Exploring Solutions to Excess Nutrients: Restoring Cape Cod's Waters

United States Environmental Protection Agency

Bulletin 4: Fall 2022

Welcome to our fourth bulletin on the Environmental Protection Agency's research to address excess nutrient loading in Cape Cod's waters. This is an update for interested community members. The team includes EPA scientists based in the Office of Research and Development, the EPA Region 1 office in Boston, Mass., and many external research partners and stakeholders.

We have been working with our partners for the past four years to pilot and evaluate nitrogen reduction approaches that could ultimately be used to develop a watershed-level plan to reduce nutrient loading in the Three Bays Watershed of Cape Cod, Mass., where nitrogen (usually in the form of nitrate) is the main nutrient of concern.

In 2022, EPA and partners continued their experiments in the field and worked to publish their results, as the official pilot stage of the project came to an end at the end of September 2022. Many aspects of this project will continue in the next phase of EPA research to monitor experimental nutrient reduction efforts and maintain relationships with key stakeholders in the region. Updates moving forward will include partner calls and focused bulletins as appropriate.

This issue of the bulletin provides updates since the end of 2021 on our efforts to tackle the nutrient loading challenges with our stakeholders in the Three Bays Watershed. This year, the team evaluated a variety of ways to monitor nutrients and water quality, shared results widely, and continued work to evaluate possible scalable solutions to this challenge. These activities are summarized in the Project Updates section below. Our Deeper Dive section explains an innovative method for monitoring seafloor conditions, and our Scientist Spotlight features EPA scientist Kate Mulvaney, Ph.D.

Map of the Three Bays Watershed

Letter from the Lab

Here, we share a few words from Dr. Timothy Gleason, the science lead of this project at EPA.

Welcome to the fourth bulletin for the Nutrients Solutions-Driven Research (SDR) Pilot. In the prior bulletins we have described the importance of partnerships and collaboration, as well as what makes SDR unique (the focus on solving an important problem). As you'll see in the updates that follow, we continue to make progress across our social and biophysical research elements.

We are particularly excited to have the enhanced septic system demonstration pilot underway. This pilot study embodies the partnerships, collaboration, and research approach needed to solve an important problem. Roughly 80 percent of the controllable nitrogen entering coastal embayments on Cape Cod comes from septic systems. We now have 13 enhanced septic systems installed in a dense neighborhood near Shubael Pond by our partners at the Barnstable Clean Water Coalition (BCWC). Our

partners from the Massachusetts Alternative Septic System Test Center (MASSTC) will monitor individual septic system performance and nitrogen reduction monthly for three years. With our partners from the U.S. Geological Survey (USGS), we will monitor groundwater nitrogen to evaluate the impact that these systems have on nitrogen levels in the groundwater. Our social science team has worked with homeowners to better understand what matters most when considering whether or not to adopt these technologies and is in the process of publishing those findings.

We look forward to continuing to build partnerships and collaborations to evaluate promising technologies and approaches for solving the nutrients problems on the Cape and across the nation.
Thank you for your attention and interest.

— Dr. Timothy Gleason

Project Updates

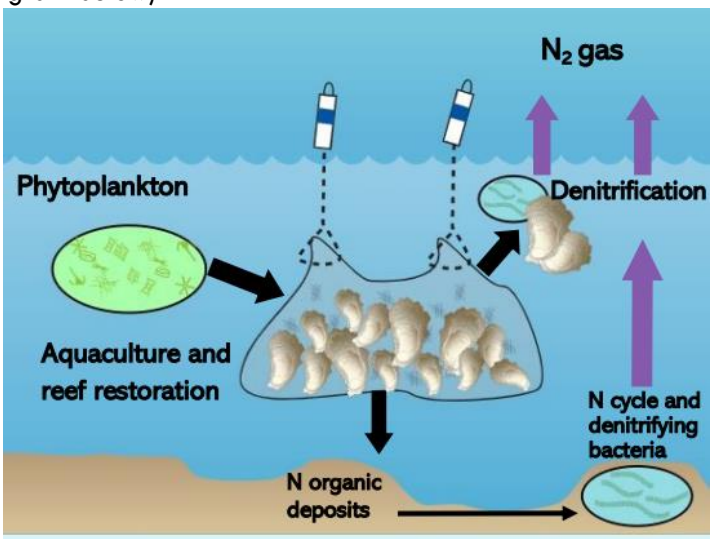
Here's a snapshot of what the research team has been working on since the end of 2021:

