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Acknowledgments

The Narragansett Bay Estuary Program developed *Currents of Change* through an open and collaborative process. While the report was written by NBEP and EPA staff, its completion involved—directly or indirectly—nearly every scientist and resource manager working on Narragansett Bay, and incorporated the work of several who are no longer with us.

*Currents of Change* is the most comprehensive report to date on environmental status and trends of the bi-state Narragansett Bay Region. Over a two-year period, more than 40 individuals participated in advisory meetings and workshops, provided information, and reviewed and commented on drafts of the report. As a result, we believe that *Currents of Change* expresses a true consensus on the condition of Narragansett Bay, its watershed in Rhode Island and Massachusetts, and adjacent coastal watersheds.

NBEP sincerely thanks all who assisted in developing this report. All are listed in the technical draft of *Currents of Change*—we encourage readers of this summary to check that out at www.nbep.org

Particular thanks to NBEP’s management committee, which provided much guidance on the report in addition to its ongoing oversight of the program. Special thanks, also, to the technical reviewers who provided each chapter with a final seal of scientific approval, and Paul Jordan, of R.I. Dept. of Environmental Management, who developed most of the maps. Tom Ardito of NBEP edited the reports, while Lesley Lambert of NBEP provided graphic design for this summary.

Our most important thanks are reserved for you, the reader—for taking an interest in the future of Narragansett Bay and its watershed. As noted elsewhere in this report, NBEP sees *Currents of Change* more as a beginning than an end—a foundation for future tracking and reporting regarding the condition of Narragansett Bay and its ecosystem. Thanks to the effort of our many partners, we believe it represents some of the best information currently available regarding the Narragansett Bay Region. We hope you find it useful!

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Go Deeper!

To download the technical draft of *Currents of Change*, comment on the report or get involved in future work, visit our website, [www.nbep.org](http://www.nbep.org)

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Narragansett Bay is central to our regional identity and culture—from Battleship Cove to Beavertail, from Waterplace Park to the Newport Bridge. Our rich history of native communities and colonial settlement; our historic mill towns; our soaring bridges and waterfront parks; our fishing and sailing traditions; our boatbuilding expertise; our Naval heritage—even our recipes for quahog chowder—have all been shaped by the Bay, just as we, in turn, shape the Bay, and have done so for hundreds of years.

Narragansett Bay is an estuary—a semi-enclosed body of water open to the ocean at its mouth or entrance, and connected to the land by rivers, streams and groundwater. More than two billion gallons of fresh water flow daily, on average, from Rhode Island and Southeastern Massachusetts into the salt waters of Narragansett Bay. This flow has a profound effect on the Bay environment—creating unique estuarine habitats for the many creatures which thrive in the zone between fresh and ocean water, while carrying thousands of tons of pollution into the Bay each year. To understand the Bay as a complete ecosystem, *Currents of Change* looks at the Narragansett Bay Region, or NBR—the lands, waters and communities which affect the Bay each day. NBR encompasses the Bay itself as well as the fresh waters that flow into it, by way of its drainage basin or watershed in Rhode Island and Massachusetts. NBR also includes the adjacent estuaries and watersheds of the Wood-Pawcatuck river system and Rhode Island’s coastal Salt Ponds—areas which are closely linked culturally and politically, if not hydrologically, to Narragansett Bay.

The Narragansett Bay Region is 2066 square miles in area, of which 1028 square miles (50%) are in Massachusetts, 984 square miles (48%) are in Rhode Island, 192 square miles (9%) are in the Bay itself. The ecosystem covers more than 2000 square miles in Massachusetts and Rhode Island.

(Continued)
and 57 square miles are in Connecticut. The Narragansett Bay estuary is 192 square miles in area, of which 95% are Rhode Island waters, with only nine square miles in Massachusetts (at the eastern end of Mount Hope Bay). Narragansett Bay’s watershed is 1707 square miles, 60% of which (1028 square miles) is in Massachusetts, with the remaining 40% (677 square miles) in Rhode Island. The Narragansett Bay Region is home to two million people in 100 cities and towns. Our daily decisions—from how we get to work, to where we live, to how we vote—affect Narragansett Bay’s ecosystem in myriad ways.

The Bay is thousands of years old, and yet it is a dynamic environment which changes constantly as a result of wind and weather, rain and snowfall, tides and seasons. The Bay is subject to longer-term trends as well: multi-year climatic cycles such as the North Atlantic Oscillation, which affects winter temperature and precipitation in the Northeast, and a long-term warming trend linked to global climate change and sea level rise. Average surface water temperature in Narragansett Bay has risen by more than one degree Celsius over the past 50 years, while sea level is rising at a rate of roughly an inch per decade. Most scientists and managers believe these to be natural trends which have been accelerated by human activity—particularly carbon emissions from consumption of fossil fuels. The warming trend appears to be causing shifts in Narragansett Bay’s estuarine fish communities—leading southern migratory species like menhaden and striped bass to become more abundant, while traditional Bay residents such as winter flounder decline.

Human activity affects the Bay ecosystem in many other ways. Invasive plants and animals, unintended consequences of international trade, have become established throughout NBR in salt water, fresh water and upland environments—and more are expected to arrive, in some cases displacing or even eliminating native species. Hundreds of dams on rivers and streams prevent migratory fish such as river herring and shad from reaching their historic spawning grounds. Stormwater from roads and parking lots carves streams into drainage ditches, destroying habitat for native species like brook trout while washing pollution into the Bay. Waste-water treatment plants discharge hundreds of tons of nitrogen into Narragansett Bay each year, with impacts on water quality, fisheries, shellfish and sea grass habitats.

There are many areas of progress and improvement in managing the Bay ecosystem, as well. Rhode Island and Massachusetts have increased regulation of waste-water treatment plants and financed extensive upgrades, leading to steep reductions in nutrient pollution. Governmental and non-governmental organizations are leading projects to restore rivers, wetlands and other habitats—removing dams, for example—using new sources of state and federal funding. New storage tunnels in Providence and Fall River will reduce sewage contamination of shellfish beds following rainstorms. And New England’s largest power plant, the Brayton Point Power Station in Somerset, Mass., is building new cooling facilities to reduce impacts to fish populations in Mount Hope Bay.

No single report could do justice to an area as large and diverse as the Narragansett Bay Region. Currents of Change is, therefore, best viewed as a beginning rather than an end. It will serve as a platform or baseline for future analysis and reporting regarding Narragansett Bay and its ecosystem, while highlighting the gaps in our knowledge. Over time, the measures provided here will be added to, improved and, in some cases, replaced. NBEP and its partners believe that Currents of Change is a vital first step toward better understanding and management of the Narragansett Bay Region. We dedicate this report to the many organizations and individuals working to preserve and restore Narragansett Bay, and express our sincere thanks to the dozens of scientists, resource managers and others who assisted in its development.

