# MWRA 2020 Outfall Monitoring Overview: **Summary**

# 2020 Outfall Monitoring Summary

Looking at Boston Harbor today, it is hard to imagine the level of pollution it once received.  For nearly 400 years, the harbor was a dumping ground for raw and poorly treated sewage.  During heavy rain, the system would become overwhelmed and release untreated sewage into the harbor.  Three decades ago, when two aging treatment plants processed 400 million gallons of sewage per day from Greater Boston's fast-growing population, the disinfected liquid sewage effluent and the solid material, called sludge, were discharged into the harbor.  Sludge was discharged off the Town of Winthrop with the outgoing tide and swept into Massachusetts Bay. Harbor sediments were said to resemble "black mayonnaise."

The Massachusetts Water Resources Authority (MWRA) was established by court order in 1984 to rebuild and upgrade this inadequate sewage system.  Most phases of the plan, dubbed the "Boston Harbor Project," were completed by 2002.  By then MWRA had separated "scum" skimmed from the raw sewage effluent, including floating trash, oil, and grease, putting it into a landfill instead of the harbor (1988); improved and increased pumping capacity to treat more sewage (1989); begun recycling sludge into fertilizer and decreasing solids discharged into the harbor by 40 dry tons per day (1991); rebuilt the primary treatment plant (1995); implemented improved, secondary treatment (1997); and, to reduce contaminants in the harbor, built a long tunnel to divert all effluent from Boston Harbor to an outfall 15 kilometers (9 miles) offshore, in Massachusetts Bay.  September 2020 marked 20 years since the startup of this bay outfall.

The $3.8 billion MWRA spent to reach these goals has proven to be a sound investment.  The harbor clean-up is widely recognized as one of the nation's greatest environmental achievements.

## NPDES Discharge Permit

During the planning for the bay outfall, predictions were made as to the type and quantity of pollutants that would be in the treatment plant effluent discharged following secondary treatment.  MWRA worked with regulators, environmental groups, and the public to create a monitoring plan to characterize the effluent and collect data on a broad range of contaminants.  To ensure the enduring health of the bay, while also documenting the harbor's recovery, state and federal regulators created detailed monitoring requirements, which were attached to MWRA's National Pollutant Discharge Elimination System (NPDES) permit.  Under the NPDES permit, MWRA must collect and report on key environmental data, particularly around the bay outfall site, which might indicate potential degradation from effluent discharge.  This Outfall Monitoring Overview report summarizes the results of these activities during 2020.

Treatment plant maintenance, something that was lacking before MWRA was created, is also an important part of MWRA's NPDES permit. As of 2020, the Deer Island Treatment Plant achieved 100% compliance with permit conditions over 14 consecutive years, earning MWRA a Platinum 14 Peak Performance Award from the National Association of Clean Water Agencies. Annual solids discharges, that portion of the MWRA effluent that contains most of the persistent organic and inorganic contaminants, remained low in 2020, only a small fraction of what was discharged to Boston Harbor in the 1990s (Figure i).

