CHESAPEAKE QUARTERLY

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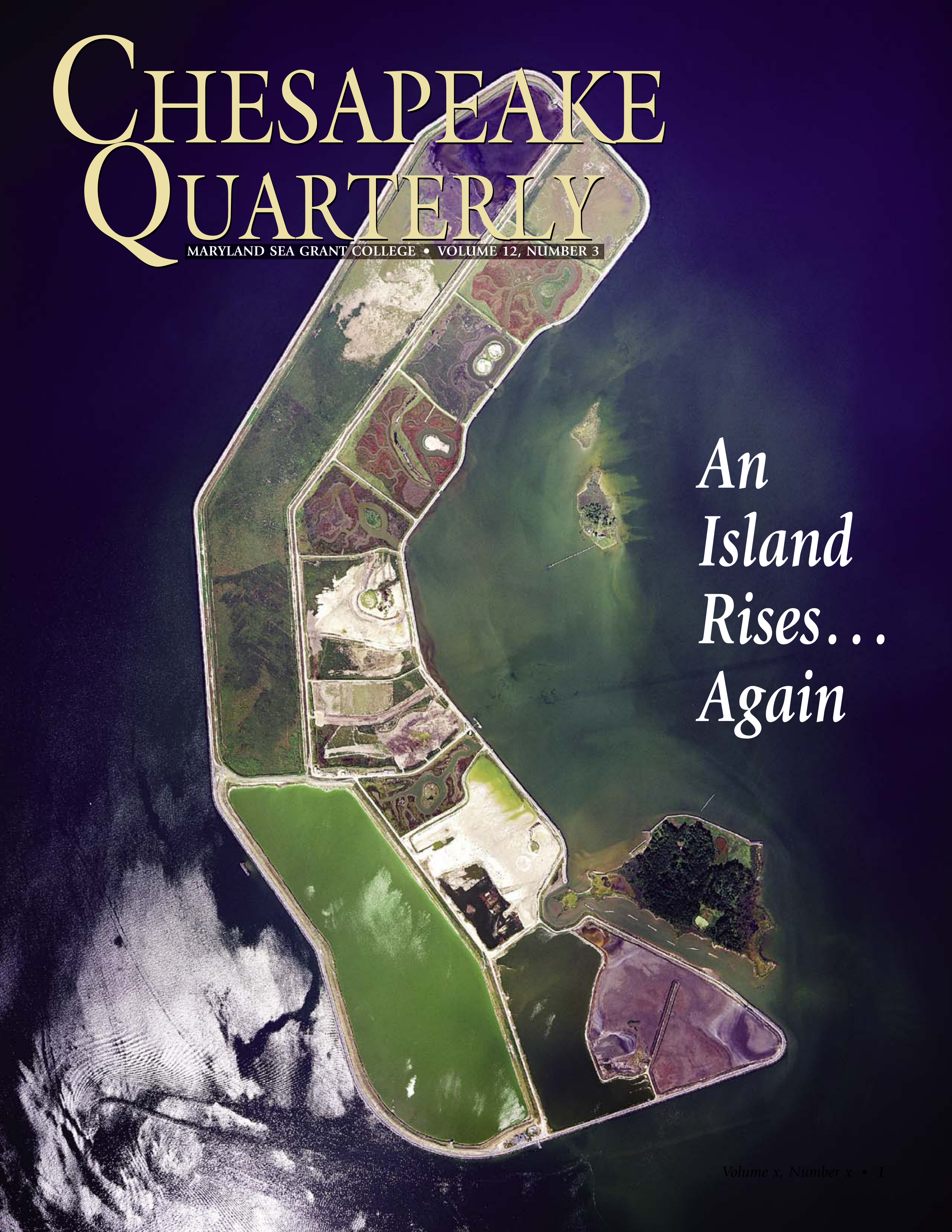

An Island Rises… Again

contents

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

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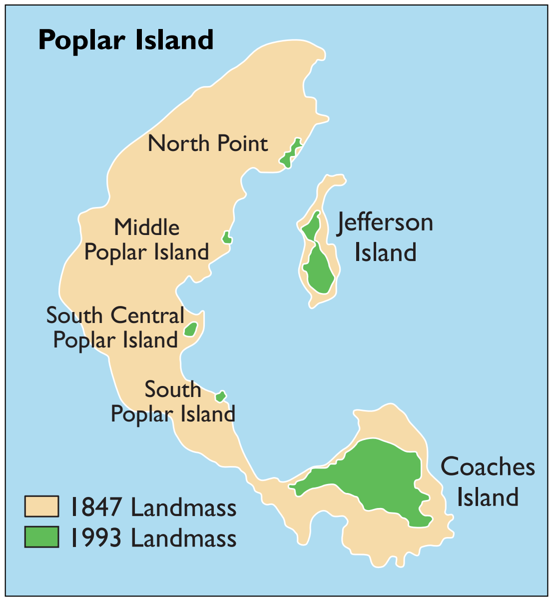
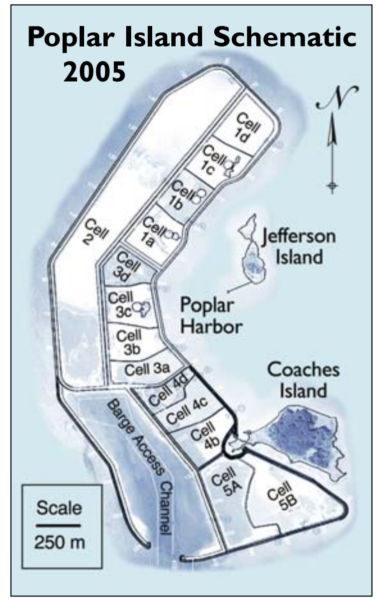
Cover photo: *A 2012 aerial shot of the reconstructed Poplar Island in the Chesapeake Bay shows the island's perimeter, which consists of boulders piled 10 feet high. A network of dikes separates marsh sections or "cells." Two natural islands, Jefferson and Coaches, lie to the right of Poplar.* ***Page 2:*** *The map on the left illustrates how much Poplar Island shrank between the mid-19th century and 1993; the schematic on the right shows the island's reconstruction plan. Marshes are being created in cells on the eastern half of the island.* ***Page 3:*** *An excavator looms over Poplar Island's Cell 5b. Dry soil shown here will eventually become a wet marshland filled with grasses.* PHOTOGRAPHS: COVER, U.S. ARMY CORPS OF ENGINEERS; P. 3, JEFFREY BRAINARD / MAP SOURCES: U.S. ARMY CORPS OF ENGINEERS

Can an Engineered Island Help the Bay?

Jeffrey Brainard





The boat is crowded on a sunny fall morning as a dozen people scramble to find seats and strap on their life jackets. These passengers belong to the Baltimore Bird Club, and they are in a buoyant mood as the crew prepares for departure.

Today's travelers have lugged aboard camera bags, binoculars, and spotting scopes. They're excited because they are about to visit what has become a popular destination for birders — Poplar Island, just off Tilghman Island on Maryland's Eastern Shore. The boat that will take them there is the *Terrapin*, operated by the Maryland Environmental Service, a state agency that manages the island.

Also sitting on the boat is a scientist. Lorie Staver is a faculty research assistant and Ph.D. candidate at Horn Point Laboratory at the University of Maryland Center for Environmental Science. She's made this trip many times over the past decade. She is studying the marsh grasses growing on this new and unusual island. The vegetation provides habitat for many species of birds — least terns, ospreys, and snowy egrets — that the birders want to glimpse today.

The boat slips away from a dock at Knapps Narrows, and the engine revs up for the 20-minute ride to Poplar Island. A bald eagle flies over us as we approach. The island clearly doesn't look like others in the Bay. Its shore is an even, uniform strip of khaki tan. Yellow excavating machines dot its landscape. As we draw closer, we can see that the shores are piled with boulders.