Go Deeper!
For more information on Narragansett Bay, including the Currents of Change technical report, check out www.nbep.org
About the Narragansett Bay Estuary Program

The Narragansett Bay Estuary Program is one of 28 National Estuary Programs created by Congress under the Clean Water Act to protect and restore estuaries designated as nationally significant. NEPs are required to develop and implement comprehensive, ecosystem-based plans to conserve, manage and restore natural resources. They engage state and federal agencies, communities and nonprofit organizations in planning and decision-making, working to find collaborative solutions.

The U.S. Environmental Protection Agency provides base funding and federal oversight for each of the NEPs, but program management is the responsibility of a stakeholder-based management committee. NBEP is overseen by a management committee consisting of Massachusetts and Rhode Island state agencies; non-profit organizations from each state; universities and federal agencies. The open decision-making process ensures that all interests are represented and increases commitment to joint planning and action.

NBEP’s mission is to protect and preserve Narragansett Bay and its watershed through partnerships that conserve and restore natural resources, enhance water quality and promote community involvement.

Ecosystem-Based Action

NBEP brings together funding, partners and projects to accomplish agreed-upon goals for Narragansett Bay: directing federal and non-federal grants toward local action; developing needed scientific information; informing public and policy-makers; convening technical and public working groups; and supporting grassroots organizations. NBEP is the only organization with a federal mandate specific to protecting and restoring Narragansett Bay’s watershed ecosystem in Rhode Island and Massachusetts, and to do so in a highly collaborative manner, based on stakeholder priorities which are the foundation of the Narragansett Bay Comprehensive Conservation and Management Plan (CCMP).

Our Mission

NBEP’s mission is to protect and preserve Narragansett Bay and its watershed through partnerships that conserve and restore natural resources, enhance water quality and promote community involvement.

Contact us!

NBEP is located at the Narragansett Bay Campus of the University of Rhode Island in Narragansett, R.I. For more information about the program, check out www.nbep.org or contact us directly:

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Since 1993, NBEP has worked to implement the Narragansett Bay CCMP by coordinating planning, policy, technical assistance, science and outreach pertaining to the Bay ecosystem. The program has taken leadership roles in Bay and watershed management, including:

• Restoration of coastal wetlands, free-flowing rivers and native migratory fish runs;
• Instituting the first comprehensive dissolved oxygen surveys of the Bay;
• Engaging Massachusetts stakeholders in Narragansett Bay planning and management;
• Developing the first comprehensive and accurate maps of Rhode Island’s coastal habitats;
• Increasing accountability and ability to measure environmental progress by developing environmental indicators for the Bay and watershed;
• Developing and publishing the Narragansett Bay Journal, to inform stakeholders throughout the watershed in Massachusetts and Rhode Island.
Dissolved oxygen (DO) in the water is critical in sustaining a diverse and healthy estuarine ecosystem. Low levels of DO signal degraded health due to excessive nutrients which can cause rapid growth (blooms) of microscopic phytoplankton and larger macroalgae (seaweed). As the blooms decompose, bacteria consume oxygen, reducing DO. Oxygen can reach stressfully low levels (hypoxia), sometimes killing fish and other organisms. In Narragansett Bay, hypoxia occurs during hot, calm summer periods, when the water is “stratified” or layered, preventing oxygen from reaching bottom waters. High river flows can increase both stratification and the level of nutrient loads to the Bay. In some areas of the Bay, events occur during which DO approaches zero (anoxia) in bottom waters, killing all but the hardiest organisms.

Dissolved oxygen should not fall below 2.9 milligrams per liter (mg/l) for more than 24 consecutive hours or 1.4 mg/l for more than one hour (RI criteria). Summers with large June river flows tend to experience more severe hypoxia in July or August of that summer, during periods of hot, calm weather and weak tides. Though hypoxic events occur most frequently in July and August, they can also happen in June and September.

Although severe hypoxia and anoxia can cause large fish kills as occurred on Narragansett Bay in August 2003, a more lasting impact is experienced by permanently-attached benthic (bottom-dwelling) biological communities. Impacted areas tend to have lower diversity and abundance of large benthic organisms, although quahogs, a hardy species, are less affected than most. In areas experiencing low DO (hypoxia) on the bottom, other large burrowing organisms are replaced by small surface-dwelling worms. This affects the way the bottom of the Bay recycles nutrients, further affecting the whole system.

Beginning in 1999, DO in the Bay has been measured through several different federally-funded monitoring programs. The datasets complement each other by providing in combination both the timing and extent of oxygen conditions in much of the Bay, allowing for reasonable estimates of the percentage of Bay bottom waters experiencing hypoxia and violating water quality criteria. Long-term trends are not yet apparent in the data because of year-to-year variability in summer conditions due to changes in river flow, water temperature and winds.

About 33 percent of Rhode Island’s estuarine waters are impaired by hypoxia. The Seekonk River, which has high nutrient loads from both Rhode Island and Massachusetts sources, experiences the most severe hypoxic events (0-1 mg/L), with the western side of Greenwich Bay a close second (see red and orange areas of the map). In the Providence and Seekonk Rivers, these events can last two weeks or more, while in shallow Greenwich Bay, where tides and winds can rapidly mix the water column, up to 12 usually short-lived (1 to 3 day) events occur each summer.

Factors implicated in Greenwich Bay’s poor water quality include the groundwater nutrient load from septic systems and poor circulation in the western side of the embayment. A century or more ago, Greenwich Bay was a high-quality habitat area, with extensive eelgrass beds and significant scallop resources. Its condition today serves as a warning that small embayments are vulnerable to nutrient loads. The Upper Bay area north of Prudence Island experiences events of one day to about a week, with rare longer events. Limited data suggest that the upper West Passage sometimes experiences severe hypoxic events ranging from five to 20 days. Even at Fox Island, two-thirds down the Bay, severe low oxygen has been recorded (less than 2 mg/L in 2006). Mount Hope Bay experiences mild hypoxia, only occasionally dropping below 3.0 mg/L. Only the mouths of the rivers in Mount Hope Bay exhibit significant concentrations of nutrients and chlorophyll, as well as poor oxygen levels.