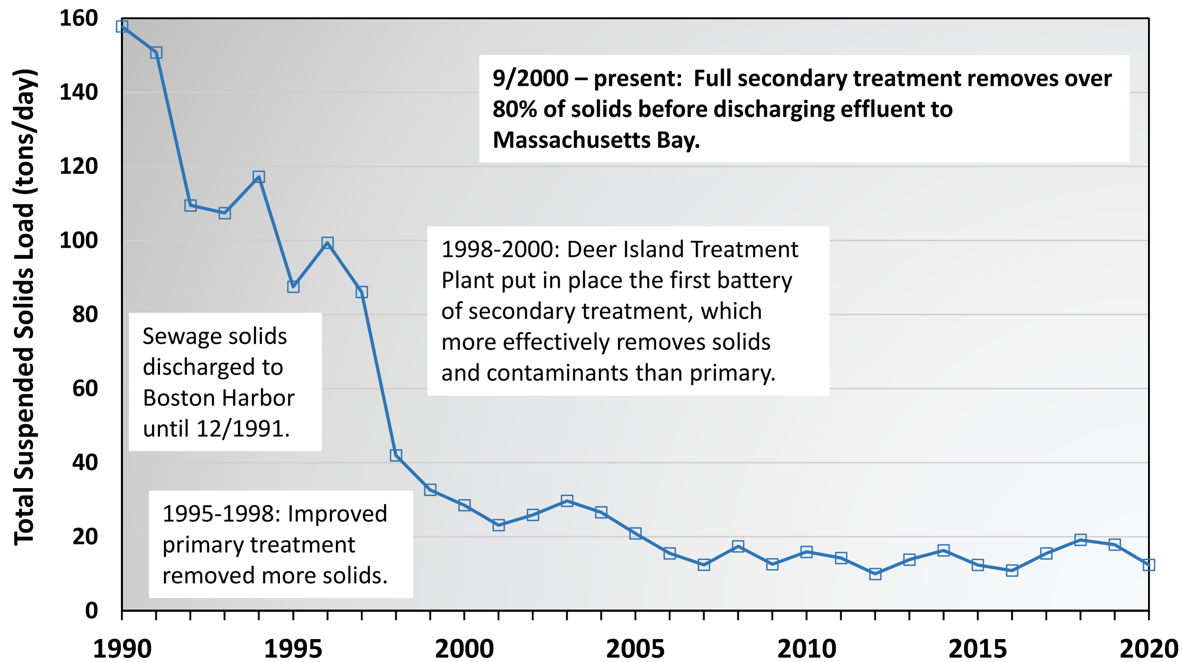


**Figure i. Annual solids discharges in 2020 remain low.**

## Twenty Years of Monitoring: Results Surpassed Expectations

Pollutant loads typically associated with wastewater effluent have been far lower in MWRA effluent than had been predicted during planning for the Massachusetts Bay outfall. That process, conducted during the 1980s, predicted the loads of conventional, metal, and organic pollutants expected to be discharged in 2020, then more than 30 years in the future. Actual 2020 loads were only a fraction of the projections, a result of MWRA's strong industrial pretreatment program and better removal of contaminants at the treatment plant (Figure ii).

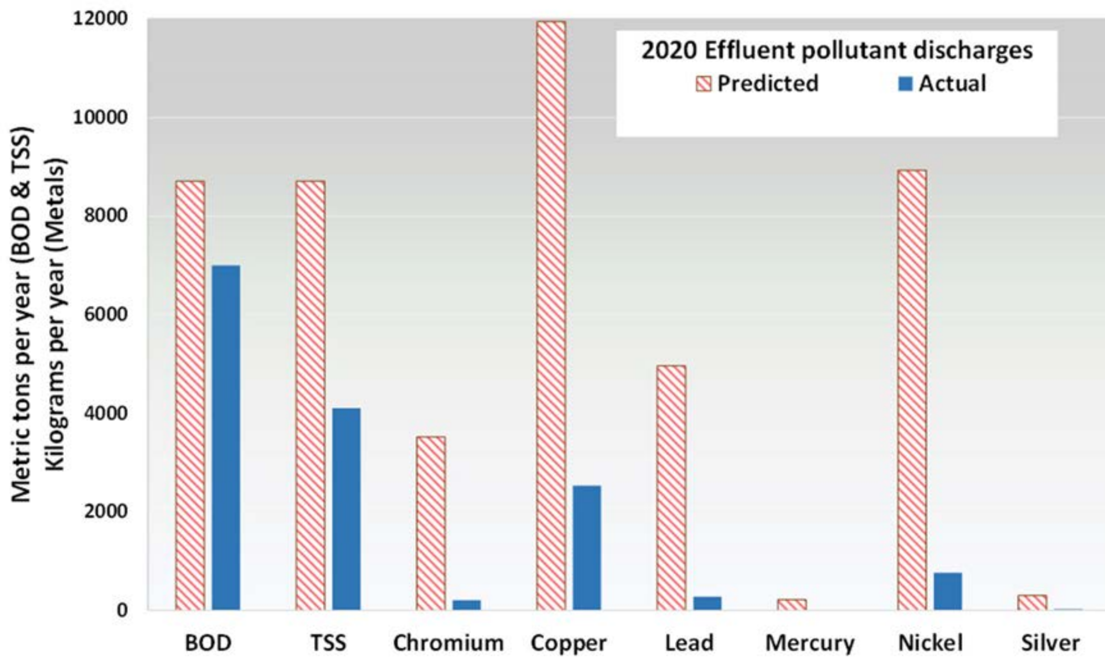


**Figure ii. Actual 2020 loads of contaminants in MWRA effluent are below original predictions.** BOD = biochemical oxygen demand, TSS = total suspended solids

