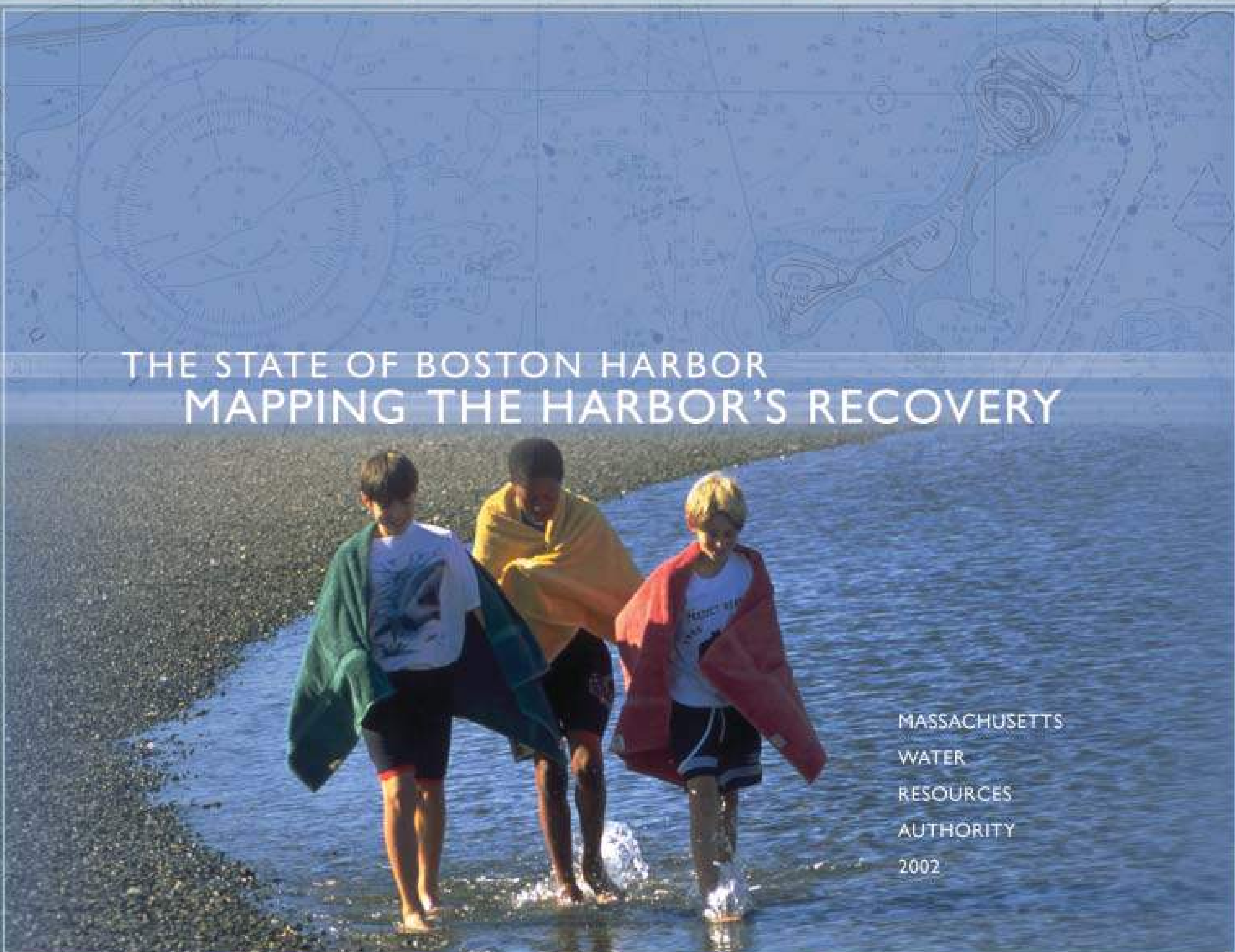
THE STATE OF BOSTON HARBOR
MAPPING THE HARBOR'S RECOVERY



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THE STATE OF BOSTON HARBOR
MAPPING THE HARBOR'S RECOVERY

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TECHNICAL REPORT NO. 2002-09

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Introduction

A decade of environmental monitoring data is displayed in maps that show both dramatic and subtle changes in Boston Harbor's water, sediment, and living natural communities since the Massachusetts Water Resources Authority (MWRA) first began the Boston Harbor Project in 1986.

From 1986 to 1995, there were marked improvements in effluent discharges after MWRA upgraded disinfection and primary treatment and then added secondary treatment. MWRA also increased enforcement of pretreatment of industrial wastewater, which significantly reduced the amounts of metals and other pollutants being sent to the treatment plants.

It is important to understand the effects that the major components of the Boston Harbor Project had on pollutant inputs to the harbor. The maps on this page illustrate how, for three time periods, MWRA minimized the impacts of sewage by improving treatment and changing the location of effluent discharges.

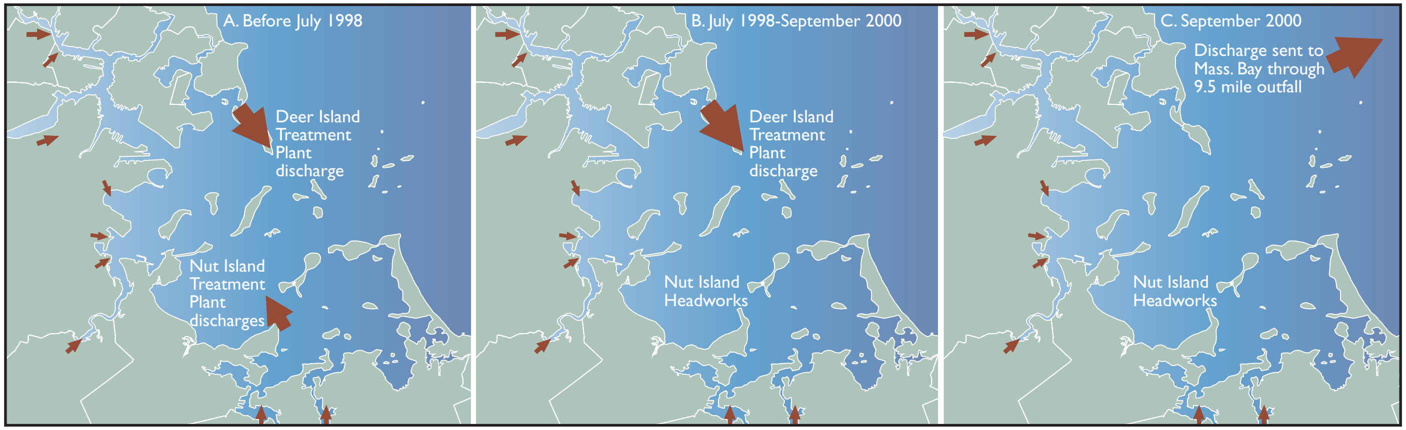
A. Before July 1998: Poorly treated wastewater was discharged from the Deer Island and Nut Island Treatment Plants. Sewage solids (sludge) were discharged into the northern harbor after digestion and disinfection, a practice that ended in 1991. The first battery of secondary treatment of sewage, which more effectively removes solids and contaminants than primary treatment, was in place at Deer Island Treatment Plant in 1997, and in 1998 up to 65% of sewage was undergoing secondary treatment.

B. July 1998 to September 2000: With the completion of the inter-island tunnel from Nut Island to Deer Island, South System sewage was sent to Deer Island for secondary treatment, and the Nut Island Treatment Plant was closed, ending direct discharges to the southern harbor. Another battery of secondary treatment was in place by September 2000, when 85% of the sewage was receiving secondary treatment.

C. After September 2000: The third and final battery of secondary treatment is in place. The new outfall transports cleaner effluent out of the harbor completely and into Massachusetts Bay for greater dilution. Now, no treatment plants are discharging directly into the harbor.

So far, data gathered on the quality of sediments, water, and sea life in Boston Harbor and Massachusetts Bay show that the new outfall has been functioning as anticipated–providing rapid dilution to the effluent–with no significant adverse impacts. Harbor data show even further improvements as nutrients decrease to levels more typical of a natural estuary.

Now that effluent discharges have moved from the harbor to the bay, a significant fraction of remaining pollution entering the harbor comes from its tributary rivers. Although there have been some improvements in river water quality, including lower bacteria levels in the Charles River, other problems, like eutrophication (high levels of nutrients), are more difficult to control. Rivers, runoff, and other "non-point" sources used to be relatively minor contributors of contamination to the harbor. In the absence of treatment plant discharges, these sources now constitute the major inputs to the harbor, and must in turn be addressed to continue the "Boston Harbor clean-up".



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The Boston Harbor Project

FROM 1986 TO 2000 THE BOSTON HARBOR PROJECT GRADUALLY REDUCED TREATMENT PLANT DISCHARGES TO THE HARBOR

This "State of Boston Harbor: Mapping the Harbor's Recovery" report arrives as MWRA marks the completion of the Boston Harbor Project. This report illustrates changes in the waters, sediments, and living natural communities of this urban marine ecosystem, which is recovering from centuries of receiving Greater Boston's sewage.

In 1985, a federal court order set an ambitious schedule for the newly formed MWRA to plan and construct new sewage treatment facilities. These facilities would end the discharge of untreated and partially treated sewage to Boston Harbor. This undertaking, the "Boston Harbor Project," included four major construction projects:

1 FACILITIES AT FORE RIVER SHIPYARD IN QUINCY to process sewage sludge into commercial fertilizer pellets, ending the discharge of sludge into the harbor.

2 A NEW SECONDARY WASTEWATER TREATMENT FACILITY, the new Deer Island Treatment Plant (DITP), to replace the failing and undersized primary treatment plants at Deer Island and Nut Island (NITP).

3 A TUNNEL FROM NUT ISLAND TO DITP to transport South System sewage to DITP for secondary treatment, enabling flows from throughout MWRA's service area to receive secondary treatment and greatly lessening pollution to the harbor.

4 AN OUTFALL-DIFFUSER SYSTEM to discharge treated effluent 9.5 miles offshore into Massachusetts Bay, increasing dilution and minimizing potential environmental impacts in the bay.

In addition to taking on these major construction projects, MWRA is addressing the problem of combined sewer overflows (CSOs), which discharge a mixture of stormwater runoff and sewage directly into the harbor during heavy rainstorms. In the 1980s, 88 CSOs in the harbor and its tributary rivers discharged an estimated 3.3 billion gallons of partially treated or raw combined sewage annually. By 2008, MWRA's CSO Plan proposes to close 36 CSOs, reduce annual discharges to 0.4 billion gallons, and provide treatment to 95% of those discharges from remaining CSOs that are necessary as safety valves to prevent sewage flooding and backups into streets and homes.

Combined Sewer Overflows (CSOs)

Boston, Cambridge, Chelsea, and Somerville have combined systems that carry sewage and stormwater runoff in the same pipe. During heavy rainstorms, the volume of flow is sometimes more than the pipes can carry, causing mixed stormwater and sewage discharges from outfall pipes into Boston Harbor and its tributary rivers.

Sanitary Sewer Overflows

Sanitary (not combinrd) sewer systems are not designed to carry stormwater runoff. Heavy rains leaking into sewer pipes can cause these systems to overflow into a stream or other body of water.

Stormwater

Drainage systems collect rainwater runoff from streets and channel it to a nearby river or harbor. Unfortunately, storm drainage is frequently contaminated with sewage from leaking pipes or illegal sewer connections from buildings. Animal waste on the streets also contaminates stormwater, as does car exhaust, street dirt, and litter.

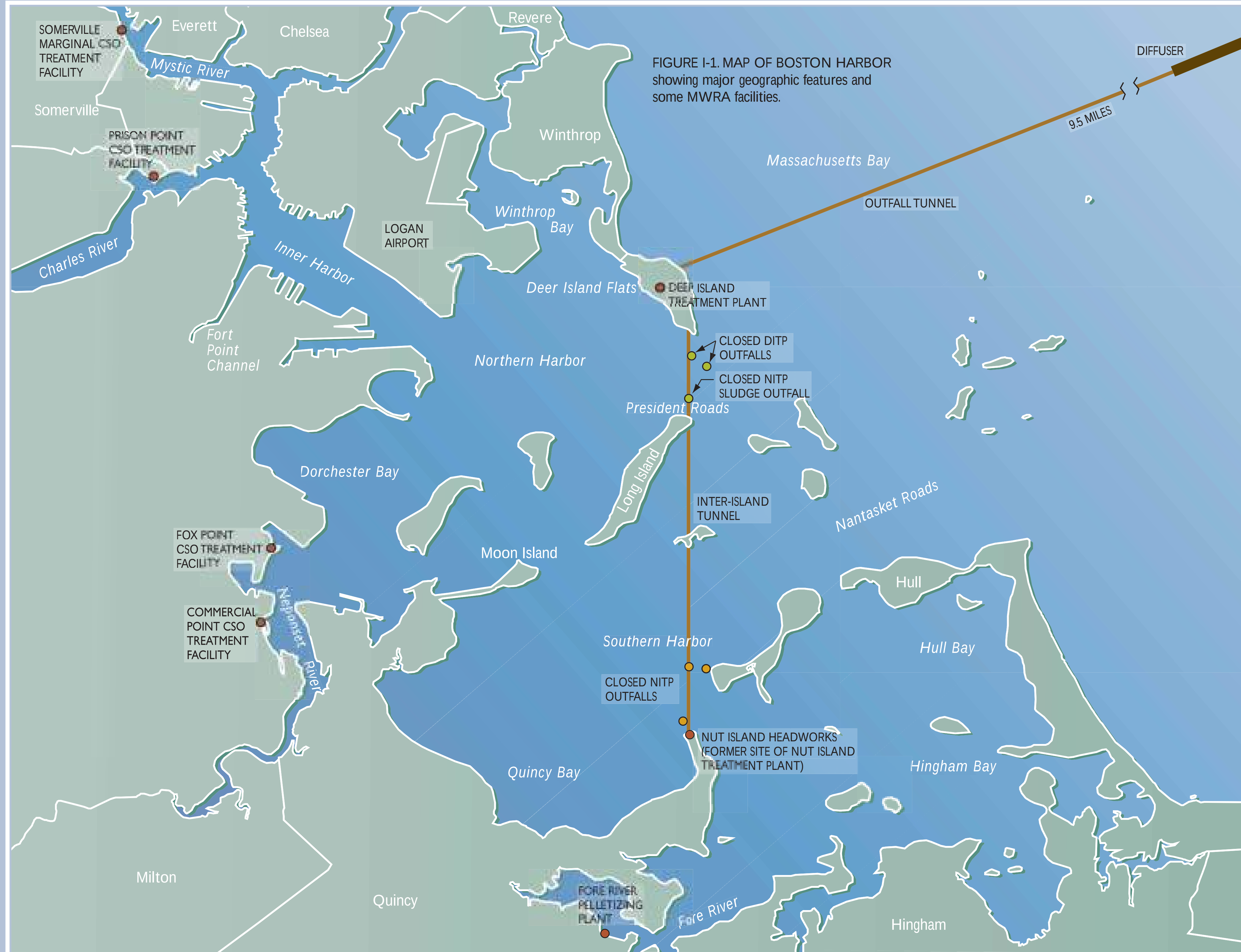


FIGURE I-1. MAP OF BOSTON HARBOR showing major geographic features and some MWRA facilities.
SOMERVILLE MARGINAL CSO TREATMENT FACILITY
Everett
Chelsea
Revere
Mystic River
Somerville
PRISON POINT CSO TREATMENT FACILITY
Winthrop
Massachusetts Bay
DIFFUSER
9.5 MILES
OUTFALL TUNNEL
Winthrop Bay
LOGAN AIRPORT
Charles River
Inner Harbor
Deer Island Flats
DEER ISLAND TREATMENT PLANT
CLOSED DITP OUTFALLS
Fort Point Channel
Northern Harbor
CLOSED NITP SLUDGE OUTFALL
President Roads
Long Island
Dorchester Bay
INTER-ISLAND TUNNEL
Nantasket Roads
FOX POINT CSO TREATMENT FACILITY
Moon Island
Hull
Neponset River
COMMERCIAL POINT CSO TREATMENT FACILITY
Southern Harbor
Hull Bay
CLOSED NITP OUTFALLS
NUT ISLAND HEADWORKS (FORMER SITE OF NUT ISLAND TREATMENT PLANT)
Quincy Bay
Hingham Bay
Milton
Quincy
FORE RIVER PELLETIZING PLANT
Fore River
Hingham

boston harbor project timeline 1985-2001

project milestones

July 1985 Following the passage of its enabling act in 1984, MWRA assumed responsibility for the Metropolitan District Commission's water and sewer systems.

May 1986 Judge A. David Mazzone ordered a 13-year schedule to the construct a new Deer Island Treatment Plant (DITP) and related facilities.

December 1988 Interim repairs and upgrades to the old DITP included the provision of a more reliable disinfection system. Also, sewage scum was landfilled instead of being discharged into the harbor.

1989-1998 Pumping capacity increased from about 700 million gallons per day (mgd) in 1989 to 900 mgd in 1998, sending more wastewater for treatment and reducing CSO discharges.

December 1991 Sludge discharges into the harbor from the old Deer Island and Nut Island treatment plants ended. Sludge-to-fertilizer pelletizing began at the new Fore River plant.

January 1995 First components of improved primary treatment put into service at the new DITP.

effects on discharges

Bunker demolition at Fort Dawes, Deer Island

1988 Scum removal left less oil, grease, and floating matter in effluent. Better disinfection resulted in fewer bacteria.

1992 Solids discharged to the harbor decreased by 40 dry tons per day. Decrease in biochemical oxygen demand (BOD), nitrogen (N), phosphorous (P), and bacteria in the harbor.

1995 Drop in total solids discharged, as well as further decreases in bacteria, BOD, N, and P.

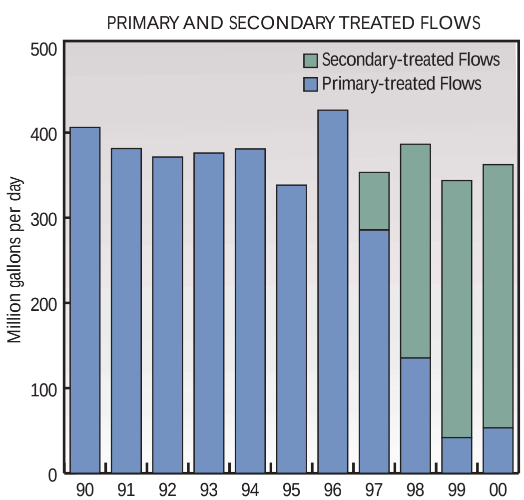


FIGURE I-2. THE PROPORTION OF WASTEWATER RECEIVING SECONDARY TREATMENT (1990-2000) has climbed since the phasing in of secondary treatment started in 1997. Secondary treatment increases the removal of solids and toxic pollutants.

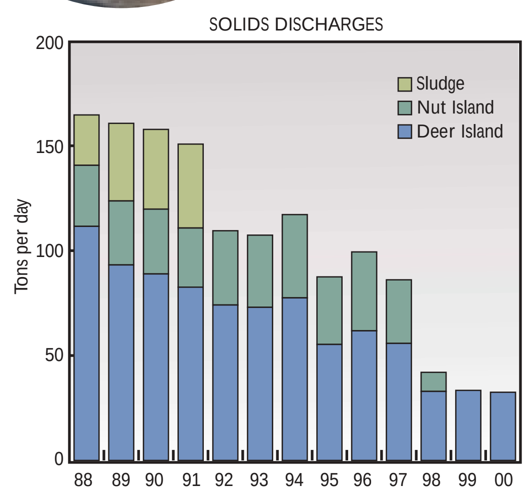


FIGURE I-3. SOLIDS IN MWRA DISCHARGES (1988-2000) have fallen steadily since the beginning of the Boston Harbor Project. Sludge discharges to the harbor ended in December 1991, and secondary treatment at DITP began in 1997, resulting in an 80% decrease in solids by 2000.

August 1997 Startup of Battery A, the first of three batteries of secondary treatment at DITP.

March 1998 Battery B of secondary treatment started up at DITP.

July 1998 Inter-island tunnel completed. South System flows transferred to DITP from the Nut Island Treatment Plant (NITP), allowing most flow to receive secondary treatment. NITP was later demolished, and replaced by a headworks facility and a park.

September 2000 Start-up of new ocean outfall diffuser; effluent now discharged through a 9.5-mile outfall into Massachusetts Bay.

March 2001 Last battery of secondary treatment placed in operation at DITP.

1997 The beginning of secondary treatment marked a dramatic decrease in BOD and continuing declines of bacteria, solids, N, and P.

1998 End of effluent discharges from NITP to the southern harbor. Continued declines in TSS, BOD, N, P, and bacteria.

2000 End of effluent discharges to Boston Harbor; effluent receives much better dilution in Massachusetts Bay.

2001 Treatment optimized at DITP. Discharge consistently meets effluent quality standards.

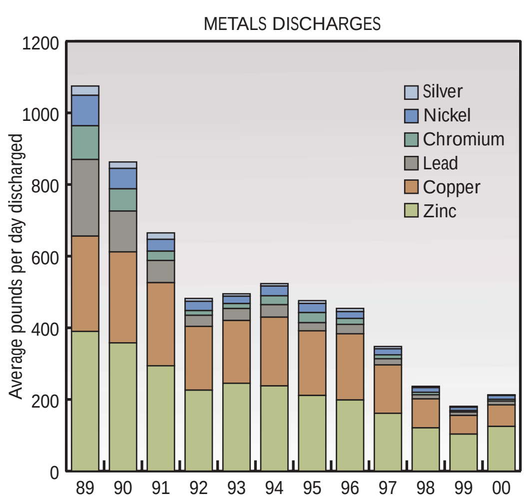


FIGURE I-4. METALS IN MWRA DISCHARGES (1989-2000) have dropped dramatically, largely because of effective industry source reduction programs, an outreach program aimed at residential customers, and the effects of secondary treatment. Now, most remaining metals are from household sources.

Discharges of solids, toxic chemicals, and bacteria decreased as MWRA improved sewage treatment.

The major milestones of the Boston Harbor Project and the resulting effects on wastewater discharges are shown on the timeline above. Increased pumping, the end of scum and sludge discharges, upgraded disinfection, and better primary and secondary treatment resulted in a cleaner harbor by the year 2000. (For further explanation of how the treatment plant operates, see the 1995 State of Boston Harbor report or visit our web site at www.mwra.com/sewer/html/sewditp.htm).

One of the earliest improvements at the old Deer Island plant was the repair of the disinfection system. Once repairs were completed, the number of days per year that the discharge had high bacteria counts dropped from 130 days in 1988 to 4 days by 2000. By comparison, other results due to better primary and secondary treatment have been relatively gradual: Figure I-2 shows how the proportion of sewage undergoing secondary treatment, which removes at least 85% of solids (primary treatment removes about half), increased after 1997. Therefore, significant drops in solids discharges (Figure I-3) correspond to both the end of sludge discharges to the harbor in 1991 and the beginning of secondary treatment.

