Exploring Solutions to Nutrient Pollution: Restoring Cape Cod's Waters

United States Environmental Protection Agency

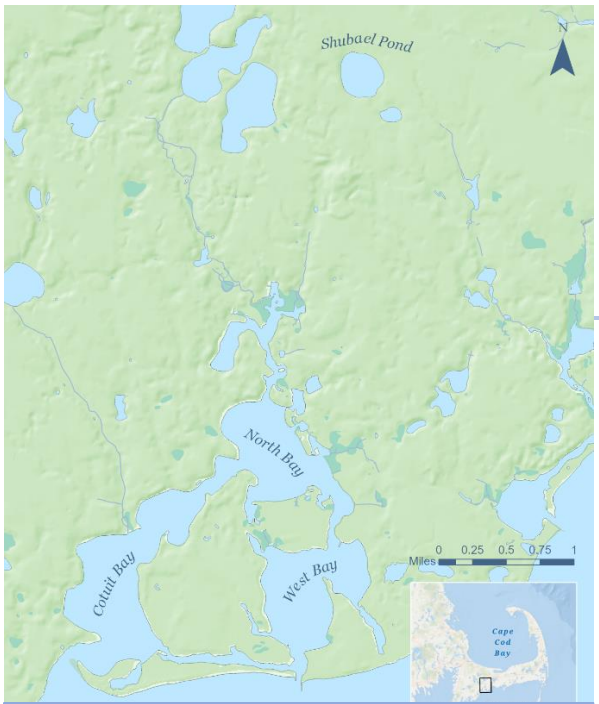
Bulletin 1: Summer 2020

Welcome to the first-ever bulletin on the Environmental Protection Agency's research to address excess nutrient loading in Cape Cod's waters! This will be a biannual update for interested community members on what EPA scientists based in the Office of Research and Development and Region 1, Boston, MA, and our many research partners and stakeholders, have been up to.

The overall goal of this research project is to work with and support our partners in developing a watershed-level plan to reduce nutrient loading in the Three Bays Watershed of Cape Cod (see map below) to meet the TMDLs.

TMDLs is an abbreviation for total maximum daily loads, and refers to a U.S. Clean Water Act regulatory requirement to reduce pollutant levels in impaired waterbodies. Our EPA research team includes hydrologists, ecologists, biologists, economists, and other social scientists, all running experiments and research in collaboration with local stakeholders to identify best practices that help meet the TMDL for nitrogen, the main nutrient of concern in this watershed.

Cape Cod has several unique characteristics that make its estuaries susceptible to impacts from excess nutrients in the form of nitrate. An estimated 80 percent of nitrogen loading on Cape Cod stems from the use of backyard septic systems. In Three Bays, there are over 5,000 septic systems. Traditional septic systems are not designed to remove nitrogen. Wastewater treatment plants are not widely used on Cape Cod due to the costs and challenges associated with widely distributed housing and large seasonal fluctuations in population due to summer tourism. Nitrate moves easily from the septic systems to the Cape's groundwater, where it is transported to ponds, streams, and estuaries. In addition to septic systems, lawn fertilization, atmospheric deposition, and storm water also contribute to excess nitrogen in the region.



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. In this edition of the bulletin, he shares more background about this project.

Thank you for your interest in our research activities. We are excited to have the opportunity to work in partnership with a growing group of talented and dedicated people from across many organizations to design and conduct research on key questions associated with how to reduce nutrient loads and restore water quality on Cape Cod. Excess nutrients from human activity (largely septic systems on Cape Cod) are an increasingly serious threat to estuaries, wetlands, and freshwater

ponds nationwide, as they contribute to algae blooms, low dissolved oxygen, degradation of seagrass, impaired freshwater and estuarine ecosystems, and, in extreme cases, fish kills. Key partners in this research include the Barnstable Clean Water Coalition, the U.S. Geological Survey, The Nature Conservancy, the Massachusetts Alternative Septic System Test Center, as well as state and local stakeholders, including the Massachusetts Department of Environmental Protection, Massachusetts Division of Ecological Restoration, the town of Barnstable, and the Cape Cod Commission.

We are using a solutions-driven research approach with extensive stakeholder engagement to identify watershed-based solutions using non-traditional interventions to address the area's important nitrogen issues. An initial stakeholder engagement and problem formulation workshop in 2018 revealed key knowledge gaps and opportunities for collaboration. This project will include baseline environmental condition assessment and pilot studies of promising interventions that integrate social science and environmental research approaches to reduce nitrogen load, including: source controls through innovative septic systems, groundwater controls through restoring a cranberry bog, water column controls through shellfish restoration and aquaculture, as well as beneficial reuse of nutrient rich dredged materials. Some of these pilots will be initiated in 2020, with others delayed due to the pandemic. The lessons learned in the Three Bays watershed will be shared with other locations across Cape Cod and beyond.

