Excess nutrients lead to dramatic ecosystem changes in Cape Cod's Waquoit Bay

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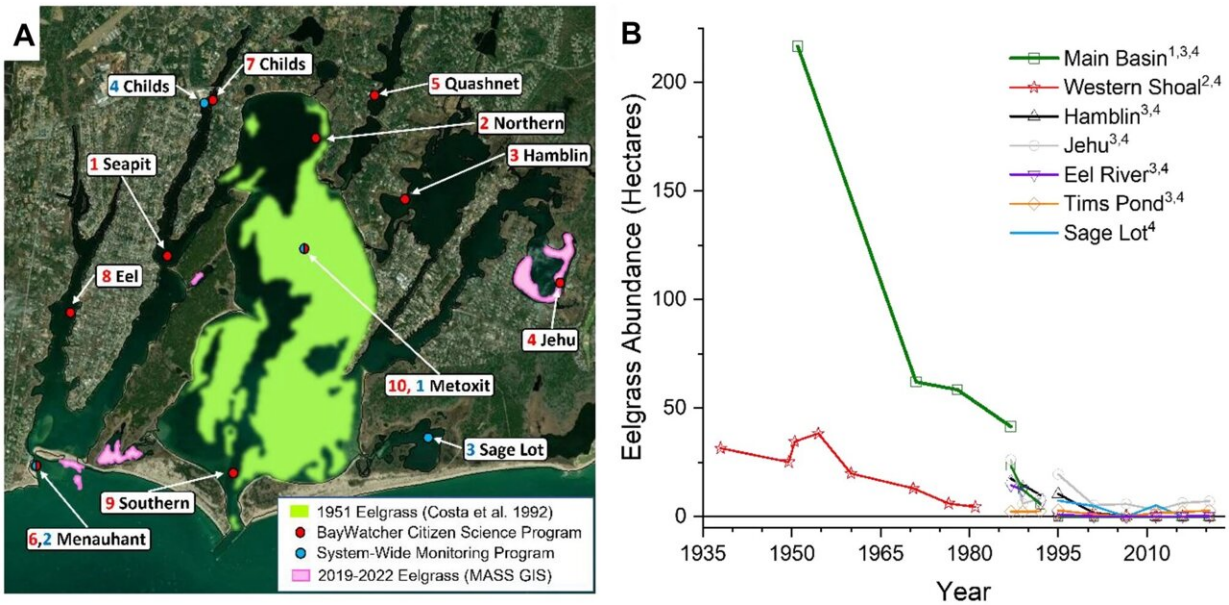

Map of Waquoit Bay showing locations of the BayWatcher Citizen Science and System-Wide Monitoring Programs run by the Waquoit Bay National Estuarine Research Reserve (A). The green shading (A) represents the 1951 eelgrass extent adapted from Costa et al. (1992), and the pink shading (A) represents the 2019–2022 eelgrass extent determined by the Massachusetts Department of Environmental Protection Eelgrass Mapping Project, both determined from aerial imagery. Credit: *Estuaries and Coasts* (2023). DOI: 10.1007/s12237-022-01166-7

When the COVID-19 pandemic hit in 2020 with associated travel

restrictions, Matthew Long thought his students could shift their overseas research projects to instead study the seagrass meadow ecosystem in Waquoit Bay. It's a shallow, micro-tidal estuary on the south side of Cape Cod in Massachusetts, near the Woods Hole Oceanographic Institution (WHOI) where Long is an associate scientist in the Marine Chemistry and Geochemistry Department.

However, when Long and his students looked for seagrass meadows where he had seen them in previous years, there were only a few shoots of dying Zostera marina eelgrass, a type of seagrass.

That prompted Long and Jordan Mora, a restoration ecologist with the Association to Preserve Cape Cod, to analyze decades' worth of local environmental monitoring data to find out what has happened to the estuary. What they determined is that Waquoit Bay has shifted from a benthic to a pelagically-dominated ecosystem due to human causes, including an excess influx of nutrient pollution along with climate change.

That disruption to Waquoit Bay's ecosystem presents broad concerns about the fate of coastal estuaries worldwide, according to the researchers.

In addition, the researchers point to the importance of tapping into and analyzing long-term monitoring data to better understand the changes to Waquoit Bay and potentially to other estuaries as well.

