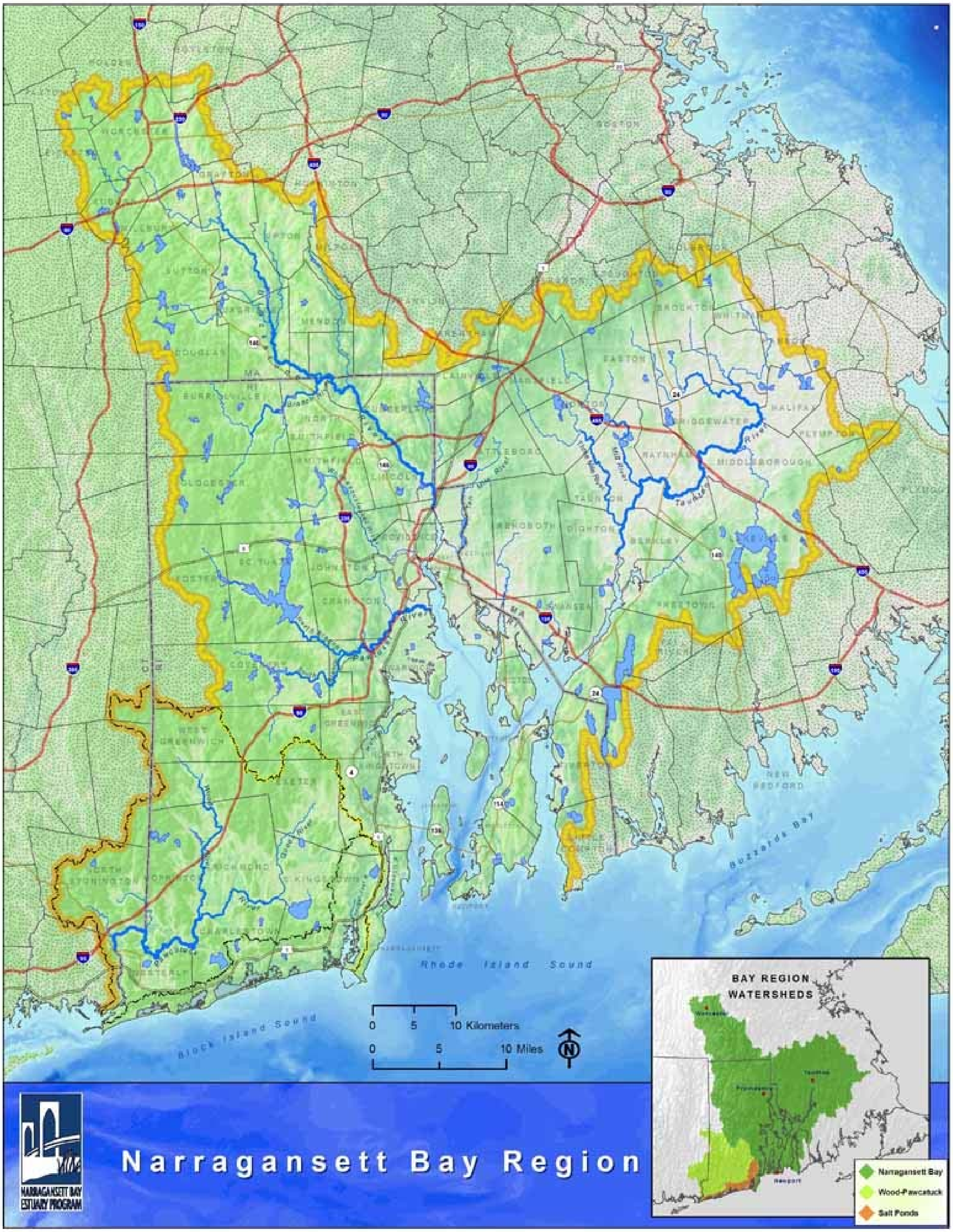

Currents of Change:

Environmental Status & Trends of the Narragansett Bay Region

Final Technical Draft

Narragansett Bay Estuary Program, August, 2009

Acknowledgements

This report is the result of work sessions, meetings and communications with dozens of Bay and watershed stakeholders from state, local and federal governments, nongovernmental organizations, watershed and community groups, and academic institutions. This report was written by Narragansett Bay Estuary Program (NBEP) staff and Margherita Pryor of U.S. EPA, with substantial and invaluable assistance from many individuals and organizations.

The report was developed through an open and collaborative process, working with a large, interdisciplinary group of experts and stakeholders who participated in scoping meetings, reviewed drafts of the report, and provided useful feedback as the work progressed. Currents of Change is a much stronger document for their participation, and we are grateful to all who contributed to the process and the report.

More than 40 scientists and resource managers who met on May 1, 2009 at Roger Williams University in Bristol, R.I. to review the report and provide final comments. Paul Jordan of the R.I. Dept. of Environmental Management analyzed spatial data and developed most of the maps for the report. Peter August, director of the URI Coastal Institute, organized a review team. Ames Colt, chair of the R.I. Bays, Rivers and Watersheds Coordination Team, provided extensive comments and suggestions. The NBEP Management Committee provided program oversight and support throughout the process; we are grateful for their interest and participation. Our Massachusetts-based Management Committee members (Donna Williams of the Blackstone River Coalition, Carolyn LaMarre of the Taunton River Watershed Alliance, and Bryant Firmin of Mass. Dept. of Environmental Protection) helped us maintain a broad focus on the Bay's bi-state ecosystem. Thanks, too, to the many scientists and others who provided data used in this report.

Most, though not all, of those who assisted in developing Change are listed in the table below. Sincere thanks to all.

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Currents of Change Technical Review

Estuarine Waters

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Ecosystem Management

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Table of Contents

1. An Anthropogenic Ecosystem

Humans have used and valued the resources of Narragansett Bay for at least 8,000 years (1.1). The oldest known site of human habitation in the Bay watershed is the Paleo-Indian village of Wampanucket, built along the Nemasket River in what is now Middleborough, Mass.— even today, the location of Narragansett Bay's most abundant herring run, where up to a million fish pass annually on their migratory path to the Assawompsett Ponds. In Colonial times, the Bay was essential to New England's shipping and agriculture. During the Industrial Revolution, hundreds of thousands of immigrants flocked here, attracted to a burgeoning manufacturing economy made possible by Narragansett Bay's rivers and ports. The Bay's naval facilities helped win the Second World War, assembling the convoys that supplied the European Front. In the late 20th century, the Bay became a world-class tourism destination, attracting vacationers to sail, fish, surf, swim and unwind along some of the country's most beautiful shorelines.

Throughout our long relationship with Narragansett Bay, we've modified its environment to suit our needs. Native Americans burned forest underbrush to create farmland and improve game populations (1.2). Colonists cleared the once-forested watershed for agriculture and fuel, with profound effects on rivers and streams (1.2). Dams were built on nearly every watercourse, first to power sawmills and gristmills; later to power factories; and finally, to develop drinking-water reservoirs (1.3). Shorelines were filled for transportation, energy, industrial, military and commercial development; railways, roads, airports and ports were built on, around and across the Bay. Cities grew; streams became storm-water pipes; wastewater treatment plants were built to handle the demands of two million people in the Bay watershed, in Rhode Island and Southeastern Massachusetts (1.4). Narragansett Bay became what it is today: a resource of tremendous natural value, and one which has been strongly influenced by the hand of man—we who live and work in the Narragansett Bay watershed.

Today, Narragansett Bay and its watershed can be considered an "anthropogenic ecosystem"—an environment created by the natural forces of climate, geology and biology, which has been, and continues to be, shaped and changed by such dynamic societal forces as democracy, immigration, suburbanization and war. This report provides a definitive picture of this ecosystem today—one which uses the past to understand the present, while looking toward the future.

Purpose: How to Use "Currents of Change"

The goal of "Currents of Change" is to understand Narragansett Bay, not as a simple body of water but as an ecosystem; not as a static feature, but as a dynamic environment—and to communicate that understanding to a broad audience by providing an overview of the Bay environment and the factors affecting it. Through this holistic approach, the Narragansett Bay Estuary Program (NBEP) and its partners seek to inform and facilitate the management of Narragansett Bay as an ecosystem, in the millions of public and private decisions that affect it—within state and federal agencies, at the voting booth, around the kitchen table.

To do so, Currents of Change establishes "environmental indicators" — a set of measures which, taken together, are intended to characterize the condition of the ecosystem as a whole, and which can be revisited and updated periodically. This "status and trends" approach is now being used for estuaries around the country, from Puget Sound to Chesapeake Bay. Such an approach can facilitate science-based management of complex ecosystems by identifying unexpected changes and helping to determine whether management objectives are being met (1.5).

In developing these measures, NBEP worked with dozens of advisers and reviewers—scientists, managers and stakeholders; experts and laypeople. While there are hundreds of environmental studies and datasets regarding the Bay and its watershed, relatively few support the two main objectives of this report: 1) to communicate something broad and meaningful about the condition of the ecosystem (status); and 2) to provide a time-series of information that communicates changes through time (trends). In many cases, therefore, Currents of Change reports on status alone, with the intention that trends information will be developed in the future.

The indicators are organized into five broad categories, each of which comprises a section of the report: Estuarine Waters, Fresh Waters, Living Resources, Watershed Lands and Ecosystem Management. Each chapter provides an interpretive context for the indicators it reports: why they are important, what they tell us, and, conversely, what they do not. Currents of Change reports and assesses existing information; NBEP did not undertake new scientific studies or environmental monitoring for this report.

The indicators follow a standard format, as follows:

- Indicator Title
- Importance: A brief statement explaining why this particular indicator is important to understanding the condition of the ecosystem;
- Information: An explanation of the sources of the information, as well as any limitations;
- Status and Trends: Presentation of the indicator information, where possible in graphic form. Again, trends are reported where possible, but in many cases, only status information was available.

In developing Currents of Change, we identified many gaps in current environmental reporting and analysis pertaining to the Narragansett Bay Region. This problem is not unique to NBR; a recent report by the Heinz Center stated:

> Despite growing environmental challenges facing the United States, the current system of collection and delivery of information about environmental trends is *unable to meet current and future needs of decision makers*. (1.6; emphasis in original).

By identifying gaps and limitations in environmental information for the Narragansett Bay Region, Currents of Change seeks to inform future decision-making regarding environmental monitoring and data management.

Another problem is presented by inconsistency of environmental information between the states of Rhode Island and Massachusetts. In reporting the condition of the watershed ecosystem, we have often had to report separately on conditions within each of the two states. By highlighting these differences, we hope that Currents of Change will help spur the states to reconcile environmental reporting and begin developing watershed-wide information.

Geographic Scope: The Narragansett Bay Region

Narragansett Bay is an estuary—a semi-enclosed body of water connected to the ocean at its mouth or entrance, and connected to the land by rivers, streams and groundwater. Less tangible but no less real from the perspective of human use and management, are its social or political connections—to the states, cities, towns and neighborhoods which manage, use and affect Narragansett Bay and its natural resources.

In order to consider all these influences on the environment of Narragansett Bay, Currents of Change establishes the Narragansett Bay Region, or NBR, as its geographic scope. NBR encompasses Narragansett Bay, its drainage basin or watershed in Rhode Island and Massachusetts, and the adjacent estuaries and watersheds of the Wood-Pawcatuck river system and Rhode Island's coastal Salt Ponds.

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, 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, of which 1028 square miles (60%) are in Massachusetts, with 677 square miles in Rhode Island (1.7).

By including the entire Narragansett Bay watershed, NBR includes all the fresh surface water (lakes, ponds, rivers, streams and wetlands) and most of the groundwater which flows into Narragansett Bay. By including the Wood-Pawcatuck and Salt Ponds watersheds, NBR captures most of Rhode Island's political "ecosystem"—the legal, social and political structure which governs Bay management. It also includes much of Narragansett Bay's "user-shed," communities which use and value the Bay and its resources for work, recreation, and amenity value. The Narragansett Bay Region, as we've defined it, is home to two million people in 100 cities and towns (1.7). Each of us has the ability to affect the Narragansett Bay ecosystem, for better or worse, through myriad decisions, from the trivial to the monumental—from how we get to work, to where we live, to how we vote.

No single report could fully describe such a large and diverse area. The task of Currents of Change is made the more difficult by the fact that there have been few previous attempts to characterize the entire Bay ecosystem, and much information is lacking. 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. NBEP dedicates this report to the many organizations and individuals concerned with its stewardship.

NBR Status & Trends Indicators Presented in Currents of Change

Core Indicator	Metrics	Status	Trends	Page
Estuarine Waters				
Hypoxia	Dissolved oxygen levels	Interannual variability due to weather and tides; follows N/S gradient; most severe in Providence-Seekonk River and Greenwich Bay; documented for Upper Bay and some embayments	Ten years of data in Upper Bay/ embayments; severity dependent on weather, tides, river flow	9
Chlorophyll	chlorophyll and macroalgae	Used as indicator of primary productivity. Highest levels in Upper Bay; also high in Greenwich Bay/Lower Taunton River	Annual bloom has shifted from winter/spring to summer in mid/lower Bay	12
Beach Closures	Enterococci	Dependent on rainfall levels and local stormwater impacts	Closures tend to follow rain events; closures affected by local conditions/stormwater runoff	13
Shellfish Restrictions & Closures	Fecal coliform bacteria	Reflects N/S gradient and local stormwater impacts; affected by weather/rainfall; operational changes allow some conditional openings	Closure rates predicted to decrease as CSO abatement projects come online	15

Core Indicator	Metrics	Status	Trends	Page
Fresh Waters				
Fresh Waters impaired by bacteria	Enterococci and fecal coliform bacteria	**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	Dependent on rainfall, wildlife populations	20
Fresh Waters impaired for dissolved oxygen	Dissolved oxygen	**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	Affected by nonpoint source inputs and, on major rivers, by point sources; varies by location; temperature; physical conditions	21
Fresh Waters impaired by nutrients	Nitrogen; phosphorus	**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.	Affected by nonpoint source inputs; varies by location; temperature; physical conditions	22
Chloride in lakes	Chloride (RI lakes data since 1988; not available for MA lakes)	No RI lakes violate criteria	Concentrations in RI lakes increasing since 1993	23
Low Flow	Water levels; changes in riverine fish communities	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	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	24

Core Indicator	Metrics	Status	Trends	Page
Living Resources				
Estuarine Fish	RIDEM/URI trawl surveys document catch data; some species missed due to equipment, location of surveys	Some species missed due to equipment limitations and location of surveys; URI trawl (since 1959) is longest continuous bay dataset; RIDEM trawl data since 1979	URI GSO studies document decrease in demersal species coupled with increases in pelagic fish and squid; suggest impacts of warming trends	28
Wetlands	Aerial photography analyses	Only permitted RI wetland losses and gains tracked; MA freshwater wetlands total acres 89,905 in 2001; RI freshwater wetlands total 79,191 acres in 1988; Coastal habitats on Narra. Bay 95,355 acres in 1996	Mass. freshwater wetlands loss - ~400 acres 1991-2001; RI coastal wetlands 548 acres lost 1950s-1990s	29
Invasive Species	Species counts (e.g. BioBlitz); rapid assessment surveys of invasive species	Marine and freshwater invasive species have been documented in Bay and watershed; Narra. Bay RAS 2000/2003 identified 21 invasive species and 17 of unknown origin	Trends data not available due to limited spatial and temporal survey work. Volunteer monitoring program now underway (floating dock surveys.) Data and annual report will be issued for distribution of AIS in Narragansett Bay	31
Seagrass Beds	Aerial photography photo-interpretation; limited field ground-truthing; historical sources (maps, interviews)	1996 and 2006 surveys; most recent survey shows about 400 acres of eelgrass; annual extent variable due to a number of factors	Trend data limited to results of 2 surveys	32

Core Indicator	Metrics	Status	Trends	Page
Watershed Lands				
Land Cover/Land Use Change	Land cover; land uses	Total developed land in RI increased 47% 1970-1995	Increasing as land is converted from undeveloped or less intensive uses; since 1995 in R.I., 30% of undeveloped land has been developed	36
Impervious Surfaces	Impervious surfaces	14% of Narragansett Bay watershed covered by impervious surfaces; R.I. area estimated at 10%	Increasing as land development and redevelopment occurs	41

Core Indicator	Metrics	Status	Trends	Page
Management				
Water Quality Improvement Actions	Upgraded WWTF; Reduced CSO frequencies; Marina Pumpout Usage	R.I. and MA seeking to resolve nutrient loadings to Blackstone River to reduce in-river and Bay impacts	Estimated 35% reduction in N from RI Bay WWTFs since 2004; Providence and Fall River CSO treatment coming online – reductions expected; Since 2000, pumpout volume more than doubled	44
Environmental Expenditures	Annual state and federal funding; staffing levels	R.I. expenditures increasing; MA expenditures declined since 2007	Increasing level of federal funding being used for environmental management in R.I.; number of FTEs for some R.I. agencies declining	47
Environmental Reporting	Availability of monitoring data and ecological assessments	States operate on separate schedules for monitoring watersheds, even shared ones; RI has limited monitoring data to report	Reports on data not consistently available	49

2. Estuarine Waters

Introduction: Narragansett Bay is an estuary with its largest sources of fresh water flowing into the upper reaches: the Blackstone, Taunton, and Pawtuxet Rivers, along with smaller rivers. The mouth of the Bay is open to the Atlantic Ocean via three large channels: the West Passage, East Passage and Sakonnet River. The East Passage is the deepest of these channels, with the majority of the ocean's clean bottom water flowing in here (2.1).

The area around Narragansett Bay is densely populated, with urban centers clustered around the upper Bay and its major rivers. This pattern has created a general water quality gradient along the Bay's north-south axis. Sources of pollution are concentrated in the Bay's upper reaches, including public waste water treatment facility (WWTF) discharges, stormwater and combined sewer overflow (CSO) outlets, and urban runoff from densely developed areas. These sources discharge either directly into estuarine waters, or into rivers which then carry pollution to the upper Bay.

Pollution tends to decrease toward the mouth of the estuary due to dilution by seawater moving up the bottom of the deep East Passage, as well as the fact that there are fewer point sources. Because of this gradient and the hydrodynamics of the Bay, the Bay has at least four significant sub-areas which do not necessarily behave similarly from the standpoint of water quality (2.2). These are:

- Providence River and Seekonk River areas, from approximately Conimicut Point (Warwick, R.I.) north;
- Upper Narragansett Bay, from Conimicut Point south to approximately the north end of Prudence Island;
- The Mid-Bay, from the northern end of Prudence south to the northern end of Conanicut Island;
- Lower Narragansett Bay, from the northern end of Conanicut south to an imaginary line drawn from Point Judith, R.I., to Sakonnet Point. This line is often used to define the southern limit of Narragansett Bay, and also serves as the seaward boundary for the Narragansett Bay Region as defined by this report.

In addition, a number of exceptions to the overall down-Bay pollution gradient are created by Narragansett Bay's complex hydrography. Small embayments, harbors and coves such as Greenwich Bay and Wickford Harbor are potentially more vulnerable to local sources of pollution due to poor flushing (2.3). Greenwich Bay has been clearly documented to exhibit significant impacts (severe hypoxia) from excess nutrients.

One of the most important forms of pollution affecting Narragansett Bay (and other marine waters) is excess nutrients, specifically nitrogen, which can have profound effects on estuarine ecosystems. Before development of the Bay watershed, the greatest source of nutrients to the Bay was ocean water. Agricultural and urban development created large new sources of runoff, carrying nutrients from the land. As development increased, human waste became a significant source of nutrients. In 1871, Providence centralized the city's public water system, bringing water initially from the Pawtuxet River to city residents and businesses. The introduction of running water changed waste disposal from an essentially dry disposal system (outhouses, etc.) to plumbing which disposed of wastewater into street gutters and cesspools, where it made its way into the rivers and bay.

The resulting pollution resulted in an immediate need for a sewage collection and disposal system (2.4). The number of people served by sewer systems in Providence and cities in the upper Bay steadily increased from 1871 until about 1950 and it has held relatively steady since that time (2.5). Today, two million people living in the Bay watershed contribute thousands of tons of nitrogen to the upper Bay annually by way of 35 wastewater treatment facilities (WWTFs) in Rhode Island and Massachusetts. Nitrogen loads have begun to decline (35% drop in total nitrogen to the Upper Bay from WWTFs estimated for 2006) due to improved treatment (nitrogen removal) at eight major WWTFs discharging to the upper Bay and its tributaries. Eventually, 11 WWTFs discharging to the Seekonk-Providence Rivers or just upstream will remove nutrients. In order to reach the State of Rhode Island's desired goal of 50% decrease in nitrogen loads to the Upper Bay from WWTFs (2.6), several major upstream plants in Massachusetts must also participate. USEPA has issued permits with nutrient limits to three major WWTFs impacting the Seekonk-Providence Rivers and the Upper Bay. Two of these plants (Worcester and Attleboro) have appealed the permit and have not yet committed to decrease nutrient level. Efforts are also being made to reduce nonpoint source loadings of nutrients including nitrogen removal by specialized onsite wastewater treatment systems for some coastal areas not served by municipal sewers and stormwater treatment using both regulatory and public education means.

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 (mid 1980s), and the decline of Northeastern manufacturing, these inputs have greatly decreased (2.7), although many of these contaminants can still be found in the sediments or mud of the rivers and upper Bay, where they create problems for fish consumption as well as management challenges. Storm water and road runoff are now possibly the greatest sources of most toxics and a major source of bacteria to Narragansett Bay, affecting estuarine habitats and prompting the closure of beaches and shellfish beds.

► Indicator: Hypoxia (Low Dissolved Oxygen)

Importance: Dissolved oxygen (DO) is necessary to sustain life in any estuarine system. In the waters of Narragansett Bay, DO saturation levels are typically around six to eight milligrams per liter (mg/L). Low levels of DO signal degraded health of the estuary. Large releases of nutrients in estuaries can cause excessive growth (blooms) of microscopic phytoplankton and larger macroalgae (seaweed) which in turn decompose. During this decomposition, bacteria consume oxygen. Under certain physical conditions, this will lead to stressfully low levels of DO (hypoxia) in bottom waters, disrupting and degrading the ecology of Narragansett Bay. Severe low bottom DO events may approach zero oxygen levels (anoxia).

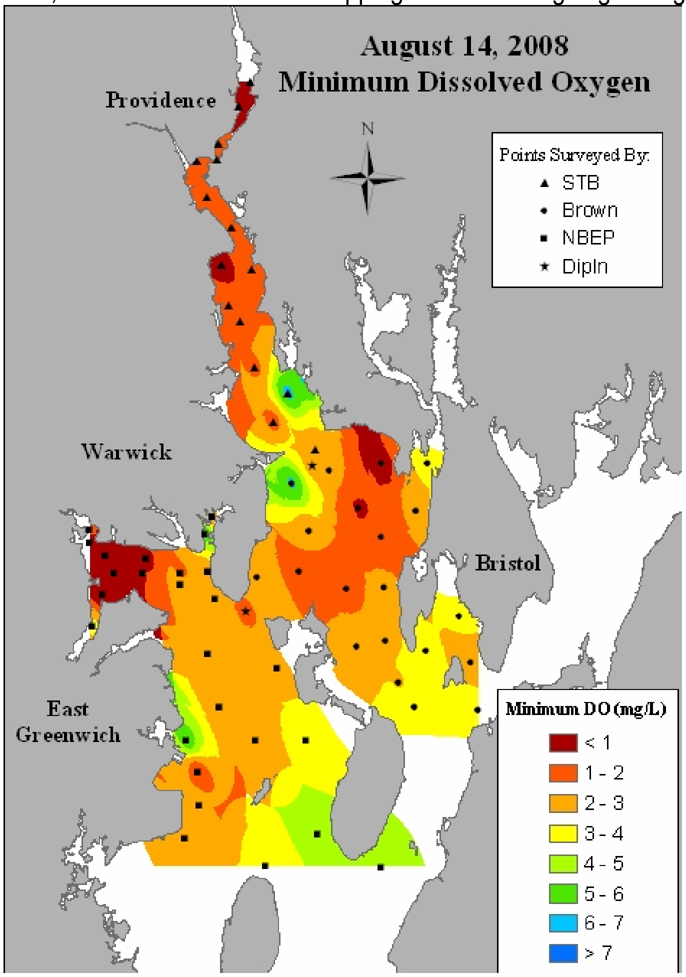
Hypoxia most often occurs during hot, calm summer periods, when the water is "stratified" or layered. High river flows have a strong influence over both stratification and changes in nutrient loads to the Bay during summer months. During this season, phytoplankton can undergo rapid growth as huge blooms that color the water. As these blooms sink and die, they are decomposed by bacteria which consume dissolved oxygen (DO). Stratification prevents re-oxygenation of the bottom water through vertical mixing, leading to low DO levels stressful or fatal to marine life. RIDEM water quality criteria for dissolved oxygen in part require that dissolved oxygen not fall below 2.9 mg/l for more than 24 consecutive hours or 1.4 mg/l for more than one hour. June river flows are the largest summer river flows, and years with high June river flows generally result in more severe hypoxia in July or August of that summer (2.9); during those months, periods of hot, calm weather and weak tides present the most risk (2.10).

Severe hypoxia and anoxia can cause large fish kills and mass mortality of benthic (bottom-dwelling) marine life, as occurred on Narragansett Bay in 2001, 2003 and 2006 (2.9). Less visible but more important in terms of the Bay's ecological health is the impact of hypoxia on the diversity and abundance of benthic biological communities. Severe hypoxia causes a shift from large, burrow-forming, long-lived organisms including mantis shrimp, lobsters, and large marine worms to tiny opportunistic worms and other small species that live right at the surface of the sediments (2.11). These changes affect the entire ecosystem by altering nutrient cycling and the estuarine food web. One species which may actually receive some benefit from hypoxia is the hardy quahog, which can survive these conditions and may find lowered predation rates on young (2.12), but it is believed their growth/reproduction may be hampered by severe low DO (2.13).

