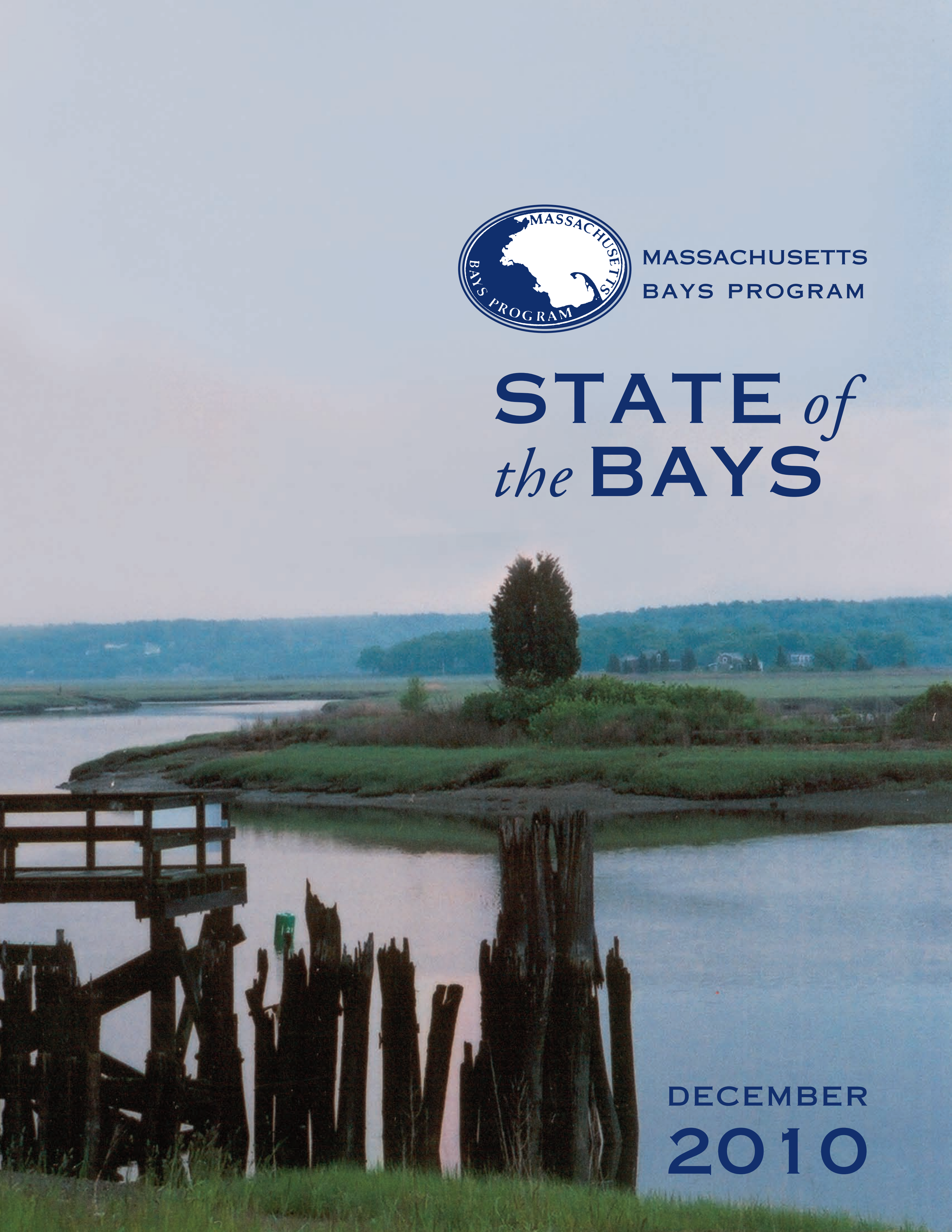

MASSACHUSETTS BAYS PROGRAM

STATE *of* *the* BAYS

DECEMBER 2010

About the

MASSACHUSETTS BAYS PROGRAM

The Massachusetts Bays Program is a partnership of citizens, communities, and government that strives to protect and enhance the coastal health and heritage of Massachusetts and Cape Cod Bays. To achieve our vision of a balanced and healthy environment, we:

-Provide support and assistance for local action

-Cultivate environmental education and stewardship

-Develop science-based initiatives to help solve management challenges

-Facilitate cooperation on local and region-wide projects and programs.

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NATIONAL ESTUARY PROGRAM

COVER PHOTO: J. KADRI

Photo: S. Weigel

ACKNOWLEDGEMENTS

The Massachusetts Bays Program and its staff would like to thank the many contributors who made this 2010 State of the Bays Report possible. The time that each author and editor invested in creating such a report convey the deep commitment on the part of a wide variety of organizations and individuals to the health of Massachusetts and Cape Cod Bays. These contributions are reflective of the collaborative nature of the Massachusetts Bays Program and the National Estuary Program system as a whole. Each of the authors who participated in this process is credited within their respective submittals in this report.

We would also like to thank Arden Miller of the Massachusetts Office of Coastal Zone Management for her design, layout, and editorial assistance, and Regina Lyons of the U.S. Environmental Protection Agency for her extensive editorial review and contributions. The State of the Bays 2010 project team at the Massachusetts Bays Program included Christian Krahforst, Carole McCauley, Prassede Vella, and Jay Baker.

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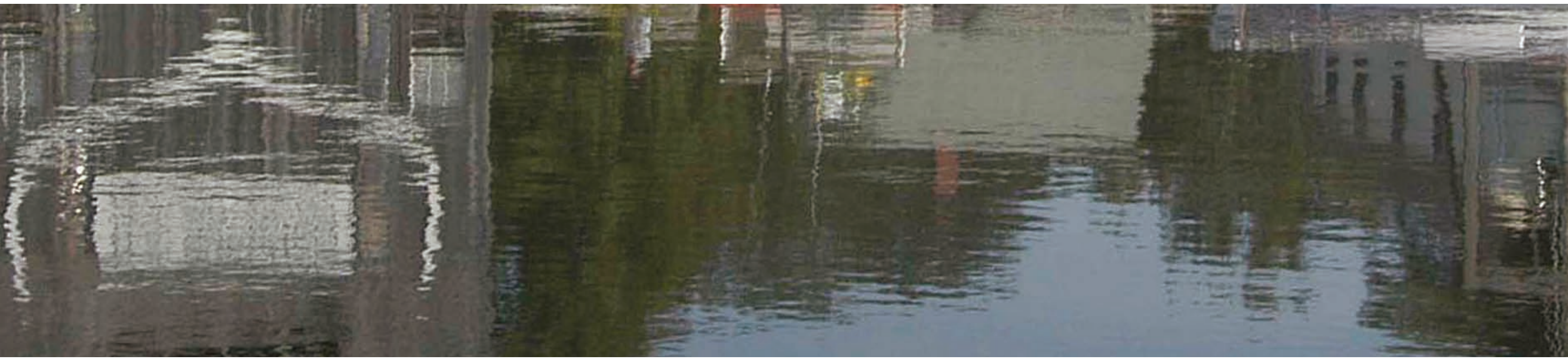

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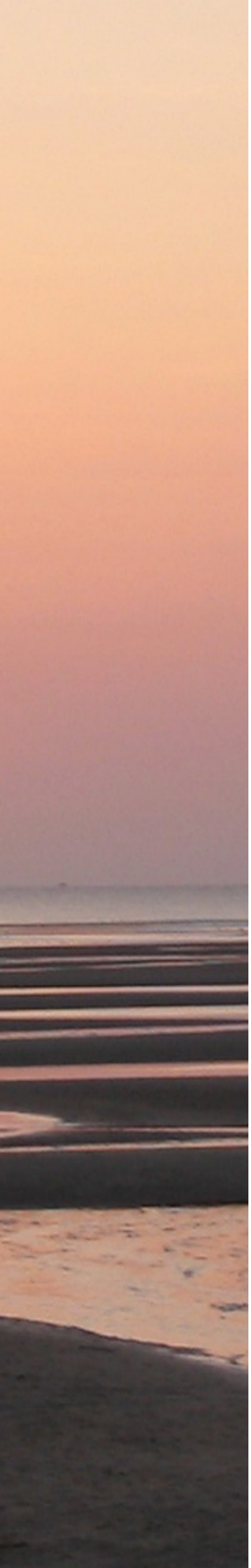


LETTER FROM THE DIRECTOR

December 2010

Dear Reader,

If you are reading through this State of the Bays Report, you likely have some meaningful connection to the Massachusetts coast. Whether that connection is your profession, a place to vacation, or a home in a coastal community, most of us have some affinity for the coast – some important link to the shoreline and its surrounding areas.

With that connection naturally comes some personal measure of the quality of our bays and ocean environments. We all have our favorite beaches, places to fish, or to launch a kayak. Whether you've thought about it or not, there's probably some formula that you use to assign value to those places. It may simply be proximity to your home or to local amenities, but it probably also has something to do with the quality and character of that spot. What does it look like? Does it feel "natural" when you are there? Is it clean? All of these factors, and probably many others, go into choosing your preferred places along the coast, and making judgments about whether they are fitting for your intended uses.

The Massachusetts Bays Program (MBP) and our partners have developed this State of the Bays report to shed some light on some of these values. The MBP works with coastal communities to protect and enhance the health of coastal environments. This report attempts to examine the degree to which our coastal systems are healthy, and to explain how we measure our progress in protecting and enhancing our coastal resources.

In the following pages we summarize the status and trends of a range of coastal resources within Massachusetts and Cape Cod Bays using 17 measures, or indicators, of coastal condition. These indicators are used to describe the quality of coastal resources such as salt marshes, seagrass, and other estuarine habitats. They assess the extent to which our coastal waters are clean and usable for fishing and recreation and provide suitable habitat for aquatic life. And they also address the degree to which a variety of human factors, such as land use and pollution discharges, can and do threaten the health and related values of these resources.

As you'll read in the following sections, we are making progress in protecting and restoring the health and quality of Massachusetts and Cape Cod Bays. However, it is clear that our coastal resources continue to face serious threats from coastal development, habitat loss, contamination of waterways, invasive species, and other human-induced impacts to coastal systems. The MBP has developed this report not only to monitor the state of the bays, but also to help in identifying and prioritizing needs for our program and our partners to focus on.

As you read on, I invite you to reflect on the connection between the quality of coastal conditions reported here and your own measures of coastal health. Thank you for your interest in the health of our shared coastal resources.

Sincerely,

Jay Baker, Director

INTRODUCTION

Home to a diverse array of species and habitats,

an estuary is a unique environment where fresh water from rivers mixes with the salt water of the sea. Being mindful of the value of estuaries, how does the Massachusetts Bays Program measure the effectiveness of efforts designed to improve or preserve the environmental integrity of our estuarine resources? One way is by tracking the status and trends of critical environmental indicators, which is the focus and intent of the State of the Bays report.

INTRODUCTION

Collectively, the coastal resources described in this report have many values and provide numerous services, many that relate directly to human quality of life. Estuaries, where fresh water from rivers meet and mingle with the sea, provide habitat for vast numbers of species, including many that are commercially valuable. Estuarine resources offer substantial shoreline protection from storm surge and flooding events. They are often used for recreational purposes such as boating, fishing, diving, birding, and beach-going, and they provide the basis for a vast array of commercial industries.

Photo: S. Gersh

Despite these values, many of which have benefits that serve people well beyond our region, there are numerous threats to coastal resources, most of which originate in human activity. Pollution, encroaching development, and overuse of resources are taking their toll. In Massachusetts, coastal habitats have suffered losses for hundreds of years due to these pressures. Although legislation enacted in past decades has done much to stem the degradation of some of these critical habitats, current and emerging threats exist. In 1987, an Act of Congress established the National Estuary Program (NEP) as an effort to address problems facing estuaries of national importance. The U.S. Environmental Protection Agency (EPA), which oversees the NEP, is directed by the Clean Water Act (CWA) to attain or maintain water quality in estuaries, including both water supply and water-dependent habitats and species such as fish, shellfish, and other wildlife.

Photo: B. Warren

THE PROGRAM

The Massachusetts Bays Program (MBP) is one of 28 programs in the NEP system. Governed by a Management Committee, whose members represent public and private interests, the program represents a collaborative effort of partners working towards common objectives. The program's work is guided by a Comprehensive Conservation and Management Plan, which is updated periodically to reflect accomplishments as well as shifting needs and priorities.

MBP serves 50 coastal communities that are grouped into five MBP regions: the Upper North Shore, Salem Sound, Metro Boston, South Shore, and Cape Cod (See map on inside back cover). Each region is served by a regional coordinator who is hosted by non-profit organizations or regional planning agencies. These coordinators play a vital role in providing direct assistance to the communities within their regions on issues related to the work and objectives of the MBP.

STATE OF THE BAYS

With all of the values of, and threats to coastal resources, how does the MBP measure the effectiveness of its work and the work of our partners in improving the quality of the region? One way is through the tracking of environmental indicators. In 2004, the MBP issued its first State of the Bays report, summarizing the status of 16 indicators that had been identified as characterizing the health of the region's estuaries and bays. This edition of State of the Bays documents the status of and trends within many of the same indicators and provides additional information on relevant topics of interest to the bays and to the program.

The selected indicators are representative of the system and its values, but are by no means comprehensive. In tracking these broad indicators, MBP management decisions will be informed by a deeper understanding of changing environmental conditions. It is our goal in tracking these indicators, that the results of the MBP partner and citizen contributions will be reflected through improved conditions and environmental quality of the MBP region. In the following pages, we report on the status of 17 indicators of the health of Massachusetts and Cape Cod Bays. These indicators have been divided into three major categories:

- Living Resources, which reports on the status of important coastal habitats within Massachusetts Bays as well as the species they support
- Water Quality, which reports on the chemical and physical characteristics of coastal waters in relation to key management practices
- Human Uses and Planning, which reports on several metrics of human population, development patterns, and their potential impact on coastal systems.

Each section has been developed by MBP staff and our many partners within state and federal agencies, local non-profit organizations, and academic institutions. The number of authors and contributors reflects the collaborative nature of MBP, as well as the importance of partnerships for addressing some of the challenging environmental issues we face.

Finally, you will find that this State of the Bays Report includes case studies related to important environmental issues and impacts that have emerged over the past decade(s). These case studies are intended to make a direct connection between the indicators of ecosystem health and specific environmental issues we face today.

For more information on the Massachusetts Bays Program, our region, and our activities, and to download the 2004 State of the Bays Report, please visit http://www.massbays.org.

WATER QUALITY

Just how clean is your water?

In many locations, it is cleaner than it was when the Clean Water Act was passed in 1972. But in many water bodies, pollution is still a serious concern. Excess bacteria in the water can render beaches unfit for swimming. Contaminants in stormwater can lead to closures of shellfish beds. It is increasingly apparent that human health is reliant on the health of estuaries and the natural environment on the whole. While water quality can be impacted by natural processes, today it is the human-induced environmental stressors that cause the most concern among citizens and scientists.

MUNICIPAL WASTEWATER IN BOSTON HARBOR

Q1 How has the diversion of the MWRA sewage discharge affected conditions in Boston Harbor?

Contributors: Andrea Rex and David Taylor, Massachusetts Water Resources Authority

Why this is important

During the construction of the Deer Island Treatment Plant and offshore outfall, the Massachusetts Water Resources Authority (MWRA) began tracking biological changes in the water and sediment of Boston Harbor. Discharge of sludge to the harbor was discontinued in 1991, and in 1998, wastewater treatment for greater Boston was consolidated on Deer Island and secondary treatment initiated. (Secondary treatment is a biological process that removes organic matter and solids from sewage). In 2000, sewage treatment plant discharges to the harbor ended with the opening of the ocean outfall and diffuser system. This secondary treatment has improved the ecological conditions of Boston Harbor by significantly reducing contaminant discharges.

State of the Bay

Extensive monitoring of Boston Harbor began in 1992 as part of the monitoring program designed by MWRA. The monitoring project measures changes in biological and other conditions in the water column and sediments of the harbor and documents ambient conditions of the adjacent Massachusetts Bay.

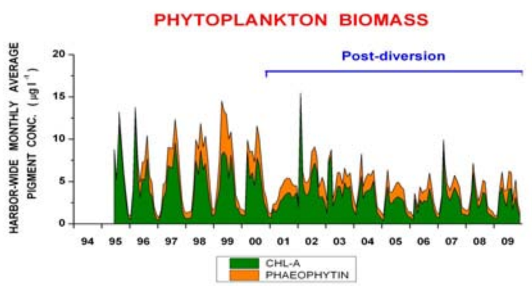


Figure 1.1. The amount of algal growth in Boston Harbor since the wastewater was diverted offshore.

Water Quality: Sewage effluent can contain a large amount of nitrogen and other nutrients, which in some situations can cause excess algal growth. Algal growth can be estimated by measuring the level of their pigments in the water column. Figure 1.1 shows the amounts of two pigments used to indicate the level of phytoplankton (chlorophyll and phaeophytin) found in the harbor from 1995 through 2009. Since 2000, the year the discharges to the harbor were ended, the amounts of algae in the harbor, especially during summer months, has decreased.

Dissolved oxygen (DO) is another key indicator of environmental health and water quality. Low DO indicates the presence of excessive amounts of organic matter, like sewage, and can result in localized zones in the water column that are unable to support aquatic life. Figure 1.2 shows the average level of DO in Boston Harbor's bottom waters. Since the MWRA discharge was diverted offshore, bottom water DO in the summer has increased by about 0.5 milligrams per liter (mg/L), and is consistently well above the state standard of 6.0 mg/L. Further, water clarity, as measured by the depth where a Secchi disc remains just visible, has increased since the outfall was diverted from the Harbor to Massachusetts Bay.

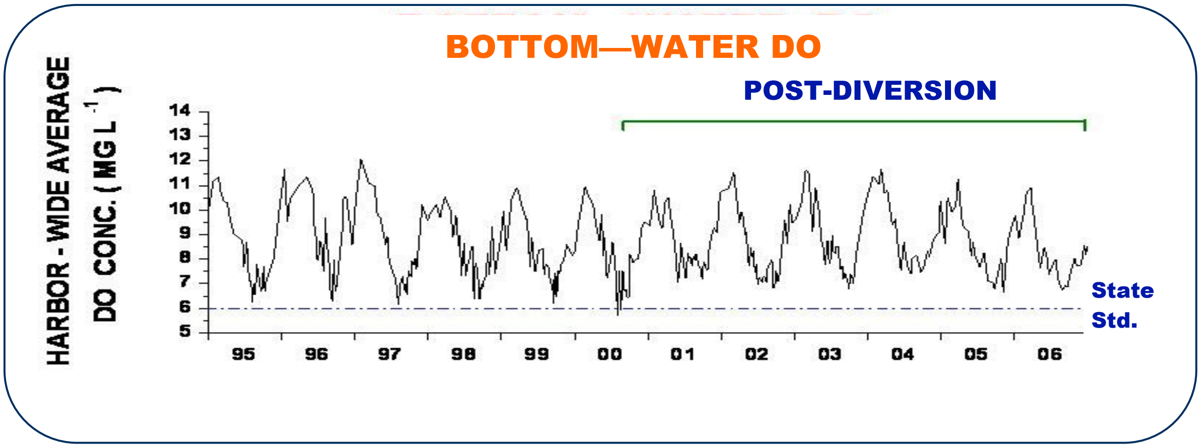


Figure 1.2. Bottom water dissolved oxygen (DO) levels during the most stressed period, summer, have increased by about 0.5 milligrams per liter since the discharge was diverted. After diversion, the average "lows" are consistently well above 6 milligrams per liter.

Habitat: In studying the response of Boston Harbor to the increasingly improved control of sewage discharges, one of the most encouraging stories is found in the animals dwelling in its sediments. The mollusks, worms, and crustaceans, called the benthic infauna, play a critical role in marine ecosystems by serving as a food source for other organisms, stabilizing and aerating sediments, and recycling nutrients and organic matter. Benthic infauna are particularly susceptible to pollution impacts because of their sedentary nature. Measures such as abundance of animals, species diversity, and the types of organisms present can all be used as indicators of ecosystem health.

Monitoring of benthic infauna in Boston Harbor indicates significant improvement over time (Table 1.1). Benthic species that had been mostly absent from the harbor have recently been observed recolonizing the harbor seafloor. Another indicator of improving conditions is the increase in the total number of species found in the harbor over time (Figure 1.3). Additional species not seen during previous years' monitoring are now being found every year. When recovery has stabilized, it is expected that new species would be observed only occasionally.

MWRA also looks at sediment oxygen demand (SOD), a measure of biological activity in the sediment. Very high SOD generally indicates too much organic matter. As bacterial decay occurs, oxygen is used up. During the time period that wastewater was discharged to the harbor, the SOD in the harbor was high (See the top bar in Figure 1.4). Since the wastewater discharges were ended, SOD in the harbor is lower, and this is viewed as another improvement. However, scientists monitoring the harbor have noted that in extremely impacted environments, the SOD increased as more organisms began to migrate into an improving area. In newly recolonized areas, the SOD can actually increase, as benthic infauna stimulate and accelerate microbial activity and organic degradation. Eventually the excess organic matter is used up, and the sediments return to a natural, relatively low SOD. In 2007 an area of the harbor previously devoid of organisms was noted to have numerous worms and other animals present and a relatively high SOD.

Table 1.1. Changes in benthic animal community measures in Boston Harbor over time show a strong movement toward increased diversity and immigration of species associated with clean waters into the harbor. (Source: James Blake and Nancy Maciolek, AECOM Corp.).

Parameter	Period		
	1991 – 1998 Harbor discharge, before secondary treatment	1999 – 2000 Centralized harbor discharge and initiation of secondary treatment	2001 – 2005 End of discharge within Boston Harbor
Number of Samples	192	47	120
Number of Species	32. 3 ± 14.3	32. 0 ± 12.5	42.3 ± 18.0
Fauna	Higher abundances of opportunistic species such as *Streblospio benedicti* and *Polydora comuta*	Transitional →	Few opportunists, more oligochaetes, some species more typical of Massachusetts Bay

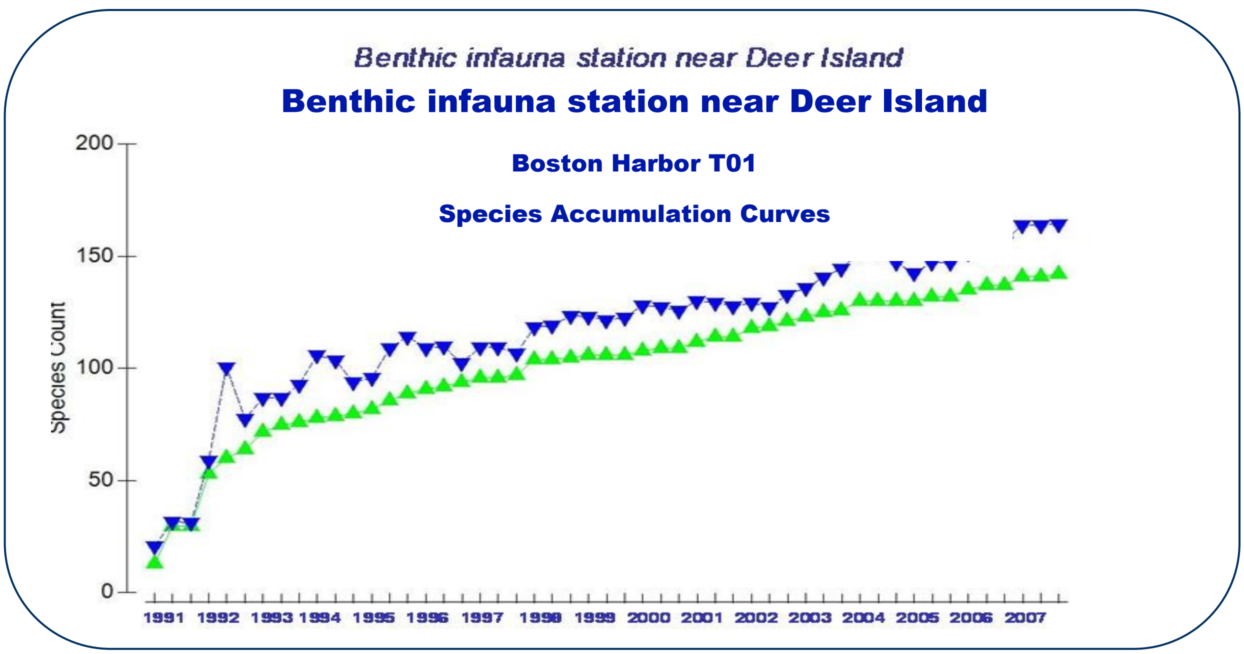


Figure 1.3. Every year since monitoring began in 1991, additional species have been observed in Boston Harbor sediments indicating continuous recovery. Green triangles are number of species observed in a sample, blue triangles represent a statistical predictor of species abundance. (Source: James Blake,

In 2008, a new area of eelgrass was discovered in Boston Harbor near the airport (See Question 8, Eelgrass Habitat). Figure 1.5 provides a schematic depicting the concept of recovery from eutrophication. The MA Division of Marine Fisheries (*MarineFisheries*) has successfully planted eelgrass on the west side of Long Island and on the southwest side of Peddocks Island within Boston Harbor.

Based on water quality criteria and hydrography, *MarineFisheries* identified several sites in Boston Harbor that now meet eelgrass habitat suitability criteria in places where sediments were probably too rich in organic matter, most likely the result of 200 years of waste mismanagement in the harbor. Considering Boston Harbor sites for eelgrass bed restoration would not have been possible 10 years ago. Thus, the decrease in the amounts of algae, the increase in bottom-water dissolved oxygen, and eelgrass recolonization in the harbor, all point to a reversal of the historic trend of over-enrichment of the harbor.

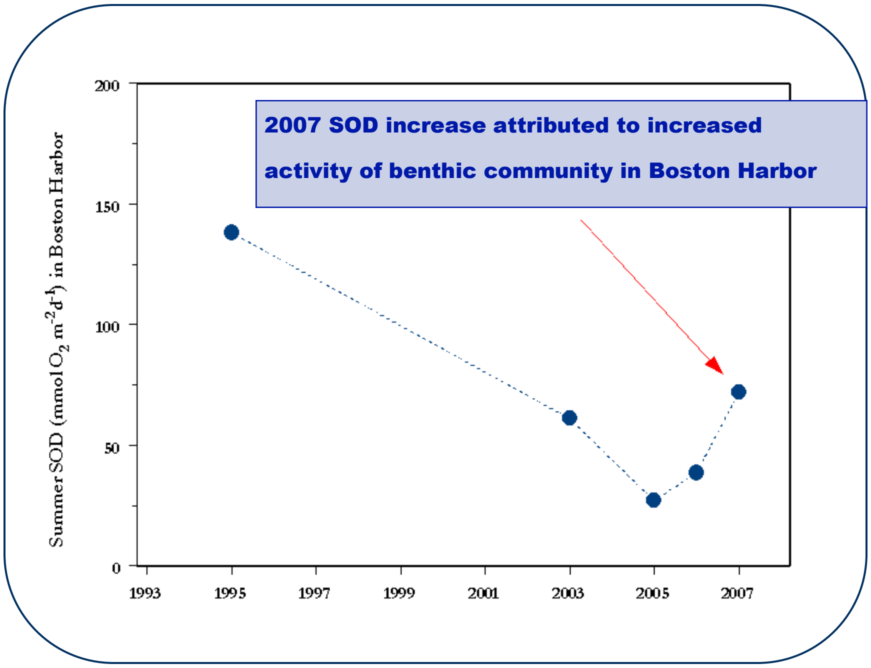


Figure 1.4. Changes in Sediment Oxygen Demand (SOD) in Boston Harbor from monitoring data by MWRA for the period of 1993—2007. In 2007, SOD increased, but scientists do not view this as degradation, rather it may signal another step toward recovery of a previously barren locations in the inner harbor. (Source: Jane Tucker, Marine Biological Laboratory, Woods Hole).

