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.

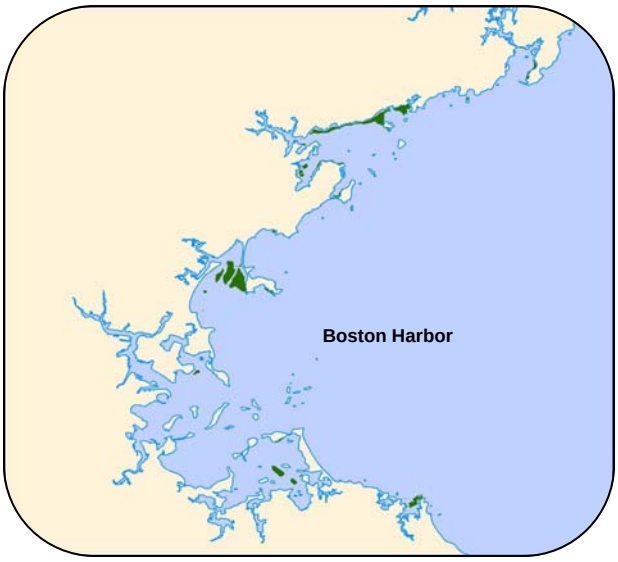


Figure 8.2. Extent of eelgrass habitat from the Merrimack River south to Boston Harbor, 2001. Based on data from MassGIS. (Area north of Cape Ann is excluded due to lack of eelgrass.

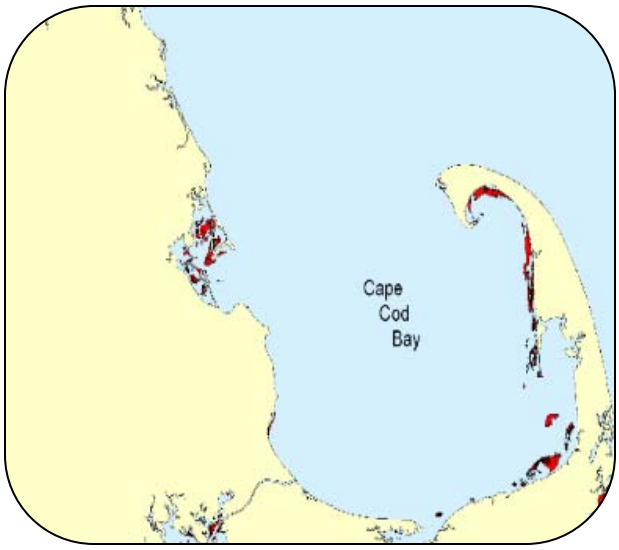


Figure 8.3. Extent of eelgrass habitat in Cape Cod Bay , 2001. Based on 2001 data from MassGIS.

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.

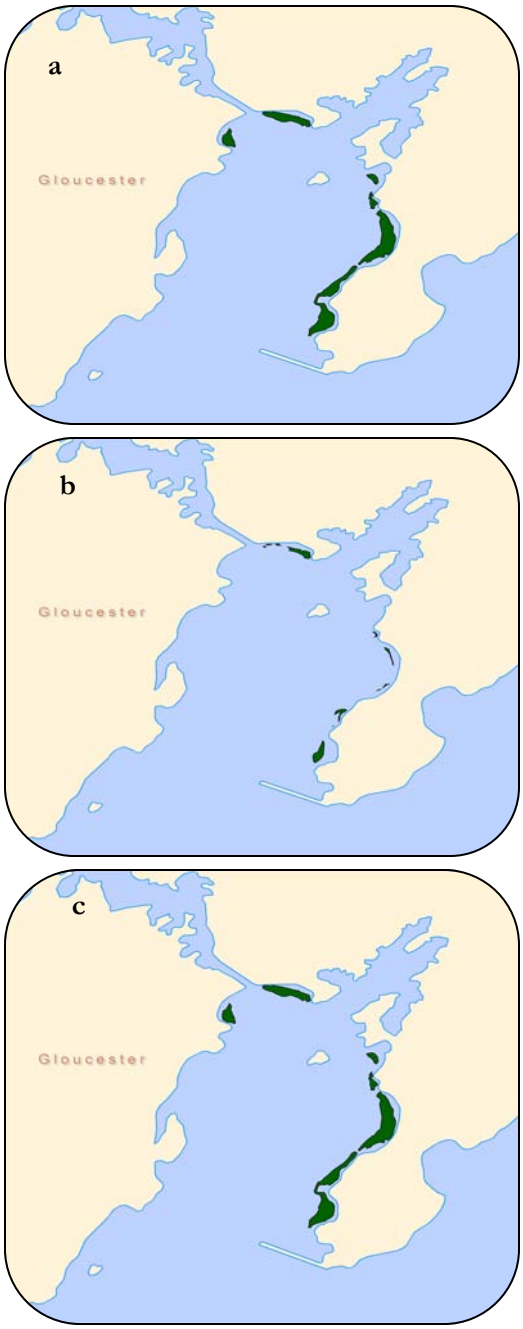


Figure 8.4. Distribution of eelgrass (*Z. marina*) in Gloucester Harbor: a)1995, b) 2001, c)2006. Source: DEP.