Information: Dissolved oxygen has been measured on a continuous basis since the late 1990s at several locations in the Bay. The network of continuous fixed-site stations, six deployed on land and seven on buoys, has grown over the last five years to 13 locations and is collaboratively operated by RIDEM, the University of Rhode Island Graduate School of Oceanography (URI-GSO), Narragansett Bay National Estuary Research Reserve (NBNERR) and Narragansett Bay Commission (NBC). These stations measure dissolved oxygen, temperature, salinity and chlorophyll fluorescence every 15 minutes (2.14). Since 1999, the Narragansett Bay Estuary Program has worked with Brown University and RIDEM to periodically monitor summer dissolved oxygen levels by profiling up to 75 locations in the upper and middle reaches of the Bay 1-2 times per month (2.15). A high-resolution, spatial-depth dataset gives a Bay-wide picture, but is limited to the shipping channels; this is provided by the US NOAA National Marine Fisheries Service towed survey of the entire Bay on a monthly basis (2.16). The datasets complement each other by providing in combination both the temporal and spatial detail needed to characterize water quality conditions in much of the Bay and allow for reasonable estimates of the percentage of Bay bottom waters experiencing hypoxia and violating DO water quality criteria. However, these monitoring efforts do not reflect conditions in small embayments, harbors and coves, which may experience low DO even at midbay areas (e.g., Allens Harbor, Wickford Cove, Bristol Harbor) due to the greater influence local nutrients have on these poorly flushed area (2.13).

The Sakonnet River represents a significant data gap. Limited information on nutrient loadings, DO and benthic communities have been developed for Mount Hope Bay (2.3, 2.9, 2.18, 2.20, 2.21). Consistent long-term DO monitoring has been initiated for mid Mount Hope Bay since 2005 (2.9). For the Sakonnet River, little or no water quality data are available on nutrients, chlorophyll, or DO.

Monitoring of benthic community health has been ongoing throughout Narragansett Bay through the US EPA funded National Coastal Assessment Program (**http://www.epa.gov/emap/html/pubs/docs/groupdocs/estuary/index.html).** In addition, URI researchers track several Bay sediment stations long-term (2.21). Also, further detailed bottom mapping efforts are ongoing throughout Narragansett Bay (2.22).



Dissolved Oxygen Concentrations Aug. 14, 2008 (Oxygen values are from D. Murray, Brown University. Data available at: http://www.geo.brown.edu/georesearch/insomniacs/)

Status & Trends: Ten years of dissolved oxygen data are now available for Narragansett Bay. However, long-term trends are not yet apparent because of large interannual variability driven by river flow and winds. Only status of the main areas of the Bay is therefore reported here. The large interannual variability in the Bay's DO is caused by the difference in stratification and weather-driven nutrient loads year to year, including differing river flows and winds.

Areas of Narragansett Bay clearly violating bottom Dissolved Oxygen (DO) water Quality Criteria and experiencing hypoxia. Areas outside these areas may also be experiencing some hypoxia, but at lower severity and frequency levels. Source: RIDEM Div. Of Water Resources 2008.

Approximately 33% of RI estuarine waters (48.16 mi^2 of 146 mi^2 assessed in RI) are impaired by hypoxia (2.3). Hypoxia in the main Bay follows a general North-South pollution gradient. Setting aside the effects of weather, the frequency, intensity and duration of hypoxia are greater in the upper Bay, and vary by sub-embayment. The most severe hypoxia (DO = 1-2 mg/L) is found in summer months in the Seekonk and Providence Rivers as well as western Greenwich Bay. The severity of hypoxia generally decreases as one heads down the main Bay channels. Western Greenwich Bay experiences short but extremely severe hypoxic events, while the upper West Passage (Mount View area) shows less frequent, but still severe bouts of hypoxia. Even at Fox Island, about two-thirds of the distance down the Bay, severe low oxygen has been recorded (less than 2 mg/L in 2006). Though these hypoxic events occur most frequently in July and August, they can also happen in June and September (2.9, 2.13).

The duration of hypoxic events varies. In the Providence and Seekonk Rivers, they can last two weeks or more, linked to stratification caused by fresh water flows from the rivers of the upper Bay. The Upper Bay area north of Prudence Island experiences events of 1 day to about a week, with rare longer events. Limited data from Mount View (north of Quonset Point) in 2005 and 2006 suggest that the upper West Passage sometimes experiences severe hypoxic events ranging from five to 20 days; this may be evidence that hypoxic waters from both Greenwich Bay and the Upper Bay affect this area (2.9, 2.13).

The Seekonk River experiences the most severe hypoxic events yet measured on Narragansett Bay, with the western side of Greenwich Bay a close second. Oxygen levels in both areas is often less than 1 mg/L DO. The Seekonk events tend to be long duration (weeks) while western Greenwich Bay has up to 12 short-lived (1 to 3 day) events per summer, with rare extensions to a week or more. The Seekonk has very high nutrient loads from both Rhode Island and Massachusetts sources, along with strong stratification. Significant groundwater nutrient loads and poor circulation in the western side of the embayment are factors contributing to the poor conditions in western Greenwich bay (2.1, 2.9, 2.13, 2.32). The events in Greenwich bay are of short duration because tides and winds can rapidly mix oxygen from the surface with bottom waters in this shallow 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 with historical high populations of natural resources like oysters and scallops are likely highly vulnerable to nutrient loads due to poor flushing, which also retains larval recruits (2.17), and should be carefully managed to minimize nutrient loads.

Mount Hope Bay experiences mild hypoxia (less than 4.0 mg/L DO), but seems to rarely to go below 3.0 mg/L (2.9, 2.18). Only the mouths of the Lee and Cole Rivers, the lower Taunton River mouth, and the Taunton River tidal area above Fall River exhibit significant concentrations of nutrients and chlorophyll, as well as poor oxygen levels (less than 3 mg/L) (2.18, 2.19). It is unclear why larger areas of Mount Hope Bay are not presently experiencing larger chlorophyll bloom and hypoxia responses based on the large freshwater flow and nutrient loading from the Taunton River, as well as a significant source from the Fall River wastewater treatment facility. More detailed studies in Mount Hope Bay are warranted to better understand the dynamics of this area.

► Indicator: Chlorophyll

Importance: Plants are essential to Narragansett Bay's estuarine functioning. The role played by phytoplankton (microscopic algae) and seaweeds (macro algae) is called primary productivity: the conversion of basic nutrients such as nitrogen, phosphorus, and carbon into plant tissue. This serves as the basis for the entire estuarine food web, from microscopic animals (zooplankton) to small fish such as anchovies (planktivores) to large fish, birds and mammals, including humans. Understanding primary productivity in the Bay is essential to understanding the basic ecological processes (nutrient cycling) which govern all life within it. The assessment of primary productivity is important for understanding the health of an estuary; eutrophication is, essentially, excess primary productivity. However, primary productivity is difficult to measure directly, and is therefore usually measured in terms of chlorophyll concentrations: the amount of plant chlorophyll pigments in the water column. Chlorophyll provides a rough yardstick of plant abundance in the estuary, and excess amounts are the "fuel" for hypoxia. However, it does not fully capture changes that can take place in an estuary, such as shifts in phytoplankton species. Depending on the species involved, this can be quite important since some species make better food sources than others, and some species can be quite problematic (e.g., the "brown tide" species, *Auereococcus anophagefferens*)(2.23).

Information: The network of monitoring buoys described under the previous indicator includes instrumentation that measures chlorophyll fluorescence and provides data that can be used to infer relative comparisons of phytoplankton concentration. The data are used in combination with the other data collected to identify when algal blooms are occurring. URI has regularly monitored phytoplankton north of Fox Island for almost 50 years, resulting in a long-term dataset of primary productivity for the lower portion of the Bay (2.24). URI also monitors chlorophyll levels at the Graduate School of Oceanography (GSO). URI monitors both the concentration of chlorophyll and changes in dominant species at the lower-Bay site. Special studies have provided a picture of the overall distribution of chlorophyll across the Bay regions (2.25). For example, the ongoing NOAA hypoxia study in Narragansett Bay with partners from URI, Brown, RIDEM and other institutions has measured C-14 primary production from summer 2006 through summer 2008 every two weeks in summer and monthly in the colder months at six stations from Bullocks Reach to GSO (2.26).

By contrast with the URI dataset, information on types of phytoplankton and total chlorophyll levels for upper Narragansett Bay is quite limited, constituting a data gap. The fixed site monitoring will help with future tracking of trends, but research that better defines past responses of the upper Bay area (e.g., sediment core work associated with past primary productivity) is critically needed for the upper half of the Bay to better assess the trends seen at the URI station midbay.

Status and Trends: In Narragansett Bay, the highest levels of phytoplankton are found in surface waters of the Seekonk (during the growing season, levels can exceed 60 ug/L). Primary productivity is very high (at times ranging 20--60 ug/L) below the Fields Point WWTF in Providence, down to Gaspee Point, as well as in the western Greenwich Bay and lower Taunton River area (2.17, 2.18, 2.25, 2.27, 2.28). The Upper Bay area north of Prudence Island, and the upper reaches of the West and East Passage have moderate chlorophyll concentrations, ranging from less than 5 to approximately 20 ug/L. The URI lower Bay stations (Fox Island and GSO) areas experience much lower chlorophyll levels (less than 20 ug/L and less than 5 ug/L respectively) (2.17, 2.27, 2.28).

In the last 30 years, the period of the maximum annual phytoplankton bloom has decreased during the winter-spring (January-April), while summer blooms have slightly increased (June-September) and shifted to warm water diatoms in the mid to lower Bay (below Wickford), possibly due to ecological changes associated with increased water temperatures (+1 to +2° C). The overall effect is a decrease in annual chlorophyll levels at the midbay station (2.23, 2.24, 2.28). Summer bloom chlorophyll concentrations are much greater in the upper half of the Bay compared with lower Bay areas (2.27), and it is unclear if the same change has occurred in those areas.

► Indicator: Beach Closures

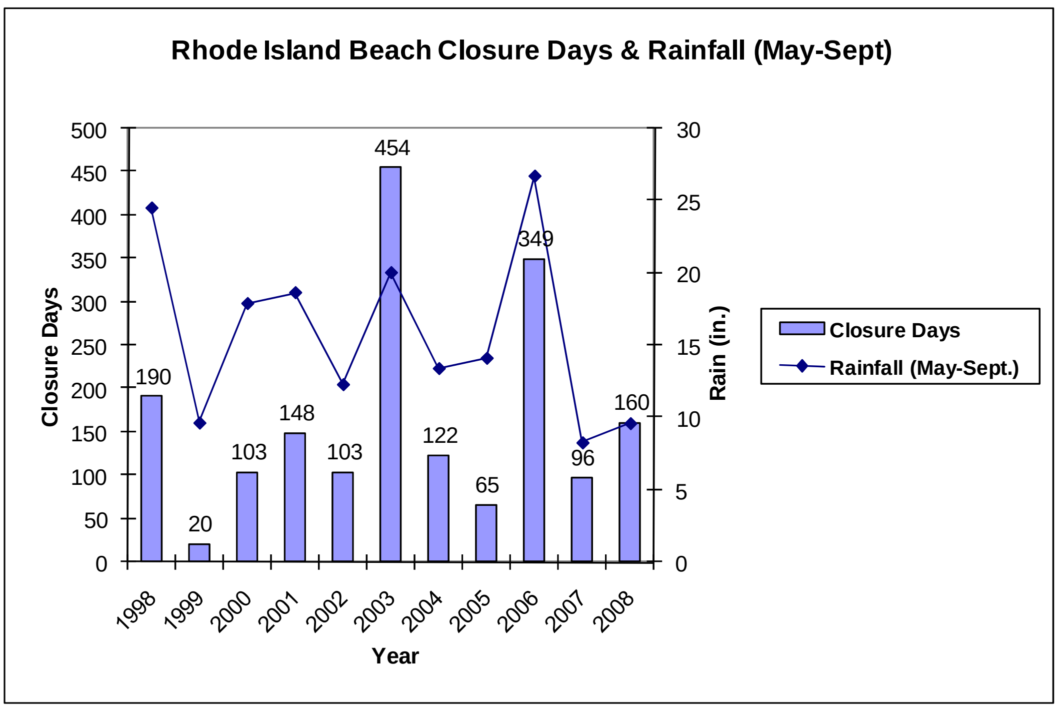
Importance: Water pollution affects human uses of Narragansett Bay as well as its ecology. Beaches are among the most popular recreational amenities offered by the Bay; yet the Bay's beaches are sometimes closed due to high bacteria indicator levels in the water. These bacteria are considered to be indicators of enteric organisms such as pathogenic bacteria and viruses which may cause disease in humans. They are used as criteria to determine the safety of beaches for "contact recreation" such as swimming. Sources of bacteria to Narragansett Bay include discharges of raw sewage from CSOs and stormwater runoff from land-based sources such as failed septic systems and cesspools, domestic animals and waterfowl as well as pet waste.

Information: Rhode Island uses Enterococci, a group of bacteria found in warm-blooded animal feces, including humans, to assess the safety of bathing waters. Enterococci bacteria in water samples from saltwater beaches must not exceed a single sample standard of 104 colony forming units (cfu) per 100 milliliters (mL). When violations occur, that particular beach is closed until samples indicate that conditions have improved. Each day a single beach is closed is considered one "beach closure day". The R.I. Department of Health conducts sampling federally funded by the US EPA at all 69 licensed saltwater beaches (including the 20 in estuarine RI waters) from two weeks before Memorial Day to two weeks after Labor Day. The "beach days closed" total closure rate/ yr based on this monitoring program is presented here (2.29).

The quality and frequency of saltwater beach monitoring has improved in recent years, including a major study in 1999 and significant methodological changes in 2006 and 2007 (2.29). As a result, beach monitoring is more protective of public health than formerly. Underlying trends are difficult to assess, since increases in beach closures appear to reflect better measurement and yearly variations in rainfall rather than worsening conditions (2.29, 2.30).

Status & Trends: Beach closures are strongly influenced by summer weather, particularly rainfall, which washes bacteria from the land into nearby storm drains. The upper reaches of the Bay, north of Conimicut Point in Warwick and Nayatt Point in Barrington, are not recommended for swimming due to high bacterial levels from urban runoff, CSOs and other sources. King's Park Beach in Newport Harbor was permanently closed in 2004 due to stormwater contamination from the nearby CSO (2.29).

Beaches in the middle and lower reaches of Narragansett Bay are monitored frequently; closures tend to follow rain events. Summer 2003 saw a record number of beach closures for Rhode Island beaches, linked to significant rainy weather that June. Summer 2006 also showed high rates of closure. The 2007 bathing season showed a significant decrease in beach closures and closure days from 2003, 2006 and 2008. The intensity and total volume of rainfall was lower during the summer of 2007 (June 1 to August 31) compared with summer 2006, showing a tight correlation between local stormwater runoff and beach closures, a common factor for beach closures nationally. Beaches located in the City of Warwick accounted for the largest percentage of closures by city/town over the last several years (2.29, 2.30). From 2006 to 2007, closures in Warwick decreased dramatically from 89 to 16 closure days but increased again to 73 in 2008. Although a portion of this improvement can be attributed to the decreased rainfall in 2007, it may also be linked to Warwick's successful program to connect over 4,000 homes to sewers throughout the city and around the beaches during this period (2.30). Recent efforts have been made to provide stormwater treatment and decrease this source at several beaches where local stormwater has been shown to be a significant source of bacteria (e.g., Scarborough Beach, Narragansett) (2.13).



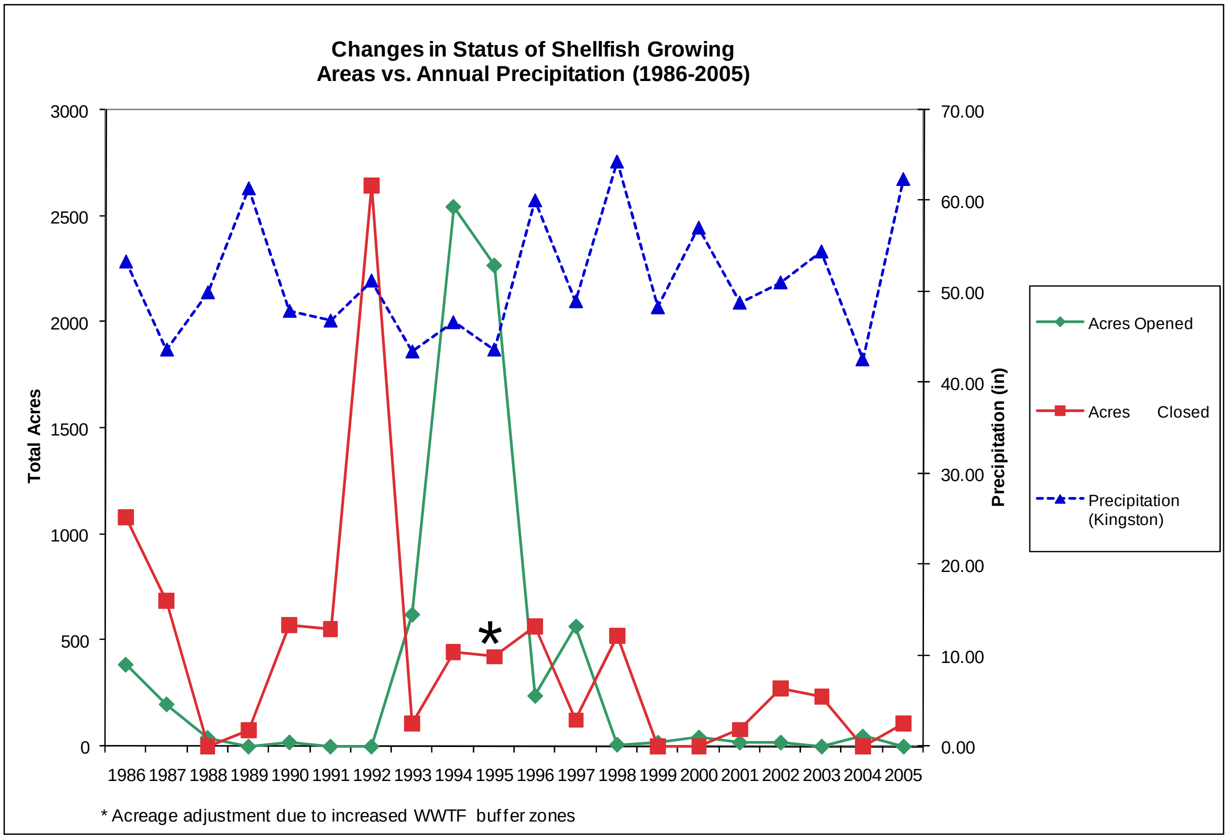
Total number of saltwater beach closure days per season for all Rhode Island salt water beaches versus seasonal total rainfall (May-Sept.). One closure day = 1 beach closed for 1 day. Total for all SW beaches presented here. Data Source: RIDOH Annual Beach Reports 2007 , 2008 (2.29)

► Indicator: Shellfish Area Restrictions and Closures

Importance: Shellfish constitute one of Narragansett Bay's most important fisheries, and the state's largest and most productive quahog beds are located in the upper Bay. As with beaches, bacteria levels are used to assess water quality with respect to shellfish edibility. In other states, including Massachusetts and Connecticut, shellfish can be grown in waters closed to shellfishing, then rendered safe for human consumption through "depuration" methods. In Rhode Island, depuration is not permitted. However, as part of its management scheme, DEM, in cooperation with shellfishermen and the Narragansett Bay Commission, coordinates annual transplant operations: harvesting quahogs from restricted areas for transplant to approved waters where the shellfish are allowed to depurate over a minimum 6 month period, at which point, harvesting in these areas is permissible (2.13, 2.31).

Information: RIDEM monitors the fecal coliform bacteria group to assess the safety of shellfishing areas, using criteria approved by the U.S. Food and Drug Administration (FDA) for interstate sale. Areas that are approved for harvesting are sampled a minimum of six times a year; conditionally approved waters are sampled monthly when they are open. There is no requirement to sample closed areas; DEM conducts sampling in these areas as resources allow. In addition, DEM conducts routine shoreline surveys of the state's shellfish growing waters for purposes of monitoring potential and actual pollution sources which may affect the sanitary condition of these waters. For purposes of monitoring the presence of potentially harmful phytoplankton (harmful algal blooms, or HABs), DEM also collects water samples for phytoplankton identification from April through November when blooms are observed (2.13). Maps of shellfish closures are available on RIDEM's website at http://www.dem.ri.gov/programs/benviron/water/shellfsh/clos/index.htm.
Rhode Island's shellfish program is one of the broadest monitoring programs on Narragansett Bay, with two small boats covering most of the state's marine waters measuring fecal coliform in surface waters Though beyond the scope of the National Shellfish Sanitation Program and DEM's current funding capacity, by expanding the measurements to include additional useful parameters such as nutrients, dissolved oxygen, chlorophyll and water clarity, this program could contribute to the continued development of a larger ecological monitoring program for Narragansett Bay. However, such increased efforts will require an evaluation of impacts on holding times and lab drop-off deadlines for bacteria samples, as well as increased costs for staff time involved.

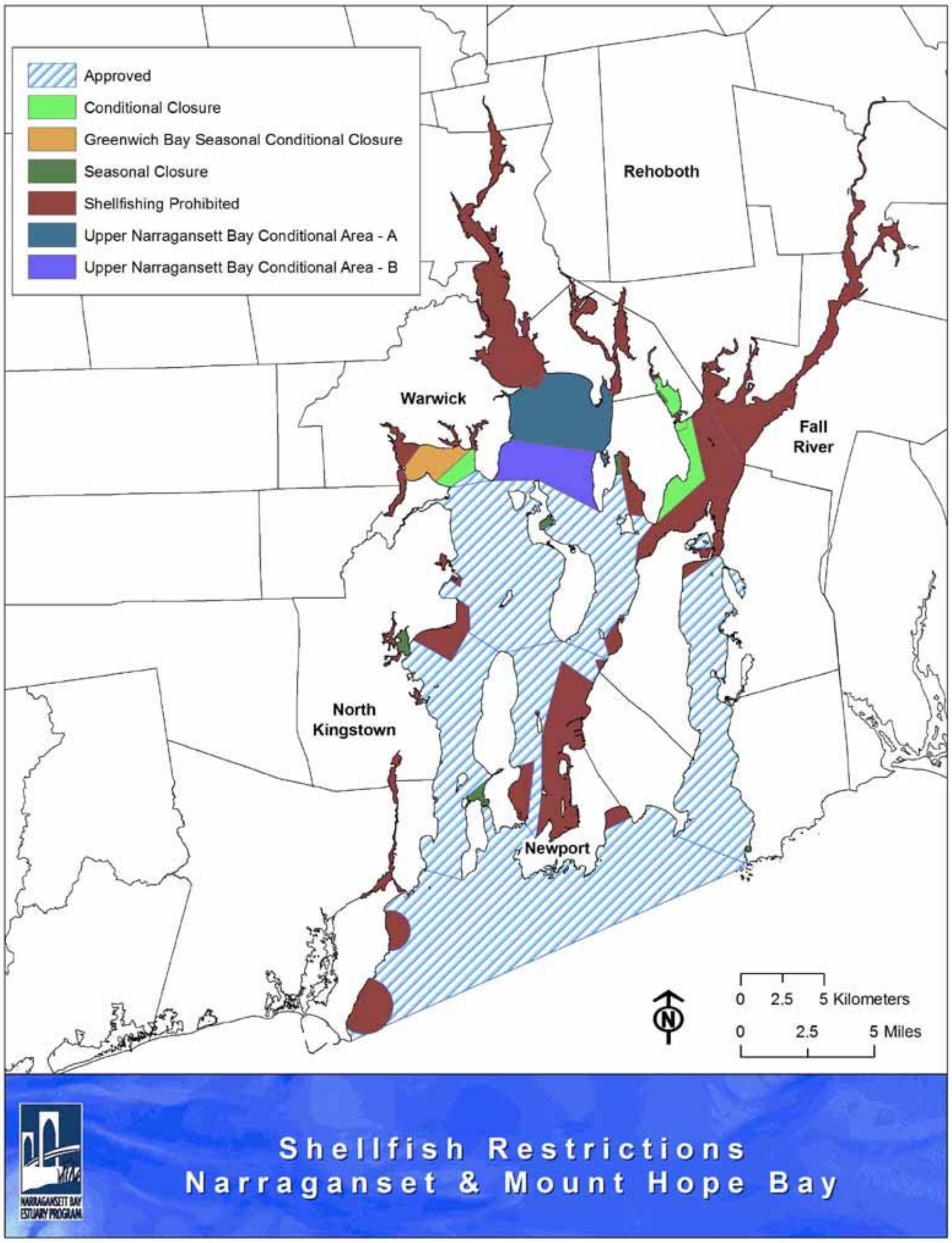
Status & Trends: As with hypoxia and primary productivity, shellfish closures on Narragansett Bay reflect a north-south pollution gradient as well as the impact of weather, particularly rainfall, and are highly influenced by local stormwater discharges and other local pollution sources as evident in the closures in place for various small embayments in Narragansett Bay and the Salt Ponds. Closure rates in the upper Bay (conditional areas A and B) are projected to decrease due to the recently completed combined sewer overflow (CSO) retention tunnel in Providence by the Narragansett Bay Commission (NBC) – Phase I of a three-phase CSO control program. DEM recently implemented a post-storm monitoring program in an effort to maximize this potential increase in shellfish harvesting in upper Bay due to expected decrease in frequency of combined sewer overflows (2.13). The 2008 Integrated Report indicates that approximately 21% (27.2 sq. mi.) of Rhode Island estuarine waters designated for shellfishing are presently impaired (2.3).



Changes in status in all shellfish growing areas vs. annual precipitation 1986-2005

In 1986, a total of 1081 acres were newly restricted. 355 acres due to increased boating use in Great Salt Pond, resulting in a change from approved to conditionally approved/seasonal. A total of 615 acres of other closures were due to exceedance of bacteriological monitoring results in the Pettaquamscutt River and Bristol Harbor areas. A total of 687 acres were closed to shellfishing in 1987, mainly due to exceedance of shellfish standards during the summer season at Green Hill Pond and the discovery of point source discharges (Sherwood area of Portsmouth) in the Sakonnet River area.

In June 1990, the conditional area of Upper Narragansett Bay was divided into Areas A and B, due to better water quality in the southern portion of the Bay. The southern portion (Area B) can remain open to shellfishing during



rainfall events up to 1". This operational change resulted in fewer closures in that area of the Bay. In August 1991 a statewide shellfish closure occurred following excessive rains from Hurricane Bob. All areas were reopened to shellfishing within nine days.

Due to a series of winter storms in 1992, 2543 acres of Greenwich Bay were closed due to an exceedance of bacteriological monitoring standards. A comprehensive sanitary survey of Greenwich Bay in conjunction with the FDA was conducted during the spring / summer of 1993 and this survey was used to develop an operating procedure for managing Greenwich Bay. In 1994, Greenwich Bay was reopened to shellfishing as a conditionally approved area. In 1995, 2265 acres of the Mount Hope and Kickemuit River area were changed from prohibited to conditionally approved due to the results of a study that determined the area could be managed on a conditionally approved basis. It is thought this water quality improvement was due to improved maintenance of CSOs in the Fall River area. More recent CSO treatment storage development in Fall River is likely to further improve this area for bacterial pollution issues.

