

The complex case of Chesapeake Bay restoration

Amid encouraging signs, researchers and activists are struggling to make progress in the face of agricultural inputs, climate change, and relentless development.

John Carey, Science Writer

On a warm October day, six researchers ventured out to a reef in Baines Creek, a tributary of Virginia's Elizabeth River. Back in 2014, the Army Corps of Engineers had dumped tons of fossil oyster shells into the water in the hopes of attracting more of one of the key inhabitants of the Chesapeake Bay—oysters. Now the researchers, wearing masks and socially distancing as they waded through the water at low tide, are measuring the progress.

What they are finding is just astounding, says Romuald Lipcius, professor of fisheries science at the Virginia Institute of Marine Science (VIMS) at Gloucester Point, and also the School of Marine Science at William & Mary University. The team counts hundreds of oysters growing on each square meter of reef. Some oysters had reached the ripe old age of five, once considered unachievable

because of diseases that had been introduced into the Bay; oysters' fecundity increases exponentially with size and age. "All these oysters peeking above the water is a beautiful sight," says William & Mary professor of geology Rowan Lockwood, who studies fossil oysters. "It is a glimpse of what the Bay was like 6,000 years ago." And maybe, what it could be like again.

But that ideal future is still a long shot. A couple of weeks after Lipcius plumbed the depths of Baines Creek, Matt Pluta piloted his small boat through a dense fog on the Choptank River, which flows into the Bay from Delaware and Maryland's Eastern Shore. Director of Riverkeeper Programs at ShoreRivers, based in Easton, MD, Pluta is making his last sampling run of 2020, working alone because of the pandemic. Over the past few years, the levels of nutrient pollution in the



Numerous tributaries feed into the Chesapeake Bay, such as the Severn River near Annapolis, MD. They enhance the beauty of the Bay's watershed—they also shuttle pollutants that imperil the Bay's ecosystems. Image credit: Shutterstock/Ladinn.

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VIMS researchers Lipcius (Right) and Rochelle Seitz sample oysters from the restored Felgates Creek reef in Virginia's York River. Large older oysters, like those pictured, produce far more larvae than smaller ones, making them crucial for restoration. Image credit: Susanne Coates (photographer).

Choptank had climbed. And now Pluta is disappointed by the murkiness of the dark waters. "This is the time of year when we usually start to see the bottom again," he says, "but we don't have that excitement this year."

That murkiness is a telltale sign of the nitrogen, phosphorus, sediment, and other pollutants that have tainted the Bay and its tributaries for decades. The sediment smothers oysters that settle on the estuary bottom and blocks the sun from reaching struggling seagrasses. The nutrients fuel algal blooms, including toxic red and brown tides, and when the algae decompose, bacteria consume oxygen in the water, creating "dead zones" that choke fish, crabs, and other creatures. Recent high-tech round-the-clock monitoring revealed a nasty surprise: Oxygen levels in shallow waters unexpectedly drop from safe during the day to dangerously low at night, flipping a biochemical switch that sends nutrient pollution that had been bound in bottom sediments squirting into the water column to worsen the problems.

And so, 37 years into an ambitious effort to save the vast Chesapeake Bay ecosystem, the results are a "mixed bag—but encouraging," says Lipcius. There is some optimism, thanks to decades of water treatment plant upgrades that have reduced sewage flowing into the Bay despite huge increases in wastewater flow. The once-enormous dead zones have shrunk. The water is a little less murky. Seagrass, which improves habitats for many other species, has rebounded somewhat. In Baines Creek and a few other spots, three-dimensional oyster reefs, like those that once stretched across the entire Bay, are thriving. Dolphins have returned. "In some respects, things are changing for the better," says Chris Patrick, director of VIMS' submerged aquatic vegetation program.

But not in others, and the improvements are too little and too slow, many say. The Chesapeake Bay is the "best studied estuary in the world," with up to 10 million data points collected every year, notes William Dennison, who oversees the main monitoring program as vice president for science applications at the University of Maryland Center for Environmental Science (UMCES) (1). Those data clearly show that the massive

nutrient and sediment reduction effort, which now includes six states, the federal Environmental Protection Agency (EPA), and the District of Columbia, has failed to reach the goals for improving crucial parameters, such as increasing dissolved oxygen or reducing nitrogen and phosphorus, and will fall short of 2025 mandated reductions set by the EPA.

