EXHIBIT 50 (AR K.27)

PISCATAQUA REGION
Estuaries
Partnership

2009

PISCATAQUA REGION ESTUARIES PARTNERSHIP

Environmental Indicators Report

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Introduction

The Piscataqua Region Estuaries Partnership (PREP) is part of the U.S. Environmental Protection Agency's National Estuary Program, which is a joint local/state/federal program established under the Clean Water Act with the goal of protecting and enhancing nationally significant estuarine resources. PREP is funded by the EPA and is administered by the University of New Hampshire.

PREP's Comprehensive Conservation and Management Plan for the estuaries of the Piscataqua Region was completed in 2000 and implementation is ongoing. The Management Plan outlines key issues related to management of the estuaries and proposes strategies (Action Plans) that are expected to preserve, protect, and enhance the estuarine resources. The priorities for PREP were established by local stakeholders and include water quality improvements, shellfish resources, land protection, and habitat restoration. Projects addressing these priorities are undertaken throughout the coastal watershed, which includes 52 communities in New Hampshire and Maine.

Every three years, PREP prepares a State of the Estuaries report with information on the status and trends of a select group of environmental indicators from the coastal watershed and estuaries. The report provides PREP, state natural resource managers, local officials, conservation organizations, and the public with information on the effects of management actions and decisions.

Prior to developing each State of the Estuaries report, PREP publishes technical data reports ("indicator reports") that illustrate the status and trends of the complete collection of indicators tracked by PREP. The indicators cover a wide range of topics from water quality to biological resources to land use and conservation. All of the indicators are presented to the PREP Technical Advisory Committee, which selects a subset of indicators to be presented to the PREP Management Committee and to be included in the State of the Estuaries report. The Management Committee reviews the indicators and finalizes the list to be included in the report. Between 10 and 20 indicators are included in each State of the Estuaries report.

The following sections contain the most recent data for the 42 indicators tracked by PREP. In some cases PREP funds data collection and monitoring activities; however data for the majority of indicators are provided by other organizations with monitoring programs. The details of the monitoring programs and performance criteria for the indicators are listed in the PREP Monitoring Plan (PREP, 2008).

In December 2007 the PREP Management Committee voted unanimously to expand PREP's focus area to the entire Great Bay Estuary watershed, including the 24 percent of the watershed in Maine. This shift is a critical step toward achieving the program's watershed-wide goals of improving water quality and protecting and restoring important habitats. Environmental indicators for the Maine portion of the watershed are still being developed. Therefore, most of the indicators in this report are oriented toward the New Hampshire portion of the watershed. The exceptions are the nitrogen load, protected conservation lands, and impervious surface indicators which cover the whole watershed in both states. Many of the water quality indicators also include data from tidal waters in Maine.

The results and interpretations for the indicators presented in this report have been peer reviewed by the PREP Technical Advisory Committee and other experts in relevant fields. The Technical Advisory Committee consists of university professors, researchers and state and federal environmental managers from a variety of disciplines and perspectives. The conclusions of this study represent the current scientific consensus regarding conditions in the estuaries of the Piscataqua Region.

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Environmental Indicators

A. Water Quality Indicators

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Indicator: BAC1 - Acre-days of Shellfish Harvest Opportunities in Estuarine Waters

PREP Goal: The goal is to have 100% of possible acre-days in estuarine waters open for harvesting.

Why This Is Important: In most cases, the reason why a shellfish growing area is closed to harvesting is somehow related to poor bacterial water quality (although closures due to PSP or "red-tide" do occur). Therefore, this acre-day indicator is a good integrative measure of the degree to which water quality in the estuary is meeting fecal coliform standards for shellfish harvesting.

Monitoring Question: Do NH tidal waters meet fecal coliform standards of the National Shellfish Sanitation Program for 'approved' shellfish areas?

Answer: No. Only 45% of NH's estuarine waters are classified as "Approved" or "Conditionally Approved" for shellfishing. Of these areas, shellfish harvesting can be done only 50% of the possible acre-days.

Explanation

The DES Shellfish Program measures the opportunities for shellfish harvesting using "acre-days", which is the product of the acres of shellfish growing waters and the amount of time that these waters are open for harvest. The acre-days indicator is reported as the percentage of the total possible acre-days of harvesting for which the shellfish waters are actually open.

Shellfishing classifications and acre-days of shellfishing opportunities have been tracked from 2000 through 2008. Table BAC1-1 shows that in 2000 and 2001, approximately 36 to 38% of the 13,718 acres of estuarine waters were classified as "Approved" or "Conditionally Approved" for shellfishing by the DES Shellfish Program. By 2003, the percentage of waters in the "Approved" or "Conditionally Approved" classifications had grown to 48%. However, some of the increased percentage was due to a reduction in the total area of estuarine waters being considered for shellfish classifications. In 2003, the DES Shellfish Program removed all of the estuarine waters on the Maine side of the border from its classification database. From 2003 to 2008, the percentage of waters in the "Approved" or "Conditionally Approved" classifications has remained relatively constant.

Table BAC1-2 shows the trends in shellfish harvesting acre-days the major growing areas of NH's estuarine waters. Shellfishing opportunities in the open portions of the estuaries varied by location in 2000-2004 but became the same by 2008. In Great Bay, the shellfishing acre-days remained nearly 90% of the possible amount in 2000-2004.In Hampton-Seabrook Harbor and Little Harbor, the acre-day percentage was only slightly above 40% for the same period. By 2008, the acre-day percentage was approximately 50% for all areas except Hampton-Seabrook Harbor which was 36%. There has been an improving trend in the Little Harbor growing area. This area was closed to shellfishing in before 2001, but by 2008 it was open 51% of the possible acre-days. In contrast, there has been a declining trend in shellfish harvesting acre-days in the Great Bay and Little Bay growing areas from approximately 90% open to 50% open.

The goal for the acre-days indicator is for all estuarine waters to be open for harvesting 100% of the time. This goal is not being met. Only 45% of the estuarine waters are classified as "Approved" or "Conditionally Approved" for shellfishing. Of these areas, shellfish harvesting can be done only 50% of the possible acre-days. Stormwater runoff is the predominant cause for the closures in all areas. Direct runoff of bacteria from the land surface and the occasional wastewater treatment plant overflow cause elevated bacteria concentrations in the shellfish growing areas.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan with the following exceptions:

1. Data were provided from DES Shellfish Program records, not annual reports.
2. The latest version of the NSSP protocols is NSSP (2007).

Table BAC1-1: Percent of NH estuarine waters in each shellfish classification

Classification	Approved or Conditionally Approved	Restricted or Prohibited	Safety Zone	Unclassified	Total Acres
2000	36.3%	10.5%	3.8%	49.4%	13,718
2001	37.8%	11.2%	7.5%	43.5%	13,718
2002	38.4%	11.2%	6.9%	43.6%	13,739
2003	48.5%	13.6%	9.3%	28.6%	11,355
2004	46.6%	5.8%	23.6%	24.0%	11,452
2005	44.2%	7.2%	29.2%	19.4%	11,597
2006	44.5%	13.0%	29.6%	12.8%	11,507
2007	46.6%	11.7%	30.2%	11.5%	11,588
2008	45.1%	13.2%	30.2%	11.5%	11,589

