1999
Outfall monitoring overview

Massachusetts Water Resources Authority

Environmental Quality Department
Report ENQUAD 2000-14

Werme C, Hunt CD. 2000. 1999 Outfall monitoring overview. Boston:
Massachusetts Water Resources Authority. Report ENQUAD 2000-14. 72p.

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Outfall Monitoring Overview

submitted to

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November 9, 2000

Executive Summary

Since its creation in 1985, the Massachusetts Water Resources Authority (MWRA) has worked to minimize the effects of discharging sewage effluent to the marine environment. The MWRA program includes source reduction, improved treatment, and effective dilution. One aspect of the program, moving the treated wastewater outfall from the harbor to Massachusetts Bay, has caused some environmental concerns. To address these concerns, MWRA implemented an extensive monitoring program to measure the health of Boston Harbor and the bays. Further, the joint federal and state permit for the new outfall will require extensive monitoring of the effluent, water column, sea floor, and fish and shellfish. The permit links the monitoring program to a contingency plan, which identifies corrective actions for unexpected impacts resulting from operation of the outfall.

This document, an annual outfall monitoring overview, presents a scientific summary of monitoring data collected through 1999 and includes information relevant to the contingency plan. Because the outfall was not yet operational, these data represent the baseline conditions in the vicinity of the outfall and further afield in Massachusetts and Cape Cod bays. Most MWRA monitoring began in 1992, resulting in a relatively long period in which to conduct baseline studies. This long period has allowed MWRA to document greater natural variability than would have been observed in briefer baseline monitoring.

During 1999, effluent monitoring reflected continued improvements in effluent quality, due to source reduction and the ongoing implementation of secondary treatment. In the water column, the year was marked by low dissolved oxygen levels in the nearfield and in Stellwagen Basin and by very high chlorophyll levels: an atypical summer phytoplankton bloom occurred in the nearfield and throughout most of Massachusetts Bay in August and September. On the sea floor, concentrations of contaminants were similar to those measured in prior years, soft-bottom species diversity appeared stable after increases in the mid-1990s, and hard-bottom communities were stable. Contaminant levels in muscle tissue of fish and shellfish remained well below levels of concern. During 1999, MWRA also conducted several special studies, including studies of Boston Harbor to assess the effects of facilities upgrades, runs of the Bays Eutrophication Model, evaluation of the usefulness of a food web model to characterize important right whale prey, a video survey of plankton, and an ongoing assessment of nutrient flux between the water column and the sediments.

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1. Introduction

Background

Since its creation in 1985, the Massachusetts Water Resources Authority (MWRA) has worked to end long-standing violations of the Clean Water Act that resulted from the discharge of sewage sludge and primary-treated effluent into Boston Harbor. Sludge discharges ended in 1991, and MWRA is working to minimize effects of wastewater discharge. These efforts include source reduction to prevent pollutants from entering the waste stream, improved treatment before discharge, and better dilution once the effluent enters the marine environment.

Source reduction has included projects to lessen household hazardous waste disposal and minimize mercury discharges from hospitals and dentists. An ongoing industrial pretreatment/pollution prevention program ensures that toxic contaminants are removed before they reach the sewer system. New operator training programs and process control and maintenance tracking systems are also in place.

Improved treatment began in 1995, when a new primary treatment plant at Deer Island was brought on line, and disinfection facilities were completed. The first battery of secondary treatment began in 1997. During 1998, the second battery of secondary treatment was completed, and discharge from the Nut Island Treatment Plant ended. Sewage from MWRA’s South System now is conveyed to Deer Island for secondary treatment; discharge into Quincy Bay has ended. A final battery of secondary treatment is scheduled to be completed in 2000 and will be operational in 2001.

Better dilution will be achieved by diverting the effluent discharge from Boston Harbor to a new outfall and diffuser system, located 9.5 miles offshore in Massachusetts Bay (Figure 1-1). The outfall location was selected because it had a water depth and current patterns that would promote effective dilution, it was the least likely to affect sensitive resources, and it was feasible to construct an outfall tunnel to the location.

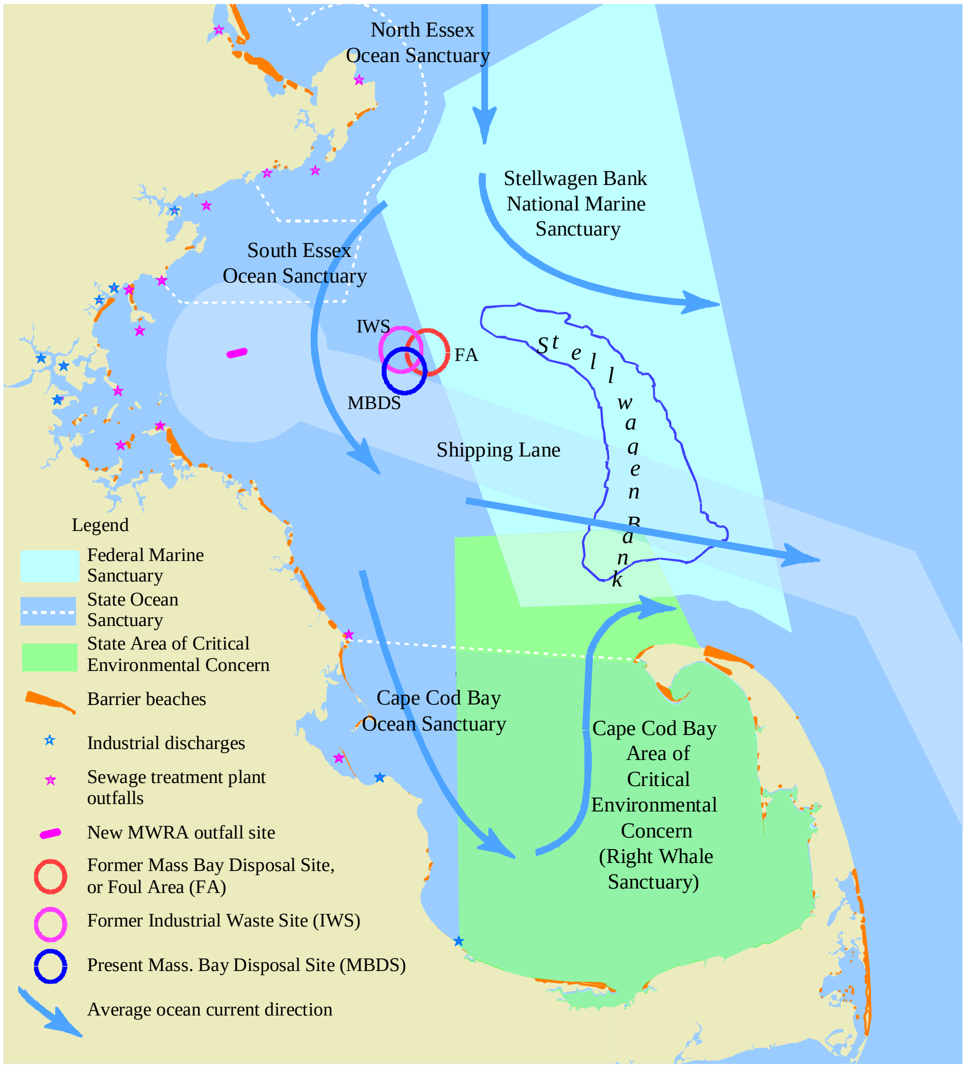

Figure 1-1. Map of Massachusetts and Cape Cod bays

The outfall tunnel is bored through bedrock. It has a diffuser system made up of 55 risers, each with 8 ports, along its final 1.25 miles. Discharge from the diffuser heads is at the sea floor, at water depths of about 100 feet (MWRA 1997a). Initial dilution at the outfall is about 5 times that of the Boston Harbor outfall, which was shallower, in 50 feet of water. The offshore location of the new outfall diffuser ensures that within a tidal cycle, even shoreward currents will not transport effluent to beaches or shellfish beds near Boston, the North Shore, the South Shore, or Cape Cod. Construction of the outfall was delayed by several logistics problems and most recently by an incident in July of 1999 that resulted in the deaths of two workers. The outfall went on-line on September 6, 2000.

MWRA's goals are to make it safe to swim in the harbor, safe to eat fish caught there, to protect marine resources, and to ensure that the harbor becomes and remains a resource that people can aesthetically enjoy, without degrading the offshore environment. For many of the components of MWRA's work, there is little or no argument that the project benefits the marine environment and the people of the region. One aspect of the project, moving the effluent outfall from the harbor to Massachusetts Bay, has caused some concerns. The concerns have been recognized by MWRA and by the joint permit for the outfall issued by the U.S. Environmental Protection Agency (EPA) and the Massachusetts Department of Environmental Protection (MADEP).

Outfall Permit

Discharges from the new outfall are regulated by a permit issued by EPA and MADEP under the National Pollutant Discharge Elimination System (NPDES). The permit, first issued in May of 1999 and finalized in July 2000, limits discharges of pollutants and requires reporting the treatment plant operation and maintenance. It requires MWRA to continue an ongoing pollution prevention program that encompasses all users of the system—industrial, commercial, and residential.

The permit requires MWRA to monitor the effluent and the ambient receiving waters for compliance with permit limits and in accordance with the monitoring plan (MWRA 1991, 1997a) developed in response to the EPA Supplemental Environmental Impact Statement (SEIS, EPA 1988). The permit requires MWRA to update, maintain, and run the three-dimensional Bays Eutrophication Model, and measure the dilution at the discharge. MWRA must implement a contingency plan (MWRA 1997b), which identifies relevant environmental quality parameters and thresholds which, if exceeded, would require corrective action.

EPA and MADEP have established an independent panel of scientists to review monitoring data and provide advice on key scientific issues related to the permit. This panel, called the Outfall Monitoring Scientific Advisory Panel (OMSAP, Table 1-1), was established in 1998, prior to issuance of the permit. OMSAP is to conduct peer reviews of monitoring reports, evaluate the data, and advise EPA and MADEP on implications. OMSAP is also to provide advice concerning any proposed modifications to the monitoring or contingency plans.

OMSAP may form specialized focus groups when specific technical issues require expanded depth or breadth of expertise. Two standing sub-committees also advise OMSAP. The Public Interest Advisory Committee (PIAC) represents local, non-governmental organizations and environmental groups and advises OMSAP on values and uses of the harbor and the bays. The Inter-agency

Advisory Committee (IAAC) represents state and federal agencies and provides OMSAP with advice concerning environmental regulations.

Table 1-1. Roster of panel and committee members

OMSAP as of December 1999

Andrew Solow, Woods Hole Oceanographic Institution (chair)
Robert Beardsley, Woods Hole Oceanographic Institution
Norbert Jaworski, retired
Robert Kenney, University of Rhode Island
Scott Nixon, University of Rhode Island
Judy Pederson, MIT Sea Grant
William Robinson, University of Massachusetts, Boston
Michael Shiaris, University of Massachusetts, Boston
James Shine, Harvard School of Public Health

Catherine Coniaris, New England Interstate Water Pollution Control Commission (OMSAP assistant)

IAAC as of December 1999

- Salvatore Testaverde (chair)
- MA Coastal Zone Management
    - Christian Krahforst
    - Jan Smith (alternate)
- MA Department of Environmental Protection
    - Russell Isaac
    - Steven Lipman (alternate)
- MA Division of Marine Fisheries
    - Jack Schwartz
- National Marine Fisheries Service
    - David Dow (alternate)
- Stellwagen Bank National Marine Sanctuary
    - Anne Smrcina
- US Army Corps of Engineers
    - Thomas Fredette
- US Environmental Protection Agency
    - Matthew Liebman
    - David Tomey (alternate)
- US Geological Survey
    - Michael Bothner

PIAC as of December 1999

- Save the Harbor/Save the Bay
    - Gillian Grossman (chair)
- Association for the Preservation of Cape Cod
    - (Membership in transition)
- Bays Legal Fund
    - Wayne Bergeron
- The Boston Harbor Association
    - Vivian Li
    - Joan LeBlanc (alternate)
- Cape Cod Commission
    - John Lipman
    - Steve Tucker (alternate)
- Center for Coastal Studies
    - Peter Borrelli
- Conservation Law Foundation
    - Anthony Chatwin
- New England Aquarium
    - Marianne Farrington
- Massachusetts Audubon Society
    - Robert Buchsbaum
- MWRA Advisory Board
    - Joe Favaloro
- Safer Waters in Massachusetts
    - Salvatore Genovese
    - Polly Bradley (alternate)
- Stop the Outfall Pipe
    - Mary Loebig
- Wastewater Advisory Committee
    - Susan Redlich

Monitoring Program

EPA and MADEP require monitoring to ensure compliance with the permit, to assess whether the outfall has effects beyond the area identified in the SEIS as acceptable, and to collect data useful for outfall management. In 1989-1991, in anticipation of these requirements, MWRA began to study winter flounder with the Woods Hole Oceanographic Institution (WHOI) and eutrophication issues with the Bigelow Laboratory for Ocean Sciences, and began a long-term sediment transport study with the U.S. Geological Survey (USGS). A broader baseline-monitoring program began in 1992. During the intervening years, both baseline and discharge ambient monitoring plans have been developed and refined (MWRA 1991, 1997a). These plans were developed by MWRA with direction from an Outfall Monitoring Task Force (OMTF), made up of scientists, regulators, and environmental advocacy groups. The OMTF was disbanded upon creation of OMSAP in 1998.

The outfall monitoring program focuses on critical constituents in treatment plant effluent, such as nutrients, toxic contaminants, organic material, pathogens, and solids (Table 1-2). Presence and potential effects of these constituents are evaluated within the context of four environmental measurement areas: effluent, water column, sea floor, and fish and shellfish. This basic program is augmented by special studies that are conducted in response to specific permit requirements, scientific questions, and environmental concerns. The monitoring program is designed to compare environmental quality of the Massachusetts Bays system, including Boston Harbor and Cape Cod Bay, before (baseline) and after (discharge) the outfall location is moved from the harbor to the bay.

Baseline monitoring, which began in 1991 and 1992, was initially planned to last for a minimum of 3 years, as the outfall was originally planned for completion in 1995. Delays in outfall construction have allowed a relatively long period for baseline studies, which has allowed MWRA to document greater natural variability than would have been measured in a briefer baseline period. The extended time has also allowed MWRA to evaluate the response in Boston Harbor to other parts of the Boston Harbor project, such as improved pretreatment, ending sludge discharges, and initiation of secondary treatment of the effluent (Leo *et al.* 1995, Pawlowski *et al.* 1996, Rex and Connor 1997, Rex 2000).

Contingency Plan

The MWRA contingency plan (MWRA 1997b) describes how, if monitoring results indicate a possible environmental problem, MWRA and the regulatory agencies will respond to determine the cause of the problem and to specify the corrective actions that should be taken if the problem appears to be related to the discharge. The contingency plan identifies the parameters that represent environmentally significant components of the effluent or the ecosystem that, if specific levels are exceeded, indicate a potential for environmental risk (Table 1-3). These levels are called thresholds. The plan provides a process for evaluating parameters that exceed thresholds and formulating appropriate responses.

Table 1-2. Summary of the monitoring program

Task	Objective	Sampling Locations And Schedule	Analyses
Effluent			
Effluent sampling	Characterize wastewater discharge from Deer Island Treatment Plant	Weekly	Nutrients
		Daily	Organic material (cBOD)
		Several times monthly	Toxic contaminants
		3x/day	Bacterial indicators
		Daily	Solids
Water Column			
Nearfield surveys	Collect water quality data near outfall location	17 surveys/year 21 stations	Temperature Salinity Dissolved oxygen Nutrients Solids Chlorophyll Water clarity Photosynthesis Respiration Plankton Marine mammal observations
Farfield surveys	Collect water quality data throughout Massachusetts and Cape Cod bays	6 surveys/year 26 stations	
Plume-track surveys	Track locations and characteristics of discharge plume, measure dilution of discharge	To be implemented after the outfall begins operation	Rhodomine dye Salinity Temperature Currents Nutrients Solids Bacterial indicators
Mooring (USGS)	Provides continuous oceanographic data near outfall location	Continuous monitoring Single station 3 depths	Temperature Salinity Water clarity Chlorophyll
Remote sensing	Provides oceanographic data on a regional scale through satellite imagery	Available daily (cloud-cover permitting)	Surface temperature Chlorophyll
Sea Floor			
Soft-bottom studies	Evaluate sediment quality and benthos in Boston Harbor and Massachusetts Bay	20 nearfield stations 11 farfield stations	Sediment chemistry Sediment profile imagery Community composition
Hard-bottom studies	Characterize marine benthic communities in rock and cobble areas	1 survey/year 21 stations on 6 transects	Topography Substrate Community composition
Fish and Shellfish			
Winter flounder	Determine contaminant body burden and population health	1 survey/year 5 locations	Tissue contaminant concentrations Physical abnormalities, including liver histopathology
American lobster	Determine contaminant body burden	1 survey/year 3 locations	Tissue contaminant concentrations Physical abnormalities
Blue mussel	Evaluate biological condition and potential contaminant bioaccumulation	1 survey/year 4 locations	Tissue contaminant concentrations

Threshold values, the measurements selected as indicators of the need for action, are based on permit limits, state water quality standards, and expert opinion. To alert MWRA to any changes, most parameters have “caution” as well as "warning" thresholds. Exceeding caution thresholds could indicate a need for increased attention or study. If a caution level is exceeded, MWRA, on the guidance of OMSAP and the regulatory agencies, may expand the monitoring to track effluent quality and environmental conditions. The data will be examined to determine whether it is likely that an unacceptable effect resulting from the outfall has occurred.

Exceeding warning levels would indicate a need for a response to avoid potential adverse environmental effects. If a threshold is exceeded at a warning level, the proposed response will include both early notification to EPA and MADEP and, if the outfall has contributed to the adverse environmental effects, the quick development of a response plan. Response plans would include a schedule for implementing actions, such as additional monitoring, making adjustments in plant operations, or undertaking an engineering feasibility study regarding specific potential corrective activities.

MWRA's contingency plan is a "living document." That is, every effort will be made to incorporate new scientific information and improved understanding resulting from the monitoring program into appropriate thresholds. A process for modifying the contingency plan is set forth in MWRA's NPDES permit.

Table 1-3. Summary of contingency plan threshold parameters

Monitoring Area	Parameter
Effluent	Fecal coliform bacteria Residual chlorine Total suspended solids Biological oxygen demand Toxicity PCBs Permit violations Total nitrogen load Floatables
Water Column	Dissolved oxygen concentration Dissolved oxygen depletion rate Chlorophyll Nuisance and noxious algae Effluent dilution
Sea Floor	Benthic community structure Sediment oxygen Sediment toxic metal and organic chemicals
Fish and Shellfish	PAHs, pesticides, mercury and PCBs in mussels and flounder and lobster meat Lead in mussels PAHs in caged mussels Liver disease in flounder

Data Management

The outfall monitoring program has generated extensive data sets documenting baseline environmental conditions. At the end of 1999, the database included more than three million measurements. Data quality is maintained through program-wide quality assurance and quality control procedures. After thorough validation, data from field surveys and laboratory analyses are loaded into a centralized project database. Data handling procedures are automated to the maximum extent possible to reduce errors, ensure comparability, and minimize reporting time. Data that are outside the expected ranges are flagged for review. Data reported by the laboratory as suspect (for example, because the sample bottle was cracked in transit) are marked as such and not used in analyses, although they are retained in the database and included in raw data reports. Any corrections are thoroughly documented. Each data report notes any special data quality considerations associated with the data set.

As discharge and monitoring results become available, they will be compared with contingency plan thresholds. Computer programs automatically calculate each threshold parameter value from the data, compare it to the threshold, and notify the project staff if any caution or warning levels are exceeded. Similar computer programs will compare thresholds with data from the effluent monitoring and ambient environment portions of the program.

Reporting

MWRA’s NPDES permit requires extensive reporting on the monitoring program, including all reports submitted to OMSAP for review and regular reports on effluent quality (Table 1-4). Changes to the monitoring program or contingency plan must be reviewed by regulators and published in the *Environmental Monitor*. Data that exceed contingency plan thresholds and corrective actions must also be reported. Data that exceed thresholds must be reported within 5 days after the results become available, and MWRA must make all reasonable efforts to report all data within 90 days of each sampling event.

Reports are posted on MWRA’s web site (www.mwra.com), with hard copies placed in repository libraries in Boston and on Cape Cod. The permit also requires an annual report to Stellwagen Bank National Marine Sanctuary that includes all monitoring data that relate to the sanctuary and documents effects of the discharge on sanctuary resources and qualities. OMSAP also holds an annual, public workshop where outfall monitoring results are presented.

Table 1-4. List of monitoring reports submitted to OMSAP

Report	Description/Objectives
Outfall Monitoring Plan Phase I—Baseline Studies (MWRA 1991) Phase II—Discharge Ambient Monitoring (MWRA 1997a)	Discusses goals, strategy, and design of baseline and discharge monitoring programs.
Quarterly Wastewater Performance Report	Summarize effluent quality, threshold exceedences, and corrective actions
Contingency Plan (MWRA 1997b)	Describes development of threshold parameters and values and MWRA's planned contingency measures.
Program Area Synthesis Reports	Summarize, interpret, and explain annual results for effluent, water column, benthos, and fish and shellfish monitoring areas.
Toxics and Nutrients Issues Reports	Discuss, analyze, and cross-synthesize data related to toxic and nutrient issues in Massachusetts and Cape Cod bays.
Outfall Monitoring Overviews	Summarize monitoring data and include information relevant to the contingency plan.

Outfall Monitoring Overview

Among the many reports that MWRA completes, this report, the outfall monitoring overview, is prepared for each year of the monitoring program (Gayla *et al.*1996, 1997a, 1997b, Werme and Hunt 2000). The report includes a scientific summary of each year of monitoring. When the outfall is discharging, this report will include information relevant to the contingency plan, such as data that exceed thresholds, responses, and corrective activities. If data suggest that monitoring activities, parameters, or thresholds should be changed, the report is to summarize those recommendations.