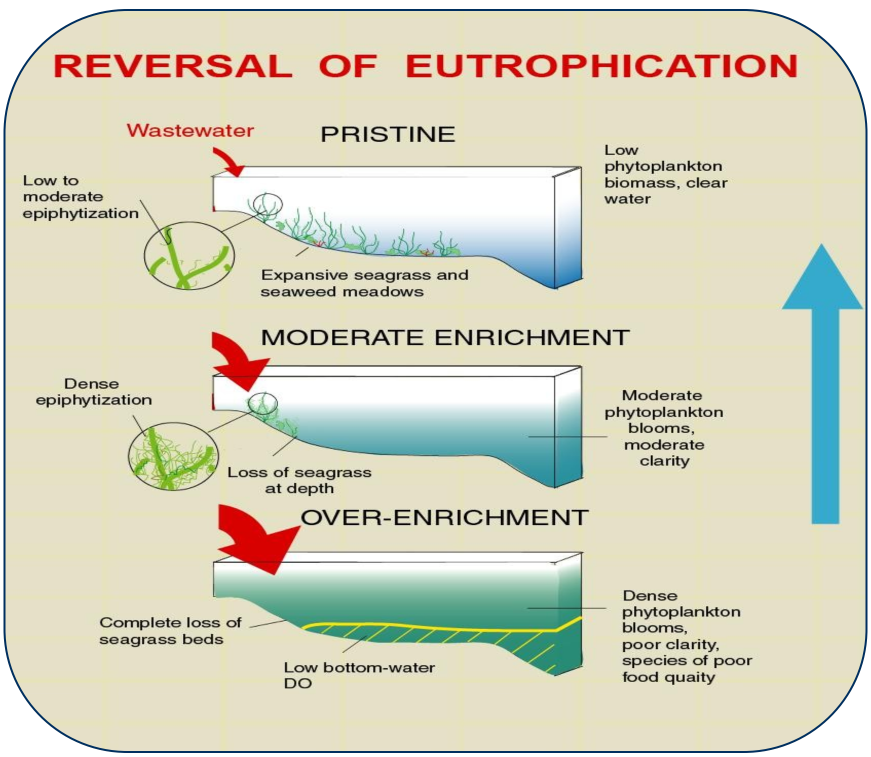


Figure 1.5. Boston Harbor may be a rare example of reversal of eutrophication.

MUNICIPAL WASTEWATER IN THE BAYS

Q2 What are the impacts of the MWRA discharge to Massachusetts and Cape Cod Bays?

Contributor: Wendy Leo, Massachusetts Water Resources Authority

Why this is Important

As indicated in the previous section, the Massachusetts Water Resources Authority (MWRA) stopped discharging all treated sewage generated in the Metropolitan Boston area into Boston Harbor in 2000. Sewage is now diverted to the Deer Island sewage treatment plant and treated wastewater effluent is discharged nine miles offshore in Massachusetts Bay. Advances in the level of treatment, combined with discharging further offshore are measures implemented to improve environmental conditions of Boston Harbor while minimizing the impacts to Massachusetts and Cape Cod Bays.

State of the Bay

In order to better understand water quality variability and provide a baseline for comparing environmental data gathered since the outfall began discharging in Massachusetts Bay, extensive monitoring by the MWRA began in 1992, prior to the major changes in wastewater discharge management.(Figure 2.1). This monitoring, which is required by U.S. Environment Protection Agency (EPA), includes characterizing the discharged sewage effluent as well as the Massachusetts Bay receiving waters. MWRA's monitoring focuses on potential impacts of nutrients, organic material, toxic contaminants, pathogens, and solids.

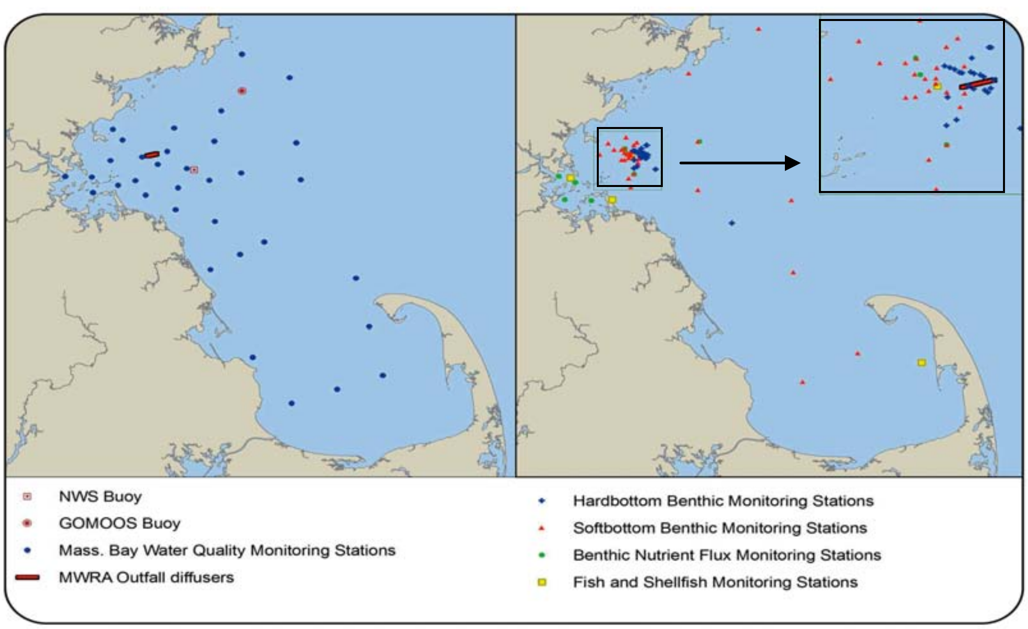


Figure 2.1. Map of outfall location, long-term monitoring buoys, and MWRA monitoring stations. NWS = National Weather Service; GoMOOS = Gulf of Maine Ocean Observing System.

Wastewater Quality: The Deer Island Treatment Plant reliably meets its National Pollution Elimination Discharge System (NPDES) permit requirements. However, from the time that the permit became effective in August 2000, some of the threshold levels established by the NPDES permit were exceeded. In 2009, MWRA reported a cumulative total of 12 NPDES violations (5 of which were due to exceeding toxicity standards) out of thousands of required tests since the NPDES permit was issued in 2000. Since July 2007 there have been no permit violations. In addition to the treatment standards, the MWRA permit has an additional safeguard in that adequate and rapid dilution of the wastewater occurs at the outfall site. The amount of solids, organic material, and toxic contaminants in the effluent has decreased substantially, and has remained consistently low since implementing more stringent influent requirements and initiating modern treatment at the Deer Island Treatment Plant. Discharges of solids and metals from the MWRA wastewater treatment facility are shown in Figures. 2.2 and 2.3, respectively.

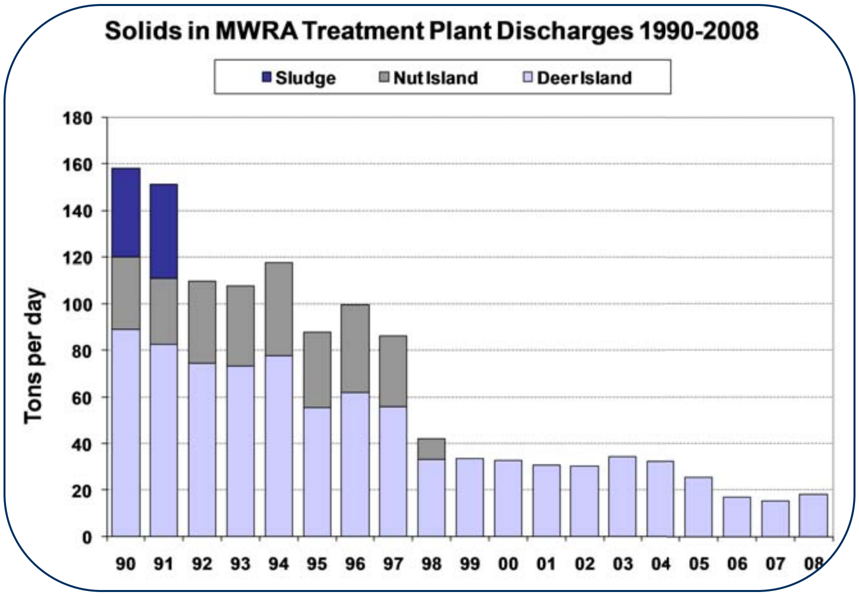


Figure 2.2. Annual solids (tons per day) 1990-2008. Note: Sludge discharge from Boston Municipal waste treatment ends by 1992. The Nut Island discharge was transferred via pipe to the Dear Island facility by 1999.

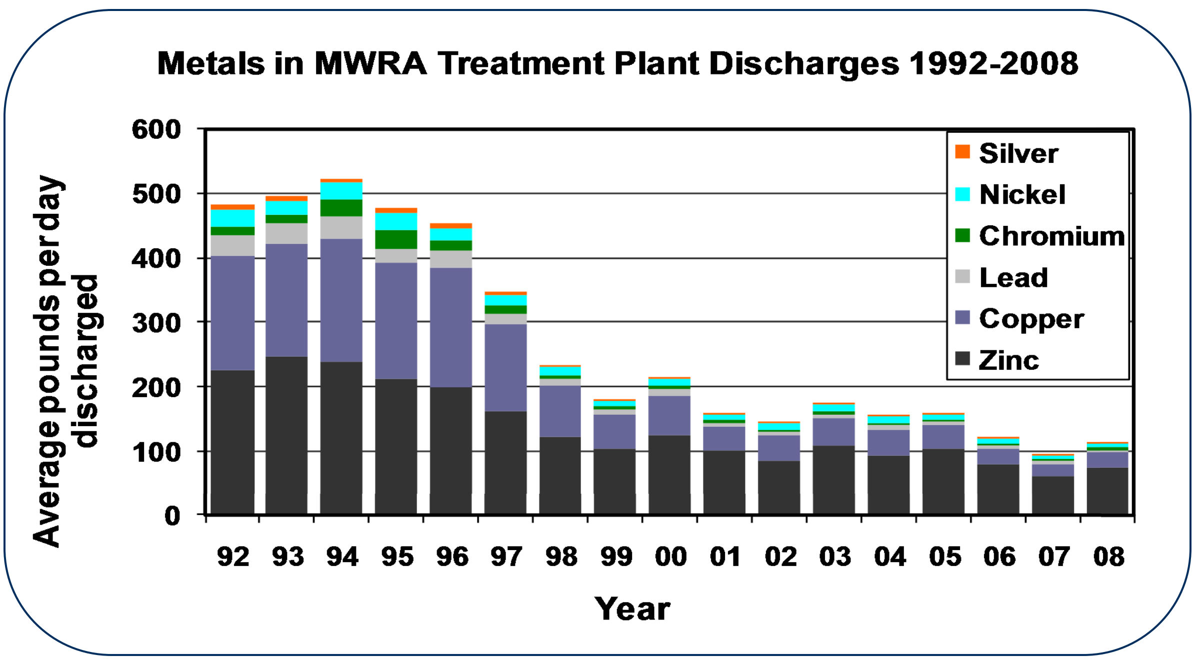


Figure 2.3. Annual volume of metals (pounds per day) discharged between 1991-2008.

***Water Quality*:** The outfall was designed to provide adequate initial dilution to ensure that levels of chemical and microbial contaminants meet water quality standards. Most contaminants actually meet standards as the effluent leaves the treatment plant, even before dilution.

Because the discharged effluent is rich in nutrients, MWRA monitors key water quality indicators of possible nutrient-related ecosystem changes. Slightly elevated ammonium levels near the outfall are observed and are attributed directly to the outfall discharge. Dissolved oxygen in bottom waters near the outfall and in the deep Stellwagen Basin nearby shows no change from pre-diversion conditions. Chlorophyll concentrations throughout the Bays have tended to be higher in the spring and lower in the fall since 2000. Changes in chlorophyll levels are the result of large scale Gulf of Maine phytoplankton dynamics and are not attributed to the outfall discharge. There are year-to-year changes in the phytoplankton production and zooplankton communities, but these changes have been within pre-discharge ranges, and no adverse effects of the outfall nutrients have been observed.

There have been two notable changes in the phytoplankton community in recent years, but both are regional phenomena with no apparent relation to the outfall discharge. The nuisance alga *Phaeocystis pouchettii* has changed from only occasionally dominating the spring bloom community, to doing so in nearly every year, probably due to larger scale factors like those associated with climate change. The organism causing paralytic shellfish poisoning (red tide) in the Gulf of Maine, *Alexandrium fundyense,* typically blooms at levels high enough to close shellfish beds every year along the Maine coastline. Red tide in Massachusetts Bay had been seen only at very low levels from 1993-2004. However, in 2005, 2006, and 2008, red tide blooms originating off the coast of Maine were transported into Massachusetts Bay causing extensive shellfish bed closures (See Question 3, Harmful Algal Blooms).

Fish & Shellfish: With several years of monitoring data before and after outfall discharge began, MWRA examined whether there have been changes in contaminant levels in fish and shellfish tissues due to the outfall. Tests conducted on flounder and lobster tissue showed no statistically significant increase in any contaminant levels after outfall diversion. For mussels placed within the mixing zone of the outfall, there were measurable increases in several organic contaminants. However, the concentrations in the mussels remained well below levels of concern to human health.

Flounder liver disease remains low at the outfall site and elsewhere in Massachusetts and Cape Cod Bays. Skin ulcers were first detected on flounder in 2003 throughout western Massachusetts Bay and Boston Harbor. After peaking in 2004, the levels of ulcers occurring in flounder have been declining, and there is no evidence of an outfall connection.

Sea Floor: Because organic material and toxic contaminants accumulate in quiescent areas of the sea floor, the sediments and bottom-dwelling organisms can be affected by sewage discharges. Sophisticated statistical analyses have also been applied to seafloor measurements of contaminants, organic carbon, soft-bottom dwelling communities, and the sewage tracer bacterium *Clostridium perfringens*. The only clear outfall association detected is a localized increase in *C. perfringens*, indicating that sewage-derived solid material is indeed settling to the sea floor near the outfall, but there is no known effect of contamination on the seafloor ecosystem. There are natural year-to-year changes in biodiversity (Figure 2.4) but these are similar near the outfall and at more distant. The MWRA monitoring has also shown that oxygen penetrates the sediment as deeply as before and that measured sediment oxygen demand has remained low, similar to that measured in other healthy bays.

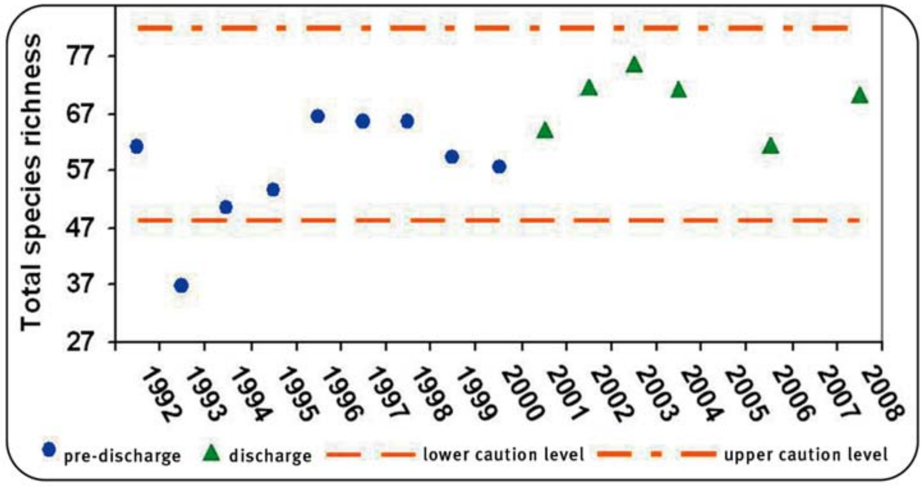


Figure 2.4. Benthic species richness has varied only within expected limits (dashed orange lines) near the outfall since the diversion in 2000.

Communities of organisms dwelling on and among the rocks near the outfall have remained relatively stable from 1996 to 2008. Semi-quantitative monitoring by MWRA has shown some subtle shifts in community structure over time, but post-discharge changes have been modest, and lush growth continues on the outfall riser caps (Figure 2.5).

Photos: Maciolek et al, 2009

Figure 2.5. Photographs taken in 2008 showing colonization of encrusting taxa and the sea anemone *Metridium senile* (left) on the head of an active diffuser.

Q3 What conditions contribute to harmful algal blooms in Massachusetts Bay?

Contributors: Donald Anderson, Woods Hole Oceanographic Institution, and Scott Libby, Battelle Memorial Institute

Why this is important

Prior the early 1970's, paralytic shellfish poisoning (PSP) toxicity was restricted to the far eastern sections of Maine near the Canadian border. However in 1972, a massive, visible red tide of *Alexandrium fundyense*, a major cause of PSP, stretched from southern Maine through New Hampshire and into Massachusetts, causing toxicity in the southern Gulf of Maine for the first time in recorded history. A potent neurotoxins (chemicals that have negative impacts on the nervous system) called saxitoxin produced by *A. fundyense* are accumulated by filter feeding shellfish and are passed on to humans and animals that consume them, leading to illness, incapacitation, and even death.

Since the 1972 outbreak, the western Gulf of Maine has experienced PSP outbreaks on an annual basis. Frequent outbreaks were observed in Massachusetts waters as well through the early 1990s (Figure 3.1). Then, after more than a decade of limited recurrence in Massachusetts Bay, a large bloom again appeared along the Massachusetts coast in 2005. Three of the last five years had significant blooms, raising questions about the cause and predictability of red tides.

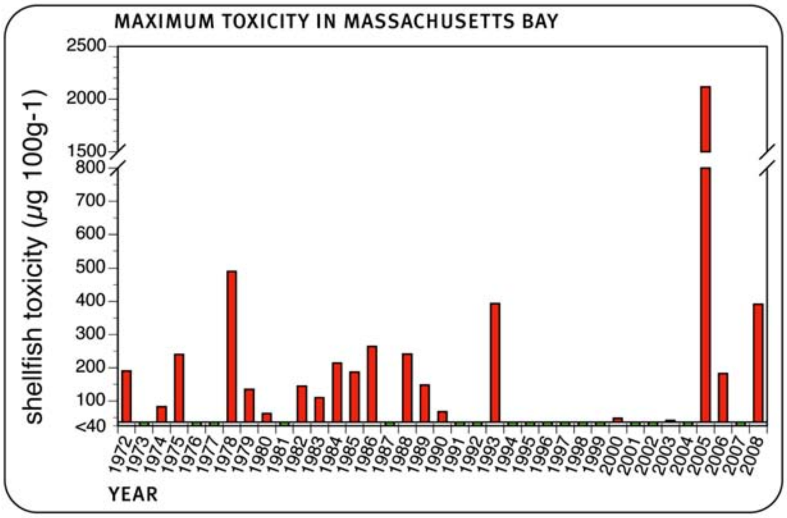


Figure 3.1. Maximum levels of PSP toxicity in Massachusetts Bay, 1972‐2009. Units are µg saxitoxin per 100 g shellfish tissue.

State of the Bay

Current research on *Alexandrium* blooms that affect Massachusetts Bay suggests that they originate off the mid‐coast of Maine and are transported southward with the western segment of the Maine coastal current (Figure 3.2). Fresh water runoff from rivers draining into the Gulf of Maine and localized wind patterns are important factors that contribute to the nature of the Maine coastal current. The blooms may enter Massachusetts Bay under suitable conditions – when a bloom passing off Cape Ann in the western

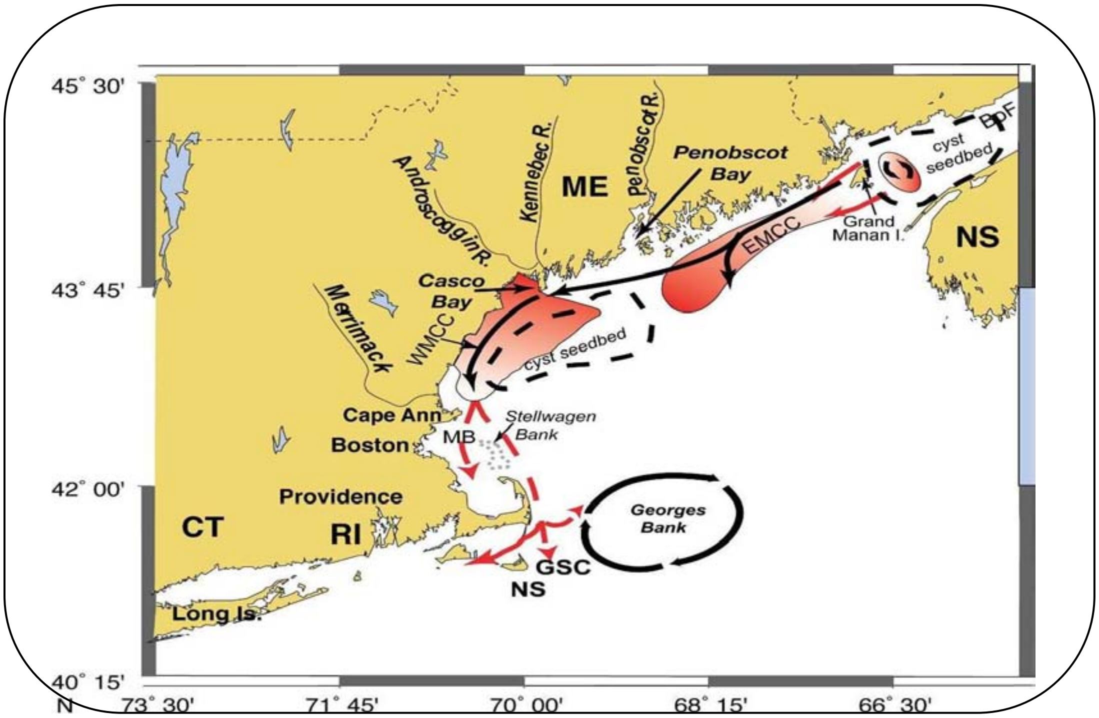


Figure 3.2. Conceptual model of *Alexandrium* bloom dynamics and PSP toxicity. Shown in solid black lines are the eastern Maine coastal current (EMCC) and western Maine coastal current (WMCC) systems, and in dashed black lines the cyst seedbeds in the Bay of Fundy (BoF) and mid-coast Maine. The red shaded zones show areas where *Alexandrium* vegetative cells accumulate at higher concentrations relative to adjacent waters. Red dashed lines show the delivery or transport pathways of these established bloom populations to southern waters. GSC = Great South Channel; NS = Nantucket Shoals; MB = Massachusetts Bay.

Maine coastal current is blown shoreward into northern Massachusetts Bay by sustained northeast winds. In addition to weather patterns, life history characteristics of *Alexandrium* likely influence the recurrence of red tides in Massachusetts. For approximately three months in 2005, a massive bloom of *Alexandrium* invaded Massachusetts Bay (Figure 3.3). This outbreak was the largest since the 1972 event, and ultimately resulted in shellfish harvesting closures that extended from eastern Maine through Massachusetts to its offshore islands of Martha's Vineyard and Nantucket (Figure 3.4). Three primary factors were cited as contributing to the extraordinary 2005 bloom: strong northeast winds, very high river flow, and abundant over-wintering *Alexandrium* reproductive cysts. Numerical model sensitivity tests showed that cysts were the most important factor causing the Gulf-wide bloom. The high abundance of cysts in western Gulf of Maine sediments provided a large vegetative cell source for the bloom, though the source of those cysts is not well documented. Given the abundant cysts, the model simulation showed a substantial Gulf-wide bloom whether or not 2005's unusual river flow and winds were taken into account.

In the five years since the 2005 bloom, there have been relatively large *Alexandrium* blooms in the western Gulf of Maine. Prevailing winds (Nor'easters in May) have been such that in 2006, 2008, and 2009, substantial PSP toxicity was present in the bays (Figures 3.2 and 3.4). In 2007, there were no strong northeasterly winds and the bloom stayed offshore.

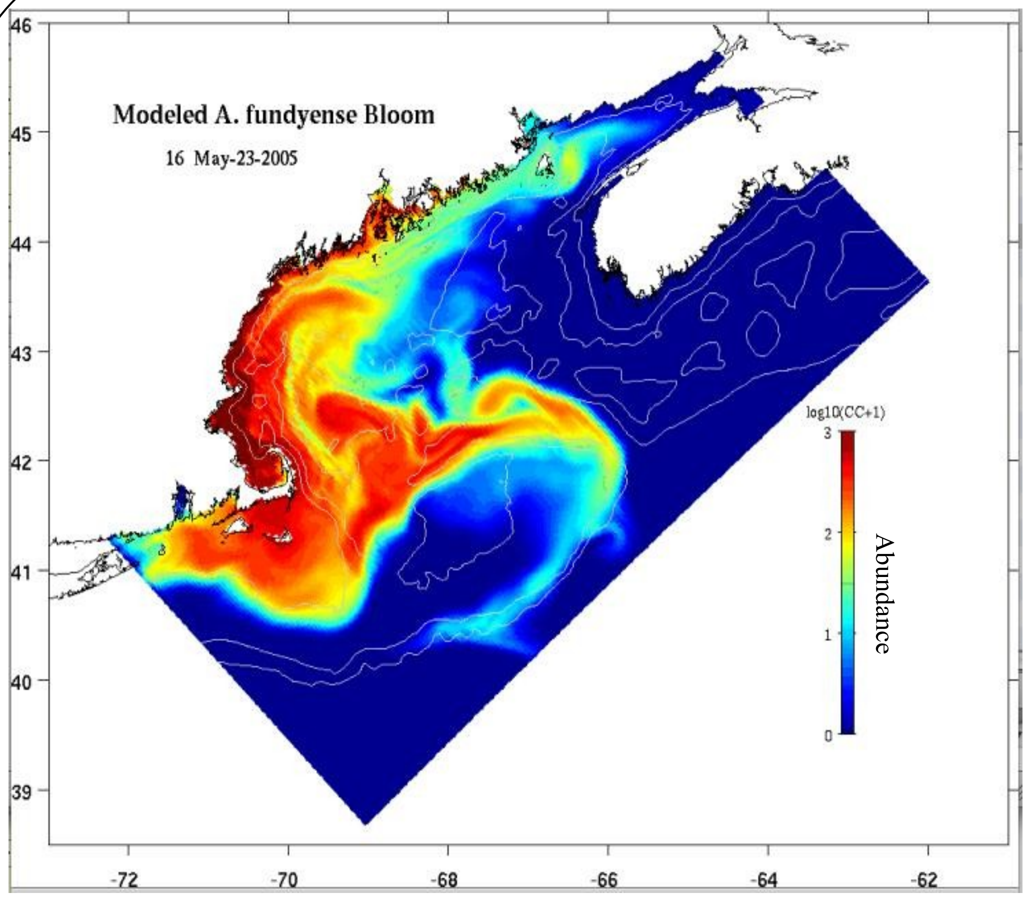
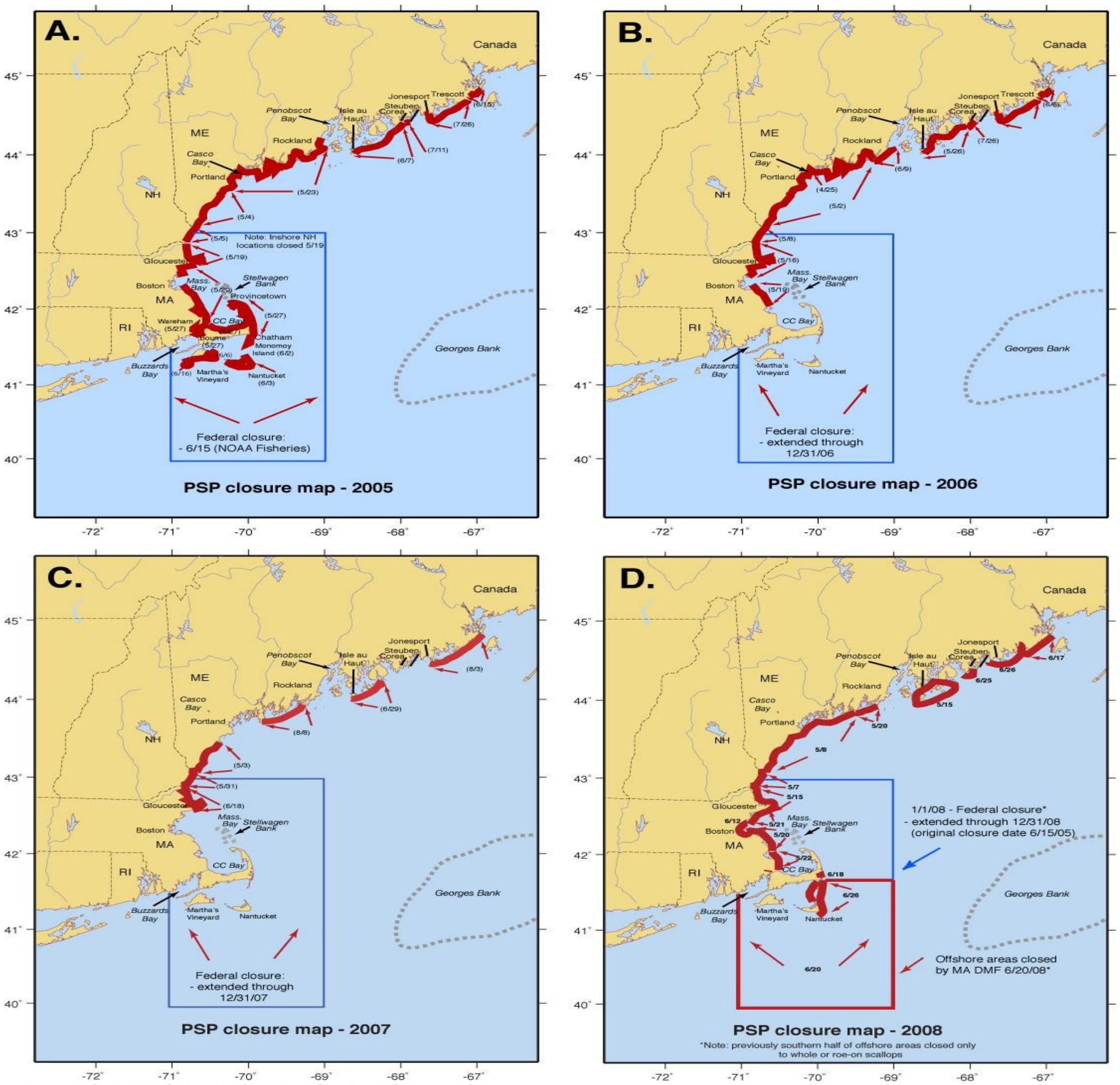


Figure 3.3. Abundance of *Alexandrium fundyense* in the Gulf of Maine as estimated by the WHOI model for May 23, 2005.

