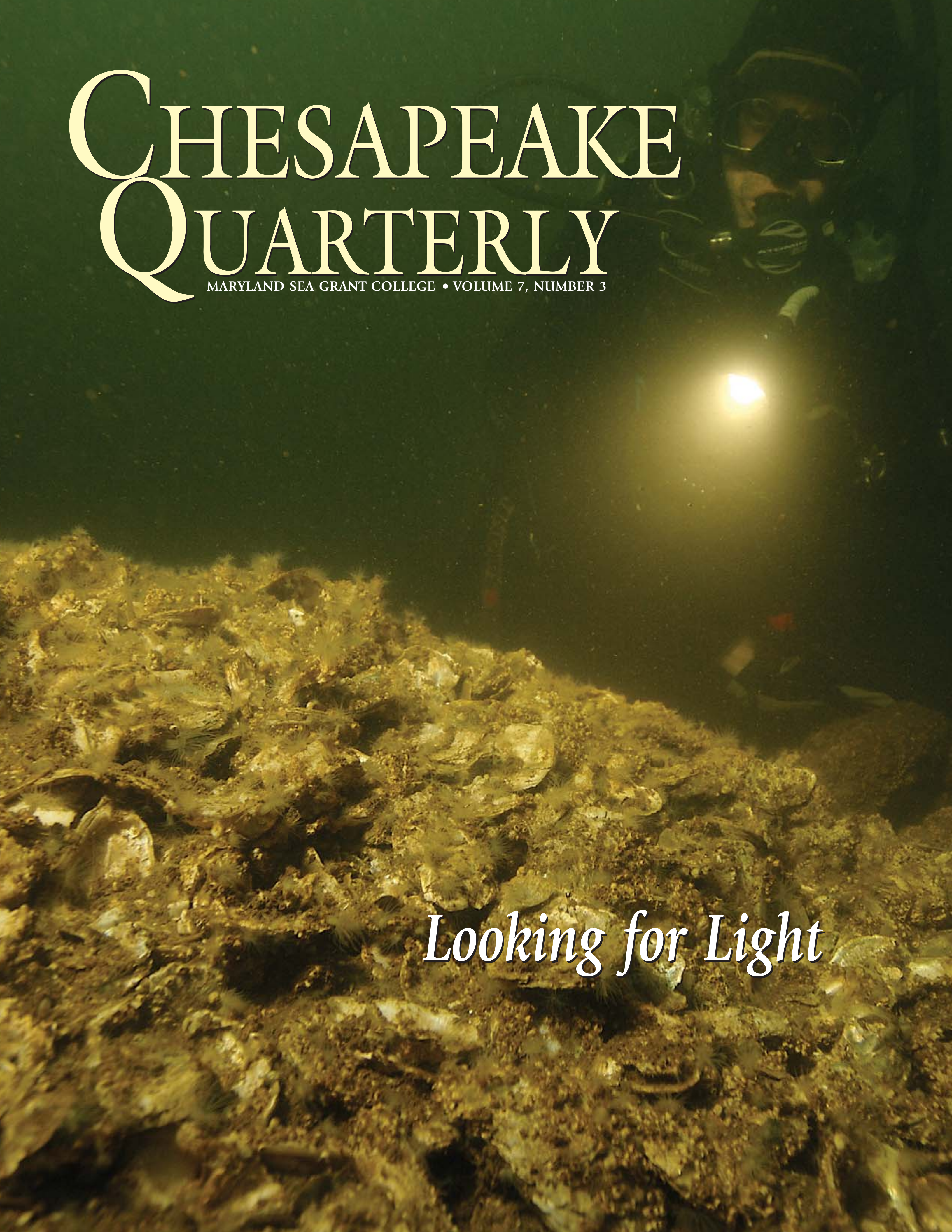
CHESAPEAKE QUARTERLY
MARYLAND SEA GRANT COLLEGE • VOLUME 7, NUMBER 3
Looking for Light

contents

Volume 7, Number 3

CHESAPEAKE QUARTERLY *September 2008*

Chesapeake Quarterly explores scientific, environmental, and cultural issues relevant to the Chesapeake Bay and its watershed.

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We gratefully acknowledge support for *Chesapeake Quarterly* from the Chesapeake Bay Trust for 2008.

Cover photo: *Light bathes an oyster bar, with a little help from professional photographers. Veteran underwater cinematographer Nick Caloyianis (pictured here, with light), carefully set up this shot of a restored oyster reef, built on rubble from the Wilson Bridge. Behind him lies the unlit gloom of the Chesapeake, which grows murkier every year.* PHOTOGRAPH BY MICHAEL EVERSMIER, AQUA VENTURES, INC. ***Opposite page:*** *Footloose in Back Creek, a crowd follows Annapolis Mayor Ellen Moyer (third from left) during an annual wade-in. Though conditions in early summer were good in the creek and in many parts of the Bay, they didn't last.* PHOTOGRAPH BY JACK GREER.

Wade in the Water

The first weekend in June, and it's going to be a scorcher. Predictions along the Chesapeake are for temperatures in the high 90s and a heat index of 105.

But this morning there's a breeze coming off the Bay, where water temperatures are just climbing out of the 60s. From a distance the water still looks cool and clear.

This is wade-in day on Back Creek in Annapolis, Maryland. A small band has gathered to try the waters, to see how far they can get and still spot their feet. In tan shorts, leaning on her hiking stick, Mayor Ellen Moyer stands at the center of the ring. She's been the mayor of Annapolis since 2001 and is today's presiding politician. There's not much political going on, though, just a dozen or so citizens standing around in wading attire. They're here to play their part in a spring ritual acted out creek by creek and river by river all around the Chesapeake.

It's a tradition started by Bernie Fowler back in 1988 in a river well south of here.

Fowler, now 85, is a former state senator and a consummate local politician. He's also the recognized champion of the Patuxent River. Twenty years ago he came up with the idea of an annual wade-in to attract public attention to what he saw happening to his home waters. He'd watched the river grow murky for years, and upset that no one seemed to care, he started wading. To anyone who listened, he told the story of how as a young man he would wade up to his armpits and still see Bay grasses and blue crabs scuttling on the bottom.

Now every June, Fowler wears white tennis shoes and wades out until he can't see them anymore. A small crowd wades

with him, in solidarity. Most years they don't have to wade very far. The yearly event in rural Calvert County attracts Maryland political heavyweights like Senator Barbara Mikulski and Congressman Steny Hoyer. It gets a lot of press.

Back Creek keeps a lower profile. But today the local lights are here. The head of the Chesapeake Ecology Center on Clay Street, in the urban heart of Annapolis. An official from the Maryland Department of Natural Resources (DNR). The environmental reporter for the local paper, *The Capital*. Everyone is taking photographs of everyone else.

At the appointed hour Mayor Moyer and her band line up facing the creek and start walking. A mallard splashes off toward the old McNasby's oyster plant, now home to the Annapolis Maritime Museum. As Moyer and friends wade on, the water climbs their ankles, their knees, their thighs. "It's cold!" she sings out. She'd probably like to stop soon — she's up to her waist — but she can still see her feet.

