2025 Outfall Monitoring Overview





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Top: MWRA's new survey vessel sampling in Boston Harbor. Photo credit Ed Whitaker, MWRA

Bottom: Sampling at Station F23 at the mouth of Boston Harbor offshore from Deer Island Treatment Plant. Photo credit Scott Libby, Battelle.

2025
Outfall Monitoring Overview

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Executive Summary

The Massachusetts Water Resources Authority (MWRA) provides water and wastewater services to more than three million people and more than 5,500 businesses in metropolitan Boston. Since its establishment by the state legislature in 1984, MWRA has strived to minimize any adverse effects of wastewater discharges on the marine environment. MWRA works with industrial dischargers to prevent pollutants from entering the waste stream and provides primary and secondary sewage treatment to remove solid material and ensure that pollutants in the remaining liquid effluent meet permitted limits before discharge. Both the solid material, known as sludge, and the liquid effluent were once discharged into Boston Harbor. Sludge is now processed into fertilizer, and treated effluent is discharged into more open waters in Massachusetts Bay. The discharge is at depth, below the sunlit portion of the water column where phytoplankton growth occurs, preventing nutrients in the effluent from overstimulating algal growth and harming marine life.

MWRA's permit to discharge treated effluent through its Massachusetts Bay outfall requires monitoring the effluent before discharge and the water column, sea floor, and living communities in Massachusetts Bay. In the more than 25 years that MWRA has discharged treated wastewater into Massachusetts Bay, there have been no findings of environmental concern.

Effluent discharges remain low

Producing the cleanest possible sewage effluent is the most important way that MWRA works to protect the marine environment. One important measure of effluent quality is the suspended solids load, that is, the total amount of solid material discharged each year. Treatment removes most of the solid material from sewage as sludge, but small particles, known as "solids," remain suspended in the effluent. The 2025 effluent solids discharges remained consistent with those of the past two decades, measuring far lower than the amounts once discharged into Boston Harbor (Figure i, top). Discharges of potentially toxic metals have followed similar patterns, remaining low for more than 20 years (Figure i, bottom). Discharges of both solids and toxic pollutants have been much lower than had been anticipated during the planning for the Massachusetts Bay outfall discharge.

There were two permit violations in 2025, failures of one test of acute toxicity on a fish species and one similar test using a mysid shrimp species. These monthly tests use sensitive organisms to assess overall condition of the effluent and were the first effluent permit violations since 2006. There were no operational upsets at Deer Island Treatment Plant at the time and no other unusual test results. The results remain under investigation but are not thought to have caused any environmental harm.

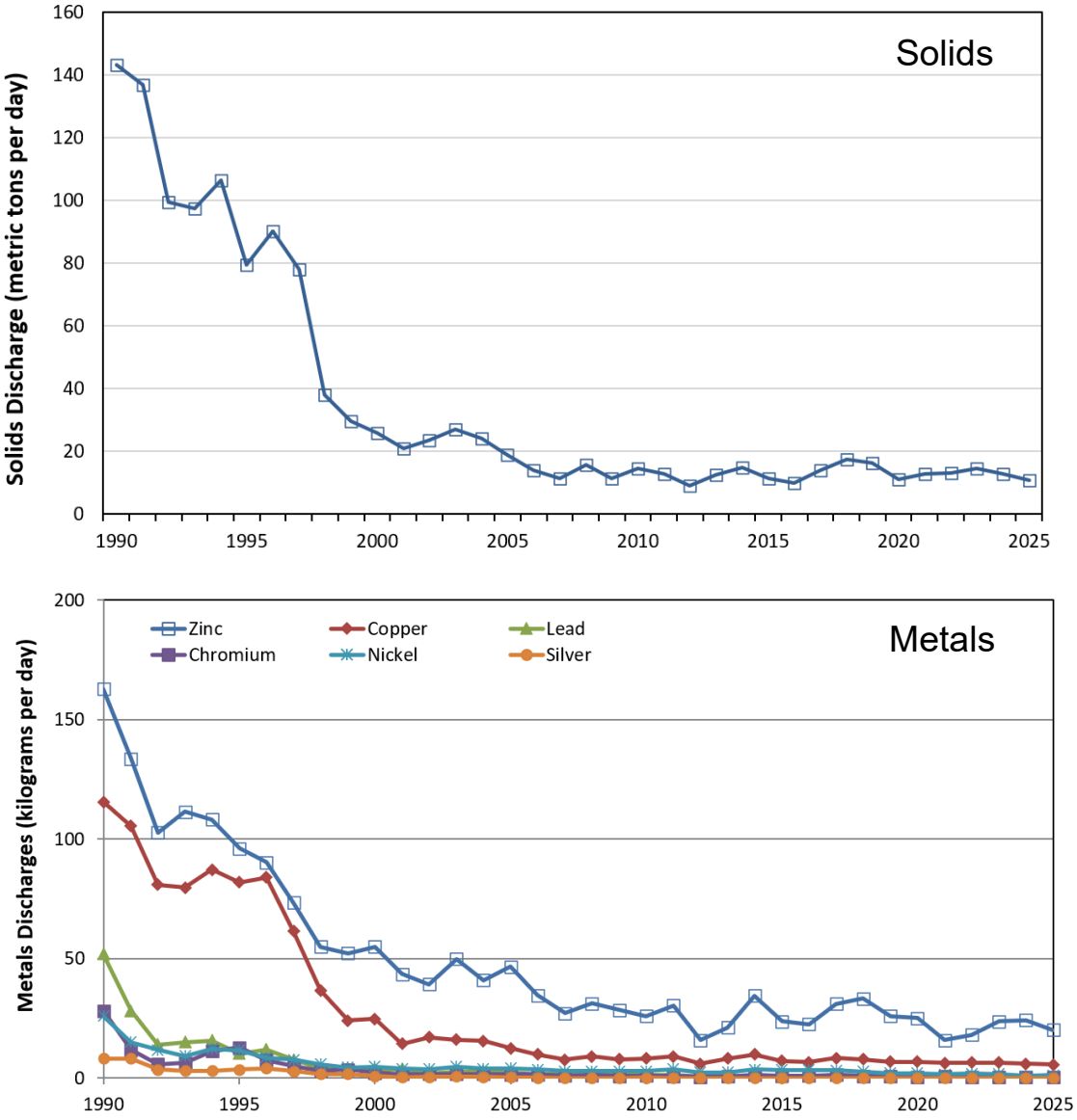


Figure i. Annual discharges of sewage solids (top) and metals (bottom), 1990–2025. Source reduction measures, including industrial pretreatment, ending sludge discharges, and secondary effluent treatment dramatically decreased solids and metals discharges. Those decreases have been sustained for more than 20 years. The effluent discharge was moved from Boston Harbor to Massachusetts Bay in September 2000.

MWRA's discharge does not cause eutrophication

Sewage treatment at Deer Island Treatment Plant removes some, but not all, of the nutrients in wastewater. MWRA water-column monitoring focuses on nutrient inputs and potential eutrophication, the excessive growth and decay of phytoplankton, the microscopic algae that live in the water column (Figure ii).

Eutrophication can lead to low levels of dissolved oxygen, potentially harming marine life. It can also stimulate nuisance or toxic algal blooms, which can threaten marine mammal and human health. In 2025, water quality analyses, including measurements of nutrient concentrations, phytoplankton biomass, and dissolved oxygen concentrations, continued to demonstrate that MWRA's treated effluent discharge does not cause eutrophication in Massachusetts Bay.

MWRA also monitors potentially toxic phytoplankton species, including diatoms in the genus *Pseudo-nitzschia* and the dinoflagellate *Alexandrium catenella*. In 2025, regional blooms of both exceeded abundance thresholds. The state briefly closed shellfishing in the southern nearshore area of Massachusetts Bay as a precautionary measure in response to the *Alexandrium catenella* bloom. The outfall is not implicated in the occurrence or extent of either bloom.

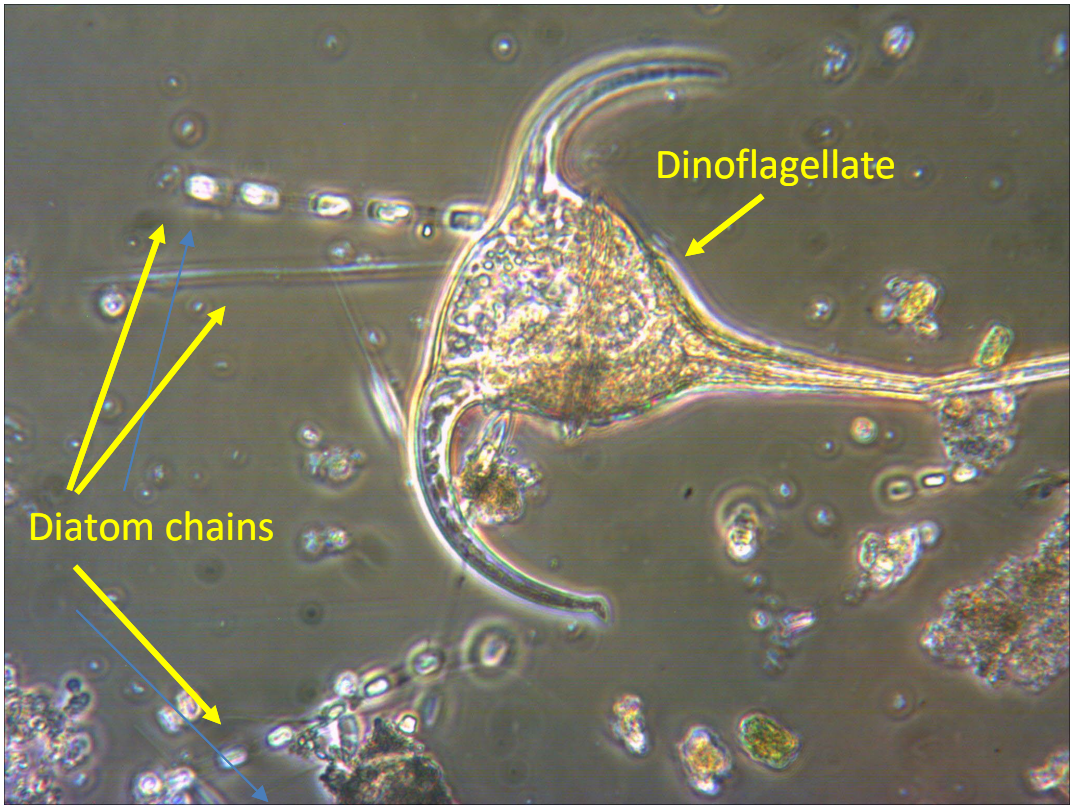


Figure ii. Typical phytoplankton from Massachusetts Bay. Phytoplankton include chains of individual diatoms and larger dinoflagellates. The very thin diatom chain is a potentially toxic *Pseudo-nitzschia* species. Photo credit David Borkman, Pausacaco Plankton, Saunderstown, Rhode Island.

Seafloor communities are thriving

MWRA's monitoring of the sediments and animals at the sea floor of both Massachusetts Bay and Boston Harbor (for example, Figure iii) show that bottom-dwelling communities are influenced by sediment types and water depth rather than by the effluent discharge. The total abundance of animals, numbers of species, and the species makeup of bottom-dwelling communities in Massachusetts Bay remain within the ranges of natural variability, while conditions in Boston Harbor have improved over time.



Figure iii. Diverse bottom communities persist in Massachusetts Bay, and sustained improvements are evident in Boston Harbor. These communities are, however, affected by other environmental threats, such as the invasive European green crab, which can disrupt eelgrass beds and preys on juvenile clams and lobsters. Green crab photographed by a sediment-profile imaging camera in Hingham Bay, Boston Harbor, in 2025. Tick marks on the side are centimeters. Photo credit RJ Diaz and Daughters, Ware Neck, Virginia.

Fish remain tumor-free

MWRA monitors the health of winter flounder, one of the region's popular commercial and recreational fish species. Flounder live and feed at the sea floor, where they are susceptible to contaminant-related physical abnormalities and health risks, but no adverse effects have been detected in response to the Massachusetts Bay effluent discharge. Instead, flounder health has improved both near the Massachusetts Bay outfall and at the former sewage effluent outfall in Boston Harbor. No cancerous tumors have been found in Boston Harbor since 2004, and none have ever been found in fish caught near the Massachusetts Bay outfall (Figure iv).

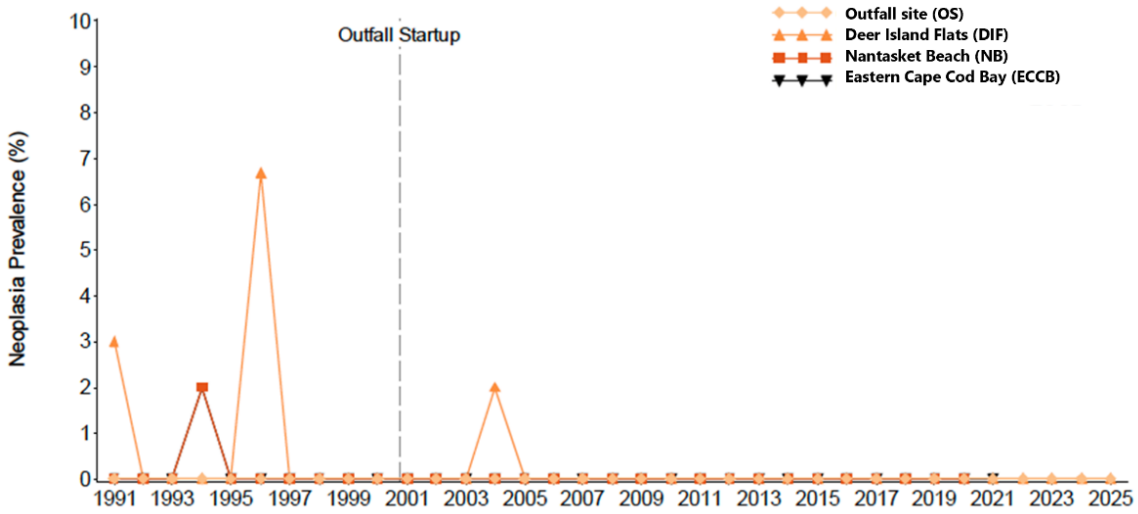


Figure iv. Annual prevalence of liver tumors in winter flounder, 1991–2025. No tumors have ever been found in fish taken from near the Massachusetts Bay outfall.

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1. Introduction

For more than 40 years, the Massachusetts Water Resources Authority (MWRA) has strived to minimize adverse effects of municipal wastewater on the marine environment. A vigorous pretreatment program, a carefully maintained treatment plant, and vigilant effluent and environmental monitoring have ensured that marine life thrives in Boston Harbor and Massachusetts Bay. September 2000 marked one of the most important milestones of the "Boston Harbor Project," when MWRA diverted its Deer Island Treatment Plant wastewater effluent discharge from the relatively shallow, enclosed waters of Boston Harbor to a deeper, more open site in Massachusetts Bay.

MWRA operates the Massachusetts Bay outfall under a National Pollutant Discharge Elimination System permit (NPDES Permit No. MA0103284, available at MWRA Permit), jointly issued by the U.S. Environmental Protection Agency (EPA) and the Massachusetts Department of Environmental Protection. An independent Outfall Monitoring Science Advisory Panel has assisted EPA in addressing scientific questions about potential environmental effects of the outfall discharge.

The NPDES permit requires MWRA to measure effluent quality before discharge and to monitor the water, sea floor, and marine life in Massachusetts Bay. A Contingency Plan attached to the permit requires MWRA to compare measured conditions against "caution" and "warning" thresholds, developed from state standards and baseline monitoring data. If a caution threshold is exceeded, MWRA must investigate the issue. A warning threshold is a higher level of concern and could require both investigation and responsive action. Threshold exceedances do not necessarily imply environmental harm but rather provide notice of changes from past conditions. Background information about the monitoring program (Werme et al. 2012), the most current monitoring plan (MWRA 2021) and Contingency Plan (MWRA 2001), past plans and overviews, and study-specific technical reports are available on MWRA's Environmental Quality Reports list.

This 2025 Outfall Monitoring Overview fulfills a requirement of the NPDES permit, which stipulates that MWRA produce an annual summary of monitoring results for Massachusetts Bay, including results relevant to Stellwagen Bank National Marine Sanctuary. The Sanctuary's closest boundary is about 12 and a half miles, 20 kilometers, to the east of the MWRA outfall. Annual overviews also present special topics selected in response to permit conditions and environmental concerns, often including research completed in cooperation with other agencies and research organizations. This year's special topic report focuses on the great changes in water quality in Boston Harbor since sewage effluent was diverted from the Harbor to Massachusetts Bay.

2. Effluent

Effective wastewater treatment protects Massachusetts Bay
MWRA's industrial pretreatment program and its primary and secondary sewage treatment minimize contaminants discharged into Massachusetts Bay.

Effluent contaminant concentrations remained low in 2025. However, two of the monthly toxicity tests that assess whole-effluent effects on sensitive animals failed to meet permit limits. Causes for these failures remain under investigation. There is, however, no indication that the toxicity test failures resulted from conditions that would adversely affect marine life in Massachusetts Bay.

MWRA's NPDES permit and Contingency Plan set limits on effluent parameters and pollutants. Contaminants of concern include **suspended solids, organic material, pathogens, nutrients, and toxic contaminants**. Because wastewater entering Deer Island Treatment Plant includes not only municipal sewage but also groundwater infiltration and stormwater inflow, rainfall is an important factor in determining annual wastewater flows and contaminant concentrations in the treated effluent. The Boston area received about 37 inches of rain in 2025, below the 1990–2024 average of just under 44 inches (Figure 2-1). Most of the rainfall occurred in the early part of the year.

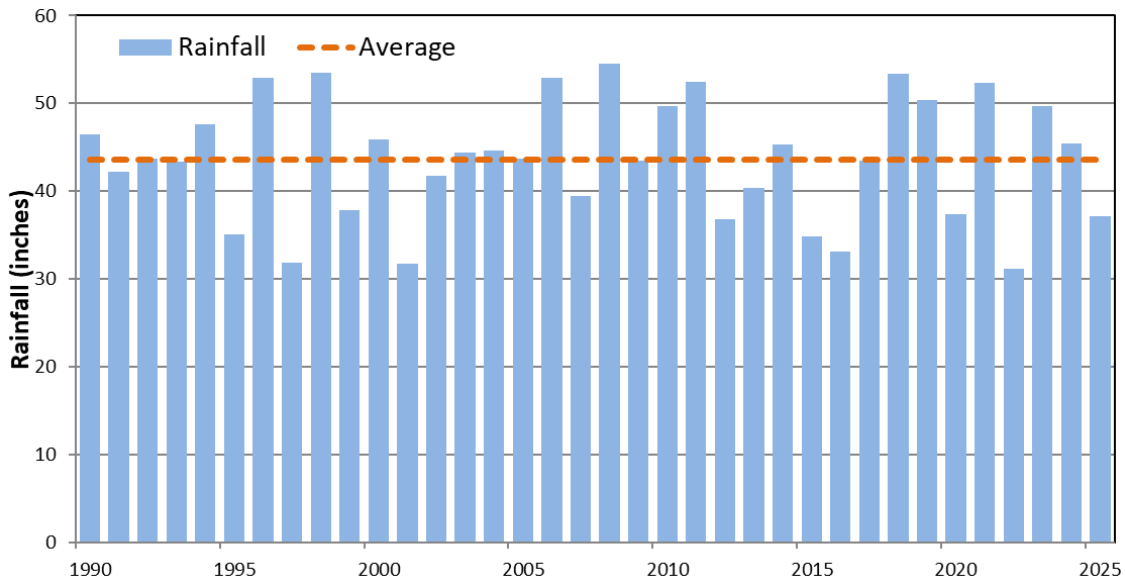


Figure 2-1. Annual and average rainfall in Boston, 1990–2025. Data are from the National Weather Service rain gauge at Boston Logan International Airport

2025 Effluent Characterization

Effluent characterization includes measurements of flow, contaminants of concern, and whole-effluent toxicity tests. In conjunction with contaminant concentration data, flow provides a measure of total discharges to the environment. In 2025, flow averaged 287 million gallons per day, lower than the 327 million gallons per day average for 1999–2024 (Figure 2-2).

Flow refers to the rate at which wastewater travels through the treatment plant. It may refer to flow entering the plant (influent) but often refers to outflow from the plant (effluent). Once effluent is released to the environment, it is often called **discharge**.

Deer Island Treatment Plant provides both primary and secondary treatment. Primary treatment uses physical processes to remove solid material through settling. Most organic material and toxic pollutants are removed from the raw sewage through primary treatment. Secondary treatment includes clarifiers to remove particles that do not settle and biological processes to break down organic matter, further reducing pollutants in the effluent. Occasionally, during intense rainfall, flow to the treatment plant exceeds what the secondary treatment system is designed to handle. Diverting some flow around the secondary treatment process prevents street flooding and sewage backups into homes and businesses. This diversion also prevents washout of the beneficial bacteria that provide a critical part of the treatment process. Massachusetts regulations require MWRA to notify regulators and the public whenever a blending event occurs. Historically, blended flows have fully met permit limits, and they continued to meet those limits in 2025.

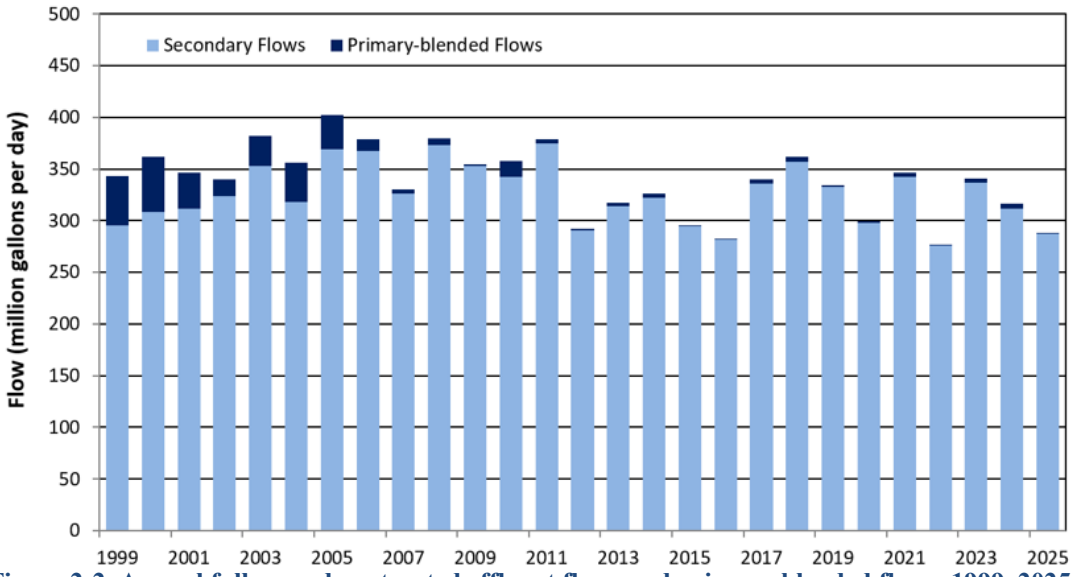


Figure 2-2. Annual full secondary-treated effluent flows and primary-blended flows, 1999–2025. Average flow during 1999–2024 was 327 million gallons per day. During large storms, flow exceeding the secondary capacity of the plant is diverted around the secondary process; this primary-treated flow is mixed with the fully treated flow before disinfection and discharge. Historically, blended flows have been minimal and met all permit limits.

Only 0.33% of the total 2025 flow was primary-treated effluent ("primary-blended flow") blended into fully treated effluent (Figure 2-3). One blending event, which occurred during intense rainfall in May, triggered "adverse condition surveys" to assess bacteria levels at the Massachusetts Bay effluent outfall site. These adverse condition surveys, required under a Memorandum of Understanding with the Massachusetts Department of Marine Fisheries, confirmed that the blended flows did not pose an environmental concern, with low levels of bacteria found near the outfall and throughout the Bay.