In 2007, DEM enacted closures of nine uncertified coastal ponds and/or marshes following notification by the federal Food and Drug Administration that experimental testing methods indicated a wild oyster sample from an uncertified (non-evaluated) area, Quicksand Pond in Little Compton, tested positive for Norovirus. DEM has begun monitoring these small inlets, ponds and marshes that, while adjacent to shellfish growing areas in class SA waters, were not previously themselves routinely evaluated. Based upon these new data, three areas are opening to the harvest of shellfish beginning Memorial Day weekend 2009: Nags Creek on Prudence Island and two areas along the Tiverton shoreline of the Sakonnet River. On an annual basis, DEM re-assesses the classification of all shellfish waters based upon the previous year's ambient water sampling and shoreline survey results. Impacts from major rainfall events like hurricanes are responded to with immediate emergency closures until bacterial data shows the conditional areas have improved. DEM has since been sampling these waters, with areas prioritized based on historic use and the lack of obvious pollution sources.

SIDEBAR: Toxic Substances in Fish Tissue

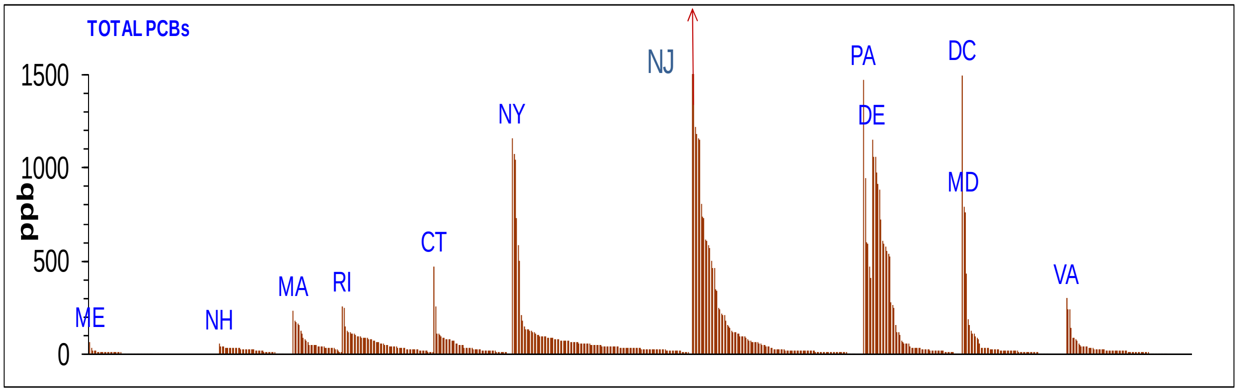
Toxic chemicals are present at low concentrations throughout the global environment, a legacy of centuries of manufacturing, energy production, transportation, and insect control. Many toxics degrade slowly in the environment, and can therefore bioaccumulate, becoming concentrated in the tissues of fish and wildlife. Substances of particular concern in this regard are toxic metals such as mercury and lead, and chlorinated organic compounds such as DDT and PCBs. Many of these chemicals can be toxic to fish, wildlife and humans and are commonly present in urbanized estuaries such as Narragansett Bay.

USEPA, through its National Coastal Assessment (NCA) Program, analyzed fish tissue samples taken from Narragansett Bay and other northeastern estuaries for the presence of a variety of toxic substances, including 25 types of polycyclic aromatic hydrocarbons (PAHs), 21 types of PCBs, chlorinated pesticides including DDT, and 13 metals, including mercury. Information on species sampled, concentrations detected, etc. is available at http://oaspub.epa.gov/coastal/coast.search. Results were compared with "screening values" (SV) using noncarcinogenic human health endpoint concentration ranges as an approximation of ecological risk. Details are available at http://www.epa.gov/waterscience/fish/advice/es.html. It should be noted that the fish sampled are all seasonal migratory species that may absorb some of these chemicals outside of Rhode Island waters.

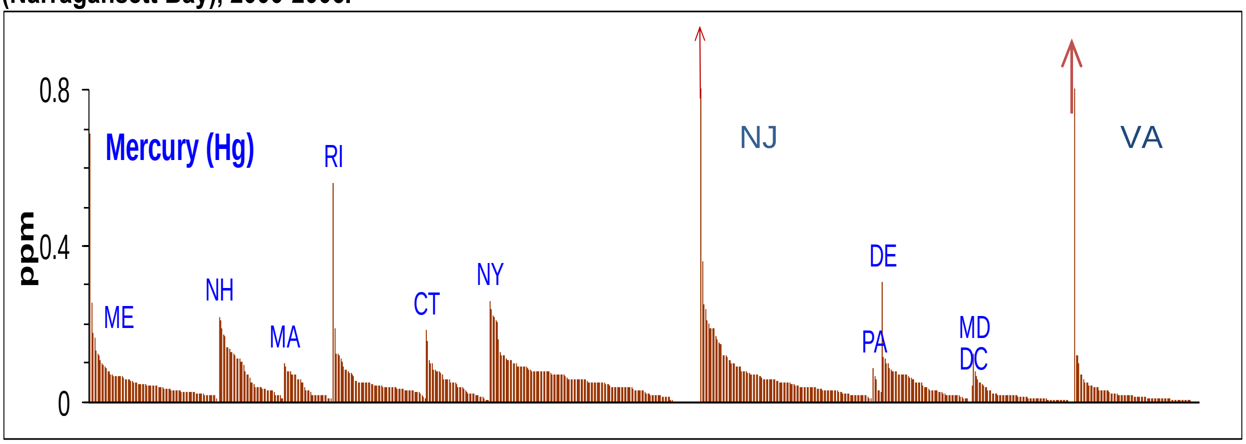
Results for Rhode Island found two chemicals violating the SV range levels: mercury (Hg) and PCBs. Most of the Rhode Island results fell within a range comparable to other industrialized states. A principal source of environmental mercury is air deposition from coal-fired power plants and other large scale burning of fossil fuels.

For total PCBs, the incidence of exceedance is more common. Again, Rhode Island falls within the pattern for the industrialized Northeast that encompasses the coast from southern Maine to Virginia. The Rhode Island fish tissue samples fall within expected ranges for this chemical group. Sources of PCBs include atmospheric deposition and runoff from the watershed, especially in historical industrial settings.

Total PCBs in individual fish samples from Northeast coastal states, including Rhode Island (Narragansett Bay), 2000-2006.



Total mercury (Hg) in individual fish samples from Northeast coastal states, including Rhode Island (Narragansett Bay), 2000-2006.



Source: USEPA National Coastal Assessment. Additional support was provided by USEPA Atlantic Ecology Division in Narragansett, R.I.

3. Fresh Waters

Introduction: 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. On average, more than two billion gallons of fresh water enter 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 (3.1). These flows deliver fresh water to the Bay and also carry pollutants which enter Narragansett Bay and nearby estuaries. The quality of fresh water resources throughout NBR is therefore tremendously important to the condition of coastal waters.

The status of NBR's fresh water resources is affected by development patterns within the watershed. During the past half century, suburban sprawl throughout NBR has resulted in a vast 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. Long term water quality trends in three New England Rivers (Merrimack, Blackstone and Connecticut) during the 20th century reflect the shift from an agricultural to urbanized landscape. During the century, nitrate, chloride and residue concentrations have increased likely due to the increased use of road de-icing salts and the increased use of nitrogen fertilizers. Sulfate and total phosphorus concentrations have decreased in many areas due to decreases in phosphorus fertilizers and detergent phosphate bans (3.2).

In the Narragansett Bay Region in recent decades, major investments in WWTFs have resulted in marked water quality improvements. Overall, the water quality of the region'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 (3.3).

Water quantity or flow is also an emerging issue of concern (3.4). Increasing and competing demands for water supply and wasteful summertime water use in some communities leads to uncertain conditions for economic development and has begun to dangerously draw down some rivers, ponds and wetlands.

Several of the indicators presented in this section are taken from the Rhode Island and Massachusetts statewide assessments of water quality required under section 305(b) of the Clean Water Act. The states report on water quality every even year (2004, 2006, 2008).

► Indicator: Fresh waters impaired by bacteria

Importance: As in salt water, 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) are not disease-carrying organisms, but as they 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) (3.5).

Information: This information is 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 (3.4) (3.6). 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 (3.7).

Status: There are 1,498 river miles in Rhode Island and 1,283 river miles in the Massachusetts portion of NBR. In Rhode Island, all assessed rivers are monitored for bacteria and all the major rivers are listed as impaired for bacteria.

Bacteria in the Narragansett Bay Region Rivers, 2008

State	Total river miles	River miles assessed for swimming	Miles impaired by bacteria	Percentage of assessed miles impaired by bacteria
Rhode Island	1,498	606	240	39.6 %
Massachusetts	1,283	376	196	52.1 %
TOTAL	**2,781**	**982**	**436**	**44.4 %**

There are 20,917 lake acres in Rhode Island and 23,346 lake acres in the Massachusetts portion of the NBR. Bacteria are a concern in lakes and ponds used for swimming and boating. Bacteria impair less than two percent of the lake acres assessed.

Bacteria in Narragansett Bay Region Lakes, 2008

State	Total lake acres	Lake acres assessed for swimming	Acres impaired by bacteria	Percentage of assessed acres impaired by bacteria
Rhode Island	20,917	14,488	562	3.9%
Massachusetts	23,346	18,222	36	0.2 %
TOTAL	**44,263**	**32,710**	**598**	**1.8 %**

► Indicator: Fresh waters impaired for dissolved oxygen

Importance: As in estuarine waters, 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 (cascading water) 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. RIDEM has freshwater standards for both cold and warm water fish habitat; cold water standards adjust to be protective of life stages of fish species. The RIDEM water quality standards are available at http://www.dem.ri.gov/pubs/regs/regs/water/h20q06.pdf.

Information: The indicator is taken from the same sources as noted above for bacteria.

Status: In Rhode Island, low DO is listed as an impairment for about five percent of assessed river miles and ten percent of assessed lake acres. In the Massachusetts portion of NBR, low DO is an impairment in 27 percent of assessed river miles and five percent of assessed lake acres.

Dissolved Oxygen in Narragansett Bay Rivers, 2008

State	Total river miles	River miles assessed for aquatic life support	Miles impaired by low DO	Percentage of assessed miles impaired by low DO
Rhode Island	1,498	650	33	5.1 %
Massachusetts	1,283	378	103	27.2 %
TOTAL	**2,781**	**1,028**	**136**	**13.2 %**

Dissolved Oxygen in Narragansett Bay Lakes, 2008

State	Total lake acres	Lake acres assessed for aquatic life support	Acres impaired by low DO	Percentage of assessed acres impaired by low DO
Rhode Island	20,917	14,941	1,493	10.0%
Massachusetts	23,346	18,222	945	5.2 %
TOTAL	**44,263**	**33,163**	**2,438**	**7.4 %**

► Indicator: Fresh waters impaired by nutrients

Importance: 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 (3.8).

Information: The indicator is taken from the state reports cited above. Rhode Island and Massachusetts do not have numerical criteria for nutrients in rivers. Rhode Island has a numerical standard for total phosphorus in any lake, pond, kettlehole, or reservoir and tributaries at the point where they enter such bodies of water. Nutrients are some of the parameters evaluated to assess Aquatic Life Use Support.

Status: In Rhode Island, four percent of assessed river miles are considered impaired by nutrients. In the Massachusetts portion of NBR, nutrients are a listed impairment in 25 percent of assessed river miles and six percent of lake acres.

Nutrients in Narragansett Bay Region Rivers, 2008

State	Total river miles	River miles assessed for aquatic life support	Miles impaired by nutrients	Percentage of assessed miles impaired by nutrients
Rhode Island	1,498	650	29	4.5 %
Massachusetts	1,283	378	95	25.1 %
TOTAL	**2,781**	**1,028**	**124**	**12.1 %**

Nutrients in Narragansett Bay Region Lakes, 2008

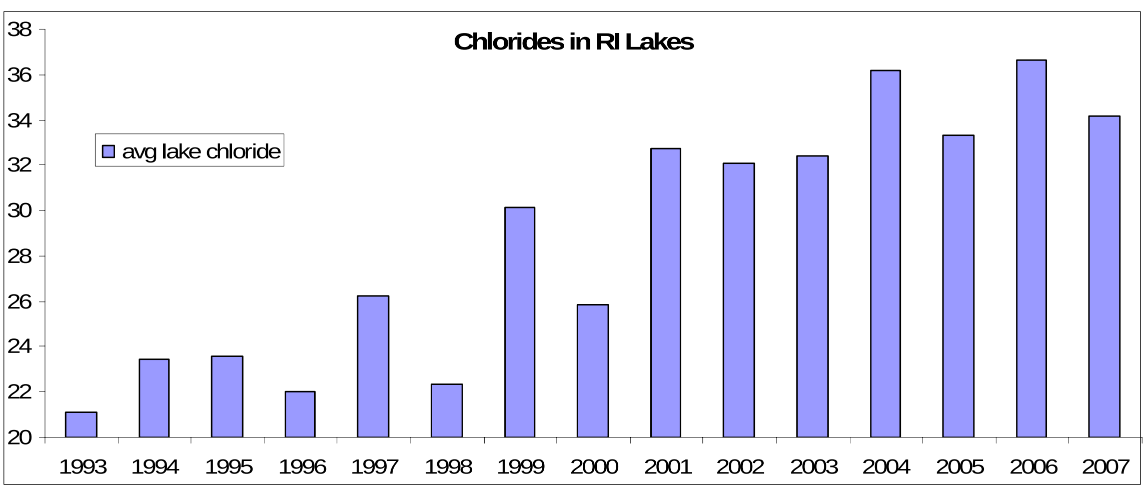
State	Total lake acres	Lake acres assessed for aquatic life support	Acres impaired by nutrients	Percentage of assessed acres impaired by nutrients
Rhode Island	20,917	14,941	2,205	14.8%
Massachusetts	23,346	18,222	1,093	6.0 %
TOTAL	**44,263**	**33,163**	**3,298**	**9.9 %**

► Indicator: Chloride in lakes

Importance: Wintertime road maintenance with salt and similar materials has been shown to harm freshwater systems. This problem is discussed in a study by the U.S. Geological Survey (USGS) of the Scituate Reservoir watershed which evaluated sources of sodium and chloride to the reservoir during water year 2000 (October 1999 – September 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 during the 2000 water year, accounting for 67 % of the 1,000 tons of sodium and 90 % of the 2,300 tons of chloride introduced into the basin (3.9).

Information: URI Watershed Watch volunteers have monitored chloride since 1988 (3.10). None of the results exceed state criteria for aquatic life (chloride concentrations of 860 mg/l (acute effects), 230 mg/l (chronic)) but many of the stations show a trend of increasing concentration over time.

Status and Trends:



Average chloride concentrations (mg/l) in lakes monitored by the URI Watershed Watch program suggest increasing concentrations over time (3.10)

► Indicator: Low Flow

Importance: 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.

Status: According to RIDEM, the following Rhode Island watersheds are showing flow stress (3.11):

- **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 (3.12).
- **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.

In **Massachusetts**, the Department of Fish and Game's Riverways Program has developed the pilot **River Instream Flow Stewards (RIFLS)** 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 (3.13):

- **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 (3.15).
- **Palmer River** due to the interbasin transfer of water out of Shad Factory Pond into the Kickemuit Reservoir in Warren, R.I.

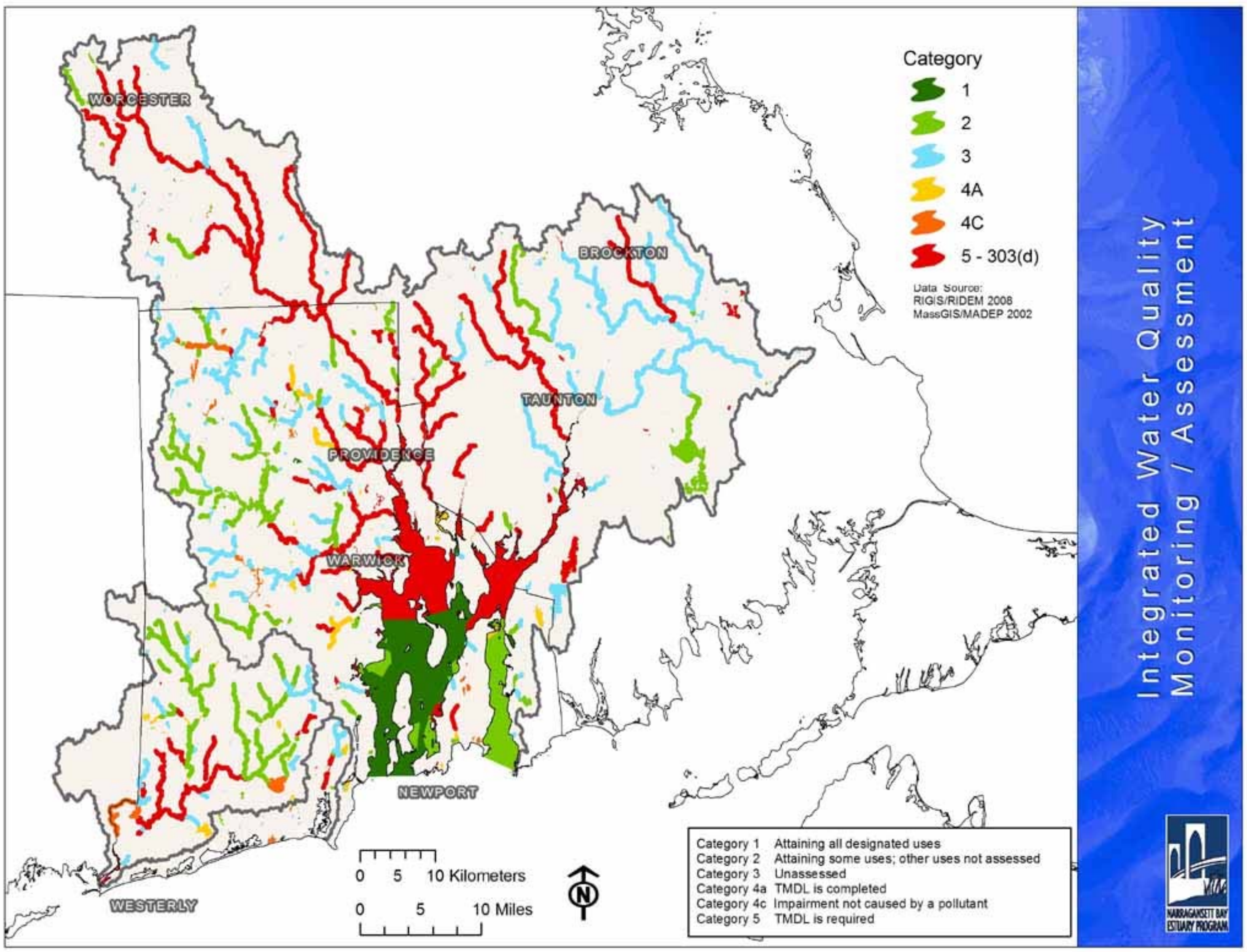
SIDEBAR: How water quality is evaluated by EPA and the states

Is the water clean or dirty? Is it safe to swim in your favorite swimming hole? Can you eat the fish that you catch?

We all want to know the answers to these important questions. In 1972, Congress passed the Clean Water Act to restore and maintain the chemical, physical and biological integrity of the Nation's waters. The Clean Water Act establishes a framework for measuring and evaluating water quality throughout the country: states establish water quality standards for all their waters, water quality is monitored and evaluated relative to the standards and at regular intervals the results are reported to the public and to EPA.

Water quality standards have three components – designated uses, water quality criteria and antidegradation. Designated uses specify how the community wants to use the waterbody – is the river used for drinking water? for canoeing? for agriculture? for fishing and swimming? (The Clean Water Act specifies that all waters must be swimmable and fishable). Water quality criteria are descriptions of the chemical, physical and biological conditions that need to be met in order for a waterbody to be considered attaining its use category. Waters that meet their criteria are said to "support their uses." Waters that do not meet their criteria or support their uses are said to be "impaired" and must be improved. Antidegradation policies provide a framework for protecting water quality once goals are reached and for protecting the quality of waters that already meet their standards.

States are responsible for monitoring water quality and determining if the water quality standards (criteria and designated uses) are being met. These assessments of water quality condition are required under Section 305(b) of the Clean Water Act (CWA). Section 303(d) of the CWA requires states to develop a list of waters that do not meet water quality standards. Following recent federal guidance, in 2008 Rhode Island and Massachusetts integrated the Section 305(b) water quality assessment report and Section 303(d) Impaired Waters List into a single document known as the Integrated Water Quality Monitoring and Assessment Report (Integrated Report). The Integrated Report, which is published every even year, includes a five-part integrated list format (five Category lists) for reporting the water quality assessment status of the state's waters. The following map describes fresh water quality for the Narragansett Bay Region, based on the 2008 Integrated Lists.



SIDEBAR: Investments in waste water treatment result in improved water quality

There are 35 publicly owned waste water treatment facilities (WWTFs) that discharge to the Narragansett Bay Region waters. Nineteen of these lie within Rhode Island borders with the remaining 16 in Massachusetts. Since the passage of the Clean Water Act in 1972, significant investment in waste water treatment has resulted in improved water quality in rivers throughout the watershed.

The Pawtuxet River is a particular success story. Three municipal WWTFs (West Warwick, Warwick and Cranston) discharge directly to the Pawtuxet River. Field studies in 1980 showed that these discharges caused oxygen

problems in the lower river. In May 1989, RIDEM required the communities to construct advanced treatment facilities to reduce the discharge of organic materials and ammonia and to evaluate alternatives to reduce the discharge of metals. As a result of discussions with RIDEM during the planning stages, the communities agreed to also reduce nitrogen and phosphorus. Construction of advanced treatment upgrades has now been completed at all three facilities and the plants are in compliance with their permit limits. In-stream monitoring of dissolved oxygen concentrations during the late summer of 2007 documented improved conditions and compliance with the dissolved oxygen water quality standard. As a result, in 2008, DO was removed as an impairment on the main stem of the Pawtuxet River. However, these studies documented that excessive plant growth is still an issue and in 2008 RIDEM re-issued the permits with lower phosphorus limits and modifications to the nitrogen limits (3.3).
Improvements to the Blackstone and Taunton Rivers can also be attributed to wastewater treatment plant upgrades. Unionized ammonia has been removed as an impairment on the Blackstone River, likely due to wastewater treatment plant upgrades. Permits were recently issued to the Woonsocket WWF and UBWPAD in Worcester requiring further nitrogen and phosphorus reductions.

SIDEBAR: Phasing out Cesspools

A cesspool is a buried chamber that receives sewage from a building for disposal into the ground. Cesspools provide little or no treatment for the waste as they often intercept the seasonal high groundwater table. Cesspools were installed throughout the state until 1968 when they were banned because of impacts on environmental quality. Although accurate statewide data on numbers or locations is not available, RIDEM estimates that there are up to 50,000 cesspools in Rhode Island. As an example, a study assessing the age of septic system in three Warwick neighborhoods adjacent to Greenwich Bay determined that 630 of 1187 systems evaluated (53%) were pre-1970, and therefore likely cesspools (3.16). Waste from these cesspools seeps into ground and surface waters negatively impacting water quality and public health.

After years of effort, the RI General Assembly passed the Rhode Island Cesspool Act of 2007 (effective June 1, 2008) to phase out high risk cesspools in close proximity to tidal waters and public drinking water (See R.I.G.L. § 23-19.15). Property owners in the following categories are required to address their cesspools in accordance with state law and RIDEM septic system regulations:

1. The cesspool has failed. It must be replaced with an approved ISDS system.
2. The cesspool serves a commercial facility or multifamily dwelling. It must be replaced with an approved ISDS system.
3. If the cesspool is located within the CRMC jurisdiction (within 200 feet of the inland edge of all shoreline features bordering tidal water areas); within 200 feet of all public wells and within 200 feet of a water body with an intake for drinking water supply, the following rules apply:
    - All cesspools must be inspected on a rotating basis, completed by January 1, 2012
    - All cesspools found to be failed will need to be replaced within a year.
    - All cesspools found in sewered areas will need to be hooked up to the sewer system within one year of the sale of the property.
    - All other cesspools will need to be replaced by January 1, 2013.

RIDEM is developing regulations governing implementation of the Cesspool Act of 2007.

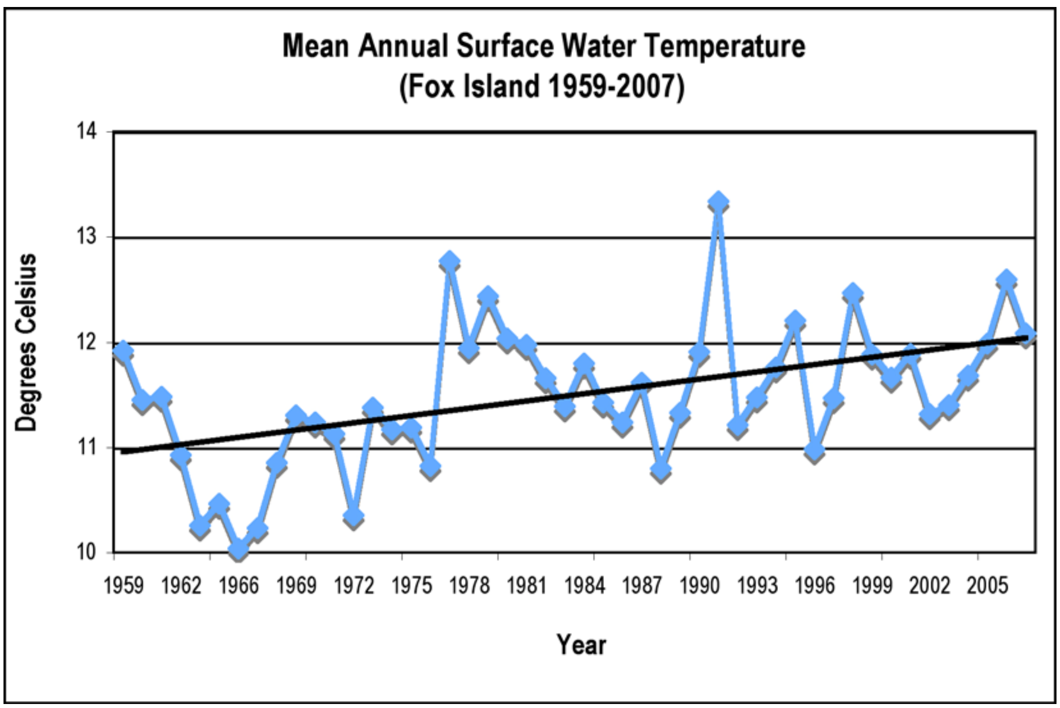
The most recent version of Title 5, the Massachusetts regulations governing onsite waste disposal, went into effect April 21, 2006. Title 5 requires the proper siting, construction, and maintenance of all on-site wastewater disposal systems. Title 5 has special requirements for repairing failed systems. Replacement of cesspools is required if cesspools show signs of hydraulic failure, if they are close to private or public water supplies, or, if for any reason, they pose a threat to public health, safety or the environment in which case they will need to be upgraded. Also, cesspools must be upgraded prior to an increase in design flow. See http://www.mass.gov/dep/water/wastewater/septicsy.htm for more information on Title 5.

