what happens on the land affects the Bay," says Mike Roman of HPL. Out of their research would come ongoing efforts to revamp farming practices, wastewater treat-ment, construction methods, and stormwater runoff.

By learning to work in teams. In contemporary research "individual scientists hardly ever make an impact," says fish biologist Ed Houde. Influential science that addresses complex ecosystem issues usually emerges from group projects that combine specialists from different disciplines. "It's definitely a team sport," says Roman.

By redrawing our picture of the underwater estuary. Oceanographers turned up new discoveries and details about features such as the stratification events that amplify dead zones, the wind mixing that dissipates them, the estuarine turbidity maximum that forms in the upper Bay, the cyclonic eddy that occurs in the lower Bay, the biological hot spots that form near river mouths, and the estuary's hydraulic control point that operates at the juncture of the Deep Trench and the Rappahannock Shallows.

By spurring revivals of key fisheries. When fisheries biologists developed a more detailed understanding of the critical life stages of blue crabs, of Bay spawners like striped bass and perch, of ocean spawners like spot and croaker and menhaden, their discoveries led to new fisheries policies for rebuilding these populations to sustainable levels.

By creating new options for oyster aquaculture. Disease-free oyster larvae, remote setting tanks, and fast-growing triploid oysters helped recreate an oyster farming industry in Maryland and expand one in Virginia.

By sparking an oyster restoration movement. The ongoing effort to rebuild oyster reefs in the Chesapeake, a project with wide public support, grew

out of science findings about the ecological roles that oysters play in filtering Bay water and in creating bottom habitat for fish and crabs.

By developing a theoretical framework for forecasting the pace and potential of Bay restoration. Biologists want to be physicists, says Mike Kemp, and systems ecologists want to be philosophers. Working with in-the-field findings about sediment memory and feedback loops, Kemp and his colleagues began examining and testing ideas about thresholds, equilibria, hysteresis, regime shifts, and resilience — concepts that may explain how ecosystem recovery could already be happening here in the Chesapeake.

This still-emerging paradigm describes how an ecosystem can "plateau" in a degraded state despite years of restoration projects. But those efforts can eventually accumulate, raising the ecosystem to a required threshold state. At that point, a change in the system (perhaps less rainfall and less runoff) can create a tipping point that unleashes a series of reinforcing feedback loops: water clarity, for example, helps seagrass recovery, and seagrass recovery helps water clarity. As feedbacks interconnect and coalesce, recoveries can accelerate.

A Threshold Generation

These and dozens of other discoveries achieved by this departing generation were due mostly to their good work — but also to their good luck.

Their first good fortune was getting hired during the mid-1970s, a decade that brought expanded federal funding for marine and environmental science. The National Science Foundation (NSF) was a traditional funding source, but now Chesapeake Bay scientists could also approach two new federal sources: the Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA). Both were created in 1970 during the administration of President Richard Nixon, and both would play important roles in Bay science: EPA with the Chesapeake Bay Program and NOAA with Sea Grant College programs in Maryland and Virginia.

Fisheries biologist Ed Houde *leads a cruise to track fish migrations and populations along the Choptank River. Opposite page: Mike Roman, a biological oceanographer, readies a deep-water sampling net to track the offshore migrations of blue crab larvae.* PHOTOGRAPHS, MICHAEL W. FINCHAM

In hopes of landing some of this new funding, research institutions with a Bay focus went to work reorganizing and expanding their programs. The Smithsonian Environmental Research Center (SERC), previously a field station for local researchers, was able to hire its first full-time scientists. The University of Maryland got busy reorganizing its field labs under the direction of the new UMCES. And it opened a new research site, now the Horn Point Laboratory (HPL) along the Choptank River on the Eastern Shore.

All this activity turned 1977 into a watershed year for starting new research on the Chesapeake Bay. At HPL, this barely started and barely staffed lab had an expansive master plan that called for hiring 75 new faculty researchers over the next decade. The EPA began funding its five-year, 25-million-dollar study focused on the Chesapeake Bay. In College Park, NOAA launched the Maryland Sea Grant Program under the leadership of marine microbiologist Rita Colwell who began funding research on water quality, fisheries, and ecosystem functions.

For Bay labs the key to landing these new funds would be well-credentialed scientists who could craft strong grant proposals. In the lab-funding structure that was then evolving, faculty scientists had to raise most of their salaries through these competitive proposals. And they had to find the money for the research technicians essential to most field and lab research. The labs would collect an overhead surcharge (usually around 50 percent) on each funded project and use that income to support buildings and grounds and buy research equipment.

It was a good time for well-prepared PhDs to be looking for a job — and not just in the Chesapeake. "In those days you could find a job relatively easy if you were a grad student," says Ed Houde, who studied at Cornell. In 1970, he typed out five job application letters and got four offers. "The timing of it all," says Don Boesch, "was that a lot of people got into the field when it was growing and became part of that next generation."

It was also a good time for PhDs to build careers at university labs. With the rising concern about the environment, more graduate students were pursuing advanced degrees at marine labs, creating a stream of talented assistants and collaborators that PhD scientists could rely on while building their reputations.

The scientists of this threshold generation were also lucky in their leaving. Careers that began in an era of increased funding seem to be ending in an era of reduced funding. The federal support for marine science that began under President Nixon is now threatened with dramatic cutbacks. For 2018, this current administration sent budgets to Congress that explicitly called for closing down the EPA's Chesapeake Bay Program and NOAA's network of Sea Grant programs — two essential sources for funding Bay science.

Congress has yet to act on these and other suggestions by this administration, but according to lab director Mike Roman, HPL is already seeing reduced overhead income as a result of fewer research grants. And the lab, he says, is now home to fewer graduate students who are choosing to pursue advanced degrees in estuarine and environmental science.

A Threshold Estuary?

Mass retirements, however, also bring opportunities. New scientists at HPL and other Bay laboratories are being recruited to bring different skills to address a different estuary, an estuary altered by natural events and by science-based efforts to restore the ecosystem. The estuary has changed and science has evolved, says Roman, and "new expertise is required to meet the environmental challenges facing the Chesapeake."

The incoming scientists are already applying their expertise: they are investigating how methane and other greenhouse gasses escape from Bay marshes, how coastal habitats respond to sea level rise, how flood modeling can improve storm-surge forecasting, how molecular biology can address the problems and unleash the potential of aquaculture, biofilms, and waste management.