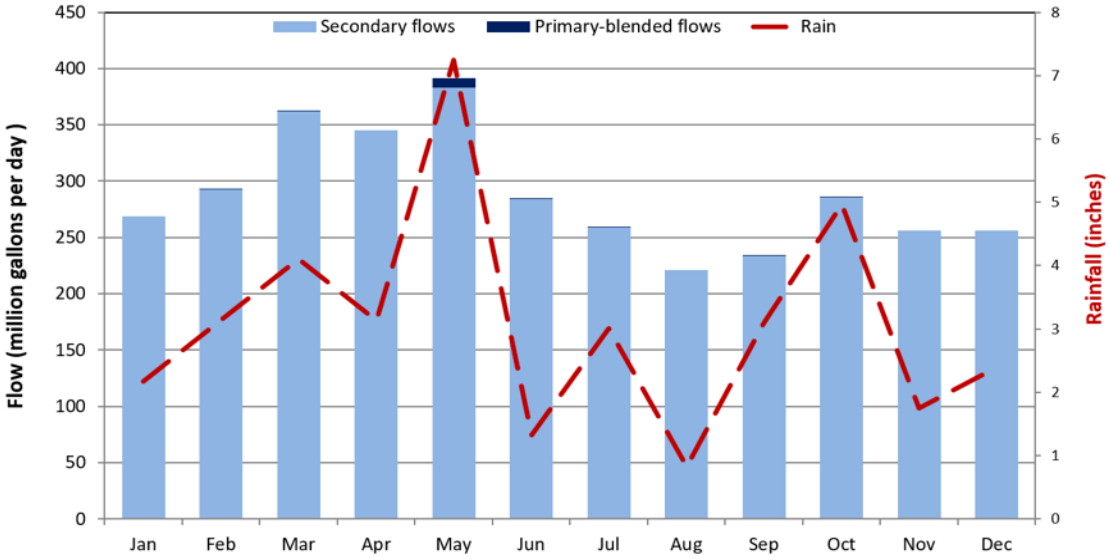


Figure 2-3. Monthly full secondary-treated and primary-blended flows (bars) and rainfall (dashed line) in 2025. Months with primary-blended flows corresponded with months of greater rainfall.

Most solid material is removed from sewage influent as sludge, and the remaining particles in the effluent are called total suspended solids or simply "solids." Daily solids discharges remained consistently low throughout 2025 (Figure 2-4). Over the past two decades, the total solids discharges have been only about 10% of what was discharged in 1990–1991, when sludge as well as effluent was disposed of in Boston Harbor.

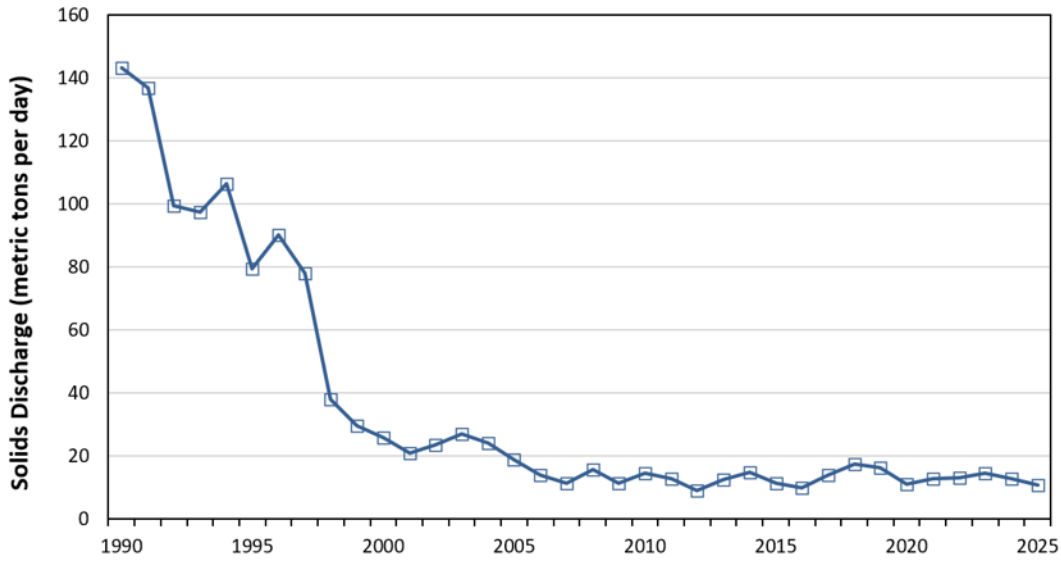


Figure 2-4. Average annual daily discharges of sewage solids, 1990–2025. Sludge discharge ended in 1991, and the secondary treatment system was completed in 1997.

Organic material, a major constituent of untreated sewage that consumes oxygen as it decays, remains at safe levels.

Decomposition of organic material in effluent consumes oxygen as it decays. Biochemical oxygen demand (BOD), a measure of the amount of oxygen needed to decompose organic material, remained well below levels that would be expected to affect dissolved oxygen levels in the environment in 2025. MWRA has consistently met its weekly and monthly BOD permit limits.

Pathogens include disease-causing bacteria, viruses, and protozoans and are found in human and animal waste. Effluent bacteria levels continue to meet permit limits.

MWRA also monitors the effluent for fecal coliform bacteria, an indicator of various pathogens that can make waters unsafe for swimming or shellfish unhealthy for human consumption. Fecal coliform bacteria levels in the effluent have consistently been well below permit limits. MWRA monitors fecal coliform bacteria and another bacteria indicator, *Enterococcus* species, in Massachusetts Bay through a Memorandum of Understanding with the Massachusetts Division of Marine Fisheries. Results from all locations sampled in that program, even those closest to the outfall and in response to the May blending event, met the stringent shellfishing standards set by the state.

Nutrients control algal growth and, in excess, can lead to lower oxygen concentrations or stimulate nuisance algal blooms.

MWRA's permit does not set limits on effluent nutrients, potentially toxic metals, or organic compounds but requires measurements and reporting. Nutrient measurements include individual components of total nitrogen (ammonium, nitrate, and nitrite). Metals with reporting requirements include zinc, copper, lead, nickel, silver, and mercury. Organic compounds include selected chlorinated pesticides and polychlorinated biphenyls (PCBs), known as legacy pollutants. These contaminants have been banned for decades; however, they break down slowly and persist in low amounts in wastewater and in stormwater runoff.

The Contingency Plan attached to MWRA's permit includes caution and warning thresholds for nitrogen discharges. The total nitrogen load for 2025 was 11,962 metric tons, below the Contingency Plan caution threshold of 12,500 metric tons per year (Figure 2-5). This threshold was set conservatively at about 90% of the warning threshold, 14,000 metric tons, which was the amount expected to be discharged annually by 2020, based on 1990s population growth projections for the MWRA service area. Actual population growth has been somewhat higher than projected, but nitrogen loads remain below the anticipated discharge, a result of water conservation, better controls on groundwater infiltration, and good removal efficiencies during treatment.

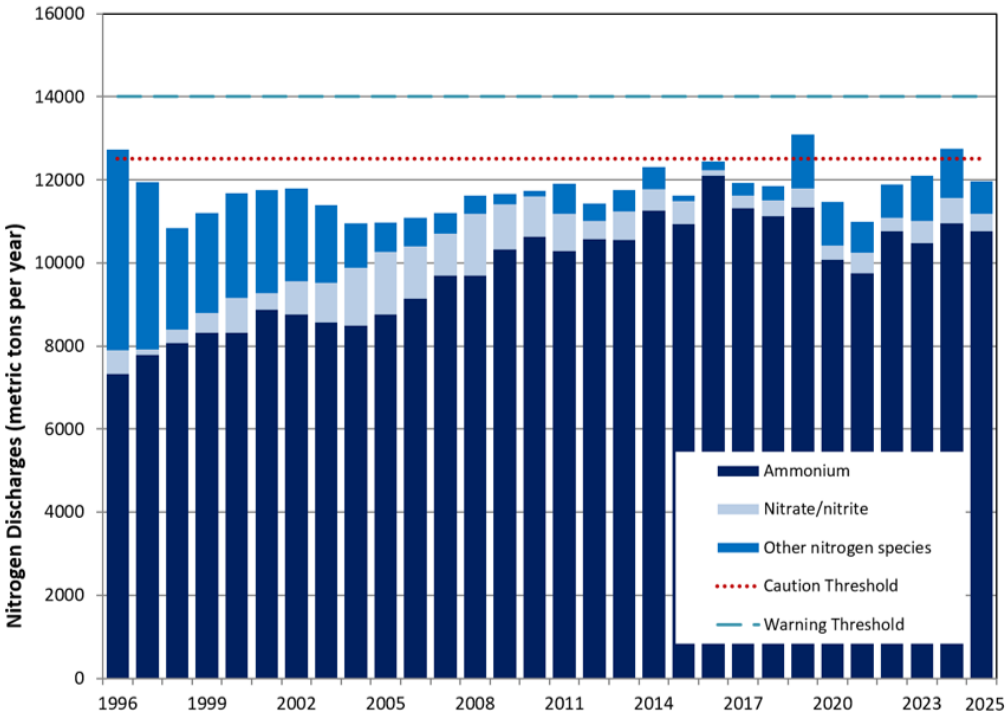


Figure 2-5. Annual nitrogen discharges, 1996–2025. The warning threshold, 14,000 metric tons per year, was set as the load anticipated for 2020; the caution threshold was set at 90% of the warning threshold.

Modeling suggests that even higher nitrogen loads than the more stringent warning threshold would not harm the environment (Deltares 2022). MWRA annually updates a report on potential nitrogen-removal strategies (most recently, Davis et al. 2026).

Ammonium is the form of nitrogen most easily taken up by phytoplankton and is also a good effluent tracer. During the late 1990s and early 2000s, ammonium discharges became a larger component of the total nitrogen discharge, a result of the treatment processes for both sewage effluent and sludge. For example, when sludge is processed into fertilizer pellets, some ammonium-rich water is returned to the treatment plant. Those increases have plateaued in recent years.

Metals discharges remained low in 2025 (Figure 2-6). Zinc continued to be the most abundant metal, followed by copper. Both zinc and copper are present in water pipes and fixtures. Other notable sources of zinc to wastewater include hair salons, automobile-repair shops, hospitals, residential household products, and street runoff. Removing lead from pipes and service lines has significantly reduced lead levels in the effluent discharge. Silver, once thought of as an effluent tracer, is now rarely measured in effluent, a result of the decline in film photography as well as sewage treatment.

Toxic contaminants in the effluent include heavy metals, such as copper and lead, and organic compounds, including some now-banned pesticides and polychlorinated biphenyls (PCBs).

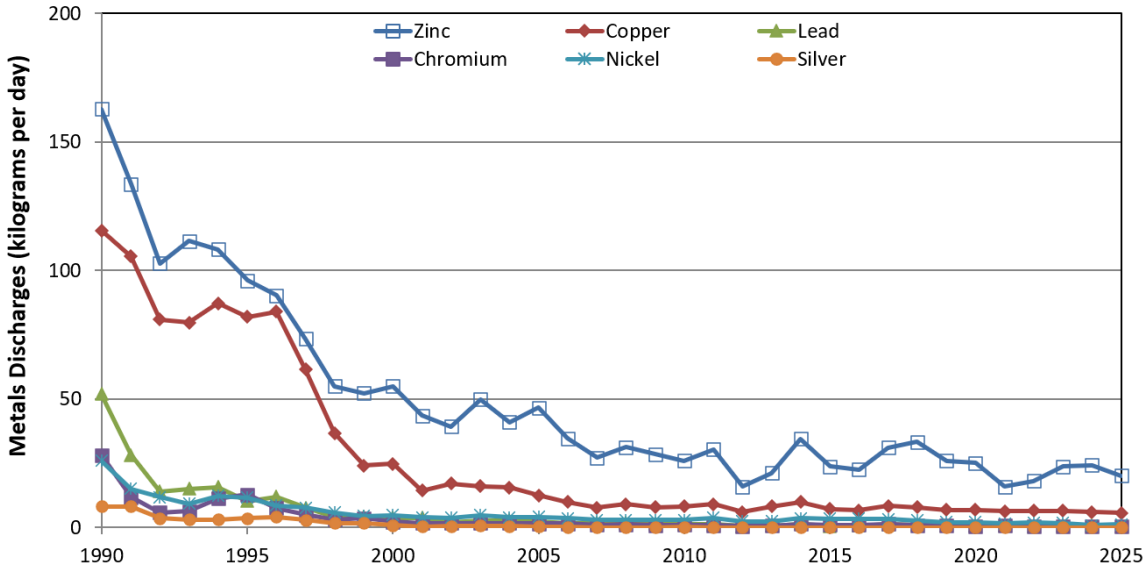


Figure 2-6. Annual metals discharges, 1990–2025. Zinc and copper from water pipes and fixtures remain the most abundant metals. Ending sludge discharge in 1991, source reduction, industrial pretreatment, and secondary treatment have dramatically decreased metals loads in the effluent.

Total loads of all metals remained small percentages of what was anticipated during planning for the Massachusetts Bay outfall (summarized in Werme et al. 2021). Copper and zinc discharges were less than 20% and most other metals discharges were less than 5% of the predictions made in the 1990s.

Except for copper, all metals meet water quality standards prior to discharge. Copper discharges meet the standard after initial dilution, the amount of mixing within a strictly defined area near the outfall.

Discharges of organic contaminants have varied slightly from year to year (Figure 2-7), but continue to be well below loads historically discharged into Boston Harbor. For example, effluent data for 4,4'-DDE, one of the most prevalent breakdown products of the chlorinated pesticide DDT, continue to show evidence of the very slow declines anticipated in the 1970s, when chlorinated pesticides were banned. Discharges of PCBs, which were once used in industrial and consumer electrical equipment, also remain well below the historic loads discharged into Boston Harbor.

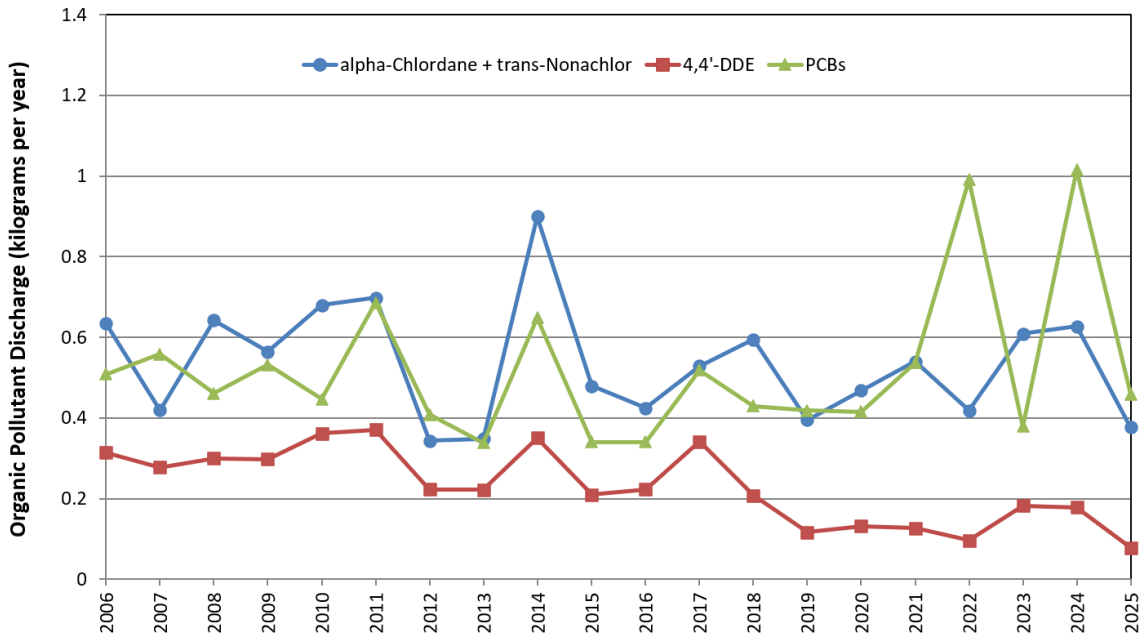


Figure 2-7. Organic pollutant discharges, 2006–2025. alpha-Chlordane + trans-Nonachlor = components of the banned pesticide chlordane, 4.4"-DDE = the most prevalent breakdown product of the banned pesticide DDT, dichlorodiphenyltrichloroethane, PCBs = polychlorinated biphenyls, banned compounds once used in electrical equipment and other products.

Annual polycyclic aromatic hydrocarbon (PAH) discharges now meet water quality standards at discharge. PAHs are ubiquitous in the environment, as some forms are present in unburned oil and petroleum products, and others are produced by natural and man-made combustion processes.

The NPDES permit also requires MWRA to conduct monthly acute and chronic toxicity tests under prescribed EPA protocols. Acute tests measure survival of the inland silverside fish *Menidia beryllina* and the mysid shrimp *Americamysis bahia*, often referred to by an old name, *Mysidopsis bahia*. Chronic tests measure growth and survival of the inland silverside and fertilization success of sea urchin *Arbacia punctulata* eggs. None of the three test species occur near the Massachusetts Bay outfall. They are selected as standards, because they are sensitive to a variety of pollutants. The tests use whole, undiluted effluent, as well as a series of effluent dilutions. None of the test dilutions are as large as the actual initial dilution at the MWRA outfall.

Two tests failed permit limits in 2025, one acute inland silverside test in June and one acute mysid shrimp test in December. These test failures were the first effluent permit violations since 2006 and are discussed further in the next section, Effluent Contingency Plan Thresholds.

Effluent Contingency Plan Thresholds

Most permit conditions, including all contaminant limits, were met in 2025, and the nitrogen discharge remained below its Contingency Plan threshold (Table 2-1). There were, however, two effluent exceedances based on permit limits in 2025. Both failures were of acute toxicity tests, one with inland silverside fish in June and the other with mysid shrimp in December. These test failures were the first permit violations since 2006, when one chronic fish test failed. Of hundreds of past tests over more than 25 years, there had been only three test failures in MWRA history before the two in 2025.

There were no obvious reasons for either failure in 2025. There were no operational upsets at Deer Island Treatment Plant and no other unusual test results. During the June test, concentrations of potentially toxic compounds, including ammonia (the more volatile and toxic form of ammonium) were within historic ranges. Relatively high pH may have exasperated natural ammonia toxicity.

Ammonia levels in the December sample used for the mysid shrimp test were also within the historic range. However, somewhat high concentrations of total organic carbon and biological oxygen demand may have contributed to a drop in oxygen levels. A change in testing laboratories could also be a factor in either or both test failures. Since 1991, MWRA has employed five different testing laboratories; the laboratory conducting the tests in 2025 was unique to that year.

Because standard toxicity tests use especially sensitive species and lower than actual effluent dilution, they are not specifically designed to mimic conditions at the outfall. For example, the concentration that would kill 50% of the fish (lethal concentration 50 or LC50) in the June test would be equivalent to about a 2:1 effluent dilution, while actual dilution at the outfall is about 70:1. More site-specific analyses generally require tests with water from the field and a comparison of laboratory and field results. The standard tests included in the permit are designed to look for changes in the treatment process that should be investigated rather than inferring environmental harm.

Table 2-1. Contingency Plan threshold values and 2025 results for effluent monitoring.

Parameter	Baseline	Caution Level	Warning Level	2025 Results
Permit Limits and Contingency Plan Thresholds				
pH	NA	NA	<6 or >9	Not exceeded
Fecal coliform	NA	NA	>14,000 fecal coliforms/100 mL	Not exceeded
Chlorine, residual	NA	NA	>631 µg/L daily, >456 µg/L monthly	Not exceeded
Suspended solids	NA	NA	>45 mg/L weekly >30 mg/L monthly	Not exceeded
cBOD	NA	NA	>40 mg/L weekly, >25 mg/L monthly	Not exceeded
Acute toxicity	NA	NA	LC50 <50%	Two exceedances
Chronic toxicity	NA	NA	NOEC <1.5% effluent	Not exceeded
PCBs	NA	Aroclor>0.045 ng/L	NA	Not exceeded
Plant performance	NA	5 violations/year	Compliance <95% of the time	99.9% compliance
Flow	NA	NA	>436 MGD average dry days	Not exceeded
Oil and grease	NA	NA	>15 mg/L weekly	Not exceeded
Contingency Plan Thresholds				
Total nitrogen load	NA	>12,500 mtons/year	>14,000 mtons/year	11,962 mtons

NA = not applicable
cBOD = carbonaceous biological oxygen demand
LC50 = 50% mortality concentration
NOEC = no observable effect concentration
PCB = polychlorinated biphenyl
Aroclor = total for a specified suite of PCB compounds (called Aroclors)
Plant performance = compliance with permit conditions
mL = milliliters
µg/L = micrograms per liter
mg/L = milligrams per liter
ng/L = nanograms per liter
MGD = million gallons per day
mtons = metric tons

3. Water Column

Water-column monitoring focuses on eutrophication
Excess nutrient inputs can lead to increases in primary productivity, which could drive low levels of dissolved oxygen or stimulate nuisance or toxic algal blooms, so water-column monitoring evaluates nutrient concentrations, water-quality parameters, and plankton. For most parameters, 2025 was a typical year in the water column, following well-established seasonal patterns.

There were no Contingency Plan threshold exceedances for chlorophyll or dissolved oxygen. Two thresholds for nuisance phytoplankton species, summer abundance of *Pseudo-nitzschia* species and abundance of *Alexandrium catenella*, were exceeded. The state briefly closed shellfishing in the southern nearshore area of Massachusetts Bay as a precautionary measure in response to the *Alexandrium catenella* bloom.

MWRA's water-column monitoring program measures and evaluates **physical oceanographic conditions, water quality, and phytoplankton and zooplankton communities** at stations in Massachusetts Bay, at the mouth of Boston Harbor, and in Cape Cod Bay. Ship-based field surveys are supported by data from instrumented buoys and satellite imagery.

Organic material, pathogens, and potentially toxic contaminants are largely removed in wastewater treatment and are not likely to have any harmful effects on water quality or plankton communities. Therefore, water-column monitoring focuses mainly on potential effects of excess nutrients, which remain at levels that could affect water quality in Massachusetts Bay after primary and secondary treatment.

Excess nutrients can cause eutrophication or promote growth of nuisance or toxic algal blooms. Potentially toxic species include *Alexandrium catenella*, which occurs regularly in Massachusetts Bay, and members of the genus *Pseudo-nitzschia*, a species group that is often present, but usually in low numbers and in its nontoxic forms. One nuisance, but not toxic, phytoplankton species, *Phaeocystis pouchetii*, was a focus in past years, but its presence and abundance were shown to vary in response to physical oceanographic conditions rather than the effluent discharge.

Each monitoring year includes nine ship-based surveys, completed monthly between February and October. Five stations are in the "nearfield," a 12×10-kilometer area centered on the outfall, where some effects of the effluent were expected and have been observed. Nine stations are in the more distant "farfield," including the mouth of Boston Harbor, Cape Cod Bay, and near Stellwagen Bank National Marine Sanctuary (Figure 3-1). Nearfield Station N18, located just to the south of the outfall, is representative of the nearfield area, as it has been consistently monitored over time.