In just two of many indicators of health, there are only enough oysters to filter the water about once every 300 days, compared with once every three days in presettlement times; after years of expansion, the total area of seagrasses plunged 39% in 2019. "It's grim," says Gerald Winegrad, who helped launch the effort to save the Bay as a Maryland state senator back in 1983. "I have the least hope than I've ever had in my lifetime for restoring the Bay."

Activists like Winegrad, an attorney and former adjunct professor at the University of Maryland, College Park, are generally more pessimistic than most of the researchers who study the Bay. But there is widespread agreement that the results have been disappointing—and there's no mystery about why. Nitrogen, phosphorus, and sediment continue to pour into the Bay from farmland and vast chicken-rearing operations on the Delmarva Peninsula, from dairy farms and cornfields in Pennsylvania and other states, from urban streets and suburban lawns, and from countless other agricultural operations.

Classic Confrontation

At the most basic, the story of the Bay is a classic clash between short-term commercial interests and long-term ecological—and even economic—health. Politically powerful watermen have successfully resisted oyster sanctuaries or moratoriums that would allow bivalve populations to rebound while improving both water quality and future harvests; some even rush to poach oysters on restored reefs. Farmers, the poultry industry, and developers, worried about expenses, have sometimes been reluctant to adopt, or have resisted, measures such as stream buffers or stormwater containment systems that cost money now but bring long-term improvements. Meanwhile, there's widespread agreement that many current regulatory requirements and incentive programs, such as requiring or paying for winter cover crops that reduce nutrient runoff, are less effective than they could be—because they're voluntary and often lack sufficient inspections and oversight.

These problems have spawned at least two responses. One is a small army of activists suing polluters and lax government regulators, challenging permits, trying to enforce zoning restrictions, and more. Patuxent Riverkeeper Fred Tutman and fellow activists, for example, have won numerous legal battles, including pressuring Maryland to tighten its stormwater regulations. "Believe me, we are in a street fight," says Tutman—once literally, when Tutman brawled with a poultry farmer outside a bar in Salisbury, MD.

A second is an effort to harness precise data about potential trouble spots, such as high-resolution imagery to pinpoint streams without protective forested buffers or drainage systems that dump runoff from fields

directly into rivers. "It's hard to understate how transformative this data set is," says Jeff Allenby, cofounder of the Chesapeake Conservancy's Conservation Innovation Center in Annapolis, MD. The idea is to work with farmers or local governments to target these hot-spots, for example creating buffers or installing "bio-reactors" (typically trenches filled with wood chips where microbes reduce nitrites and nitrates to gaseous nitrogen) to prevent nutrient pollution from reaching the waterways. This "precision conservation" approach has seen "a real coming of maturity in the last year," says Carly Dean, a project manager at the Chesapeake Conservancy, which has identified about 800 properties in Pennsylvania where restoration measures could bring major improvements in water quality—and which has begun a handful of projects.

The unanswered question, though, is whether these efforts will be enough to accelerate restoration of a sprawling bay that has more than 11,000 miles of shoreline and a watershed that is home to more than 18 million people. "It is important to remember that we are looking at two centuries of environmental insults, especially the ramp up of chemical fertilizers and expansive growth in development after World War II," says Nick DiPasquale, director of EPA's Chesapeake Bay Program Office from 2011 to 2017.

Progress and Regress

By the early 1970s, the Bay ecosystem was in obvious distress, with growing dead zones and declining harvests of crabs, oysters, and fish. State and federal governments started to take notice. A key turning point came in December 1983, when Maryland Governor Harry Hughes forged a one-page agreement with three states—Maryland, Virginia, and Pennsylvania—the District of Columbia, the EPA, and the Chesapeake Bay Commission to develop a plan to tackle the growing problems.

The first big step, starting in the 1990s and continuing in the 2000s, was improving sewage treatment. Maryland and Virginia, for example (but not Pennsylvania), moved to "enhanced nutrient removal" (ENR) technology, which adds filters laden with microorganisms to cut the discharge of nitrogen to less than three milligrams per liter and phosphorus to under one mg, says DiPasquale. That effort "has been the singular phenomenal success of the Bay program," says Winegrad, cutting nutrient pollution from wastewater by up to 50%—even as the population in the watershed grew. Moreover, emissions reductions from power plants and cars have reduced the substantial amounts of nitrogen pollution wafting into the Bay from the air by at least 50% since 1985.

