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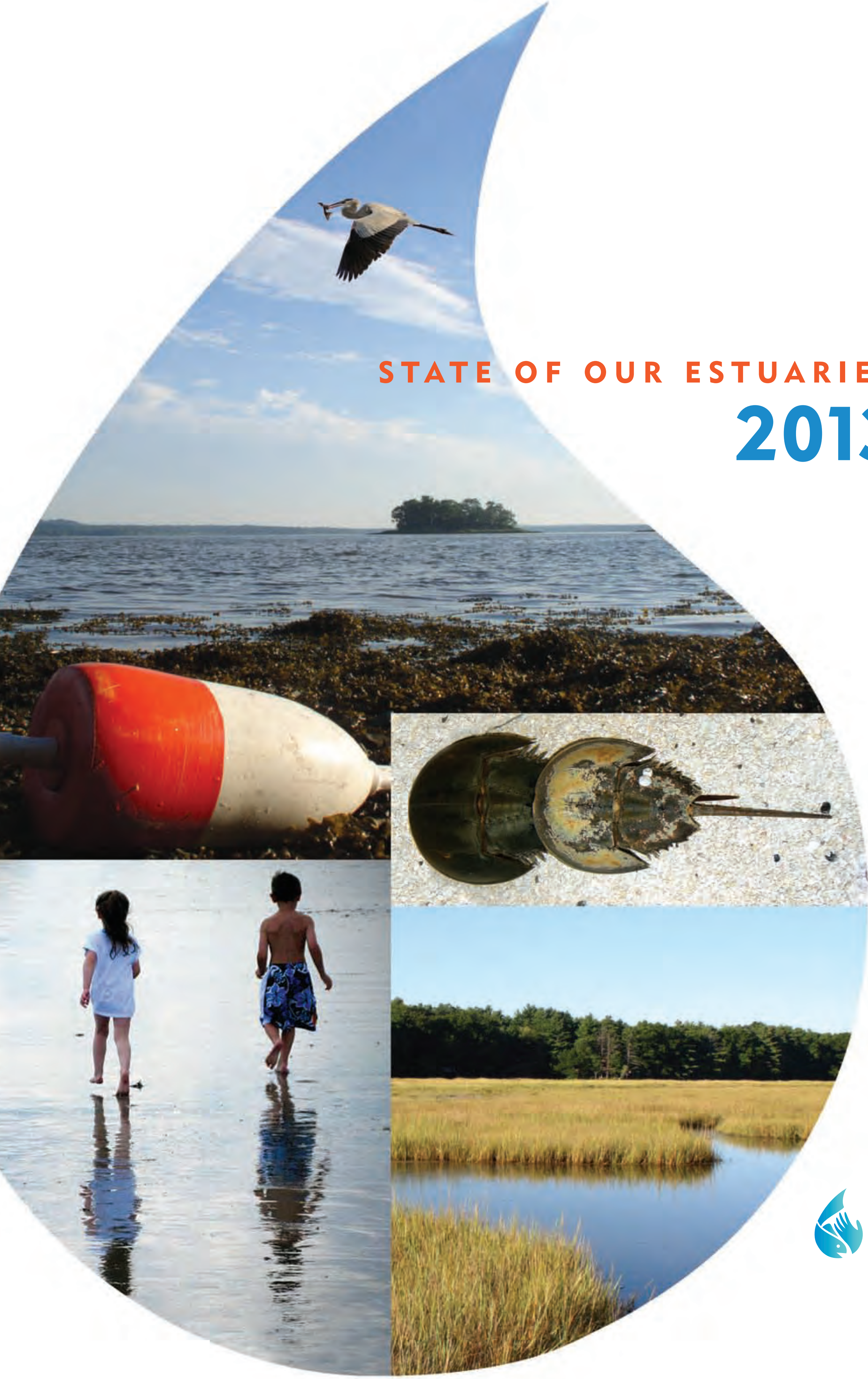

STATE OF OUR ESTUARIES 2013

PREP
Piscataqua Region Estuaries Partnership

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LETTER FROM THE EXECUTIVE DIRECTOR

We all benefit from a clean, healthy estuary.

Each of us has an important role to play in ensuring that our waters continue to provide the essential benefits and services that our communities have come to rely upon.

Our two largest estuaries – The Great Bay Estuary and Hampton Seabrook Harbor – help define who we are as a region. Whether it's swimming in one of the many rivers of the estuary, going on a bird watch, or simply dining at one of our many local restaurants, these waters provide a profound sense of place for the tens of thousands who live and visit our region every year. Our economy – from our fishermen, to recreation, to the many businesses that call our region home – relies heavily upon a vibrant and healthy estuary system.

For those of us who live, work and play in the waters of the estuary, it is imperative that we monitor, study, report and educate ourselves on the challenges facing the estuary. And, we also need to identify solutions to the challenges we face that each of us can undertake – from policymakers to businesses to citizens – to keep our estuaries in balance. That is the purpose of the State of Our Estuaries Report: to provide you with information on the relative health of our estuaries as measured by 22 indicators, and ways that you can help make our waters healthier.

Scientists often say that estuaries are some of the most complicated ecosystems in the world to study – due to the dynamic nature of tides, human activity and the mixing of fresh and salt water. Through extensive monitoring and data collection, this State of Our Estuaries Report paints a complicated and dynamic picture of our estuarine ecosystem – one that is altered by the natural forces of weather and climate, and damaged by human activity such as pollution and loss of habitat.

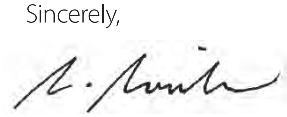
Even though our estuaries show troubling signs of decline, the news is not all bad. Through the work of many organizations, municipalities and individuals, about 90,000 acres in the estuary watershed have been permanently protected. Restoration projects have begun to rebuild lost oyster reefs, restore nearly 300 acres of saltmarsh, and re-open about 18 miles of our coastal rivers to migratory fish runs. You will read about many of these success stories in this report.

We hope that this report provides you with a sense of both hope and concern – because fundamentally, that is the story behind these dynamic estuary systems.

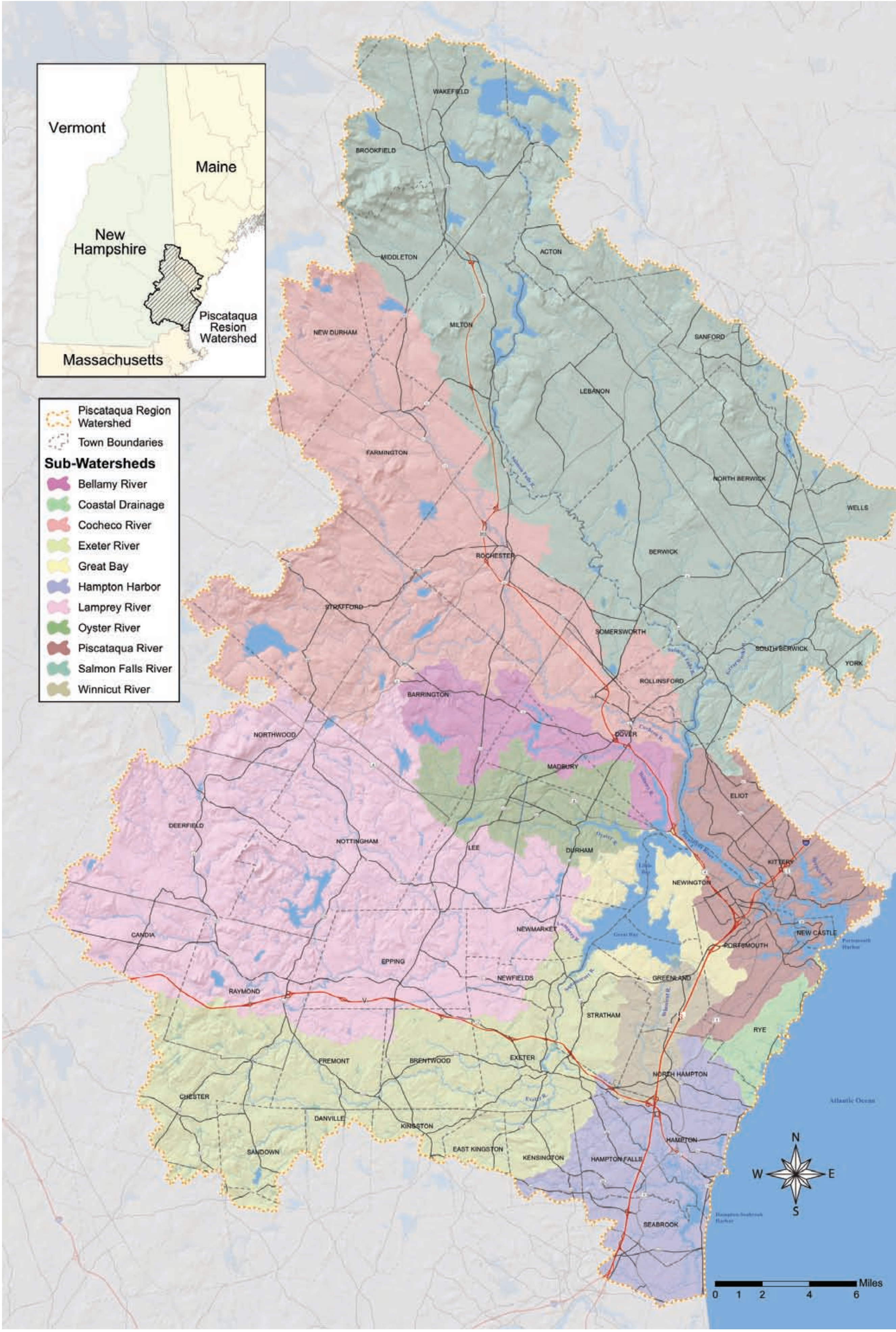
Perhaps most importantly, we have seen our communities come together to discuss the challenges facing our estuaries, and ways in which we can work together towards solutions. PREP remains committed to providing you with the information, data and research needed to make informed decisions that benefit our estuaries and the communities that rely upon them.

We hope that this report provides you with a sense of both hope and concern – because fundamentally, that is the story behind these dynamic estuary systems. But above all, we hope that this report better connects you with the place and with the community in which you live, work and play. Let's work together to improve our estuaries for today and for our future generations.

Sincerely,



Rachel Rouillard



PISCATAQUA REGION WATERSHED

Rivers flowing from 52 communities in New Hampshire and Maine converge with the waters of the Atlantic Ocean to form the Great Bay and Hampton-Seabrook estuaries. The watershed covers 1086 square miles. These bays provide critical wildlife habitat, nurseries for seafood production, buffering from coastal flooding, recreational enjoyment, and safe harbor for marine commerce. Our estuaries are part of the National Estuary Program, and recognized broadly as exceptional natural areas in need of focused study and protection.

EXECUTIVE SUMMARY OF THE STATE OF OUR ESTUARIES

We all benefit from keeping our estuaries healthy and clean. The Great Bay and Hampton-Seabrook estuaries are recognized as two premiere model systems in our nation for protection and study.

Every three years the Piscataqua Region Estuaries Partnership (PREP) produces this condition and environmental trends report in an effort to provide communities and citizens with an informed and comprehensive evaluation of what is being observed in our estuaries. This report presents our assessment of 22 key indicators of the health of our bays: 15 of which are classified as having cautionary or negative conditions or trends, while 7 show positive conditions or trends. The overall assessment shows that there is reason to be concerned about the health of our estuaries, and that increased efforts to study and restore our estuaries are needed. It also shows that there are effective efforts that can be made now to begin to reverse trends of concern.

We also recognize that the topic of nutrient levels in wastewater has become a publicly debated and contentious issue, but urge citizens and decision makers to examine all 22 indicators that together illustrate the wide-ranging challenges our system faces. While those challenges are many, this report also highlights the good work of many partners who are implementing solutions in their communities to address these environmental concerns, and perhaps most importantly, reaffirms our goals and priorities for future action.

What has been observed?

Indicators of Stresses on Our Estuaries

Our estuaries are complex and responsive to factors (stresses) both within and outside of our control. Changing climatic conditions resulting in more intense storms, polluted runoff from paved areas, human and animal waste, and excessive fertilizer application are examples of factors that can stress the ecological balance in our bays. There are two indicators that help us better understand these stresses.

- Impervious cover (paved parking lots, roadways and roofs) continued to increase throughout the region over the past three years. During rain storms and snow melt, water running over impervious areas carries pollutants which negatively impact the cleanliness of our rivers, lakes, streams and bays.
- While data has not been collected long enough to determine a long-term trend in nitrogen/nutrient loading to the Great Bay Estuary, this issue continues to be of concern. Traditional signs of nutrient-related problems such as loss of eelgrass habitat, periods of low oxygen in the water of the tidal rivers, and increases of nuisance seaweeds have been observed.