## Water Quality: Nutrients are Higher at Sites Nearest the Outfall but Far Lower in Boston Harbor

An important focus of outfall monitoring is to prevent eutrophication, a condition that Boston Harbor showed before the discharge was diverted to Massachusetts Bay. Protecting the bay against eutrophication means ensuring that nutrients from the effluent discharge do not fuel an overgrowth of phytoplankton and other plant life, which could deplete dissolved oxygen when it decays. The nutrient ammonium is watched closely, because it is the largest component of the total nitrogen in wastewater; it is also the form of nitrogen most readily taken up by phytoplankton and is less likely to be removed by secondary treatment than other sewage components.

Ammonium concentrations plummeted in Boston Harbor when harbor discharges ended (Station F23 in Figure iii). As had been anticipated, elevated concentrations of ammonium have been consistently detected at stations close to the outfall, and intermittently at stations within 10 to 20 kilometers (6 to 12 miles), but not at stations farther away. The deeper water of the bay protects against eutrophication, because the pycnocline, a naturally occurring mid-depth layer separating colder deep water from warmer shallow water, confines the summer outfall discharge to beneath the well-lit depths where most phytoplankton growth occurs.

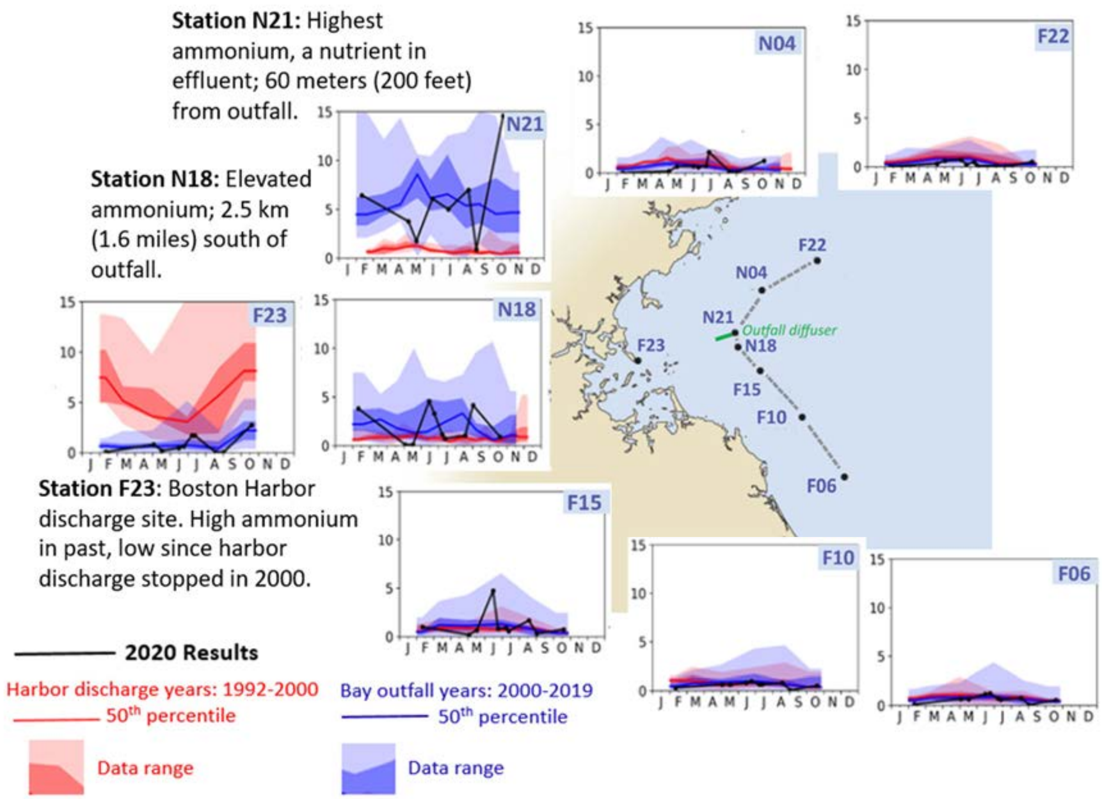


**Figure iii. Ammonium concentrations have increased at stations nearest the outfall, while concentrations in Boston Harbor have fallen.** COVID-19 protocols limited sampling in 2020, and for some stations, historic data (shading) extend later in the year than the current survey schedule. Black points and line are results from individual surveys in 2020. Red lines and shading show data from 1992-2000, Boston Harbor discharge years. Blue lines and shading show data from September 2000–2019, Massachusetts Bay discharge years. Red and blue lines are the 50th percentile, dark shading spans the 25th to 75th percentile, and light shading spans the range. The spike at Station N21 in October 2020 may have resulted from sampling directly within the turbulent mixing zone of the outfall diffusers, where the initial mixing dilution process was not complete.