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.

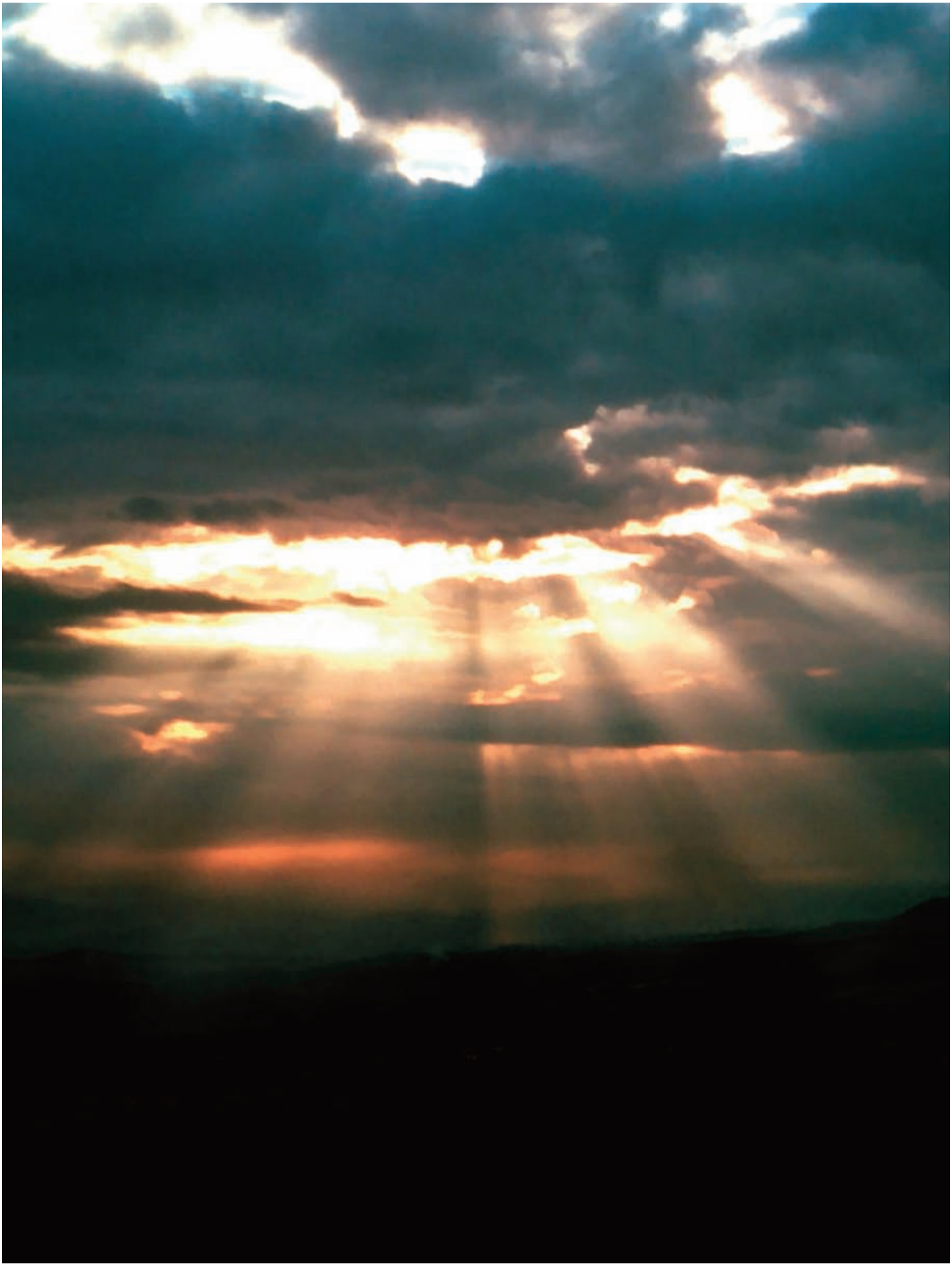
culverts along the creek by the Massachusetts Highway Department, this project also restored fish passage to important spawning habitat in upstream Scargo Lake.