This year's outfall monitoring overview presents monitoring program results for baseline effluent and field data collected through 1999. The report discusses some baseline results in comparison to contingency plan thresholds that will be based on fixed standards. It also presents data that will be used to develop thresholds once the complete set of baseline data is finalized.

2. Effluent

Background

Pollution Prevention and Wastewater Treatment

The MWRA strategy for improving the environmental quality of Boston Harbor without degrading the Massachusetts and Cape Cod bays region relies on reduction of pollutants at their sources and effective treatment. MWRA's Toxic Reduction and Control Program sets and enforces limits on the types and amounts of pollutants that industries can discharge into the sewage system. Secondary treatment at the Deer Island Treatment Plant is designed to remove at least 85% of the total suspended solids, 85% of the biological oxygen demand, 50-90% of toxic contaminants, 10-15% of the nutrients, and 80 to more than 99% of the pathogens (before disinfection). Making sure that the source reduction program and the treatment plant are working as designed is the most important action MWRA can take to ensure that the relocated outfall does not cause any harm to the environment.

Environmental Concerns

Effluent constituents of concern include nutrients, organic material, toxic contaminants, pathogens, solids, and "floatables." Floatables include oil and grease slicks, as well as plastic and other debris.

In marine waters, nitrogen is the limiting nutrient that controls growth of algae and other aquatic plants. Excess nitrogen can be detrimental, leading to eutrophication and low levels of dissolved oxygen, excess turbidity, and nuisance algal blooms. Compared to other pollutants, nutrients, particularly dissolved forms, are the only components of sewage entering the treatment plant that are not substantially reduced by secondary treatment.

Organic material consumes oxygen as it decays. Even under natural conditions, oxygen levels decline in bottom waters during the late summer, so any effluent component that might further decrease oxygen levels is a concern. An additional effect of too much organic material is disruption of the sea-bottom ecosystem.

Some toxic contaminants can accumulate in marine life, potentially affecting human health if contaminated seafood is consumed. Toxic contaminants can lower survival and reproduction of marine organisms. Toxic metals and organic contaminant levels in MWRA wastewater have dramatically declined since 1989, due to source reduction and secondary treatment. Continued source control and monitoring of contaminants in the effluent should ensure that concentrations remain at low levels.

Pathogens, including bacteria, viruses, and protozoa from human and animal waste, can cause disease. Human exposure to water-borne pathogens can occur through consumption of contaminated shellfish or through ingestion or physical contact while swimming. MWRA is required to meet water quality standards for bacteria.

Suspended solids, small particles of debris in the water column, decrease water clarity, sometimes adversely affecting algae and other marine plants. Excess suspended solids detract from people's aesthetic perception of the environment, as do oil and grease slicks and floating debris.

Table 2-1. Reporting requirements of the outfall permit

Parameter	Sample Type	Frequency
Flow, million gallons/day (MGD)	Flow meter	Continuous
Flow Dry Day, MGD	Flow meter	Continuous
cBOD	24-hr Composite	1/Day
TSS	24-hr Composite	1/Day
pH	Grab	1/Day
Fecal Coliform Bacteria	Grab	3/Day
Chlorine, Total Residual	Grab	3/Day
PCB, Aroclors	24-hr Composite	1/Month
LC50	24-hr Composite	1/Month
C-NOEC	24-hr Composite	1/Month
Settleable Solids	Grab	1/Day
Chlorides (Influent only)	Grab	1/Day
Mercury	24-hr Composite	1/Month
Chlordane	24-hr Composite	1/Month
4,4 – DDT	24-hr Composite	1/Month
Dieldrin	24-hr Composite	1/Month
Heptachlor	24-hr Composite	1/Month
Ammonia-Nitrogen	24-hr Composite	1/Month
Total Kjeldahl Nitrogen	24-hr Composite	1/Month
Total Nitrate	24-hr Composite	1/Month
Total Nitrite	24-hr Composite	1/Month
Cyanide, Total Recoverable	Grab	1/Month
Copper, Total Recoverable	24-hr Composite	1/Month
Arsenic (Total)	24-hr Composite	1/Month
Hexachlorobenzene	24-hr Composite	1/Month
Aldrin	24-hr Composite	1/Month
Heptachlor Epoxide	24-hr Composite	1/Month
PCBs, Total	24-hr Composite	1/Month
Volatile Organic Compounds	Grab	1/Month

Monitoring Design

The main purpose of effluent monitoring is to measure the concentrations and variability of chemical and biological constituents of the effluent. Effluent monitoring is designed to assess compliance with NPDES permit limits, which are based on state and federal water quality standards and criteria, ambient conditions, and the projected dilution at the outfall (Table 2-1). Effluent monitoring also provides accurate mass loads of effluent constituents, so that fate, transport, and risk of contaminants can be assessed.

The permit includes numeric limits for suspended solids, fecal coliform bacteria, pH, chlorine, polychlorinated biphenyls (PCBs), and biological oxygen demand (BOD). In addition, state water quality standards establish limits for 158 pollutants, and the permit prohibits any discharge that would cause or contribute to exceeding of any of those limits. The permit also prohibits discharge of nutrients in amounts that would cause eutrophication. The permit requires MWRA to test the toxicity of the effluent as a whole on sensitive organisms and establishes strict limits based on the tests. Allowable concentrations of contaminants are based on the predicted dilution at the new outfall. Actual dilution will be measured when outfall operation begins, and the allowable concentrations will be altered if dilution is less than had been predicted.

Most parameters require 24-hour composite samples, and some must meet daily, weekly, or monthly limits. Flow is measured continuously. Nutrient measurements include total Kjeldahl nitrogen, ammonia, nitrate, nitrite, total phosphorus, and phosphate. Organic material is monitored by measuring the carbonaceous biological oxygen demand (cBOD). Monitoring for toxic contaminants includes analyses for heavy metals of concern, chlorinated pesticides, PCBs, volatile organic compounds, acid-base neutral compounds, total residual chlorine, and cyanide. Toxicity is tested using whole effluent samples. Tests for acute toxicity include 48-hour survival of mysid shrimp (*Americamysis bahia*, formerly known as *Mysidopsis bahia*) and inland silverside (*Menidia beryllina*). Chronic toxicity is assessed through inland silverside growth and survival and sea urchin (*Arbacia punctulata*) 1-hour fertilization tests. Pathogen monitoring consists of enumeration of fecal coliform bacteria. Total suspended solids (TSS) and settleable solids are also measured. Methods for measuring floatables remain under development.

Results

Average daily flow of effluent from the Deer Island treatment plant in 1999 was 344 million gallons per day, about 10% less than the 5-year average (Figure 2-1). This low flow reflected a drought that occurred during much of the year and resulted in a concentrated influent. Approximately 88% of the flow received secondary treatment. When the final battery of secondary treatment begins operation in 2001, MWRA anticipates that 98% of the flow will receive secondary treatment.

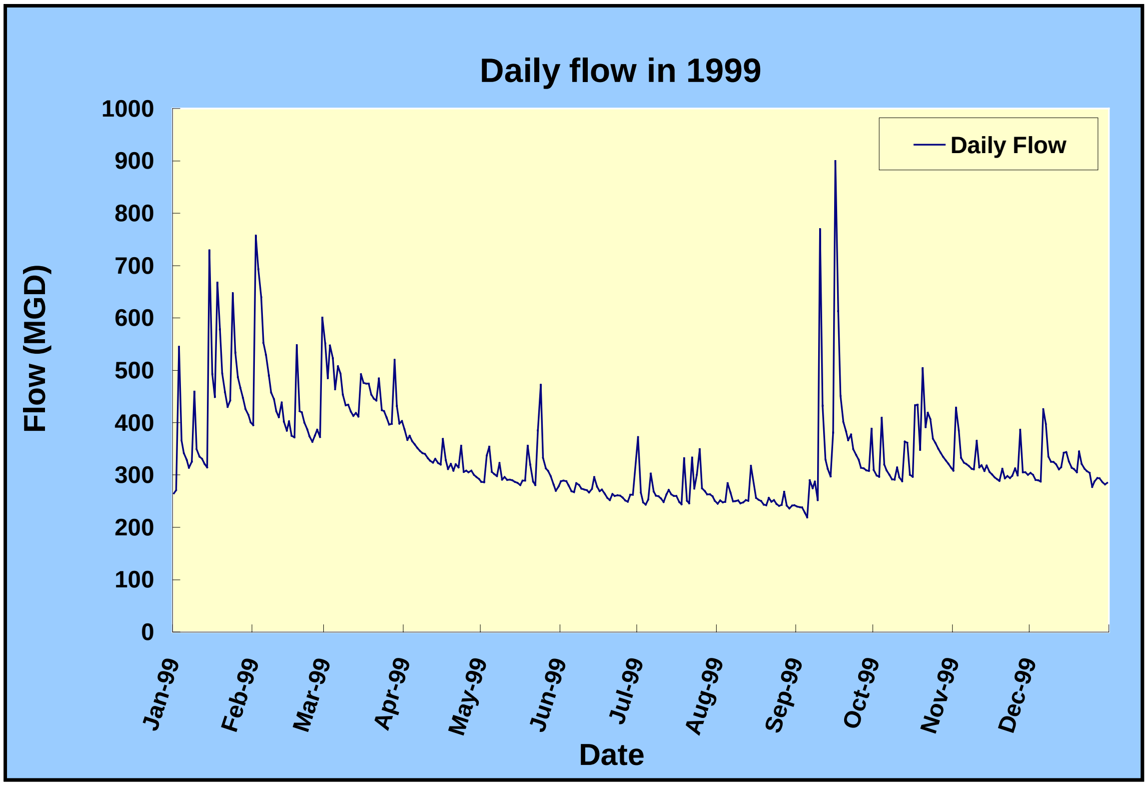

Figure 2-1. Daily effluent flow in 1999

Total solids discharged in the effluent remained low (Figure 2-2). Solids removal has steadily increased, and will continue to improve. When implementation of secondary treatment is completed, MWRA anticipates removal of 94% of the solids. Monthly average TSS and cBOD also remained low in 1999, reflecting the implementation of secondary treatment.

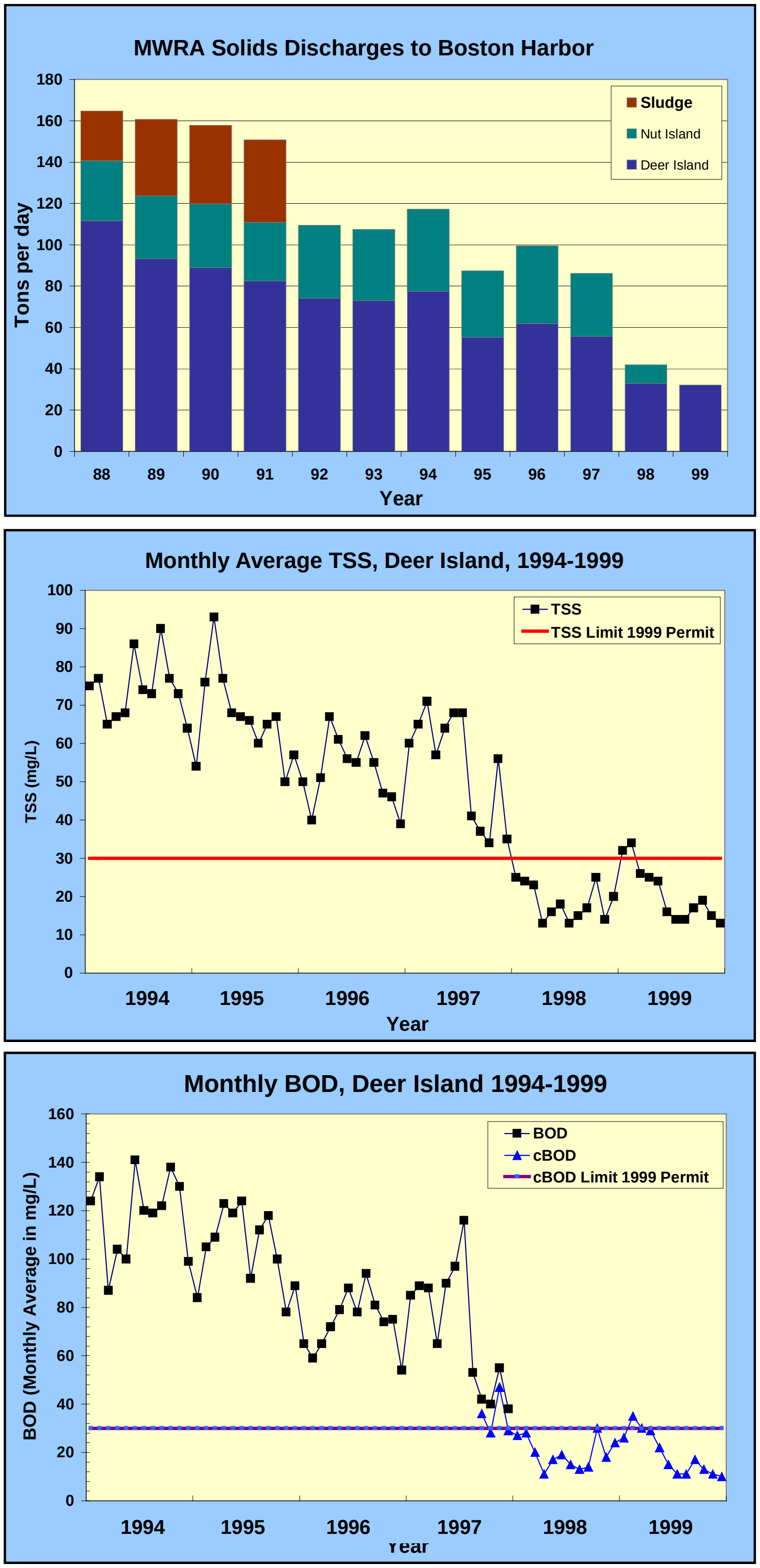

Figure 2-2. Annual solids discharges, monthly TSS, and monthly BOD (measured as cBOD since 1997)

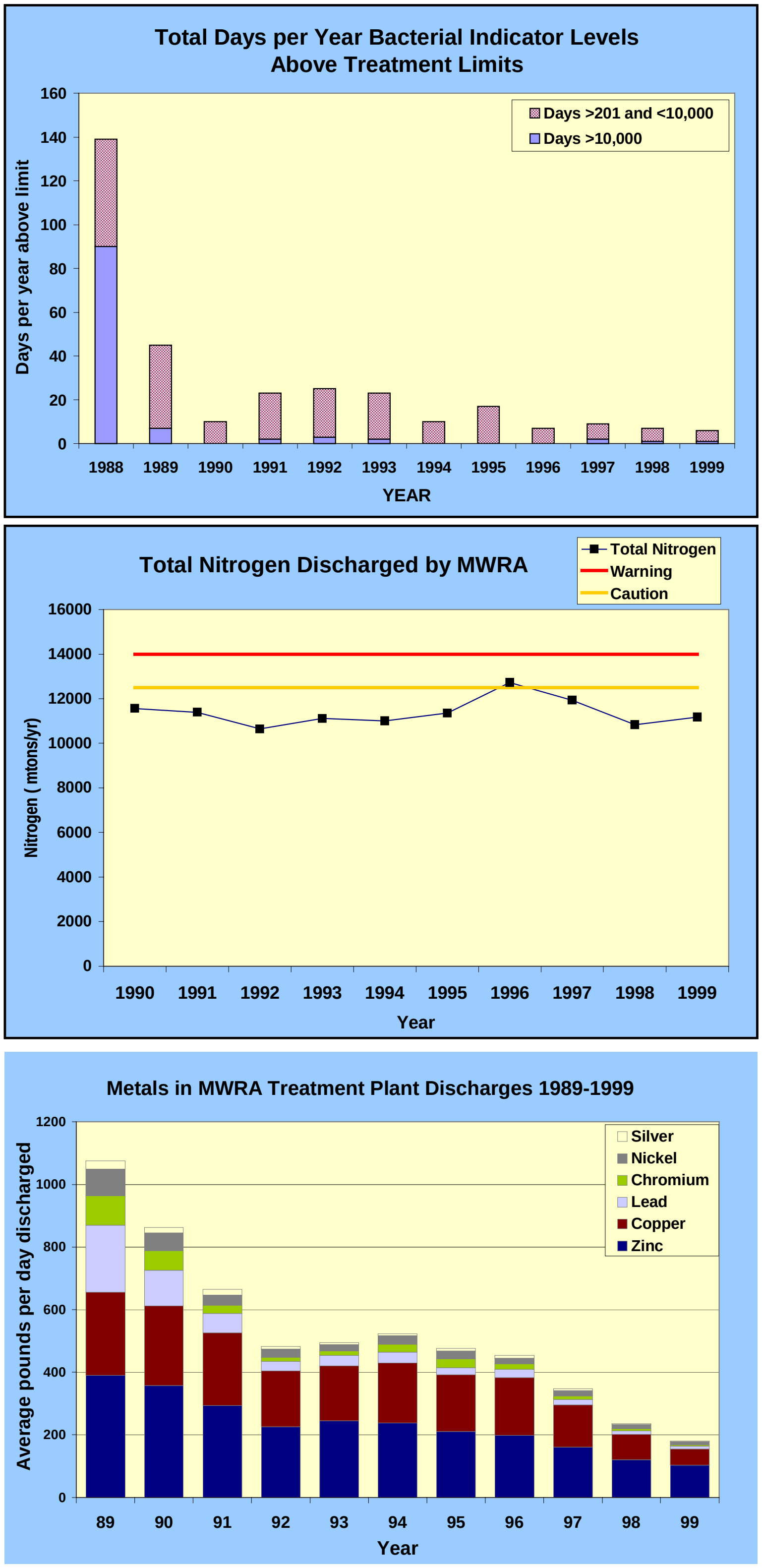

Figure 2-3. Total days per year exceeding bacterial indicator levels, annual nitrogen discharges, and annual metals discharges

The number of days that bacterial indicator levels were above treatment plant levels remained low in 1999, and measurements of contaminant loads were below levels of concern (Figure 2-3). Although secondary treatment effectively removes most contaminants, it has less effect on nutrients. Primary treatment removes 8-9% of the nitrogen, and secondary treatment removes approximately 18-19%. As a result of implementation of secondary treatment in 1997 and 1998, nitrogen loads have been reduced to levels that meet contingency plan thresholds. Of the nitrogen released, 80% is dissolved inorganic nitrogen, and of that, 90% is ammonia.

Removal of toxic compounds continues to improve. For example, the removal rate of the most common metals found in MWRA effluent was 69% in 1999. Overall, contaminant loads are less than had been predicted in EPA's SEIS for the outfall. These differences result from lower than expected flows, effective industrial pretreatment, and also from dramatic improvements to analytical methods since the preparation of the SEIS. Predictions in the SEIS were based on presumptions of contaminant concentrations in samples for which the concentrations were below detection limits. With analytical improvements that have lowered detection limits, MWRA has found that concentrations of contaminants are lower than had been assumed.

Contaminant loads are also lower than had been predicted in a 1997 pilot plant study. That study evaluated high flow and stressed conditions. The actual treatment plant under ambient conditions performs better than the test plant. The lower than predicted loads suggests that potential effects of the outfall may also be less likely than might have been predicted.

Contingency Plan Thresholds

Treatment plant and outfall construction were not complete, and the permit and contingency plan were not in effect during 1999 (Table 2-2). MWRA anticipates continued improvements when the final battery of secondary treatment becomes operational and as secondary treatment continues to be optimized. For example, levels of TSS and cBOD were high in January and February, when flows were high. Only 77% of the flow received secondary treatment in January, and 74.9% received secondary treatment in February. When the third battery of secondary treatment comes on line, it would take an extreme event to have so little flow receiving secondary treatment.

Table 2-2. Threshold values for effluent monitoring (Note that permit was not in place, so direct comparisons to projected caution or warning levels were not routine.)

Parameter	Caution Level	Warning Level	1999 Results
Fecal coliform bacteria*		14,000 fecal coliforms/100 ml (monthly 90th percentile, weekly mean, and daily minimum—minimum of 3 consecutive samples)	Not exceeded
Chlorine, residual		631 ug/L daily, 456 ug/L monthly	Dechlorination not yet available
Total suspended solids		45 mg/L weekly 30 mg/L monthly	Higher than the projected warning level in January and February due to high flows and incomplete implementation of secondary treatment
cBOD		40 mg/L weekly, 25 mg/L monthly	Higher than the projected warning level in January and February due to high flows and incomplete implementation of secondary treatment
Toxicity		Acute: effluent LC50<50% for shrimp and fish Chronic: effluent NOEC for fish survival and growth and sea urchin fertilization <1.5% effluent	Different toxicity tests in place
PCBs		Aroclor=0.045 ng/L	Not exceeded
Permit violations	5 violations/year	>5% of the time	Permit was not in place
Total nitrogen load	12,500 mtons/year	14,000 mtons/year	Not exceeded
Floatables			Threshold revision pending

* Existing standard is 200 col/100 ml; threshold is based on a 70-fold dilution at the new outfall.

3. Water Column

Background

Circulation and Water Properties

Circulation, water properties, and consequently, the biology of Massachusetts and Cape Cod bays are mainly driven by the larger pattern of water flow in the Gulf of Maine (Figure 3-1). A general coastal current flows southwestward, into the bays by Cape Ann to the north of Boston and back out to the north of Race Point at the tip of Cape Cod. During much of the year, a weak counterclockwise circulation persists within eastern Massachusetts Bay and Cape Cod Bay.