Soon her shirt is getting wet, and the two young girls next to her are practically swimming. Finally she stops, and Claudia Donegan, the designated helper from DNR, plunks down her meter stick. It disappears under water. "You're going to need a bigger stick," someone shouts. Donegan takes Moyer's hiking stick, marks off a meter with one hand and then lifts the measuring rod with the other to gauge the water's surface. "Forty-three inches!" she calls out.

Someone pulls out a tape measure and confirms the depth.

This is the deepest record yet for their Back Creek wade-in, and even better than the 30 inches recorded in nearby Weems Creek earlier that morning.

Moyer turns back toward shore. She says she's glad she took her cell phone out of her pocket. The two young girls dive the other way, out into the creek, and start swimming. The water drips from their arms as they glide.

From the dock that runs along the old oyster house, the water looks pretty clear. White oyster shells glimmer in the shallows. Rocks set offshore to break the energy of waves rolling in from the southeast show clear outlines even as they descend toward the bottom. Donegan reaches down and plucks a wisp of green floating past her thighs. "Horned pondweed," she says. It looks crisp, healthy.

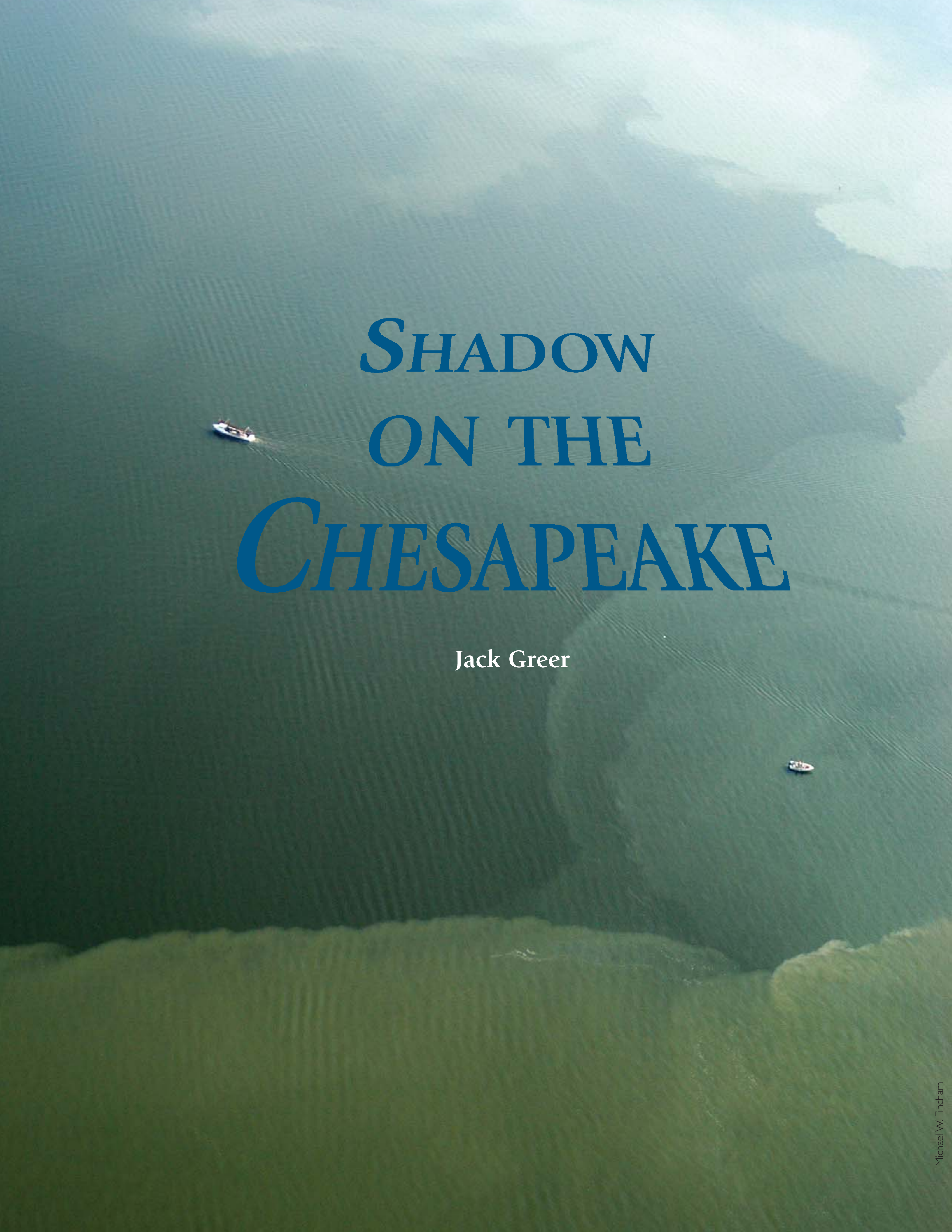
"We've seen a fair amount of horned pondweed this year," she says. "And redhead grass." Everyone nods and stares. For a moment it seems that the grasses may be coming back, that the long shadow that darkens the Bay each summer is lifting.

As June turns to July, the water loses its luster. The good news fades, and once again summer brings a murkiness that obscures the bottom, even in shallow water. Like an annual migration, summer's shadow returns, and with it unanswered questions. Will the promise of this year's wade-in ever be fulfilled? Will the shadow that darkens the Bay each year ever be lifted?

— *Jack Greer*

Shadow on the Chesapeake

Jack Greer



Michael W. Fincham

A cownose ray breaks into the light, raising one dark wing. As soon as it dips, the ray disappears into a watery haze. Though Maryland's Choptank River gleams in the mid-summer sun, it's hard to see much beneath the surface. Only a foot or so down, the ray and everything else vanishes in a greenish blur.

The ray performs its disappearing act near the research laboratory at Horn Point, just down river from Cambridge, where scientists are puzzling over a nagging mystery. With every passing year, the water's summer haziness appears to get worse.

Fishermen find it harder to see what's on the end of their line. Boaters find it harder to see the bottom, even in shallow water. Every year, even in years with low flow, when fewer nutrients and less sediment wash into the estuary, resource managers watch measurements of water clarity worsen (see graph, p. 7). What's driving this decline in water clarity? What, they ask, is snuffing out the light in the Chesapeake?

Robert F. Murphy

Light once brightened *the bottom of the Bay. There underwater grasses trapped sediment, provided habitat for fish and crabs, and gave off oxygen during photosynthesis. Now turbid waters shade out many grass beds and leave them starving for sunshine. Plumes of sediment (opposite page) billow off Maryland's Eastern Shore, darkening the waters. Though silt can cloud the water, scientists think there is something more complicated behind the Bay's continuing decline in water clarity.*

The Dark of Summer

Sediment is one suspect, a prime suspect. For a quarter century, Larry Sanford has been on the trail of sediment, tracking its movements. He's one of the scientists working on the banks of the Choptank at the Horn Point Laboratory, part of the University of Maryland Center for Environmental Science (UMCES). He measures where sediment goes, how it moves, and he puzzles over the gathering cloudiness in the river — what scientists call turbidity.

Seated in his cluttered office, Sanford says that the study of turbidity in the Bay has a long way to go. When he began his academic career, most students in his field studied sand. Sanford, who has piercing blue eyes and still looks athletic in his fifties, started that way as well. But while others focused largely on preserving and rebuilding sandy beaches, he zeroed in on fine sediment transport — the movement of silt and clay.