Dissolved Oxygen Concentrations August 14, 2008.
Oxygen values are from D. Murray, Brown U. Data available at: www.geo.brown.edu/georesearch/insomniacs
Beach and Shellfishing Closures

Water pollution affects human uses of Narragansett Bay as well as its ecology. Beachgoing and shellfishing are among the most popular recreational activities on the Bay. Yet many areas of the Bay are permanently or periodically closed to swimming and shellfishing due to high levels of bacteria, considered an indicator of disease-causing organisms. Sources of bacteria include discharges of raw sewage from combined sewer overflows (CSOs), failing septic systems, cesspools, and wild and domestic animals.

Rhode Island uses Enterococci, a group of bacteria found in warm-blooded animals, to assess the safety of bathing waters, while a broader group known as fecal coliform is used for shellfishing areas based on U.S. Food and Drug Administration requirements. Once a beach violates state criteria, it remains closed until new samples indicate that conditions have improved. Shellfishing areas are either permanently closed, permanently open, or conditional, meaning they’re closed to shellfishing for a week following heavy rain. In addition, the R.I. Department of Environmental Management (RIDEM) conducts routine shoreline surveys near shellfish growing waters to locate potential bacterial sources.

The R.I. Dept. of Health has conducted federally funded sampling at all 69 licensed saltwater beaches since 1995, while RIDEM runs the state-funded monitoring of all commercial shellfishing areas. Both beach and shellfishing area closures are strongly influenced by summer weather, particularly rainfall, which washes bacteria from the land into nearby stormdrains. Beach closures in the middle and lower reaches of Narragansett Bay also tend to be related to local stormwater runoff, a common factor for beach closures nationally. The upper reaches of the Bay, north of Conimicut Point in Warwick and Nayatt Point in Barrington, are closed to swimming and shellfishing due to high bacterial levels from urban runoff, CSOs and other sources. Newport Harbor has long been closed to shellfishing, and King’s Park Beach was permanently closed to swimming in 2004 due to stormwater contamination from the nearby CSO.

Beaches on Greenwich Bay and Conimicut Point accounted for the largest percentage of closures over the last several years, with beaches in a number of other areas also strongly impacted by stormwater runoff. In some of these areas such as Greenwich Bay, new efforts to connect homes to sewer lines are expected to help improve the situation. In addition, recent efforts have been made to provide stormwater treatment and decrease this source at several beaches where it has been a problem, such as Scarborough Beach and Narragansett Town Beach.

Shellfish closures on Narragansett Bay reflect a north-south pollution gradient as well as the impact of local stormwater runoff. Bacteria levels impair 21 percent of Rhode Island’s estuarine waters for shellfishing, but closure rates in the Upper Bay are projected to decrease due to the CSO retention tunnel recently completed in Providence by the Narragansett Bay Commission. RIDEM completes a yearly re-assessment of the bacterial condition all shellfish waters based upon the previous year’s water sampling and shoreline survey results. Maps of shellfish closures are available on RIDEM’s website at www.dem.ri.gov.

Total number of saltwater beach closure days per season for all Rhode Island salt water beaches versus seasonal total rainfall (May-Sept.). One closure day = 1 beach closed for 1 day. Total for all SW beaches presented here. Data Source: RIDOH Annual Beach Reports 2007, 2008.
Fresh Water Impairments

The fresh waters of the Narragansett Bay Region—rivers, streams, lakes, ponds and ground water—are a critical natural resource, providing habitat for fish and wildlife, drinking water for about two million people, and exceptional opportunities for recreational boating, fishing and swimming. The status of NBR’s fresh water resources is affected by development patterns within the watershed. During the past half century, suburbanization throughout NBR has significant redistribution of population. As people move from urban centers to rural areas, infrastructure follows and the accompanying roads, houses, schools and businesses affect water quality.

In the Narragansett Bay Region in recent decades, major investments in Waste Water Treatment Facilities (WWTFs) have resulted in marked water quality improvements. Overall, the water quality of the state’s major rivers are impacted by both point and non-point sources, whereas stormwater and nonpoint sources — rain runoff from developed landscapes — are the predominate sources to lakes.

These indicators are taken from state (R.I. and Mass.) biennial integrated assessments of water quality — the R.I. 2008 Integrated Water Quality Monitoring and Assessment Report, and Massachusetts Year 2008 Integrated List of Waters. These assessments bring together water quality data collected by a variety of organizations including state and university scientists and trained citizen volunteers. In Rhode Island, RIDEM monitors rivers and streams using a rotating basin approach that was adopted in 2004. The approach integrates biological, chemical and physical monitoring to characterize water quality conditions throughout a watershed. RIDEM will have completed monitoring of all targeted rivers and streams in the state using the rotating basin approach by the fall of 2009.

### Bacteria

Bacteria are used as an indicator of the safety of fresh waters for human contact such as swimming. The bacteria measured (fecal coliform or enterocci) originate in the intestines of warm-blooded animals: their presence indicates that fecal contamination may have occurred and pathogens may be present in the water. Sources of bacterial contamination of rivers, streams, lakes and ponds are similar to those for estuarine waters and include stormwater runoff from developed landscapes that may carry bacteria from pets, domestic animals, waterfowl and other wildlife, as well as human waste from failed or substandard septic systems and in some locations sewer system overflows (SSOs) or combined sewer overflows (CSOs).

<table>
<thead>
<tr>
<th>State</th>
<th>Total river miles</th>
<th>Miles known to be impaired by bacteria*</th>
<th>Miles known to be impaired by low DO*</th>
<th>Miles known to be impaired by nutrients*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhode Island</td>
<td>1,498</td>
<td>240</td>
<td>33</td>
<td>29</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>1,283</td>
<td>196</td>
<td>103</td>
<td>95</td>
</tr>
<tr>
<td>TOTAL</td>
<td>2,781</td>
<td>436</td>
<td>136</td>
<td>124</td>
</tr>
</tbody>
</table>

### Dissolved Oxygen

Dissolved oxygen concentrations (DO) are an important indicator of ecosystem health. Oxygen concentrations are affected by physical and biological conditions. Oxygen is introduced to rivers and streams through the aerating action of wind or turbulence and from plant photosynthesis during daylight hours. Oxygen concentrations are consumed by the decomposition of organic matter and respiration by aquatic animals and plants. If more oxygen is consumed than is produced, DO concentrations decline and some sensitive animals may disappear. DO levels fluctuate daily and seasonally. They also vary with water temperature - cold water holds more oxygen than warm water. The most critical time for many aquatic animals is early morning on hot summer days, when river flows are low, water temperatures are high, and plants have not been producing oxygen since sunset.