Figure BAC1-1: Percent of NH estuarine waters in each shellfish classification

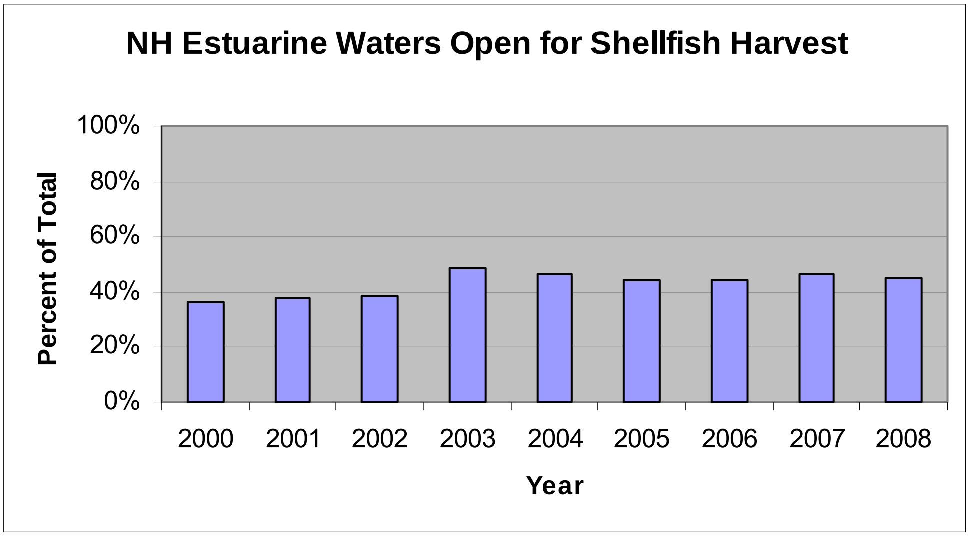

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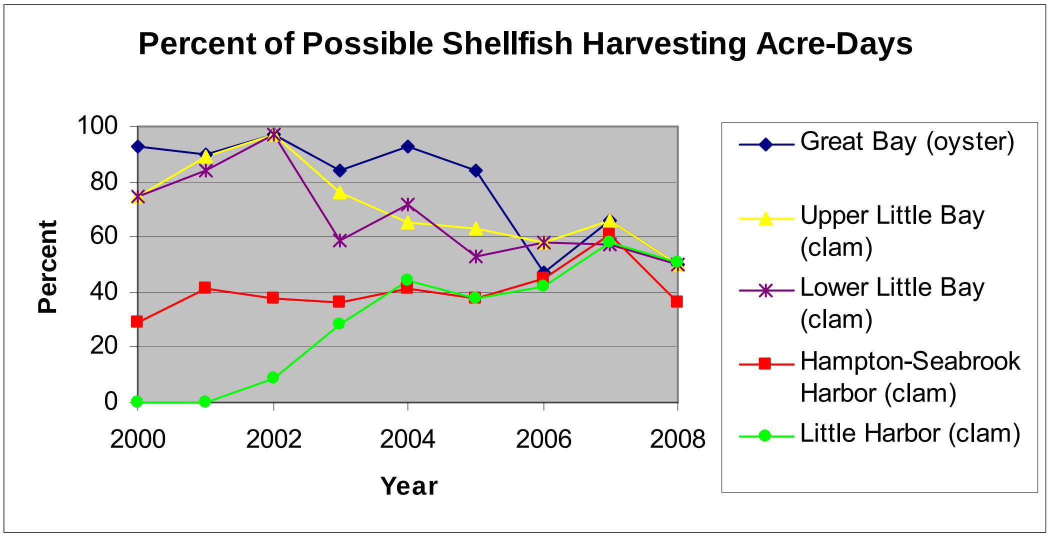
Table BAC1-2: Percent of possible acre-days during which shellfish harvesting was allowed in approved or conditionally approved estuarine waters

Year	Great Bay (oyster)	Hampton-Seabrook Harbor (clam)	Upper Little Bay (clam)	Lower Little Bay (clam)	Little Harbor (clam)	Goal
2000	93	29	75	75	0	100
2001	90	41	89	84	0	100
2002	97	38	97	97	9	100
2003	84	36	76	59	28	100
2004	93	41	65	72	44	100
2005	84	38	63	53	38	100
2006	47	45	58	58	42	100
2007	66	61	66	57	58	100
2008	50	36	50	50	51	100

Figure BAC1-2: Percent of possible acre-days during which shellfish harvesting was allowed in approved or conditionally approved estuarine waters



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Indicator: BAC2. Trends in Dry-Weather Bacterial Indicators Concentrations

PREP Goal: The goal is to have statistically significant decreasing trends in bacteria concentrations at stations in the tidal tributaries to the estuary. Significant trends are not expected at the stations located in the middle of Great Bay (e.g., Adams Point).

Why This Is Important: Fecal coliform bacteria in surface waters may indicate the presence of pathogens due to sewage contamination. Pathogens, which are disease-causing microorganisms, pose a public health risk and are the primary reason why shellfish beds are closed to harvesting.

Monitoring Question: Has dry-weather bacterial contamination changed significantly over time?

Answer: Yes. Fecal coliform concentrations in Great Bay have decreased by 66 percent over the past 20 years, but the concentrations have not changed significantly in the past 10 years.

Explanation
The results of the trend analysis at the four stations are summarized in Table BAC2-1. Graphs of the bacteria indicator species over time at each station are shown in Figures BAC2-1 through BAC2-4. For each station, the graphs show the trends over the full period of record on the left and for the most recent 10 years on the right. The locations of the trend stations are shown in Figure BAC2-5.

Fecal coliform and *Escherichia coli* concentrations decreased at the three long-term trend sites in the Great Bay, Lamprey River, and the Squamscott River for the full period of record. The magnitude of the decrease at each station was between 58 and 90 percent. No significant trend was apparent at station GRBCML in Portsmouth Harbor. The bacteria concentrations at this site were much lower than at the other sites. There were no statistically significant, increasing trends at any of the long-term trend sites.

In the most recent 10 years (see Table BAC2-1B), no statistically significant trends were observed. It is not clear whether the lack of recent trends is because the concentrations are approaching background levels, or if bacteria source reduction efforts are stalling, or if new loads are being added that offset successful reduction efforts.

Therefore, for the full period of record (1989-2008) the goal of observing decreasing trends in the tidal tributaries is being met. WWTF upgrades and stormwater management projects are likely major contributors to the decreasing trends. However, only two of the seven tributaries to the Great Bay Estuary have been monitored for long enough to allow for trend analysis. All of the trend conclusions are based on data from only four stations in the estuary. Moreover, most of the trends became non-significant in the last decade. The observed trends may have been driven by large decreases in the late 1980s and early 1990s, with smaller changes occurring in the past decade. Alternatively, continued population growth in coastal watershed may be counteracting the ongoing pollution control efforts.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan with the following exceptions:
1. Results reported as below the reporting detection level were included using the reporting detection level as a value. These results were a small percentage of the dataset (<10%).
2. Field duplicate samples were not included in the dataset. These results were a small percentage of the dataset (<0.5%).