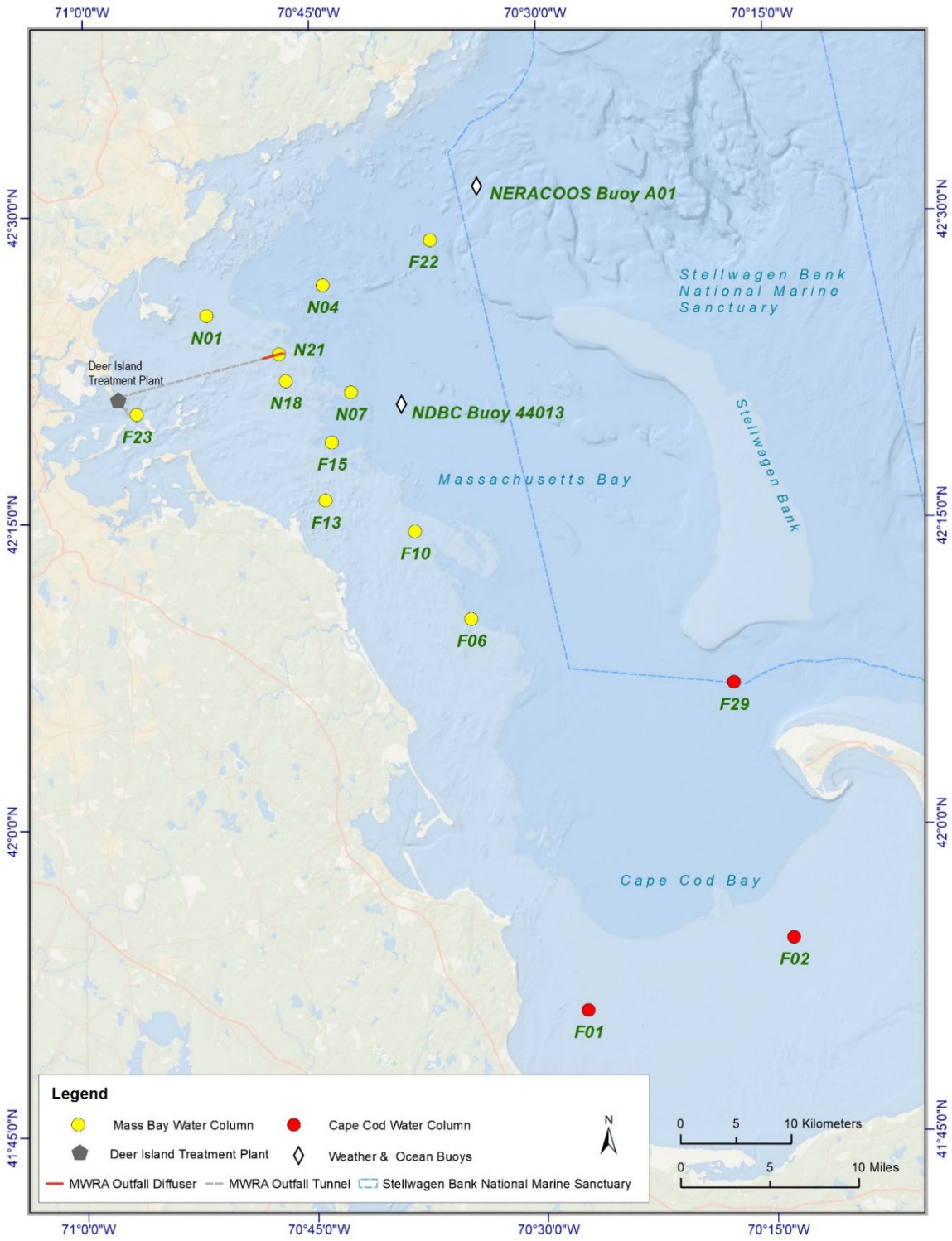


Figure 3-1. Water-column monitoring stations and instrumented buoys in Massachusetts and Cape Cod Bays. Data are obtained from surveys, the NERACOOS A01 and NDBC 44013 buoys, and satellite imagery. Also shown are the outfall and the Stellwagen Bank National Marine Sanctuary. Nearfield station labels begin with N, while farfield stations begin with F. NERACOOS = Northeastern Regional Association of Coastal Ocean Observing Systems; NDBC = National Data Buoy Center.

Additional surveys may be triggered by elevated abundance of *Alexandrium catenella* in MWRA water samples or by presence of its toxin in shellfish. These "*Alexandrium* Rapid-Response Study" surveys (Libby et al. 2013) provide hydrographic data and water samples for measuring nutrients and *Alexandrium catenella* abundance at up to 19 stations. In late May 2025, the Massachusetts Division of Marine Fisheries detected toxin in mussels, triggering a series of four rapid-response surveys and additional stations added to the regular June survey.

The monitoring program benefits from collaboration with the Center for Coastal Studies in Provincetown, Massachusetts, which samples the three stations in Cape Cod Bay and near Stellwagen Bank National Marine Sanctuary. The permit sets a 48-hour target window for completing sampling in both bays. In 2025, the August Cape Cod Bay survey was completed three days before the Massachusetts Bay survey. All other surveys were completed within the 48-hour window.

Surveys are supplemented by measurements at two instrumented buoys: the Northeastern Regional Association of Coastal and Ocean Observing Systems (NERACOOS) Buoy A01, off Cape Ann at the northern limit of Massachusetts Bay, and the National Oceanic and Atmospheric Administration (NOAA) National Data Buoy Center (NDBC) Buoy 44013 in central Massachusetts Bay. The National Aeronautics and Space Administration publicly shares satellite imagery of chlorophyll fluorescence, which, along with chlorophyll measurements in water samples, is a measure of phytoplankton biomass.

Physical Conditions

Circulation and physical properties in Massachusetts Bay are driven by the larger patterns of water flow in the Gulf of Maine. Water typically enters Massachusetts Bay from the north, circulates in a counter-clockwise direction, and exits by Provincetown, at the tip of Cape Cod. Consequently, Station F22, to the north and east of the outfall, is considered a reference station for water entering the Bay, while stations to the south of the outfall are more likely to have detectable outfall influences. Water flows vary from week-to-week and depend on the strength of the current and on wind speed and direction. The coastal current is strongest during spring runoff from rivers and streams.

As in other temperate regions, there are seasonal patterns to the physical structure of the water column, the vertical profile extending from the surface to the sea floor. In winter, the water column is well mixed, and dissolved oxygen levels are uniformly high. Warm water is less dense than cold water, so as surface waters warm, the water column stratifies, separating warmer surface waters from the cooler bottom.

Stratification separates warm, surface water from colder, denser bottom water. The boundary between layers is called the thermocline or the pycnocline.

Stratification isolates bottom waters from the atmosphere and from oxygen production by phytoplankton, which occurs in shallower, sunlit waters. This isolation, combined with respiration and decomposition of organic material, leads to lowered bottom-water dissolved oxygen levels in late summer and fall. In the fall, cooling surface waters and strong winds promote mixing, ending the stratified season and re-oxygenating deeper waters.

Rainfall and river flow also influence stratification in Massachusetts Bay. Freshwater inputs, which are less dense than seawater, strengthen stratification by trapping heavier saltwater beneath a lighter surface area. The Merrimack River, which enters the Gulf of Maine just to the north of Massachusetts Bay, is the largest river in the region and plays an important role in freshwater delivery to Massachusetts Bay. Discharge from the smaller Charles River, which flows into Boston Harbor, also influences conditions in the Bay.

Physical conditions in 2025 were within the ranges of past years (Libby et al. 2026). Over the course of the year, Massachusetts received below-average rainfall (see Figure 2-1 on page 2), with most of the rain falling in the early months of the year. Flows from both the Merrimack and Charles Rivers reflected that pattern, with highest river discharges in the late winter and spring and low discharges through the summer and fall (Figure 3-2).

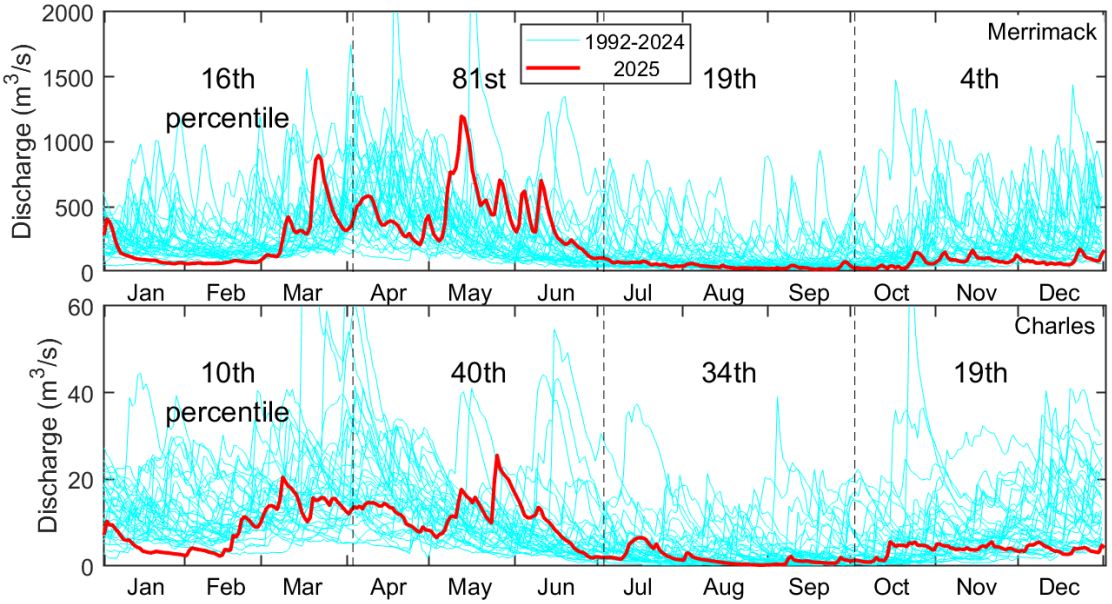


Figure 3-2. Flows of the Merrimack (top) and Charles (bottom) Rivers. The much larger Merrimack River flows into the Gulf of Maine just south of the New Hampshire border and greatly influences the physical conditions in Massachusetts Bay. The Charles River flows into Boston Harbor. Note differences in scale. The quarterly percentiles represent the 2025 discharges in comparison to the entire record. m^3/s = cubic meters per second.

Wind speeds and wave heights showed typical seasonal variations in 2025, with the largest waves occurring during a storm with winds from the northeast in May. Air temperatures, which are measured at both the NERACOOS and NDBC buoys, fluctuated during that May storm, and some fluctuation continued throughout the summer. Water temperatures at both buoys showed similar patterns, with sharp drops in temperature during the May storm and continued fluctuation throughout the summer months.

At Station N18 just south of the outfall, surface- and bottom-water temperatures were average or slightly warmer than past years (Figure 3-3, top two panels). Bottom-water temperatures were somewhat high in the spring, but temperatures decreased during the May storm. Surface- and bottom-water salinities at Station N18, the station considered most representative of the nearfield, reflected the river discharges in early 2025 (Figure 3-3, bottom panels), with particularly low surface salinities recorded during May and June.

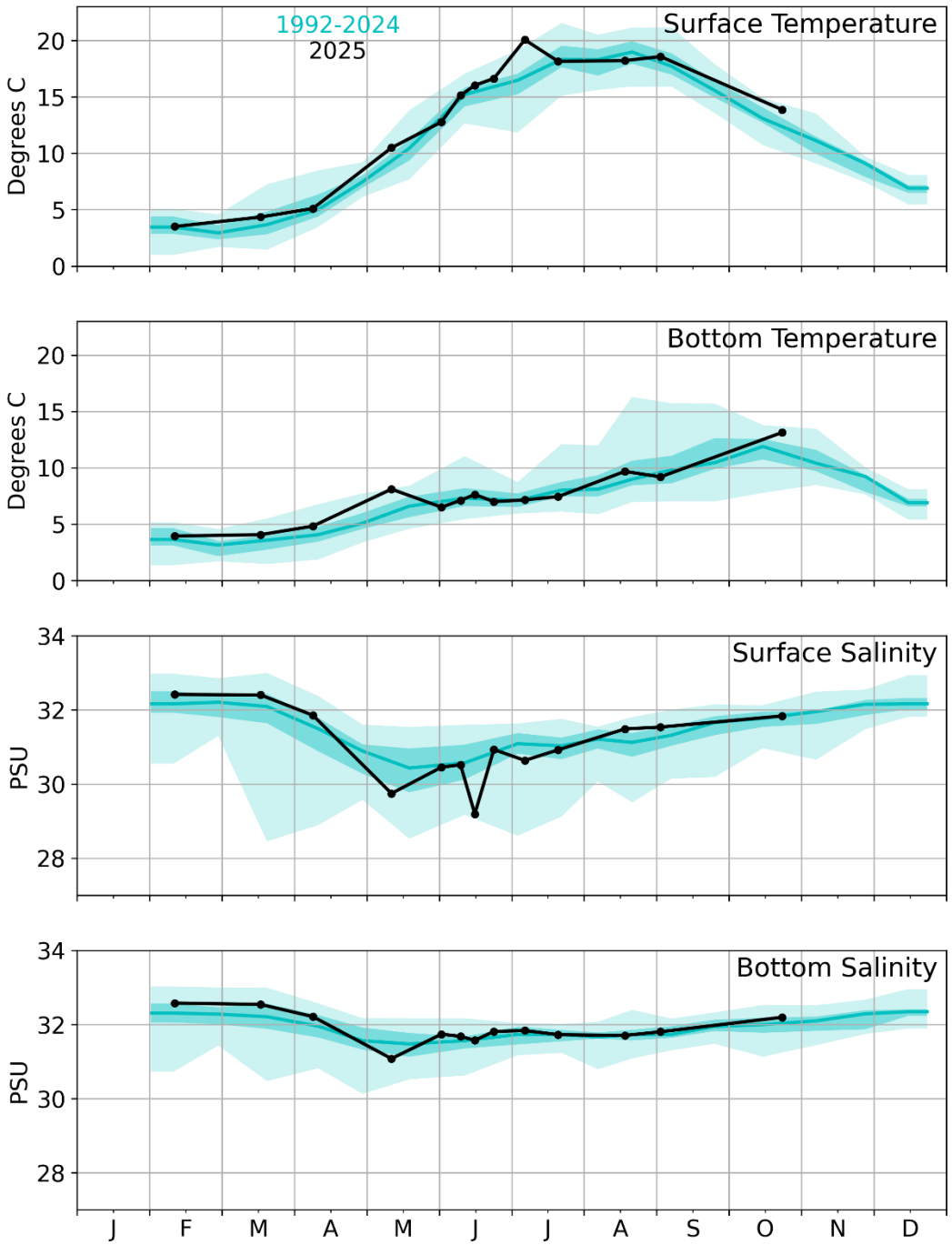


Figure 3-3. Surface- and bottom water temperature and salinity at Station N18 just to the south of the outfall in 2025 compared to prior years. PSU = practical salinity units or parts per thousand.

A process called downwelling occurs when winds come from the north and push water masses from the Gulf of Maine into Massachusetts Bay. The inverse, upwelling, occurs when wind directions are from the south, pushing surface waters offshore and bringing bottom waters to the surface (Figure 3-4). Upwelling promotes cooling throughout the water column and alleviates the natural declines in dissolved oxygen concentrations that occur throughout the summer. As is typical in the region, wind directions in 2025 promoted downwelling in the spring and fall and upwelling in the summer months, although winds in the spring and fall 2025 were somewhat more conducive to downwelling than in many past years. Moderately strong downwelling occurred only in January and October.

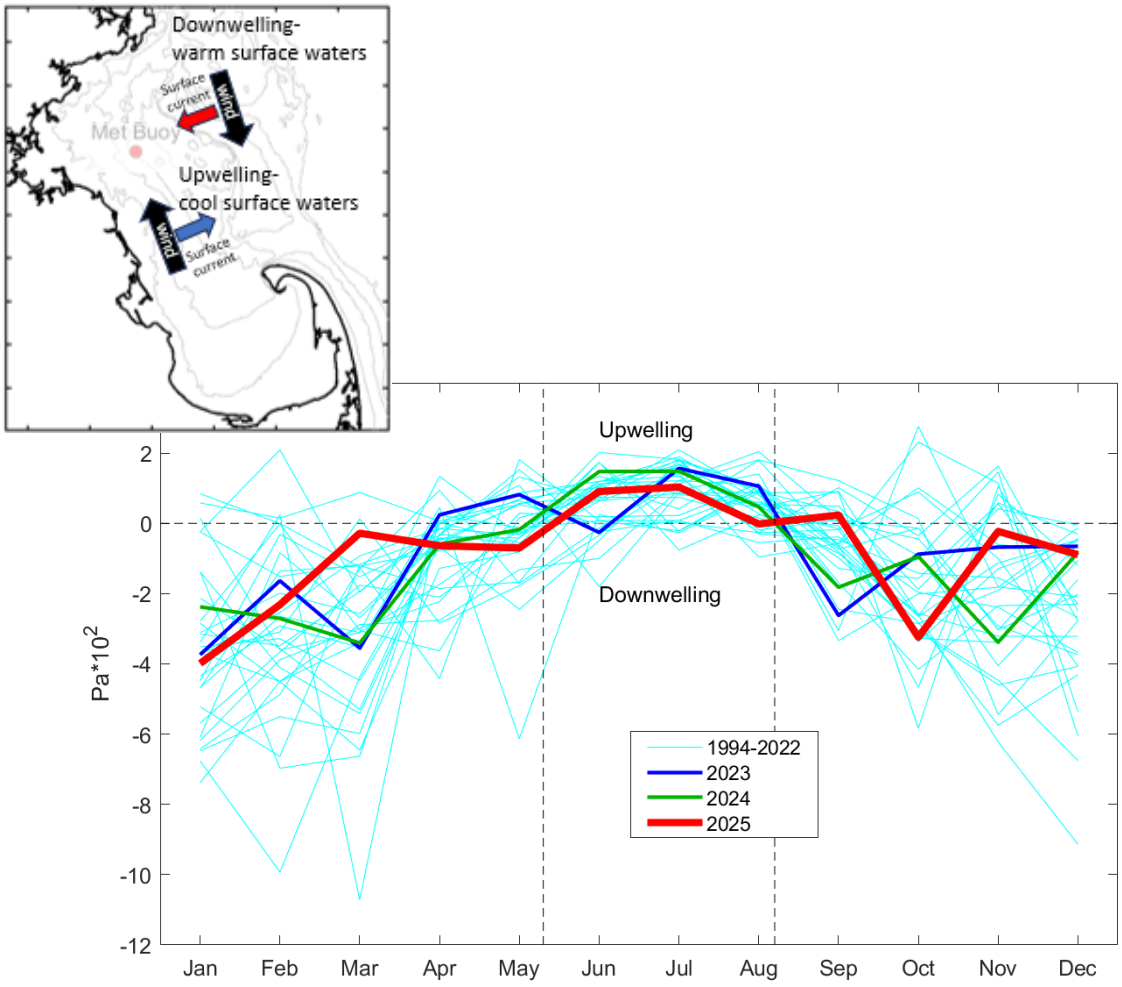


Figure 3-4. Upwelling and downwelling conditions in 2025 compared to prior years. Pa = Pascal, a unit used to quantify wind stress and other pressure-related measurements.

Water Quality

Water quality measurements include **nutrients** (nitrogen, phosphorus, and silica), **phytoplankton biomass** (measured as chlorophyll and particulate organic carbon), and **dissolved oxygen** (concentration, percent saturation, and the rate of decline during the stratified season). As in past years, results for 2025 confirmed influence of the outfall discharge on some nutrient concentrations at stations near the outfall, but no increases in other nutrients, no increases in phytoplankton biomass, and no decreases in dissolved oxygen parameters (Libby et al. 2026).

Nutrients

The most important nutrients that fuel phytoplankton growth in Massachusetts Bay are two forms of nitrogen (nitrate and ammonium), phosphate, and silicate. Similar to other temperate coastal waters, nutrient concentrations follow seasonal patterns, naturally varying with phytoplankton uptake, seasonal stratification, river flow, and water exchange with the Gulf of Maine. In general, nutrient concentrations in 2025 were lower than average during the first half of the year and close to the long-term median in the later months.

Ammonium is the largest fraction of the total nitrogen in wastewater (see Figure 2-5, page 6), and ambient seawater concentrations are relatively low for most of the year, making it a good effluent tracer. As anticipated by baseline field studies, modeling, and monitoring, increased concentrations of ammonium (and, to a lesser extent, phosphate) were detected in the immediate vicinity of the outfall in 2025.

Since the discharge was relocated from the Harbor to the Bay in late 2000, MWRA monitoring has detected elevated and variable ammonium concentrations at stations nearest and immediately to the south of the outfall, in the direction of the predominant current (Figure 3-5). The increases in ammonium concentrations are usually measured within 10 kilometers of the outfall. More intermittent signals can sometimes be detected at up to 20 kilometers. MWRA has not detected changes in nitrate or silicate concentrations in response to the effluent discharge.

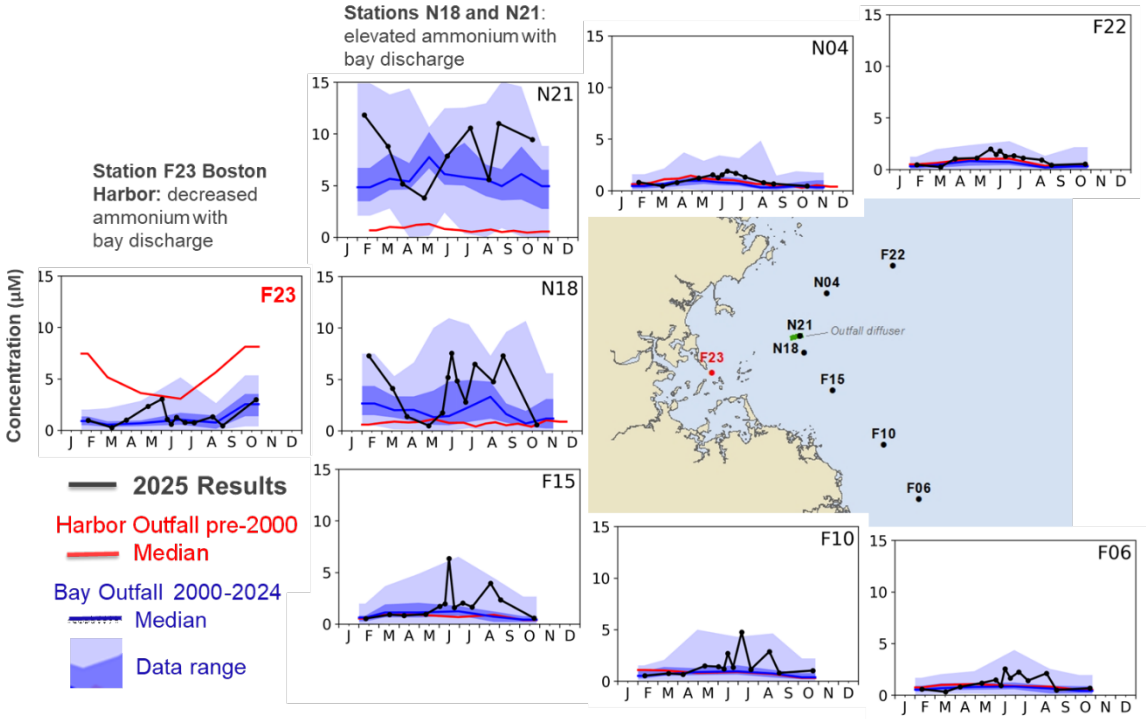


Figure 3-5. Ammonium concentrations at selected stations in 2025 compared to prior years. Increased and more variable concentrations of the sewage tracer ammonium are found at stations closest to the outfall, while stations farther away have maintained concentrations similar to pre-2000 levels. Ammonium concentrations at Station F23 at the mouth of Boston Harbor decreased abruptly when discharge to Boston Harbor ended in 2000 and remained low. µM = micromoles.

Especially high ammonium or phosphate concentrations at stations closest to the outfall are sometimes a result of a sample being taken directly in the effluent plume. For example, ammonium concentrations were especially elevated at Station N18 near the outfall during the June, August, and September surveys, but were very low in May and October. Consistent with past years, ammonium levels remained lower than the baseline concentrations at Station F23 at the mouth of Boston Harbor. Ammonium concentrations dropped precipitously at Station F23 and at all stations sampled as part of MWRA's separate Boston Harbor monitoring program as soon as effluent discharge to Boston Harbor ended and the Massachusetts Bay outfall discharge began.

As was anticipated during outfall siting and has occurred every year, the effluent plume's ammonium signature was detected in the surface water of stations closest to the outfall during the winter surveys, when the water column was relatively well-mixed (Figure 3-6). During the summer, when the water column was stratified, the plume was confined beneath the pycnocline, below depths where maximum phytoplankton growth occurs.

