Evaluating Whether Oyster Aquaculture Can Help Restore Water Quality

Project Location

Waquoit Bay, Massachusetts

Project Duration

November 2017 to December 2020

Project Leads

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Project Type

Collaborative Research – generating science that informs decisions

Products

- Eight video modules about aquaculture and nitrogen
- Best practices guide for using aquaculture for nitrogen removal
- New grower training
- Teacher professional development
- Infographic and interpretive sign
- Article in *Frontiers of Marine Science*

Project Partners

- Town of Falmouth
- Science Wares Inc.
- Waquoit Bay National Estuarine Research Reserve
- Woods Hole Oceanographic Institution

Project Webpage

nerrssciencecollaborative.org/project/Rogers17

Overview

Water quality—and the overall health of coastal systems—has been deteriorating in coastal communities, such as those on Cape Cod, Massachusetts, due to nitrogen pollution. Excess nitrogen in coastal waters, which can come from septic systems, fertilizers, and atmospheric deposition, can lead to algal blooms, fish kills, and shellfish and beach closures. Towns along Cape Cod are under pressure to improve coastal water quality, but many approaches are very costly, such as developing centralized sewer treatment infrastructure for homes that currently have septic systems. Instead, many towns are exploring the use of various shellfish aquaculture systems to improve water quality.

This project addressed a critical information gap identified by water quality managers and regulators—specifically, how much nitrogen is removed from coastal waters by common oyster aquaculture methods, and which culturing practices should be adopted to maximize benefits for water quality? To address this question, researchers worked closely with the Town of Falmouth to establish an experiment that mimicked commercial aquaculture practices and allowed for a robust comparison of nitrogen removal rates from three oyster growing systems. They found that all three oyster culturing methods stimulated natural microbial processes that remove nitrogen, which can measurably improve water quality. Project findings have been shared through innovative products to help new growers adopt best practices and allow towns and regulators to decide when shellfish aquaculture is a viable strategy for improving coastal water quality.

Approach

This project was developed in response to specific requests from the Town of Falmouth, Massachusetts, and Waquoit Bay National Estuarine Research Reserve, with strong support from other end users, including the Massachusetts Department of Environmental Protection and the Cape Cod Commission, whose portfolios cover water quality, fisheries, land use planning, and environmental protection. The Coastal Training Program at Waquoit Bay Reserve facilitated ongoing communication with key end users to ensure that research would be aligned with management questions. Those end users included state and local officials and shellfish managers who reviewed plans and draft research products.

The project team installed and closely monitored three oyster culturing systems and a bare sediment control site in Waquoit Bay to assess their potential to mitigate nitrogen pollution. Project partners from Falmouth deployed and maintained the aquaculture set-up using three popular gear types: floating bags of oysters, oyster bags suspended in midwater (Oyster Gro' systems), and bottom cages of oysters. The growing systems were maintained for two full growing seasons (2018 and 2019) and compared to a nearby control site. Every two weeks during the growing season, the team took measurements to provide a robust estimate of nitrogen fluxes and microbial activity below each of the aquaculture operations. Measurements included nutrient analyses of sediment, porewater, and bottom water samples; genetic sequencing of RNA and DNA extracted from sediment samples to determine the presence and activity level of certain bacteria; and measurements of nitrogen (N_2) fluxes from sediment cores placed in flux chambers to measure denitrification rates (see "Results" section for more information on N_2 fluxes).

Project results have been shared through innovative modes for different audiences. For example, the team developed a training curriculum and best practices manual for shellfish growers, installed a demonstration site and interpretive signs about aquaculture for the public and school field trips, and provided training for teachers on using oysters for classroom experiments. Because a final in-person workshop was not possible due to the COVID-19 pandemic, the team hosted a webinar and created an eight-part video series about shellfish aquaculture and water quality to serve as a lasting educational resource for municipal officials, shellfish growers, and residents.

Results

As oysters grow, they incorporate nitrogen into their shells and tissue, and this nitrogen is removed from the coastal ecosystem when the shellfish are harvested. By enhancing the naturally occurring microbial process that leads to nitrogen removal from the sediment below aquaculture gear, this project helped quantify another important mechanism by which oysters can improve water quality.