Indicators of Conditions in Our Estuaries

There are 14 indicators that help us understand more about the health and condition in the estuaries themselves. They provide a diverse picture of a number of key factors, integral to a healthy and productive system.

- Where measured in Great Bay, concentrations of the most reactive form of nitrogen, dissolved inorganic nitrogen, have increased significantly over the long term.
- Microalgae (phytoplankton) in the water have not shown a consistent long term trend in Great Bay. However, invasive and nuisance seaweed populations have increased.
- Dissolved oxygen levels in the water are at good levels in the bays and harbors, but are frequently too low in the tidal rivers with possible negative effects on marine life.

Stresses impacting the health of our estuaries are increasing, and there is reason to be concerned.

- The long term decline of eelgrass throughout most of the Great Bay Estuary is of continued concern. In spite of small increases in some areas, the total eelgrass coverage in all the bays and rivers shows a declining trend.
- Suspended sediment conditions, where measured in Great Bay, have increased over the long term which means that the water appears to be getting cloudier. Cloudy water can have adverse impacts on eelgrass, oysters, and fish.
- Bacterial contamination in Great Bay has declined substantially since 1989, but still contributes to shellfish harvest closures during rainy periods.
- The population status of oysters in the Great Bay Estuary and clams in the Hampton-Seabrook Estuary are in generally poor condition, falling well below recent historical abundances.
- Migratory fish populations exhibit cautionary trends, with high variability between years and among different rivers.
- Our region's beaches are almost always safe for swimming and the concentration of toxic chemicals in shellfish are almost all below levels deemed safe for human consumption.

Indicators of Progress on Conservation and Restoration of the Estuaries

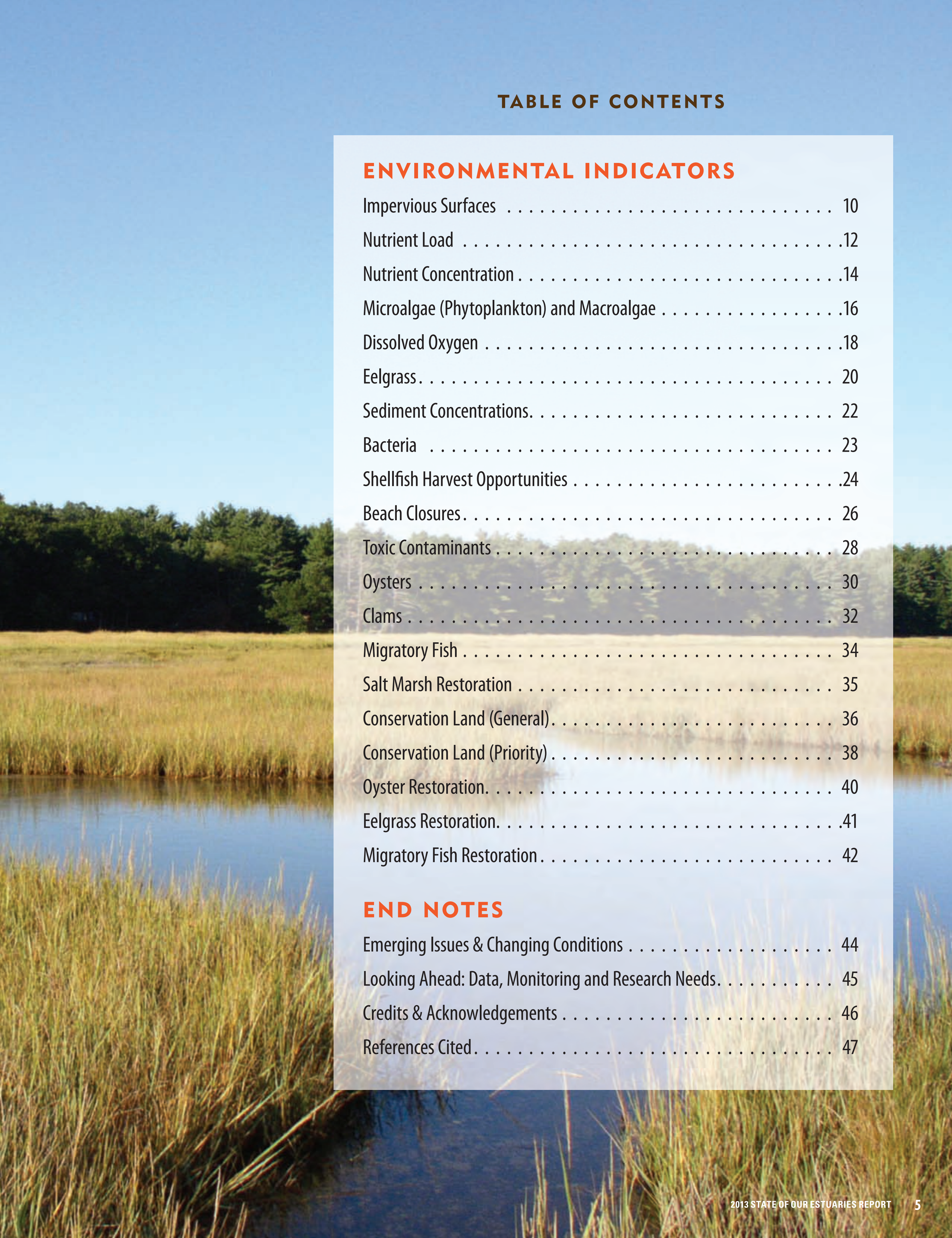
- Gains have been made in overall land conservation, oyster bed restoration, and stream miles re-connected to the estuaries for migratory fish. However, many of the region's best natural areas are not being protected fast enough, and the results of eelgrass restoration efforts have been poor.
- Substantial progress has been made on restoring salt marshes since 2000, but there has been insufficient progress made on needed salt marsh enhancement work.

Where Do We Go From Here?

The conditions and trends documented here emphasize the need for both more research and action. In this report there are sections on emerging issues and research priorities that identify questions and target knowledge gaps in order to better inform our work over the next three to seven years. As a community of people who want to ensure a healthy environment and economy, we need to take action to:

- Expand the monitoring of our estuaries and fund additional research to address knowledge gaps.
- Protect important natural areas and waterways through land conservation and improved land use planning and development practices.
- Increase the pace and scale of restoration efforts for oysters, eelgrass, salt marsh, and migratory fish populations.
- Invest in clean water through appropriate infrastructure upgrades and reduce stormwater pollution from paved areas.

These priorities are part of the 2010 Piscataqua Region Comprehensive Conservation and Management Plan, which is a stakeholder-developed, 10-year strategy for protecting and restoring our estuaries. In addition, along with a number of public and private sector partners, PREP is building a Community for Clean Water movement to work together to make a difference. Join us at www.prep.unh.edu.



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ENVIRONMENTAL INDICATORS

END NOTES

INDICATOR TABLE

Indicator Organization

Indicators are things that we can measure to characterize the pressures on our estuaries, the conditions in our estuaries, and the steps we are taking to respond to challenges in our estuaries. This report is organized with pressure indicators first, followed by condition indicators, and ending with response indicators.

There are many, many more things that are being done to respond to challenges and to restore our estuary. Look for the "Success Stories" and "Case Studies" in the sidebars of the indicator spreads as well as in the "Citizens' Guide to the State of Our Estuaries" to learn more about what's being done and how you can help.

This list of indicators is not exhaustive and does not reflect every pressure, condition, or response that does or could exist for our estuaries. Several important indicators that are missing are harmful algal blooms, fishing pressure, and climate change. However, the list of indicators covers the major issues and provides a reasonably complete picture of the State of Our Estuaries.

Pressure Indicators

Pressure Indicators measure key human stresses on our estuaries

Condition Indicators

Condition indicators monitor the current conditions in our estuaries

Response Indicators

Response indicators track what we are doing to restore our estuaries

POSITIVE Demonstrates good or substantial progress toward the management goal.

CAUTIONARY Demonstrates moderate progress relative to the management goal.

NEGATIVE Demonstrates minimal progress relative to the management goal.

POSITIVE Demonstrates improving or generally good conditions or a positive trend.

CAUTIONARY Demonstrates a possibly deteriorating condition(s) or indicates concern given a negative trend.

NEGATIVE Demonstrates deteriorating conditions or generally poor conditions or indicates concern given a negative trend.

↑ **NEGATIVE INCREASE** Statistically significant trend over the full period of record.

↓ **NEGATIVE DECREASE** Statistically significant trend over the full period of record.

↓ **POSITIVE DECREASE** Statistically significant trend over the full period of record.

INDICATOR	STATUS	STATE OF THE INDICATOR	PAGE
PRESSURE INDICATORS: STRESSES ON THE ESTUARY			
Impervious Surfaces	↑	In 2010, 9.6% of the land area of the Piscataqua Region watershed was covered by impervious surfaces. Since 1990, the amount of impervious surfaces has increased by 120% while population has grown by 19%.	10
Nutrient Load		Total nitrogen load to the Great Bay Estuary in 2009-2011 was 1,225 tons per year. There appears to be a relationship between total nitrogen load and rainfall. Although typical nutrient-related problems have been observed, additional research is needed to determine and optimize nitrogen load reduction actions to improve conditions in the estuary.	12

INDICATOR	STATUS	STATE OF THE INDICATOR	PAGE
CONDITION INDICATORS: THE CURRENT STATE OF CONDITIONS IN THE ESTUARY			
Nutrient Concentration	↑	Between 1974 and 2011 data indicates a significant overall increasing trend for dissolved inorganic nitrogen (DIN) at Adams Point, which is of concern. When examining variability at other monitoring stations with shorter periods of data, no consistent patterns can be found. Recent data considered in the context of long-term data show no pattern or trend.	14
Microalgae		Microalgae (phytoplankton) in the water, as measured by chlorophyll-a concentrations, has not shown a consistent positive or negative trend in Great Bay between 1975-2011.	16
Macroalgae		Macroalgae, or seaweed, populations have increased, particularly nuisance algae and invasives.	16
Dissolved Oxygen (Bays)		State standards for dissolved oxygen are nearly always met in the large bays and harbors.	18
Dissolved Oxygen (Rivers)		State standards for dissolved oxygen in the tidal rivers are not met for periods lasting as long as several weeks each summer.	18
Eelgrass	↓	Data indicate a long-term decline in eelgrass since 1996 that is not related to wasting disease. Due to variability even recent gains of new eelgrass still indicate an overall declining trend.	20
Sediment Concentrations	↑	Suspended sediment concentrations at Adams Point in the Great Bay Estuary have increased significantly between 1976 and 2011.	22
Bacteria		Between 1989 and 2011, dry weather bacteria concentrations in the Great Bay Estuary have typically fallen by 50 to 92% due to pollution control efforts in most, but not in all, areas.	23
Shellfish Harvest Opportunities		Only 36% of estuarine waters are approved for shellfishing and, in these areas, periodic closures limited shellfish harvesting to only 42% of the possible acre-days in 2011. The harvest opportunities have not changed significantly in the last three years.	24
Beach Closures		Poor water quality prompted advisories extremely rarely in 2011. There are no apparent trends.	26
Toxic Contaminants	↓	The vast majority of shellfish tissue samples do not contain toxic contaminant concentrations greater than FDA guidance values. The concentrations of contaminants are mostly declining or not changing.	28
Oysters		The number of adult oysters decreased from over 25 million in 1993 to 1.2 million in 2000. The population has increased slowly since 2000 to 2.2 million adult oysters in 2011 (22% of goal).	30
Clams		The number of clams in Hampton-Seabrook Harbor is 43% of the recent historical average. Large spat or seed sets may indicate increasing populations in the future.	32
Migratory Fish		Migratory river herring returns to the Great Bay Estuary generally increased during the 1970-1992 period, remained relatively stable in 1993-2004, and then decreased in recent years.	34

INDICATOR	STATUS	STATE OF THE INDICATOR	PAGE
RESPONSE INDICATORS: WHAT WE'RE DOING TO RESTORE THE ESTUARY			
Salt Marsh Restoration		280.5 acres of salt marsh have been restored since 2000, and 30.6 acres of salt marsh have been enhanced since 2009, which is moderate overall progress towards PREP's goals.	35
Conservation Lands (General)		At the end of 2011, 88,747 acres in the Piscataqua Region watershed were conserved which amounted to 13.5% of the land area. At this pace, the goal of conserving 20% of the watershed by 2020 is likely to be reached.	36
Conservation Lands (Priority)		In 2011, 28% of the core priority areas in New Hampshire and Maine were conserved. At this pace, the goal of conserving 75% of these lands by 2025 is unlikely to be reached.	38
Oyster Restoration		A total of 12.3 acres of oyster beds have been created in the Great Bay Estuary, which is 61% of the goal. Mortality due to oyster diseases is a major impediment to oyster restoration.	40
Eelgrass Restoration		A total of 8.5 acres of eelgrass beds have been restored which is only 17% of the goal. Poor water quality is often the limiting factor for eelgrass transplant survival.	41
Migratory Fish Restoration		River herring access has been restored to 42% of their historical distribution within the mainstems of the major rivers in the Piscataqua Region. This represents substantial progress in meeting PREP's goal of restoring 50% of the historical distribution of river herring by 2020.	42