4. Living Resources

Introduction: The Narragansett Bay Region lies near the boundary of two major biogeographical regions: the Virginian Province along the mid-Atlantic coast and the Acadian Province along the coast of Northern New England and the Canadian Maritimes (4.1). This location contributes to NBR's biodiversity, as both southern and northern species are present, but may also increase the region's vulnerability to climate change, as many native species are at the geographic limit of their ranges.

The ecology of NBR has been greatly altered by human habitation and use, particularly over the past 300 years, and continues to change as a result of human influence at all scales. Global warming appears to already be affecting the region, and is likely to have significant impacts over the next century (4.16). Increases in average air and water temperatures affect species composition, leading southern species to become more abundant while northern species decline. Accelerated sea level rise is likely to cause loss of coastal wetlands, as described below. Climate change is believed to be linked with changes in precipitation patterns, such as reduced snowfall, with potential impacts on terrestrial, aquatic and estuarine ecosystems. And warming can, in some cases, foster the proliferation of invasive species, such as the wooly adelgid, which is presently destroying native stands of hemlock trees throughout New England (4.15).

The University of Rhode Island's fish trawl survey provides long-term data on water temperature at Fox Island in Narragansett Bay. For the following graph, NBEP averaged URI's sea surface data on an annual basis, then graphed it using Excel to illustrate the statistical trend, which suggests an increase of about one degree Celsius since 1959. These results are similar to temperature increases reported for Buzzards Bay, Mass. (4.17).



Source: URI Trawl Survey, www.gso.uri.edu/fishtrawl

In recent years, a new class of positive human impact has become significant—habitat restoration, whereby ecological functions can be restored to rivers, wetlands and other natural systems that have been damaged or destroyed. Since the mid-1990's, partnerships comprised of federal, state, local and non-governmental organizations, working together, have restored hundreds of acres of valuable habitat throughout the Narragansett Bay Region.

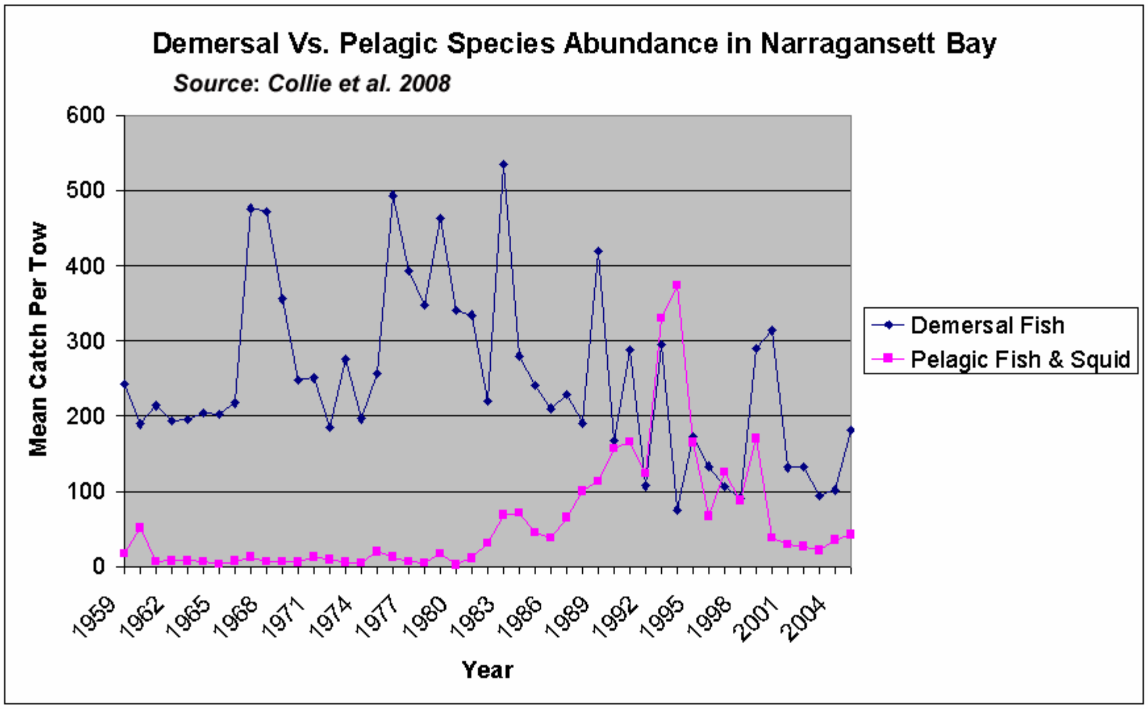
► Indicator: Estuarine Fish

Description: 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 fisheries and commercial fisheries generate hundreds of millions of dollars annually (4.2). 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.

Information: Both the University of Rhode Island and the R.I. Department of Environmental Management conduct fish trawl surveys which collect detailed data at several locations in Narragansett Bay. The URI trawl survey in particular, begun in 1959, offers the longest-running continuous ecological dataset on Narragansett Bay.

Trawl survey methodology catches most, but not all estuarine species. For example, American eel are not represented in the datasets because they slip through the mesh of the nets. Also, trawl surveys can only be done in deeper, open-water areas where fishing vessels can operate; they do not, therefore, provide information on habitat utilization in nearshore areas.

Status & Trends: An analysis conducted by Collie et al. (4.3) examined long-term shifts in species composition of Narragansett Bay fish and shellfish, using the URI trawl survey data. The study found a general decrease over time in demersal, or bottom-dwelling fish, coupled with increases in benthic invertebrates such as crabs and lobsters, as well as pelagic (mid-water) fish and squid. The researchers suggest that these changes appear to be driven primarily by warming trends (due to correlation with changes in sea-surface temperature) and secondarily by fishing pressure (as evidenced by a decrease in average fish size over time). These findings are generally consistent with the conclusions of the R.I. Dept. of Environmental Management, which reported that resident demersal species such as flounders and sculpins—even those which are not the target of commercial or recreational fisheries—have "declined substantially relative to historic levels" (4.4). As with any complex resource, there are undoubtedly many factors affecting Narragansett Bay's fish populations, and different factors affecting different species.



► Indicator: Wetland Change

Description: Wetlands are among the most important habitats in the Narragansett Bay Region. Fresh-water wetlands include a wide variety of swamps, bogs, fens, marshes, riverine floodplains and other types. They provide habitat for fish and wildlife and are essential to water quality, serving as natural treatment areas to filter pollution from urban stormwater. Freshwater wetlands help maintain groundwater quality and quantity by providing areas where surface and rainwater can recharge aquifers. They also 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.

Information: Freshwater wetlands are monitored in Massachusetts by the state Dept. of Environmental Protection, which uses aerial photography to identify wetland areas and track changes over time (4.5). At the request of NBEP, Paul Jordan of R.I. Dept. of Environmental Management undertook GIS analysis of these data, in order to determine status and trends of freshwater wetlands in the Massachusetts portion of the Narragansett Bay Region (Blackstone, Ten Mile and Taunton River sub-basins) during the period 1991 to 2001. Results of this analysis are provided below. In Rhode Island, actual freshwater wetland change is not monitored, although the state tracks permitted losses and gains, as well as losses and gains related to enforcement actions. Data on coastal wetland change on Narragansett Bay is provided by an NBEP study, completed in 2004, which assessed trends from the 1950's to the 1990's using aerial photography (4.6).

The most significant data issue is that Rhode Island does not monitor actual (as opposed to reported) wetland change for either coastal or inland wetlands. In the case of inland wetlands, an up-to-date baseline does not exist, as the state's current GIS information is based on 1988 data; so, in order to track wetland change in a meaningful way, an updated baseline inventory of freshwater wetlands would first need be established. The Massachusetts data are fairly current, providing an up-to-date baseline, and there is an active program to monitor future change. In the case of Narragansett Bay's coastal wetlands, there is a solid analysis of wetland change over a 44 year period and a solid 1996 baseline. However there is no ongoing program to track changes or update baseline data. The two states characterize wetland types differently, making cross-border or watershed-based analyses difficult. For purposes of environmental monitoring and reporting, it would be useful to establish a uniform coverage for all types of wetlands throughout NBR, and to track wetland change at regular intervals. 10 year intervals would provide a powerful time series of wetland change.

Status & Trends: During the 19th and 20th centuries, wetlands were destroyed and altered on a grand scale throughout the Narragansett Bay Region (4.7). Wetlands were drained and filled for agriculture, land development (industrial, urban, commercial and residential) and transportation—road, rail, marine and air. 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, albeit at a slower pace than formerly. 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 (4.8). As sea level rise accelerates, a concern is that this process of sediment accretion may not keep pace, resulting in loss of coastal wetlands (4.9).

The NBEP/DEM analysis of the Mass. DEP wetlands data produced the following trends table summarizing freshwater wetland gains and losses in the Massachusetts portion of NBR over a recent ten-year period:

Freshwater Wetlands in Mass. Portion of the Narragansett Bay Region.   Source: Mass. GIS, 2008

Wetland Type	Total Acres 2001	Approx. Percent of Mass/NBR Land Area	Acres Lost, 1991-2001
Bog	1218	< 1%	1
Cranberry Bog	3022	< 1%	0.5
Deep Marsh	5228	< 1%	30
Shallow Marsh Meadow or Fen	5652	< 1%	50
Shrub Swamp	11,417	2%	47
Wooded Swamp (Coniferous)	2568	< 1%	5
Wooded Swamp (Deciduous)	41,455	6%	169
Wooded Swamp (Mixed Trees)	19,345	3%	96
Total	*89,905*	*14%*	*398.5*

An analysis was also undertaken on freshwater wetlands in the Rhode Island portion of NBR. The state categorizes wetlands differently than Massachusetts and lacks map-based change data. The following table, therefore, summarizes status only. Existing GIS data are for 1988.

Freshwater Wetlands in R.I. Portion of the Narragansett Bay Region

Wetland Type	Total Acres, 1988	Approx. Percent of R.I./NBR Land Area
Emergent Wetland (Fen or)	190	< 1%
Emergent Wetland (Marsh/Wet Meadow)	3703	< 1%
Forested Wetland (Coniferous)	9564	2%
Forested Wetland (Dead)	134	< 1%
Forested Wetland (Deciduous)	55,672	11%
Scrub-Shrub Swamp	8175	2%
Scrub-Shrub Wetland (Fen or)	1753	< 1%
Total	*79,191*	*16%*

Source: RIGIS, 2008

Trends in coastal vegetated wetlands from the NBEP study are provided in the following table.

Coastal Vegetated Wetlands on Narragansett Bay

Habitat Type	Total Acres 1950's	Total Acres 1990's	Acres Lost, 1950s – 1990s	Approx. Percent Lost
Estuarine Marsh	2966	2660	306	10%
Estuarine Oligohaline Marsh	283	356	(gain) 73	(gain) 26%
Estuarine Scrub-Shrub Wetland	129	147	(gain) 18	(gain) 14%
Total	*3378*	*3163*	*215*	*6%*

Source: Tiner et al. 2004

► Indicator: Invasive Species

Importance: 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 (4.10). Invasive species are a principal threat to native biodiversity of an ecosystem (4.11). 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.

Information: In 2000 and 2003, NBEP, R.I. Coastal Resources Management Council and the Narragansett Bay National Estuarine Research Reserve coordinated a "Rapid Assessment Survey" (link: http://massbay.mit.edu/exoticspecies/exoticmaps/index.html) 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 RAS focused only on sessile (stationary) organisms and did not produce a time series. It did, however, provide a robust baseline dataset for use in tracking future changes.

Status & Trends: Although there are no time series data on the subject, it is clear that invasive species are present in estuarine, fresh water and terrestrial systems, and that many of these introductions are recent.

The NBEP rapid assessment survey of Narragansett Bay fouling organisms identified 124 species altogether, of which 92 were identified as native, 21 were clearly introduced from Europe or the Pacific, and 17 were "cryptogenic" (origin unknown). 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 (*Hemigrapsus sanguineus*), a small crab found under rocks in the intertidal zone. The Narragansett Bay National Estuary Research Reserve, located on Prudence Island, initiated an invasive crab monitoring program targeting this species in 2007. Preliminary work involving four sites on Prudence Island was used to refine field protocols that will establish a permanent invasive crab monitoring program. Working with URI, the NBNERR is continuing full-scale Bay surveys.

The next invader expected to be seen in southern New England waters is the Chinese mitten crab (*Eriocheir sinensis*). This species invaded Europe during the early 1900's and the U.S. West Coast during the 1990's, and has become established and abundant in both areas. On the U.S. East Coast, the crabs first appeared in Chesapeake Bay in 2005, and Delaware Bay and the Hudson River in 2007.

Unlike native species, this crab is catadromous—living in fresh water as adults, and migrating to estuarine salt water in the fall in large numbers to mate and release planktonic larvae. Young crabs settle in estuaries and move up to tidal freshwater areas in spring and summer to mature, usually burrowing into river banks and levees between the high and low tide marks. However, this crab can leave the water, cross dry land and enter a new river system. They are capable of migrating around dams, over levees and across roads. Older juveniles are found further upstream than younger juveniles, and in China and Europe they have been reported several hundred miles from the sea. In California they have been found in swimming pools.

Mitten crabs apparently do not burrow as extensively in non-tidal areas, so within 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.

► Indicator: Seagrass Beds

Importance: Sea grass or "submerged aquatic vegetation" (SAV) is a valuable estuarine habitat, providing protection and forage for fish, shellfish, waterfowl and other fauna. On Narragansett Bay, the major species of concern is eelgrass *(Zostera marina).* This plant was once widespread throughout Narragansett Bay, but is now limited to the lower half of the Bay—another indication of the pollution gradient discussed in the first chapter of this report. Eelgrass is extremely sensitive to increased nutrient loads as well as increased temperatures. Changes in the extent of eelgrass serve as an excellent indicator of habitat quality in the estuary, and can help determine whether eutrophication is occurring (4.12).

Information: NBEP, Save The Bay, the Narragansett Bay National Estuarine Research Reserve, and University of Rhode Island have undertaken two studies, one in 1996 and another in 2006, which used aerial surveys and GIS mapping to measure the extent of eelgrass in the Bay (4.13). NBEP also developed a long-term assessment of eelgrass in the Bay using a variety of historical sources, including 19th century nautical charts and interviews with former fishermen (4.14). Long-term trends analysis is limited by lack of historical photos or surveys specifically targeting this species. The more recent studies are quite definitive, but are not part of a regular monitoring effort.

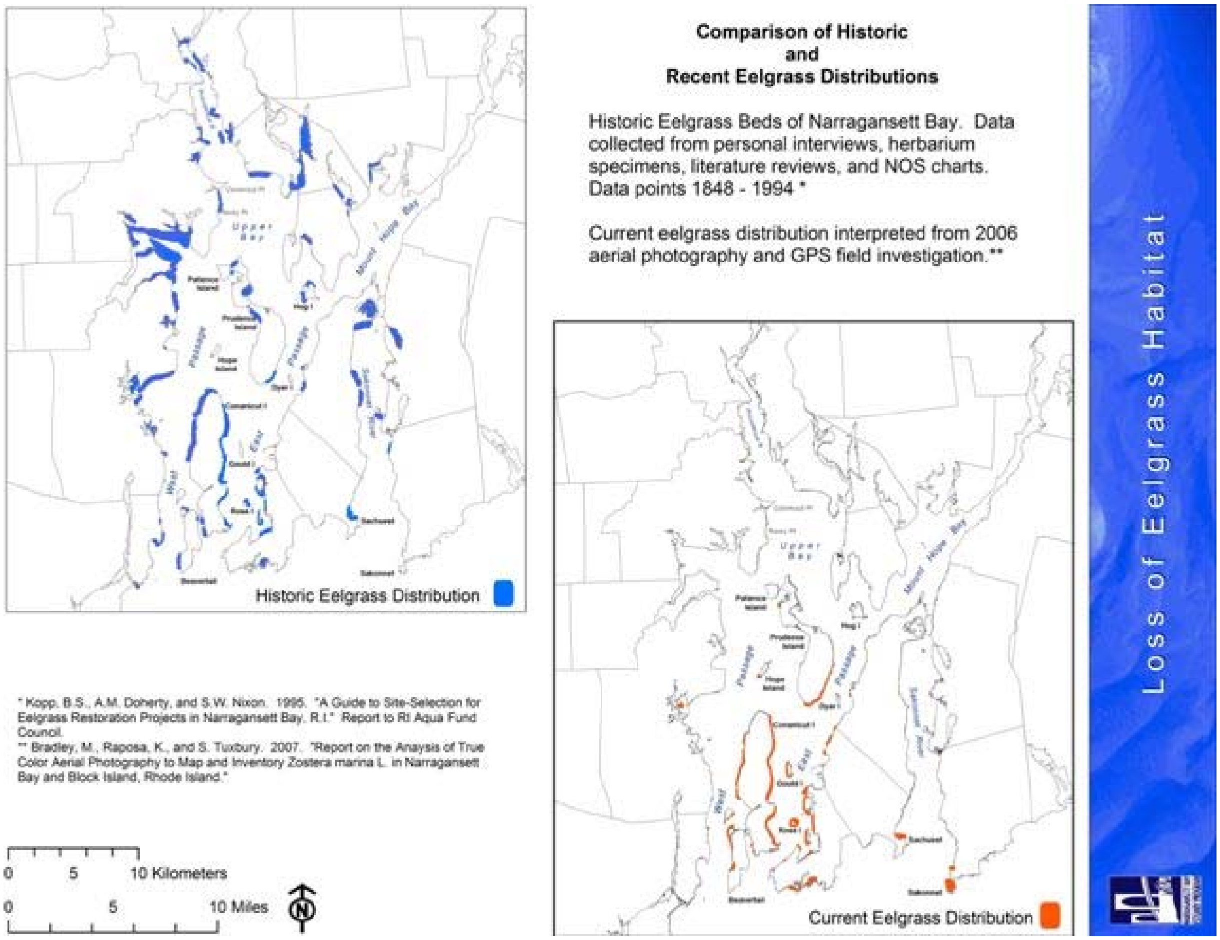
Status & Trends: Eelgrass was once widespread throughout Narragansett Bay, but is now present only in the lower Bay, from Prudence Island south. Upper-Bay eelgrass beds have been entirely lost over the past 50-100 years. While several factors have been implicated in the loss of eelgrass coast-wide, excess nutrients from WWTFs and urban runoff are believed to be important factors (4.12).

According to the 2006 study (4.13), there are 404 acres of eelgrass in Narragansett Bay, distributed as follows:

Eelgrass in Narragansett Bay, 2006 (4.13)

Location	**Acres mapped**
East Passage	208.9
Narragansett Bay – Marine (south-facing Atlantic edge)	114.2
Sakonnet River	28.4
West Passage	52.8
Total Acres Mapped	*404.3*

Jamestown (Conanicut Island) is well-fringed by a thin ribbon of eelgrass beds; significant beds are also present off Newport and Narragansett. The 2006 survey found an increase in eelgrass versus the 1996 study; this may represent the beginnings of a reversal in the historic trend, or may simply reflect year-to-year variability.



Long-term eelgrass trends in Narragansett Bay, based on historical maps, interviews and other sources.

Sidebar: Habitat Restoration

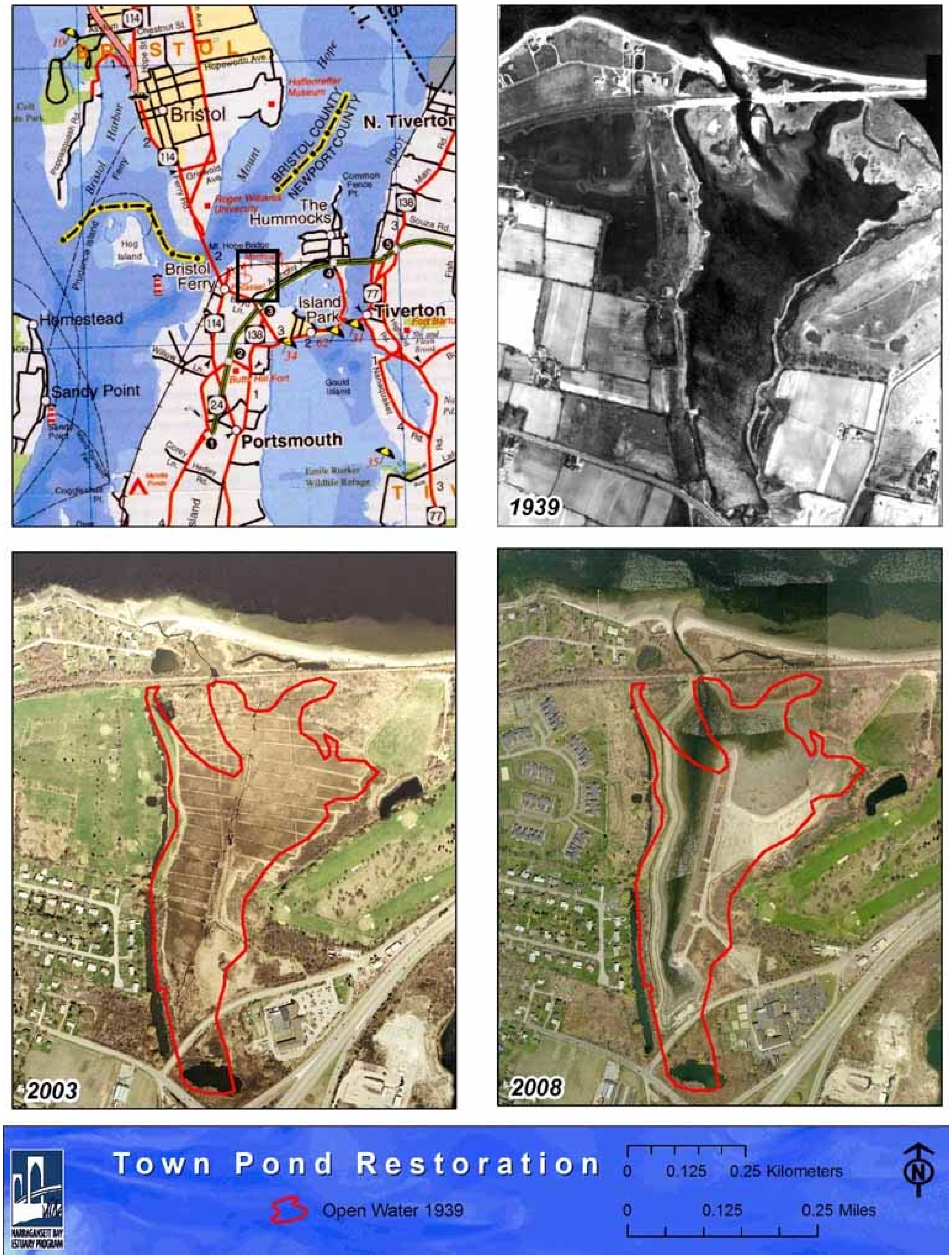
In recent decades, habitat restoration has emerged as a powerful approach to restoring wetlands, rivers and other natural habitats damaged or destroyed by human activity. Funding is provided by state, federal and local agencies, generally working in partnership with local and non-governmental organizations. On Narragansett Bay, coastal wetlands have been restored by re-establishing tidal hydrology and by grading filled areas to restore tidal inundation, 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 anadromous fish.

The largest wetland restoration project completed to date on Narragansett Bay is the Town Pond restoration. Before 1949, Town Pond was a tidal 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 dredged material 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. Over time, the invasive reed *Phragmites* colonized the site and, by the 1990's, established a monoculture on 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 began planning restoration of Town Pond. The plans called for excavation of 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 approximately $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 and R.I. Coastal Resources Council, Aquidneck Island Land Trust and Ducks Unlimited. In-kind support was provided by Town of Portsmouth, Save The Bay and other local partners.


Bristol
N. Tiverton
BRISTOL COUNTY
NEWPORT COUNTY
The Hummocks
Bristol Ferry
Island Park
Tiverton
Homestead
Sandy Point
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NARRAGANSETT BAY ESTUARY PROGRAM

5. Watershed Lands

Introduction: The major story regarding watershed lands is the change from more natural vegetative landscapes to residential, commercial and industrial uses. In Rhode Island, between 1970 and 1995, land has been developed at a rate nine times greater than population growth; trends in the Massachusetts parts of the watershed have been similar. Development often alters the flow of water in the watershed—where rain formerly entered wetlands and groundwater, to be released slowly to surface waters, much of it is now channeled directly to fresh and salt waters through storm drains, pipes and ditches. This storm water runoff carries a variety of pollutants into the Narragansett Bay Regions' rivers, lakes and estuaries, as described elsewhere in this report. Other impacts of land development include habitat destruction and fragmentation, increased noise and light pollution, and even global warming as vegetation is reduced and carbon emissions increase.

Until 2008, land development continued at a strong pace throughout the Narragansett Bay Region, with some slowdowns associated with variations in the economic climate. Now, as the U.S. faces a major economic downturn, development has slowed. If history is an indicator, land development will again increase as the economy recovers. Even at current rates, impacts from existing developed land remain a significant challenge for communities and states.