The reduced nutrient pollution from sewage and air deposition then brought one swift and encouraging biological response: "The seagrass explodes," says Patrick. That kicks off a cascade of positive effects. The bed of plants traps sediment and causes suspended particles to settle, allowing more light to penetrate, further boosting growth. The grasses also grab dissolved nitrogen and phosphorus from the water and provide forage, shelter, and habitat for a wide variety of



VIMS ecologist Chris Patrick samples eelgrass in the York River. His team collects and plants seagrass seeds to help restore the Bay's underwater vegetation. Image credit: Susanne Coates (photographer).

species. "Seagrasses are a fantastic indicator of water quality," says Patrick. By 2000, what Dennison calls an "amazing" recovery of seagrass in an area known as the Susquehanna Flats had begun, aided by a drought year that further reduced nutrient pollution flowing into the watershed.

Flying over the Bay to measure the overall extent of seagrass, researchers documented a remarkable 316% increase between 1984 and 2015, from about 7,900 hectares to nearly 29,000 hectares, as reported in a 2018 article in PNAS (2). "When the PNAS paper came out, everyone was celebrating this amazing success story," says Patrick. "Then 2019 happened."

Record rainfalls in 2018 swept immense amounts of sediment and nutrients into the Bay, and the total area of seagrass plunged by 38% according to a 2019 survey. At the same time, warmer water temperatures caused by climate change have begun to wipe out the once-dominant species, eelgrass, which is being replaced by another species, widgeon grass, with as yet unknown ecological consequences. Still, despite the setbacks of 2019, the overall health of the Bay is "heading in the right direction," argues Patrick. "I'm not ready yet to throw in the towel and say we've failed."

Oyster restoration offers another cautiously optimistic story. The conventional scientific wisdom in early 2000s was that efforts were doomed to "continued failure," as a 2007 article reported, because newly settled oysters would be smothered by sediment or felled by disease (3). But even then, there were hints that the scientific establishment was wrong, says Lipcius.

Back in 2005, Lipcius dove into the Rappahannock River to investigate an artificial reef built, using concrete from a bridge replacement project, by an eccentric retired naval engineer known as Capt'n Bob Jensen. Lipcius estimated that millions of oysters had settled on the structures, some up to seven years old (4). Meanwhile, the Army Corps of Engineers also had begun building three-dimensional reefs using piles of fossil oyster shells or lumps of concrete or granite. Those too were thriving, Lipcius found, especially in areas closed to harvesting because of bacteria in the river or where



To restore oyster reefs, researchers dump three-dimensional structures into the water, such as piles of oyster shells, lumps of granite, or these concrete "castles." Image credit: Susanne Coates (photographer).

the concrete or rock reef discouraged poaching by damaging oyster dredges (5). Now his team is starting to work with the Navy to restore oysters in a section of the York River also unlikely to be poached.

In addition, Lipcius and others have documented a few natural relict reefs where oysters have survived for decades despite overharvesting and poor water quality, evolving to cope with the diseases. "The relict reefs and artificial reefs are telling us without a doubt that oyster restoration can succeed," says Lipcius. Because oysters are ecosystem engineers, both filtering the water and providing crucial habitat, that would be good news for the Bay—especially if there were the political will for additional measures such as more oyster sanctuaries. "I have always believed that we know how to restore the oysters; we are just choosing not to," says Lockwood.

Serious Threats

These successes, though, pale in comparison with the threats facing the Bay. Researchers and activists both say that the Chesapeake Bay Program and the states are still failing to tackle the big remaining problems: sediment and nutrient pollution from agriculture and stormwater runoff.

According to Winegrad, the original 1983 agreement and updates in 1987 and 2000, when Delaware, New York, and West Virginia officially signed onto the water quality goals, had a serious flaw: The goals were voluntary. Then, even though a lawsuit and court action forced mandatory limits for so-called total maximum daily loads (TMDLs) for pollutants, the EPA hasn't held any of the jurisdictions accountable for meeting those limits. Pennsylvania, in particular, has historically been "a problem," says DiPasquale. "They haven't pushed hard on wastewater treatment, on stormwater, or on agriculture—and EPA fell down on the job of holding their feet to the fire."