INDICATOR SUMMARY

There are 16 environmental indicators and 6 management indicators presented in this report:

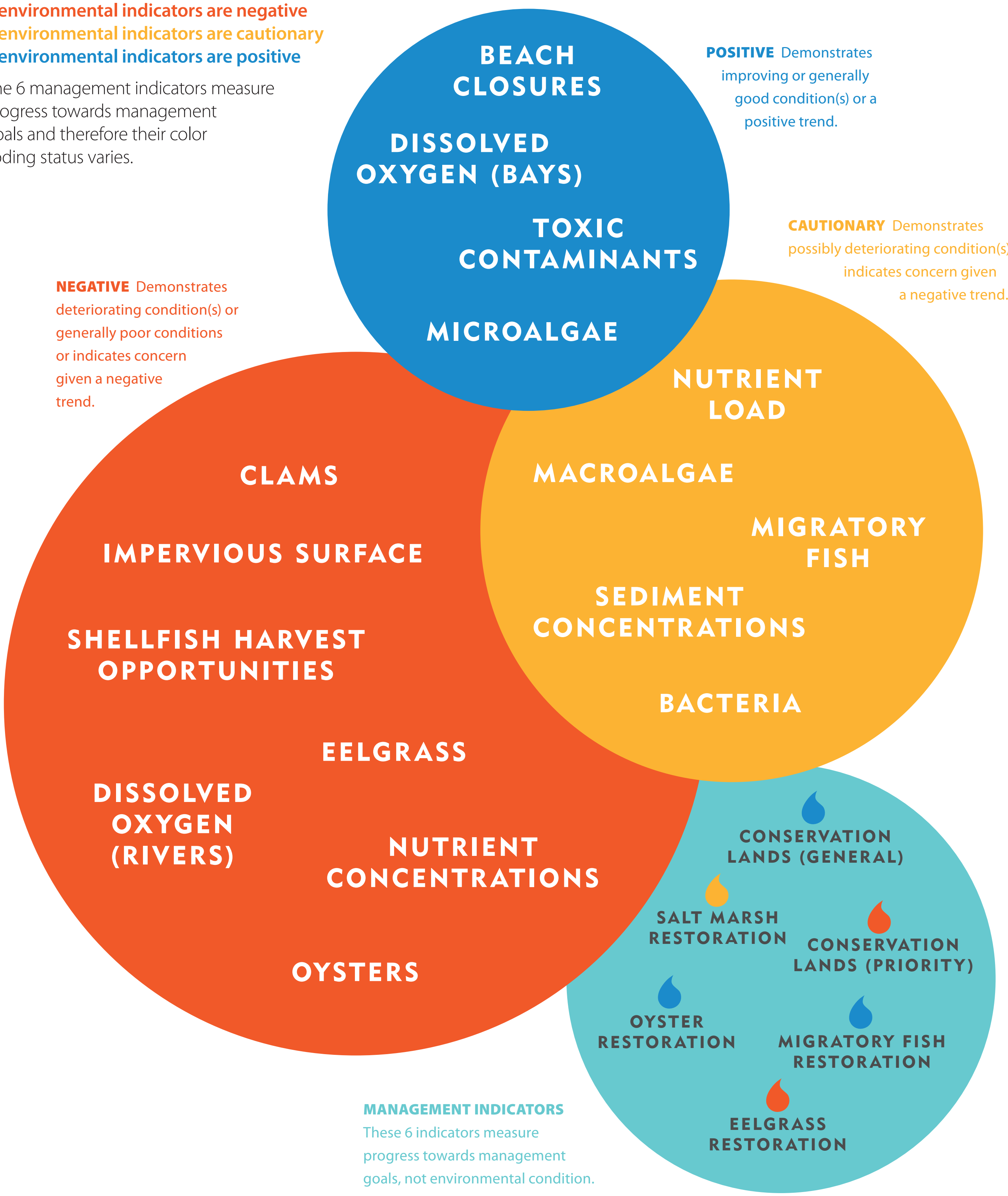
7 environmental indicators are negative
5 environmental indicators are cautionary
4 environmental indicators are positive

The 6 management indicators measure progress towards management goals and therefore their color coding status varies.

POSITIVE Demonstrates improving or generally good condition(s) or a positive trend.

CAUTIONARY Demonstrates possibly deteriorating condition(s) or indicates concern given a negative trend.

NEGATIVE Demonstrates deteriorating condition(s) or generally poor conditions or indicates concern given a negative trend.

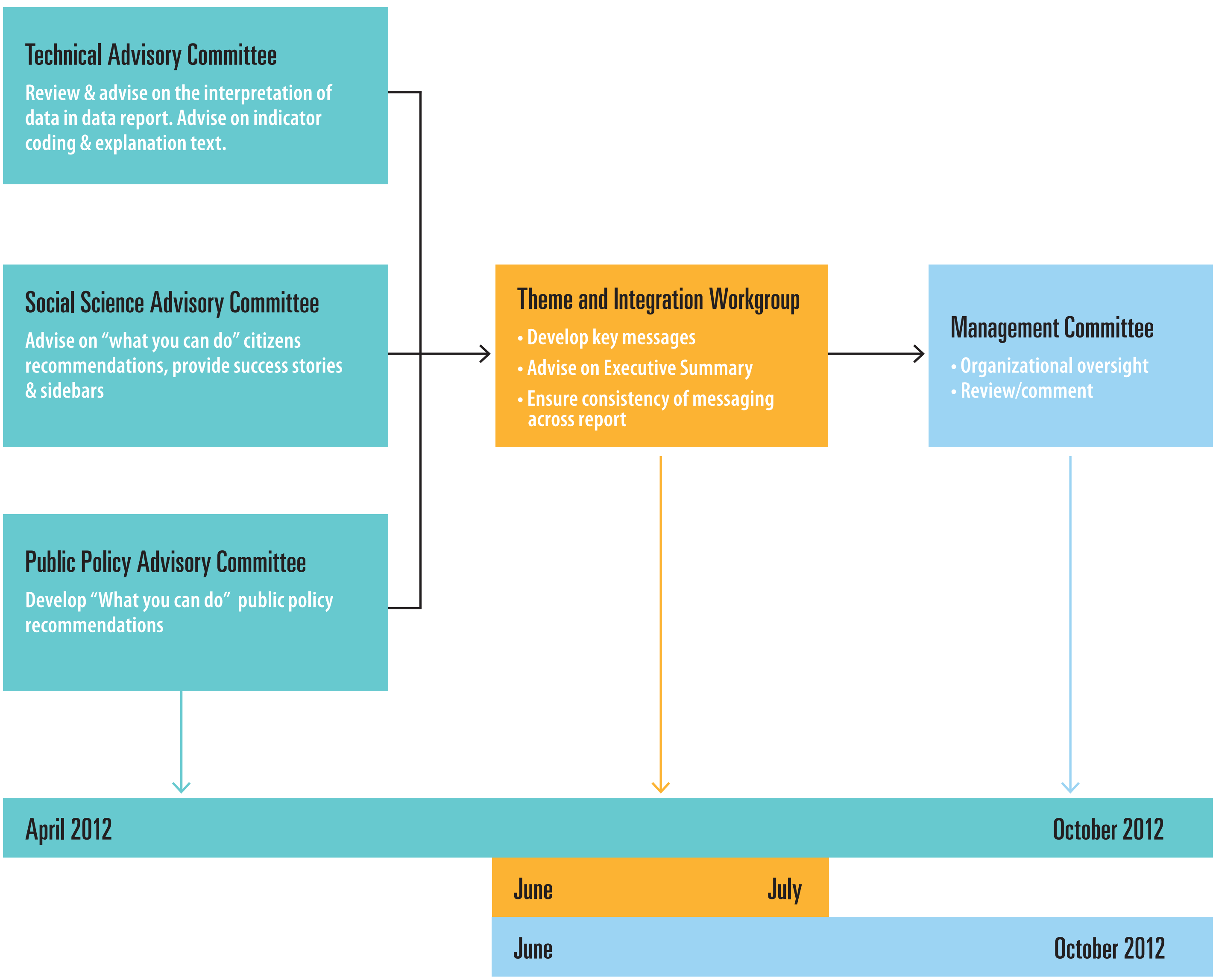


MANAGEMENT INDICATORS
These 6 indicators measure progress towards management goals, not environmental condition.

REPORT DEVELOPMENT PROCESS

This 2013 State of Our Estuaries report was developed somewhat differently than in previous years. Given the recent environmental and social changes in our watershed, it was important to construct a new, stakeholder driven process to inform the development of the report. As a science-based, stakeholder-driven organization, PREP maintained its Technical Advisory Committee (TAC) with the core function of reviewing and interpreting the data used in this report.

The TAC is comprised of 24 independent scientists; 13 from University of New Hampshire and other partner groups including the US Environmental Protection Agency, The National Oceanic and Atmospheric Administration, NH Department of Environmental Services, The Nature Conservancy, NH Fish and Game Department, United States Geological Survey, Northeastern Regional Assoc. of Coastal & Ocean Observing Systems, Great Bay National Estuarine Research Reserve, and US Fish and Wildlife Service. In addition, PREP convened three other stakeholder groups to provide input during the process, as noted below. The purpose of these groups was to increase the diversity of feedback and perspectives from municipal, state, private, regional, public policy, and social science leaders and practitioners. A full listing of those who participated is noted on page 46 of this report in acknowledgement and appreciation of their dedication and efforts in helping to develop a comprehensive report that can be used by many as a resource over the next three years.



Impervious Surfaces

How much of the Piscataqua Region is currently covered by impervious surfaces and how has it changed over time?

Rain into a stormdrain in Portsmouth. Photo by D. Kellam

In 2010, 9.6% of the land area of the Piscataqua Region watershed was covered by impervious surfaces. Since 1990, the amount of impervious surfaces has increased by 120% while population has grown by 19%.

EXPLANATION The amount of impervious surface covering our land has grown from 28,695 acres in 1990 to 63,241 acres in 2010. On a percentage basis, 9.6% of the land in the watershed was covered by impervious surfaces in 2010 (Figure 1.1).

The impervious surfaces were not evenly spread out across the watershed. The percent of impervious surfaces in each of the Piscataqua Region subwatersheds in 2010 is shown in Figure 1.2. The watersheds with greater than 10 percent impervious surfaces are along the Atlantic Coast, Exeter River watershed and up the Route 16 corridor along the Cocheco River. The highest percent impervious values of 35 to 40 percent were found in the Portsmouth-New Castle area. Town-by-town information on impervious surfaces in 2010 is shown in Figure 1.3.

Between 1990 and 2005, impervious surfaces were added at an average rate of 1,441 acres per year. Between 2005 and 2010, the rate of new impervious surfaces nearly doubled to 2,585 acres per year. On average, 1,840 acres of impervious surfaces were added to the watershed each year for the 20-year period between 1990 and 2010.

Overall, the population for the 52 municipalities in the watershed has grown by 19% from 316,404 in 1990 to 377,427 in 2010. During this same period, the total impervious surfaces within the towns grew by 120%. Therefore, the rate of increasing impervious surfaces has been six times the rate of population growth.

Why This Matters

Impervious surfaces are paved parking lots, roadways, and roofs. During rain storms and snow melt, water running off of impervious surfaces carries pollutants and sediments into streams, rivers, lakes and estuaries. To keep waters clean, impervious surfaces should be a low percentage of the total amount of land area of the watershed basin.

PREP GOAL No increases in the number of watersheds and towns with >10% impervious cover and no decreases in the number of watersheds and towns with <5% impervious cover.

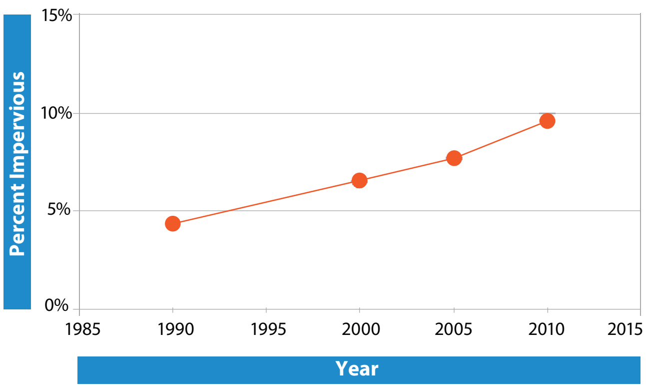
Success Story

The Hodgson Brook Restoration Project in Portsmouth has worked to install over 7 residential rain gardens in neighborhoods across the city. Rain gardens help to soak up the rain and snow melt from impervious surfaces and let it seep into the ground where pollutants can be filtered out through the soil.