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Table BAC2-1: Trends in dry weather bacteria concentrations at low tide at long-term monitoring stations

A. Trends for full period of record

Station	Parameter	Period of Record	Median (cts/100ml)	Trend	Percent Change
GRBAP (Adams Point)	Fecal coliforms	1989-2008	8.0	**Decreasing**	-66%
	Enterococcus		3.0	No significant trend	
	E. coli		6.0	**Decreasing**	-58%
GRBLR (Lamprey River)	Fecal coliforms	1992-2008	60.5	**Decreasing**	-88%
	Enterococcus		36.0	No significant trend	
	E. coli		52.0	**Decreasing**	-90%
GRBCL (Squamscott River)	Fecal coliforms	1989-2008	68.0	**Decreasing**	-72%
	Enterococcus		34.5	No significant trend	
	E. coli		50.0	**Decreasing**	-62%
GRBCML (Portsmouth Harbor)	Fecal coliforms	1991-2008	6.9	No significant trend	
	Enterococcus		2.1	No significant trend	
	E. coli		5.0	No significant trend	

B. Trends for the most recent 10 years

Station	Parameter	Period of Record	Median (cts/100ml)	Trend	Percent Change
GRBAP (Adams Point)	Fecal coliforms	1999-2008	6.0	No significant trend	
	Enterococcus		2.9	No significant trend	
	E. coli		4.0	No significant trend	
GRBLR (Lamprey River)	Fecal coliforms	1999-2008	44.0	No significant trend	
	Enterococcus		35.0	No significant trend	
	E. coli		38.0	No significant trend	
GRBCL (Squamscott River)	Fecal coliforms	1999-2008	50.0	No significant trend	
	Enterococcus		48.5	No significant trend	
	E. coli		39.0	No significant trend	
GRBCML (Portsmouth Harbor)	Fecal coliforms	1999-2008	6.0	No significant trend	
	Enterococcus		2.9	No significant trend	
	E. coli		5.0	No significant trend	

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Figure BAC2-1: Long-term trends in bacteria indicators at Adams Point in Great Bay

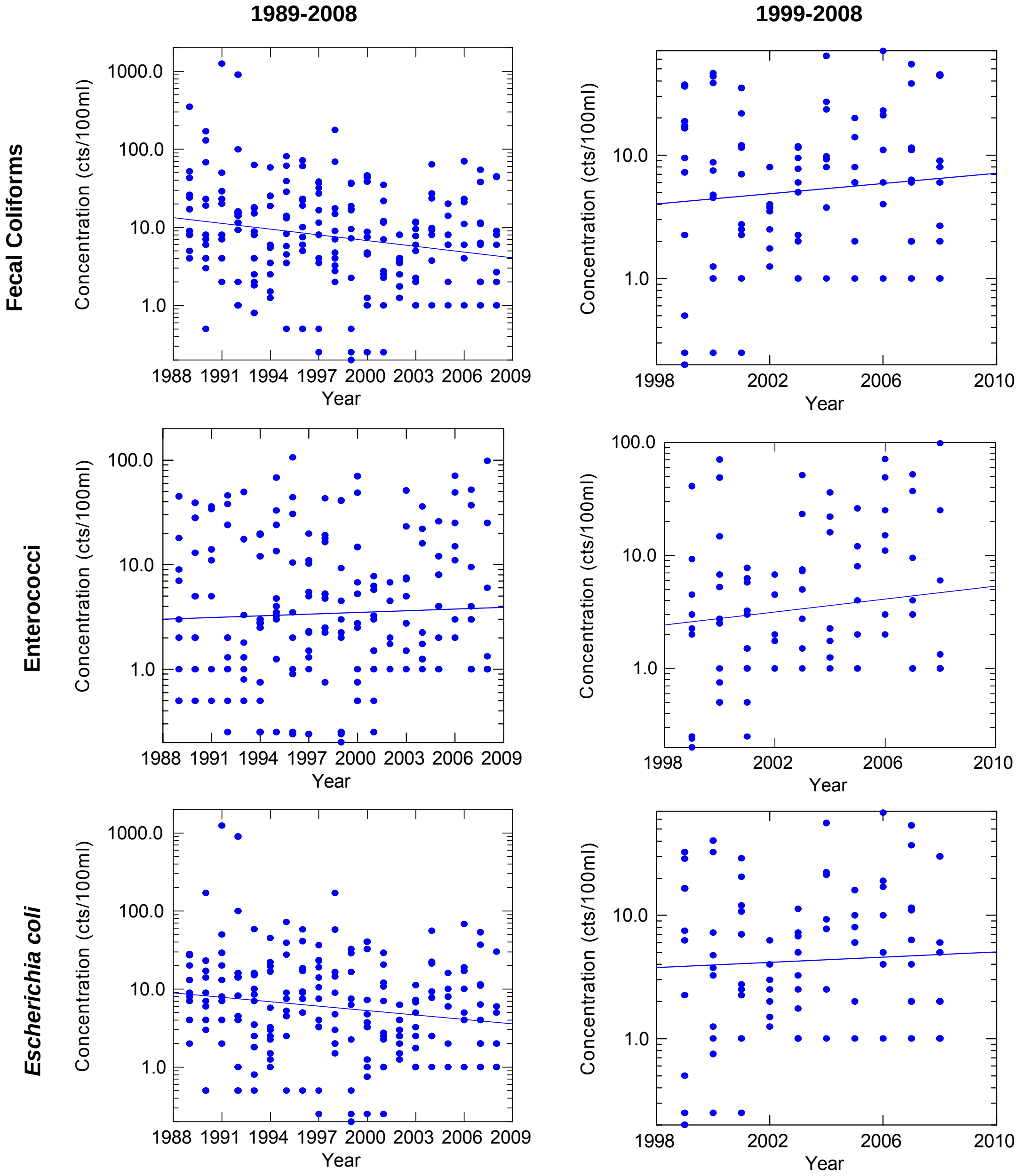

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Figure BAC2-2: Long-term trends in bacteria indicators at the Newmarket Town Landing on the Lamprey River (tidal portion)