They may, if they are lucky, find themselves applying expertise to another kind of challenge: the task of responding to an estuary in active recovery. Recent years have turned up new evidence for optimism, strong signs that Bay restoration could be approaching a threshold. Nutrient inputs, especially from air pollution and sewage treatment, are down. Seagrasses in certain places in certain years are up dramatically. Striped bass and blue crab fisheries are rebounding. Oyster reefs are being rebuilt. Oyster farming is rising.

Call it progress.

Or call it proof of concept. The concept that says science-based restoration can work for the Chesapeake Bay.

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40 YEARS OF SCIENCE AND RESOURCE MANAGEMENT

Maryland Sea Grant has long supported both fundamental and applied research — studies on basic ecosystem processes, for one example, or tests of fishery forecast models for another. But our underlying assumption is that both forms of research eventually pay off with practical results as a deeper understanding of the ecosystem can drive more precise and appropriate decision making about resource management issues. A few highlights from our history:

Promoting ecosystem-based fisheries management

Our program led efforts to develop a scientific framework for ecosystem-based fisheries management (EBFM) in the Chesapeake Bay, an alternative to managing fish and shellfish species individually, as though harvests of one do not affect the other. The framework recognizes the complex interactions of the food web and provides guidance for maximizing harvests of blue crabs, striped bass, Atlantic menhaden, oysters, and other species without undercutting the ecological role each species plays in the estuary's ecosystem. To examine the benefits of this approach, Sea Grant commissioned fisheries scientist Edward Houde to write *Managing the Chesapeake's Fisheries,* a book that assesses the state of key Bay species and evaluates the prospects for shifting from single-species to multi-species management.

Supporting research on Bay "dead zones"

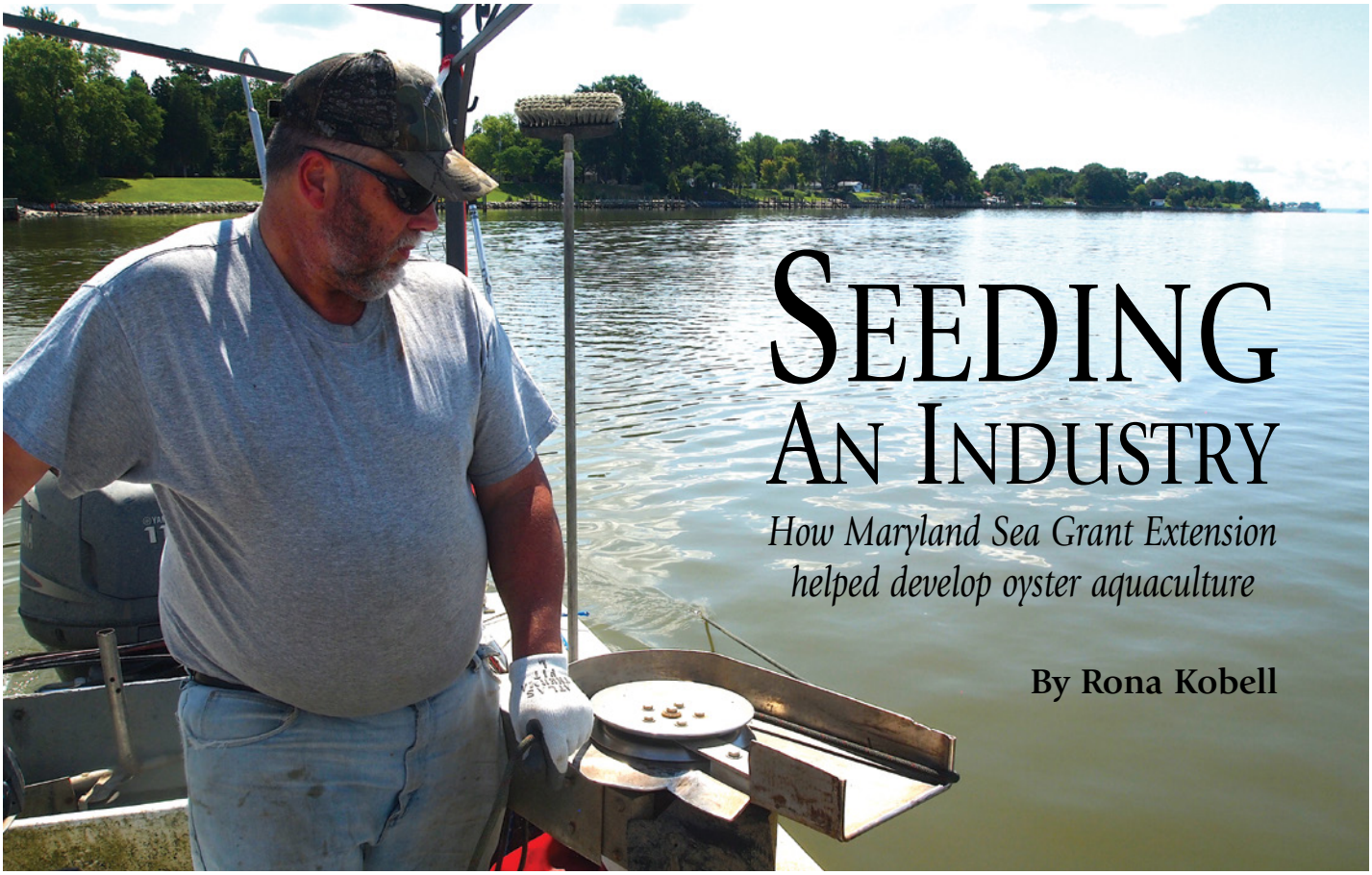
Maryland Sea Grant has supported extensive research efforts to detail how nutrients, sediments, and waterflow lead to areas of oxygen depletion (hypoxia) in bottom waters and, during the summer, to the complete absence of oxygen (anoxia). Such regions cannot support fish and plant life. The results of this research are summarized in Maryland Sea Grant's *Oxygen Dynamics in Chesapeake Bay: A Synthesis of Recent Research,* an oft-cited book edited by David R. Smith, Merrill Leffler, and Gail Mackiernan. A follow-up scientific consensus, *Dissolved Oxygen in the Chesapeake Bay,* presented a plain-language explanation of this complex issue.

Underwater grasses and water quality

The widespread disappearance of submerged aquatic vegetation (SAV) that began more than 50 years ago has been, in part, a response to declining water quality throughout the Chesapeake Bay system. Maryland Sea Grant support of research on the causes of SAV loss over many years has been key in determining the role of nutrient overloading and the cascade of negative impacts. Studies of the recent resurgence of grasses in the Susquehanna Flats have begun to reveal how the interactions of seasonal waterflow and climatic factors affect the resilience of grass beds, and how the beds themselves, through feedback loops, influence their own survival. The implications of these findings offer a more nuanced understanding of what is involved in programs to restore submerged grasses.