From the cyst abundance patterns, and the long term pattern of shellfish toxicity, it appears that we have entered an era of frequent red tide bloom events in the western Gulf of Maine. In effect, the 2005 red tide, and the factors that led to the high cyst abundance in 2004, have "reset" the system. Conditions now resemble those after the 1972 outbreak, which was followed by several decades of high and frequent toxicity in the western Gulf of Maine. Fortunately, cyst levels in Massachusetts Bay remain low and the occurrence of *Alexandrium* blooms in these waters still depends upon meteorological conditions conducive to drawing the western Gulf of Maine coastal waters into the Bay. It is anticipated that Massachusetts Bay will continue to see frequent PSP toxicity closures over the next decade or two, similar to those in the 70s and 80s.



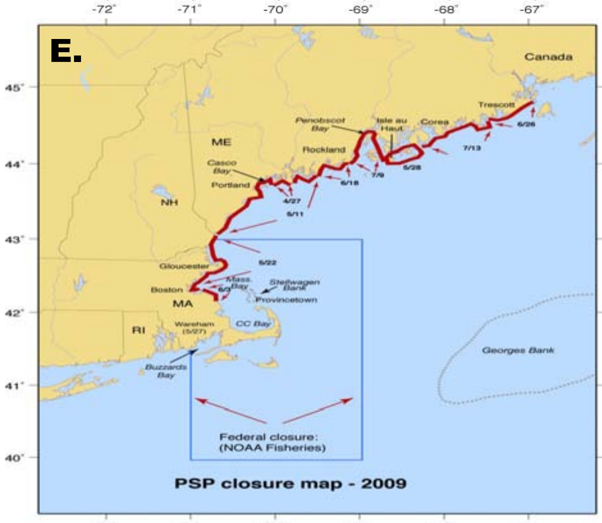


Figure 3.4. Shellfish closures along the Massachusetts coast and the adjacent offshore waters due to detection of PSP toxins during the *Alexandrium* blooms in 2005(a), 2006(b), 2007(c), 2008(d) and 2009 (e). Issuance dates of these closures are indicated. (Source: D. Anderson, Woods Hole Oceanographic Institution)

Q4 What levels of contaminants have been found in blue mussels in the Massachusetts and Cape Cod Bay regions?

Contributor: Christian Krahforst, Massachusetts Bays Program

Why this is important

Coastal waters nation-wide continue to face the threat of degradation in spite of efforts to improve resource management. Degradation of coastal waters is due, in part, to the continued release of contaminants such as metals, pesticides, and organic pollutants that result from human activities and the legacy of pollution in coastal watersheds. Contaminants from sewage and industrial discharge, stormwater runoff, atmospheric deposition, and other sources of pollution pose hazards to fish, wildlife, and humans when concentrations reach excessive levels. The actual threat posed by contaminants depends on the level of contamination, the sensitivity of resident organisms, and long-term environmental fate and persistence of the pollutants.

One method used to assess the importance of contaminants in both aquatic and terrestrial systems is to measure the accumulation of pollutants in resident organisms. The blue mussel, *Mytilus edulis,* is particularly useful for these types of assessments because it is an abundant, immobile, resident organism in the Gulf of Maine (GOM) that is relatively easy to collect. In partnership with the GOM Council on the Marine Environment, the Massachusetts Bays Program (MBP) has helped monitor contaminant levels in blue mussels since 2003 through the Gulfwatch program. While statistically valid conclusions are still difficult to draw because of the relatively small sample size to date, spatial and temporal trends in contaminant levels are beginning to emerge in the MBP planning area and throughout the region.

State of the Bay

Since 1993, Gulfwatch program scientists and volunteers have been collecting mussels at over 60 stations throughout the GOM. Of these, 14 stations are located along the coast of Massachusetts and Cape Cod Bays (Figure 4.1). Tissue samples from mussels collected at these sites are used to measure the quantity of trace metals and important classes of organic contaminants such as DDT, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs) that have accumulated in the tissues of *M. edulis* (Table 4.1). Results can be compared regionally within Massachusetts Bay and the Gulf of Maine as well as nationally with parallel assessments conducted by the National Oceanic and Atmospheric Administration's (NOAA) Mussel Watch Program.

As observed in the 2004 State of the Bays report, concentrations of contaminants in mussels tended to be

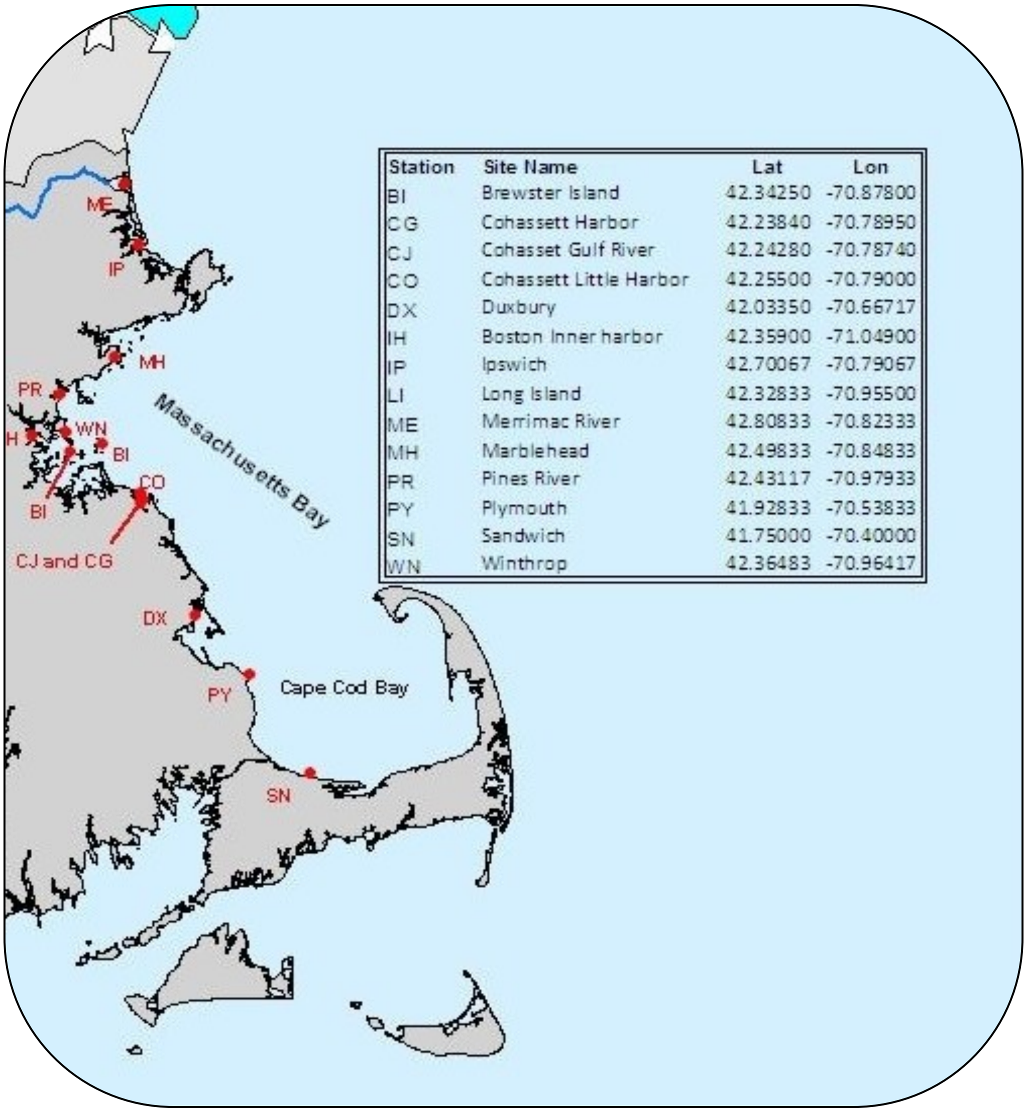


Figure 4.1. Contaminant monitoring sites in the Massachusetts Bays region where blue mussels (*Mytilus edulis*) are collected.

higher in the southwestern portion of the GOM where coastal watersheds are more industrialized, and locally in areas near or adjacent to urban centers along the coast. Many of the contaminants monitored by Gulfwatch are found to be in greater concentration in mussels collected in Massachusetts waters. Notable exceptions are mercury and PAHs, which are equal or higher at locations within the Great Bay Estuary of New Hampshire. A site in Boston Harbor still shows the highest concentrations of many of the monitored contaminants when compared to all the Gulfwatch monitoring sites. Except for lead in Boston Harbor, no contaminant concentrations in mussels collected from coastal Massachusetts exceeded the U.S. Food and Drug Administration federal standards for human consumption.

INORGANIC CONTAMINANTS:

Ag (silver), Al (aluminum), Cd (cadmium), Cr (chromium), Cu (copper), Fe (Iron), Hg (mercury), Ni (Nickel), Pb (lead), Zn (zinc)

ORGANIC CONTAMINANTS:

Aromatic Hydrocarbons(ΣPAH$_{24}$)	***Chlorinated Pesticides(ΣPEST$_{21}$)***
Naphthalene	Hexachlorobenzene (HCB)
1-Methylnaphthalene	γ-Hexachlorocyclohexane (γ-HCH)
2-Methylnaphthalene	α-Hexachlorocyclohexane (α-HCH)
Biphenyl	Heptachlor
2,6-Dimethylnaphthalene	Heptachlor epoxide
Acenaphthylene	Aldrin
Acenaphthalene	cis-Chlordane
2,3,5-Trimethylnaphthalene	γ-Chlordane
Fluorene	trans-Nonachlor
Phenanthrene	Dieldrin
Anthracene	α-Endosulfan
1-Methylphenanthrene	β-Endosulfan
Fluoranthene	Endrin
Pyrene	Metoxychlor
Benz [a] anthracene	Mirex
Chrysene	***DDT and Homologues (incl. in ΣPEST$_{21}$)***
Benzo [b] fluoranthene	2,4'-DDE 4,4'-DDE
Benzo [k] fluoranthene	2,4'-DDD 4,4'-DDD
Benzo [e] pyrene	2,4'-DDT 4,4'-DDT
Benzo [a] pyrene	***PCB Congeners (ΣPCB$_{24}$)***
Perylene	PCB 8+5, PCB 18+15, PCB 28, PCB 29,PCB 44, PCB 50, PCB 52, PCB 66+95,PCB 77, PCB 87, PCB 101+90, PCB 105, PCB 118, PCB 126, PCB 128, PCB 138, PCB 153+132, PCB 169, PCB 170+190, PCB 180, PCB 187, PCB 195+208, PCB 206, PCB 209
Indeno [1,2,3-cd] pyrene	
Dibenz [a,h] anthracene	
Benzo [g,h,I] perylene	

Table 4.1. Inorganic and organic compounds analyzed by the Gulfwatch Program in mussel tissue collected from sites in the nearshore coastal region of the Gulf of Maine.

Temporal Trends

Only two of the Gulfwatch stations in Massachusetts coastal waters, the lower Merrimack Estuary and Town Beach in Sandwich, have been sampled enough times (i.e., greater than 5 individual years) where confidence can be placed in observed trends. For the Merrimack Estuary, chromium concentrations (Figure 4.2) have significantly decreased during the Gulfwatch monitoring period, probably the result of the reduction in paper mills and tanning industries over the last century. Silver concentrations in mussels collected at the Sandwich site have also decreased since 1993, possibly due to improved wastewater treatment, both in terms of contaminant reduction within waste streams and the relocation of the Boston municipal outfall site from Boston Harbor to further offshore into Massachusetts Bay (See Questions 1 & 2, MWRA discharge).

No other significant trends were observed for monitored contaminants in Massachusetts Bay. Some other Massachusetts stations indicate possible trends, however they have not been sampled frequently enough to provide the basis for statistically significant trends analyses.

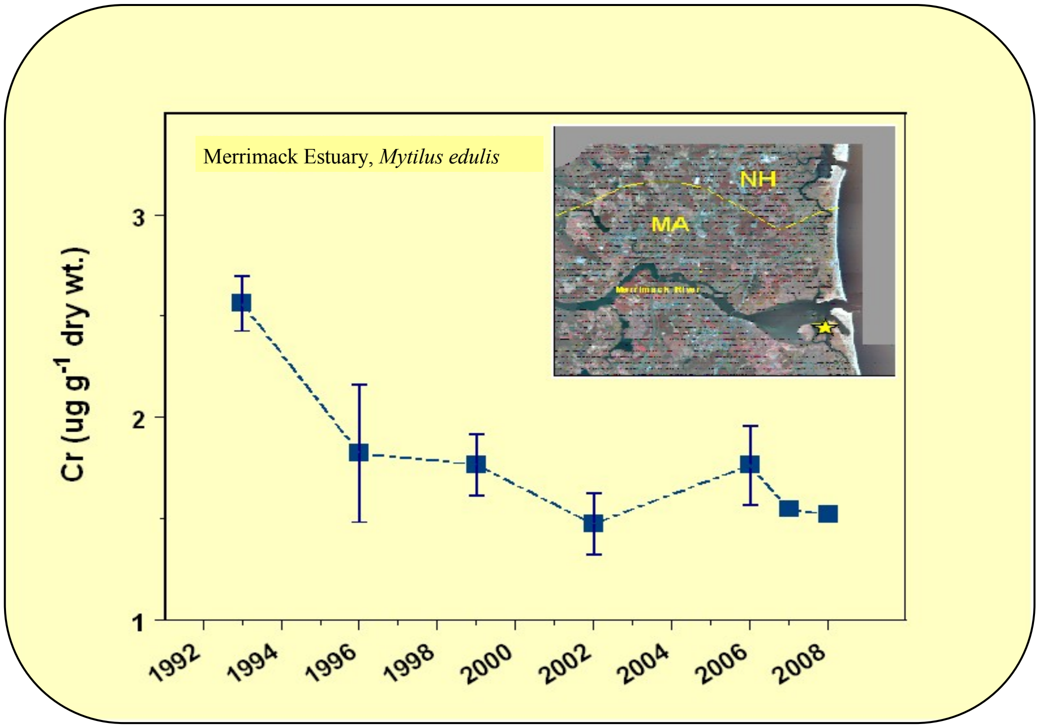


Figure 4.2. Chromium (Cr) found in mussel tissue collected in the lower Merrimack Estuary, 1993 –2008. (Error bars represent one standard deviation of replicate analyses). Data source: GOMC Gulfwatch Program.

Spatial Trends

In order to provide a contemporary view of contaminant exposure, changes in contaminants accumulated in the soft tissue of mussels across the GOM region were evaluated using the median of annual values from the Gulfwatch data over the period of 2004-2008. The median values for mercury, lead, copper, DDT, PAH, and PCBs in each of the jurisdictions within the GOM region as well as summary values for the United States, are shown in Figure 4.3. Within the GOM, only mercury and lead exceeded the median values reported by the national Mussel Watch Program of NOAA. Both of these contaminants have strong atmospheric sources and may reflect the downwind orientation of the Northeast and the cumulative atmospheric loading of these contaminants from a trajectory that extends to the continental mid-west. For Massachusetts, mercury, lead, DDT, and PCB significantly exceeded the NOAA Mussel Watch national median values for contaminants in mussels. Massachusetts had the highest median values of all the five GOM jurisdictions (Massachusetts, New Hampshire, Maine, New Brunswick, and Nova Scotia) for lead, copper, DDT, and PCB. DDT, a chlorinated pesticide that was used to control mosquitoes and banned in Canada and the U.S. in 1972, still persists in the environment and was most likely more extensively used in Massachusetts compared to the other states along the GOM.

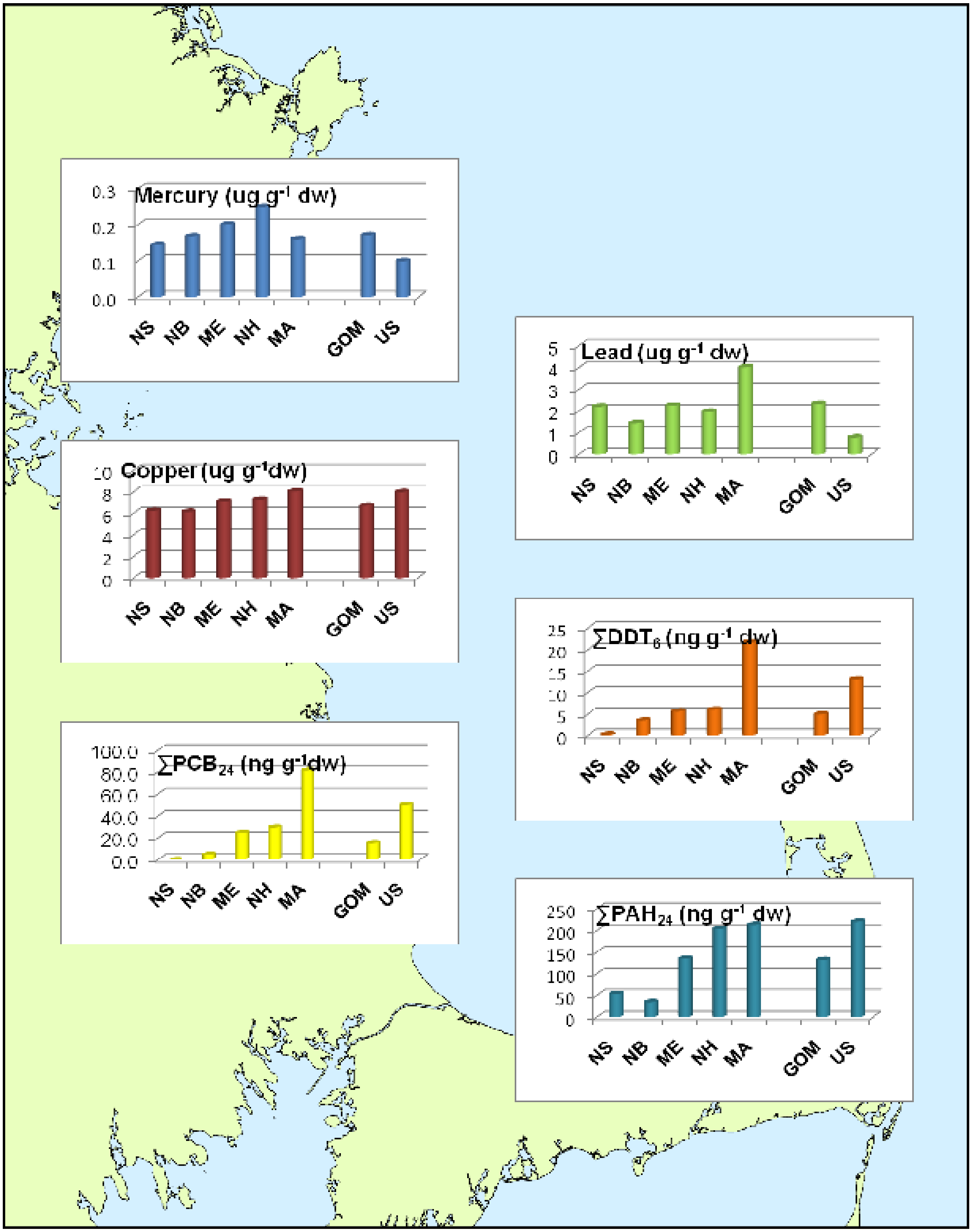


Figure 4.3. Selected contaminants in mussels from the jurisdictions along the Gulf of Maine (GoM): Nova Scotia (NS), New Brunswick (NB), Maine (ME), New Hampshire (NH), and Massachusetts (MA). Averaged data from the National Oceanic and Atmospheric Administration's national monitoring program, Mussel Watch, are shown for comparison (US).

Q5 Is it safer to swim at Massachusetts beaches than it was five years ago?

Contributors: Michael Celona, Massachusetts Department of Public Health, and Matt Liebman, U.S. Environmental Protection Agency

Why this is Important

Beaches, and the recreational opportunities they provide, are clearly an important part of recreation and tourism industry in Massachusetts, the state's economy, and the culture of the Commonwealth. The Massachusetts Bays region boasts excellent and diverse beaches for wading, swimming, surfing, fishing, and boating. Thus it is important that beach water quality meet or exceed standards for pathogens to help protect human health. Pathogens are disease-causing organisms, which are often associated with fecal contamination. Pathogens associated with fecal contamination are one of the major health threats facing people who swim in the coastal waters of the Massachusetts Bays.

One of the main sources of pathogens in our coastal waters is stormwater, which is often discharged near swimming beaches via small coastal streams that drain the surrounding developed areas. Stormwater often carries elevated levels of bacteria. Scientists use certain types of indicator bacteria, such as *Escherichia coli* and *Enterococcus*, to test for the possible presence of pathogens from both human sources (e.g., septic systems and illicit sewer connections) and animal waste (e.g., pets, livestock, waterfowl, and wildlife). In Boston area beaches, combined sewer overflows are also a major source of fecal contamination (see Question 6, Combined Sewer Overflows). People who swim or recreate in fecal-contaminated waters are at increased risk of contracting diseases or illnesses, such as gastroenteritis, hepatitis, and dysentery.

If water quality standards are not met, the public is advised to avoid contact with the waters via signage at the beach or through traditional and electronic news sources. At beaches where bacteria levels exceed water quality standards, communities are required to post notices at access points stating that the water is unsuitable for swimming. The Massachusetts Department of Public Health (DPH) now operates a web site (http://mass.digitalhealthdepartment.com/public_21) that reports water quality data and closure status on a daily basis; data are reported about 24 hours after samples are collected. As a result of increased monitoring and improvements in the quality of monitoring, the number of beach postings and closings has actually increased since the law went into effect. Increased monitoring and improved notification of water quality conditions reduces human contact with contaminated waters.

All Massachusetts coastal beaches are monitored at least weekly for fecal indicator bacteria. The exception are those beaches that are granted waivers from regular weekly monitoring based on historical water quality data that have met water quality standards and from sanitary surveys that documented no nearby pollution sources

State of the Bay

The amount of rainfall and associated volume of stormwater runoff can significantly contribute to the contamination of coastal waters. The number of beach water closures, or the percent of water quality samples that exceed water quality standards roughly tracks the summer rainfall in coastal Massachusetts (Figure 5.1). For example, in the early summer of 2009, above-average rainfall levels caused a record-breaking number of beach closures in Massachusetts.

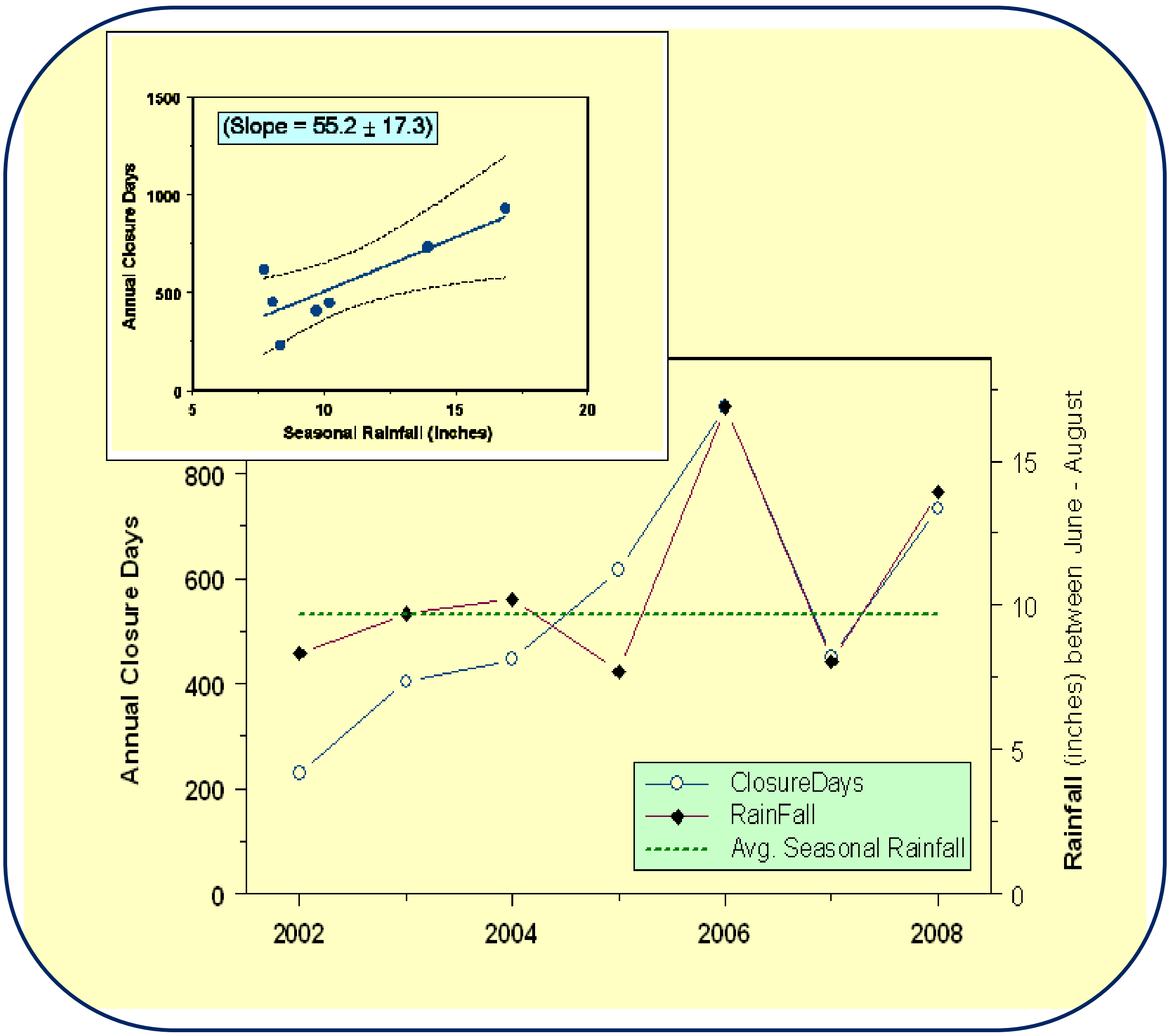


Figure 5.1. The percent of beach monitoring water quality samples in communities bordering Massachusetts and Cape Cod Bays that exceed the bacteria standard associated with summer rainfall as measured at Logan Airport. Graph insert shows the relationship between area closures and seasonal rainfall (r^2 0.67) for beach seasons 2002—2008.

Remediation of stormwater discharges, in turn, can result in reduced bacterial contamination. Some beaches have shown improvements in water quality and, subsequently, reduced beach closures. For instance, the city of Salem's Juniper Beach experienced a reduction in beach water closures after stormwater outfall modification and periodic cleaning prior to the 2006 beach season (Figure 5.2). Annual cleaning of storm drains and remediation efforts by local communities generally reduce the level of bacterial contamination. Regular testing of water quality at individual beaches needs to be maintained because stormwater quality is so variable.