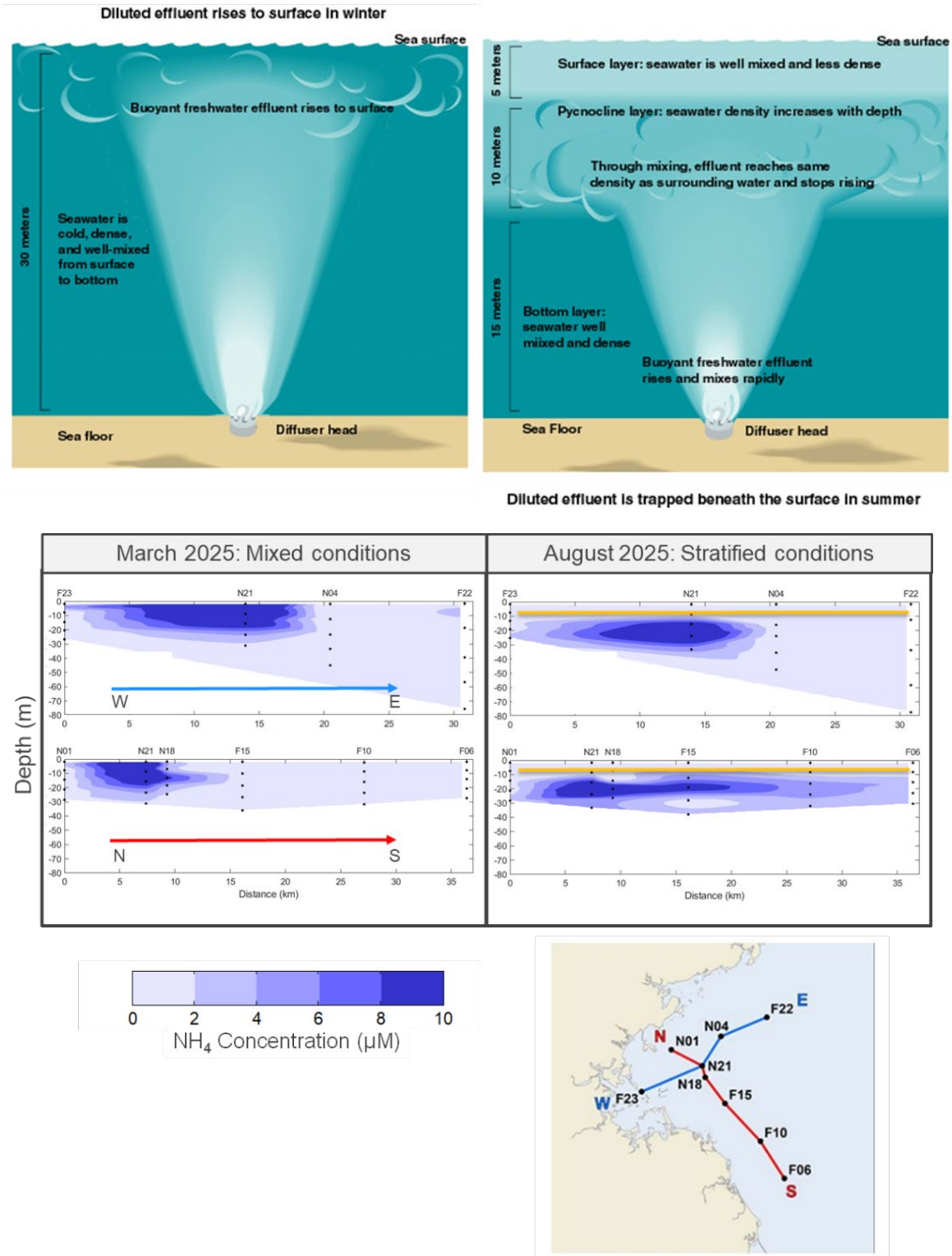


Figure 3-6. Surface- and bottom-water ammonium concentrations during mixed and stratified conditions. During winter, well-mixed conditions, the plume was evident in surface waters. During the summer, the plume was confined below the pycnocline (yellow line) and below the depth of most phytoplankton growth. Station N21 is directly over the outfall; m = meters; NH_4 = ammonium; µM = micromoles.

Phytoplankton Biomass

The increases in ammonium concentrations near the outfall have not stimulated phytoplankton growth or resulted in increased phytoplankton biomass at any station. Phytoplankton biomass in the water column is determined from measurements of chlorophyll concentrations, chlorophyll fluorescence, and particulate organic carbon concentrations.

Chlorophyll levels in 2025 were relatively high in the early part of the year, a result of a winter-spring phytoplankton bloom, typical of many temperate waters. Levels were close to historic means across all stations throughout the summer and elevated at some stations in the fall (Figure 3-7). The early and late peaks resulted in an annual average chlorophyll level that equaled the Contingency Plan threshold, but there was no exceedance.

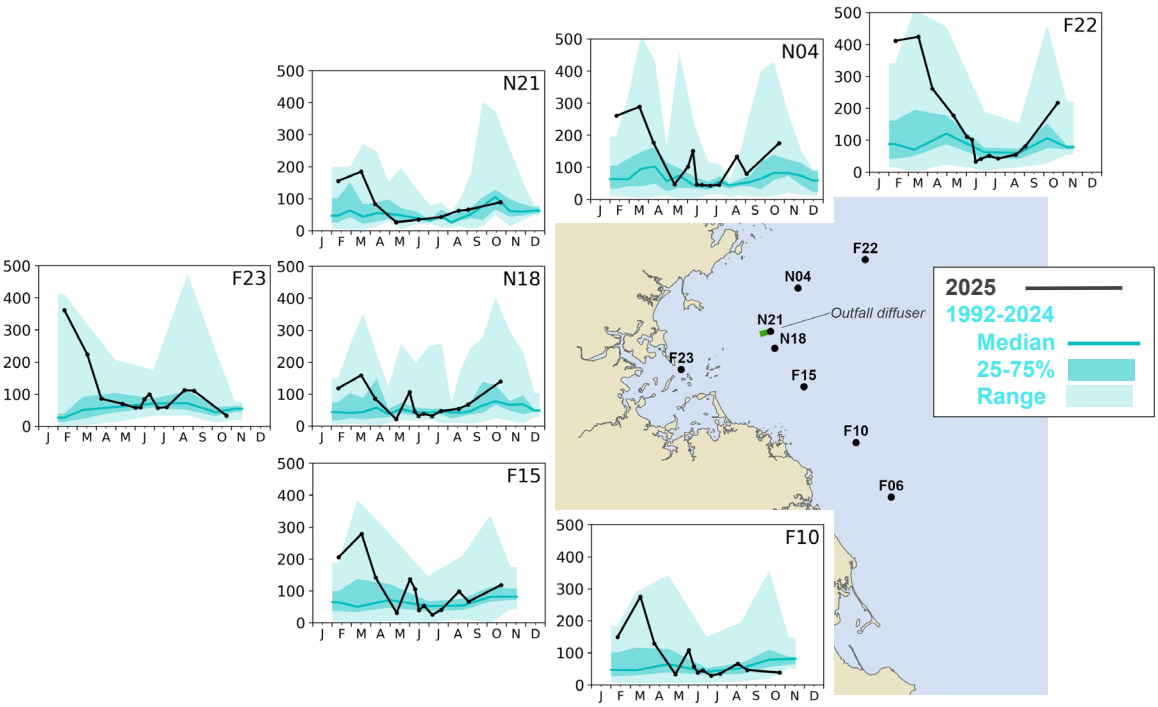


Figure 3-7. Monthly areal chlorophyll concentrations at selected stations in 2025 compared to prior years. Survey phytoplankton biomass is reported as vertically summed (areal) chlorophyll from measurements throughout the water column, from the surface to the sea floor, rather than as an amount within a fixed volume. mg/m^2 = milligrams per square meter summed over depth.

Dissolved Oxygen

Typically, bottom-water dissolved oxygen concentrations and percent saturation begin the year relatively high and steadily decline throughout the summer. Stratification prevents exchange between the atmosphere and bottom waters, so dissolved oxygen levels naturally decline at depth, as animals and microbes respire. That general pattern persisted in 2025 (Figure 3-8).

From May to June, dissolved oxygen levels decreased at all stations except for Station F23 at the mouth of Boston Harbor, but upwelling in late June re-oxygenated the water column. Continued upwelling-favorable conditions persisted in July, averting the especially low dissolved oxygen levels later in the summer and fall that occur in some years. Annual minimum concentrations were greater than 6.5 milligrams per liter throughout Massachusetts Bay. Minimum dissolved oxygen levels were also more moderate in Cape Cod Bay than in some past years, when hypoxic levels threatened marine life.

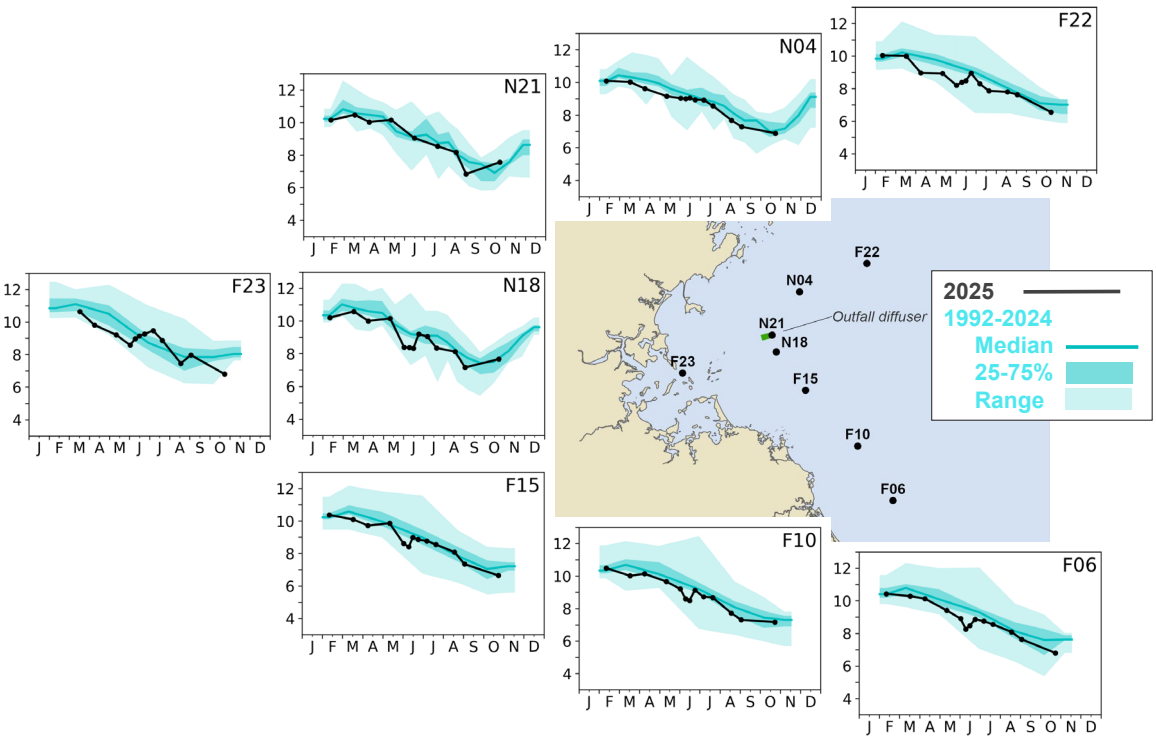


Figure 3-8. Near-bottom water dissolved oxygen concentrations in 2025 compared to prior years.
DO = dissolved oxygen; mg/L = milligrams per liter.

Plankton Communities

Marine plankton is made up of plants and animals that have limited or no ability to swim against winds, tides, and currents. MWRA monitors **phytoplankton and zooplankton abundance and species composition** to detect any changes that might be associated with the outfall discharge (Cibik et al. 1998). A focus on potentially toxic or nuisance phytoplankton species addresses concerns for marine mammal and human health.

Massachusetts Bay phytoplankton includes small algae and other plant-like organisms, such as microflagellates, centric (rounded) and pennate (elongated) diatoms, and dinoflagellates (Figure 3-9). Microflagellates are small and spherical, typically about three micrometers in diameter, and are typically the most abundant phytoplankton type in Massachusetts Bay. Centric and pennate diatoms have silica-rich cell walls and often dominate spring blooms. Dinoflagellates have two perpendicular whip-like flagella, which propel them up and down in the water column. Dinoflagellates are classified as phytoplankton, because many species, although not all, photosynthesize like plants.

A group of pennate diatoms in the genus *Pseudo-nitzschia* is of special interest, as some *Pseudo-nitzschia* species produce domoic acid, a neurotoxin that causes amnesic shellfish poisoning (ASP), a life-threatening condition in seabirds, marine mammals, and humans that consume contaminated shellfish. *Pseudo-nitzschia* are needle-like and form filamentous chains. Species with cell widths larger than three micrometers are more likely to produce toxin than smaller-width species. Most species of *Pseudo-nitzschia* found in Massachusetts Bay are smaller in width and do not produce ASP toxin.

One common dinoflagellate, *Alexandrium catenella*, often blooms in Massachusetts Bay and the wider Gulf of Maine region. The species known in New England for causing “red tide,” *Alexandrium catenella* is found in cold and temperate waters around the world. The toxin produced by *Alexandrium catenella* causes paralytic shellfish poisoning (PSP), a potentially deadly condition for people and marine mammals that consume shellfish.

Zooplankton communities in Massachusetts Bay include animal species that live their entire lives as plankton, including small shrimp-like copepods, and species that live in the plankton for only a part of their life cycles, such as barnacle and clam larvae. Most species are small, but larger animals, including jellyfish, are also part of the zooplankton community. Zooplankton provide food for many animals, including other zooplankton, fish, sea turtles, and the endangered North Atlantic right whale. Zooplankton abundance and species composition are highly variable through the seasons and between years.

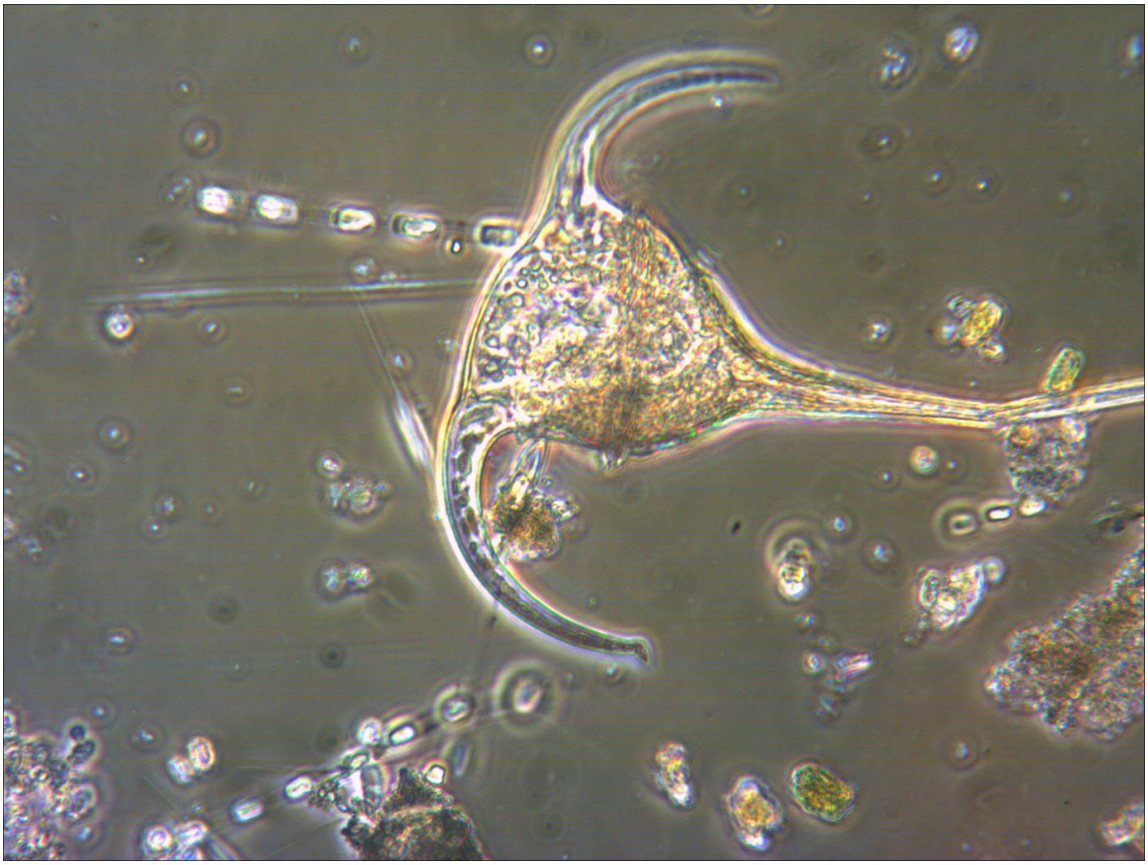


Figure 3-9. Typical phytoplankton from Massachusetts Bay. The large, hooked organism is the dinoflagellate *Tripos muelleri*. The box-like chains are centric diatoms in the genus *Skeletonema*, and the very thin chain is a species of the pennate diatom genus *Pseudo-nitzschia*. *Tripos muelle*ri typically ranges from 200 to 400 micrometers in length. Photo credit David Borkman, Pausacaco Plankton, Saunderstown, Rhode Island.

Phytoplankton Communities

Total phytoplankton abundance was typical at most stations and during most surveys in 2025 (Figure 3-10; Libby et al. 2026). Average overall abundance was about 0.67 million cells per liter, similar to recent years but lower than in 1992 through 2010.

Microflagellates, which have consistently remained the most numerically abundant plankton group, continued to dominate. Microflagellates made up 66% of the total phytoplankton community in 2025. A winter and early spring centric diatom bloom, dominated by *Skeletonema* species, was especially evident at Station F23 at the mouth of Boston Harbor and at Station F13, located south of the outfall and offshore from Scituate, Massachusetts. *Skeletonema* species are found world-wide and are typical members of the centric diatom community in Massachusetts Bay.

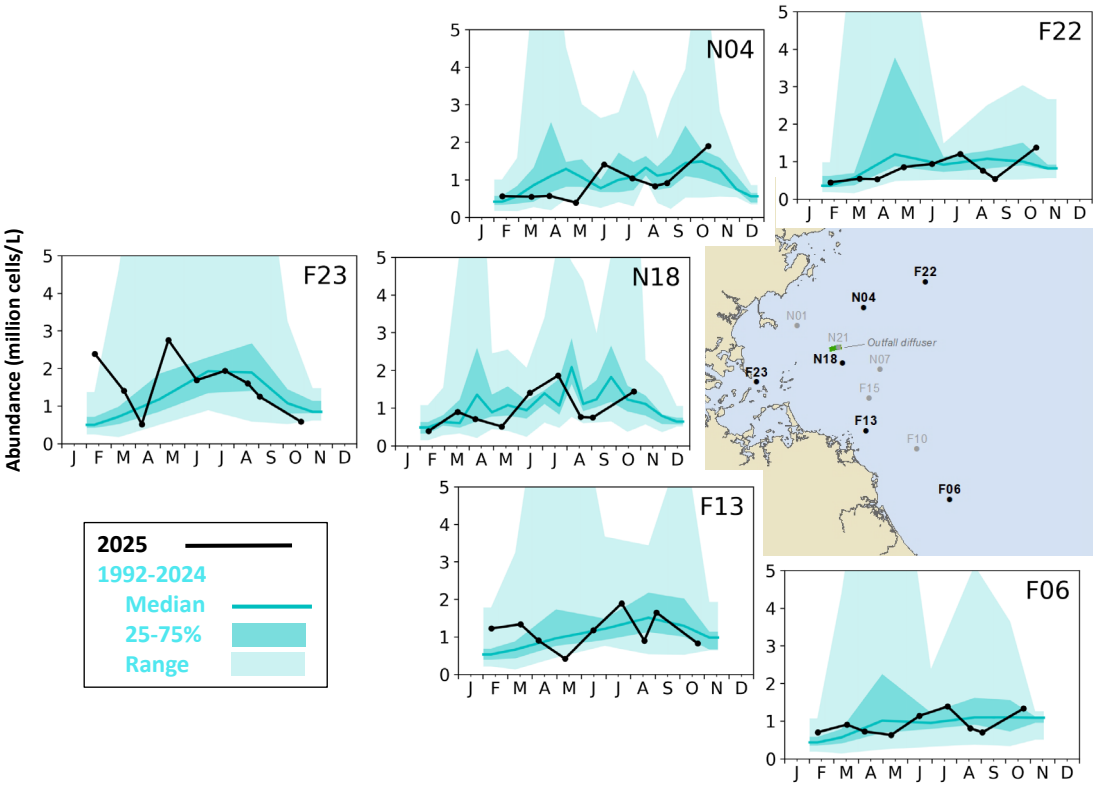


Figure 3-10. Total phytoplankton abundance at selected stations in 2025 compared to prior years. cells/L = cells per liter

The potentially toxic pennate diatoms in the genus *Pseudo-nitzschia* bloomed in June and were present throughout the region during the summer. Summer abundance, 74,400 cells per liter, exceeded the Contingency Plan summer threshold of 43,100 cells per liter. Most of the cells observed were small in width, indicative of the low-toxicity species that are most frequently found in Massachusetts Bay. No ASP toxin was detected in state shellfish monitoring. Historically, ASP has not caused shellfish harvesting closures in Massachusetts or Cape Cod Bays. Another pennate diatom *Asterionellopsis glacialis* bloomed in September. *Asterionellopsis* species are not toxic, and blooms, when they occur, are typically in the fall.

Total dinoflagellate abundance was high in 2025, particularly in October, when a common species *Prorocentrum cordatum* bloomed in Massachusetts and Cape Cod Bays. Dinoflagellates tend to have cyclic population abundance patterns, that rise and fall over several-year periods.

Abundance of the potentially toxic dinoflagellate *Alexandrium catenella* remained low until May 2025, when cells were detected in 19 of 20 samples, and state shellfish toxicity testing triggered *Alexandrium* Rapid-Response Surveys. Abundances in June exceeded the Contingency Plan threshold, but the bloom ended by early July (Figure 3-11). The pattern of the bloom was consistent with those in the past, suggesting that cells entered Massachusetts Bay from the Gulf of Maine.

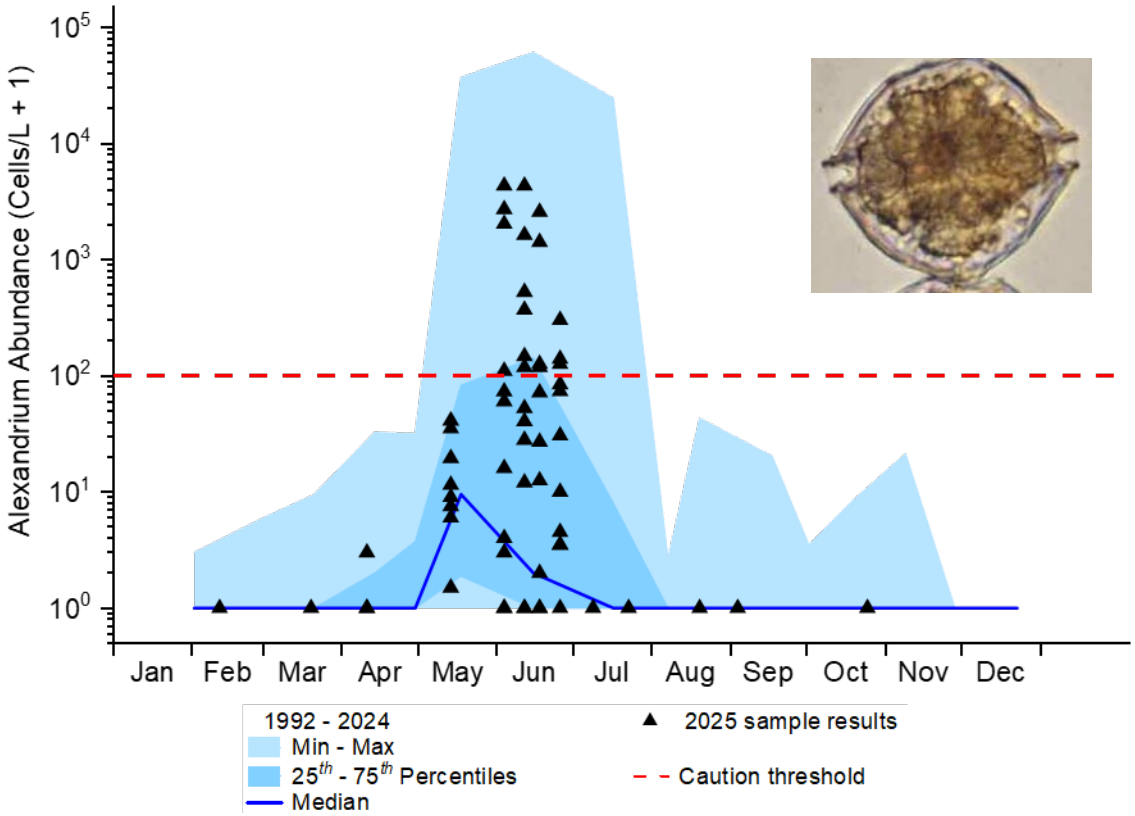


Figure 3-11. *Alexandrium catenella* abundance in 2025 compared to 1992–2024. Photo credit Donald M. Anderson, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts. Cells/L + 1 = cells per liter plus 1, a convention that allows abundances of zero to be displayed on the scale.