Effluent toxic metals decreased early on in the Boston Harbor Project (Figure I-4), largely because of MWRA's increased enforcement of industrial requirements to pre-treat wastewater, preventing metals and other toxic pollutants from entering the sewage system. Since metals attach to solids, increased solids removal further decreased effluent metals.

Multiple ports on diffuser heads help dilute the effluent discharged into Massachusetts Bay.

Mapping the Harbor's Recovery

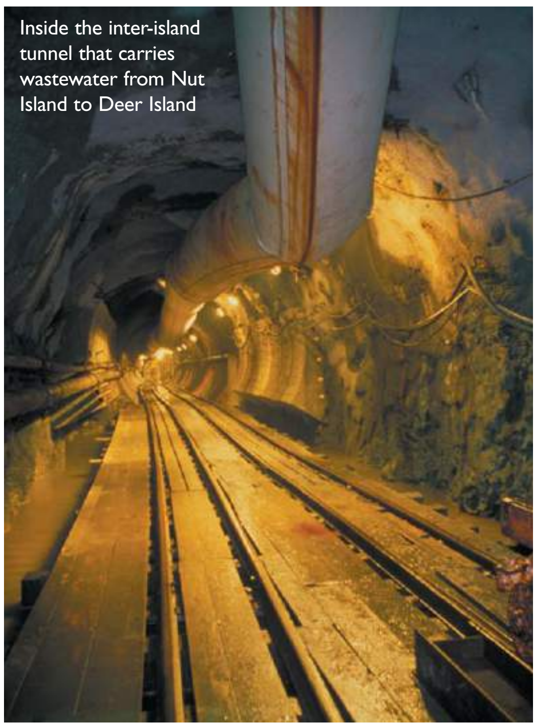
THE STATE OF BOSTON HARBOR BEFORE THE BAY OUTFALL STARTED UP IN SEPTEMBER 2000

In this section, we report on the health of Boston Harbor's marine environment over the past decade as the Boston Harbor Project progressed. Monitoring data help answer the questions of greatest public concern: Is it safe to swim and to eat shellfish? Is the ecosystem healthy, and are aesthetics protected? Changes in bacteria, water clarity, nutrients, dissolved oxygen, toxic contaminants, and other indicators provide a picture of how the harbor is recovering.

To compare "before" and "after" conditions, we chose July 1998 as a turning point, the date the Nut Island Treatment Plant (NITP) was decommissioned and its flow re-routed to the Deer Island Treatment Plant (DITP) for secondary treatment. After July 1998, most of the wastewater discharged to the harbor received secondary treatment, except during the highest flow periods caused by rainstorms. This point also marks when MWRA discharges to the southern harbor ended (Figure II-1).

By September 2000, virtually all the major milestones of the Boston Harbor Project were complete, except for the new Massachusetts Bay outfall and one remaining battery of secondary treatment. For many data analyses in this section, "before" is the period up to July 1998, and "after" is the period July 1998-September 2000, representing the near-completion of the Boston Harbor Project.

Part II is organized into three sections, focusing on the harbor's water, sediments, and fish and shellfish. The health of each of these ecosystem "compartments" is closely intertwined with the others through the physical movement of water and sediments, and biological interactions.



Inside the inter-island tunnel that carries wastewater from Nut Island to Deer Island

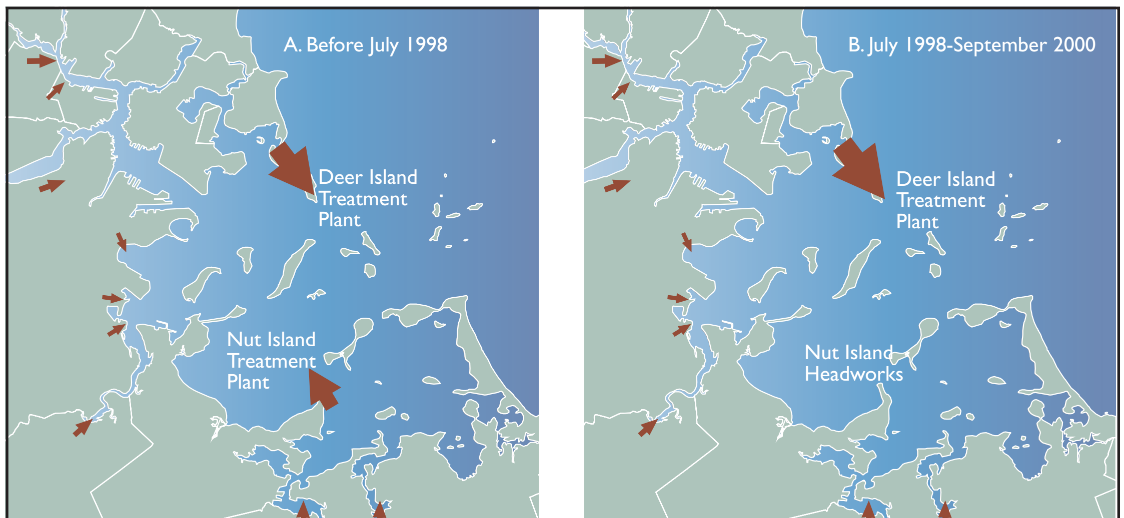


FIGURE II-1. CHANGE IN LOCATIONS OF HARBOR CONTAMINATION SOURCES. A: BEFORE JULY 1998. The major wastewater sources in Boston Harbor were the Deer and Nut Island Treatment Plants (big arrows). Rivers, CSOs, and runoff (indicated by small arrows) contributed significant but smaller amounts of contaminants. B: JULY 1998-SEPTEMBER 2000. NITP closed in July 1998 and all flows were transferred to the new DITP, which became the harbor's main point source of treated wastewater. Average discharges from Deer Island increased from 250 to 350 million gallons per day. Rivers, CSOs, and runoff remained.

water quality

PHYSICAL OCEANOGRAPHY OF THE HARBOR

TIDAL CURRENTS CAN MOVE POLLUTION FAR FROM ITS SOURCES

The harbor's patterns of pollution depend on the movement of water within the harbor–its physical oceanography. The harbor is relatively shallow with an average depth of about 15 feet, and is well flushed by strong tides. The average residence time of water in Boston Harbor is short; Massachusetts Bay and river waters replace all the harbor water in five to seven days. When MWRA effluent was discharged into the harbor, traces were detected six miles out in the bay.

Computer modeling by the United States Geological Survey (USGS) shows that the deep channels at the mouth of the harbor are most rapidly flushed, while the Inner Harbor and shoreline areas are flushed more slowly (Figure II-2). As solids and attached pollutants can accumulate in calmer areas, Boston Harbor shoreline embayments and the Inner Harbor tend to be most affected by pollution.

Early on, engineers did well to site the old DITP and NITP outfalls near deep shipping channels at the mouth of the harbor where strong tidal currents would dilute and flush waste out to the bay, lessening the impact. Figure II-3 shows what happened to wastewater discharged from DITP and NITP through the former harbor outfalls. DITP discharges were flushed offshore and diluted relatively rapidly, but a significant portion of the discharge flowed toward the Inner Harbor on the incoming tide. NITP discharges were rapidly carried out Nantasket Roads, but a portion of the discharge, more poorly diluted, entered Hingham Bay.

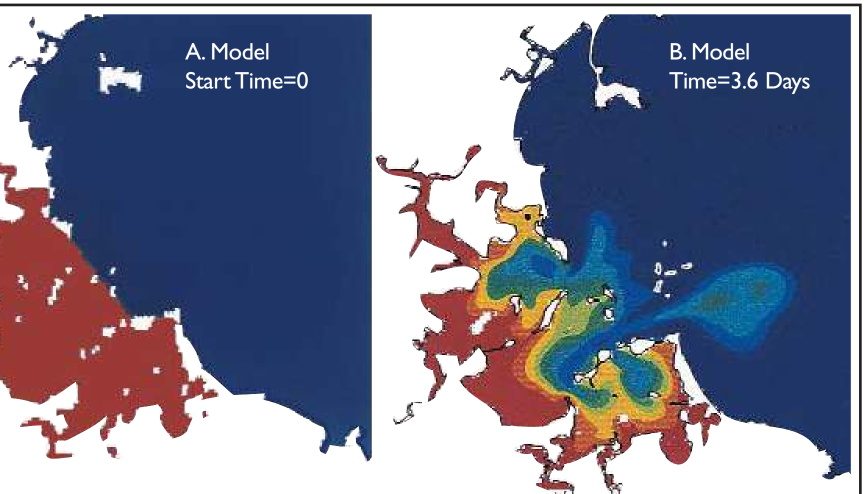


FIGURE II-2. MODEL OF TIDAL MIXING IN BOSTON HARBOR. R. Signell of the U.S. Geological Survey used a computer model to investigate tidal flushing of Boston Harbor. A: SHOWS THE HARBOR AT MODEL START TIME. Boston Harbor water is indicated in red, Massachusetts Bay water in blue. B: THE EFFECT OF TIDAL FLUSHING AFTER 3.6 DAYS, OR 7 TIDAL CYCLES. Most of the water in the harbor has mixed with bay water. However, the inner harbor and the shoreline remain relatively unmixed. The shoreline takes longer to flush than the deep channels at the harbor's mouth. For a movie of this mixing process, go to the web at http://woodshole.er.usgs.gov/operations/modeling/movies/fli/boston.html.

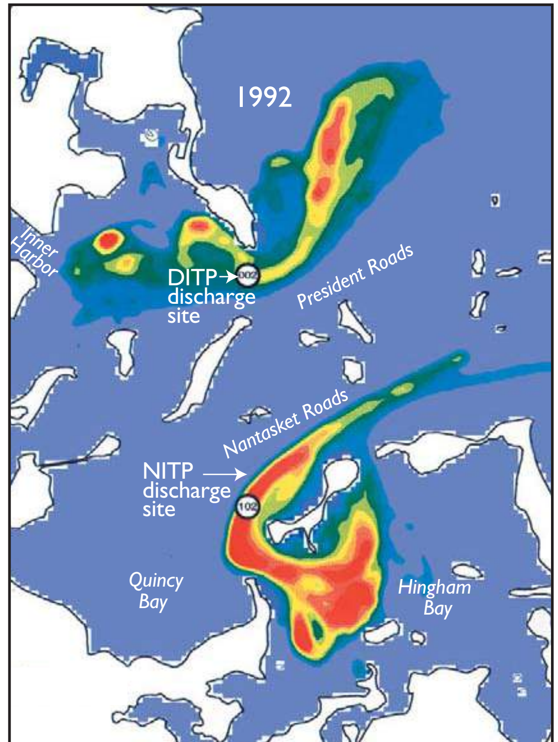


FIGURE II-3. MODELED DILUTION PATTERNS OF TREATMENT PLANT DISCHARGES INTO BOSTON HARBOR. In this computer model, yellow and red areas represent less dilution, green and blue are more diluted. Wastewater from DITP was swept northeast, with some of the discharge returning on the incoming tide. In the southern harbor, wastewater from NITP was not as well diluted as from DITP (Signell, 1992 USGS).


Enterococcus faecium magnified 2, 345 times

BACTERIAL POLLUTION IN THE HARBOR

INDICATOR BACTERIA SHOW DECREASE IN PUBLIC HEALTH RISK

Untreated or poorly treated sewage can carry disease-causing microorganisms (pathogens): bacteria, viruses, and parasites. These pathogens can threaten public health if sewage contaminates swimming areas or shellfish. Indicator bacteria like *Enterococcus* and fecal coliform are found in sewage. If high numbers of these indicator bacteria are present in the water, there is a risk of disease. Historically, poorly treated wastewater and discharges of sewage solids, or sludge, were significant sources of bacteria to the harbor, documented as far back as the 1930s (Figure II-4).

Figure II-5 compares the patterns of *Enterococcus* in the harbor, averaged over time. *Enterococcus* is the measure of recreational marine water quality recommended by the U.S. Environmental Protection Agency (EPA). From 1987 to 1998, bacteria counts were high around Deer Island, Nut Island, and the sludge outfalls; they were also high in the Inner Harbor, along the shoreline, and in the rivers. From July 1998 to August 2000, (when all wastewater was receiving secondary treatment and updated disinfection at Deer Island and being discharged to the harbor), bacterial water quality improved so much that most of the harbor met EPA's most stringent swimming criteria.

Sources of bacterial pollution to the harbor are now local: stormwater, CSOs, boats, animals, and birds all potentially contribute to the problem. These local sources of pollution primarily affect the harbor's shoreline and beaches, the least well-flushed areas of the harbor. "Hot spots" of bacteria persist at the mouth of the Neponset River and southern Dorchester Bay; in the Inner Harbor, especially Fort Point Channel; the mouth of the Mystic River, and along Wollaston Beach. Beach water quality is discussed in more detail on pages 10 and 11.

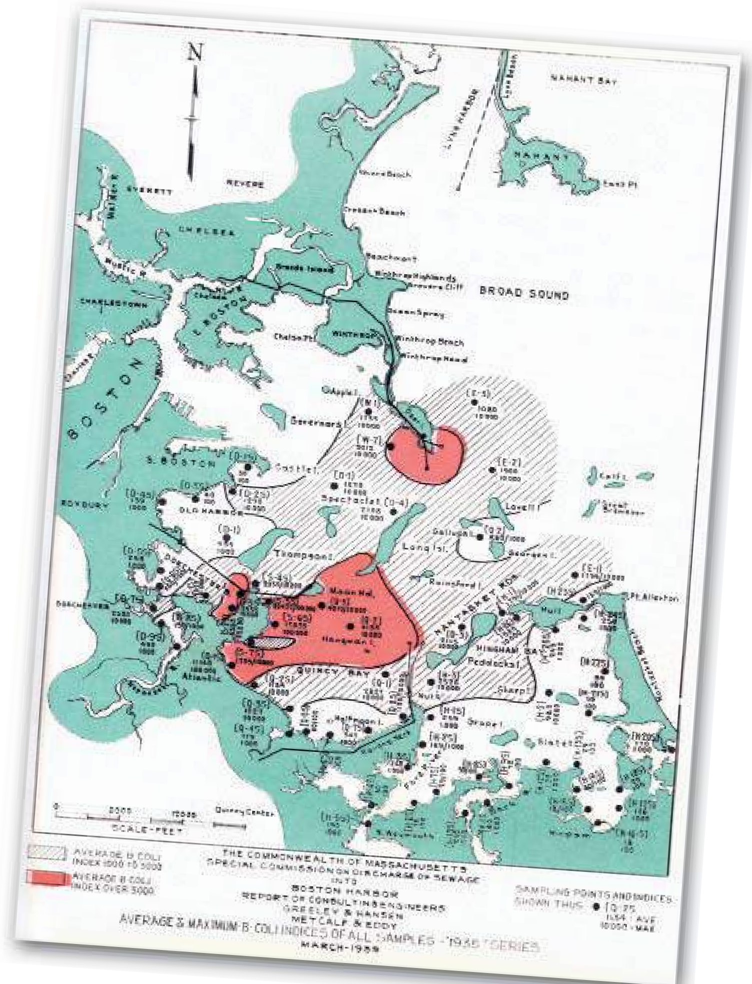


FIGURE II-4. A 1939 REPORT ON COLIFORM BACTERIA shows levels in excess of 1,000 colonies per 100 ml over large portions of the harbor. Areas over 3,000 colonies per 100 ml were recorded around Deer Island, Moon Island, and parts of Quincy Bay, caused by the discharges of untreated sewage in these areas (Commonwealth of Massachusetts, 1939).

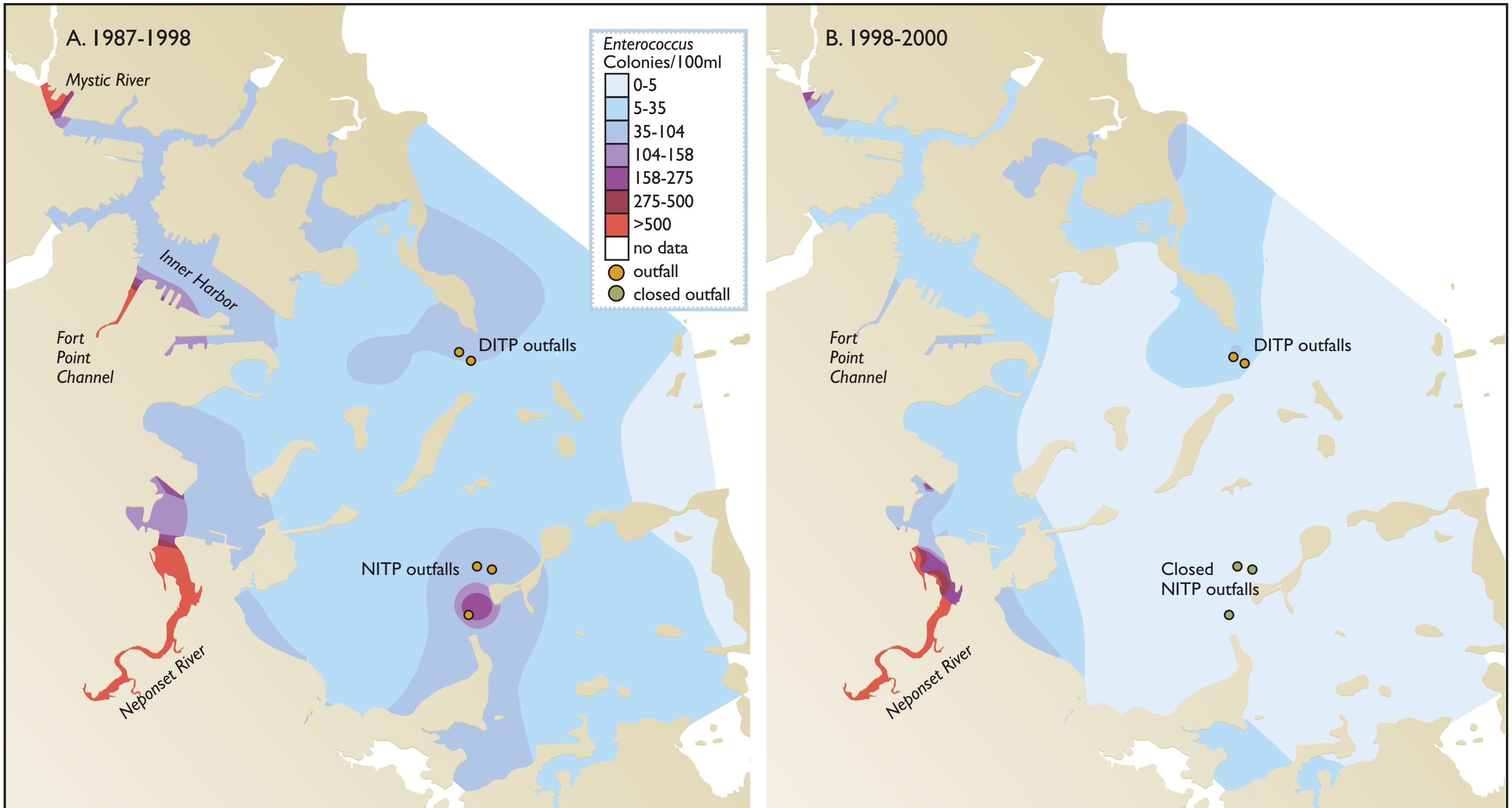


FIGURE II-5. *ENTEROCOCCUS* BACTERIA IN BOSTON HARBOR. *Enterococcus* is the indicator recommended by EPA for monitoring the quality of marine recreational waters. The maps show contours generated from average *Enterococcus* counts collected during MWRA's harbor surveys (since 1989) and from MDC's beach monitoring (since 1987). The contours are drawn at the detection limit (5 colonies/100 ml), and at the EPA guidelines for a designated bathing beach (35 colonies/100 ml), moderate use (158 colonies/100 ml), light use (276 colonies per 100 ml) and infrequent recreational use (500 colonies/100ml).

A: 1987-1998. Data averaged from 1987-1998 show that Boston Harbor as a whole was generally within swimming standards. The contour plots show a pattern of elevated bacteria levels around the treatment plant outfalls. Most of these high counts were in the early part of this period. Bacteria were elevated at the shoreline, in embayments, and the Inner Harbor. The highest bacteria levels were in the rivers and in Fort Point Channel.

B: 1998-2000. Data averaged from July1998-August 2000 show the cumulative impact of the Boston Harbor Project and early CSO control projects, even before the new ocean outfall came on-line in 2000. The addition of south system flows to DITP discharges was accomplished without increasing bacterial contamination around DITP outfalls. Now, almost all the outer harbor is at or below the detection limit or within the swimming standard. However, problems still remain along the shoreline, especially in the rivers.

The L-Street Brownies swim in the harbor even in winter

BEACHES

HARBOR BEACHES ARE SWIMMABLE MOST OF THE TIME. WATER QUALITY VARIATIONS REFLECT A COMPLEX URBAN COASTLINE.

Beaches in Boston Harbor are generally swimmable. Table II-1 shows that bacteria counts typically are well within standards. However, swimming advisories are still posted at harbor beaches each summer, with some beaches posted more frequently than others. There are two parts of the swimming standard: the water should have an average (geometric mean) *Enterococcus* count of less than 35 colonies/100 ml, and there should be no more than 104 *Enterococcus* colonies/100ml in a single sample.

High bacteria counts, when they do occur, may result from a variety of different sources, which can include CSO discharges, storm drain and street runoff, illegal boat discharges, and even bird waste.

TABLE II-1. *ENTEROCOCCUS* BACTERIA AT HARBOR BEACHES, 1996-2001.

Beach	Geometric mean *Enterococcus* count (col/100ml)	% of samples meeting 104 col/100ml
Pleasure Bay	4	95%
Carson	5	94%
Constitution	6	92%
Short	9	92%
Winthrop	9	96%
Tenean	11	86%
Malibu	12	96%
Wollaston	13	87%

The causes of variations in water quality are not obvious. For example, Carson Beach in South Boston is the second cleanest beach in the harbor, but has seven CSO outfalls and storm drains. On the other hand, Wollaston Beach in Quincy—one of the most contaminated beaches in the harbor—has no CSO or other sewage discharges but has eight storm drains which discharge along its shoreline.

At beaches affected by CSO discharges and storm drains, rainfall has a major impact on beach water quality. Heavy rains are often followed by high bacteria counts. However, high counts during dry weather also occur at all beaches. In fact, most elevated bacteria counts occur in dry weather or light rain, as is shown in Table II-2 (facing page). The proportion of high counts to low counts in dry weather, though, remains low overall. The sources of dry weather contamination are not completely understood, but likely include animal waste and cross-connections of sewer pipes into storm drains.

