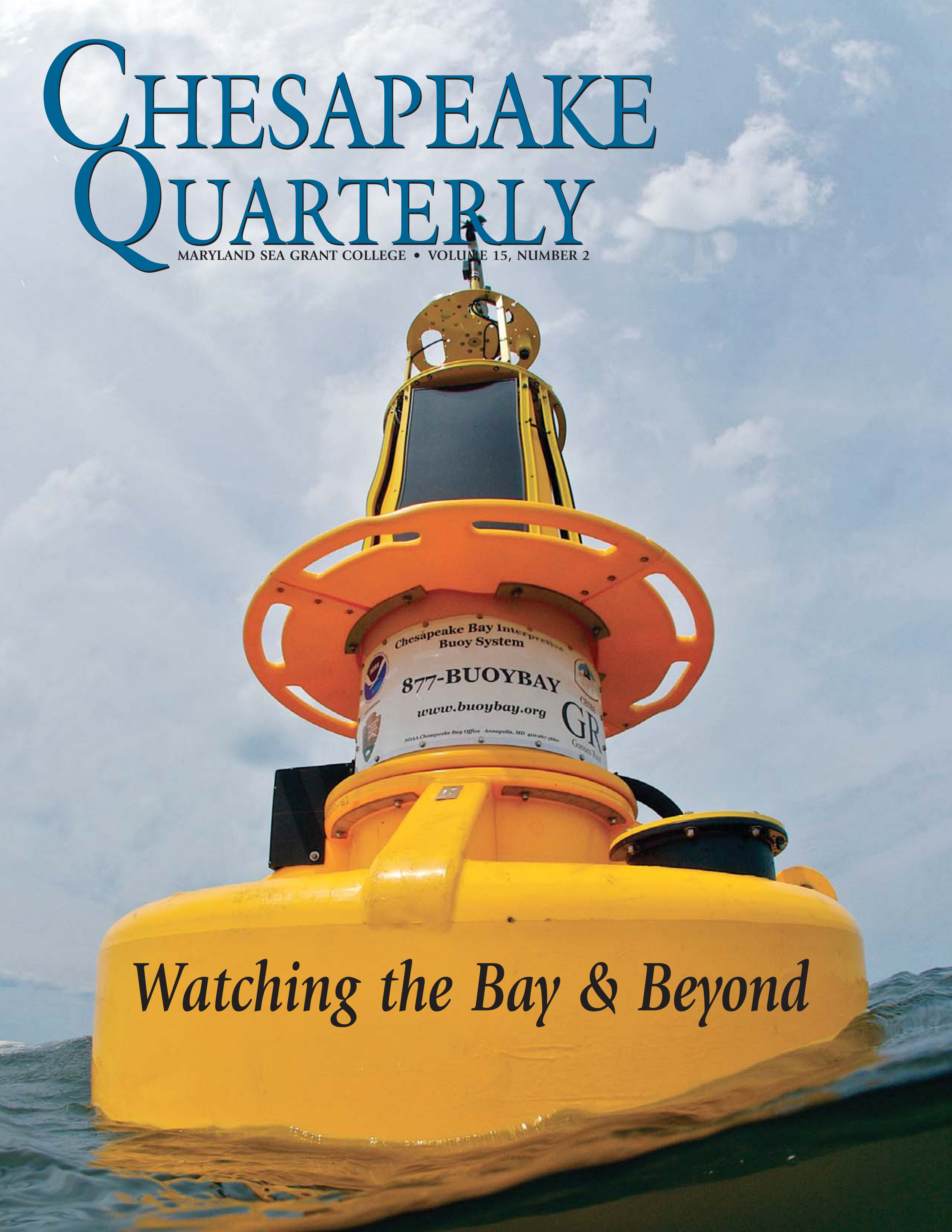
Chesapeake Quarterly

MARYLAND SEA GRANT COLLEGE • VOLUME 15, NUMBER 2



Watching the Bay & Beyond

contents

Volume 15, Number 2

CHESAPEAKE QUARTERLY June 2016

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.

Send items for the magazine to:

Maryland Sea Grant College
4321 Hartwick Road, Suite 300
University System of Maryland
College Park, Maryland 20740
301.405.7500, fax 301.314.5780
e-mail: mdsg@mdsg.umd.edu
www.mdsg.umd.edu
www.chesapeakequarterly.net

Cover photo: *This photograph was taken on the day this buoy was deployed for the Maryland Artifical Reef Initiative. Part of the Chesapeake Bay Interpretive Buoy System (CBIBS), the buoy collects data for boaters, students, and scientists.*
PHOTOGRAPH BY MICHAEL EVERSMIER FOR THE MARYLAND ARTIFICIAL REEF INITIATIVE

Observing the Bay, the Coast, & the Ocean

***Instruments at the end of** the Chesapeake Biological Laboratory's research pier at the mouth of the Patuxent River have measured water quality continuously since 1938.*
PHOTOGRAPH, SARAH BRZEZSINSKI

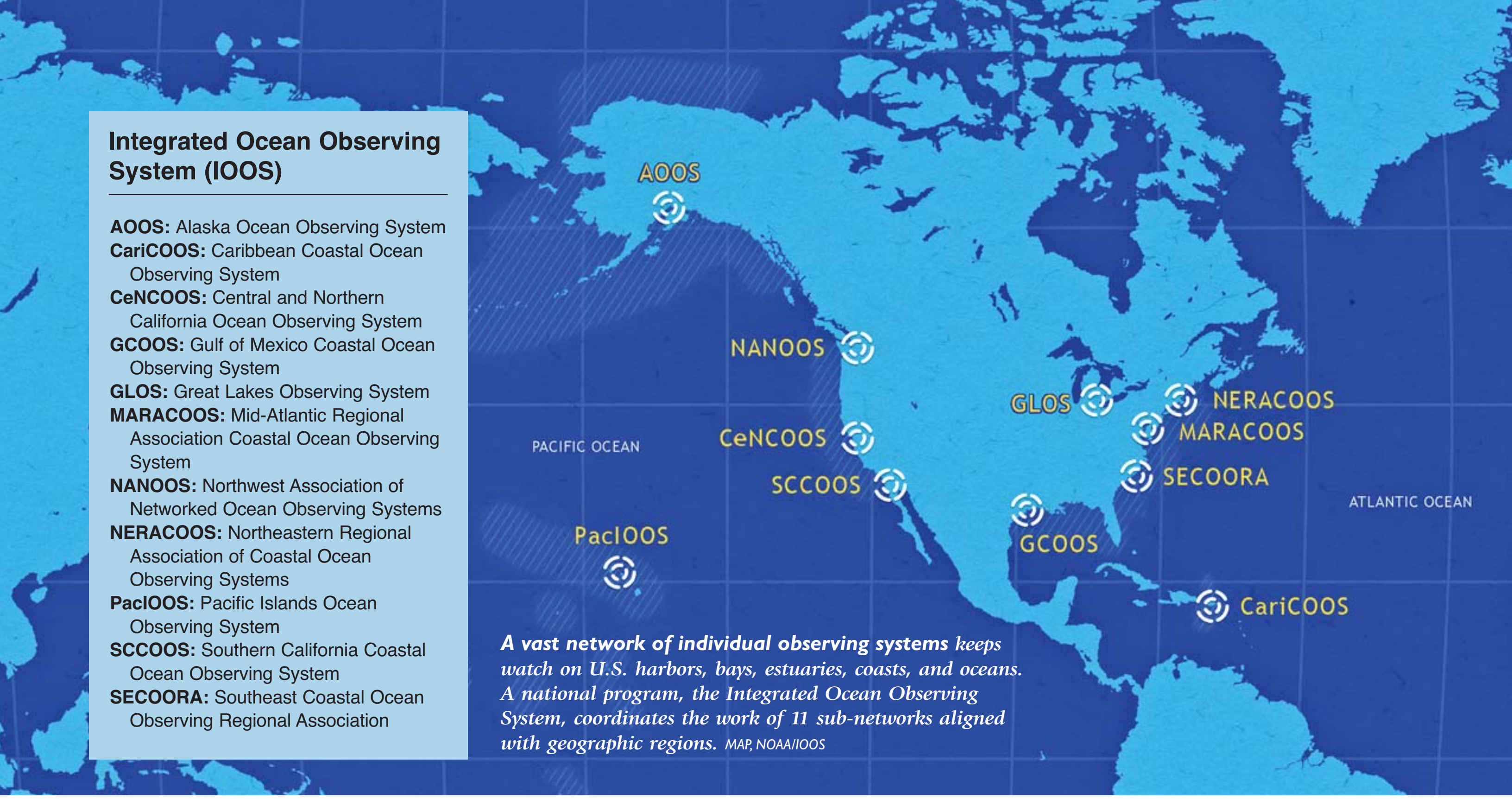
Carlos Lozano starts his days at the Chesapeake Biological Laboratory (CBL) by checking a website that displays information about water quality and weather conditions in the Bay. Modern digital instruments at the end of the lab's historic research pier test the waters every 15 minutes. "If I see any issues with it, I'll go out there and check," says Lozano, a research assistant with the University of Maryland Center for Environmental Science. As he marches along a wooden pier that now juts 750 feet out into the mouth of the Patuxent River, Lozano follows in the footsteps of generations who have walked the CBL pier for science. Reginald Truitt, the founder of the CBL, started the monitoring program in 1938. In the early days, instruments were basic; to take the temperature of the water, someone had to walk to the end of the pier and lower a thermometer at the end of a metal tube to a depth of one meter.