After graduating magna cum laude

During the eighteenth and nineteenth centuries . . . sediment did not cause the kind of turbidity we see now.

from Brown University in Providence, Rhode Island, he earned advanced degrees in coastal engineering from the Massachusetts Institute of Technology (MIT) and the Woods Hole Oceanographic Institute (WHOI). Then in 1984 he came to the Chesapeake, to Horn Point. He had no idea just how complex "sediment transport" in estuaries could get.

Once on the Bay, he sharpened his focus on fine "cohesive" sediment — call it mud. In the Chesapeake, sediment-laden waters drain from a 64,000-square-mile watershed to meet a rising sea that erodes riverbanks and shorelines. Here, he says, especially in the middle Bay, "mud is where the action is." Unlike sand, which slides and sinks in relatively predictable ways, mud can be, in Sanford's words, "ungodly complicated." Muddy particles can hang in the water for hours, for days. They get resuspended. They move around a lot.

"I'd never studied estuaries before," he says. It was a steep learning curve.

The first thing he learned, a lesson he now preaches to others, is that the Bay needs sediment — to replenish its tidal marshes, for example. The Bay depends on seasonal runoff of minerals and particles, including bits of plant material scientists call detritus, to stoke the fires of its great protein factory and to keep up with sea level rise.

"A blanket statement that 'sediment is bad' is just wrong," he says.

Besides, the biggest sediment loads to the Bay occurred long ago, he points out, during the eighteenth and nineteenth centuries, when trees came down and mold-board plows cut the earth. This sediment filled harbors and smothered oyster bars, but it did not cause the kind of turbidity we see now. It did not rob enough light from the Bay to shade out large areas of underwater grass, which remained relatively abundant until the 1960s and 70s.

If sediment is not new to the Bay, then why is turbidity increasing?

Jack Greer

Courtesy of Larry Sanford

On the trail of sediment, *researcher Larry Sanford holds a laser-shooting LISST, an instrument he uses to measure fine particles in the Bay. Looking like a cross between a robotic fish and a torpedo rack, the array he calls a DIPSTIC (above, right) carries a LISST on the back, as well as torpedo-like tubes and other instruments that capture snapshots of sediment all around the Chesapeake.*

"Something is different," Sanford says. "Something has changed."

He finds this change "really intriguing." And, he says, "really, really worrisome."

It's Not Just Sediment

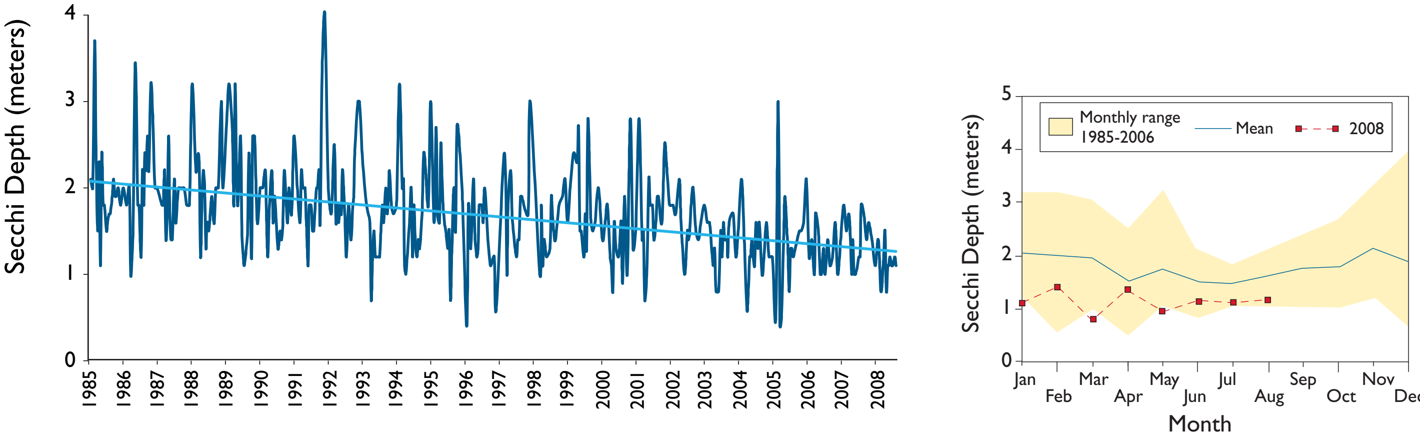
When Sanford heads out on the river to track turbidity, he takes a boatload of high-tech tools that would impress any crime scene investigator.

On the back of his boat he carries a contraption that he's hauled all over the Bay. Called a DIPSTIC (for Digital Imaging Particle Settling Tube with In-situ Capture), it sports a metal frame large enough to hold the common household stove, and it's packed with monitoring equipment that he drops or drags or anchors in the water. One instrument called a LISST (Laser In-Situ Scattering and Transmissometry) shoots out red laser beams that measure the quantity and size of tiny sediment particles. Another tool sends out sound waves that detect water velocity and turbulence. Other instruments measure depth, temperature, and salinity, telling Sanford and his assistant Yong Hoon Kim the conditions surrounding their sediment samples.

There is a lot of sediment at large in the Bay…many of these sediment particles are very, very small.

The gangly frame also holds two tubes that point skyward — they look like torpedoes aimed at heaven. While Sanford's laser beams and acoustics can count and measure millions of tiny particles, the two torpedo-like tubes have a different payoff. They can produce motion pictures.

When Sanford and Kim lower the frame-load of instruments off the back of the boat, the two tubes submerge and



Wild variability characterizes turbidity *in the Bay (shown in Secchi disk measurements, left graph), but since 1985 the general trend in water clarity has been down, down, down. In any given year, there is a fairly predictable pattern (right graph). Waters become clearest during the cold of winter and cloudiest after the spring bloom and during the summer. At this mid-Bay station, 2008 is shaping up to be an unusual — and particularly bad — year.* SOURCE: MARYLAND DEPARTMENT OF NATURAL RESOURCES AND EYES ON THE BAY.

swing forward, like torpedoes should. But instead of moving through the water, they let water move through them. Their end-caps pop open, allowing water and sediment to enter slowly, so sediment particles remain unaltered. When the end-caps click shut again, each tube captures a snapshot of suspended sediment in that part of the Bay.

After the device is hauled out, the tubes tip back up and sediment begins to rain down toward the bottom — just as it would in the Bay. At the bottom of the tube sits a high-resolution video camera that captures a microscopic view of the particles. Sanford and his colleagues are able to record this rain of suspended solids and to measure each particle's precise behavior. Modern computers can easily analyze these graphical images, giving Sanford a large digital data set.

All these laser beams, sound waves, and torpedo cameras help Sanford and Kim see sediment clearly, even in waters where cownose rays would vanish in the gloom. The scientists can see the exact size of particles, how many there are, and how they behave.

One obvious finding: there is a lot of sediment at large in the Bay. A less obvious finding: many of these sediment particles are very, very small. Sanford says that one of his colleagues in Virginia determined that individual particles suspended above the bottom typically measure no more than 10 microns. That's about one-tenth the diameter of a human hair.