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

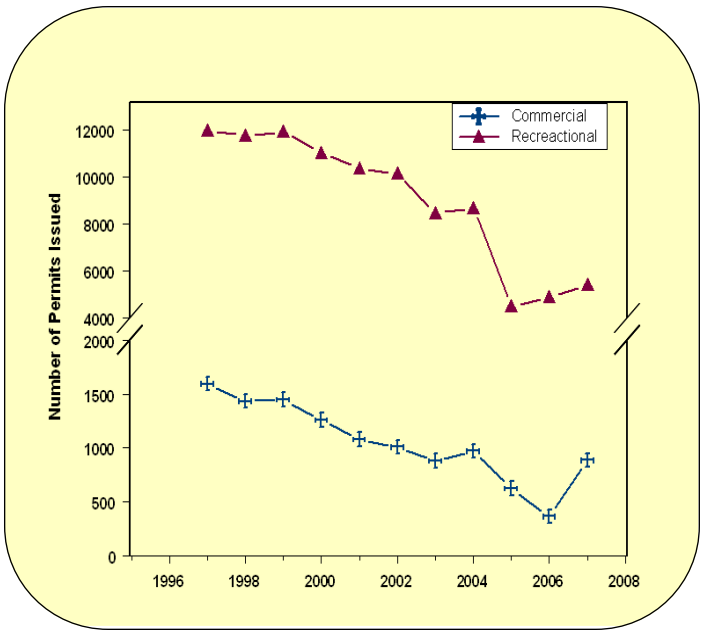


Figure 10.1. Shellfish permits issued by cities and towns in the Massachusetts Bays region (1996-2008). (Note axis break)

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.

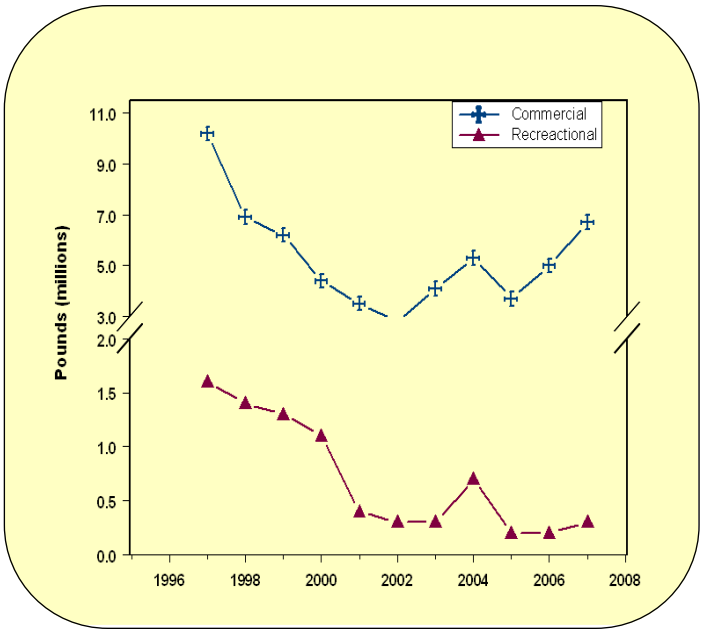


Figure 10.2. Reported landings (millions of lbs) for all species of shellfish from Massachusetts Bays. (Note axis break)