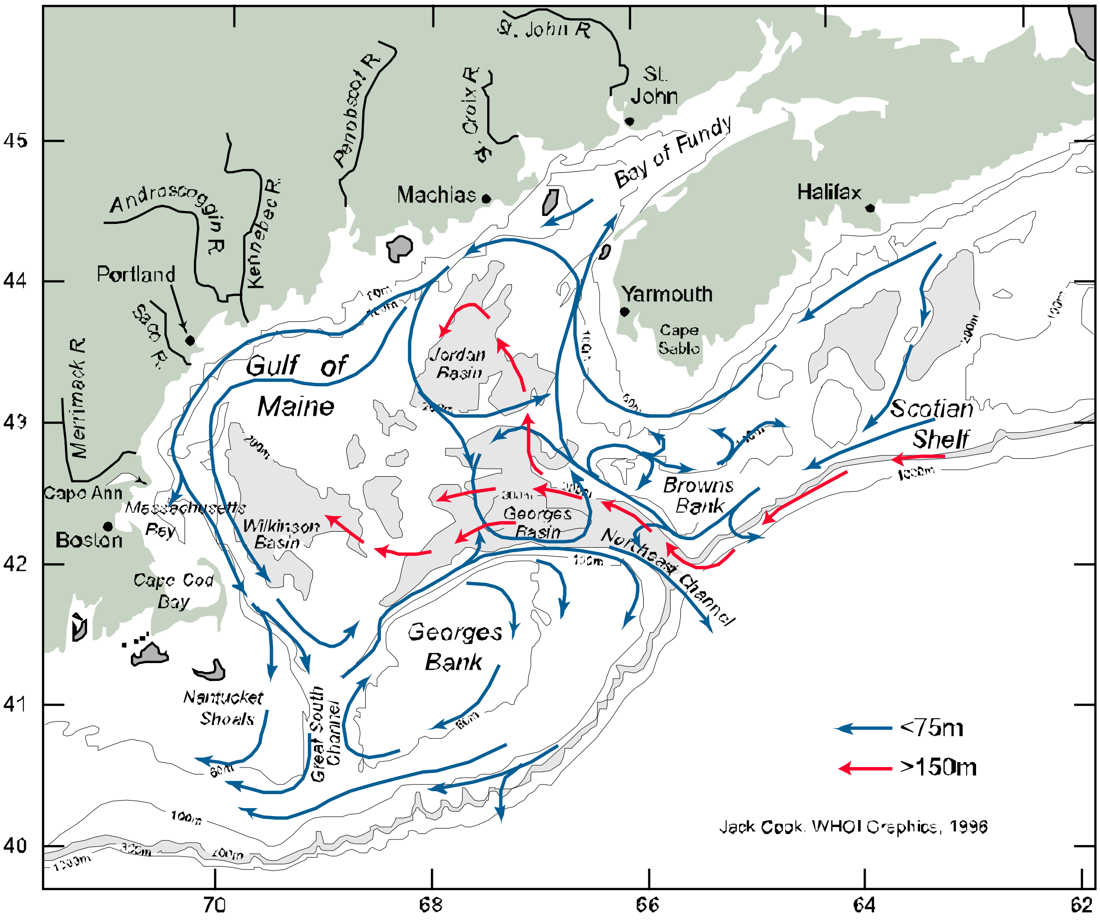

Figure 3-1. General circulation on Georges Bank and in the Gulf of Maine during the summer stratified season

The water quality and biology of the bays have been thought to follow an annual cycle typical for coastal waters, although it is now known that wind and other factors greatly influence the pattern. Typically, during November through April, waters are well mixed, and nutrient levels are high. As light levels increase in the early spring, phytoplankton begin the period of rapid growth known as a spring bloom. Spring blooms do not occur every year in this system. During the years in which a spring bloom does occur, it begins in the shallowest waters of Cape Cod Bay. Blooms in deeper waters begin 2 to 3 weeks later. Spring phytoplankton blooms are typically followed by an increase in zooplankton abundance. Zooplankton populations are food for many animals, including the endangered right whale.

Later in the spring, the surface waters warm, and the water column stratifies. Inputs of freshwater from rivers can contribute to the stratification, with lower salinity water remaining at the surface. Stratification effectively separates the surface and bottom waters, preventing replenishment of nutrients to the surface and of oxygen to the bottom. Surface-water phytoplankton deplete the available nutrients and then undergo senescence, sinking to the bottom. Oxygen levels remain high in the surface waters throughout the year, but oxygen is depleted in the bottom waters. Bottom-dwelling animals respire, and bacteria use up oxygen as they decompose the phytoplankton, so bottom-water oxygen levels are typically lowest during August through October.

In the fall, cooling surface waters and strong winds promote mixing of the water column. Nutrients brought to the surface can stimulate a fall phytoplankton bloom. Typically, fall blooms end in the early winter, when declining light levels limit photosynthesis. Plankton die and decay, replenishing nutrients in the water column.

Surface water temperatures show nearly the same pattern each year. Bottom water temperatures are more variable and are affected by wind patterns. If strong southerly or southwesterly winds, that is, winds from the south or southwest, persist during the summer, then upwelling occurs. Upwelling leads to colder bottom-water temperatures and also higher concentrations of dissolved oxygen. Weaker southerly winds result in less upwelling, with warmer bottom-water temperatures and lower levels of dissolved oxygen.

Environmental Concerns

Water column monitoring focuses on concerns that relocation of the outfall will introduce effects from organic material, nutrients, and toxic contaminants in the effluent. Because organic material and toxic contaminants are effectively removed by secondary treatment, but nutrients are not, changes to the nutrient balance of Massachusetts and Cape Cod bays are thought to have the most potential for affecting the health of marine life in the water column.

Excess nutrients, particularly nitrogen, could promote algal blooms followed by low levels of dissolved oxygen when the phytoplankton die, sink, and decompose. Changes in the relative levels of nutrients could stimulate the growing of undesirable algae. Three nuisance or noxious species are of particular concern: the dinoflagellate *Alexandrium tamarense*, the diatom *Pseudo-nitzschia multiseries*, and the flagellate *Phaeocystis pouchetii*. *Alexandrium tamarense* typically blooms during April to June and can cause paralytic shellfish poisoning, known as PSP or red tide. The toxin, when sufficiently concentrated, can be fatal to marine mammals, fish, and humans. Paralytic shellfish poisoning toxin has been periodically found in Massachusetts since the 1970s. *Pseudo-nitzschia multiseries* blooms can occur during November to March and produce domoic acid, which can cause a condition known as amnesic shellfish poisoning. *Phaeocystis pouchetii* blooms usually occur during February to April but can occur at any time. The species is not toxic, but individual cells can aggregate in gelatinous colonies that are poor food for zooplankton.

Although it is effectively removed by secondary treatment, excess organic material from the wastewater effluent remains a concern. Decomposition of organic matter consumes the oxygen necessary for survival of marine life. Because of the concern that low levels of dissolved oxygen could affect animals in the vicinity of the outfall, it has been important during the baseline-monitoring period to develop an understanding of the natural fluctuations within the system. Modeling and measurements have shown that the periods of low oxygen that are typical in bottom waters appear to be related to temperature and salinity (Figure 3-2, Libby *et al. 2000*). Understanding physical conditions in the region will be important in interpreting monitoring data when the outfall begins operation.

Due to source reduction and treatment, toxic contaminants discharged in the MWRA effluent are projected to be at extremely low concentrations. Effluent dilution will be measured when the outfall begins operation to confirm concentrations of toxic contaminants in the water. Most monitoring for the effects of toxic contaminants will be focused on the sediments, which are known to be contaminant sinks, and on fish and shellfish, which could accumulate organic compounds or metals.

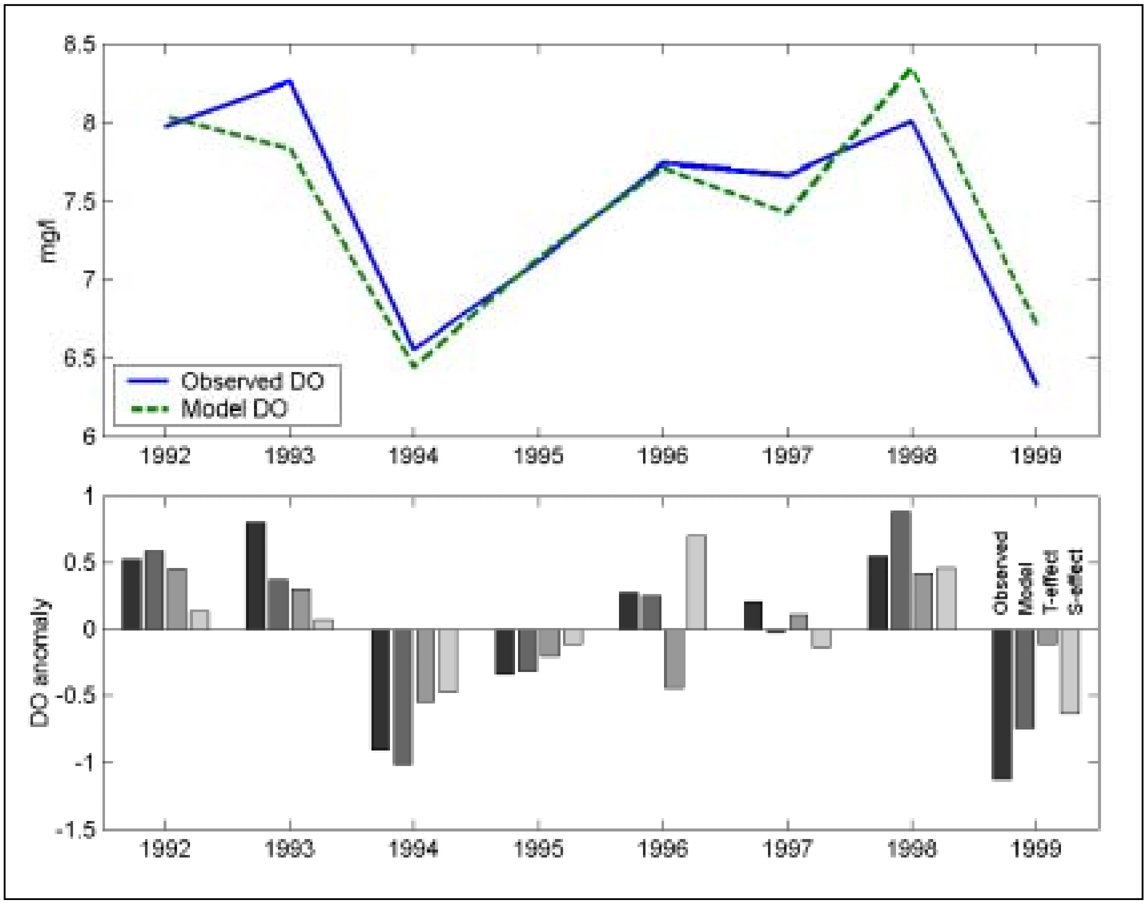

Figure 3-2. Average near-bottom dissolved oxygen during September-October, compared with a linear regression model based on temperature and salinity

Monitoring Design

Water column monitoring includes assessments of water quality, phytoplankton, zooplankton, and incidental marine mammals in Massachusetts and Cape Cod bays. Baseline monitoring includes four major components: nearfield surveys, farfield surveys, continuous recording, and remote sensing. Plume-tracking surveys will be added when the outfall begins operation.

Nearfield surveys provide vertical and horizontal profiles of physical, chemical, and biological characteristics of the water column in the area around the outfall where effects of the effluent would be detected. Farfield surveys assess differences across the bays and seasonal changes over a large area. During 1999, 17 surveys were conducted, including 6 surveys of farfield stations. Samples were taken from 48 stations in Boston Harbor, Massachusetts Bay, and Cape Cod Bay (Figure 3-3). Five stations marked the boundary of the monitoring area and were in or near the Stellwagen Bank National Marine Sanctuary. Additionally, a survey conducted in February 1999 used a towed video microscope to obtain broad regional, high-resolution data on the distribution of dominant plankton species (see Section 6, Special Studies).

Parameters measured in water column monitoring include dissolved inorganic and organic nutrients, particulate forms of nutrients, chlorophyll, total suspended solids, dissolved oxygen, productivity, respiration, phytoplankton abundance and species composition, and zooplankton abundance and species composition. Nutrient measurements include the major forms of nitrogen, phosphorus, and silica.

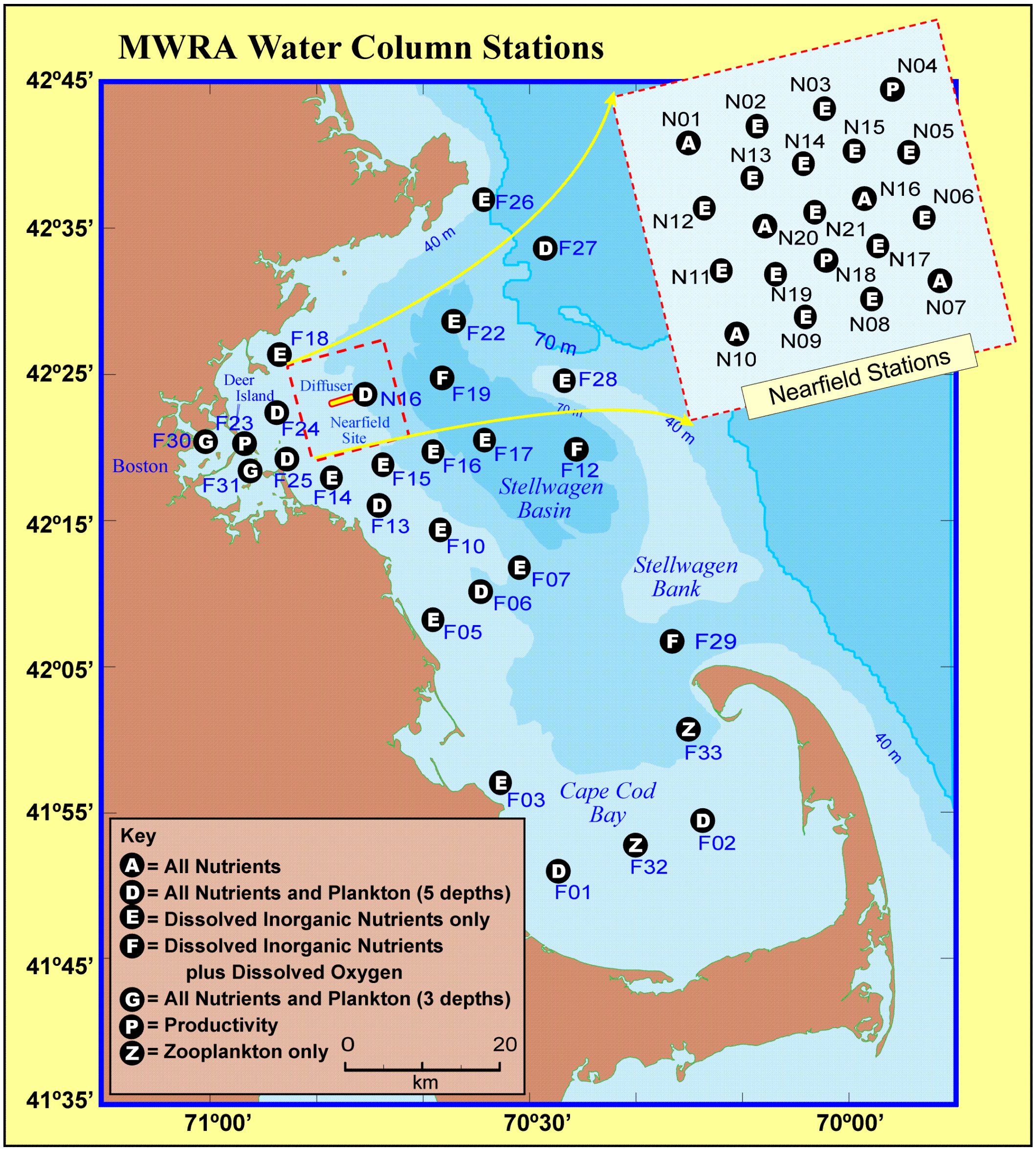

Figure 3-3. Water column sampling stations

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Plume-tracking surveys, not performed in 1999 because the outfall was not on line, will determine the location, migration, and biological and chemical characteristics of the effluent plume leaving the outfall and mixing with the ambient waters. The continuous recording component of the program captures temporal variations in water quality between nearfield water quality surveys. Remote sensing captures spatial variations in water quality on a regional scale.

Certified whale watchers monitor marine mammals on all nearfield surveys and on farfield water column surveys conducted between February and April. Besides providing monitoring data, presence of trained marine mammal observers addresses a request by the National Marine Fisheries Service that MWRA provide observational data and minimize the chances of collision of its survey vessels with a right whale.

Results

Physical Conditions

The winter and spring of 1998-1999 were relatively warm, and the warm trend continued until August. The first part of the year was wet, but from April through September, the region experienced a drought. Boston had the driest April in 129 years of keeping records, and no measurable precipitation fell during the entire month of June. July was the first month since January with greater than average precipitation. September and October brought an active hurricane season. Hurricanes Dennis and Floyd made September one of the wettest in history. The late fall and early winter were relatively dry and warm, and unusually, no snow had fallen on Boston by the end of the year.

Because of the drought, freshwater inputs to the region from the Charles River, the Merrimack River, and the Gulf of Maine were less than average, particularly during April through September (Figure 3-4, Libby *et al.* 2000). Consequently, salinity in surface and bottom waters was high. (Surface salinity in the region of the outfall is inversely correlated with flow from the Charles River, and salinity in deep water is inversely correlated with flow from the Merrimack River.)

Conditions resulted in a typical annual pattern of stratification for 1999. Because of high salinity waters, stratification was largely controlled by water temperature rather than salinity through August. The stratification pattern was broken by fluctuations during the hurricane season.

Wind stress in 1999 was typical for the region. During the winter, winds were predominantly from the northeast, promoting downwelling. During the summer, southwest winds, which promote upwelling, persisted.

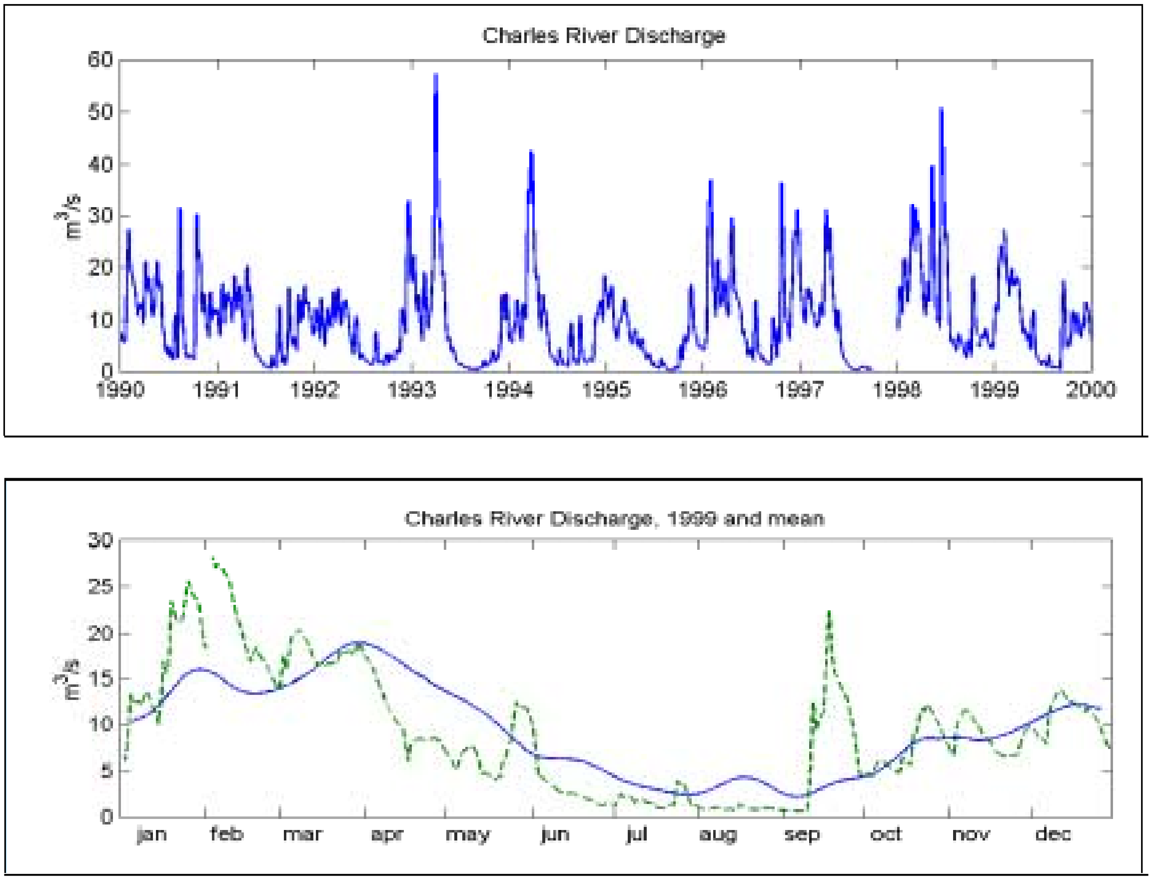


Figure 3-4. Charles River discharge, 1990-1999, and 1999 discharge compared to the historical mean

Water Quality

In a broad sense, the temporal patterns of water quality, primary production, and respiration were typical in 1999, although for many parameters, measurements were the highest or lowest of the monitoring period. An early winter and spring phytoplankton bloom occurred from early February to April, depleting nutrients in the surface waters (Libby *et al.* 2000). Nitrate depletion was not as dramatic as in some years, such as 1992 or 1996 when there were substantial single-species blooms, but it was also not delayed, such as in 1998 when no spring bloom occurred. The highest productivity of the year was measured during this winter and spring bloom. An unusual summer bloom occurred during August, and nutrient concentrations in the nearfield remained depleted throughout this period.