1992-2008 **1999-2008**

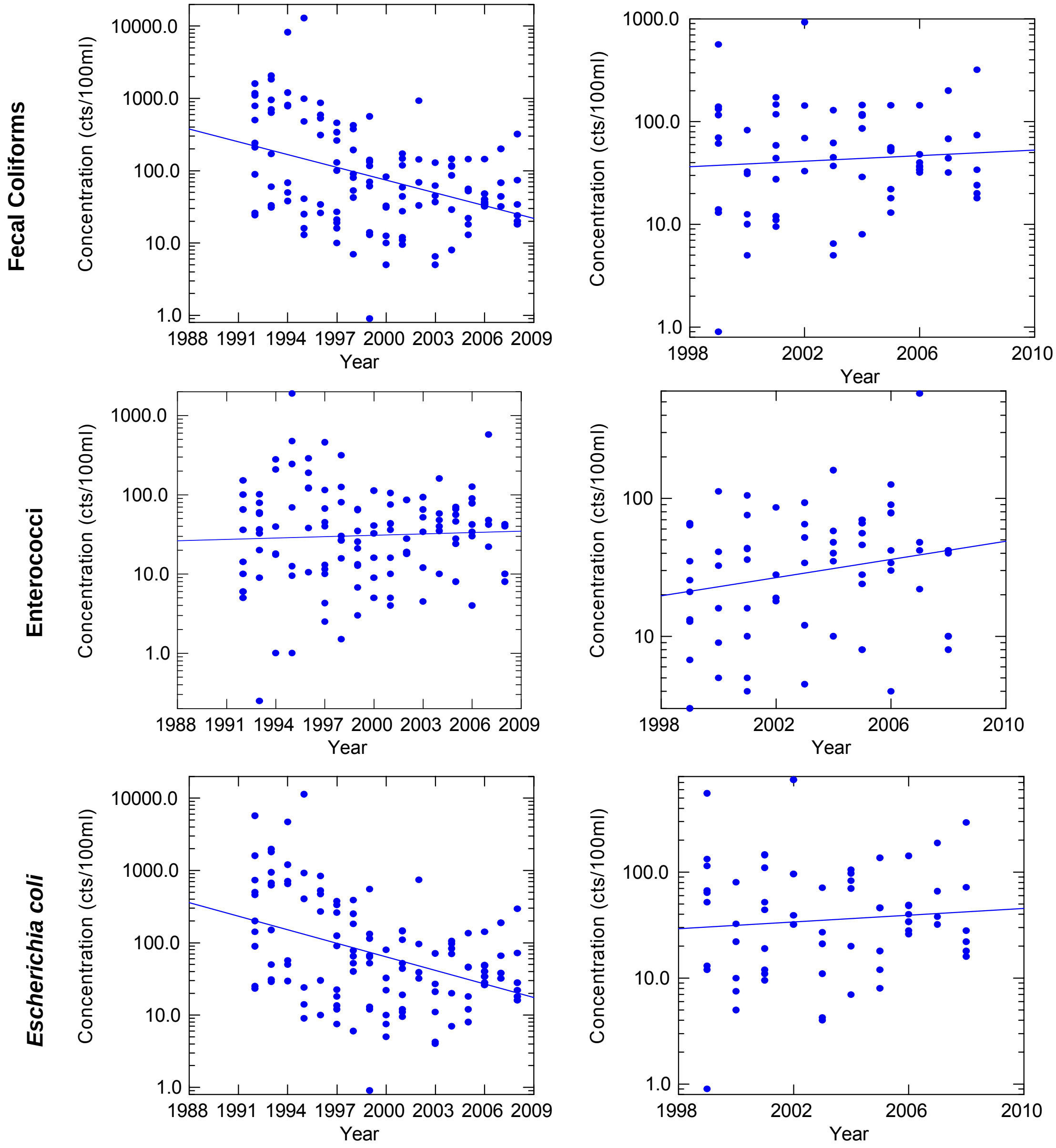

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Figure BAC2-3: Long-term trends in bacteria indicators at Chapmans Landing on the Squamscott River

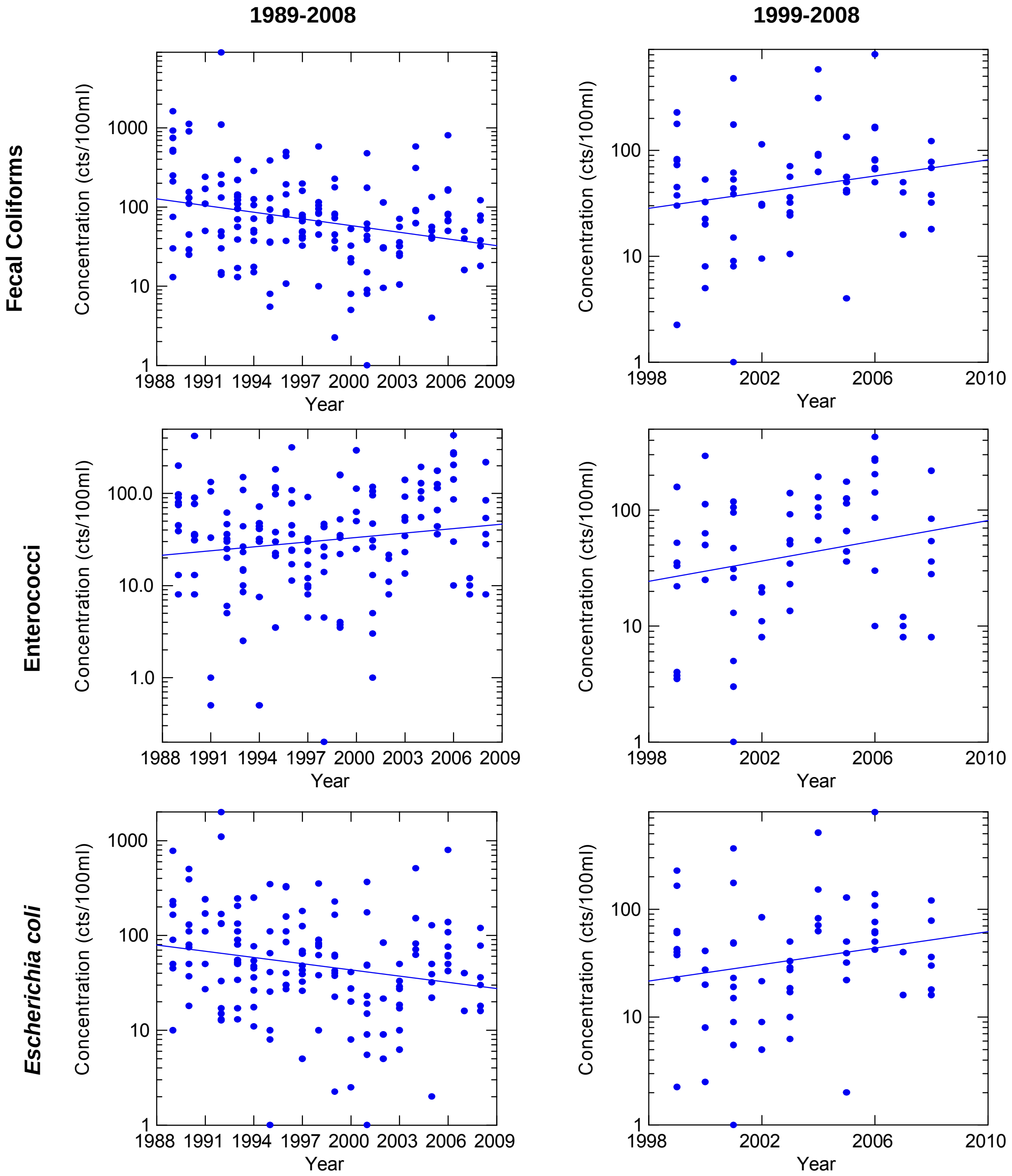

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Figure BAC2-4: Long-term trends in bacteria indicators at Fort Point in Portsmouth Harbor