Figure II-6 shows the percent of bacterial samples failing to meet the swimming standard for *Enterococcus* for each swimming season since 1987. Water quality is generally good, but there is no clear trend, with year to year variations at each beach. The effect of rainfall is complicated. Tenean Beach, for example, shows an increased frequency of high counts during rainy summers, but Wollaston does not.

While posting frequencies remain variable, efforts by MWRA and communities have significantly reduced the volume of untreated CSO discharges to the harbor since the late 1980s. Implementation of MWRA's CSO Control Plan closed its CSO treatment facility near Constitution Beach, eliminated CSO discharges to the Neponset River, and will eliminate the remaining CSOs in South Dorchester Bay (near Tenean and Malibu Beach). With community input, MWRA is developing the CSO plan for North Dorchester Bay (Carson Beach) to determine how best to control CSOs and protect beaches there.

Treatment plant discharges and much of the combined sewage in the harbor have been eliminated, revealing the importance of other sources of coastline contamination. Identifying and eliminating cross-connections, controlling CSO, and maintaining local storm and sewer systems will be essential to realizing the full benefits of the Boston Harbor project.

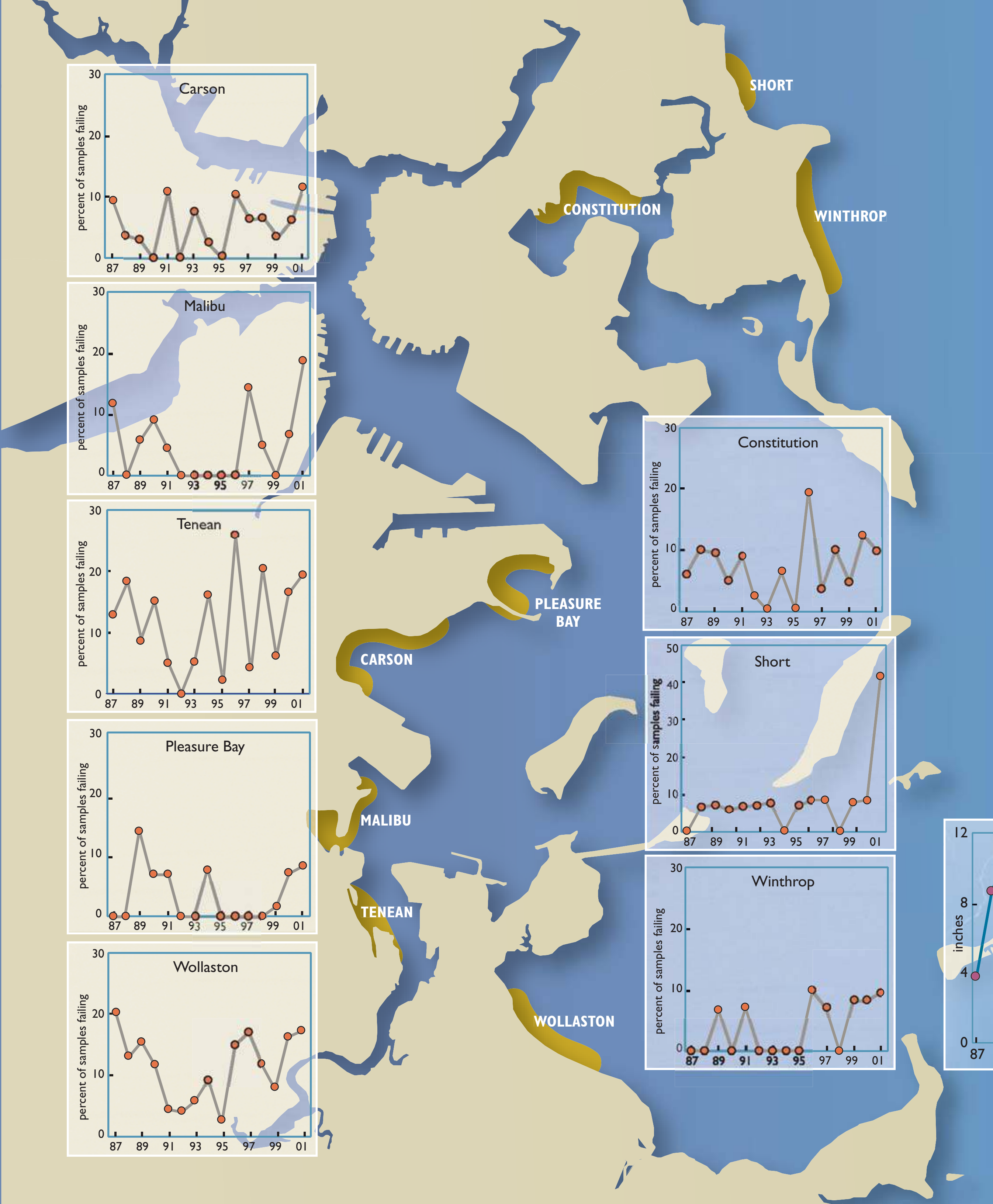
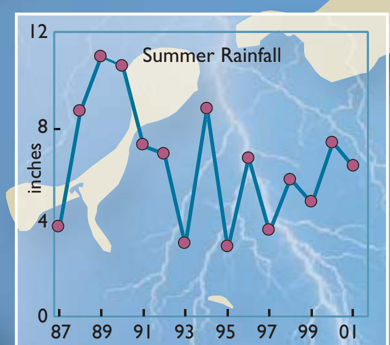


TABLE II-2. ASSOCIATION BETWEEN BACTERIA COUNTS AND RAINFALL AT HARBOR BEACHES. *Enterococcus* samples were collected at Carson, Constitution, Tenean, and Wollaston beaches as part of summer daily monitoring between 1996 and 2000. "Failing" is when a sample is above the single sample limit of 104 colonies/100 ml. CSOs generally do not activate unless rainfall exceeds 0.5 inches in 24 hours.

	Dry Weather no rain for previous 48 hours	Damp Weather less than 0.2 inches in previous 24 hours	Wet Weather more than 0.2 inches in previous 24 hours	Total
# of samples meeting standards	1,829	1,616	386	3,821
# of samples failing standards	99	161	191	451
Total	1,928	1,777	577	4,282
% failing	5%	9%	33%	11%

FIGURE II-6. ANNUAL PATTERN OF HIGH BACTERIA COUNTS AT BOSTON HARBOR BEACHES, 1987-2001. The percent of samples failing to meet the *Enterococcus* limit of 104 colonies per 100 ml ranges from none to about 25%. Over the past 13 years there has been no clear trend over time, even as the Boston Harbor Project remediated high bacteria counts near sewage and sludge outfalls. Shoreline sources are the dominant cause of contamination at beaches.



WATER CLARITY

WATER CLARITY INCREASED IN SOME PARTS OF THE HARBOR

Water clarity is one of the factors that determine whether people swim in a body of water like Boston Harbor. It also determines how much light reaches the plants in the water. These plants, which include algae and seagrasses, are important to the ecology of the harbor.

Measurements of clarity in the harbor (and anecdotal observations by the public) indicate that water clarity has improved since 1993. One of the measurements that has shown this improvement is Secchi depth. This is the depth at which a white disk, a Secchi disk, lowered into the water is no longer visible.

Water clarity shows a west-to-east increasing gradient across the harbor. This can be seen in Figure II-7. Water is more turbid toward the rivers and shallow margins of the harbor, and clearer (deeper Secchi depths) toward the mouth of the harbor and bay. Water in Dorchester Bay is naturally turbid, because it is a shallow depositional area for sediments carried down by the Neponset River. Figure II-7 compares water clarity across the harbor during the periods 1993-1998 and 1998-2000. Water clarity improved off NITP and in Nantasket Roads after 1998.

A Secchi disk is used to measure water clarity in Boston Harbor.

NADINE SMOSKE

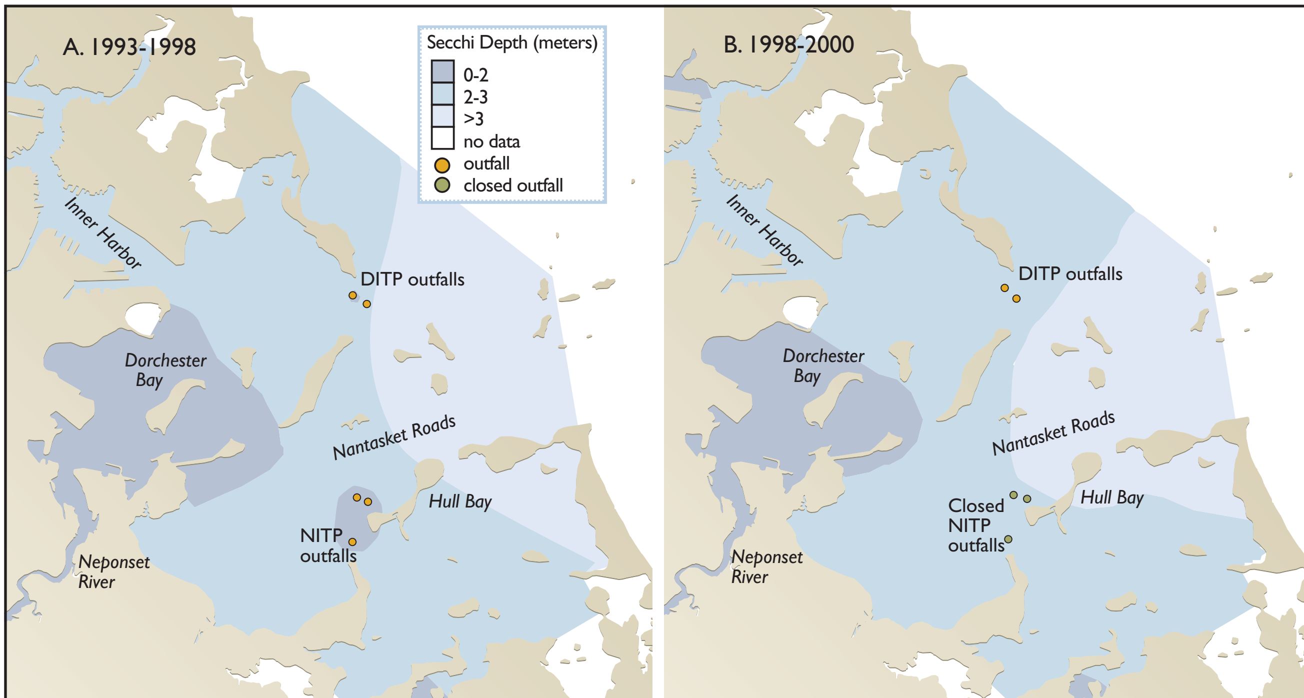


FIGURE II-7. WATER CLARITY IN BOSTON HARBOR. Water clarity showed noticeable improvements after South System flows were transferred to DITP for secondary treatment in July 1998.
A: BEFORE. Up to July 1998, Secchi depths were generally >2 meters (6.6 feet) over most of the harbor, but were noticeably shallower around the Nut Island outfalls and in Dorchester Bay.
B: AFTER the closing of NITP in July 1998, Secchi depths increased by more than a meter near the old NITP outfalls. In other parts of the South Harbor, the increase in clarity was smaller, ranging from 0.2 to 0.6 meters (8 inches-2 feet). Water clarity off DITP showed no decrease, despite the added flows from the South System; secondary treatment increased solids removal, compensating for the increased flows.

NUTRIENTS

NUTRIENT CONCENTRATIONS HAVE DECREASED

Nutrients such as nitrogen and phosphorus are familiar as the active ingredients in lawn and agricultural fertilizers. In marine environments such as Boston Harbor, excessive amounts of nutrients—especially nitrogen—can stimulate the overgrowth of phytoplankton and seaweed. Ammonium is the form of nitrogen that most stimulates this overgrowth.

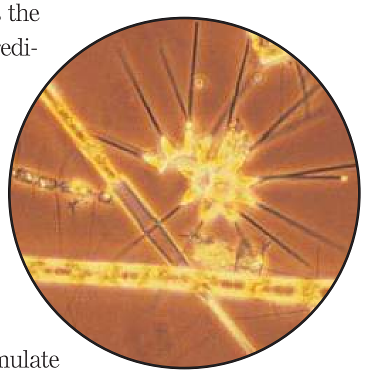
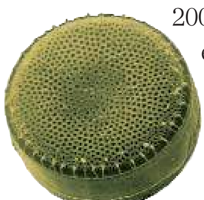


Figure II-8 shows the changes in ammonium concentrations at the former Deer Island and Nut Island outfalls. Note the very large decrease in ammonium at the NITP outfall site after discharges from NITP ended (II-8B). Now, ammonium at this site shows a typical, low seasonal cycle seen in healthy estuaries.

Ammonium increased at the DITP outfalls after the south system flows were added to the discharge; this was expected. The increase was not as great as the decrease at Nut Island because of the greater dilution of wastewater near Deer Island. After the Massachusetts Bay outfall went on-line in September 2000, ammonium in both the northern and the southern harbor dropped to a more pristine level.



Excess nutrients can cause the overgrowth of algae like this microscopic diatom.

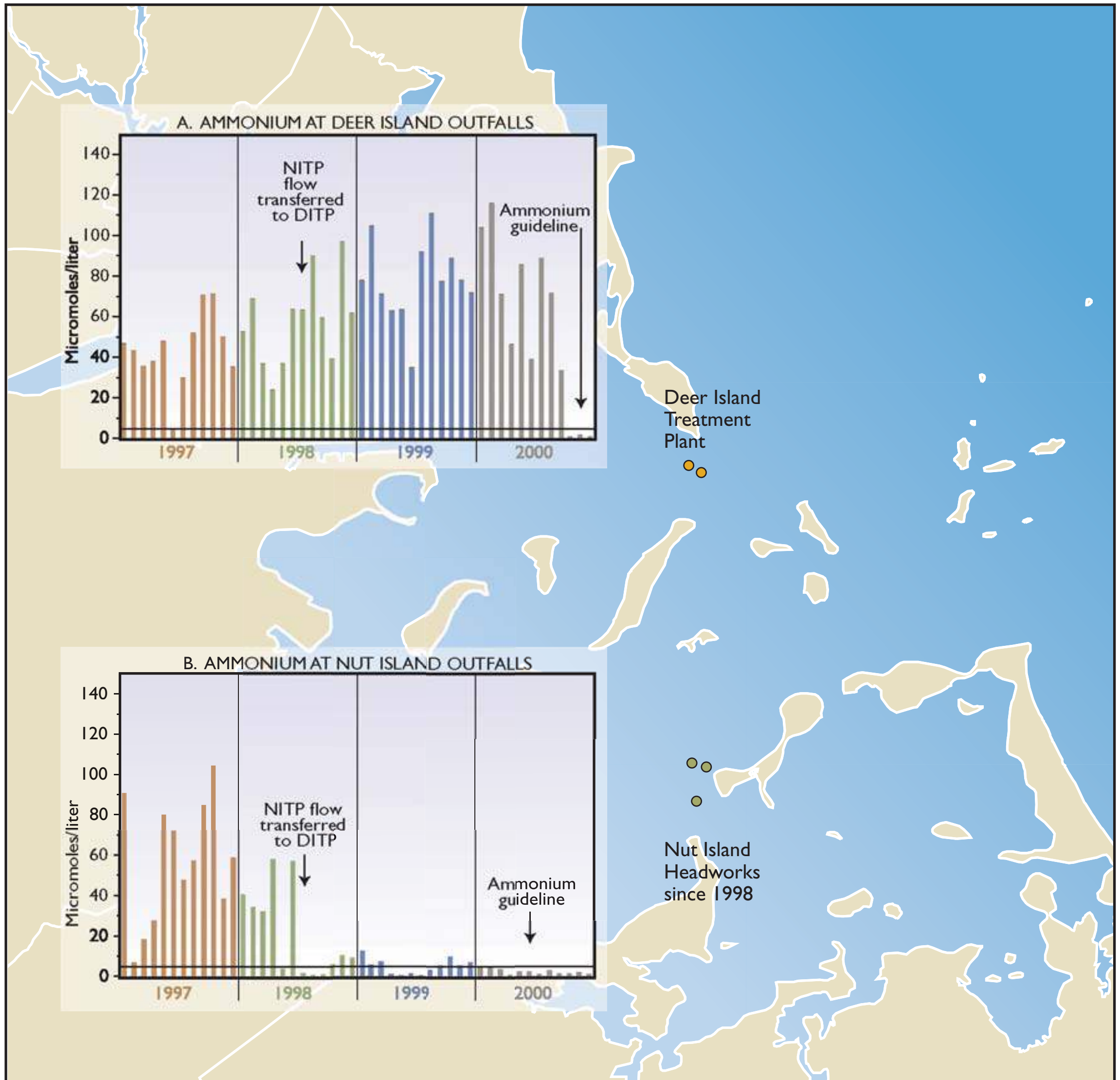


FIGURE II-8. AMMONIUM LEVELS AT THE PREVIOUS HARBOR OUTFALL SITES, 1997-2000.

A: DEER ISLAND OUTFALL SITE. Before July 1998, measurements around the two outfalls sometimes reached very high levels, up to 100 micromoles per liter. Healthy ammonium values in estuaries are typically less than 5 micromoles per liter. After July 1998, ammonium levels around Deer Island increased.

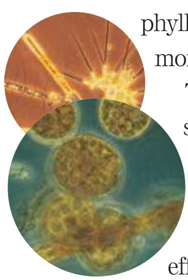
B: NUT ISLAND OUTFALL SITE. Ammonium levels around Nut Island dropped to nearly zero after MWRA diverted flows to DITP. Ammonium levels also decreased elsewhere in the southern harbor. There was a dramatic drop at the DITP outfalls in late 2000 after the new outfall came into use (discussed further in part IV of this report).

TRACY VILLAREAL

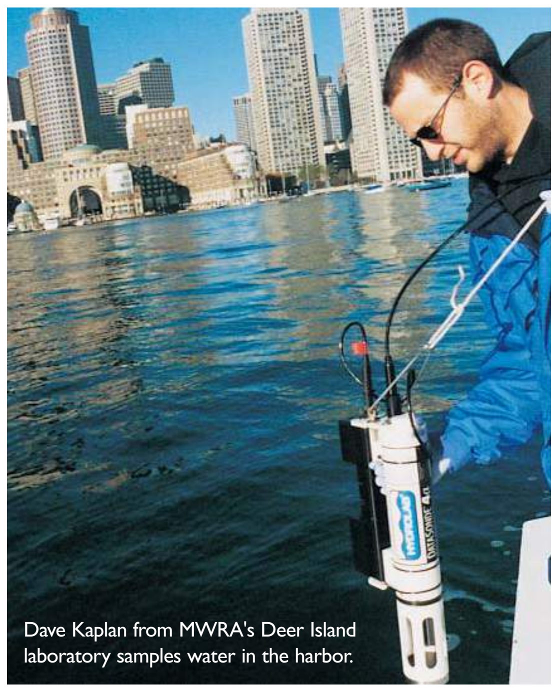
CHLOROPHYLL & ALGAE

ALGAE HAVE DECREASED TO MORE NATURAL LEVELS

As expected, one of the changes we found was a decrease in the amount of microscopic algae (phytoplankton) in the water. Figure II-9 compares concentrations of chlorophyll across the harbor before and after NITP flows were transfered to DITP for secondary treatment. Chlorophyll, a photosynthetic pigment in algae cells, is used to measure quantities of algae. The amounts of chlorophyll in the water decrease away from the shoreline toward the bay. After harbor discharges from NITP ended, chlorophyll in the South Harbor decreased to more natural levels.



The North Harbor showed only a small increase in chlorophyll confined to the region near Deer Island. Overgrowth of algae was offset by the greater dilution of effluent at this site. The outer North Harbor is the region where we expect to see the largest decreases in algae in the years to come.



Dave Kaplan from MWRA's Deer Island laboratory samples water in the harbor.

NADINE SMOSKE

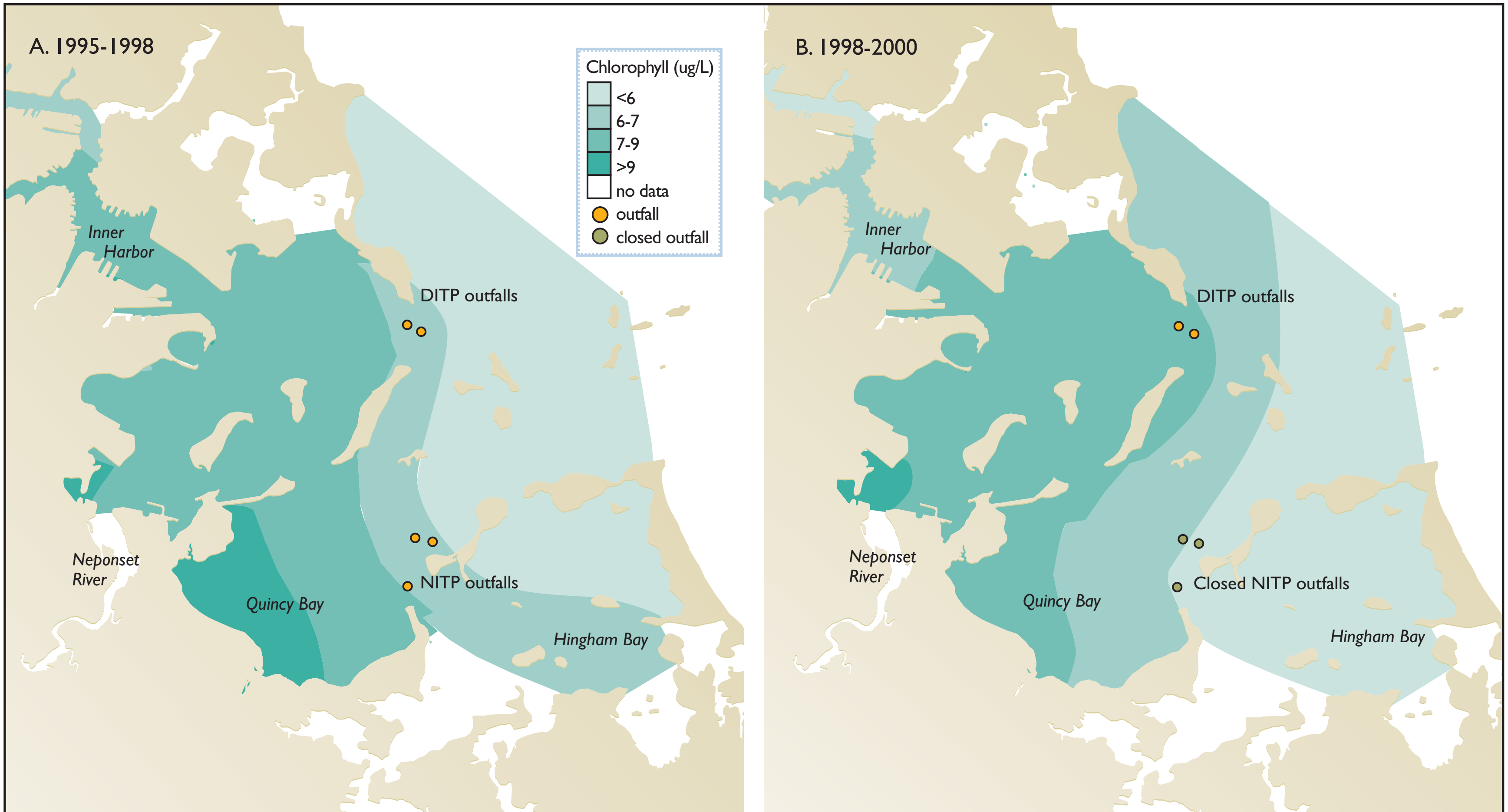
Seagrasses: Can the nurseries of the harbor recover?