<table>
<thead>
<tr>
<th>State</th>
<th>Total lake acres</th>
<th>Acres known to be impaired by bacteria*</th>
<th>Acres known to be impaired by low DO*</th>
<th>Acres known to be impaired by nutrients*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhode Island</td>
<td>20,917</td>
<td>562</td>
<td>1,493</td>
<td>2,205</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>23,346</td>
<td>36</td>
<td>945</td>
<td>1,093</td>
</tr>
<tr>
<td>TOTAL</td>
<td>44,263</td>
<td>598</td>
<td>2,438</td>
<td>3,298</td>
</tr>
</tbody>
</table>

* Not all waters are assessed for these parameters.

### Nutrients

Aquatic plants and algae require nutrients (primarily nitrogen and phosphorus) to grow and survive. In fresh water as in estuarine areas, however, an over-abundance of nutrients can cause eutrophication—excessive plant growth which degrades habitat and interferes with human uses such as boating and swimming. In lakes, ponds and slow-flowing river segments, excessive plant growth can cause DO concentrations to fluctuate — becoming very high during the daylight hours when the plants are photosynthesizing, and very low (or absent) during the night hours. Point sources such as WWTFs, CSOs and storm drains contribute nutrients to rivers and streams, while non-point sources (primarily stormwater runoff from developed areas) carry nutrients from fertilizer, animal waste, septic systems and other sources.
In 1972, Congress passed the Clean Water Act (CWA) to restore and maintain the “chemical, physical and biological integrity” of U.S. waters. CWA establishes a framework for measuring and evaluating water quality throughout the country which is implemented by states.

States are required to establish water quality standards for all surface waters. Water quality standards have three components: designated uses, water quality criteria and antidegradation policies. Designated uses are the state’s goals for the waterbody—for example, is the river used for drinking water? for agriculture? for fishing and swimming? (CWA requires that all waters must be swimmable and fishable). Water quality criteria are the chemical, physical and biological conditions that must be met in order for a waterbody to support its designated use. Those which meet criteria are considered “supporting” or “attaining” (Category 1 on the map below). Those which are monitored for all uses and do not meet criteria are considered “impaired” (Categories 4A, 4B and 5 below). States are not able to monitor all their waters, so some are listed as unassessed (Category 3 below). Other waters meet criteria for a portion of their uses, but are not monitored for others (Category 2 below).

States use a water quality restoration planning approach called Total Maximum Daily Load, or TMDL, to improve impaired waters. Antidegradation policies, which apply to all waters, are intended to prevent further degradation to ensure clean water goals are maintained.

States are responsible for monitoring and evaluating water quality relative to the standards, and reporting the results to EPA and the public. Rhode Island and Massachusetts accomplish this through biennial Integrated Water Quality Monitoring and Assessment Reports. These list all the surface waters of the state—rivers, lakes, streams and estuarine waters—evaluating each according to the five categories described above, and keyed on the map below.

For more on fresh and salt water quality in the Narragansett Bay Region, check out the Currents of Change technical report at www.nbep.org

For Rhode Island’s integrated water quality report, see www.dem.ri.gov

For more on water quality management in Massachusetts, see www.mass.gov/dep

For national water quality reports, compiled by EPA from state reports, see www.epa.gov/305b
Fresh Water Flow

On average, more than two billion gallons of fresh water flow into Narragansett Bay daily from its drainage basin or watershed—through major rivers such as the Blackstone, Taunton and Pawtuxet; smaller streams such as the Ten Mile and Hunt; and through ground water. These flows are critical components of the region’s fresh water habitats, and contribute to the Bay’s estuarine habitats as well.

The Narragansett Bay Region has abundant freshwater resources, but some areas are showing signs of stress linked to human withdrawals—for example, changes in riverine fish communities caused by low summer flows, and changes to wetlands caused by drawdown of local water tables by public wells.

According to the R.I. Department of Environmental Management (RIDEM), the following Rhode Island watersheds are showing flow stress:

- **Wood-Pawcatuck watershed, Chipuxet sub-basin.** Private and public wells withdraw water for a variety of uses, including drinking water supply for several public water systems and the University of Rhode Island and irrigation for South County turf farms. A significant portion of the total water withdrawn is exported out of the basin via sewer systems that discharge directly into the Atlantic Ocean. According to USGS, the combined water withdrawals can exceed the river’s capacity.
- **Hunt River.** Three public water suppliers withdraw water from the Hunt-Annaquatucket-Pettaquamscutt (HAP) aquifer. Extreme low flows occurred in the lower Hunt river during 2005 and 2007 and impacts to fish populations have been documented by RIDEM studies.
- **Initial analyses by RIDEM suggest that water withdrawals in Westerly, Jamestown, the Annaquatucket area of North Kingstown, Cumberland and Woonsocket warrant further evaluation to address the potential for withdrawals exceeding levels considered sustainable.**

**Massachusetts** has developed the River Instream Flow Stewards (RIFLS) program to help local groups identify, document and restore rivers and streams suffering from abnormally low flows. They identify the following areas as impacted by low flow:

- **Blackstone River watershed.** The mainstem of the Blackstone River in Rhode Island has adequate water which is supplemented by the discharge from the Worcester and Woonsocket wastewater treatment plants. But many reaches of the rivers and streams throughout the upper Blackstone watershed in Massachusetts suffer from unusually low stream flows due to human activity.
- **Taunton River Watershed.** In summer, 2002, several tributaries of the Taunton were found to be completely dewatered by withdrawals.
- **Palmer River** due to interbasin water transfer out of Shad Factory Pond into the Kickemuit Reservoir in Warren, R.I.

Photos show the Hunt River at Forge Road, East Greenwich, R.I., in September 2007 under extreme low-flow conditions and immediately after a small rainstorm. Water from the Hunt aquifer provides water to North Kingstown, Kent County and the Quonset Development Corporation.
Wintertime road maintenance with salt and similar materials can harm freshwater habitat. A study of the Scituate Reservoir watershed by the U.S. Geological Survey (USGS) evaluated sources of sodium and chloride to the reservoir from 1999 to 2000. Sodium concentrations in the reservoir have been increasing, despite the use of reduced-sodium deicing materials on state roads in the watershed. The study concluded that deicing of state and local roads was the major source of sodium and chloride in the drainage basin, accounting for 67 percent of the 1,000 tons of sodium and 90 percent of the 2,300 tons of chloride introduced into the basin.

University of Rhode Island Watershed Watch volunteers have monitored chloride in Rhode Island lakes since 1988. None of the results exceed state criteria for aquatic life (chloride concentrations of 860 milligrams per liter (mg/l) (acute effects), 230 mg/l (chronic)) but many locations show a trend of increasing concentration over time.