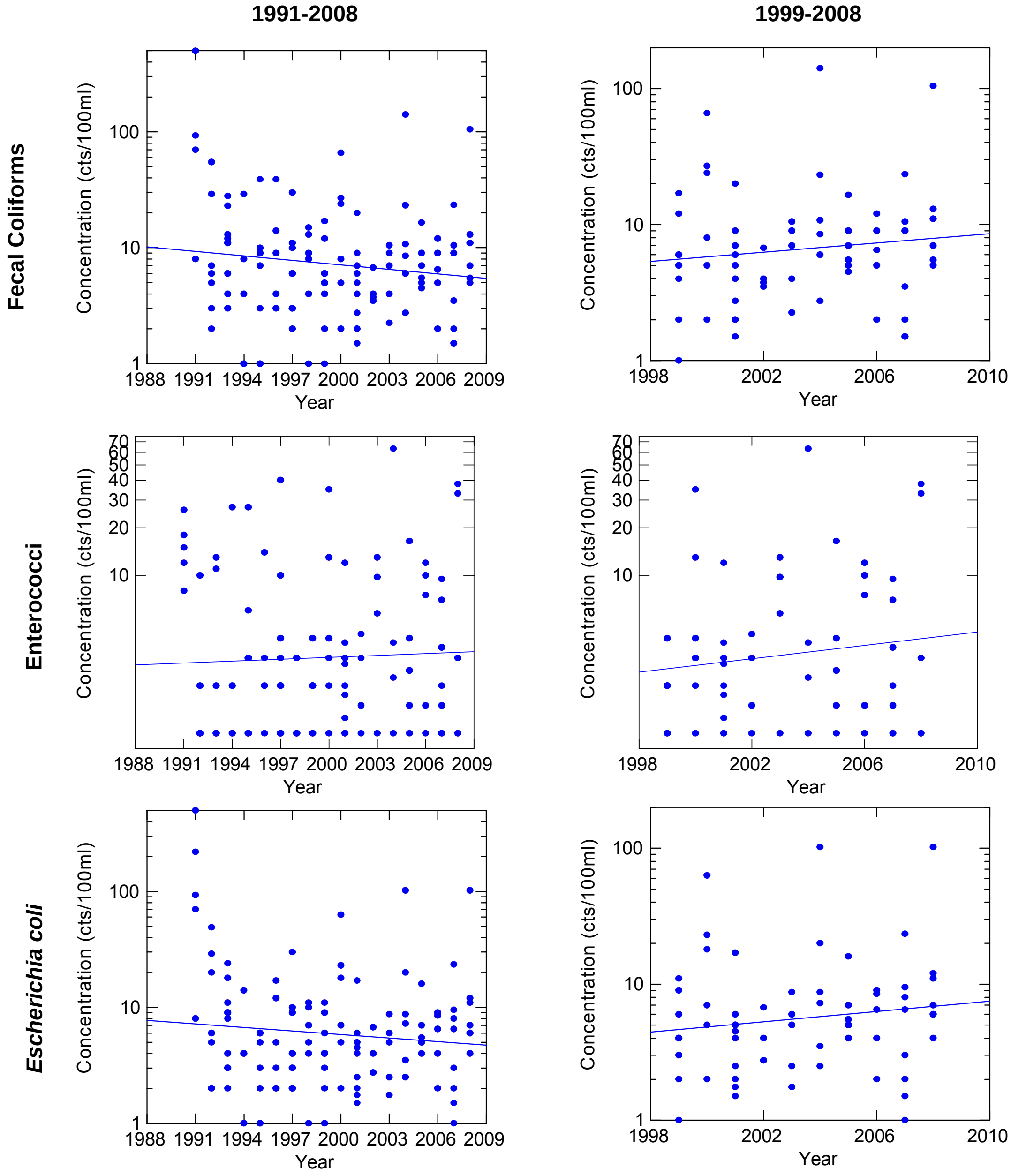

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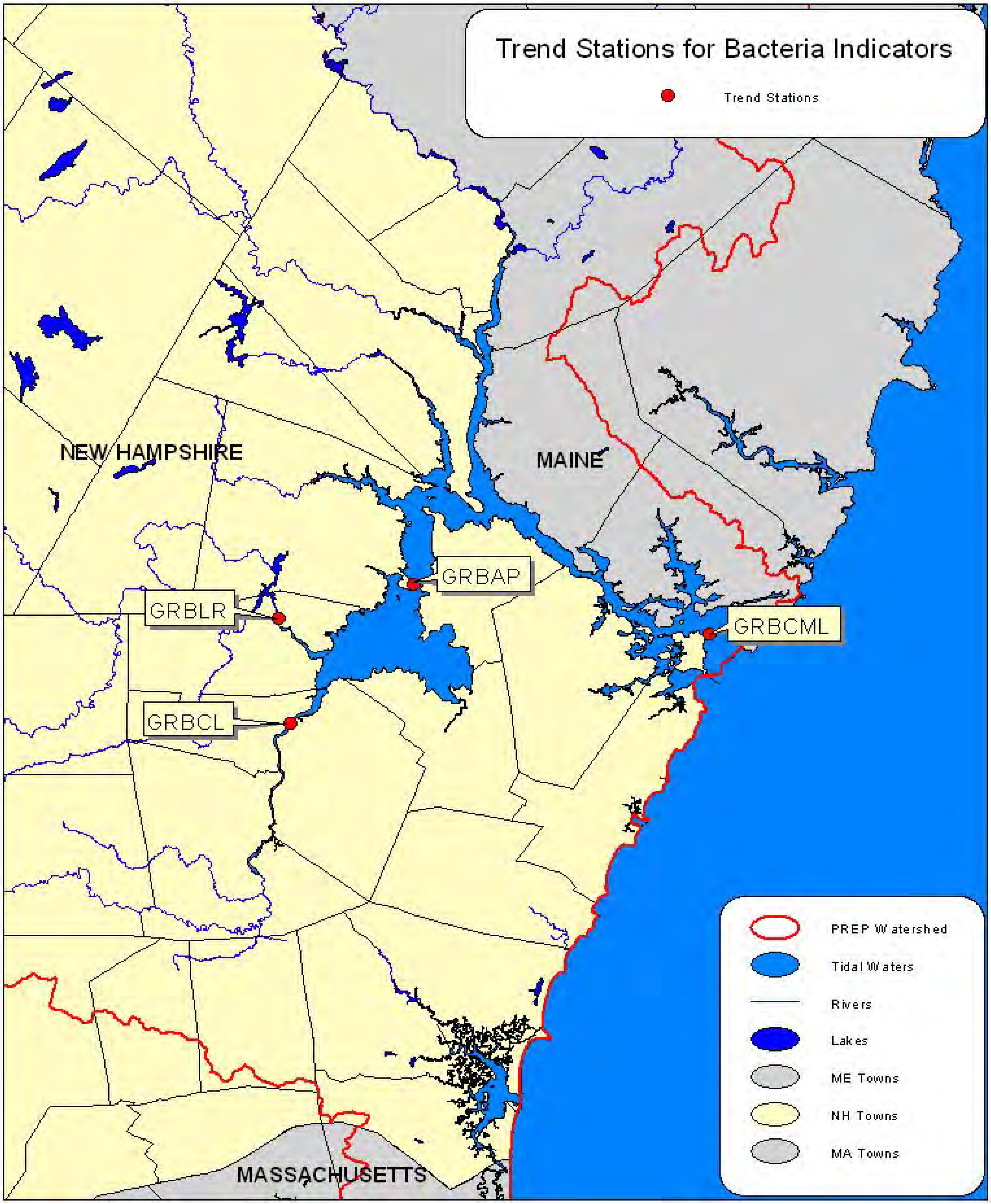
Figure BAC2-5: Trend stations for bacteria indicator species



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Indicator: BAC4. Tidal Bathing Beach Postings

PREP Goal: The goal is to have zero postings at the tidal bathing beaches over the summer season.

Why This Is Important: The DES Beach Program monitors designated tidal bathing beaches along the Atlantic Coast of NH during the summer months (Memorial Day to Labor Day). If the concentrations of enterococci in the water do not meet state water quality standards for designated tidal beaches (104 Enterococci/100 ml in a single sample), DES recommends that an advisory be posted at the beach. Therefore, the number of postings at tidal beaches should be a good indicator of bacterial water quality at the beaches.

Monitoring Question: Do NH tidal waters, including swimming beaches, meet the state enterococci standards?

Answer: No. In 2008, poor water quality prompted advisories at four tidal beaches in New Hampshire for a total of 19 days.

Explanation
The advisories posted at tidal beaches in New Hampshire are show on Figure BAC4-1. Before 2003, there had never been any advisories issued for the tidal bathing beaches in New Hampshire. However, in every year since 2003, there has been at least one advisory posted for a tidal beach. The greatest number of advisories occurred in 2006 (6 advisories at 5 beaches). In 2008, there were six advisories affecting four beaches for a total of 19 days. Therefore, the PREP goal of zero advisories at tidal beaches is not currently being met. The beaches with the most advisories are the New Castle Town Beach and the State Beach in North Hampton. Advisories have also been posted at Sawyer Beach, Jenness Beach, Pirates Cove Beach, Bass Beach, Foss Beach, and Seabrook Harbor Beach.