Aquaculture

The aquaculture team includes participants from EPA's Region 1 and Office of Research and Development, as well as multiple contractors. Their 2022 field season included continuing the past year's bimonthly water sample collection from Potter's Pond, R.I. They are continuing to identify additional sites for monitoring water clarity. During the pilot study from 2019 to 2022, our studies found that oysters can contribute to improved water quality through water clarity and reducing nitrogen loads in the water. This occurs when oysters filter algae and convert nitrogen into oyster growth, which is then removed when oysters are harvested (bioextraction). Oysters further contribute to reduced nitrogen loads via denitrification when the bacteria associated with oyster reefs and aquaculture convert oyster waste products to nitrogen gas (see the diagram below).

For further description of the denitrification process, see our team's infographic on how shellfish can improve water quality. It aims to be useful for shellfish farmers in explaining the environmental benefits of shellfish.

Oysters alone won't solve Cape Cod's water quality issues, but they can help improve water quality in coastal embayments. Future research will evaluate how oyster aquaculture may positively impact the abundance and restoration of seagrass. Restoration of seagrass would further improve water quality, habitat for other marine organisms, and can also increase the carbon stored in sediments (blue carbon). In exciting news, our team received funding to collaborate with seagrass experts in EPA Region 1 to describe the role of oyster aquaculture for enhancing seagrass beds and improving the ecosystem services they provide.



Simplified diagram of the influence of shellfish on the conversion of nitrate to nitrogen gas, or denitrification.
Graphic adapted from images from Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/imagelibrary/)

Benthic conditions research

Benthic, or seafloor, conditions are an important indicator of ecosystem health. Benthic habitats in many Cape Cod estuaries have been negatively impacted by excess nitrogen loading for decades. Details of the innovative methods used in this work are discussed in the Deeper Dive section of this bulletin.

Data collection on benthic conditions occurred largely in 2019. Over the past three years, researchers have been preparing results of this work. A summary of benthic conditions in the Three Bays estuary, as of 2019, is now

published. The report compares recent habitat conditions to those encountered during a prior survey conducted in the early 2000s as part of the Massachusetts Estuaries Project. Results indicate similar or worse conditions for marine life at revisited stations. Details for additional randomized stations and measures included in the survey are available at EPA's Environmental Dataset Gateway. Data are also available at the National Water Quality Monitoring Council's Water Quality Portal.

Reuse of dredged sediments

The wetland team has two projects associated with nutrients management on Cape Cod. The first project is a wetland study. The team developed a model to simulate nitrate concentrations in each of the layers of a constructed freshwater wetland in the greenhouse of the EPA Narragansett (R.I.) lab. This constructed wetland had an excavated layer of dredged Mill Pond (Wareham, Mass.) sediments sandwiched between sand layers. This study showed rapid removal of nitrate in the upper sand layer, removing roughly 86 percent of the added nitrogen. This experiment helps support the intentional application of sediments to wetlands to reduce nitrogen loading in wetlands.

The second project is a collaboration among state, local, and federal partners. This recently published work reports on a dredged sediment placement project, examining the responses of plants, fish, birds, and sediment chemistry to the placement of dredged, sandy sediments on a drowning salt marsh in Ninigret, R.I. The added sediment successfully increased elevation and soil drainage, while die-off marsh areas were reduced. Much of the marsh vegetation was re-established within a few years, with little or no effect on the fish and birds. Great news for Ninigret!

Recreational benefits of improved water quality

Since 2016, social scientists at EPA have been studying how water quality on Cape Cod affects visitation to coastal areas and the value of recreation in coastal waters. This work has been moving through publication processes and is now more available for public viewing!