Massachusetts Bay remains susceptible to periodic spring blooms of the potentially toxic dinoflagellate *Alexandrium catenella*, commonly known in New England as red tides. *Alexandrium* blooms have been documented in Massachusetts Bay since the early 1970s and were especially common in the 1970s and 1980s, followed by a lull in the 1990s and early 2000s. Historically, *Alexandrium* blooms have occurred solely when strong spring winds from the northeast have brought algal cells from coastal Gulf of Maine waters into Massachusetts Bay, and to date, monitoring has shown no influence from the outfall. In comparison with past years of the MWRA monitoring program, the 2020 bloom was moderate (Figure iv). The elevated counts were sparsely distributed, and no toxicity was detected in Massachusetts Bay.

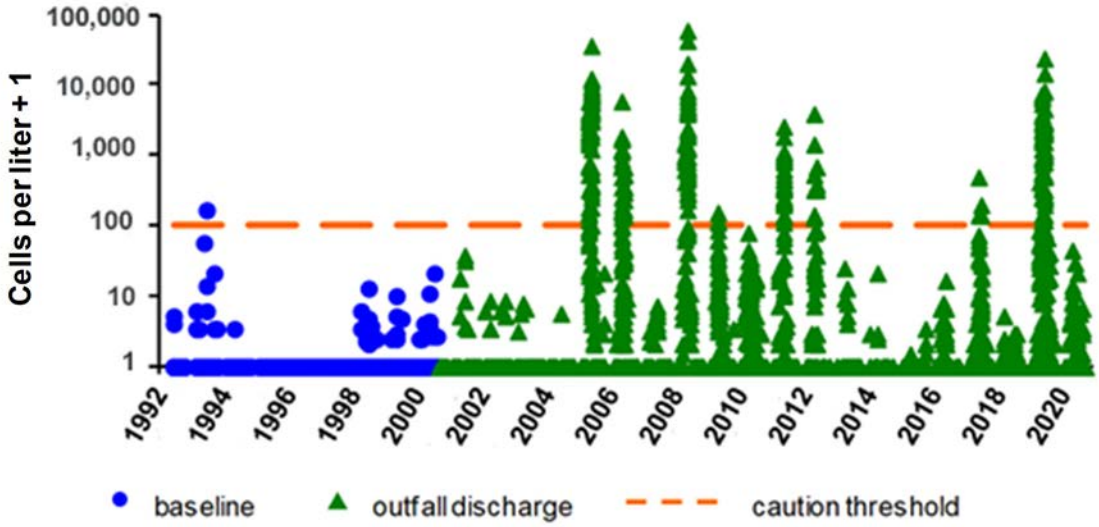


**Figure iv. Nearfield abundance of *Alexandrium catenella*, commonly known as a "red tide" phytoplankton, 1992–2020; the 2020 bloom was moderate.** The nearfield is a 12 by 10-kilometer (7 by 6-mile) area centered on the outfall. Note log scale.

*Alexandrium* cells spend part of their life cycle as cysts, overwintering in the sediments before germinating. The long-established cyst beds in coastal Maine have been the source of past blooms in Massachusetts waters. However, *Alexandrium* cysts were detected in Massachusetts Bay in the fall of 2019 and again in the fall of 2020, prompting some concern that a future bloom could originate locally, from within Massachusetts Bay rather than offshore. The moderate and geographically sparse bloom in 2020 did not provide sufficient evidence to establish a source. MWRA is working with regional experts on the biology of *Alexandrium* to evaluate the potential influence of this local cyst bed on future blooms.