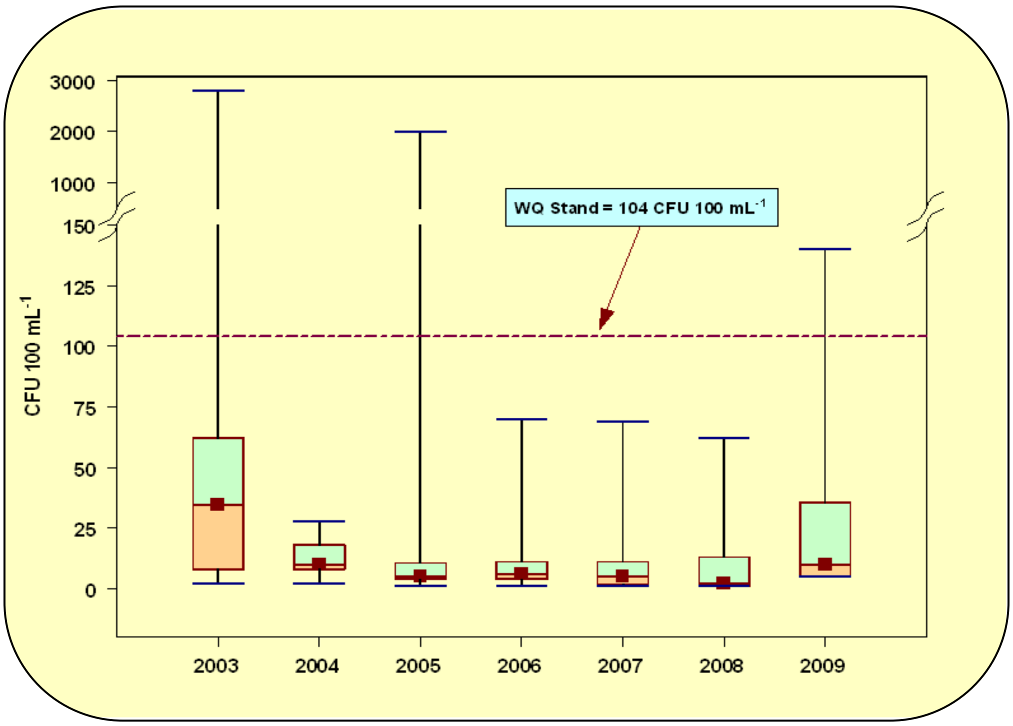
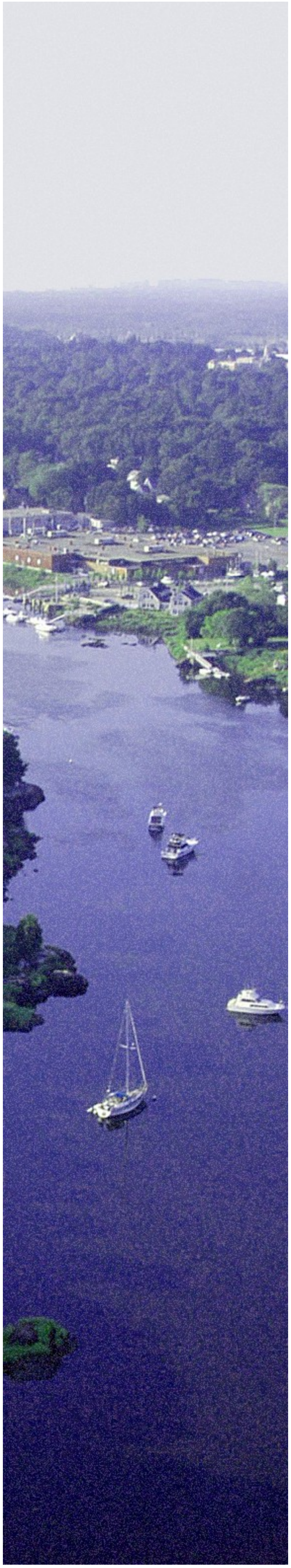


Figure 5.2. Beach water quality data (*Enterococci*, cfu/ 100 mL) reported by the Massachusetts Department of Public Health for Juniper Beach in Salem, MA. After stormwater outfall cleaning and remediation with a "duckbill" tide gate prior to the 2006 beach season, Juniper Beach closures were reduced. For more information on how to read "box and whisker" plots see *Box Note* at the end of this section.



The number of beaches monitored for fecal indicator bacteria increased by 30% in 2003, due in part to passage of the Federal Beaches Environmental Assessment and Coastal Health Act of 2000 and the subsequent allocation of funding for beach monitoring. Additionally, the Massachusetts Beach Act, which is implemented by the DPH, requires all communities to monitor bacteria levels at public and semi-public bathing beaches while the beaches are in operation. Acceptable bacteria levels have been set in accordance with new, stricter U.S. Environmental Protection Agency standards for indicator bacteria. As a result of the stronger legislation, it is safer to swim at a number of area beaches due to an increase in the number of sanitary surveys used to identify and remediate pollution sources, increased frequency of monitoring, and improved public notification of water quality conditions through various media (e.g., signage, website).

The number of beaches with closures, however, is still significant. Although many communities have made progress in improving water quality at beaches through implementation of wastewater and stormwater permit requirements as well as other strategies, such as installing trash containers that prevent access by birds and other wildlife using it as a source of food. Many communities, such as Provincetown, Salem, and Quincy, are also using best management practices such as more frequent catch basin cleaning, which can reduce the number of pollutants that are discharged from the stormwater system. Local communities continue to face technical and budgetary challenges for identifying and remediating indicator bacteria sources, but in spite of these challenges, local, state, and federal authorities are finding new and innovative ways to improve water quality in Massachusetts.

Box Note*:* Box and whisker plots (e.g., Figure. 5.2) are used to convey summary statistics like the median (i.e., the value that is exactly in the middle of the ordered data set), lower and upper quartiles (upper and lower edges of the box) and the lower and upper extremes (the "whiskers") of the data of interest in graphical form.

COMBINED SEWER OVERFLOWS

Q6 How many CSOs remain in the Massachusetts Bay Program's planning area?

Contributor: Cathy Vakalopoulos and Kevin Brander, Massachusetts Department of Environmental Protection

Why this is important

Combined sewer overflows (CSOs) are found in older cities where household and industrial wastewater as well as stormwater flow through the same pipes. When the system is subject to very high flow associated with large rainstorms or snowmelt events, there are "relief locations" known as CSOs. CSOs are designed to discharge directly to waterways in order to prevent street flooding or backups through service connections into basements. These discharges of untreated wastewater can result in dramatically diminished water quality, resulting in beach closures, restrictions to recreational activities, fish and shellfish contamination, and other adverse impacts to the aquatic habitat. Pollutants include pathogens, particles, elevated water temperatures, and excess nutrients that can contribute to eutrophication. Unfortunately, reducing or eliminating CSO discharges is an extremely complex and costly endeavor. Reduced discharge from CSOs and resulting water quality improvements are difficult to track because rain and snowfall amounts vary from year to year. In addition, increases in impervious areas often result in increased discharges to combined sewers, thus increasing the likelihood of untreated discharges at CSOs.

State of the Bay

CSOs are regulated by the U.S. Environmental Protection Agency's (EPA) and Massachusetts Department of Environmental Protection's (MassDEP) CSO Policies as well as the state Water Quality Standards. EPA's CSO Control Policy provides national guidance for controlling CSO discharges through the National Pollutant Discharge Elimination System (NPDES) permitting program. Communities with CSOs are first required to implement minimum controls that reduce the frequency and volume of CSO discharges without requiring major planning or construction. Communities with CSOs are also required to develop Long-Term CSO Control Plans in order to comply with the Clean Water Act and meet state Water Quality Standards.

Massachusetts Bays communities that have CSOs are Gloucester, Lynn, Chelsea, Somerville, Boston, and Cambridge. CSOs in Chelsea, Somerville, Boston, and Cambridge are either maintained by the municipalities or the Massachusetts Water Resources Authority (MWRA). Figures 6.1 and 6.2 show approximate locations of known CSO outfalls in the MBP planning area (Metro Boston and North Shore, respectively).

Gloucester has seven active CSO outfalls that discharge to Pavilion Beach and Gloucester's inner harbor. Figure 6.2 shows five locations since two locations each have two CSOs located close together (004/004A and 006/006A). Gloucester remains under a state/federal order to move forward with measures to address CSO discharges, in accordance with an approved $14.6 million Final Long Term CSO Control Plan (Control Plan). The most critical elements of the Control Plan address CSO discharges from outfall 002 to Pavilion Beach.

Figure 6.1. CSO locations in the Metro Boston region (includes Chelsea, Somerville, Boston, and Cambridge). Data source: MWRA.

Gloucester has completed substantial construction work to address discharges from CSO 002. This work, along with efforts to maximize flows to the wastewater treatment facility through modifications of the CSO 002 regulator structure, have served to dramatically reduce CSOs to Pavilion Beach. The Control Plan indicates that the work will reduce CSO discharges to once a year with typical rainfall.

Figure 6.2. CSO locations in the city of Gloucester. Data source: EPA, Region I.

The approved Control Plan also recommended sewer separation work in CSOs 004, 005, and 006 subareas. During the course of the design work, the City noted that not all CSO outfalls are included in the original Control Plan (004A and 006A), and has requested a new compliance schedule to re-evaluate the most cost-effective alternatives for addressing discharges from other CSOs. EPA and MassDEP are currently reviewing this request.

The Lynn Water and Sewer Commission (LWSC) treats wastewater from Lynn, Saugus, Swampscott, and Nahant and has four active CSOs that directly discharge to Lynn Harbor, Stacy Brook, and the Saugus River. To date, $80 million in abatement work has been completed, resulting in near elimination of CSOs to King's Beach. However, stormwater flows to the beach continue to cause water quality impairments. LWSC has submitted a supplemental CSO control plan requiring an additional $55 million to address CSO pollution issues. This plan is currently under review by EPA and MassDEP.

The MWRA is proceeding with approximately $1 billion in work to address CSO discharges in their system. They have reduced the number of CSOs that discharge to the Charles, Mystic, and Neponset Rivers and Boston Harbor from 84 in 1987 to 24 currently. Further, the total volume of untreated discharge through CSOs has been reduced by 81% since 1987 (see *Box Note*, next page). Three CSO facilities screen, chlorinate, and store wastewater until it can be pumped to the MWRA Deer Island Treatment Plant. However, if the capacity of the existing sewer system is exceeded by excessive and prolonged storm events, they are still able to discharge directly to receiving waters. The remaining CSO facilities are located in Union Park in Boston, and Cottage Farm and Prison Point in Cambridge. The Somerville Marginal Facility can also partially treat wastewater, but there are no storage facilities. During intense storm events, wastewater flowing to Somerville Marginal is discharged once it is screened, chlorinated, and dechlorinated.

One of the MWRA CSO mitigation projects currently underway is outlined in the North Dorchester Bay CSO Control Plan. The purpose of this project is to reduce CSO discharges and control stormwater along South Boston beaches, Pleasure Bay, and Reserved Channel. Components of this project include the installation of the North Dorchester Bay CSO storage tunnel, new stormwater piping, and a remote odor control facility. Once completed, it is expected that CSO discharges will be eliminated with the exception of "greater than 25-year storms". Currently, these CSOs, on average, discharge 16 times per year.

Box Note: Much of the information about the Metro Boston region's CSOs can be found in technical and outreach documents provided by MWRA at: http://www.mwra.state.ma.us/harbor/html/bhrecov.htm.

Though significant progress has been made in reducing the frequency and amount of untreated CSO discharges to coastal waters, more work still needs to be done. CSO projects are costly, time consuming, and potentially disruptive to local neighborhoods. The public desire to swim, boat, and fish in clean waters continues to serve as impetus for improving the regulatory process that mandates CSO improvements needed to meet compliance with the mandates of the Clean Water Act.

Q7 How have the amount and quality of point source pollution discharges changed in Massachusetts and Cape Cod Bays?

Contributor: Todd Callaghan, Massachusetts Office of Coastal Zone Management

Why this is important

Point source pollution discharges emanating from sewage treatment plants, power generating facilities or other industrial operations can cause a variety of water quality impairments due to contaminant loading and thermal pollution. For example, sewage treatment plants discharge large enough quantities of nitrogen to increase undesirable macroalgae or phytoplankton, decrease water clarity and dissolved oxygen levels, and cause changes in benthic communities through changes in predominant invertebrate species. Sewage treatment plants also discharge microorganisms that lead to shellfish bed closures and illness in swimmers if the effluent is not treated properly.

Due to the large quantities of heat that they discharge, power plants can change the biological communities in the water bodies into which they discharge and can kill millions of organisms when they get trapped in power plant cooling systems. Most industrial discharges in coastal Massachusetts have been eliminated, but the ones that remain, like power plants, discharge heat to coastal waters and can potentially have negative effects. In 1972, the federal Clean Water Act gave the U.S. Environmental Protection Agency the authority to regulate these and other point sources of pollution by requiring that parties dumping pollutants into national waters obtain a National Pollutant Discharge Elimination System (NPDES) program permit. The Act also authorized funds for the construction and upgrade of sewage treatment plants or Publicly Owned Treatment Works (POTWs), which were required to achieve secondary treatment (advanced removal of pollutants) by July 1, 1977.

Ultimately, the goal of the Clean Water Act and associated programs has been to reduce and eventually eliminate pollutants discharged to the nation's surface waters. The 2004 State of the Bays report documented an overall decrease in the number of discharges between 1991 and 2003, but an increase in permitted discharge volume due to increased demand for cooling water by power plants. More recent trends suggest that both the number and volume of discharges have decreased since 2003.

State of the Bay

In 2003, there were 30 NPDES discharges permitted (those allowed to release more than 1 million gallons per day), a decrease from 33 major discharges in 1991. These 30 major discharges registered a total flow of 2.82 billion gallons of effluent per day (BGD). In 2008, there were 27 major NPDES permittees discharging 2.25 BGD, a decrease of 20% by volume (Figure 7.1).

Thermal Discharge

In 2004, eight power plants discharged 2.23 BGD of thermal effluent to the bays. In 2008, the number of plants remained the same but the amount of thermal discharge decreased by 24% to 1.70 BGD. Most of this decrease was due to the addition of two new energy-generating units by Mystic Station in Everett that use closed-cycle cooling and thus do not have large thermal discharges. These highly efficient units have taken the place in the electrical grid of older, less efficient and water-use-intensive units.

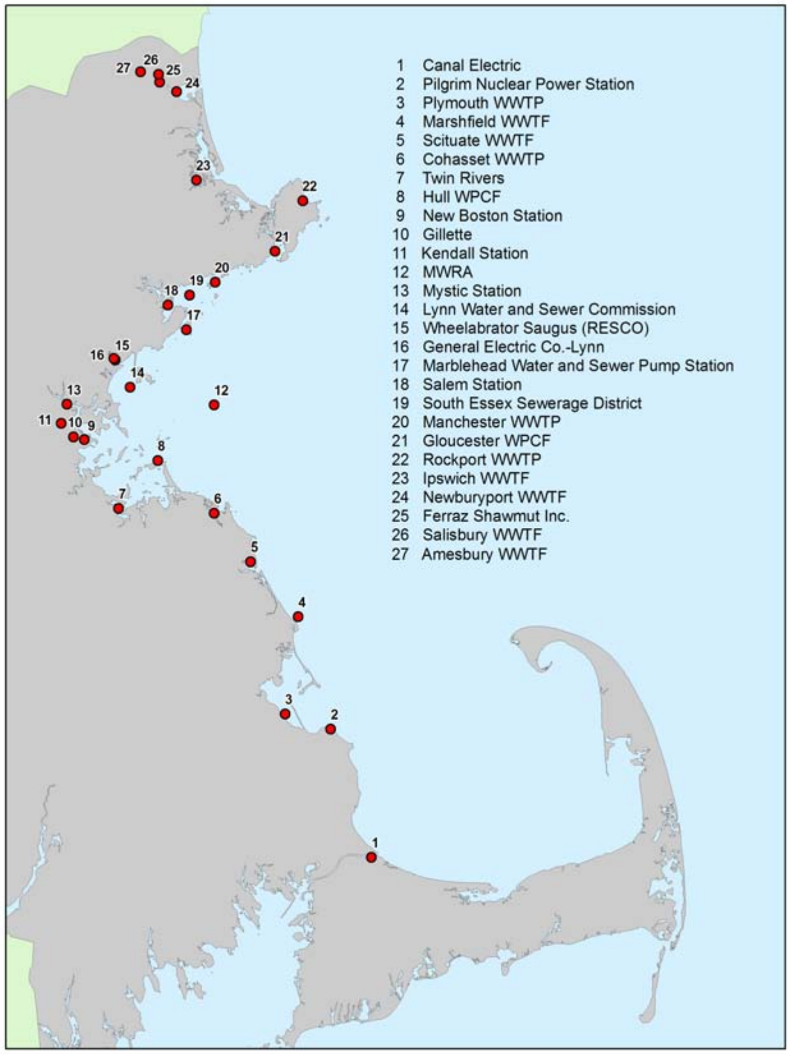


Figure 7.1. Locations of large point source pollution sources (>1 MGD) permitted under the National Pollution Discharge Elimination System program, as of 2008, in the Massachusetts Bays Program region. Location data provided by CZM.

Sewage Treatment Plants

In 2003, there were 18 POTWs that discharged 553 million gallons per day (MGD) of sewage and other pollutants to the bays, of which the Massachusetts Water Resources Authority (MWRA) facility contributed over half (See Question 1, Municipal Wastewater in Boston Harbor). In 2008, the number of POTWs remained the same, but the amount of discharge decreased by 7% to 513 MGD. The decrease in POTW discharge is striking given that significant areas along the Massachusetts Bays coastline have been serviced by sewers since 2003. The decrease in POTW discharge is likely due to the replacement of old, leaky sewer infrastructure that experienced significant stormwater and groundwater surcharging. All plants except for Gloucester are equipped with at least secondary sewage treatment, where much of the effluent material is digested by microbes and the less soluble material is collected and removed as solids. The Gloucester POTW operates under a Clean Water Act 301(h) waiver that allows it to use only primary treatment as long as its discharge meets stringent water quality requirements through the enhanced dilution and dispersion provided by the deep ocean waters, strong tidal mixing, and substantial currents characteristic of the outfall location. Two POTWs, located in Cohasset and Plymouth, have initiated or are taking steps toward the implementation of tertiary treatment, which employs technology to remove additional nitrogen or phosphorus from their effluents.

Industrial Discharge

In 2003, the number of non-power plant industrial permittees was four, discharging 32.5 MGD. There were only two non-power plant industrial facilities in 2008 (Gillette, and a new discharger: Twin Rivers Technologies), since Ferraz Shawmut tied into a POTW and Lucent Technologies eliminated its outfall. In the current assessment, the volume of industrial discharge appears to have increased slightly to 35.6 MGD because of the increased flow from Twin Rivers Technologies.

Box Note: Summary of changes in discharges since 2003:

Discharges Discontinued

- The discharges from Ferraz Shawmut (NPDES # MA00002816) and Lucent Technologies (NPDES # MA0001261) on the Merrimack River were discontinued
- Sithe New Boston station discharge was discontinued as the site was closed down
- The Exxon Island End Terminal (NPDES # MA0000833) reduced its discharge to less than 1 MGD, so it is no longer part of this evaluation

New Discharges

- The Twin Rivers Technologies thermal discharge (NPDES # MA0004073) to the Weymouth Fore Harbor was not on the 1991 or 2003 lists

Facilities Renamed

- U.S. Gen New England, Inc. Salem Station (NPDES # MA0005096) was renamed

No Discharge Areas

Contributor: Jo Ann Muramoto, Massachusetts Bays Program Cape Cod Regional Coordinator

Nonpoint sources of pollution to coastal waters can come from a variety of sources including stormwater runoff, failing septic systems, lawn care products (e.g., pesticides and fertilizers), and many others. Wastewater from commercial and recreational boats can also lead to significant water quality impairment. As a result, the discharge of untreated sewage within navigable U.S. waters is prohibited under federal law. However, vessels can still discharge treated sewage from Type I and Type II Marine Sanitation Devices (MSDs), which provide limited onboard treatment of wastewater – unless the water body is designated as a No Discharge Area (NDA). Treated boat sewage often contains nutrients, toxic chemicals, and harmful bacteria at levels that can be up to 70 times higher than state water quality standards allow (Figure NDA.1).

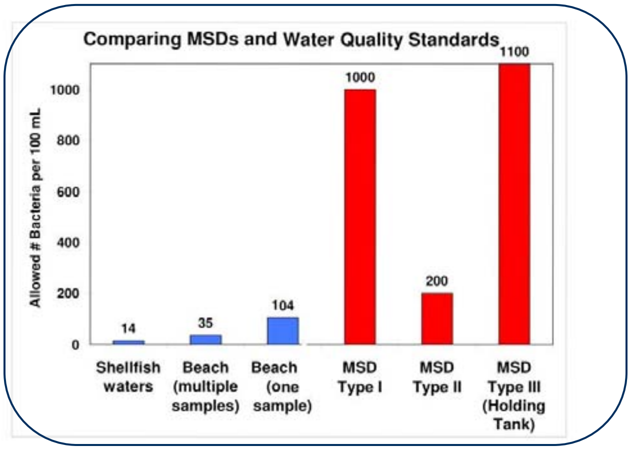


Figure NDA.1. Comparison of bacteria treatment standards for Marine Sanitation Devices (MSDs, red columns) and water quality standards for harmful bacteria in shellfishing waters and bathing beaches (blue columns). MSD standards and shellfishing standards are based on fecal coliform colonies per 100 milliliters (mL), while beach water quality standards are based on *Enterococcus* colonies per 100 mL.

Under Section 312 of the federal Clean Water Act, states can designate a body of water as an NDA and petition for approval by the U.S. Environmental Protection Agency. An NDA is an area in which the discharge of treated and untreated boat sewage is prohibited. A body of water may be designated as an NDA if it is demonstrated that the area's ecological and recreational values warrant this protection. Within an NDA, treated and untreated boat sewage must be discharged to a boat waste pumpout facility, and the sewage is then taken to an approved wastewater treatment facility. T he purpose of NDAs is to improve water quality and support the protection of public health, aquatic ecosystems, and local economies that rely on clean water for safe swimming, boating, shellfishing, fishing, and aesthetic appeal.

Nationwide, there are 26 states with NDAs, and many Massachusetts marine water bodies have recently been designated as well (Figure NDA.2). All of Massachusetts and Cape Cod Bays are designated as NDAs. To complete coverage of the entire Massachusetts coastline, efforts are underway to secure designations for NDAs on Mount Hope Bay and

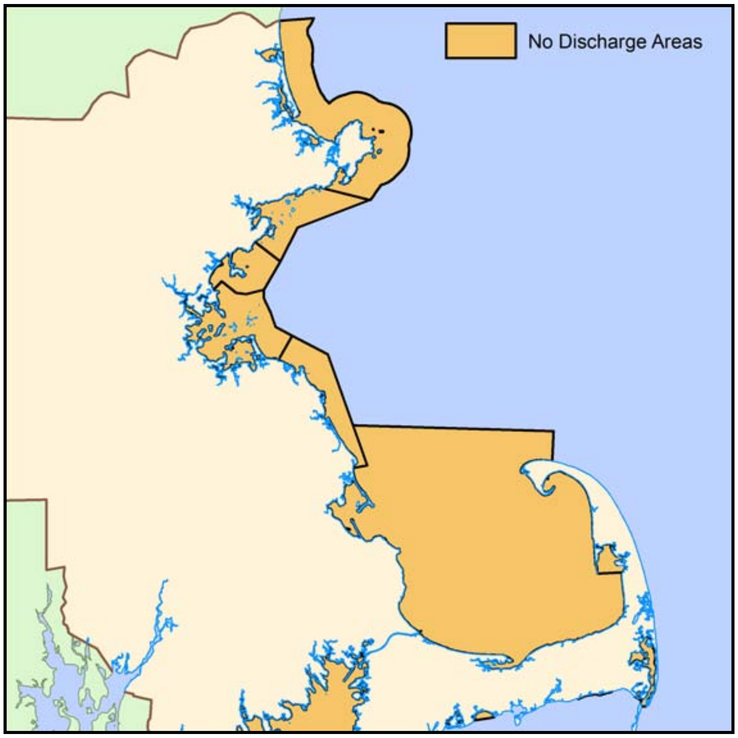


Figure NDA.2. NDAs in Massachusetts, 2010.

the waters south and east of Cape Cod. There are currently over 120 pumpout facilities along the Massachusetts coast that are available to almost 50,000 vessels, about a third of which are thought to have some form of MSD aboard.

Because NDA designation requires sufficient pumpouts (see Figure NDA.3) to serve the existing population of boats, vessel inventory is an important part of the NDA application. The data are used to estimate the numbers of MSDs that need to be pumped, which are then used to determine if additional pumpouts are needed in the area before designation can occur. For NDA designation, a general goal for the ratio of MSDs to pumpouts is about 300 to 400 MSDs per pumpout depending on vessel size, category, and type of harbor. If sufficient pumpouts do not exist in the area being considered for NDA designation, additional pumpouts must be installed before the NDA application is accepted.

Figure NDA.3. Boat waste pumpout station

Following designation, discharge of any boat sewage is a violation of state and federal law. In late 2008, state legislation was passed which gives local and state environmental law enforcement officials, including Harbormasters, as well as their state counterparts, the express authority to enforce NDA provisions and to impose a $2,000 fine for each offense. Generally, however, the most effective enforcement is to provide effective outreach to the boating community.

With New England currently leading the country in the percentage of area covered by NDAs, it is hoped that area boaters will embrace the new regulations and that the collective response will benefit the region's water quality in years to come.

National Coastal Condition Assessment

Contributor: Christian Krahforst, Massachusetts Bays Program

Understanding the conditions that affect the health and well being of our coastal ecosystems is critical for sound resource management. In an effort to gain a greater understanding of the status of the marine and estuarine waters of Massachusetts, the Commonwealth began participating in the National Coastal Assessment (NCA) in 2000. Led by the U.S. Environmental Protection Agency (EPA), the NCA was developed to evaluate and report on the condition of the nation's coastal resources. In Massachusetts, the Massachusetts Bays Program (MBP), Office of Coastal Zone Management, Department of Environmental Protection, Division of Marine Fisheries (*MarineFisheries*), and the University of Massachusetts collaborated to collect biological, sediment, and water samples at 99 stations in the Massachusetts Bays region from 1999 to 2006 (Figure NCA.1). In addition, *MarineFisheries* provided data from their annual trawl surveys, which were used to evaluate contaminant levels in fish populations.

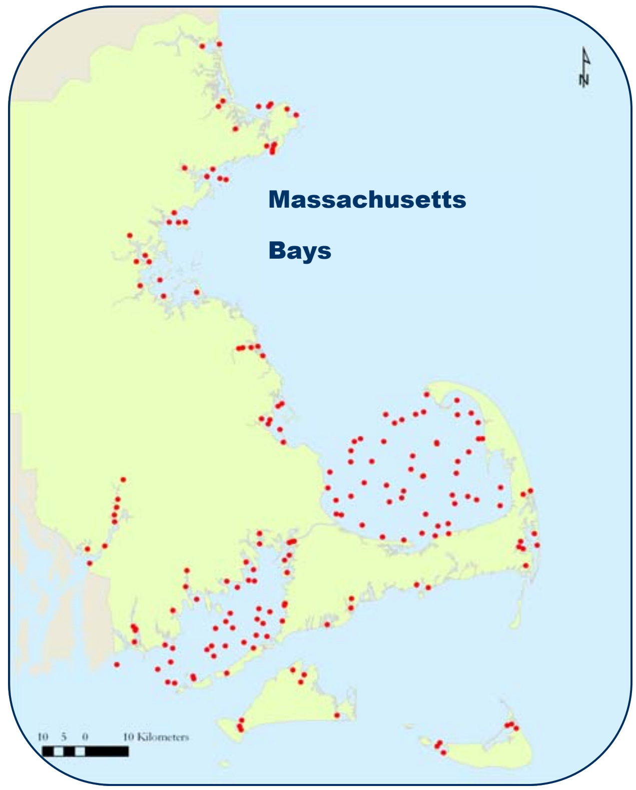


Figure NCA.1. The location of 186 National Coastal Condition Assessment stations in Massachusetts coastal waters sampled during 2000—2006. Of these, 99 stations were located in the Massachusetts Bays region.

To evaluate the data, the U.S. EPA Office of Research and Development created a rating system based on five indices of ecological condition: water quality, sediment quality, benthic quality, coastal habitat, and fish tissue contaminants. The most recent National Coastal Condition Report, published in 2008, states that the overall condition of the nation's coastal waters is "fair." while the Northeast region, which includes the MBP planning area, was found to be "fair -to-poor." The rating was generally due to indicators related to sediment quality, benthic community structure, and contaminants in fish tissue. The report can be accessed at: http://www.epa.gov/owow/oceans/nccr3/downloads.html.