Poplar Island is an artificial creation rising out of the Bay's waters, 3.5 miles long and a half-mile wide. The U.S. Army Corps of Engineers designed and built it in partnership with the state of Maryland. Starting in 1998, workers placed tons of sand and rock in a circle on the Bay's bottom. Then they began filling up the interior with sediment dredged from the Bay's shipping channels, a job that is still underway.

This massive feat of engineering — the largest of its kind in the United States — was conceived as a large-scale test of solutions to several challenges facing the Bay. One is to create enough storage space to contain all of the sediment dredged from the channels for years to come. The goal is to ensure that large cargo ships can continue to reach Baltimore Harbor to ply their valuable trade.

Another challenge for the Bay is to prevent small, low-lying islands from being completely eaten away by erosion and drowned by rising sea level. Poplar Island had almost completely disappeared for these reasons when it was chosen for the restoration project.

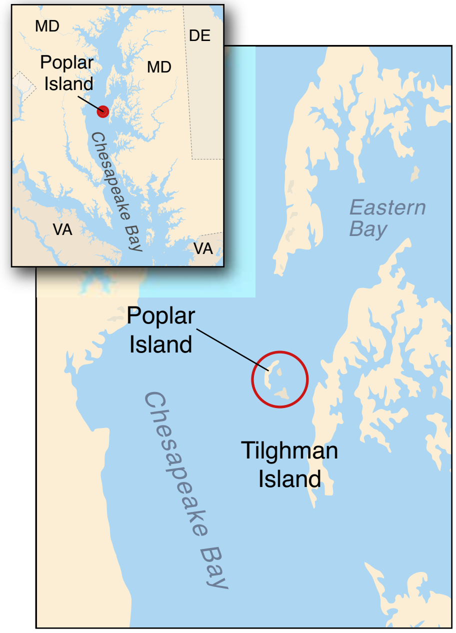
Yet another challenge is to reverse the loss of natural marsh and wildlife habitat around the Bay. Poplar's contribution to that effort is to transform its acres of barren silt and clay into a natural landscape. Establishing marshes on Poplar is considered important for the overall project to succeed. And a decade into the experiment, Staver and her colleagues have found some interesting clues about how the marshes are faring in Poplar's unusual growing conditions. The plants look lush and green, but Staver says there is more to the story than these appearances.

"This is where the rubber meets the road in marsh restoration," says Court Stevenson, who is Staver's graduate adviser and a marsh ecologist at the Horn Point Laboratory. Given the money and effort put into the project, he says, "If we can't get it right here, it's not likely we're going to get it right somewhere else."

An Island Reborn

We arrive at the dock on Poplar Island as the sun rises higher in a cloudless blue sky. The birders head off for a bus that will ferry them to choice viewing spots around the island.

Lorie Staver exits the boat, loads a handcart with research gear, and wheels it across the island's hard-packed perimeter



road to a pickup truck. She is petite, standing 5 foot 3 inches tall, but is plenty practiced at hauling equipment stands, duffle bags, even a metal dinghy on the island. She will use the truck today to ferry the gear and show me the research sites she is studying. We walk past the sign for the "Paul S. Sarbanes Ecosystem Restoration Project," naming the U.S. senator who helped to obtain federal funding for this $1.2-billion project.

The project built up the remnants of the original Poplar Island that had nearly vanished. In 1847 a survey measured it at 1,140 acres. In the 1800s, it was home to 100 residents in a community called Valiant. But over time the island eroded into smaller pieces, and the residents moved away. Later, Presidents Franklin Roosevelt and Harry Truman took retreats at a hunting lodge built on a remnant, renamed Jefferson Island. But by the early 1990s, only about four acres of the original Poplar Island remained above water. Many other small, low-lying islands in the Bay have disappeared beneath its surface for the same reasons, erosion and rising sea level.

The Maryland Port Administration, working with the Corps of Engineers and other partners, picked Poplar as one island that could be saved. They needed a new sediment disposal site to replace one at Hart-Miller Island, near Baltimore Harbor, that was reaching capacity. Residents in and around Tilghman Island supported the choice, in part because scientists determined that sediments dredged from the navigation channels did not pose environmental or public-health risks.

In contrast to the Hart-Miller project, where the original goal was focused on sediment containment, the initial plan for Poplar called for the deliberate, "beneficial reuse" of the dredged sediment. That meant establishing nearly 600 acres of marshland and wildlife habitat across the rebuilt island, which measures 1,140 acres as it did in 1847.

Poplar's rebirth is important because the Bay has lost more than half its acreage of marshlands since European settlement, and the loss continues today. Also missing are the many benefits that marshes provide. Tidal wetlands help to filter nutrients and sediment out of the water and improve water clarity. A healthy, established marsh can help shorelines resist erosion. And the open, offshore location of islands like Poplar offer nesting places and refuge from predators for dozens of species of shorebirds and waterfowl.

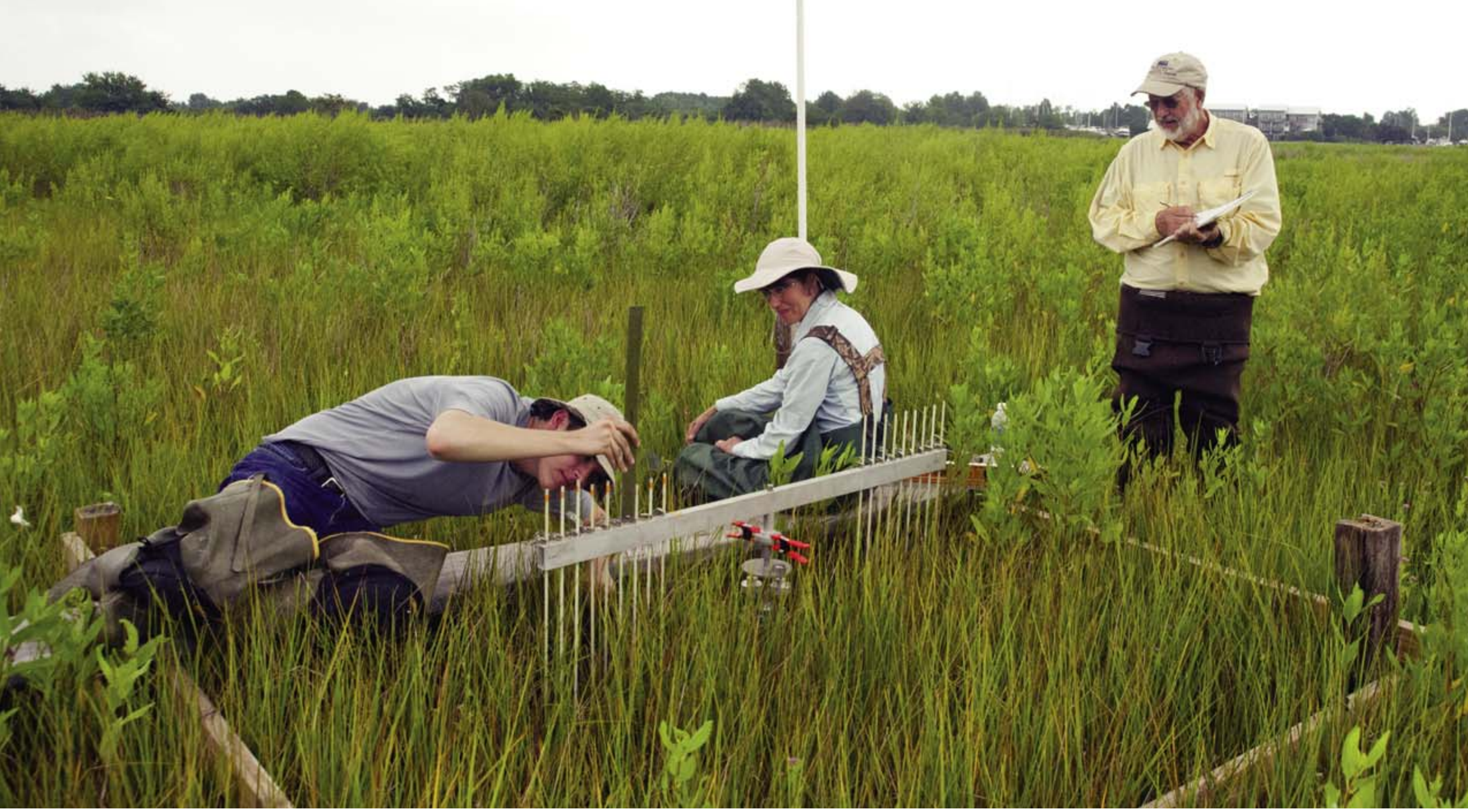
Lorie Staver has been coming to this island since 2003, when the Corps of Engineers completed the first wetland area. She and her colleagues at the Horn Point Laboratory are funded by the Maryland Environmental Service to study the marshes there. The managers of the habitat restoration at Poplar are tracking a variety of measures of progress in the effort. These include marsh size and waterbird populations on the island (see "The Return of the Birds," page 8) and fish species and sea grasses in the waters around it.