A somewhat minor phytoplankton group called coccolithophores was also present in 2025. Coccolithophores are small, flagellated cells that are protected by calcium carbonate scales. Coccolithophore blooms have been documented in the Gulf of Maine and Massachusetts Bay, but until recently, they were rare in MWRA samples. During 1992–2010, coccolithophores were present in fewer than 1% of the total phytoplankton samples, but they have been present in 3–6% of samples collected from 2020–2025, and abundances have been as high as 100,000 cells per liter. Eleven coccolithophore taxonomic groups have been identified, but more than 90% of the organisms are marked as "unidentified." The increases may be associated with advection of warm, salty water masses from offshore waters.

Zooplankton Communities

Total annual zooplankton abundance in 2025 was typical of past years, although there were some less typical seasonal patterns (Figure 3-12). For example, there were modest increases from usual winter low abundance through the spring, and the more typical summer peaks did not occur.

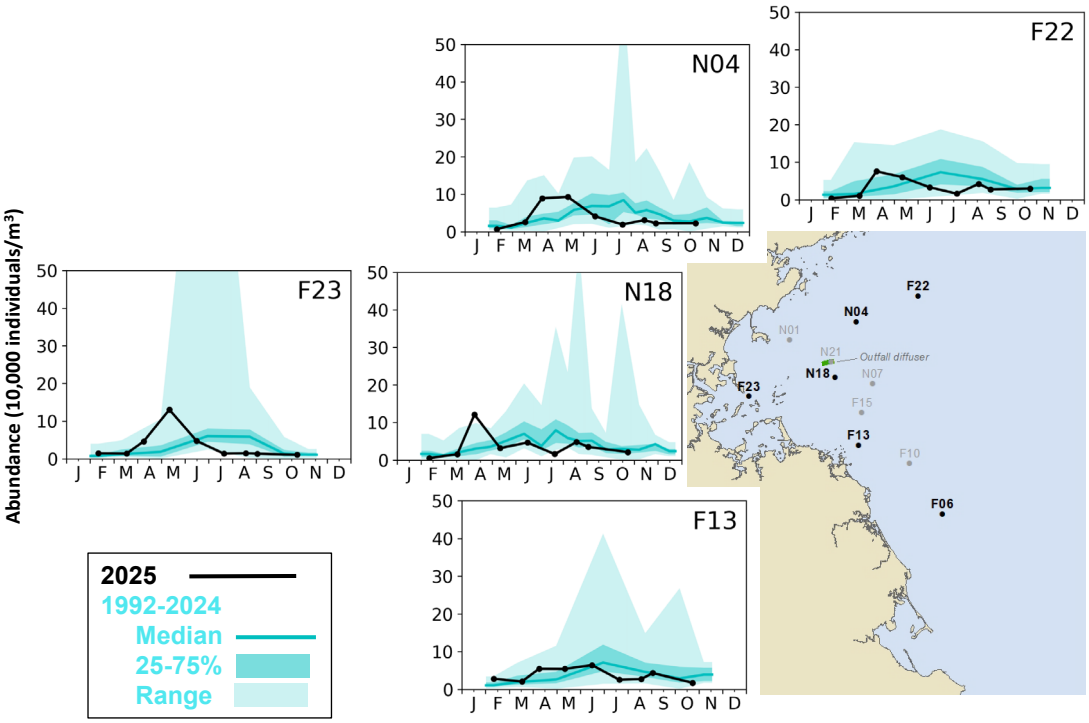


Figure 3-12. Total zooplankton abundance at selected stations in 2025 compared to prior years. The peaks that occurred in May was largely due to early-life-stage copepods called nauplii. The high historical values in July occurred in 2015, when sampling took place just after a major bivalve spawning event. individuals/m^3 = individuals per cubic meter.

As in past years, copepod adults and younger life stages dominated throughout the year. The small copepod species *Oithona similis* remains the numerically dominant species in the zooplankton community, as it has been since the beginning of the monitoring program. Early life stages of the common *Pseudocalanus* species peaked in the spring, and life stages of larger species *Calanus finmarchicus* were elevated, particularly at offshore stations. *Calanus finmarchicus* provides food for the endangered North Atlantic right whale.

Barnacle larvae were present throughout the year, particularly in the spring. The planktonic tunicate *Oikopleura dioica* was most abundant in April and May. *Oikopleura dioica* resemble small tadpoles and are found in surface waters around the world.

Every year since 2020, MWRA has identified single-celled zooplankton called radiolarians in its summer and fall samples (Figure 3-13). None were present in any year prior to 2020. Radiolarians are protozoans that build ornate exoskeletons, most often made of silicate. The organisms found in MWRA samples have not been identified, but may be members of a subgroup, the acantharians, which have robust structures and spines made of strontium sulfate rather than silicate. In 2025, radiolarians were present in samples collected from August through October, with particularly high abundances in August and September. Radiolarians are more typically found in offshore waters, and their presence each year since 2020 may reflect annual influxes of warm water masses from offshore.

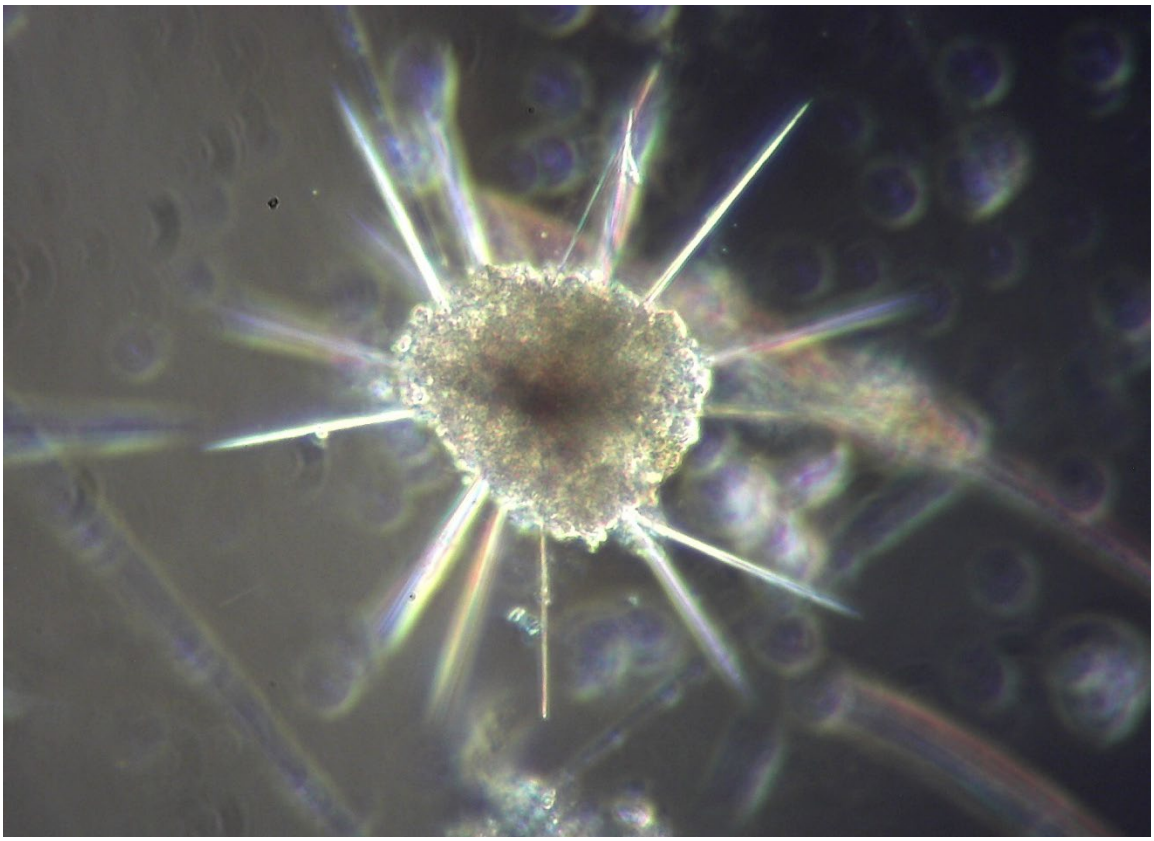


Figure 3-13. Radiolarian, possibly in the group acantharians, which have been found in Massachusetts Bay each year since 2020. Acantharians range in size from about 200 micrometers to several millimeters, if the spines are included in the measurement. Photo from a sample taken at MWRA station N01 in August 2026**.** Photo credit David Borkman, Pausacaco Plankton, Saunderstown, Rhode Island.

Stellwagen Bank National Marine Sanctuary

The NPDES permit to discharge into Massachusetts Bay requires MWRA to report on results relevant to Stellwagen Bank National Marine Sanctuary. Water column Station F22 is north of Stellwagen Basin, just to the west of the Sanctuary, and is representative of offshore conditions. The instrumented NERACOOS Buoy A01 is located in the northwest corner of the Sanctuary.

Ammonium concentrations did not increase at Station F22 in the years after the outfall began to discharge (see Figure 3-5, page 19), and there have been no observed effects on phytoplankton biomass or dissolved oxygen levels. Dissolved oxygen concentrations remained above state standards throughout 2025 (Figure 3-14).

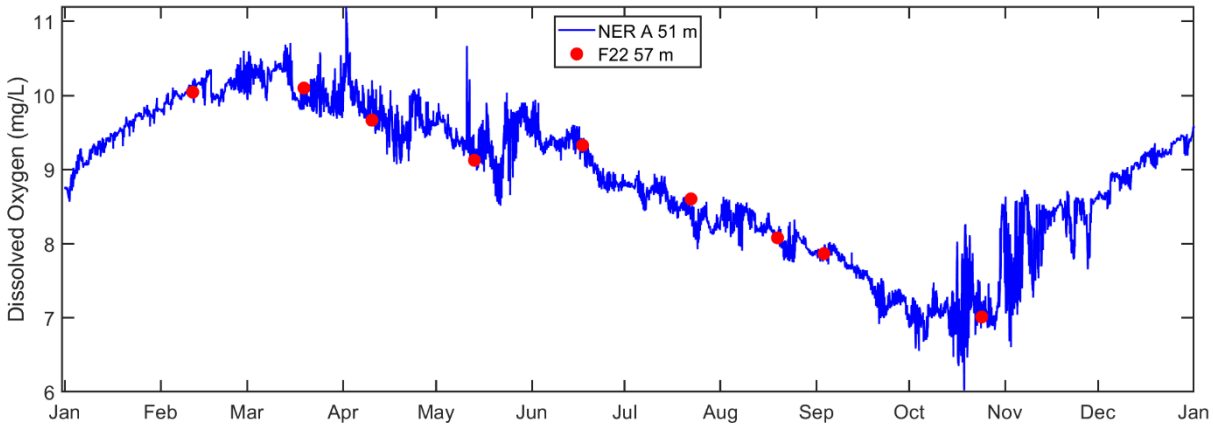


Figure 3-14. Dissolved oxygen concentrations at the NERACOOS Buoy A01, calibrated with and compared to field measurements from nearby deepwater MWRA survey Station F22 in 2025. Buoy values are daily means. The state water quality standard for dissolved oxygen is a minimum of 6 milligrams per liter. mg/L = milligrams per liter.

The Sanctuary's most recent condition report rated water quality within its borders as "good." Its most recent management plan endorsed MWRA's assessment that the outfall is not adversely affecting its waters (NOAA Office of Marine Sanctuaries 2020, 2023).

Boston Harbor Water Quality

Water quality in Boston Harbor greatly improved during the Boston Harbor Project, and those advances remained evident in 2025. Perhaps the most dramatic improvement in Boston Harbor was the decrease in ammonium concentrations, which dropped precipitously when the effluent discharge was diverted from the Harbor to Massachusetts Bay in 2000. Those concentrations have remained low. The decreases in nutrient inputs have been accompanied by decreases in previously over-stimulated primary production and phytoplankton biomass, an abatement of the Harbor's historically high level of eutrophication (Werme et al. 2018, Taylor et al. 2020).

MWRA recently completed a new assessment of shifts in environmental controls on nutrients and primary production since wastewater discharges ended in Boston Harbor. The results of that assessment are presented in Section 6, Special Topics, on page 52.

Water-Column Contingency Plan Thresholds

There were no exceedances of water quality thresholds in 2025, but there were two exceedances of parameters related to nuisance algal blooms (Table 3-1). Summer nearfield *Pseudo-nitzschia* abundance and nearfield *Alexandrium catenella* abundance exceeded caution-level thresholds. Both blooms occurred throughout a wide region, and there is no evidence that either exceedance was caused or exacerbated by the effluent discharge.

Table 3-1. Contingency Plan threshold values and 2025 results for water-column monitoring.

Parameter	Baseline	Caution Level	Warning Level	2025 Results
Chlorophyll				
Annual	72 mg/m^2	>108 mg/m^2	>144 mg/m^2	108 mg/m^2
Winter/spring	50 mg/m^2	>199 mg/m^2	None	186 mg/m^2
Summer	51 mg/m^2	>89 mg/m^2	None	50 mg/m^2
Autumn	90 mg/m^2	>239 mg/m^2	None	109 mg/m^2
Dissolved oxygen*				
Nearfield concentration	6.05 mg/L	<6.5 mg/L	<6.0 mg/L	6.97 mg/L
Nearfield percent saturation	65.3%	<80%	<75%	75.7%
Stellwagen concentration	6.23 mg/L	<6.5 mg/L	<6.0 mg/L	6.55 mg/L
Stellwagen percent saturation	67.2%	<80%	<75%	67.2%
Nearfield depletion rate	0.024 mg/L/d	>0.037 mg/L/d	>0.049 mg/L/d	0.015 mg/L/d
Nuisance algae nearfield *Pseudo-nitzschia*				
Winter/spring	6,735 cells/L	>17,900 cells/L	None	0 cells/L
Summer	14,635 cells/L	>43,100 cells/L	None	74,400 cells/L
Autumn	10,050 cells/L	>27,500 cells/L	None	1,400 cells/L
Nuisance algae nearfield *Alexandrium catenella*				
Any nearfield sample	Baseline maximum 163 cells/L	>100 cells/L	None	2,695 cells/L
PSP toxin extent	NA	New incidence	None	No new incidence

"Nearfield" refers to the five stations closest to the outfall, where effects might be detected, if they were to occur. Red shading shows a warning-level exceedance; orange shading shows a caution-level exceedance. For dissolved oxygen parameters, "exceedances" refer to values less than the threshold.
*Dissolved oxygen caution and warning levels represent numerical criteria, with the caveat "unless background conditions are lower." Results are therefore compared to the baseline as well as the caution and warning levels.
PSP = paralytic shellfish poisoning
NA = not applicable
mg/m^2 = milligrams per square meter
mg/L = milligrams per liter
mg/L/d = milligrams per liter per day
cells/L = cells per liter

The *Pseudo-nitzschia* exceedance was the first since the effluent discharge was diverted from Boston Harbor to Massachusetts Bay in 2000 (Figure 3-15, top). *Pseudo-nitzschia* cells were first observed during the May survey, peaked in June, and quickly declined in July and August. During the June peak, almost all organisms were of smaller-width *Pseudo-nitzschia* species, which are unlikely to produce toxin. The bloom appeared to be regional, extending from north of Massachusetts in the Gulf of Maine, south to Rhode Island. There were no shellfishing closures in response to the bloom.

The *Alexandrium* exceedance was typical of past blooms, with cells entering Massachusetts Bay from the Gulf of Maine when winds were from the northeast (Figure 3-15, bottom). Toxicity was low throughout the duration of the bloom, although there was a precautionary shellfishing closure along the Massachusetts South Shore during June 13–27.

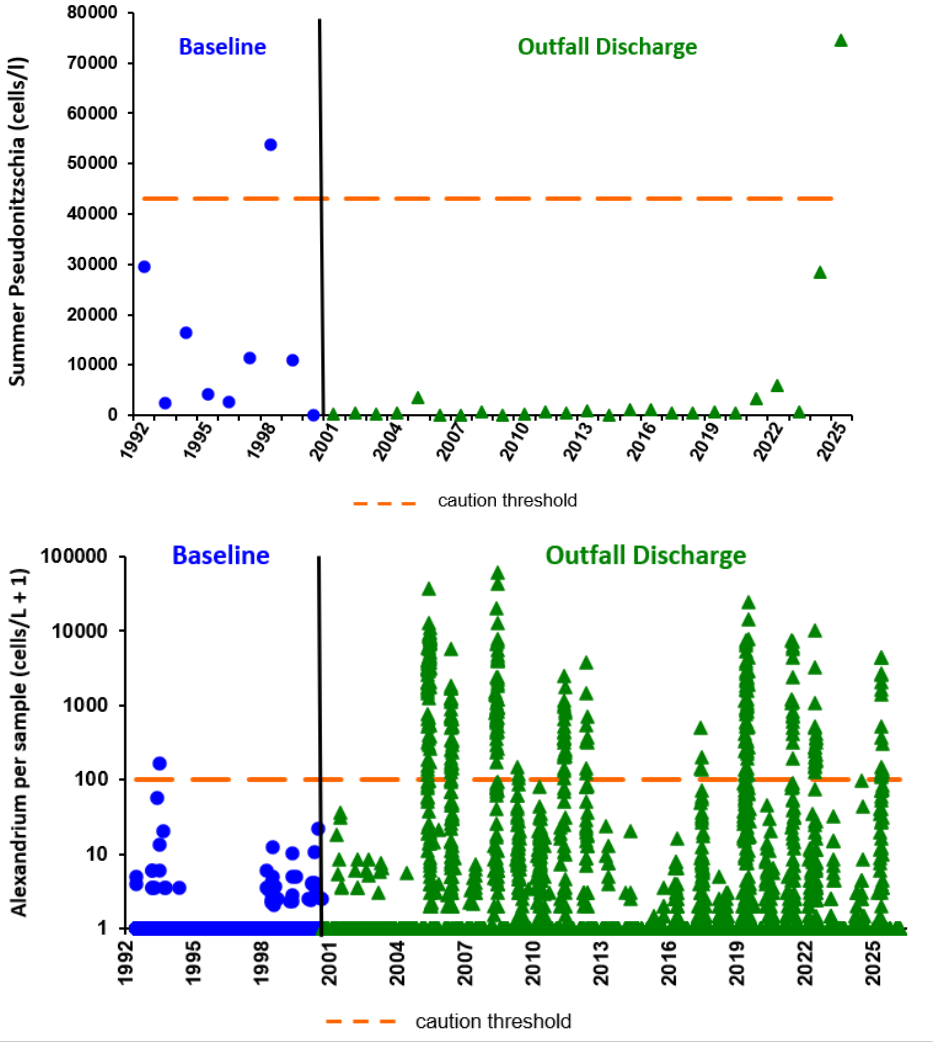


Figure 3-15. (Top) Summer abundance of *Pseudo-nitzschia* species, 1992–2025; (Bottom) Total abundance of *Alexandrium catenella*, 1992–2025.

4. Sea Floor

Seafloor monitoring assesses habitats and communities
MWRA measures sediment characteristics and assesses animal communities living in soft-bottom and rocky, hard-bottom habitats. No effects of the outfall have been detected in either area. Seafloor animal communities vary within typical natural cycles and are mostly influenced by sediment types and water depths.

The sea floor of Massachusetts Bay was shaped by glaciers. As glaciers advanced and retreated, they scoured the bottom to create Stellwagen Basin, deposited rocky debris in elongated hills called drumlins, and left the sand-and-gravel ridge that forms Stellwagen Bank. Tides and currents continue to shape the sea floor, particularly during major storms with waves large enough to resuspend and transport sediments. Seafloor habitats range from mud composed of sand, silt, and clay in soft-bottom, depositional areas to rocky cobbles and boulders on the tops and flanks of drumlins.

Seafloor monitoring assesses potential effects of the outfall on the animal communities of both the soft-bottom areas and rocky, hard-bottom drumlins. Most seafloor-monitoring studies focus solely on soft-bottom sediments, but such depositional sites are somewhat rare in the immediate vicinity of the outfall. MWRA conducts annual soft-bottom sampling surveys, while photographic and video assessments of the hard-bottom areas occur every three years, most recently in 2023. A separate monitoring program in Boston Harbor includes annual soft-bottom sampling and analysis and photographic sediment-profile imagery.

In August 2025, MWRA sampled 14 soft-bottom stations for analysis of sediment grain-size distribution, the wastewater tracer *Clostridium perfringens* spores, percent total organic carbon, and animal abundance and species composition (Figure 4-1). The stations included four “inner nearfield” stations located within two kilometers of the outfall; six “outer nearfield” stations in western Massachusetts Bay but farther from the outfall; one station in the “transition” area between Boston Harbor and the nearfield; and three “farfield” reference stations in Massachusetts and Cape Cod Bays.

Contingency Plan threshold calculations include both inner and outer nearfield groups and the transition station, for a total of 11 stations. The transition area is included in the calculations, because early modeling studies suggested that it would continue to be a depositional site, where elevated concentrations of particulate organic carbon might be detected (Kropp et al. 2000). Some scientific analyses do not include the transition station when comparing results from the nearfield to those from the farfield, as it is near to and remains affected by historic and continued inputs from Boston Harbor and other coastal sources.

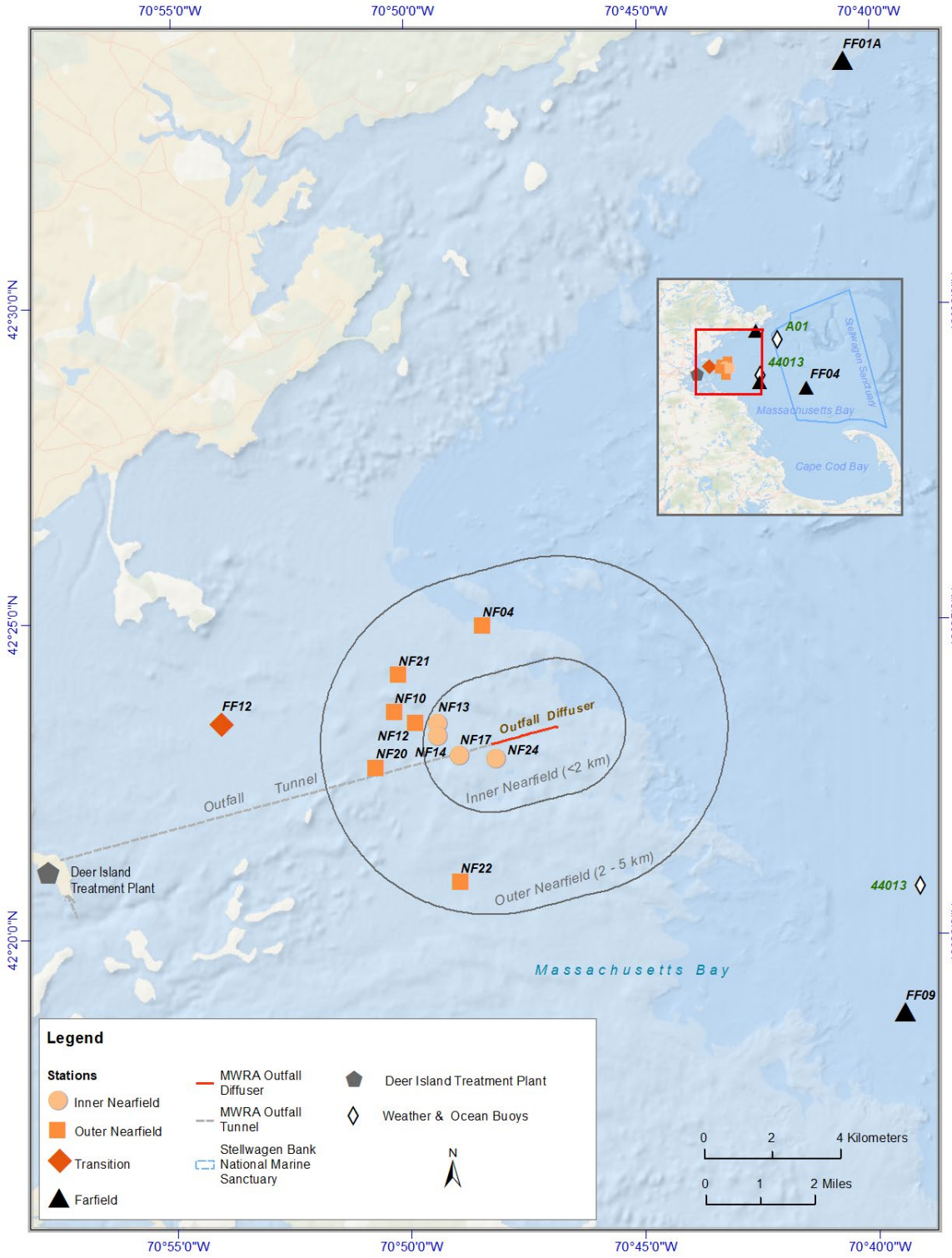


Figure 4-1. Soft-bottom monitoring stations. Also shown are the instrumented buoys, the MWRA outfall diffuser, and Stellwagen Bank National Marine Sanctuary. Nearfield station labels begin with NF, while farfield stations and the transition station begin with FF. The transition station FF12 is included with the nearfield stations to calculate Contingency Plan threshold parameters.