Truitt knew that continuous, long-term records were essential to understanding the Bay and exposing future changes. In fact, in 2006 — almost 70 years after the measuring began at the end of his Solomons Island research pier — the record revealed the subtle trace of global climate change in the Bay. And today, the record continues to grow, nearing 80 years long. Regular monitoring remains essential to understanding key processes in the estuary, managing its fisheries sustainably, and anticipating the impacts of climate change.

Since Truitt's time, the business of measuring things has dramatically surpassed the thermometer-on-a-stick approach. The CBL pier has become a point on a nationwide map of coastal observation systems. Networks of sensors keep watch on estuaries, coastlines, the Great Lakes, the continental shelf waters, and the open ocean.

If you have spent time on the Chesapeake Bay, you've probably seen at least one example of the region's observing systems at work: an instrumented buoy. Some of them measure winds, tides, and water temperature and salinity, which ship pilots use to navigate the Bay. Or you may have seen one of the research boats that stop at multiple spots along the mainstem of the Bay to measure dissolved oxygen, nutrient levels, and other key indicators of the estuary's ecological health.

Beyond the mouth of the Bay, other observation systems monitor the Mid-Atlantic coastal ocean. The platforms include shore radars, jumbo-sized buoys, untethered "drifters" that ride the global currents, and torpedo-shaped robotic underwater vehicles that cruise under the waves. Hundreds of miles above, satellites scan the sea surface.



***A vast network of individual observing systems** keeps watch on U.S. harbors, bays, estuaries, coasts, and oceans. A national program, the Integrated Ocean Observing System, coordinates the work of 11 sub-networks aligned with geographic regions.* MAP, NOAA/IOOS

And we have learned important things from this mass of measuring. For one thing, ocean observing has advanced our understanding of the global climate system and our ability to predict it. The Tropical Atmosphere Ocean (TAO)/TRITON array of 70 buoys measures heat in the upper layer of the tropical Pacific Ocean. The array makes it possible to predict the periodic pattern of warming and cooling known as the El Niño Southern Oscillation (ENSO). And it's important to know, because ENSO can affect weather patterns far away. For example, the 2015-2016 El Niño was linked to a snowier winter in Maryland.

In the early 2000s, the federal government moved to wrangle the nation's multitude of coastal and ocean observing systems into a coherent whole. It came to be called the Integrated Ocean Observing System, or IOOS. This national "system of systems" would also be the United States' contribution to the United Nations-sponsored Global Ocean Observing System.

IOOS, an interagency program led by the National Oceanic and Atmospheric Administration (NOAA), coordinates observing systems spread among 17 federal agencies and scores of universities, research labs, and other organizations. Each of 11 major geographic areas hosts a regional observing system. The Chesapeake Bay, for example, lies within the Mid-Atlantic Regional Association Coastal Ocean Observing System (see map). The "I" in IOOS is integration, shorthand for the ways this program helps observation systems to work together to serve key national needs — like ensuring maritime safety, managing fisheries, protecting ecosystem health, and adapting to climate change.

The Chesapeake Bay region's major observation systems are plugged into the IOOS switchboard. This issue of *Chesapeake Quarterly* offers stories about coastal observing systems — past, present, and future — and how they benefit the Bay. "The Buoys That Never Sleep" (p. 4) recounts the rise and fall of the Chesapeake Bay Observing System (CBOS), a pioneering effort to continuously monitor the Bay's water and weather. "Where the Wild Fish Are" (p. 10) explains how Bay scientists are working with IOOS to create a national database for tracking the far-ranging migrations of striped bass and other species in the Chesapeake and Mid-Atlantic region. "Coastal Radar to the Rescue" (p. 13) highlights the critical contribution that coastal radar systems make to Coast Guard search-and-rescue missions in the Bay and beyond. Finally, "Better Tools for Cleaner Water" (p. 14) explains how a coalition of federal agencies is working with private industry and academic labs to create inexpensive real-time sensors that could form networks to monitor nutrient pollution in the Chesapeake Bay and many other places affected by this problem.

As the CBOS story highlights, building new observing systems is just the first step. It can be much harder to keep them fully funded and operating, day after day, year after year. IOOS's management believes the key to sustaining support for observing systems is creating successful new "information products" — like a national fish tracking database — that fulfill the needs of multiple users and help them solve important problems.

The benefits of coastal and ocean observing are not always foreseeable in the beginning — as when the signal of global warming emerged nearly 70 years after Reginald Truitt launched the measuring program at the end of Chesapeake Biological Lab's pier. But it's wise to invest in long-term measurement-making because of the many ways it can inform science and natural resource management, says Thomas Miller, the lab's current director. "Monitoring data is one of those things that you don't realize you need — until you do."

— *Daniel Pendick*

The Buoys That Never Sleep

Could a network of data-gathering buoys finally reveal the mysterious inner working of the Chesapeake Bay?

By Daniel Pendick

On a freezing February morning in 1996, the phone rang in Carole Derry's office at the Horn Point Laboratory. "Hey, your buoy is in the Choptank River," the caller said. On the line was an officer on one of Maryland's icebreaking ships that was opening channels in the Chesapeake. He knew the buoy did not belong in the river. And so did Derry. She was the research assistant at the lab charged with maintaining a fleet of data-gathering buoys stationed along the mainstem of the Chesapeake Bay. "I said, no," Derry recalls. "I don't believe you."

But the officer on the Maryland Department of Natural Resources (DNR) ship was right: a winter storm had uprooted a one-ton scientific buoy moored off James Island and shoved it 22 miles north, with its mooring chains and anchors — a pair of cast-iron boxcar wheels — trailing behind like a giant watch bob.

Then Derry got another call: the buoy had made it as far upriver as Castle Haven Point. This was just a few miles from Derry's office at Horn Point Laboratory, part of the University of Maryland Center for Environmental Science (UMCES), where the buoy was outfitted. "So we went down to Castle Haven and it was right there," Derry says. "That was the buoy that was coming home to me."

The bright-yellow buoy, 18 feet tall from its base to the top of its instrumented metal mast, had stopped transmitting data to shore on February 3rd. Slabs

of winter ice, propelled by storm winds, had pulled the buoy free and dragged it north; then the wind shifted, blowing it eastward into the Choptank River. The DNR boat eventually snagged the buoy, craned it aboard, and ferried it into Cambridge Creek near the lab. Derry greeted the banged-up traveler at the dock. "I went down to see it and said, 'That's my buoy!'"

It was actually Bill Boicourt's buoy. He was Carole Derry's boss and a physical oceanographer who strung a network of scientific buoys down the mainstem of the Chesapeake Bay. This pioneering effort came to be known as the Chesapeake Bay Observing System (CBOS).

Boicourt came into oceanography as a protégé of Don Pritchard, the distinguished scientist who founded the Chesapeake Bay Institute at John Hopkins University and then made the measurements and worked out the mathematics that documented the basic two-layer flow of the estuary — along the bottom, an incoming surge of dense, salty water from the ocean; along the surface, an outgoing stream of fresh water from all the Bay's rivers.

With his training, Boicourt was uniquely qualified to build a network of scientific buoys in the Chesapeake Bay. While still a graduate student, he had led expeditions to study large-scale circulation patterns in the continental shelf waters beyond the mouth of the Bay. To do that, Boicourt deployed scientific buoys for collecting long-term records of ocean temperature, salinity, and currents. These records led to new insights into the physical structures and processes in those offshore waters — including the Chesapeake Bay plume, the vast tongue of estuarine water that extends far out to sea from the mouth of the Bay. CBOS would allow Boicourt to use the methods he refined on the continental shelf to probe the rhythms and processes of the Chesapeake.

In two decades with CBOS, Boicourt's team fielded as many as seven different buoys. They kept tabs 24 hours a day on winds, temperature, humidity, currents, salinity, dissolved oxygen, and other essential information about the Bay and transmitted the data live on the internet.