## Seafloor Communities: Life Remains Diverse and Abundant

Seafloor communities in Massachusetts Bay have remained unaffected by the relocated outfall. A bacterial effluent tracer, *Clostridium perfringens* spores, can be detected in sediment samples at stations closest to the outfall but there has been no evidence of increased organic carbon content, which would indicate disturbed conditions. Total abundances, numbers of species, and diversity measurements of bay soft-bottom communities have remained within expected ranges over the 29 years of harbor discharge and bay discharge monitoring. Community assemblages appear to be structured by sediment grain size and water depth rather than by proximity to the outfall. Likewise, hard-bottom communities have continued to flourish throughout the bay. Lush growth occurs on the outfall diffusers, without negatively affecting discharge (Figure v).

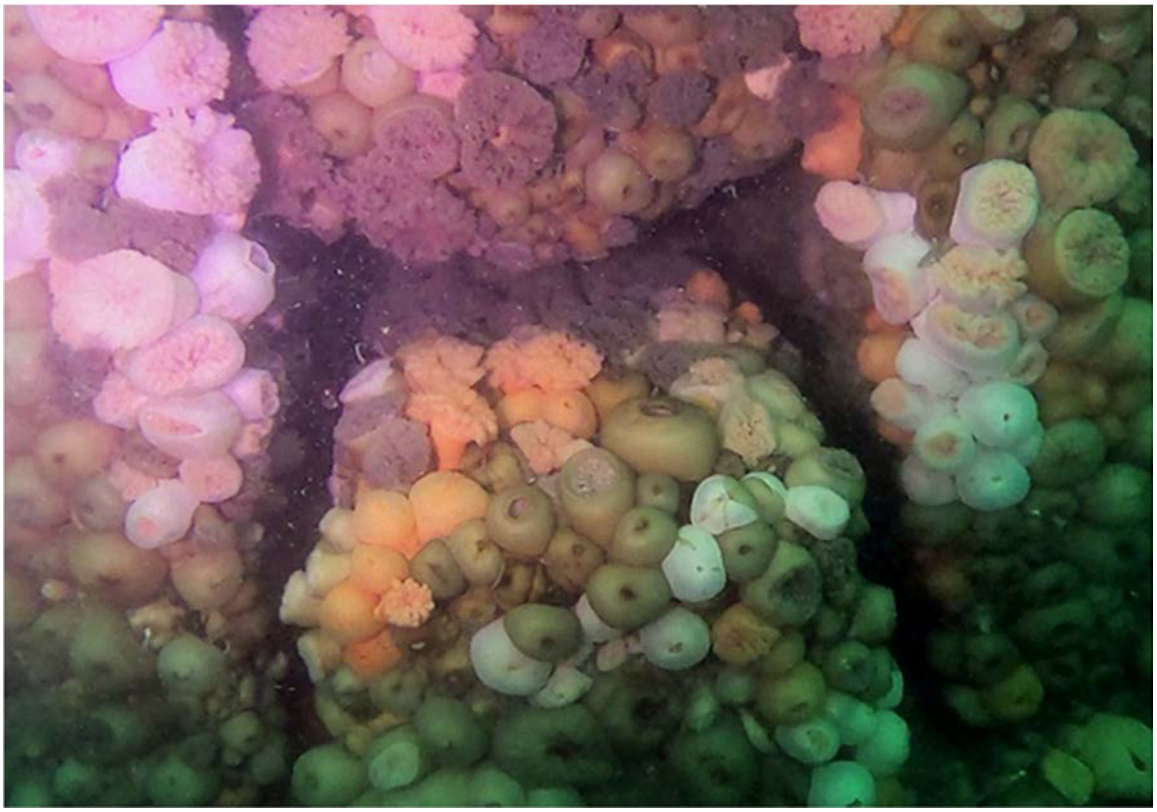
**Figure v. Marine life thrives on an outfall riser in 2020 without impeding discharge.**

## Winter Flounder Remain Healthy

In the 1980s and 1990s, many flounder from Boston Harbor showed precancerous conditions and tumors. Improvements in harbor flounder health began in the first years of the Boston Harbor Project, and incidence of cancer precursors has also declined rather than increased at the Massachusetts Bay outfall site. In 2020, few fish taken from near the bay outfall showed precancerous conditions, and no tumors have been found in fish from any location since 2004 (Figures vi and vii). The improvement in flounder health correlates well with declines in total solids and organic-contaminant discharges and has been one of the most notable successes of the Boston Harbor Project.