New prospects for controlling *Phragmites* invasions of tidal marshes

A common reed, *Phragmites australis,* a non-native species, has been spreading in wetlands throughout the Chesapeake Bay and in other regions of the nation. In an extensive field study, Maryland Sea Grant-supported scientists found that high levels of nitrogen and carbon dioxide in Bay marshes promote increased rates of *Phragmites* invasion, which can displace native plants and, in turn, negatively affect species, for example, mummichog that are a prey for commercially important fish. Findings suggest that management practices to limit nitrogen and/or carbon dioxide could curtail future invasions.



Seeding An Industry

How Maryland Sea Grant Extension helped develop oyster aquaculture

By Rona Kobell

Growing up in Southern Maryland, Mike McWilliams spent all the time he could fishing with his grandfather and cousins on the Wicomico River, a tributary of the Potomac. Every boy had his own skiff, or knew how to run one. In the summer, the boys followed Capt. Walter Saunders's lead and crabbed in the shallows close to the banks. In the winter, they would watch the hardy souls set out at dawn, headed downriver towards the Potomac, masts up, hoping to catch enough oysters to provide for their families until summer.

But under those placid Wicomico waters, Capt. Walter, as he was known to everyone, kept something special: millions of native Chesapeake Bay oysters, growing on fossilized shells. It was a relic of the old days when watermen could lease a patch of river bottom from the state of Maryland and try their hand at cultivating a private crop of a species that almost everyone else saw as one meant for a public fishery.

For most of the 20th century, obtaining oyster leases was nearly impossible in every Maryland tributary except the Nanticoke River, where a large oyster shucking and canning company operated. Watermen opposed leasing at every turn, arguing that it would open the Chesapeake to large corporate interests and put them out of business. They preferred the system they had, where the state planted shell and seeded beds at oystermen's request so they could harvest oysters during a limited season.

That changed in 2009, when the Maryland legislature allowed oyster leasing in every county. The law, though, would come with a stipulation that those who held on to leases needed to use them or lose them. Capt. Walter, who died the year before the law changed, had passed his crab license on to Mike McWilliams, his grandson. But Capt. Walter's oyster leases had remained unchanged; he hadn't seeded them in years.

"My uncle got the letter that they were going to take these things away. I said, 'No, don't let them go,'" McWilliams recalls. "When your family's been out there all this time, it's in your blood."

Today, McWilliams still glides his skiff along the river at the town of Chaptico, near where his grandfather lived. But now, under the surface, something new sits on Capt. Walter's old shell beds: hatchery-raised seed that McWilliams spread on 28 acres across five leases, that will grow into millions of market-sized oysters. With the price hovering between $50 and $70 for a bushel, Capt. Walter's leases will supplement the income McWilliams earns as a crabber, deer meat processor, and butcher.

***Mike McWilliams** looks down at the waters above the oyster-ground leases his grandfather once worked in the Wicomico River, a Potomac River tributary. Now he raises oysters there himself, a participant in Maryland's growing aquaculture industry.* PHOTOGRAPH, RONA KOBELL

Critical to developing the industry, McWilliams and other oyster farmers say, are two programs with connections to Maryland Sea Grant and its Extension program. The MARBIDCO program, a state loan fund, provides low-interest loans to prospective oyster farmers who can't obtain start-up capital through conventional means. And the remote-setting program, which Don Meritt, a Sea Grant Extension shellfish specialist, brought to Maryland from the U.S. West Coast nearly 40 years ago, teaches the farmers how to set their own larvae on oyster shells in large tanks on land, creating spat-on-shell they can then put in the Bay on substrate — usually beds of shell — to help them grow. Regional Extension Specialist Don Webster, based at the Wye Research and Education Center on the Eastern Shore, trains farmers in remote setting. Matt Parker, a Sea Grant business expert based in Clinton, helps oyster growers apply for the MARBIDCO loans and develop their business plans.

"He's been instrumental in assisting these leaseholders," said Karl Roscher, director of the Aquaculture and Business Development unit for the Maryland Department of Natural Resources. "Many of the applicants don't have a familiarity with business plans."

Those tools have helped to build Maryland aquaculture from a handful of worked leases in 2012 to 6,500 acres under lease today, with an oyster harvest expanding from 1,000 bushels to nearly 65,000 bushels in 2016, according to Roscher. Today's oyster aquaculture fishery is worth about five million dollars, Roscher estimates. It's still a fraction of the wild harvest in Maryland, but in Virginia, oyster aquaculture has surpassed the public fishery, and Roscher says Maryland's is on pace to keep expanding.

The growth of oyster aquaculture in Maryland is good news for both oyster farmers like McWilliams and also an estuary like the Chesapeake Bay. Oysters, down to less than one percent of their historical abundance, filter the Chesapeake Bay's excess nutrients — particularly the nitrogen and phosphorus entering the nation's largest estuary from farm-field runoff, sewage treatment plants, and suburban development. Oyster reefs also create habitat for juvenile fish and other bottom-dwelling organisms that provide food for bigger fish. Oyster decline in the Chesapeake, the result of decades of overharvesting and two devastating diseases, is both an economic and an ecological heartbreak. But aquaculture can help turn the tide, at least a little bit.

"There's no way I could have gotten it started without the MARBIDCO loan and the remote setting program," McWilliams says. "There's just no way."

Karl Roscher *(left), of the Maryland Department of Natural Resources, works with oyster farmer Bobbie Leonard at his remote setting tank. Leonard, like many oystermen, is involved in several water-related businesses.*
PHOTOGRAPH, DON WEBSTER

MARBIDCO Saves the Day

Known mostly as a revolving loan fund for farm- and forestry-based businesses, the Maryland Agricultural and Resource-Based Industry Development Corporation (MARBIDCO) has been a lifeline for oyster farmers.

At first, after the state made oyster aquaculture legal in every county, it

gave priority to funding those who held a tidal fish license; the state was funding the program with federal money provided in 2008 to counteract economic losses watermen suffered from a crash in the blue crab population. Though some money is still earmarked for watermen, MARBIDCO has loaned to plenty of applicants who don't have licenses to crab or fish. Since 2011 the program reports it has approved more than 50 shellfish aquaculture loans totaling over three million dollars.

Mike McWilliams got one of the first loans, for $25,000, to buy shell, a mast, a rig, and an oyster dredge to work the Bay's bottom. Two years later, he borrowed $10,000 more for additional shell. Parker helped him write business plans that MARBIDCO required in the loan application. McWilliams also received in-kind training from Meritt and Webster in how to set the oysters on the shell.