Road salt can harm lakes and other aquatic ecosystems by increasing the salinity of fresh waters. It also has corrosive effects on cars, sewer grates and roads. Many states are looking toward alternative methods of deicing that are less corrosive and damaging to the environment.
Living Resources Indicators
Estuarine Fish

Narragansett Bay is home to hundreds of species of estuarine fish and shellfish. Many of these species are migrants which spend only a portion of their lifecycle in the Bay. Others are residents, which may spawn in the Bay and spend a significant portion of their lifecycle here. The Bay’s fisheries have been an important cultural institution for centuries. In both Rhode Island and Massachusetts, recreational and commercial fisheries generate hundreds of millions of dollars annually. Narragansett Bay’s fish and shellfish are also the subject of some of the longest-running and most detailed environmental datasets related to Bay ecology, and therefore provide a window into long-term biological trends on Narragansett Bay.

Over the past 50 years, demersal, or bottom-dwelling fish, have declined in Narragansett Bay. Over the same time period, benthic invertebrates such as crabs and lobsters, as well as pelagic (mid-water) fish and squid have increased. Warming trends appear to be a primary cause of these changes; the Bay’s average sea-surface temperature at Fox Island has increased by about two degrees Celsius since 1959. A second, but important cause appears to be fishing pressure. As with any complex resource, there are undoubtedly many factors affecting Narragansett Bay’s fish populations, and different factors affecting different species.

Toxins in Fish

Heavy metals and other toxic compounds were formerly a major source of pollution to Narragansett Bay, as with other urbanized estuaries. Due to modern discharge regulations, improved wastewater pretreatment, and the decline of Northeastern manufacturing, these inputs have greatly decreased, but toxic substances can still be found in the muddy sediments of the rivers and upper Bay. Storm water and road runoff are now possibly the greatest sources of most toxins as well as bacteria to Narragansett Bay.

Substances of particular concern are toxic metals such as mercury and lead, and organic compounds such as DDT and Polychlorinated biphenyls (PCBs). The U.S. Environmental Protection Agency, through its National Coastal Assessment Program, analyzed fish tissue samples taken from Narragansett Bay and other northeastern estuaries for the presence of a variety of toxic substances, including hydrocarbons, PCBs, DDT and other pesticides, and 13 metals, including mercury and lead. Detailed information is available at: oaspub.epa.gov/coastal/coast.search. Results were compared with “screening values” (SV) as an approximation of ecological risk. Most of the fish sampled are seasonal migrants, so some of the toxic compounds may come from sources outside of Narragansett Bay.

Results for Rhode Island found two chemicals in a number of fish samples violating the screening range levels: mercury (Hg) and PCBs. For total PCBs, the incidence of exceedance was more common. Both fell within a range comparable to other industrialized eastern coastal states from southern Maine to Virginia.

Go Deeper!
To learn more about seafood safety visit: www.msc.org
Invasive species are organisms which are 1) non-native (or alien) to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health. Invasive species are a principal threat to native biodiversity of an ecosystem. As human disturbance of an ecosystem increases, the percentage of invasive species tends to increase, replacing native species and degrading native biological communities and habitats. By tracking invasive species in Narragansett Bay, we can track impacts to native estuarine biodiversity and, by implication, the health of the Bay ecosystem.

In the Narragansett Bay Region (NBR), invasive species are increasingly prevalent in terrestrial, aquatic and estuarine environments. In 2000 and 2003, NBEP and partners conducted a “Rapid Assessment Survey” of marine invasive species in Narragansett Bay. The team studied local “fouling organisms”—plants and animals which attach to pilings, docks and other underwater structures. This work produced the most complete information to date on invasive species in Narragansett Bay. The study suggests that up to 26% of the Bay’s fouling community is comprised of non-native species.

One invader already here in large numbers is the Asian shore crab. Although this species was first identified in Narragansett Bay less than 15 years ago, today it is the most common crab along many of our shorelines, and can be found by turning over nearly any rock in shallow estuarine water.

Another crab which is likely to appear in southern New England waters in the near future, and can be very harmful to native species and habitats is the Chinese mitten crab. This species invaded Europe during the early 1900’s and the U.S. West Coast during the 1990’s, and has become abundant in both areas. On the U.S. East Coast, the crabs first appeared in Chesapeake Bay in 2005, and were found in the Hudson River in 2007. Chinese mitten crabs dig extensive burrows in riverbanks, which can accelerate erosion. In NBR, the most vulnerable areas are likely to be rivers which are tidal in their lower reaches, such as the Taunton, Seekonk, Woonasquatucket and Pawcatuck, as well as smaller tidal systems such as Buckeye Brook.
Healthy habitats are central to the environmental quality of the Narragansett Bay Region. NBR’s native fish and wildlife depend upon a diversity of natural habitats—fresh and salt water wetlands, undammed rivers, clean lakes and ponds, native forests and grasslands.

Wetlands are another important habitat type in NBR, providing many values beyond fish and wildlife habitat. Freshwater wetlands help maintain groundwater quality and quantity by providing areas where surface and rainwater can recharge aquifers. They serve an important function in protecting developed areas, as riverine wetlands and floodplains store floodwaters after storms. Coastal wetlands such as salt marshes serve as important nursery areas for juvenile fish while helping to protect coastal communities from the impacts of hurricanes and storm surges.

During the 19th and 20th centuries, wetlands were destroyed and altered on a grand scale throughout the Narragansett Bay Region. Wetlands were drained and filled for agriculture, land development and transportation. Many others were flooded, converted to open-water areas by dams—first for mill power, later for drinking-water supply. In Southeastern Massachusetts, natural wetlands were altered to create cranberry bogs. Enactment of state wetlands laws and the federal Clean Water Act in the late 20th century curbed the pace of destruction, but wetlands continue to be lost and damaged throughout NBR.

A new threat to coastal wetlands is global warming. Since the last ice age, coastal wetlands have generally grown in area as mineral and organic sediments accumulated in low-energy areas of the shoreline. As sea level rise accelerates, a concern is that this process of sediment accretion may not keep pace, resulting in loss of coastal wetlands.