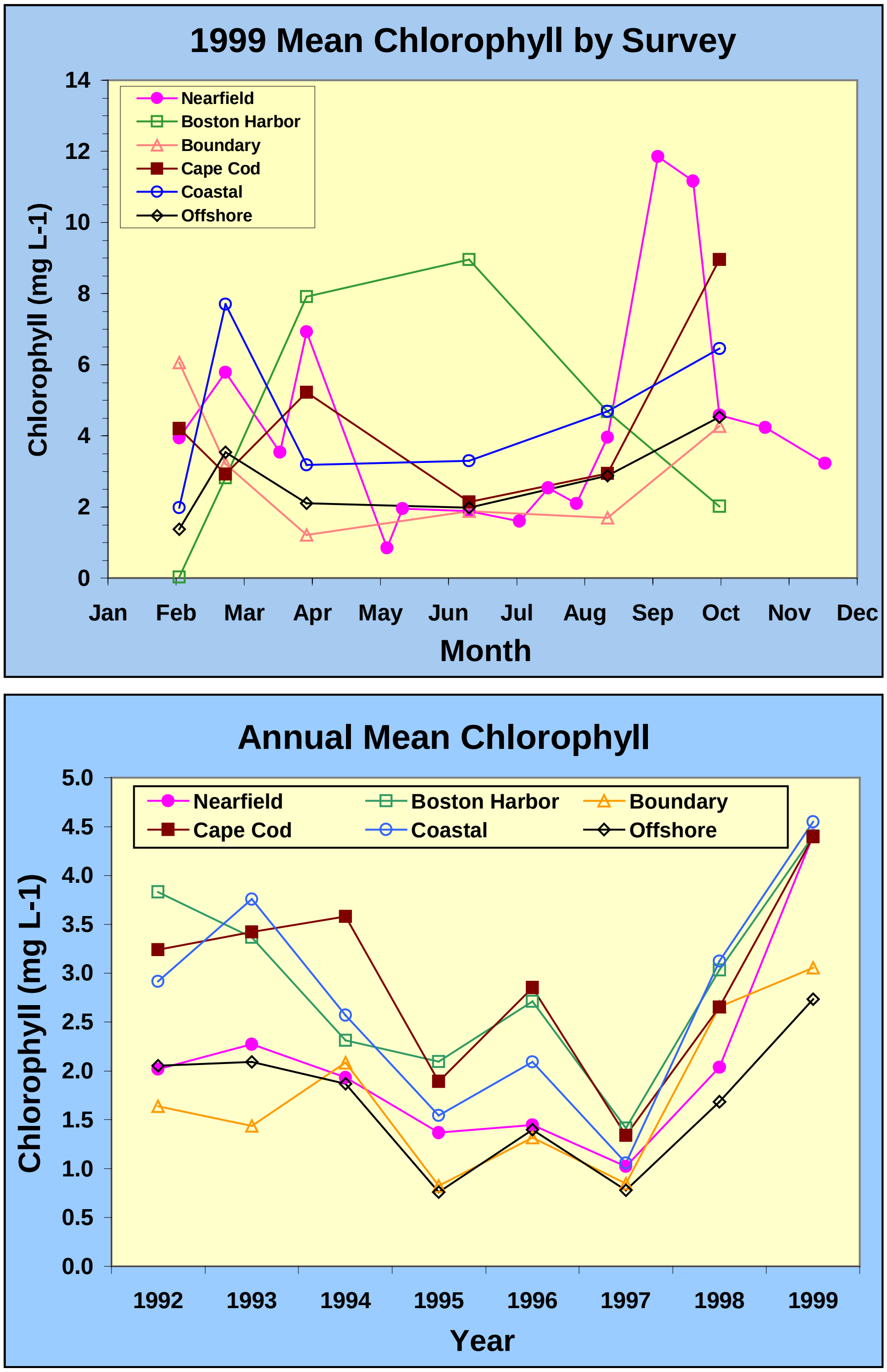


Figure 3-5. Seasonal (top) and annual (bottom) mean chlorophyll. (Stations were grouped regionally: 21 stations in the nearfield, 3 in Boston Harbor, 5 at the system boundary on an arc from Cape Ann to Provincetown, 6 along the coast from Nahant to Marshfield, 8 in offshore waters, and 5 in Cape Cod Bay.)

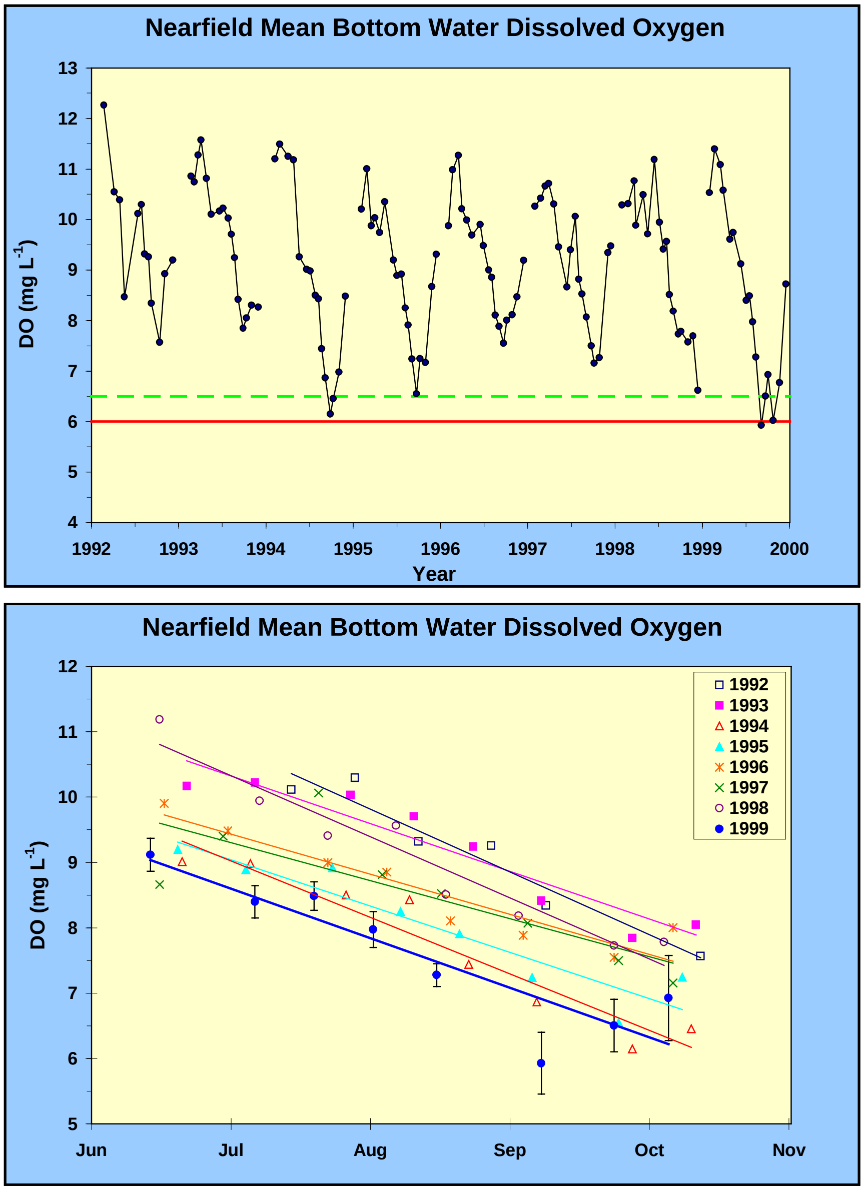
While the annual pattern was typical, concentrations of nutrients and chlorophyll were higher in 1999 than in other years. In 1999, the minimum concentrations of nitrate following the spring bloom were higher than in most previous years for all regions except Cape Cod Bay.

Silica minima exhibited a similar pattern. Ammonia and phosphate concentrations also showed evidence of gradual increases throughout the monitoring period, particularly from 1997 to 1999.

Measurements of chlorophyll concentration reflected the winter and spring bloom, the elevated summer concentrations, and the fall bloom (Figure 3-5, top). Overall, chlorophyll concentrations were extremely high in 1999, particularly in Boston Harbor, the coastal region, and the nearfield, but also in the farfield and at the boundary (Figure 3-5, bottom). In the nearfield, mean chlorophyll concentrations during the winter and spring were higher than in any preceding year, more than twice the levels measured during 1992, 1994, and 1996, years also noted for their spring blooms. Although the 1999 fall bloom was not as substantial as blooms that occurred in 1993 or 1995, chlorophyll concentrations remained high through the summer and fall. Consequently, average chlorophyll concentrations in the fall of 1999 were the highest on record. No significant trend in annual mean chlorophyll concentrations has been detected for the entire baseline period, but there have been increases from 1997 to 1999.

The minimum concentration of dissolved oxygen in the nearfield was lower in 1999 than in any previous baseline-monitoring year (Figure 3-6). Concentrations in Stellwagen Basin bottom waters were also lower than had been measured throughout the monitoring period. The dissolved oxygen minima occurred in September, earlier than some years. Minimum concentrations could have become even lower if Hurricane Floyd had not disrupted the pycnocline in mid-September. The rates of decline in dissolved oxygen concentrations were typical for the period, both in the nearfield and in Stellwagen Basin.

One goal of the MWRA monitoring program has been to develop a better understanding of the environmental processes responsible for anomalies detected during the baseline period. In 1999, the anomalously high salinity resulting from the drought apparently contributed to low dissolved oxygen concentrations. Scientists hypothesize that greater freshwater input into the region increases flow from the Gulf of Maine, reduces residence time of water in Massachusetts Bay, and results in less depletion of the dissolved oxygen (Geyer *et al.*, manuscript in preparation). Dissolved oxygen concentrations are also affected by high biomass and consequent respiration in the water column and the benthos and by the concentration of oxygen at the onset of stratification. During 1999, concentrations of dissolved oxygen were relatively low in June. The input of organic material during the late summer bloom also contributed to the decline.



Year	Slope (mg/L/day)	Intercept* (mg/L)	R^2
1992	-0.024	11.0	0.808
1993	-0.025	11.1	0.885
1994	-0.031	10.1	0.929
1995	-0.027	9.9	0.932
1996	-0.025	10.3	0.978
1997	-0.020	9.8	0.632
1998	-0.032	11.5	0.938
1999	-0.021	9.1	0.964

*Predicted DO on June 1 based on:
DO = Slope * Date + Intercept

Figure 3-6. Survey mean dissolved oxygen and rate of decline in oxygen concentrations in nearfield bottom waters

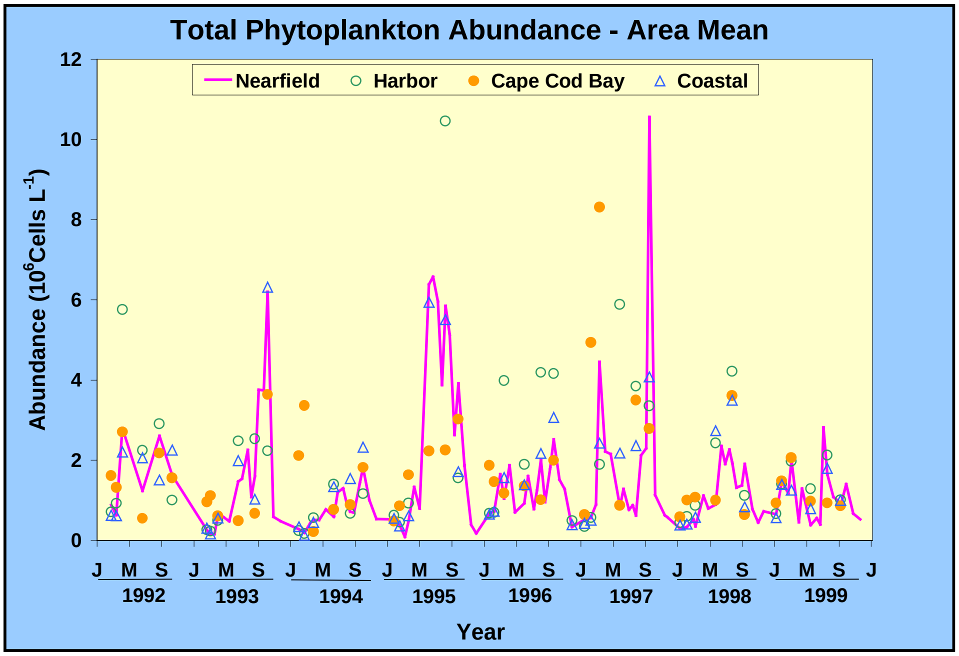


Figure 3-7. Annual mean phytoplankton abundance

Phytoplankton Communities

Species abundance and composition of the phytoplankton communities in 1999 were similar to several years of the baseline monitoring period, including 1992, 1994, 1996, and 1998 (Figure 3-7; Libby *et al.* 2000). As is typical, microflagellates were numerically dominant over much of the year, with diatoms dominating during the winter. Despite the record levels of chlorophyll in 1999, phytoplankton abundance was not exceptional, possibly due to domination by large species, such as chain-forming diatoms in the genus *Chaetoceras*. The peaks in abundance observed during 1993, 1995, and 1997 were not seen in 1999.

The spring bloom in 1999 was primarily made up of diatoms *Chaetoceras* spp. The nuisance species *Phaeocystis pouchetii* was not recorded. Typically, spring communities include diatoms, dinoflagellates, and cryptomonads. In some years, such as 1992 and 1997, *Phaeocystis pouchetii* blooms and dominates the community.

The 1999 summer bloom was composed primarily of microflagellates and the centric diatom *Leptocylindrus danicus*. The summer increase of *L. danicus* was not seen in Cape Cod Bay. Microflagellates, cryptomonads, and diatoms usually dominate much of the region during the summer.

The dinoflagellates *Ceratium longipes* and *C. tripos* were common from August through October of 1999. In western Massachusetts Bay, the 1999 fall bloom was largely made up of diatoms in the genus *Thalassiosira*. Typically in the fall, diatoms are dominant, along with cryptomonads and gymnodinoid dinoflagellates. Single-species blooms may occur. For example, there was a bloom of the diatom *Asterionellopsis glacialis* in the fall of 1993, and there have been periodic outbursts of *Ceratium* spp.

The potentially toxic *Pseudo-nitzschia multiseries* may have been included among taxa identified as *Pseudo-nitzschia pungens* noted in February and in the fall, but *P. pungens* abundance was well below the numbers that call for vigilance and confirmation of the species identity. The toxic dinoflagellate *Alexandrium tamarense* was not recorded during 1999, although a few cells that could not be identified positively were noted during April, May, and July. (Massachusetts Department of Marine Fisheries reported no incidences of paralytic shellfish poisoning toxin in shellfish from the bays during the year.) This species has been recorded in trace but not abundant amounts throughout the baseline period. The frequency of sampling by the general MWRA program may not be appropriate for monitoring this toxin-producing species; programs that target *A. tamarense* during the red-tide season tend to record higher abundances.

Consequently, MWRA also evaluates data from a targeted program directed by Donald M. Anderson at the Woods Hole Oceanographic Institution. *A. tamarense* blooms are thought to originate from seedbeds in Casco Bay, Maine and be transported southward by currents (Anderson 1997). These blooms only occasionally reach Massachusetts Bay when northeast winds cause downwelling conditions and press the Maine coastal current along the shoreline. The southwest winds and upwelling conditions that predominated during the summer of 1999 were not conducive to presence of *A. tamarense* in Massachusetts Bay.

Zooplankton Communities

The 1999, zooplankton assemblages were typical of the baseline-monitoring period (Libby *et al.* 2000). Average abundance was high (Figure 3-8). From February through May, nearfield zooplankton communities were dominated by nauplii, copepodites, and females of the small copepod *Oithona similis* and gastropod veligers. Farfield stations were also dominated by *Oithona similis* and gastropod veligers, as well as the tunicate *Oikopleura dioica*. For several years, large numbers of salps have been recorded in late summer in the region. Typically, salps are considered to be tropical or semi-tropical, and they visit the area incidentally. Overall zooplankton abundance was higher during the summer of 1999 than for any other period during the monitoring program, except for a 1992 pulse of polychaete larvae and other meroplankton. Abundance of the copepodites of the larger copepods *Pseudocalanus* spp. was high during 1999, and there were summer pulses of meroplankton that exceeded similar pulses of previous years.

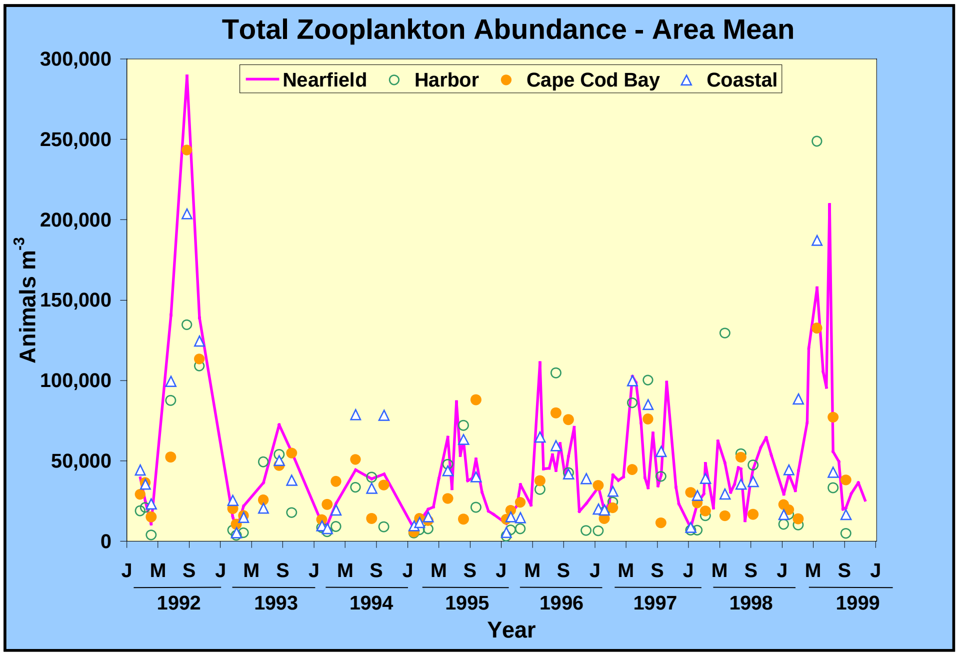


Figure 3-8. Annual mean zooplankton abundance

The usual high abundance of the copepods *Acartia* spp. (*Acartia hudsonica* and *Acartia tonsa*) in Boston Harbor was not observed during 1999. Since these species inhabit low-salinity harbor waters, it is possible that the drought affected the species, particularly the nauplii in the upper reaches of the harbor. Interestingly, an increase in nutrient levels, especially ammonia, in Boston Harbor during 1999 did not stimulate *Acartia* spp. populations. *Acartia* spp. had been thought to be responsive to nutrient loading and therefore a good indicator species for the monitoring program. That relationship has been in doubt for several years, and the 1999 data support the idea that salinity rather than nutrient loading limits *Acartia* spp. abundance.

Marine Mammal Observations

Marine mammal observers were present on all nearfield surveys, 3 of the 6 farfield surveys, and 3 fecal coliform surveys conducted in 1999 (McLeod *et al.* 2000). (As part of an agreement with the Massachusetts Division of Marine Fisheries, MWRA conducts monthly monitoring for fecal coliform bacteria in the outfall area. Other data from those surveys are not included in this report.) During these surveys, 59 individual whales, 10 harbor porpoises, and more than 56 Atlantic white-sided dolphins were sighted by the observers or other members of the survey team (Figure 3-9). Species observed included right, humpback, finback, and minke whales. Forty-nine of the sightings were within the boundaries of the Stellwagen Bank National Marine Sanctuary, and 2 whales were seen in the nearfield.

The data from these surveys are difficult to interpret, because the observations are opportunistic rather than systematic, and whale populations are known to fluctuate between years. In general, observations in 1999 were similar to those in 1998, with at least one large, baleen whale sighted in the vicinity of the outfall in each of the years.