Residential rain garden. Photo by PREP

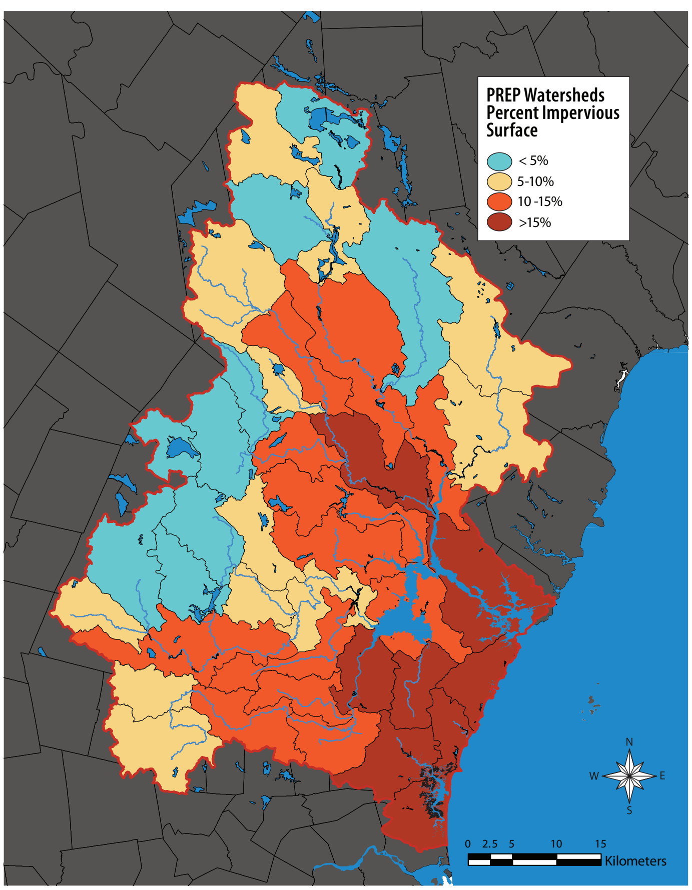
Between 2005 and 2010, the rate of new impervious surfaces nearly doubled to 2,585 acres per year.

FIGURE 1.1 Percent of land area covered by impervious surfaces in the Piscataqua Region watershed, 1990-2010



Data Source: UNH Complex Systems Research Center

FIGURE 1.2 Impervious surface cover in Piscataqua Region subwatersheds



Data Source: UNH Complex Systems Research Center

FIGURE 1.3 Percent of land area covered by impervious surfaces for coastal municipalities, 1990-2010

		Percent Imperviousness (%)			
Town	Land Area (Acres)	1990	2000	2005	2010
Barrington, NH	29,718	2.6	4	4.7	6.3
Brentwood, NH	10,738	5	7.7	9.5	12.2
Brookfield, NH	14,593	1	1.3	1.4	1.8
Candia, NH	19,340	2.7	4.1	4.8	6.4
Chester, NH	16,618	2.5	4.3	5.1	6.8
Danville, NH	7,439	3.5	6	7.2	9.5
Deerfield, NH	32,584	1.5	2.4	3	4
Dover, NH	17,033	11	15.4	18.7	22.7
Durham, NH	14,252	4.7	7.2	7.7	9.9
East Kingston, NH	6,318	3.5	5.3	6.9	8.9
Epping, NH	16,465	4	6.5	7.8	10.3
Exeter, NH	12,549	7.5	10.9	12.4	15.6
Farmington, NH	23,218	3	4.2	4.7	6.1
Fremont, NH	11,035	3	4.9	6	7.9
Greenland, NH	6,722	6.7	10.5	12.5	15.7
Hampton, NH	8,017	14.7	20.1	21.5	25.6
Hampton Falls, NH	7,519	4.5	7.1	9.3	12
Kensington, NH	7,636	3.2	5	6.2	7.8
Kingston, NH	12,494	5.2	8.2	9.7	12.5
Lee, NH	12,686	3.7	5.8	6.6	8.8
Madbury, NH	7,399	3.4	5.3	5.3	7.2
Middleton, NH	11,559	1.8	2.5	3	4.1
Milton, NH	21,089	2.8	4	4.7	6.2
New Castle, NH	506	21.4	30.6	33.8	41
New Durham, NH	26,345	1.7	2.4	2.8	3.8
Newfields, NH	4,541	3.1	5.5	6.8	8.6
Newington, NH	5,216	13	17.9	20.1	23.8
Newmarket, NH	7,939	6	8.9	10.3	12.7
No. Hampton, NH	8,862	7.3	10.8	12.4	15.4
Northwood, NH	17,973	2.4	3.4	4	5.4
Nottingham, NH	29,874	1.5	2.3	2.8	3.8
Portsmouth, NH	10,002	21.4	27.3	30.6	35.1
Raymond, NH	18,439	5.3	8	9.3	11.8
Rochester, NH	28,322	8.5	11.7	13.9	17.4
Rollinsford, NH	4,681	5.7	8.2	9.3	11.9
Rye, NH	7,997	7.2	10.9	12.7	15.5
Sandown, NH	8,888	3.8	6.1	7.9	10.5
Seabrook, NH	5,215	15.4	23.1	29.5	34.7
Somersworth, NH	6,219	12.3	16.4	20.1	24.4
Strafford, NH	31,151	1.4	2	2.3	3.2
Stratham, NH	9,657	6.5	10.1	12.9	16.2
Wakefield, NH	25,264	3.5	4.8	5.6	7.4
Acton, ME	24,120	1.6	2.5	2.9	3.8
Berwick, ME	23,786	2.6	4.4	5.5	6.8
Eliot, ME	12,610	4.1	7.4	9.2	11.3
Kittery, ME	11,308	8.1	11.9	13.9	16.4
Lebanon, ME	35,055	1.8	3	3.7	4.7
North Berwick, ME	24,265	2.2	3.5	4.2	5.2
Sanford, ME	30,315	5.9	9.1	10.1	11.8
South Berwick, ME	20,469	2.4	3.9	4.7	5.9
Wells, ME	36,749	3.7	6	7.4	8.8
York, ME	34,908	4.3	7.1	8.3	9.9

Data Source: UNH Complex Systems Research Center

Nutrient Load

How much nitrogen is coming into the Great Bay Estuary and have nutrient-related problems been observed?

Sagamore Creek Panne, Portsmouth. Photo by D. Kellam

Total nitrogen load to the Great Bay Estuary in 2009-2011 was 1,225 tons per year. There appears to be a relationship between total nitrogen load and rainfall. Although typical nutrient-related problems have been observed, additional research is needed to determine and optimize nitrogen load reduction actions to improve conditions in the estuary.

EXPLANATION The load of all forms of nitrogen into the Great Bay Estuary in 2009-2011 was 1,225 tons per year (Figure 2.1). Nitrogen loads to the bay tend to be higher in years with more rainfall. Since 2003, when nitrogen loads began to be measured, the total nitrogen load to the bay was highest in 2005-2006. The increase appeared to be driven by higher amounts of nitrogen carried into the bay by rain runoff and river flow during years with heavy rainfall, especially 2005 and 2006 (Figure 2.2). In more recent years load has decreased, which again may be related to drier years with less rainfall. It is due to these fluctuations in data that no long or short term trends can be determined.

One important component of nitrogen needing consideration is the most reactive type called dissolved inorganic nitrogen (DIN). This type is known to cause faster plant and algae growth than other forms of nitrogen. Between 2009-2011, 597 of the 1,225 tons of nitrogen entering the bay was DIN.

Nitrogen enters the bay primarily in two ways. First, nitrogen from fertilizers from lawns and farms, septic systems, animal wastes, and air pollution from the whole watershed is carried into the bay through rain and snowmelt runoff, river flow, and groundwater flow. These sources account for 68% of the nitrogen entering our system (Figure 2.1). Second, there are 18 municipal sewer treatment plants that discharge treated wastewater out through pipes either into the bay or into rivers that flow into the bay. Wastewater discharges are concentrated sources of nitrogen, primarily in the reactive DIN form (Figure 2.1).

Regardless of the particular sources, the major contributors of nitrogen to the bay are related to population growth and associated building and development patterns. The PREP goal is to reduce nutrient loads to the estuaries and the ocean so that adverse, nutrient-related effects do not occur. At this time the Great Bay Estuary exhibits many of the classic symptoms of too much nitrogen: low dissolved oxygen in tidal rivers, increased macroalgae growth, and declining eelgrass. Although the specific causal links between nitrogen load and these concerning symptoms have not yet been fully determined for Great Bay, global, national and local trends all point to the need to reduce nitrogen loads to the estuary.[3] Additional data collection and research is critical to a better understanding of these links and where the most effective reductions can be targeted.

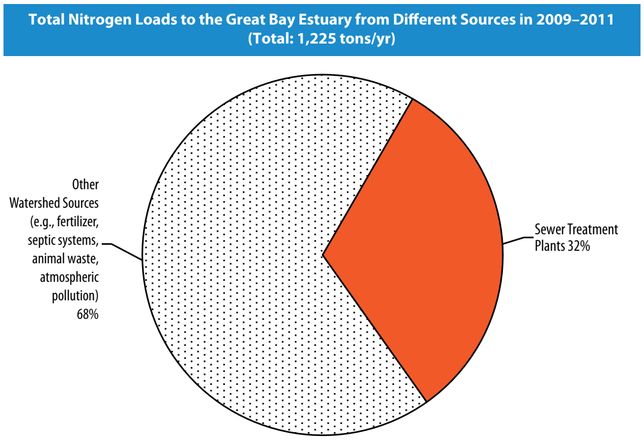
Why This Matters

Nitrogen is a nutrient that is essential to life in the estuaries. However, scientific understanding of estuaries is that high levels of nitrogen may cause problems like the excessive growth of plants and algae.[1] When the plants die, oxygen needed by fish is pulled out of the water and can cause fish to suffocate. The rapid plant growth can also shade or smother underwater eelgrass meadows and other important habitats, limiting important functions such as providing food and shelter and cleaning the water. Excess nitrogen is a problem across the US and around the world.[2]

PREP GOAL **Reduce nutrient loads to the estuaries and the ocean so that adverse, nutrient-related effects do not occur.**

Non-point sources of nitrogen include lawn fertilizers, septic systems, animal wastes, and atmospheric deposition on to land.

FIGURE 2.1 Nitrogen loads to the Great Bay Estuary from different sources, 2009-2011



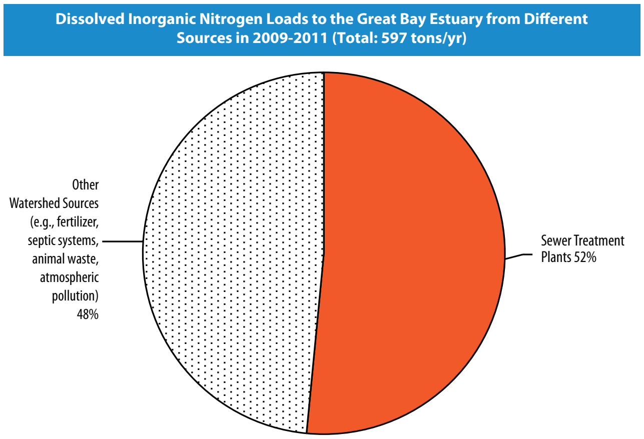


FIGURE 2.2 Trends in nitrogen loads and precipitation, 2003-2011

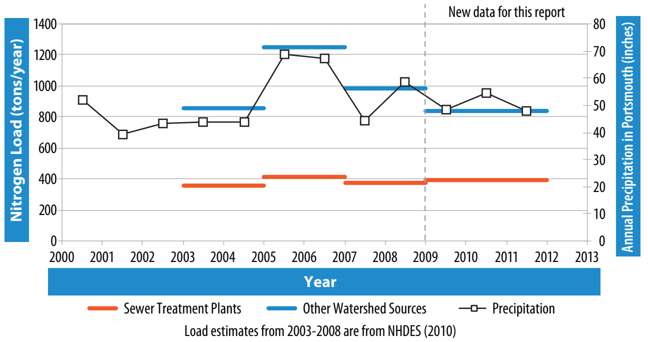
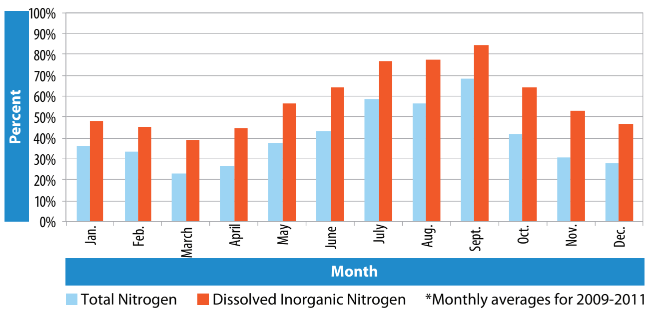


FIGURE 2.3 Percent of nitrogen load to the Great Bay Estuary from sewer treatment plants by month



The percent of the nitrogen load to the estuary from sewer treatment plants varies month-to-month over the course of the year. Sewer treatment plants contribute the majority of the nitrogen load during the warmer months when algae growth typically occurs.