Sediment Characteristics and Tracers

As in past years, sediment grain-size distributions in soft-bottom habitats varied broadly in 2025, ranging from silt and clay at some stations (for example, Station NF12 just northwest of the outfall and Station FF04 within Stellwagen Basin) to almost entirely sand at others, including several stations nearest the outfall (Rutecki et al. 2026).

Within individual stations, sediment textures have remained generally consistent over the years of monitoring, with occasional changes following large storms. The percentage of fine silts and clays increased at some stations in recent years, including Stations FF01A at the northern boundary of Massachusetts Bay and NF17 just to the southeast of the outfall. Those increases were sustained in 2025.

Clostridium perfringens, an anaerobic bacteria species found in the digestive tracts of humans and other mammals, is not completely removed by wastewater treatment. It forms resting spores, which provide a sensitive tracer of sewage effluent in sediments. Since spores can persist for decades, they do not always reflect immediate deposition onto the sea floor; instead, they can provide evidence of wastewater discharges over years.

In 2025, as in most other years, *Clostridium* spore abundance was elevated at stations closest to the outfall (Figure 4-2). Highest spore counts occurred at Station NF24, the station just to the south and closest to the outfall, suggesting that the effluent discharge was the source.

Percent total organic carbon content in the sediments was consistent with past results, with no increased organic carbon concentrations at stations near the outfall (Figure 4-3) or at the transition station. In general, there are higher concentrations of total organic carbon at stations with finer sediments, such as Station FF04 in Stellwagen Basin and lower concentrations at stations with coarser sediments, such as NF17 near the outfall. Overall, the total organic carbon data show no signs of organic enrichment from wastewater effluent, consistent with predictions made before the outfall began to discharge. These results are also consistent with an MWRA special study of sediment metabolism, which was completed in 2010 (Tucker et al. 2010, Tucker et al. 2014).

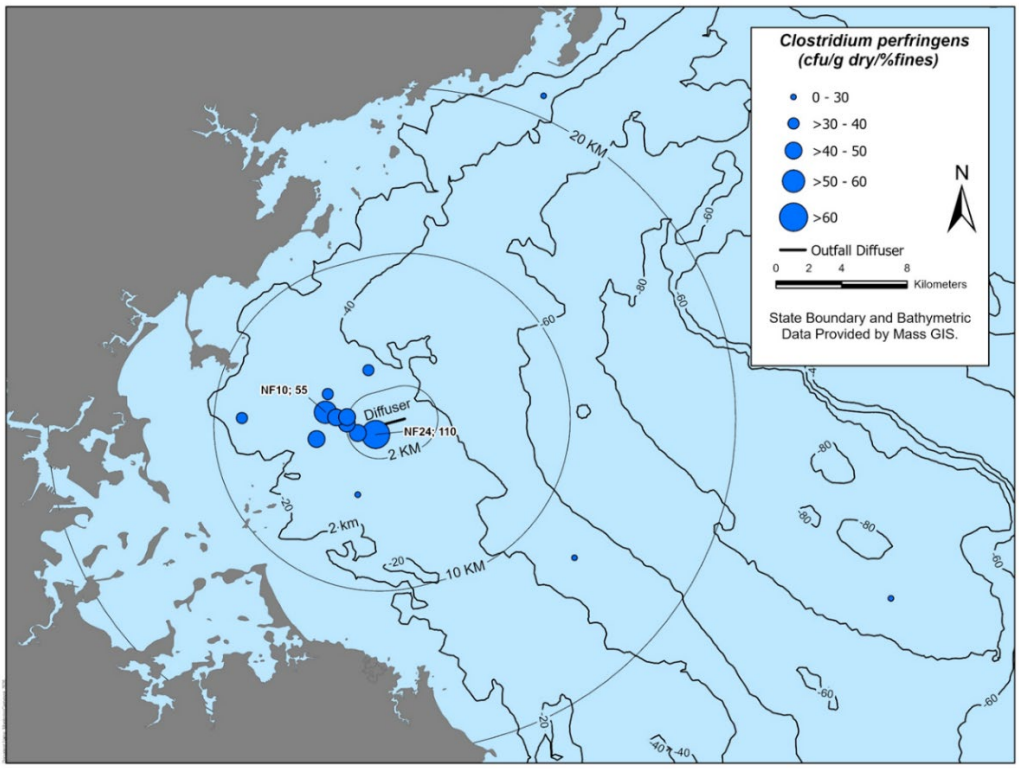


Figure 4-2. Concentrations of the effluent tracer *Clostridium perfringens* spores in 2025. Concentrations represent spore counts normalized to the percent of the sediment made up of fine silts and clays, removing any effect of grain size from the analyses. As anticipated during outfall planning, *Clostridium* spore concentrations are elevated at stations closest and to the southwest the outfall, in the most prevalent direction of current flow. cfu = colony forming units, the measure used in spore counts.

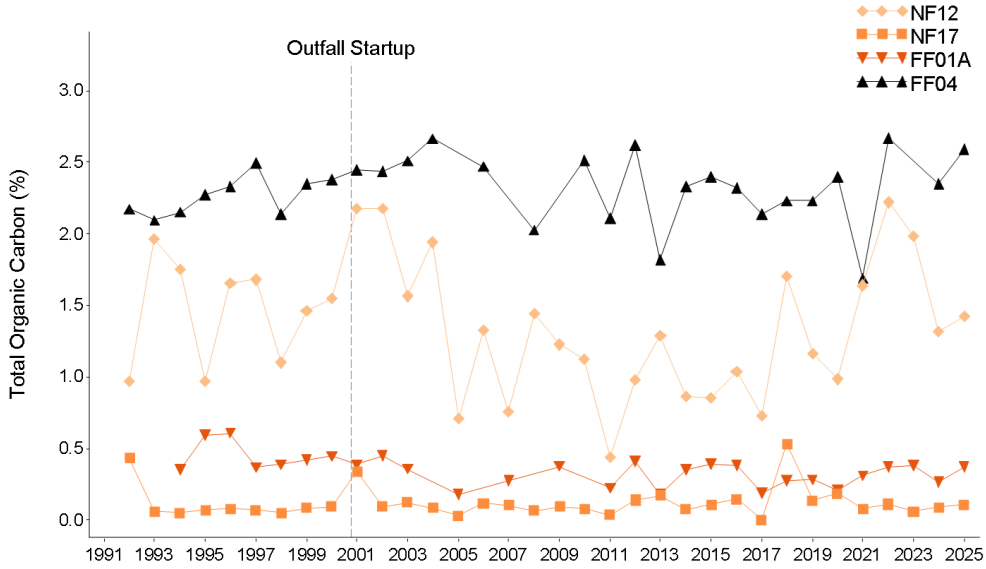


Figure 4-3. Total organic carbon at selected stations, 1992–2025. No effects of the discharge have been observed at any station. NF12 is in the outer nearfield and northwest of the outfall. NF17 is in closer proximity and southwest of the outfall, where the effects of the discharge might be expected but have not been measured. FF01A is the northern reference station, and FF04 is in Stellwagen Basin; both farfield stations are farther than 20 kilometers from the outfall.

Soft-bottom Communities

A variety of small animals live in the sediments, including segmented polychaete worms, mollusks, and crustaceans. MWRA monitors abundance and species composition of animals living within soft-bottom communities to document any changes that might be associated with the outfall discharge, such as decreased biodiversity or increased presence of the opportunistic species typically found in disturbed habitats.

The 14 soft-bottom samples collected and analyzed in 2025 contained 19,123 organisms, classified into 157 species and 27 other discrete taxonomic groups of animals that could not be identified to the species level (Rutecki et al. 2026). The total numbers of organisms at both nearfield and farfield stations were slightly lower than in 2024, while the number of species increased. Both totals remained within historic ranges (Figures 4-4, 4-5). The several community diversity measures calculated for nearfield samples remained at levels typical of past years.

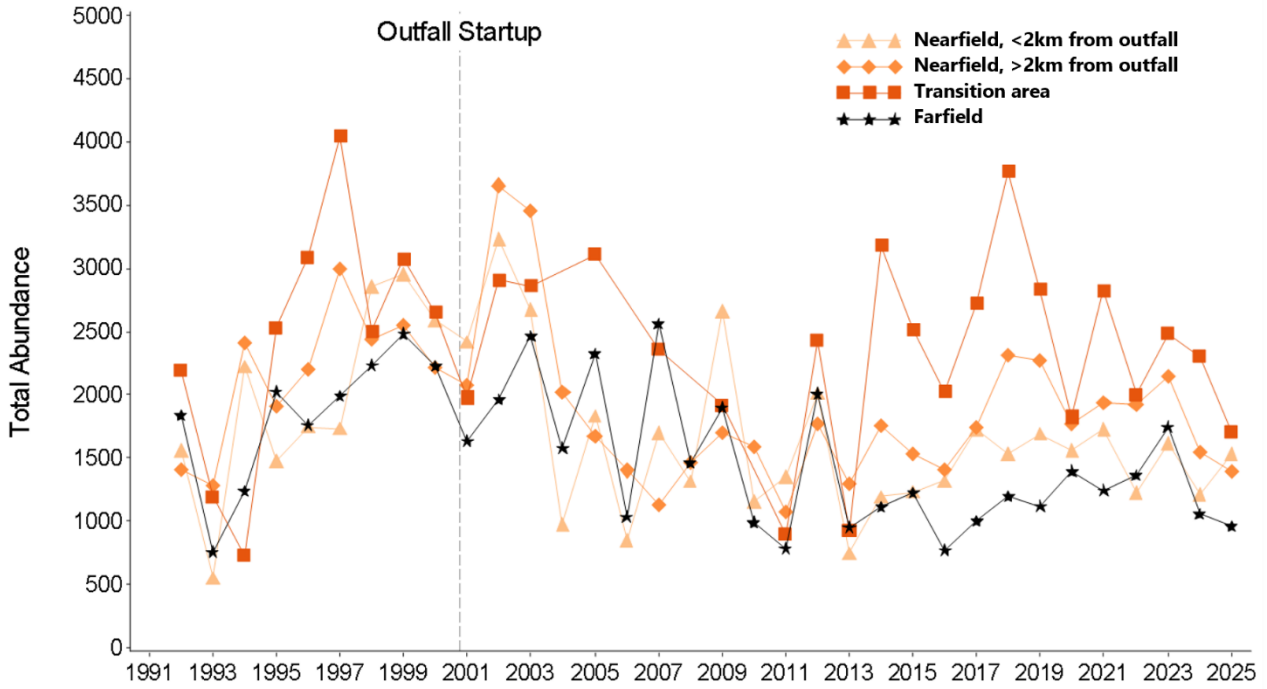


Figure 4-4. Total abundance of soft-bottom organisms by region, 1992–2025. Regions include the nearfield within two kilometers of the outfall, the outer nearfield farther than two kilometers from the outfall, the transition area between Boston Harbor and the outfall, and the farfield.

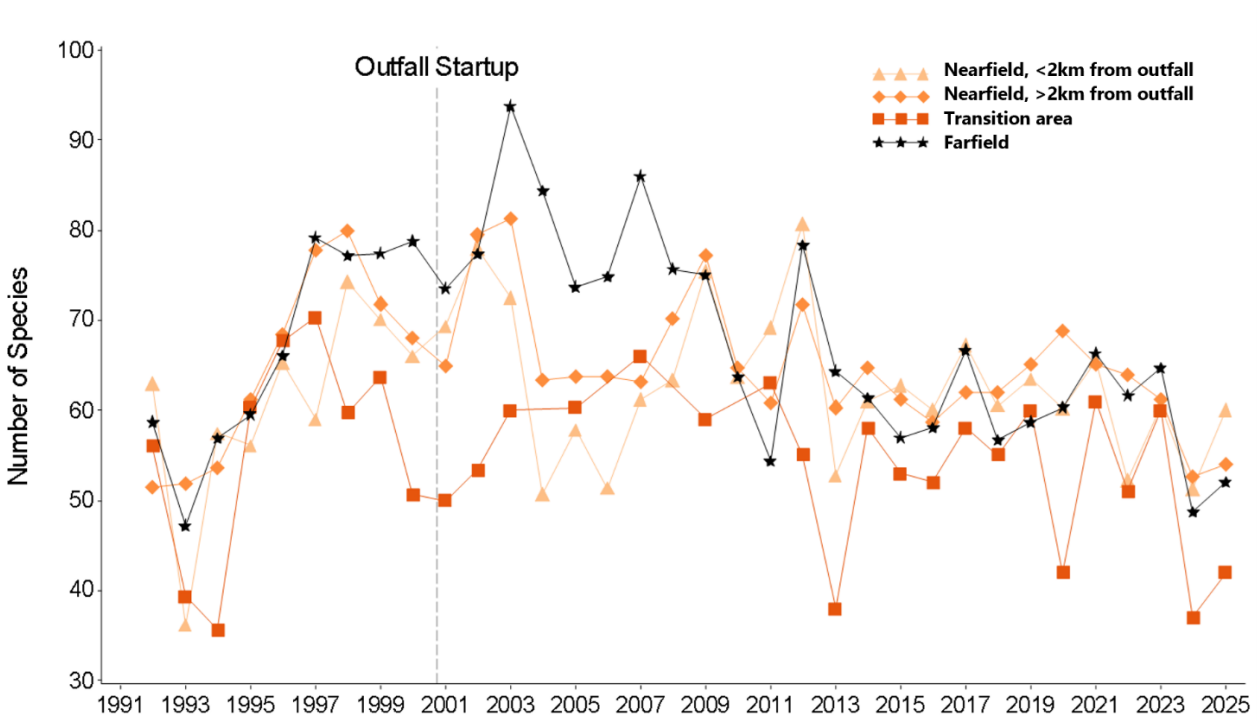


Figure 4-5. Total abundance of species by region, 1992–2025. Regions include the nearfield within two kilometers of the outfall, the outer nearfield farther than two kilometers from the outfall, the transition area between Boston Harbor and the outfall, and the farfield.

Small polychaete worms, sometimes known as bristle worms (Figure 4-6), dominated the samples at most stations, as they have for the duration of the monitoring program. These segmented worms are among the most common marine organisms. The polychaete *Prionospio steenstrupi*, which is found in many locations around the world, was the numerically dominant species in 1997–2005. It has declined in abundance since 2005, but remains among a group of dominant species and was the most numerous organism in 2025. Other common polychaetes included *Aricidea catherinae*, *Tharyx acutus*, and *Mediomastus californiensis*, which also have wide geographic distributions and were present in numbers comparable to other recent years.



Figure 4-6. Polychaete worms dominate the soft-bottom habitats in Massachusetts Bay. This image shows sample species from polychaete families Spionidae, Maldanidae, Cappitellidae, Phyllodocidae, and Orbiniiddae, which are common in Massachusetts Bay. Polychaetes range in length from less than a millimeter to several meters; most are very small. Photo credit Jessica Buckingham, Normandeau Associates, Bedford, New Hampshire.

As in other years, analyses of the seafloor communities by location showed no effect of the outfall on total abundance of animals, abundance of species, or community composition. A series of analyses assessed patterns in the soft-bottom communities over space and time and found no particular species or type of community specifically associated with the outfall.

One type of community analysis, called cluster analysis, groups stations by similarity in species composition and abundance. Cluster analysis of the 2025 samples identified two main groups (I and II) and one outlier station, FF04. Group I was dominated by crustaceans and polychaete worms. Group II included greater abundances of polychaetes and mollusks than Group I. Station FF04 is the offshore station located within Stellwagen Basin and has consistently supported a unique polychaete community, typical of the other deepwater, offshore stations that were sampled in early years of the MWRA monitoring program.

Some of the stations within Group II could be further separated into more specific nearfield subgroups, based on slight differences in species composition and abundance. Group II also included two individual farfield stations, FF01A and FF09. Station FF01A is located near the northeast boundary between Massachusetts Bay and the Gulf of Maine. Offshore Station FF09 is located to the southeast of the outfall.

Further assessment of the groups, called ordination analysis, provides a picture of how closely the groups identified in the cluster analysis relate to each other. As in past years, the 2025 ordination analysis showed no indication of any relation between community composition and proximity to the outfall (Figure 4-7). Both main Groups I and II included stations located at various distances and directions from the outfall. Group II included stations from both nearfield station groups, the transition station between the Harbor and the outfall, and farfield stations to the northeast and southeast of the outfall.

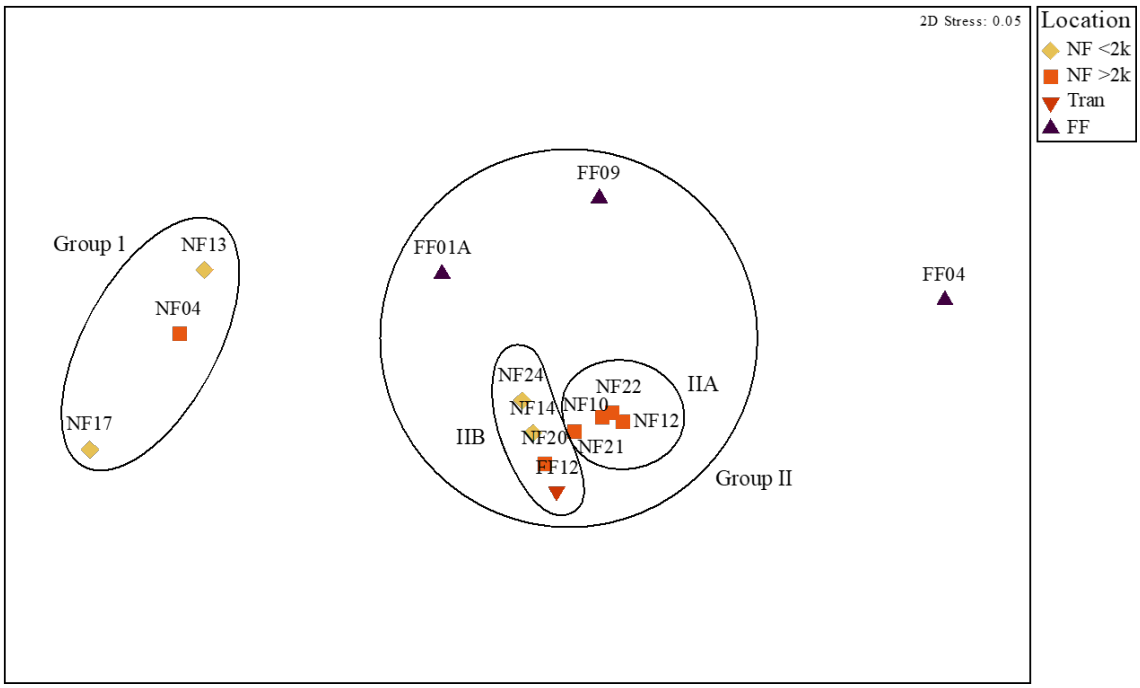


Figure 4-7. Ordination plot of 2025 Massachusetts Bay samples by location. The ordination analysis shows that the distance from the outfall does not correspond with bottom community composition and abundance. Each point on the plot represents one of 14 stations, and varying colors and shapes depict locations. The closer two points are to each other in the figure, the more similar their seafloor communities. NF<2k = stations within two kilometers of the outfall; NF >2k = stations near but more than two kilometers from the outfall; Tran = the one transition station between Boston Harbor and the outfall; FF = stations far from the outfall. (The 2D Stress value of 0.05 noted in the upper right is a measure of good confidence in the analysis.)

Additional assessment of the ordination analysis demonstrated that variations in species distributions largely follow differences in sediment grain size (Figure 4-8) and water depth. Seafloor animal communities at stations with similar sediment textures or water depths tended to be more closely related, as shown by closer proximity on their ordination plots. These results validated past findings that the Massachusetts Bay seafloor communities are driven by physical factors rather than by the effluent discharge. The strong physical forces in the Bay, as well as the low pollutant levels in the discharge, help to maintain diverse soft-bottom habitats throughout Massachusetts Bay.

Similar ordination analyses demonstrated the stability of Massachusetts Bay habitats and communities over time. For example, an analysis of selected stations consistently monitored over 34 years showed that individual stations remained closely grouped compared to other stations throughout the baseline period and continuing after the outfall discharge began in 2000 (Figure 4-9).

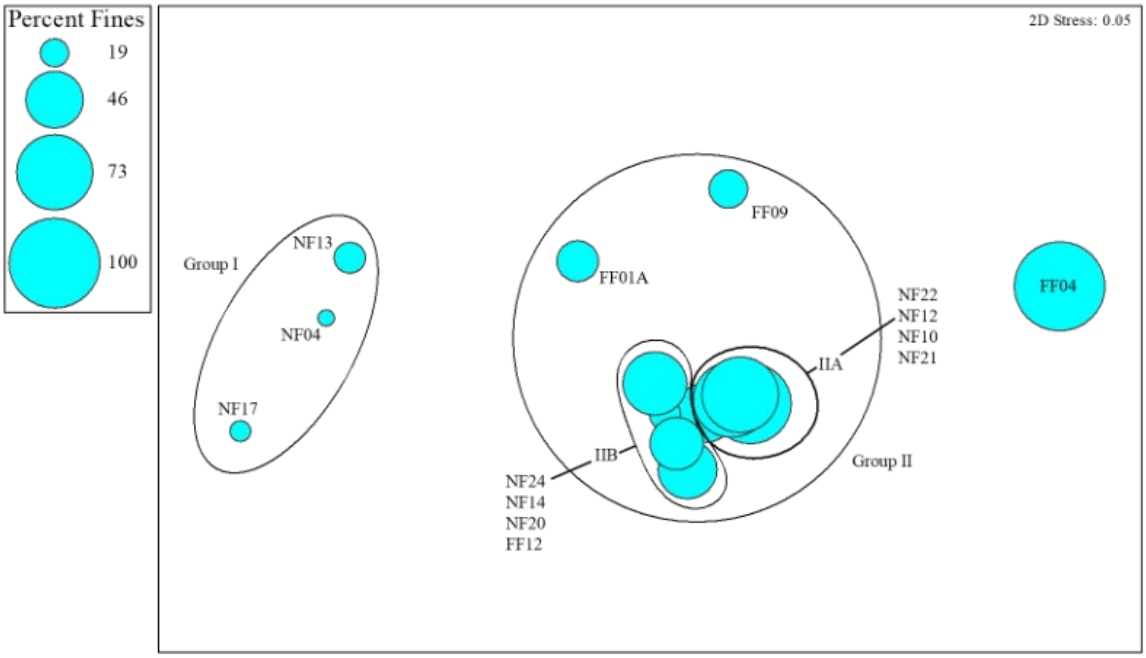


Figure 4-8. Percent fine sediments superimposed on the ordination plot of the 2025 samples. Combining the ordination analysis with sediment grain-size data shows that sediment texture is a strong driver of community composition and abundance. (The 2D Stress values noted in the upper right of each figure are a measure of good confidence in the analysis.)