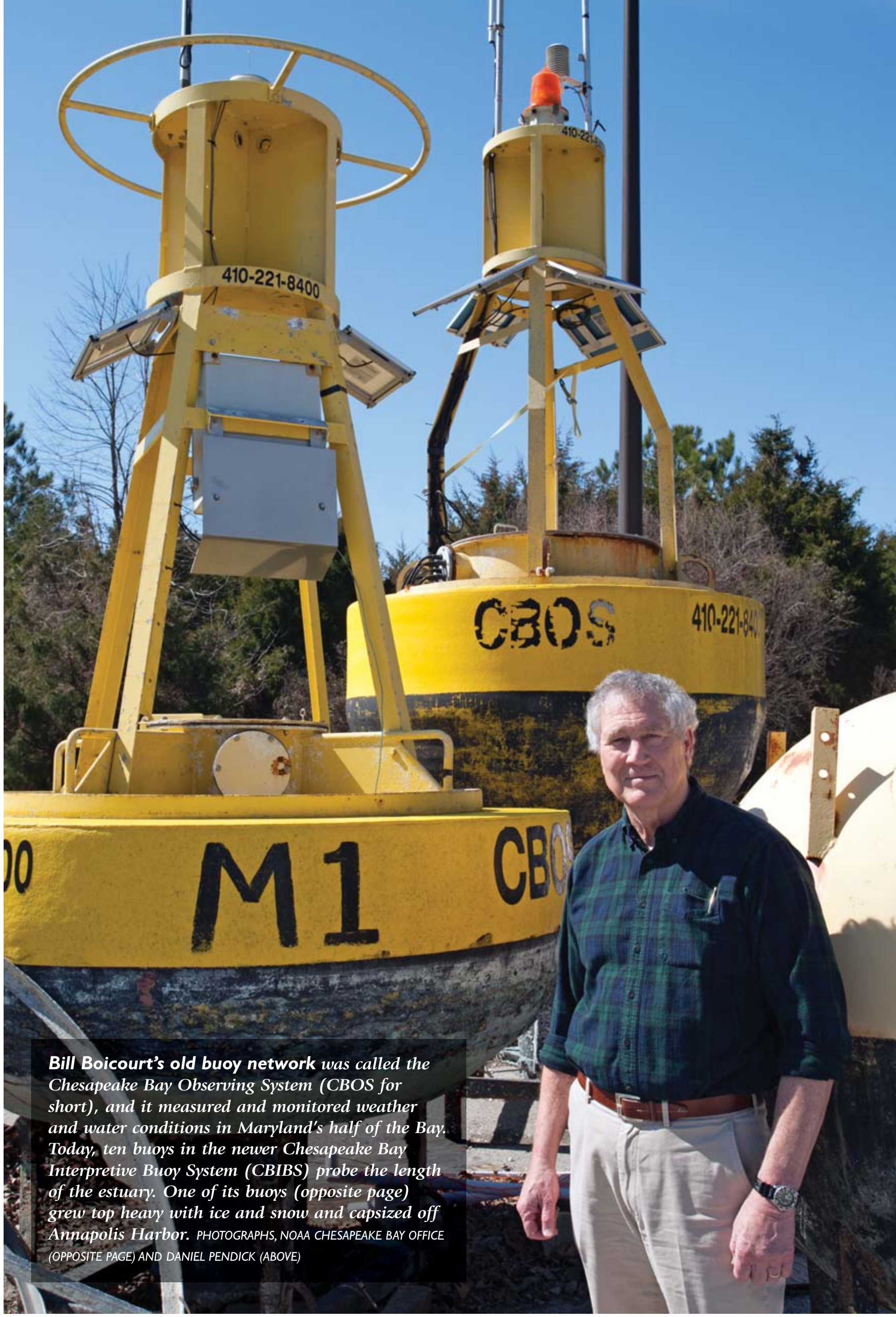
That wild winter ride up the Choptank was just one in a long series of challenges that Boicourt faced in keeping CBOS alive and collecting data. Other showstoppers included buoys being struck by boats, burned-out light bulbs, dead batteries, and instruments gummed up by seaweed and barnacles. But along the way, the network would generate reams of valuable data that advanced Boicourt's research — particularly his understanding of estuarine circulation — and teach valuable lessons about how to build coastal and ocean observing systems that last.

CBOS Comes to North Bay

On December 18, 1990, Boicourt stood in a parking lot by the docks at Millard Tydings Memorial Park in Havre de Grace, Maryland, clutching the end of a long red ribbon and smiling for the camera. VIPs and guests stood along the length of the ribbon, stretched taut for cutting by the ceremonial scissors.

Behind them stood the first buoy in the CBOS network, gleaming with its fresh coat of yellow paint. Dubbed the North Bay buoy, it had a disc-shaped hull that housed advanced radio telemetry equipment. The top of its tall mast sported a suite of meteorological instruments.

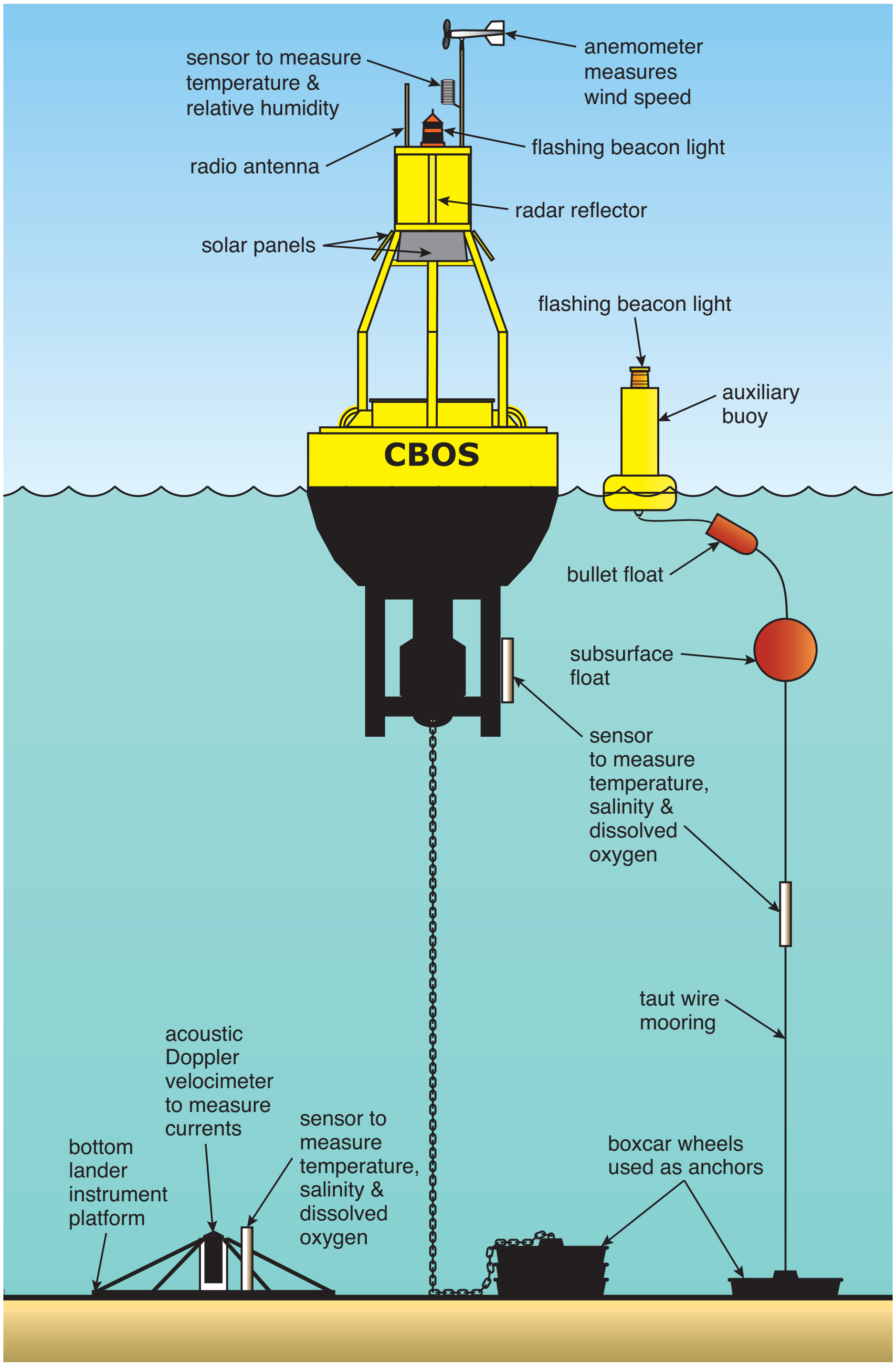
Boicourt was getting his chance to take long-term data gathering in the Chesapeake Bay to a new level — thanks to Cathy Riley, a state senator from Harford County at the north end of the Bay. She had secured an appropriation to build the Northern Chesapeake Bay Research and Monitoring Facility at Tydings Park. This modest one-story building and its 50-foot radio mast would receive hourly bursts of data from the North Bay buoy — as soon as the spring thaw allowed Boicourt to moor the scientific sentinel into the Bay.



***Bill Boicourt's old buoy network** was called the Chesapeake Bay Observing System (CBOS for short), and it measured and monitored weather and water conditions in Maryland's half of the Bay. Today, ten buoys in the newer Chesapeake Bay Interpretive Buoy System (CBIBS) probe the length of the estuary. One of its buoys (opposite page) grew top heavy with ice and snow and capsized off Annapolis Harbor.* PHOTOGRAPHS, NOAA CHESAPEAKE BAY OFFICE (OPPOSITE PAGE) AND DANIEL PENDICK (ABOVE)

The small building in Tydings Park housed considerable hope — that this would be the start of a new kind of observation system for Bay science. Boicourt and several other scientists at UMCES hoped to build a network of six permanent buoy observation stations down the axis of the estuary, from the mouth of the Susquehanna River in the north to the mouth of the estuary in the south. It had never been done, but the scientists thought it was time.

By then, the state of the art in estuary observing was the Chesapeake Bay Program run by the Environmental Protection Agency. This state-federal partnership was taking monthly measurements down the length of the estuary, primarily from ships. But that left gaps in which short-term events, like storms, could alter the Chesapeake ecosystem undetected. The architects of CBOS argued that the buoys could fill those



***A typical CBOS observing station** consisted of two moorings: one for the main buoy, which contained a computer and radio gear to transmit data to shore, and a smaller, auxiliary buoy to hold additional instruments. Stations collected continuous data on weather and water conditions and beamed them back to shore. A bottom lander platform supplemented the moorings, collecting data that needed to be retrieved later by hoisting the triangular rig to the surface.* ILLUSTRATION ADAPTED BY SANDY RODGERS FROM A DRAWING BY CAROLE DERRY AND BILL BOICOURT

gaps by continuously monitoring the Bay from permanent observing stations with buoys that would provide stable moorings for a variety of scientific instruments at the surface, at mid-water, and on the bottom.