"Poplar Island is a good place to learn about marsh ecology because it's a system that's been built from the ground up," she says. "And to build that sort of system, you have to understand how the natural system works."

Staver climbs up behind the wheel of the parked pickup truck. We're joined by her daughter, Charlotte, an undergraduate at the University of Maryland, who rode out with us today to help her mother take field measurements. Near the truck, we can see dense stands of marsh grasses growing. Staver starts the engine and begins our driving tour by heading for the island's south tip. "When we get to the end of the island," she says, "you'll see a real difference."

Studying a New Habitat

We arrive and park on a dusty road on the island's rim. To our right are the waters of the Chesapeake Bay and rocks piled ten feet high to form the island's perimeter. To our left is a landscape that



***Scientists want to know how fast** soil is building up on Poplar Island marshes from natural processes. Here a research team (above) is measuring soil height using a tool called a Surface Elevation Table. They attach it to a concrete tube permanently set into the marsh, allowing for consistent measurements over time. This natural marsh is located near Knapps Narrows on the Eastern Shore's mainland; the scientists want to compare figures recorded here to ones from Poplar Island. Daniel Stevenson (left) assists his father, Court Stevenson (right), and Lorie Staver (center), both researchers at the Horn Point Laboratory of the University of Maryland Center for Environmental Science. Visitors to Poplar Island are greeted by a sign at the exit of the island's dock (opposite page).* PHOTOGRAPHS: ABOVE, JEFFREY BRAINARD; OPPOSITE PAGE, ARMY CORPS OF ENGINEERS / MAP: ISTOCKPHOTO.COM/UNIVERSITY OF TEXAS MAP LIBRARY

looks like a dry lake-bed out west. "Cell 5" is one of the last sections of the island to be filled in, and today it looks like it was hit by a bad drought. Staver walks out into the cell, surrounded by acres of cracked earth.

But this appearance is all part of the plan for Poplar. Cell 5 is one of 15 cells that the Corps of Engineers created by diking off the island's interior. Workers have progressively filled up each cell by pumping in dredged sediment from barges, which deliver about three million cubic yards of the stuff to the island annually. Think of it like filling a giant ice-cube tray with mud.

Now the engineers have left the sediment in Cell 5 to settle and dry before they begin the next steps to transform it into a wetland. Machine operators will grade the cell to a carefully pre-determined slope. That will let tides ebb and flow across the surface in a predictable way designed to deliver just enough water for the marshes to grow and persist. Each marsh cell is connected to the Bay via pipes running through the island's perimeter wall of rock and sand. These culvert pipes, set at sea level, will allow the tide to flow in and out.

To complete the cell, workers will plant hundreds of cordgrass plants (*Spartina alterniflora* and *Spartina patens*) in tidy rows during a single day. Eventually the entire eastern half of the island will be transformed into salt marsh. That, at least, is the plan.

As we leave Cell 5, we drive north, past a series of backhoes and dump trucks, and Staver points out a progression of constructed marsh cells of differing ages. They provide her and her colleagues a good research opportunity to measure how plants are growing in each cell and how well the marshes are doing over time.

Staver parks the truck and pauses the tour so she can record new data points to add to her long-standing record. She and Charlotte make their way down an embankment and into Cell 4d, completed in 2003, the oldest and most-mature marsh on the island. "This was the place we first started monitoring, the first place we saw plants take over," she says.

Staver has come back again and again to measure the marsh plants' height, always the same way. One by one, she finds a series of meter-tall markers set into the soil. At each marker, she finds the five tallest *Spartina* stems within a one-meter radius and uses a ruler to measure their height. Charlotte writes down each measurement on a clipboard. Later, Staver will average the measurements and compare them over time to study growth trends.

Staver calls off the centimeters: "81…77…89…74…71." One set of measurements down. Thirty-five more markers to go.

It's a lot of work. But it's a gorgeous, bright day, and Staver seems at home in the marsh. A botanist, she easily points out unusual plants other than the ubiquitous *Spartina*. Other species have begun to fill out and diversify the marsh cells. There's *Pluchea*, whose pink flowers give off a strong odor of camphor. Some people use it as an herbal remedy.

Sections of Poplar Island look barren *before workers plant rows of marsh grasses in May (top, left). But by September, greenery is abundant as plants soak up the rich supply of nutrients present on the island (top, right). But nutrients also have a negative effect: after flourishing for several years, marsh plants experience "dieback," little or no growth for an entire growing season (bottom).*
PHOTOGRAPHS: TOP, LEFT AND RIGHT, U.S. FISH AND WILDLIFE SERVICE; BOTTOM, JEFFREY BRAINARD

A young terrapin scuttles by our feet, another small sign that something like a normal ecosystem is becoming established here.

But in many ways, these relatively new marshes are far different than those found in established, natural ecosystems. A big difference is age: it can take a big, natural marsh, like Blackwater National Wildlife Refuge on the Eastern Shore, more than 1,000 years to form. It's a slow-motion process where the plants grow, die, and decompose in tidal areas. The decomposed stalks and roots can become marsh soil, trapping mud and sand, and slowly a marsh can grow, higher and wider.

Poplar is not only much younger, but the dredge material used as soil is not what you'd find in a natural marsh. The material consists almost entirely of fine-grained sediments — clay and silt. These small particles are readily carried through the Bay and eventually settle in the Bay's deep navigation channels. In contrast, natural marshes rise up atop diverse sediments, including heavier sand grains; this material tends to settle to the bottom of the Bay in shallow areas close to shores and doesn't reach the deeper channels.

This matters for the marsh-restoration effort on Poplar because the fine-grained sediment deposited there dries hard and dense. That presents a challenge for the newly planted marsh plants. Their roots need oxygen to grow (which is why gardeners turn the soil in their backyards each year), but it's hard for oxygen to penetrate into this hard-packed soil, Staver explains. As we walk across another recently created section — Cell 1b — the jet-black surface is a bit slippery but much firmer than in natural marshes not far from Poplar Island, where you can take a single step and sink up to your hip in muck.

Poplar is also unusual because the dredged sediments are very high in nutrients, like nitrogen and phosphorus. The concentrations are up to 100 times what you would find in the soil of natural marshes, Staver says. That's because as the sediments lay at the Bay's bottom before they were dredged, they were steeped in a rich brew of these nutrients from a variety of human and natural sources. These include farms, sewage treatment plants, and stormwater drainage pipes, among other sources.

