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

United States Environmental Protection Agency

Bulletin 3: Winter 2021-2022

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

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

In 2021, the team took to the field, conducting experiments and analyzing data to learn more about addressing excess nutrients on Cape Cod. While some aspects of the project have been necessarily reimagined due to the ongoing pandemic, we have managed to stay in close contact with our various EPA and external team members and have found ways to continue much of our research.

This issue of the bulletin provides updates since March 2021on our efforts to tackle the nutrient loading challenges with our stakeholders in the Three Bays Watershed. On the Cape, septic systems are the source of 80% of the nutrient loading. While these water treatment systems treat bacteria in wastewater, traditional septic systems do not remove much nitrogen, which then flows through groundwater to ponds, streams, and estuaries. This year, the team evaluated a variety of ways to monitor nutrients and water quality 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 our cranberry bogs work with partners, and our Scientist Spotlight features EPA scientist Darryl Keith, Ph.D.

Map of the Three Bays Watershed in Barnstable County, Massachusetts

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 third bulletin for the Nutrients Solutions-Driven Research Pilot. In the prior bulletin we described the importance of partnerships and collaboration for the success of this Pilot. In this issue I would like to briefly highlight what we mean by solutions-driven research (SDR). For me, the

novelty of SDR isn't only about engaging with partners and stakeholders (though that is a critical component), what makes SDR unique (for me) is the focus on solving an important problem as opposed to studying a problem.

The long-term objective for our partners is to meet the nitrogen reduction goals needed to restore water quality in coastal embayments, such as Three Bays. This long-term goal of restoring water quality was incorporated into our SDR planning. Each of the social and biophysical research elements described in this bulletin (aquaculture, benthic conditions research, reuse of dredged sediments, recreational benefits of improved water quality, cranberry bog restoration, innovative/alternative septic systems, and harmful algal bloom research) is directed towards a key component of that long-term goal. By carefully evaluating nitrogen reducing approaches across the watershed (at the source, during transport in groundwater, and in receiving waterbodies), the SDR is designed to inform watershed plans to achieve nitrogen reduction targets and related water quality goals.

Solutions-driven research, almost by definition, requires partnerships and collaboration. We are extremely fortunate to have such talented and engaged partners, as the Barnstable Clean Water Coalition (BCWC), the U.S. Geological Survey, The Nature Conservancy, the Massachusetts Alternative Septic System Test Center, the Town of Barnstable, Mount Holyoke College, and the state of Massachusetts Department of Environmental Protection and Department of Ecological Restoration. We look forward to expanding our list of research partners as we move forward with the project.

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 last bulletin March 2021:

Aquaculture

The shellfish group completed a productive 2021 field season collecting data related to shellfish aquaculture and water clarity benefits in shallow-water systems. Increased water clarity can provide conditions for the return of seagrass and can influence where people choose to recreate. The group sampled two different aquaculture sites: Matunuck Oyster Farm in Potter's Pond, RI, and at the Town of Falmouth Fisheries Propagation Unit's farm in Little Pond, Falmouth, MA. The Potter's Pond seven-acre site uses floating cages that hold multiple bags of oysters of different ages. The Falmouth Little Pond site is comparatively smaller than the Potter's Pond site, with a floating bag aquaculture operation that is restricted to growing one-year-old oysters. Sampling occurred numerous times at both sites from spring through fall. Throughout each site visit, measurements were taken for chlorophyll a, turbidity, water temperature, salinity, dissolved oxygen, and nutrients at the upstream and downstream position at each pond. Researchers are currently analyzing samples, and the data will then be further analyzed by a statistician to determine the nutrient reduction impact of the shellfish. The results from the current sampling season will be shared with the Potter Pond oyster farmer and the Town of Falmouth and will inform research planning for the 2022 field season.

Additionally, the team produced an infographic on how shellfish can improve water quality. It aims to be useful for shellfish farmers in explaining the environmental benefits of shellfish.

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.

Data collection on benthic conditions occurred largely in 2019. Over the past two 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

EPA scientists are also exploring the reuse of clean dredged sediments from the watershed. The dredged sediments may be used to build elevation of nearby marshes to mitigate sea level rise, or to create new wetlands that could reduce nutrient loading in the Three Bays watershed.

Created wetlands for the Mill Pond Restoration Project. Photo by Natalie Schafer.

The Mill Pond Restoration Project (Barnstable, MA) is part of the integrated watershed restoration plan for the Marstons Mills River and the Three Bays Estuary. The Restoration Project at Mill Pond proposes to remove nutrient-rich sediments from the bottom of the pond that have accumulated over the 300-year history of the system. The study collected some of the nutrient-rich sediments from the Mill Pond and experimentally tested these samples to determine if the dredged sediments could successfully be used in a "layer-cake" created wetland. The layers of the created wetland included sand, wood chips, and Mill Pond sediment. The dredged sediment was sandwiched between sand and woodchips. The layered wetland was seeded in the early summer with various freshwater plants. Researchers have been monitoring and modeling nitrogen movement through the created wetland. The experiment ended in early November and the data collected will be used to model the capacity of the created wetland system to remove nitrogen.