Pennsylvania's Department of Environmental Protection (DEP) acknowledges that the state has not met EPA's requirements to reduce water pollution (6), and

in a statement, DEP Secretary Patrick McDonnell faulted a past approach that "didn't achieve significant buy-in from local partners." But now, eight counties responsible for the largest nutrient and sediment pollution have plans in place to reduce pollution, he says, and "Pennsylvania is at an unprecedented turning point in improving the health of the watershed."

In Maryland, both the regulations and actual monitoring of the rules are inadequate, argues Kathy Phillips, Assateague Coastkeeper and executive director of the Assateague Coastal Trust, headquartered in Berlin, MD, which has repeatedly sued the Maryland Department of the Environment (MDE) for not sufficiently overseeing the massive poultry farms on the Delmarva Peninsula. Those operations raise more than 600 million chickens a year for agricultural giants such as Perdue Farms and Tyson Foods and add millions of pounds of nitrogen to the Bay from manure and ammonia (7, 8)—yet each one gets inspected only about once every five years, and the ammonia that wafts into the air and then is deposited in the water has been completely unregulated. "These are business models that are toxic not just to the water and the air but the local economy as well," charges Tutman, referring to low wages they pay and the flow of dollars into corporate coffers. In March, Phillips and the Chesapeake Legal Alliance won a major lawsuit when a Maryland court ruled that MDE must begin to regulate the ammonia, which has been linked to health issues as well (9, 10).

Still, regulators and farmers in Maryland insist that they are working hard to improve the health of the Bay. "The Maryland Department of the Environment is steadfast in its commitment to inspecting facilities and taking appropriate actions to ensure compliance with environmental laws and regulations," MDE Secretary Ben Grumbles notes in a statement. And Andrew McLean, who raises 850,000 organic chickens a year for Coleman Natural Foods, a division of Perdue, says that farmers have come a long way compared with 20 to 30 years ago. "Now we understand that having too many nutrients is a problem," he says, adding that the amount of poultry manure spread on fields has dropped from more than 15 tons an acre in the 1990s to 2 to 3 tons per acre today.

Drastic Measures

But even precisely assessing progress can be a big challenge. Farmers get credit (or are paid) for implementing practices based on the size of effort, such as the number of hectares planted in winter cover crops. Yet obviously, a field planted in winter wheat or rye along a stream is far more effective at capturing nutrients and preventing runoff than the same number of hectares in cover crops far from any watercourse. "There is a lack of accountability for performance," says Don Boesch, professor of marine science and former president of UMCES.

In addition, the Chesapeake Bay Program measures progress by using estimates of nutrient reductions that are based on the effort devoted to pollution control practices, not on the empirical results. That's

causing some estimated reductions to be overstated, according to a study published in May 2020 by US Geological Survey hydrologist Scott Ator and colleagues, which sent ripples of alarm through the scientific community (11, 12). By using a model based on actual monitoring data, the researchers showed that nitrogen pollution from agriculture barely declined, if at all, between the early 1990s and early 2010s, compared with the double-digit percentage decrease predicted by the management model.

There is some encouraging news. Researchers and activists laud the state of Virginia for increasing funding for a program paying farmers to install fencing along streams to keep cattle out, which cuts the amounts of sediment and nutrient pollution ultimately reaching the Bay (13). Nascent precision conservation pilot projects have installed bioreactors, forested buffers, and other control measures in a few dozen places on the Eastern Shore and in Pennsylvania, which can bring the added benefit of improving habitat for native trout. Because many fields on the Delmarva Peninsula are already saturated with phosphorus after years of using poultry manure as fertilizer, there's growing interest in collecting and transporting the manure to farms elsewhere, such as former tobacco fields in Maryland or mushroom farms in Pennsylvania, to replace chemical fertilizers. And President Joe Biden is expected to be much more supportive of Bay restoration than his predecessor, who repeatedly tried to gut the entire program.

There is also hope for less confrontation and more cooperation. Instead of pointing fingers at farmers as the culprits, "what we are finding more effective is to work with them to address our shared goals," says

Choptank Riverkeeper Pluta. "We all want to maintain the rural, agricultural Eastern Shore, if we can lessen its impact on rivers." Indeed, UMCES is now planning to include economic and social data in its official Bay report card, recognizing that a thriving, sustainable farm economy is part of the solution. And some chicken farmers, like McLean, regularly meet with researchers and environmental activists. "As long as we can find groups of people who want to solve the problem, and not just fundraise, we can work towards solutions," McLean says.