"You have a whole ecosystem [on Poplar Island] that has this rich supply of nitrogen," Staver says. "So I think that's part of the value of this monitoring project…. What does a marsh system that gets exposed to these high nitrogen concentrations do over the long term?"

During the next 10 to 15 years, the young, growing marsh plants will consume nitrogen and phosphorus, and the nutrient levels in the sediments will decline and approach the lower ones observed in natural marshes, she says. For now, the high level of nutrients on Poplar provide abundant fertilizer for the plants.

But, Staver's research indicates, that abundance can be too much of a good thing.

Extremes in the Environment

The high nutrients and the packed soil make "a fairly harsh environment," Staver says. But places like this tend to interest and draw ecologists and other biologists. She admires another ecologist, the late Scott Nixon of the University of Rhode Island, who wrote that such environments existed at "the borders of what is possible for life…. Perhaps where life is pressed to its limits, it is pared to its essentials, and the basic nature of the ecosystem is more accessible to our understanding."

Staver gazes out over a marsh cell and says, "It really struck me, that's the way I think of this place…. I think you learn the most about an ecosystem when it is under stress. To me that's the most interesting part of the marsh out here, is how the system responds."

She has been able to make so many repeat trips here because she has been working for years for her doctorate in environmental science at a slower pace than many Ph.D. students. Staver pursued graduate studies in Maryland in the 1980s, then took time off to raise three children with her husband, Ken, also a scientist. But she held on to her goal of completing her degree one day, and for the past decade she has focused her dissertation work on Poplar Island. She expects to defend her thesis in 2014.

Despite living in this extreme environment, many of the *Spartina* plants we see look like they are thriving. As a demonstration, Charlotte Staver (who is taller than her mother) walks into a stand of the plants — and disappears. The plants are about six feet tall. In natural marshes, they would measure closer to three or four feet. Charlotte walks back and rejoins us in the truck with a grin.

But after the initial lush growth at Poplar, things change. In a number of cells, the tall plants have fallen over during the growing season, a phenomenon called "lodging."

Jeffrey Cornwell, a biogeochemist *at the Horn Point Laboratory (left), works to set a porewater equilibrator down into the marsh's muck. Cornwell is studying how the chemistry of Poplar's marshes is changing over time. He wants to know whether they will, on balance, store nitrogen or release it over time to the Bay. Scientist Lorie Staver (right) stands on the cracked ground of Cell 5, where dredged sediments have been left to dry.*

PHOTOGRAPHS: LEFT, JEFFREY BRAINARD, RIGHT, MICHAEL FINCHAM

Staver suspects that this may be caused by the high nutrient levels. The *Spartina* plants grow so tall so fast that their stems and stalks are too long to stay upright in heavy wind. Unchecked, the lodging may interfere with the marsh plants' normal metabolism, Staver says. During the following year's growing season, many marshes containing plants that lodged have shown extensive "dieback" — persistent, large patches of brown. These plants didn't put up new shoots. The lodging may have reduced the plants' ability to transfer oxygen down to their roots and rhizomes buried in the oxygen-poor sediment, according to Staver.

"Lodging" isn't unique to *Spartina* — it has also been observed in agricultural crop plants exposed to high nutrients in fertilizer. But crop scientists have selectively bred crop plants to resist lodging. The *Spartina* plants on Poplar weren't bred that way. So Staver and her colleagues are conducting an experiment to see if they can reduce the lodging by fertilizing the plants with a soil treatment high in silicate, a compound that helps grasses and other plants to form rigid stems and stalks. The gray, granular fertilizer is something like taking calcium supplements to keep your bones strong.

Even without silicate treatments, the marshes that show dieback don't remain brown for long. By the following summer, many of these cells have rebounded with green growth. But then these same cells have undergone subsequent diebacks. Scientists have seen boom-and-bust cycles like this in natural marshes but not to the extent seen on Poplar, Staver says. These extreme fluctuations in growth may reduce the marshes' long-term prospects for survival, she says.

A Race Against Sea Level

Staver and her colleagues have also studied another kind of upward growth. The marshes' soil level is rising vertically, and scientists want to know whether it is rising fast enough to keep pace with the rising sea level of the Chesapeake Bay. In an expanding marsh, it is not only the plants that grow upward. The soil they sit on also accumulates, raising the entire marsh.

The researchers' preliminary finding is that the soil in three of the longest-established cells on Poplar Island is indeed rising at a healthy clip. The scientists studied three cells completed in 2005, 2009, and 2011. The increase there averaged around one centimeter, or roughly a half-inch, per year. That is more than double the rate of sea level rise recorded in the Chesapeake Bay during the past century. And it is on par with increases observed in natural, mature marshes located elsewhere at the Bay's edge.

"I was very surprised that there was as much accretion as there is" at Poplar, Staver says. "At first, I said, this can't be

Continued on p. 10

Return of the Birds

Bird lover Jan Reese has counted important species on Poplar Island

For more than a decade, Jan Reese has ridden a bicycle down the dusty dirt roads of Poplar Island year-round, at least once every two weeks. His mission: try to count every single bird on this 3.5-mile-long island and record its species name.

Over the course of one day's visit, Reese makes his way from one diked section to the next. He brings high-powered scopes to see the birds. And he carries hand-held clicker counters. "I have a clicker on one hand, another clicker on another, and another in my head," he says.

Reese, an environmental consultant and long-time birder on the Eastern Shore, was contracted in 2002 by Maryland Environmental Service, which manages Poplar Island, to do regular counts. The project's monitoring committee wanted to track the numbers as one of several indicators of progress in the multiyear effort to rebuild the island in the Chesapeake Bay. Reese was a fitting choice because his experience on Poplar goes back much further — he studied birds there starting in the 1960s when it was a natural island.

Providing this habitat for shorebirds, waterfowl, and other birds in the Bay was one of many reasons that the Maryland Port Administration and its partners decided in the 1990s to build up Poplar Island using dredged sediments. Secluded islands like this provide valuable space for nesting and migratory birds, but such islands have steadily disappeared in the Chesapeake because of rising sea level, sinking land, and erosion. By the time construction began in 1998, Poplar had shrunk to only a few acres.

So far, Reese's figures have helped to show that bird populations there have vastly increased, according to wildlife scientists involved in the project. More than 175 different species have been observed, up from about 50 before the project began. Many of these are migratory birds that touch down on the island awhile to rest and eat.

Of that total, about 25 species have been seen nesting on the island, up from ten before the project. These included species whose numbers have declined in the Bay. In 2012, there were an estimated 300 pairs of common terns, which are not known to nest anywhere else in the Maryland portion of the Bay. Also counted were about 45 pairs of American black ducks, a species popular with hunters and diners. The birds, scientists say, are one indicator that this manmade island is beginning to function like a natural ecosystem.

"[The numbers are] a huge success for us at this point," says Peter McGowan, a wildlife biologist with the U.S. Fish and Wildlife Service who oversees wildlife management activities on Poplar Island. "And we're expecting more species to move in." Located about two miles from the nearest part of the Eastern Shore mainland, Poplar offers relatively few predators and good supplies of food.

"God, what bird wouldn't want to nest there?" Jan Reese says during a recent interview at his home in Saint Michaels.

A Life Counting Birds

For Reese, 75, counting the island's birds has been not just a job but also a passion for much of his life. With his tall and slender frame and thin features, he resembles a shorebird himself.

Reese grew up on Tilghman Island, not far from Poplar, and when he was a young man, one of his high school teachers introduced him to birding. Reese was hooked. He educated himself about birds, later studying the reasons for the decline of ospreys. He pursued the subject through formal study, earning master's degrees in wildlife management and avian ecology.

To pay his bills, he worked in the construction industry on the Eastern Shore but kept active in bird research by collaborating with scientists at the

Patuxent Wildlife Research Center in Laurel, Maryland. In 1990, he started his own consulting business, primarily conducting environmental assessments required for land developers.