Boicourt hoped that CBOS would answer important scientific questions about the Chesapeake Bay, like how winds influenced the workings of the estuary in different ways. Research by Boicourt and others suggested that winds blowing across the surface could perturb its two-layer flow. Depending on direction, winds can speed up or slow down those outgoing and incoming flows. Summer winds can let low-oxygen water slip out of the deeps and into the shallows. Autumn winds can help oxygen-rich surface waters mix with deeper waters. In fact, strong winds appeared to stir up the Chesapeake so much that the two-layer flow temporarily disappeared. But how, when, and why were winds driving these changes? What were the physics?

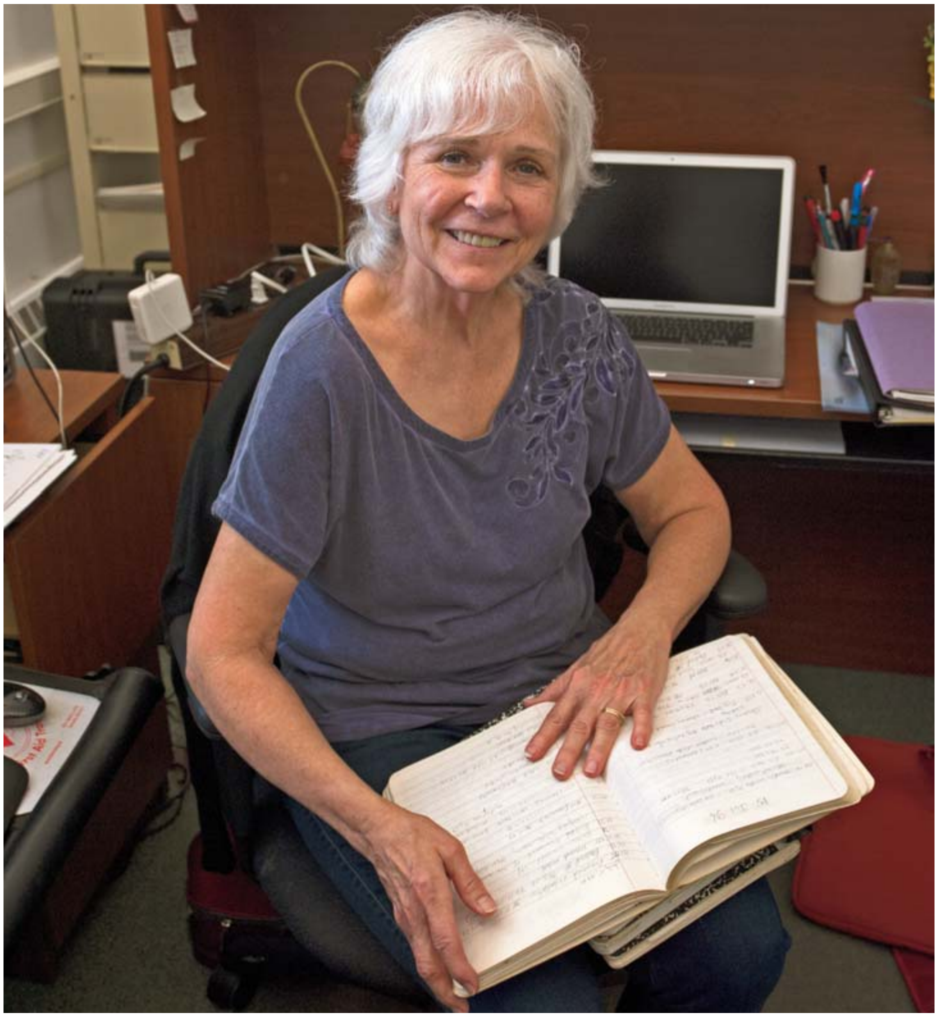
The veteran oceanographer in Boicourt knew that to answer such questions, Bay scientists needed long, continuous records like the ones he had painstakingly pieced together with buoys on the continental shelf. To start to see patterns and understand the underlying processes, you had to be there when it happened. You needed a buoy out there, waiting, watching, measuring.

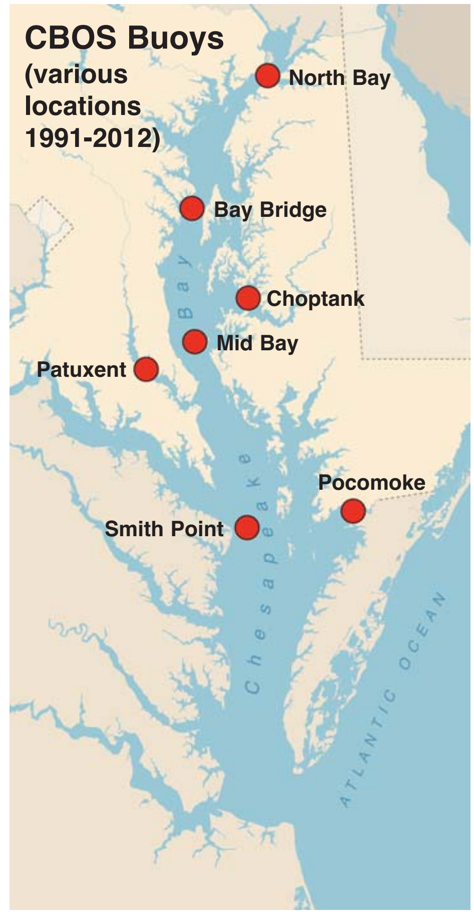
Keeping CBOS Alive

The North Bay buoy was tethered to its mooring in the spring of 1991 off Howell Point, at the mouth of the Sassafras River. Then it started beaming data across ten miles of open water to the Tydings Park receiving station. A second buoy started taking data in 1993, at the Mid Bay observing station in the waters off the Calvert Cliffs nuclear power plant.

The North Bay and Mid Bay buoys remained in continuous service for more than two decades. Five other buoys went in and out of the water, some for only a season or two. Their moorings were positioned at various locations: at the Bay Bridge (known as Baltimore Approach in the CBOS network); at the mouth of the Choptank River; upriver in the Patuxent and Pocomoke Rivers; and as far south as Smith Point, at the Virginia border (see map). CBOS never expanded as far south as the estuary mouth, as originally envisioned.

Once CBOS was open for business, the hardest work lay ahead: keeping it running. The project hit some practical challenges that buoys of all kinds still face





***Carole Derry holds a stack of handwritten maintenance logs** that detail scores of repairs, upgrades, and deployments of the CBOS buoys (locations shown in map at right). The senior faculty research assistant, now retired, was on call to fulfill requests for CBOS data, go out on frequent boat trips to tend the buoys, and manage the reams of scientific data streaming from the CBOS observing network.* PHOTOGRAPH, DANIEL PENDICK; MAP, CREATED BY SANDY RODGERS ON A BASE MAP FROM VECTORSTOCK.COM

in the Chesapeake. Carole Derry, who worked as a senior faculty research assistant for Bill Boicourt until her retirement in May 2016, kept a binder of photos documenting the numerous insults visited upon CBOS buoys by man and nature — like being run over by boats or cracked open by winter ice.

Derry also built up a stack of handwritten maintenance logs in composition notebooks that documented the constant attention that CBOS demanded. The North Bay buoy, in particular, needed to be taken out of the water every winter to avoid ice damage. In general, the buoys needed personal tending every four to six weeks, whether to change instruments or batteries or make repairs.

Putting large buoys in the water or taking them out required large boats with rigging that could handle buoys weighing a ton or more as well as moorings with anchors and chain weighing up to one-and-a-half tons. Such trips were difficult to schedule and expensive. Boicourt sometimes had to depend on Coast Guard buoy vessels — when they weren't too busy tending to their own buoys.

As for Boicourt, his perpetual struggle was finding the money to pay for operating and expanding CBOS. It could cost $50,000 or more per year to equip and operate a CBOS observing station. The original funding for the North Bay station and shore facility ran out, but Boicourt still had buoys to tend and salaries to pay.

He had to piggyback much of the cost of purchasing, outfitting, and maintaining CBOS buoys onto his research projects. If a project involved collecting data with a buoy, CBOS could draw on that — until the funds ran out. Then Boicourt and his team had to secure new funding for Chesapeake science that could make use of the CBOS buoys.

CBOS Data for Science

Through all the day-to-day challenges of keeping CBOS running, the buoys collected reams of data on meteorological and water conditions and beamed it back to shore. In the mid-90s, the data went live on the internet at www.CBOS.org. The science-curious general public — Boicourt calls them the "AOLers" — and recreational boaters often accessed CBOS's real-time data on wind, temperature, and humidity. Boicourt also discovered to his surprise that some professionals on the Chesapeake were visiting the site regularly. But the web addresses ended in ".mil," not "aol.com."

That's .mil as in military. Weather forecasters at the Patuxent River naval air station were tapping CBOS data on meteorological conditions over the estuary. So were computer modelers at the Army's Aberdeen Proving Ground, just across the water from the North Bay CBOS station. The Army tests weapons and ammunition at Aberdeen, and the modelers used CBOS data to improve their predictions of how far the concussions from the weapons explosions would travel and how strong they would be. "They had the fear of blowing out stained glass windows in churches on the Eastern Shore," Boicourt says.

***A beat-up buoy from the CBOS network** lies on its side in open-air storage at the edge of a parking lot at the Horn Point Laboratory. During a winter storm in 1996, fierce winds dragged this buoy and its mooring miles up the Choptank River. Despite the dings in its foam outer shell, the buoy continued to serve Bay science for many years.*
PHOTOGRAPH, DANIEL PENDICK

Of course, he and his students were also using CBOS data. In September 2003, as Hurricane Isabel passed through the Chesapeake region, the Mid Bay buoy got a chance to demonstrate the scientific value of having a real-time monitoring system in the Bay.