The terms of MARBIDCO loans are far better than those of any conventional loan. They run five years; for the first three, the borrower pays only interest at 3.25 percent. If borrowers make all payments, MARBIDCO forgives 25 percent of the principal.

When everything goes well, about 30 percent of a farmer's oysters will reach the market size of three inches, though McWilliams prefers they get to four to maximize their ecological value. Usually, everything does not go well. In McWilliams's first year, so much rain fell on Southern Maryland that it washed out a bridge near Chaptico. Salinity levels, ideally between 10 and 22 parts per thousand for oyster growth, fell to just 4. McWilliams lost 90 percent of his crop that year.

For Parker, helping people apply for a MARBIDCO loan is the start of a larger conversation about business plans. He's advised several farmers in the region and is proud most of them remain in what is still a risky business and have started paying back their loans. He helps prospective farmers grapple with a series of questions. How much money do they need to make before taxes? How large a farm would they like? Would they sell directly to restaurants or go through wholesalers? Would they try culturing oysters on the Bay's bottom, as McWilliams does, versus growing them in cages that sit on the bottom, as other farmers do?

Besides business decisions, there is also the red tape. McWilliams avoided this snag by taking over his grandfather's leases, but many first-time oyster farmers endure months if not years of headaches navigating the bureaucracies of both the U.S. Army Corps of Engineers and the Maryland Department of Natural Resources to obtain their oyster leases and permits. Certain choices can save lots of time, such as picking the right site and getting the community on board before submitting applications. Parker can put farmers in touch with state officials who can assist with that.

"My view is that anyone can get into aquaculture, but if you don't have a plan to succeed, your success is going to be limited," Parker says. "It's not rocket science, but it can be as expensive as rocket science."

Beyond the Spatmobile

If MARBIDCO democratized oyster-farmer funding, remote setting took the act of growing oysters from behind the walls of hatcheries and into the hands of lay people.

Maryland has been in the remote setting business since the 1980s, when Meritt, who manages the University of Maryland Center for Environmental Science's Horn Point Oyster Hatchery, brought the approach back from the West Coast, where remote setting techniques revolutionized the industry. Instead of having trained scientists set the larvae, oyster farmers could do it themselves, on their own farms, in their own tanks. Oyster farmers now had the ability to create and control their own inventory. They could keep the larvae cool and moist for several days.

"It was a real innovation in the industry, because what it allowed you to do was store the larvae. You could ship them," Webster says.

An oyster grower could also make a business setting spat for other growers. It took the growing process out of the expensive realm of hatcheries, with their trained scientists and expensive water-flow systems, and put it in the hands of growers who could learn quickly how to perfect the technique.

"No," Webster says, "remote setting is not hard for growers to learn."

In 1982, Meritt and Webster took setting tanks to one of the few places in the state where aquaculture leasing was viable at the time: the Nanticoke River. Harold Kennerly Jr., owner of H.B. Kennerly & Son Inc., had locked up many leases on the river, where watermen also held leases. Kennerly was supportive of any efforts to get more oysters in the water, so the Extension team set up workshops showing how to set larvae to produce spat. Later, they put the equipment on a trailer, dubbed the "Spatmobile," and drove it to other locations. Several watermen and seafood business owners learned the technique. One was Casey Todd, who owned Metompkin Seafood in Crisfield with his father, I.T. Todd Jr.

A lawyer by training, the younger Todd always had an eye on the future — his father was the last baby born on Holland Island in 1918 before everyone left due to rising waters. Aquaculture, Todd reasoned, provided a hedge against the oyster diseases ravaging the Chesapeake and also a year-round supply of a crop at that time only sell-able in the winter. (Many oyster farmers use sterile oysters, known as triploids, which put all of their energy into growth instead of reproduction. Where wild oysters are runny in the summer, triploid-raised aquaculture oysters are firm and safe to eat.) Other states were already doing it; but Maryland's politicians would not be moved to loosen lease laws. Todd, in Somerset County, knew he would have to defer his plans.

"We had it in the back of our minds, the industry was moving along

in other states, and we were sitting here in a backwater," Todd says. "We knew what could be done, but we're just individuals, and we can't change public policy. . . . But when it did change, we were ready."

Now, Metompkin operates six tanks along the Annamessex River in Crisfield. Todd has planted 13 million oysters, which he will use to supplement the wild catch Metompkin buys from local watermen. His son, Josh Todd, is helping with the oyster operation — if that's not an assured future, Todd says, it's as close as a recent college graduate can get to one. Demand for oysters is high, and prices have been near stratospheric since the one-two punch of Hurricane Katrina and the Deepwater Horizon oil spill reduced the supply of oysters coming from the Gulf of Mexico.

Remote setting has reinvigorated the Nanticoke, too, where many of Kennerly's leases languished after the company went out of business in the 1990s. Eric Wisner, a waterman and former logger, has 500 acres under lease in the river and set about 150 million larvae last summer. Webster jokes that, if someone has a hot tub on the Eastern Shore and is not using it, Wisner might sneak some shell and larvae in there to get a set.

The idea, Webster says, is to train the oyster farmers and then have them do their own remote setting. In 2011 the program had 12 growers who produced 33 million spat; in 2017, 45 growers produced 259 million seed oysters. It's grown from a few setting tanks to 38 systems placed in eight locations around the Chesapeake. Maryland Sea Grant estimates the Extension outreach work created 60 new businesses and 130 new jobs in 2016.

Occasionally, Webster, who chairs the Maryland Aquaculture Coordinating Council, runs into Todd. They reminisce about the Spatmobile, the hope they held on to, and the pride in what the industry is today.

"I told him I didn't think I'd ever live to see it," Todd says. "I'm 63 years old. Lo and behold, it looks like I made it."

A Food Truck to Save the Bay?

Back in Chaptico, Mike McWilliams is struggling with his motor. Fixing equipment is just one of the many unanticipated expenses he encounters working on the water. With Matt Parker, he has worked on a plan to generate more income. He'd like to start a food-truck business with a steam trailer that could travel the state and serve oysters at wineries and festivals. A new Spatmobile, but all grown up and with food ready to eat. He even came up with a name: Capt. Walter's Oyster Co. — The Pride of the Wicomico River.