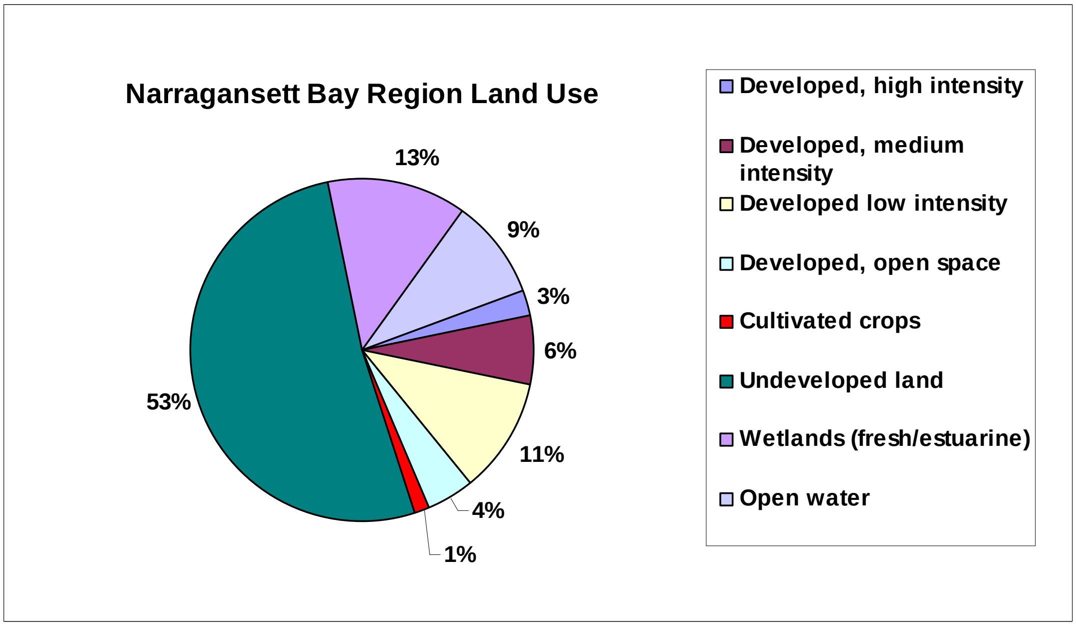
► Indicator: Land Use/Land Cover

Importance**:** The landscape of the Narragansett Bay Region 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.

Information: Measurement of land use is generally based on remote sensing data, using either satellite or aerial photography. In either case the imagery must be interpreted, either by computer, manually, or a combination of the two. Much of this information is now available as state GIS layers; however the coverages are variable. Some studies (such as the Salt Ponds study described below) have involved detailed analysis of aerial photos or building permits; these approaches are labor intensive, and have only been applied to smaller areas within NBR. This report provides basic land use status but not trends for the Narragansett Bay Region and the watershed; however, trends information is more readily available for Rhode Island and Massachusetts, and is reported separately.

Land use and land cover data in NBR is derived from information created at different times and scales, and using a variety of technologies, making it difficult to develop consistent and up-to-date watershed-based analyses. Further, there are inconsistencies between the two states. For example, Rhode Island's most recent land-use data was developed from 2003/2004 aerial photography; while Massachusetts' data is based on aerial photos from 2001 (for R.I. town scale land use maps, see the R.I. Digital Atlas at http://www.edc.uri.edu/atlas). The scale and type of photos also varies: for example, color aerial photos taken by Massachusetts in 2005 are not as detailed as Rhode Island's 2003/2004 data. However, the Massachusetts photos included infrared coverage, more useful in identifying water resources. In 2008, Rhode Island commissioned oblique aerial photos that are useful for some applications; however, it did not obtain standard color orthophotos which would have been consistent with recent data sets. The situation may improve in the future as a new federal dataset becomes available. A group of federal agencies formed the Multi-Resolution Land Characteristics Consortium in 1992 to develop a land cover data set from satellite imagery; this group intends to develop satellite data on land use and impervious surface at five-year intervals beginning with 2000. This quarter-acre resolution data will create a useful time series.

Status - Narragansett Bay Region (includes salt pond watersheds, Wood-Pawcatuck watershed; total area equals 2,066 square miles.



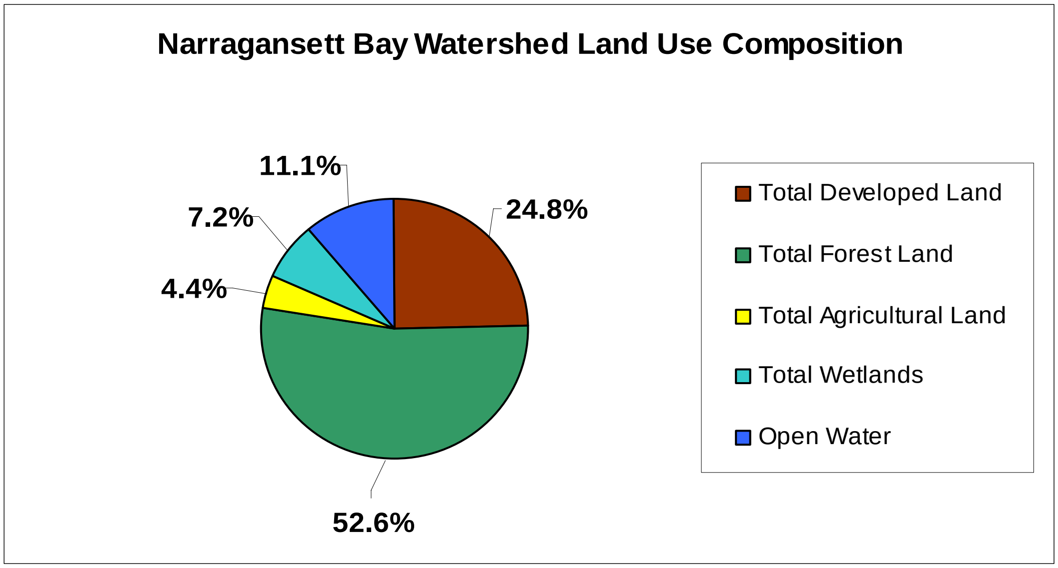
Narragansett Bay Region Land Use categories (5.1):

Developed, high intensity: 80 to 100% impervious	Cultivated crops: land used for crop production, orchards, tilled land
Developed, med. Intensity: 50-79% impervious	Undeveloped land: forested, shrub, scrub, barren land, grasslands
Developed, low intensity: 20-49% impervious	Wetlands (fresh/estuarine): forested, shrub/scrub, herbaceous, emergent, aquatic beds
Developed, open space: mostly vegetated; lawns, parks, golf courses, other vegetated areas; less than 20% impervious cover	Open water: all areas of open water

Status - Narragansett Bay Watershed

Land use for Narragansett Bay watershed is as follows (5.2)

- Watershed area: 1,839.57 square miles including estuarine waters
- Watershed area in Rhode Island – 802.17 sq. miles including estuarine waters; 664.25 sq. miles excluding estuarine waters
- Watershed area in Massachusetts – 1,038.07 sq. miles including estuarine waters; 1,028.34 excluding estuarine waters



Total developed land – 455.25 sq. miles (24.8%)	Total wetlands – 131.62 sq. miles (7.2%)
Total forested land – 967.15 sq. miles (52.6%)	Total open water – 203.66 sq. miles (11.1%)
Total agricultural land – 80.04 sq. miles (4.4%)	Other (bare rock) – 1.85 sq. miles (0.1%)

Status & Trends – Rhode Island

Since 1970, Rhode Island's population increased by about 10%, while land consumption accelerated dramatically as the state's population migrated to rural and coastal areas and employment moved away from 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.

Land Use 2025, the state land use and policy plan, adopted in 2006 by the R.I. Statewide Planning Program, developed the following statistics on the status of Rhode Island land use in 1995, which was the most recent year for which data was available when the plan was adopted (5.3):

Residential - 20%	Agriculture – 7.1%
Commercial land – 1.9%	Wetlands, water, gravel pits, other undeveloped – 19.8%
Commercial/Industrial mixed – 0.2%	Roads, transportation, utilities - 1.9%
Forested land – 43.6%	Developed recreation, institutions, cemeteries, waste disposal, urban vacant – 4.1%
Industrial – 1.2%	

From 1970 – 1995, the report documents the following trends:

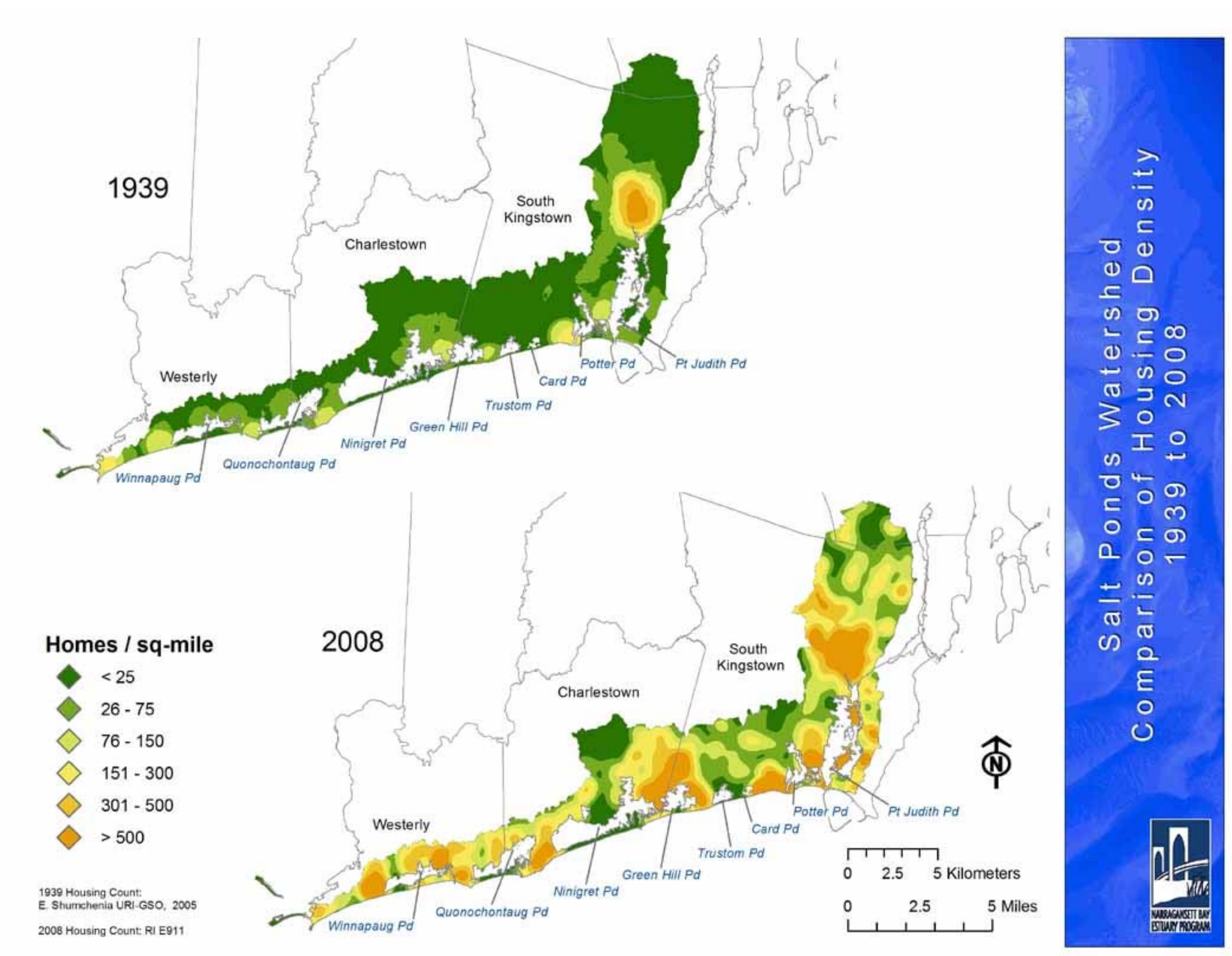
• Residential land – 55% increase	• Industrial land – 62.3% increase
• Commercial land – 88.6% increase	• Total developed land increased by 43%

The same plan estimated that 30 percent of the land which was undeveloped in 1995 has since been developed. The plan states that, 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.

The following land cover change table documents change over a 27-year period based on analysis of LANDSAT remote sensing data (5.4). Units are in square miles.

	1972	1985	1999	Percent change
Urban	140.12	168.8	200.3	43.9
Agriculture	75.13	57.24	46.65	-37.9
Forested	627.5	610.5	599.09	-4.5
Brushland	13.76	10.6	3.85	-72

The increased rate of development and population change was greatest in coastal and rural areas. From 1990 to 2000, the average population of towns in the Rhode Island Salt Ponds region (Westerly, Charlestown, South Kingstown and Narragansett) increased by 12.5 percent, more than double the state's overall growth rate (5.3). A recent study (5.6) documented growth of housing in the Salt Ponds watershed. The map below shows change in density of housing units from 1939 to 2008. Areas of low housing density in this watershed have nearly disappeared (see figure below) as the number of houses has increased: from 2,821 houses in 1939; to 8,487 in 1972; to 14,691 houses in 2003.



Status & Trends—Massachusetts

Trends in Massachusetts are similar those of Rhode Island (5.8). Since the 1970s, land consumption in this area has dramatically outpaced population growth. Between 1971 and 1999, residential land in Massachusetts increased by nearly 47% (5.7). In Massachusetts, nearly 40 acres a day were lost to development between 1985 and 1999, with Worcester County having one of the highest rates of loss (5.7). Nearly nine out of each ten acres lost were used for residential development (5.8). In that same period, Massachusetts lost 143,013 acres of wildlife habitat and much of the remaining forest is highly fragmented (5.8). In a May 2009 update to the MassAudubon *Losing Ground* report, new land use change information was developed: Between 1999 and 2005, twice the amount of land that was developed was protected and the rate of land developed was 22 acres a day. 87% of land use change was due to residential housing development; more than 30,000 acres of forest and 10,000 acres of farmland were converted to residential development over 1999-2005.

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 impacts the lower reaches of the rivers and Narragansett Bay, particularly with respect to nutrient loading and damage to biological systems from alterations to watershed hydrology.

The **Blackstone River** has a watershed of about 640 square miles (382 square miles in Massachusetts) in 29 communities (5.9). 63.3% of the watershed is forested; 8.1% is farmed; and 17.6% is urban. Half of its 48 river miles are in Massachusetts and the entire watershed contains 1,300 acres of lakes, ponds and reservoirs. At the head of the Blackstone River is the city of Worcester with a 2007 population of 173,966 – a 0.9% increase since 2000. Although at one time an industrial center with steel works and other heavy industries (some located directly on the Blackstone), the city is now surrounded by residential, commercial and light industrial areas. Though a 1990 EPA report called the Blackstone, "*the most polluted river in the country with respect to toxic contaminants*", it has seen significant water quality improvements over the last 15 years (5.9).

The **Taunton River** watershed is the second largest in Massachusetts. It has an area of 562 square miles with full or partial land area in 43 towns. As the lower mainstem of the river is undammed, it is tidally influenced 18 miles inland and supports the largest spawning runs of river herring in the state. The river was designated a federal Wild and Scenic River in April 2009. The watershed population in 2003 was estimated at 700,000 (5.10). Current land uses are:

• forested - 55.9%;	• water – 3.3%;
• residential and commercial – 27 %;	• wetlands – 2.7%.
• open land – 11.7%;	

Over the last 25 years, land in the Taunton River watershed has been developed at a rate of 2.5 times the rate of regional population growth. From 1975 to 2005, residential, commercial, and industrial uses increased by 55.4%; forested lands decreased by 12.6%; and wetlands decreased by 5.2%. Since 1971, about 40% of agricultural lands in southeastern Massachusetts have been lost. One study (5.11) projects that, if the current rate of development prevails, developed land in southeast Massachusetts will increase from 29% to 63% by 2030. One-third of that area's open space and agricultural lands have been lost over the past thirty years. In the past thirty years, the populations of the region's three largest cities have increased by only 3.6 %, but the rest of the region has seen population grow by 80.9 %.

Other Massachusetts watersheds that drain to the Bay are the **Ten Mile** (54 square miles), **Palmer, Runnins, Cole and Lee's Rivers** as well as coastal areas adjacent to Mount Hope Bay (112 square miles) (5.10). Though they are smaller than the Blackstone and Taunton, these watersheds drain both urbanized and agricultural areas and can have an effect on Bay water quality.

► Indicator: Impervious Surface

Importance: The change in watershed hydrology—the timing and delivery of water in a watershed—is perhaps the most significant cause of ecological damage in watersheds. Impervious surfaces are rooftops, roads, parking lots, and other hard surfaces characteristic of urban areas that prevent rainwater from infiltrating into the ground. Impervious surfaces channel rainwater into pulses of storm water which increase both the volume and speed at which water drains off the land (5.12). They prevent rain from infiltrating into the ground to replenish groundwater aquifers which bypasses natural pollutant removal processes in soil, while delivering it directly to surface waters (5.13). 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 carries sediments and pollution into streams, lakes, and coastal waters, causing many of the water quality impacts documented elsewhere in this report. The changed hydrology also creates thermal impacts, reducing habitat value (5.14). 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 (5.15, 5.16, 5.17). Storm water from impervious surfaces is also a major source of bacteria, leading to the closure of swimming areas and shellfish beds as discussed in the Fresh and Estuarine Waters sections.

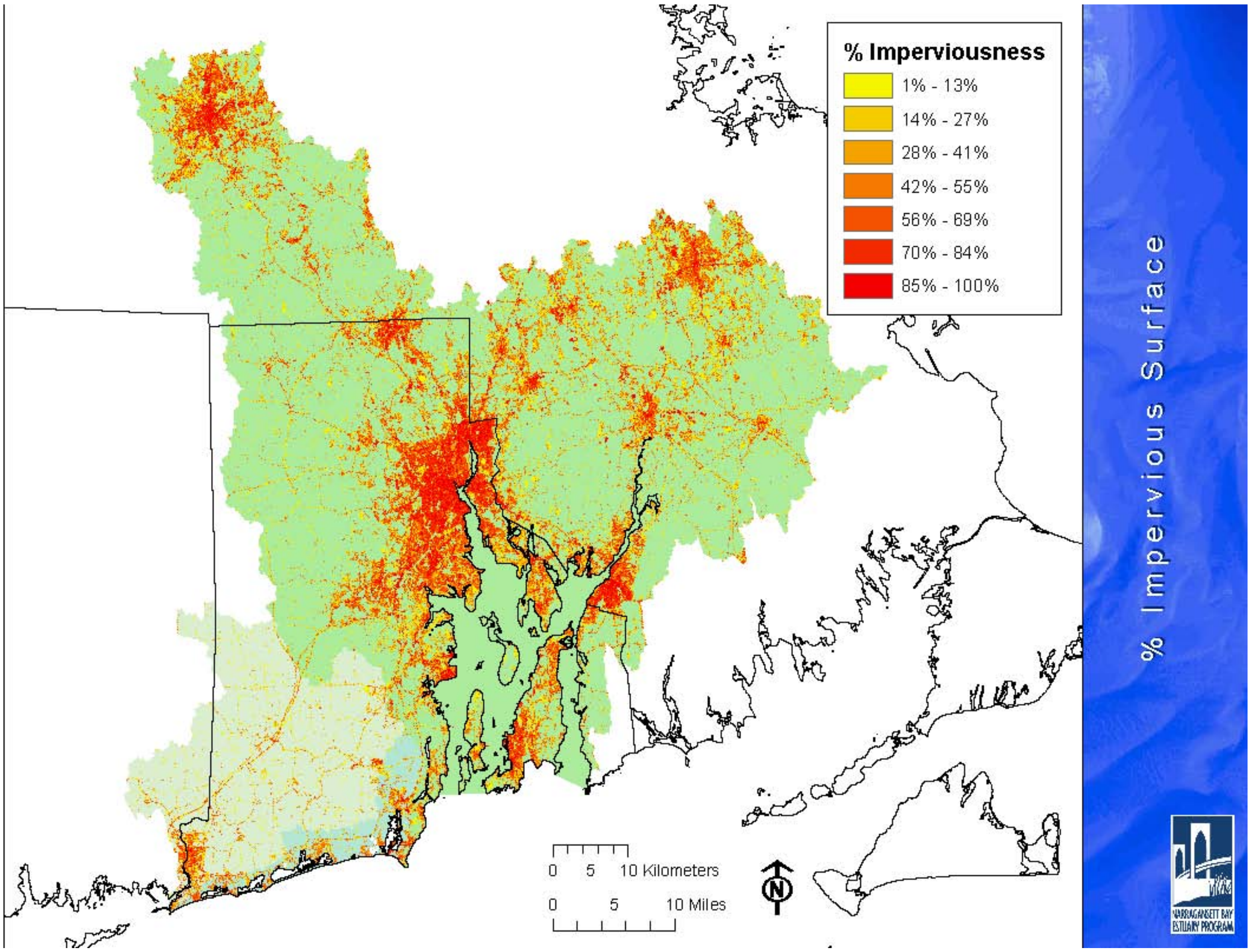
Status & Trends**:** Recent GIS analysis of data from aerial photographs indicates that about 14 percent of the land area in the Narragansett Bay watershed (R.I. and Mass.) is covered by impervious surfaces (5.1). These surfaces are distributed unevenly within watersheds; here in New England, developed areas tend to be near watercourses, where the impact of runoff is greater. The GIS analysis shows that 56.4% of all subwatersheds in the Bay watershed have greater than 10% impervious surface cover.

A 2007 analysis of 2004 true-color digital orthophotos in Rhode Island showed that 10 percent of the state was covered by impervious surfaces, with coverage greater than 30 percent in major population centers (5.18). Only 17 of 39 Rhode Island municipalities have less than ten percent impervious surface area with coastal towns averaging 14% impervious surface area (5.18).

These analyses provide what is essentially baseline data specific to impervious areas so we are at the start of a period when we can begin to make definitive statements regarding trends. It is clear, however, that, based on documented land use/land cover trends, there has been and continues to be 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 (5.19, 5.20, 5.21).

Information: Impervious surface is currently measured using a combination of data sources including aerial photographs and satellite imagery. As mentioned previously, the Multi-Resolution Land Characteristics Consortium intends to use NASA satellite data to develop land use and impervious surface coverages at five-year intervals beginning with 2000. 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 both orthophotography 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 not only satellite and/or orthophotography data but also the analytic capacity needed to accomplish this work.



SIDEBAR: Protected Lands

Land protection and preservation are critical to reducing the impacts of land use and impervious surfaces described above. Protection also encourages more efficient use of resources by making possible such approaches as smart growth. Land protection efforts in both states have benefitted by the increasing capacity of local land trusts working with state governments and other partners to acquire and manage protected lands.

Because Rhode Island and Massachusetts define and calculate protected lands differently, different estimates of area under conservation are generated. Developing trends information will require analysis of state's data and discussion with state lands data managers; for this effort, only status is reported. This status calculation includes state, federal, municipal and privately-owned parks and wildlife management areas; drinking water protection areas; public recreational amenities such as bike paths and public beaches; and lands protected by agricultural or conservation easements. Based on a 2009 RIDEM GIS analysis, the amounts of permanently conserved land in the region are: Rhode Island - 192 square miles; Massachusetts - 146 square miles; and Connecticut - 16 square miles (5.1). A total of 354 square miles or just over 17% of the Narragansett Bay Region is permanently protected.

6. Ecosystem Management

Introduction: The constitutions of both Rhode Island and Massachusetts accord great deference to the protection of natural resources. Rhode Island's constitution specifically calls for the preservation, regeneration and restoration of the natural environment of the state, while in Massachusetts, the constitution specifies the people's rights to clean air and water and the natural, scenic, historic, and esthetic qualities of their environment (6.1, 6.2). Protecting these rights and resources requires a framework that provides timely, credible information, the means to act effectively on the information, and the measures to know if the actions have succeeded, including meaningful indicators that track progress against goals, baselines, and some measure of performance.

As part of a recent effort to assess stakeholder concerns about watershed management, the NBEP interviewed nearly 40 Bay and watershed stakeholders from key agencies and organizations and asked them to identify critical issues that affect management of the Bay and its watershed (6.3); their summary responses included:

- Management of ecosystem not effective enough
- Need broader watershed-wide engagement/ public involvement
- Need to move the system to action/ remove bureaucratic delay
- Lack of collaboration and coordination
- Turf impedes transparency and collaboration
- Need better connections between managers and scientists
- Need trustworthy information sources
- Lack of consensus on solutions
- Lack of neutral forum for multiparty discussions

These priorities substantially mirrored previous findings from an exhaustive survey across the watershed in 2003 (6.4) in which stakeholders clearly expressed a need for regional managers to align their activities and find a clear path, including reliable funding, to prioritize action and assess the effectiveness of programs underway in the watershed. Together, these surveys pointed to three major needs: a framework of common goals to which many participants can contribute and which will help to coordinate activities; adequate resources to manage effectively; and sustained support for monitoring and data interpretation and communication.

Partly in recognition of the need to better coordinate the state's resource work, the R.I. General Assembly in 2004 enacted legislation to create the Rhode Island Bays, Rivers, and Watersheds Coordination Team (BRWCT). The BRWCT consists of seven state and quasi-state agencies charged with together developing and implementing a systems-level plan. The plan, finalized in July 2008, identifies strategies for eight broad areas: waterfront and coastal development; watersheds; Rhode Island's water-reliant economy; natural hazards; fresh water supply; water quality; fisheries and aquaculture; and aquatic habitats and invasive species (6.5). The plan explicitly declines to identify measurable objectives for these areas, but anticipates the Coordination Team's annual workplan will serve as a primary mechanism for coordinating state agencies' work by linking them to strategies in the plan and recommending allocation of responsibilities among them. The expectation is that this framework will promote a more integrated approach to policy and management. Similar goal-setting efforts inform the 28 separate plans found in the State Guide Plan, including the 1992 Comprehensive Conservation and Management Plan for Narragansett Bay, (6.6) and the 2004 Report of the Governor's Commission (6.7).

In Massachusetts, at least 13 offices with responsibilities related to environmental management are formally housed within the single administrative organization of the Executive Office of Energy and Environmental Affairs. During the 1990s the state launched a statewide watershed initiative to overcome "stove-piping" among its resource agencies. The initiative provided significant resources, including state-funded coordinators, to develop watershed plans in the state's 27 major basins with the input of local environmental groups, watershed organizations, and stakeholders. In the Narragansett Bay Region, watershed plans for the Blackstone and Taunton Rivers, and for Mt. Hope Bay/Narragansett remain important documents for regional watershed groups. Information in these plans has also been incorporated and updated in a new web-based program targeted specifically at abating nonpoint source pollution, and appears as appropriate in the state's periodic rotating basin assessments.