The buoy's current meters, at depths of eight feet and 33 feet, recorded the strong water motions generated as the storm's winds rocked the entire contents of the estuary northward; then, as the winds died down, the Bay sloshed back southward.

The storm furiously mixed the estuary, too, which temporarily erased its normal two-layer structure. Boicourt's buoy caught the process in the act, because the current meter down at 33 feet also included an instrument that measured the amount of oxygen dissolved in the water. This device, installed just a month earlier, sat within the Bay's low-oxygen or "hypoxic" layer. Deeper, at 62 feet, a salinity sensor was also testing the waters.

As the hurricane winds mixed the Chesapeake up, the sensors caught the rise in oxygen and the fall in salinity as the fresh upper layer and saltier lower layer swirled together. This "destratification" of the Bay is exactly the type of thing that Boicourt hoped CBOS would see. Such real-time monitoring, coupled with later computer modeling studies, can confirm hypotheses and generate new questions — in this case, about "wind forcing" of the Bay system and the effect that has on oxygen conditions.

Ironically, by the time of CBOS's shining moment during Isabel, the constant scramble to piggyback the cost of running the buoys onto Boicourt's research funding had started to wear thin. One by one, the observing stations in the Chesapeake were shut down. "We were reduced from seven to about three and then finally two," Boicourt says.

In 2004, only the North Bay and Mid Bay observing stations were still taking data. North Bay went dark in 2005. The Mid Bay station struggled along until 2010. "In 2010, it started having problems," Carole Derry says. It recorded no data in 2011. Derry says she is pretty sure it was struck in 2012 by a boater. "It was decapitated."

That may have been the end of Bill's real-time buoy network, but the dream of building a real-time scientific observing system for the Chesapeake Bay lives on. By the time the last CBOS buoy stopped transmitting data, the National Oceanic and Atmospheric Administration (NOAA) was completing a new network of scientific sentinels: the Chesapeake Bay Interpretative Buoy System (CBIBS).

The intended purpose of CBIBS seems right out of the playbook of early CBOS. The new system provides real-time information about weather and water conditions for scientists and citizens. The buoys stretch the full length of the Bay, from the Susquehanna River to the mouth of the estuary. Buoys sit at the mouths of major rivers as well as at stations far upriver — from Jamestown in Virginia, to the National Harbor in Maryland.

The CBIBS network initially obtained funding as part of the Captain John Smith Chesapeake National Historic Trail, with buoys marking key spots in the estuary that Captain John Smith visited from 1607 to 1609. The first three buoys went in the water in 2007 — one at historic Jamestown — to mark 400 years since Smith's arrival in the Chesapeake region. A boater or kayaker can call the historic markers by cell phone and hear the historic background for each location.

NOAA is working to make CBIBS buoy data useful and available to as many researchers as possible. Making that happen is Byron Kilbourne's new assignment. The recently minted Ph.D. oceanographer from the University of Washington in Seattle joined the small CBIBS team in Annapolis in January 2016. Kilbourne is charged with keeping CBIBS fully functional, reaching out to potential users in the science community and making sure the data comply with quality standards. Kilbourne hopes to also use CBIBS information to do some original research of his own.

Thanks in part to Boicourt's buoys, CBIBS has an opportunity to fulfill the dream of a real-time observing system for the Chesapeake Bay. CBOS showed what such a system could look like. "We

The Chesapeake Bay Interpretive Buoy System (CBIBS) *(at left) collects water and weather data at the mouths of major rivers and farther up river, too. Keeping the ten buoys up and running is challenging, and CBIBS's lead buoy repairwoman, Katie Kirk (below, bottom), makes frequent trips to service the buoys. This buoy (below, top), located off Jamestown, Virginia, is part of the Captain John Smith Chesapeake National Historic Trail.*

PHOTOGRAPHS, COURTESY NOAA CHESAPEAKE BAY OFFICE (BELOW, BOTTOM) AND U.S. ARMY CORPS OF ENGINEERS (BELOW, TOP); MAP, CREATED BY SANDY RODGERS ON A BASE MAP FROM VECTORSTOCK.COM

learned a great deal about what it takes to deploy an observing system and what it takes to maintain an observing system," says Thomas Miller, director of the UMCES Chesapeake Biological Laboratory. "I think it was a visionary exercise, well ahead of its time, and in no way did it fail. It was just not sustainable."

That lesson — that observing systems are expensive and hard to maintain over the long haul — is a key lesson of the CBOS saga, Boicourt says. CBOS never lacked for what he calls "cheerleaders" like the AOLers and the computer modelers at Aberdeen Proving Ground. But that did not translate into a sustained annual budget — like the one CBIBS draws on.

"We learned the hard lesson of what sustainable systems required," Boicourt says. "They require you to not just collect data and make it available, but package it for specific users in a way that will get them to either pay for or support the collection of it."

Although CBOS.org's real-time data stream has ceased, the buoys themselves continue to serve Bay science. Several of the big old buoys — including the one that took that wild ride up the Choptank in 1996 — stand at the edge of a parking lot at Horn Point Lab, where they greet Boicourt as he comes to work every day. They sit amidst a jumble of spherical steel floats, metal platforms for holding instruments on the Bay bottom, cast-iron boxcar wheels, and rusting piles of mooring chains.

Boicourt has continued to deploy the buoys for research or loan them to other investigators. Though battered and bruised, several of the buoys were bobbing in the Chesapeake as recently as 2013, part of a flotilla of 20 buoys that studied the physical processes that link winds to changes in the large-scale circulation and mixing of the estuary.

Boicourt says this recent multi-investigator project was the culmination of all the previous years of work with CBOS observing the effects of wind on the Bay. The study benefitted from the latest technology — like special sonars that look upward from the estuary's floor to measure currents at multiple levels. One of the studies that came out of the observing project, led by Woods Hole scientist Malcolm Scully, offers new insights into the details of how winds mix the Chesapeake. Wind-driven breaking waves create spiral flows in the air above the Bay, called Langmuir turbulence, which pumps energy deep below the surface and mixes the upper and lower layers like an eggbeater.

CBOS was put in the Bay in hopes of gaining these kinds of physical insights. Although Boicourt is happy to tell you how hard it was to keep CBOS afloat all those years, his efforts did bear fruit. "You could argue that the time would have been better spent otherwise, but we got a chance to do some good science," he says. "We have learned a lot from looking at that old CBOS data — and I still look at it. We know now that what happens from one month to another, like storms and wind, is important."

— *pendick@mdsg.umd.edu*

Where the Wild Fish Are

What oceanic highways do Chesapeake fish travel? Fish trackers, wind farm builders,and cargo ship captains need to know.

By Daniel Pendick

***By implanting a small electronic tracking** device in a cownose ray off Tilghman Island, Maryland, biologist Rob Aguilar and colleagues with the Smithsonian Environmental Research Center (SERC) can track the animal in the Bay as it mates, raises its young, and migrates to the coastal ocean.* PHOTOGRAPH, SERC

When David Secor goes fishing, he doesn't bring a pole or tackle box. He brings a laptop computer. He doesn't even look for fish in the water; he looks for them in black plastic cylinders about the size of a small kitchen fire extinguisher. These are underwater microphones that Secor and his research assistant Mike O'Brien hang in the water off buoys and bridge pilings in the Chesapeake Bay. These sensors listen for the telltale sounds of passing fish.

But not any fish. Secor is a fisheries scientist from the Chesapeake Biological Laboratory at the University of Maryland Center for Environmental Science, and he is angling for fish that he has previously caught, implanted with finger-sized electronic "pingers," and released back into the Bay. These gadgets emit chirps of sound into the water every 90 seconds that are coded to identify or "tag" each fish. If an electronically tagged fish pings within the range of one of his receivers, Secor can download it. If someone else's receiver picks up his fish, he can eventually recover that "detection" as well, though it will take time and effort.

This technology, called acoustic telemetry, is an important advance. It allows scientists, for the first time, to track individual fish as they move through their environment. They do not need to surface to be detected, as is the case for satellite tagging. By tracking fish in their natural element as they pass by and ping different receivers, researchers can ask important questions about fish behavior.

In the past few years, for example, this technology has helped Secor and O'Brien conduct a study tracking striped bass native to the Bay as some of them head for the coastal ocean on far-flung migrations. "We know that within a month or two after tagging a large striped bass in the Potomac River, it can be off Cape Cod," Secor says.

Acoustic fish tracking, in cases like this, offers valuable streams of hard-to-get data. Not just hard to get, but also a little too easy to lose. After all, fish taggers retire or pass away, but data should be forever. A lot of it, however, currently resides on hard drives on shelves and desks in the labs and offices of individual taggers. It worries Secor. "This is really precious data," he says. "If we don't have a place to put that data it could be lost forever. Which is awful."

Fish tracking in the Chesapeake is heading for a major technology leap that could protect the precious pings recorded by fish taggers and also reduce some of the drudgework and delay associated with sharing that data. The new tool is called the Mid-Atlantic Acoustic Telemetry Observation System, or MATOS. In essence, it's a database that could make it easier for scientists to collect, share, and safely store records of marine animal migrations in the estuary and coastal ocean. MATOS would also make it easier for federal resource managers to tap into fish-tracking data from across large areas of the coastal ocean.