There are about 90,000 acres of freshwater wetlands in the Massachusetts portion of NBR. According to an analysis of Massachusetts wetland change data undertaken by NBEP and the R.I. Dept. of Environmental Management, less than one percent of wetlands were lost during the period 1991–2001, while certain types of wetlands (primarily wooded swamps) increased in area. Comparable fresh water wetland change data are not available for In Rhode Island. However, a study by NBEP documented changes to Narragansett Bay’s coastal wetlands over the period 1952-1996. The study found that six percent of the Bay's vegetated wetlands were lost over this 44 year period.
Habitat Restoration

In recent decades, habitat restoration has emerged as a powerful approach to restoring wetlands, rivers and other natural habitats damaged or destroyed by human activity. Funding is provided by state, federal and local agencies, generally working in partnership with local and non-governmental organizations. On Narragansett Bay, salt marshes have been restored by replacing culverts to restore tidal flooding, while sea grass planting has helped spur the recovery of eelgrass beds. On river systems throughout the Bay watershed, projects are underway to remove dams or construct fish ladders, in order to restore annual spawning runs of migratory fish.

The largest wetland restoration project completed to date on Narragansett Bay is the Town Pond restoration. Before 1949, Town Pond was a salt pond on Aquidneck Island, connected to Mount Hope Bay by a tidal channel or breachway. The pond was fringed by salt marshes, comprising altogether about 40 acres of valuable wetland habitat.

In 1949-50, the U.S. Army Corps of Engineers used Town Pond as a disposal site for mud dredged from the Mount Hope Bay shipping channel. The operation filled the pond with fine sediments, raising it above the level of the tide, converting the former pond and marshes into a barren mudflat and destroying its value as fisheries habitat. By the 1990s, the invasive reed Phragmites had completely taken over the entire site. The former salt pond had lost most of its native biodiversity.

Beginning in 2000, the Narragansett Bay Estuary Program, U.S. Army Corps of Engineers, R.I. Dept. of Environmental Management and other partners restored salt water habitat at Town Pond, excavating the site to restore open-water and salt marsh habitat, while enhancing public access to the shore. The project was completed in 2008 at a cost of $6 million. More than 20 acres of coastal habitat have been restored and the area has become a popular recreational site. Estuarine fish such as silversides returned to the pond almost immediately, while Roger Williams University is now restoring oysters.

As is almost always the case with coastal habitat restoration projects, Town Pond was funded through a combination of federal, state and non-governmental sources, including funds from the Corps, U.S. Environmental Protection Agency, Narragansett Bay Estuary Program, R.I. Dept. of Environmental Management, R.I. Coastal Resources Management Council, Aquidneck Island Land Trust and Ducks Unlimited. In-kind support was provided by Town of Portsmouth, Save The Bay and other local partners.
The landscape of the Narragansett Bay Region (NBR) has evolved through four centuries of economic change, yet for most of that time, has managed to maintain its characteristic pattern of distinct urban centers surrounded by rural lands. Over the past 40 years, however, that pattern has become increasingly blurred by sprawl development. The result has been the emergence of non-point source pollution such as storm water as a primary threat to the health of the Bay ecosystem, as described throughout this report. Sprawl degrades wildlife habitat through destruction and fragmentation; less tangible but no less real are its impacts on the visual character of the landscape—destroying or obscuring the very amenities, such as historic settlement patterns, which make the communities of NBR unique.

From 1999 to 2005 in Massachusetts, land was developed at a rate of 22 acres per day—converting 40,000 acres of forest and farmland to residential uses.

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A Changing Landscape

Since 1970, Rhode Island’s population increased by about 10 percent, while land consumption accelerated dramatically as the state’s population migrated to rural and coastal areas, and employment decreased in mill towns and city centers. Recently, older cities and suburbs have attempted to reverse this trend by encouraging infill development and reuse, for example by redeveloping former textile mills as housing and rezoning downtown areas to encourage denser development.

Throughout Rhode Island, 30 percent of the land which was undeveloped in 1995 has since been developed. If current land use trends continue, 45 percent of Rhode Island lands would be developed by 2025.

Forest and farmland are the land use types most often converted to other uses.

Status & Trends – Rhode Island

Status & Trends – Massachusetts

Since the 1970s, land consumption in the Massachusetts portion of NBR has dramatically outpaced population growth. Between 1971 and 1999, residential land in Massachusetts increased by nearly 47 percent. Nearly 40 acres per day were lost to development between 1985 and 1999, of which nearly 90 percent was for residential purposes. During this period, Massachusetts lost 143,000 acres of wildlife habitat and much of the remaining forest is highly fragmented. Worcester County, in the Blackstone River sub-basin of NBR, had among the highest rates of loss.

From 1999 and 2005, the pace of land development in Massachusetts slowed, but remained significant at an average rate of 22 acres per day. Consistent with the earlier period, 87 percent of land use change during this period was due to residential housing development, converting more than 30,000 acres of forest and 10,000 acres of farmland into housing areas.

The Blackstone and Taunton River watersheds make up the majority of the Narragansett Bay watershed in Massachusetts. Land use in the Massachusetts parts of NBR affects two of the three largest tributaries of Narragansett Bay along with numerous smaller streams, generating stormwater flows and other sources of water pollution, with impacts on the biology of fresh water habitats and the Bay.

Go Deeper!

For more on land use in the Narragansett Bay Region, see the Currents of Change technical report at www.nbep.org

For more on land use trends in Rhode Island, including the state report “Land Use 2025,” see www.planning.state.ri.us/landuse

For more on trends in Massachusetts, including the recent report by Mass. Audubon, “Losing Ground,” see www.massaudubon.org/losingground
Impervious surfaces are roads, parking lots, rooftops, and other hard surfaces characteristic of urban areas that prevent rainwater from infiltrating into the ground, delivering it instead as stormwater to rivers, lakes and estuaries. As a result, rivers in developed landscapes tend to have higher maximum flows and lower minimum flows than those in more pristine settings. This “flashy” flow pattern degrades riverine habitat and causes property flooding.

Runoff from impervious surfaces bypasses natural pollutant removal processes in soil, carrying sediment and pollution into streams, lakes, and coastal waters, causing many of the water quality impacts documented elsewhere in this report. The changed hydrology raises water temperature, reducing habitat value. Many studies have shown that rivers, lakes and coastal waters surrounded by watersheds with a high percentage of impervious surface tend to have poor habitat and reduced biodiversity. Storm water from impervious surfaces is also a major source of bacteria, leading to the closure of swimming areas and shellfish beds.

**Status & Trends:** Recent GIS analysis of data from aerial photographs indicates that about 14 percent of the land area in the Narragansett Bay watershed (R.I. and Mass.) is covered by impervious surfaces. These surfaces are distributed unevenly within watersheds; developed areas tend to be near watercourses, where the impact of runoff is greater.

The analysis shows that more than half of all subwatersheds in the Bay watershed have greater than 10 percent impervious surface cover.