These institutional arrangements in both states may help to provide a more comprehensive perspective in solving environmental, economic, and social problems. In addition, the six major planning efforts for the Narragansett Bay Region have individually identified similar goals and objectives which could be consolidated and accepted as a common framework for action. In order of development, these planning efforts include:

- 1992 Comprehensive Conservation and Management Plan for Narragansett Bay
- 2003 Visioning Technical Report for Partnership for Narragansett Bay
- 2004 Report of the Governor's Narragansett Bay and Watershed Planning Commission
- 2006 Marine Resources Development Plan (6.8)
- 2006 5-Year Action Plan for Taunton River Watershed (6.9)
- 2008 Bays, Rivers, and Watersheds Coordination Team Systems Level Plan
- 2008 Blackstone River ~Clean by 2015, Blackstone River Coalition (6.10)

However, both states acknowledge the need for better mechanisms to work across state boundaries and with a variety of partners, and for considering the broader, ecosystem context of their own and other programs.

Finally, accountability emerges from a system that reports regularly on key performance measures. These typically include indicators both of management effectiveness and of environmental condition. In order to provide meaningful information, both types of indicator require overall goals to set targets for action and to serve as a baseline against which progress can be assessed, and a system of robust, regular monitoring to deliver data that can become information. Together, these elements will enable us to know whether programs are making a difference.

This section of Currents of Change looks briefly at the existing management framework for the Narragansett Bay ecosystem with the goal of summarizing the region's capacity and resources. It is included here because management response to environmental challenges is critical to ecological outcomes, and because a key question is how well our knowledge of the ecosystem – as portrayed in the other assessment chapters of this report – aligns with our management of it. An appendix to the report provides a matrix of current goals and objectives that highlights potential areas for priority consideration and shows where these recommendations have already been implemented, are underway, or are not yet begun (6.11).

Management Actions to Improve Water Quality

As detailed in Chapters 1 and 2, wastewater treatment facilities (WWTFs), including those in the Massachusetts portion of the watershed, are a major source of nitrogen to the Bay. Those that treat combined sanitary and sewer systems (CSOs) are also major sources of pathogens and other contaminants when heavy rains overwhelm plant operational capacity and the resulting flows bypass treatment partially or entirely, discharging directly into receiving waters. Such untreated or partially treated discharges are responsible for shellfish and beach closures, and also contribute their own stew of nutrients, toxics, and sediments to those generated by nonpoint sources and stormwater alone. Together these inputs are responsible for the failure of many localized segments 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.

Evaluating progress in addressing these problems can be measured currently by tracking treatment plant upgrades 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. In the long term, better metrics will track attainment of water quality standards for dissolved oxygen, pathogens, and aquatic life, eventually including biological indicators.

Rhode Island

Upgraded WWTFs: A goal of achieving a 50 % reduction in seasonal summer nitrogen pollutant loadings from Rhode Island's treatment plants was first recommended by DEM and subsequently adopted in the spring of 2004 by the Governor's Narragansett Bay and Watershed Planning Commission, In 2004, the Rhode Island General Assembly enacted into state law the same goal. For the 11 Rhode Island wastewater treatment plants discharging to the Upper Bay, implementation of nitrogen removal would initially reduce the summer season nitrogen load by 65%, although that loading may increase again if plant flows increase to their approved design capacity. Currently, 10 of the 11 Rhode Island facilities that discharge to the Seekonk River, Providence River, and Upper Bay are operating under revised permits. Since July 2006, improvements at eight of these have resulted in a 35% reduction in overall nitrogen loadings from upper bay WWTF's (6.12).

Status and Trends: Four Rhode Island WWTF have completed construction (Burrillville, East Greenwich, Smithfield, and West Warwick); three have completed construction but require minor modifications to ensure reliable compliance (Cranston, NBC Bucklin Point, and Warwick); one has completed construction of interim modifications with facility planning underway for additional upgrades (Woonsocket); one design is underway (East Providence); and one design is completed (NBC Fields Point) (6.12).

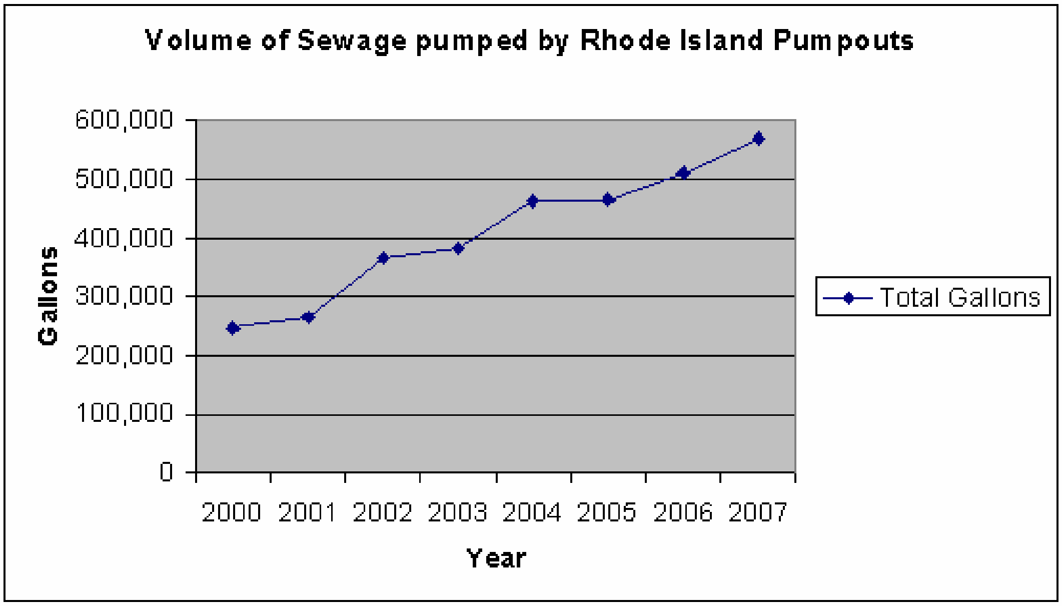
Cesspool replacements, sewer tie-ins, and installation of denitrifying OWTS: In addition to addressing discharges from treatment plants, the General Assembly also passed legislation requiring a phased replacement of cesspools around the state; Special Area Management Plans developed by the Coastal Resources Management Council have called for denitrifying systems and sewer tie-ins for specific areas (6.13).

Status and Trends: DEM's Onsite Wastewater Treatment System (OWTS) Rule 39 combined with CRMC's policies require denitrification systems in the Salt Pond and Narrow River watersheds. In addition, to comply with the Greenwich Bay Special Area Management Plan (SAMP), the city of Warwick has enacted a mandatory sewer connection program with the goal that 100 percent of properties with sanitary sewers available should be tied-in by 2015.

Combined Sewer Overflow Frequencies: To alleviate the impacts of CSO discharges, the NBC and the state in 1997 launched an ambitious $350 million plan to capture combined discharges in an enormous tunnel stretching for miles in the bedrock under the city of Providence.

Status and Trends: The first phase of the system went online in November of 2008 and is expected to capture 800 million gallons annually, reducing by 40% the two billion gallons of untreated wastewater discharged from the service area after rain events. Phase I of the project is completed; phase II will address outfalls along the Woonasquatucket, Seekonk, and Moshassuck Rivers, with preliminary design completed. Projections are that with completion of phase one, areas conditionally closed to shellfishing will be closed 50% less in the Upper Bay and 78% less in the lower Bay. In addition, the city of Newport is also completing engineering and design for CSO abatement (6.12).

Volume of Marine Sewage Pumpouts: Since 2000, the volume of boater sewage pumped out has more than doubled – from 247,024 gallons to 569,854 gallons. This is due to the installation of over 30 new pumpout facilities , many subsidized by DEM Clean Vessel Act grants, and the generally high level of maintenance by pumpout operators. This may also be due to an increase in boat usage. The number of boats registered with DEM increased from 39,776 in 2006 to 42,999 in 2008, although problems in the economy may lead to fewer registrations and less boat use (6.14, 6.15).



Massachusetts

Upgraded WWTF**:** Massachusetts facilities that affect Rhode Island waters include the Upper Blackstone Water Pollution Abatement District (UBWPAD) in Worcester, as well as six smaller plants along the Blackstone River and the 10-Mile Rivers; the Fall River treatment plant and CSOs; and treatment plants in Taunton and Brockton. RIDEM has estimated that discharges from UBWPAD represent approximately 64 percent of the nitrogen load discharged at the mouth of the Blackstone River from municipal wastewater treatment facilities. In turn, the Blackstone River discharges into the headwaters of the Seekonk River, where the greatest impairments in the Narragansett Bay basin have been measured. Beginning 2006-2007, EPA Region 1 committed to develop and implement a plan for establishing the nitrogen discharge limits for five Massachusetts WWTFs to ensure equitable regulation of discharges impacting the Seekonk River, Providence River, and Upper Narragansett Bay. EPA also agreed to develop a plan to ensure that compliance by Massachusetts facilities is achieved within the timeframes established for Rhode Island facilities (6.12).

Status and Trends: As of March 2009, EPA issued NPDES permits to UBWPAD, Attleboro, and North Attleborough. The UBWPAD and Attleboro permits are under appeal; North Attleborough is under an administrative order to complete the necessary upgrades (6.12).

Combined Sewer Overflow Frequencies**:** The city of Fall River has 19 CSO outfalls discharging to Mt. Hope Bay and the Taunton and Quequechan Rivers. The city has spent nearly $160 million thus far on phased CSO abatements, including a treatment plant upgrade, storage tunnels, interceptors, and a screening and disinfection facility. In addition to four drop shafts constructed in 2005, two others were completed in December 2008, with the last three under construction and expected to be finished by spring 2009. Also underway for completion in April 2009 are expansion of a surface interceptor and work on the Cove Street Screening and Disinfection Facility. Phase 2B of the abatement program will evaluate screening/disinfection, separation (new storm drain system) and other alternatives to determine the best plan for the north side of Fall River. Phase 3, to be completed by 2018, involves limited sewer separation between the tunnel and the river; the city expects compliance with the 3-month storm criteria. DEP has not yet quantified results, but reports that work to date has significantly reduced overflows (6.16).

Volume of Marine Sewage Pumpouts: Mt. Hope Bay is one of three remaining coastal areas, including the Upper North Shore and South Side of Cape Cod, working with CZM to complete applications to become No Discharge Areas for boat sewage by 2010.

Status and Trends: The communities of Fall River and Somerset operate pumpout boats. In 2007, Fall River pumped 16,220 gallons and Somerset pumped 12,635 gallons, diverting almost 30,000 gallons of marine sewage from the Bay (6.17).

Indicator: Environmental Expenditures

Importance: Although funding and number of staff do not always translate into effective management, there is a threshold below which it can be very 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.

Information: Annual state appropriations and staff allocations for each state's principal environmental agencies. In Rhode Island, these are identified in the state's budget documents as the R.I. Department of Environmental Management (RIDEM), Coastal Resources Management Council (CRMC), and Water Resources Board (WRB). In Massachusetts, these are the agencies housed under the Executive Office of Environmental and Energy Affairs (EOEEA). Because of the significant additional resources they provide, federal grants to Rhode Island through the clean water and drinking water revolving funds and the coastal beach monitoring program are also listed.

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 EOEEA. Data for Massachusetts that reflect staff work and state expenditures in the watershed are still to be developed.

The tables below are a first-cut assessment of state funding for environmental and natural resource programs; it will require additional work to ensure the categories, departments, and budget allocations are correct for at least the current fiscal year and going forward.

Status and Trends: Rhode Island

Natural Resource Agencies (DEM, CRMC, WRB)				Federal Funds, Clean Water SRF	Federal Funds, Drinking Water SRF	Federal Funds, Beach Grant	Total Federal	Total Fed %
Year	Total Agency Funding	Federal Contribution	Percent Federal					
1997					12,558,800			
1998	74,001,268	10,504,224	14%	9,033,100	7,118,300		26,655,624	36%
1999	82,316,494	13,238,892	16%	9,033,800	7,463,800		29,736,492	36%
2000	56,124,333	11,989,391	21%	9,002,900	7,757,000		28,749,291	51%
2001	64,349,628	12,658,963	20%	8,921,900	7,789,100	58,675	29,428,638	46%
2002	63,070,357	16,531,643	26%	8,942,000	8,052,500	214,225	33,740,368	53%
2003	66,423,923	16,714,101	25%	8,883,300	8,004,100	212,340	33,813,841	51%
2004	67,676,501	16,731,282	25%	8,888,700	8,303,100	213,290	34,136,372	50%
2005	71,194,728	19,303,754	27%	7,208,600	8,285,500	213,140	35,010,994	49%
2006	74,654,552	20,974,464	28%	5,839,300	8,229,300	212,640	35,255,704	47%
2007	81,718,031	23,043,344	28%	7,159,200	8,229,000	212,640	38,644,184	47%
2008	94,725,989	32,627,896	34%	4,515,300		209,650	37,352,846	39%
2009	95,672,816	34,888,888	36%			213,000	35,101,888	37%
	891,928,620	**229,206,842**	**26%**	**87,428,100**	**91,790,500**	**1,759,600**	**410,185,042**	**46%**

2009 figures still subject to change (6.18)

Trends in Natural Resource Agency FTEs

Year	RIDEM	CRMC	Water Resources Bd.	Totals
2004	539.7	28	9	576.7
2005	538.7	29	9	576.7
2006	531.3	30	9	570.3
2007	505.3	30	9	544.3
2008	482	30	6	518
2009*	460	29.2	5.8	495
* preliminary allocation				

RIDEM shows 14.7% decline since 2004.
WRB show 35.5% decline since 2004

Status & Trends: Massachusetts

Massachusetts Annual Totals for Environment, Recreation, & Agriculture 1998-2009*			
Year	**Annual Allocations**	**Federal Contribution**	**Percent Federal**
1998	213,300,000	18,594,000	9%
1999	240,756,000	22,204,000	9%
2000	260,747,000	30,159,000	12%
2001	285,616,000	30,727,000	11%
2002	295,247,000	69,929,000	24%
2003	274,458,000	66,114,000	24%
2004	264,148,339	83,100,255	31%
2005	250,058,686	76,419,760	31%
2006	247,901,744	75,048,645	30%
2007	293,895,091	103,227,656	35%
2008	222,909,000	43,412,357	19%
2009**	238,743,000	62,303,925	26%
TOTALS	**3,087,779,860**	**681,239,598**	**22%**

** based on governor's budget only for some years, and final legislature appropriations in 2008 and 2009; includes federal and trust fund sources **2009 figures still subject to change (6.19)*

Indicator: Environmental Reporting

Importance**:** Numerous studies have found that robust, effective organizations value approaches that actively seek input on their progress from their chief stakeholders, and 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.

Measurement: Availability of synoptic regular reports to management and the public on environmental conditions, coupled with periodic technical and more specific programmatic information: Federal guidance has recently established reporting and format requirements to ensure consistent water quality data in the future, but until now, each assessment reported information differently, making it difficult to assess changes in water quality, even in the same segments. Given Rhode Island's limited monitoring, as of the 2008 Integrated Report, many waterbodies were characterized as unassessed. The percent of unassessed waters should decrease in the 2010 Integrated Report now that a substantial amount of data collected between 2005 and the present under the rotating basin approach is available for the assessments." Confounding attempts to look comprehensively at the watershed, Rhode Island's segments and assessment criteria are different from those of Massachusetts -- even for shared water bodies -- and the two states' schedules for monitoring are not consistent. For example, Massachusetts' assessments of aquatic life identify and discuss obstructions to fish passage and channelization as indications of impairment, while Rhode Island's do not (6.20).

Rhode Island

Status and Trends: Since 2000, all Rhode Island state agencies have developed and reported on measures intended to represent the outcomes of their activities, but these measures, typically found in technical appendices to annual budget documents, do not appear to serve as drivers of agency priorities (5.16). The most routinely published water quality report has been the biennial State of the State's Waters, which is 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. Chapters 1 and 2 of this report summarize findings from Rhode Island's and Massachusetts' 2008 reports. From 1998 to 2004, RIDEM reported roughly annually on its activities as a department, and provided annual workplans for public comment and input; other organizations also produced irregular or ad hoc assessments, including 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 their own watershed action plans on which they report more or less regularly. The Wood-Pawcatuck Watershed Association issues annual reports, including their water quality monitoring data; the Woonasquatucket River Watershed Council participates in the state's Watershed Watch program and posts data from its monitoring stations on its website.

Dozens of Rhode Island's state and quasi-state agencies, including the BRWCT and its member agencies DEM, NBC, WRB, and EDC, are required to submit annual reports to the General Assembly, but there are gaps in compliance. According to the website, since 2005 only NBC has complied annually. The last DEM report on the site is dated 2004, the last Water Resources Board report is 2005, and as of March, 2009, EDC has posted a report on the Renewable Energy Development Fund, although not a report on its overall operations. On their individual websites, the agencies other than NBC do not appear to produce synoptic reports of their annual activities, although they do post periodic reports on individual programs. For example, CRMC reports on rights of way and aquaculture, DEM produces the Integrated Report (as noted above), as well as periodic specialized reports alone and with partners such as a wetlands status and trends report and an eelgrass inventory, and the Division of Planning in the Department of Administration develops multi-year plans for transportation and land use. If the Economic Development Corporation, Water Resources Board, and Rivers Council publish agency reports, these are not listed on their websites after 2005 at the latest.

Massachusetts

<u>Status and Trends</u>: Massachusetts, the Department of Environmental Protection (DEP) produces a number of related resource management reports. Annually, these include Environmental Progress Reports, water quality monitoring reports, and water quality assessment reports. Both the monitoring and the assessment reports are based on a 5-year rotating basin approach, and feed not only into the overall annual progress report, but also into 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.

Currents of Change References

1. Introduction

1.1. Taunton Wild & Scenic River Study Committee. 2005. Taunton River stewardship plan.

1.2. Cronon, W. 1983. Changes in the land: Indians, colonists, and the ecology of New England.

1.3. Walter, R. and D. Merritts. 2008. Natural streams and the legacy of water-powered mills. Science, 18 January 2008, pp. 299-304.

1.4. Nixon, S. 2005. Anthropogenic nutrient loadings to Narragansett Bay: A twenty-five year perspective. Report to the Narragansett Bay Commission and R.I. Sea Grant.

Nixon, S., B. Buckley, S. Granger, L. Harris, A. Oczkowski, R. Fulweiler, and L. Cole. 2008. Nitrogen and phosphorus inputs to Narragansett Bay: past, present and future. In: Science for Ecosystem-Based Management: Narragansett Bay in the 21st Century. Springer Series in Environmental Management, eds., A. Desbonnet and B. A. Costa-Pierce, pp.101-177. New York: Springer.

1.5. Heinz Center. 2008. State of the nation's ecosystems. http://www.heinzctr.org/ecosystems/.

1.6. The Heinz Center. 2008. Environmental information: A roadmap to the future.

1.7. *Geographic and demographic statistics for the Narragansett Bay Region were calculated in 2008 and 2009 by Paul Jordan of R.I. Dept. of Environmental Management using data from the R.I. Geographic Information System.*

2: Estuarine Waters

2.1. Rogers, J.M. 2008. Circulation and transport in the heart of Narragansett Bay. M.S. Thesis, University of Rhode Island, Graduate School of Oceanography.

2.2. Costa-Pierce, B.A. and A. Desbonnet. 2008. An "ecofunctional" approach to ecosystem-based management for Narragansett Bay. In: Science for Ecosystem-Based Management: Narragansett Bay in the 21st Century. Springer Series in Environmental Management, eds., A. Desbonnet and B. A. Costa-Pierce, pp.537-554. New York: Springer.

2.3. RIDEM. 2008. 2008 Integrated Report . Currently under review by EPA.

2.4. Nixon, S. 1995. Metal Inputs to Narragansett Bay: A history and assessment of recent conditions. Rhode Island Sea Grant, Narragansett, R.I. Publication #P1388.

2.5. Nixon, S., B. Buckley, S. Granger, L. Harris, A. Oczkowski, L. Cole, and R. Fulweiler. 2005. Anthropogenic nutrient inputs to Narragansett Bay: A twenty five year perspective. A report to the Narragansett Bay Commission and Rhode Island Sea Grant. Narragansett, RI. www.seagrant.gso.uri.edu/research/bay_commission_report.pdf.

2.6. Colt, A. 2008. Bays, Rivers, and Watersheds Systems-Level Plan: 2009-2013. The Rhode Island Bays, Rivers, & Watersheds Coordination Team Strategic Plan. www.rilin.state.ri.us/Documents/BRWSLPFinal.pdf.

2.7. Narragansett Bay Commission. 2007. Pretreatment annual report Jan-Dec 2006. www.narrabay.com/pretreatmentAnnRep.asp.

2.8. RIDEM, Office of Water Resources. 2006. Water quality regulations. www.dem.ri.gov/programs/benviron/water/quality/surfwq/index.htm.

2.9. Codiga, D., H.Stoffel, C.Deacutis, S.Kiernan, and C.Oviatt. 2009. Narragansett Bay hypoxic event characteristics based on fixed-site monitoring network time series: Inter-annual variability, geographic distribution, intermittency, and spatial synchronicity. In press Estuaries and Coasts.

2.10. Bergondo, D., D. Kester, H. Stoffel, W. Woods. 2005. Time-series observations during the low sub-surface oxygen events in Narragansett Bay during summer 2001. Marine Chemistry 97: 90-103.

2.11. Diaz, R., and R. Rosenberg. 2008. Spreading dead zones and consequences for marine ecosystems. Science 321: 926-929.

2.12a. Altieri, A. 2008. Dead zones enhance key fisheries species by providing predation refuge. Ecology, 89(10): 2808-2818.

2.12b. Marroquin-Mora, D. and Rice, M. 2008. Gonadal cycle of northern quahogs, *Mercenaria mercenaria* (Linne, 1758), from fished and non-fished subpopulations in Narragansett Bay. Jouornal of Shellfish Research 27 (4): 643-652.

2.13. Susan Kiernan, Deputy Chief RIDEM Office of Water Resources. March 27, 2009. Interoffice Memo to Richard Ribb.

2.14. Stoffel, H. and S. Kiernan. 2009. Narragansett Bay fixed-site monitoring network: Final report on activities during 2005-2008.

2.15. Prell, W., D. Murray, and C. Deacutis. 2006. Summer-season surveys of dissolved oxygen in upper Narragansett Bay. http://www.geo.brown.edu/georesearch/insomniacs.

2.16. Berman, M., E, Calderone, J. Jossi, C. Melrose, and C. Oviatt. 2006. Mariner shuttle: Cutting edge technology circling the bay. 41 Degrees North. Volume 3 (1):12-13. http://seagrant.gso.uri.edu/41N/Vol3No1/berman.html.

2.17. Deacutis, C. 2008. Evidence of ecological impacts from excess nutrients in Upper Narragansett Bay. In: Science for Ecosystem-Based Management: Narragansett Bay in the 21st Century. Springer Series in Environmental Management, eds., A. Desbonnet and B. A. Costa-Pierce, pp.349-381. New York: Springer.

2.18. Howes, B. and R. Samimy. 2007. Water quality monitoring program for the Mount Hope Bay embayment system (2004-2006), summary of 604(b) grant DEP # 2004-04/604, 2005-05/604, 2006-04/604.

2.19. Prell, W., E. Saarman, D. Murray, and C. Deacutis. 2004. Summer-season, nighttime surveys of dissolved oxygen in Upper Narragansett Bay (1999-2003). http://www.geo.brown.edu/georesearch/insomniacs.

2.20. Melrose, D., and C. Oviatt, M. Berman. 2007. Hypoxic events in Narragansett Bay, Rhode Island during the summer of 2001. Estuaries and Coasts 30: 47-53.

2.21. Calabretta, C. and C. Oviatt. 2008. The response of benthic macrofauna to anthropogenic stress in Narragansett Bay, Rhode Island: A review of human stressors and assessment of community conditions. Mar. Poll. Bull. 56: 1680-1695.

2.22. August, P. and B Costa-Pierce. 2007. Mapping submerged habitats: A new frontier. 41 Degrees North. Volume 4(1): 2-3.

2.23. Windecker, L. A. and S.W.Nixon. 2009. The phytoplankton of mid-narragansett bay, 1999-2008: Quality control and analyses. Presentation + Published abstract. NEERS Fall meeting. Salem, MA, April 2-4 2009.

2.23. Nixon, S. W., R. Fulweiler, B. Buckley, S. Granger, B. Nowicki, and K. Henry. 2009. The impact of changing climate on phenology, productivity, and benthic–pelagic coupling in Narragansett Bay Estuarine, Coastal and Shelf Science. 82(1): 1–18.

2.25. Oviatt, C., A. Keller, L. Reed. 2002. Annual primary production in Narragansett Bay with no bay-wide winter-spring phytoplankton bloom. Estuarine, Coastal and Shelf Science. 54: 1013-1026.

2.26. Oviatt, Candace. 2009. University of Rhode Island Graduate School of Oceanography. Personal communication.

2.27. Melrose, C. and M. Berman. 2007. Spatial and temporal patterns in chlorophyll fluorescence in Narragansett Bay, RI. Published Abstract, Estuarine Research Federation National Meeting, Providence, RI Nov. 4-8, 2007.

2.28. Smayda, T., and D. Borkman. 2008. Nutrients and plankton dynamics in Narragansett Bay. In: Science for Ecosystem-Based Management: Narragansett Bay in the 21st Century. Springer Series in Environmental Management, eds., A. Desbonnet and B. A. Costa-Pierce, pp. 431-484. New York: Springer.

2.29. Blair, B., and A. Parris. 2008. Rhode Island Department of Health beach monitoring program: 2007 & 2008 season report. www.ribeaches.org/news.cfm.

2.30. Ernest, J., Rhode Island Department of Health. 2007. Public Presentation: Beach monitoring program - 2007 Greenwich Bay season report October 25, 2007. Warwick City hall, Warwick, RI. www.ribeaches.org/docs/GreenwichBayPublicForumPresentationOct2007.pps.

2.31. Erkan, D. 2009. An annual rite of spring: The 2009 quahog transplant program. Wild Rhode Island, Spr. 2009. Vol 2 (2):1-2. www.dem.ri.gov/programs/bnatres/fishwild/pdf/wrispr09.pdf.

2.32 Rhode Island Coastal Resources Management Council. 2005. Greenwich bay Special Area Management Plan. Adopted May10, 2005. 498 pp incl App.

3: Fresh Waters

3.1. Pilson, M. 2008. Narragansett Bay amidst a globally changing climate. In: Science for Ecosystem-Based Management: Narragansett Bay in the 21st Century. Springer Series in Environmental Management, eds., A. Desbonnet and B. A. Costa-Pierce, pp.35-47. New York: Springer.