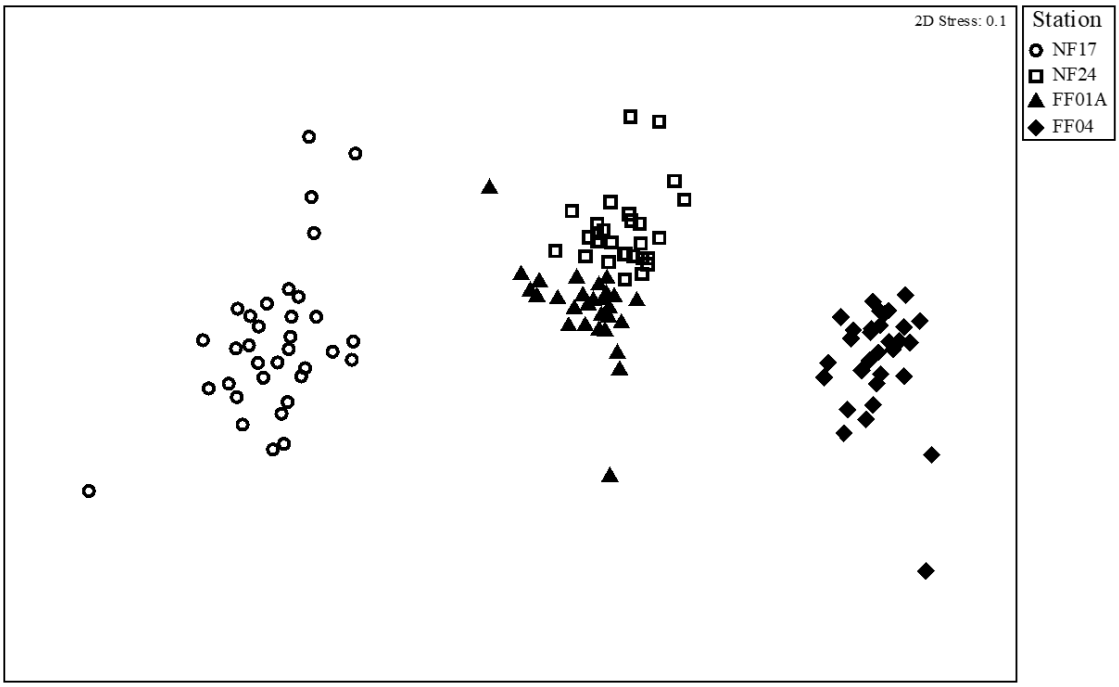


Figure 4-9. Ordination plot of selected stations over time, 1992–2025. Each point represents one year, demonstrating that communities have remained relatively stable within stations over time. NF17 is in closer proximity and southwest of the outfall, where the effects of the discharge might be expected but have not been found. NF24 is the station closest to the outfall. FF01A is the northern reference station, and FF04 is in Stellwagen Basin; both farfield stations are farther than 20 kilometers from the outfall.

Stellwagen Bank National Marine Sanctuary

The NPDES permit to discharge from Deer Island Treatment Plant into Massachusetts Bay requires annual reporting on results relevant to Stellwagen Bank National Marine Sanctuary. MWRA's deepwater seafloor reference Station FF04 lies within the depositional part of the Sanctuary, Stellwagen Basin, where long-term accumulation of pollutants would most likely be detected if they occurred.

Station FF04 is typical of deepwater, offshore habitats and is representative of a larger group of stations that MWRA monitored in earlier years of the program. It supports a soft-bottom community typical of what had been found at the larger suite of deepwater stations. Communities at those stations had always shown distinct differences from those found in shallower areas, probably due to the distance from shore, as well as greater depth and finer-grained sediments. Analyses of the relation of sediment texture in 2025 and historic data from throughout the duration of the monitoring program demonstrate the consistency of the seafloor community at that station (Figures 4-8 and 4-9, above).

The most recent management plan for the Sanctuary (NOAA Office of Marine Sanctuaries 2023) includes an action plan to assess all the major habitats within its borders, including sand, boulder, gravel, mud, rocky areas, and shipwrecks. The most recent environmental assessment (NOAA Office of Marine Sanctuaries 2020) found that changes to seafloor habitats and animal communities came mostly from fishing rather than the MWRA outfall or other human activity. Fishing gear physically scrapes the sea floor, and fishing pressures can change the species makeup of both seafloor and fish communities.

Boston Harbor Seafloor Monitoring

Seafloor conditions are much better in Boston Harbor than they were in the 1970s and 1980s, when both sewage sludge and effluent were discharged into its relatively shallow, confined waters. MWRA has conducted ongoing seafloor monitoring in Boston Harbor since 1991, the year that sludge discharges ended. Each year, sediment samples are taken from nine stations, and sediment-profile images are made at 61 locations throughout the Harbor.

Sediment textures vary throughout the Harbor, ranging from mostly sand at some stations, particularly in the outer Harbor, to silt and clay at others. Percent total organic carbon in Harbor sediments has declined over time, reflecting the end of sludge and effluent discharges. Concentrations of the sewage effluent tracer *Clostridium perfringens* spores were very low in 2025 (Figure 4-10). Intermittent spikes in spore concentrations at Station T08 in the outer Harbor may be indicators of localized wastewater discharges from the city of Quincy and town of Hull, located on the southern Harbor shoreline.

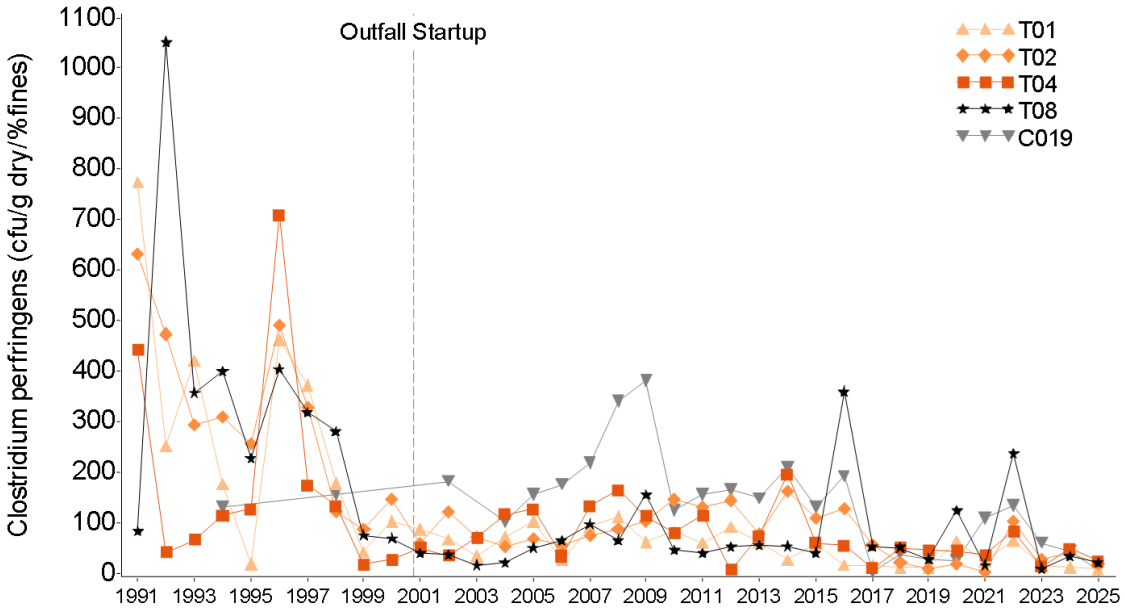


Figure 4-10. Concentrations of the effluent tracer *Clostridium perfringens* spores in at selected Boston Harbor stations in 2025. Stations T04 and C019 represent the inner Harbor, Stations T01 and T02 the boundary between the inner and outer Harbor, and Station T08 the outer Harbor.

Over the past decade, the total abundances of organisms and number of species per sample from the Harbor have stabilized compared to past conditions when opportunistic species were more likely to boom and then disappear. In 2025, samples contained 23,614 organisms, classified into 130 species and 14 other discrete taxonomic groups.

As in past years, the seafloor animal communities in 2025 varied along an inner-to-outer Harbor gradient, reflecting the greater river inputs to the inner Harbor and greater tidal flushing at the outer-Harbor stations. Sediment-profile imaging confirms the gradient and clearly documents sustained improvements to habitat conditions throughout the Harbor over time. Sediment-profile images from 1991 through 2025 depict the increasingly healthy conditions, with increasingly deeper light-colored layers, which indicate deeper oxygenation of the sediments (Figure 4-11).

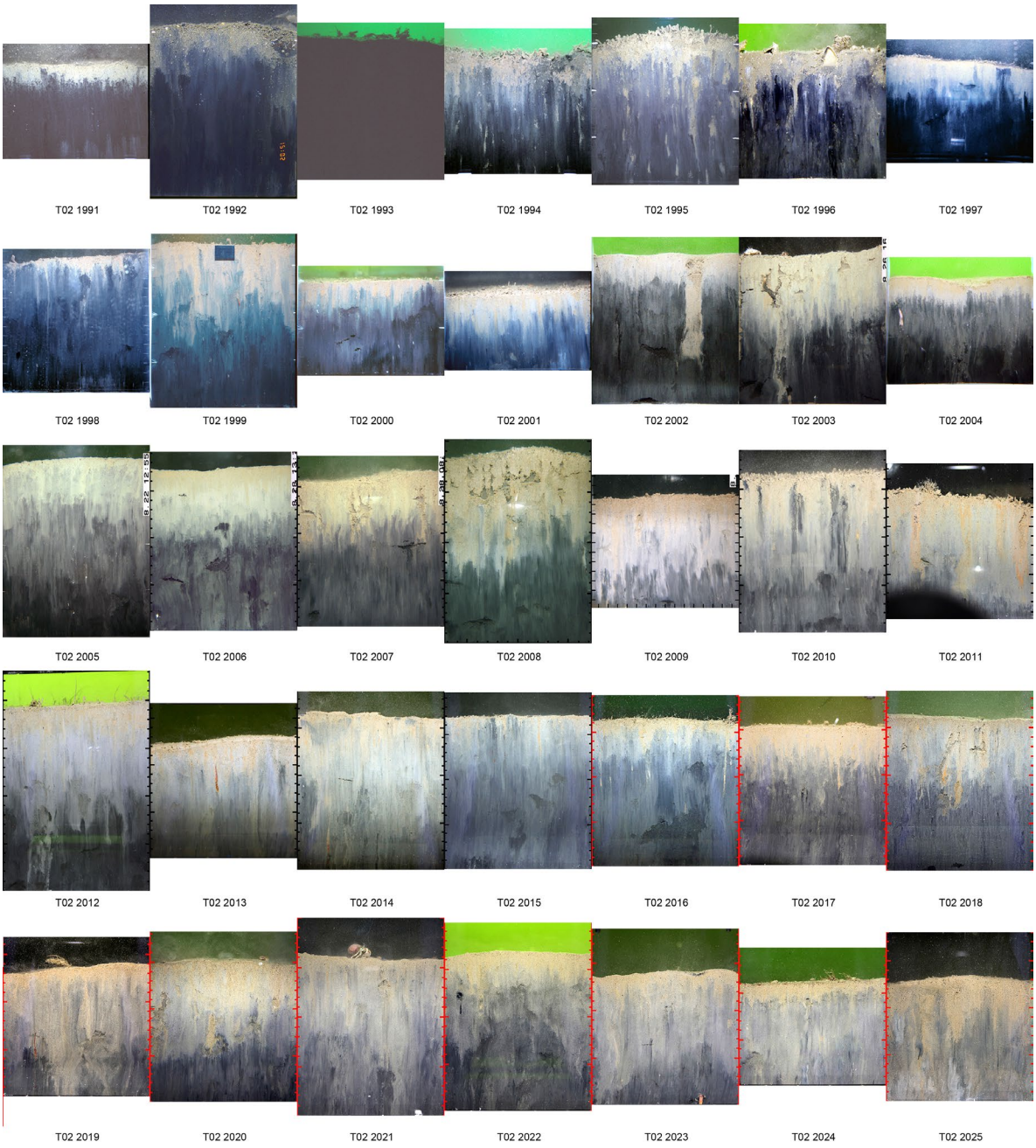


Figure 4-11. Sediment-profile images from Station T02 west of Deer Island at the boundary between the inner and outer Harbor, 1991–2025. The change from light to dark color in each image shows the transition from oxygenated to unoxygenated sediment; this transition zone deepened over time in response to improved conditions. Presence of organisms and feeding structures further indicate improved conditions. Scales at the sides of the image are in centimeters. Photo credits RJ Diaz and Daughters, Ware Neck, Virginia.

Seafloor Contingency Plan Thresholds

Seafloor threshold calculations include stations from both nearfield groups (nearer and farther than two kilometers from the outfall) and the station in the transition area between Boston Harbor and the Massachusetts Bay outfall. There were no exceedances of the seafloor Contingency Plan thresholds in 2025 (Table 4-1).

All threshold parameters continued to confirm that the Massachusetts Bay outfall does not affect seafloor habitats. Number of species per sample and the several diversity and evenness indices used to evaluate community structure remained higher than Contingency Plan limits. The percent opportunistic species, an indicator of disturbed or polluted habitats, was negligible, far lower than the caution and warning thresholds of 10% and 25%.

Table 4-1. Contingency Plan threshold values and 2025 results for seafloor monitoring.*

Parameter	Baseline	Caution Level	Warning Level	2025 Results
Species per sample	NA	<42.99	NA	55.1
Fisher's log-series alpha	NA	<9.42	NA	11.7
Shannon diversity	NA	<3.37	NA	3.92
Pielou's evenness	NA	<0.57	NA	0.68
% opportunists	NA	>10%	>25%	0.05%

NA = not applicable

* Number of **species per sample** is often referred to as species richness. **Fisher's log-series alpha** and **Shannon diversity** are indicators of diversity, calculated from both numbers of species and numbers of individuals per species. **Pielou's evenness** assesses how evenly numbers of individuals are distributed among the species in the sample. **Percent opportunists** is the percentage of the total number of animals that are indicators of disturbed habitat. The percent opportunist threshold is a maximum; all other thresholds are minimum values.

5. Fish and Shellfish

Fish are healthy and tumor-free
MWRA monitors winter flounder health each year and quantifies chemical pollutants that occur in wastewater effluent in flounder, lobster, and mussel tissues every three years. In 2025, monitoring included only flounder health assessments in fish from near the Massachusetts Bay outfall and in Boston Harbor. Flounder health has improved in both areas over time, and no tumors have been found in fish from near the Massachusetts Bay outfall at any time.

Fish and shellfish are important to the regional identity and economy of Massachusetts and can be good indicators of overall environmental quality. The monitoring program focuses on winter flounder, lobster, and cage-deployed blue mussels. Flounder and lobster are economically and ecologically important species that live on the sea floor. They are vulnerable to contaminant exposure through direct contact and by feeding on bottom-dwelling animals. The blue mussel is also economically and ecologically important. Mussels filter large volumes of water and can concentrate potentially toxic metals and organic compounds in their tissues.

Winter flounder are collected for health assessments each year, and tissues samples from all three species are analyzed for chemical contaminants every three years, most recently in 2024. Flounder health assessment was the only fish-and-shellfish monitoring completed in 2025.

Sampling and deployment locations vary by species (Figure 5-1). Sampling locations for winter flounder and lobster were selected to be far enough away from each other to maximize the likelihood of sampling separate populations. Winter flounder are unlikely to range farther than about two kilometers in areas with ample food. Lobster migration is less well understood, although they are known to move from shallower Boston Harbor to deeper water in the fall. Off the coast of New Hampshire, one study found that most lobsters outfitted with ultrasonic transmitters and released into the Gulf of Maine remained close to their original release site throughout a year (Goldstein and Watson 2015).

In 2025, when winter flounder were the only monitoring species, fish were collected near the Massachusetts Bay outfall site and at Deer Island Flats, near the location where wastewater effluent was once discharged into Boston Harbor (Moore et al. 2025). Flounder sampling occurred over two days in May. A full complement of 50 fish was collected in Massachusetts Bay, but only 21 fish were taken at Deer Island Flats in Boston Harbor. Overall, winter flounder abundance has declined throughout its range (see Werme et al. 2025), and Boston Harbor sampling is hampered by kelp, other large seaweeds, and entangled lost fishing gear, which foul the trawls and can tear nets.

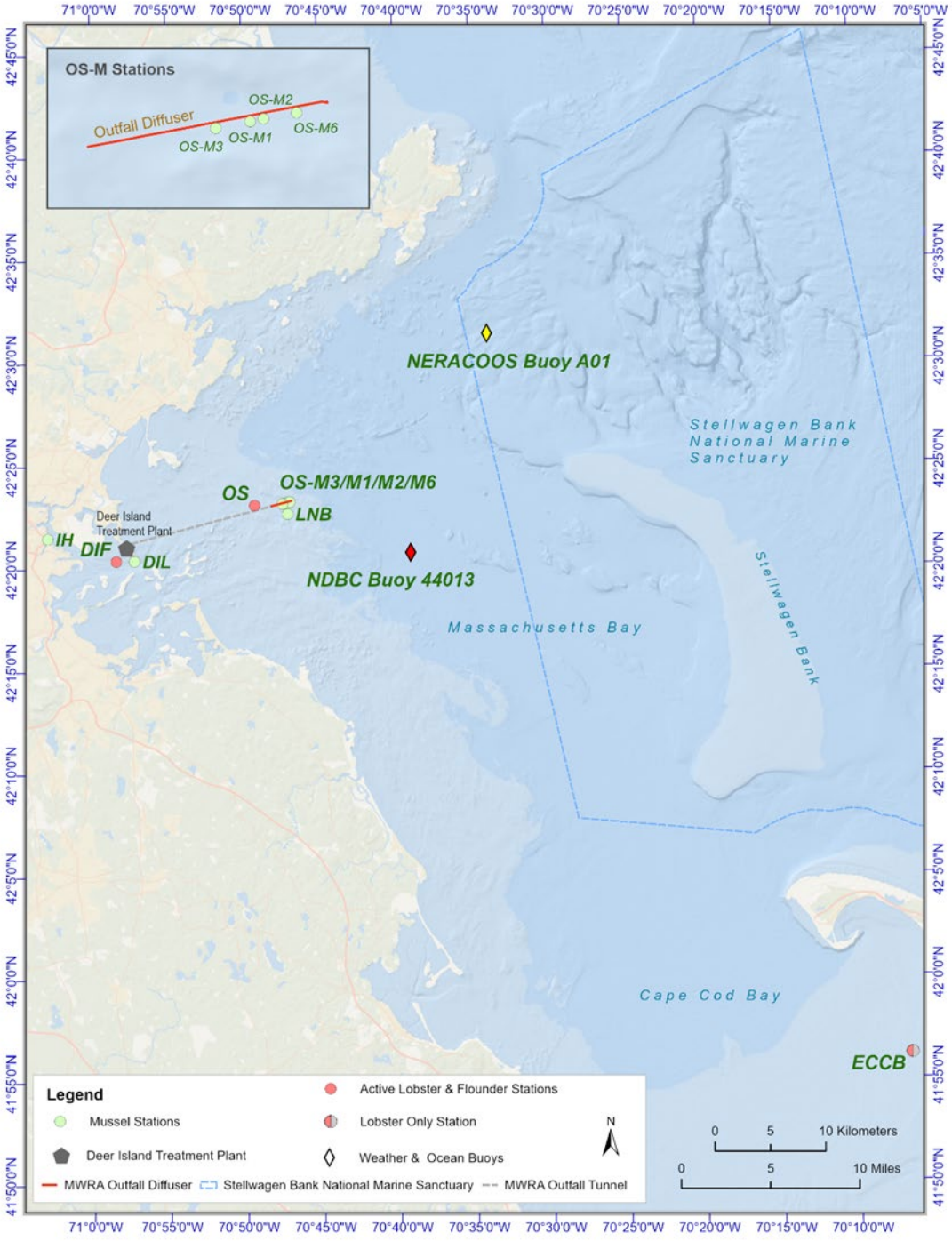


Figure 5-1. Fish-and-shellfish monitoring stations. IH = Inner Harbor; DIF = Deer Island Flats; DIL = Deer Island Light; OS = Outfall Site; OS-M = Outfall Site, Mussels; LNB = Large Navigation Buoy (buoy south of the outfall); ECCB = Eastern Cape Cod Bay. Also shown are the outfall, the instrumented buoys, and Stellwagen Bank Marine Sanctuary.

Mean age was 5.29 years, mean total length was 251 centimeters, and mean weight was 540 grams, all within the ranges for the monitoring program. Catches continued to be dominated by females, which is typical for the region. Measures of external condition, such as bent fin rays and occurrence and severity of fin erosion, remained variable, but continued to reflect improved conditions since the 1980s and 1990s. Incidence of fin erosion, which is associated with excess ammonium and other pollutants, was 43% at Deer Island Flats and 14% at the Massachusetts Bay outfall site. Ulcers, which are observed on the bottom or "blind side" of the fish in some years, were found on one fish from Massachusetts Bay.

Incidence of centrotubular hydropic vacuolation (CHV), a key tumor precursor and mild liver condition associated with exposure to contaminants (Figure 5-2), was only 2.0% at the Massachusetts Bay outfall, a record low, and 24% at Deer Island Flats, an increase from recent years but still healthier than historic conditions (Figure 5-3, top). More than 75% of Boston Harbor flounder livers in the late 1980s showed at least some level of CHV. Incidence decreased across all age groups in both the Harbor and the Bay, alleviating the concern prior to the Massachusetts Bay outfall startup that there could be increased liver disease in the Bay. In the few fish where CHV has been found, severity of the condition has also declined over time (Figure 5-3, bottom).

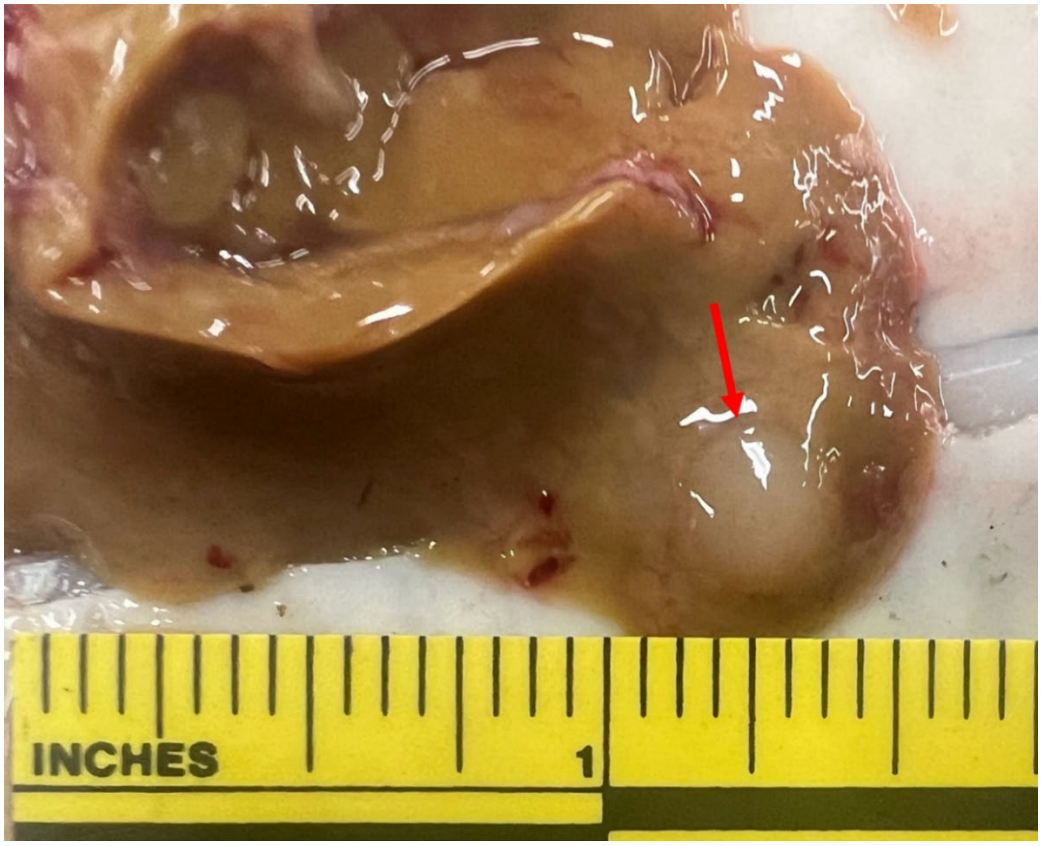


Figure 5-2. Centrotubular hydropic vacuolation (CHV) in flounder liver. In the 1980s and 1990s, Boston Harbor winter flounder were riddled with similar nodules. Now they are rare. Photo credit Michael Moore, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.