In 2004, 10 percent of Rhode Island was covered by impervious surfaces, with coverage greater than 30 percent in major population centers. Only 17 of Rhode Island’s municipalities have less than ten percent impervious surface area, with coastal towns averaging 14 percent.

These analyses provide baseline data regarding impervious areas, in order to begin making definitive statements regarding trends. It is clear, however, that there is a trend toward increasing impervious surface coverage throughout the Narragansett Bay Region. It is also clear that, in many areas, impervious surface coverage has already reached the point at which significant ecological impacts can be expected. Studies have shown that this threshold ranges from four to 20 percent, depending upon how directly the surfaces are connected to water bodies and other local factors.

**Information:** Impervious surface is currently measured using a combination of data sources including aerial photographs and satellite imagery. A new consortium of researchers and information-users intends to use NASA satellite data to develop land use and impervious surface coverages at five-year intervals. Impervious surface data for Rhode Island was developed from 2004 aerial photography, processed by computers; the results were then checked by technicians on the ground.

Improvements in technical hardware and software should provide increasingly finer resolution data for this data from aerial photography and satellite imagery. Finer resolutions will allow improved assessments at the subwatershed and even down to the neighborhood level, increasing watershed managers’ ability to develop better management tools. This is, however, dependent on the availability of sufficient resources to fund satellite and aerial photography as well as the analytic capacity needed to interpret this information.
Environmental Reporting

Numerous studies have found that robust, effective organizations value approaches that actively seek input on their progress from their chief stakeholders, implement those approaches by finding ways to provide technical assistance and information, and by reporting frequently to the public and engaged constituencies on their activities.

In both Rhode Island and Massachusetts, the most routinely published water quality report has been the biennial assessment of state waters required under Section 305(b) of the federal Clean Water Act. The content and structure of this report is regulated by EPA for specific water quality reporting needs. The water quality sections of this report summarize findings from the states’ 2008 reports.

But other sources of information can be equally if not more important to the public, including annual departmental reports and opportunities to review workplans, and assessments by environmental and other organizations of condition such as the 1998 RIDEM water quality status and trends report, the 2000 NBEP/RIDEM State of the Bay report, and Save The Bay’s State of the Bay 2007. In addition, individual watershed groups have developed watershed action plans on which they report more or less regularly; the Wood-Pawcatuck Watershed Association, for example, produces annual reports.

In Massachusetts, the Department of Environmental Protection (DEP) produces a number of reports based on a 5-year rotating basin approach, which feed into annual progress reports, and the biennial Integrated Report required under the Clean Water Act. In addition, Massachusetts has developed strong watershed organizations; the Blackstone River Coalition produces an annual water quality report card and in 2008 published a state of the river report. The Taunton River Watershed Alliance is developing a water quality monitoring program.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Rhode Island</th>
<th>Massachusetts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved* CSO Systems*</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Nutrient Treatment Upgrades**</td>
<td>10 of 11 WWTF</td>
<td>3 of 10 WWTF</td>
</tr>
<tr>
<td>Marine Vessel Sewage Pumped***</td>
<td>569,854 gallons</td>
<td>28,855**</td>
</tr>
</tbody>
</table>

* Volume storage or other discharge elimination/reduction systems underway or in place (Providence, Newport, and Fall River)
** Nutrient treatment installed, under construction, or in planning/design phase (Note: Two of the three Massachusetts facilities have appealed recently issued permits requiring upgrades for nitrogen treatment)
*** Fall River and Somerset only

Wastewater treatment facilities (WWTFs) in both Massachusetts and Rhode Island are major sources of nutrient pollution to Narragansett Bay.

In addition to nutrients such as nitrogen, WWTFs can become major sources of pathogens and other contaminants when heavy rains overwhelm plant operational capacity and the resulting flows bypass treatment, discharging directly into receiving waters. The untreated or partially treated discharges are responsible for shellfish and beach closures, and also add nutrients, toxics, and sediments to the mix of those from nonpoint sources and stormwater. Together these inputs are responsible for the failure of many parts of Narragansett Bay and its rivers to meet the threshold of “fishable, swimmable” waters demanded by the Clean Water Act. Failing septic systems and cesspools also contribute bacteria and nitrogen contamination.

Progress in addressing these problems can be measured by tracking treatment plant upgrades, combined sewer overflow (CSO) capture systems, and elimination of other sources of pathogens and nutrients such as cesspools, poorly performing septic systems, and sewage discharges from vessels, all of which will enable measurement of reductions in nutrient and pathogen loadings and volume of CSOs captured and treated.

Because the positive impacts of management decisions can take decades to show up in the environment, we often turn to metrics such as permits issued or reductions in pollutant loadings to serve as interim measures of success.

In addition to their help in assessing condition, management responses are also important in their own right; properly implemented, they tell us how well our knowledge of the ecosystem aligns with our management of it; and they point the way to more effective decision-making.

Looking up from the new CSO tunnel in Providence — 300 feet below ground.
Funding and number of staff do not always translate into effective management, but there is a threshold below which it can be difficult for organizations to perform well or even to meet basic program commitments. Over the past several years, fiscal situations in both states have led to reduced appropriations for program budgets, including reduced allocations for department staff.

These tables are a first-cut assessment of state funding for environmental and natural resource programs; though this information provides a useful yardstick, it does not capture all environmental expenditures. Much land preservation, for example, is funded with private or municipal dollars. Stormwater mitigation is often funded through state departments of transportation, and some federal grant programs are not reflected in these figures, while others not directly associated with water quality are included.