That's not easy, though, and the toughest challenges lie ahead. Now that the upgraded sewage treatment plants have successfully eliminated the biggest point sources of pollution in most states, continued progress depends on tackling the non-point sources with countless small efforts. That includes trees planted on stream banks, farm drainage systems diverted into cleansing wetlands instead of dumping directly into ditches and creeks, more winter cover crops, no more dumping of chicken excrement on phosphorus-saturated fields, and hundreds of thousands of rain barrels to stop rains from pushing nutrients along the pavement and into streams.

"Any rehabilitation will take decades," cautions Scott Phillips, Chesapeake Bay Coordinator for the US Geological Survey. "And I hesitate to use the word 'restore' since the goal is to improve conditions, but we will never completely restore the Bay." Nevertheless, with the combined efforts of scores of researchers and activists, along with a more supportive EPA, the oysters, seagrasses, and countless other denizens of the Bay may have a more promising future.

- 1 University of Maryland Center for Environmental Science, Chesapeake Bay Watershed report card. <https://ecoreportcard.org/report-cards/chesapeake-bay/>. Accessed 19 February 2021.
- 2 J. S. Lefcheck et al., Long-term nutrient reductions lead to the unprecedented recovery of a temperate coastal region. *Proc. Natl. Acad. Sci. U.S.A.* **115**, 3658–3662 (2018).
- 3 R. L. Mann, E. N. Powell, Why oyster restoration goals in the Chesapeake Bay are not and probably cannot be achieved. *J. Shellfish Res.* **26**, 905–917 (2007).
- 4 M. Boorstein, Reef dream awakens interest. *The Washington Post* (26 June 2005). <https://www.washingtonpost.com/archive/local/2005/06/26/reef-dream-awakens-interest/35d0ea89-5c83-4360-a93e-197d091b501a/>. Accessed 6 March 2021.
- 5 D. M. Schulte, R. P. Burke, R. N. Lipcius, Unprecedented restoration of a native oyster metapopulation. *Science* **325**, 1124–1128 (2009).
- 6 Pennsylvania Department of Environmental Protection, Pennsylvania's Chesapeake Bay Watershed: What's new. <https://www.dep.pa.gov/Business/Water/Pennsylvania's%20Chesapeake%20Bay%20Program%20Office/Pages/default.aspx> Accessed 5 March 2021.
- 7 Environmental Integrity Project, Poultry Industry Pollution in the Chesapeake Region (22 April 2020). <https://environmentalintegrity.org/reports/poultry-industry-pollution-in-the-chesapeake-region/>. Accessed 3 June 2021.
- 8 Environmental Integrity Project, Poultry and Manure Production on Virginia's Eastern Shore (22 April 2020). <https://environmentalintegrity.org/reports/poultry-and-manure-production-on-virginias-eastern-shore/>. Accessed 3 June 2021.
- 9 C. Condon, Court decision will require Maryland to regulate gaseous ammonia emissions from poultry farms. *Baltimore Sun* (2021). <https://www.baltimoresun.com/news/environment/bs-md-court-decision-gaseous-ammonia-emissions-poultry-farms-eastern-shore-20210316-lplqea7l6jgj3e3h6zpoevjvpy-story.html> Accessed 18 March 2021.
- 10 N. M. Poulsen et al., High-density poultry operations and community-acquired pneumonia in Pennsylvania. *Environ. Epidemiol.* **2**, e013 (2018).
- 11 S. W. Ator, J. D. Blomquist, J. S. Webber, J. G. Chanat, Factors driving nutrient trends in streams of the Chesapeake Bay watershed. *J. Environ. Qual.* **49**, 812–834 (2020).
- 12 D. F. Boesch, It's time to match cleanup assumptions with results, not give up. *Bay Journal* (21 October 2020). https://www.bayjournal.com/opinion/forum/it-s-time-to-match-cleanup-assumptions-with-results-not-give-up/article_8c5bbeda-0efb-11eb-9c8f-e3afbe8a7a01.html. Accessed 5 March 2021.
- 13 J. Wetzler, More funding coming for livestock fencing. *Daily News-Record* (21 December 2020). https://www.dnronline.com/news/local/more-funding-coming-for-livestock-fencing/article_8742f91f-36f3-5f14-9bad-0bc52dc052b7.html. Accessed 2 March 2021.