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. The overall goals of this work are to quantify how many people are recreating on estuary waters and the value of improving water quality in estuaries and coastal waters on the Cape. Data collection for this work was completed in 2019, and the socioeconomic analyses are in various phases of completion. The current available products from this work can be accessed on the EPA 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.

Renewed effort this year has been focused on restoring cranberry bog sites to self-sustaining wetlands, and evaluating the nutrient reduction involved in such efforts. Towards that end, EPA researchers and U.S. Geological Survey partners have installed an integrated stream gauge and nitrate sensor station at the outflow of a proposed

bog restoration site, and at the headwaters of the Marstons Mills River in Barnstable, MA. The station is a key component of monitoring this site before, during, and after restoration. The data, available at the station link, will inform restoration design and impact evaluation. The larger team, including BCWC, Massachusetts Division of Ecological Restoration, and Interfluve, walked the bog site in late summer to initiate early planning for the restoration project. EPA researchers are also preparing research on the social impacts of bog restoration.

Along with restoration research, further effort has been made in installing bioreactors at the Hamblin Bogs in Marstons Mill, MA. More details on the science of these new bioreactors can be found in the Deeper Dive section of this bulletin.

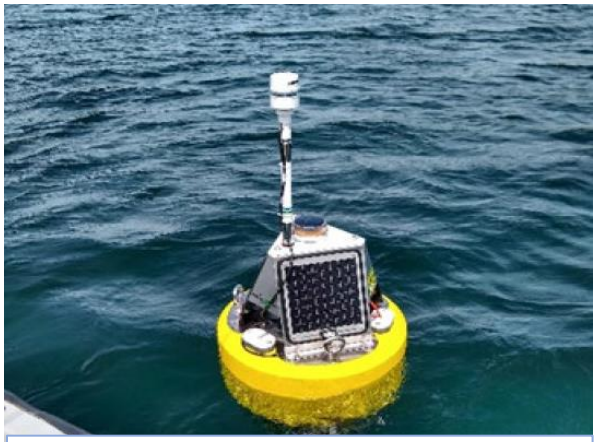
Innovative/Alternative (I/A) septic systems research

Research and experimentation around installing enhanced innovative/alternative (I/A) septic systems has continued with our partners for the past six months. This work has involved social science, biophysical science, and significant engagement with our partners. In early June 2021, EPA ORD researchers co-hosted, with the Region 1 Southeast New England Program, a three-day workshop: *Developing & Evaluating Promising Technologies: Pushing the Ball Forward on I/A Septic Systems*. The workshop was designed to present the latest information on I/A septic systems for nitrogen removal and to identify key action steps for overcoming implementation challenges. During the workshop, EPA social scientists presented a costing analysis for I/A systems under consideration in this SDR pilot, and compared them to traditional wastewater treatment systems. The analyses showed the target cost and performance ranges needed to make the I/A systems comparable to traditional treatment. A workshop summary report and session recordings are available at the workshop link.

In related work, our partners at the Barnstable Clean Water Coalition have begun installing innovative septic systems demonstration project in a neighborhood near Shubael Pond in Barnstable.

To date, six I/A septic systems have been installed with provisional use approval for <11 mg/L total nitrogen. The team has completed an extensive groundwater monitoring network to better understand the impact of these and future installations on water quality. Our partners at USGS initiated quarterly sampling of the well network earlier this year. Sampling of septic influent and effluent with partners at the Massachusetts Alternative Septic System Test Center will begin later this year. Costs and logistical considerations are being tracked by our partners at the Barnstable Clean Water Coalition, who are leading the replacement effort.

The social science team also led a complementary study to understand challenges and opportunities for the use of I/As at a household level. This research involved gathering information from focus groups in 2020 comprised of I/A adopters and potential adopters. Results from that study have been presented at several meetings and written into a scientific paper that is now in review at EPA.



Water quality buoy collecting data about physical, chemical, and biological qualities to monitor for HABs conditions in the Three Bays Watershed.

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. A team, including EPA researchers, BCWC members, and the town of Barnstable, began research this summer to monitor water properties that can indicate ecosystem health and HAB occurrences.

This research has involved EPA deployment of buoys in Shubael and Hamblin Ponds, which collected frequent data on water properties and evaluating satellite imagery of water-color data for HABs monitoring. Darryl Keith, our Scientist Spotlight

for this issue, has led this preliminary analysis. The buoy sensors collected data throughout summer and fall 2021, which included data from a summer hurricane and a Nor'easter. The collected data will be analyzed by EPA researchers in coming months. This research is expected to give insight into how nutrients, water temperature, and other drivers of algal blooms change over time, and how potential HABs species react to these changing drivers. More information about this research can be found in this factsheet about the project.