A close-up of tiny animals on blades of seagrass.

ROBERT MICHELSON

Dense meadows of seagrass are characteristic of pristine, shallow depositional environments in New England. A century ago, seagrass meadows covered hundreds of acres of subtidal flats of Boston Harbor. Important nursery areas for young fish and shellfish, these meadows had all but vanished by the late 1980s, victims of turbid water, viral diseases, and excessive nutrients which promote the growth of algae on seagrass leaves.

Boston Harbor now supports only small areas of seagrasses in Hingham Bay and in the North Harbor near Logan Airport. Until recently, nutrient concentrations in the harbor have been very high, and the water in most areas has not been clear enough for seagrasses. With the reduction in nutrients in the water and the increase in clarity, especially in the South Harbor, we might expect to see recolonization of the harbor floor by these important habitats in the years to come.




JOSEPH INGOLDSBY
Mouth of the Neponset River

FIGURE II-9: SUMMER CHLOROPHYLL IN BOSTON HARBOR. Changes in the amounts of algae in the harbor have been seen since 1995.

A: AUGUST 1995-JULY 8,1998. While both DITP and NITP were discharging, chlorophyll had a west-to-east decreasing gradient, with the highest levels in Quincy Bay and at the mouth of the Neponset River.

B: JULY 9, 1998-AUGUST 2000. With the transfer of South System flows to DITP, the shape of chlorophyll contours shifted subtly, with lower chlorophyll levels in the southern harbor and a small, localized increase in chlorophyll at the outer North Harbor.

Smelt schooling in the harbor's Fore River. These fish require high oxygen levels in spawning areas.

ROBERT MICHELSON

Massachusetts water quality standards for dissolved oxygen in marine waters are 5 milligrams per liter (mg/l) for class SB, and 6 mg/l for class SA, the same as for fresh water. EPA's new recommended marine dissolved oxygen standard (at present applicable only from Cape Cod south to Cape Hatteras) is an average of 4.8 milligrams per liter, with a minimum of 2.3 milligrams per liter.

Most of Boston Harbor is Class SB; parts of Dorchester and Quincy bays are SA.

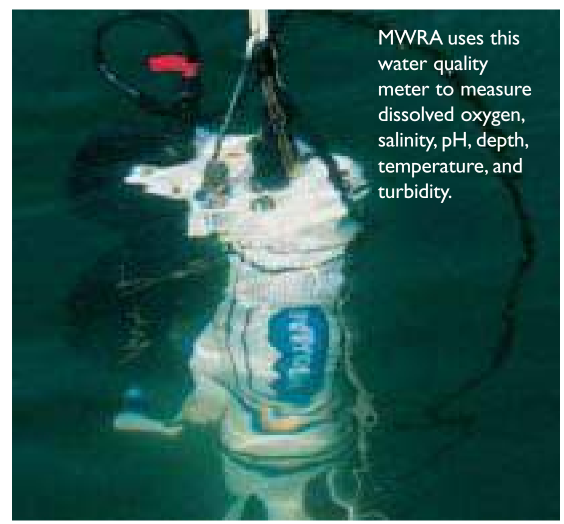
Under water quality standards, marine class SA is designated an excellent habitat for fish and other aquatic life, and class SB is good.

DISSOLVED OXYGEN

DISSOLVED OXYGEN IN THE HARBOR REMAINS AT HEALTHY LEVELS

One of the early perceptions about the effects of pollution in Boston Harbor was that dissolved oxygen (DO) in the water was too low. We now know that, except for a few isolated locations, DO levels in the harbor were high enough to support healthy marine life even before the Boston Harbor Project began. This change in perspective is not only based on more monitoring data, but also on new studies by the EPA showing that DO requirements for marine life are actually lower than previously thought.

DO levels in Boston Harbor have benefited from the harbor being so well-mixed and well-flushed. MWRA's monitoring has revealed little change in DO concentrations in the harbor's waters over the past 10 years. Figure II-10 illustrates Boston Harbor's summer pattern of dissolved oxygen, which is high even at the end of the summer, when DO is typically at its lowest. DO concentrations increase with distance from the shoreline. The lowest levels are in the Inner Harbor and the mouths of rivers. Figure II-11 shows data from a moored instrument in the Inner Harbor, illustrating the daily pattern of DO.



MWRA uses this water quality meter to measure dissolved oxygen, salinity, pH, depth, temperature, and turbidity.

NADINE SMOSKE

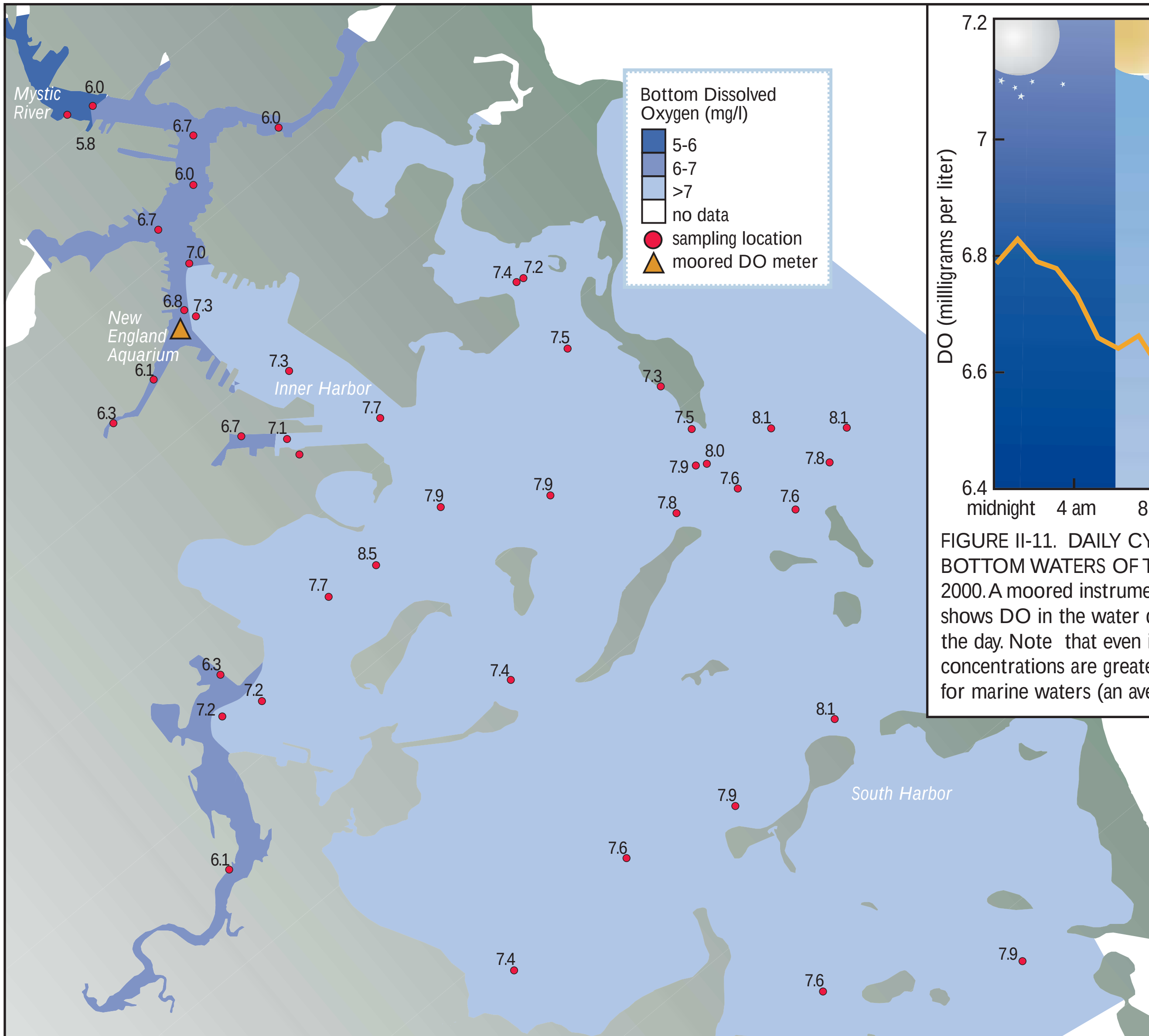


FIGURE II-10: DISSOLVED OXYGEN IN BOSTON HARBOR. This map shows the average pattern of DO in the bottom waters of the harbor during the summer. DO is typically lowest in the summer, and in the bottom water. DO levels in the harbor are healthy, ranging from 4.9 milligrams per liter in the Mystic River/Inner Harbor, to 8.1 mg/l in the South Harbor. DO is lower in the river basins and the Inner Harbor. Note, DO shows a decreasing east-west pattern, reflecting effects of different levels of tidal flushing.

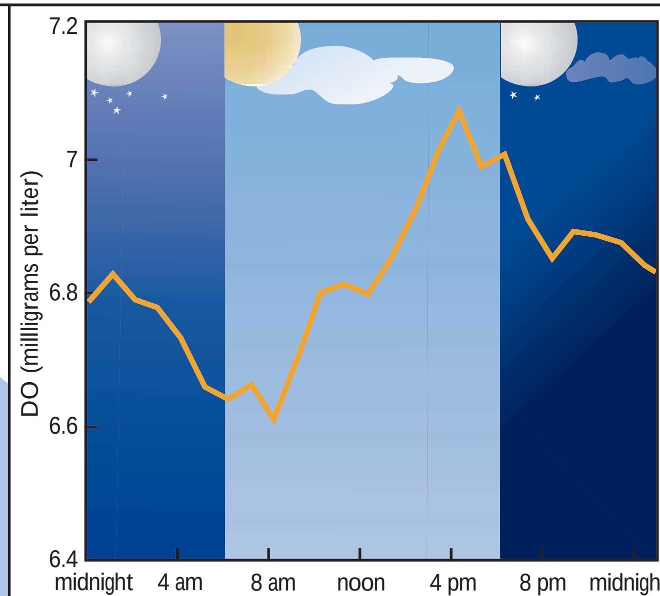


FIGURE II-11. DAILY CYCLE OF DISSOLVED OXYGEN IN THE BOTTOM WATERS OF THE INNER HARBOR in September 2000. A moored instrument near the New England Aquarium shows DO in the water decreases at night, and increases through the day. Note that even in the early morning when DO is lowest, concentrations are greater than EPA's new recommended standard for marine waters (an average of 4.8 mg/l).

Aurelia, a common jellyfish in Boston Harbor.

the floor of the harbor

Since the Boston Harbor Project began, some of the most surprising stories have been about the rapidity of change in the sediments at the bottom of the harbor. For example, U.S. Geological Survey studies found that levels of lead and other heavy metals in the harbor's sediments are about half of what they were 20 years ago. There is less organic matter settling on the harbor floor, and the sediments are more oxygenated, both of which are good for the bottom-dwelling community, or benthos. The benthos is not only increasingly abundant, it is more diverse. These are truly signs of a recovering Boston Harbor.


Tiny worms are important parts of a healthy seafloor community.

DR. JAMES BLAKE

SEDIMENT TYPES IN BOSTON HARBOR

In depositional areas, weak tidal currents or depressions in the seafloor allow solids to settle and become soft sediments. These areas are most affected by pollution because toxic materials and oxygen-consuming organic matter tend to adhere to solid particles and settle with them. Such contaminants are often swept away from erosional areas, which have strong tides and lots of water movement. Intermediate areas are sometimes depositional and sometimes erosional, depending on changing currents and waves. Figure II-12 shows where different sediment types are in Boston Harbor.

The locations of the Deer Island and Nut Island outfalls in erosional areas minimized the local impacts of those discharges on the sediments, because the solids were carried to depositional areas elsewhere in the harbor or further offshore. Depositional sediments in the harbor can collect contaminants from quite distant sources. A University of Massachusetts study conducted in the late 1980s illustrates this phenomenon. The study found that contaminants in a muddy area of Dorchester Bay did not come from a nearby CSO as expected, but from sewage sludge discharged from the Nut Island Treatment Plant—more than 4 miles away.

Sediment type determines where different benthic animals and plants live, and their exposure to contamination. The benthos is particularly vulnerable to contaminants in the sediments because most benthic organisms are immobile or move very little—they cannot escape if environmental conditions deteriorate. In contrast, fish and other mobile animals will actively try to move to a higher quality habitat when conditions get worse—for example, if dissolved oxygen drops to stressful levels.

Soft-bottom benthic communities that live in potentially more contaminated, depositional areas include worms, crustaceans, clams, and other animals, mostly living below the surface of the sediments. Because these communities have the potential for more exposure to pollution, MWRA's benthic monitoring in the harbor focuses on soft sediment habitats and investigates:

1. sediment contamination,
2. sediment metabolism, and
3. the benthic community.

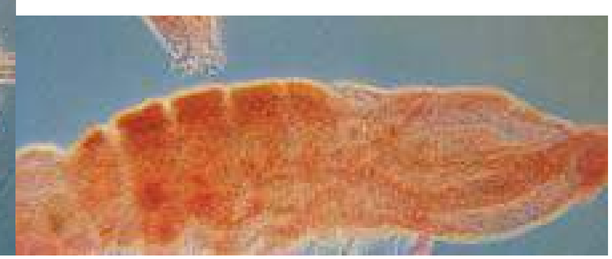
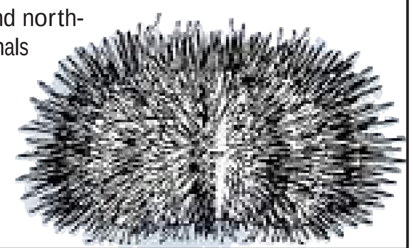


FIGURE II-12. BOSTON HARBOR SEDIMENT TYPES. The types of sediment in Boston Harbor determine the biology of the seafloor ecosystem and also correlate with pollutant impacts. This map categorizes harbor sediments into three types: erosional, depositional, and intermediate. Land contours, currents, and waves create these different sedimentary environments. Erosional areas include much of the harbor's shoreline as well as the Outer Harbor islands. In Boston Harbor, these are typically rocky and support seaweeds and animals like snails, blue mussels, barnacles, and sea urchins. Large areas of the central, southern, and northwestern harbor are depositional. These muddy bottoms are home to animals like worms, clams, and crustaceans. Intermediate environments have some characteristics of erosional and depositional areas, depending on weather. MWRA's monitoring focuses on depositional environments, which can accumulate contaminants attached to particles that settle to the bottom. Note: shoreline sediment types are estimated based on very limited data. (Map after Knebel *et al* 1991.)



Sewage sludge discharges ended in 1991.

Before 1991, the solids and scum removed during sewage treatment were treated in a very different manner from the way they are today. As part of primary treatment, wastewater is channeled into settling tanks, where heavy particles (sludge) sink to the bottom of the tank. Anything that floats, such as plastics, fats, cooking oils, and sticks, is called scum. Before the Boston Harbor Project, the sewage solids and floating material was digested–broken down by bacteria–to reduce its volume and oxygen-demanding organic matter. Then, the digested sludge and scum were simply re-combined with chlorinated effluent and discharged into the harbor on the outgoing tide. The sludge-scum mixture from NITP was digested and then pumped to an outfall about 5 miles away off Long Island (see Figure I-1, page 3). This black, smelly substance, adorned with pieces of trash, represented the worst results of the old treatment plants, and the most memorable ones for boaters. Today, scum is landfilled. Sludge is processed into fertilizer pellets for gardening and landscaping. The days of scum and sludge in the harbor are, fortunately, long-gone.

SEDIMENT CONTAMINATION

HEAVY METALS ARE LOWER IN RECENT YEARS

The United States Geological Survey has been monitoring trends in metals concentrations at four locations in Boston Harbor (Figure II-13). This study showed that, over the last two decades, lead has decreased approximately 50% in harbor sediments (Figure II-14), as have most other heavy metals at the four sites sampled. This is related to a decrease in metals inputs from many sources, including sewage discharges.

FIGURE II-13. USGS METALS SAMPLING LOCATIONS IN BOSTON HARBOR.

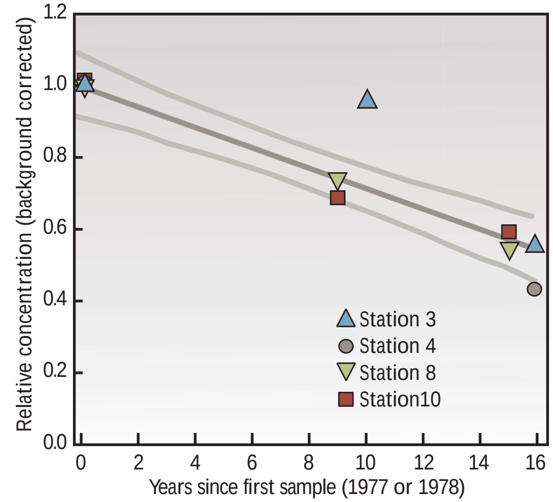


FIGURE II-14. LEAD DECREASES OVER TIME IN BOSTON HARBOR SEDIMENTS. From data collected at four stations throughout Boston Harbor, USGS scientists have shown a distinct downward trend in lead concentrations in surface sediments since the late 1970s. (Bothner *et al.* 1998)

SEDIMENT METABOLISM

SEDIMENT METABOLISM MEASURES THE EFFECT OF ORGANIC MATTER ON THE HARBOR FLOOR

Bacteria and other organisms metabolize organic matter, depleting oxygen. If the sediments use up oxygen too quickly, it can mean that they are polluted by excess organic matter. In the early 1990s, Boston Harbor sediments showed some of the highest rates of oxygen use ever measured in any sediments! In the decade since MWRA stopped discharging sludge, rates of metabolism in the harbor's sediments have dropped to levels that are more typical of a healthy ecosystem (Figure II-15).

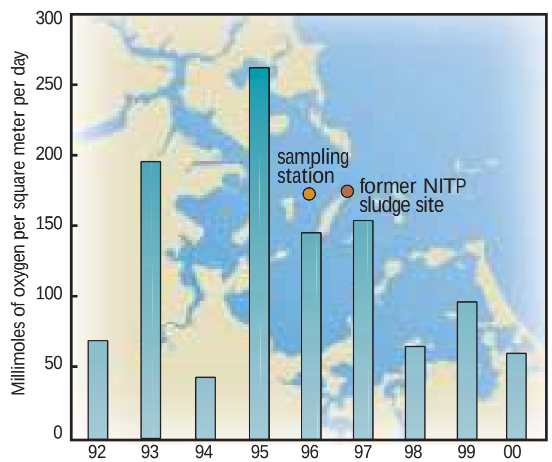


FIGURE II-15. SEDIMENT OXYGEN DEMAND IN BOSTON HARBOR, 1992-2000. The rate at which sediments use up oxygen indicates if they are degraded by too much organic matter. This graph shows the change in sediment oxygen demand from 1992-2000 near the former NITP sewage sludge discharge site near Long Island. Extremely high rates were recorded in 1993, and even higher rates in 1995, as burrowing and feeding activities by benthic animals ventilated the sediments, making more oxygen available to bacteria. Metabolism rates have declined in recent years to normal levels—indicating that the sediments have been "mined out" of organic matter. (Tucker *et al.* 2001)

THE BENTHIC COMMUNITY

AFTER DECADES OF POLLUTION, THE BENTHIC COMMUNITY IS RECOVERING

Some of MWRA's most exciting findings in Boston Harbor have come from two studies of the soft-bottom benthic community—sediment profile imaging (SPI) and benthic sampling—that examine benthic species diversity and abundance. The biggest changes became evident a few years after the end of sludge discharges to the harbor in December 1991.

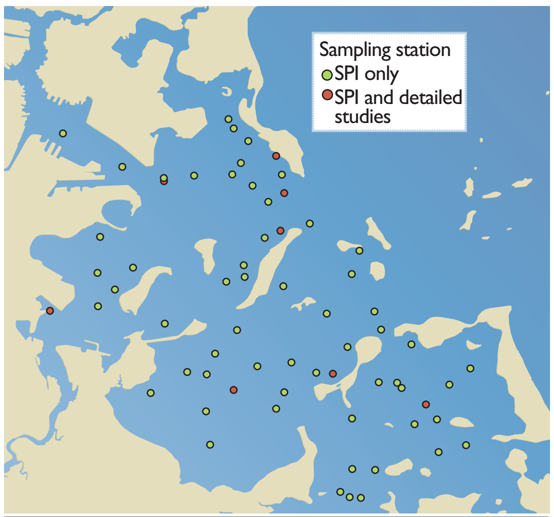
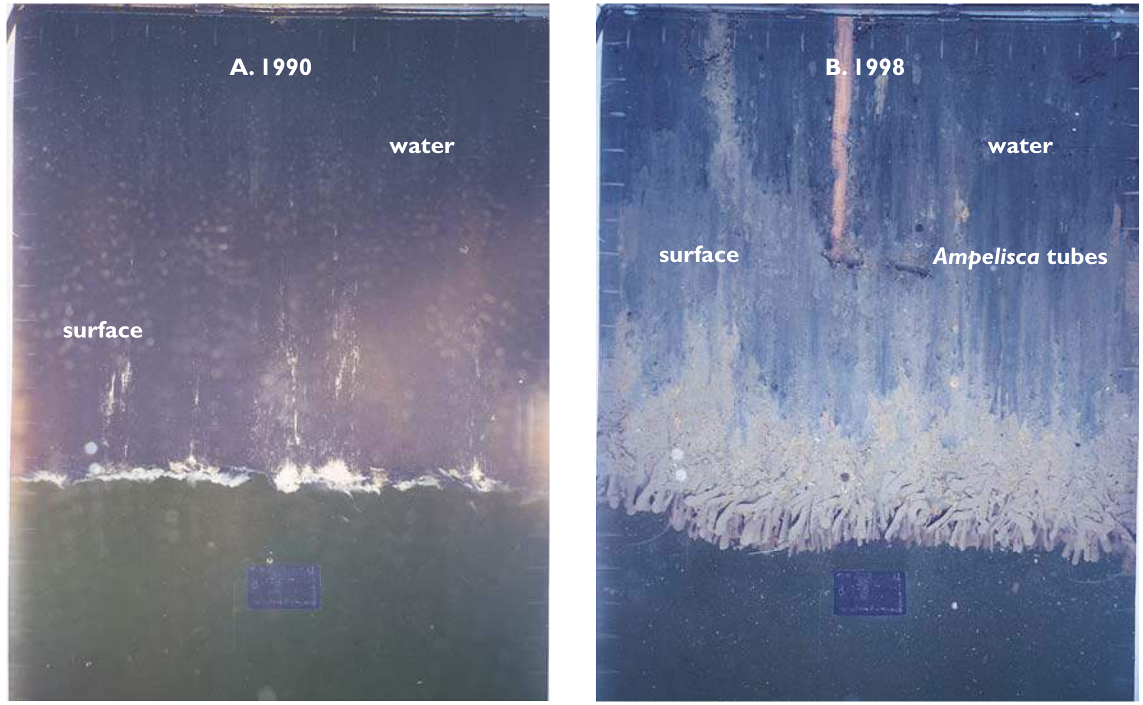


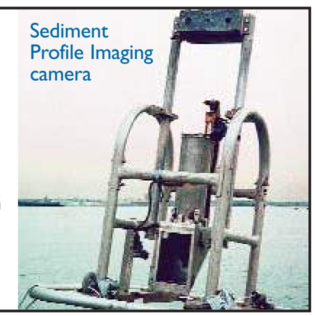
FIGURE II-16. SEDIMENT PROFILE IMAGING SITES AND SAMPLING LOCATIONS for detailed studies of bottom-dwelling animals.