Reese had visited Poplar to observe birds as the original island steadily lost acreage to the Bay. As the island disappeared, so did the birds. After work began to rebuild the island, Reese returned in 2002, this time as a consultant.

"It's one reason I like this job — I saw Poplar Island die, and then I saw it reborn," he says.

"In terms of the biology out there, I think he's got the best feel of anyone familiar with the project," says Michael Erwin, an emeritus professor at the University of Virginia and a former research wildlife biologist with the Patuxent Wildlife Research Center who has collaborated with Reese. "He's usually the first one to find species that have taken up residence on the island."

Erwin and federal and state wildlife managers have paid attention to counts of five "species of concern" that they especially wanted to establish on Poplar: common terns, least terns, snowy egrets, ospreys, and black ducks. Wildlife managers wanted to track these species for several reasons. These species were chosen because they frequented the Poplar Island area for nesting, feeding, or both before the restoration project began. In addition, scientists had good historical data on those species' populations in the Bay. And as a result of habitat loss, McGowan says, those numbers showed declining populations.

Priority Bird Species on Poplar Island*

Species	2002	2004	2006	2008	2010	2012
Common Tern	380	809	504	361	509	c. 300**
Least Tern	40	50	35	112	175	75
Osprey	5	7	5	11	7	17
Snowy Egret	5	45	50-60	55	68	85
Black Duck	0	?	3-4	3-4	3-4	45

*Figures represent estimates and counts of the number of nesting pairs
**Range of 270-330 estimated

Five "species of concern," *including snowy egrets (opposite page, top) and ospreys (above), have been chosen by wildlife managers to track on Poplar Island because their numbers are dwindling and they were known to feed and nest on the island before reconstruction. Environmental consultant Jan Reese, here riding a scooter (opposite page, bottom), makes biweekly counts of these and other species. Figures reported by him and other observers are included in the table above.* PHOTOGRAPHS: BIRDS, MARYLAND ENVIRONMENTAL SERVICE; JAN REESE, U.S. FISH AND WILDLIFE SERVICE / TABLE SOURCE: U.S. GEOLOGICAL SURVEY

Handling Predators and Disease

Predators — especially owls — have presented one of the bigger challenges to the bird restoration effort.

Great horned owls are probably the principal reason that terns have largely failed to reproduce on the island, scientists say. Terns nest in wide-open sandy areas at Poplar where marsh grasses have not yet been planted and other vegetation is sparse. That makes them easy pickings for sharp-eyed nocturnal raptors.

"Whenever you start concentrating birds, such as at Poplar Island, it can be devastating because the owls are pretty quick to find that location and cause a lot of damage," Erwin says.

Diseases and toxins that afflict birds present another threat. Many birds on Poplar Island have died or become sickened at times from avian botulism, caused by bacteria. Another cause of death and illness has been microcystin, a toxin produced by a common species of blue-green algae called *Microcystis aeruginosa*. The 2012 season was the deadliest so far; more than 750 animals were killed or sickened, mostly from botulism, during a 15-week period. The creatures affected included 35 species of birds and one species of mammal, muskrats.

Both the botulism-causing bacteria and *Microcystis* prefer to grow in shallow, warm bodies of water on Poplar, fueled by hot summer temperatures and an abundance of nutrients. It's a mystery why the particular strain of *Microcystis* found on Poplar Island has prospered in the relatively salty water there, McGowan says — the toxin-producing algae typically inhabit water that is fresh or relatively low in salinity.

A team of scientists led by the Chesapeake Research Consortium has begun studying this strain, work that may help inform how the bodies of water on the island are managed, says Kevin Sellner, the consortium's director. The research may also indicate under what conditions this strain might grow and present a threat in other brackish parts of the Bay, he says.

It's an indication of how Poplar Island has become an important laboratory for a range of studies, McGowan says. Other researchers are examining, for example, the reproductive biology of osprey and other waterbirds.

Meanwhile, Jan Reese has continued his rounds, moving up from his old bicycle to an all-terrain vehicle provided by project managers in 2012. That's made it easier for him to get around on the island and continue counting the return of the birds.

— *J.B.*

Poplar Island, *cont. from p. 7*

right." But the results were double-checked, and they were confirmed.

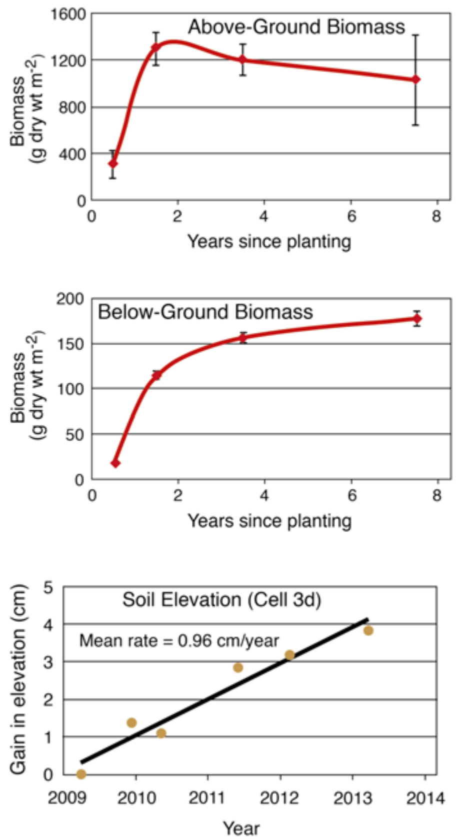
Although the finding seems like good news for Poplar's future, there's a problem — sea level rise in the Bay has accelerated since the early 1990s. And sea level is projected to increase by about two feet between 2000 and 2050, according to the latest scientific estimate. If marsh plants are flooded with too much water too often, they can drown and die. And if the Bay rises faster than the marshes, the eastern half of Poplar Island could become a tidal pond hemmed in by the island's rock perimeter. Staver and her colleagues will continue to monitor and worry about this race between the marshes and the Bay.

Changes on Poplar Island aren't occurring only above ground. Something good is happening below. To put it simply, the marsh plants measured by Staver are starting to grow bigger roots. That's important because they help marsh plants stay anchored and resist being washed away by tides, storms, and winds.

This stability is notable because recent research in Louisiana and other locations indicates that chronically high levels of nitrogen can actually harm mature natural marshes by reducing the size of the plants' roots. Staver and her colleagues wanted to find out if the newly planted marsh grasses at Poplar Island were responding in a similar way.

"The old paradigm was that marshes can act sort of like a sponge to take up nutrients, that they can take up a tremendous amount of nitrogen and phosphorus," Staver says. "And they can do that without too many negative effects." But the new research from other states indicated that negative effects were occurring, below the ground.

Finding out the effects of high nitrogen on the Poplar marshes required labor-intensive work. Staver has raked up plant stalks and stems in test areas of the marsh in the fall, at the end of the growing season. She dried this above-ground biomass and weighed it. She also dug up roots and rhizomes to a depth of 25



Over time, in marshes on Poplar Island, *plant biomass below ground and soil elevation have slowly increased — good signs for the marshes' future progress and survival. Figures for biomass are averages based on plant matter collected from sample sites at the end of each year's growing season.* GRAPH SOURCE: DATA COURTESY OF LORIE STAVER

centimeters and took the same steps to weigh them.

Staver found that when the marshes were first created, the amount of below-ground biomass — the anchoring root material — was relatively small. With access to abundant nutrients in the soil, the plants weren't forced to devote their energy or biomass to growing big, long roots to suck up the nutrients.

But as nitrogen levels have declined, below-ground biomass in the older marsh cells has increased while above-ground biomass appears to have leveled off, Staver's evidence indicates. Over all, the ratio of below- to above-ground biomass in Poplar marshes remains abnormally low compared with this ratio in natural marshes. But the balance on Poplar appears to be shifting in favor of the plant roots. Bigger root structures may improve the prospects that the marsh will remain stable and survive the forces of erosion, she says.