Featured Photo

This bulletin's featured photo comes from the enhanced Innovative/Alternative (I/A) septic systems research team. This image depicts the installation of an I/A system in a volunteer participant's backyard near Shubael Pond. Alongside our numerous partners in Massachusetts, EPA was involved in installing six of these systems in late summer 2021.

Deeper Dive

Experimenting with biochar bioreactors in cranberry bogs for nutrient management

Water pollution is a major challenge in Cape Cod, Massachusetts. Home septic systems introduce nutrients into the groundwater in the form of reactive nitrogen. Groundwater then transports nitrogen to the ponds, estuaries and coasts of Cape Cod. High levels of nutrients can fuel algae blooms that negatively impact water quality, aquatic habitat, and various forms of recreation popular on Cape Cod beaches and waterbodies.

Bioreactors are one of the nature-based solutions that EPA scientists and partners are testing to treat nutrient-rich water. While initial bioreactors were installed in the Hamblin Bogs in 2020, researchers have continued to experiment with different forms of bioreactor filtering systems in 2021. Recent progress includes EPA researchers assisting BCWC and Mt. Holyoke researchers with the May 2021 installation of three 30-foot bioreactors experimenting with the use of biochar for nutrient reduction.

In appearance, these new bioreactors are collections of woodchips and biochar in a ditch. Since actively cultivated cranberry bogs often have preexisting ditches to manage waterflow, these sites serve as great locations to install bioreactors. Another benefit of this technique is that farmers can continue their production of necessary crops while also tackling nutrient concerns in unused ditches.

A woodchip bioreactor operates like a biological filter that removes nitrate and keeps it from reaching areas where it would have a polluting impact. The bioreactor consists of a combination of woodchips (a carbon source), naturally occurring bacteria, and an oxygen-free, or anoxic environment. This is the form of bioreactor that was installed on the Hamblin Bog in 2020.

Woodchips and biochar are carbon sources that serve as essential ingredients in the denitrification powers of the bioreactor. Woodchips have naturally existing microorganisms, or microbes, that can remove nitrogen from water in anoxic conditions. Biochar is a charcoal formed when organic waste, like brush and trees, are burnt in low oxygen conditions. Rather than directly supporting microorganisms like woodchips, the surfaces of biochar improve microbial habitat and the reactive nature of biochar attracts nitrogen-based molecules. Biochar is a valuable bioreactor companion to woodchips in nutrient management as its structure allows for anoxic conditions that support full conversion of nitrate into harmless nitrogen gas. The bioreactors installed in mid-2021 experimented with use of biochar to manage nutrients in water flowing through the bog.

As nutrient-rich water passes through the woodchip-filled ditch towards the coast, the microbes consume the nitrate and produce harmless nitrogen gas in the process removing nutrients from the water. The bio in bioreactor comes from the fact that microscopic bacteria are the drivers of denitrification. Extending bioreactor length or using densely packed woodchips will ensure that nutrient-rich water flows slowly enough for bacteria to treat nutrients before water leaves the system.

Updates on the data collection from this work were shared at a virtual meeting with partners in early December 2021.

Scientist Spotlight

Dr. Darryl Keith

Dr. Darryl Keith is a researcher studying harmful algal blooms in the Three Bays watershed. This is what he had to say in response to our questions about his time at EPA and experiences with the project.

How long have you been at the EPA?

I have been with EPA for 32 years

What kind of scientist are you?

I am an oceanographer that has conducted water quality research in estuaries, coastal waters, and inland lakes using aircraft, spacecraft, and satellite as remote sensing platforms.

What led to your interest in this field of study?

There are two primary reasons: Recreating in coastal waters of North Carolina during my youth and my fascination with exploring earth from space.

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

Harmful algae bloom monitoring using spacecraft and working with data from unmanned aerial vehicles (drones).

What do you like most about working on this project?

The opportunity to bring the spatial and temporal advantages of using remotely sensed data for monitoring to Shubael Pond.

Darryl Keith with the in-water HyperSAS profiling radiometer system which measures the spectrum of the underwater light field. This system will provide in-water validation of remote sensing algorithms to map seagrass density and estimate phytoplankton and cyanobacteria concentrations derived from satellites, aircraft, and UAV data

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

Casey D. Chatelain at Barnstable Clean Water Coalition

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

Hopefully, my research will allow for more accurate estimations and mapping of concentrations of cyanobacteria in coastal ponds which bloom in response to the introduction of excess nutrients.

What is your favorite outdoor memory?

My favorite outdoor memories include sailing on Narragansett Bay and rafting the Colorado River in the Grand Canyon.

What are your favorite ways to spend time outdoors?

Cycling, walking, and vegetable gardening

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