3.2. U. S. Geological Survey. 2003. Water-quality trends in New England Rivers during the 20th century. Water-Resources Investigations Report 03-4012.

3.3. Susan Kiernan, Deputy Chief RIDEM Office of Water Resources. March 27, 2009. Interoffice Memo to Richard Ribb.

3.4. RIDEM, Office of Water Resources. 2008. Final 2008 integrated water quality monitoring and assessment report: Section 305(b) State of the State's waters report and section 303 (d) List of impaired waters.

3.5. RIDEM, Office of Water Resources. 2001. Fecal coliform Total maximum daily load for the Pettaquamscutt (Narrow) River Watershed, Rhode Island including: Narrow River estuary, Gilbert Stuart Stream, Mumford Brook.

RIDEM, Office of Water Resources. 2001. Fecal coliform Total maximum daily load development for Hunt River, Rhode Island.

RIDEM, Office of Water Resources. 2001. Fecal coliform Total maximum daily load development for Fry Brook, Rhode Island.

RIDEM, Office of Water Resources. 2001. Fecal coliform Total maximum daily load development for Scrabbletown Brook, Rhode Island.

RIDEM, Office of Water Resources. 2007. Woonasquatucket River fecal coliform bacteria and dissolved metals total maximum daily loads.

RIDEM, Office of Water Resources. 2007. Total maximum daily load analysis for Point Judith Pond waters pathogen/bacteria impairments (Billington Cove, Point Judith Pond, Champlin Cove, Potter Pond Channel, Lower Saugatucket River, Narragansett and South Kingstown).

RIDEM, Office of Water Resources. 2006. Total maximum daily loads analysis for Greenhill Pond, Ninigret Pond, Factory Pond Stream and Teal Pond Stream in South Kingstown and Charlestown, Rhode Island.

RIDEM, Office of Water Resources. 2006. Fecal coliform and total phosphorus total maximum daily loads Kickemuit Reservoir, Rhode Island (RI0007034L-01); Upper Kickemuit River (RI 0007034R-01); Kickemuit River (MA 61-08_2004).

RIDEM, Office of Water Resources. 2005. Total maximum daily load for the Sakonnet River – Portsmouth Park and The Cove – Island Park.

RIDEM, Office of Water Resources. 2002. Fecal coliform Total maximum daily load development for Barrington River, Rhode Island.

RIDEM, Office of Water Resources. 2002. Fecal coliform Total maximum daily load for Palmer River, Rhode Island.

RIDEM, Office of Water Resources. 2002. Fecal coliform Total maximum daily load for the Runnins River, Rhode Island.

RIDEM, Office of Water Resources. 2003. Pathogen Total maximum daily load for Saugatucket River, Mitchell Brook, Rocky Brook and Indian Run Brook.

3.6. Massachusetts Executive Office of Energy and Environmental Affairs, Division of Water Management. 2008. Massachusetts Year 2008 Integrated List of Waters.

3.7. Susan Kiernan, Deputy Chief RIDEM Office of Water Resources, personal communication

3.8. RI TMDL reports on waters impaired by nutrients: RIDEM, Office of Water Resources. 2007. Total maximum daily load for dissolved oxygen and phosphorus in Mashapaug Pond, Rhode Island.

RIDEM, Office of Water Resources. 2007. Total phosphorus total maximum daily load for Sands Pond, New Shoreham (Block Island) Rhode Island.

RIDEM, Office of Water Resources. 2007. Indian Run Brook dissolved metals total maximum daily loads.

RIDEM, Office of Water Resources. 2007. Total maximum daily loads for phosphorus to address nine eutrophic ponds in Rhode Island (Almy Pond, Newport; Brickyard Pond, Barrington; Gorton Pond, Warwick; North Easton Pond, Middletown, Newport; Roger Williams Park Ponds, Providence; Sand Pond, Warwick; Spectacle Pond, Cranston; Upper Dam Pond, Coventry; Warwick Pond, Warwick).

RIDEM, Office of Water Resources. 2004. Total phosphorus total maximum daily load for Chickasheen Brook, Barber Pond, and Yawgoo Pond, Rhode Island.

RIDEM, Office of Water Resources. 1998. Total maximum daily load for total phosphorus loads to Stafford Pond.

3.9. Nimiroski, M., and M. Waldron. 2002. Sources of sodium and chloride in the Scituate Reservoir drainage basin, Rhode Island: U.S. Geological Survey water-resources investigations report 02-4149.

3.10. University of Rhode Island Watershed Watch program. Lake chloride data, Linda Green, Personal communication. www.uri.edu/ce/wq/ww/index.htm.

3.11. Alisa Richardson, RIDEM Office of Water Resources, personal communication.

3.12. Hershberger, J., H. Johnston, H. Meyer and K. Cute. 2004. Out-of-basin transfer subcommittee report to the RI Water Resources Board.

3.13. Massachusetts Riverways Program River Inflow Stewards Program. www.rifls.org.

3.14. Blackstone River Coalition. 2008. The Blackstone River – Clean by 2015.

3.15. Taunton Wild & Scenic River Study Commission et al. 2005. Taunton River stewardship plan, Taunton River Wild & Scenic River Study.

3.16. Sinnamon, M. 2004. Protecting Greenwich Bay from cesspools and septic systems: risk management strategies. Unpublished master's thesis, Brown University.

4: Living Resources

4.1. Ayvazian, S., L. Deegan and J. Finn. 1992. Comparison of habitat use by estuarine fish assemblages in the Acadian and Virginian zoogeographic provinces. Estuaries. Volume 15: 2

4.2. NOAA. 1996. Fisheries economics of the United States.

www.st.nmfs.noaa.gov/st5/publication/economics_communities.html.
According to this report, which compiles statistics on the economic value of fisheries on a state-by-state basis, recreational and commercial fisheries in Rhode Island generate more than $800 million in annual sales, while Massachusetts' combined fisheries generate more than $5 billion.

4.3. Collie, J., H. Wood and H. Jeffries. 2008. Long-term shifts in the species composition of a coastal fish community. Can. J. Fish. Aquat. Sci. 65: 1352-1365.

4.4. RIDEM. 2006. Rhode Island marine fisheries stock status and management: 2005 in review. Division of Fish & Wildlife, Jamestown, R.I.

4.5. For information on Massachusetts' wetland change mapping. www.mass.gov/mgis/wetchange.htm.

4.6. NBEP. 2004. Narragansett Bay Coastal Wetland Restoration Analysis. CD. Narragansett Bay Estuary Program Report # NBEP-04-121.

4.7. Bromberg, K. and M. Bertness. 2005. Reconstructing New England salt marsh losses using historical maps. Estuaries and Coasts, Volume 28: 6.

4.8. Nixon, S. 1982. Ecology of New England high salt marshes: a community profile. U.S. Fish & Wildlife Service report FWS/OBS/55.

4.9. Titus, J. and V. Narayanan. 1995. Probability of sea level rise. Washington, D.C., U.S. EPA.

4.10. Executive Order 13112, 3 February 1999.

4.11. Simberloff, D. Introduced species: the threat to biodiversity and what can be done. www.actionbioscience.org/biodiversity/simberloff.html.

4.12. Lee, K., F. Short and D. Burdick. 2004. Development of a nutrient pollution indicator using the seagrass, *Zostera marina*, along nutrient gradients in three New England estuaries. Aquatic Botany, Volume 78: 3.

4.13. Bradley, M., K. Raposa, and S. Tuxbury. 2007. Report on the analysis of true color aerial photography to map and inventory *Zostera marina L.* in Narragansett Bay and Block Island, R.I. Kingston, R.I.: R.I. Natural History Survey.

4.14. Doherty, A.M. 2003. Historical distributions of eelgrass (*Zostera marina*) in Narragansett Bay, R.I. 1850-1995. Narragansett Bay Estuary Program Report # NBEP-03-120.

4.15. Massachusetts Technology Collaborative, Renewable Energy Trust, http://www.masstech.org/IS/public_policy/climatechange/facts.htm

4.16. Smith, L.M., S. Whitehouse and C. A. Oviatt, (in press). Impacts of climate changes on Narragansett Bay. Northeastern Naturalist.

4.17. Nixon, S.W., S. Granger, B.A. Buckley, M. Lamont and B. Rowell. 2004. A one hundred and seventeen year coastal water temperature record from Woods Hole, Massachusetts. Estuaries and Coasts, 27: 397-404.

5: Watershed Lands

5.1. GIS analysis of impervious surfaces in the Narragansett Bay watershed, statistics for the Narragansett Bay Region were calculated in 2008 and 2009 by Paul Jordan of R.I. Dept. of Environmental Management using data from the R.I. Geographic Information System.

5.2. Boothroyd, J., and P. August. 2008. Geologic and contemporary landscapes of the Narragansett Bay

5.3. Rhode Island Statewide Planning Program. 2006. Land Use 2025: R.I. State Land Use Policies and Plan.

5.4 Novak, A., and Y.Q. Wang. 2004. Effects of suburban sprawl on Rhode Island's forests: A LANDSAT view from 1972 to 1999. Northeastern Naturalist 11(1):67-74

5.5. Rhode Island Sea Grant. 2002. Salt Ponds of Rhode Island fact sheet.

5.6. Shumchenia, E. 2008. House counts in R.I. salt ponds watershed. Unpublished data.

5.7. MassAudubon. 2003. Technical notes to losing ground: At what cost? Changes in land use and their impact on habitat, biodiversity, and ecosystem services in Massachusetts. Third Edition of the Losing Ground series. Lincoln, Massachusetts

5.8. MassAudubon. 2003. Losing Ground: At What Cost? Changes in land use and their impact on habitat, biodiversity, and ecosystem services in Massachusetts. Third Edition of the Losing Ground series. Lincoln, Massachusetts

5.9. Blackstone River Coalition. 2008. The Blackstone River – Clean by 2015.

5.10. Massachusetts Executive Office of Environmental Affairs. 2008. Taunton River Watershed. http://www.mass.gov/?pageID=eoeeahomepage&L=1&sid=Eoeea&L0=Home.

5.11. Stone, T. 2007. Critical mass: Land use change in Southeastern Massachusetts. Woods Hole Research Center, Falmouth MA.

5.12. Brabec, E., S. Schulte, and P. Richards. 2002. Impervious surfaces and water quality: A review of current literature and its implications for watershed planning. Journal of Planning Literature 16:499-514

5.13. Weng, Qihao. 2001. Modeling urban growth effects on surface runoff with the integration of remote sensing and GIS. Springer Series in Environmental Management, Vol. 28, No. 6. pp 737-748, New York: Springer

5.14. Galli, J. 1991. Thermal impacts associated with urbanization and stormwater management best management practices. Metropolitan Washington Council of Governments, Maryland Department of Environment. Washington, D.C.

5.15. Beach, D. 2002. Coastal sprawl: The effects of urban design on aquatic ecosystems in the United States.

5.16. Wang, L., J. Lyons, P. Kanehl, and R. Bannerman. 2001. Impacts of urbanization on stream habitat and fish across multiple spatial scales. Springer Series in Environmental Management, Vol. 28, No. 2, pp. 255-266. New York: Springer

5.17. Center for Watershed Protection. 2003. Impacts of impervious cover on aquatic systems. Watershed Protection Research Monograph No. 1

5.18. Zhou, Y., and Y. Wang. 2007. An assessment of impervious surface areas in Rhode Island. University of Rhode Island, Dept. of Natural Resource Sciences. Northeast Naturalist 14(4):643-650.

5.19. Ourso, R., and S. Frenzel. 2003. Identification of linear and threshold responses in streams along a gradient of urbanization in Anchorage, Alaska. *Hydrobiologia* 501(July):117-131.

5.20. Clausen, J., G. Warner, D. Civco, and M. Hood. 2003. NEMO impervious surface research – Final report. University of Connecticut Dept. of Natural Resources Management and Engineering.

5.21. Ladson, A., C. Walsh, T. Fletcher, S. Cornish, and P. Horton. 2004. Improving stream health by reducing the connection between impervious surfaces and waterways. Monash University.

6: Ecosystem Management

6.1. Rhode Island constitution, Article 1, Section 17: Fishery rights -- Shore privileges -- Preservation of natural resources. – "The people shall continue to enjoy and freely exercise all the rights of fishery, and the privileges of the shore, to which they have been heretofore entitled under the charter and usages of this state, including but not limited to fishing from the shore, the gathering of seaweed, leaving the shore to swim in the sea and passage along the shore; and they shall be secure in their rights to the use and enjoyment of the natural resources of the state with due regard for the preservation of their values; and it shall be the duty of the general assembly to provide for the conservation of the air, land, water, plant, animal, mineral and other natural resources of the state, and to adopt all means necessary and proper by law to protect the natural environment of the people of the state by providing adequate resource planning for the control and regulation of the use of the natural resources of the state and for the preservation, regeneration and restoration of the natural environment of the state."

6.2. Massachusetts constitution, Article 97: "The people shall have the right to clean air and water, freedom from excessive and unnecessary noise, and the natural, scenic, historic, and esthetic qualities of their environment; and the protection of the people in their right to the conservation, development and utilization of the agricultural, mineral, forest, water, air and other natural resources is hereby declared to be a public purpose."

6.3. NBEP Strategic Plan Report 2007, http://nbep-2009-implementation-review.wikispaces.com/4_Program+Products.

6.4. Developing a Collective Vision, Core Principles and Goals for Narragansett Bay, Coastal Rhode Island and Their Watersheds in Rhode Island, Massachusetts and Connecticut, http://nbep-2009-implementation-review.wikispaces.com/4_Program+Products.

6.5. 2008 Rhode Island Bays, Rivers, and Watersheds Systems Level Plan, www.dem.ri.gov/bayteam/documents/slpfinal.pdf.

6.6. NBEP. 1992. State of Narragansett Bay comprehensive conservation and management plan (CCMP) and appendices. Narragansett Bay Estuary Program Report # NBEP-92-112.

6.7. Governor's Narragansett Bay and Watershed Planning Commission: Phase 1 Strategic Workplan Short-Term Recommendations, 2004. www.ci.uri.edu/GovComm/Documents/Phase1Rpt/Docs/Phase1_Final_Report.pdf.

6.8 Marine Resources Development Plan: RI Coastal Resources Management Council, 2006. www.crmc.ri.gov/mrdp.html .

6.9. Massachusetts Executive Office of Environmental Affairs. 2006. Five-Year Watershed Action Plan for the Taunton River Watershed.

6.10. Blackstone River Coalition. 2008. The Blackstone River: Clean by 2015.

Massachusetts Executive Office of Environmental Affairs. 2004. Blackstone River Watershed Five-Year Action Plan.

6.11. Matrix of goals and implementation actions for Narragansett Bay and Watershed. NBEP Status and Trends Workshop, May 16, 2008, updated January 2009; Appendix A is a compendium of completed, ongoing, and future actions recommended in the six major planning efforts identified in notes 6.3 – 6.8.

6.12. Susan Kiernan, Deputy Chief RIDEM Office of Water Resources, http://narrabay-statustrends.wikispaces.com/3_Comments+-+Review+Draft.

6.13. James Boyd, CRMC, http://narrabay-statustrends.wikispaces.com/3_Comments+-+Review+Draft.

6.14. RIDEM, Office of Water Resources. 2007. Rhode Island pumpout facility evaluation report.

6.15. Alex Kuffner, "From builders to marinas, R.I.'s boating industry is in the doldrums", Providence Journal, March 24, 2009, data source RIDEM.

6.16. Narragansett and Mt. Hope Bay Watersheds 2003-2008 Water Quality Assessment Report, Appendix C; personal communication, Terry Sullivan, Community Utilities Administrator, City of Fall River, MA.

6.17. Personal communication, Eileen Feeney, Massachusetts Division of Marine Fisheries

6.18. Budget Office, Rhode Island Department of Administration www.budget.ri.gov; the site includes current and prior year budgets from state fiscal year 2001; budget documents include proposed and enacted versions, as well as appendices covering personnel and capital budgets, and technical instructions.

6.19. The website of the General Court of the Commonwealth of Massachusetts, www.mass.gov/legis; the site includes current and prior year budgets from state fiscal year 1998

6.20. Listings for major organizations providing regular, periodic, or special reports

* http://www.dem.ri.gov/pubs/index.htm for a listing of periodic and special reports,
* http://www.mass.gov/?pageID=eoeeautilities&L=1&sid=Eoeea&U=sitemap for information to drill into web pages listing programs and publications of individual EOEEA departments
* See organization chart at www.mass.gov/bb/gaa/fy2009/app_09/sect_09/hc200.htm
* http://www.wpwa.org for publications and annual report of the Wood-Pawcatuck Watershed Association
* http://www.mass.gov/dfwele/river/watershed/
* http://www.ririvers.org/watershed%20councils.htm

Other sources used

Atlantic States Marine Fisheries Commission. 2007. Addendum XI to Amendment 3 to the American Lobster Fishery Management Plan. www.asmfc.org/speciesDocuments/lobster/fmps/addendumXI.pdf.

Environmental Defense Fund. 2005. Saving small fish on Long Island will help big predators too. www.edf.org/article.cfm?contentID=4447 .

Frumhoff et al. 2007. Confronting climate change in the U.S. northeast. Pp. 52-53. Cambridge, MA: Union of Concerned Scientists.

Gibson, M. 2002. Winter flounder abundance near Brayton Point Station, Mt. Hope Bay revisited: separating local from regional impacts using long-term abundance data. R.I. Dept. of Environmental Management. www.dem.ri.gov/topics/brayton/pdfs/flounder.pdf.

Mashamoquet Brook State Park website. 2008. www.nochildleftinside.org/parks/mashamoquet.php.

National Marine Fisheries Service. 2008. Fisheries statistics database. www.st.nmfs.noaa.gov/st1.

Oviatt, C.,S. Olsen, M. Andrews, J. Collie, T. Lynch, and K. Raposa. 2003. A century of fishing and fish fluctuations in Narragansett Bay. Reviews in Fisheries Science, 11(3), Pp. 221-242.

RIDEM 2005. Rhode Island's Comprehensive Wildlife Strategy. www.dem.ri.gov/programs/bnatres/fishwild/pdf/swgplan.pdf.

Save The Bay. 2000. State of the Bay. www.savebay.org/NetCommunity/Page.aspx?pid=481&srcid=253.

Taylor, D.L. and J.S. Collie, 2003. A temperature and size-dependent model of sand shrimp (*Crangon septemspimosa*) predation on winter flounder (*Pseudopleuronectes americanus*). Can. J. Fish. Aquat. Sci. 60: 1133-1148.

USFWS. 2008. U.S. Fish & Wildlife Service, Migratory Songbird Conservation webpage. http://library.fws.gov/Bird_Publications/songbrd.html.

Welker, G. 2008. Dominion's big plans. The Herald News, 22 Jan. 2008. www.heraldnews.com/business/x254751044.

Goals & Implementation Actions Matrix: Narragansett Bay Ecosystem

Goal Source	Actions to Implement
	Water Quality (Fresh and Salt)
1992 Comprehensive Conservation and Management Plan for Narra. Bay (CCMP)	Establish wastewater management districts to assure proper inspection and maintenance of on-site sewage disposal systems and amend existing regulations governing siting, design, construction, and maintenance of ISDS
	Reconcile RIDEM, CRMC, and Massachusetts water quality and water use standards
	Prepare marina pumpout siting plan that includes written policies for 1) regulating construction of marinas, docks, and mooring fields, and 2) enforcing prohibitions against boater discharges
	Revise existing municipal and industrial discharge permits to include and enforce limits for all toxic chemicals listed on Narragansett Bay "List of Toxic Chemicals of Concern"
	Include significant non-industrial sources in regulatory programs in order to meet state water quality goals
	Abate CSOs in Mt. Hope Bay, and the Providence and Blackstone Rivers
2004 Report of the R.I. Governor's Commission	Issue final DO report for Greenwich Bay and plan for nutrient reductions in Bay
	Prepare comprehensive SWMPs for all communities bordering Bay and tributaries
	Implement nutrient removal at all WWTF discharging to Bay and tribs
2006 5-Year Action Plan for Taunton River Watershed	Identify sites for Low Impact Development (LID) storm water retrofits. Apply LID retrofits at "example" sites for showcasing LID function, which can be used for public outreach and awareness in promoting LID technologies in the watershed
	Increase monitoring at all six wastewater treatment plants (WWTPs) in the watershed. Monitor at 20 new points at the Brockton WWTP and expand monitoring from 10 to 20 points at the Taunton WWTP
	Investigate new wastewater treatment technologies. Identify sources of funding to research innovative wastewater treatment technologies for application in WWTPs.
	Increase water quality monitoring of fisheries (including anadromous fisheries). This includes (1) develop a QAPP for volunteers to ensure data integrity and (2) identify and register rare cold water fisheries in the watershed.
2008 R.I. Systems Level Plan	Ensure operator training to support and maintain efforts in advanced plant operations associated with nutrient removal and biosolids management
	Showcase successful biological nutrient removal facilities.
	Complete Phase 1 of the CSO abatement plan for NBC regional system and monitor resulting reductions in pathogen concentrations.
	Where warranted, extend or establish public sewer service to mitigate pollution problems resulting from continued reliance on septic systems in densely developed coastal areas: Portsmouth (Island Park and Portsmouth Park), Greenwich Bay, and Green Hill Pond.
	Promote proper WWTF maintenance and institute asset management for collection systems as a strategy for reducing sewer system overflows
	Ensure financial assistance is available to support necessary WWTF improvements and to address repair and replacement of aging infrastructure.
	Institute tiered-aquatic life water quality standards.
	Develop multi-parameter TMDL's.
	Implement requirements for on-site wastewater treatment in sensitive coastal areas such as embayments and coastal lagoons.
	Promote the network pump-out stations and services throughout state waters. Assess and work to increase boater compliance.
	Promote and enforce no-discharge zone provisions in all Rhode Island's marine waters

Goal Source	Actions to Implement
	Water Quality (Fresh and Salt)
	Phase out cesspools in sensitive coastal regions via implementation of the 2007 cesspool phase-out law.
	Improve DEM's, DOH's, and DOT's collaborations to investigate and the increase their resources for resolving pollution affecting public beaches and bathing water quality, particularly those due to stormwater such as Scarborough Beach.
	Support and finance sewage treatment upgrades in the town of Portsmouth.
	Provide technical outreach and environmental education to homeowners and other on-site wastewater treatment system (OWTS) owners.
	Improve how financial assistance programs (CSSLP) meet local community needs for OWTS.
	Adopt low impact development (LID) site permitting approaches new construction and redevelopment that reduce stormwater pollution..
	Beef up state and federal training and technical assistance to municipalities for implementing stormwater Phase II plans and regulations.
	Strengthen state requirements for retrofits of existing stormwater systems.
	Ensure that state and quasi-state facilities to demonstrate leadership in adopting effective stormwater management practices.
2008 Blackstone River - Clean by 2015, Blackstone River Coalition	Reduce pollutants washed into the waterways and the volume of stormwater
	Implement more stringent limits on nutrients such as nitrates and phosphate

Goal Source	Action to Implement
	Living Resources (Fish and Wildlife, Habitat
1992 CCMP	Develop species-specific management plans for: commercially, recreationally, and ecologically important fish and shellfish; all threatened and endangered estuarine-dependent plants and animals; native anadromous and catadromous fisheries to Bay tributaries
2004 Report of the R.I. Governor's Commission	Prepare strategic plan for restoration and protection of Bay as fish habitat
	Open 35 miles of river to anadromous fish passage
	Restore 100 acres of coastal wetland
	Restore 100 acres of riparian buffer
	Protect 1500 acres of sensitive coastal resource areas
	Reduce shellfish closure days by 50% and re-open 200 acres of shellfish beds
	Restore and protect those areas of the Bay identified as critical fish habitats
	Open 100 miles of anadromous fish passage
	Restore fish passage on Blackstone, Pawtuxet, 10-mile, and W-P rivers
	Restore additional 100 acres of coastal wetland
	Restore additional 100 acres of riparian buffer
2003 Visioning Technical Report for Partnership for Narragansett Bay	Achieve desirable levels of key fish and shellfish species
	Restore anadromous fish to the Blackstone River
	Increase forest buffers to 40 miles

Goal Source	Action to Implement
	Living Resources (Fish and Wildlife, Habitat
	Increase salt marsh restoration to 200 acres and eelgrass to 150 acres
	Designate the upper and lower Taunton as National Wild and Scenic River
	Develop an interstate plan to permanently protect the Pawcatuck Borderlands as unfragmented forest
	Working with local stakeholders, designate 500 scenic vistas for permanent protection
	Conditionally re-open 1000 acres of currently closed shellfish beds in upper bay and rivers
	Increase amount of rivers/streams open to anadromous fish by 502 acres
	Increase forest buffers by 25 miles
	Restore 160 acres of salt marsh and 50 acres of eelgrass beds
	Permanently protect 500 acres of fresh and salt water marshes and 150 acres of eelgrass
	Reduce by 90% the loss of fish by entrapment and other causes at power plants and industrial facilities (2000 baseline)
2008 R.I. Systems Level Plan	Expand protection and restoration of stream buffers.
	Increase emphasis of state, federal, and non-profit land acquisition programs upon the protection of critical headwater parcels.
	Minimize impervious cover to prevent stormwater runoff from impairing water quality and habitat.
	Implement DEM strategic plan for restoration of anadaromous fisheries.
	Improve rivers protection regulations, which will benefit riverine vegetated buffers, coastal water quality, and fish and wildlife habitat. (2004 Gov's Commission recommendation)
	Fund coastal and riparian buffer restoration site identification projects, which is a crucial first step in restoring riverine habitats,
	improving riverine and coastal water quality and is a requirement for federal funding. (2004 Gov's Commission recommendation)
	Develop incentives for private property owners to participate in habitat restoration projects. (2004 Gov's Commission recommendation)
	Assist and encourage communities to adopt and implement conservation development that will protect sensitive habitats. (2004 Gov's Commission recommendation)
2008 Blackstone River ~Clean by 2015, Blackstone River Coalition	Restore wetlands and riparian areas
	Protect cold water fishery streams
	Restore streamflow by methods such as improving impoundment management, breaching or removing dams, and establishing fish passage for anadromous species at the four lower-most dams

Goal Source	Action to Implement
	Watershed Lands
1992 CCMP	Develop municipal guidance on nonpoint source BMPs, innovative land management and growth practices, and local and regional stormwater management plans to reduce or treat runof
	Develop statewide critical resource protection policies that include objective criteria for designating critical resources and resource protection areas, GIS-based resource inventory,regulatory and non-regulatory controls for protecting resources, and special area management for Greenwich Bay
2004 Report of the R.I. Governor's	Complete final dredged material master plan, including 20-year O&M strategic plan for port activity and marine transportation