The team's work estimating the benefits of improvements in surface water recreation found that coastal and estuary water quality improvements provide a benefit to the public. Based on their estimates, a typical trip for coastal recreation in the region is worth $26-$28. The team also found that changes in clarity and bacterial conditions affected trip values, with a $4-$5 change for a meter in reduced clarity measured with remote-sensing, and $0.13 for a one-unit change in bacteria loads, measured using most probable number (MPN) statistical growth estimates and colony-forming units (CFU). These results can be used to estimate the social value of common coastal water quality improving policies, such as stormwater and wastewater management. The study is demonstrated using scenarios for Cape Cod's estuaries as well as Narragansett Bay.

Pond at Hamblin Bogs in Marstons Mills, MA, where restoration in being planned.

Work on estimating visitation to beaches on Cape Cod using cellular device location datasets provided high-resolution, daily visitation information for coastal areas. The methods the social science team developed can detect the impact of beach closures on visitation when compared to what a typical day of visitors would have looked like. These researchers found Cape Cod's waters to be relatively clean, and that there was only a minor visitation impact due to bacteria closures for the Cape. Only 1800 visits, or .026 percent of all beach trips to the Cape over the season were affected by bacteria closures. Additional products from this work can be accessed on EPA's Human Dimensions of Water Quality Research webpage.

Cranberry bogs

Cranberry bogs are an iconic part of the Cape Cod landscape and provide an opportunity for addressing excess nutrients. Researchers are conducting experiments on how to manage nutrients on operating bogs and on retired

sites. This involves a broad team of partners across the region. The restoration design team has begun work (engineering and permitting) under contract at Hamblin Bogs in land purchased by Barnstable Clean Water Coalition (BCWC) currently on pause pending some stakeholder agreements. Partners at EPA and U.S. Geological Survey (USGS) continue to monitor discharge and nitrate at the bog system outflow to develop a record of water quality before restoration against which to assess how restoration impacts nutrient levels.

Social science work has advanced significantly this year. Initial data collection involved interviews in early 2022 with key stakeholders involved in decision-making and research on restoring cranberry bogs in the region and the potential impacts for both users and the natural environment. Along with key informant interviews, a team of social scientists visited sites at various stages of restoration from May through October of 2022 to collect the perspectives of recreators at these sites about what makes them important recreation destinations, and how restoring cranberry bogs to wetlands would affect their experiences at these places. Sites visited include Century Bogs in Wareham, Mass., Eel River Reserve in Plymouth, Mass., Hamblin Bogs in Barnstable, Mass., Mattapoissett Bogs in Acushnet, Mass., Millbrook Bogs in Freetown, Mass., and Tidmarsh Bogs in Plymouth, Mass. This winter, researchers will analyze the findings of these interviews to improve community communication about planned restoration, and to improve restoration practitioners' understanding of recreators key concerns and priority uses of these sites.

Innovative/Alternative (I/A) septic systems research

Researchers with visiting EPA managers on a tour of field sites in Barnstable, MA.

There are now 13 new or upgraded septic systems that have been installed as part of the I/A demonstration project. This includes 12 of KleanTu's NitROE™ systems and one nonproprietary system designed by the Massachusetts Alternative Septic System Test Center (MASSTC), both of which were designed for enhanced nitrogen removal (reducing levels to less than 10 milligrams per liter of total nitrogen (TN)). Sampling of nutrient contents and water levels flowing into and out of the systems has been occurring monthly for up to eight months (depending on install date), and quarterly groundwater monitoring has occurred for more than a year. Early data are promising, but it is too soon to draw conclusions about system performance or impact on groundwater quality. Interim findings are regularly communicated among project partners, including a visit from EPA managers to the research lab and field sites in July 2022. Social scientists have been learning from strategies that have been applied to spread environmental technologies with characteristics similar to Innovative/Alternative systems to better communicate these systems and help address barriers to their wider use. At the end of September 2022, stakeholders from EPA, BCWC, and MASSTC attended a meeting to provide monitoring updates to homeowners who have installed these systems.