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/

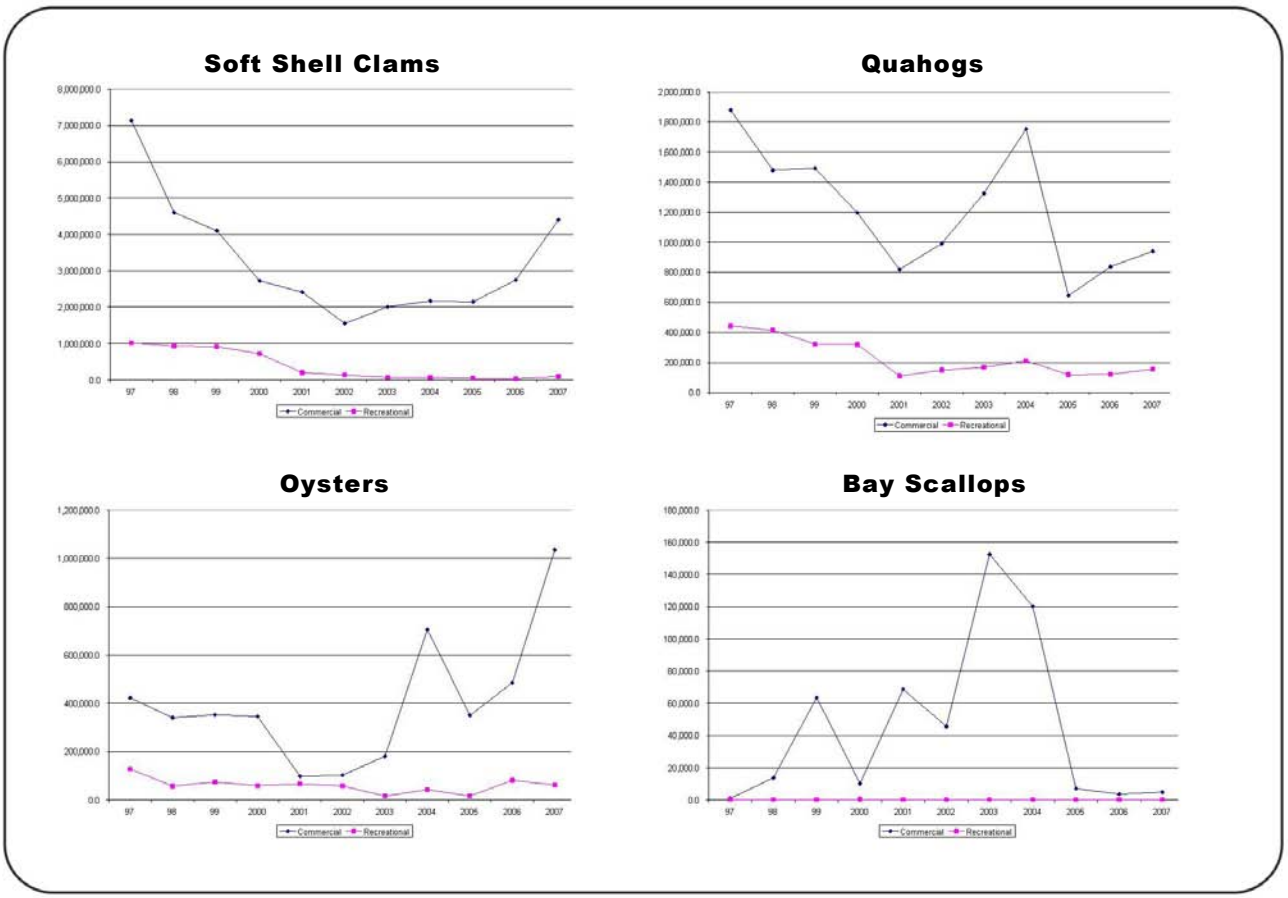
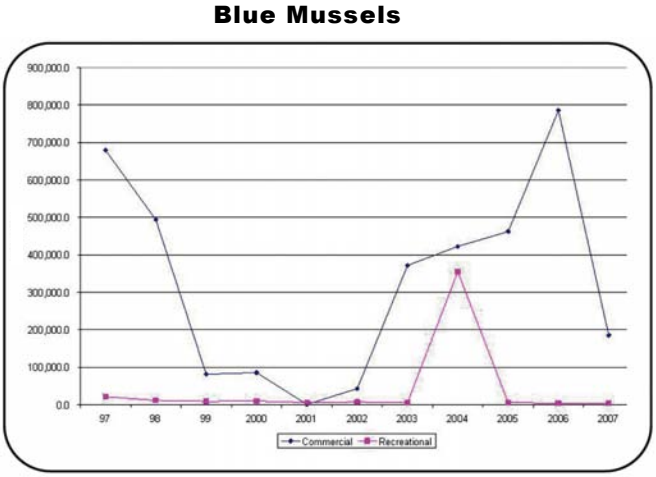


Figure 10.3. Reported landings (thousands of lbs) for selected species of shellfish from Massachusetts Bays communities.



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.

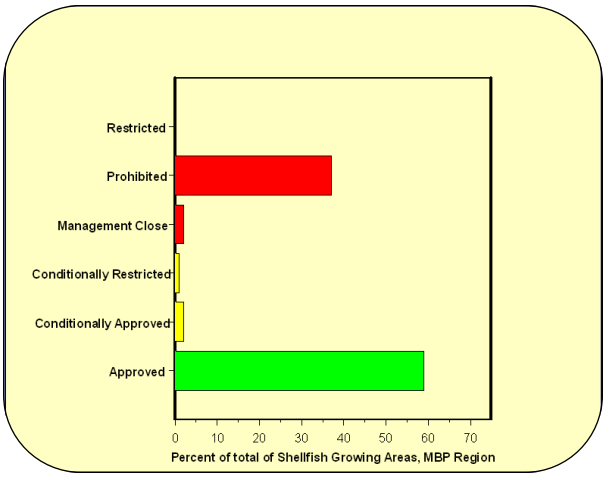


Figure 10.4. Percentage of acreage within each Shellfish Growing Area designation Data maintained by *MarineFisheries* and obtained from MassGIS.

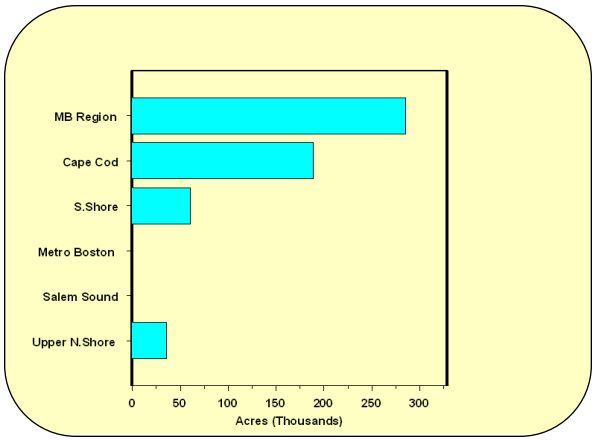


Figure 10.5. *MarineFisheries* "Approved for harvesting" Shellfish Growing Area (thousands of acres) by sub-regions of the Massachusetts Bays Program. Based on data from MassGIS.