Once each summer, large amounts of data on sediment quality are quickly gathered at more than 50 stations (Figure II-16) in Boston Harbor by photographing a cross-section of the top several inches of the sediment. Sediment profile imaging can measure oxygen penetration, an important measure of benthic health, as "redox potential discontinuity" (RPD) depth. Figure II-17A shows that, at a heavily polluted site, little or no oxygen penetrates into the sediments and few benthic



ROBERT DIAZ

FIGURE II-17. BOSTON HARBOR SEDIMENT PROFILE IMAGES. The depth of oxygen penetration (RPD) is indicated by the thickness of light-colored, oxygenated sediments on top of black, sulfide-rich anoxic sediments. A: UNHEALTHY SEDIMENTS This photograph shows mostly dark sediments—these are oxygen-deprived. The RPD is shallow, and there is no visible life on the surface. In this extreme case, hydrogen sulfide produced by anaerobic bacteria feeds mats of sulfur bacteria that build up on the sediment surface. Underneath is black, anoxic mud. B: RECOVERING SEDIMENTS This photograph shows a recovering site that has developed a deep RPD. Individual *Ampelisca* tubes protrude from the surface. *Ampelisca* pump water into their tubes, thereby aerating the sediments below.



animals survive. At a recovering site (Figure II-17B), there is a thick surface layer of light-colored oxygenated sediment and abundant evidence of animal activity.

Figure II-18 shows average RPD depths in the harbor. In 1989 and 1990 (Figure II-18A), sediment imaging showed minimal oxygen penetration at the sludge discharge sites and other heavily polluted locations. There was little evidence of benthic animal activity at such stations. By 2000, conditions had improved, with deeper oxygen penetration and greater

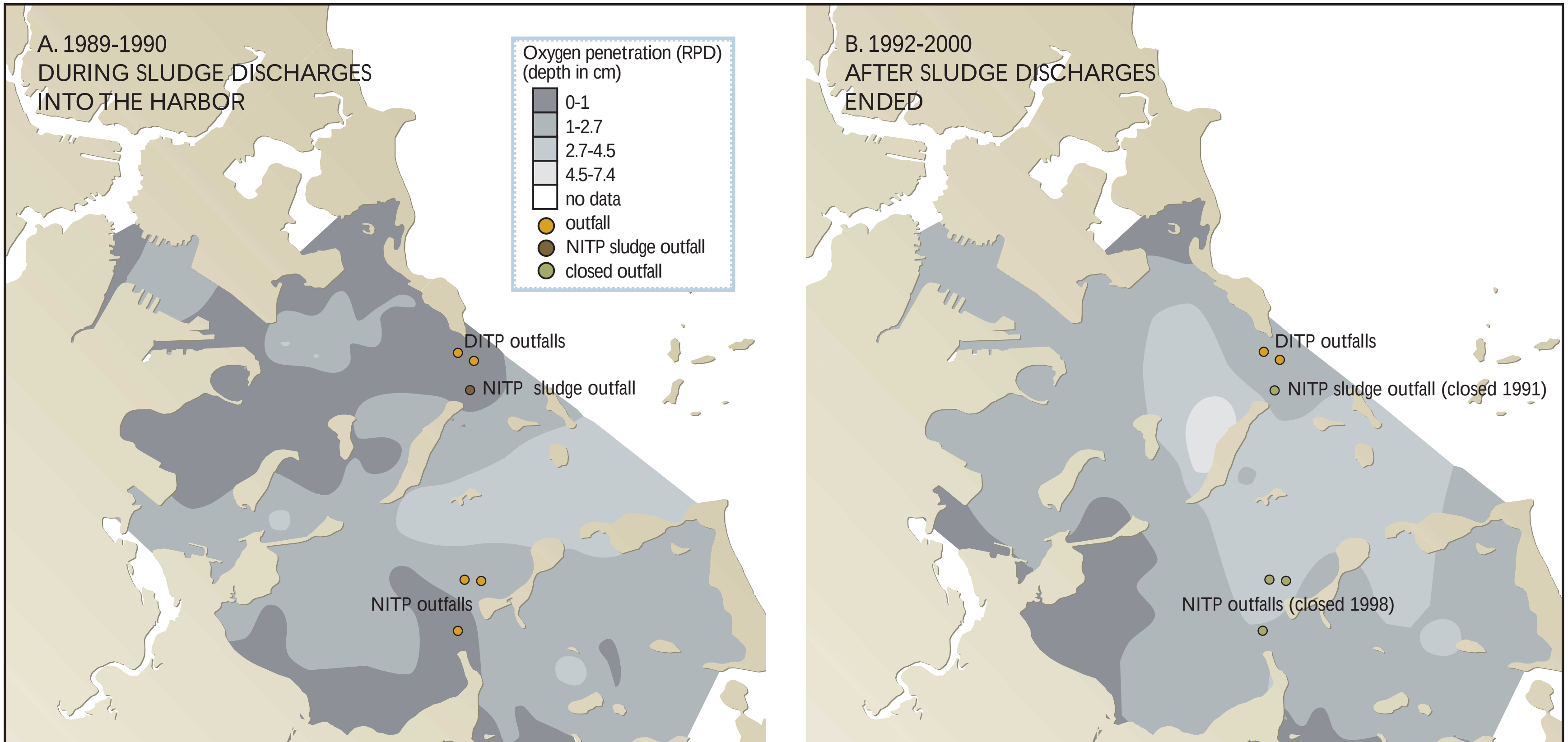
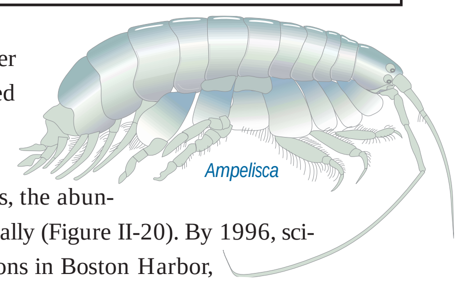


FIGURE II-18. OXYGEN PENETRATION INTO HARBOR SEDIMENTS, 1989-2000. These contour maps were created by averaging annual RPD data collected from 1989-1900 and 1992-2000, as measured by sediment profile imaging. A: 1989-1990. Early in the Boston Harbor Project the northern harbor and the southern harbor around the NITP outfalls had very shallow RPDs. Nearly half of all stations had RPD depths of less than one centimeter. B: 1992 to 2000. Later data show better sediment oxygenation, especially in the northern harbor, which had been more impacted by sludge discharges. One apparent factor in this improvement is the presence of *Ampelisca* tubemats. These mats, which promote the oxygenation of the sediments, correlate well with RPD depths of 2.7 centimeters or greater in the northern harbor, Nantasket Roads, and parts of Hingham Bay.

RPD (Figure II-18B). Scientists attribute some of this improvement to a tiny, shrimp-like crustacean called *Ampelisca*.

Ampelisca is a sensitive indicator of sediment conditions. While this animal can tolerate moderate levels of organic matter and oxygen loss, it is vulnerable to contamination from toxic metals and pesticides. Thus, its increase in the harbor after many years may signal less contaminated sediments. In 1989-90, *Ampelisca* tubemats were found at only 24% of the harbor sampling stations (Figure II-19). In summer 1991, harbor sediment samples indicated an environment under stress–diversity was low, with an average of just 18 species per sample. The total number of animals captured was also quite low. By the mid-1990s, as the *Ampelisca* communities spread and their tubemats provided shelter to other organisms, the abundance of benthic animals increased dramatically (Figure II-20). By 1996, scientists found *Ampelisca* at over 80% of stations in Boston Harbor, and diversity more than doubled through the 1990s (Figures II-19 and II-20B).



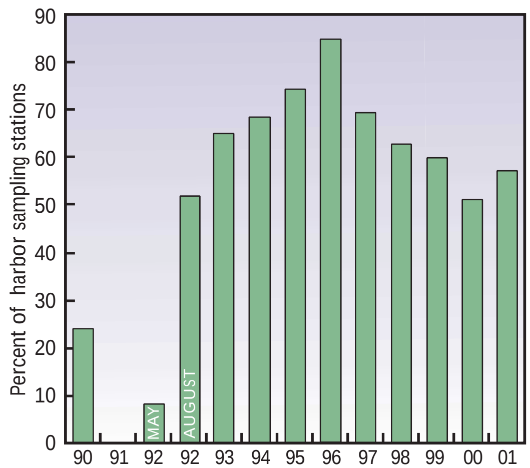


FIGURE II-19. PREVALENCE OF *AMPELISCA* IN BOSTON HARBOR, 1989-2001. This graph shows the percent of benthic monitoring stations with *Ampelisca* tubemats. Except for 1992, when results are shown for May and August, all bars show results from August. *Ampelisca* was found at increasing numbers of stations through the early to mid-90s, indicating that Boston Harbor sediments were steadily recovering. In 1989-1990, *Ampelisca* tubemats were found at only 24% of the harbor sampling stations. In May 1992, the tubemats were found at fewer than 10% of the stations, with many stations showing signs of disturbance from a major storm in October 1991 (the "Halloween Nor'easter" or "The Perfect Storm"). This storm caused the highest storm surge in Boston Harbor in two decades, and scoured soft sediments from the seafloor in many parts of the harbor. This sediment transport and mixing, together with a reduction in pollution inputs, may have promoted the establishment of more vigorous benthic communities and set the stage for the increases in abundance and diversity observed afterward. By August 1992 more than 50% of the harbor stations contained *Ampelisca* tubemats, and this proportion increased throughout the mid-1990s, peaking at over 80% of stations in 1996. The recent decline in *Ampelisca* abundance seems to be a result of succession from *Ampelisca* to a more diversified and healthy benthic community.

Ampelisca can also benefit the sediments. They build tubes that can grow in thick mats on the seafloor, and these mats often host other animal species. *Ampelisca* irrigate the sediments with oxygenated water, increasing the depth of oxygen penetration. The average August RPD depth contours from 1992 through 2000 (Figure II-18 B) closely track the presence of the *Ampelisca*-dominated communities—stations with greater oxygen penetration consistently supported these communities throughout the 1990s.

However, *Ampelisca* tubemat communities have been declining since 1996. Biodiversity in harbor samples remained high, even as *Ampelisca* started to decline. It is likely that, as pollution inputs were cleaned up, even more pollutant-sensitive species were able to move in. Future sampling will show if *Ampelisca* is in turn being replaced by a more diverse community that is more typical of unimpacted New England estuaries.

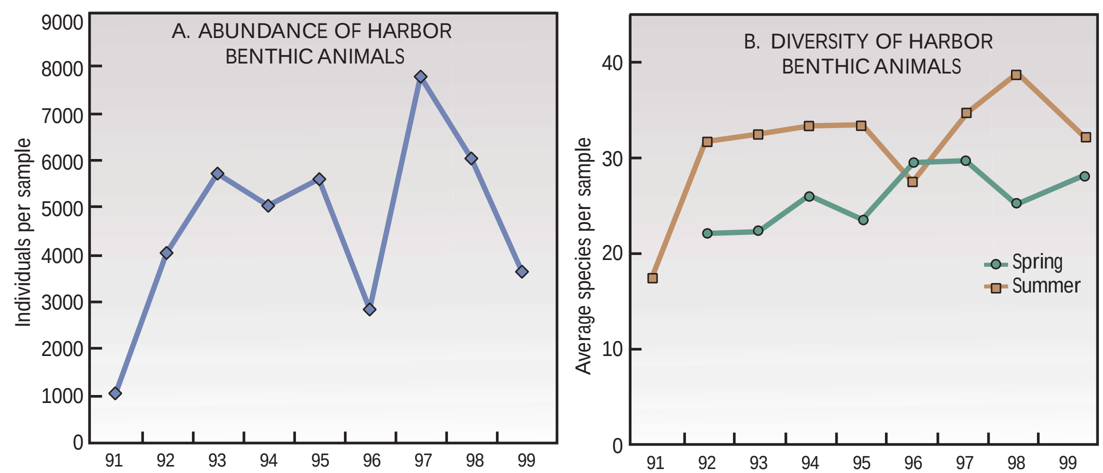
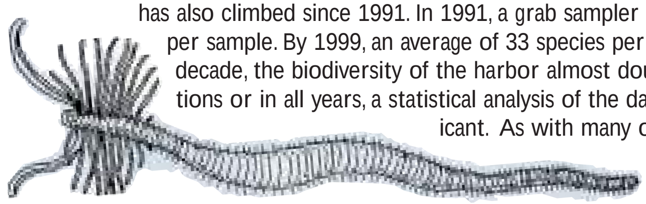


FIGURE II-20. ABUNDANCE AND DIVERSITY OF ANIMALS ON THE HARBOR FLOOR 1990-1999. Each summer since 1991 MWRA has collected sediment samples at eight stations in Boston Harbor. At each station, three sediment grab samples are collected, and the animals in these samples are preserved, identified, and counted in the laboratory. These graphs are from averages of all eight stations. A: ABUNDANCE. The number of animals brought up per sample has increased dramatically since 1991. In 1991, a single grab sample brought up approximately 1,000 individual animals. By 1998, there were about 6,000 animals per sample. Increases were most noticeable in the early 1990s, as communities quickly recovered after sludge discharges stopped in December 1991. B: DIVERSITY. Measured by the number of different species found in a grab sample, diversity has also climbed since 1991. In 1991, a grab sampler would bring aboard about 18 different species per sample. By 1999, an average of 33 species per sample was collected. Thus, in less than a decade, the biodiversity of the harbor almost doubled. Although the increases are not at all stations or in all years, a statistical analysis of the data confirmed that the overall increase is significant. As with many other benthic measurements, biodiversity increased sharply in the 1990s after sludge discharges to the harbor ended.



fish&shellfish

MWRA studies fish and shellfish from two aspects: the condition of the animals themselves, and whether their contaminant levels pose a health threat to consumers. Since 1992, MWRA has monitored winter flounder, lobster, and blue mussels. Flounder and lobster are important biomonitoring tools because locally, these two species are commercially important for food, and they live in close contact with potentially contaminated bottom sediments. Mussels are used because they feed by filtering particles out of the water, and can concentrate (bioaccumulate) toxic materials from the water in their tissues.

Flounder and lobster for testing are collected near Deer Island. Mussels are collected from relatively pristine sites and then transferred to cages which are placed near Deer Island and in the Inner Harbor for up to 60 days, to permit bioaccumulation of contaminants. (Monitoring locations are shown in Figure II-21.)

ROBERT MICHELSON

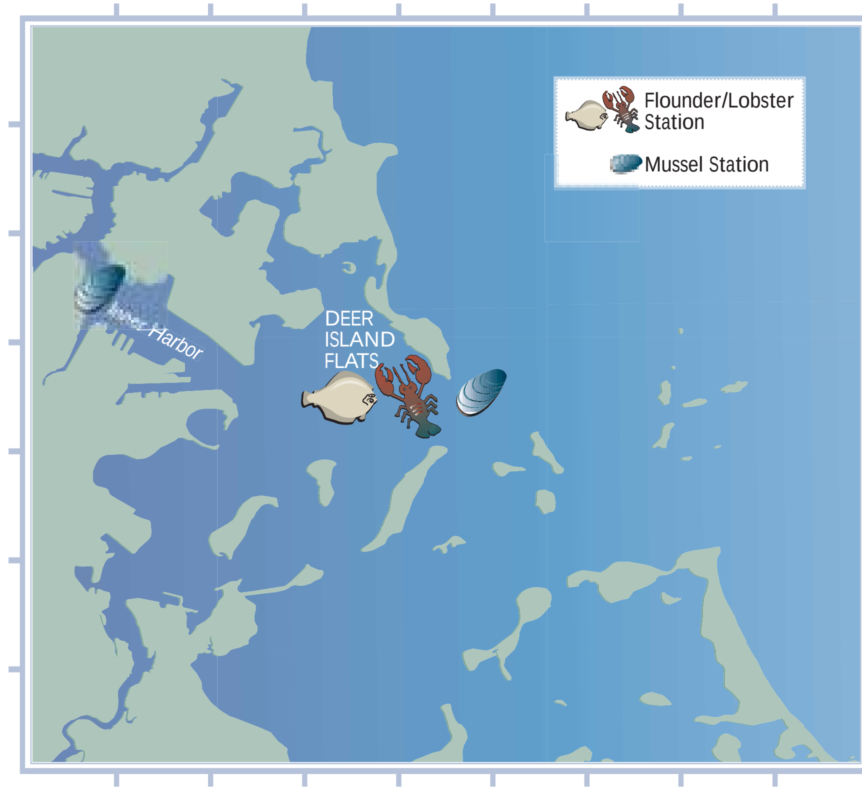


FIGURE II-21. BOSTON HARBOR FISH & SHELLFISH MONITORING LOCATIONS.

Flounder caught near Deer Island have a much lower prevalence of liver disease than those in the 1980s, and liver tumors are now rare. Levels of mercury, PCBs, and pesticides in flounder fillet are well within U.S. Food and Drug Administration (FDA) guidelines. Lobster also are healthy, and have low levels of contaminants in the meat. However, PCBs in lobster hepatopancreas (tomalley) are above FDA guidelines, consistent with existing advisories against consuming tomalley. Mussels have lower levels of PAHs than in the early 1990s. PCBs and pesticides in mussels remained relatively stable throughout the decade at levels well within FDA guidelines. Overall, the contaminant data show that fish and shellfish in the harbor are healthy and meet FDA guidelines. (For definitions of PCBs and PAHs, see page 26.)

Flounder live in contact with the ocean floor.

ROBERT MICHELSON

WINTER FLOUNDER

BOSTON HARBOR FLOUNDER ARE IN GOOD HEALTH AND MEET FDA STANDARDS

Flounder live on the bottom, eating worms and other tiny animals that live in the sediments, and thus can be exposed to sediment contaminants directly through the skin and from feeding. In the mid-1980s, a scientific paper identified Boston Harbor flounder as having among the highest incidence of liver tumors in the northeastern United States.

Since 1992, the flounder caught near Deer Island have not exhibited gross abnormalities, such as fin erosion, that had been observed during the mid-1980s; the fish generally appear healthier. Of the liver lesions, a type called "centrotubular hydropic vacuolation" (CHV) has been the most common. Figure II-22A shows that, on average, the rate of CHV is about two-thirds of the levels found in the 1980s, although this may be partially explained by the age of the fish: the tested fish from Boston Harbor have been younger, and younger fish tend to have lower CHV levels. Liver tumors, which indicate more serious health effects, have not been observed since 1996 (Figure II-22B).

The flounder livers are tested for levels of lead, mercury, cadmium, copper, nickel, silver, zinc, chromium, PAHs, PCBs, DDT, and ten other pesticides. In order to test for potential human health effects, mercury, PCBs, DDT, and seven other pesticides are measured in the edible flounder fillets. For many fish species, consumption advisories because of mercury are a concern. However, mercury levels in winter flounder have been stable at about 50-100 parts per billion, well below the FDA limit of 1,000 parts per billion. Levels of PCBs and DDT are also well below FDA limits (Table II-3).

TABLE II-3. CONTAMINANTS IN FLOUNDER FILLET, 1993-2001. PCBs, DDT, and mercury in fillet of flounder caught in the harbor have fluctuated between years with no clear pattern. However, all these chemicals have measured well below the U. S. Food and Drug Administration (FDA) action limits.