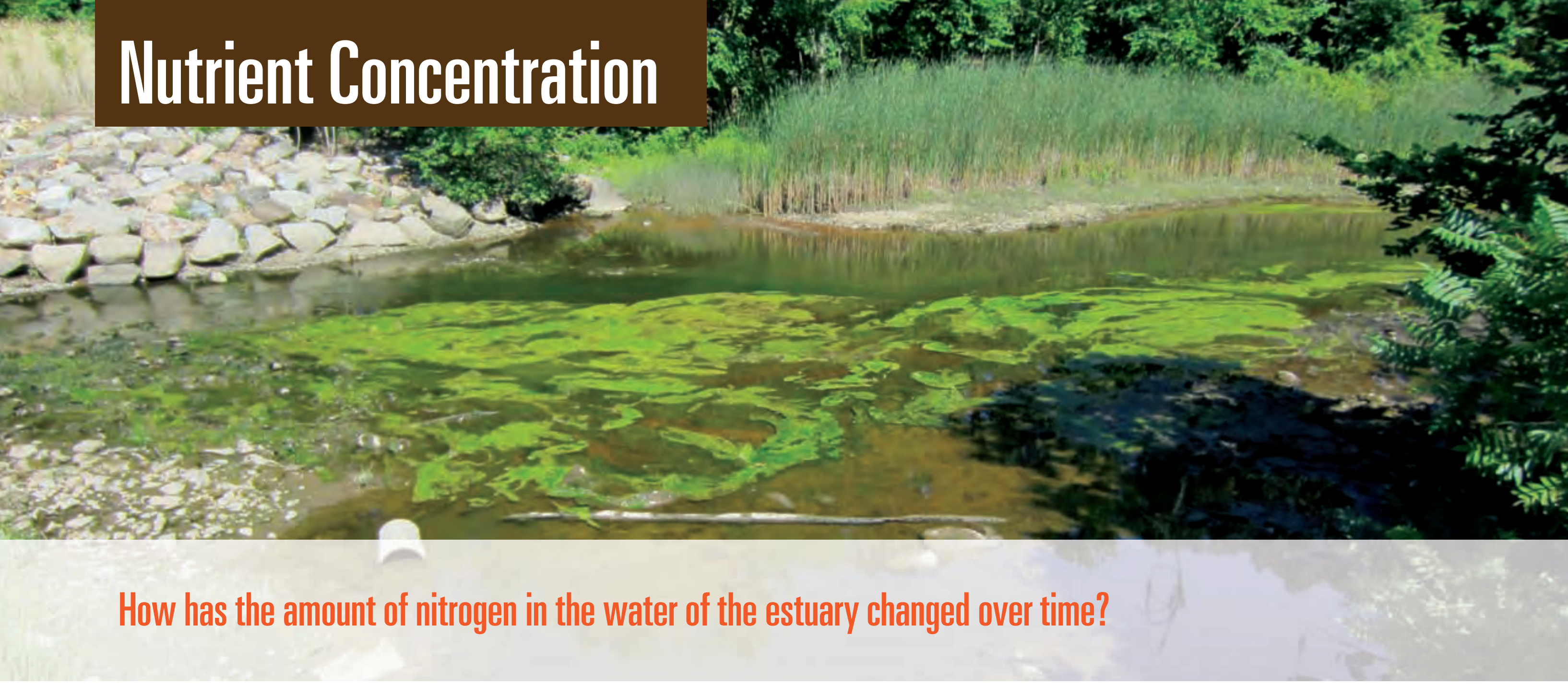
Success Story

York's Lawns to Lobsters

The Town of York, Maine has created a public education effort focused on environmentally sound lawn care practices focused on having a beautiful lawn without harming the rivers or the ocean from increased nutrients or pesticides. The program has spread around the coast of Maine and is now being adopted by the town of New Castle as well. The program has 10 tips every homeowner can practice visit www.lawns2lobsters.org to learn more.

Photo by PREP

Nutrient Concentration



How has the amount of nitrogen in the water of the estuary changed over time?

Algae growth in the Winnicut River below the fish ladder, Greenland, NH. Photo by S. Demers

Between 1974 and 2011 data indicates a significant overall increasing trend for dissolved inorganic nitrogen (DIN) at Adams Point, which is of concern. When examining variability at other monitoring stations with shorter periods of data, no consistent patterns can be found. Recent data considered in the context of long-term data show no pattern or trend.

EXPLANATION Total nitrogen measures all of the nitrogen in the water, both the nitrogen dissolved in the water and the nitrogen in floating algae. Total nitrogen concentrations in Great Bay have been monitored since 2003, but have not shown any consistent trends (Figure 3.1). The average concentration of total nitrogen in Great Bay in 2009-2011 was 0.38 mg/L.

Photo by PREP

However, as previously noted in this report, there is concern for the implications of dissolved inorganic nitrogen (DIN) as it is the most reactive form of nitrogen in the system. The long-term trend for all of the data collected between 1974 and 2011 shows an average increase of 68% for DIN (Figure 3.2). The DIN concentrations in the last three years fell below the average trend line to 0.116 mg/L. These levels are comparable to the DIN concentrations that were measured for some of the years in the 1970s.

The apparent conflict between the long-term increasing trend for DIN at Adams Point and recent overall low concentrations for DIN may be explained by the fact that DIN is highly variable. It is rapidly taken up into plants and removed from the water or converted to other forms of nitrogen. Total nitrogen concentrations are a better measure of overall nitrogen availability in the estuary.

In other areas of the estuary besides Great Bay, some trends for total nitrogen and other forms of nitrogen have been observed. Increasing trends for total nitrogen and total dissolved nitrogen were apparent in the Squamscott River, while decreasing trends for DIN were observed in the Oyster River.

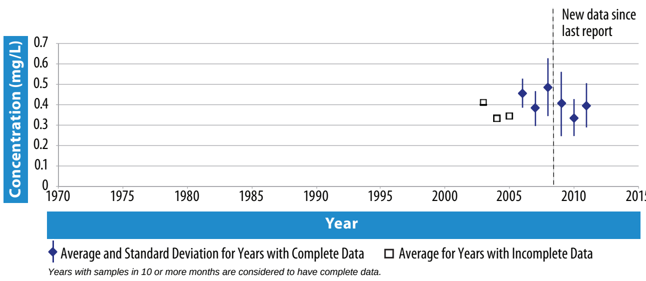
The variety of results highlights the complexity of nitrogen cycling in the estuary. More data and study is needed to better understand these relationships.

Why This Matters

Nitrogen is an essential nutrient to life in the estuaries. However, scientific understanding of estuaries is that high levels of nitrogen may cause problems from the excessive growth of plants and algae. The amount of nitrogen present in the water (the nitrogen "concentration") is an important indicator of nutrient availability for plants and algae[1] growth in the estuary. However, because nitrogen is rapidly removed from the water by plants, the nitrogen concentration in the water does not always reflect the amount of nitrogen that has been loaded into the estuary.

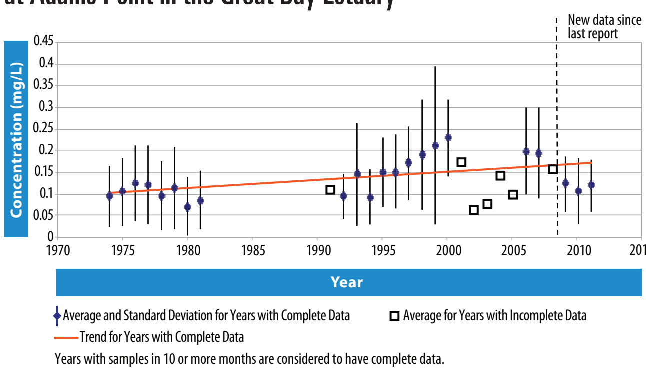
PREP GOAL **No increasing trends for any nitrogen or phosphorus species.**

FIGURE 3.1 Total nitrogen concentration trends at Adams Point in the Great Bay Estuary

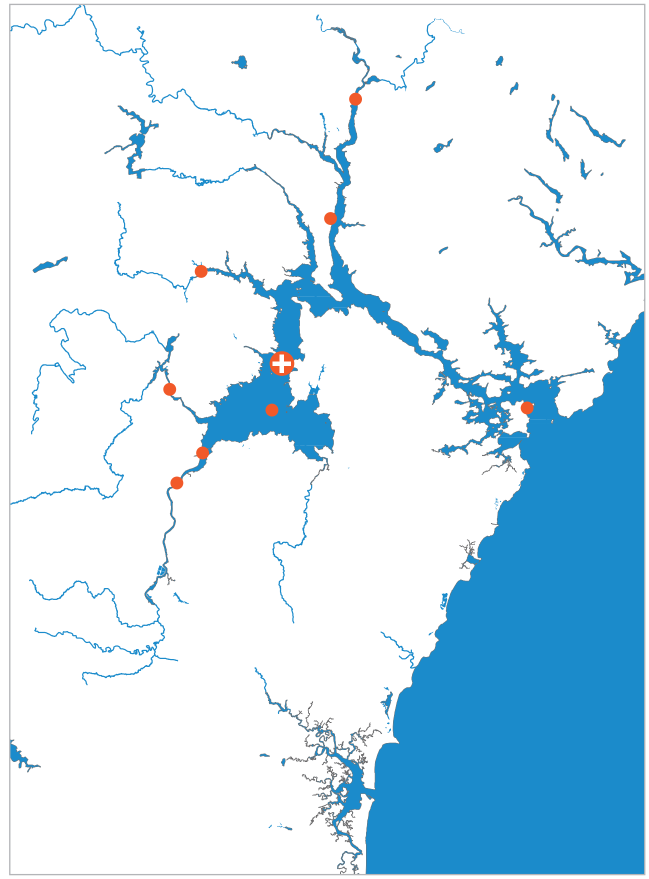


Data Source: UNH Jackson Estuarine Laboratory

FIGURE 3.2 Dissolved inorganic nitrogen concentration trends at Adams Point in the Great Bay Estuary



Data Source: UNH Jackson Estuarine Laboratory



Monitoring location for Fig. 3.1 & 3.2 is marked by a red circle with a white plus sign. Other red dots indicate additional water quality monitoring locations.

Flooding in Newmarket, NH. Photo by PREP

Climatic trends, including extreme rain and snow events, can affect the delivery of nitrogen loads to our estuaries. The highest nitrogen loads calculated for the Great Bay Estuary appear to correlate with years of high annual precipitation (Figure 2.2). It appears that more nitrogen is "flushed" from the landscape during wet periods. New England is experiencing more frequent higher intensity rain storms, and this trend is anticipated to continue. Therefore additional research on how climate and weather affect the amount and timing of nitrogen delivery to the estuary is needed.

Microalgae (Phytoplankton) and Macroalgae

How has the amount of algae in the estuary changed over time?

Ulva Lactuca in Great Bay off of Portsmouth Country Club, Greenland,NH. Photo by J. Nettleton

Microalgae (phytoplankton) in the water, as measured by chlorophyll-a concentrations, has not shown a consistent positive or negative trend in Great Bay between 1975-2011.

Macroalgae, or seaweed, populations have increased, particularly nuisance algae and invasives.

EXPLANATION This is a new indicator for this year's report because of its known relationship to nutrients and the role algae plays in an estuarine system. Plant growth can take many forms in estuaries. There can be microscopic plants, called phytoplankton, that float in the water. The amount of chlorophyll-a present in the water is a measure of these microscopic plants. In addition, there can be larger rooted and un-rooted seaweeds, called macroalgae, that grow in the estuary. Of particular concern are certain types of nuisance macroalgae that grow quickly in high nutrient environments and crowd out or smother the slower growing eelgrass populations.[5]

Measurements of chlorophyll-a in the water in Great Bay since 1975 have not shown any consistent long-term trends, nor were there any short term changes in the last three years (Figure 4.1). Blooms of microscopic plants are episodic and variable in size depending on factors such as weather. As a result, it can be difficult to detect trends in chlorophyll-a based on a monthly monitoring program which is how monitoring is currently conducted.