Harmful algal bloom research

Harmful algal blooms (HABs) affect waters across the country and have long been a concern on Cape Cod. In freshwater environments HABs often refer to cyanobacteria blooms with potential toxic or harmful effects on humans and their pets. These blooms have resulted in pond closures in the Three Bays Watershed. Harmful algal bloom work is ongoing in both Shubael and Hamblin Ponds. Buoys with sensors that collect various data including nutrient levels, oxygen levels, and weather have been deployed in both ponds since May 16, 2022, and continued collecting data until the middle of November. Aside from an early season sensor failure, the team has continuous data for all parameters for most of the season. In addition to the buoy data, EPA researchers have been collecting and processing water samples for both ponds approximately every two weeks. These samples provide information on nutrients and cyanotoxins, and identify which algal species are present. Researchers are also field testing a new system, the Fast Limnological Automated Measurements system, aka the FLAMe. The FLAMe will provide detailed spatial information on water quality in the ponds. The team is working to make these data available to the public on a provisional basis. Additionally, the team has been developing remote sensing approaches to using satellites to evaluate water quality in the ponds.

Social science research on recreators' awareness of HABs in freshwater bodies has included interviews across five ponds in Rhode Island and Massachusetts, including the two ponds EPA researchers are monitoring in the Three

Bays Watershed. This work aims to improve public awareness of the risks of HABs and standardize communication efforts across the region. Interviews with key informants identified various needs, including expanding research on human risks of HABs exposure and increased funding for local monitoring programs. The work of the HABs teams was the focus of a stakeholder meeting in October 2022, where researchers shared the findings of their field seasons.

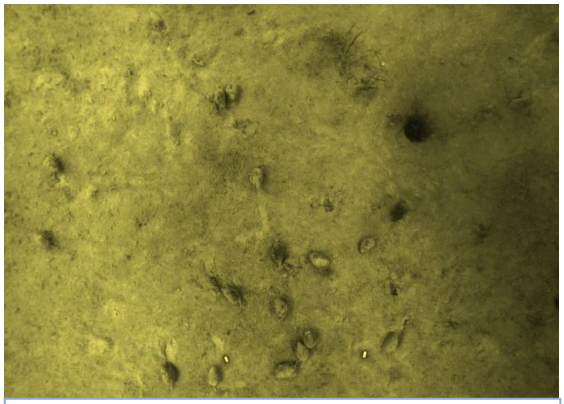
Featured Photo

This bulletin's featured photo comes from a summer field day with the EPA Narragansett-based social science research team. This image at Georgiaville Pond in Smithfield, R.I., shows two EPA researchers (far left and second from the right) interviewing recreators at this popular swimming destination. These interviews are a part of social science research on key informant and recreator perceptions of harmful algal bloom events (HABs), including research needs, risks, and frequency of events. While focused on New England to date, future social science efforts will expand to evaluate social aspects of HABs nationally.

Deeper Dive

Picturing an innovative method for monitoring seafloor conditions

In the age of smartphones and video cameras that can fit in your pocket, documenting each moment has become an everyday activity for many of us. For some environmental researchers based out of EPA's research lab in Narragansett, R.I., they have turned this everyday activity of taking pictures into a new method for evaluating conditions on the seafloor!



A picture taken of the seafloor using video stills collected with a GoPro.

Monitoring seafloor, or benthic, conditions is an important way to assess the health of a waterbody. Based on what is, or is not, observed living in benthic habitats, scientists are able to provide a rating of water conditions. As Three Bays and Cape Cod are vacation destinations for water recreation, having high quality water is essential to the community. Completing an assessment of benthic conditions provided researchers with a baseline of conditions to compare future assessments against and defined the current status of the bays to inform management choices.

Researcher Giancarlo Cicchetti led the implementation of this new gear and analysis method. He noted that while cameras have been used for years in analyses, this approach is innovative in that it standardizes image analysis. Using a structured dictionary of ecological terms, analysts can quantify the seafloor health, explaining why conditions are considered "poor" or "good." The Coastal and Marine Ecological Classification Standard (CMECS) is used across the U.S. in coastal and marine ecological research to ensure consistent language and a framework for

interpreting observational data, like images. The analysis is similar to identifying features, like cars, buildings, and trees, from an image taken from an airplane.