It is significant that advisories have been consistently issued for NH's tidal beaches since 2003. This trend may indicate a decline in water quality in near coastal areas. However, there is another possible explanation. The DES Beach Program changed its monitoring protocols in 2002. First, the number of beaches in the program increased from nine in 2001 to 16 by 2005. Of the five advisories issued, three have been for beaches added to the program since 2002. Second, the sampling season was expanded to cover the period of June 1 to Labor Day. Third, the sampling frequency increased at some of the beaches. Therefore, the trends in beach advisories must be interpreted with caution until the effects of the new protocols are better understood.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

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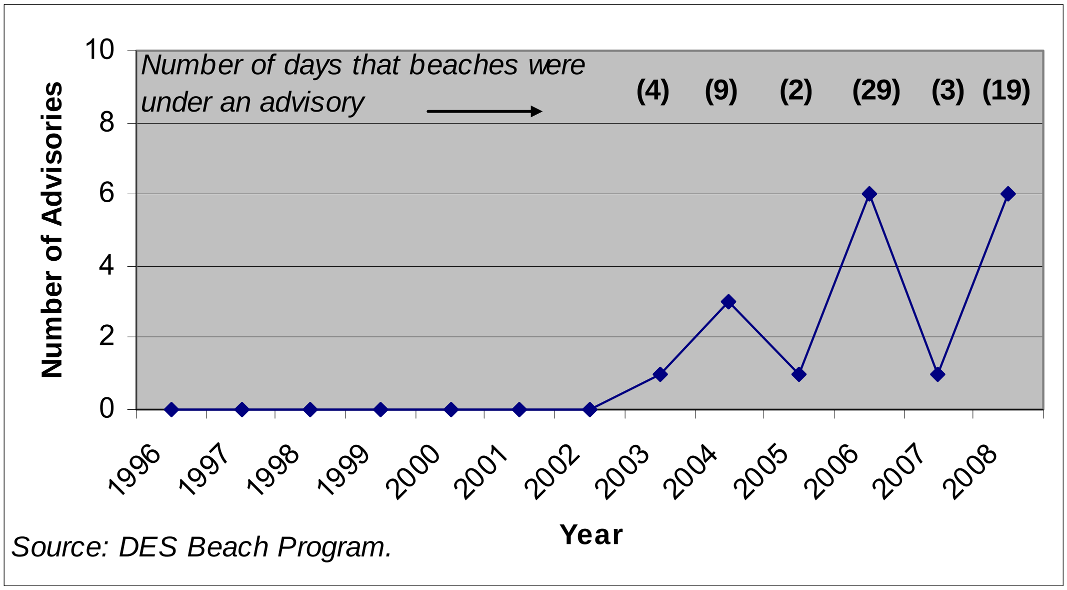
Figure BAC4-1: Number of advisories at tidal beaches 1996-2008



Source: DES Beach Program.

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Indicator: BAC6. Violations of Enterococci Standard in Estuarine Waters

PREP Goal: The goal is to have zero percent of the estuarine area in violation of NH RSA 485-A:8 (i.e., bacteria standards for swimming).

Why This Is Important: Bacteria concentrations are not only important at designated bathing beaches. People swim and boat throughout the estuary. Therefore, it is important to know whether bacteria concentrations meet water quality standards for swimming in all areas of the estuary.

Monitoring Question: Do NH tidal waters, including swimming beaches, meet the state enterococci standards?

Answer: No. In the 2006-2007 probabilistic survey, enterococcus concentrations were greater than the water quality standard for swimming in 10% of estuarine waters.

Explanation

This indicator is based on results from a probabilistic survey. In effect, a probabilistic monitoring program is a “poll” of water quality the estuary. In a typical public opinion poll, a subset of the population is chosen at random and then asked questions about a topic. The responses of this group are taken to be representative of the overall public opinion within a known margin of error. The same general process was followed for the probabilistic monitoring program in estuaries. Out of the all the possible sampling locations in the estuaries, a subset of stations were chosen randomly. Since the stations were chosen at random, it was assumed that the water quality at the chosen stations was representative of water quality in the entire estuary. A margin of error was assigned when the results were extrapolated to the entire estuary.

The probabilistic survey in 2006-2007 revealed that 90% of the estuarine area was expected to have enterococci concentrations less than 104 cts/100ml (Figure BAC6-1). In contrast, 10% of the estuarine area was expected to have concentrations greater than 104 cts/100ml, which would be a violation of the water quality standard. The error bars on the estimate show that the result is significantly different from zero. Therefore, the goal is currently not being met. The enterococcus concentrations throughout the estuary from the 2006-2007 survey are shown in Figure BAC6-2.

In the 2004-2005 survey, only 1% of the estuary was found to have enterococcus concentrations greater than the standard. A different set of randomized stations were used for the 2004-2005 survey. The difference between the results from the two surveys may be due to random variability, differing rainfall amounts during the two surveys, or actual changes in pollution sources.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

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Table BAC6-1: Percent of estuarine waters with Enterococcus concentrations greater than the water quality standard

Survey	Enterococcus >104 cts/100ml	Enterococcus <=104 cts/100ml	Not Sampled	Error
2002-2003	0.3%	68.2%	31.6%	1.2%
2004-2005	1.0%	98.9%	0.1%	2.2%
2006-2007	10.0%	90.0%	0.0%	8.4%

Figure BAC6-1: Percent of estuarine waters with Enterococcus concentrations greater than the water quality standard