These small particles are major players in what Sanford calls background suspended sediment (BSS). In an estuary like the Chesapeake, a lot of particles get stirred up by wind and waves — during storms, for example — but even after the waves die down some particles remain suspended for a long time. These become background sediment, and Sanford suspects that there is more of this background sediment now in the Bay.

From his torpedo-tube tapes, Sanford can see that all these fine grains often glom together in clumps he calls "flocs." That's short for flocculants, aggregations made up of many thousands of smaller particles that behave quite differently from other forms of sediment. Some of these flocs are 97 percent water. They don't sink like sand but settle at different rates, depending on size, shape, and composition.

Surprisingly all these flocs can actually improve visibility by clumping particles together. It's easier to see through big fat rain drops, Sanford notes, than through millions of tiny droplets (fog). "It's the packaging that counts."

The case against sediment is not as straightforward as it once seemed. Suspended sediment, Sanford says, does not equal turbidity. It may be an accomplice, but something else is at work. In the end turbidity has to do with how light penetrates the water. It's a question of light.

His advice: "You need to talk to Chuck Gallegos."

A Question of Light

Perhaps no one has been more perplexed by the Bay's rising turbidity — its gathering haze — than Charles Gallegos. Gallegos works on the other side of the Bay from Sanford, on the Rhode River just south of Annapolis, at the Smithsonian Environmental Research Center (SERC). For years he's measured light as it filters through the Chesapeake Bay, and lately the data have puzzled him.

He says his puzzlement came to a head when the local riverkeeper, Bob Gallagher, issued a scorecard for the West and Rhode rivers. Riverkeepers are part of a national network of watchdogs appointed to look out for local water quality. And scorecards, like annual wade-ins, have become a popular way of characterizing local water quality — including water clarity.

Gallegos, who's thin and looks studious in silver-rimmed glasses, says he's a big believer in public outreach. He wanted to contribute to this effort. But as he struggled to summarize information about turbidity for the public, he

Now You See It, Now You Don't

It's not much more than a plastic circle attached to the end of a rope. But despite its humble structure (or perhaps because of it), the Secchi disk holds its own among oceanographic instruments.

"It's one of the simplest tools we use, says University of Maryland Center for Environmental Science ecologist Walter Boynton. "And it's an important one."

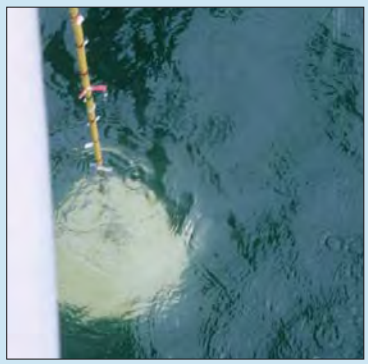
He should know. Boynton's been dropping the disks overboard for more than three decades of studying water quality in the Chesapeake Bay — following a protocol that has roots in 19th century Europe.

In 1865, Italian Pietro Angelo Secchi, a professor and Jesuit priest, conducted a series of experiments aboard a papal ship at the request of the commander of the Vatican Navy. The commander had read an account by a captain who observed a dish caught in a net 40 meters underwater. He wondered: Could this simple observation apply to studies of the transparency of the sea?

On board the *SS L'Immacolata Concezione*, Secchi observed how sunlight and shadow influenced when he could and couldn't see a disk lowered into the water below. His experiments and writings led to an established procedure for observing water clarity using the instrument now named for him. Oceanography is not the only field upon which Secchi left his mark. He trained originally as an astrophysicist, and craters on the moon and Mars also bear his name.

The Secchi disks used today by Walter Boynton and others are no doubt similar to the ones first dropped beside the Vatican's steam sloop. Gradations on the line used to lower the disk allow researchers to record the depth at which it first becomes invisible in the water. After lowering the rope a bit more, they then slowly raise it and record when the disk comes back into view. The average of the two measurements yields the Secchi depth.

Sandy Rodgers



Harold Anderson

Sometimes low tech *is best. Researchers, teachers, students, and citizen volunteers can all collect useful data by lowering a simple round disk into water until it disappears. A century and a half after its invention, the Secchi disk still helps researchers explore how light penetrates the Chesapeake.*

The Secchi depth provides a measure of water clarity. Waters rich in suspended matter — things like plankton, detritus, and sediment — generally have a shallow Secchi depth reading. The particular mix of sediment and organic material in the Chesapeake has led to increasingly shallow readings in the Bay in recent years (see Shadow on the Chesapeake, p. 4).

The earliest reliable Secchi measurements for the Chesapeake date back to the 1950s. This affords a historical perspective that Boynton says is useful in an era of high-tech instrumentation. While today's sophisticated tools gather more accurate and precise water clarity data than the comparatively crude Secchi disk, many of these instruments didn't come into use until the 1980s or after, Boynton notes. The Secchi disk's longevity allows a look at trends for particular sampling sites over a longer period of time.

Even so, Boynton wishes he could find regular Secchi measurements from earlier in the 20th century. He suspects this data lie scattered among forgotten notebooks of scientists from long ago and would require considerable sleuthing to piece together.

But it's detective work that could be worth the effort. "I think it would really be a help in trying to understand how turbid the Bay and its tributaries have gotten over a 100-year period," he says.

As Boynton continues to work to understand the Chesapeake's water clarity woes, he seems sure to remain faithful to the easy-to-use, inexpensive Secchi disk.

"It's the one device that my colleagues and I routinely use, but haven't been able to break," he quips.

"It's pretty daggone dependable."

— *Jessica Smits*

soon ran into a snag. His two main sources of data on light didn't match.

When it comes to light, Gallegos has amassed a lot of data. Both algae and underwater grasses need light for photosynthesis, and to study this he's become a leading expert in the way light moves through water. He's lowered instruments called radiometers down near the bottom in many parts of the Bay to measure how much light gets through. He uses radiometers because they help him gauge precisely how much light an underwater grass plant can see.

Oddly, the data from the radiometers didn't track well with mainstream turbidity records, most of which come from Secchi disks. These are simple disks — sometimes white, sometimes black-and-white — that researchers lower into the water until they can't see them anymore. The Secchi disk method, both easy and cheap, has a long history (see Now You See It, Now You Don't, at left). Turbidity charts presented by the Chesapeake Bay Program and others have generally relied on Secchi disk measurements.

To show the difference between the measurements, he pulls out graphs of data he's gathered from around the Bay. One group of charts — measurements from radiometers — looks variable, swinging up and down, with no clear trend. Charts based on data from Secchi disks show a general trend downward, toward decreasing water clarity — consistent with Bay Program reports.

This discrepancy between his two ways of tracking light stymied him. How could he explain turbidity trends to the public, when his data were apparently giving him conflicting results?

What he wanted was a better sense of how these two different measurements related to each other. He decided to do some simple math that would give him a "dimensionless coefficient" — a number that would stand for the product of these different units taken together. It was a way to compare the apples of the Secchi disk with the oranges of the radiometers.

It was a simple calculation, but what emerged startled him.

Searching for light, *researcher Charles Gallegos lowers a radiometer (light meter) into the murky waters of the Rhode River. His measurements of light led him to new theories about what darkens the Bay.*
PHOTOGRAPH BY SKIP BROWN.