Additionally, EPA issued the National Estuary Program Coastal Condition Report (NEPCCR) in June 2007. For this report, NCA results were supplemented with data collected by the National Estuary Programs (NEPs) in partnership with state environmental agencies, universities, and volunteer monitoring groups. In the Northeast, this report stated that 43% of the estuaries (12 of 28) served by NEPs were generally in "poor" condition. The MBP NEP received an overall rating as "fair." For individual indices, the MBP region rated "good" for water quality, "fair" for fish tissue contaminants, and "poor" for sediment quality and benthic community structure. Tissue contaminant levels in fish and lobster collected from Massachusetts and Cape Cod Bays were significantly below average for the Northeast region. The NEPCCR can be downloaded from http://www.epa.gov/owow/oceans/nepccr/index.html.

It is important to note that the NCA was designed to assess large scale, national water quality characteristics and trends. Because NCA sampling stations are distributed over a large area within Massachusetts and Cape Cod Bay, and because data are collected only once at each station, specific conclusions about the water quality of coastal Massachusetts, which may change quickly, can be difficult to draw. However, NCA data can be useful to document the condition of sediment and associated indicators that tend to be more stable over time. NCA data have further value in that they can supplement local analyses that have been developed to monitor water quality and sediment condition within Massachusetts and Cape Cod Bays.

NCA data are clearly contributing to a better understanding of ecological conditions and revealing processes that may help us better manage water, sediment, and biotic quality. For example, preliminary analysis of surface sediment of Cape Cod Bay show the amount of certain contaminants to be closely related to the amount of organic carbon. Sediments rich in organic content in Cape Cod Bay may be an important "trap" for these contaminants. Chemical databases for sediments often contain organic carbon information and are useful in guiding management efforts that require an understanding of where pollutants may accumulate and developing strategies for protecting and improving benthic habitat quality. The concentration of organic carbon increases in the central region of Cape Cod Bay (Figure NCA.2).

The NCA program continues to be a priority for EPA, and, under a redesigned program, sampling is scheduled to occur every five years. Sampling for the 2010 Assessment began in July 2010 and concluded in September 2010. Data analysis is ongoing.

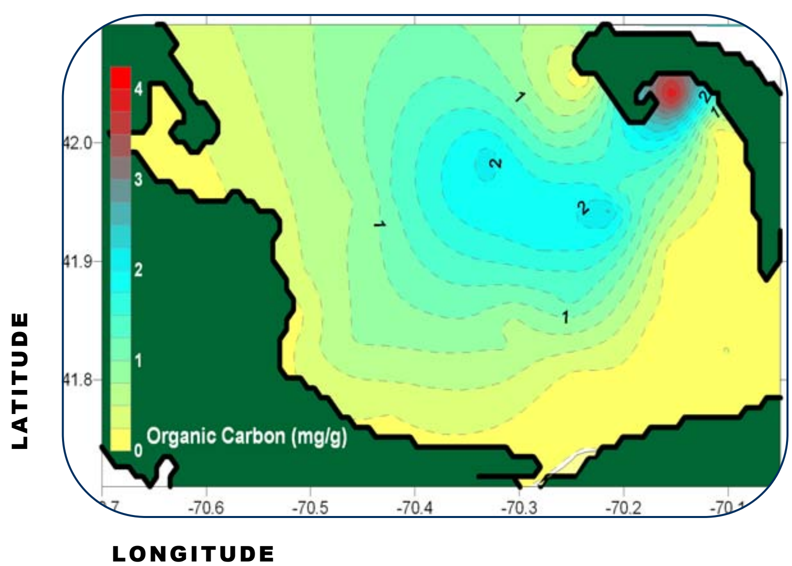


Figure NCA.2. Organic carbon gradient in surface sediment (0-2 cm) in Cape Cod Bay. Based on NCA assessment data, 2000—2006.

LIVING RESOURCES

Our living resources depend on a diverse range of habitats—teeming with life— that include shellfish beds, eelgrass meadows, herring runs, beaches and dunes, rocky shores, and salt marshes. *These resources are widely valued in our society, contributing to public health, commerce, education, aesthetics, and much more. In addition to these human values, living resources and habitats perform critical ecological functions such as providing shoreline protection, serving as nurseries for juvenile fish, and filtering sediment and pollution from the water. For residents and visitors alike, it is essential that these living resources thrive, because these coastal habitats are important to our quality of life, providing an array of livelihoods, unique places for recreational activity, and signature coastal landscapes that are often referred to as quintessentially New England.*

EELGRASS HABITAT

Q8 Has eelgrass habitat in Massachusetts and Cape Cod Bays changed over time?

Contributors: Anthony Wilbur, Massachusetts Office of Coastal Zone Management, Phil Colarusso, U.S. Environmental Protection Agency, and Charles Costello, Massachusetts Department of Environmental Protection

Why this is Important

Eelgrass, *Zostera marina*, is a flowering marine plant that forms one of the most valuable shallow-water coastal habitats in Massachusetts. Eelgrass beds provide a wide variety of ecosystem services vital to the health of coastal systems. They provide habitat for a variety of small organisms that serve as food for larger species. Grass blades provide structure and protective cover for lobster, fish, and many other kinds of marine life. In addition to its habitat value, eelgrass roots bind and stabilize the sediments along the Massachusetts shoreline.

Changes in abundance or distribution of this resource are likely to have a significant impact on the many species that depend on eelgrass habitat. Eelgrass and other seagrass species are commonly used as an indicator of ecosystem health because they are extremely sensitive to natural and human perturbations that affect water clarity and quality. In addition to the functions described above, eelgrass filters nutrients from the water. Loss of eelgrass beds can trigger a negative feedback loop that contributes to further decline in water quality. The loss of eelgrass meadows can result in reduced water quality and clarity, potentially leading to additional loss of this important habitat.

Photo: T.Evans

Figure 8.1. Divers from *MarineFisheries* conducting monitoring of eelgrass meadows in the upper North Shore region.

State of the Bay

The Massachusetts Department of Environmental Protection (DEP) began mapping the statewide distribution of eelgrass in 1993. Eelgrass maps were produced for Massachusetts waters from aerial photos taken in 1995, 2000-2001, and in 2006 for selected embayment and nearshore areas. The distribution of eelgrass habitat for the Massachusetts Bay region, as mapped in 1995 and updated in 2001, is shown in (Figures. 8.2-8.3).

This mapping effort, along with studies conducted in localized areas along the Massachusetts coast; show that eelgrass habitat is at risk, with substantial losses in eelgrass abundance throughout Massachusetts (Costello and Kenworthy, *in press*. See *Box Note* at the end of this section). This decline is particularly apparent in Massachusetts Bay during the interval from 1995-2001. Overall, about 1,094 acres of eelgrass were lost from Massachusetts and Cape Cod Bays during this time period. (This analysis excludes Billingsgate Shoals, which supports one of the largest eelgrass beds in Massachusetts, but does not have a complete data record). Analysis of trends in seven specific embayments from Plymouth Harbor north to Gloucester Harbor show a median decline of 3.59% yr^{-1} (Table 8.1). Declines are even more significant in embayments along the South Shore of Cape Cod (-7.73% yr^{-1}) and Buzzards Bay (-4.5% yr^{-1}).

The picture begins to change in the interval from 2001-2006, however. Four of the seven embayments studied in Massachusetts Bay showed increases in eelgrass coverage during this time period. These include Gloucester Harbor (Figure 8.4), Salem Harbor, Lynn Harbor, and Boston Harbor. It is noteworthy that each of these embayments was the subject of major wastewater treatment plant upgrades or reductions in combined sewer overflow (CSO)

Region	Median decline (% y^{-1})
Massachusetts Bay	-2.39
South Cape Cod	-3.39
Buzzards Bay	-3.51
The Islands	-2.21

Table 8.1. Regional median decline in eelgrass extent between 1995 and 2006.

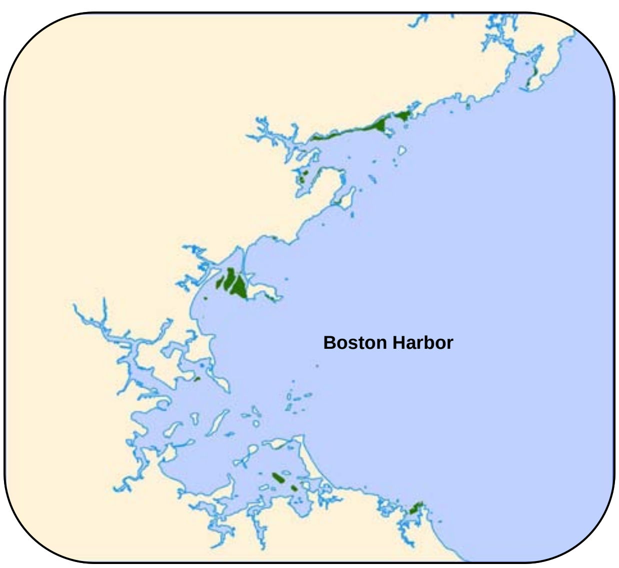


Figure 8.2. Extent of eelgrass habitat from the Merrimack River south to Boston Harbor, 2001. Based on data from MassGIS. (Area north of Cape Ann is excluded due to lack of eelgrass.

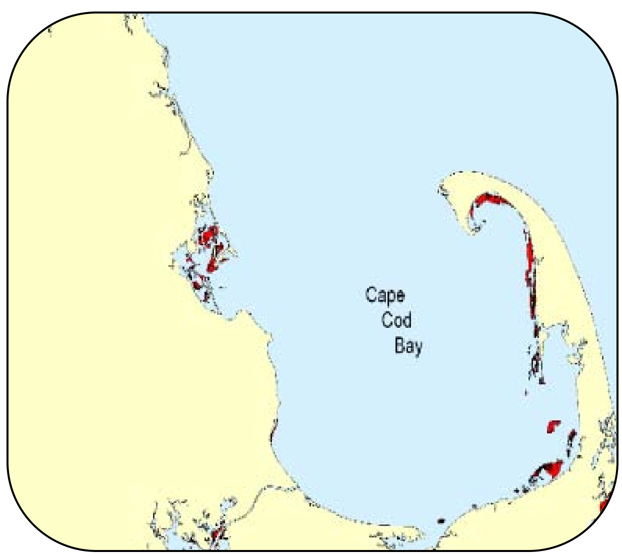


Figure 8.3. Extent of eelgrass habitat in Cape Cod Bay , 2001. Based on 2001 data from MassGIS.

discharges immediately prior to or during this interval (See Question 1, Municipal Wastewater in Boston Harbor, and Questions 6, Combined Sewer Overflows). Overall, however, eelgrass in these seven Massachusetts Bays embayments showed a median decline of 0.5% yr^{-1} and a decline of 2.39% per year over the course of the 12 year study (Table 8.2).

Location	Change analyses by interval (%/yr)		
	t1-t2	t2-t3	t1-t3
Gloucester Harbor	-4.21	9.46	2.39
Salem Harbor	-33.86	9.73	-10.9
Lynn Harbor	-2.21	0.97	-0.56
Boston Harbor	-22.11	29.22	-5.49
Cohasset Harbor	0.75	-0.88	-0.06
Scituate Harbor	-2.97	-0.04	-1.50
Duxbury/Plymouth H.	-2.77	-0.50	-3.28
Region median decline	**-3.59**	**-0.50**	**-2.39**

Table 8.2. Data depicting changes in Mass Bays embayments for eelgrass over time where t_1=1994-1996, t_2= 2000-2001, t_3= 2006-2007.

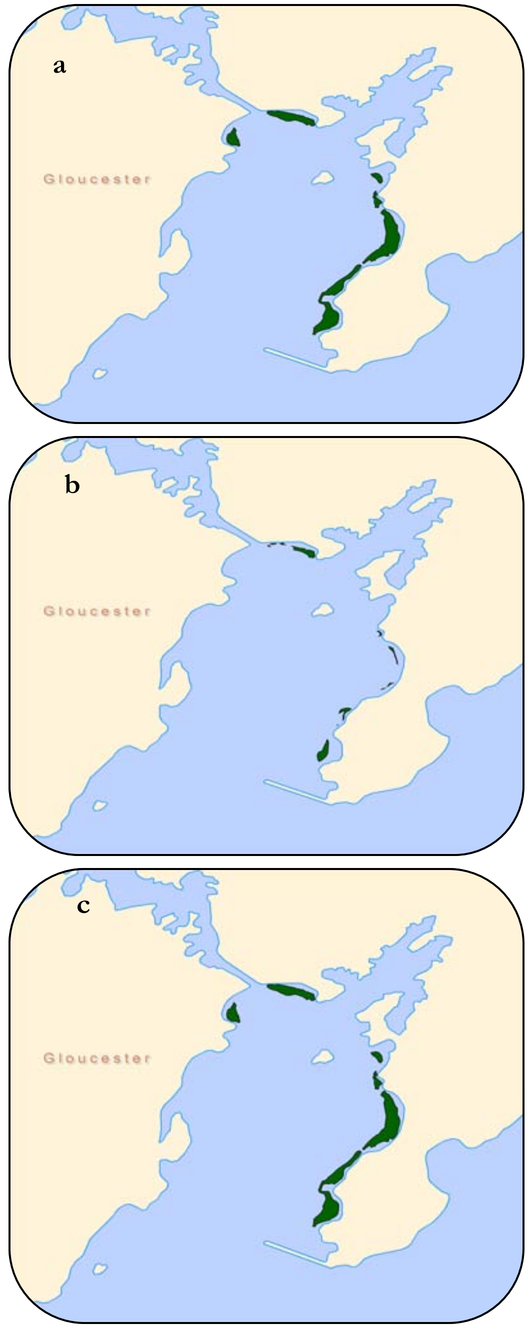


Figure 8.4. Distribution of eelgrass (*Z. marina*) in Gloucester Harbor: a)1995, b) 2001, c)2006. Source: DEP.

While poor water quality is thought to be the greatest threat to eelgrass habitat quality and spatial coverage, physical disturbances from moorings, construction, dredging, and other activities have resulted in direct losses to the habitat, which are difficult to quantity through analysis of aerial imagery. Several acres of eelgrass were recently impacted by the construction of a gas pipeline in Salem Sound. In Gloucester, a new stormwater pipe was constructed in an eelgrass bed as part of a CSO remediation project. Replanting eelgrass along the construction corridor of the Gloucester remediation project appears to have resulted in a moderate level of success.

Other stressors that impact eelgrass beds include increased levels of suspended sediments that degrade water quality, mooring gear directly disturbing the seafloor and attached boats shading the bottom, propeller scarring, wake-induced erosion of the seafloor and the spread of invasive species in eelgrass habitat. Due to its sensitive nature, it is important that resource managers actively provide conservation and protection measures to eelgrass habitat, and look for restoration opportunities in suitable locations.

Capitalizing on recent improvements in the water quality, the Massachusetts Division of Marine Fisheries (*MarineFisheries*) recently completed an eelgrass habitat restoration project in Boston Harbor, which resulted in the establishment of several discrete eelgrass meadows. The potential to restore eelgrass habitat in the Gloucester's Annisquam River was also studied through efforts lead by CZM and *MarineFisheries*. As of this writing, the Massachusetts Bays Program, *Marine Fisheries*, and other partners are testing the use of low impact mooring technology in eelgrass beds in Manchester and Provincetown Harbors. While this and other monitoring and restoration efforts are relatively small-scale, these projects provide local assessments that supplement the statewide eelgrass mapping effort, help develop effective restoration techniques, and improve our understanding of the relationship between water quality and habitat health.

Box Note: All mapping data attributed to Charles Costello as summarized in: Costello, C.T. and W.J. Kenworthy. 2010. Twelve year mapping and change analysis of eelgrass (*Zostera marina*) areal abundance in Massachusetts (U.S.A.) identifies statewide declines. *Estuaries and Coasts* (*In press*).

Photo: A. Wilbur

Figure 8.5. Eelgrass beds (*Zostera marina*) serve as feeding and nursing grounds for various marine fauna.

Q9 How much wetland habitat has been restored within the estuaries of Massachusetts and Cape Cod Bays?

Contributor: Hunt Durey, Massachusetts Division of Ecological Restoration

Why this is important

Wetlands are important habitats in the Massachusetts Bays region, serving a myriad of functions. They act as nurseries for fish, crabs, and other shellfish, many of which have tremendous commercial value later in life. They also provide habitat to a wide variety of birds and insects, and are enjoyed by many passive recreational users such as birders and kayakers. Their water retention capacity allows them to serve as a critical buffer from coastal flooding. Wetland soils and plants are one of nature's most efficient water filters, removing excess pollutants and nutrients before water percolates into the ground or flows into lakes, rivers, and estuaries. Many animals use wetlands for foraging, migration, and/or reproduction. The ability of wetlands to recycle nutrients makes them critical to the water quality of many coastal ecosystems.

Figure 9.1. Urban wetland habitat near Logan Airport in Boston.

The Massachusetts Bays region has experienced significant historical loss and degradation of its coastal wetlands. A recent research article published in the journal *Estuaries and Coasts* found that Massachusetts has lost an estimated 41% of its pre-colonial salt marshes (See *Box Note,* at the end of this section). Thousands of wetland acres have been filled, drained, flooded, and restricted from tidal flow to meet development and other societal aims. In the Boston Harbor region alone, total salt marsh losses from pre-colonial times are estimated to be as high as 81%. To combat these losses, partners representing public, private, and non-profit interests have made major investments in coastal wetland restoration projects since the mid-1990s.

State of the Bays

Significant progress has been made in restoring Massachusetts coastal wetlands over the past few years. In 2009, the Massachusetts Office of Coastal Zone Management's Wetlands Restoration Program (WRP) joined forces with the state Department of Fish & Game's Riverways Program to form the Division of Ecological Restoration (DER). DER continues to work closely with partners to develop and implement priority projects and is actively supported by the Massachusetts Bays Program (MBP). Between January 2004 and April 2009, 24 restoration projects were completed; restoring tidal flow and ecological integrity to 300 acres of tidal marshes. Since the WRP was established in 1994, the program has helped partners complete 62 projects restoring approximately 817 acres of wetlands. The program currently supports over 40 active priority projects representing more than 3,000 acres of future restoration potential.

Monitoring needs have increased substantially along with the number of completed projects. To address this, DER has developed, and made significant investments in a regional, volunteer-based salt marsh monitoring network. Since 2004, the program has provided significant grant funding and technical support to regional non-government organizations that recruit, train, and manage volunteers for field monitoring. Uniform data collection protocols have been developed, with standardized data sheets and data management tools, which promote statewide consistency and facilitates data transferability. These tools include a proprietary software program for data entry, management, and transfer, as well as protocols to facilitate data analysis and reporting.

***Project Spotlights*:** On June 13, 2008, over 100 project partners and supporters came together to celebrate completion of the Sesuit Creek project in Dennis—the largest salt marsh restoration to date in Massachusetts. For more than 80 years, the Bridge Street crossing of Sesuit Creek had choked upstream wetlands from natural tidal flows, causing severe degradation of the marsh and obstructing fish passage (Figure 9.2, left photo). The project replaced a failing two-foot diameter pipe beneath the road with two 10 x 12 foot concrete culverts (Figure 9.2, right photo). This increased stream flow capacity 60-fold, and restored natural tidal conditions to the 65-acre marsh. Combined with the recent enlargement of other road

Photos: DER

Figure 9.2. Pre- and post-restoration efforts in Sesuit Creek culvert in Dennis, Massachusetts.

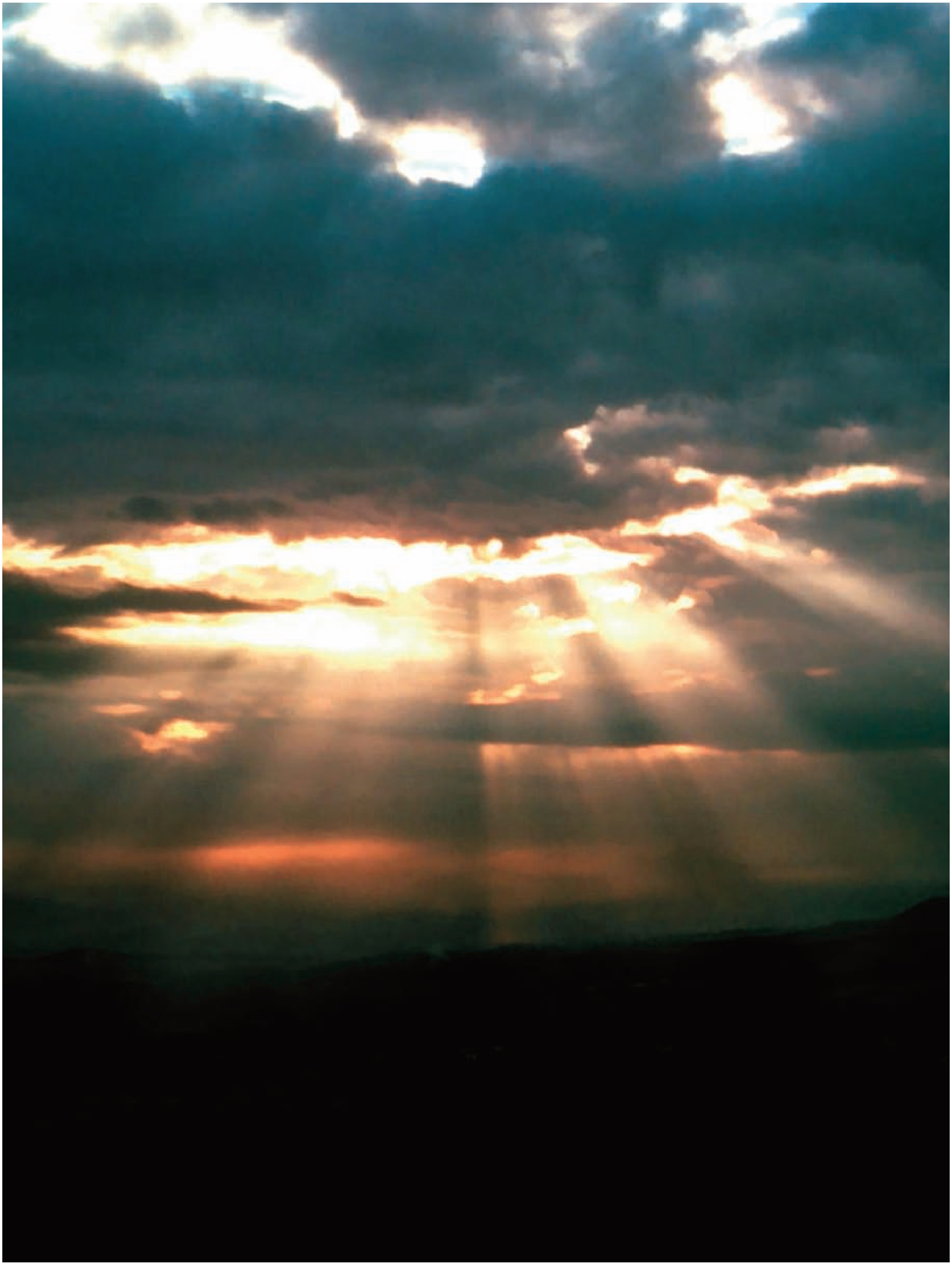
culverts along the creek by the Massachusetts Highway Department, this project also restored fish passage to important spawning habitat in upstream Scargo Lake.

At the Bass Creek restoration site on the Cape Cod Bay side of Yarmouth, a four-foot corrugated metal culvert beneath an old earthen dike was replaced with a 35-foot-long walking bridge over an open channel (Figure 9.3). The project, located in Yarmouth's Callery-Darling Conservation Area, has dramatically improved tidal exchange to a degraded 35-acre marsh upstream of the earthen dike.

Box Note: Pre-colonial salt marshes estimates rely on the synthesis provided in K.D. Bromberg and M.D. Bertness. 2005. “Reconstructing New England salt marsh losses using historical maps” . *Estuaries and Coasts,* Volume 28: 823-832.

Figure 9.3. Pre-and post-restoration images of Bass Creek, Yarmouth, Massachusetts.

Photos: WRP



Q10 How are shellfish landings changing in Massachusetts and Cape Cod Bays?

Contributor: Michael Armstrong, Massachusetts Division of Marine Fisheries

Why this is important

Shellfish have historically been one of the most abundant and heavily utilized resources along the coast of the Massachusetts Bays. Even the casual explorer of the Bays' shallow coves, salt marshes, and coastal ponds will usually find exposed shellfish or signs of shellfish buried in the mudflats. The inshore shellfishery of the Massachusetts Bays is an important part of the state's coastal heritage. A wide array of shellfish species in the Bays are harvested for human consumption, including soft-shell clams, quahogs, oysters, bay scallops, blue mussels, and razor clams.

The Massachusetts Division of Marine Fisheries (*MarineFisheries*) collects shellfish landings and permit data supplied by municipal shellfish constables and *MarineFisheries* shellfish biologists. Additional data is taken from the yearly catch reports submitted by the commercial shellfish permit holders. Recreational data is supplied by the municipal shellfish constables. Reporting of harvest quantities and prices are required by Massachusetts General Law Chapter 130, but obtaining accurate, local reports is an ongoing challenge. As a result, *MarineFisheries* assumes that actual quantities of some species of shellfish harvested and prices obtained are as much as 40 to 60% higher than what is reported. According to the National Marine Fisheries Service, recent landings of quahogs, clams, and oysters netted Massachusetts shellfish fishermen between 18 and 30 million dollars annually (See *Box Note,* next page). Further, *MarineFisheries* assesses the status of Shellfish Growing Areas (SGA), and provides periodic updates through the Massachusetts Geographic Information System (http://www.mass.gov/mgis). The information

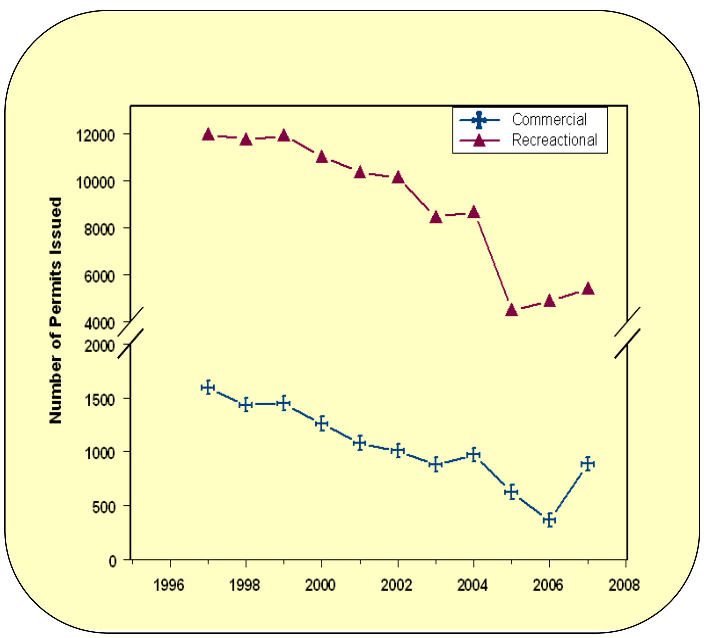


Figure 10.1. Shellfish permits issued by cities and towns in the Massachusetts Bays region (1996-2008). (Note axis break)

collected and the assessments are used to assist managers involved with developing fisheries management plans and informing local regulatory decisions.

State of the Bays

Conducting trend analyses of shellfish landings from the Massachusetts Bays region is difficult for a number of reasons. The most significant problem is that variable reporting systems are used by shellfish constables within and between towns. For instance, some constables produce estimates based on the number of permits issued (Figure 10.1), available fishing days, and the number and size of flats open to fishing. Others conduct actual daily catch observations and tallies. Still others use a combination of both. These methods can vary over time in a single town, often as a result of changes in personnel, which makes comparisons and trend analyses challenging.