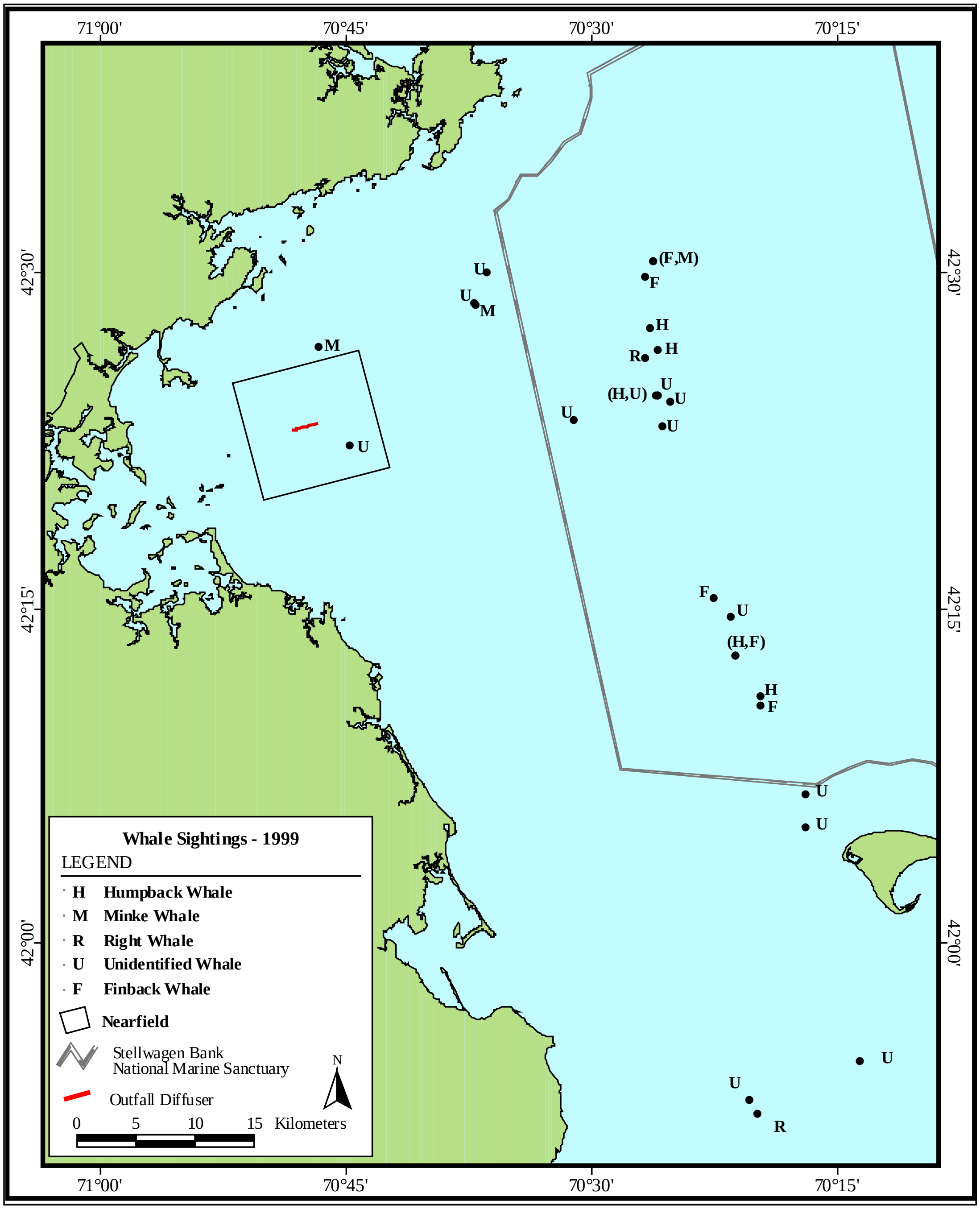


Figure 3-9. Whale sightings in 1999

Contingency Plan Thresholds

Threshold parameters for water-column monitoring include minimum dissolved oxygen concentrations in nearfield and Stellwagen Bank bottom waters, dissolved oxygen depletion rate in nearfield bottom waters, chlorophyll levels, abundance of nuisance algal species, geographic extent of PSP toxin, and initial dilution (Table 3-1). Had 1999 not been a baseline year, thresholds would have been exceeded for low dissolved oxygen in the nearfield and in Stellwagen Basin. These results will be important to consider in evaluating results when the outfall becomes operational. EPA is currently evaluating the national saltwater criterion for dissolved oxygen. OMSAP will consider the national review as well as baseline data in evaluating potential effects of the outfall.

Table 3-1. Threshold values for water column monitoring

Location	Parameter	Caution Level	Warning Level	1999 Results
Bottom water (nearfield and Stellwagen Basin)	Dissolved oxygen concentration	Monthly mean <6.5 mg/L (June-October)	Monthly mean <6.0 mg/L (June-October)	Would have exceeded warning threshold
Bottom water (nearfield)	DO depletion rate	1.5x baseline (June-October)	2x baseline (June-October)	Would not have exceeded projected thresholds
Nearfield	Chlorophyll level	Annual mean >1.5x baseline	Annual mean >2x baseline	Would have exceeded projected warning threshold
Nearfield	Chlorophyll level	95th percentile of the baseline seasonal mean		Would have exceeded projected warning thresholds for winter, spring, and fall
Nearfield	Nuisance algae abundance	Appreciable change in seasonal mean concentration of *Phaeocystis pouchetii*. Also *Pseudo-nitzschia multiseries* > 500,000 cells/L		Nuisance species not abundant in 1999
Farfield	PSP toxin extent	New incidence		No toxin detected in bays
Plume	Initial dilution		Effluent dilution less than predicted by EPA as basis for NPDES permit	No results

Had thresholds developed from 1992-1998 data been in place, chlorophyll concentrations for 1999 would have exceeded the annual warning threshold of 1.5 times the baseline and seasonal warning thresholds for the winter, spring, and fall. The increase in chlorophyll from 1997 to 1999 may reflect both regional and local conditions. Regional cycles and variability in productivity are known to occur. An increase in ammonia discharge from Deer Island may have stimulated productivity within the harbor and in western Massachusetts Bay (see Section 6, Special Studies). MWRA is currently reviewing regional and local information, so that monitoring information collected after the outfall begins operation can be interpreted correctly.

A Massachusetts Department of Marine Fisheries (DMF) monitoring program addresses extent of paralytic shellfish poison toxin in the area. The program traditionally has been conducted from early April through November and has involved sampling of shellfish, primarily blue mussels, from 16 primary stations and, if significant toxin is measured at the primary sites, 47 secondary stations. (Table 3-2 presents the stations of interest to the outfall-monitoring program). PSP toxin was not detected in bay waters in 1999.

Table 3-2. Massachusetts DMF shellfish PSP monitoring stations

Primary Stations	Secondary Stations
Gloucester—Annisquam Yacht Club	Rockport—Granite Street
Hull—Point Allerton	Cohasset—Border Street
Cohasset—Little Harbor	Scituate/Marshfield—South River, Humarock
Scituate—Scituate Harbor	Marshfield—Green Harbor
Marshfield—Damon's Point	Duxbury—Eaglenest Creek
Plymouth—Manomet Point	Plymouth—Plymouth Harbor
Sandwich—Cape Cod Canal	Plymouth—Elisville Harbor
Dennis—Sesuit Harbor	Sandwich—Sandwich Harbor
	Barnstable—Marispan Creek
	Provincetown—The Dike

A Sea Grant program conducted by Donald M. Anderson of the Woods Hole Oceanographic Institution is currently evaluating 30 years of data to refine the monitoring threshold for extent of paralytic shellfish poison toxin. His work to date suggests that significant toxicity at northern stations can be used to predict toxicity at southern stations. After the outfall begins operation, occurrence of toxicity at southern stations without a prior bloom or with low toxicity in the north could be indicative of an outfall effect.

Initial dilution will be measured through a dye study when discharge begins. A warning level would be exceeded if dilution is less than was predicted by EPA as a basis for the permit, and permit conditions would be adjusted.

4. Sea Floor

Background

Bottom Characteristics and Sediment Transport

The sea floor of Massachusetts and Cape Cod bays was originally shaped by the glaciers, which sculpted the bottom and deposited debris, forming knolls, banks, and other features. Within Massachusetts Bay, the sea floor ranges from mud in depositional basins to coarse sand, gravel, and bedrock on topographic highs. The area around the new outfall is marked by drumlins, which are elongated hills about 10 m high, with crests covered by gravel and boulders. Cape Cod Bay, Stellwagen Basin, and Boston Harbor represent long-term sinks for fine-grained sediments (USGS 1997a, 1998).

Sediment transport in the region occurs primarily during storms. Typically, waves during storms with winds from the northeast resuspend sediments, which are transported by shallow currents from western Massachusetts Bay toward Cape Cod Bay and by deeper currents to Stellwagen Basin, where they are likely to remain. Cape Cod Bay is partially sheltered from large waves by the arm of Cape Cod, and storm waves are rarely large enough to resuspend sediments in Stellwagen Basin, which is the deepest feature in the region.

Environmental Concerns

While studies of Boston Harbor sediments are documenting its recovery following the cessation of sludge discharge, improvements to CSO systems, and improved sewage effluent treatment, there are concerns about potential effects of the relocated outfall on the sea floor. Concern is focused on three issues: eutrophication and related low levels of dissolved oxygen, accumulation of toxic contaminants in depositional areas, and smothering of animals by particulate matter. If transfer of the nutrient loads to offshore were to cause eutrophication, depressed levels of dissolved oxygen could profoundly affect bottom communities. Although source control and treatment plant performance are designed to keep effluent contaminant concentrations too low to affect the sediments, the location of the outfall in an area of considerable sediment transport causes concern about accumulation of toxic contaminants in the depositional areas of Cape Cod Bay and Stellwagen Basin. Similarly, concentrations of particulate matter are expected to be low, but there remains some concern that bottom communities could be smothered. The most likely adverse effect of the outfall would be a disruption of normal benthic community structure in the vicinity of the discharge by increasing the amount of food available to the bottom.

Monitoring Design

Sea floor monitoring includes several components: measurements of contaminant concentrations in sediments, sediment-profile imaging to provide a rapid assessment of potential effects, studies of nearfield and farfield soft-bottom communities, and study of hard-bottom communities. For farfield stations located within Stellwagen Bank National Marine Sanctuary, MWRA has obtained a permit to collect sediments. USGS has conducted long-term studies of sediment transport and contaminant levels in Boston Harbor and Cape Cod bays. These projects continue to be active and the data they generate are used by the MWRA monitoring program.

USGS has periodically sampled 4 stations within Boston Harbor since 1977, and on 24 surveys since 1989 they have taken sediment cores three times a year from 2 stations, one sandy and one muddy, near the Massachusetts Bay outfall (USGS 1997b). The MWRA sediment contaminant studies were considered complete after 1995, and then were resumed at four stations in 1998. These stations were selected because they include a high percentage of fine-grained material, with those percentages remaining stable during the monitoring period. They have high concentrations of total organic carbon (TOC) and are located in the zone of effluent particle deposition predicted by the Bays Eutrophication Model. The stations were sampled once per year in 1998 and 1999. After the outfall begins operation, they will be sampled three times per year. Samples are analyzed for spores of the sewage indicator bacterium *Clostridium perfringens*, sediment grain size, TOC, and contaminants.

Sediment-profile image surveys are conducted in August of each year at 20 nearfield and 3 farfield, western Massachusetts Bay, stations to give an area-wide assessment of sediment quality and benthic community status. They provide a more rapid assessment of benthic habitat conditions than is possible from traditional faunal analyses. A system called “Quick Look,” which uses digital video cameras along with film, provides an even faster assessment. A real-time narration of the videotape describes the substrate and estimates depth of the oxidation-reduction potential discontinuity (RPD), the depth at which sediments change from being oxic to anoxic. Later, complete analyses of films provide information on sediment grain size, sediment layering, fauna and structures, general benthic successional stage, prism penetration, surface relief, and apparent color RPD depth.

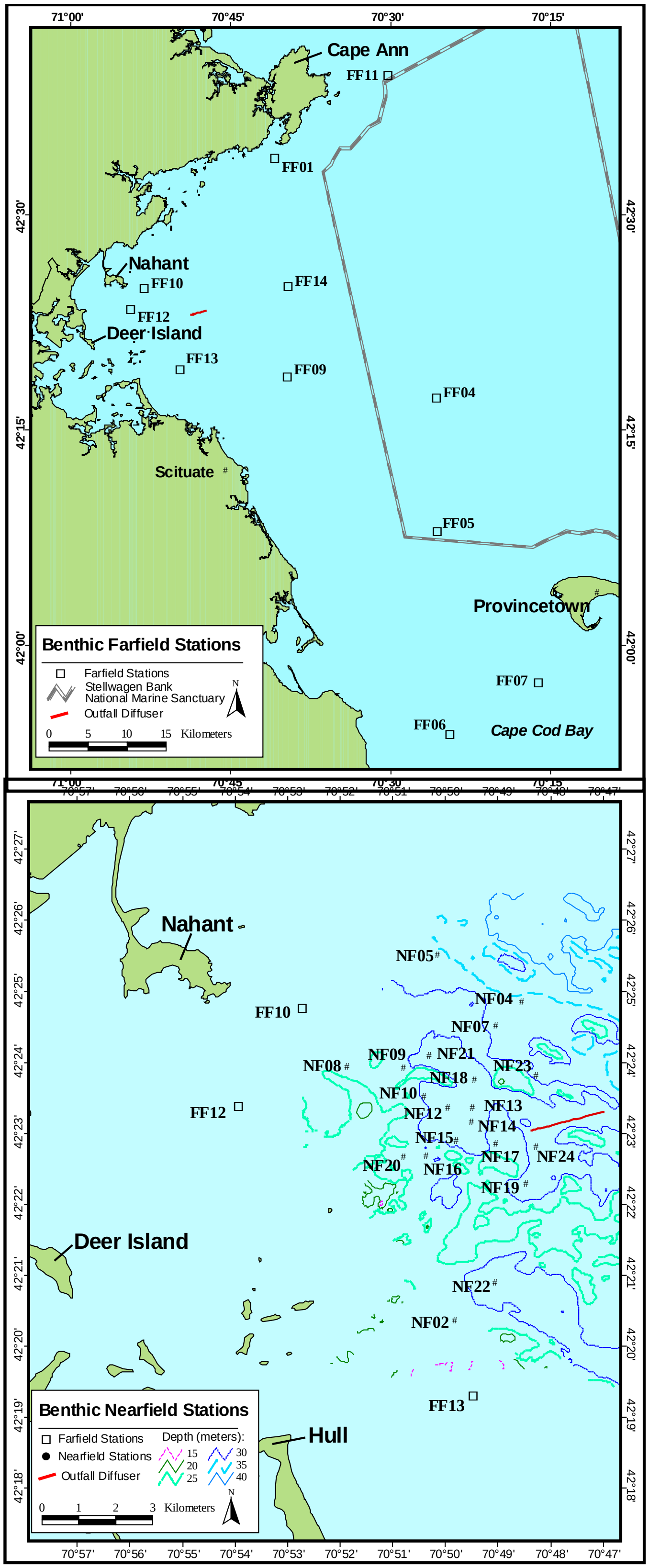


Figure 4-1. Locations of near- and farfield soft-bottom stations (NF12 and NF17 are also sampled by USGS.)

Nearfield and farfield soft-bottom surveys are also conducted in August. Sampling of 20 nearfield stations is designed to provide spatial coverage and local detail about the fauna in depositional areas located within 8 km of the diffusers (Figure 4-1). Farfield sampling of 11 stations in Massachusetts and Cape Cod bays will contribute reference data on soft-bottom habitats. Samples are analyzed for community parameters, *Clostridium perfringens* spores, sediment grain size, and TOC content.

While most studies of benthic communities, including the MWRA monitoring program, focus on the soft bottom areas with finer-grained sediments, such depositional areas are limited in the vicinity of the outfall. Therefore, MWRA also conducts video and photographic surveys of the hard-bottom habitats found on the tops and flanks of drumlins in western Massachusetts Bay (Figure 4-2). Video and still photographs are taken at waypoints along 6 transects and at Diffuser #44 of the outfall (which will not be operational). These surveys are conducted annually in June. Photographs are examined for substrate type, amount of sediment drape, and biota.

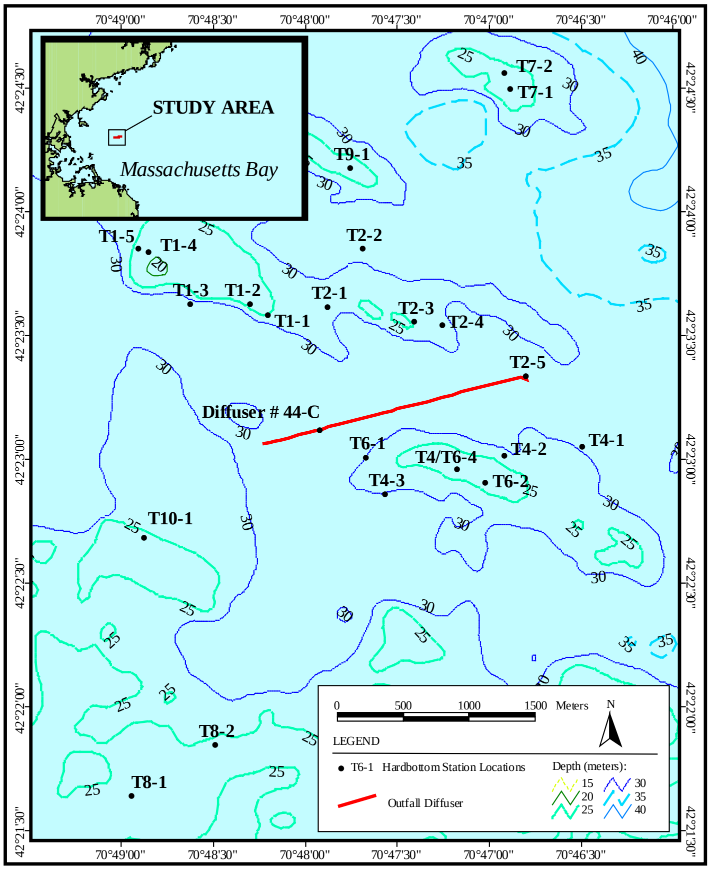


Figure 4-2. Locations of hard-bottom transects

Results

Sediment Contaminants

Spatial distribution of sediment-grain-size patterns and TOC content remained stable in 1999, with no change from 1998. As in previous years, organic and inorganic contaminant concentrations measured in sediments sampled during 1999 were low (Kropp *et al.* 2000). Levels of contaminants remained well below established EPA or NOAA guidelines. Concentrations of chlorinated pesticides remained extremely low, averaging less than 0.1 ng/g. Although consistently low, variability in the concentrations of organic contaminants was found within and among the four stations. Higher concentrations were found in samples with fine sediments and high concentrations of TOC. Concentrations of metals were also extremely low, less than 10 times the method detection limits, and generally less variable than the organic compounds. Contaminant concentrations were less variable in the farfield than in the nearfield, and concentrations of contaminants in Cape Cod Bay were not higher than those in other areas, which might have been predicted from the depositional patterns.

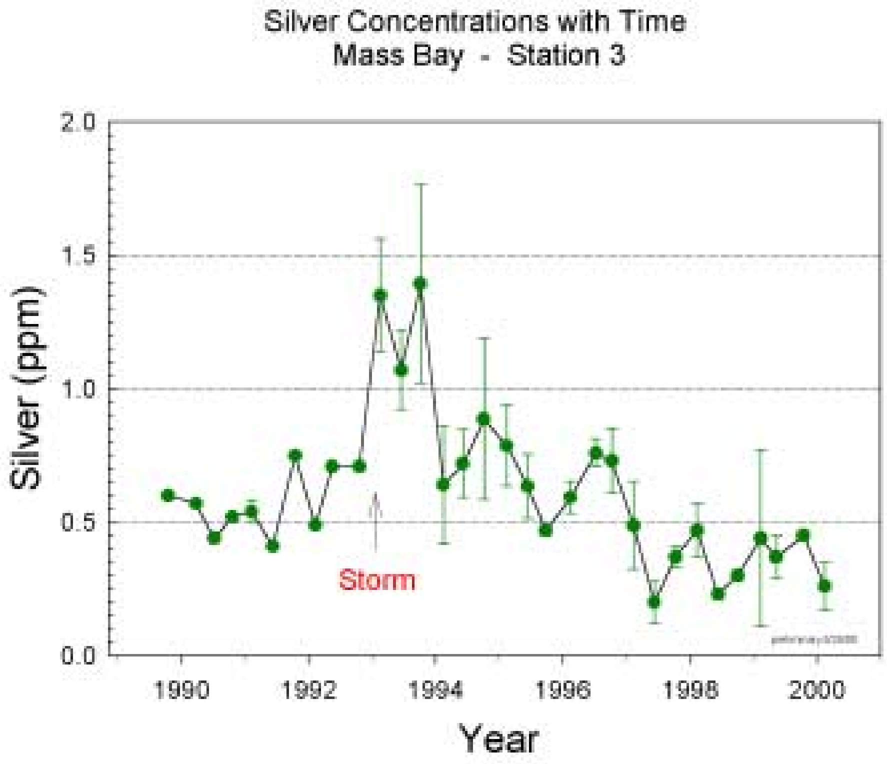


Figure 4-3. Silver concentrations, courtesy of M. Bothner, USGS

The USGS studies have indicated that storms can affect concentrations of contaminants in the sediments (USGS 1997b). Concentrations of silver, *Clostridium perfringens* spores, inventories of natural radioisotopes, and sediment texture in samples from Massachusetts Bay stations changed abruptly between surveys conducted during October of 1992 and February of 1993. Silver concentrations in surface samples from the muddy, depositional station almost doubled during that period (Figure 4-3). USGS attributes these changes to a December 1992 storm with wave heights of 8 m, which probably transported near-shore sediments to the offshore. After 1993, the surface silver concentrations declined to approximately their pre-storm levels.

Figure 4-4. Typical sediment profile image

Sediment Profile Imaging

Sediment profile imaging surveys were conducted in 1992, 1995, and 1997-1999 (Kropp *et al.* 2000). The surveys have focused on areas with fine-grained sediments, and throughout the monitoring period, the sampling stations have consistently had fine sand to silty-fine sand as the dominant sediment type (Figures 4-4, 4-5). Despite the consistently fine sediments, assessment of the apparent color RPD at many stations has suffered from shallow penetration of the prism. At many stations, one or more replicate image has not penetrated deeply enough to see the RPD layer. Allowing for these difficulties, there appears to be no temporal trend in depth to the RPD. If a trend could be detected, it would seem that the depth to the RPD has become shallower, although the average depth to the RPD was slightly deeper in 1999 than in 1998. On the other hand, the surveys have indicated that in more recent years, biological rather than physical processes are structuring the environment. In 1992, 1995, and 1997, pioneering or “Stage I” communities prevailed in the nearfield.

Stage II fauna became more prevalent in 1998 and 1999. During 1998, many pictures indicated the presence of tube-dwelling animals, and in 1999 surface-tube-building animals became abundant. These changes appear to be regional rather than local and are likely to be related to the physical forces that dominate the area.