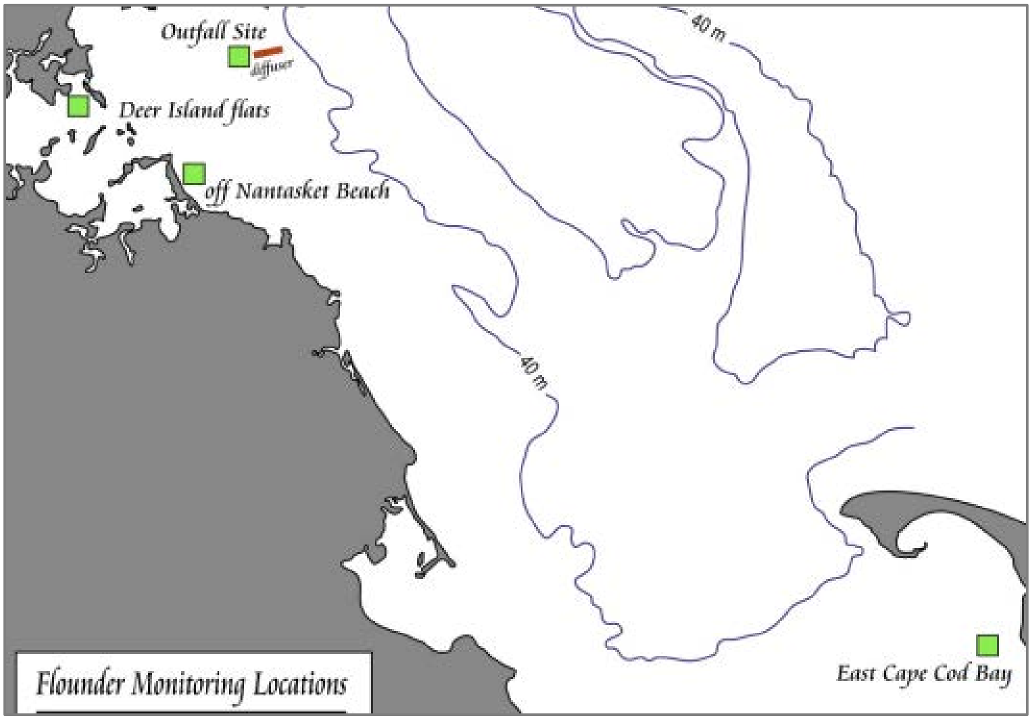


**Figure vi. Winter flounder monitoring locations.** Four sites were sampled to collect winter flounder for histological analyses: Outfall Site (OS), to detect potential impacts from MWRA's treated wastewater; Deer Island Flats (DIF) in Boston Harbor, historically impacted by contaminants; off Nantasket Beach (NB), a coastal reference station near Boston Harbor; and East Cape Cod Bay (ECCB), a clean coastal reference station.

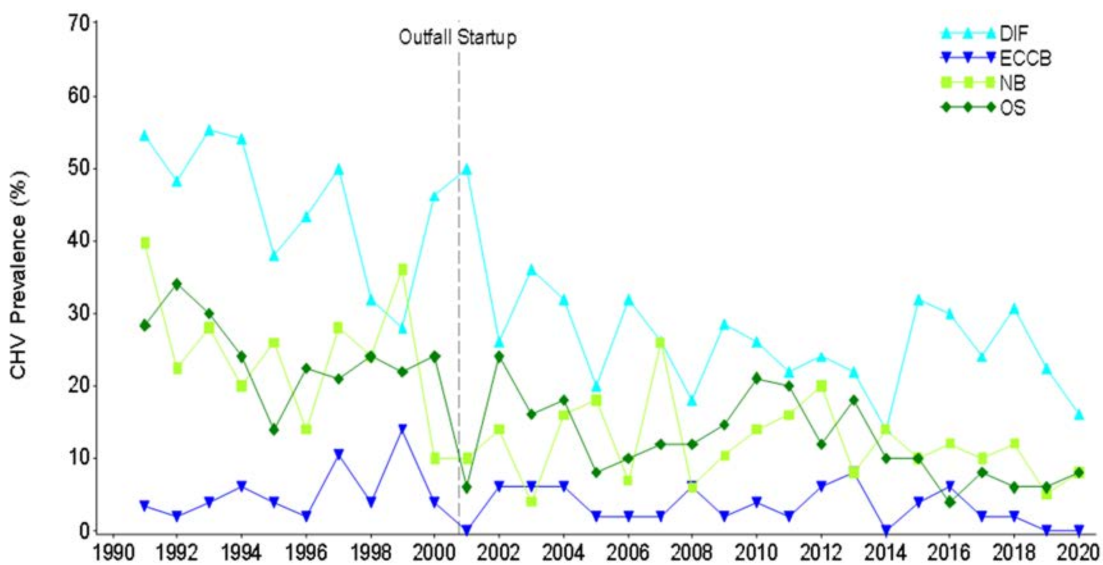


**Figure vii. Flounder precancerous disease and tumors have declined.** Annual prevalence of the precancerous condition, centrotubular hydropic vacuolation (CHV), 1991–2020.