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

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.

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

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.

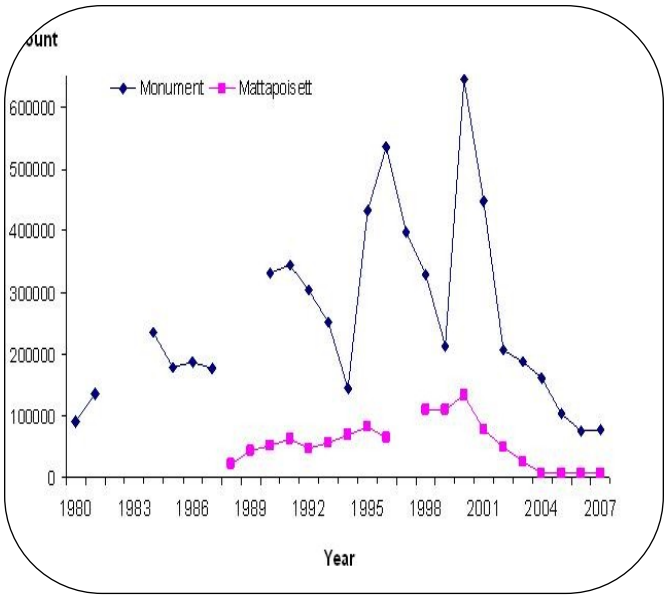


Figure 11.2. Census counts of Alewife at Mattapoisett River, Mattapoisett, and river herring at Monument River, Bourne, MA. Source: *MarineFisheries*.

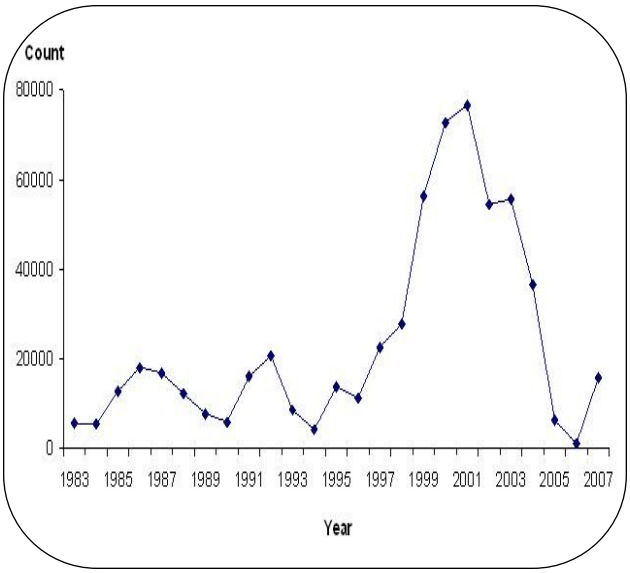


Figure 11.3. Census counts of American shad at the Essex Dam fish lift on the Merrimack River, MA. Source: Technical Committee for Anadromous Fishery Mgt. of the Merrimack. River Basin.

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.

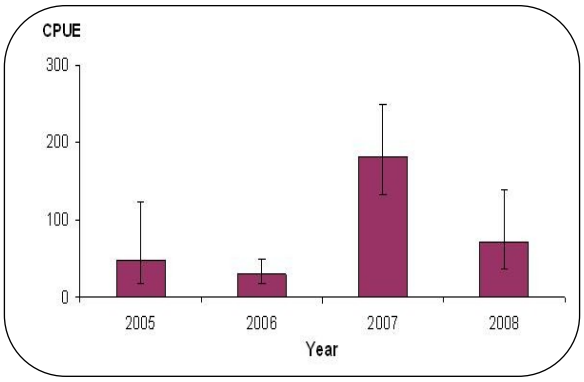


Figure 11.4. Rainbow smelt catch-per-unit-effort during April and May at the fyke net station in Fore River, Braintree, MA. Graphed CPUE data are geometric means with back-transformed 95% confidence intervals.

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).

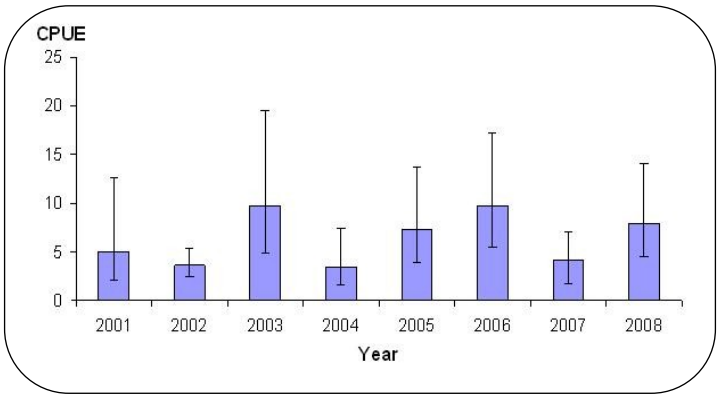


Figure 11.5. Juvenile American eel catch-per-unit-effort during April and May at the, eel trap station in Jones River, Kingston, MA. Graphed CPUE data are geometric means with 95% confidence intervals.