Even with these caveats, accurate information is difficult to obtain from sources readily available to the public. The key source in Rhode Island is the website of the state’s Budget Office in the Department of Administration. In addition to posting the annual budget from the Governor’s proposal through final revisions and supplemental decisions, the Budget Office also provides budget documents from previous years. In Massachusetts, budget information can be found on the legislature’s website and on the websites of a number of independent groups that analyze annual appropriations and their impacts. A difficulty is that budget format and categories have changed from year to year, including departments incorporated under the Massachusetts Executive Office of Energy and Environmental Affairs. In addition, rapidly changing fiscal situations may affect budget information for 2009. Finally, data for Massachusetts that reflect staff work and state expenditures in the watershed are still to be developed. A full and accurate picture of investments in the Bay and watershed will require agreement among all parties on how to characterize and account for categories of expenditures, including which departments, federal grants, and staff to track.
<table>
<thead>
<tr>
<th>Core Indicator</th>
<th>Metrics</th>
<th>Status</th>
<th>Trends</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Estuarine Waters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypoxia</td>
<td>Dissolved oxygen levels</td>
<td>Interannual variability due to weather and tides; follows North/South (N/S) gradient; most severe in Providence-Seekonk River and Greenwich Bay; documented for Upper Bay and some embayments.</td>
<td>Ten years of data in Upper Bay and embayments; severity dependent on weather, tides, river flow.</td>
</tr>
<tr>
<td>Chlorophyll</td>
<td>Chlorophyll and macroalgae</td>
<td>Used as indicator of primary productivity. Highest levels in Upper Bay; also high in Greenwich Bay/Lower Taunton River.</td>
<td>Annual bloom has shifted from winter/spring to summer in mid/lower Bay.</td>
</tr>
<tr>
<td>Beach Closures</td>
<td>Enterococci</td>
<td>Dependent on rainfall levels and local stormwater impacts.</td>
<td>Closures tend to follow rain events; closures affected by local conditions and stormwater runoff.</td>
</tr>
<tr>
<td>Shellfish Restrictions &amp; Closures</td>
<td>Fecal coliform bacteria</td>
<td>Reflects N/S gradient and local stormwater impacts; affected by weather/rainfall; operational changes allow some conditional openings.</td>
<td>Closure rates predicted to decrease as CSO abatement projects come online.</td>
</tr>
<tr>
<td><strong>Fresh Waters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh Waters impaired by bacteria</td>
<td>Enterococci and fecal coliform bacteria</td>
<td>Not all waters assessed. Of those assessed, 40% RI river miles impaired; 52% MA river miles impaired; 4% RI lake acres impaired; 0.2% MA lake acres impaired.</td>
<td>Dependent on rainfall, wildlife populations.</td>
</tr>
<tr>
<td>Fresh Waters impaired for dissolved oxygen</td>
<td>Dissolved oxygen</td>
<td>Not all waters assessed. Of those assessed, 5% RI river miles impaired; 27% MA river miles impaired; 10% RI lake acres impaired; 5% MA lake acres impaired.</td>
<td>Affected by nonpoint source inputs and, on major rivers, by point sources; varies by location; temperature; physical conditions.</td>
</tr>
<tr>
<td>Fresh Waters impaired by nutrients</td>
<td>Nitrogen; phosphorus</td>
<td>Not all waters assessed. Of those assessed, 4% RI river miles impaired; 25% MA river miles impaired; 15% RI lake acres impaired; 6% MA lake acres impaired. Neither state has numeric standards for nutrients in rivers.</td>
<td>Affected by nonpoint source inputs; varies by location; temperature; physical conditions.</td>
</tr>
<tr>
<td>Chloride in lakes</td>
<td>Chloride (RI lakes data since 1988; not available for MA lakes)</td>
<td>No RI lakes violate criteria.</td>
<td>Concentrations in RI lakes increasing since 1993.</td>
</tr>
<tr>
<td>Low Flow</td>
<td>Water levels; changes in riverine fish communities</td>
<td>Several RI rivers exhibit extreme low flow conditions; some impacts to fish populations documented; affected by user demand/drought conditions; MA fisheries staff observed no flow conditions in some Dighton brooks.</td>
<td>Existing data limited for many waters; large river stream gauge data show summer flow declines over time; Aug. flows in one Blackstone river basin declined 55% since 1979.</td>
</tr>
</tbody>
</table>
# Core Indicators

## Living Resources

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Metrics</th>
<th>Status</th>
<th>Trends</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estuarine Fish</td>
<td>Trawl surveys document catch data; some species missed due to equipment, location of surveys</td>
<td>Overall abundance of fish and shellfish in Narragansett Bay is generally stable since 1959.</td>
<td>Decrease in demersal (bottom-dwelling) species coupled with increases in pelagic (mid-water) fish and squid; suggest impacts of global warming trends.</td>
</tr>
<tr>
<td>Invasive Species</td>
<td>Rapid assessment surveys of marine invasive species</td>
<td>Marine and freshwater invasive species have been documented in Bay and watershed; 2000/2003 survey identified 21 invasive species and 17 of unknown origin in Bay.</td>
<td>Trends data not available due to limited spatial and temporal survey work. Volunteer monitoring program now underway (floating dock surveys).</td>
</tr>
<tr>
<td>Seagrass Beds</td>
<td>Aerial photography and interpretation; limited field work; historical sources (maps, interviews)</td>
<td>1996 and 2006 surveys; most recent survey shows about 400 acres of eelgrass; annual extent variable due to a number of factors.</td>
<td>Trend data limited to results of 2 surveys; possible signs of improvement.</td>
</tr>
</tbody>
</table>

## Watershed Lands

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Metrics</th>
<th>Status</th>
<th>Trends</th>
</tr>
</thead>
<tbody>
<tr>
<td>LandCover/Land Use Change</td>
<td>Land cover; land uses</td>
<td>NBR land use: 53% undeveloped; 3% high-intensity developed; 6% medium intensity; 11% low-intensity developed.</td>
<td>Total developed land in RI increased 47% 1970-1995.</td>
</tr>
<tr>
<td>Impervious Surfaces</td>
<td>Impervious surfaces</td>
<td>14% of Narragansett Bay watershed covered by impervious surfaces; R.I. area estimated at 10%.</td>
<td>Increasing as land development and redevelopment occurs.</td>
</tr>
</tbody>
</table>

## Ecosystem Management

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Metrics</th>
<th>Status</th>
<th>Trends</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Quality Improvement Actions</td>
<td>Waste-water treatment upgrades; improvements to combined sewer over- flow systems; use of marine pumpouts</td>
<td>Much of Narragansett Bay and tributaries does not meet Clean Water Act “fishable, swimmable” goals. MA and RI working to reduce nutrients and bacteria through legislation, permitting and construction.</td>
<td>Estimated 35% reduction in nitrogen from RI Bay WWTFs since 2004; Providence and Fall River CSO treatment coming online – bacterial reductions expected; since 2000, pumpout volume has more than doubled.</td>
</tr>
<tr>
<td>Environmental Expenditures</td>
<td>Annual state and federal funding; staffing levels</td>
<td>Environmental expenditures by state: $96 million (Rhode Island); $239 million (Mass.)</td>
<td>R.I. expenditures increasing; MA expenditures declined since 2007.</td>
</tr>
<tr>
<td>Environmental Reporting</td>
<td>Availability of monitoring data and ecological assessments</td>
<td>Rhode Island and Massachusetts operate on separate schedules for monitoring watersheds, even shared ones; both states post some data, but data are not necessarily the same, nor are all data available or shared online</td>
<td>Reports on data not consistently available, although Massachusetts publishes an annual environmental progress report.</td>
</tr>
</tbody>
</table>