## Special Studies: Dissolved Oxygen in Cape Cod Bay

In addition to carrying out its mission to provide water and sewer services to Greater Boston while safeguarding the health of the affected environment, MWRA participates in focused studies that respond to a variety of environmental concerns. These investigations can stem from permit requirements, emerging scientific questions, or input from regulators and the public.

For example, in 2020, MWRA found that dissolved oxygen fell to low levels, less than five milligrams per liter, at one of its routine monitoring stations, F02, in Eastern Cape Cod Bay (Figure viii). Even lower oxygen levels had been found in the shallower, nearshore waters of southwestern Cape Cod Bay in 2019. In 2020, MWRA partnered with other interested parties to investigate, finding concentrations lower than four milligrams per liter at some of those shallow stations. Fortunately, the hypoxia was short-lived in 2020 and did not produce the fish and lobster mortality of 2019.

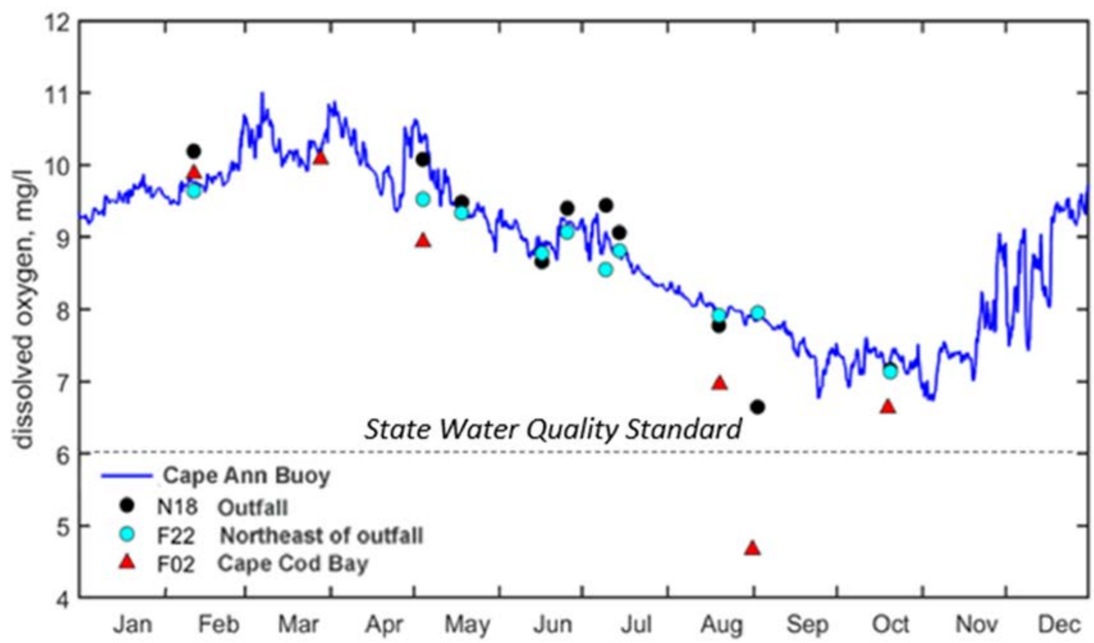


**Figure viii. Dissolved oxygen concentrations in 2020.** Dissolved oxygen was measured continuously at the instrumented buoy off Cape Ann (50 m depth) and at near-bottom samples from Station N18 near the outfall, Station F22 northeast of the outfall, and Station F02 in Cape Cod Bay. In late August, Station F02 fell below the 6.0 mg per liter state water quality standard for dissolved oxygen in these waters.