That's promising news not only for Poplar Island marshes but those elsewhere in the Chesapeake. Efforts are underway Baywide to reduce the excess nutrients contained, for example, in outflows from sewage-treatment plants. If that work succeeds and nutrient levels drop significantly across the estuary, natural marshes may respond favorably, growing bigger root systems fairly quickly, Staver says.

"Controlling or reducing nutrient inputs to an impacted marsh should yield a response within just a few years," she says. "And that's good news in terms of building the sediment elevation so that the marsh is keeping up with sea level rise."

The Long Haul

The research on these marshes should help inform similar projects elsewhere that involve dredging sediment or restoring wetlands or both, says Jeffrey Cornwell, a biogeochemist at Horn Point Laboratory who is a co-principal investigator with Court Stevenson on the Poplar marsh research. "[The results] are going to be guidance for people from all coasts in the U.S. that have to dredge fine-grained materials and find something to do with them," he says. "Nationally and internationally, there's a tremendous interest in the effect of high nutrients on marsh functioning, and in particular how marshes keep up with sea level rise."

The research findings by Staver and her colleagues promise to help inform future management efforts on Poplar Island, says Mark Mendelsohn, a biologist in the Baltimore office of the Corps of Engineers who has participated in the project since its inception.

Poplar Island could continue to receive dredged sediment for years to come. Its current storage capacity is expected to be reached by 2019. But the Corps of Engineers has sought federal funds to expand the island by an addi-

Poplar Island in Images

Check out our photo gallery and video highlighting the Poplar Island project and ongoing research there at: www.chesapeakequarterly.net

tional 575 acres, which could extend the facility's capacity until 2029.

The Corps and Maryland Port Administration have considered other sites for additional disposal once the Poplar project is finished. Candidates include James Island and Barren Island, located to the south of Poplar, which have shrunk because of erosion. So far no new sites have been chosen.

As shorebirds fly overhead on Poplar Island, Staver packs up her gear for the return trip on the *Terrapin*. Evaluating the success of the marshes on the island could take decades, she notes. Studies in Maryland and elsewhere have found that some projects to restore wetlands have not succeeded because they were not designed and managed adequately and for long enough. Here on Poplar, the management effort is active and is planned to last longer than in typical restoration projects. The Maryland Environmental Service plans to continue monitoring the marshes and wildlife until the project's expected conclusion in 2041.

For now, there's a lot more to learn about how to help newly planted marshes persist. "It's not that the marshes here are not successful," Staver says, "but they are different from natural marshes."

Staver joins the boatload of satisfied birders as the *Terrapin* pulls away from the dock for the trip back to Tilghman Island. One sure bet is that she will be back to continue to study those differences.

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***"It looks like a lot of the other marshes** I walk through" elsewhere around the Chesapeake Bay, says researcher Jeffrey Cornwell about cordgrass (*Spartina alterniflora*) on Poplar Island. Grasses are planted in small rows, at first resembling fields of crops. But eventually the marshes fill in and become more natural looking. Cornwell and other colleagues are studying the pace of that transformation.* PHOTOGRAPH: JEFFREY BRAINARD

Journey to the James

An Oceanographer Discovers an Estuary

Michael W. Fincham

This is the third article in a series about the pioneers of Chesapeake Bay science.

On a June morning in 1950, along a deep-water creek near Annapolis, a scientist named Don Pritchard climbs aboard an 85-foot research vessel, lights his pipe and gives his crew the order to cast off for the southern reaches of Chesapeake Bay. His ship is the *Joan Bar II*, a converted motor yacht. His crew includes a ship's captain and several other scientists. Their mission: help figure out what forces were behind some mysterious booms and slumps in the harvests of oysters and blue crabs and finfish in the largest estuary in the country.

Only 27 years old, Pritchard is already used to leading men on science missions. When he was 22, he waded ashore on Omaha Beach on D-Day-plus-two to lead a squad of soldiers to the bluffs above the beaches of the Normandy invasion. His mission on the cliffs: figure out a daily forecast for sea swell and surf conditions so all those American and British ships floating out there in the English Channel could keep offloading tanks and trucks and soldiers. In the photos from that war, he was wiry, black-haired, and bespectacled, already a pipe smoker, a good leader, said one of his team, an outgoing guy who got things done.

Heading out onto Chesapeake Bay, Pritchard is now one year into his first professional job: setting up a new marine lab at Johns Hopkins University, a lab jointly funded by the U.S. Navy and by both Maryland and Virginia, two states that share the estuary but seldom agree on how to manage it. This new Chesapeake Bay Institute is focusing, for the first time, on the entire estuary, and Pritchard, still a year shy of his Ph.D., is the first professional oceanographer to investigate an ecosystem where the harvests of oysters and blue crabs and finfish produce more seafood per acre than any other estuary on the planet.

As an oceanographer, Pritchard is here to focus on the physics — not the biology — behind that up-and-down bounty. His goal is to discover and describe the different water masses that are sloshing around the Chesapeake system and measure their force and flow. How are those water masses affecting all the life forms that float or swim in the Bay or grow along its bottom?

Nearly half a century later six famous Bay scientists would gather at a 1998 meeting where they would be asked a different question: who made the decisive discovery in the history of Chesapeake Bay science?

Five of the six picked Don Pritchard. The sixth scientist at the meeting was Pritchard. He politely nominated someone else.

They picked Pritchard because his work had created a paradigm shift, a turning point for Bay science. According to Gene Cronin, former director of the Chesapeake Biological Laboratory, Pritchard's discovery changed the way biologists thought about the Bay more than any other single piece of research.

And the key evidence for that discovery came from his journeys down along the James River during the dawn of his career.

As the *Joan Bar II* nears the southern end of the Bay the young Pritchard turns the yacht west, sailing past Hampton, Virginia, before veering northwest to head up the historic James River, home of the Bay's richest beds for seed oysters. Ten miles upriver of Newport News, the boat approaches the sprawling anchorage for the Navy reserve fleet, a "ghost fleet" that holds more than 800 war ships, troop ships, and transport ships left over from World War II, all empty now and lashed together in long gray lines, waiting for the next war.

In the shadow of the Ghost Fleet, the crew drops anchor — not a simple job on this kind of research cruise. Instead of one anchor, Pritchard wants four anchors put out, a technique that will nail the ship stiffly in place in one barely moving position in this ever-moving, tidal river. Once they get the boat well tethered to Pritchard's satisfaction, the crew begin hauling out a collection of tools, some of them adapted from deep-water oceanography, some of them newly designed by scientists and engineers that Pritchard has recruited for his new lab.

They know they're in for a busy day. Work life on these cruises is usually hectic for the first 48 hours: they have long watches to stand and 12 stations to hit along the river. When the cook announces lunch, Pritchard, still in Army mode, is heard to snap, "We didn't come out here to eat." He's on the hunt for his data.

Pritchard is mounting his attack on the physics of the Bay by collecting massive amounts of data from all over the estuary: up-Bay and down-Bay, upriver and downriver, along the western shore and the Eastern Shore, along the deeps and the shallows. In his first year-and-a-half on the job, he will run 10 Baywide cruises, making stops at 120 stations on average and sampling for dissolved oxygen, light levels, phosphates, pH — and especially for salinities and temperatures and currents. Nobody has ever collected so much data, much of it hard to measure, in so many places.

One of the odd tools the crew pulls out on deck is a $15 homemade current drag. Pritchard calls it a biplane but it looks more like a primitive paddle wheel with four plywood panels (see photo on p. 12). He uses it to measure currents by hoisting the whole contraption over the side of the boat. As his crew lowers his paddle wheel sideways into the river, they pause every five feet so they can note which way the current is pulling the drag. Pritchard can then measure the angle of the drag line and calculate the speed of the current at different depths. Near the surface, the current is usually pulling downriver. Near the bottom, it's usually pulling upriver.