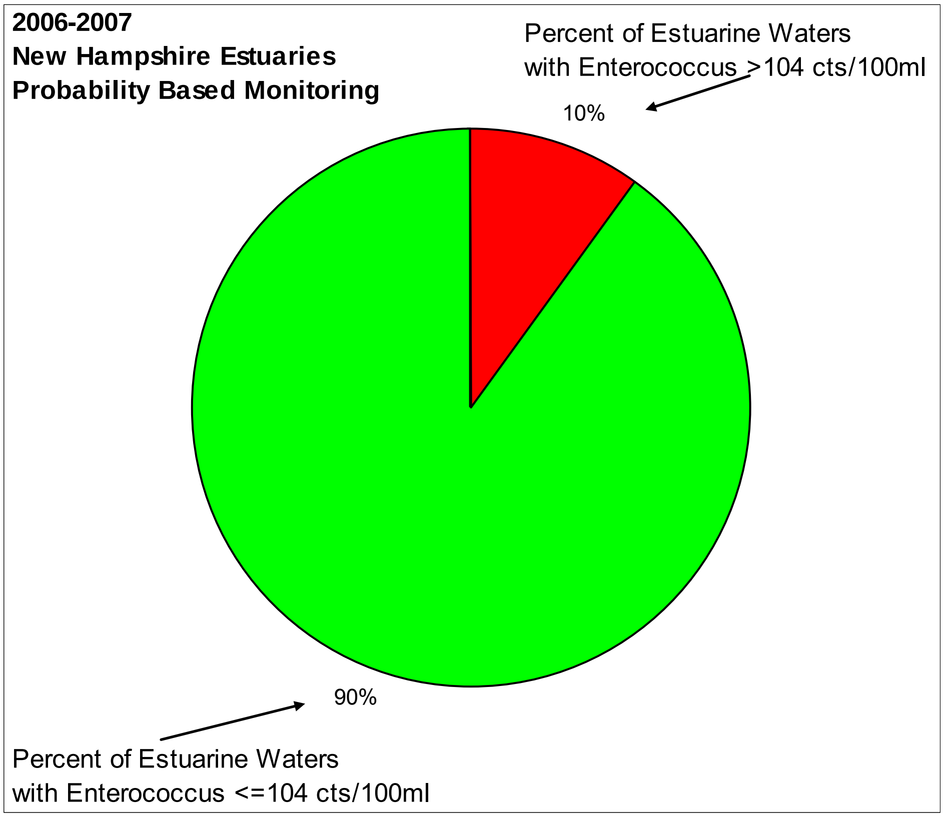

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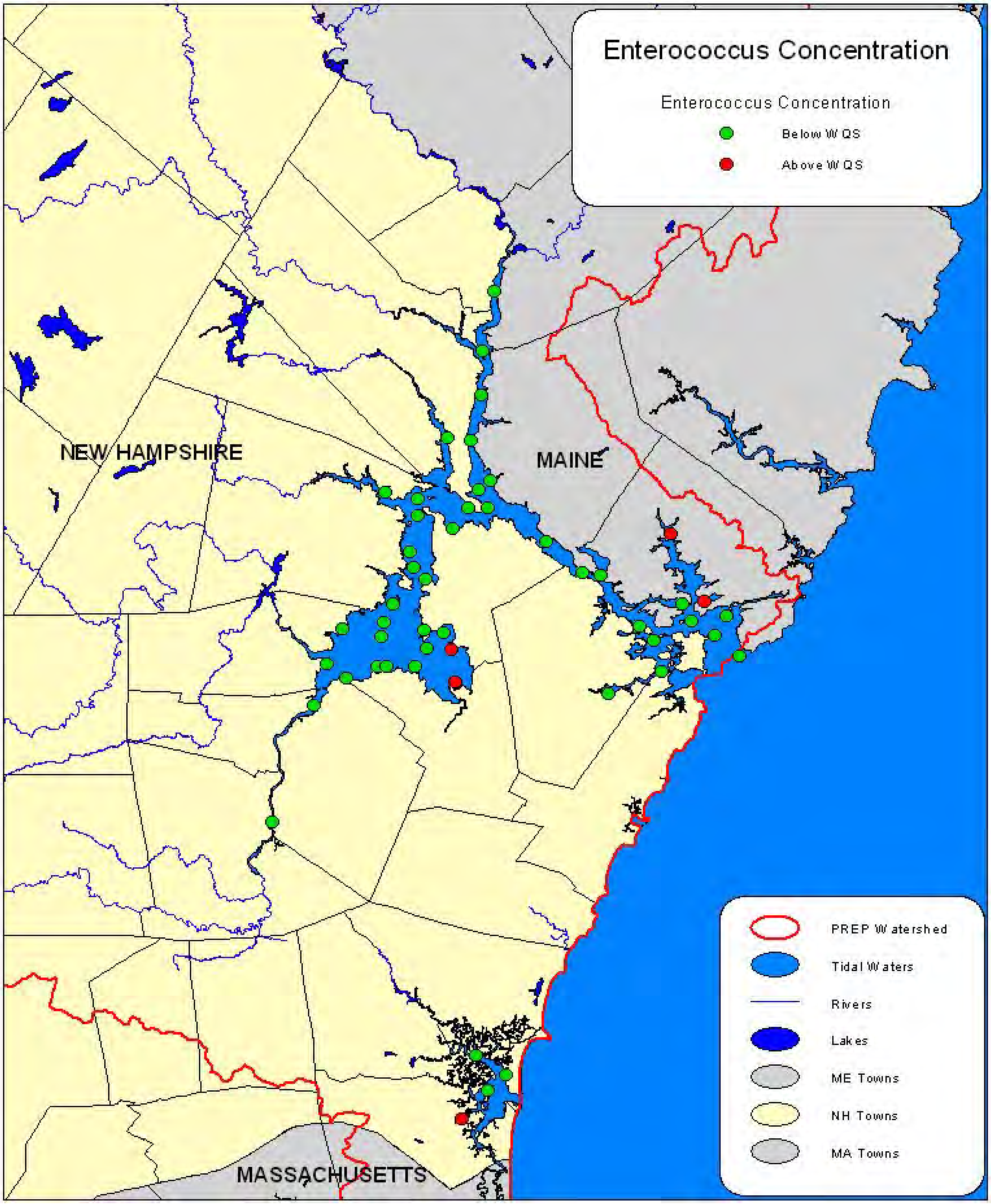
Figure BAC6-2: Enterococcus concentrations in samples from the 2006-2007 survey relative to the water quality standard



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Indicator: BAC7. Freshwater Bathing Beach Postings

PREP Goal: The goal is to have zero postings at the freshwater bathing beaches in the coastal watershed over the summer season.

Why This Is Important: The DES Beach Program monitors designated freshwater bathing beaches in the NH portion of the coastal watershed during the summer months. If the concentrations of *E. coli* in the water do not meet state water quality standards for designated freshwater beaches, DES recommends that an advisory be posted at the beach. Therefore, the number of postings at freshwater beaches should be a good indicator of bacterial water quality at the beaches.

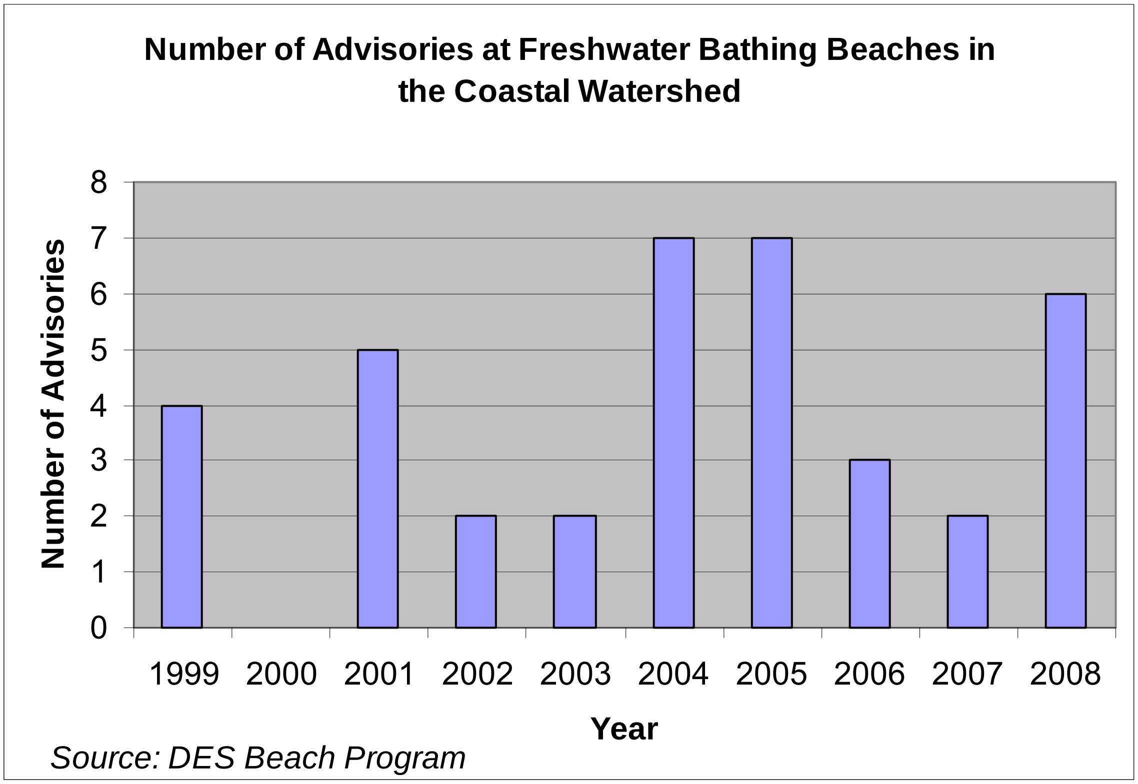
Monitoring Question: Do NH designated freshwater beaches in the coastal watershed meet the state *E. coli* standards?

Answer: Not completely. There consistently have been between 2 and 7 advisories posted at freshwater beaches in the NH portion of the coastal watershed each year.

Explanation
Since 1999, there have typically been at least two advisories issued for freshwater beaches in the coastal watershed. The number of advisories has been as high as 7 in 2004 and 2005. Therefore, the goal of zero advisories is not being met. The number of beaches in the program since 1999 has not changed significantly. There are a number of sources of bacteria at freshwater bathing beaches, including the bather load itself.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

Figure BAC7-1: Number of advisories posted at freshwater beaches in the coastal watershed



Source: DES Beach Program

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Indicator: TOX1. Shellfish Tissue Concentrations Relative to FDA Standards

PREP Goal: The goal is for zero percent of sampling stations in the estuary to have mean shellfish tissue concentrations greater than FDA guidance values.