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40 YEARS OF FISHERIES AND AQUACULTURE

One focus for Maryland Sea Grant has been addressing the problems facing commercial fisheries in the Chesapeake Bay. Our research findings have helped improve management of the fisheries for oysters and blue crabs, and the University of Maryland Extension specialists have been providing the technology and training for reviving oyster aquaculture. In addition, our staff experts helped reshape the state's fisheries policies by working with the Bi-State Blue Crab Advisory Committee and the Governor's Oyster Advisory Commission. Some other highlights include:

Surprising journeys of blue crabs in the Chesapeake Bay

Since the 1980s, Sea Grant programs in Delaware, Maryland, and Virginia, have supported coordinated research projects leading to a paradigm-changing model of blue crab recruitment to Mid-Atlantic estuaries. Based initially on intensive lab experiments with different stages of blue crab larvae and extensive field sampling, the model hypothesized that larvae spawned at the mouth of the Chesapeake Bay are transported offshore, to the open sea. The subsequent recruitment of larvae back to the Bay was largely regulated by a number of physical processes, including wind and ocean currents. The development of this counter-intuitive model has significantly influenced resource management decisions. In 1982, Maryland Sea Grant published the results of this multi-year project, *The Blue Crab in Mid-Atlantic Bight Estuaries: A Proposed Recruitment Model.* In the 2000s, field studies confirmed and refined this model, highlighting the importance of wind and density-induced current flows, rather than tidal currents as an important mechanism to drive larvae into the Chesapeake.

Raising oyster seed for Bay-wide restoration

The Horn Point Laboratory on Maryland's Eastern Shore has been the site of expanding oyster hatchery operations. Starting as a small experimental project in 1980 under the direction of Sea Grant Extension specialists, hatchery production has become a major factor in Maryland's efforts to promote sustainable restoration of the Chesapeake Bay's wild oyster populations.

Growing seaweed for water quality and profits

Scientists have been working to commercialize research findings about the potential water-quality benefits of farming oysters in combination with *Gracilaria* microalgae, an economically valuable seaweed. Field trials show that *Gracilaria* can take up nutrients created by intensive oyster cultivation, and also remove carbon dioxide and phosphorus — all of which contribute to oxygen depletion in bottom waters. The plant can then be harvested for use in feedstock and biofuels. In large-scale enterprises, growing seaweed and oysters together could also create jobs and generate additional income. Researchers have identified investors and created business plans to implement commercial production of *Gracilaria* in the estuary.

The science on the Eastern oyster and the blue crab

Maryland Sea Grant published two definitive resource works on the oyster and the blue crab: *The Eastern Oyster: Crassostrea virginica,* edited by Victor S. Kennedy, Roger I.E. Newell, and Albert F. Eble and *The Blue Crab: Callinectes sapidus,* edited by Victor S. Kennedy and L. Eugene Cronin. Invaluable for researchers, resource managers, and students, both books have received accolades as the most comprehensive works now available on those species.

Living Micro-Reefs Bring Excitement to the Classroom

Science educators teach aquatic ecology through innovative techniques

By Jeffrey Brainard

On a warm September morning in Baltimore's Inner Harbor, the traffic steadily moving along on Pratt Street, Chris Tollini is perched on a ledge just above the harbor's murky water. He's pulling up the first of thirteen PVC pipes, each with stacks of black-encrusted discs along the length of the pipes. These acrylic discs were clean when first lowered into the water nearly six months before — now they are teeming with life: mussels, barnacles, and other organisms such as bryozoans and hydroids. These living microcolonies are destined for high school labs and students who are studying the ecology of this polluted urban harbor.

Tollini is with the Institute of Marine and Environmental Technology (IMET) Aquaculture Research Center housed steps away in the Columbus Center, which fronts onto Pratt Street. This morning he's with the supervisor of science education for Carroll County's public schools, Jim Peters, who will put the pipes and discs in coolers and deliver them to county science teachers.

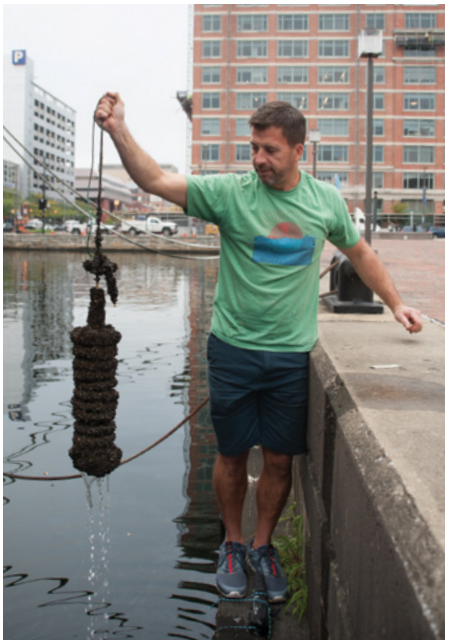
By explaining how these marine colonies got started in the first place and thrived in contaminated waters, teachers will be able to guide their students in hands-on research about complex ecological processes.

A Toehold for Life

More than twenty years ago, Adam Frederick and his colleagues at the Center of Marine Biotechnology (IMET's predecessor) conceived the idea of hanging discs in the harbor in order to collect organisms that could be used by Maryland pupils to study aquatic biology. Now Maryland Sea Grant's assistant director for education, Frederick began collaborations with other research scientists at the center.

This effort grew into the Biofilms and Biodiversity Project, a program which uses biofilm discs and an interactive web resource to educate students and teachers who visit the Columbus Center. There they are invited to examine the colonized discs in a learning lab, called SciTech, which is run by Towson University. Teachers also participate in professional development workshops given by Frederick.

Earlier in his career, Frederick taught high-school courses in biology and environmental science, and he still speaks of the living discs with the zeal of a teacher eager to share new worlds with his students. The discs, he says, are not only inexpensive but an effective tool for teaching nonscientists about the harbor's marine life.



Aquacultural engineer Chris Tollini *(above) pulls up a rack of discs that became encrusted with marine life after they were immersed for six months in the murky waters of Baltimore's Inner Harbor. One of the discs might shelter a lacy crust bryozoan, shown here with its colonial plumes (top).* PHOTOGRAPHS, J. ADAM FREDERICK (TOP); NICOLE LEHMING (ABOVE)

"You look at these discs under the microscope, and it is like seeing a miniature reef," Frederick says. In this small space, many interesting-looking animals live together in a community. The mussels dominate, opening and closing their shells as they filter food particles from the water. You can see barnacles extending their feeding legs, tiny worms, perhaps anemones, and even the occasional mud crab.

In examining the disc-bound communities, students and visitors learn about the coating of life that forms the foundation for the entire colony. Though not visible to the eye, this coating consists of microorganisms — bacteria and diatoms — that are the first colonizers. Once established, they send out chemical signals that attract mussel larvae and other life forms that settle and attach themselves. It's like hanging out a sign, "Free land for settlers!"