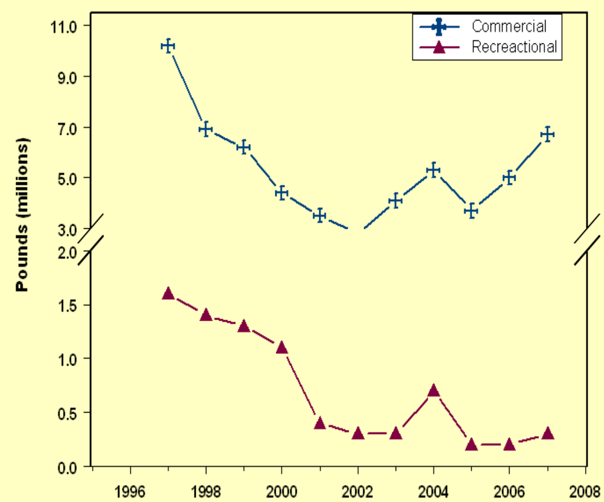


Figure 10.2. Reported landings (millions of lbs) for all species of shellfish from Massachusetts Bays. (Note axis break)

Figure 10.2 portrays "in the shell" pounds landed annually for all regulated shellfish. The last year of full reporting for the Massachusetts Bays region was 1999, and it is noteworthy that some municipalities have not submitted landing records for 2000-2007. With incomplete data, extrapolation to a regional understanding on the "state" of shellfish in Massachusetts is difficult. However, if available data were presumed to be indicative of the state of shellfisheries, some shellfish species landings appear to be generally declining and are likely related to several factors. Some of the more important factors other than decreased reporting, include diminished population size due to harvest pressure, changes in habitat quality, and changes in predator-prey relationships. For instance, loss of eelgrass habitat (See Question 8, Eelgrass Habitat) and decline of the quality and quantity of bay scallop populations that rely on this habitat in Massachusetts coastal waters may be related. Another potentially harmful factor is the increase in the abundance and number of marine invasive species (See Question 13, Invasive Species) such as the Asian shore crab (*Hemigrapsus sanguineus*), a species that has flourished in Massachusetts coastal waters and often displaces other resident organisms by out-competing them for both food and space.

Box Note: The National Oceanic and Atmospheric Administration provides annual estimates of the commercial value of fisheries for the nation. Individual statistics for each state can be found at: http://www.st.nmfs.noaa.gov/st1/commercial/landings/

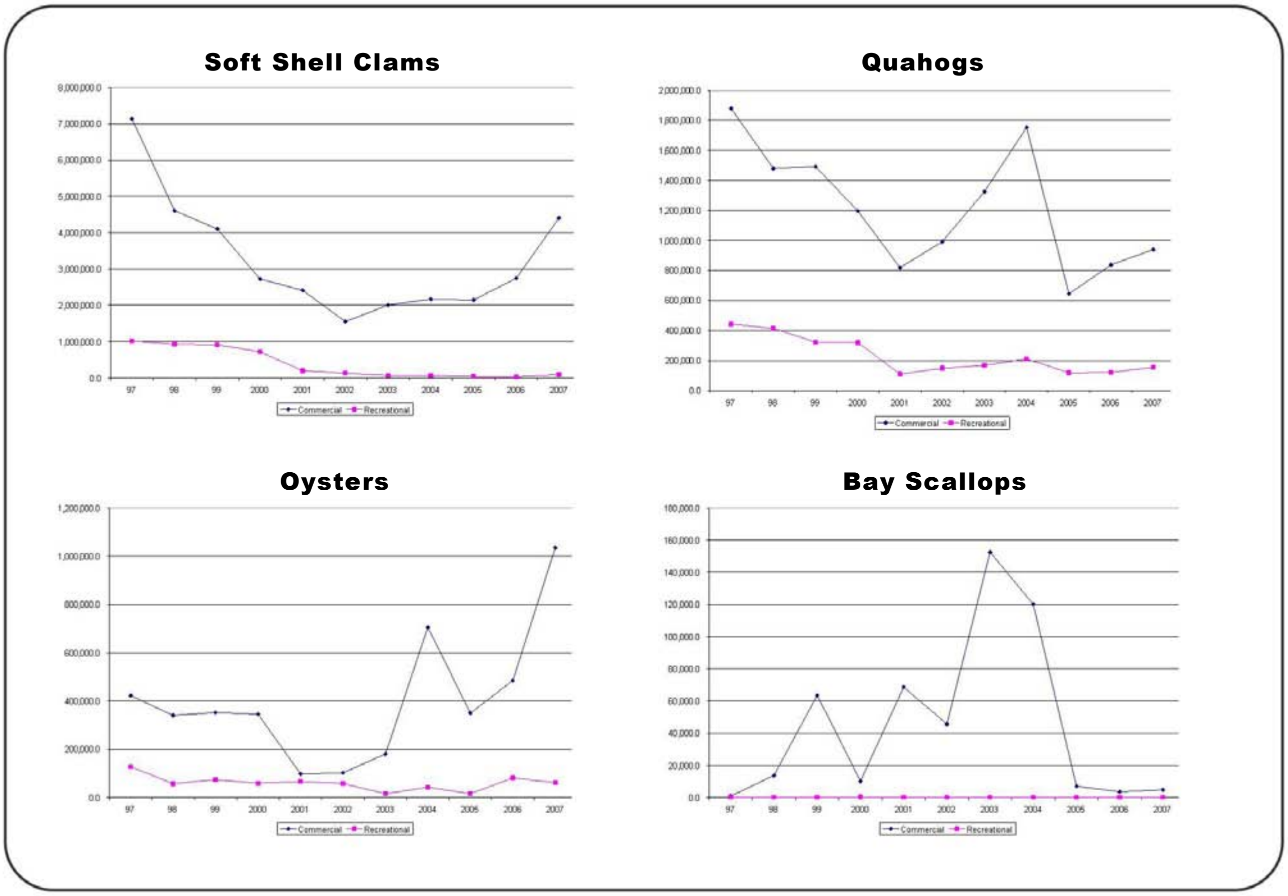
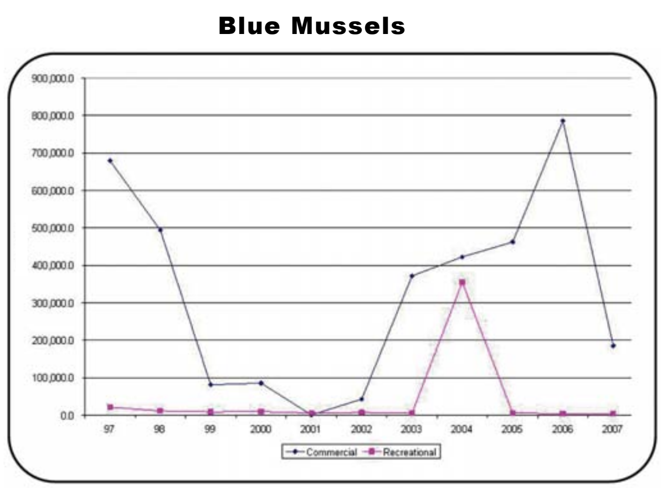


Figure 10.3. Reported landings (thousands of lbs) for selected species of shellfish from Massachusetts Bays communities.



Since 1997, total shellfish landings reported by shellfish permits have decreased steadily overall, but have increased since bottoming out in 2002. Beginning in 2005, landings of shellfish decreased from the previous year, but there was an increase in 2006 and 2007. It is noteworthy that the annual total reported shellfish landing is influenced largely by reported landings for soft shell clams, *Mya arenaria*. Four important species are shown in Figure 10.3. Of these, only bay scallops and blue mussels appear to have flat or downward trends.

Generally, the shellfish habitats fall into two categories; those approved for shellfish harvesting and those areas where harvest is prohibited. For the Massachusetts Bays region, nearly 60% of the shellfish growing areas are designated as "approved" (Figure 10.4). As might be expected, the shellfish habitats approved for harvesting are located in the less urban areas (Figure 10.5).

As observed in the 2004 *State of the Bays Report*, 15 towns north of Boston Harbor report no landings because all of their waters are closed to shellfishing due to continued poor water quality. However, there are areas designated as approved (shoreline of Plum Island), conditionally approved (parts of the Parker River, Mill Pond, and the Annisquam River in Gloucester, and Castle Neck River in Essex and Ipswich), and conditionally restricted (portions of the lower Merrimack River and the lower Pines River, Saugus). Six other towns (Boston, Hingham, Hull, Quincy, Weymouth and Winthrop) have landings of only soft-shell clams that are harvested for depuration, a process by which bacteria and viruses that may be harmful for human consumption are removed at the *MarineFisheries* Shellfish Purification Plant in Newburyport. A portion of Sandwich Harbor is the only area south of Boston that has recently been designated as approved for shellfish harvesting, although several areas on the south shore and Cape Cod have received conditional approval since 2004.

Overall, the changes with respect to *MarineFisheries* designation over the past 5 years represent less than 1% of the total shellfish growing areas. Since 2004, in the MBP region, approximately 1,000 acres have been approved and conditionally approved, while slightly more than 300 acres have been closed.

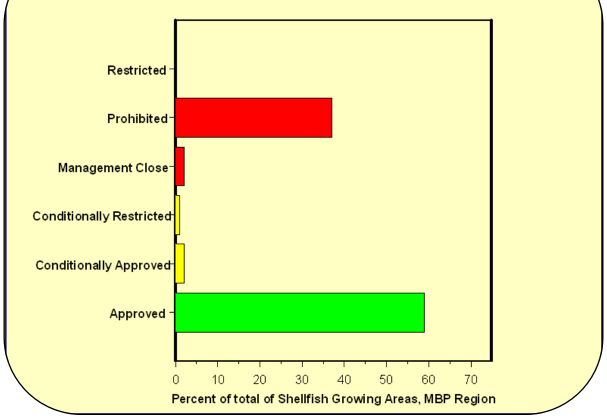


Figure 10.4. Percentage of acreage within each Shellfish Growing Area designation Data maintained by *MarineFisheries* and obtained from MassGIS.

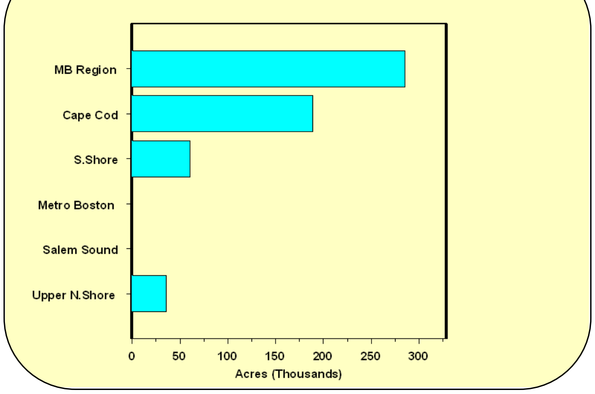


Figure 10.5. *MarineFisheries* "Approved for harvesting" Shellfish Growing Area (thousands of acres) by sub-regions of the Massachusetts Bays Program. Based on data from MassGIS.

Box Note: The *MarineFisheries* Shellfish Growing Area designation consists of 5 categories. These are:

- **Approved** (open for harvest for direct human consumption),
- **Conditionally Approved** (approved for a specified period of time),
- **Conditionally Restricted** (approved for a specified period of time with depuration),
- **Management Closure** (closed for harvest because of insufficient testing), and

Q11 What is the state of diadromous fish in Massachusetts and Cape Cod Bays?

Contributors: Jo Ann Muramoto, Massachusetts Bays Program
Cape Cod Regional Coordinator and the Association to Preserve Cape Cod

Why this is important

Figure 11.1. Alewife (*Alosa psuedoharengus*), one of the common river herrings found in Massachusetts streams and rivers.

Diadromous fish species use both marine and freshwater systems for key portions of their life cycle. Two types of diadromous fish can be found in Massachusetts waters. Anadromous fish, which include river herring, shad, smelt, and many other species (Table 11.1), spawn in freshwater systems such as rivers, streams, and ponds, and migrate to sea during the non-reproductive seasons. Catadromous fish, such as the American eel, have reversed this strategy; residing for most of the year in freshwater habitats, but travelling annually to the sea for spawning. Diadromous fish were formerly very important to coastal Massachusetts for commercial and subsistence fisheries. Their populations have declined dramatically from historical levels but remain extremely valuable for supporting popular recreational fisheries, as forage for many fish and wildlife species, and for nutrient cycling between freshwater and marine habitats. The "health" of these fisheries is increasingly viewed as an indicator of the health of the ecosystem these species inhabit.

State of the Bays

The status of diadromous fish populations in Massachusetts and Cape Cod Bays has not been fully assessed in recent decades, although many information sources point to declining trends for most species. The causal factors for the declining numbers of fish are not well understood. Most species have some aspect of their life history challenged by impediments to migration and loss of spawning and nursery habitats. The following five diadromous species have generated much concern in the past five years due to apparent population declines. Currently, the Massachusetts Division of Marine Fisheries (*MarineFisheries*) produces indices of population abundance for these species based on fish run counts, catch-per-unit-effort, and age composition.

River Herring: Over 100 coastal rivers support spawning runs of river herring in Massachusetts. River herring is the common term for two closely related species, the alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*). Historically, river herring runs supported large commercial fisheries. Present river herring runs are at historically low levels, prompting *MarineFisheries* to establish a moratorium on the harvest and sale of all herring occupying Massachusetts waters in 2005. Monitoring of herring runs shows a sharp decline in run strength during the period of 2000-2005 (Figure 11.2). The available size, age, and composition data suggest declining trends in river herring length and increasing mortality from the 1970s and 1980s to the present period.

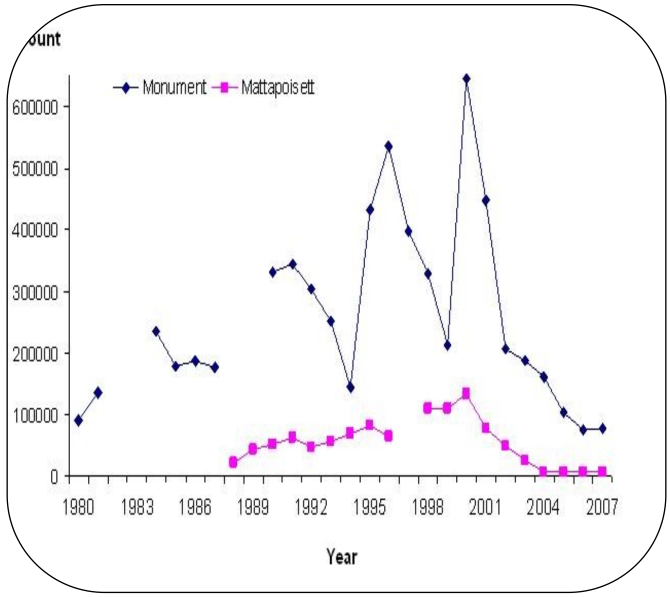


Figure 11.2. Census counts of Alewife at Mattapoisett River, Mattapoisett, and river herring at Monument River, Bourne, MA. Source: *MarineFisheries*.

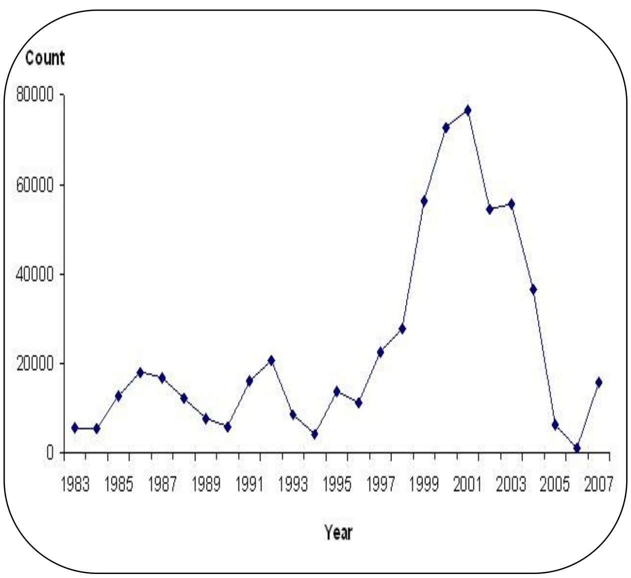


Figure 11.3. Census counts of American shad at the Essex Dam fish lift on the Merrimack River, MA. Source: Technical Committee for Anadromous Fishery Mgt. of the Merrimack. River Basin.

American Shad : American shad (*Alosa sapidissima*) are the largest species of the genus *Alosa* occurring in the Gulf of Maine, attracting much interest from recreational anglers. Shad spawn in the main stem freshwater habitat of larger coastal rivers. There are relatively few rivers remaining that support shad spawning runs. However, the largest rivers in Massachusetts, the Connecticut and Merrimack Rivers, have historically supported important commercial and recreational shad fisheries. In recent decades shad spawning runs have depended on the operations and passage efforts at major dams. The sharp decline of Merrimack River shad over the past five years is shown in Figure 11.3.

Rainbow Smelt: Rainbow smelt (*Osmerus mordax*) are highly regarded for the unique winter fisheries they provide and their fine taste as a fried fish. Smelt spawn at the interface of tidal and non-tidal waters (the "head of tide") in coastal rivers and continue to be found in areas that are often subject to urban watershed alterations and stormwater pollution. Information on their stock status is limited. There appears to have been a sharp decline across the region following the early 1980s. *MarineFisheries* began a monitoring project in 2004 to record catch per unit effort and age composition data. Of the eight monitoring stations currently maintained, the highest catch rates are found in the Fore River, Braintree (Figure 11.4). The catch data represent too few years to discern population trends. However, the available data indicate the runs have a truncated age structure with higher mortality than found during studies conducted 25-30 years ago.

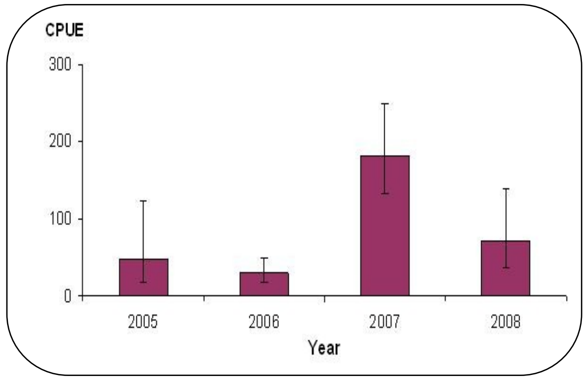


Figure 11.4. Rainbow smelt catch-per-unit-effort during April and May at the fyke net station in Fore River, Braintree, MA. Graphed CPUE data are geometric means with back-transformed 95% confidence intervals.

American Eel: The American eel (*Anguilla rostrata*) is the only catadromous fish in the state of Massachusetts. American eel are born far offshore in the Sargasso Sea and migrate to coastal rivers seeking freshwater habitat where they reside until maturity. Recent population declines throughout much of their North American range prompted the designation of American eel as a Candidate Species under the Endangered Species Act in 2005 and the development of interstate management efforts. As part of this process, all east coast states monitor commercial harvest of eels and the spring runs of juvenile eels in select rivers. Commercial eel landings have been at historic lows for Massachusetts during the past five years; in the range of 3,000 to 5,000 pounds. Juvenile eel abundance is recorded from eel trap catches at four coastal rivers in Massachusetts. The Jones River, Kingston, has the longest running station that shows relatively stable numbers since 2001 (Figure 11.5).

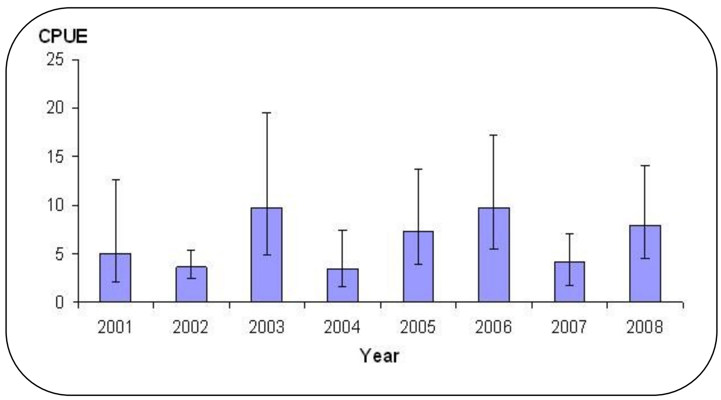


Figure 11.5. Juvenile American eel catch-per-unit-effort during April and May at the, eel trap station in Jones River, Kingston, MA. Graphed CPUE data are geometric means with 95% confidence intervals.

In Massachusetts and Cape Cod Bays, there are approximately 95 coastal streams and rivers that *MarineFisheries* evaluated for the presence of diadromous fish species (Table 11.1). There are a number of runs with obstructions to fish passage including tide-gates, dams, undersized culverts, aging or non-functioning fish ladders, and other barriers to fish passage. Typical restoration activities include removal of tide-gates, installation of larger culverts, replacement or repair of fish ladders, and removal or modification of other barriers to better enable fish to migrate.

Table 11.1. Diadromous fish of Massachusetts and Cape Cod Bays.
Source: *MarineFisheries.*

American eel	*Anguilla rostrata*
Atlantic sturgeon	*Acipenser oxyrinchus oxyrinchus*
shortnose sturgeon	*Acipenser brevirostrum*
American shad	*Alosa sapidissima*
alewife	*Alosa pseudoharengus*
blueback herring	*Alosa aestivalis*
hickory shad	*Alosa mediocris*
gizzard shad	*Dorosoma cepedianum*
Atlantic tomcod	*Microgadus tomcod*
striped bass	*Morone saxilitus*
white perch	*Morone americanus*
rainbow smelt	*Osmerus mordax*
sea lamprey	*Petromyzon marinus*
Atlantic salmon	*Salmo salar*
brown trout (salter)	*Salmo trutta*
brook trout (salter)	*Salvelinus fontinalis*
rainbow trout (salter)	*Oncorhynchus mykiss*

Volunteer river herring counting has proved to be a popular monitoring activity all along the Massachusetts Coast. *MarineFisheries* has developed a protocol for citizen groups to conduct visual counts in a quantitative manner. There are several volunteer programs that count river herring along 12 streams and rivers in the Massachusetts Bays region and three new habitats that are in the initial planning stages.

In 2010, the Massachusetts Bays Program began a project to monitor coastal streams in the MBP regions using water level and temperature data loggers and volunteer fish counts. While primarily focused on improving understanding of anadromous fish populations, this project is also an initial effort to evaluate potential climate change impacts to coastal streams.

Q12 Have there been any observed changes in the fisheries of Massachusetts and Cape Cod Bays?

Contributors: Jeremy King, Massachusetts Division of Marine Fisheries, and Christian Krahforst, Massachusetts Bays Program

Why this is important

According the National Marine Fisheries Service, commercial landings of finfish are reported to net Massachusetts fisherman between $110 and $120 million annually (See *Box Note* below). Commercial and recreational fisheries are important to the Massachusetts economy, not only with respect to the value of fish as a food source, but also due to revenue generated by recreational fishing and tourism. Pollution, overfishing, and changes in habitat due to impacts from coastal development and other anthropogenic stressors have strained fisheries resources of the world's oceans for many years. The relationship between causes and effects is complex. However, it is clear that efforts to preserve or restore important coastal habitats such as eelgrass beds or salt marshes are essential elements of fisheries management, in addition to careful management of commercial and recreational fishing. Monitoring of finfish populations is a critical component of finfish management, and results can signal important changes in the overall health of Massachusetts and Cape Cod Bays.

State of the Bays

Since 1978, the Massachusetts Division of Marine Fisheries (*MarineFisheries*) has conducted bottom trawl surveys during the spring and fall in the coastal waters of the Commonwealth, including Massachusetts and Cape Cod Bays. On average, 41 stations are surveyed each May and September in Massachusetts and Cape Cod Bays (Figure 12.1). The survey results are useful for monitoring population trends in many fish species that reside on or near the seafloor. Figure 12.2 displays the biomass trends of ten species that have comprised nearly 90% of the 1978- 2008 spring survey finfish biomass in Massachusetts and Cape Cod Bay. Recent trends in the biomass are mixed. Winter flounder, ocean pout, winter skate, and red hake show declining trends, while yellowtail flounder, little skate, spiny dogfish, and American plaice indices have improved. Atlantic cod and longhorn sculpin indices have been relatively stable near the median in recent years.

Box Note: The National Oceanic and Atmospheric Administration's Office of Science and Technology maintains a database that provides the pounds, dollar value and price per pound of commercial fishery landings for each state and the U.S.as a whole by year and species. As of this writing, the URL is: http://www.st.nmfs.noaa.gov/st1/commercial/landings/gc_runc.html.

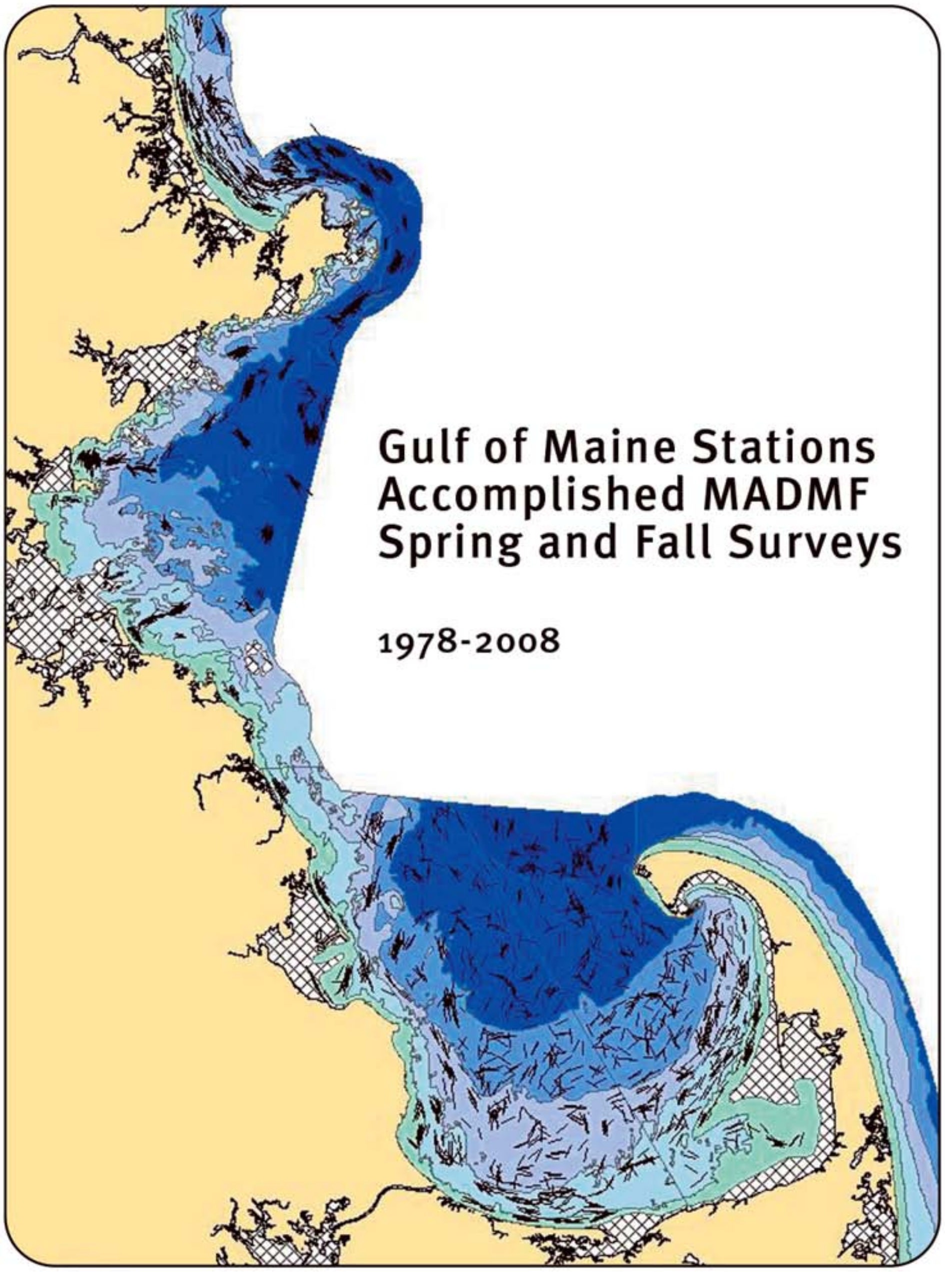
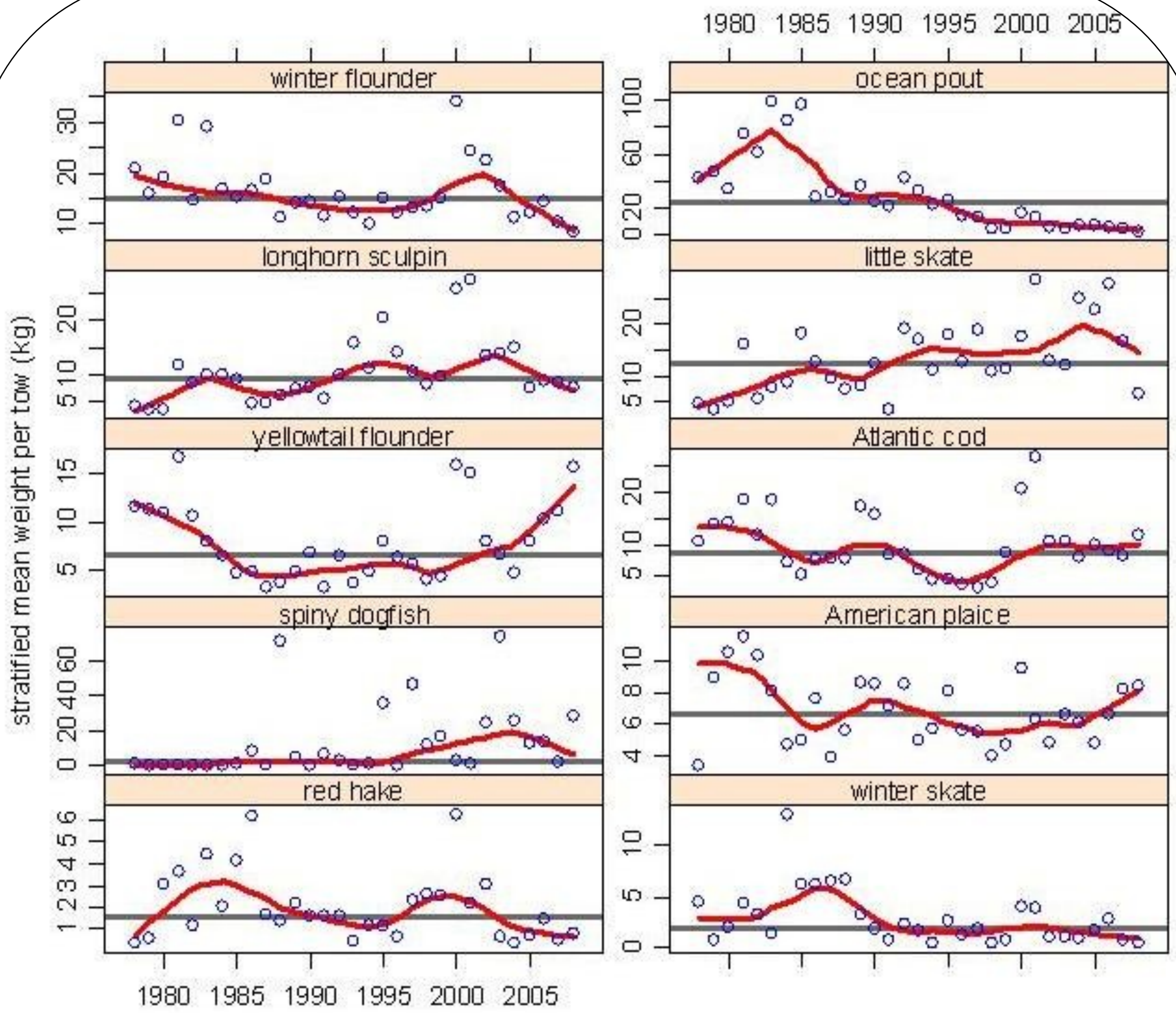


Figure 12.1. Location of trawl survey tows (black lines) conducted by *MarineFisheries*, 1978—2002.