-Dr. Timothy Gleason

Project Updates

In all our bulletins, we'll provide quick snapshots of each EPA-based research team's work on the project since the last bulletin. This time around, we'll introduce you to our projects:

Innovative/Alternative (I/A) septic systems research

Beginning in 2020, project partners plan to replace traditional septic systems with enhanced nitrogen reducing septic systems in up to 40 houses in Barnstable's Shubael Pond neighborhood. While traditional septic systems are designed to treat and remove pathogens from domestic wastewater, they are not designed to remove nitrogen from wastewater. The new enhanced I/A septic systems are being piloted to help Cape Cod meet its TMDL for nitrogen.

In fall of 2019, in partnership with the Barnstable Clean Water Coalition (BCWC) and the United States Geological Survey (USGS), our researchers examined groundwater quality in four candidate neighborhoods with elevated nitrate levels, and selected the Shubael Pond neighborhood for the enhanced I/A demonstration project. Septic system upgrades will be offered by BCWC to neighborhood homeowners with properties aligned along a similar groundwater flow path to the pond. These enhanced I/A systems will be monitored collectively for nitrogen removal performance for approximately three years following installation. Wells installed by USGS located up- and downgradient from participating homes will be monitored to determine the total effects of I/As on groundwater pollutants.

Concurrently, EPA scientists are researching the factors that influence social acceptance of these nitrogen-reducing systems. To learn from existing regional pilots, this research will involve a series of focus groups across southern New England that began in mid-July 2020 with I/A adopters and those using traditional septic systems. This research will inform outreach to potential participants on Cape Cod and other areas seeking to address potential social barriers associated with I/A systems and improve communications to the public about these systems. Researchers have been working closely with BCWC to listen to community concerns and create materials to answer frequently asked questions.

End goals of the demonstration project include quantifying nitrogen reduction and cost effectiveness of the enhanced IA systems; evaluating how clustering these systems influences groundwater nitrogen, inferring the

reduction in nitrogen loading to Shubael Pond; and communicating lessons learned to local, state, regional and federal partners in watersheds similarly compromised by legacy septic systems.

Cranberry bogs

Cranberry bogs are an iconic feature of the Cape Cod landscape. In the last twenty or so years, however, the reduced cost effectiveness of farming cranberries across southeastern Massachusetts and Connecticut has led many multigenerational farmers to consider retiring their farms and/or partnering with the state to restore them to wetlands. Past research has found that wetlands have the ability to use nitrate, and transform it to less harmful nitrogen gas, reducing the flow of nitrate to estuaries through nitrogen processing. In partnership with BCWC, EPA researchers are quantifying how retired or partially retired cranberry bogs can help address the Cape's nutrient problem. In December 2019, EPA co-organized a workshop with The Nature Conservancy and BCWC to bring together local stakeholders to discuss priorities and develop an action plan for the bogs in the headwaters of the Marstons Mills River. Two working groups were formed around the use of controlled flooding and woodchip bioreactors to decrease nitrogen in the bogs and reduce the nutrient load to the Marstons Mills River and the Three Bays estuary. Scientists have designed multiple options for the flooded wetland experiment, and plans are in the works for implementation. Changes in nitrogen processing due to the bioreactor will be measured and modeled in an experiment that began July 28, 2020.

Completed bioreactor installation in Marstons Mills, Massachusetts in July 2020

Co-developed social science research at EPA aims to understand local perspectives of alternative uses of retired bogs for nutrient management and how other ecosystem services are perceived. This research will center on interviews with researchers and practitioners involved in past bog restorations on Cape Cod, as well as recreational users of active, retired, and restored bogs. Recognizing the intergenerational significance of bogs on the Cape, the goal of this work is to understand how various stakeholders value these landscapes, and how land use changes impact this value.

Aquaculture

Shellfish are filter feeders, and as such, have the capacity to improve coastal water condition, and also reduce nutrient impacts in coastal waterbodies. EPA researchers have collaborated with shellfish aquaculturists in Rhode Island to quantify the amount of nitrogen shellfish can remove from an ecosystem when raised for aquaculture. These experiments were run on active oyster farms in Rhode Island. Along with quantifying the removal of nitrogen from the aquaculture systems, researchers are investigating improvements to water clarity around the shellfish aquaculture operations both in Rhode Island and on the Cape. Social scientists on the team are conducting research to assess the social benefits of and barriers to shellfish aquaculture, including the impacts on viewshed. Overall, this project aims to quantify the benefits of using shellfish aquaculture as part of a multipronged approach to nutrient management on the Cape.