Marissa Harbison, *a senior at South Carroll High School in Sykesville, Maryland, examines one of the biofilm discs in her Science Research class, guided by her teacher, Judy Plaskowitz.*
PHOTOGRAPH, NICOLE LEHMING

Project-based Learning

Over the years, the biofilm discs have become a vehicle for educational outreach beyond the Columbus Center, and Jim Peters has become one bridge for that outreach. After filling two large coolers with the PVC pipes and their discs, he delivered them to seven high schools in Carroll County. Science teachers were ready and waiting: all had prepared aquariums in their classrooms with water containing salinity at 11 parts per thousand — the same level found in the waters of the Inner Harbor when the discs were collected. These saline conditions would keep the colonies alive until science classes later in the week.

The discs fit well in a broader approach routinely used by Carroll County science teachers that emphasizes hands-on learning. Students record their observations and collect specific data. Unlike conventional biology where pupils may do microscopic studies of prepared slides and dissect animals furnished by a biological supply house, the biofilms project gives them an unusual opportunity. "They rarely get to see living things from an environment like the harbor, let alone a community of living things," says Frederick. "The level of engagement is high — the school bell could ring, and they're still engaged."

In Carroll County, the discs are the basis for a lesson in an elective course called Science Research that offers students an intensive series of project-based science learning activities, some of them focused on aquaculture, the cultivation of fish in tanks. Students take this course in addition to others in physics, chemistry, and biology. For two decades, Frederick has worked with Peters and the county's science teachers to help refine the Science Research course curriculum.

"I feel incredibly lucky to have this program," says Judy Plaskowitz, who teaches the class at South Carroll High School in Sykesville. One reason it has prospered, she says, is the technical support she and other teachers receive from Frederick and other scientific experts working at IMET. Peters adds, "We couldn't sustain any of this without their help."

The day after Peters's special delivery to Plaskowitz, 25 students file into her Science Research class. Safety first: she has the students put on protective gear — latex gloves and goggles. The Inner Harbor's water can contain potentially harmful bacteria.

Plaskowitz had removed 12 discs from the PVC shaft, placed each in a separate glass bowl, and spread them around the classroom. "They know that Baltimore Harbor is really polluted, but I don't know if they know the life you can find there," she tells a visitor before groups of two or three students take their places around each bowl.

"Here are examples of things you might see on the discs," Plaskowitz says, pointing to a set of photos on a screen titled "Rogues Gallery," an illustration from Maryland Sea Grant's Biofilms and Biodiversity website (bit.ly/MDSG-biofilms) that shows classes of marine organisms, such as bryozoans with their feathery tentacle crowns, hydroids with branching plumes, transparent anemones.

She tells the students about random sampling, a critical tool in ecological science for estimating the abundance of species in a particular space. She helps the students to identify and count species on each side of the disc at ten randomly chosen locations. Each location is only a fraction of the disc's surface area, about 78 square centimeters per side. From measurements made at the ten locations, the students can extrapolate to estimate abundances across the entire disc — or an even larger area.

"You get to go deeper in this class — it's more hands-on," says

Marissa Harbison, a senior. "Hands-on makes it interesting. . . . It's dope!"

Mussels were the most abundant species she and her classmates counted. And that, Frederick says later, offers a key lesson about the harbor's ecology. "It's an example of a principle that ecologists have known about for a long time called dominance diversity," he says. "That's what we have in Baltimore Harbor because it's a stressed environment — you end up with a few species that dominate the space and crowd out everything. You see more well-balanced biodiversity in less-stressed environments."

Some Carroll County students in the Science Research class have seen those kinds of differences first-hand: they have analyzed biofilm discs they deployed in other, less-stressed aquatic settings, including freshwater ponds around Carroll County and saltier water adjacent to Ocean City, Maryland.

Sharing the Model

For some years now, Frederick has been spreading the word among Maryland educators about the value of biofilm discs for teaching science. Any Maryland science teacher can ask him to deploy discs in the Inner Harbor. Besides supplying them to Carroll County, he's also provided a source for discs for teachers in Baltimore City and Baltimore County. In addition, a series of lesson plans created by Frederick and his colleagues can be downloaded from his program's Biofilms and Biodiversity website. These pages are among the most viewed on Maryland Sea Grant's website.

Over the years Frederick has also helped science educators in California, Hawaii, Rhode Island, South Carolina, and Texas get started using biofilm discs for teaching.

In fact, his work has gone international: Frederick led an effort to connect science educators in the United States with their counterparts in Europe who want to use biofilm discs to help secondary-school students learn about marine biodiversity. The project, which began in 1997, is called the Virtual University Education project or VIRTUE; partners include the University of Gothenburg, in Sweden; institutions in Germany and Spain; and Maryland Sea Grant through the University of Maryland Center for Environmental Science. Participating faculty members have collaborated to create lesson plans, and the University of Gothenburg created an online portal for students and teachers to share data about their projects. As part of a research field experience, Swedish high-school students connected with VIRTUE have traveled to South Carolina's Grice Marine Laboratory, where they examined biofilm discs removed from Charleston's harbor.

VIRTUE is based on a premise that students, whether they examine discs pulled from Baltimore's Inner Harbor or Scandinavia's Baltic Sea, can learn principles about aquatic biodiversity that are important to understanding ocean and coastal waters everywhere. In this way, each acrylic disc encompasses its own little world, as well as a piece of the wider world.

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40 YEARS OF EDUCATION

A core mission for Maryland Sea Grant is preparing students to succeed in science. The U.S. ranks 24th in science education out of 71 nations analyzed in the latest survey. And roughly 40 percent of American undergraduates who try to major in science or engineering switch majors or fail to graduate. To address this national need Maryland Sea Grant develops innovative approaches to improving science education from middle school through graduate school.

Raising fish in schools: project-based science

Aquaculture in Action — a project developed by Adam Frederick of Maryland Sea Grant and by Jackie Takacs of the University of Maryland Extension — has been training middle and high school teachers to design, build, and operate recirculating systems for raising native fish in their schools. To date, 23 schools in eight counties and Baltimore City use these systems. Thousands of students have participated in programs that integrate the teaching of biology and chemistry by conducting real-world experiments.