The tides, of course, move up and down the river twice a day, so Pritchard has to subtract out the force of these flood tides and ebb tides. That calculation gives him the *net movement* at different depths of the river. Near the surface, the *net movement* is downriver. Near the bottom, it is upriver.

All his samples for temperature and salinity tell him something else: the water masses near the surface are very different from those near the bottom. The surface waters moving down the river are low-salinity freshwater. The bottom waters moving up the river are high salinity.

On trips like this, the work grows less hectic after the first two days, and the *Joan Bar II* sometimes makes one more stop, a swimming station, not a data station. Most of the crew members strip off their clothes and leap naked into the river.

Estuaries have a structure, Pritchard will soon write, a structure composed of two distinct layers. Along the surface is river water sliding seaward. Along the bottom is ocean water pushing up the estuary. In the Chesapeake Bay, the salty ocean layer is shifted towards the east side of the estuary, pushed there by the rotation of the earth. In any estuary, salinities are highest at the mouth and decline steadily towards the head of the estuary.

What Pritchard described accurately for the first time was the basic two-layer flow, the secret structure that dominates water movement throughout the tidal Chesapeake and its tributary estuaries. That is the simple core of his discovery. It is "the fundamental insight" says a contemporary oceanographer.

It's an insight based on measurements and mathematics. From all his data points, so painstakingly acquired, Pritchard worked out the basic equations of motion that describe the circulation of the James River and then scaled his equations to explain the circulation for the entire Chesapeake Bay. His model of estuarine physics applied well beyond the Bay: it helped define what an estuary is, and when he published his paper on "Estuarine Hydrography," it revolutionized ideas about estuaries around the world.

"Don Pritchard created a whole new

Don Pritchard (with pipe) *measures current speeds at different depths along the James River (opposite page). The crew lowers a $15 tool called a "biplane," and Pritchard records the angle of the line, numbers that will help reveal the two-layer flow of the estuary. Already a pipe smoker in his early twenties, Pritchard got his introduction to oceanography during World War II when he worked out forecasts for sea swells and surf conditions for the Normandy invasion (above). At left, Pritchard with a tank damaged during offloading.* PHOTOGRAPHS: COURTESY OF THE PRITCHARD FAMILY

***Harald Sverdrup, a renowned Norwegian** scientist and Arctic explorer, taught Pritchard and other American oceanographers to become meteorologists of the ocean by focusing on the movement of masses of water and the underwater "fronts" they cause. During WWII, Sverdup worked with Walter Munk to develop the surf forecasting technique that saved American lives during amphibious assaults. As director of the Scripps Institution of Oceanography, he founded the country's first professional graduate program in oceanography.*
PHOTOGRAPH: SCRIPPS INSTITUTION OF OCEANOGRAPHY

world for us when he revealed that estuaries have a typical circulation pattern," said Gene Cronin. "It had been going on for thousands of years, but he brought it to our attention. He had the tools, he invented some of them, to observe that process. To discover it."

Why was Pritchard the first to see the pattern? He brought the right tools to the job, but he brought something more: he brought the right *ideas*, the concepts that would let him look at the Chesapeake Bay in a way no one had ever tried before.

But where did he get those ideas? Don Pritchard went to college to be a chemical engineer, not an oceanographer.

When the Japanese bombed Pearl Harbor in 1941, he was a sophomore at the California Institute of Technology working through his required courses and playing quarterback on the JV football team. Cal Tech, of course, was noted not for football but for its science, engineering, and math courses, a fact that would change his life, but not in ways he expected. He expected to become starting quarterback on the varsity, graduate, get a job as a chemical engineer, and marry Thelma Alming, his high school girlfriend. That was the plan.

The outbreak of war brought a new plan: Pritchard decided to serve his country with his chemistry. When he volunteered to be an aerial photographic cadet, however, he learned that the Army had its own plans for Cal Tech students. It was setting up schools at UCLA and the University of Chicago, hoping to turn scientists into meteorologists who could forecast weather for air missions and amphibious landings. "They were looking for anybody with math and physics," said Pritchard. The Army accepted their volunteer and sent him to UCLA.

In his new school, Pritchard prepared for the Second World War by studying under Jacob Bjerknes, the Norwegian scientist who used the First World War to create some of the key concepts of modern meteorology. In the rainy port city of Bergen, Bjerknes worked at a research center during WWI where he collaborated with his father Wilhelm Bjerknes, the physicist who first began applying the principles and equations of fluid dynamics to understanding weather. To create their wartime forecasts, the father and son began collecting massive amounts of data from all over Norway. They set up a network of 75 weather stations that reported observations three times a day, and Jacob Bjerknes and his co-workers then drew up daily synoptic maps, creating large-scale pictures of regional weather conditions. The result was a breakthrough insight — and a new theory.

Weather events, he observed, seem to be driven by collisions of cold air masses with warm air masses. Jacob Bjerknes called these collision zones "fronts," comparing these battlefields in the sky to the front line clashes of World War I. He then developed a theory explaining how cold and warm fronts can interact to form cyclonic storm systems that rotate around low pressure centers. When he was 20 years old, Bjerknes spelled out his revolutionary ideas in an eight-page paper, and the Bergen School became the the launching pad for modern meteorology.

During World War II, Jacob Bjerknes would try to explain his ideas to Army soldiers at UCLA — but not always successfully. "Cadets would march in after lunch," said Robert Reid, a classmate with Pritchard, "and Bjerknes would turn off the lights and start showing slides." In his soft, soothing voice inflected with a Norwegian accent, Bjerknes would try to interest his audience in cold fronts, warm fronts, cyclonic storm patterns, and the math used to describe them. "When Bjerknes turned the lights on again," said Reid, "about half the students were asleep."

Pritchard, however, stayed awake long enough to finish near the top of his class. Out of 100 soldiers in his group, the Army picked Pritchard and Reid and about ten others and sent them south to the Scripps Institution of Oceanography in La Jolla, California. There they studied a secret new technique for forecasting sea swell and surf conditions during amphibious assaults. The would-be chemical engineer was on his way to becoming an oceanographer. His instructor would be yet another Norwegian scientist: Harald Sverdrup, the co-creator of the secret forecasting technique, the director of Scripps, and the most famous oceanographer of his era.

When Pritchard excelled again, this time in Sverdrup's classes, he was assigned to the forecasting team that would advise Dwight Eisenhower on when to launch the largest military landing in history — the Normandy invasion. Two days after D-Day, Pritchard landed on Omaha Beach and climbed up Pointe du Hoc, the bloody clifftop taken two days earlier by Army Rangers. There he got to play quarterback for the varsity, taking charge of Detachment YK of the 21st Weather Squadron, a team of two officers and up to six enlisted men.

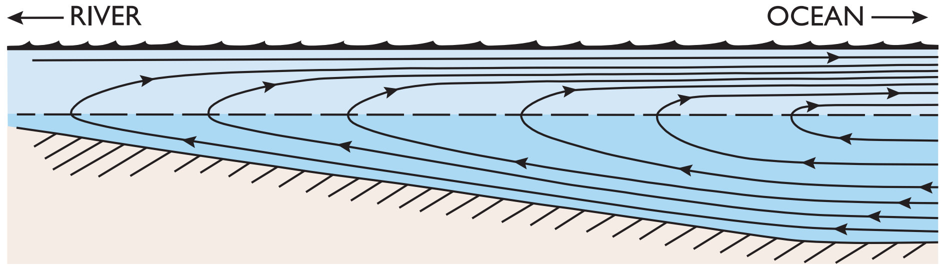
Don Pritchard was working at the hinge of history. For six months he and his squad operated out of tents, creating forecasts for waves, sea swells, and surf conditions as Allied ships offloaded troops, tanks, and artillery across the beaches. Forecasting waves, according to Reid, was still more an art than a science. Standing atop German bunkers, Pritchard and Reid would peer through binoculars, count waves, and try to estimate wave heights. Their forecasts helped the Allies turn the beaches of France into the doorway to Europe, enabling troops to head inland in force while the Germans kept thousands of soldiers tied up waiting to defend the port cities of France and the Netherlands.