Project results revealed that all three oyster growing methods enhanced nitrogen removal in bottom sediments when compared to the control site. Nutrient-rich waste products from the oysters stimulate microbial processes in the sediment that transform problematic forms of nitrogen into a benign gaseous form of nitrogen (N_2)—a process known as denitrification. Genetic data revealed that shellfish aquaculture does not change the types of microbes present, but it does affect their activity levels and the metabolic processes happening in the sediment. The project's combination of genetic and biogeochemical measurements confirmed that denitrification rates are higher under aquaculture operations and rates increase over the course of the growing season as oysters grow and waters get warmer.

This project's experimental set-up revealed that nitrogen removal rates are somewhat higher in the sediment under bottom cages, compared to the midwater or floating bag methods used to grow oysters. Bottom cages seem to concentrate oyster waste and limit circulation in a way that promotes denitrification; however, over time the ecology seemed to shift and some nitrogen began to be stored as ammonium in the sediment, which needs to be studied further.

This is critical and novel information that can help towns and regulators select an oyster culturing method that maximizes improving water quality benefits. However, other factors will also affect decisions about shellfish aquaculture methods, including available labor and budget, access to potential sites, and resident preference about the aesthetics of different aquaculture methods.

This project also illustrated that there are many microbial processes in coastal sediments, with different implications for water quality. For example, high concentrations of sulfide in the water and sediment favor nitrogen retention processes that prevent nitrogen removal (via denitrification). Therefore, the setting of an aquaculture operation—including the natural chemistry, water depth, bottom characteristics, and exposure to wind and waves, as well as the culturing method and stocking density of oysters—will affect nitrogen cycling. Monitoring sulfide concentrations and organic content of sediments at a potential or current aquaculture site can help predict whether nitrogen removal rates will follow patterns observed in Waquoit Bay, or whether nitrogen-retaining processes may be favored over time. This project generated specific recommendations for measurements to make to inform siting and ongoing maintenance of aquaculture. The team found that two relatively simple genetic assays (for dissimilatory nitrate reduction to ammonium and denitrification genes) combined with sulfide concentrations in bottom sediments can indicate whether nitrogen removal or retention processes are more likely to dominate a site.