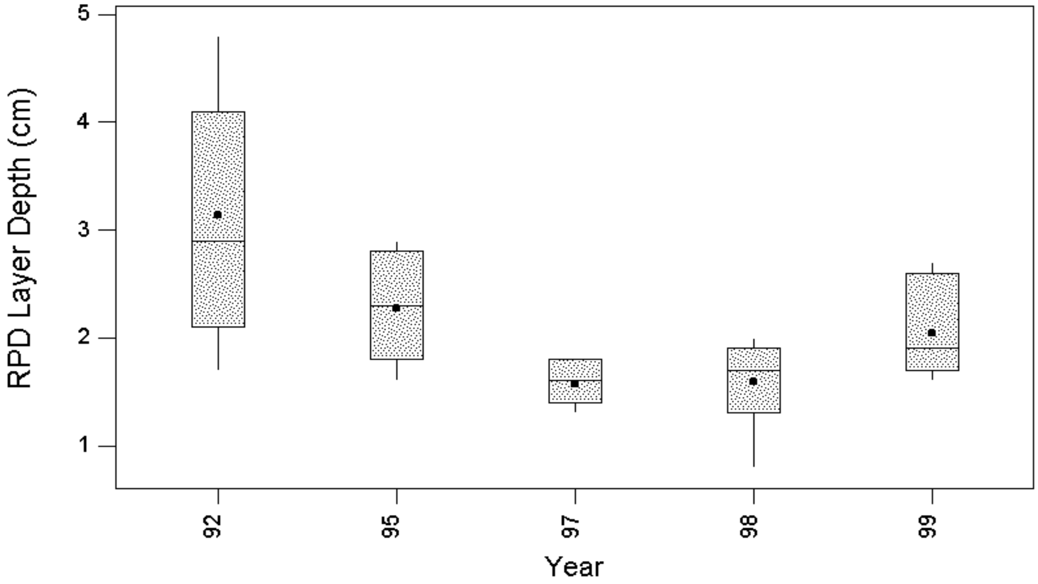


Figure 4-5. Apparent color RPD layer depth for the seven nearfield stations that had no missing values. (Center bar is median, dot is mean, box is interquartile range, and whiskers are total range of the station data.)

Soft-bottom Communities

Soft-bottom benthic communities have been distinguished throughout the monitoring program by their patchiness (Kropp *et al.* 2000). As in previous years, annelid worms were the most abundant higher-level taxon at both nearfield and farfield stations in 1999, accounting for more than 80% of the fauna at most stations. Crustaceans were the second most abundant fauna in the nearfield, and mollusks were typically the second most abundant in the farfield.

Multivariate analyses have indicated that the grouping by which stations can be sorted vary somewhat from year to year. In the nearfield, there are two major groups. One group is associated with medium to fine sandy sediments, and tends to include polychaetes and crustaceans. Another group, associated with siltier sediments, includes polychaetes, particularly the most common organism in the nearfield, *Prionospio steenstrupi*, and the nutclam *Nucula delphinodonta*. Some nearfield stations with variable sediments can be similar to either group in different years.

Multivariate analyses divide the farfield stations into three groups. An inshore group is characterized by polychaetes, including *P. steenstrupi*, and the nutclam. An offshore, deeper group, with siltier sediments, is characterized by a diverse set of polychaetes and the bivalve *Yoldia sapotilla*. Stations within Cape Cod Bay have silty sediments, dominated by polychaetes, including *Tharyx acutus*, and the amphipod *Leptocheirus pinguis*.

Over the course of the baseline monitoring period, the benthic communities of nearfield and farfield stations have exhibited somewhat different patterns (Figure 4-6). In both regions, there has been an increase in the total number of individual animals per sample and species richness over the course of the entire program. (Species richness is measured as the number of species within a sample and as log-series alpha, an index that is insensitive to sample size or evenness.) In the nearfield, the average number of species decreased about 33% from 1992 to 1993. Numbers of species subsequently rose until they appear to have leveled off in 1997-1999. Diversity, measured as log-series alpha, also decreased between 1992 and 1993 and then increased until leveling off. In the farfield, there was no decrease in number of species or log-series alpha between 1992 and 1993. There were, however, subsequent increases in both measurements.

MWRA has considered various explanations for the increase in species richness at both nearfield and farfield stations. There is no evidence of any effect due to changes in methods or increasing familiarity of analytical staff with the fauna.

There has also been no evidence that eutrophication has resulted in increased transfer of nutrients to the bottom communities. Although the water-column monitoring program has suggested that nutrients and chlorophyll have increased (Libby *et al.* 2000, summarized in Section 3, Water Column), those increases appear to primarily have occurred during the late 1990s, while the increased benthic species richness occurred earlier. Concentrations of chlorophyll in both nearfield and farfield waters were lower during 1995-1997, the years of increasing benthic species richness, than were chlorophyll concentrations during 1992-1994 or 1998-1999. Further, there are no concurrent trends in benthic oxygen metabolism or nutrient flux to the bottom that would indicate that the region became more eutrophic during the mid 1990s (Tucker *et al.* 2000, summarized in Section 6, Special Studies).

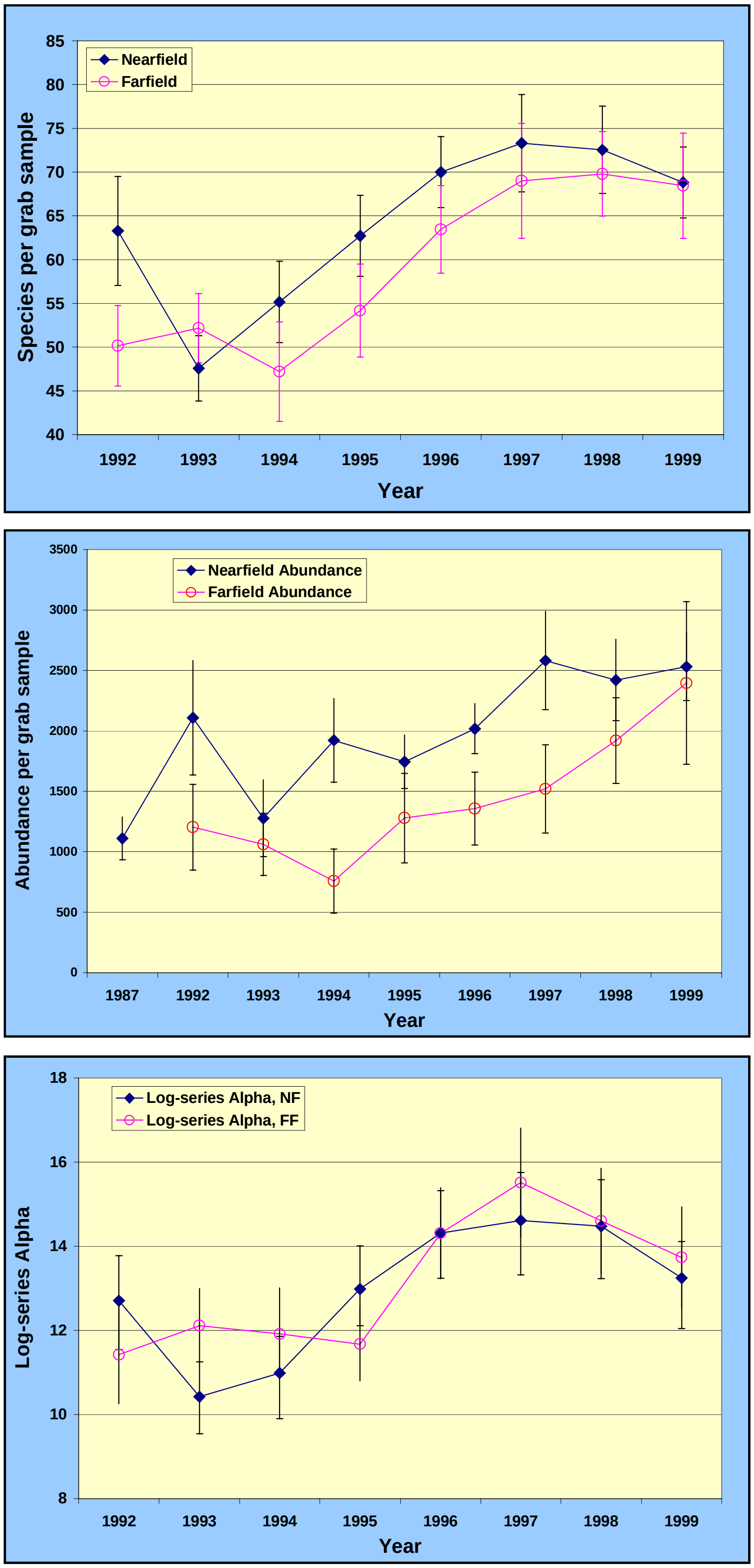


Figure 4-6. Community parameters for soft-bottom communities

The pattern in the nearfield soft-bottom communities may reflect the destruction and recovery from storm surges following the mid-December 1992 storm, which also seemed to have affected concentrations of silver in the surface sediments. Between 1992 and 1993, the sediments at one MWRA station changed from 80% mud to 99% sand.

It is also possible that the benthic populations of the region are exhibiting a cyclic pattern. Cycles of 7-8 years, driven by weather patterns, have been observed in other benthic communities. Although the MWRA baseline-monitoring program has been conducted over a relatively long period, such cyclic patterns would be on a time scale that could not be confirmed without additional years of study. Recognizing that a change in species richness at the time that the outfall begins operations could be interpreted as an effect of the outfall, MWRA will continue to compare trends observed in the nearfield with those observed in the farfield.

Hard-bottom Communities

Analyses of the past 5 years of video and still photographs have shown a temporally stable pattern in the structure of hard-bottom communities (Figure 4-7; Kropp *et al.* 2000). MWRA was not able to include Diffuser #44 in its 1999 survey, however videotape recorded as part of an engineering study indicated that the community at the diffuser also remained stable. There was no indication that the amount of sediment drape was greater in 1999 than in prior years, an outcome that had been suggested to be a possible effect of the strong spring phytoplankton bloom. The amount of sediment drape varied within sites, with totally clean rocks adjacent to rocks heavily covered with sediment. Consequently, there was considerable small-scale, within-site heterogeneity in distributions of many taxa. However the consistency over time indicates that a major change between years should be readily detectable.

As in previous years, algae were the most predominant taxa in 1999, including the encrusting coralline algae presumed to be *Lithothamnion* spp., dulse, and red filamentous species. Among animal taxa, the sea star *Asterias vulgaris* was the most common, along with horse mussel *Modiolus modiolus*. The cunner *Tautogolabrus adspersus* was the most common fish. Algae usually dominated the tops of drumlins, while encrusting or attached invertebrates were increasingly dominant on the flanks. Abundance of the encrusting coralline algae has been inversely correlated with sediment drape throughout the baseline-monitoring program, percent cover being greatest in areas with the least sediment. This relationship is not surprising, because an encrusting growth form makes organisms susceptible to smothering. Consequently the coralline algae may be good indicators of outfall effects.

Figure 4-7. Typical hard-bottom survey photograph

Contingency Plan Thresholds

Threshold parameters for sea floor monitoring include contaminant concentrations, RPD depth, and benthic diversity and species composition in soft-bottom communities (Table 4-1). For contaminants, a caution level has been set at 90% of EPA or NOAA sediment guidelines. To date, all contaminant concentrations have been well below that level. The number of sampling stations included in the program would readily detect a caution level of decline in the RPD depth to half of its baseline level. Levels measured have ranged from 1.73 cm in 1998 to 3.02 measured in 1995.

The caution level for a change in species diversity will also be based on the entire set of baseline data. During 2000, OMSAP plans to refine the wording of the threshold. While modest changes are expected and acceptable in the area right around the outfall, "modest" has not been well defined, nor has the shape and extent of the area of impact. MWRA has evaluated the possible outcomes of setting thresholds as the 5th and 95th percentiles of baseline parameters. Two community measurements, Shannon's diversity *H'* and Pielou's evenness *J'*, have decreased since 1996, and if these decreases continued, the threshold would be likely to be crossed. Two other measurements, total number of species and log-series alpha, are so closely correlated that only one measurement may be necessary for a meaningful threshold.

Table 4-1. Threshold values for sea floor monitoring

Parameter	Caution Level	Warning Level	1999 Results
Depth of redox potential discontinuity	Redox potential discontinuity declines to less than half the baseline depth		Within baseline range, would not have exceeded projected threshold
Contaminants	90% of EPA or NOAA sediment guidelines	EPA sediment criteria	Not exceeded
Benthic diversity	Appreciable change after allowing for storm effects		Within baseline range, would not have exceeded projected threshold
Species composition	10% of abundance is opportunistic species	25% of abundance is opportunistic species	Not exceeded

5. Fish and Shellfish

Background

Fisheries

The fish and shellfish industry is an important part of the regional identity and economy of Massachusetts. During 1998 (NMFS fisheries statistics for the most recent year for which data are available), the total Massachusetts fishery was valued at more than $200 million. Almost 25% of that total was attributed to the lobster fishery. Winter flounder, cod, goosefish (marketed as monkfish), and sea scallops made up another 40% of the total value of the fishery. Although many shellfish beds are closed due to coastal bacterial contamination, the potential fishery for oysters and clams remains important to the region.

Recreational fishing is also important in coastal Massachusetts. Striped bass, bluefish, flounders, and cod are the most popular sports fisheries within the Massachusetts territorial sea (NMFS recreational fisheries data for 1998).

Environmental Concerns

One concern about relocating sewage effluent offshore, into relatively clean waters, is that contaminants could adversely affect resource species, either through direct damage to the fishery stocks or by contamination of the fish, lobster, and other shellfish. Because many toxic contaminants adhere to particles, animals that live on the bottom, in contact with sediments, and animals that eat bottom-dwelling organisms are most likely to be affected. Exposure to contaminated sediments could result in fin erosion, black gill disease, or other, more subtle, abnormalities in flounder, lobster, or other bottom-dwelling animals. Shellfish that feed by filtering suspended matter from large volumes of water are also potential bioaccumulators of toxic contaminants. These shellfish are themselves resource species. Also, consumption of these animals by predators could result in transferring contaminants up the food chain and ultimately to humans.

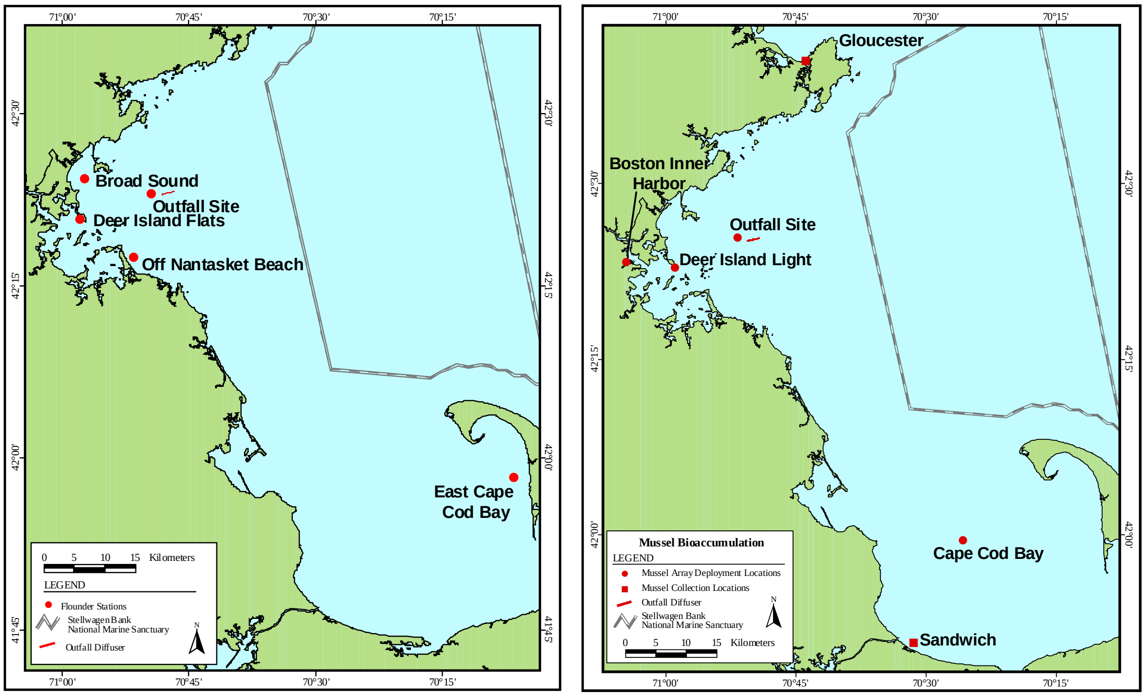


Figure 5-1. Flounder sampling stations (left) and mussel deployment sites (right). Lobsters are taken from Deer Island Flats, eastern Cape Cod Bay, and the outfall site.

Monitoring Design

The monitoring program focuses on three indicator species: winter flounder, lobster, and blue mussel (Figure 5-1). Winter flounder and lobster are important resource species in the region. The blue mussel is also a fishery species and, when deployed in caged arrays, is a common biomonitoring organism.

Like all flatfish, winter flounder live on and eat food from the bottom, often burying themselves in the sediments. Consequently, flounder can be exposed to contaminants directly, through contact with the sediments, or indirectly, by ingesting contaminated prey. Flounder are collected from stations within Boston Harbor and the bays to obtain specimens for age determination, gross examination of health, chemical analyses, and liver histology. Chemical analyses of tissues are made to determine tissue burden and to evaluate whether contaminant burdens approach human health consumption limits. Chemical analyses of composite samples of fillets and livers include PCBs/pesticides and mercury. Liver samples are also analyzed for PAHs, lead, silver, cadmium, copper, nickel, and zinc. Livers are examined to quantify three types of vacuolation (centrotubular, tubular, and focal, representing increasing severity), microphage aggregation, biliary duct proliferation, and neoplasia or tumors. These histology parameters have been associated with chronic exposure to contaminants.

Lobsters live on a variety of surfaces within the region, including mud, sand, gravel, and rock outcrops. Commercial lobstermen collect lobsters for the monitoring program, with on-board scientists verifying the sampling locations. Lobsters are taken from Deer Island Flats, the area near the new outfall in Massachusetts Bay, and eastern Cape Cod Bay to determine specimen health and tissue contaminant burden. Chemical analyses are performed on composite samples. Meat (from the tail and claw) and hepatopancreas are analyzed for PCBs/pesticides and mercury. Hepatopancreas samples are also analyzed for PAHs, lead, silver, cadmium, chromium, copper, nickel, and zinc.

Like other filter feeders, blue mussels process large volumes of water and can concentrate toxic metals and organic compounds in their tissues. Mussels can be readily maintained in fixed cages, so they are convenient monitoring tools. Mussels are collected from reference sites in Gloucester and Sandwich and deployed in replicate arrays at five sites. Gloucester mussels provide a reference for organic contaminant analyses, and Sandwich mussels provide a reference for inorganic contaminants. Separate groups are used as references, because mussels harvested in Gloucester have very low levels of organic contaminants, and mussels from Sandwich have very low levels of metals. After a minimum deployment of 40 days or a preferred deployment of 60 days, chemical analyses are performed on composite samples of mussel tissue. Gloucester mussel tissue is analyzed for PCBs/pesticides and PAHs. Sandwich mussel tissue is analyzed for mercury and lead.

Results

Winter Flounder

Fifty sexually mature (4-5 years old) winter flounder were taken from each of the five sampling sites in April and May 1999 (Lefkovitz *et al.* 2000). Each of the fish was examined for physical characteristics, then 15 were designated for chemical analyses, and all 50 were used for histological analyses. Few fish were caught at Deer Island Flats in April, making it necessary to sample in May. In May, catch per unit effort, defined as the number of fish obtained per minute of bottom trawling, was particularly high at Deer Island Flats. Those fish taken in May from Deer Island Flats were also significantly larger than the fish from other sites.

Overall, the fish appeared healthy, without the severe fin erosion that was prevalent in fish from Deer Island Flats in the mid- to late-1980s. Tumors were absent. As in previous years, the milder centrotubular hydropic vacuolation (CHV) was the most common form of vacuolation.

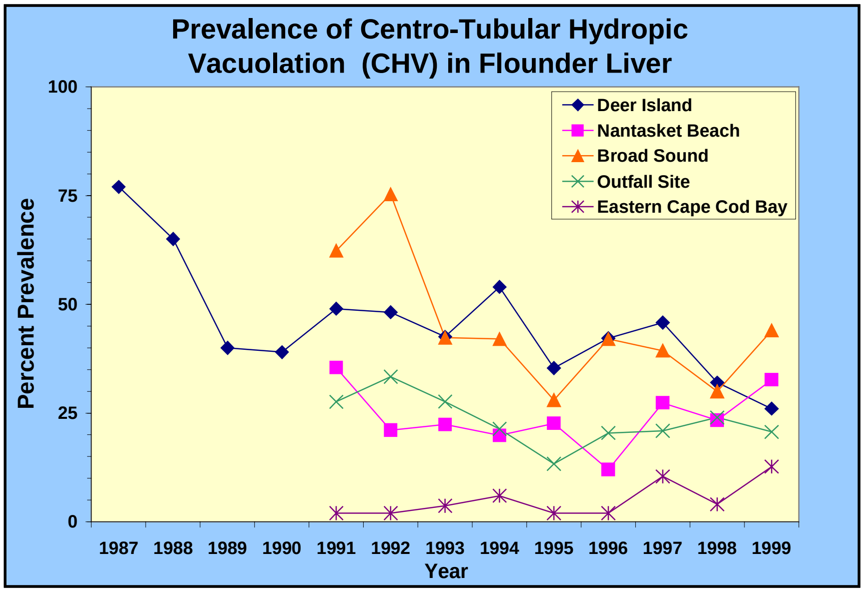


Figure 5-2. Prevalence of centrotubular hydropic vacuolation (CHV)

However, CHV prevalence at Deer Island Flats was lower than it has been throughout the monitoring period (Figure 5-2), possibly due to collenting fish in May rather than April. As in previous years, there were no obvious relationships between age or length and lesion presence, indicating that differences among sampling areas are indicative of differences in environmental conditions.