To get to this brave new world of fish-following, trackers will have to upload their data to a distant computer via the web. And the architects of MATOS will need to assure these trackers that they can still control whom they want to share their data with — and whom they don't.

Fisheries ecologist Matthew Ogburn of the Smithsonian Environmental Research Center is one fish tagger who sees the potential of the new tagging technology. "It's a very different way of doing research," Ogburn says, "but it also allows you to answer very different, larger-scale questions."

Fish Finders

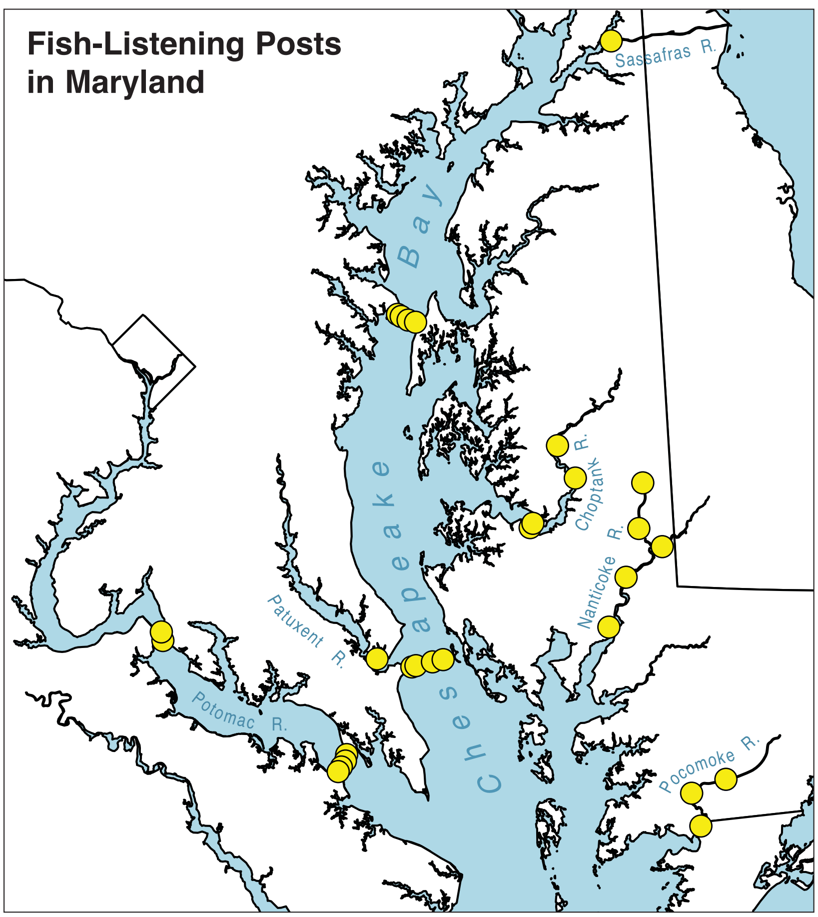
Who is going to fund this expanded system? The seed money to develop MATOS came from the Atlantic States Marine Fisheries Commission, a state compact that works to manage fisheries sustainably. The other partners include the National Oceanic and Atmospheric Administration (NOAA) Chesapeake Bay Office, the Smithsonian Institution, and the Mid-Atlantic Regional Association Coastal Ocean Observing System (MARACOOS). The observing system is one of 11 regional organizations in the national Integrated Ocean Observing System (IOOS), a NOAA-led partnership of federal agencies, universities, and other organizations.

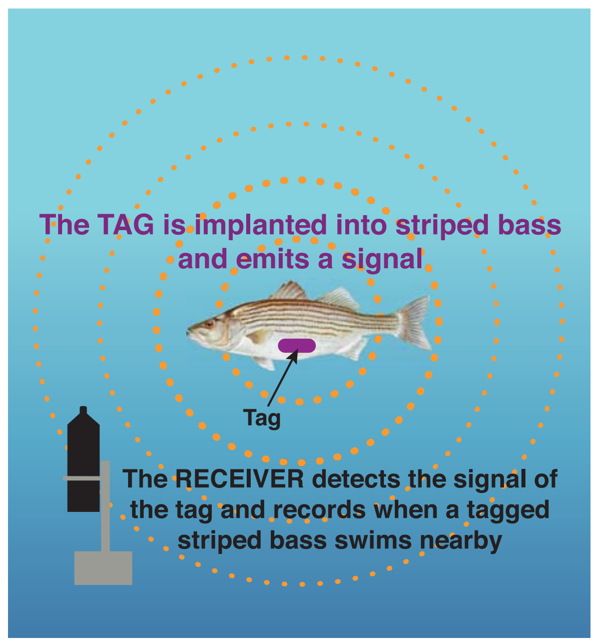
Tracking fish and collecting the data are time consuming and difficult, and that's where MATOS would help. The process starts when an acoustic receiver in the water picks up a ping and stores the time of detection and the unique identifying code of the tag that emitted it. This allows a researcher like Secor to recognize "his" fish. It's like the way the E-ZPass electronic toll systems know to debit your account for a toll by detecting that little transponder stuck behind the windshield.

Every few months, fish taggers go out in the field to visit their receivers and download the data via a Bluetooth connection. This is where it gets complicated: the receivers pick up pings from any tagged fish that passes by — not just those tagged by the owner of a particular receiver. So when Secor and O'Brien download from their receivers, they also capture fish "owned" by other taggers.

Taggers in the Mid-Atlantic region have developed a way to make sure everyone gets back their fish. It's a workable but not entirely user-friendly sharing system called the Atlantic Cooperative Telemetry (ACT) network, comprising marine animal taggers from Maine to Florida.

Rule One of the ACT network is that if you tag a fish, any data that results belongs to you. But getting your fish data back if someone else's receiver detects it is not always quick and easy. After O'Brien downloads the files from receivers and takes it back to the lab, he has to look up each "foreign" tag and its





A network of underwater microphones *was installed in the Chesapeake Bay by David Secor and his partners with Maryland Department of Natural Resources. These acoustic receivers listen for the telltale sounds sent by transmitters (or tags) implanted in fish such as striped bass and sturgeon. Receivers are often placed in narrow waterways to be in broadcast range of tagged fish passing nearby.* MAP, COURTESY OF MIKE O'BRIEN/CHESAPEAKE BIOLOGICAL LABORATORY; ILLUSTRATION (ABOVE), RECREATED BY SANDY RODGERS FROM THE ORIGINAL BY THE FISHERIES CONSERVATION FOUNDATION, EXCEPT THE STRIPED BASS , WHICH IS BY DUANE RAVER

A range of marine animal tracking devices *(above) called pingers or tags can be implanted in living fish, as fisheries scientist David Secor (left) has often done with striped bass in the Chesapeake Bay. The tags identify the individual fish, allowing scientists to track them as they move through their underwater environment. Some stripers are migrators: they breed, feed, and leave the Chesapeake for the Atlantic Ocean.*
PHOTOGRAPHS, COURTESY OF VEMCO (ABOVE) AND DAVID SECOR (LEFT)

owner on an online spreadsheet that ACT members have access to on Google Docs. He emails the person and says in so many words, "I detected your fish. Should I send you the files?"

If the tag code is not on the ACT list, O'Brien has to email the data to Vemco, a Canadian company that makes the tags and receivers. They try to identify the owner and forward the contact information of whoever has the data. More emails ensue. Delays of months, known as "tag lag," are not unusual.

A Better Way?

Retired NOAA oceanographer Doug Wilson came up with the basic idea for MATOS and has been working since 2009 to allow taggers to transition from an informal sharing to a structured "database-driven" system. At the time, Wilson was building the Chesapeake Bay Interpretive Buoy System for the NOAA Chesapeake Bay Office, and had placed acoustic fish-tag receivers on the buoys that could report hearing a fish pinger immediately via its connection to the internet. "But we lacked a way to immediately identify the tag owners to provide them with the information," he says.

Wilson's goal is to help fish taggers maintain precise control over their data. His solution is to allow taggers to assign "permissions" to the digital files uploaded to the system from acoustic receivers. It will work this way: A tagger establishes an account on the MATOS database. He or she would enter the identifying code of their pingers into the system and designate who would have access to any detections of that tag — colleagues they are working with on a project, for example. When anyone uploads receiver data, the time, place, and date of all the fish detected are then available in the database to those with permission to see them.

"It's sort of like fish telemetry Facebook," O'Brien says. "If I am working with you, I want you to see my data when I upload it." In other words, if you "friend" someone in MATOS, that person gets to see your fish; if not, the taggers can see only their own fish.

MATOS is still a demonstration project, overseen by MARACOOS, the Mid-Atlantic arm of IOOS. A prototype version of the tool is under development by the private company, RPS Applied Science Associates, that handles information systems for MARACOOS. Secor and O'Brien are working with the tool's developers to test the prototype, using some of their own data.

The winds appear to be blowing in the direction of database-driven tools like MATOS, according to Matthew Ogburn, who has worked with colleagues at the Virginia Institute of Marine Science to track cownose rays as far south as Florida. Tagging can also provide insights into the location of critical habitats and breeding areas. The shellfish-munching rays mate and give birth to pups in the Chesapeake in the summer, animal behaviors that acoustic tagging allows researchers to understand.