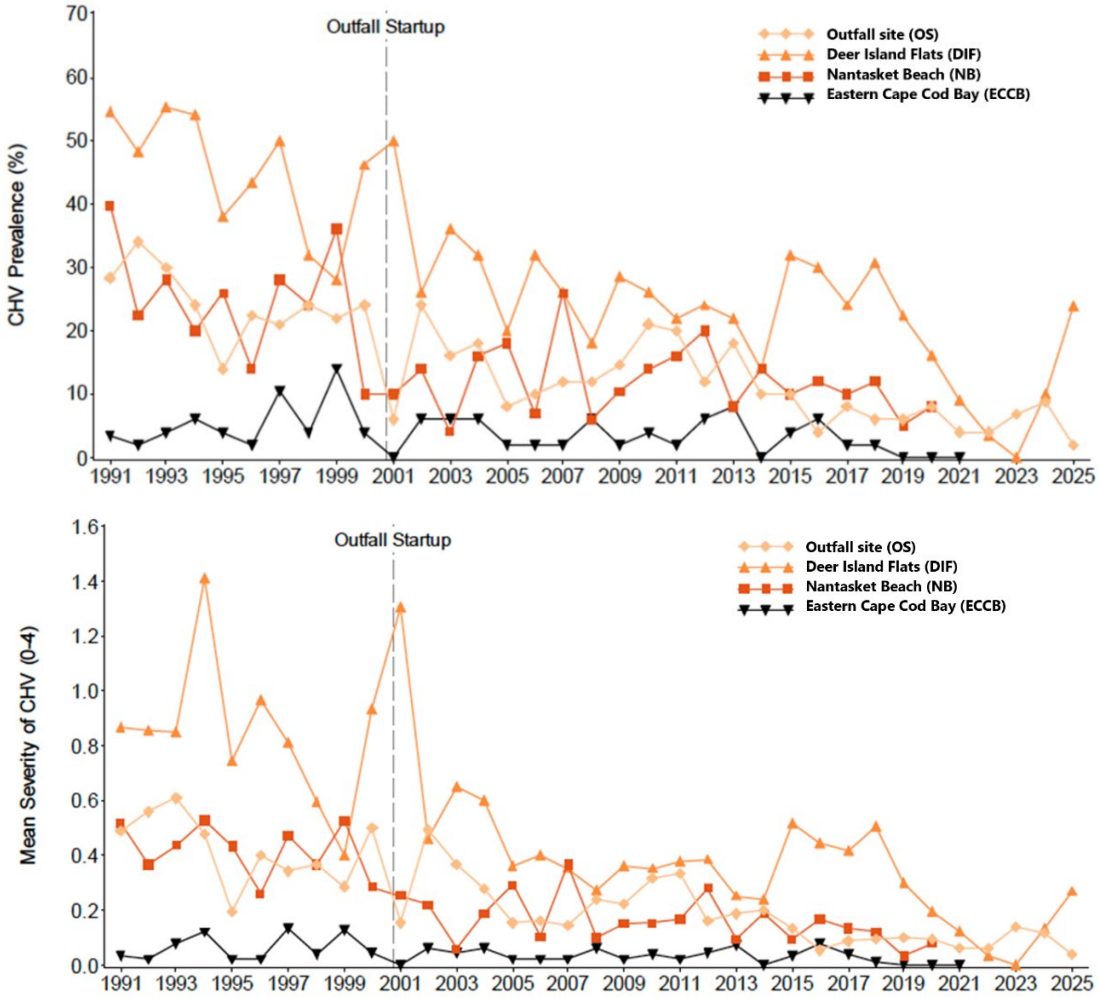


Figure 5-3. Annual prevalence (top) and severity (bottom) of the tumor precursor CHV in winter flounder, 1991–2025. In 2025, sampling was limited to the outfall site and Deer Island Flats. Severity is measured on a scale of 0 to 4. Nantasket Beach and Eastern Cape Cod Bay are no longer sampled.

Cancerous liver tumors, also called neoplasia, which were present in up to 10% of flounder from Boston Harbor in the 1980s, were absent, as they have been since 2004. Tumors have never been found in a fish taken from near the Massachusetts Bay outfall site (Figure 5-4; see also Moore et al. 2018).

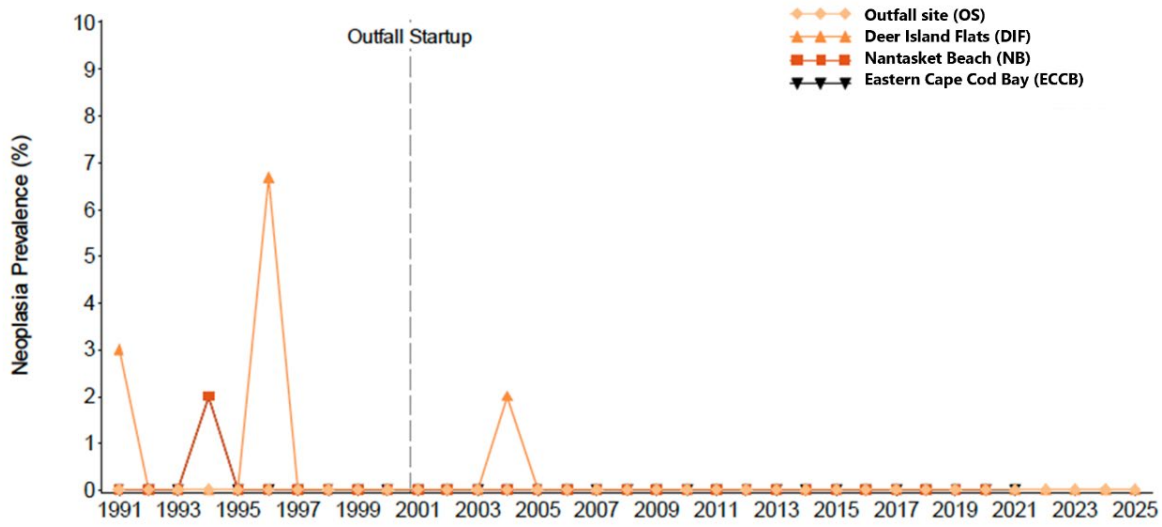


Figure 5-4. Annual prevalence of liver tumors (neoplasia) in winter flounder, 1991–2025. No tumors have ever been found in fish taken from near the Massachusetts Bay outfall. In 2025, sampling was limited to the outfall site and Deer Island Flats.

Fish and Shellfish Contingency Plan Thresholds

There was no Contingency Plan threshold exceedance for CHV, the only fish-and-shellfish parameter measured in 2025 (Table 5-1). CHV occurred in just 2.0% of the fish collected near the outfall, compared to the 24.4% baseline and a caution threshold of 44.9%.

Table 5-1. Contingency Plan threshold values and 2025 results for fish-and-shellfish monitoring.

Parameter	Baseline	Caution Level	Warning Level	2025 Results
Flounder disease				
Liver disease (CHV)	24.4%	>44.9%	None	2.0%

CHV = centrotubular hydropic vacuolation

6. Special Topics

In addition to the permit-required monitoring of the effluent and the water column, sea floor, and fish and shellfish in Massachusetts Bay, MWRA also initiates or collaborates on studies of Boston Harbor, Massachusetts Bay, Cape Cod Bay, and the wider Gulf of Maine. These studies meet specific permit conditions or better inform interpretations of MWRA monitoring results. This year's special topic report focuses on the great improvements in Boston Harbor water quality resulting from the Boston Harbor Project.

The Boston Harbor Project

When Boston was founded in 1630, its city regulations prohibited the fouling of its waters and shorelines. However, those regulations could not prevent centuries of dumping municipal, agricultural, and industrial wastes. As early as the 1700s, disease outbreaks were often blamed on poor water quality. Sewage treatment began in earnest in the 1800s, and by the mid-1900s, wastewater was being treated at primary treatment plants on Nut Island in the southern part of the Harbor and Deer Island in the north. Following treatment, both the liquid effluent and the solids removed as sludge were discharged into the Harbor.

Those practices were insufficient to keep Boston Harbor waters safe from low oxygen levels and bacterial and chemical pollution. In the 1960s, a rock band, the Standells, facetiously sang that they loved hometown Boston's "dirty water." In 1988, when then-Massachusetts governor Michael Dukakis became his party nominee for the presidency, his opponent George H.W. Bush referred to Boston as the "harbor of shame," the dirtiest harbor in the nation. In fact, Boston's cleanup was already underway in 1988. Court proceedings in the early 1980s had dictated actions and schedules for cleanup. Most notably, in 1984, the state legislature established MWRA, with specific goals to improve sewage treatment and clean up the Harbor. The Boston Harbor Project ended sludge dumping to the Harbor, began construction of a new secondary treatment plant at Deer Island, and diverted effluent discharge from Boston Harbor to Massachusetts Bay. This final big step, the "outfall diversion" from the Harbor to the Bay, was accomplished in September 2000.

Boston Harbor Water-Quality Monitoring

MWRA began environmental monitoring in Boston Harbor in 1991 and launched a comprehensive water-quality monitoring program in both the Harbor and Massachusetts Bay in 1992. In Boston Harbor, twice-monthly water samples are taken at 10 locations (Figure 6-1) and analyzed for nutrients such as nitrogen and phosphorus, chlorophyll (or more precisely, chlorophyll a, the pigment that drives photosynthesis), the indicator bacteria *Enterococcus*, and physical oceanographic parameters.

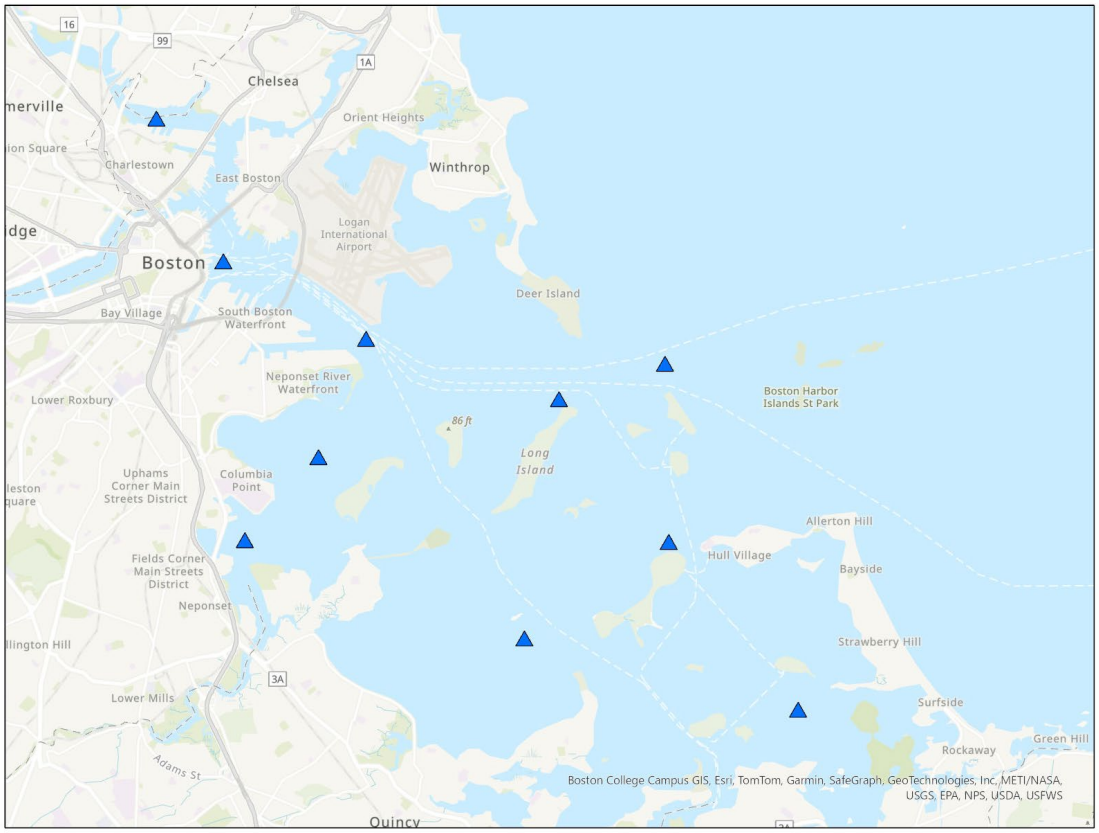


Figure 6-1. Long-term water-quality sampling stations in Boston Harbor. Stations are represented by blue triangles.

Nutrients and Phytoplankton Biomass

Diverting the effluent discharge from the Harbor to the Bay in September 2000 had an immediate positive effect on water quality in Boston Harbor. Discharges of total dissolved inorganic nitrogen (ammonium, nitrate, and nitrite) decreased by 50% (Figure 6-2). Annual average concentrations of inorganic phosphate fell by 43% (Figure 6-3).

Those decreases in nutrient concentrations in the water column also resulted in decreased chlorophyll concentrations (Figure 6-4). Post-diversion chlorophyll concentrations dropped and then quickly stabilized, with average summertime levels of about four micrograms per liter of water.

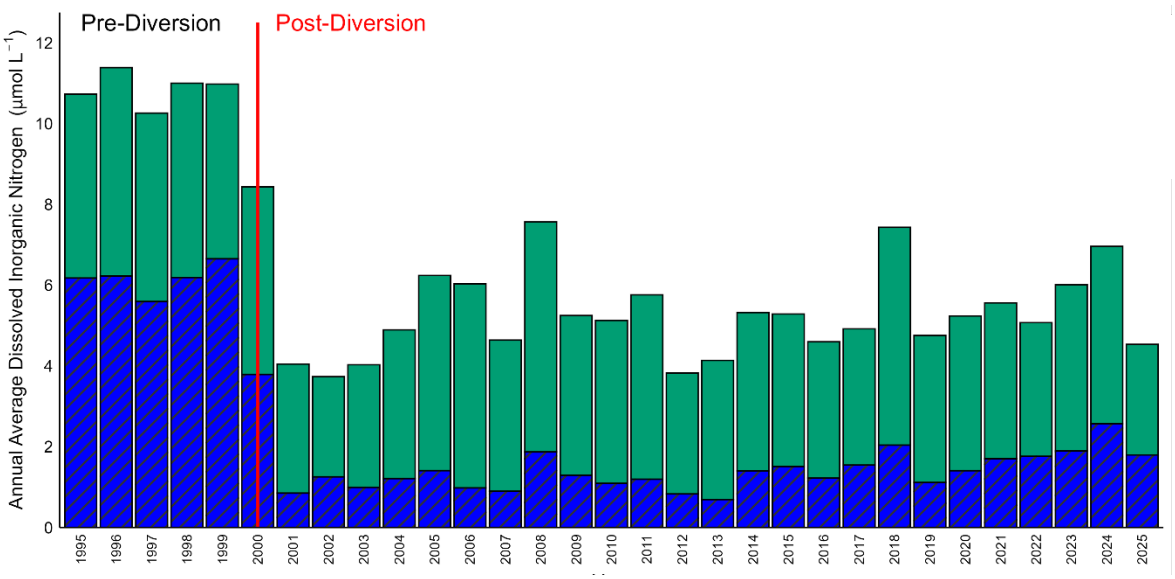


Figure 6-2. Annual average dissolved inorganic nitrogen concentrations, 1995–2025. Ammonium concentrations are represented by the blue hatched bars and nitrate + nitrite concentrations are represented by the green solid bars. Ammonium is the most abundant form of inorganic nitrogen in sewage effluent, so the post-diversion decline was especially dramatic. µmol L^{-1} = micromoles per liter

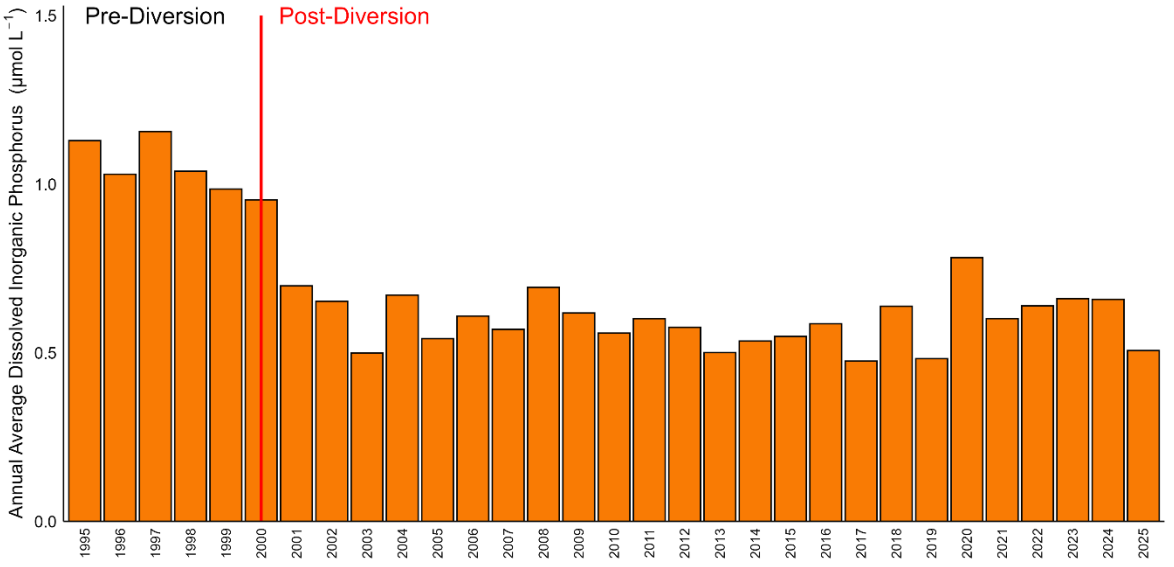


Figure 6-3. Annual average dissolved inorganic phosphorus concentrations, 1995–2025. Similar to nitrogen, phosphate concentrations dropped immediately when effluent discharge was diverted from the Harbor to the Bay. µmol L^{-1} = micromoles per liter

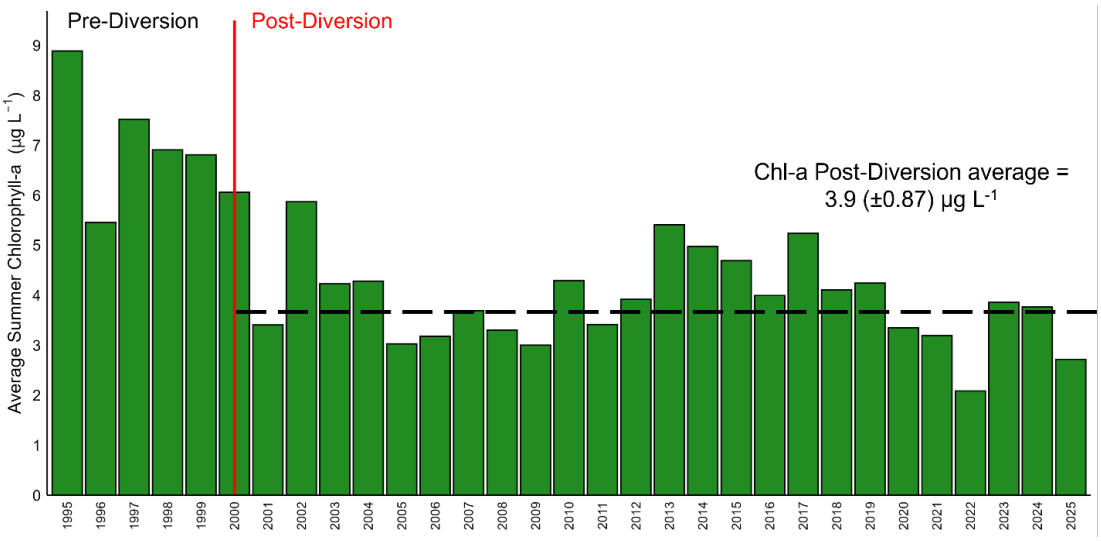


Figure 6-4. Average summer chlorophyll concentrations, 1995–2025. µg L^{-1} = micrograms per liter

Shifting Environmental Controls

MWRA recently analyzed results from pre- and post-diversion years to assess potential shifts in the relationships among environmental parameters most often associated with water quality and ecosystem productivity. The immediate reductions in nutrient and chlorophyll concentrations in water samples and improved water quality throughout the post-diversion period suggested that environmental controls on the Harbor ecosystem have changed.

Preliminary results from these analyses suggest that the environmental controls within the Harbor shifted from a system strongly affected by wastewater discharge to one driven by physical mixing and natural biogeochemical processes. Before the diversion, concentrations of individual nutrients, such as ammonium, nitrate, and nitrite, were closely correlated with each other, increasing and decreasing at the same times over the course of the year. Since the diversion, concentrations of ammonium in water samples are less correlated with concentrations of nitrate and nitrite. Similarly, correlations between total inorganic nitrogen and total inorganic phosphorus decoupled. Nitrate concentrations, for example, are now more closely linked to seasonal river flow and possible biochemical nitrification processes than they are to other forms of nitrogen. Ammonium and phosphate concentrations may be driven by releases from sediments and by estuarine tides and currents rather than by inputs from sewage effluent.

Changing environmental controls can affect phytoplankton productivity and water clarity. Pre-diversion, phytoplankton growth was limited by light, as light penetration into the water was blocked by the small solid particles in the effluent. Post-diversion, phytoplankton growth is now more strongly correlated with available nutrients, particularly nitrogen. Water clarity is no longer driven by effluent solids but rather by seasonal cycles of nutrient runoff from land and by phytoplankton growth.

Regime Change and a Cleaner Harbor

Marine ecologists define regime change as a sudden and persistent transition in a waterbody's biological community structure following the crossing of a "tipping point" after a change in environmental stressors (Duarte et al. 2009). In Boston Harbor, 25 years of stable nutrient and chlorophyll levels suggest a shift from a degraded state, dominated by wastewater inputs, to a new regime, characterized by seasonal river flow and tides, stable primary productivity, and improved water clarity.

However, the diversion of wastewater is just the last chapter in a long history of human intervention that has shaped the environment. Boston Harbor has undergone many changes besides the inputs of sewage and other discharges since Boston's founding in 1630. In 1630, for example, the city occupied just a small peninsula jutting into the Harbor. In the intervening years, Boston has expanded its footprint manyfold, filling in the Back Bay, much of the Financial District, South and East Boston, and much of Logan International Airport. Boston Harbor has also been subjected to building, dredging, fishing, and other human activities. Whether water quality in the Harbor could ever return to its condition before effluent was first discharged remains uncertain. Duarte (2009) suggests that a complete return to a historical "Neverland," the pre-human state, may be impossible.

Weather and climate also play a role in the ecosystem's ongoing change. Many scientists believe that changing environmental conditions over the broader region of the Gulf of Maine could result in other regime shifts beyond what has been observed from ending wastewater discharge (for example, Thomas et al. 2017, Brickman et al 2021, Pershing et al. 2021).

While changes will continue, the Boston Harbor Project is considered a notable environmental success story. The Harbor met a major milestone in early 2026, when the Massachusetts Division of Marine Fisheries (Massachusetts DMF news, January 1, 2026) announced that some areas of the Harbor would open for shellfishing for the first time in more than 100 years. Shellfishing was closed throughout the Harbor in 1925, following a nation-wide typhoid epidemic. Bacteria and pollutant levels kept the shellfisheries closed through 2025. Timing and regulations for re-openings will be under the purview of individual towns, some of which have never needed to manage shellfishing. The Division of Marine Fisheries is assisting those communities with shellfish management plans and anticipates that additional openings will follow in coming years.

Overall, Boston Harbor is no longer one of the dirtiest in the nation, but instead is a source of increased use and regional pride. MWRA's commitment to the Harbor has shown that strategic infrastructure investments can help restore degraded urban marine ecosystems and invigorate public use of the waterfront and the Bay.

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List of Acronyms

ASP	Amnesic shellfish poisoning
BOD	Biochemical oxygen demand
cBOD	Carbonaceous biochemical oxygen demand
cells/L	Cells per liter
cfu	Colony forming units
CHV	Centrotubular hydropic vacuolation
DDT	Dichlorodiphenyltrichloroethane
DIF	Deer Island Flats
DIL	Deer Island Light
DO	Dissolved oxygen
ECCB	Eastern Cape Cod Bay
EPA	U.S. Environmental Protection Agency
FF	Farfield
IH	Inner harbor
LC50	50% mortality concentration
LNB	Large navigation buoy
m	Meters
m^3	Cubic meters
m^3/s	Cubic meters per second
mg/L	Milligrams per liter
mg/L/d	Milligrams per liter per day
mg/m^2	Milligrams per square meter
mL	Milliliters
MGD	Million gallons per day
mtons	Metric tons
MWRA	Massachusetts Water Resources Authority
µg/L	Micrograms per liter
μgL^{-1}	Micrograms per liter
µM	Micromoles
$\mu molL^{-1}$	Micromoles per liter
NA	Not analyzed/not applicable
NB	Nantasket Beach
NDBC	National Data Buoy Center
NERACOOS	Northeastern Regional Association of Coastal and Ocean Observing Systems
NF	Nearfield
ng/L	Nanograms per liter
NH_4	Ammonium
NOAA	National Oceanic and Atmospheric Administration
NOEC	No observed effects concentration
NPDES	National Pollutant Discharge Elimination System
OS	Outfall site
OS-M	Outfall site mussels
Pa	Pascal
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PSP	Paralytic shellfish poisoning
PSU	Practical salinity units



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