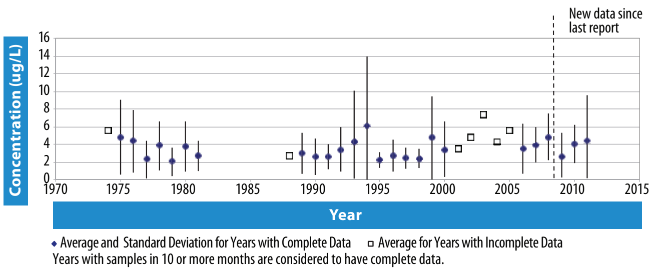
For nuisance macroalgae, there is evidence that populations have increased. Baseline measurements of some macroalgae species at some locations were made by UNH researchers between 1972 and 1980.[7] In 2008-2010, these field studies were repeated using the same methods to document changes in populations.[7] The report concluded that "Great increases in both mean and peak *Ulva* and *Gracilaria* biomass and percent cover have occurred in the Great Bay Estuarine System."[8] For example, at a site in Lubberland Creek in the Great Bay, the mean percent cover of a common macroalgae, *Ulva lactuca,* had increased from 0.8% of the area covered in 1979-1980 to 39% of the area covered in 2008-2010. (Figure 4.2) Increases in macroalgae cover of up to 90% have been measured at some sites in the Great Bay Estuary on some dates. In 2007, another UNH field study[9] documented that there were 137 acres of macroalgae mats in the Great Bay in August 2007, which amounted to over 3% of the entire bay surface (Figure 4.3) and occupying areas formerly covered with eelgrass. Due to the variable nature of algae, more data collection and study is needed to gain a better understanding of the extent and causes of these increases.

Why This Matters

Increasing nitrogen inputs to estuaries can stimulate plant growth. Excessive algae growth in the water and on the bottom can make the water cloudy, deplete dissolved oxygen in the water, or can entangle, smother and cause the death of important eelgrass habitat.[4]

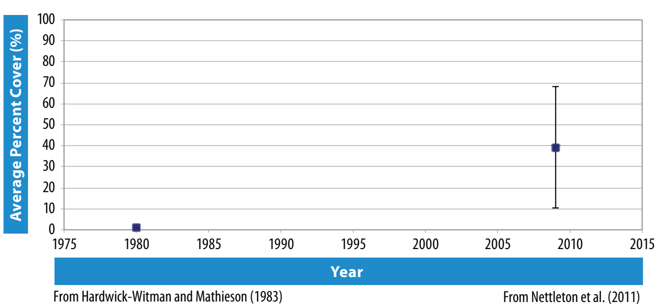
PREP GOAL **No increasing trends for algae.**

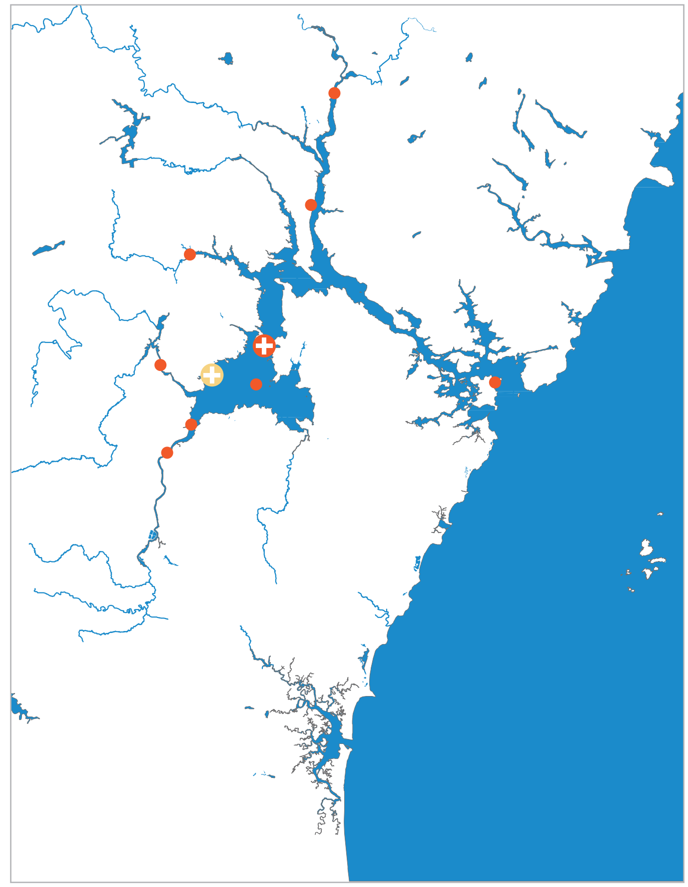
FIGURE 4.1 Chlorophyll-a trends at Adams Point in the Great Bay Estuary



Data Source: UNH Jackson Estuarine Laboratory

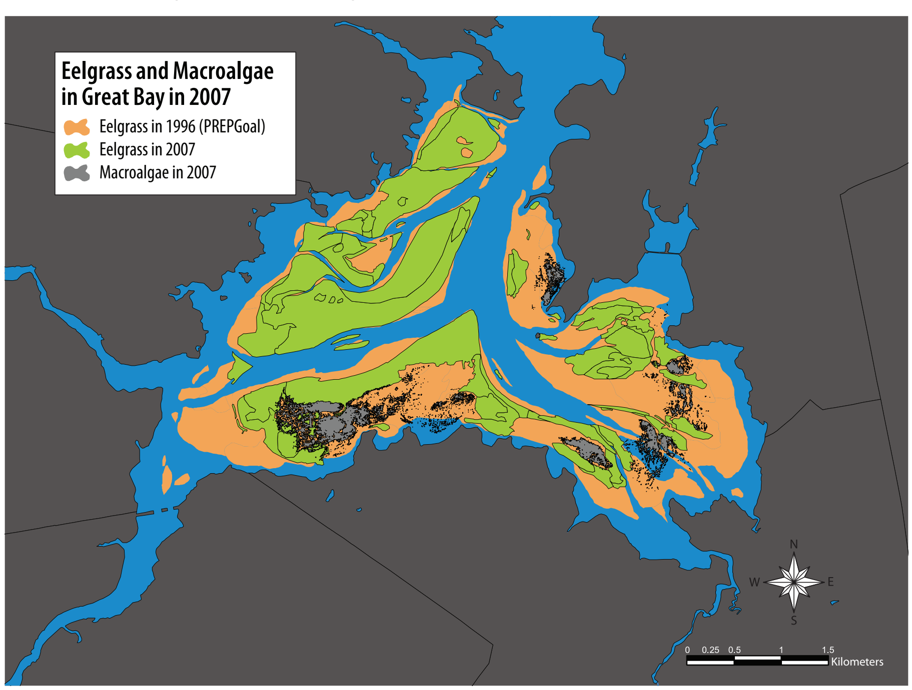
FIGURE 4.2 Macroalgae percent cover at the Lubberland Creek site in Great Bay in 1979-1980 and 2008-2010





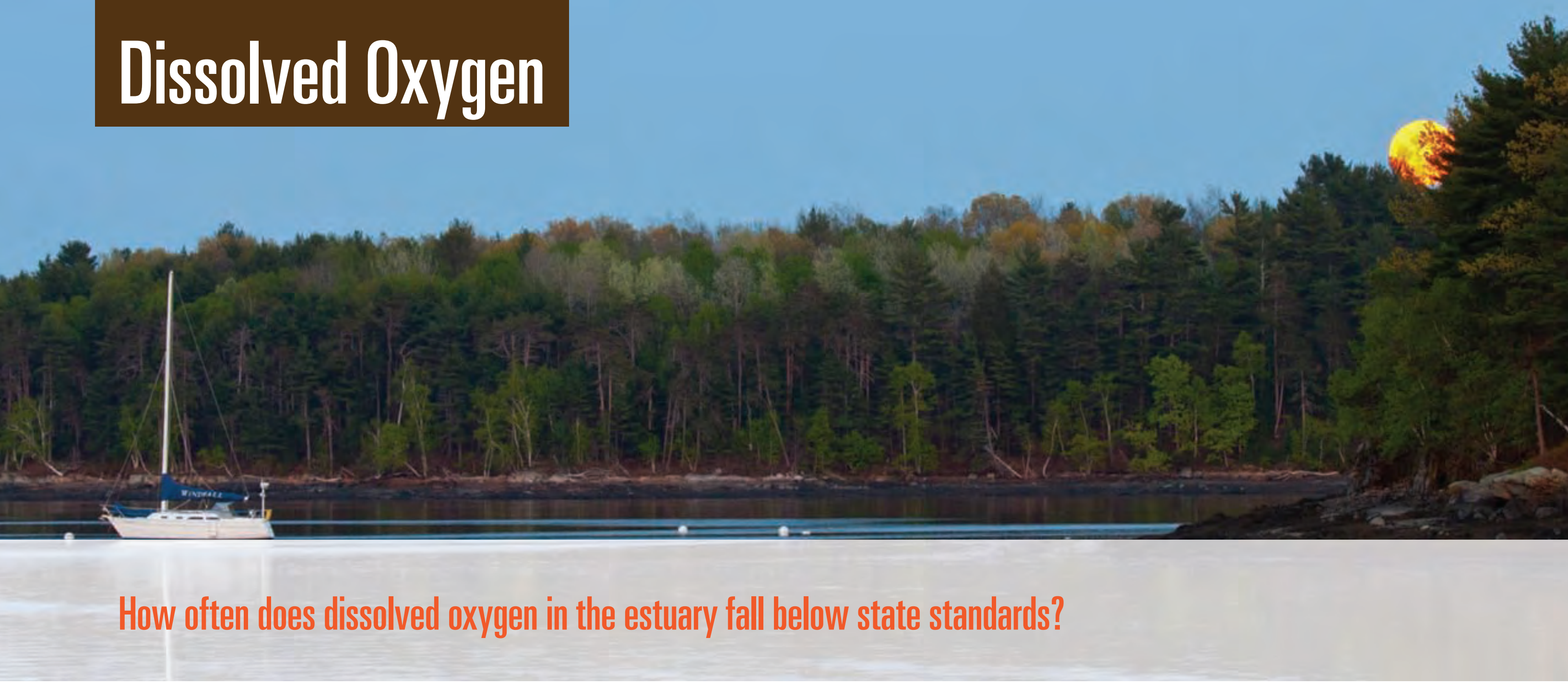
Monitoring location for Fig. 4.1 is marked by a red circle with a white plus sign. Monitoring location for Fig. 4.2 is marked by a yellow circle with a white plus sign. Other red dots indicate water quality monitoring locations.

FIGURE 4.3 Eelgrass and macroalgae in Great Bay in 2007



Data Source: Eelgrass data provided by UNH Seagrass Ecology Laboratory Macroalgae data from Pe'eri et al. (2008)

Dissolved Oxygen



How often does dissolved oxygen in the estuary fall below state standards?

Moon over Great Bay. Photo by C. Keeley

State standards for dissolved oxygen are nearly always met in the large bays and harbors.
State standards for dissolved oxygen in the tidal rivers are not met for periods lasting as long as several weeks each summer.

EXPLANATION The most accurate measurements of dissolved oxygen (DO) are made using datasonde instruments (see figure 5.1) that are installed in the water to collect measurements every 15 minutes. The six locations where datasondes are deployed are shown on Figure 5.2. The figure also contains charts summarizing the number of days in the summer when the DO fell below the water quality standard (5 mg/L) at each station (Figure 5.3).

The dissolved oxygen concentrations in Great Bay in the summer have never been measured below 5 mg/L. In Portsmouth Harbor there has been only one day with dissolved oxygen less than 5 mg/L (in 2010). Based on these data, the well mixed areas of Great Bay and Portsmouth Harbor typically meet the water quality standard for DO.

In contrast, there have been persistent and numerous violations of the dissolved oxygen standards at stations in the tidal rivers that flow into the estuaries. The number of summer days with violations varied over time at the stations. No major fish kills due to low dissolved oxygen have been reported for the tidal rivers in recent years. However, fish and other organisms may still experience negative effects in areas where the state standard is not attained.

The most exceedences and the lowest dissolved oxygen concentrations have been observed in the tidal rivers, particularly the Lamprey River. UNH conducted a detailed study of this river and concluded that the datasonde accurately represents the dissolved oxygen in the river but that density stratification was a significant factor related to the low dissolved oxygen concentrations that were observed.[12]

Similarly, the Great Bay Municipal Coalition hired HydroQual to conduct a study of dissolved oxygen in the Squamscott River in 2011.[13] The study confirmed that dissolved oxygen concentrations in the river periodically exceeded the state standard and that algae discharged in the wastewater from the Exeter sewer treatment plant was a factor affecting dissolved oxygen levels. Overall, the relationship between nutrients, dissolved oxygen and algae growth is a complex one and more data/study is needed to specifically understand those linkages in our system.

Why This Matters

Low dissolved oxygen (DO) concentrations in bays are a common impact of excessive nitrogen in estuaries.[10] Fish and many other aquatic organisms need dissolved oxygen in the water to survive. Prolonged periods of low dissolved oxygen are harmful or lethal to aquatic life.[11] There are state water quality standards for dissolved oxygen to protect against these effects. Other factors besides nutrients may cause or contribute to periods of low DO.