MATOS would also make it easier to combine fish-tracking data with information about water conditions collected by oceanographic observing systems. By doing this, fish biologists could gain insight into why fish and other marine animals do what they do. That opens the possibility of predicting where the fish are, a forecast which can inform policy decisions. For example, knowing fish migration routes would help planners choose sites for offshore wind farms with the least potential to impact marine animals. The same goes for planning shipping routes to protect marine mammals.

"If you are interested in preventing whales from being struck by ships, or if you are trying to find out what the best nursery habitat is for a species, or trying to look at migration routes, or how distribution of species will shift because of climate change, that's the real power of some of this tracking data," Ogburn says.

But first, the makers of MATOS will need to entice the diverse mix of animal tagging researchers into a centralized system. The payoffs will be worth it, says Carl Gouldman, deputy director of the NOAA IOOS program office in Silver Spring, Maryland. "It's going to be messy and complicated, but we're going to do it."

— *pendick@mdsg.umd.edu*

COASTAL RADAR TO THE RESCUE

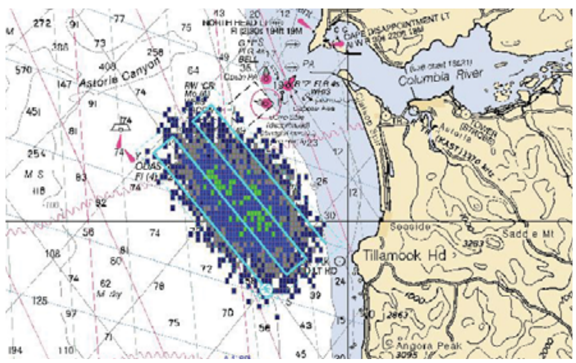
By Daniel Pendick

When John Aldridge fell off his lobster boat in the middle of the night off Long Island, his chances of rescue seemed somewhere short of nil. He had no life preserver, his boat was motoring steadily away from him, and his partner, asleep in the forward cabin, would not stir from his bunk for another three hours. When he did wake up, he called the Coast Guard.

The call came in to the U.S. Coast Guard office in New Haven, where personnel responsible for search and rescue in Long Island Sound and coastal Connecticut turned to a computer program called SAROPS — the Search and Rescue Optimal Planning System. This software tool crunches data — like the last known location of a person or ship lost at sea, the type of vessel, wind direction, and ocean currents — and uses all this information to predict the area where rescuers are most likely to find a drifting fisherman like Aldridge.

In the Mid-Atlantic region, SAROPS draws on 41 radars along the coast that measure ocean surface currents. The radar network is operated by the Mid-Atlantic Regional Association Coastal Ocean Observing System, or MARACOOS, based at Rutgers University. It's part of the nationwide Integrated Ocean Observing System managed by the National Oceanic and Atmospheric Administration and its federal partners. Other U.S. coastal regions also have radars and ocean observing systems that feed data to SAROPS.

To contribute to SAROPS operations in the Mid-Atlantic, Hugh Roarty, the Rutgers scientist who manages the radar system, must keep enough of the 41 radars up and running to provide information on currents over more than 100,000 square miles of ocean for at least 80 percent of the time. To do that, Roarty coordinates the work of four radar technicians from Massachusetts to Virginia.



On the beach at Loveladies, New Jersey *(above, top), a radar antenna broadcasts microwaves more than 100 miles out to sea, probing the speed and direction of surface currents. The information streams to the U.S. Coast Guard, which uses it to design search patterns (above) to find a vessel or person lost at sea.* PHOTOGRAPH, RUTGERS UNIVERSITY; MAP, U.S. COAST GUARD

Roarty's team worked hard to attain that 80 percent goal. MARACOOS was ready in spring 2008 to deliver its radar "data product" to SAROPS. The Coast Guard system became fully operational in May 2009.

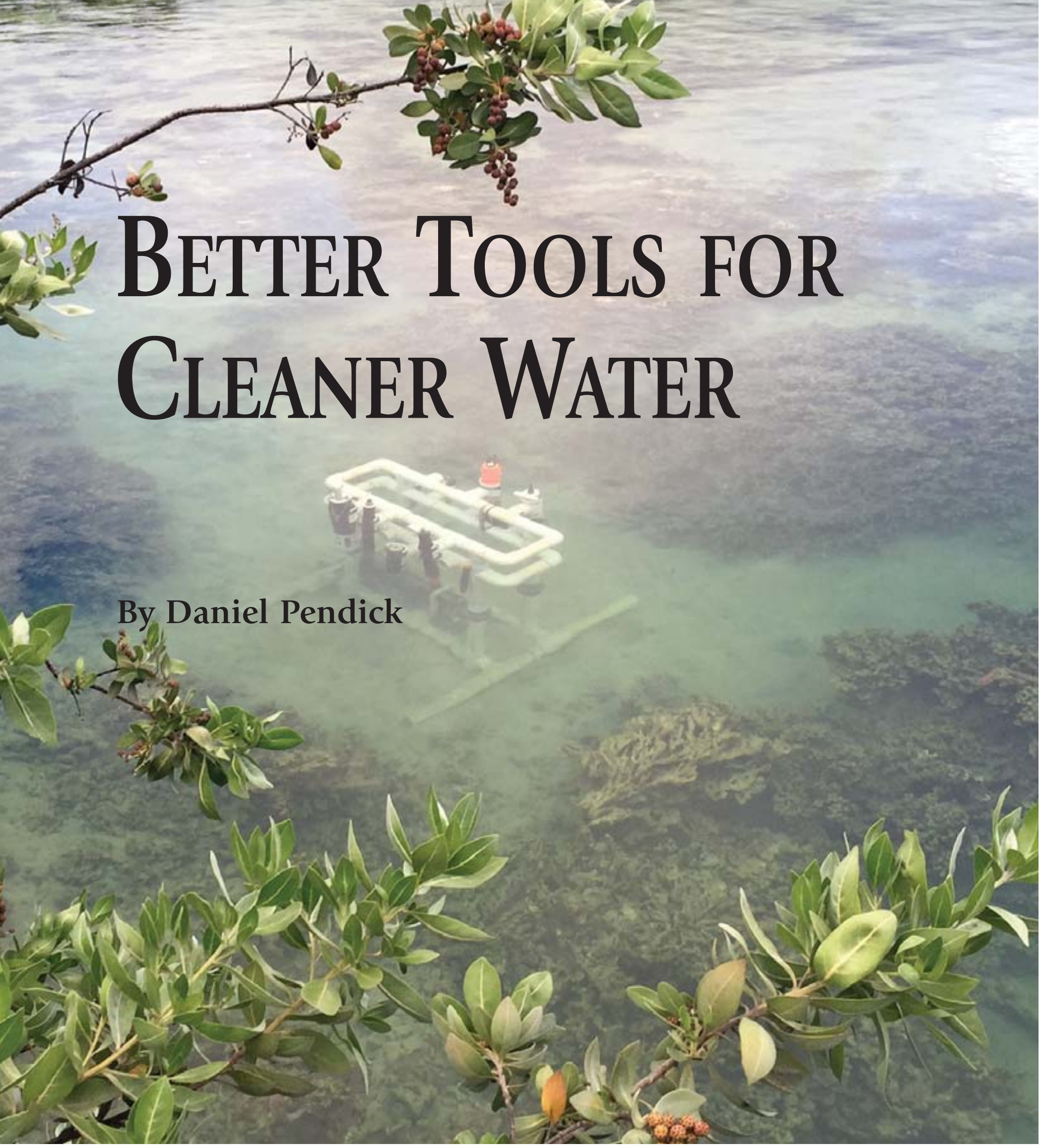
Here's how it works: Antennae on the shore bounce signals off the ocean surface. Electronic gear converts the radar echoes into digital maps of surface currents, which then go to a computer model that predicts the speed and direction of currents in the near future. Those predictions go to a data server in South Kingstown, Rhode Island, where SAROPS controllers can access them at any time.

At regional Coast Guard headquarters along the Mid-Atlantic, SAROPS controllers draw on the predicted currents and other information to generate search patterns on maps to guide helicopters, planes, and ships. Using information on currents from coastal radar helps to narrow the search area, thus increasing the odds of finding a person or vessel lost at sea.

When John Aldridge was reported missing off Long Island, SAROPS controllers went to work at the New Haven office. Whenever a boater is reported missing in the Chesapeake, SAROPS controllers in Baltimore, Maryland, or Hampton Roads, Virginia, start downloading data. Around the country, SAROPS operators cover 22 million square miles of territory by drawing on other regional radar networks similar to the one managed by Rutgers.

Coast Guard statistics show that its search-and-rescue operations save about 10 people per day, but they lose three. Thankfully, John Aldridge wasn't one of them. Nearly 12 hours after he fell overboard, a Coast Guard helicopter found him. Real-time radar current data from MARACOOS helped SAROPS controllers put their rescue helicopter in the right ocean neighborhood, where a sharp-eyed pilot flying back to Cape Cod was able to spot the lobsterman as he floated in the ocean below, hanging between two roped-together buoys, still hoping for an unlikely rescue.

— *pendick@mdsg.umd.edu*



Better Tools for Cleaner Water

By Daniel Pendick

The race is on to invent the technology needed to solve the nation's nutrient pollution problem

Every month, biologists in boats cruise along the rivers and mainstem of Chesapeake Bay, stopping at certain predetermined sites to collect water samples and take them back to a laboratory to measure nitrogen, phosphorus, and other nutrients. Later, researchers plug this boat-gathered data into the computer models they use to study excess levels of nutrients in the Bay.

But those monthly readings leave large data gaps in our view of the estuary — gaps that limit our ability to understand the causes of poor water quality and how to improve it. Why are those gaps a problem? Imagine trying to appreciate a symphony by listening to every tenth note.