After the war, Pritchard found himself present at another hinge point: the creation of modern American oceanography. Recruited back to Scripps by Harald Sverdrup, he joined the country's first graduate program in oceanography, a program encouraged and supported by a U.S. Navy now eager to expand America's edge in ocean sciences. At Scripps, Pritchard studied with a number of former "weather warriors" also recruited by Sverdrup. As graduates from his new program, they would soon be called Sverdrup's "apostles" as they began creating and staffing new departments of oceanography at universities around the country.

Sverdrup, who had studied meteorology with both Wilhelm and Jacob Bjerknes, had good reason to think weather warriors would make excellent oceanographers. "What Sverdrup did was to take the model of meteorology that he learned from Bjerknes and apply it to the oceans," says Naomi Oreskes, a science historian at the University of California, San Diego. "Sverdrup thinks about the oceans in terms of the movement of masses of water in the same way that Bjerknes trained him to think about the movement of masses of air."

Bjerknes trained Sverdrup, and both trained Pritchard. By the time he arrived at Johns Hopkins, Pritchard was well primed to go hunting for whatever hidden water masses could be at work in the Chesapeake Bay.

There is a weather under the ocean and the estuary, and it's the job of oceanographers to figure it out. That was the way Pritchard went about looking at the Bay when he arrived at Johns Hopkins and that's the way he trained the new oceanographers who worked with him there. "We are sort of the meteorologists of the ocean," says Bill Boicourt, a Pritchard protégé who is now a research professor at the Horn Point Laboratory of the University of Maryland Center for Environmental Science.



"It is possible to establish a picture *of the circulation pattern," wrote Don Pritchard in 1951. And this is his picture: Freshwater flows into the estuary from rivers and moves seaward. It slides atop a lower layer of heavier, salty ocean water pushing in from the mouth of the estuary. The dotted line marks the boundary between the two layers, the point of no net motion. The curving lines show the transfer of salty water into the river water above, the mixing that creates a brackish water estuary.* GRAPHIC SOURCE: CHESAPEAKE BAY INSTITUTE

An oceanographer reads a weather made up of water masses, sliding above or below or bumping against each other, often mixing in various ways, the result of winds and tides, salinities and temperatures, and topography. And this weather features fronts of all kinds including upwelling fronts, lateral fronts, and plume fronts at the mouths of major rivers. Figuring out the physics of all these forces would keep Pritchard busy for decades and leave plenty to do for oceanographers who followed him, most of whom went to work expanding and revising and critiquing Pritchard's basic model.

Oceanographers would eventually identify estuarine features like turbidity maximum zones, eddies, internal waves, lee waves, hydraulic control points, vertical mixing, stratification, and anoxic zones — features that can move fish, fish larvae, and fish food, creating biological hot spots in some areas and deserts in others.

And Pritchard, mindful that he was hired to clarify the ups and downs in fish harvests, began lecturing biologists about how physics affects fish. Oyster larvae spawned in the lower reaches of the James River, he wrote, are able to reach the upstream seed beds by hitching a ride along the saltier, low-level ocean waters that were surging upstream. Early stage croaker spawned in the ocean can move up the Bay by hitching a ride on the same train. If they stay 20 feet down, he said, they can move 130 miles up the Bay in only 20 days. Blue crab larvae, on the other hand, could be heading in the opposite direction. Spawned near the mouth of the Bay, they could be washing out to sea on surface waters.

It became quickly clear to biologists that the life cycle of nearly every major fish species in the Chesapeake was shaped in some way by the physics of all this underwater weather. "In terms of understanding how the Bay works," said Gordon "Reds" Wolman of Johns Hopkins, "Don Pritchard's physical model was absolutely essential."

Pritchard's science would last but his new lab would not. The Chesapeake Bay Institute (CBI) that he led was, in essence, the creation of the U.S. Navy, and that connection, though hugely profitable at first, would eventually help sink the lab.

The lab began with a 1947 proposal by the Office of Naval Research (ONR): the Navy would help fund a new research center to study the hydrography of the entire Chesapeake Bay — but Maryland and Virginia had to chip in matching monies. That deal gave Don Pritchard the kind of core funding seldom seen today. He could set up a lab, rent some boats, hire scientists and technicians, and launch the most ambitious research forays yet attempted on the Bay. And he could put his new lab in the middle of a fast-growing funding stream. American oceanography was entering a golden age fueled for nearly two decades by the U.S. Navy and by the new National Science Foundation.

The result was an outburst of exploration both in the Bay and in nearby

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coastal waters. "Ship time was unlimited," says Bill Boicourt. And so were research funds. "I spent about $150,000 by myself as a student," he says, "not even realizing where the money came from." While still a graduate student he could ask for and get the money and boat time and authority to lead six-week cruises out along the waters of the continental shelf.

There was a method behind this mad rush to explore, says Jerry Schubel, a student of Pritchard who is now director of the Aquarium of the Pacific. "Don's approach to science was that you picked problems that were interesting and important and that you asked good questions," says Schubel. "If you had an idea and needed a few days of ship time to test it out, you had it."

The rationale for the Navy was national defense: it wanted a physical and chemical profile of the Chesapeake. The result, however, was an in-depth analysis of a shallow-water estuary, the kind of basic research that Maryland and Virginia had never been able to fund. Under Pritchard the lab also did plenty of applied research. State agencies wanted to know where to place dredge spoils from shipping channels. The Atomic Energy Commission wanted to know where to place nuclear power plants.

The funding stream was strong enough to erect on the Johns Hopkins campus a new building jointly paid for by the Office of Naval Research, the National Science Foundation, and the

***Don Pritchard adapted the tools** of oceanography to the study of estuaries. He also invented new tools for data gathering.* PHOTOGRAPH: COURTESY OF THE PRITCHARD FAMILY

Atomic Energy Commission, a building designed to house the Department of Oceanography and the Chesapeake Bay Institute.

The day in 1964 when the new McAuley Hall opened may have been the high tide point for Pritchard's lab. In one of the ironies of history, military connections that were a bonus during the post-World War II era soon became a liability during the Vietnam War era. "Receiving support from any part of the defense department was controversial, especially with students," says Schubel. "If you did semi-classified research, as we did with the Navy and the Atomic Energy Commission, you were looked at with great scrutiny."

There were other apparent liabilities. "The fact that CBI did applied research was looked down upon by some of the more academic departments," says Schubel. Pritchard's Department of Oceanography would be absorbed into a larger department. His Chesapeake Bay Institute would be moved out of the building and eventually relocated off campus. The Navy affiliation would end.

Academic wars, according to witnesses, can leave some bitterness. And this one did. At the height of the conflict, Don Pritchard withdrew as director to recover from cancer. Jerry Schubel, associate director under Pritchard, left in 1974 to lead a new marine research center at what is now Stony Brook University, on Long Island. "At the end," said Schubel, "it was not very much fun being at Johns Hopkins."

When Pritchard recovered from cancer, he also left for Stony Brook to be its associate director and play a major role in building another major marine research center, this one focused on Long Island Sound.

In 1992, Johns Hopkins University closed its research center focused on Chesapeake Bay. The people were gone, but a research record remained. "The Chesapeake Bay Institute had a greater impact on our understanding of estuaries than any organization anywhere," says Schubel. "And the person largely responsible for that was Don Pritchard."

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