In fall of 2019, Dr. Suzy Ayvazian co-organized an event at Boston University that brought together researchers investigating the use of shellfish for nutrient management. The "Deeper Dive" article in this issue of the bulletin provides a more in-depth summary of this event, and the processes by which shellfish remove nitrogen from waterbodies.

Benthic conditions survey

Benthic, or seafloor, conditions are an important indicator of overall water quality and a key metric for the nitrogen levels in Cape Cod estuaries as high nitrogen levels negatively impact benthic condition. In consultation with the Massachusetts Department of Environmental Protection, EPA researchers designed a benthic condition survey for the Three Bays estuary that updates and expands upon a prior survey conducted under the Massachusetts Estuaries Project approximately 15 years ago. In fall of 2019, researchers collected video, sidescan sonar imagery, and seafloor sediment samples accompanied by water quality measurements in Three Bays. Researchers are currently beginning their analysis of these data and preparing for further sediment profile imaging in the coming months to document conditions above and within the seafloor.

Reuse of dredged material

Another approach EPA scientists are exploring is the reuse of dredged materials from the watershed. The dredged materials 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 water. Beginning in spring 2019, researchers conducted a greenhouse experiment to evaluate the potential benefits of placing thin layers of dredged material on the surface of salt marsh samples and assessed plant growth and water quality processes (such as denitrification). Denitrification is the process whereby nitrate is reduced to nitrogen gas and released from the system. Researchers are planning a wetland creation experiment that will involve creating a microcosm of a wetland system in the EPA lab's greenhouse in Narragansett, using dredged sediments and collected rainwater. Scientists will measure nitrogen processing in the experiment and use that information to inform modelling to aid in design of created wetlands to most efficiently reduce nitrogen in the system and improve water quality.

Recreational benefits of improved water quality

Since 2016, social scientists at EPA have been studying how improving water quality on Cape Cod affects the visitation and value of the 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 improved water quality in the Three Bays Estuary and other estuaries and coastal waters on the Cape. Understanding the number of users and types of use (for example, kayaking or birdwatching) can help determine how many visitors are affected by water pollution on the Cape and how their valuation of recreation might change with improvements or degradations in water quality. These visitation estimates are also important in helping local planners and managers understand how people use the coast. Our team is using an innovative, straightforward observational method to build realistic estimates for visitation and types of recreational use in the Three Bays estuary system. EPA scientists are also using survey data to research the monetary value of improving water quality in New England. These results, when combined with the visitation estimates, will be useful for describing the impact of improved water quality in terms that are relatable for decision-makers and residents on Cape Cod.

EPA researchers conducting counts of users of a coastal access point on Cape Cod for a past study

Harmful Algal Blooms

While not initially identified as a research area at the onset of this project, the study of Harmful Algal Blooms (HABs) could take on additional significance as we move along based on expressed interest from our stakeholders. As we continue to work with stakeholders at Shubael Pond, it is likely that more research will develop in this area.

Featured Photo

This bulletin's featured photo comes from the benthic survey team. Here, EPA scientists Drs. Laura Erban (left) and Donald Cobb (right) are using the sediment grab tool to collect sediment samples from the Three Bays Estuary in summer of 2019.

Deeper Dive

Using shellfish to augment nutrient reduction efforts

While Cape Cod is known for its shellfish, ongoing research at EPA is poised to make these filter feeders even more celebrated. EPA scientist Dr. Suzy Ayvazian and her team have been working to determine how much nitrogen shellfish, especially oysters, can remove from the water around them. This research has occurred in Rhode Island to date, but discussion of possible value of related work extend across the southern New England. Notably, last fall, Ayvazian worked with Boston University's Dr. Robinson W. Fulweiler to coordinate the "Workshop on Synthesizing the Nitrogen Removal Capacity of Oyster Habitats via Denitrification" at Boston University.

The September 2019 workshop brought together researchers from across southern New England to discuss the status of research on the use of oysters to supplement other interventions to reduce nitrogen levels in estuarine and coastal systems. The goals of the workshop were to answer two major questions:

1. Can we standardize how we measure the denitrification benefits of shellfish?
2. If the rates of denitrification can be verified and are repeatable, what should the policy process be for incorporating these values of nitrogen removal into a nutrient management plan? What should the policy process be for using shellfish for denitrification credits?