Goal Source	Action to Implement
	Watershed Lands
Commission	
	Prepare strategic plan for recreational boating infrastructure
	re-open 25% of currently closed swimming areas
	reduce by 50% number and frequency of beach closures
	Make Blackstone, Woonasquatucket, W-P, and GB fishable and swimmable
	make Seekonk, Moshassuck, Providence, Pawtuxet, Upper Bay and Mt. Hope Bay fishable and swimmable
2003 Visioning Technical Report for Partnership for Narragansett Bay	From 2010 baseline of vacant or underused sites, re-use an additional 25 % more
	Double the economic value of heritage-based tourism in the Region
	Re-open 5 historically used beaches in the upper bay
	Make all rivers swimmable
	Implement water conservation plan
	Add 2000 new jobs to the maritime sector
	Develop interstate water conservation and use plan
	Re-use 25 % of identified major vacant or underused sites suitable for economic development
	Complete a public process to develop revitalization plans for priority urban areas of the west side of Aquidneck Island; the Fall River waterfront; the Weir section along the Taunton; the East Providence, Providence, and Pawtucket waterfronts on the Providence and Seekonk Rivers; and Quonset – Davisville
	Complete needs analysis for navigation/recreation channels, marinas, and basins
	Add 20 new access points and 200 miles of trails along rivers and bayfront
	Establish 400 miles of canoe and kayak river trails
	Require public access in all substantial non-industrial development and redevelopment projects, river and bay
	Locate half of new residential and commercial development in designated growth centers
	Double economic value of heritage-based tourism in region
	Locate two-thirds of new residential and commercial development in designated growth centers
	Provide at least 34,200 new employment opportunities for RI residents, achieving and maintaining full employment
2008 R.I. Systems Level Plan	Work with Municipalities to expand utilization of zoning tools such as performance standards to encourage appropriate development of industrial waterfront sites.
	Continue to invest in the remediation of waterfront brownfield sites.
	Encourage communities to adopt more compact growth techniques such as village centers and conservation development to reduce impervious cover from roads and parking lots.
	Evaluate the capacities of existing infrastructure systems to support the planned and/or anticipated build-out at local and regional levels.
	Target applicable grant funds for infrastructure improvements, recreation, and housing to designated community growth centers.
	Continue to assess the best means to accommodate growth while preventing impacts to the aquatic environment as well as community character.
	Develop and apply statewide incentives, training, outreach, and technical assistance to localities to "grow greener" via conservation development

Goal Source	Action to Implement
	Watershed Lands
	and related strategies.
	Link future growth to water supply availability.
	Maintain and expand when possible public rights of way to the shore.
2006 5-Year Action Plan for Taunton River Watershed	Preserve and protect working and historic farms
	Remove remnants of the Plymouth Street Dam in Bridgewater, allowing for a "source to the sea" continuous canoeable passage from the Matfield River to Fall River.
	Develop a walking/equestrian trail system at the Assawompset Pond complex, including signage, public awareness programs, trail maps, parking areas and ADA-access.
	Develop a basin-wide trail system map to identify existing trail systems. This map would also be planning tool to identify potential connection points between trail systems. Assess the previously completed "Taunton River Trail Plan" as a starting point for this effort.
	Develop basin-wide recreational maps that identify canoe access points and historical sites. Printed copies of maps may be provided at kiosks within the watershed. Develop a digital, interactive watershed map of that incorporates information from existing digital Public Access Board maps.
	Develop and install signage to promote awareness of important watershed features.
	Examples of signage may include “Entering the Taunton River watershed” and tributary stream signage at major stream crossings, Water Supply Protection Areas, and Source Water Protection Areas.
	Develop laminated canoe trail maps for canoeable rivers in the watershed (e.g. Three Mile River, Mill River and Town River) and distribute in kiosks at canoe access points. The maps may identify historical and archeological sites.
2008 Blackstone River - Clean by 2015, Blackstone River Coalition	Build a system of river access points to increase opportunities to fish, paddle, and enjoy passive recreation

Goal Source	Actions to Implement
	Management
1992 CCMP	Cooperate to execute a long-term monitoring program to measure effectiveness of CCMP actions and evaluate trends in Bay status and health
	establish fisheries research program
	plan an IAG for WQ monitoring program
	Establish a Narragansett Bay Implementation Committee, Policy Committee, and planning section to coordinate/oversee CCMP implementation; participate in CCMP implementation through legislation, regulations, and policy, and by commenting in federal consistency reviews; supervise/review results of long-term monitoring program; supervise CCMP based on new scientific, policy, or economic information
	study feasibility of Bay/Watershed Restoration bond
2008 R.I. Systems Level Plan	Support and advance Special Area Management Planning for critical coastal regions.
	Ensure that development regulations, including SAMP’s and local zoning are adequately coordinated with each other, up-to-date, and enforced.
	Develop headwater tributary maps and set priorities for their protection.
	Pursue the development and utilization of community asset maps state-wide.

Goal Source	Actions to Implement
	Management
	Create an aquaculture research and technology facility on Narragansett Bay.
	Support the RI Aquaculture Initiative as a means to promote collaboration between state agencies, The Slater Fund, industry, and university-based research and outreach programs.
	Plan for future climate change and sea level rise through timely implementation of Section 145 of the Rhode Island Coastal Resources Management Program.
	Develop mechanisms for intra-state regional cooperation in water resource management.
	Evaluation of ambient and watershed-scale water conditions to track consequences of WWTF's upgrades for biological nutrient removal.
	Significantly increase the capacity of state agencies in partnership with private interests to prevent, respond to, and reduce invasive species through implementation of the Rhode Island Aquatic Invasive Species (AIS) Plan.
	Establish a status and trends for coastal habitats program to assess habitat changes, impacts, and protection/restoration progress over time and to effectively direct funding programs addressing habitat protection and restoration. (2004 Gov's Commission recommendation)
	Update coast-wide wetland and seagrass mapping, which will allow improved restoration and conservation planning and enhanced wetland enforcement. (2004 Gov's Commission recommendation)
	Invest in communications regarding science, policy, and agency programs to the media, user groups, and the general public.
	Promote life-long education in aquatic environmental science.
	Increase support of local watershed organizations via the RI Rivers Council.
	Increase state support for URI Watershed Watch
	Coordinate the efforts of RI Sea Grant, the URI Coastal Institute, the URI Cooperative Extension Program, The RI Rivers Council and the Narr. Bay Estuary Program via the Narr. Bay National Estuarine Reserve's Coastal Training Program.
	Invest in the development and maintenance of key data archive networks such as **NarrBay.org**.
	Develop an integrated economic and environmental indicator system through the efforts of the Environmental Monitoring Collaborative and the Economic Monitoring Collaborative.
	Invest in systems modeling from hydrography to biology to human uses.
	Invest in baseline data development eg. Seafloor and inshore mapping via **BayMap** and **MapCoast**.

Acronyms

Acronym	Definition
RIBRWCT	R.I. Bays, Rivers and Watersheds Coordination Team
CCMP	Comprehensive Conservation and Management Plan for Narragansett Bay
CSO	Combined Sewer Overflow
CZM	Coastal Zone Management
DO	Dissolved Oxygen
EBM	Ecosystem Based Management
EOEEA	Mass. Executive Office of Energy and Environmental Affairs
FTE	Full Time Employee
GIS	Geographical Information System
GSO	University of R.I. Graduate School of Oceanography
HAP	Hunt-Annaquatucket-Pettaquamscutt
KWD	Kingston Water District
MADEP	Massachusetts Department of Environmental Protection
NASA	National Aeronautics and Space Administration
NBC	Narragansett Bay Commission
NBEP	Narragansett Bay Estuary Program
NBNERR	Narragansett Bay National Estuarine Research Reserve
NBR	Narragansett Bay Region
NOAA	National Oceanographic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
PNB	Partnership for Narragansett Bay
PPA	Performance Partnership Agreement
RAS	Rapid Assessment Survey
RICRMC	R.I. Coastal Resources Management Council
RIDEM	R.I. Department of Environmental Management
RIDOH	R.I. Department of Health
RIGIS	R.I. Geographical Information System
RINHS	R.I. Natural History Survey
SAV	Submerged Aquatic Vegetation
SLP	RIBRWCT System Level Plan
STB	Save The Bay, Narragansett Bay
TMDL	Total Maximum Daily Loads
UBWPAD	Upper Blackstone Water Pollution Abatement District
URI	University of Rhode Island
US FDA	U.S. Food and Drug Administration
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WRB	R.I. Water Resources Board
WWTF	Waste Water Treatment Facility

Glossary

Term	Definition
Abiotic	The non-living physical and chemical factors in the environment such as sunlight, temperature, and atmospheric gasses.
Anadromous	Fish that spend most of their lives in the ocean, but move up rivers to spawn.
Anoxia	The absence of or insufficient levels of oxygen in a system or living being.
Anthropogenic	Man made factors affecting the ecosystem; such as carbon dioxide released from burning fossil fuels, and impervious surfaces such as parking lots.
Aquifers	An underground layer of permeable rock (sandstone, limestone), sediment or soil (sand, silt, clay or gravel) that yields water. The pore spaces in aquifers are filled with water and are interconnected.
Baseline	Data and information known about an environment at the starting point of a study.
Bathing Beach	Any natural area or tract of land which is used in connection with swimming and/or bathing in any waters of the state provided it is maintained and open to the public, either by membership, fees, or free.
Benthic	The lowest level of a body of water such as a lake or estuary, including the sediment surface and sub-surface layers.
Biotic	Naturally occurring organisms in a system including the interactions between the organisms and their environment and community
Chloride	A salt used during the winter to de-ice roads which enters a body of water through runoff.
Chlorophyll	A green pigment found in plants responsible for photosynthesis, allowing plants to obtain energy from sunlight.
Clean Water Act	The principal federal law (established 1977) that governs water pollution through goals of eliminating releases to water of high amounts of toxic substances, ensuring that surface waters would meet standards necessary for human health and recreation
Contact Recreation	Recreational activities involving a significant risk of ingestion of water, including wading by children, swimming, water skiing, diving and surfing.
Demersal Fish	Fish that feed on or near the bottom of the ocean or deep lake. Demersal fish are also known as bottom feeders, ground fish or benthic fish.
Depuration	Removal of impurities from the body. Shellfish harvested in closed waters can be cleansed of potential toxins by conditioning them in a closed system and disinfecting the water through the application of ozone and ultraviolet light.
Diatoms	One of the most common types of phytoplankton, characterized by their unique cell wall made of silica. Diatoms are unicellular organisms with asymmetrical sides that can also live in colonies.
Dinoflagellates	One of the most common types of phytoplankton, characterized by the presence of two flagella that allow them to propel themselves through the water. Their populations are distributed depending on temperature, salinity and depth.

Discharge	Point sources such as pipes or man-made ditches that release pollutants to surface waters. Industrial, municipal, and other facilities must obtain permits if their discharge goes directly to any surface water.
Drainage Basin	An extent of land where water from rain and snowmelt drains downhill into a body of water such as wetlands, lakes, rivers and estuaries. Also referred to as watershed, or catchment area.
Eelgrass	Also known as seagrass, this aquatic vegetation is found on sandy substrates in estuaries growing up from extensive branching roots called rhizomes. Eelgrass beds are important for sediment deposition and substrate stabilization and serve as nursery grounds for many species, providing protection to economically important fish and shellfish.
Embayment	An indentation of a shoreline larger than a cove, but smaller than a gulf.
Enterococci	A type of bacteria that live in the intestines of animals, including humans. They can cause a number of medical problems in humans from urinary tract infections to meningitis.
Estuary	A partially protected body of water where the rivers meet the sea. Estuarine waters are brackish, meaning they have a lower salinity than the open ocean, but higher than fresh water.
Eutrophication	Excess nutrients, particularly nitrogen and phosphorous which increase an ecosystem's primary productivity. Further effects include a lack of oxygen and severe reductions in water quality and many organisms inhabiting that body of water.
Fecal Coliform	A bacteria found in feces of humans and wildlife that is used as an indicator in evaluating water quality. High levels of fecal bacteria indicate a failure in water treatment and possible contamination of pathogens.
Fish Ladder	Also known as fishways, fish steps, or fish passages, are man-made structures on or around barriers such as dams and locks that facilitate anadromous fish passage. Fishways are engineered such that the flow attracts fish to the opening of the ladder.
Floodplains	The flat land adjacent to a stream or river that experiences occasional or periodic flooding.
Fragmentation (Habitat)	Environmental changes in the connectivity of an organism's preferred habitats, frequently caused by agriculture, development and urbanization.
Groundwater	Water located beneath the ground surface in soil pore spaces and fractures in rock.
Hydrology	The study of the movement, distribution and quality of water, thus addressing both the hydrologic cycle and water resources.
Hypoxia	The point at which dissolved oxygen (DO) levels in water are reduced to a point detrimental to aquatic organisms living in the system
Impervious Surface	Artificial structures such as pavement (roads, sidewalks, and parking lots) and rooftops that are covered by impenetrable materials such as asphalt, concrete, brick, or compacted soil.
Indicators	A set of metrics used to evaluate the status and trends of the quality of the environment.
Infrastructure	The services and facilities necessary for an economy to function. The development of roads, water supply, sewer systems, power grids and buildings.

Invasive Species	An organism that is introduced into an environment in which it has an advantage to the native species and out competes them for habitat and food.
Invertebrate	An animal lacking a vertebral column, classified in over 30 phyla ranging from simple sea sponges to complex animals such as arthropods and mollusks.
Macroalgae	Also known as seaweed; algae that is visible to the naked eye.
Main stem	The principal channel within a given drainage basin into which all of the tributary streams flow.
Marsh	A type of wetland which is subject to frequent or continuous flooding. Typically featuring grasses, reeds and low growing shrubs or woody plants growing in shallow water.
Microorganisms	An organism too small to see with the naked eye and include a diverse array of bacteria, fungi, viruses and plankton. They are critical to nutrient recycling in the ecosystem as the act as decomposers.
Nonpoint source	Water pollution affecting a water body from diffuse sources such as agricultural runoff, pet waste and drainage from highways.
Nutrient Loading	The amount of nutrients moving into a system through point and nonpoint sources.
Pathogen	An infectious biological agent that causes disease or illness to the host.
Pelagic	Water in a bay or ocean that is not close to the sea floor; mid- and upper-levels of the water column.
Periphyton	A complex mixture of algae, cyanobacteria, microbes and detritus attached to submerged surfaces in most aquatic ecosystems, serving as an important food source for invertebrates, tadpoles and some fish. It can also serve as a filter, absorbing contaminants from the water column and limiting their movement through the environment.
Phytoplankton	Microscopic algae that obtain nutrients through photosynthesis. Most simply drift through the water column with the currents, but some have limited mobility of their own known as flagella.
Plankton Bloom	A rapid increase in the population of a specific species of algae in an aquatic ecosystem. Some blooms such as "red tide" are known as harmful algal blooms (HAB) and can cause illness to humans and aquatic organisms.
Point Source	An identifiable, localized source of pollution such as a water discharge outlet at a power treatment plant, smog from an industrial smoke stack, and intrusive lights form a city.
Pollution Gradient	Refers to the continuous decrease in measure of total pollutants as one moves away from the source of the pollution.
Primary Productivity	The base of the food chain where production of organic compounds from aquatic and atmospheric carbon dioxide, principally through photosynthesis.
Pump-out Facility	An on-shore holding tank where a ship's sewage is discharged and sent to a treatment plant.
Respiration	In animal physiology, it is the transport of oxygen from the outside air to the cells within tissues and the transport of carbon dioxide in the opposite direction.
Rotating Basin	A program to assess and document water quality of all waters in an area, designed so that all waters are monitored on a set periodic basis.

Runoff	The water flow which occurs when soil is infiltrated to full capacity and excess water from rain, snowmelt and other sources flows over the land.
Seagrass Bed	Submerged aquatic flowering plants that provide essential habitats to mollusks and nursery grounds for many species of fish and invertebrates.
Sediment Profile Imaging	A technique for photographing the interface between the seabed and overlying water, used to estimate biological, chemical and physical processes occurring in the first few centimeters of sediment.
Sprawl	The spreading of suburban development requiring extensive road surfaces over rural land at the fringe of an urban area.
Stakeholder	A person, group, organization or system that affects the decisions made by an organization or a project.
Stormwater	Water that originates during precipitation events that does not soak into the ground becomes surface runoff containing pollutants and is most often channeled into waterways and storm sewers.
Stratification	The layering of water due to differences in temperature, salinity, and light penetration.
Sub-basin	One of a number of smaller watersheds systems within a larger watershed
Tidal Inundation	The intrusion of tidal waters into the mouth of a river.
Trawl Survey	A method of collecting biological specimens (such as fish) by towing a net as a defined depth in a water body.
Un-ionized Ammonia	The principal form of ammonia that is toxic to aquatic life. Proportions are controlled by water temperature and pH.
Water Quality Standards	State-adopted and US EPA approved ambient standards for certain chemical, biological and physical parameters in a water body.
Watershed	The geographic area in which water drains into a specific water body.
Wetland	Ecosystems characterized by having a water table that stands at or near the land surfaces for a long enough season each year to support aquatic plants.
Zooplankton	Organisms, or creatures, ranging from copepods to jellyfish, that drift in the water column, but differ from phytoplankton in that they do not photosynthesize.

Narragansett Bay Estuary Program May/June 2009

NARRAGANSETT BAY ESTUARY PROGRAM

CURRENTS of Change

Summary Report

Workshop Identifies Needs for Narragansett Bay Region

On May 1st, more than 50 scientists and resource managers met in Bristol, R.I., for a workshop to consider the implications of a draft report on environmental status and trends of the Narragansett Bay Region. The meeting, titled Currents of Change, was organized by the Narragansett Bay Estuary Program (NBEP) following its release of a draft report by the same name, and was held at Roger Williams University, overlooking Mount Hope Bay.

To take stock of Narragansett Bay's watershed ecosystem as well as the state of knowledge about it, the workshop participants engaged in panel discussions and small-group breakout sessions. They discussed challenges to sustainable management of the Narragansett Bay ecosystem, learned about approaches that are working elsewhere, and began developing collaborative solutions. John Howell of Washington state's Cascade Agenda provided an overview of a 100-year regional vision to preserve environmental quality in the Pacific Northwest, while Bill Howland of the Lake Champlain Basin Program shared his experience in managing an international watershed which spans Vermont, New York state and Canada.

The day of discussion and debate was intended to lay a foundation for action to meet the environmental challenges facing Narragansett Bay. These notes summarize the results of the Currents of Change workshop—recognizing that the day's discussions were far too diverse and interesting to capture completely in this brief report!

Download the full report
Currents of Change
Collaborative Action Toward Sustainable Management of the Narragansett Bay Region
www.nbep.org

INSIDE

Thank You!

Sincere thanks to the many individuals and organizations that helped make Currents of Change a reality. We're grateful to all who provided expertise and information in developing both the report and workshop; those who reviewed and commented on the draft report; and workshop panelists and presenters. Special thanks to the members of NBEP's management committee for supporting this effort. We look forward to working with you all—and, we hope, many new partners—in ensuring a sustainable future for the Narragansett Bay Region!

Workshop and report contributors

- Blackstone River Coalition
- Brown University
- Cascade Land Conservancy
- Friends of the Moshassuck
- Grow Smart Rhode Island
- Mass Audubon
- Mass. Department of Environmental Protection
- Massachusetts Bays Program
- Narragansett Bay Commission
- Narragansett Bay National Estuarine Research Reserve
- R.I. Bays, Rivers and Watersheds Coordination Team
- R.I. Coastal Resources Management Council
- R.I. Dept. of Environmental Management
- R.I. Dept. of Administration
- R.I. Natural History Survey
- R.I. SeaGrant
- R.I Statewide Planning Program
- Roger Williams University
- Save the Bay
- The Nature Conservancy
- Taunton River Watershed Alliance
- U.S. Environmental Protection Agency
- U.S. Geological Survey
- University of Rhode Island
- University of Massachusetts
- USDA Natural Resources Conservation Service
- Woonasquatucket River Watershed Council

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Findings of the Report

Currents of Change uses environmental indicators to describe "status and trends" of the ecosystem—that is, to assess current conditions and provide a means of tracking changes, in order to inform future management. The report describes an ecosystem which has seen significant environmental improvements in recent years, but which still faces substantial challenges. Findings of the report:

- Control of pollution point sources is improving—for example, wastewater treatment plants have reduced nitrogen discharges by one-third over the past five years, leading to improvements in river water quality. New combined sewer overflow (CSO) capture systems in Providence and Fall River will reduce bacterial contamination of beaches and shellfish beds following rain storms.
- Non-point source pollution from storm water, cesspools and failed septic systems, has major impacts on water quality. Runoff from impervious (non-infiltrating) surfaces in developed areas is a principal source of pollution to rivers, lakes and Narragansett Bay, degrading fish and wildlife habitat and contributing to closures of beaches and shellfish beds. By contrast with point sources, existing sources of non-point source pollution are not well controlled. New cesspool phase-out requirements in Rhode Island will help improve water quality.
- Land use in the Narragansett Bay Region is a principal contributor to non-point source pollution. Impervious surfaces have been increasing (covering more than 30 percent of the land in coastal population centers), increasing storm water flows and reducing the ability of the land to filter pollution. New development has continued, despite modest or flat population growth regionally.
- Environmental information is of variable quality and coverage, often lacking trends information and generally inconsistent across state lines. At present, therefore, it is difficult to assess ecosystem trends or determine the effectiveness of environmental management.

Currents of Change is available on NBEP's website, www.nbep.org, and is open for public comment through the end of May. In June, NBEP will incorporate public comments as well as those from the workshop, for a final report to be released in July.

Join Us!

www.nbep.org

To read and comment on the *Currents of Change* report, review detailed recommendations from the May 1 workshop, and get involved in shaping Narragansett Bay's environmental future, visit our website or contact us:

Email: currents@nbep.org
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Workshop Recommendations

Recognizing the environmental challenges described by the report, workshop participants focused on finding solutions for the Narragansett Bay Region. Among the day's wide-ranging discussions, several key themes emerged, and a number of ideas generated consensus. Together, they point to an urgent need for "ecosystem-based management:" an approach which transcends political boundaries and recognizes the importance of both human and natural systems within the Narragansett Bay Region.

Participants widely agreed that these actions are necessary to achieve sustainable management of the Bay ecosystem:

- ***Develop a stakeholder-based vision and goals:*** While many reports have set goals for the Narragansett Bay ecosystem, workshop participants agreed on the need to more broadly engage stakeholders, to create a shared vision of a positive environmental future and identify priority actions for the Narragansett Bay Region.
- ***Take a long-term view:*** Employ a significant time horizon—like the 100-year vision used by the Cascade Agenda—to capture stakeholders' imagination and inspire positive change on a grand scale.
- ***Improve environmental information:*** Refine and improve the indicators reported in Currents of Change, aligning indicators with ecosystem goals so that stakeholders and managers can better assess environmental progress and management effectiveness.
- ***Work across state lines:*** Help Rhode Island and Massachusetts improve interstate information and collaboration in order to adequately manage Narragansett Bay's bi-state watershed.
- ***Increase resources:*** Improve institutional commitments and identify alternative funding mechanisms, such as market-based approaches to environmental protection.
- ***Focus on liveable communities:*** To preserve open land and reduce storm water impacts, focus on improving existing communities—by redeveloping the built environment, "greening" transportation systems, and fostering environmental justice.
- ***Transcend "home rule":*** To overcome municipalities' parochial interests, investigate and employ new or alternative approaches such as regional planning and inter-municipal transfer of development rights.
- ***Find the right organization to advocate for long-range thinking, planning and change:*** Government leadership changes too frequently to sustain visions and initiatives; we need broad-based coordination outside of government, with demand for government accountability.
- ***Improve technical assistance and collaboration to address storm water impacts:*** Provide municipalities and private property owners with information, incentives and resources to reduce storm water flows.
- ***Develop strategic solutions to environmental problems—***for example, a regional approach to dam removal and river restoration.
- ***Foster understanding among the public of the value provided by intact ecosystems—***such as drinking water, pollution filtration, flood control, tourism, and fish and wildlife habitat.

Next Steps

Over the next several months, the Narragansett Bay Estuary Program will work collaboratively with the members of its management committee and other partners to begin carrying out the recommendations of the workshop. Specifically, we will:

- Distribute, by July, a final report and executive summary of Currents of Change;
- Improve environmental indicators, working with existing technical groups and convening new groups as necessary to consider informational needs (such as environmental monitoring) as well as resource requirements;
- Reach out to decision-makers and other stakeholders, engaging them as leaders to develop consensus on a vision and goals for the future of the Narragansett Bay Region—building on past and current work in science, management and planning.

In the spirit of the Currents of Change workshop recommendations, our goal is to broaden understanding of the Narragansett Bay Region as a ecosystem, facilitating the engagement of communities throughout the region in determining its—*our*— shared environmental future.

Go Deeper!

About NBEP

The Narragansett Bay Estuary Program is one of 28 National Estuary Programs created by Congress under the federal Clean Water Act. 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. Since 1987, NBEP has worked throughout the Narragansett Bay Region to improve scientific knowledge, restore rivers and wetlands, and empower communities and local organizations to plan for, manage and enjoy natural resources. For more information, check out our website—

www.nbep.org

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The Narragansett Bay Region

The subject of *Currents of Change* is the Narragansett Bay Region (NBR), an area which encompasses Narragansett Bay, its drainage basin or watershed in Rhode Island and Massachusetts, and the adjacent estuaries and watersheds of the Wood-Pawcatuck river system and Rhode Island's coastal Salt Ponds. NBR includes the land areas which have the most significant physical effect on the estuary—the source of all fresh water (more than two billion gallons per day) which flows into Narragansett Bay by way of rivers, streams and ground water. By including the Wood-Pawcatuck and Salt Ponds watersheds, NBR captures the Bay's political geography as well: lands and waters which are managed under the same framework as Narragansett Bay—for example, by means of Rhode Island's water quality programs.

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, and 57 square miles are in Connecticut. *Currents of Change* describes NBR as an "anthropogenic ecosystem"—an environment created by the natural forces of climate, geology and biology, profoundly influenced by more than two million people who live, work and vacation here. The region is truly subject to "currents of change," as lands and waters are shaped by large-scale trends as well as millions of individual actions each day—from climate change to daily commuting; commercial development to environmental legislation.