Overall, body burdens of organic contaminants in edible tissues were similar or lower in 1999 than in previous years (Figure 5-3). Total PCB may have declined since the early 1990s in fish from Deer Island Flats. Dieldrin concentration, however, appeared to increase at all sites, possibly due to co-elution encountered during the analyses for PCBs and pesticides. In fish from Deer Island Flats, the outfall site, and eastern Cape Cod Bay, mercury concentrations were higher than in 1998. Mercury concentrations have been variable at all sites.

Concentrations of organic contaminants in flounder livers were comparable to or lower than concentrations measured in prior years, and generally similar to 1998 measurements. Over all the years of sampling, concentrations of organic compounds have been highest in fish from Deer Island Flats and lowest in those from Cape Cod Bay. Metals concentrations have been highest at the outfall site and eastern Cape Cod Bay.

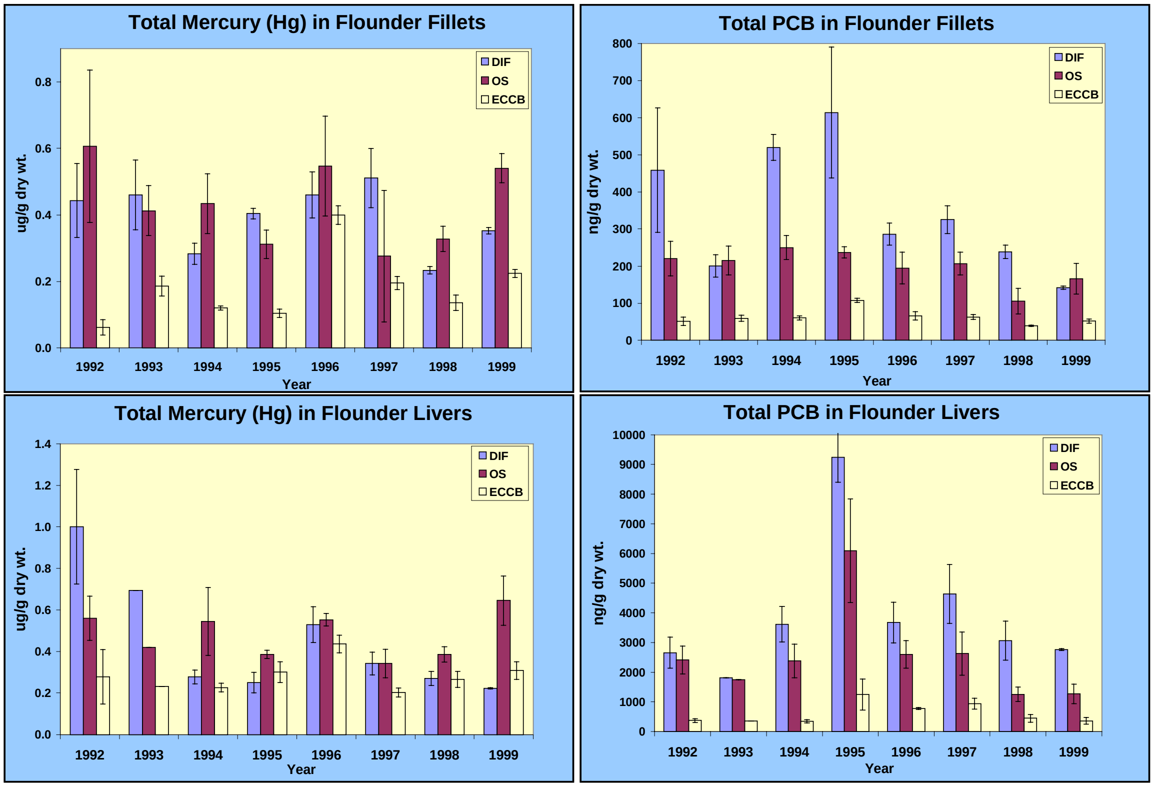


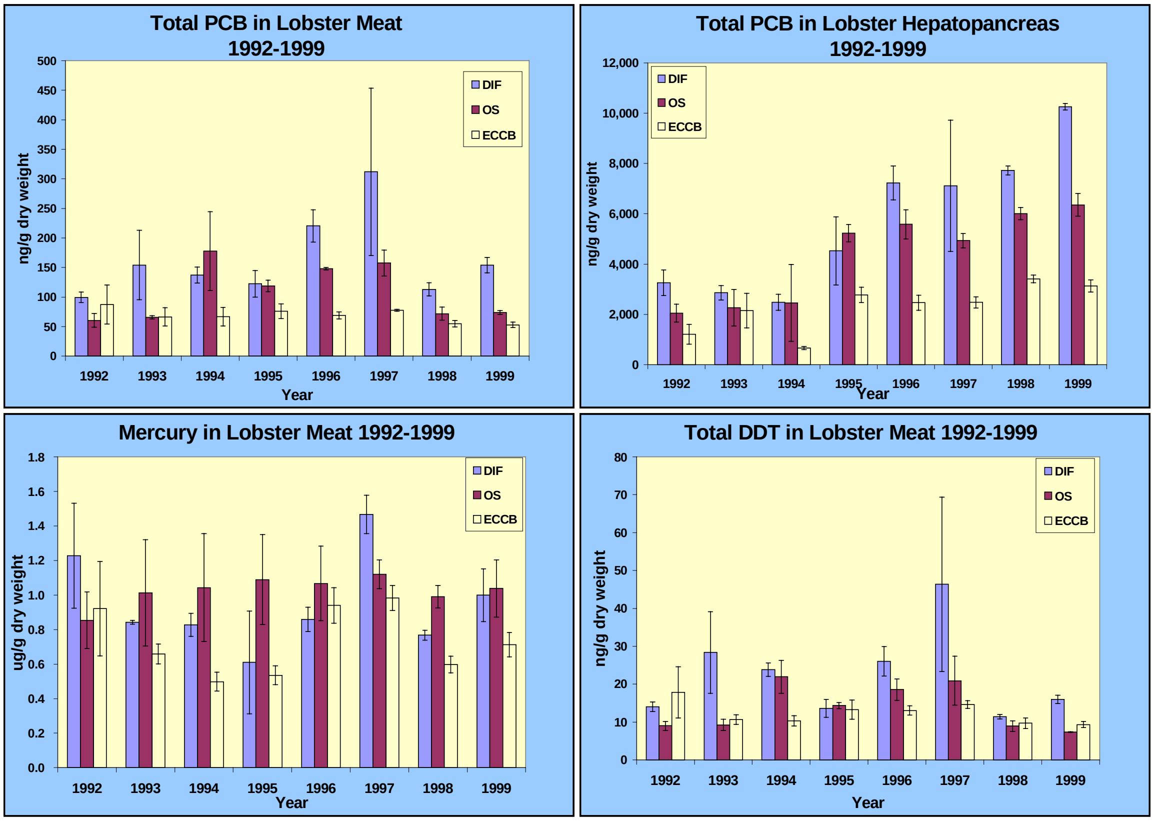
Figure 5-3. Concentrations of contaminants in flounder fillets and livers (DIF = Deer Island Flats, OS = Outfall Site, and ECCB = Eastern Cape Cod Bay)

Lobster

Fifteen lobsters were taken from each sampling location during July, September, and November (Lefkovitz *et al.* 2000), with completion of sampling occurring later than in some prior years. The lobsters were approximately the same weight and size at all sites. Mostly males were found at Deer Island Flats and eastern Cape Cod Bay. Females predominated at the outfall site. In general, there were no gross abnormalities noted in any of the lobsters collected during the survey.

As in previous years, the highest concentrations of most organic contaminants in tail and claw meat were found in lobsters taken from Deer Island Flats, and the lowest concentrations were found in lobsters taken from eastern Cape Cod Bay (Figure 5-4). This pattern has been found throughout the baseline-monitoring period, possibly indicating that lobsters do not migrate between the sites or that contaminants are quickly equilibrated within an organism. Concentrations of PCBs in lobsters from Deer Island were slightly higher in 1999 than in 1998 but were within the historical range of values. Following a different pattern, mercury concentrations were highest in samples taken at the outfall site and lowest in those from Cape Cod Bay. This pattern has also been consistent throughout the baseline-monitoring period. Concentrations of mercury in the claw and tail meat were within the historical range.

The inter-regional pattern of organic contaminant burdens in lobster hepatopancreas was the same in 1999 as in prior years, with the highest concentrations in lobsters from Deer Island Flats. PCB and DDT concentrations appear to have increased at Deer Island Flats and the outfall site during the 1990s, particularly since 1996. Because there are no obvious environmental reasons for these increases MWRA is evaluating the sampling and analysis program and will present the evaluation in an upcoming report. The pattern could be a consequence of one or several factors, for example: (1) a real increase over time, (2) an artifact of chemical methodologies, (3) a result of lobsters being sampled later in the season, or (4) lobsters migrating into areas with greater contamination.


Total PCB in Lobster Meat 1992-1999

Total PCB in Lobster Hepatopancreas 1992-1999

Mercury in Lobster Meat 1992-1999

Total DDT in Lobster Meat 1992-1999

Figure 5-4. Concentrations of contaminants in lobster meat and hepatopancreas

Some apparent increases may result from an analytical artifact caused by co-elution encountered during the PCB and pesticide analyses. The increases may also reflect later collection of lobsters than in earlier years. The lobsters taken in the summer and fall may have spent a longer period inshore, while those taken in the spring may have just arrived from deeper water. The 1999 drought may also have contributed to higher concentrations if lobsters followed the salt wedge upstream into more contaminated areas and then moved back downstream before they were caught. In contrast to PCBs and pesticides, total PAHs (not shown) appear to have decreased during the baseline monitoring.

Historically, concentrations of metals in lobster hepatopancreas have been more variable than concentrations of organic contaminants, with concentrations often as high or higher in animals from the outfall site and eastern Cape Cod Bay as in those from Deer Island Flats. In 1999, concentrations of silver increased at all sites, copper concentrations increased to the highest levels measured during the program in lobsters from Deer Island Flats and the outfall site, and lead concentrations increased in lobsters from Deer Island Flats (data not shown).

Blue Mussel

At Boston Inner Harbor, the outfall site, and Cape Cod Bay, full mussel arrays were recovered after 40 days (Lefkovitz *et al.* 2000). After 60 days, full arrays were also recovered from Cape Cod Bay, and partial samples were recovered from Boston Inner Harbor and the outfall site. Unfortunately, no mussels were recovered at the Deer Island site, despite a side-scan sonar survey and hard-hat diver search. Survival was high among all mussels recovered.

As in previous years, contaminant burdens were highest in mussels deployed in the Inner Harbor and lowest in mussels deployed at the outfall site and in Cape Cod Bay (Figure 5-5). Overall, contaminant concentrations were low in 1999. Mercury and lead (not shown) concentrations were lower than the already low 1998 concentrations. PCB concentrations were at the low end of the range for the baseline-monitoring period. Pesticide and PAH (not shown) concentrations were also low.

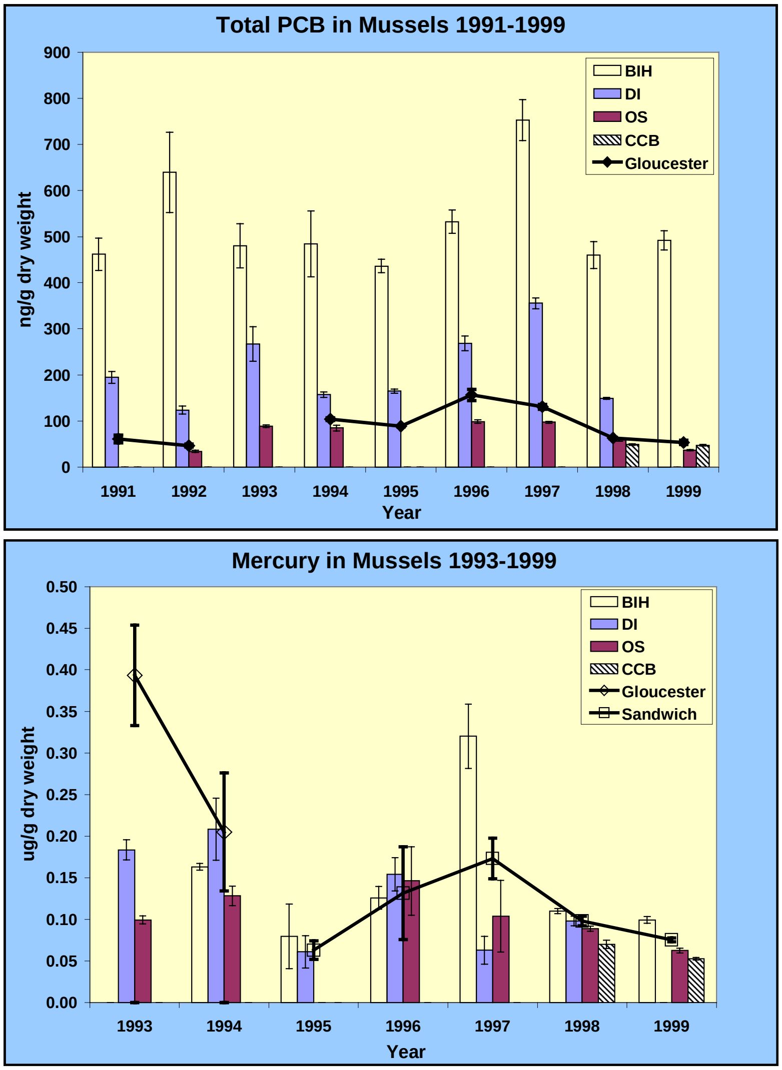


Figure 5-5. Concentrations of PCBs and mercury in mussels deployed in Boston Inner Harbor (BIH), Deer Island (DI), the outfall site (OS) and Cape Cod Bay (CCB)

Contingency Plan Thresholds

For fish and shellfish monitoring, contingency plan warning thresholds are based on U.S. Food and Drug Administration (FDA) limits for maximum concentrations of specific contaminants in edible portions of fish and fishery products (Table 5-1). Caution levels will be based on a complete set of baseline monitoring data. Parameters with warning and/or caution levels include mercury, total chlordane, dieldrin, total DDT, and PCBs in winter flounder fillet, lobster meat, and mussels, lead and PAHs in mussels, and liver disease in flounder.

Table 5-1. Threshold values for fish and shellfish monitoring

Organism	Parameter	Caution Level	Warning Level	1999 Results
Mussels, flounder, lobster meat	Toxic compounds, PAH, pesticides, mercury, total PCBs	2x baseline	80% of FDA advisory level for all listed contaminants	Caution level for dieldrin in flounder fillet would have been exceeded at the outfall site if 1999 had not been a baseline year
Mussels	Lead	2x baseline	3 ug/g wet weight	Concentrations below projected caution level
Flounder	Liver disease incidence	Flounder liver disease (CHV) greater than harbor baseline prevalence	None	Prevalence less than projected caution level

Although no warning level has been set for flounder liver disease, a caution level has been set as a CHV prevalence that is greater than the prevalence detected in baseline monitoring within Boston Harbor. As in previous years, the results from 1999 did not approach the projected range for that threshold.

Also in 1999, as in previous baseline monitoring years, concentrations of contaminants in muscle tissues of winter flounder and lobster and in total edible tissue from mussels were well below the thresholds based on FDA limits.

In the past, lipid-normalized organic contaminant concentrations were used to define the thresholds. Evaluations of lipid-normalized data (Mitchell *et al.*1998) concluded that there was no appreciable reduction in variability in temporal trends when using lipid-normalized data. Therefore, MWRA monitors lipids but has calculated threshold values based on the wet-weight concentrations of interest to FDA.

If the caution level for dieldrin in flounder fillet had been based on data from 1992-1998, then the values for 1999 would have exceeded the threshold. This increase could be due to co-elution encountered during the analyses of PCBs and pesticides during 1999 and may not reflect a real trend in dieldrin concentrations. MWRA is evaluating the coelution issue and will issue a report in late 2000.

6. Special Studies

Background

Besides monitoring the effluent, water column, bottom, and fish and shellfish, MWRA conducts special studies in response to specific permit requirements, scientific questions, and public concerns. During 1999, OMSAP held a workshop to review baseline information and discuss possible effects of the outfall. Also during 1999, MWRA conducted studies of Boston Harbor that documented effects of facilities upgrades. MWRA completed runs of the Bays Eutrophication Model (BEM) to test the model, to assess the effects of magnitude and point of effluent discharge on water quality, and to determine a total mass balance of nitrogen in the system. Following a permit requirement, MWRA completed a scope of work to evaluate the usefulness of a food-web model to characterize important prey of endangered species. To address specific scientific questions, MWRA conducted a video survey of phytoplankton and zooplankton and continued an ongoing assessment of nutrient flux between the water column and the sediments.

OMSAP Workshop

The OMSAP charter calls for regular public forums to present scientific information, explain its significance, and hear and respond to public concerns. In support of this charge, in September of 1999, OMSAP hosted a 2-day workshop to review the status of the Boston Harbor Project and the monitoring program. MWRA supported the workshop by presenting updates on the Boston Harbor Project, including outfall construction and results of the baseline-monitoring program. Scientists, regulators, and the interested public who attended the workshop were encouraged to review and discuss the baseline information and potential or predicted effects of the outfall. All attendees received copies of the materials presented at the workshop. In addition, MWRA has made the workshop materials available on CD-ROM (Trulli *et al.* 2000) and at the MWRA website, www.mwra.com.

Boston Harbor Studies

Over the past decade, MWRA has been documenting improvements to Boston Harbor, due to source reduction and facilities upgrades, including ending of sludge discharges to the harbor, transfer of all effluent to Deer

Island for secondary treatment, and implementation of plans to control CSOs.

Transfer of South System Flows to Deer Island

When MWRA originally planned to discharge all effluent from Deer Island, it was anticipated that the Massachusetts Bay outfall would be completed in time to receive that effluent. Delays in outfall construction resulted in a temporary use of Deer Island outfalls for all effluent discharge. Consequently, MWRA predicted that while water quality in the southern portion of the harbor should improve, water quality in the northern harbor and western Massachusetts Bay could decline.

During 1998 and 1999, MWRA studied wastewater loadings, water quality, and macroalgae colonization rates in the northern and southern portions of the harbor (Taylor 2000). During that period, total effluent flow to the northern harbor increased 30%. Loadings of total nitrogen increased 44%, dissolved inorganic nitrogen increased 73%, and total suspended solids increased 26%, but BOD declined 13% during the period. Direct effluent flow and loadings to the southern harbor decreased to zero.

The transfer of wastewater to Deer Island coincided with a period of dredging in the northern part of the harbor, and this activity may have contributed to changes in water quality. Water clarity in the northern harbor was slightly lower, and chlorophyll concentrations and macroalgae colonization rates were higher. In the southern harbor, nutrient levels declined, but no significant changes in phytoplankton and macroalgae biomass were detected. These studies will continue.

CSOs and Sediment Quality

MWRA has conducted a series of studies aimed at measuring the impacts of CSOs on toxic contamination of sediments. The rationale behind focusing on toxic contaminants in sediments rather than the water column is that contaminants tend to be associated with particles that can accumulate on the sea floor. Concentrations of metals and organic chemicals in the receiving water after a CSO discharge are usually low and transient, and therefore they are difficult to monitor effectively. Dorchester Bay was chosen as the study site, because it has many CSOs, is relatively distant from other sources of toxic pollutants (except for stormwater), and has extensive poorly flushed depositional areas. During 1990, 1994, and 1998, MWRA sampled sediments from north and south Dorchester Bay. In 1998, 14 stations were sampled, and sediments were analyzed for chemical and microbiological parameters (Lefkovitz *et al.* 2000). Results indicated that sediments in the vicinity of CSOs have higher concentrations of sewage tracers than do sediments located at a distance from the CSOs. The effects of improvements to the CSO system on sediment quality are more difficult to elucidate. Sediment quality has improved throughout the region but may be related to source reduction of certain contaminants, such as PCBs and DDT, and improved sewage treatment, as well as to the improvements in the CSO system.

Bays Eutrophication Model

The outfall permit requires that MWRA update, maintain, and run the Bays Eutrophication Model (BEM) developed by HydroQual, Inc. and USGS. The water quality model has been used to investigate and define the relationships between bay circulation, nutrient loadings, primary production, and dissolved oxygen in Massachusetts and Cape Cod bays.

The BEM was initially calibrated using data from the 1992 baseline harbor and outfall monitoring programs (HydroQual and Normandeau 1995) and prior studies of Massachusetts Bay (Geyer *et al.* 1992, Townsend *et al.* 1991). Recently, a new run of the 1992 data with updated hydrodynamic functions was generated, along with runs for 1993 and 1994, years that varied significantly from 1992 (HydroQual 2000). The results of the comparison indicated that the BEM captured the principal processes that relate primary production and dissolved oxygen to bay-wide circulation, water column temperature and stratification, nutrients, and light. The model captured a number of the spatial and temporal features of phytoplankton biomass and primary production observed in Boston Harbor and Massachusetts and Cape Cod bays, although it did not reproduce the single-species bloom of *Asterionellopsis glacialis* that was observed in the late summer and fall of 1993. The model also missed the minimum levels of dissolved oxygen observed at some nearfield stations in September and October of 1994, but it did predict that 1994 dissolved oxygen concentrations would be lower than those for 1992 or 1993.

The BEM was then used to evaluate the effects of the magnitude of nitrogen loading and the point of discharge on the system (Figure 6-1). Model runs compared the current outfall location with the Massachusetts Bay location and evaluated effluent organic carbon and nutrient levels set at zero, the 1992 level, and twice the 1992 level. Results of these model runs indicated that relocation of the effluent discharge would have little or no effect on the water quality of Massachusetts and Cape Cod bays, while significantly improving conditions in the harbor. The model results indicated that the region is more sensitive to the magnitude of nutrient inputs than to the location of the discharge. The results also suggested that an extremely large change, such as a doubling of nutrient inputs, would be necessary for perceivable changes in plankton biomass to occur in Cape Cod Bay. Such a change is not realistic and represents a worse-than-worst-case scenario.