He saw that the difference between these two measurements has been widening for almost two decades — almost since he began measuring with the radiometers, around 1990.

In other words, according to his data, the gap between what a Secchi disk shows and what a radiometer sees has grown steadily wider with every passing year.

"It's one of the most remarkable trends I've seen in the data," he says.

Why is this so important? Because it means that two main methods of measuring light — visually (with a Secchi disk) and by direct measurement (using radiometers) — seem to be saying different things. And year by year that difference has increased.

Why would these two ways of measuring light in the Bay be drifting farther and farther apart?

Scattering

To unravel the mystery of his conflicting data, Gallegos had to think harder about the behavior of light.

Light, physicists tell us, is both a particle and a wave. It's hard to imagine how something can be both a particle and wave, but there it is. When asked which way he pictures light as it bounces around, Gallegos says he thinks of it more like a wave — as in a wave pool, for example, where ripples bounce off everything. In the end, though, he says it's both.

Small specks of sediment will not absorb much light but instead will bounce it around.

We know that when light hits the water, a lot of it gets absorbed — especially at the red end of the spectrum. That's why clean, deep water looks blue. It's the blue light that's left. But when light hits the Bay, it also smacks into a sea of particles, especially in summer. Some of those particles, like algae, will absorb light — grabbing it and keeping most of it. That's not surprising, since algae contain chlorophyll, the substance that gathers light for photosynthesis. Other particles, like small specks of sediment, will not absorb much light but instead will bounce it around (see What's in the Water, p. 12). This bouncing around is what Gallegos calls scattering.

Imagine a particle-wave of light landing in a pinball machine. It will ping around madly until it drops into a hole. (In the Bay that hole might be an algal cell.) This is what happens in water filled with suspended solids. In the turbid Chesapeake there is a lot of pinging around, a lot of scattering.

What does this have to do with a Secchi disk? According to Gallegos, scattering can quickly confuse the human eye. All that bouncing light reduces the contrast between bright shapes and dark shapes and creates a haze. In that haze the Secchi disk disappears quickly, along with everything else.

The same occurs in the atmosphere on a muggy summer day. Even when the sun is shining, buildings look hazy, indistinct, light scattered by countless water droplets in the humid air. An increase in scattering would explain why Secchi disk data would look worse than data from radiometers.

It would also explain why water clarity doesn't always track closely with algae blooms.

Everyone knows that algae blooms block light. Too much algae is a major problem in the Chesapeake Bay. It leads to low oxygen zones and shades out

Not All Sediment Is Created Equal

Bushkill Nature Conservancy/David Brandes

The word "sediment" conjures up different things, especially in a muddy estuary like the Chesapeake. There's sand, silt, clay. There's organic matter. According to sediment expert Larry Sanford, most geologists focus primarily on "what's on the bottom," but more and more he's turning his attention toward suspended sediment — sediment so fine or so light that it drifts through the Bay and settles slowly.

The simplest way to categorize sediment is by grain size. Sand is biggest, silt next, then clay. But these grains can also have different properties. Clay is stickier and more plastic than silt or sand. Even finer than clay are so-called colloidal particles, which are less than one micrometer — that's one millionth of a meter, the size of a speck of dust. Colloidal particles are so small they tend to stay suspended in a liquid.

Here is a quick primer on different kinds of sediment in the Chesapeake.

Sand: Most of the sediment coming into the Bay is sand, and most sand is from the sea. Sand from the sea enters at the Bay mouth and washes up the estuary. Scientists using colorful pellets to track sand movement have followed them as far up the Bay as Tangier Island. The next biggest pulse of sand is from the head of the Bay, as sand particles wash down the Susquehanna. Much of that sand ends up behind Conowingo Dam or on the Susquehanna Flats, a kind of sand delta. Sand is good habitat for many of the underwater grasses that populate the Bay. Because of its relatively large grain size, sand sinks quickly and doesn't stay suspended for long in the water.

Silt: Washing down rivers and forming plumes during rainstorms, silt is finer than sand and will stay suspended longer. The upper and middle Bay see a lot of silt, which is good for marshes — building them up and keeping them one step ahead of sea level rise — but bad for water clarity.

Clay: Layers of clay, exposed by construction for example, also erode and wash downstream. Generally smaller than silt, clay particles can stay suspended for long periods. If the grains are small enough, they qualify as "colloidal." Clay particles are sticky, so they tend to attach to each other to form flocs and cohesive bottom sediments. Combinations of clay, underwater grasses on the bottom. But trends in algae abundance (measured by chlorophyll *a*) don't necessarily equal changes in water clarity. If algae were the only cause of the Bay's murkiness, when chlorophyll levels dropped, visibility would improve. But monitoring shows that in many parts of the Bay, even where algae abundance has decreased, water clarity has not improved — in fact in some places it seems worse.

For Gallegos, here was an answer. Increased scattering of light would explain why Secchi disk readings would be worse, even where algae counts are down. Suspended solids — mostly inorganic particles, not algae — would create the haze in the water. But why would light be scattering more now than in the past?

Gallegos thinks that suspended particles in the Bay are getting smaller. The smaller the particle, the greater the surface area. That means more reflectance, more scattering.

According to this hypothesis, tiny particles are creating a haze in the Bay, just as humidity and ozone create a summer haze in the city.

Where are all these fine particles coming from? Both Gallegos and Sanford are eager to do more experiments to find out. At present, they say, there is not enough conclusive data to know for sure. There are, of course, some likely candidates. For one thing, there is the construction boom that's been underway in many parts of the Bay watershed since World War II. Construction practices often loosen fine "colloidal" particles that wash into streams and rivers — some so tiny that they pass right through sediment fences.

Others point to stormwater from existing developed areas. Channeled by gutters, culverts, and pipes, stormwater forces high velocity runoff into streams and scours them. Many of those streams already hold sediment gathered over many years, perhaps dating back to the clearing of land for agriculture. As new development reshapes hydrology and concentrates runoff, these old sediments may be blasted downstream and into the Bay. Experts at the Anne Arundel County Department of Public Works have documented precisely this pattern in the South River.

Sanford also notes that dams — like the Conowingo at the mouth of the Susquehanna — are more likely to trap heavier particles, allowing the lightest and finest particles to flow over and into the Bay.

"Right now there's a lot of guesswork going on," Sanford says.

Into the Soup

A fine haze of sediment. That's one change that seems to be plaguing the Bay, but there is more to the mystery. The fine particles hanging in the Bay appear to behave in strange ways. Even though they are extremely small, these inorganic particles should sink more quickly to the bottom. Why are they hanging around so long? Why doesn't this haze clear out, the way the air clears after a summer storm?

The second clue to the Bay's haze lies in what Sanford calls "packaging." In Sanford's view, the flocs now floating in the Bay are not necessarily bigger but they are lighter.

Gallegos explains it this way. The Bay is so full of nutrients, he says, that it feeds all kinds of organic productivity. The result is a rich organic soup — by-products of broken cells, dead algae, pieces of jellyfish, and countless other biological castoffs from the Bay's protein factory.

All this material drifts through the water and acts like glue, sticking particles

Sandy Rodgers

University of Southern California

Siim Sepp

silt, and organic matter are commonly referred to as mud.