The response of fish populations to complex and subtle environmental and ecosystem change as well as to fishery management actions differs from one species to the next. For example, both winter flounder and yellowtail flounder are valued commercial fish that have been managed increasingly conservatively to effect recovery. There has been a positive response in the yellowtail flounder biomass, while winter flounder biomass has continued to decline in recent years. Although ocean pout have not been targeted by any fisheries in recent years, biomass continues to decline. Changes in the fishery resources in the Bays vary across both commercially valuable and unexploited species.



YEAR
Grey line: time series median
Red line: Loess smoothed index, span = 03, degree=1
Note that the y-axis scales differ

Figure 12.2. Biomass trends of 10 species of fish in Massachusetts and Cape Cod Bays
Source: *MarineFisheries*, Spring trawl surveys, 1978—2008.

Q13 Are threats from marine invasive species increasing in Massachusetts and Cape Cod Bays?

Contributors: Adrienne Pappal, Jan Smith, Massachusetts, Office of Coastal Zone Management, and Judith Pederson, Massachusetts Institute of Technology-SeaGrant Program

Why this is important

Non-native species have emerged as one of the leading environmental threats to our coastal habitats. These species have been recognized globally as a major threat to biological diversity as well as to agriculture and other human interests. Human activities, such as shipping, aquaculture, and recreation, can result in the transfer of species from their native ranges to new areas. Non-native species, once introduced, have the potential to spread rapidly and become invasive, resulting in profound, adverse effects on marine ecosystems and economies. Along the coast of Massachusetts and around the world, scientists have witnessed numerous invasions and subsequent impacts. While most foreign species are harmless, there are many examples of plants and animals that have caused ecological and/or economic problems when moved to new areas. As some introduced species become invasive, the physical conditions and habitats of native species can be altered in a variety of ways that result in the exclusion of native species and favor those of the invader. Invasive can cause a decrease in native species populations, a decline in native species diversity, alteration of habitat, and changes in nutrient dynamics or productivity. Invasive species can also result in major economic impacts resulting from losses of important commercial resources and expenditures related to control and management (e.g., zebra mussels that clog intake pipes for water systems in the Great Lakes).

State of the Bays

There are two monitoring programs for marine invasive species operating in the Massachusetts Bay region: The Rapid Assessment Survey, and the Marine Invader Monitoring and Information Collaborative. Each of these programs is summarized below.

Marine Invader Monitoring and Information Collaborative

The Massachusetts Office of Coastal Zone Management (CZM) established the Marine Invader Monitoring and Information Collaborative (MIMIC) in 2006 to serve as a regional early-detection and monitoring network for marine invasive species. MIMIC is a partnership between interagency staff, scientific experts, volunteers, and not-for-profit organizations who train citizen scientists to monitor for thirteen established marine invasive species (Table 13.1) and seven potential invaders (Table 13.2) at coastal sites across New England. In 2008, CZM worked with four partners (Salem Sound Coastwatch, North and South Rivers

Watershed Association, Provincetown Center for Coastal Studies, and independent volunteers to monitor 28 sites within the Massachusetts Bays region (Figure 13.1).

The most commonly reported non-native species was the sheath tunicate, *Botrylloides violaceus*, (Figure 13.2) found at 94% of all monitoring sites overall, followed by the star tunicate, *Botryllus schlosseri*, and the club tunicate, *Styela clava*. The green crab, *Carcinus maenus* and Asian shore crab, *Hemigrapsus sanguineus* were most common at cobble shore sites.

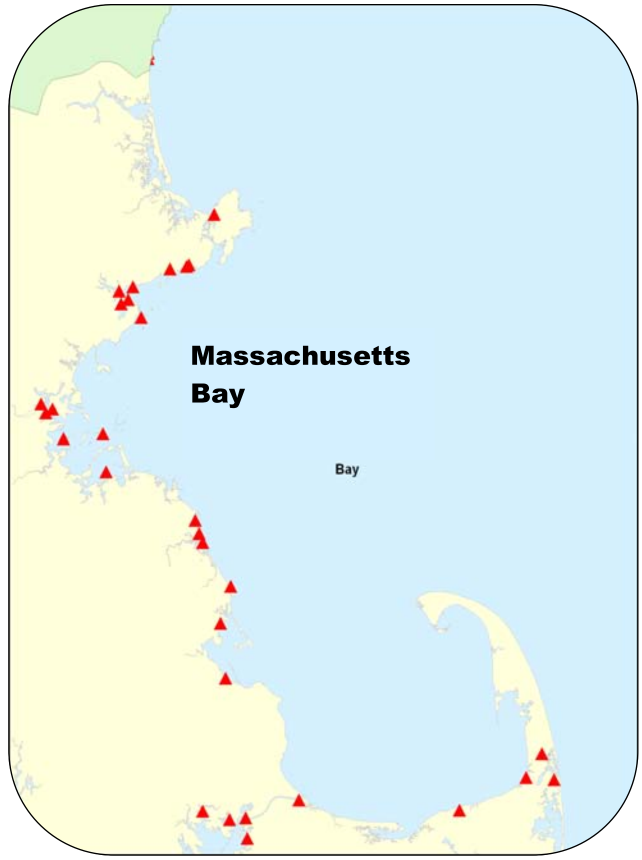


Figure 13.1. Location of MIMIC sites, summer 2008.

The Salem Sound region had the highest number of species overall (Table 13.1). All but one of the 13 established non-native species (the red algae, *Grateloupia turuturu*) monitored for by MIMIC occurred in Salem Sound in 2008. Salem Sound is also the only location where the non-native oyster, *Ostrea edulis*, was detected. Rowes Wharf in Boston and Sandwich Marina on Cape Cod have both reported the presence of eight monitored species, the highest number detected at a single site. No new marine invaders were detected. Table 13.1 provides a list of species found within each region during the 2008 MIMIC sampling.

Although many of the species listed in Tables 13.1 and 13.2 have the potential to negatively impact ecosystems and economic resources of the Massachusetts Bays Region, a few species of particular concern are:

Figure 13.2. An invasive colonial tunicate, *Didemnum vexillum*.

Didemnum vexillum (mystery tunicate):
The colonial tunicate, *Didemnum vexillum* (Figure 13.2), first observed in the Gulf of Maine in the early 1980s, is an aggressive invader that continues to expand its range in in the Salem Sound Region. It was first reported in Beverly Marina in 2007 and has since been discovered in abundance at a large number of

Table 13.1. Monitoring results of 2008 MIMIC season, monitored species in each Mass Bays Region.

Taxonomic Species	UNS	SS	MB	So. S	CC
Cholorophyceae					
Codium fragile ssp. tomentosoides (green fleece)		●			●
Rhodophyceae					
Grateloupia turuturu (red algae)			○		○
Cnidaria					
Diadumene lineata (orange striped anemone)	●	●	●		●
Mollusca					
Ostrea edulis (flat oyster)		●			
Arthropoda					
Carcinus maenus (green crab)	○	○	○	○	○
Hemigrapsus sanguineus (Asian shore crab)		●	●	●	●
Bryozoa					
Membranipora membranacea (lacy crust)	○	○	○		
Tunicata					
Ascidiella aspersa (European sea squirt)		●	●	●	●
Botrylloides violaceus (sheath tunicate)	○	○	○	○	○
Botryllus schlosseri (star tunicate)	●	●	●	●	●
Didemnum vexillum (mystery tunicate)		○		○	○
Diplosoma listerianum (compound tunicate)		●	●		●
Styela clava (club tunicate)	○	○	○	○	○
Totals	**6**	**12**	**10**	**7**	**11**

Upper North Shore (UNS), Salem Sound (SS), Metro Boston (MB), South Shore (So. S), Cape Cod (CC).

Table 13.2. Species considered to be potential invaders.*

Phaeophyceae *Undaria pinnatifida* (wakame) *Sargassum muticum* (wireweed)
Mollusca *Rapana venosa* (rapa whelk)
Anthropoda *Synidotea laevidorsalis* (Asian isopod) *Hemigrapsus takanoi* (brush-clawed shore crab) *Eriocheir sinensis* (Chinese mitten crab)
Tunicata *Corella eumyota* (transparent sea squirt)
***as of 2008**

sites. *D. vexillum* was also reported at numerous locations in the Cape Cod and South Shore regions. This species has no known predators and currently there are no means to control its spread.

Grateloupia turuturu (red alga): *G. turuturu* (Figure 13.3), a red algae native to Asia, was first discovered in Boston and the Cape Cod Canal during the Rapid Assessment Survey of 2007. In 2008, MIMIC participants once again detected this species, suggesting that *G. turuturu* is capable of reproducing and spreading in the Massachusetts Bay Region. While the effects of this new invader are unclear, competition with native species, overcrowding, and shading of habitat could be potential impacts. MIMIC participants will closely track the spread of this species in the Massachusetts Bays region and coastal New England in the coming years.

Figure 13.3. Invasive red alga, *Grateloupia turuturu*.

Eriocheir sinensis (mitten crab): *E. sinensis* has not been reported in Massachusetts waters to date, but it has been expanding its range along the Atlantic coast since it was first detected in Maryland in 2006. It is a catadromous species that migrates from freshwater rivers and tributaries to reproduce in saltwater. Primary impacts include riverbank erosion from burrowing activity, clogging of intake pipes and screens and strong competition with native species. This species also has possible human health impacts (it is an intermediate host to a parasitic lung fluke). As *E. sinensis* has recently been found in the Hudson River and New Jersey waters, MIMIC citizen scientists will continue to keep a close watch for this species.

While the MIMIC program only monitors a subset of species out of necessity, the importance of having this type of regional monitoring program and early detection system cannot be overstated. New species may arrive at any moment, and effective early detection and rapid response may be the only way to mitigate the future impacts of marine invasive species in the Massachusetts Bays Region and elsewhere. MIMIC and the Rapid Assessment Surveys will continue to partner with Mass Bays to ensure that new species arrivals are detected in a timely manner, track the distribution of established invaders, and educate the public about marine invasive species.

Rapid Assessment Survey:

Based on the protocols of similar survey in 2000 and 2003 and led by MBP and MIT SeaGrant, taxonomic experts and volunteers conducted a rapid assessment survey in August of 2007 to identify native and non-native species found on floating docks and piers throughout coastal New England (See *Box Note.* at the end of this section). On some of the docks sampled (Figure 13.4), introduced species covered large areas and were the most abundant species.

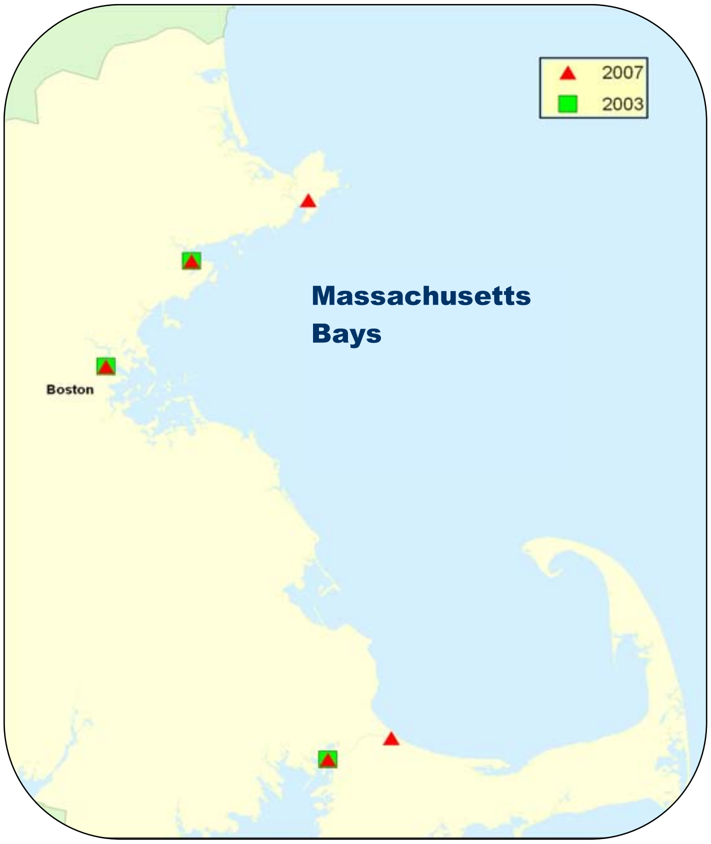
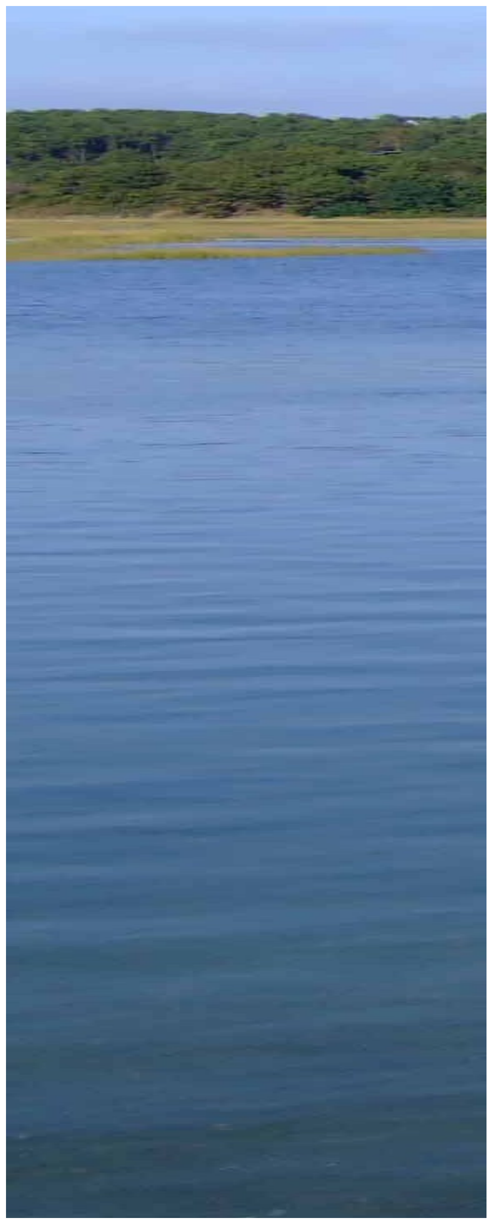


Figure 13.4. Location of Rapid Assessment sites during summer, 2003 and 2007.

During the initial rapid assessment survey of 2000, 260 species of plants and invertebrates were identified at 21 sites in New England. 55 species (22%) were either cryptogenic (organisms whose native geographic distributions are unknown) or introduced. Additional surveys were conducted in 2003 and of the five sites in Massachusetts, 18 and 22 introduced and cryptogenic species were observed, respectively. In 2007, seven sites were visited in Massachusetts. Of the 200 species identified, 18 were considered introduced and 20 cryptogenic. Another rapid assessment was completed during the summer of 2010, and results are forthcoming.

Box Note: The MIMIC data are available to view on Massachusetts Ocean Resource Information System (MORIS) (http://www.mass.gov/czm/invasives/monitor/index.htm)

More information about the New England rapid assessment surveys, species identification, and invasive species updates can be found at http://massbay.mit.edu.



Horseshoe crabs

Contributor: Sara Grady, Massachusetts Bays Program
South Shore Regional Coordinator and the North and South Rivers Watershed Association

A fortunate visitor to a sandy beach in Massachusetts has probably encountered a horseshoe crab scuttling about near the surf or in shallow waters. Although the overall status of this species as a whole is not fully understood due to insufficient data, the research suggests that populations have been declining in the past few decades due to overharvesting. But while additional data are being gathered to inform future management decisions, a recent tightening of harvest regulations in Massachusetts is aimed at safeguarding local populations of this iconic species.

Photo: J. Galluzzo, MA Audubon

Figure HC.1. Sara Grady of the North and South Rivers Watershed Association and South Shore coordinator for the MBP, teaching students how to distinguish between female and male horseshoe crabs (*Limulus polyphemus*).

Not a true crab at all, the horseshoe crabs (*Limulus polyphemus*) are more closely related to scorpions and spiders. They are harvested as bait for the eel and conch fisheries, as well as for biomedical purposes. The *Limulus* amoebocyte lysate (LAL) compound found in their blood is widely used to test the sterility of medical products. In biomedical harvest, horseshoe crabs have about 30% of their blood volume extracted and are then returned to their home estuaries. This process results in a 10-15% incidental mortality rate. In late spring and early summer, horseshoe crabs come to shore to lay their eggs in the sand. This predictable event, paired with the innocuous nature of the horseshoe crab, make them relatively easy to harvest.

Horseshoe crab harvest in Massachusetts and Cape Cod Bays accounted for 14% of the total harvest of crabs in the state from 2003-2007. Over those five years, roughly 81,000 crabs were harvested for bait from the embayments on the northern side of the Cape, more than half of which occurred during 2006 and 2007. This may be due to a tightening of harvest restrictions in the Delaware Bay states in 2004, likely increasing harvest demand in states with fewer restrictions. In addition, a major red tide occurred in 2006 that caused harvesters to switch from shellfish to horseshoe crabs, and these factors fueled a large spike in the Massachusetts harvest. There was a particularly large increase in Pleasant Bay, a shallow embayment on the elbow of Cape Cod with a large and easily harvested horseshoe crab population. The Massachusetts Division of Marine Fisheries (*MarineFisheries*) instituted an emergency closure for bait harvest in that estuary, which continues to this day. It is speculated that this closure caused a shift in harvest to other Cape Cod Bay embayments, especially Wellfleet Harbor and points south. *MarineFisheries* has since instituted a stricter annual quota for harvest in Massachusetts of 165,000 crabs, which is approximately half the quota set by the Atlantic States Marine Fisheries Commission, and a 400 crab/day limit in order to address issues of local depletion. Additional regulations are currently being evaluated.

Photo: S. Grady

Figure HG.2. *Limulus polyphemus* in Pleasant Bay, Chatham, Massachusetts.

In 2008, *MarineFisheries* worked with a host of partners – including the Massachusetts Audubon Society, National Park Service, U.S. Fish and Wildlife Service, University of Rhode Island, and others – to survey multiple spawning beaches in southern New England. Compared to data available from 2000 to 2002, spawning indices have decreased. With the harvest restrictions maintained, it is hoped that populations will stabilize or increase while also supporting a viable horseshoe crab fishery.

HUMAN USES & PLANNING

Home to nearly 1.7 million people and representing more than a quarter of all Massachusetts residents, the 50 communities of the Massachusetts Bays Program region have tremendous value to the Commonwealth. While fishing and tourism are a substantial source of revenue for local communities, the Bay State as a whole relies on the industrial contributions made by coastal areas, including the generation and transport of energy resources, wastewater treatment, and cargo shipping. Recreational opportunities along the coast, particularly in the many protected areas of the region, are enjoyed by both residents and visitors alike. Considerable planning goes into ensuring that values are balanced between human use and environmental well-being.

Q14 How is human population distributed among the MBP communities and how does it compare state-wide?

Contributor: Christian Krahforst, Massachusetts Bays Program

Why this is important

Understanding human population dynamics and change is critical for effective environmental management. High concentrations of people in coastal regions have produced many social and economic benefits including improved transportation links, creation of jobs, revenue from industry and tourism, and food production. However, the cumulative effects of intense coastal development often have negative impacts on coastal environments primarily through increased development and consumption of coastal resources, alteration of natural ecosystem processes, and production and disposal of wastes. Thus, human population dynamics and environmental change are intrinsically linked. Humans are a major source of environmental degradation, especially when the population exceeds the threshold limits of the ecosystem. Known impacts associated with high population density include loss of biodiversity, air and water pollution, and losses of forests, open space, and arable land. Therefore, human population dynamics are extremely important when it comes to the health and future of our environment.

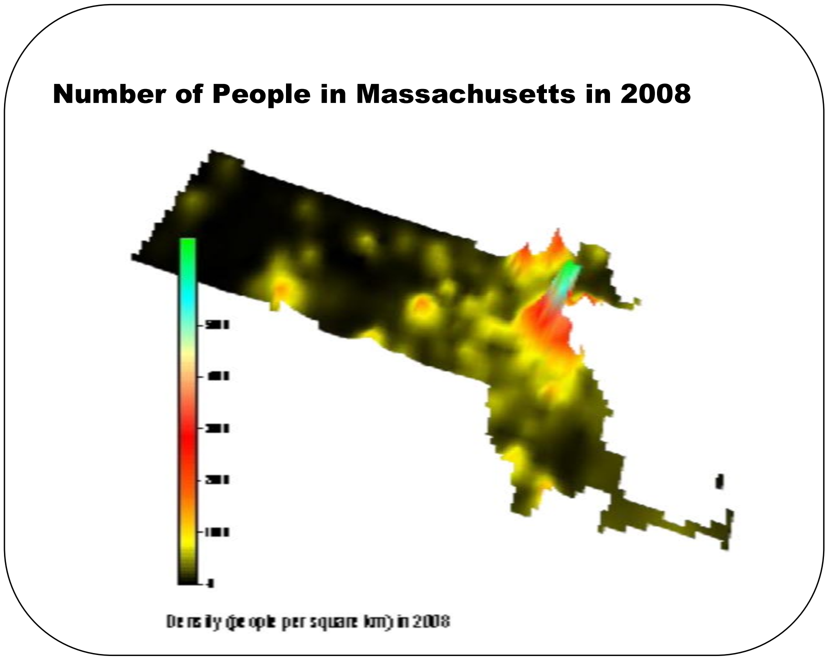


Figure 14.1. Population distribution in Massachusetts (# people km^{-2})

Coastal areas are particularly stressed since most of our global population resides within 200 km of the coast (worldwide, this represents approximately 3 billion people — about half of the world's population).

State of the Bays

Nearly one third (27 %) of Massachusetts citizens live in the coastal communities of the Massachusetts Bays region (Figure 14.1). This value has been relatively consistent since 2000 (only a 0.3% increases overall by 2008). Thus, human population within the five Massachusetts Bays Program (MBP) regions has not changed dramatically since 2000 (Figure 14.2). Revere and Chelsea were the communities with the greatest amount of change, exhibiting a 24% and 18% increases, respectively, but these double-digit increases are uncharacteristic of the MBP planning area. Communities on Cape Cod generally saw small decreases in population densities since 2000 with Dennis and Yarmouth losing the greatest amounts (around 4%).

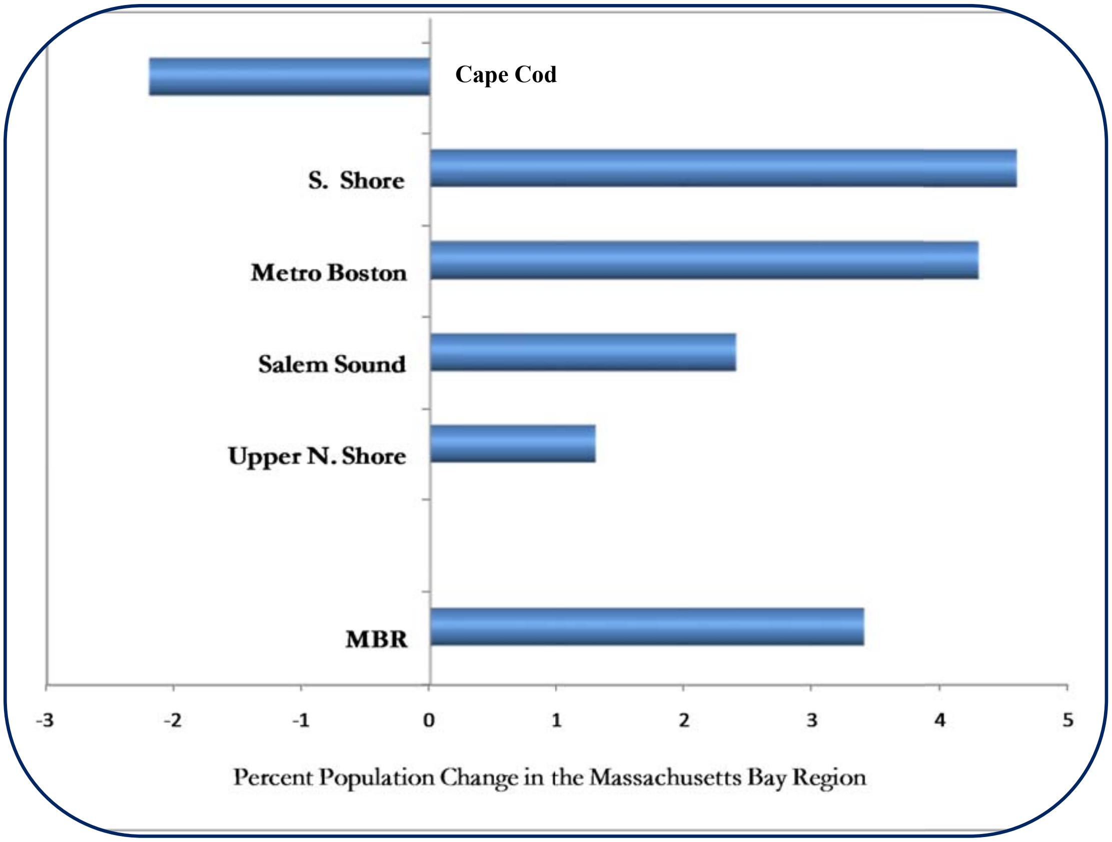


Figure 14.2. Percent change in human population (2000-2008) for the Massachusetts Bays region (MBR), including the subregions: upper North Shore, Salem Sound, Metro Boston, South Shore and Cape Cod. Based on US Census data.

IMPERVIOUS SURFACE

Q15 How much of the Massachusetts Bays region is covered by impervious surface?