The water quality and overall health of estuaries continue to degrade due to excess nutrients from leaching septic systems, agricultural runoff, and other anthropogenic sources, the researchers note. In addition, warming water temperatures from climate change, particularly in the northeastern United States, exacerbates the nitrogen loading problem by reducing dissolved oxygen levels and accelerating microbial metabolism which

further reduces oxygen levels.

"This shift toward pelagic dominance in Waquoit Bay may indicate that other eutrophic and warming estuaries may also shift toward pelagic dominance in the future, as the Northeastern US is one of the fastest warming," according to "Deoxygenation, Acidification and Warming in Waquoit Bay, U.S., and a Shift to Pelagic Dominance," a paper co-authored by Long and Mora published in *Estuaries and Coasts*.

"The range of nitrogen loading across the Waquoit Bay sub-watersheds is comparable to the range of nitrogen loading across 90% of the world's estuaries making it an ideal site for investigating eutrophication impacts."

The scientists note that their research results in Waquoit Bay "cannot disentangle the contributions of global change or eutrophication to estuary decline. However, they do point to a potential combined effect that may result in other similar estuaries becoming dominated by pelagic metabolism in the future, and the resulting deleterious effects of harmful algal blooms, hypoxia, and the loss of species diversity and ecosystem function."

The researchers' analyses revealed recent and unexpectedly large increases in chlorophyll a concentrations, an indicator of microalgal blooms, in the water column throughout the estuary, which coincided with ongoing decreases in macroalgal density on the bottom of the estuary. In addition, the analyses showed an increase in temperature over the last 20 years and significant declines in oxygen and pH levels, among other changes.

The analyses relied on long-term monitoring data collected over decades from two monitoring programs coordinated by the Waquoit Bay National Estuarine Research Reserve, including the reserve's System-

Wide Monitoring Program and the Waquoit BayWatchers, that latter of which is a citizen science water quality monitoring program.

One of the main objectives of the current study was to apply time-series analysis techniques and substantial knowledge about the history of the monitoring programs to reveal long-term trends in water quality, according to the paper. "These methods can be applied to other monitoring data to advance the knowledge gained from similar monitoring programs, enhance our understanding of estuarine biogeochemistry, and investigate estuarine responses to long-term change," the paper states.

Long said eelgrass provides a number of ecosystem benefits including stabilizing sediments and offering habitat for a variety of organisms. In addition, eelgrass is a great indicator of good estuarine water quality and also serves as a carbon sink.

"Carbon storage is extremely important across the world, and we're actively trying to figure out ways to store and sequester carbon. Seagrass meadows represent a really significant and efficient carbon storage sink," Long said. "Let's not lose the seagrass meadows and the carbon sequestration that we already have in place, and let's actively maintain and restore seagrass meadows. With the loss of seagrass meadows, such as what we've seen in Waquoit Bay, we're actively releasing that carbon back to the atmosphere."

Long added that using environmental monitoring data helped to put together the story of the switch from a seagrass-dominated system to a macroalgal-dominated system from the 1980s to the present in Waquoit Bay. Without the long-term data, gradual changes to the system would be more difficult to detect, he said.

"This paper isn't just significant because it demonstrates that the

estuaries on southern Cape Cod, and more generally the northeastern US, are entering a new level of degradation where not even macroalgae or seaweeds can persist, but also because it provides clear evidence that long-term monitoring programs are extremely important and worth maintaining," said Mora, who worked at the Waquoit Bay National Estuarine Research Reserve for 10 years collecting water quality and submerged vegetation data with visiting scientists, volunteers, and other staff, and witnessed the gradual decline in habitat quality firsthand.

"My hope is that by showing the impact of increasing temperatures on already degraded systems, this paper will help facilitate local and regional management discussions and accelerate the decision-making needed to mitigate the overload of nutrients in our estuaries," Mora added.

The paper notes that "there is an urgent need to address wastewater handing to improve the estuary, especially in the face of global changes."

Long said, however, that if local stressors including nutrient pollution can be addressed, and if we can reduce carbon emissions and slow down global warming and the amount of carbon that diffuses into the ocean, "we could turn this situation around before it happens to many similar estuarine systems across the world, preserve the valuable ecological functions of seagrass meadows, and enable their carbon storage potential."

More information: Matthew H. Long et al, Deoxygenation, Acidification and Warming in Waquoit Bay, USA, and a Shift to Pelagic Dominance, *Estuaries and Coasts* (2023). DOI: 10.1007/s12237-022-01166-7

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