Scientists from a number of universities and agencies also established three working groups to identify:

1. Best practice recommendations for quantifying denitrification
2. Practical pathways, barriers, and possible values to incorporating oyster-mediated denitrification in nutrient trading schemes and management plans; and
3. Public support/opposition to incorporation of oyster-mediated denitrification in nutrient trading schemes and management plans, and opportunities to improve communication between stakeholders

Research resulting from these working groups was supposed to be presented at the National Shell Association conference in March 2020 but was cancelled due to the COVID-19 pandemic. While interventions like I/A septic systems, sewering, and capturing nitrate in cranberry bogs all focus on reducing nutrient levels on the landward side, oysters and other shellfish can help to remove the nutrients that do enter the marine environment. While not a standalone solution, researchers, including EPA-based economists, see oysters as a cost-effective complement to land-based interventions to address excess nutrients. A major difficulty in this work is quantifying just how much oysters can reduce nutrient loads. In the Chesapeake Bay there has been interim approval to consider denitrification benefits in nutrient trading schemes. On Cape Cod, the use of denitrification values still requires multiple years of experimentation to ensure that policy is developed on the best science available.

Oysters can remove reactive nitrogen (such as nitrate, but not nitrogen gas) from their environment in multiple ways. **Bioextraction** refers to removal of nitrogen from the marine environment through harvesting of oysters. This can be through both aquaculture and recreational harvests. This removes the nitrogen that oysters have assimilated in their tissues and shells from their consumption of nitrogen-rich phytoplankton. Nitrogen removal through bioextraction is already being considered in management plans in Chesapeake Bay and potentially in certain municipalities on Cape Cod. **Denitrification** from oysters is an indirect benefit of their feeding activity. The presence of the oysters enhances bacteria mediated denitrification in the ocean sediment below them. Denitrification refers to converting reactive nitrate in the water to nitrogen gas that is removed permanently from the water column. Researchers are continuing to work to quantify just how much reactive nitrogen is removed from the environment through these processes and what the policy process would look like for counting oysters towards denitrification goals. We'll keep you posted as their work progresses in providing this complement to other nutrient management techniques.

Scientist Spotlight

Dr. Laura Erban

Today, we'd like to introduce you to Dr. Laura Erban, a scientist involved with multiple aspects of this project. 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've been at the EPA since the end of 2015, after finishing my doctorate at Stanford. Before that I worked for the USGS in Woods Hole, MA, on the same problem of excess nutrients in groundwater discharging to the coast. We have learned a lot, but the problem is vast.

What kind of scientist are you?

I am a groundwater hydrologist, but I am broadly trained in earth system science and civil engineering. It is the relationships between groundwater and other earth systems, including social systems, that motivate my work.

What led to your interest in this field of study?

I had a number of great teachers and research opportunities that sparked and cultivated my interest in earth sciences. But I was especially influenced, as an undergraduate, by my studies in groundwater hydrology. Groundwater is so mysterious and important, and I couldn't believe how little I knew about it up to that point. How had I never asked, where does the water in a river come from when it's not raining?

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

I am most involved in the research on enhanced septic systems and cranberry bogs. In the former effort, we seek to cluster a large group of enhanced septics and evaluate each system's ability to remove nitrogen from household wastewater along with their combined effect on groundwater quality. I work closely with collaborators at EPA and USGS to assess sites, design, and implement the network of wells to monitor nutrients in groundwater. As for the bogs, they are large depressions in the landscape that collect groundwater and expose it to the surface. Bogs can likely be more effective at reducing the amount of excess nitrogen that flows into them with groundwater, but that depends on how water is managed within them. With other researchers at EPA and U.S. Department of Agriculture (USDA), I plan to study how the amount of water held in former cranberry bogs and the duration of water residence influence nitrogen removal, to inform restoration efforts.

What do you like most about working on this project?

I like that we are working closely with partners and stakeholders on solutions-driven research. We expect these projects will remove excess nitrogen from the watershed while we assess how much and answer related questions about costs and benefits. Our team members have diverse roles within and well outside of my earth science wheelhouse, from integrating social science, to addressing regulatory, financial, and other key components of implementation, to public engagement and communication. I enjoy being part of a team that can magnify the impact of my own contributions.

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

My work is done most closely with the organizations already mentioned (BCWC, USGS, USDA), as well as with the Massachusetts Alternative Septic Testing Center and The Nature Conservancy.

Dr. Erban logging sediment core samples during well installations for the project in November 2019.

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

The research is based on deploying interventions that can immediately reduce excess nutrients on Cape Cod. While we study how well they work, we are also learning how to implement interventions at a larger scale, not only on the Cape, but other areas facing similar issues around the country. The ultimate goal is to reduce excess nutrients to levels that the environment can process without adverse impacts.

In a sentence or two, what is your favorite outdoor memory?

I spend as much time as I can outside and have many great memories from around the world. But some of my dearest are childhood memories from the Cape, where we would spend the last week of August savoring sun, sea, and time with family.

What's your favorite way to spend time outdoors?

On a trail by the sea

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