Several factors triggered the low-oxygen events in Cape Cod Bay in 2019 and 2020. In both years, warm temperatures led to strong and persistent summer stratification, which separated surface from bottom waters and led to low dissolved oxygen levels in those bottom waters. Observations show that Massachusetts Bay temperatures have been warming since 1990, consistent with trends seen region-wide.

Another possible contributor to low oxygen is the phytoplankton species *Karenia mikimotoi*, first observed in Massachusetts Bay in 2017 (Figure ix). *Karenia* was present in Cape Cod Bay during both the 2019 and 2020 low-oxygen events. While the intensities of *Karenia* blooms were insufficient to strongly affect deeper areas, such as the MWRA sampling stations, they may have been large enough to influence shallow, inshore Cape Cod Bay. MWRA continues to work with its monitoring partners to better understand the processes that lead to these hypoxic events and other environmental challenges.

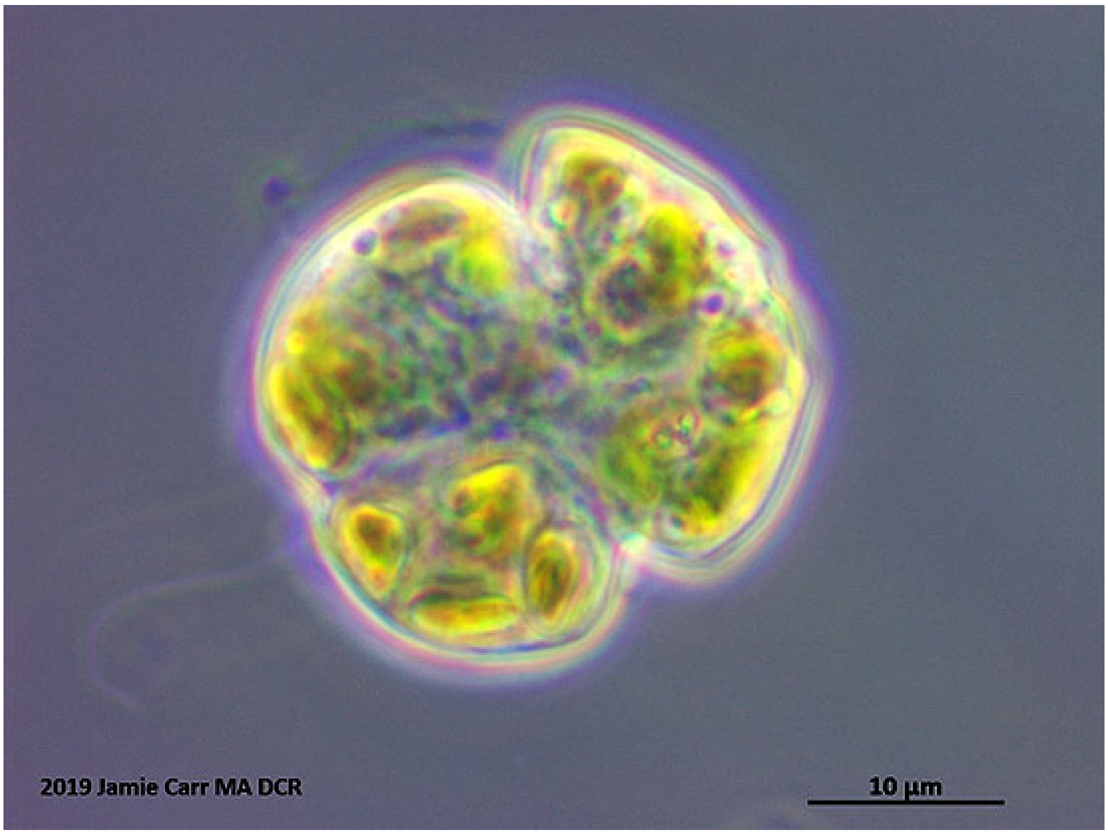


**Figure ix. Image of the dinoflagellate *Karenia mikimotoi* collected from Boston Harbor in 2019.** This single-celled photosynthetic organism is approximately 20-25 micrometers in diameter (about one quarter the thickness of a typical sheet of copy paper). Although invisible to the naked eye, under certain conditions, *Karenia* can accumulate to form water-discoloring blooms having millions of cells in a liter of seawater. Image courtesy of the National Centers for Coastal Ocean Science.

The full 2020 outfall monitoring overview report can be downloaded at **https://www.mwra.com/harbor/enquad/pdf/omo.pdf**

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