Some solutions may be coming to help fill the gaps. This summer, prototypes of new high-tech nutrient sensors will start probing the waters at three field testing sites, including one in the Chesapeake.

The tests mark the culmination of a four-year effort to upgrade scientists' ability to monitor and understand nutrient pollution. A key player is the Alliance for Coastal Technologies. This federally funded program is based at the Chesapeake Biological Laboratory (CBL), part of the University of Maryland Center for Environmental Science.

The alliance is a consortium of research labs, resource managers, and private companies that work together to develop and apply new tools to study and monitor aquatic environments — whether in streams and rivers, estuaries, or oceans. Among other things, the alliance conducts independent evaluations of equipment, like the new nutrient sensors.

In a series of laboratory tests and field trials at the three sites, alliance scientists will assess how well the sensors perform over a wide range of water conditions and nutrient levels. CBL is one of the field sites where the prototypes will run through their paces for three months off the lab's 750-foot research pier.

The sensors that meet the tough test criteria could be a boon to scientists and natural resource managers in the many locations that struggle with nutrient pollution. When dissolved in water, nitrogen and phosphorus form chemicals such as nitrate and phosphate. Plants need these nutrients to thrive. But excessive nutrient levels fuel algae overgrowth or blooms, which lead to large and persistent oxygen-starved "dead zones" in the Chesapeake.

A better way to track the nutrients is part of the solution. And that's why the Challenging Nutrients Coalition, made up of federal agencies and the alliance, launched a technological I-dare-you called the Nutrient Sensor Challenge. The coalition thinks the key first step to reining in nutrient pollution is creating a new generation of affordable, compact, easy-to-use sensors that can detect and measure nitrogen and phosphorus in a variety of environments. If this new hardware meets a critical price point — less than $5,000 — the number of nutrient sensors in operation could rise exponentially.

More sensors mean more data, both to feed the computer models scientists use to study nutrient pollution and to inform management decisions. Better and cheaper nutrient sensors could also be a boon to wastewater treatment plants, aquaculture operations, and hydroponic farms.

That is, if the new sensors can pass muster in tough laboratory and field tests. The project's tester-in-chief is Mario Tamburri, a marine biologist and expert on aquatic instruments who directs the Alliance for Coastal Technologies. The

Nutrient Sensor Challenge is unlike anything the alliance has done before, and Tamburri is excited. "We are transforming the way nutrients are monitored," he says.

The Road to the CBL Pier

The Nutrient Sensor Challenge grew out of an effort at the White House to identify important national problems that could be solved with technology challenges. To spur new solutions to worthy problems of broad public interest, technology challenges offer an incentive — typically a cash prize.

The White House's Office of Science and Technology Policy (OSTP) asked for advice from its staff experts and others in federal agencies. "They said that nutrient management and pollution is a huge problem, and we are just not solving it," says Bruce Rodan, OSTP's assistant director for environmental health.

But what was the solution? To find out, the coalition held another meeting at the White House with experts on nutrient management. They said that progress in solving the nutrient problem would require better tools to measure nutrients and more data — collected more often, in many more locations.

In most nutrient monitoring, someone collects water samples and carts them back to a lab for analysis. This sharply limits the frequency and coverage of the sampling, creating blind spots. "You miss things like the true range — the true highs, the true lows," Tamburri says. "It doesn't tell you the total amount of the nutrients present because you don't have enough samples to get a good estimate."

To fix that, scientists could try putting out more of the automated nutrient sensors currently on the market. But these devices can be difficult to operate and are expensive, costing $15,000 to $25,000. The coalition decided to sponsor a grand challenge to develop more affordable and easy-to-use nutrient sensors.

That's when the Alliance for Coastal Technologies got involved. It was tapped for its expertise in testing aquatic sensors and its connections to equipment manufacturers and academic labs. The alliance could help to figure out the key capabilities that the sensors needed to have to advance nutrient monitoring. How sensitive and precise would they need to be? What nutrients should they measure? And how cheap would they need to be to help clean up America's nutrient pollution problem?

Through a series of surveys, studies, workshops, webinars, and numerous phone calls and conversations, alliance and coalition experts discovered that a diverse range of professions could benefit from new sensors. Researchers and natural resource managers wanted them, but so did citizen scientists, environmental nonprofits, wastewater-treatment-facility engineers, and even hydroponic-greenhouse operators and farmers, who could use them to fine-tune the amounts of fertilizer they applied.

The sensors should be able to measure either nitrogen or phosphorus, or both, in a variety of settings — freshwater, estuary, and ocean.

***In a competition to produce better sensors** for measuring nutrient chemicals like nitrate and phosphate, the Alliance for Coastal Technologies (ACT) tests prototypes at field sites. One site is off a research pier at the mouth of the Patuxent River (above, top), where ACT scientists previously tested sensors for water acidity. Another ACT field station is on a coral reef in Hawaii (opposite page), shown with a submerged rack of sensors under test. The sensors that pass muster might become new products, similar to the solar powered nitrate sensor (above) for measuring nitrates in farm soils.* PHOTOGRAPHS, ALLIANCE FOR COASTAL TECHNOLOGIES (OPPOSITE PAGE AND ABOVE, TOP) AND DECAGON DEVICES (ABOVE)

They should keep good data flowing under a range of temperatures and depths, and be accurate and precise enough to meet high scientific standards.

They had to perform well in water clouded with sediment or organic matter.

They had to take measurements at least every hour, but every minute if needed.

Users wanted the ability to deploy the sensors in a variety of ways — handheld devices, on floating buoys, at the edge of the water, and from boats.

The sensors needed to keep working on their own for at least three months — a tall order. That meant special design features to combat biofouling, in which devices get overgrown with bacterial films, algae, seaweed, sponges, barnacles, and even shellfish. Biofouling causes sensors to either fail altogether or spit out bad data.

And one more really important thing: the sensors needed to be affordable. Careful analysis showed that if the sensors cost less than $5,000 they would proliferate, potentially changing what we know about nutrient pollution and how we know it.

The Challenging Nutrients Coalition was asking for a lot. In return, the companies that entered the challenge would

Maryland Sea Grant College
4321 Hartwick Road, Suite 300
University System of Maryland
College Park, Maryland 20740

Address Service Requested

Non-Profit Org.
U.S.Postage
PAID
Permit No. 04386
College Park, MD

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

gain an early foothold in a lucrative new market for nutrient sensors. An alliance market study determined that companies could sell 24,000 to 30,000 sensors in the United States alone in the first five years, with total sales of $120 to $150 million. The alliance was also providing free lab and field testing of the sensor prototypes.

Start Your Sensors

Out of 29 companies or teams that initially expressed potential interest in the Nutrient Sensor Challenge in early 2015, five made it to the final testing phase in 2016. Some of the devices are lap-sized miniature chemistry labs; other instruments scan water samples with ultraviolet light to capture the spectral fingerprint of the nutrients. The entrants included companies from England, Ireland, Italy, Canada, and one firm in the United States.

To start the testing, the alliance will stage laboratory trials at Chesapeake Biological Laboratory to subject the sensors to the wide range of temperatures, salinities, sediment and organic material levels, and nutrients levels they are likely to encounter in actual use. That would test for accuracy, precision, and range.

Then the devices go to three alliance partner field sites, representing a range of typical freshwater, estuarine, and ocean environments.

Biologists on boats *measure nutrients in the Bay once or twice a month, but this leaves gaps in the record that real-time automated sensors can fill and help to improve understanding and management of nutrient pollution.* PHOTOGRAPH, COURTESY OF THE CHESAPEAKE BAY PROGRAM

The University of Michigan will test the sensors in the freshwater conditions of the Maumee River, which contains relatively high levels of sediment and nutrients because of agricultural activity in that watershed.

The Hawaii Institute of Marine Biology will test the sensors on a shallow reef in Oahu's Kaneohe Bay, where the ocean waters are relatively low in nutrients.

The sensors will also be dunked off the research pier at CBL, where the brackish waters contain moderate levels of nutrients but where biofouling is extremely high. Three months in this environment will show just how well the instruments' anti-biofouling features work.

At the end of 2016 or early in 2017, independent judges will award prizes identifying what might be the next generation of nutrient sensors.

How Will the Sensors Help?

Jeremy Testa is eager for the data that would flow from real-time sensors. The CBL researcher uses computer models to study nutrients in the Chesapeake Bay. Are there data gaps he would like to fill? "Always, everywhere," he says. For example, automated sensors could better characterize the sharp spikes in phosphorus in waterways when rainstorms wash that nutrient off the land surface.

Testa and other Chesapeake nutrient modelers rely heavily on monthly boat sampling, but they rarely have data to bridge the gaps. "Having continuous nutrient sensors would be transformative for us," he says, "not just for modeling, but also for doing experiments and understanding natural variability."

New products from the Nutrient Sensor Challenge could start appearing in 2017. And more data could soon make a difference for a lot of scientists and managers working to reduce the impacts of nutrient pollution on the health of Chesapeake Bay. "All kinds of things are going to fundamentally change," says Tamburri, "because we will have the tools to understand them."

— *pendick@mdsg.umd.edu*

To see online articles and to send us your comments, scan the code at left or go to www.chesapeakequarterly.net
A Maryland Sea Grant publication • www.mdsg.umd.edu • Follow us on Facebook and Twitter

Want to support this publication and our work? Donate online at: http://mdsg.umd.edu/donate