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.

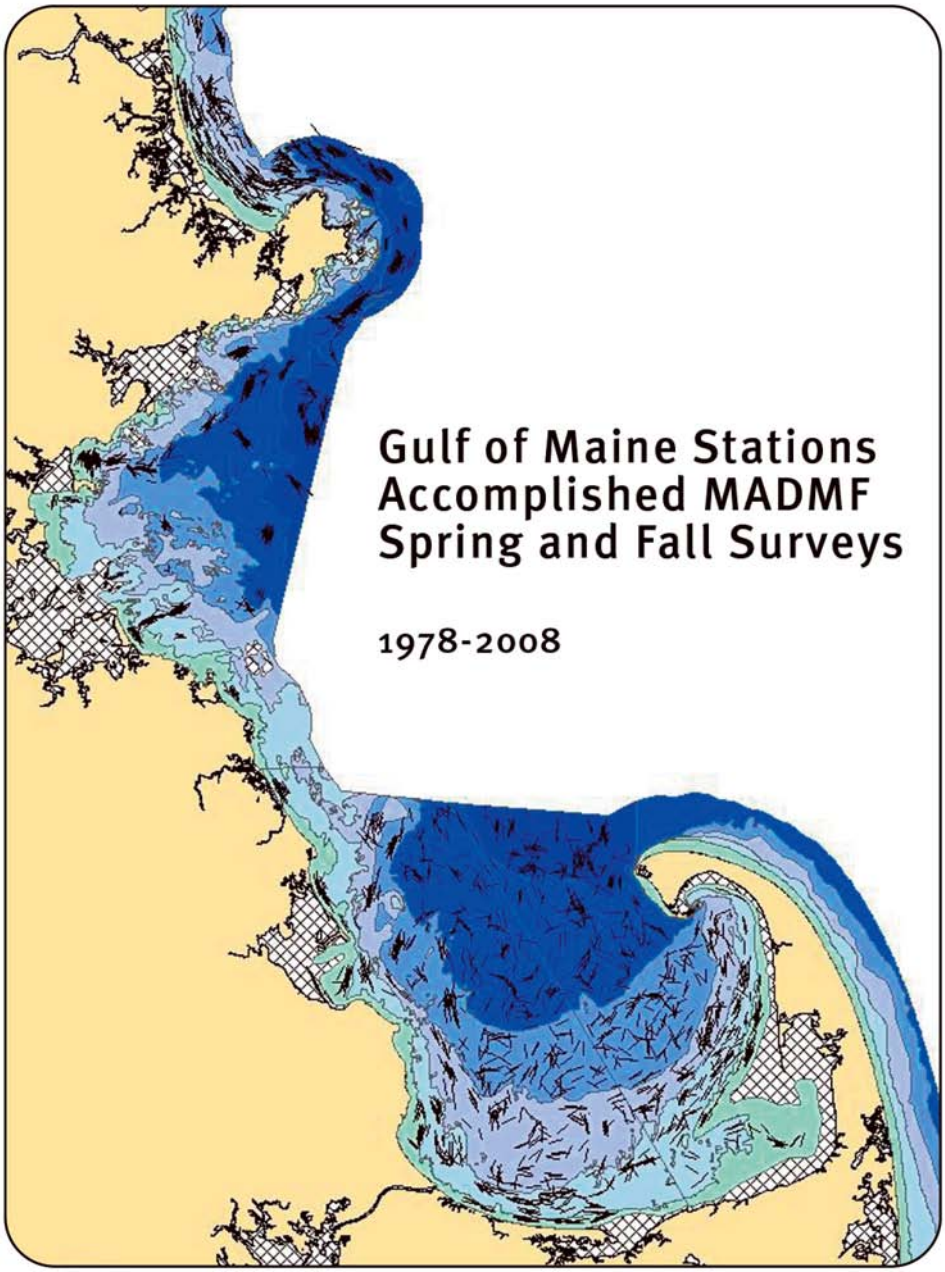


Figure 12.1. Location of trawl survey tows (black lines) conducted by *MarineFisheries*, 1978—2002.

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.