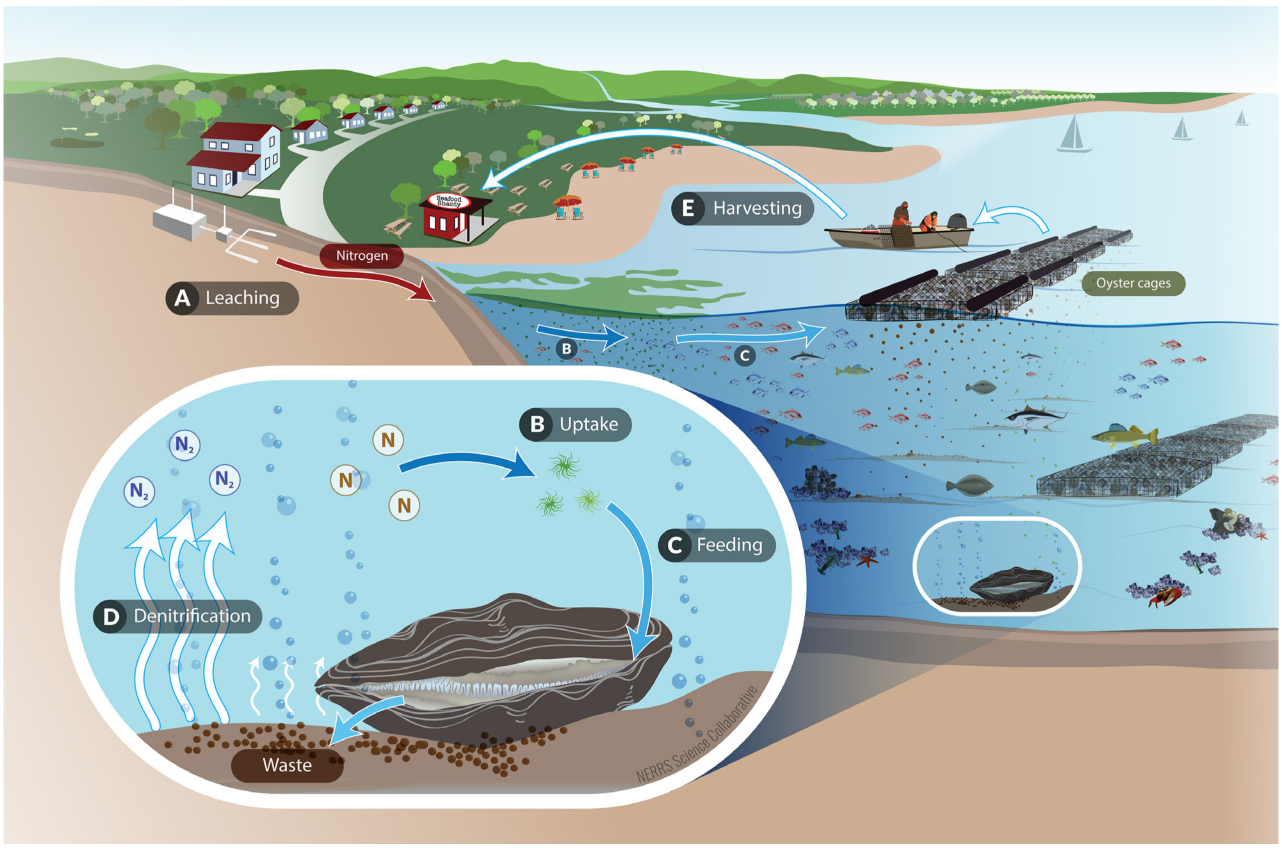
Benefits

This project fostered a unique and highly productive collaboration between academic researchers, municipal and state decision-makers, and the Waquoit Bay Reserve, which has led to a number of benefits.

- Providing new options for towns. Towns along Cape Cod are now required to develop and get approval for plans to mitigate nitrogen inputs to coastal waters. Study results are helping towns decide if shellfish aquaculture is an appropriate and cost-effective strategy for improving water quality along their coastline.
- Informing regulatory decisions. Project results are currently informing Massachusetts Department of Environmental Protection's deliberations on whether and how much regulatory credit communities can get for using shellfish aquaculture as part of their nitrogen mitigation strategy.
- Promoting beneficial oyster growing practices. The new grower training curriculum, which was delivered through one-day workshops in 2018 and 2019, as well as the new best practices manual, are helping commercial and municipal oyster growers choose and maintain culturing methods that maximize benefits for water quality. To date, 40 growers have been trained in best practices.
- Raising awareness. Public attitudes around aquaculture are critical for the success of any potential shellfish culturing plan. This project raised awareness about the benefits of shellfish aquaculture through a number of efforts, including establishment of a demonstration site, new signage, and public programs that reached 650 people, as well as the involvement of 30 volunteers in the set-up and maintenance of the aquaculture experiment. In addition, the project's new video series will continue to be used by reserve educators and trainers to further educate communities throughout Cape Cod.
- Training the next generation of scientists. This project provided a unique opportunity for students to learn the communication and technical skills that are critical for collaborative science. Much of this project's field and lab work was completed by undergraduate students from Stonehill College and high school students interning at the Woods Hole Oceanographic Institution.

Next Steps

- The project team will continue to share results broadly and will work to integrate project data sets and products into the suite of tools provided by the Cape Cod Commission to help towns develop water quality plans that meet regulatory requirements.
- Excitement around this project prompted a trustee of Stonehill College to fund a similar remediation study on the Bass River in Yarmouth, Massachusetts, that will involve student researchers as funded interns.
- Research findings suggest there may be important benefits of rotating aquaculture practices at a site over multiple years. This project detected a shift in the sediment ecology over time toward storing nitrogen as ammonium rather than removing nitrogen. As with land-based farming, rotating gear or animals or allowing a site to rest could improve outcomes, but this has not been adequately researched yet. The project team plans to pursue this question in subsequent research.



This graphic helps explain how nitrogen gets into coastal waters, and how oysters can help remove nitrogen by stimulating denitrification in the sediment and through the harvesting of oysters for food.

About the Science Collaborative

The National Estuarine Research Reserve System's Science Collaborative supports collaborative research that addresses coastal management problems important to the reserves. The Science Collaborative is managed by the University of Michigan's Water Center through a cooperative agreement with the National Oceanic and Atmospheric Administration (NOAA). Funding for the research reserves and this program comes from NOAA. Learn more at nerrssciencecollaborative.org or coast.noaa.gov/nerrs.