ROBERT MICHELSON

	Parts per billion, wet weight	
	Actual range of annual averages	FDA limit
PCB	24.9 - 72.9	2,000
DDT	3.1 - 7.2	5,000
Mercury	40 - 90	1,000

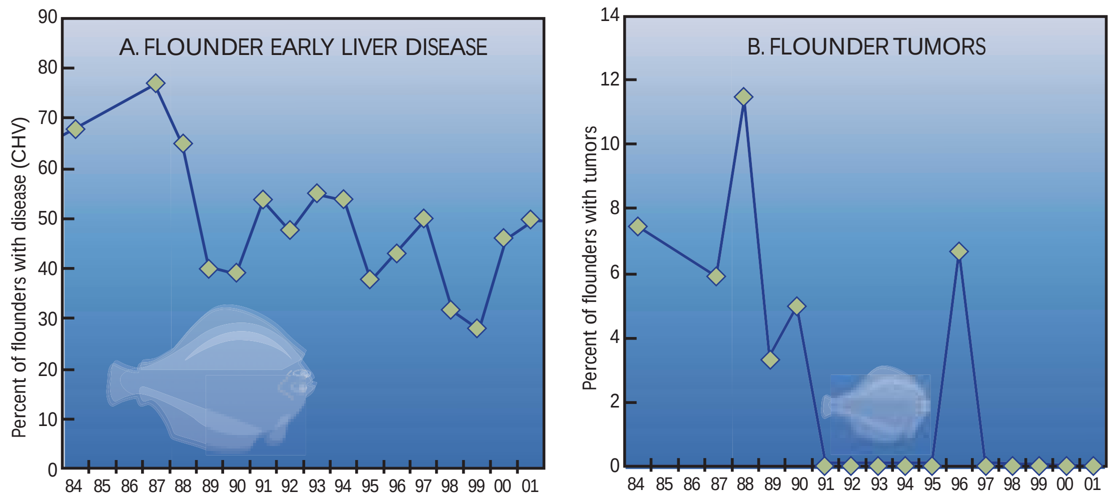
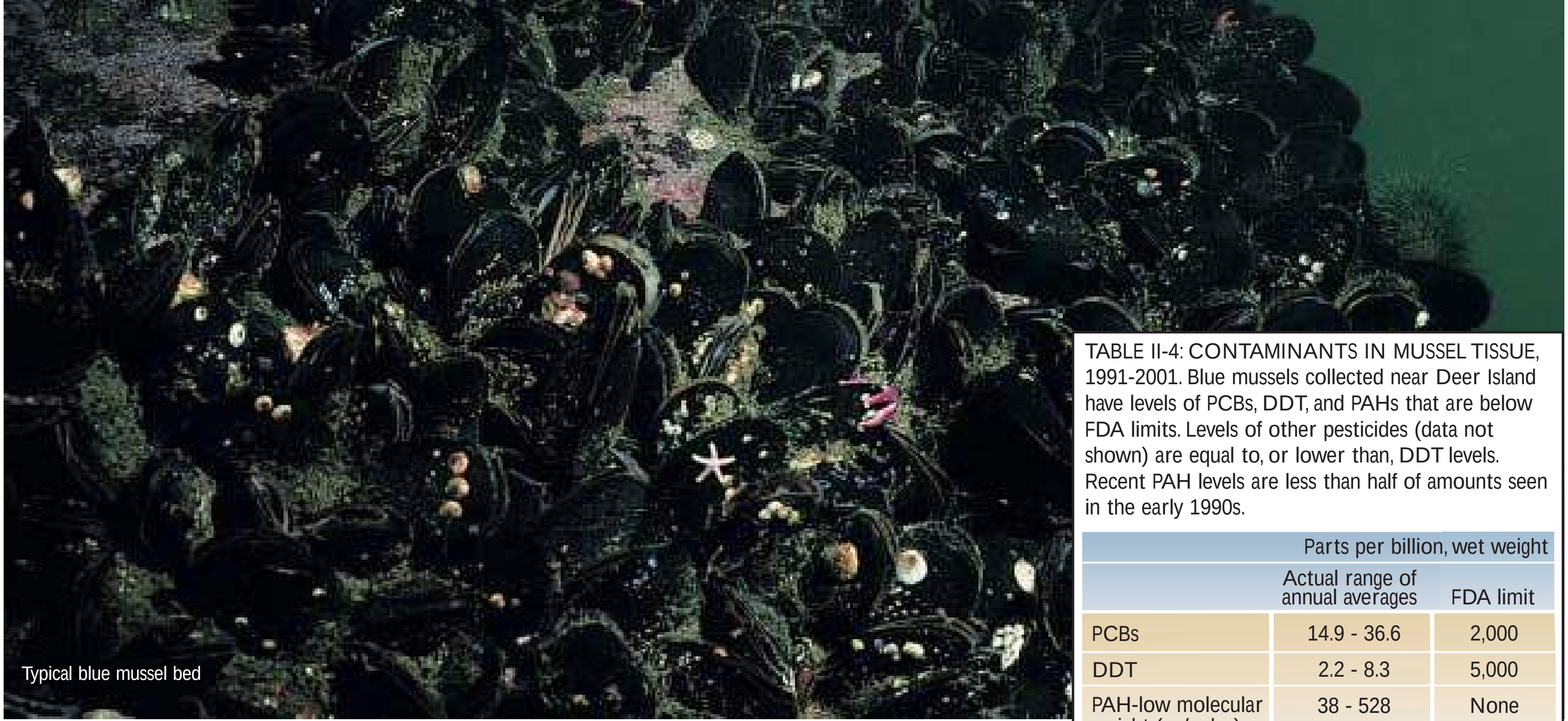


FIGURE II-22. LIVER DISEASE IN WINTER FLOUNDER, 1984-2001.
Liver disease is a sensitive indicator of pollution effects on Boston Harbor flounder because the liver can be damaged as contaminants are metabolized. A: EARLY LIVER DISEASE. On average, the rate of early liver disease (measured as centrotubular hydropic vacuolation or CHV) is about two-thirds the levels found in the 1980s, when nearly 70% of fish were affected. B: LIVER TUMORS. This more serious abnormality, once found at an unusually high incidence, has not been seen since 1996 (when one tumor was found out of 16 fish collected). Other forms of liver disease (not shown) also have dropped substantially since the late 1980s but seem to have leveled off over the last decade. Although encouraging, these observations should be interpreted with caution, because the fish caught in Boston Harbor recently have been younger, and younger fish tend to have a lower prevalence of liver disease.



Typical blue mussel bed

ROBERT MICHELSON

TABLE II-4: CONTAMINANTS IN MUSSEL TISSUE, 1991-2001. Blue mussels collected near Deer Island have levels of PCBs, DDT, and PAHs that are below FDA limits. Levels of other pesticides (data not shown) are equal to, or lower than, DDT levels. Recent PAH levels are less than half of amounts seen in the early 1990s.

	Parts per billion, wet weight	
	Actual range of annual averages	FDA limit
PCBs	14.9 - 36.6	2,000
DDT	2.2 - 8.3	5,000
PAH-low molecular weight (ng/g dry)	38 - 528	None

Mussel cages being deployed

BLUE MUSSELS

PAH LEVELS IN MUSSELS HAVE DECREASED BY MORE THAN 50% IN THE LAST DECADE.

MWRA studies blue mussels to assess how water quality may affect levels of toxic contaminants in marine animals. Mussels feed by filtering large volumes of water, and can accumulate dissolved toxic metals and organic compounds in their tissues. For this study, hundreds of mussels from relatively clean areas in Gloucester and Sandwich are put in cages and placed on moorings for one to two months at two locations: the Inner Harbor near the New England Aquarium, and Deer Island Flats (Figure II-20). Upon retrieval, the mussels are analyzed for lead, mercury, PCBs, PAHs, DDT, and ten other pesticides. There has been little change in PCBs and DDT over time, but PAHs in mussels are lower than in the early 1990s.

PCBs: Polychlorinated biphenyls

A group of banned toxic chemicals, formerly used in a variety of commercial applications, including electrical transformers and condensers, batteries, and lubricants. PCBs are known to cause skin diseases and suspected of causing birth defects and cancer.

PAHs: Polycyclic aromatic hydrocarbons

Complex organic chemicals found in petroleum and in products of fossil fuel combustion. Many PAHs are known carcinogens.

LOBSTER

LOBSTER MEAT SHOWS LITTLE CONTAMINATION, BUT THE TOMALLEY EXCEEDS LIMITS FOR PCBs

Each year, MWRA tests 15 lobsters caught near Deer Island. The lobsters are examined for external signs of disease, such as black gill disease, shell erosion, parasites, and tumors. The tail and claw meat is tested for mercury, PCBs, DDT, and ten other pesticides. The tomalley is tested for the same contaminants plus lead, cadmium, copper, nickel, silver, zinc, chromium, and PAHs. Table II-5 shows the average results of this testing for mercury, PCBs, and pesticides in lobster meat. The levels of contaminants in lobster meat are well below the FDA limit for human consumption.

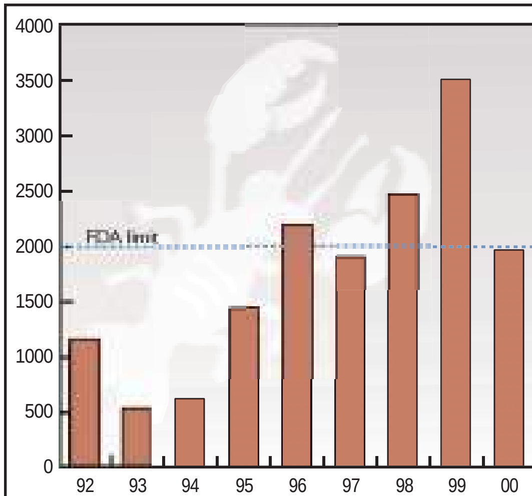


FIGURE II-23: PCBs IN LOBSTER HEPATOPANCREAS (TOMALLEY), 1992-2000. From 1993-1999 there was an upward trend in PCB levels in lobster caught in the harbor. Scientists have been unable to definitively explain this trend—there are several plausible hypotheses (see text). Longstanding consumer advisories against eating lobster tomalley are supported by these MWRA data.

An unanticipated finding in the lobster study has been a trend of increasing concentration of PCBs in lobster hepatopancreas since 1993 (Figure II-23). Industrial PCBs are potential carcinogens and were phased out of production beginning in 1971. Although PCB levels are extremely low in MWRA discharges, PCBs break down very slowly and are therefore very persistent in the environment; historical inputs of PCBs from a variety of sources have accumulated in marine sediments.

MWRA examined whether the apparent increase in lobster tomalley PCBs could be explained by the better laboratory testing methods that have been used recently, but the trend was found no matter which method was used. One explanation for the trend is that, due to the lower amount of sewage solids in the harbor, lobster could be foraging less in the Outer Harbor and more in the Inner Harbor and Dorchester Bay, where there are more pollutants. Another possible factor is that, in recent years, sampling for lobster has been later in the year. This may mean that the length of time the lobsters that were sampled were exposed to PCBs in the harbor has increased. No matter what the cause, the levels of PCBs in lobster tomalley now are at, or slightly over, the FDA limit. This finding confirms existing consumer advisories against eating lobster tomalley.

ROBERT MICHELSON

TABLE II-5: CONTAMINANTS IN LOBSTER MEAT, 1992-2001. MWRA tests the tail and claw meat of lobsters near Deer Island for PCBs (polychlorinated biphenyls), DDT, and mercury. The levels of contaminants vary from year to year, yet are always well under FDA limits.

	Parts per billion, wet weight	
	Actual range of annual averages	FDA limit
PCBs	10.8 - 39.8	2,000
DDT	0.7 - 6.0	5,000
Mercury	70 - 260	1,000

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Boston Harbor's Tributary Rivers

INTRODUCTION TO BOSTON HARBOR'S THREE MAJOR RIVERS

Trees along the Charles River

ERIC ENDLICH

Boston Harbor is an estuary—a marine ecosystem where freshwater enters the ocean. The largest rivers draining into Boston Harbor are the Charles, the Neponset, and the Mystic. Since 1989, MWRA has regularly monitored water quality in these rivers, primarily to assess impacts of combined sewer overflows (CSOs). The monitoring also measures the effect of the rivers on harbor water quality. Measured water quality indicators include bacteria, water clarity, chlorophyll, and dissolved oxygen.

THE CHARLES RIVER meanders nearly 80 miles from its headwaters at Echo Lake in Hopkinton before emptying into Boston Harbor.

Pollution sources to the lower Charles include upstream community wastewater treatment plants, contaminated stormwater runoff, and leaking septic systems. Thirteen CSOs discharge to the lower Charles, including MWRA's Cottage Farm CSO treatment facility, which screens and disinfects wet-weather combined sewage discharges. Historically, the Charles was heavily used for industrial waste disposal, and hotspots of toxic contaminants remain in its sediments.

The river mouth, originally a tidal estuarine saltmarsh, has been dammed since the early 1900s and a new dam and locks system was built in 1978. This dam controls river flow and flooding, and fills the Charles River Basin, a popular urban recreational area. However, the dam has some adverse impacts on the river's ecosystem. It prevents tidal flushing, trapping pollutants in the basin. Seawater leaks upstream into the river through the dam—in the summer the heavy saltwater slides up the river bottom, forming a cold saltwater "wedge" with freshwater above it. These layers prevent vertical mixing, inhibiting replenishment of oxygen from the air to the bottom waters. Large amounts of decaying organic material in the bottom sediments use oxygen, so that sometimes the river bottom water has almost no oxygen at all. The decay process also produces toxic sulfides, which prevent a normal benthic community from developing on the bottom.

An aerial view of the Neponset Estuary

JOSEPH INGOLDSBY

Bridge over the Mystic River

ERIC ENDLICH

THE MYSTIC RIVER flows from the Mystic Lakes in Winchester and Arlington, east through Medford, Somerville, and Chelsea to Boston Harbor.

Storm drain

ERIC ENDLICH

Only five miles long, much of the river flows through dense residential and industrial areas, and is impacted by pollution from surrounding development. Like the Charles, the Mystic River is dammed at its mouth where it enters Boston Harbor, but it does not suffer from the same saltwater wedge and low dissolved oxygen that affect the Charles.

Water quality problems in the Mystic Basin include toxic pollutants in industrialized areas, eutrophication, and bacterial contamination from sanitary sewer overflows, stormwater, and eight CSOs.

Alewife Brook, a tributary to the Mystic in Cambridge and Arlington, is also heavily affected by stormwater and combined sewage, and the brook is an additional source of pollution to the Mystic. At the river mouth, MWRA's Somerville Marginal CSO Treatment Facility discharges screened, chlorinated combined sewage during heavy rains.

THE NEPONSET RIVER is 28 miles long, flowing from its headwaters in Foxboro to the river mouth in central Boston Harbor. Unlike the Charles and Mystic Rivers, the Neponset River mouth is not dammed, so an estuarine habitat, the Neponset estuary, remains as Boston Harbor's largest saltmarsh. The marsh is important wildlife habitat and is also a natural filter of pollutants. Just upstream of the saltmarsh is the harbor's largest smelt spawning area. In the Neponset watershed are three Areas of Critical Environmental Concern (ACECs): the Neponset Estuary, Fowl Meadow, and Ponkapoag Bog. ACECs are recognized as especially sensitive and important regions for wildlife habitat, flood control, or recreational and historical resources.

The Neponset Marsh

JOSEPH INGOLDSBY

Water quality problems in the Neponset watershed include bacterial contamination, eutrophication, and toxic chemicals in sediments. In recent years, CSOs in the river have been eliminated, but the lower Neponset still receives contaminants from leaking septic systems further upstream and from stormwater runoff. During rainstorms, MWRA's Commercial Point CSO Treatment Facility discharges screened and disinfected combined sewage to southern Dorchester Bay at the mouth of the river.

trends in river water quality

Neponset Marsh

JOSEPH INGOLDSBY

Homes along the Mystic River

ERIC ENDLICH

RIVER BACTERIA

In general, the harbor's tributary rivers have poorer bacterial water quality than the harbor, reflecting the impacts of CSOs and urban storm runoff on relatively small water bodies. In contrast with most of Boston Harbor, the rivers frequently do not meet the Massachusetts state water quality standard of average fecal coliform counts of less than 200 colonies per 100 ml. Figure III-1 shows the spatial variation of bacteria counts along the Charles, Mystic, and Neponset Rivers in the year 2000, averaged for all weather conditions.

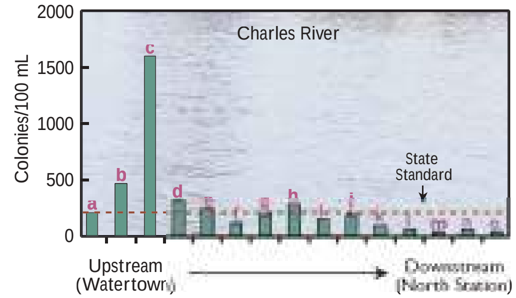
Figure III-2 shows changes in river bacteria over three time periods corresponding to phases of implementation of MWRA's plan to control CSOs.

Head of the Charles race

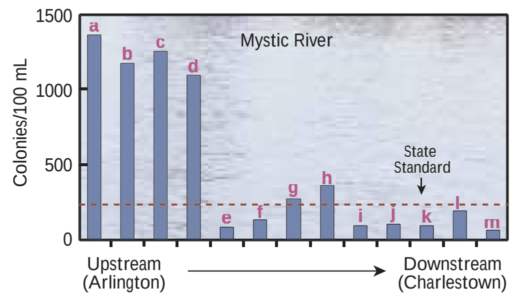
ERIC ENDLICH

In the Charles, improvement in water quality over the past ten years has been dramatic; fecal coliform counts (geometric mean) fell by over five-fold. Although the Mystic River shows slight improvement over this period, the Mystic and Alewife Brook are still plagued with contaminated stormwater and CSOs. Implementation of MWRA's CSO Plan will control CSOs, but stormwater is a major source of bacteria. Although closing CSOs and better CSO treatment at MWRA facilities has reduced inputs of bacteria to the Neponset, stormwater sources are so much larger than were CSOs that water quality in the lower Neponset has remained about the same since monitoring began.

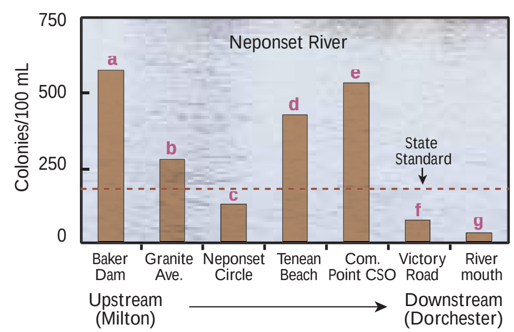
FIGURE III-1. SPATIAL PATTERN OF RIVER BACTERIA IN 2000*



A. CHARLES: Most fecal coliform readings hovered around or below the state standard of 200 colonies per 100 milliliters. The area between the Watertown dam and the Arsenal Mall (upstream of any CSO discharges) was the most consistently contaminated section surveyed; and the Charles River Basin, the important recreational area between Cambridge and Boston, had the best bacterial water quality.

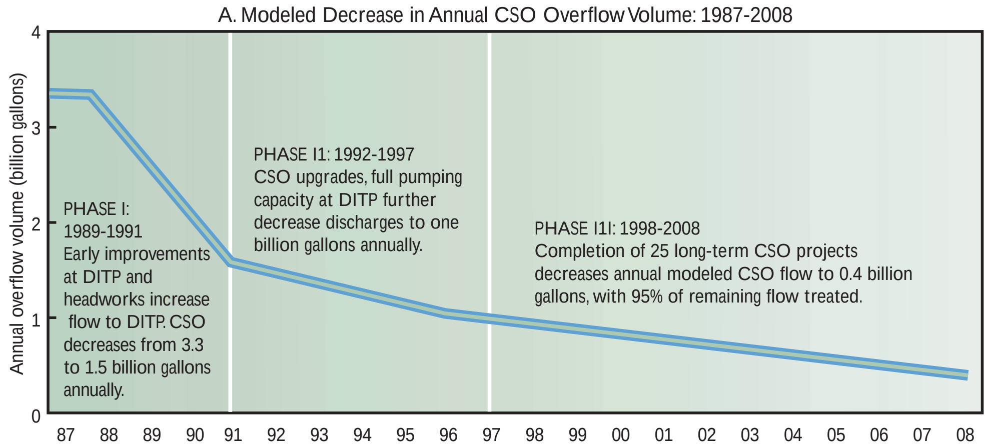


B. MYSTIC: Bacterial counts in the Mystic River vary greatly depending on location. A tributary, Alewife Brook, is one of the most contaminated water bodies in the Boston area, mostly due to stormwater and CSOs. Here, fecal coliform counts routinely fail to meet the state standard. However, downstream, in the Mystic River proper, bacterial water quality is fairly good, except for a noticeable increase near Medford Square (h). Counts decrease near the river's mouth.



C. NEPONSET: Except near its mouth, the Neponset River consistently fails to meet state bacterial water quality standards. The Baker Dam in Milton is affected by leaking septic systems upstream and contaminated stormwater. At the river mouth, where river water mixes with the cleaner harbor water, fecal coliform counts meet the standard. Unfortunately, water quality does not consistently meet standards near Tenean Beach or the Commercial Point CSO Treatment Facility outfall. Although the effluent from the facility is effectively disinfected, these sites are impacted by contaminated stormwater.

* Samples collected during all weather conditions.



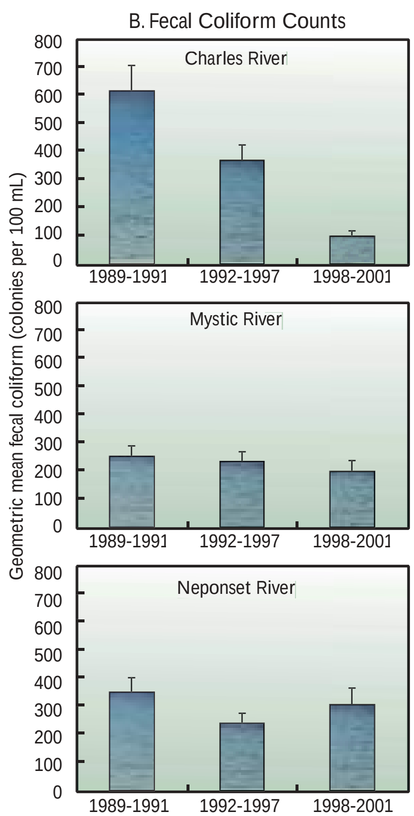


FIGURE III-2. PATTERNS OF RIVER BACTERIA COMPARED TO PHASES OF CSO CONTROL. Bacterial counts for the three rivers are grouped in time by the three phases of the MWRA's CSO Plan.
A: Model predictions for CSO discharges, CSO Control Plan.
B: Average bacteria levels in the Charles have decreased 80%, while the Mystic and Neponset Rivers have shown little or no improvement. The Mystic and Neponset are more affected by stormwater than by CSO. Improved pumping and hydraulic capacity at DITP greatly decreased discharges from Charles River CSOs. Also, communities along the Charles have been working to clean up stormwater discharges. Although there have been local improvements at the mouth of the Mystic River near MWRA's Somerville Marginal CSO Treatment Facility, the overall average water quality in the Mystic has changed very little.

While CSOs have been eliminated in the Neponset, stormwater still contaminates that river. (Lines above bars indicate margin of error.)

RIVER CLARITY

MWRA tests for water clarity by measuring Secchi depth in the rivers. Generally, the tributary rivers are not as clear as the harbor

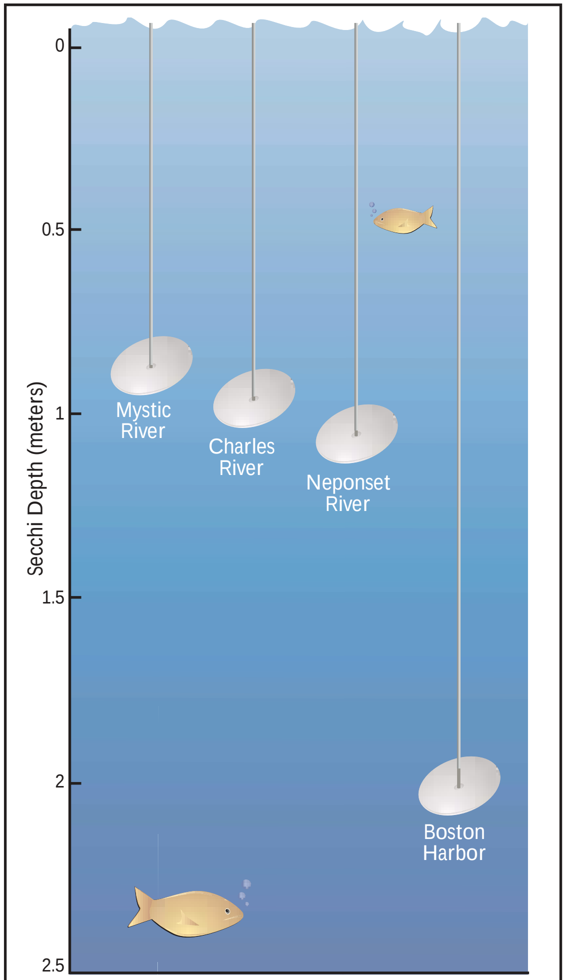


FIGURE III-3. COMPARISON OF WATER CLARITY IN THE RIVERS AND THE HARBOR. Average Secchi depths in the rivers are roughly comparable, at about one meter. However, clarity in the harbor is more than double that of the clearest tributary, the Neponset.

because they have higher concentrations of particulates and algae (Figure III-3). The water clarity in the rivers has not changed significantly since monitoring began in 1992. The Charles River has an interesting pattern of water clarity: the water is more clear in the urbanized basin than it is upstream (Figure III-4).