Beyond simply being excited to test out the new gear, Cicchetti explained this project was important to him in making benthic assessments more accessible to people passionate about their local waterbodies.

"I want to make it available to the public…so that people can go out and assess the condition of their estuary or bay, year after year at no additional cost, just the time to drop the samples and look at the images," he said. The team is currently developing a guidance document for anyone to apply this new technique. Because these are video stills of the seafloor rather than collections from under the sediment, most of the features are relatively obvious to characterize compared to traditional methods of benthic assessments.

The set up involves connecting a GoPro underwater video camera to a frame made of PVC pipe so that the camera is stationed above the seafloor (see Figure 1). It is estimated to cost about $500 to put together. This device can be deployed from a boat or a dock.

Figure 1. *The set up for the cost-effective benthic assessment method. Researchers collected images by deploying this device off a research boat.*

This innovative seafloor imaging complemented additional work done using well-established approaches to help validate the new camera method. The more common method of sediment grab analysis involves using specialized gear that is more expensive to use, and the samples require more time and money to analyze compared to Cicchetti's method. When comparing the results of the two benthic assessment approaches, they both concluded that the seafloor conditions in Three Bays are "poor." While disappointed to find that the conditions were poor, the consistent results between these methods were encouraging for researchers in being able to provide reliable results with a cost-effective method. For anyone eager to dip their cameras into water quality analysis, keep an eye out for the guidance document so you can become a benthic ecologist in your favorite coastal waterbody!

Scientist Spotlight: Dr. Kate Mulvaney

Dr. Kate Mulvaney is a researcher studying social impacts of water pollution and perceptions of water quality on Cape Cod and beyond. This is what she had to say in response to our questions about her time at EPA and experiences with the project.

How long have you been at the EPA?

I started as an ORISE Fellow in December of 2013, and then I have had several roles leading up to my current position as a social scientist since March of 2021.

What kind of scientist are you?

Social scientist. At EPA, we study the human dimensions of environmental challenges and programs.

What led to your interest in this field of study?

I originally wanted to study, and did my undergraduate degree in, marine science because I find it so interesting, and the marine environment is a place of great importance to me. What I found was that in order to protect the ocean and the environment more generally, we had to motivate a lot of people, and that we needed to know better how people value the environment in order to motivate those changes. This led me to working with communities and policies both professionally and academically.

Kate Mulvaney on a recent boat trip with her kids in Narragansett Bay, Rhode Island.

Which aspect(s) of the nutrients research on Cape Cod are you involved in?

I work on several aspects of the Cape project: quantifying recreational benefits of water quality improvement, identification of best practices in stakeholder engagement, and barriers and opportunities for the adoption of nitrogen-mitigating technologies.

What do you like most about working on this project?

The partners on this project are smart, dedicated, concerned, and insightful. I have greatly appreciated collaborating with a range of folks on this work. I am also excited to see how some of the initial findings transfer to locations across the Cape and beyond.

Who have you been working with outside of the EPA as a stakeholder/collaborator on this project?

We have different partners for the different aspects of the project. Barnstable Clean Water Coalition, Buzzards Bay Coalition, and Cape Cod Commission have provided great connections to the communities who are implementing some of the technologies. The Town of Barnstable has really helped to frame our research and what is needed. Massachusetts Division of Ecological Restoration has also been incredible in helping us develop research that connects communities with their bog restoration program.

How does your research strive to address excess nutrients on Cape Cod?

We connect the excess nutrients to people, not only as the source of the problem, but also as the pathway for solutions.

What is your favorite outdoor memory?

My single favorite ocean moment was a time when I happened to be at Race Point on the Cape as the North Atlantic right whales were breeching and feeding as they were migrating through. Pure magic!

What's your favorite way to spend time outdoors?

I have two kids who make everything way more fun, but especially outdoors. We spend a lot of time outside to manage the mayhem.