Contributors: Dan Sampson, Massachusetts Office of Coastal Zone Management, Josh Daskin and Christian Krahforst, Massachusetts Bays Program

Why this is important

Land covered by asphalt, concrete, buildings or heavily-compacted earth is classified as impervious surface. These areas do not allow water to seep into the ground. Instead, impervious surfaces increase stormwater runoff into surrounding surface waters. Some of the sediment, pathogens, nutrients, and toxic contaminants associated with stormwater are delivered to local water bodies, adversely impacting water quality and other coastal resources. Increased runoff also means decreased recharge to underground aquifers, which provide important sources of drinking water to many MBP communities. A review of nationwide studies found that stream water quality begins to decline when 10% of the watershed is covered by impervious surface and that severe degradation occurs at 25%. (Visit the Center for Watershed Protection's website: http://www.cwp.org for supporting documents). The locations and hydrologic associations of impervious surface, open land, and waterways, as well as use of best management practices for removing contaminants and mimicking natural flows, all interact to determine the actual impact on receiving waters. Despite these complexities, percent cover of impervious area is often used as a starting point for estimating the impact of local land use on wetlands and waterways.

Figure 15.1. Catch basin collecting rainwater following a storm.

State of the Bays

According to the MassGIS Impervious surface data layer, 17% of the MBP region was covered in impervious surface in 2005. Impervious surface cover within individual municipalities ranged from 4.5% to nearly 80%. Of the five MBP regions, only the Upper North Shore had less than 10% of its area covered by impervious surfaces as of 2005 (Figure15.2). Out of the 50 communities that make up the MBP region, only nine communities (Essex, Newbury, Ipswich, Rowley, Wellfleet, Truro, Provincetown, Norwell, and Duxbury) had less than 10% of their area covered with impervious surfaces (Figure 15.3). Because the methodology used by MassGIS had changed significantly since MBP reported on this indicator in the 2004 State of the Bays Report, direct comparison to the 2005 data is not possible. A recent uptick in land acquisition and conservation in the MBP planning area (See Question 16, Protected Lands) and a relatively stable population (See Question 14, Human Population) are positive signs that impervious surface cover has not increased significantly over the past five years. However, Mass Audubon's "*Losing Ground*" report (2009) on patterns of development (See *box note* below) suggests that southeastern Massachusetts continues to be part of the "sprawl frontier" where development pressure, primarily residential development, remains high.

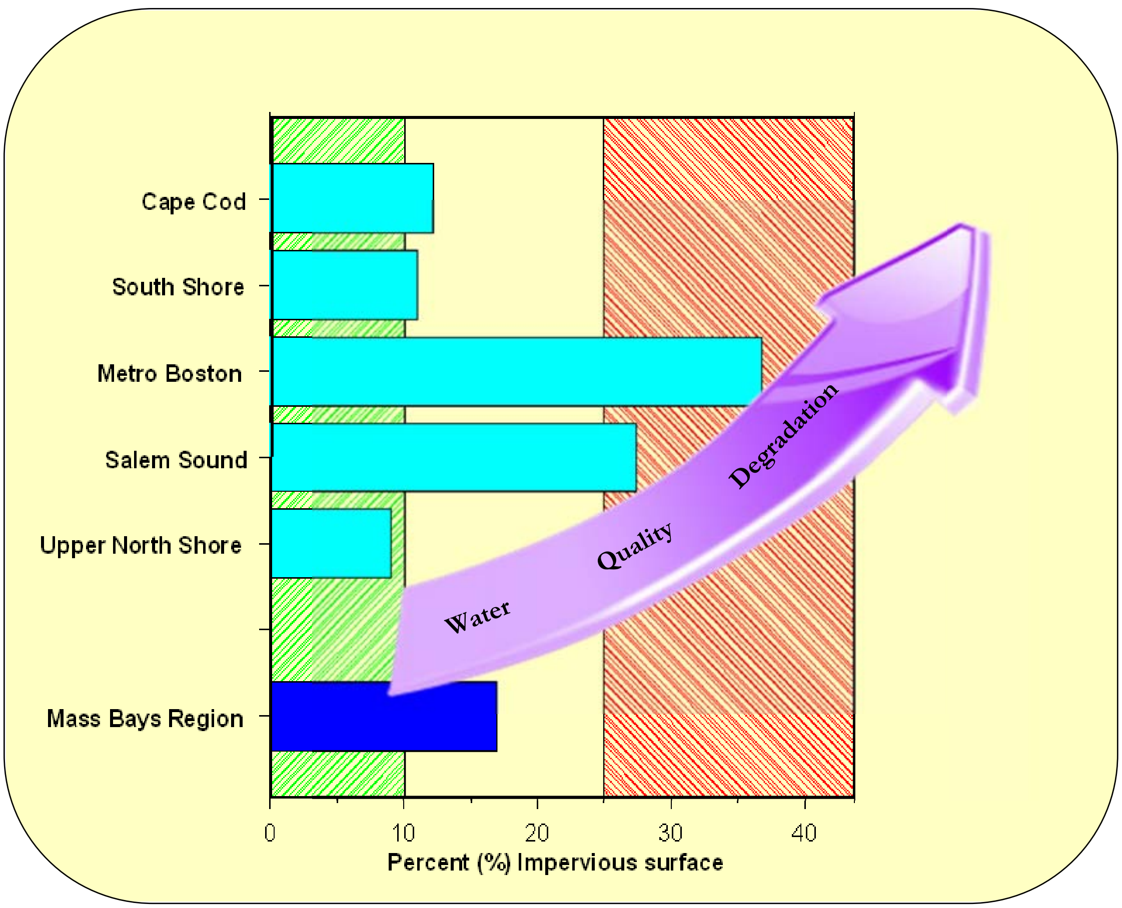


Figure 15.2. Percent Impervious surfaces in the five regions of the Massachusetts Bays Program region. Shading represents water quality thresholds identified by the Center for Watershed Protection. Based on 2005 Data from MassGIS.

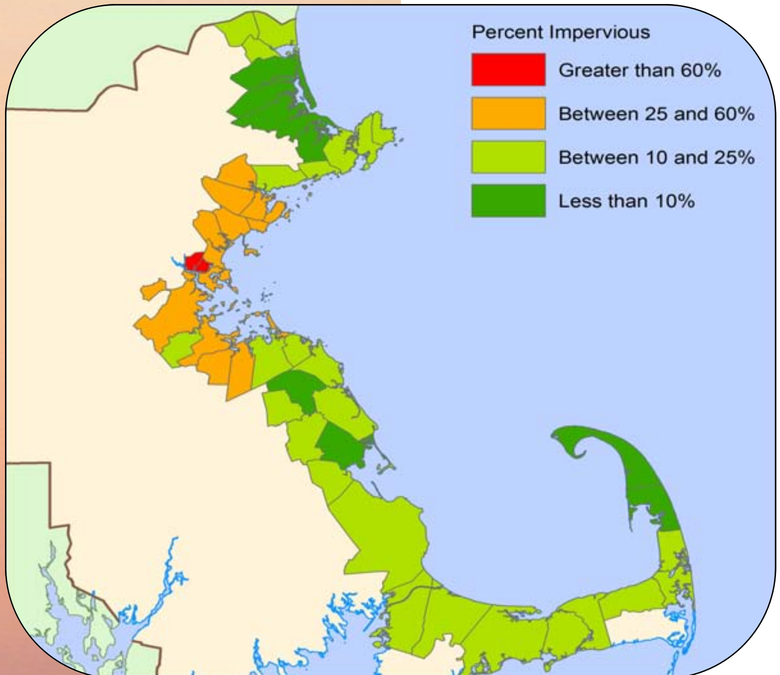


Figure 15.3. Percent impervious surface in the 50 towns of the Mass Bays region. Based on 2005 data from MassGIS.

Box Note: Beginning in 1991, Mass Audubon began producing a periodic analysis of land use in Massachusetts that summarizes environmentally relevant changes in land use. Their *Losing Ground* series is updated every five years and provides a web-based tool that allows users to view these changes at the town, watershed, ecoregion, county, and regional planning agency levels. To learn more about development patterns in your town, visit: http://www.massaudubon.org/

PROTECTED LANDS

Q16 How much of the Massachusetts Bays region is protected from development?

Contributors: Dan Sampson, Massachusetts Office of Coastal Zone Management,
Josh Daskin and Christian Krahforst, Massachusetts Bays Program

Why this is important

Protection of forests, farms, wetlands, parks, beaches and historic sites serves many purposes. Among other benefits, protected lands typically have minimal impervious cover (See Question 15, Impervious Surface), help conserve biodiversity and the ecosystem services we derive from it, provide recreational and community space, and help safeguard water quality. A variety of tools are used to protect these lands including acquisition and designation of state and local parks, forests and preserves, purchase of conservation easements, and adoption of zoning regulations that limit the types and location of allowable development. In light of the continuing pressure from developed land in the Massachusetts Bays Program (MBP) region, land protection activities continue to be an important indicator of ecosystem health.

State of the Bays

As of October 2009, over 26% of land in the MBP region was permanently protected from development (See *box note*, next page) up from the 25% reported for 2003. This aggregated land use category is represented by approximately 194,200 acres of protected lands and includes conservation and recreation lands; town forests and parkways; agricultural, aquifer, and watershed protection lands; as well as cemeteries and forest legacy areas.

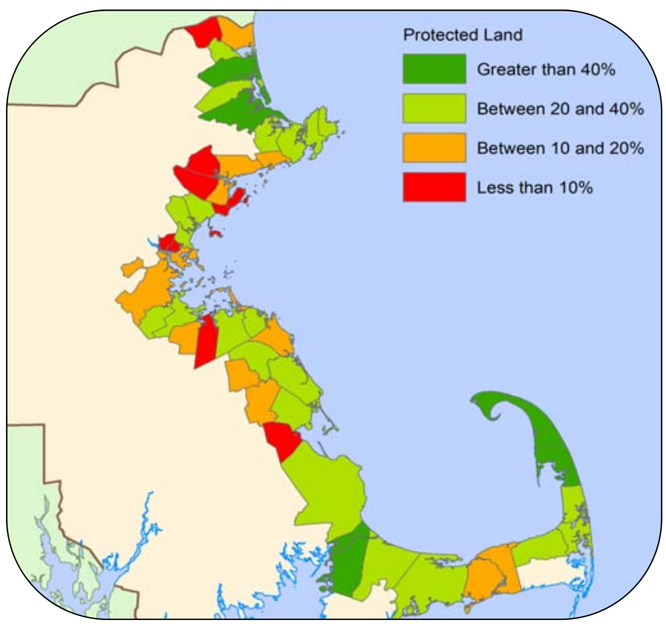


Figure 16.1. Percent of permanently protected area in the 50 communities of the Massachusetts Bays Program. Based on 2003 data from MassGIS.

As shown in Figure 16.1, the percent of land protected varies from town to town. As might be expected, the towns with the highest percentages of protected land are found in the more rural areas of the MBP region: on Cape Cod and in the upper North

Shore sub regions. The lowest levels of permanently protected land (communities with 10% or less) were found in Chelsea, Amesbury, and Kingston. Of the five MBP regions, the Upper North Shore and Cape Cod exceeded the MBP average with protected areas of 29.6% and 35.6%, respectively (Figure 16.2). MBP communities with protected land areas that exceeded 40% were Milton, Ipswich, Newbury, Bourne, Wellfleet, Truro, and Provincetown.

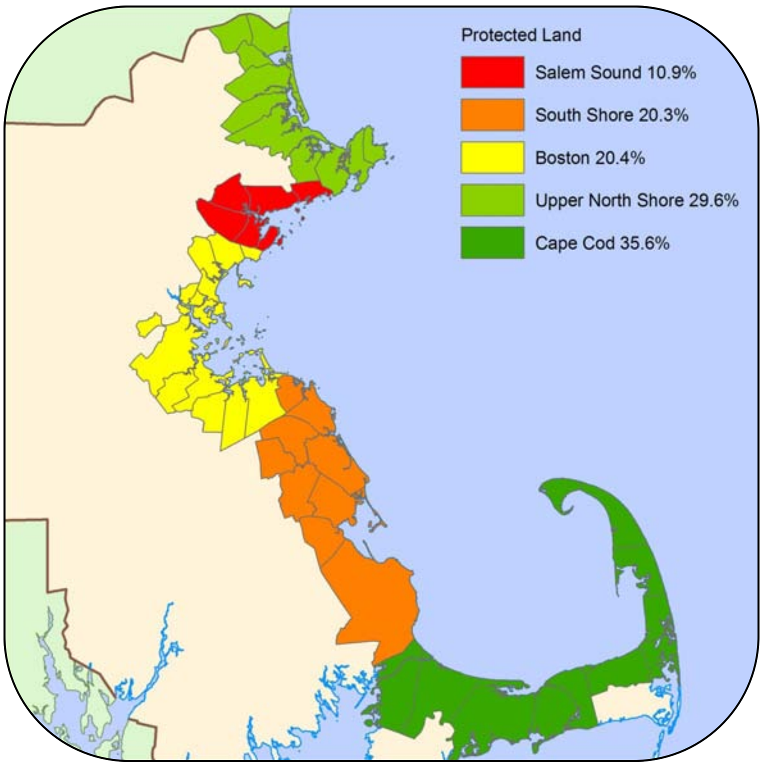


Figure 16.2. Percent of permanently protected lands in the five regions of the Massachusetts Bays Program. Based on 2005 data from MassGIS.

Box Note: Data from the MassGIS layer "protected and recreational open space – December 2009" identifies parcels of "conservation lands *and* outdoor recreational facilities in Massachusetts." Data were aggregated by city/town and summary statistics (e.g., number of acres protected, total number acres per city/town, and percent protected by city/town) were calculated and reported in Figures 16.1and16.2.

Q17 What patterns of coastal development have taken place within the Massachusetts Bays region?

Contributors: Dan Sampson, Massachusetts Coastal Zone Management, and
Christian Krahforst, Massachusetts Bays Program

Why this is important

Approximately one third of the Massachusetts population, 1.7 million people, lives within 50 communities bordering Massachusetts and Cape Cod Bays (See Question 14, Human Population). This distribution places tremendous pressure on the natural resources of the Bays' coastal waters and the number of residents continues to grow moderately. Continued monitoring of the changing uses of our coastal lands can provide useful information for coastal resource management and lend insight to how people may be impacting the Bays' natural resources. Many of the communities in the Massachusetts Bays region recognize the need to balance development and natural resources preservation. Tools for protecting these natural resources include adoption of the Community Preservation Act, creation of wetland bylaws, development of water resources protection overlay zoning districts, completion of open space plans, to name a few.

State of the Bays

Nearly 36% of the land in the Massachusetts Bay region is currently considered developed (See *box note,* next page). Developed lands include 14 land use categories, consisting mostly of residential, commercial, industrial and recreational uses. Comparison between 1999 and 2005 MassGIS land use layers is difficult since the methodologies in creating the layers were markedly different. For example, the 2005 "forest" land-use category includes stands of trees in large backyards, which were included as part of the residential polygons in the 1999 Mass GIS land use layers. (For comparison, approximately 73,000 acres in the Massachusetts Bays region were classified in the forested land use category in 2005 compared with about 59,000 acres in 1999). According to MassGIS 2005 data, the Upper North Shore

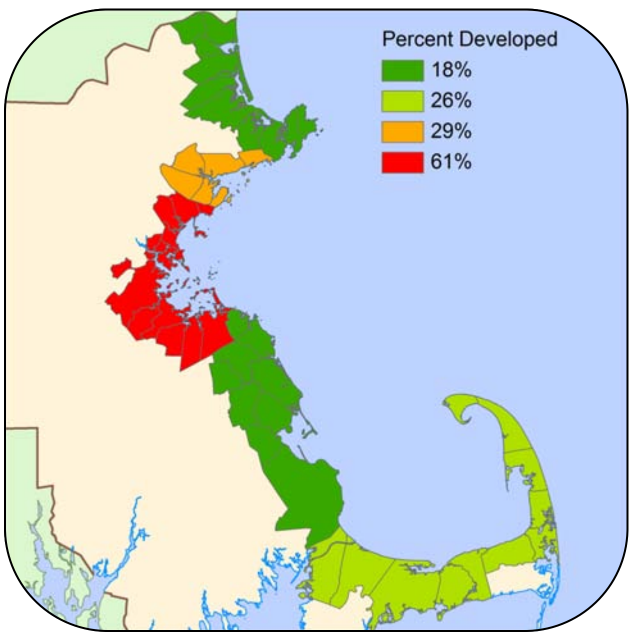


Figure 17.1. Percent developed lands summarized for the five Massachusetts Bays regions.

and South Shore regions were the least developed of the five regions of the Massachusetts Bays Program (Figure 17.1), while Salem Sound and Metro Boston were approximately 30% and greater than 60% developed, respectively. The percent of developed land in each of the 50 communities within the Massachusetts Bays planning area is also shown in Figure 17.2.

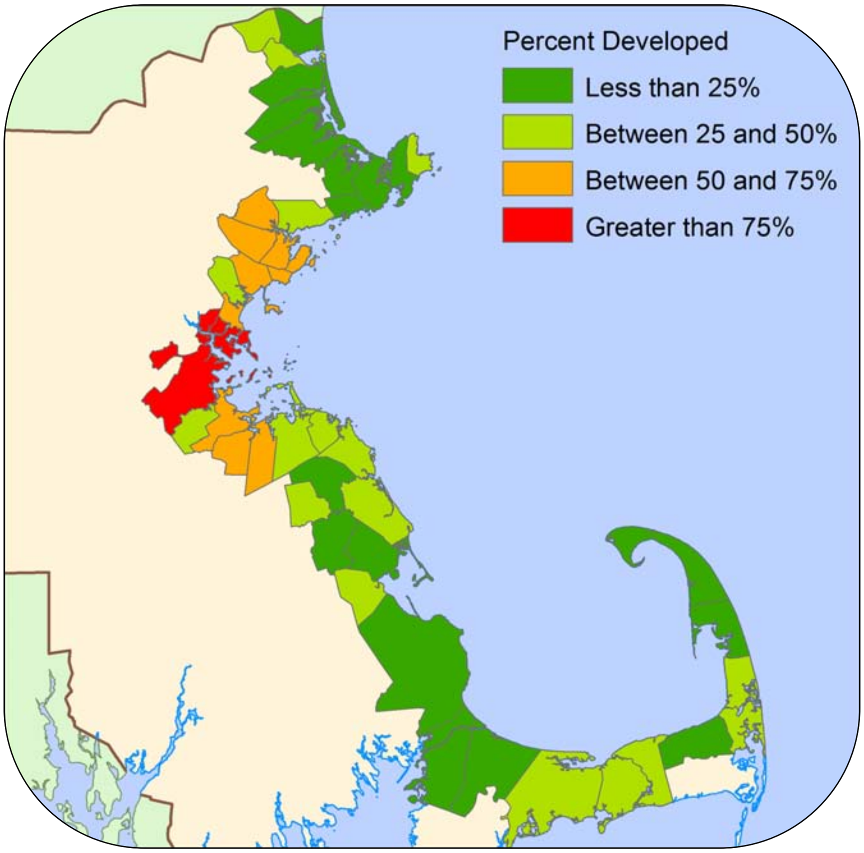


Figure 17.2. Percent developed lands within the 50 Massachusetts Bays Program Communities

Box Note: The Developed Lands category consisted of aggregating 2005 MassGIS land use categories, which includes mining, recreation, waste water management, residences, commercial and industrial, transportation, marinas, urban public/ institutional purposes, and automotive salvage.

SPECIAL TOPIC

Status of liquid natural gas transport in Massachusetts

Contributor: Bob Boeri, Massachusetts Office of Coastal Zone Management

Offshore liquefied natural gas (LNG) terminals have come to the waters of Massachusetts. Forty percent of the state's electric power and home heating currently comes from natural gas. Traditionally, LNG was delivered via landside pipelines from the Gulf of Mexico and Canada, as well as shipments to a port in Everett. Increased demand for energy resources and a high coastal population make Massachusetts offshore waters an attractive location for LNG facilities.

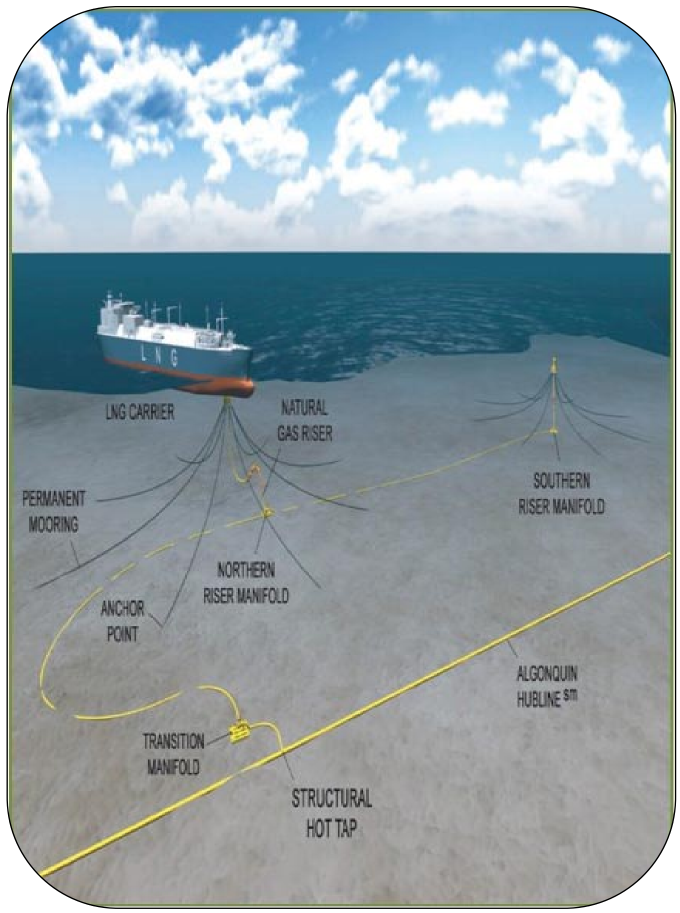
The first offshore LNG facility to enter service in Massachusetts was the Northeast Gateway Deepwater Port, owned and operated by Excelerate Energy, LLC, which is located approximately 13 miles offshore of Gloucester at the termination of a 16-mile sub-sea lateral pipeline (Figure LNG.1). The construction and commissioning of the facility was completed in 2007. The second project, the Neptune Deepwater Port, is owned and operated by GDF Suez and is located approximately 10 miles off the coast of Gloucester at the end of a 13-mile sub-sea lateral pipeline. Construction of this pipeline and port, as well as commissioning of the facility, were completed in 2010. Currently only two other licensed offshore LNG facilities are operating in the United States—Louisiana's Gulf Gateway Deepwater Port in Louisiana, and Maryland's Dominion-Cove Point.

Figure LNG.1: Locations of presently permitted LNG pipelines. (Map courtesy of E. Chambliss, MA CZM).

Both facilities tie into the existing 24-inch HubLine natural gas pipeline, operated by Spectra Energy, which stretches undersea from Beverly to Weymouth, and is part of a distribution network originating in Canada. If operated at projected capacity, these facilities would deliver a daily total of 900 million cubic feet of natural gas, enough to heat an estimated three million homes.

The port facilities for both projects, located in federal waters, consist of dual submerged unloading buoys connected via a riser and transition manifold to the lateral pipeline (Figure LNG.2). Each buoy is anchored to the sea floor by eight suction piles connected to mooring lines. These buoys, which also act as a mooring for the LNG tankers, are submerged between 90 and 100 feet below the sea surface when not in use. Upon arrival, the specially designed tanker draws the unloading buoy into a receiving cone in the forward part of the vessel and connects it to onboard re-gasification equipment. The LNG on the ship is then vaporized and unloaded into the connecting pipeline for distribution—a process that takes four to eight days. The projects operate so that as one tanker is concluding the unloading operation, a second tanker would tie into the unoccupied buoy and begin unloading, thereby ensuring continuous gas flow.

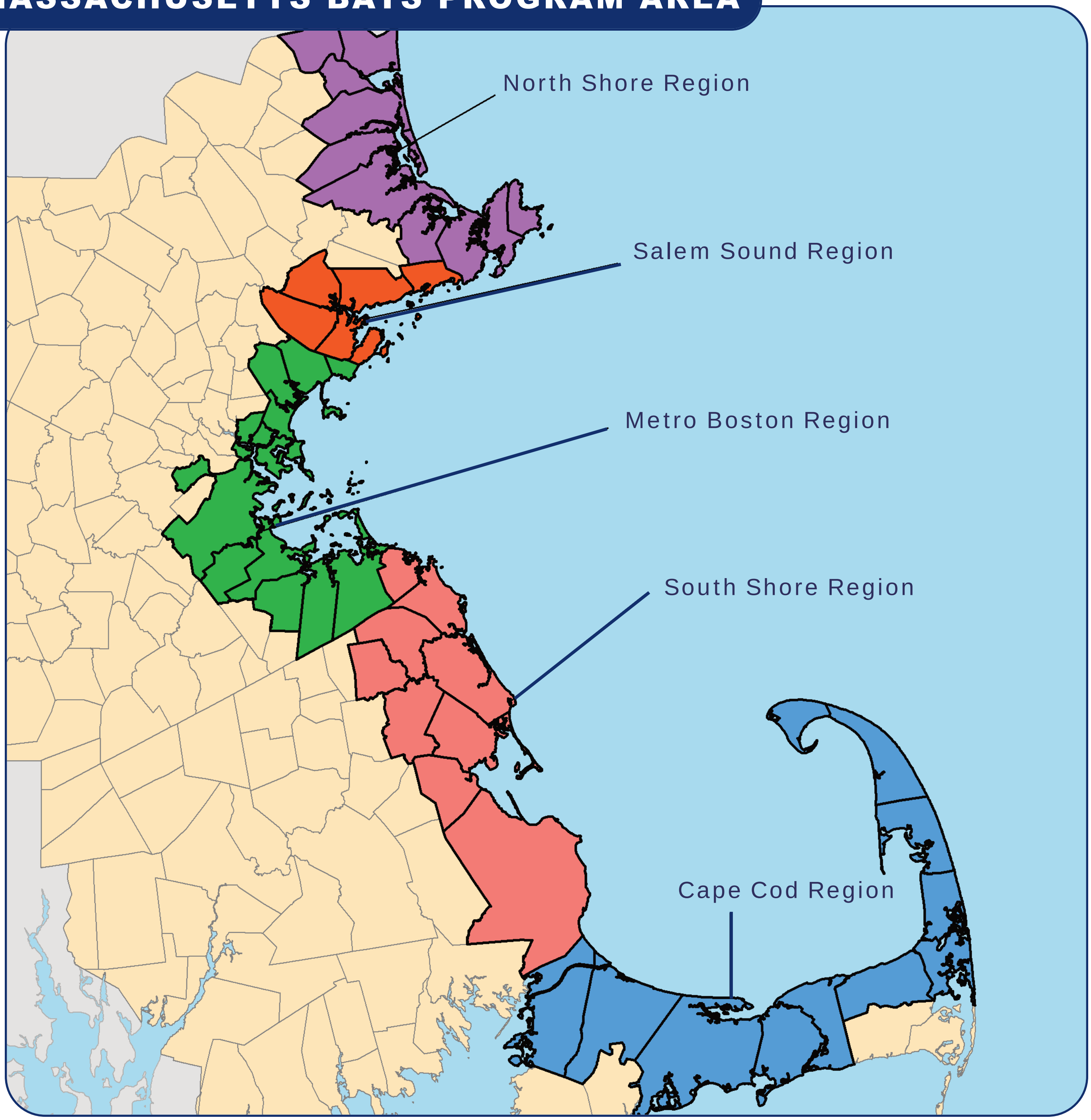
Environmental concerns were a primary focus during the state's review of the projects prior to permitting. Potential impacts to marine mammals, benthic organisms, fisheries, water quality, and plankton were among the many issues evaluated. Because of the potential for a variety of adverse impacts, an exhaustive evaluation of pre-construction conditions was acquired during the permitting process. The final approvals of the projects included conditions that monitoring be conducted for up to three years after construction is completed. Annual monitoring reports are required to be evaluated by a team of state and federal agency scientists. In addition, the companies building these facilities were required to pay $46 million to compensate for impacts that could not be avoided or minimized. These funds are being distributed for projects related to ocean habitat mapping and monitoring, right whale management, impacts to commercial fishing, public access, marine transportation infrastructure, and outreach.



Courtesy of Hoegh LNG AS

Figure LNG.2. Conceptual offshore LNG site plan.

MASSACHUSETTS BAYS PROGRAM AREA

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