Of course sand, silt, and clay not only wash downstream, they also collect in streambeds, until flushed out by storms. And they can crumble off eroding riverbanks. This erosion is especially important in the Bay, where sea level rise pushes tidal waters farther into the fields and forests of the coastal plain — a process underway since the glaciers began melting some 15,000 years ago, and one that appears to be speeding up with global warming.

And then there's organic matter. In lakes and streams scientists often study organic matter, including the leftovers of leaf litter and other woody debris.

In the Chesapeake, we may be taking organic matter to new levels. In addition to all the plant material (detritus) that normally flows into the Bay, a steady flow of nutrients like nitrogen and phosphorus have led to large algal blooms and to other kinds of productivity, from microbes to macroalgae. All this productivity has led to a rich organic soup, with the remains of broken cells, pieces of jellyfish, and all manner of organic material.

Research by Charles Gallegos and others (see Shadow on the Chesapeake, p. 4) suggests that all this organic material may be combining with very fine sediment to create a worsening turbidity in the Bay.

— *Jack Greer*

What's in the Water Makes a Difference

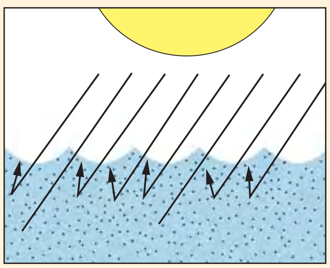
Light heading for the bottom of the Bay gets lost in two ways, not counting shading. It gets scattered or it gets absorbed.

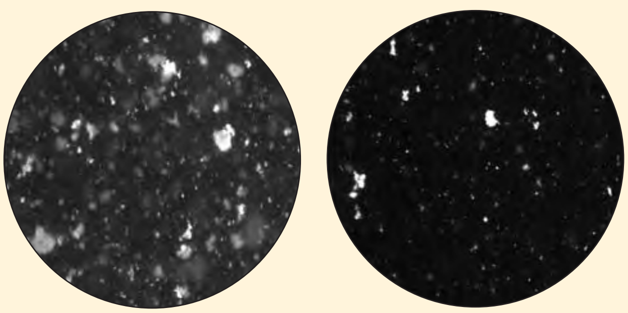
Scattering. When light hits water filled with fine inorganic sediment, it bounces around (see figure below left). Some light will eventually get to the bottom, though greatly reduced or "attenuated."

Absorption. When light hits an algae cell, much of it gets absorbed (see figure below right). Phytoplankton are great absorbers of light — in a very real way, they "feed" on light.

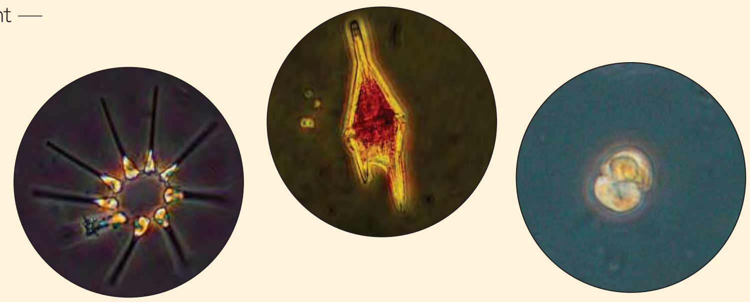
Larry Sanford (an expert in fine sediments) and Charles Gallegos (a phytoplankton expert) are reaching between their disciplines to discover the ways in which the inorganic and organic interact to create the turbidity we now see in the Chesapeake Bay. To learn more about light and turbidity, see For More Information (opposite page).

Sediment scatters light . . .

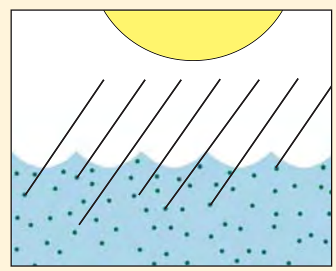




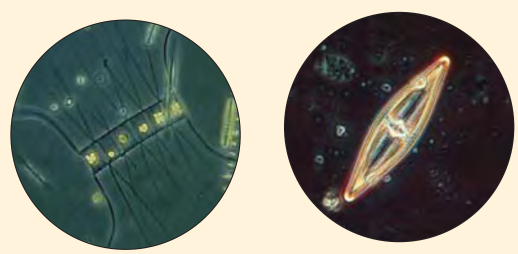
These images, captured on video by researcher Larry Sanford, show fine grains of sediment and flocculants — aggregations made up of many thousands of smaller particles. "Flocs" behave quite differently from other forms of sediment. Some of them are 97 percent water and settle at unpredictable rates.



. . . Algae absorbs it



These are a few examples of the dozens of phytoplankton species found in the Bay. Counterclockwise from upper left: Asterionella glacialis, Ceratium furca, Karlodinium veneficum, Pinnularia sp., *and* Chaetoceros affinis. C. furca *and* K. veneficum *are dinoflagellates; the rest are diatoms.* IMAGES BY SHARYN HEDRICK, COURTESY OF THE SERC PHYTOPLANKTON LAB.



together. The result: clumps of both organic and inorganic particles. Since organic matter is full of water, these clumps weigh only a little more than water itself. They almost float. Even though most fine particles floating in the Bay are inorganic (think dust), Gallegos suspects that it's largely organic matter that buoys up the clumps and keeps them hanging in the water for a long time. And as the organic part keeps them drifting, the inorganic part scatters light.

Sanford cautions that it will take more research to know for sure. For now, he says, the most likely explanation is that the abundance of these organic-inorganic particles relates to a larger shift in the Bay. That shift came about when the Bay changed from an ecosystem rich with bottom (or benthic) life to one where much of the productivity occurs in the water column. Organisms on the bottom once processed and packaged many of these particles, but now large clouds of this material continue to hang in suspension for long periods.

Even when this organic-inorganic mix falls to the bottom, it causes problems. It's highly "fluidized," Gallegos says, full of water — and that makes it mobile. A canoe paddle will stir it, as will wind or waves.

Call it "fluff." That's what Gallegos calls it. Benthic fluff. He's found it all over the Bay. He thinks that most of this fluff is formed in the shallower parts of the estuary and, because it drifts so easily, it tumbles into the Bay's mainstem. That's why we see it even in the lower Chesapeake, he says, where sediments are sandier and settle out fast. This fluff drifts over sandy bottom and lies there.

Underwater grasses can't root in fluff — it's too unstable. In fact, it's probably not good for many things that live on the bottom, where most Bay creatures are adapted to sand or mud. There are, though, some organisms that might thrive in fluff. Gallegos thinks it may be good habitat for dinoflagellates, some of which are harmful or even toxic.

In the end, this organic-inorganic mix, this fluff, moves particles around that would normally settle out. It's like attaching tiny balloons to sediment. It's like tumbleweed. Or dust bunnies. Fluff keeps things floating around.

But didn't Sanford say that particles sticking together should cause better visibility? Wouldn't joining smaller particles into bigger clumps reduce the haze?

Normally, according to Sanford and Gallegos, it would. Sanford remembers seeing this effect while diving. Particles sticking together at a certain depth (flocculation) make the water clearer at that level. The problem is that the flocs and fluff now floating in the Bay are different. These clumps of fine particles easily break apart. Their connection, Sanford suggests, is "weak." They drift like fragile storm clouds that break up in wind and waves.