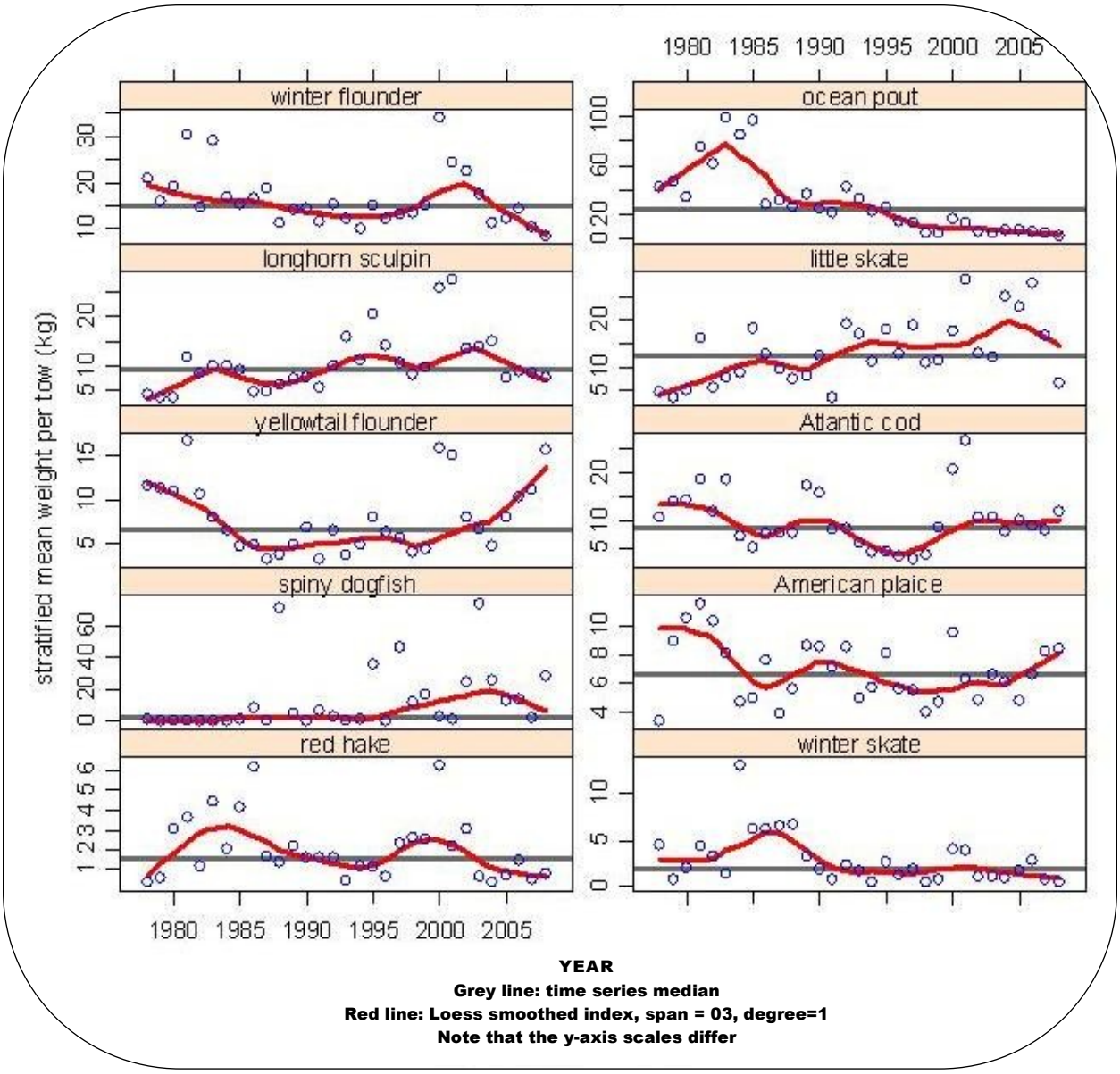


Figure 12.2. Biomass trends of 10 species of fish in Massachusetts and Cape Cod Bays
Source: *MarineFisheries*, Spring trawl surveys, 1978—2008.

MARINE INTRODUCED SPECIES

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 Instituted 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.

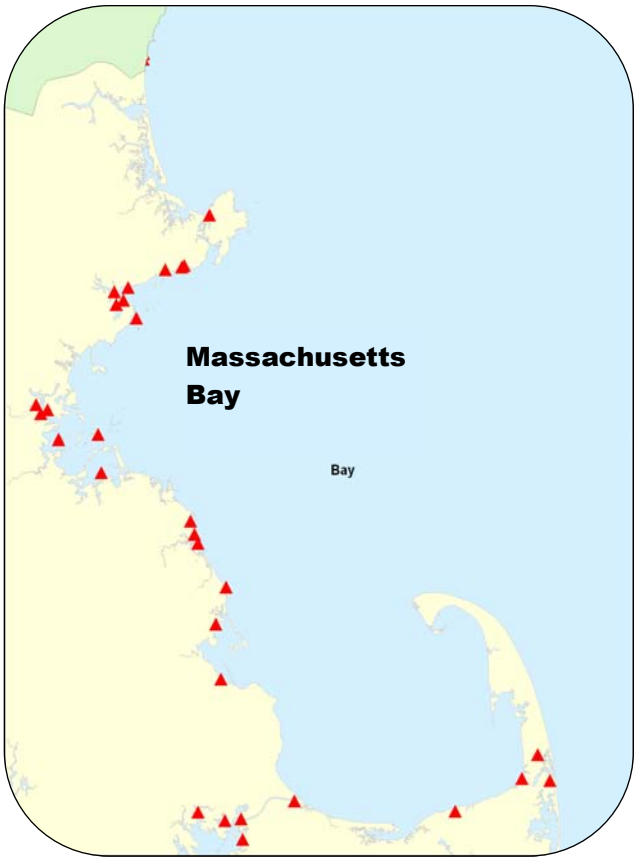


Figure 13.1. Location of MIMIC sites, summer 2008.