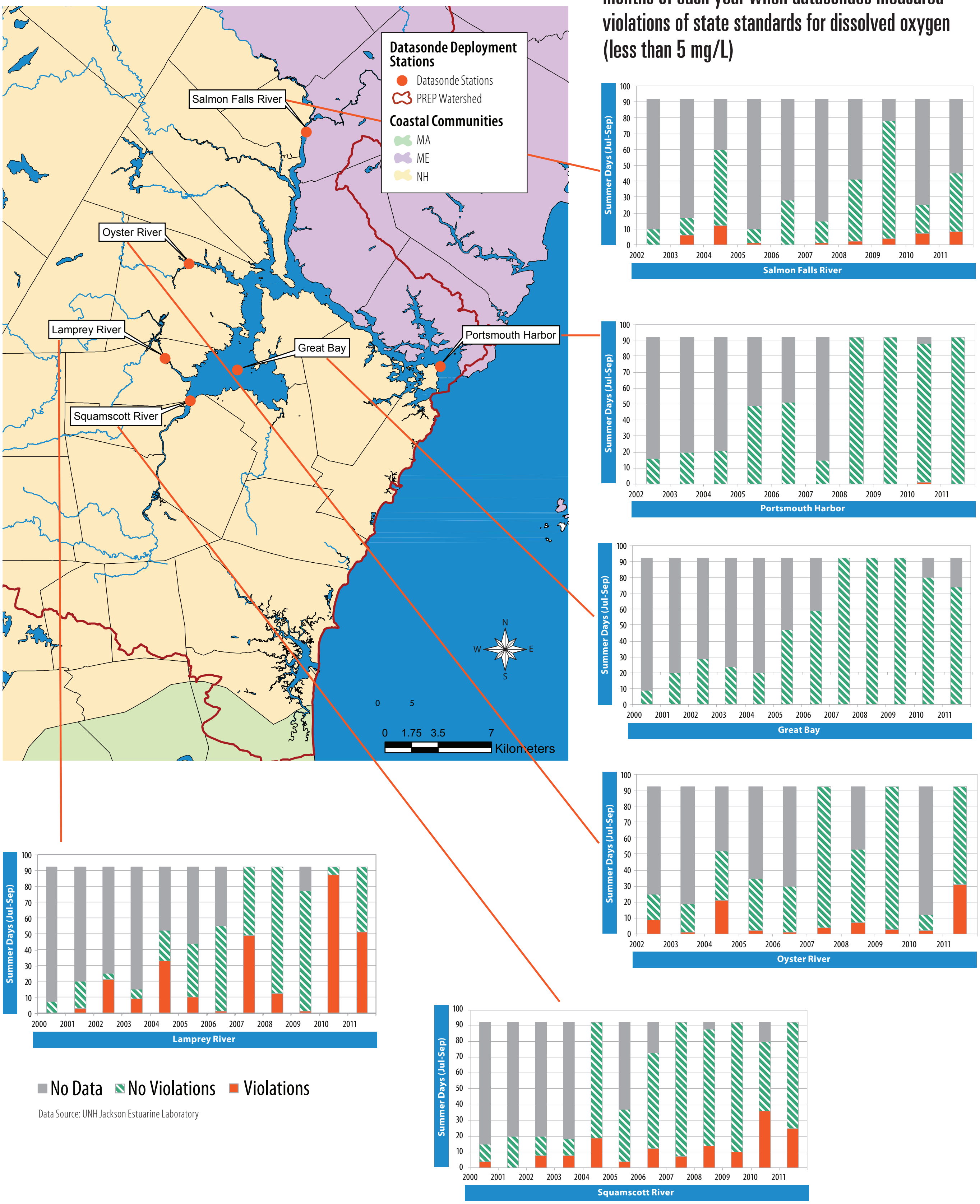
PREP GOAL **Zero days with exceedences of the state water quality standard for dissolved oxygen.**

FIGURE 5.1 Datasonde buoy deployed in Great Bay

The most exceedences and the lowest dissolved oxygen concentrations have been observed in the tidal rivers, particularly the Lamprey River.

FIGURE 5.2 Locations of Datasondes in the Piscataqua Region Estuaries

FIGURE 5.3 Number of days during summer months of each year when datasondes measured violations of state standards for dissolved oxygen (less than 5 mg/L)



DISSOLVED OXYGEN

Eelgrass

How much eelgrass habitat is in the Great Bay Estuary and how has it changed over time?

Eelgrass on the bottom of Little Bay. Photo by J. Carroll

Data indicate a long-term decline in eelgrass since 1996 that is not related to wasting disease. Due to variability even recent gains of new eelgrass still indicate an overall declining trend.

EXPLANATION The total eelgrass cover in the entire Great Bay Estuary for years with complete data is plotted in Figure 6.1. In 2011, the total eelgrass cover in the estuary was 1,891 acres, 35% below the PREP goal of 2,900 acres derived from the 1996 eelgrass maps. The total acreage has been relatively steady for the past three years and higher than the previous three years (2006-2008), which were 44 to 48% below the goal. There are also indications, based on estimates of the density of the eelgrass beds, that the remaining beds contain fewer plants and, therefore, provide less habitat.

The majority of the eelgrass in the estuary is in the Great Bay itself. Eelgrass in this important area has been mapped each year. The data show that, since 1990, there has been a statistically significant, 38% decline of eelgrass in Great Bay (Figure 6.2). Statistically significant declines of eelgrass have also been observed in other sections of the estuary: the Winnicut River, Little Harbor, Portsmouth Harbor, and the Piscataqua River. However, the total amount of eelgrass lost in these areas is much smaller than the losses in Great Bay.

The actual location and connectivity of the remaining eelgrass in the estuary is important. Figures 6.3, 6.4, and 6.5 show the 2011 eelgrass maps relative to the 1996 eelgrass maps. These figures show that: (1) the loss of eelgrass in the Piscataqua River disrupts the connectivity of eelgrass between Portsmouth Harbor and Great Bay, (2) eelgrass is absent from the tidal rivers, and (3) the new eelgrass bed in Little Bay is larger than the one that was mapped in 1996.

The new eelgrass bed in Little Bay may be a positive sign. Starting in 1996, eelgrass had declined in this area over time and was essentially absent from 2007 through 2010. However, in 2011, a 48-acre eelgrass bed was observed in this area. The large variance in eelgrass cover in this area shows the variability of eelgrass recovery. Data from 2012 and future years are needed to determine if this bed will persist showing an improving trend in Little Bay.

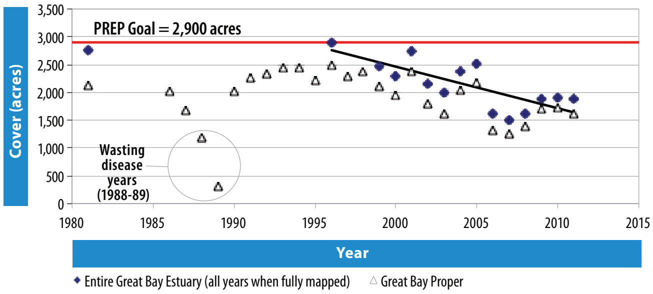
Why This Matters

Eelgrass (*Zostera marina*) is at the base of the estuarine food web in the Great Bay Estuary. Healthy eelgrass beds filter water and stabilize sediments[14] and provide habitat for fish and shellfish.[15] While eelgrass is only one species in the estuarine community, the presence of eelgrass is critical for the survival of many species.

PREP GOAL **Increase the aerial extent of eelgrass cover to 2,900 acres and restore connectivity of eelgrass beds throughout the Great Bay Estuary by 2020.**

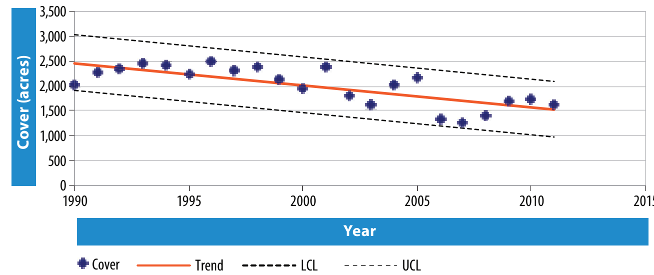
There are indications that remaining beds contain fewer plants and, therefore, provide less habitat.

FIGURE 6.1 Eelgrass Cover in the Great Bay Estuary



Data Source: UNH Seagrass Ecology Laboratory

FIGURE 6.2 Eelgrass cover in Great Bay proper



Data Source: UNH Seagrass Ecology Laboratory Statistically significant trend

FIGURE 6.3 Eelgrass cover in Great Bay and its tributaries in 1996 and 2011

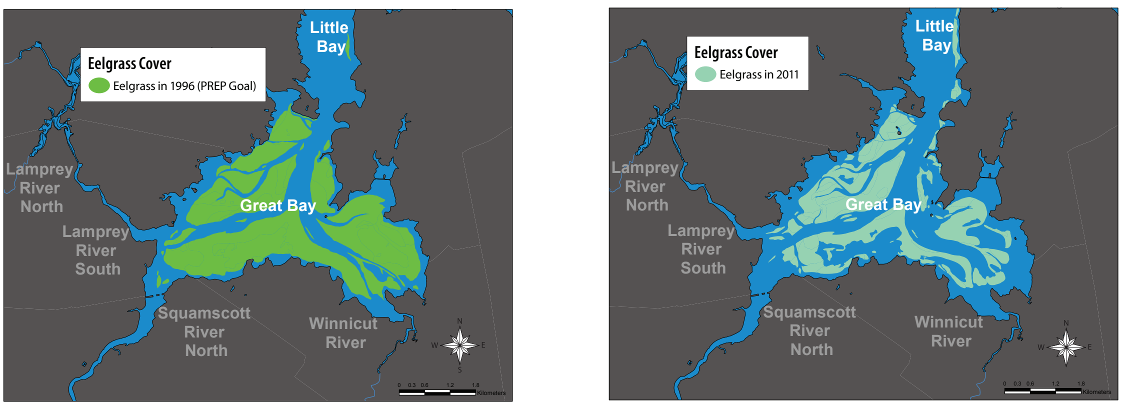


FIGURE 6.4 Eelgrass cover in Little Bay and its tributaries in 1996 and 2011

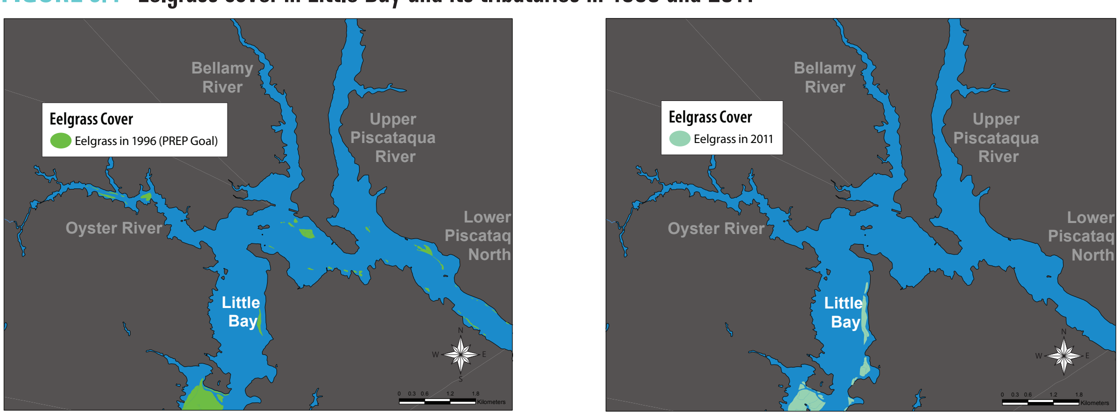
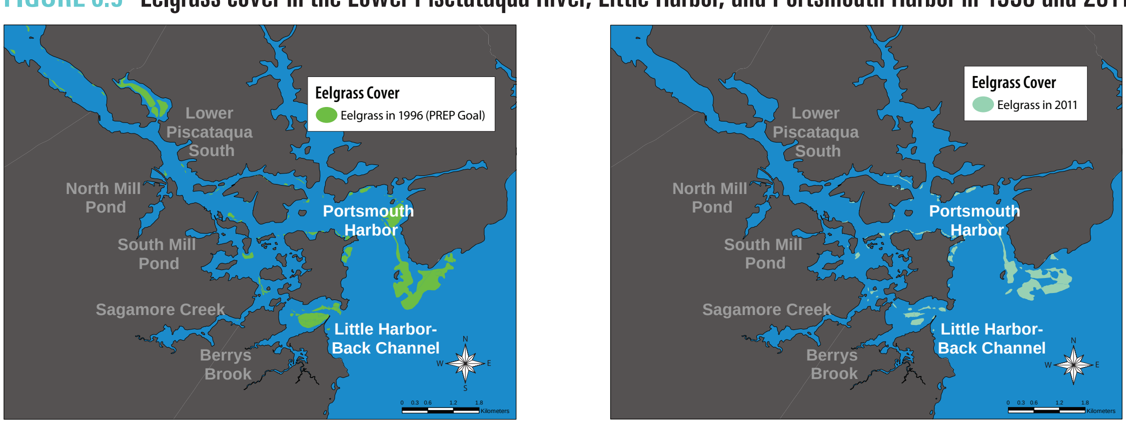


FIGURE 6.5 Eelgrass cover in the Lower Pisctataqua River, Little Harbor, and Portsmouth Harbor in 1996 and 2011



Data Source: UNH Seagrass Ecology Laboratory

Sediment Concentrations

How has the amount of sediment in the water of the estuary changed over time?