Sanford says that when these flocs break apart they can explode into "a million bits" — you see "nothing but haze."

Clouds of inorganic particles that scatter light and cause a widespread haze. Organic material that keeps them floating about. These are the answers that Sanford and Gallegos give to the riddle of the Bay's increasing turbidity.

Where Do We Go from Here?

As summer turns to fall, the Bay's water begins to clear. "We have the cycle down pretty well," Gallegos says. Relatively clear water in winter, a big algae bloom in spring, followed by a pause in early summer when waters may clear again slightly. After this lull, water clarity drops, usually hitting its worst levels in mid-summer.

Such is a year in the life of turbidity in the Chesapeake Bay.

"The bottom line," says Gallegos, "is eutrophication." The result of too many nutrients and too much organic matter piling up. He feels that the Bay has become "chronically eutrophic." He thinks this process is cumulative, and that's why the turbidity graph keeps looking worse year by year, even in periods of low flow.

This interaction between inorganic and organic material may have pushed the Bay into a new phase of degradation.

This means that as bad as sediment may be as it washes off farm fields and construction sites, it's nutrients that are — in his view — making it worse. Sanford and Gallegos suggest that this interaction between inorganic and organic material may have pushed the Bay into a new phase of degradation. The Bay may have crossed another ecological threshold, they say, heading in the wrong direction.

Sanford and Gallegos both caution that much of this work is still in progress. There is a lot more to learn about precisely how suspended sediment is behaving in the Bay. A lot more to learn about ecological thresholds, and whether or not we have passed another one. "The truth is," Sanford says, "we don't know."

Is the Bay's clouded water here to stay?

Not necessarily, Gallegos says. Without an overabundance of nutrients, these processes would not occur — at least not to the degree that they do now. He points to work by UMCES researcher Walter Boynton and others that suggests that the Bay does not have a long nutrient memory. That means that if we can reduce inputs of nutrients to the Bay and its rivers, the estuary will respond.

And if we don't reduce the flow of nutrients into the Bay? If we don't bring an end to what Gallegos calls "chronic eutrophication"? Then the Bay's haze — its cloud of fine particles — will arrive next year and the year after that, a new summer ritual that no one wants to celebrate.

— email the author, greer@mdsg.umd.edu

For More Information

Smithsonian Environmental Research Center
Light & Water
www.serc.si.edu/labs/phytoplankton/ primer/water.jsp
Light & Phytoplankton
www.serc.si.edu/labs/phytoplankton/primer/components_phyto.jsp

Maryland Department of Natural Resources
Tracking Water Quality (Eyes on the Bay)
mddnr.chesapeakebay.net/eyesonthebay/

EcoCheck
Water Clarity
www.eco-check.org/reportcard/chesapeake/2007/indicators/water_clarity/
Chesapeake Report Card
www.eco-check.org/reportcard/chesapeake/2007/

Chesapeake Bay Program
About Chesapeake Wade-Ins
www.chesapeakebay.net/news_wadeins08.aspx?menuitem=28072

National Oceanic and Atmospheric Administration
Interactive Turbidity Exercise
www.buoybay.org/site/public/classroom/water.php

Maryland Sea Grant
Water Quality & Underwater Grasses
www.mdsg.umd.edu/programs/research/projects/past/R_P-53/
Chesapeake Quarterly Photo Gallery
www.mdsg.umd.edu/cq/gallery

Join the Conversation

Turbidity is only one of the complicated issues that face the Chesapeake Bay. Blue crabs. Oysters. Sprawl. Restoring urban environments. We think about all these and more, and we know you do too. We'd like to hear what you think. Visit our BayBlog and join us in an on-going conversation. There is so much to speak about.

www.mdsg.umd.edu/cq/bayblog

Portrait of an Undergraduate Scientist

A Summer in the Marsh

Jonathan Berlin

Lora Harris

August 14, 2008. An osprey soars at high altitude above the Patuxent River in southern Maryland. Tucking its mottled brown and white wings, the bird of prey plummets. It dives four times, moving in a straight line upriver, until it emerges clutching a fish. Fighting gravity, the osprey beats its wings and wheels toward golden spires of wild rice on the western bank.

The osprey is one standout in the rich biological community of Jug Bay. This tidal fresh marsh, located just 20 miles southeast of Washington, D.C., is both far enough downstream to experience daily tides and far enough upriver to avoid the infiltration of salt. And without the salinity that limits the biodiversity of saltwater marshes closer to the Atlantic Ocean, a large number of species flourish.

This biodiversity is why Keala Cummings, a rising senior at Scripps College in southern California, spent the summer researching the marsh at Jug Bay Wetlands Sanctuary on the eastern bank of the river. As part of the Research Experiences for Undergraduates (REU) program, administered by Maryland Sea Grant and funded by the National Science Foundation, she conducted a pilot study that will help scientists adapt a predictive model of the relatively simple saltwater marsh to the more complex tidal freshwater marsh. Cummings researched one component of that model — the effect of diverse plant shapes on the capture of free-floating sediment in the river.

"Freshwater marshes are just amazing," says Cummings' mentor Lora Harris, an expert in ecosystem modeling at the UMCES Chesapeake Biological Laboratory in Solomons, Maryland. Unlike the saltwater marsh, where spaghetti-like *Spartina patens* and stiff, reed-like *Spartina alterniflora* are the main species, there's a huge diversity of broadleaf plants, she says.

According to Cummings, these plants serve as a "catcher's mitt" for the suspended sediment in the Patuxent River. "As soon as all this free-floating plant debris and organic matter hits the marsh," she says, "it physically hits the plants and gets caught." She adds that the plants slow down the water as well, so that suspended solids sink and settle on the marsh floor.

To find out just how much sediment the plants of Jug Bay capture, Cummings spent four days wading in the marsh. A self-described "hardcore backpacker," she was excited to get her feet wet. She wears her misadventures in the marsh as a badge of pride, not pity.

One day Harris lowered her off the dock at Observation Creek in Jug Bay, and Cummings found herself in the midst of a patch of cutting grass — a plant that can cause a troublesome rash. A leaf blade poked her in the left eye, leaving a burning pain.

Next time, Harris helped Cummings mount a defense against the plant. "I got this towel, I got a cape and a pole to beat the cutting grass with," says Cummings, her dark brown eyes full of mirth. "I felt like a superhero." After whacking through a 30-foot swath of cutting grass, she emerged in one piece. "It's like backpacking — constantly testing yourself and finding the joy in adversity," she adds.

Cummings braved the cutting grass to collect plant specimens in quarter-meter squares along two lines stretching from the Patuxent River to the upland side of the marsh. She also collected sediment that settled on white tiles beneath the plants. Finally, for comparative purposes, she measured free-floating sediment in each square.

For her lab work, Cummings meticulously washed the sediment from the plants she'd collected, filtering it and measuring its mass. To this she added sediment from the tiles. She used these numbers to calculate a ratio of sediment-capturing efficiency in each square. Finally, she traced each plant to determine its surface area.