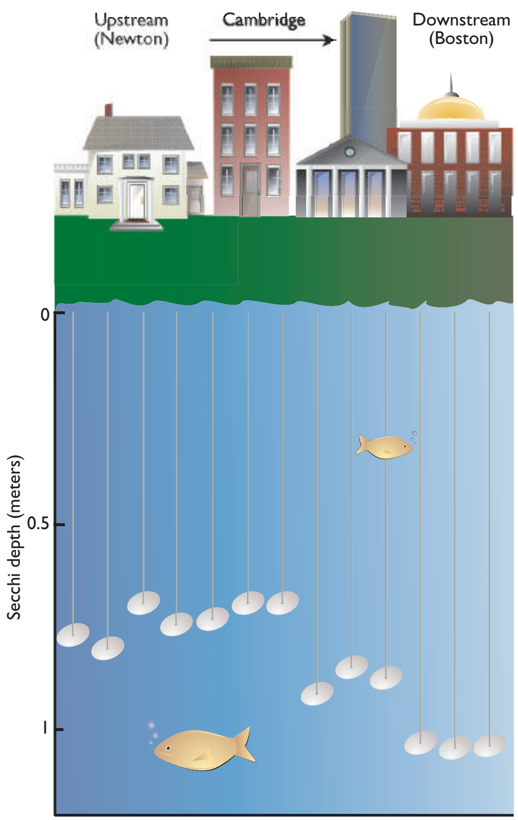


FIGURE III-4. SPATIAL TREND IN CHARLES RIVER WATER CLARITY. Secchi depths along the Charles River from Newton to downtown Boston show a trend of increasing clarity in the downstream stretches near Boston. As the river slows and widens through Cambridge and Boston, the rate of flow decreases, allowing solids to settle out. As a result, Secchi depths increase downstream.

Boating in the Mystic River is an important recreational resource for Greater Boston.

ERIC ENDLICH

RIVER ALGAE & CHLOROPHYLL

Chlorophyll concentrations are typically higher in the rivers than in the harbor, because nutrient levels are higher in rivers. Also, the residence time of water is greater in the dammed portions of the rivers than in the harbor. Both these factors allow more algae to build up. Algae levels are at their highest in the rivers and the harbor in the summertime (Figure III-5). The Mystic and Charles Rivers have the highest amounts of algae; the Neponset River the least. Since river chlorophyll monitoring began in 1992, there have been no significant trends in algal blooms over time.

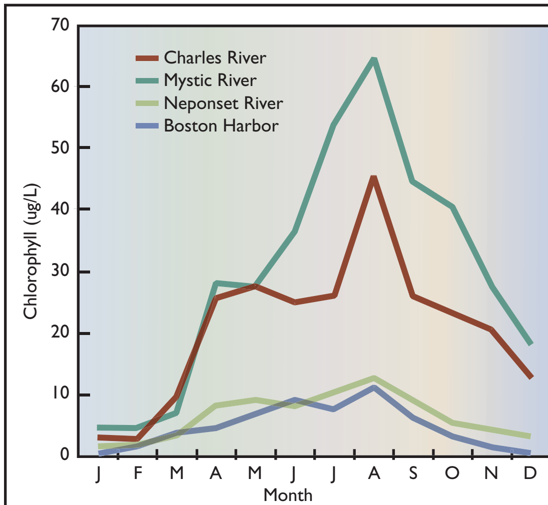


FIGURE III-5. COMPARISON OF CHLOROPHYLL IN THE RIVERS AND THE HARBOR. Rivers have higher chlorophyll levels than the harbor, but both ecosystems are subject to dramatic seasonal fluctuations. Chlorophyll levels are high in the summer when the light is intense, and low in the dimmer winter months. River chlorophyll is measured downstream near the river mouth but before mixing with saltwater. Both the Mystic and Charles are very eutrophied, with high average chlorophyll due to poor flushing and high nutrient inputs. The Neponset has the lowest chlorophyll of all the rivers, probably due to a relatively natural river flow and lower nutrient inputs.

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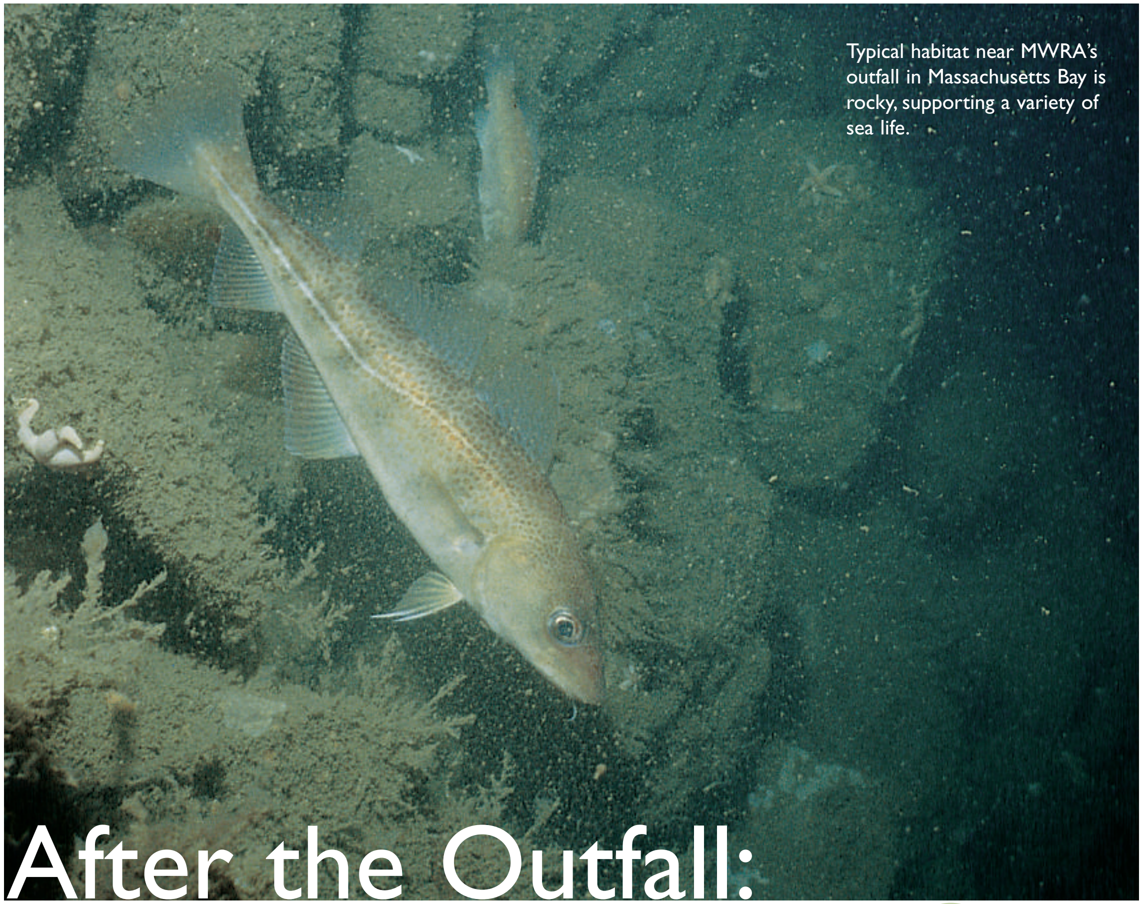


Typical habitat near MWRA's outfall in Massachusetts Bay is rocky, supporting a variety of sea life.

BARBARA HECKER

After the Outfall: Changes in the Harbor & Bay

MONITORING RESULTS SINCE SEPTEMBER 2000

The opening of the new 9.5-mile ocean outfall on September 6, 2000 relocated effluent away from Boston Harbor to Massachusetts Bay. MWRA scientists have already noted a number of changes in harbor water quality that appear to be related to the relocation. The most dramatic changes have occurred near the former harbor outfalls, especially changes in bacteria, ammonium concentrations, and water clarity. This section describes observations during the first four months after the DITP discharges to the harbor ended. Now, the major sources of contaminants—especially nutrients—are from the rivers and stormwater runoff, shown schematically in Figure IV-1.

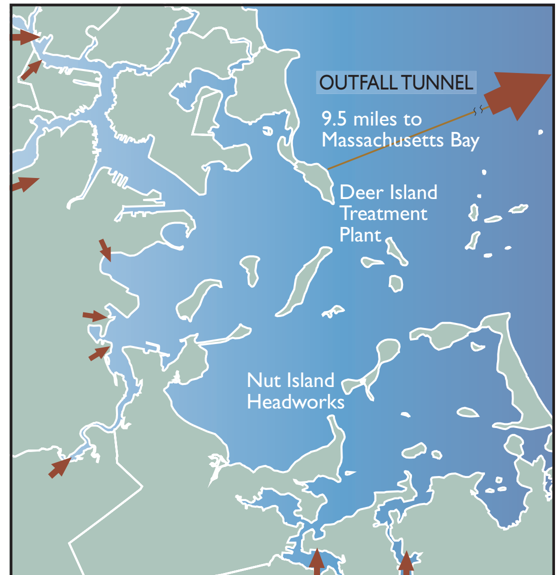


FIGURE IV-1. LOCATIONS OF HARBOR CONTAMINATION SOURCES AFTER SEPTEMBER 2000. After the opening of the Massachusetts Bay outfall in 2000, wastewater inputs to the harbor dramatically changed. Where large amounts of treated wastewater had been discharged at the mouth of the harbor, now only smaller sources still remain.

A tiny ocean pout rests on pink coralline algae in Massachusetts Bay.

ROBERT MICHELSON

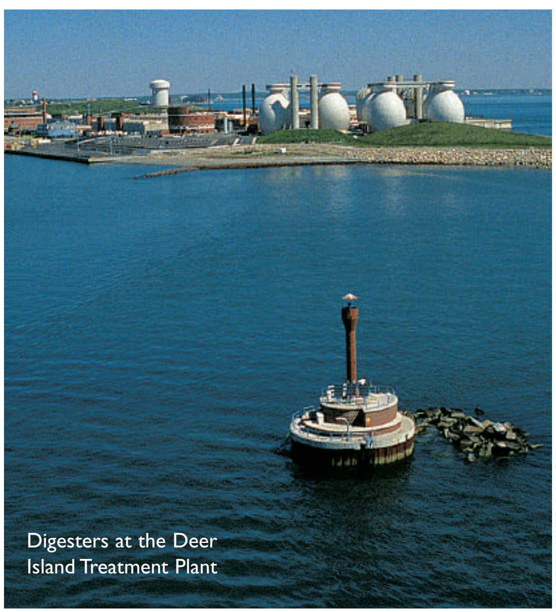
Changes in Boston Harbor

During the first weeks after the bay outfall started up and all harbor discharges ended, water quality improved greatly near the former harbor outfalls. During subsequent months, improvements were seen harbor-wide.

BACTERIA

LOW FECAL COLIFORM COUNTS AT THE FORMER HARBOR OUTFALLS

Since DITP discharges to the harbor ended in September 2000, bacteria counts at the former harbor outfalls have been consistently low (Figure IV-2). Counts decreased first at the NITP outfalls in 1998, and then at the DITP outfalls in September 2000.



Digesters at the Deer Island Treatment Plant

KAREN-JAYNE DODGE

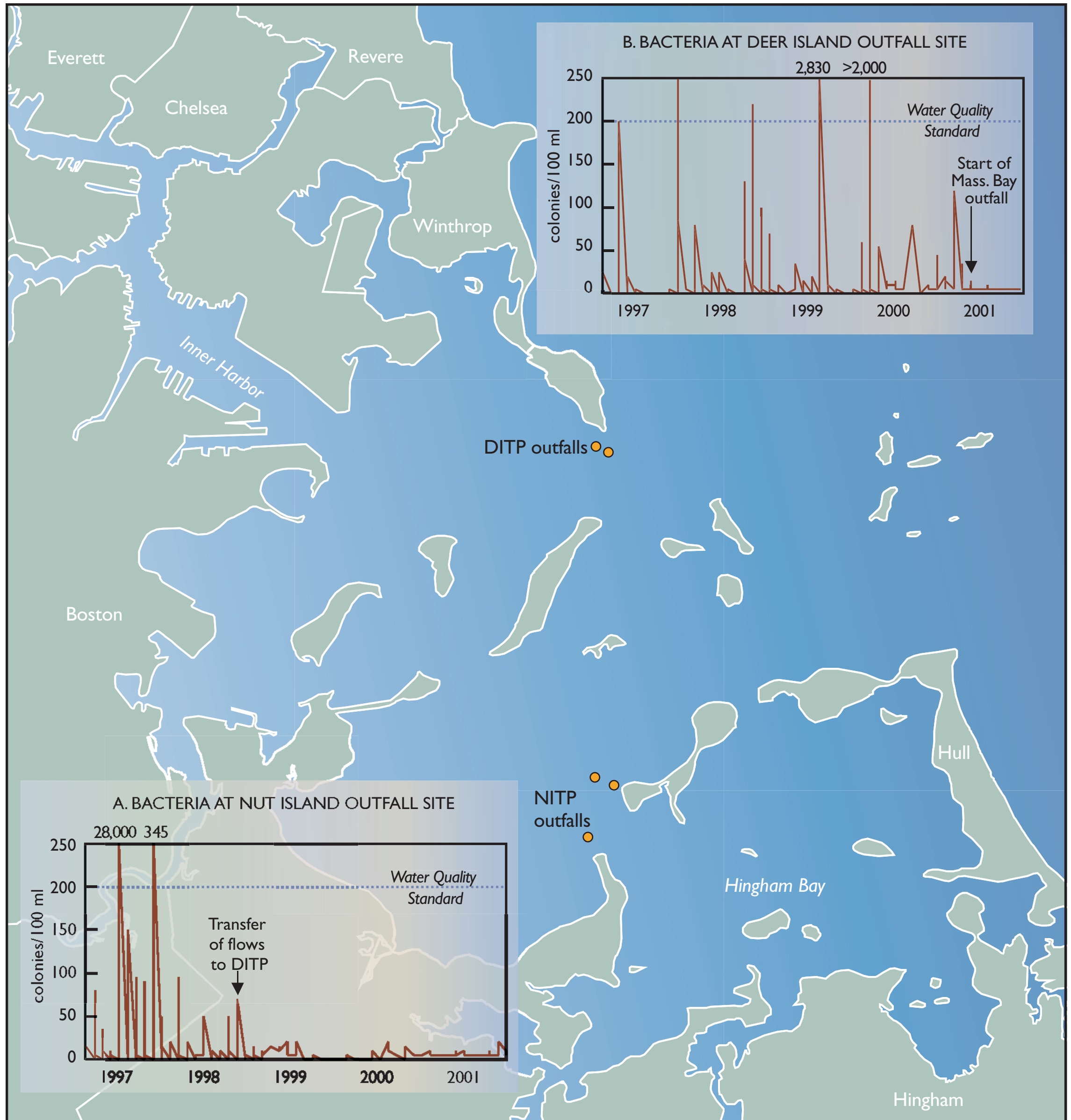


FIGURE IV-2. TRENDS IN BACTERIA AT THE PREVIOUS HARBOR OUTFALL SITES (shown as orange circles). A: Fecal coliform levels at the old NITP outfalls dropped after 1998. B: Fecal coliform decreased at the DITP outfalls after 2000. Since the closing of the NITP and DITP outfalls in July 1998 and September 2000 respectively, fecal coliform counts have been consistently far below the state standard of 200 colonies per100 milliliters.

WATER CLARITY

WATER CLARITY HAS INCREASED AT THE FORMER OUTFALLS

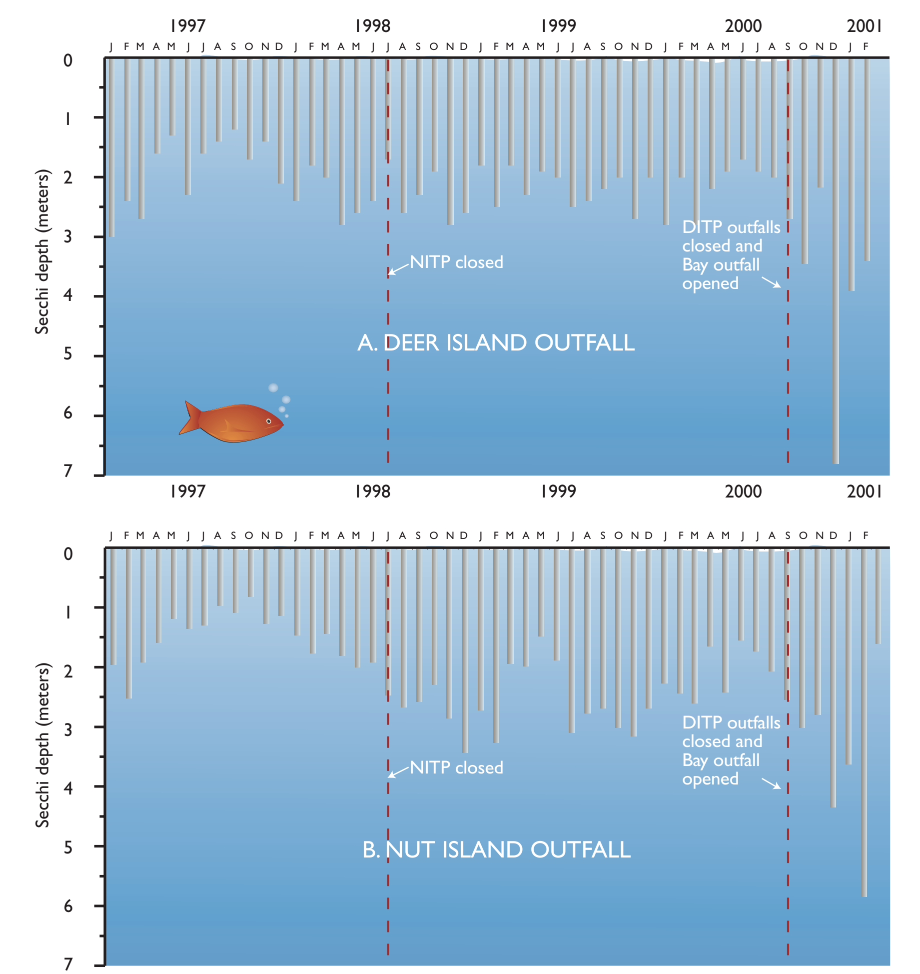


FIGURE IV-3. WATER CLARITY AT THE FORMER HARBOR OUTFALL SITES. A. NEAR DEER ISLAND, clarity doubled in 2000, a direct result of the opening of the bay outfall. B. SECCHI DEPTHS also increased at the Nut Island outfall site first after the opening of the inter-island tunnel in July 1998, and then after the opening of the bay outfall.

NADINE SMOSKE

AMMONIUM

80% LESS AMMONIUM AROUND THE FORMER OUTFALLS

Figure IV-4 compares average concentrations of ammonium by month, 1993-1999, with levels measured in 2000. The rapid, harborwide decrease in ammonium after discharges ended was especially notable in the winter months, the period when ammonium had formerly increased.

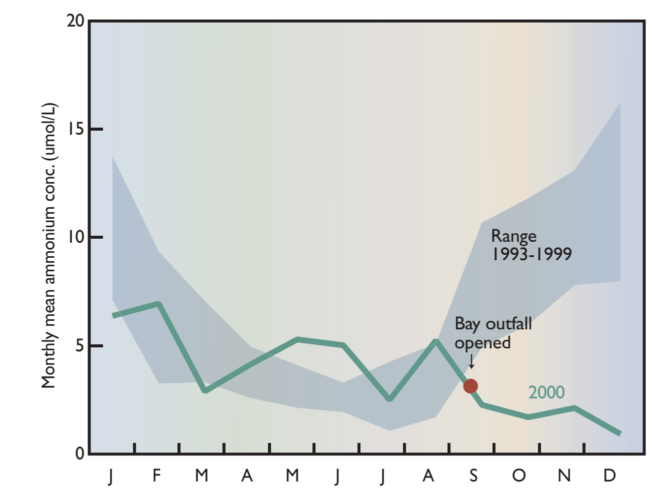


FIGURE IV-4. DECREASED AMMONIUM LEVELS AFTER THE BAY OUTFALL OPENED. Range of average ammonium levels harbor-wide between 1993-1999 (shaded area) compared to 2000 (green line), the year the bay outfall opened. The 2000 line after September decreases to below the range of concentrations seen during harbor discharges. This rapid and large decrease in ammonium may prove to be one of the largest improvements in Boston Harbor.

What is the future of the harbor?

In the next decade, we expect that Boston Harbor will continue to improve. Sewage effluent, which formerly constituted 40% of the freshwater flow into the harbor, is gone. Because the harbor is no longer the receptacle for sewage effluent and sludge, water quality will get better, the bottom sediments will continue to cleanse themselves, and sea life will grow healthier.

However, as the large and obvious problems in the harbor are being resolved, other challenges have become more apparent. Now, the Mystic, Charles, and Neponset rivers are the major freshwater sources to the Boston Harbor estuary—and the rivers carry pollutants to the harbor from upstream watersheds. Furthermore, Boston Harbor still experiences pollution problems typical of any water body near a major city. Contaminants from the air, storm runoff, and combined sewer overflows have measurable impacts, affecting people and wildlife.

These watershed protection and pollution prevention problems are difficult to assess and require new approaches that cross many traditional jurisdictions—in a sense, they are even more challenging than MWRA's construction of modern wastewater treatment facilities. The Boston Harbor Project has helped to transform what was once called the "dirtiest harbor in America" to the centerpiece of metropolitan Boston. Realizing the full benefit of this investment will require better technical understanding of the remaining pollution sources and their impacts, as well as coordinated efforts by local, state, and federal agencies, businesses, and residents.

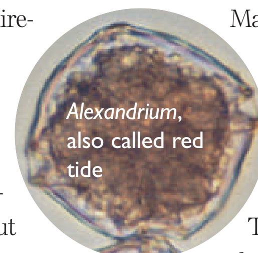
Humpback whale in Massachusetts Bay. Certified marine mammal observers are on all MWRA surveys.