Oysters in the classroom

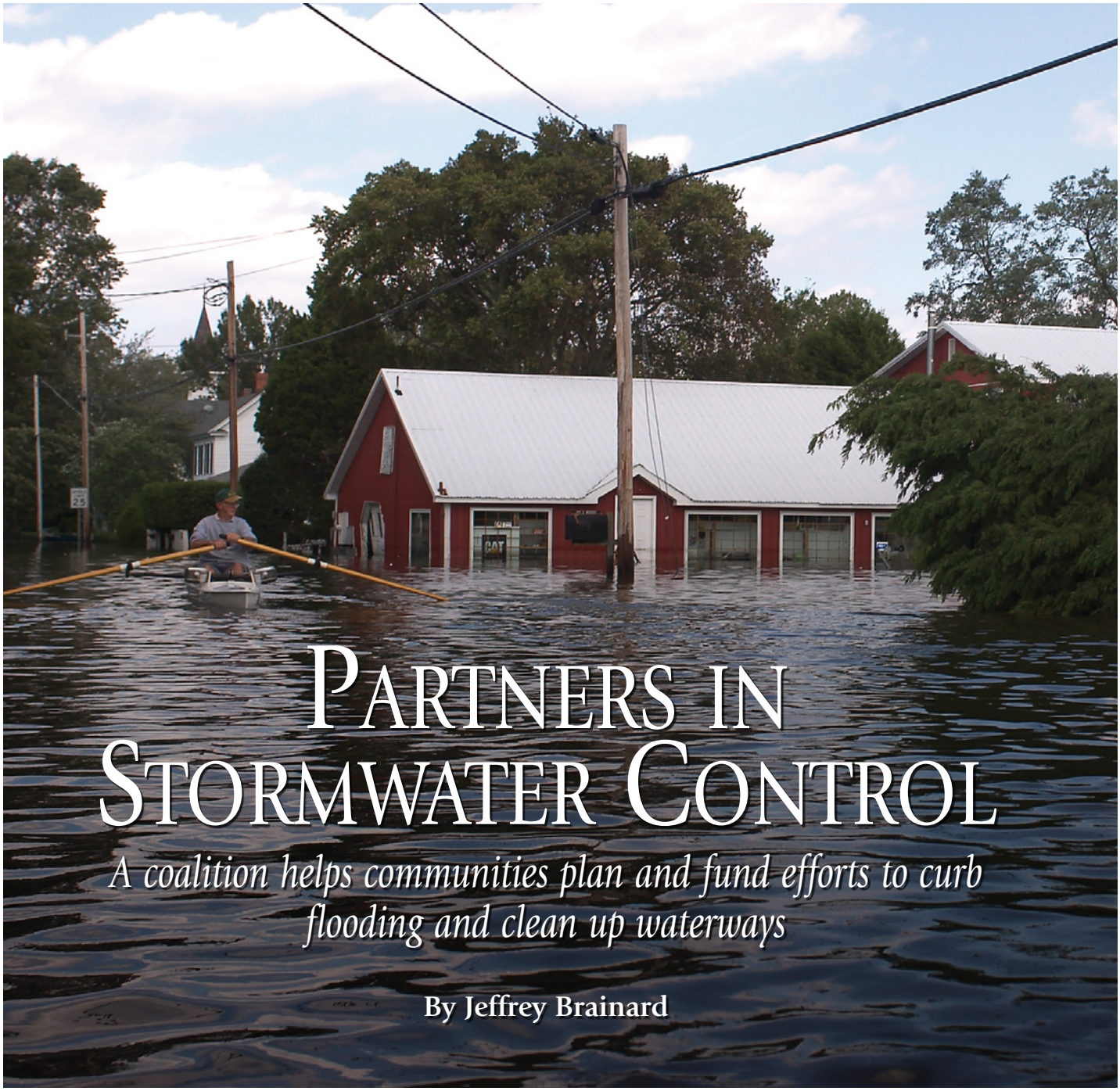
Maryland Sea Grant education specialists have developed an interactive web-based resource on *Crassostrea virginica,* the oyster native to the U.S. eastern seaboard. The resource includes in-depth materials on such subjects as oyster biology and ecology, an anatomy lab, procedures for studying the oyster immune system, and links to articles on the history of oystering in the Chesapeake Bay. A downloadable version of these interactive lessons also features videos of the many small organisms that inhabit the oyster's world, among them, hydroids, bryozoans, mud worms, and mussels.

Undergraduate research at Maryland labs

Since 1989, Maryland Sea Grant has been matching students from universities and colleges nationwide with scientists at the Horn Point and Chesapeake Biological laboratories for summer research. With funding from the National Science Foundation (NSF), this program of Research Experiences for Undergraduates has prepared students for careers in marine science. Funding from NSF has also enabled Maryland Sea Grant to bring underrepresented populations into the marine sciences and to create partnerships with universities in Puerto Rico to establish a year-round program for coastal research and education.

Graduate education in cutting-edge research

To prepare future research scientists, Maryland Sea Grant has been sponsoring graduate fellowships that provide students with the freedom to focus on learning how to investigate complex marine and environmental issues, translate scientific findings for diverse constituencies, and assist policymakers in making informed decisions. In addition, the Knauss Marine Policy Fellowship offers opportunities to work in the legislative or executive branch of the U.S. government in the area of Washington, D.C.



Partners in Stormwater Control

A coalition helps communities plan and fund efforts to curb flooding and clean up waterways

By Jeffrey Brainard

When the rains fall on Maryland's Eastern Shore and the tide is high, flooding is often not far behind. Some residents in Oxford move their cars to higher ground when the forecast predicts only light rain.

Like other low-lying coastal communities, Oxford has often endured flooding — the soil drains slowly and stormwater can linger for days, sometimes stranding residents in their homes. A stretch of Maryland Route 333, the main road into town, floods several feet deep; some people call it "Lake Oxford."

In 2012 town leaders set out to upgrade their aging stormwater-control system. What did the town actually need, what were the costs, and how were they to be paid? With a population of some 650, Oxford's leaders knew they needed outside help.

They obtained that help from two programs long affiliated with Maryland Sea Grant — the University of Maryland Environmental Finance Center, which Sea Grant helped establish in 1992, and Maryland Sea Grant Extension. Those groups and others that helped Oxford had formed a partnership in 2008 called the Watershed Assistance

In the town of Oxford *on Maryland's Eastern Shore, stormwater has at times made streets impassable. A coalition of organizations has helped the town plan and fund solutions.*
PHOTOGRAPH FROM ENVIRONMENTAL FINANCE CENTER

Collaborative (WAC) that to date has provided technical and financial expertise on stormwater management to more than 40 communities, including small ones like Oxford and large ones like Columbia. Two other key members of WAC are the Maryland Department of Natural Resources and the Chesapeake Bay Trust.