The model was also used to evaluate total nutrient loading to the system. A global mass balance analysis of the system using 1992 data indicated that approximately 3% of the nitrogen entering Massachusetts Bay derived from the effluent outfall. Approximately 93% of the total nitrogen entered with inflowing waters from the Gulf of Maine.

During 1999, OMSAP convened a special committee, the Model Evaluation Group (MEG) to independently review the BEM and the recent model runs. The BEM was originally derived from a Chesapeake Bay model that has been severely criticized for inaccuracies and lack of objective review. However, the BEM is a more recent model, has received ongoing independent review, and results in a closer match between field data and model predictions than does the Chesapeake Bay Model.

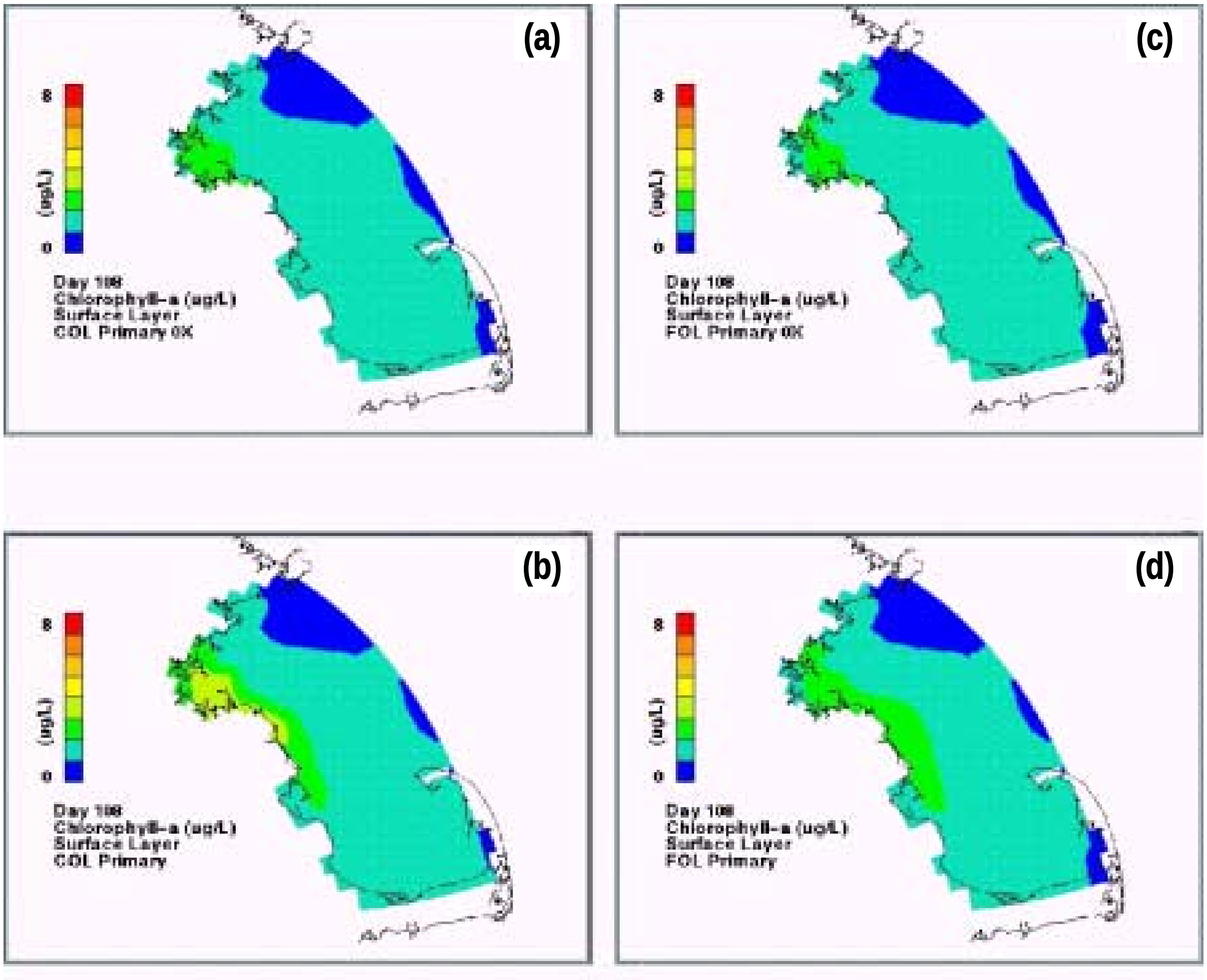


Figure 6-1. Spatial representation of modeled late April chlorophyll in surface waters of Massachusetts Bay in response to 0X (a and c) and 1X (b and d) nutrient loading and shift in discharge location from the harbor (COL) to the new outfall (FOL).

Food Web Issues

MWRA's NPDES permit notes that during 1998, MWRA developed a scope of work for determining the value of a food web model to characterize the seasonal abundance of important prey species for endangered species, particularly right whales, in Massachusetts and Cape Cod bays. The final permit required EPA and MADEP to comment on the scope of work, MWRA to submit a revised plan, and the regulators to determine whether developing a food web model would be warranted. After submitting the scope of work, MWRA carried out additional evaluations of the need for such an approach (Hunt *et al.* 1999), including a review of the evaluations of potential impacts conducted during the outfall planning and construction. This review used new data to assess whether environmental conditions would worsen as a result of relocating the outfall, and if so, whether the changes would be likely to harm whales.

Results of the review indicated that environmental conditions would not worsen as a result of relocating the outfall. Present nitrogen loads in the effluent are less than had been predicted (Hunt *et al.* 1999). The BEM calculates that effluent contributes only a small fraction, about 3%, of the total nitrogen entering the system. Modeling results indicate that elevated nutrient concentrations will be confined to a small patch in the immediate vicinity of the outfall. Changes in the nutrient fields will be highly localized and have little to no impact on the phytoplankton and zooplankton species composition in the bay. Nutrient levels will not be enriched to levels that could promote the growth of nuisance species.

Video Plankton Survey

Phytoplankton and zooplankton abundances are known to vary on a wide range of spatial and temporal scales. This patchiness is not well described by traditional plankton surveys, but may be important, as it affects whale feeding. Consequently, as requested by the OMSAP predecessor, the OMTF, MWRA has collaborated with NMFS and EPA to fund pilot surveys using a towed video microscope called a Video Plankton Recorder. The towed apparatus, developed by Cabell Davis and Scott Gallager at the Woods Hole Oceanographic Institution, includes a high-magnification camera, which images a 7-mm field, and a low-magnification camera, which images a 25-mm field. Video Plankton Recorder studies were conducted in March 1997, March and June 1998, and February 1999 (Davis and Gallager 2000). The images resulting from the cameras provide information on the patchiness of plankton populations.

Each of the surveys has documented a bloom dominated by a different species. For example, the 1997 survey took place during a bloom of

Phaeocystis pouchetti, an undesirable species that forms dense, gelatinous colonies. That year was also marked by limited whale foraging in the region. The March 1998 survey documented a bloom of rod-shaped diatoms. No dense patches of zooplankton were found, however, there was extensive foraging by right whales in the region that year.

The 1999 survey took place on the same dates as a regular water column survey. Both surveys found *Chaetoceras socialis*, a large colonial diatom, to be the most prevalent phytoplankton species. Rod-shaped diatoms and *Chaetoceras* chains also dominated the communities. *Chaetoceras* colonies were so abundant that they obscured the screen and precluded the use of the high magnification video camera necessary to identify the dominant zooplankton species *Oithona similis* or other small species. Somewhat larger copepods, such as prime whale prey *Pseudocalanus* spp., could be seen and quantified with the lower magnification camera, although not at the species level. Within these constraints, the traditional and video surveys agreed on the magnitude of copepod abundance. Both surveys found the zooplankton communities to be dominated by copepods. Results from the video survey suggested that MWRA's traditional surveys are descriptive of the plankton communities located within 5-10 km of the stations.

Presence of the large phytoplankton species during the 1999 video survey was not correlated with fluorescence, indicating that smaller species were responsible for the high fluorescence. Copepod abundance was inversely correlated with fluorescence, suggesting that the large copepods were feeding on larger phytoplankton species, particularly the *Chaetoceras* chains.

Nutrient Flux

Sediments in coastal areas such as Boston Harbor can play an important role in nutrient cycling and oxygen dynamics. Breakdown of organic matter in the sediments consumes oxygen and releases nutrients. Through denitrification, which converts nitrate to gaseous forms of nitrogen, which are lost to the atmosphere, coastal sediments can also act as a nitrogen sink. If denitrification rates are high within the harbor, then moving the outfall into deeper waters with lower denitrification rates may change the nitrogen load to the region.

MWRA has conducted studies of benthic nutrient cycling within Boston Harbor since 1992. In 1999, studies were conducted at four sites: the central outer harbor, off Long Island in the former sludge disposal area, Hingham Bay in the southern harbor, and Quincy Bay, also in the southern harbor (Tucker *et al.* 2000). Results of the studies have shown that while denitrification rates within the harbor are high, only a small fraction of the nutrient inputs to the harbor are cycled through the sediments and lost to the system. Consequently, moving the outfall offshore is unlikely to affect the total nitrogen load to the bay. The studies have also documented recovery of the harbor since the cessation of sludge disposal in 1991. For the first years after sludge inputs ceased, rates of respiration and nutrient flux were extremely high at the former disposal site. Rates have decreased in 1998 and 1999.

In 1999 MWRA resumed studies of nutrient cycling and oxygen dynamics in Massachusetts Bay. Studies were conducted at three stations near the new outfall and at one station in Stellwagen Basin. The effects of the 1998 fall bloom, which persisted through the winter, and the unusual 1999 late summer bloom appeared to have been quickly but unevenly manifested in the benthos. Responding to the deposition of organic matter from the water column, sediment respiration and silica flux rates were very high at two of the nearfield stations.

7. Summary

Background

Since its creation in 1985, MWRA has worked to end long-standing violations of the Clean Water Act that resulted from discharge of sewage sludge and inadequately treated effluent into Boston Harbor. Sludge discharges have ended, and MWRA is working to minimize the effects of effluent discharge. The MWRA program includes source reduction, improved treatment, and effective dilution when the effluent reaches the marine environment. More effective dilution will be accomplished by diverting the effluent from the harbor to a new outfall and diffuser system, located 9.5 miles offshore in Massachusetts Bay.

MWRA's goals are to make it safe to swim in the harbor, safe to eat the fish caught there, to protect marine resources, and to ensure that the harbor becomes and remains a resource that people can aesthetically enjoy, without degrading the offshore environment. For many of the components of MWRA's work, there is general agreement that the project benefits the marine environment and the people of the region. One aspect of the project, moving the effluent outfall from the harbor to Massachusetts Bay, has caused some concerns.

EPA and MADEP recognized these concerns when they issued the NPDES permit for the new outfall. The permit includes high standards for plant performance, a monitoring program to ensure compliance with permit conditions and assess potential effects, and a contingency plan, which describes how MWRA and the regulatory agencies will respond to determine causes and implement corrective actions for problems detected by monitoring. The contingency plan identifies thresholds for environmentally significant components of the effluent and the ambient ecosystem that, if exceeded, indicate a potential for environmental risk.

This outfall monitoring overview is one of a series of annual reports required by MWRA. It provides a scientific summary of each year of monitoring and includes information relative to the contingency plan. This year's report presents monitoring results for baseline studies conducted through 1999. After the outfall begins operation, annual reports will describe any threshold exceedances, responses, and corrective actions.

Effluent

The MWRA strategy for improving the environmental quality of Boston Harbor without degrading the offshore environment relies upon source reduction and improved treatment. Ensuring that the effluent meets permit limits is the most important action MWRA takes to ensure that the outfall does not harm the marine environment.

Wastewater constituents of concern include nutrients, organic material, toxic constituents, human pathogens, and solids. Effluent monitoring assesses compliance with permit limits for contaminant concentrations, which are based on national water quality criteria, ambient conditions, and projected outfall dilution. (Actual dilution will be measured when the outfall begins operation.) Monitoring also provides calculations of total loads of contaminants to the system.

When the second of three batteries of secondary treatment began operation in 1998, the treatment plant essentially began to operate in compliance with the permit. (The permit was not in effect at that time, becoming effective with the commissioning of the outfall.) Due to a drought that lasted for much of the year, average daily flow was about 10% lower in 1999 than the 5-year average. About 88% of that flow received secondary treatment. Loadings for many contaminants were lower in 1999 than had been predicted by the EPA SEIS for the outfall siting process or by a pilot plant study. For example, total loading of PCBs in 1999 was approximately 2.4 pounds, compared to a projected 90.2 pounds in the SEIS. Recent advances in analytical techniques have found that the SEIS projections, based on high detection limits, overestimated actual loads.

Water Column

Circulation, water properties, and biology of Massachusetts and Cape Cod bays are mainly driven by the larger pattern of water flow within the Gulf of Maine. During much of the year, a weak counterclockwise current persists in Massachusetts Bay and Cape Cod Bay. When monitoring began, the water column was projected to follow a typical coastal cycle of spring and fall phytoplankton blooms. Monitoring has shown that wind and weather greatly influence the actual observed annual cycles.

Water column monitoring focuses on concerns that relocation of the outfall will introduce effects from the organic material, nutrients, and toxic contaminants in the effluent. Of the possible outcomes, changes in the nutrient balance are considered to have the most potential for affecting the health of the bays. Water column monitoring includes five major components: nearfield surveys, farfield surveys, continuous recording, remote sensing, and plume-tracking surveys. (Plume-tracking surveys will be conducted when the outfall begins operation.)

The winter and spring of 1998-1999 were relatively warm, and the warm trend continued until August. The first part of the year was relatively wet, but from April until September, the region experienced a drought. An active hurricane season brought an end to the drought. Wind stresses were typical for the region, with summer winds from the southwest and consequent coastal upwelling.

A spring phytoplankton bloom occurred from early February through April of 1999, depleting nutrients in surface waters. Another phytoplankton increase occurred in August, and there was a protracted fall bloom. The high production correlated with record levels of chlorophyll in 1999, particularly in Boston Harbor, the coastal region, and the nearfield.

Dissolved oxygen levels in bottom waters of the nearfield and in Stellwagen Basin reached extremely low levels in September of 1999. The low levels of dissolved oxygen during 1999 were caused in part by existing low levels at the time of stratification and by the low flow of freshwater to the system due to the drought.

Had the contingency plan for the outfall been in effect, warning threshold parameters for chlorophyll levels and dissolved oxygen concentrations would have been exceeded by the values measured in 1999. Existing water quality criteria for dissolved oxygen in marine waters may be too high; EPA is currently considering whether to apply regional criteria for the Virginian province nationally.

Phytoplankton and zooplankton communities were typical in 1999. There were no blooms of toxic phytoplankton species. Despite high levels of nutrients within Boston Harbor, populations of the copepods *Acartia* spp., once thought to be indicators of eutrophication, were low.

Sea Floor

Sediment transport within the bays occurs primarily during storms. Typically, strong storms with winds from the northeast resuspend and transport fine sediments, which are transported by currents to western Massachusetts Bay and toward Cape Cod Bay, where they are likely to remain. Cape Cod Bay is sheltered from large waves by the arm of Cape Cod, and waves are rarely large enough to resuspend sediments in Stellwagen Basin, which is the deepest feature in the region.

There are several environmental concerns about possible effects of the new outfall on the region: eutrophication and related low dissolved oxygen levels, accumulation of toxic contaminants in depositional areas, smothering of animals by particulate matter, and disruption of normal community structure by excess food input. Sea floor monitoring includes measurements of contaminants in sediments, sediment profile imaging, studies of near- and farfield soft-bottom communities, and study of hard-bottom communities.

As in previous years, concentrations of contaminants within sediments were low, particularly in the farfield. Sediment profile imaging showed that the RPD layer has deepened in recent years, indicating that benthic communities in fine-grained areas are being controlled more by biological than by physical factors. Total infauna abundance and diversity have increased during the same period. At least in the nearfield, patterns of sediment contamination, depth to the RPD, and benthic community parameters may reflect disruption and subsequent recovery from a 1992 storm. There is also some suggestion that benthic communities are exhibiting a region-wide trend of increasing abundance, perhaps as part of a long-term cycle. Hard-bottom communities have been stable since monitoring began in 1995.

Fish and Shellfish

The fish and shellfish industry is an important part of the regional identity and economy of Massachusetts. One concern about relocating the sewage effluent offshore is that contaminants will adversely affect resource species, either through direct damage to the fishery stocks or by contamination of fish, lobsters, and other shellfish.

The monitoring program focuses on three indicator species. Winter flounder and lobsters are important resources in the region. The blue mussel, deployed in caged arrays, is a common biomonitoring species. Monitoring includes examination of health and measurement of organic and inorganic contaminants.

As in previous years, levels of most contaminants were highest in flounder taken from Deer Island Flats. Similar to previous years, levels of most contaminants in lobsters were highest in animals taken from Deer Island Flats. Levels of some organic contaminants in lobster hepatopancreas appear to have increased during the 1990s. These apparent increases may reflect actual changes but also could result from sampling or analysis artifacts. In mussels, concentrations of all contaminants were highest in Boston Inner Harbor. Overall, contaminant concentrations were lower than in previous years.

Some contingency plan thresholds for fish and shellfish are based on FDA limits for maximum concentrations of specific contaminants in edible portions of fish and fisheries products. Others will be developed from a complete set of baseline data. As in previous years, concentrations of contaminants in muscle tissues of winter flounder and lobster were well below thresholds based on FDA limits. If data from 1992 through 1998 had been used to develop the thresholds based on baseline conditions, the warning level for dieldrin in winter flounder liver would have been exceeded in 1999. MWRA is examining the implications of the high measurements during the baseline period, including a possibility that the measurements reflect an analytical artifact rather than a real change.

Special Studies

Besides monitoring the effluent, water column, bottom, and fish and shellfish, MWRA conducts special studies in response to specific permit requirements, scientific questions, and public concerns. In 1999, MWRA conducted several studies. During September of 1999, OMSAP held a workshop to review the monitoring program. The workshop was attended by scientists, regulators, and the public. MWRA has prepared a compact disk that includes all information presented at the workshop.

While the outfall-monitoring program is focused on the potential effects of moving the effluent outfall offshore, MWRA has also studied the changes within Boston Harbor as a result of removing sludge from the system, upgrading CSOs, implementing secondary treatment, and diverting discharge from Nut Island to the Deer Island Treatment Plant. During 1999, MWRA evaluated effects of the diversion of effluent from Nut Island and found that an increase in chlorophyll levels in western Massachusetts Bay may have resulted from the increased discharge in the northern part of the harbor. Also during 1999, MWRA conducted a third study of sediments near CSOs and found that discharges from CSOs probably cause elevated levels of contaminants in near-by sediments. Improving sediment quality may in part be due to improvements to the CSO system but also to the ending of sludge discharges, better source control, and improved effluent treatment.

Following permit requirements, in 1999 MWRA completed runs to test the BEM, assess the effects of magnitude and point of discharge on water quality, and determine a total mass balance of nitrogen in the system. Those model runs indicated that the region is more sensitive to the magnitude of discharge than to its location. Model results also indicated that the effluent discharge accounted for only about 3% of the total nitrogen entering Massachusetts Bay. Also in 1999, OMSAP appointed a committee to review the BEM and the model runs.

As part of a study to determine the utility of developing a food web model to characterize important prey for endangered species, in 1999 MWRA reviewed the past evaluations of the need for such an approach. The review used new data and incorporated the results of the BEM runs. The results are being evaluated by OMSAP.

MWRA has conducted ongoing assessments of nutrient cycling and oxygen dynamics of the sediments to determine whether moving the outfall offshore could cause a change in the nutrient budget. Those studies have indicated that although denitrification rates of harbor sediments are high, that only a small portion of the nitrogen in the system is cycled through the sediments and therefore lost through denitrification. Studies in Massachusetts Bay in 1999 showed that productivity within the water column was quickly transported to the sediments.

MWRA will continue to conduct special studies as they are required by the permit or warranted by monitoring results, scientific questions, and public concerns. The primary mechanism for initiating special studies is expected to be the regular review of monitoring data by OMSAP and its committees.

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List of Acronyms

BEM	Bays Eutrophication Model
BIH	Boston Inner Harbor
BOD	Biological oxygen demand
cBOD	Carbonaceous biological oxygen demand
CCB	Cape Cod Bay
CD-ROM	Compact disk
CHV	Centrotubular hydropic vacuolation
C-NOEC	No observable effect concentration
CSO	Combined sewer overflow
DI	Deer Island
DIF	Deer Island Flats
DMF	Massachusetts Division of Marine Fisheries
ECCB	Eastern Cape Cod Bay
EPA	U.S. Environmental Protection Agency
FDA	U.S. Food and Drug Administration
IAAC	Inter-agency Advisory Committee
LC50	50% mortality concentration
MADEP	Massachusetts Department of Environmental Protection
MEG	Model Evaluation Group
MGD	Million gallons per day
MWRA	Massachusetts Water Resources Authority
NPDES	National Pollutant Discharge Elimination System
OMSAP	Outfall Monitoring Science Advisory Panel
OMTF	Outfall Monitoring Task Force
OS	Outfall site
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PIAC	Public Interest Advisory Committee
RPD	Redox potential discontinuity
PSP	Paralytic shellfish poisoning
SEIS	Supplemental Environmental Impact Statement
USGS	U.S. Geological Survey
TOC	Total organic carbon
TSS	Total suspended solids
WHOI	Woods Hole Oceanographic Institution

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