ROBERT MICHELSON

Massachusetts Bay monitoring

MWRA's discharge permit for the bay outfall has strict monitoring requirements designed to identify unexpected impacts from operation of the outfall.

There is little doubt that the Boston Harbor Project benefits the marine environment and the people of the region, but moving the effluent outfall from the harbor to 9.5 miles out into Massachusetts Bay caused some concern. To address these concerns, MWRA implemented an extensive monitoring program to measure the health of the bay (Figure IV-5). The monitoring is managed by MWRA scientists and carried out by teams from consulting firms, universities, research institutions, and government agencies. These scientists conduct oceanographic studies of the bay's water, plankton, sediment, and fish and shellfish to understand how the ecosystem functions, and to measure environmental effects of MWRA pollution abatement projects.



Alexandrium, also called red tide

MWRA's goals for Boston Harbor and Massachusetts Bay are based on concerns expressed by the public during the planning of the Boston Harbor Project. These goals include beaches safe for swimming, healthy marine resources, seafood safe for eating, and protection of harbor and bay aesthetics.

The remainder of this report describes some early observations of the environment of Massachusetts Bay since the outfall began operating in September 2000.

Outfall Monitoring Science Advisory Panel

An independent panel of scientists, the Outfall Monitoring Science Advisory Panel (OMSAP), reviews monitoring data and provides advice on key scientific issues related to the discharge permit. OMSAP also provides advice concerning any proposed modifications to the monitoring or contingency plans. (Visit OMSAP's web page at: www.epa.gov/region01/omsap/).

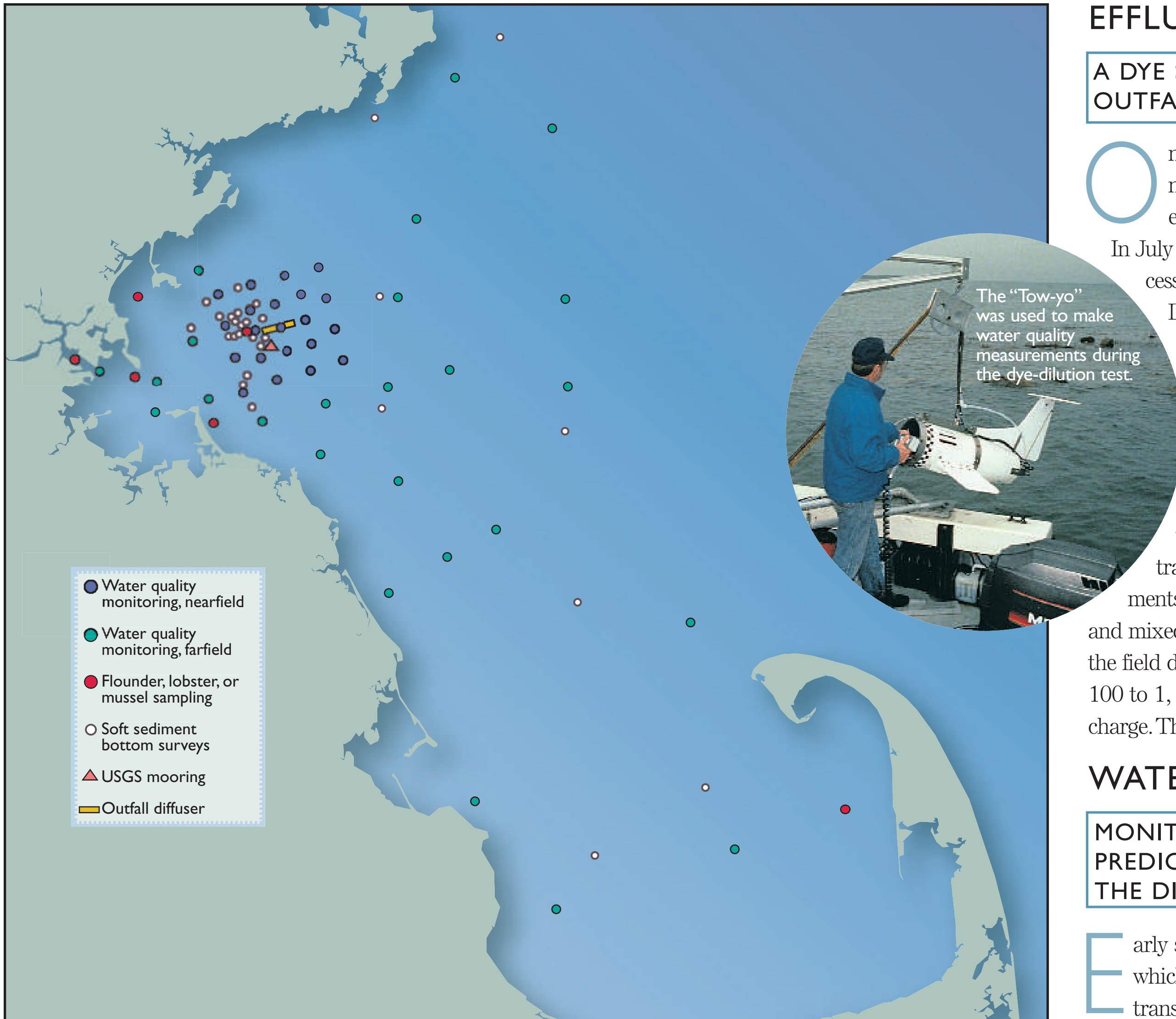


FIGURE IV-5. SAMPLING SITES THROUGHOUT MASSACHUSETTS BAY. As part of the permit that allows the MWRA to operate its new Massachusetts Bay outfall, MWRA scientists and consultants have set up "nearfield" and "farfield" stations. The nearfield stations are within about 3 miles of the outfall diffuser, to monitor any changes occurring in the immediate vicinity of the discharge. The farfield stations are in Boston Harbor, Massachusetts Bay, Cape Cod Bay, and the Stellwagen Bank National Marine Sanctuary to assess any changes that may be occurring distant from the discharge. A cooperative USGS-MWRA project maintains a moored array of water and current meters, and suspended sediment samplers near the outfall site.

EFFLUENT PLUME STUDIES

A DYE STUDY SHOWED THAT THE OUTFALL IS WORKING AS DESIGNED

One of MWRA's tasks was to determine if the new outfall was working as expected–was the effluent going where it should?

The "Tow-yo" was used to make water quality measurements during the dye-dilution test.

In July 2001, a major dye study of the effluent successfully tracked the location and dilution of the DITP effluent discharge in Massachusetts Bay. The study measured the actual dilution factor at the outfall to confirm whether the outfall is working as expected. The monitoring team added an environmentally friendly, rose-colored dye (rhodamine) in a measured amount at the DITP. The dilution of the dye at the outfall was followed by tracking it and sampling with shipboard instruments as the dye emerged from the outfall diffuser and mixed with the surrounding water. Results from the field data showed effluent initial dilution of about 100 to 1, at a minimum, within 50 meters of the discharge. This was within the expected range.

WATER COLUMN STUDIES

MONITORING DATA MATCHED OUTFALL PREDICTIONS FOR BEFORE AND AFTER THE DISCHARGE BEGAN

Early sampling studies also measured ammonium, which is a useful tracer of the effluent plume. The transfer of effluent discharge from the harbor to the bay clearly affected concentrations close to the new outfall. Prior to outfall start-up, ammonium was relatively low throughout the nearfield. By late September, concentrations were higher, indicating the presence of effluent. The ammonium monitoring data showed a pattern that was similar to the computer model's prediction of outfall dilution (Figure IV-6).

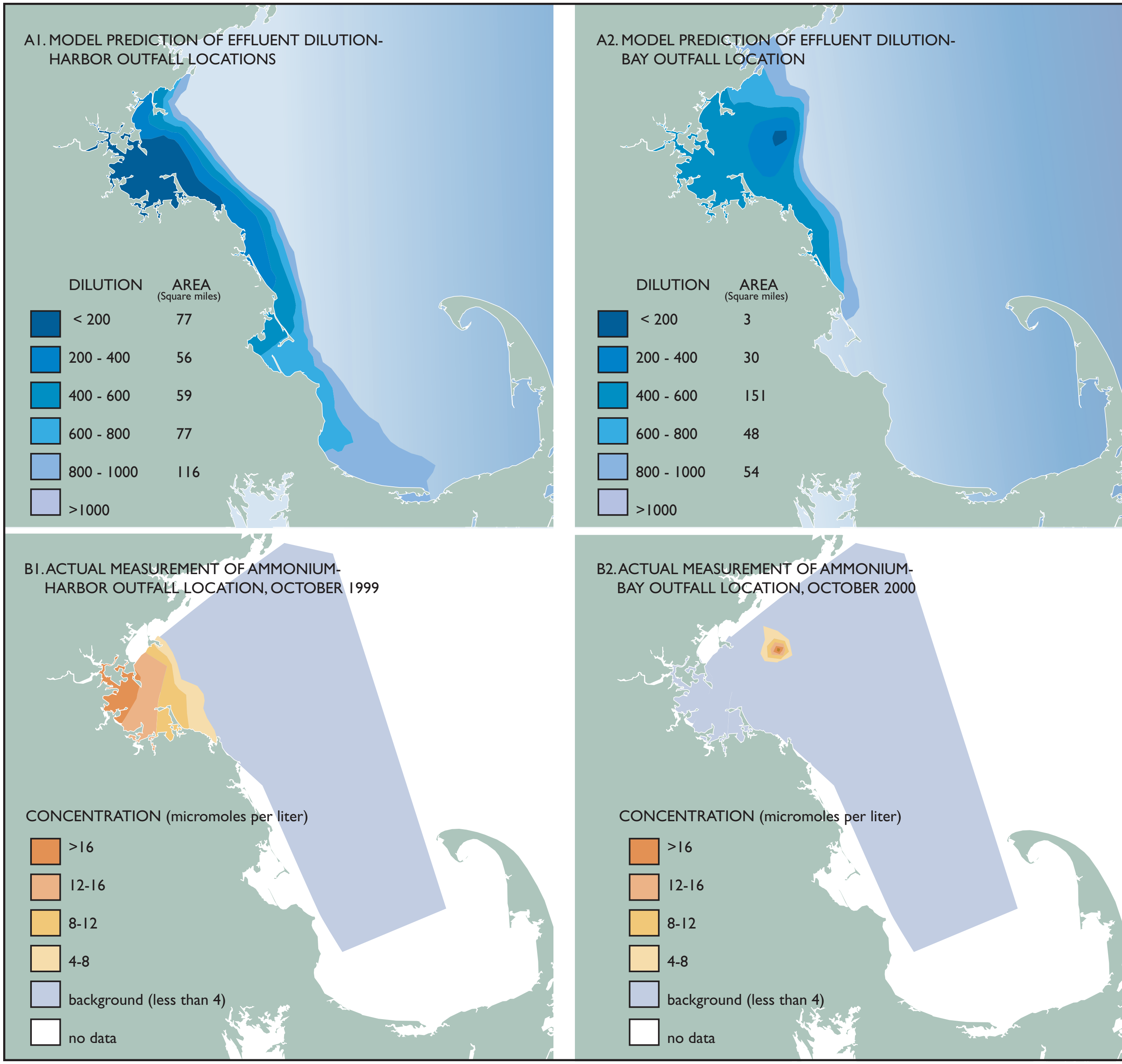


FIGURE IV-6: MODEL PREDICTIONS OF EFFLUENT DILUTION COMPARED TO MONITORING RESULTS.

A: Averaged computer model predictions of effluent dilution. These maps, generated by USGS before the outfall was built, show dilution contours from the harbor and bay outfall locations. The harbor model shows a large area of highly concentrated effluent centered in the harbor but spreading east and south, into Massachusetts Bay and south of Boston. In comparison, the bay outfall has a small patch of effluent centered around the diffuser, with dilution rapidly increasing away from the outfall.

B: Ammonium concentrations, a good tracer of effluent, were measured while the outfall was at Deer Island, and after the bay outfall went on-line. The pattern of ammonium concentration agrees well with the model, giving scientists and engineers confidence that we understand how the outfall is functioning. A lesser area is affected, and ammonium levels in the harbor have decreased dramatically.

CHLOROPHYLL A LARGE FALL BLOOM IN 2000

There was an unusually large bloom of chlorophyll at the time the outfall began operating. The detection of the event, and subsequent use of data from many sources to understand it, shows how MWRA's monitoring was able to detect an unusual environmental occurrence and discern if it was outfall-related.

When the outfall began operation, chlorophyll levels were already unusually elevated, and continued to increase during the fall of 2000.

Scientists compared chlorophyll levels near the outfall to those elsewhere and found that chlorophyll was high throughout the region. Satellite imagery confirmed that there was a region-wide algal bloom that ranged from New Jersey to the Bay of Fundy (Figure IV-7, last panel). Boston Harbor, Cape Cod Bay, the coastal stations, and the offshore stations had annual mean chlorophyll levels that were higher in 2000 than had been observed since 1992.

The monitoring team closely followed the progress of this bloom throughout the fall, winter, and following spring. Throughout this period, there were no unusual elevations of nuisance algal species, and dissolved oxygen in the water column was somewhat higher than usual.

Factors causing this unusual fall bloom apparently did not last until spring. By the winter/spring of 2001, chlorophyll levels had declined to levels lower than in 1998 and 1999 (Figure IV-8). All the evidence suggested that this unusual bloom was independent of the MWRA outfall and that there were no adverse effects.

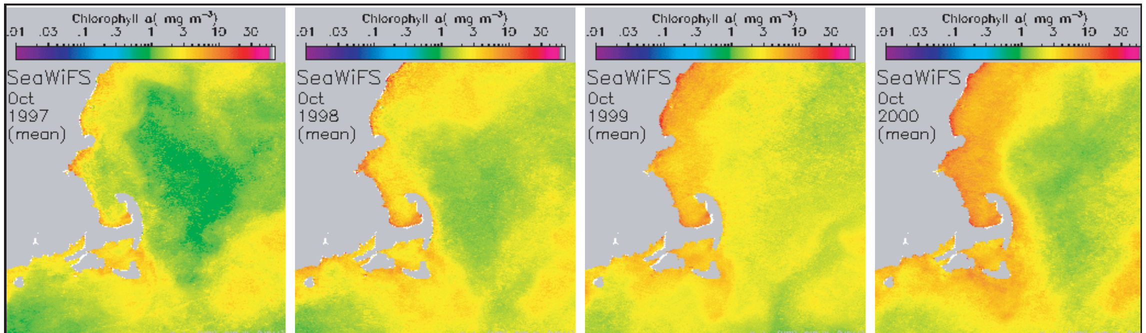


FIGURE IV-7. SATELLITE IMAGES OF CHLOROPHYLL IN THE SOUTHERN GULF OF MAINE show a region-wide increasing trend in chlorophyll levels throughout the Gulf of Maine since 1997. This regional information is an important aid to MWRA's monitoring team in interpreting sampling data like the elevated chlorophyll measurements in fall 2000. It is clear from the satellite image that the high chlorophyll was widespread, and not just near MWRA's outfall. Scientists are unsure what caused this pattern of increases, but suspect that an ocean-wide fluctuation in nutrient levels may have been a factor. In 2001, chlorophyll levels declined (not shown).

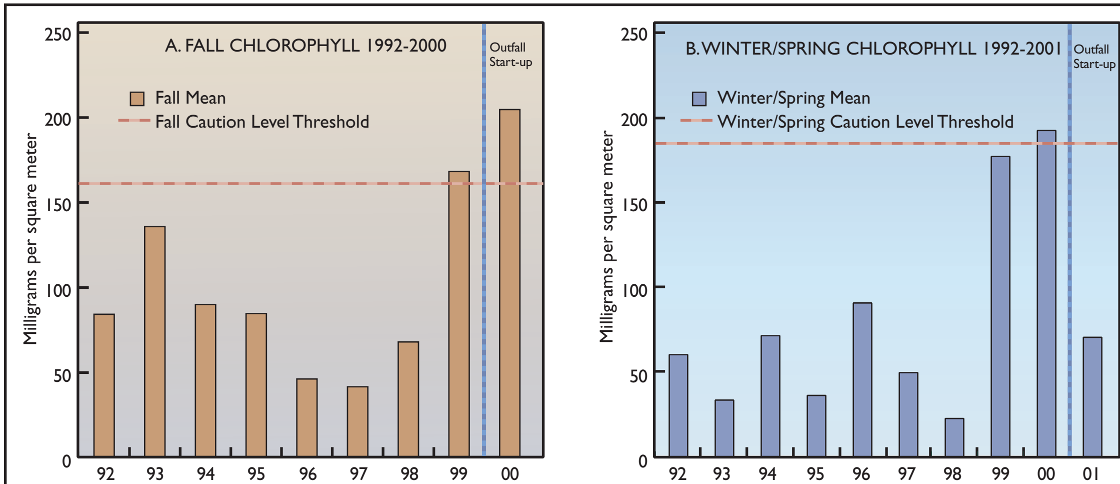


FIGURE IV-8. SEASONAL CHLOROPHYLL LEVELS NEAR THE BAY OUTFALL, 1992-2001.
These are average nearfield chlorophyll levels for each year by season.
A: FALL: In 2000, chlorophyll was very high, just as the outfall started-up
B: WINTER/SPRING: Although the winter/spring of 1999 and 2000 had relatively high chlorophyll, the winter of 2001 following the large fall bloom in 2000 had only average chlorophyll levels.

For both graphs, MWRA's contingency plan thresholds are indicated. When the threshold is exceeded, this indicates an unusual occurrence that may warrant further study or other action.

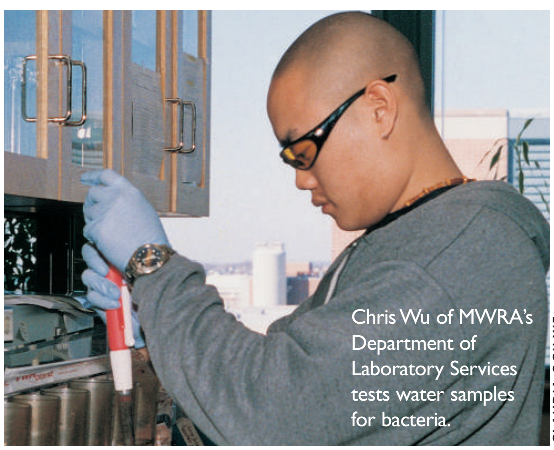
BACTERIA IN THE BAY

COUNTS REMAIN LOW

MWRA monitors bacterial water quality in the bay to assure that the operation of the outfall does not adversely affect shellfish-growing waters. Every month, MWRA collects water samples at twelve locations in the bay. The samples are analyzed for the sewage indicator bacteria fecal coliform and *Enterococcus*. Fecal coliform and *Enterococcus* counts in Massachusetts Bay have remained low following the opening of the new outfall (Table IV-1). The study was able to detect a slight increase at stations directly over the outfall diffuser; no changes were found further away.

TABLE IV-1: BACTERIA COUNTS AT THE BAY OUTFALL SITE. The FDA shellfishing standard is less than 14 fecal coliform colonies per 100 ml.

	Geometric mean bacteria counts (colonies/100 ml) at new outfall site	
	Fecal coliform	*Enterococcus*
Before outfall start-up	2.0	1.0
After outfall start-up	2.2	1.1

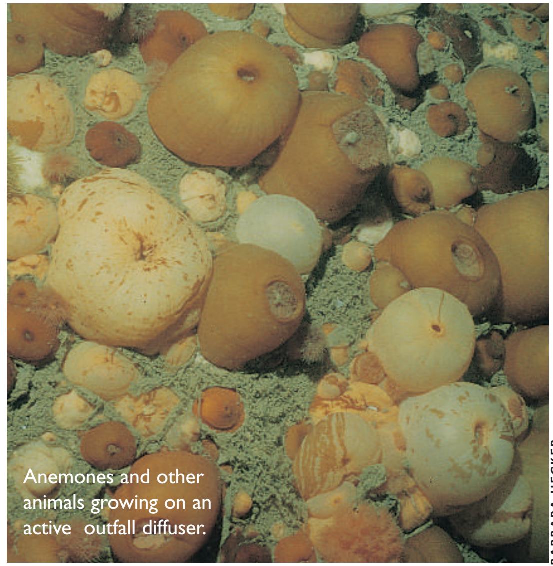


Chris Wu of MWRA's Department of Laboratory Services tests water samples for bacteria.

CLAUDIA OGILVIE

EARLY OBSERVATIONS ON THE SEAFLOOR

ABUNDANT SEA LIFE AT THE OUTFALL



Anemones and other animals growing on an active outfall diffuser.

BARBARA HECKER

A sediment contaminant survey was conducted in the fall of 2000 after the outfall came on line. Concentrations of organic and inorganic contaminants were similar to those measured prior to the outfall coming on line. In July 2001, the monitoring team carried out the annual video and photographic survey of the plant and animal communities that live on rocks near the outfall. Using a remotely operated vehicle, or "ROV," scientists were able to document abundant life on and near active diffuser heads, including densely growing sea anemones, sea squirts, starfish, flounder, cod, sponges and other animals, shown below. Data gathered so far show that the outfall is functioning as anticipated—providing rapid dilution to the effluent—and no significant adverse impacts have been observed.

Conclusion

It is rewarding to witness the recovery of a significant resource like Boston Harbor, but this report makes clear that although the "Boston Harbor Project" is finished, the "Harbor Clean-up" is not. The removal of treatment plant effluent from the harbor exposed shoreline contamination. The harbor's tributary rivers suffer from urban runoff and low river flow. MWRA's CSO Plan, scheduled for completion in 2008, will reduce wet-weather pollution at the shoreline and in the rivers. But there are many causes of the remaining pollution problems, some as simple as a sewer pipe incorrectly connected to a storm drain, and others as complex as eutrophication in rivers caused by watershed-wide patterns of water use and land development. MWRA's investment in environmental quality continues beyond the Boston Harbor Project, exemplified by extensive monitoring in Massachusetts Bay for outfall effects, implementation of the CSO Plan, control of infiltration and inflow, and construction and maintenance of the sewer system. MWRA's work must be complemented by continued efforts by municipalities, advocacy groups, and regulatory agencies to understand and address water quality problems, and to ensure the continued recovery of the harbor and its watershed.

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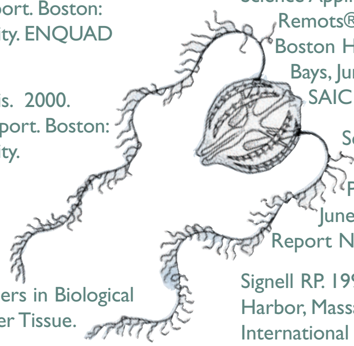

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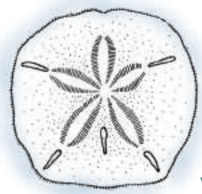

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