Cummings expected that as plant surface area increased, so would the amount of sediment captured. Instead, she found no correlation. On a community level, however, one plant with elongated heart-shaped leaves showed particular promise. Spadderdock, although less dense than other plants in the marsh, collected significantly more sediment. It also happens to occupy the low marsh, the area beside the river channel. "It's possible that the marsh evolved this way to protect the areas most vulnerable to being submerged," she suggests.

Sediment captured at Jug Bay matters because it reduces the amount of suspended solids that the Patuxent River dumps into the Chesapeake Bay, says Harris. There, sediment and organic matter cloud the waters and suppress the growth of underwater grasses. These

Continued on p. 16

Students and Maryland Sea Grant

For twenty years, Maryland Sea Grant's Research Experiences for Undergraduates (REU) program has brought college students from around the country to the labs of the University of Maryland Center for Environmental Science (UMCES) to work alongside marine scientists. Funded by a grant from the National Science Foundation, the REU program pairs fourteen students with faculty mentors to conduct 12-week research projects in fields ranging from fisheries to botany to physical oceanography. Find out more at www.mdsg.umd.edu/reu/.

In addition to the REU program, Maryland Sea Grant supports a variety of programs in marine and environmental sciences for K-12 students and teachers, graduate students, and the general public. These include workshops, special programs, and interactive web lessons. Maryland Sea Grant also offers fellowships in research and science policy and an internship for undergraduate students in communications.

Essay

Footprints of an Observer

Keala Cummings, *REU Student 2008*

The "observer effect" tells us that it is impossible to observe something without changing it. Whether an animal's behavior or a speeding electron, characteristics of both are inevitably altered in our attempt to know them. Science is supposedly a pure discipline, untainted by bias or prejudice in its search for truth. Of course its practitioners know this for the utopic optimism that it is, but still the question must be asked: if the mere act of observation biases results, how can conclusions be drawn from them in good faith? Observation is the scientist's greatest tool. What does it mean then, if using it undermines the principles science is founded upon? Is it truly possible to know something?

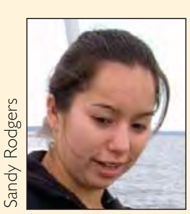
I found myself pondering these questions while standing thigh deep in marsh mud and spadderdock, having just looked back along my transect at the wide swath of destruction I'd left in my wake. The sun had turned the marsh into a sauna and you could almost hear the cattails and arrow arum panting in the heat. With sweat rolling down my arms and my skin complaining of one hundred little stings, courtesy of the patch of cutting grass I had fallen into, I'd be the first to admit it was an odd time for reflection. These were strange musings also, since sedimentation rates in freshwater tidal marshes are a far cry from quantum particle behavior, which was what initially sparked discussion of the observer effect. But looking back at the trail of broken stems and shredded leaves that suggested a hippopotamus had blundered through instead of a 120-pound girl, I couldn't help but wonder if I was causing more harm than good. After all, I wanted to understand the marsh, not destroy it.

Other scientists have faced the same dilemma, and in matters much more serious than a couple of trampled plants. From toxicologists to medical scientists to anyone who has worked in an animal lab, we must constantly ask ourselves if the ends justify the means. This is not a new moral question and most times the answer is "yes"; the good for the many that will come from the research overshadows the sacrifices of the few needed to get there.

But what about the observer effect? Doesn't this change the situation entirely? What if the question was, "do the ends justify the means, even if the ends might be flawed?" How many would answer yes to that? Take my own situation. I wanted to know how plant morphology affects the rate at which sediment settles to the bottom of the marsh. My results would help create a model that would ultimately predict whether freshwater marshes could survive rising sea levels. But sedimentation is a complex phenomenon, influenced by hydrology, sediment load, plant composition, and a myriad of other factors too numerous to list. Like the proverbial flutter of a butterfly wing that eventually spawns a hurricane, a small change in any of those factors might have far-reaching effects. And I had just ripped up 50 meters of marsh along the very same line where I was taking measurements. How could I think for an instant that my presence was not affecting the variables I was measuring?

In science this is called "error," and there are tricks and computations used to minimize them, including mathematical, mechanical, and other more creative techniques that are probably seldom mentioned in the materials and methods section. This in itself suggests the answer is still, "yes," that it is still worth it and that the results we get are valuable, be they flawed or limited.

But in my own case? Luckily I am spared from having to answer. When I returned to my study site the next day the path of destruction I had left had disappeared. The mud had settled, the plant stalks had unbent, and the marsh was an unbroken sea of green once more. Of course that is not the end of the issue. My results might still be compromised and I will never stop asking myself whether the ends justify the means, but still I am not too concerned. Who knows what will happen in projects to come, but that day it seemed the marsh was giving me a message. I should worry about my own data — the marsh could take care of itself.



Sandy Rodgers

Keala Cummings wrote this essay for an ethics seminar as part of her REU fellowship at the UMCES Chesapeake Biological Laboratory. She is currently a senior at Scripps College.

grasses provide habitat for bottom-dwelling organisms like mature blue crabs. Sediment also smothers the hard substrates on which oysters grow. And toxic metals and chemicals are often bound up in this sediment.

The sediment-capturing function of the tidal freshwater marsh proves especially important in the face of extensive development. Development in the Patuxent River watershed has increased the river's sediment load, explains Mike Lucas, an archaeologist who conducts digs at the Mount Calvert plantation house across the river from Jug Bay Wetland Sanctuary. Sedimentation rates in the marsh in the 20th century averaged about ten times more than before European colonization, according to one study of sediment cores in Jug Bay's marshes by Johns Hopkins University. Lucas suspects that the recent real estate boom has now caused another sediment spike.

Capturing sediments not only protects water quality downstream, it's also how marshes stay afloat. As land in the Chesapeake Bay region slowly sinks and sea level gradually rises, wetlands must capture enough sediment to compensate. On the western side of the river, at Patuxent River Park, senior naturalist Greg Kearns has witnessed an overall reduction of the low marsh, which borders open water. There sedimentation has not kept up with a water level that Kearns says has risen 6 to 9 centimeters (2.4 to 3.5 inches) during his 30 years at the park. Some plants are effectively drowning.

Keala Cummings

Waltzing across Jug Bay, *a plant with the unlikely name of spadderdock may help to preserve the marsh. According to one student's research, the plant captures much-needed silt for the wetland and protects water clarity in the Patuxent River downstream.*

Chris Swarth, who's directed the Jug Bay Wetlands Sanctuary since 1989, acknowledges that he also worries about the long-term sustainability of the marsh at Jug Bay. "We're all concerned that if sea level begins to rise rapidly, we could lose some marshland," he says. For now, though, Swarth says that his part of the marsh is probably keeping pace with sea level pretty nicely. He cites water depth measurements that have remained stable for the last 20 years.

Cummings may have discovered an important line of defense against the threat of rising water levels — the ability of one low-marsh plant species to trap large amounts of sediment. If spadderdock proves adept at capturing sediment, the wetlands of Jug Bay will continue to thrive.

Jonathan Berlin was a communications intern at Maryland Sea Grant this summer. He is currently a senior in the Journalism Department at the University of Maryland, College Park.

Read BayBlog, see the Photo Gallery, and send your comments at *Chesapeake Quarterly Online* at www.mdsg.umd.edu/CQ

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