In addition to flood control, a motivation for Oxford was helping to improve deteriorating water quality. In 2010, the U.S. Environmental Protection Agency issued regulations for a "pollution diet" that would require communities in the Chesapeake Bay watershed to curtail stormwater runoff. The agency wanted to reduce the amount of excess nutrients and sediments carried by runoff into Bay waters, where they harm the ecosystem.

Oxford began a planning process in 2012 with public meetings, where residents pored over maps and marked areas of the town where flooding was chronically bad.

Sean Williamson of the Environmental Finance Center studied potential engineering solutions for the stormwater problems and researched funding mechanisms to pay for them. In a 2013 report, he proposed that Oxford pay for needed improvements in stormwater management by creating a dedicated town fund financed by local revenues. Larger cities, like Baltimore and Annapolis, and smaller ones like Takoma Park had already levied fees to pay for these improvements. Such environmental-based fees, however, are unusual in smaller communities. In 2013, Berlin was the only Eastern Shore community that had one.

In 2014, the Oxford Town Commission created a Stormwater Management and Shoreline Protection Fund, financed by a surcharge to the town's property-tax rate. The surcharge raises $100,000 per year, but the Environmental Finance Center's report had identified stormwater projects costing more than two million dollars. Jen Dindinger, a watershed restoration specialist with Maryland Sea Grant Extension, shared information with Oxford's town manager about sources of grant funding that the town could pursue to pay for infrastructure projects.

A grant from the state of Maryland's CoastSmart Communities Initiative enabled Oxford to develop a master plan that prioritized proposed projects, and the town got another grant from the state's Watershed Assistance Grant Program (WAGP) to fund an engineering study.

Those planning efforts positioned Oxford to apply successfully for $650,000 from the Chesapeake and Atlantic Coastal Bays Trust Fund, which Maryland created to finance such large projects. That money, awarded in 2017, will pay for the installation of vegetated areas on town property that retain stormwater, reducing the amount that floods onto Maryland Route 333. These "bioretention" areas will also benefit water quality by capturing nutrients and sediment carried by the stormwater before they reach the Chesapeake Bay.

Helping communities obtain grants to move from planning to constructing stormwater control projects is straight out of the Watershed Assistance Collaborative's playbook. The Watershed Assistance Grant Program is a major source of support for this work, annually awarding grants of up to $75,000 for either planning projects or small-scale demonstration projects — both key steps towards building stormwater efforts. The program is run by the Chesapeake Bay Trust and the Maryland

40 YEARS OF WORK WITH SHORESIDE INDUSTRIES AND COMMUNITIES

The first Sea Grant employee in Maryland was an Extension agent hired to work with the seafood industry. Since then Sea Grant has kept expanding its outreach efforts, adding Extension agents and specialists who now provide many of the state's Tidewater industries and communities with training, technical information, and environmental planning help.

Preventing invasions of non-indigenous species

To counter the threat of nonnative species, Maryland Sea Grant has developed projects and publications designed to guide prevention efforts and to recruit key audiences like sports fishers into anti-invasive campaigns. The program helped shape frameworks for reducing the spread of zebra mussels, Chinese "mitten" crabs, and other invasive aquatic species which can disrupt food webs and cause economic harm. A Maryland Sea Grant publication edited by Fredrika Moser and Merrill Leffler summarized those action frameworks in *Preventing Aquatic Invasive Species in the Mid-Atlantic: Outcome-Based Actions in Vector Management.* In addition, Extension specialists spearheaded a pilot project that works with bait shop owners to educate sports fishers about the safe disposal of the seaweed used to package bloodworm bait. Seaweed is a common means for accidentally spreading nonnative snails, mites, and crabs into new water systems.

Ensuring food safety for Maryland seafood products

Thomas Rippen and Cathy Liu, seafood technology specialists with Maryland Sea Grant, helped train workers in the seafood processing industry in best practices for avoiding microbial contamination in products such as pasteurized crabmeat. Extension specialists also developed new technologies for processing seafood, including a technique for flash freezing blue crab that helped Maryland's seafood industry gain a competitive marketing edge.

Training volunteers to develop stormwater projects

Specialists with Maryland Sea Grant Extension worked to establish Watershed Stewards Academies around Maryland which train community leaders to develop stormwater control projects. Academies now serve Anne Arundel, Cecil, Harford, Howard, Montgomery, Prince George's, and St. Mary's Counties. Since 2009, 340 participants have been certified as master watershed stewards.

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College Park, MD

Chesapeake Quarterly is printed on recycled paper, processed chlorine free, using soy-based inks

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Departments of Natural Resources and the Environment. Some of the program's funding comes to the Bay Trust from sales of Maryland's "Treasure the Chesapeake" license plates.

More than 90 percent of the WAGP grantees have gone on to get larger grants from the Chesapeake and Atlantic Coastal Bays Trust Fund. Matt Fleming, who oversees this trust fund as director of Maryland DNR's Chesapeake and Coastal Service, says that the high success rate reflects how the planning grants help communities produce good, reliable designs for stormwater projects that are "shovel ready."

Unfortunately there isn't enough state and federal grant money to pay for all of the stormwater management projects on priority lists. That's why the Environmental Finance Center (EFC) works to help communities write financial plans and identify stable revenues for stormwater management projects.

Maryland Sea Grant Extension specialists play an important role in providing communities with on-the-ground support and technical assistance in ways that the Collaborative's other partners aren't easily able to do, says Jen Cotting, associate director of the EFC. Extension's five watershed restoration specialists — Kelsey Brooks, Eric Buehl, Jennifer Dindinger, Amanda Rockler, and Jackie Takacs — serve different regions of the state. Maryland Sea Grant started creating this corps of specialists with funding from DNR in 2009, shortly after the Watershed Assistance Collaborative was formed. The specialists also work on other stormwater management and water quality projects in their regions.

Buehl, who serves the upper and mid Eastern Shore, recently provided this kind of on-the-ground support to another Eastern Shore town, St. Michaels. When the Environmental Finance Center helped the community plan a green infrastructure project, Buehl helped local residents and businesses identify areas prone to flooding. He also wrote a maintenance manual and provided a training session for the town's Department of Public Works about how to maintain existing rain gardens — vegetated areas designed to collect stormwater and remove nutrients that would otherwise end up in Bay waters.

"What's unique about the collaborative," adds Fleming of DNR, "is that it's about maximizing existing resources and partnering with other entities and playing off their strengths. If we can leverage our resources and use all of these existing programs, it is a more efficient and effective way of providing coordinating capacity to local governments. I have definitely seen this working really well."

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