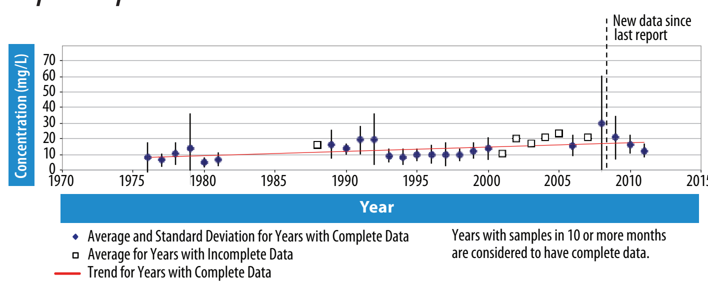
Oyster River Reservoir, Durham, NH. Photo by D. Kellam

Suspended sediment concentrations at Adams Point in the Great Bay Estuary have increased significantly between 1976 and 2011.

EXPLANATION Suspended sediments have been measured at Adams Point in Great Bay since 1976. At this station, the concentrations of suspended sediment have increased by 122% between 1976 and 2011 (Figure 7.1).

Suspended sediment concentrations are important because a UNH study found that non-algal particles contributed significantly to light availability for the underwater eelgrass in the vicinity of the Great Bay Coastal Buoy in 2007.[16] Increased suspended sediments are expected in estuaries where eelgrass has been lost . Eelgrass stabilizes the sediments in the estuary. When this habitat is lost,[17] the sediments are more easily stirred up by wind and waves.

FIGURE 7.1 Suspended sediment trends at Adams Point in the Great Bay Estuary

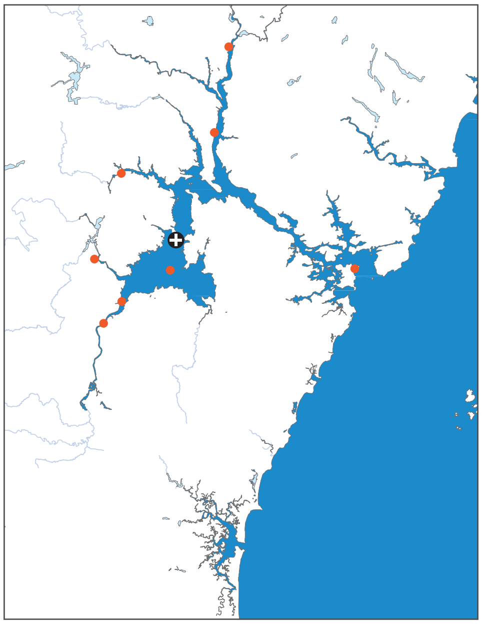


Why This Matters

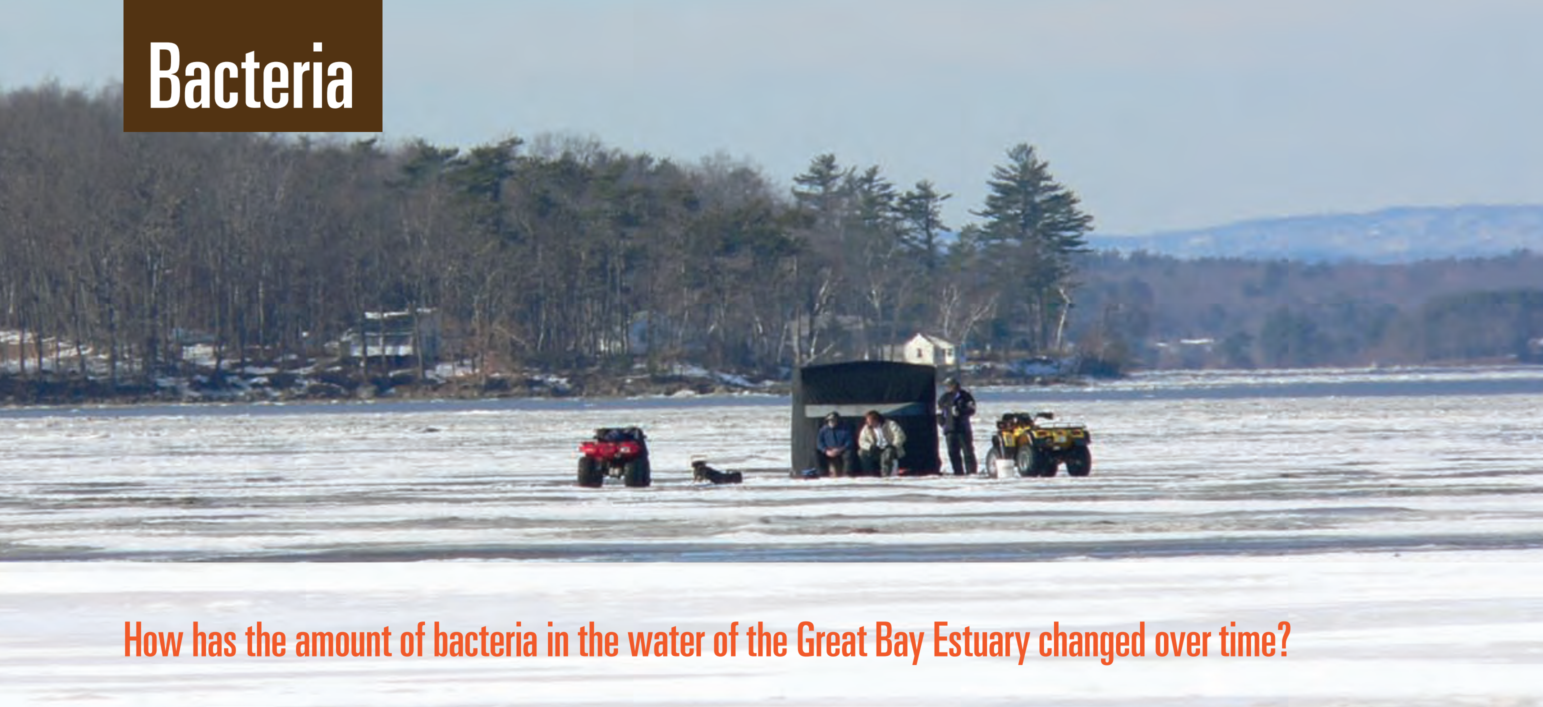
Suspended sediments are soil and plant particles that hang in the water and cause the water to look cloudy. This cloudiness blocks sunlight from entering the water which can inhibit eelgrass growth and can also smother eelgrass and oysters. Soil and plant particles mostly get into the water from turbulent mixing that carries bay sediments up from the bottom into the water or rain and snow melt running off from developed land.

PREP GOAL No increasing trends for suspended sediments.

FIGURE 7.2 Monitoring site for sediment concentration is marked by a black dot with a white cross.



Bacteria



How has the amount of bacteria in the water of the Great Bay Estuary changed over time?

Smelt Fishing on Great Bay. Photo by D. Kellam

Between 1989 and 2011, dry weather bacteria concentrations in the Great Bay Estuary have typically fallen by 50 to 92% due to pollution control efforts in most, but not in all, areas.

EXPLANATION High amounts of fecal coliform bacteria, which is found in human and animal waste, is an indication of sewage pollution from leaking septic systems, overboard marine toilet discharges, sewer treatment plant overflows, cross connections between sewers and stormdrain systems, farm animals and wildlife waste, polluted mud on the estuary floor being stirred up, and polluted water running off from paved surfaces. PREP uses fecal coliform bacteria measurements from days without signficant rainfall for this indicator because storm runoff can cause large spikes of pollution. Data on this indicator is only available for the Great Bay Estuary.

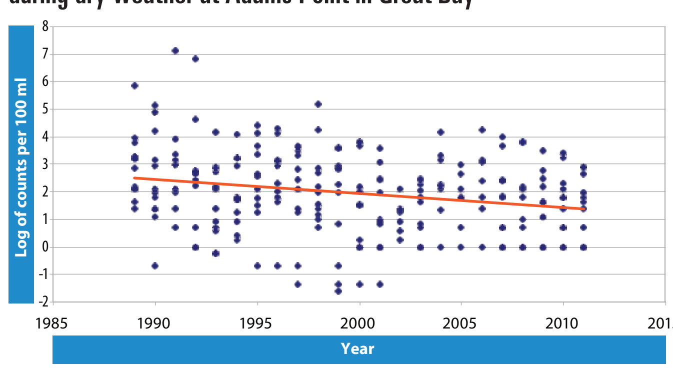
At all four long-term water pollution monitoring stations in the estuary, there has been a decrease in fecal coliform bacteria during dry weather over the past 23 years. For example, in the middle of Great Bay at Adams Point, fecal coliform bacteria decreased by 68 percent between 1989 and 2011 (Figure 8.1). Sewer treatment plant upgrades and removal of sewage flowing into cities' and towns' storm drain systems are likely major contributors to the long-term decreasing trend. In the most recent 10 years, bacteria levels have mostly remained the same. The observed trends may have been driven by large decreases in the late 1980s and early 1990s. Alternatively, continued population growth in the Piscataqua Region watershed may be counteracting the ongoing pollution control efforts. It should be noted that not all trends were decreasing. Concentrations of enterococcus, a different type of bacteria, increased in the Squamscott River but did not show any trends in other locations.

Why This Matters

Increased amounts of bacteria in bay waters often indicate the presence of pathogens due to sewage pollution or other sources. Pathogens, which are disease-causing microorganisms, pose a public health risk and are the primary reason why shellfish beds and public beaches can be closed.

PREP GOAL **No increasing trends for any bacteria species.**

FIGURE 8.1 **Fecal coliform bacteria concentrations at low tide during dry weather at Adams Point in Great Bay**



Source: UNH Jackson Estuarine Laboratory

Shellfish Harvest Opportunities

How much of our estuaries are open for shellfish harvesting and how has it changed over time?

NH Dept. of Environmental Services measuring shellfish size. Photo by PREP

Only 36% of estuarine waters are approved for shellfishing and, in these areas, periodic closures limited shellfish harvesting to only 42% of the possible acre-days in 2011. The harvest opportunities have not changed significantly in the last three years.

EXPLANATION There are still many closures of shellfish beds due to bacterial pollution, particularly after it rains. In 2011, the most recent year with data, 64% of the shellfish growing areas were closed to harvesting on a year-round basis (Figure 9.1). The major open areas are in Hampton-Seabrook Harbor, Great Bay, Little Bay, and Little Harbor (Figure 9.2). None of the Piscataqua Region estuary waters in Maine are open for harvesting. In 2000 and 2001, approximately 29 to 31% of the estuarine waters were classified as open for shellfishing by NH Department of Environmental Services and Maine Department of Environmental Protection shellfish programs. The percentage of waters in these open categories grew to 38% in 2003 and then remained relatively constant from 2004 to 2011, ranging from 35 to 36%. In the areas where harvesting was allowed, the shellfish beds were closed at least 50 percent of the time in 2011 due to water pollution after rain storms (Figure 9.3).

Why This Matters

Shellfish beds are closed to harvesting when there are high amounts of bacteria or other pollution in the water. The closures can be permanent or temporary. Therefore, the amount of time that shellfish beds are open for harvest is an indicator of how clean the water is in the estuary. Shellfishing aquaculture provides a living for some area fishermen and brings in money for the Seacoast region through retail sales.

PREP GOAL **100% of possible acre-days in estuarine waters open for harvesting.**

Success Story

Septic-sniffing dogs

FB Environmental Associates recently hired Environmental Canine Services LLC to help collect data on fecal bacteria sources in Kittery, ME. Hailing from Michigan, Environmental Canine Service (ECS) is a K-9 illicit discharge detection unit made up of animal handlers, scientists and two furry data collectors, Sable and Logan. By sniffing outflow pipes and areas where stormwater or wastewater discharges into rivers, estuaries, and beaches, they can tell if it's contaminated with harmful bacteria and then Kittery officials can work to identify and correct the sources.