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.

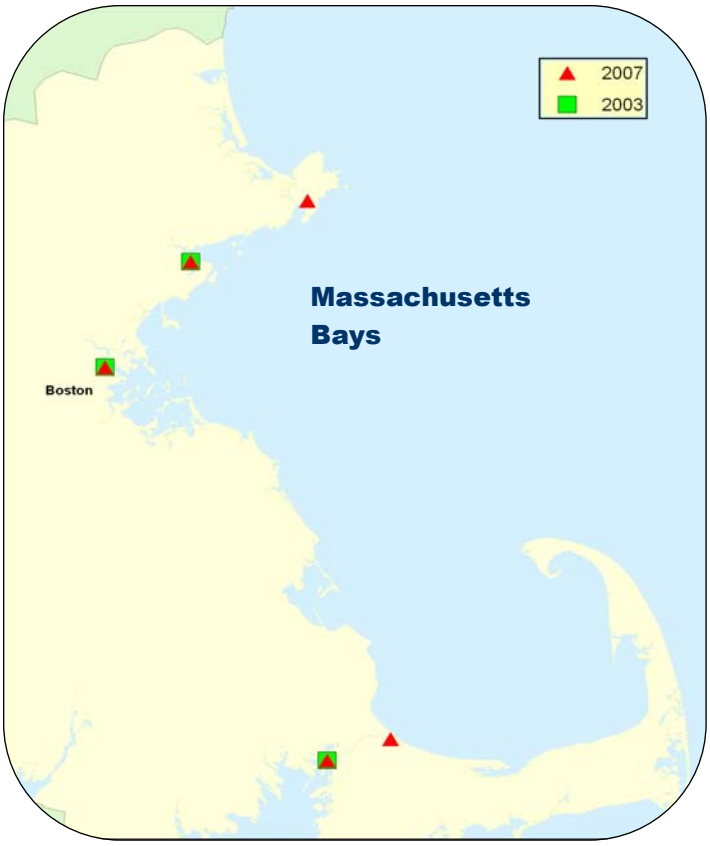
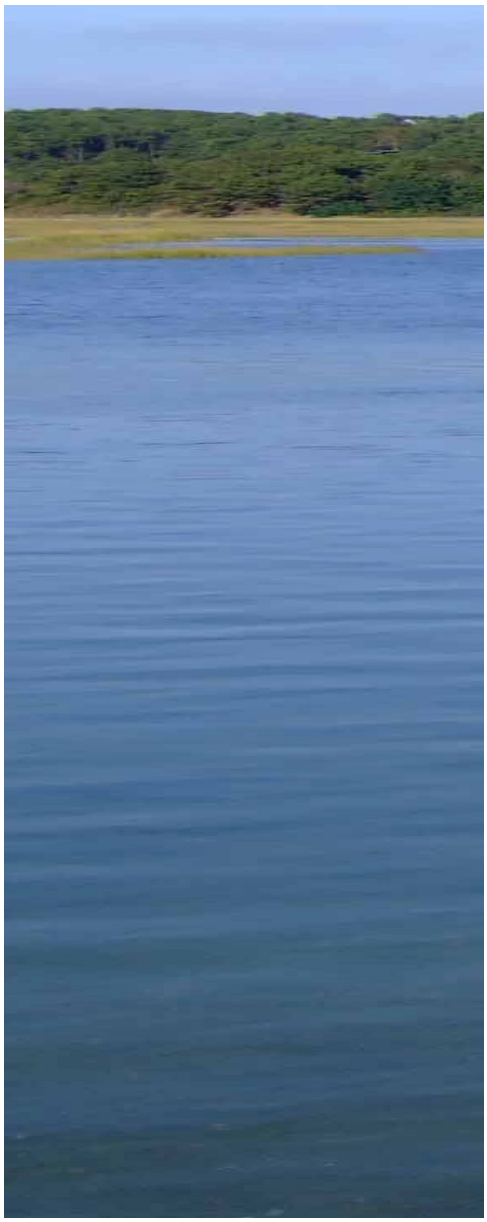


Figure 13.4. Location of Rapid Assessment sites during summer, 2003 and 2007.

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.

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.



SPECIAL TOPIC

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.