Why This Is Important: Mussels, clams, and oysters accumulate toxic contaminants from polluted water in their tissues. In addition to being a public health risk, the contaminant level in shellfish tissue is a long-term indicator of water quality in the estuaries.

Monitoring Question: Are shellfish, lobsters, finfish, and other seafood species from NH coastal waters fit for human consumption?

Answer: Yes. The majority of shellfish tissue samples do not contain toxic contaminant concentrations greater than FDA standards. The one exception is lead in South Mill Pond. This area is already closed to shellfish harvesting due to bacteria pollution.

Explanation

Between 1993 and 2008, 20 stations in NH's estuaries have been tested for toxic contaminants in blue mussel tissue under the Gulfwatch Program (Figure TOX1-1). The stations cover all of the major shellfish growing areas in the estuaries. Most of the shellfish collected have been mussels; however, eight stations each have been tested for clam and oyster tissue.

Table TOX1-1 shows that lead was the only compound with a maximum value above its FDA guidance value. This exceedence only occurred for mussels collected from station NHSM in South Mill Pond. The concentrations of contaminants in clam and oyster tissue were all below FDA values. Figure TOX1-2 shows all of the measurements of lead in mussels from station NHSM. There has been a steady increase in lead concentrations between 1999 and 2006. Cadmium, zinc and aluminum concentrations have also increased at this station. One explanation for the increasing concentrations of metals is that a restoration project has increased tidal flushing in South Mill Pond in recent years. The increased flushing may have changed the geochemistry of the sediments resulting in the release of metals which were previously not bioavailable.

The results in Table TOX1-1 illustrate the differences in tissue concentrations between the three shellfish species. Copper concentrations tend to be higher in oyster tissue relative to the tissue of other species due to differences in metabolism.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan with the following exceptions:

1. In 2008, the Gulfwatch Program changed the sample design from collecting four replicates at each station to collecting three replicates plus one composite of the three replicates at trend stations in NH and just one composite sample at other stations. Therefore, it is not always possible to complete t-tests for all stations. Instead, all of the results were used to identify stations with parameters greater than the screening values, which were then graphed to illustrate trends.
2. Concentrations of PAH, PCBs, and pesticides from samples collected in 2008 at stations NHFP (mussel), NHSS (mussel), NHNM (clam), and NHWC (clam) were not available in time for this analysis.

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Table TOX1-1: Maximum concentrations of toxic contaminants measured in clam, mussel and oyster tissue between 1993 and 2008

Parameter	Clam Tissue	Mussel Tissue	Oyster Tissue	FDA Screening Value	Units
ALUMINUM	2435	778	449		mg/kg-dw
CADMIUM	2.3	3.6	3.5	25	mg/kg-dw
CHROMIUM	7.1	24	3.1	87	mg/kg-dw
COPPER	21.9	15.1	178.8		mg/kg-dw
IRON	7501	1200	514		mg/kg-dw
LEAD	9.1	17.1	0.9	11.5	mg/kg-dw
MERCURY		0.4		6.7	mg/kg-dw
NICKEL	4.9	8.2	2.5	533	mg/kg-dw
SILVER	2.1	0.8	9.4		mg/kg-dw
ZINC	121	240	7056.8		mg/kg-dw
TOTAL PAHS	312.4	1127.8	470.6		ug/kg-dw
SUM PCBS	3.4	93.8	106.7	13000	ug/kg-dw
TOTAL DDT	2.1	76.4	40.8	33000	ug/kg-dw

Source: NH Gulfwatch Program

1. Cells with results higher than the screening value are shaded.

2. FDA screening values were converted from wet-weight to dry-weight basis by dividing the value by 0.15 (the average fraction of solids in tissue samples).

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Figure TOX1-1: Gulfwatch stations tested between 1993 and 2008

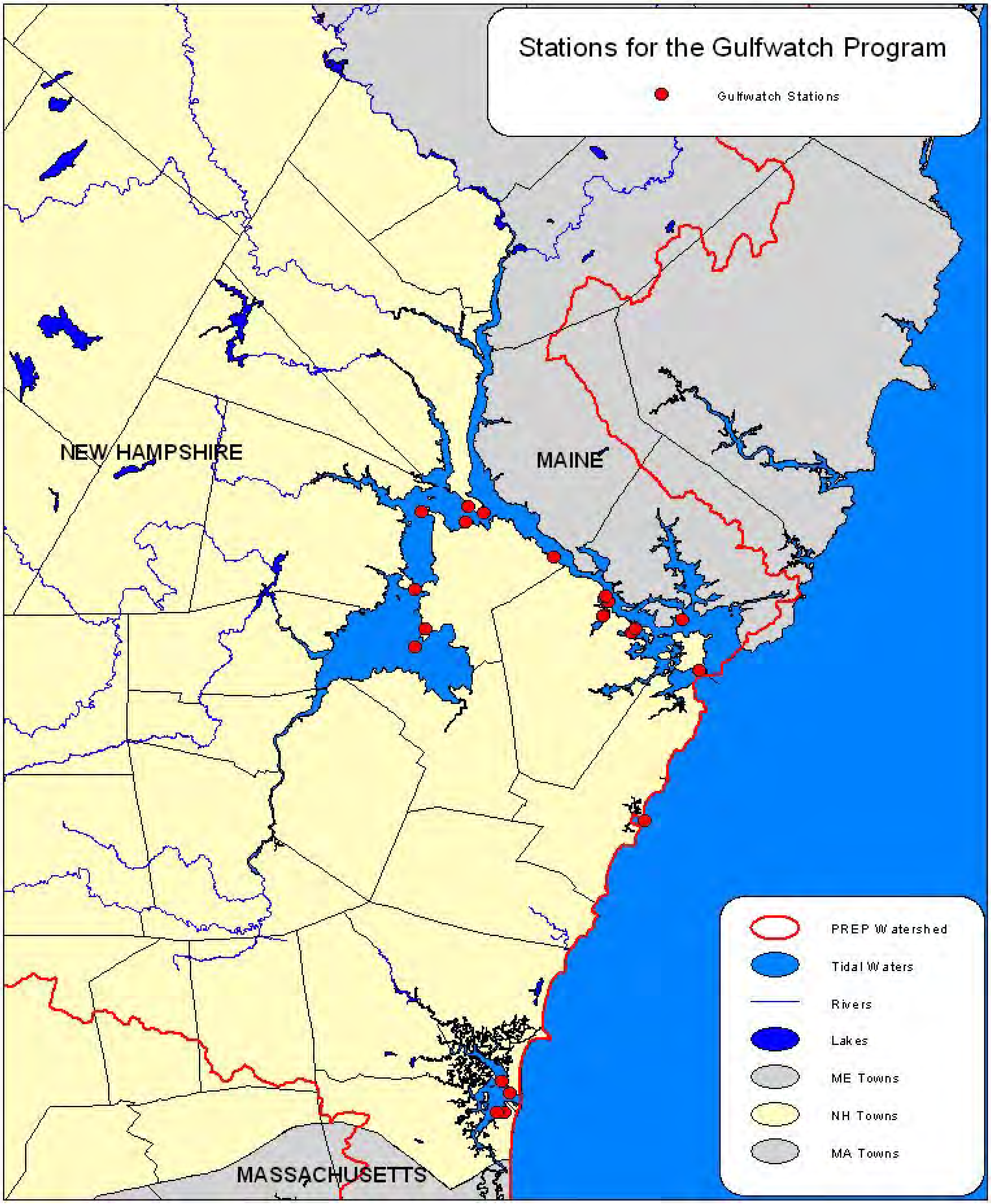

EXHIBIT 50 (AR K.27)

Figure TOX1-2: Lead concentrations in mussel tissue from South Mill Pond

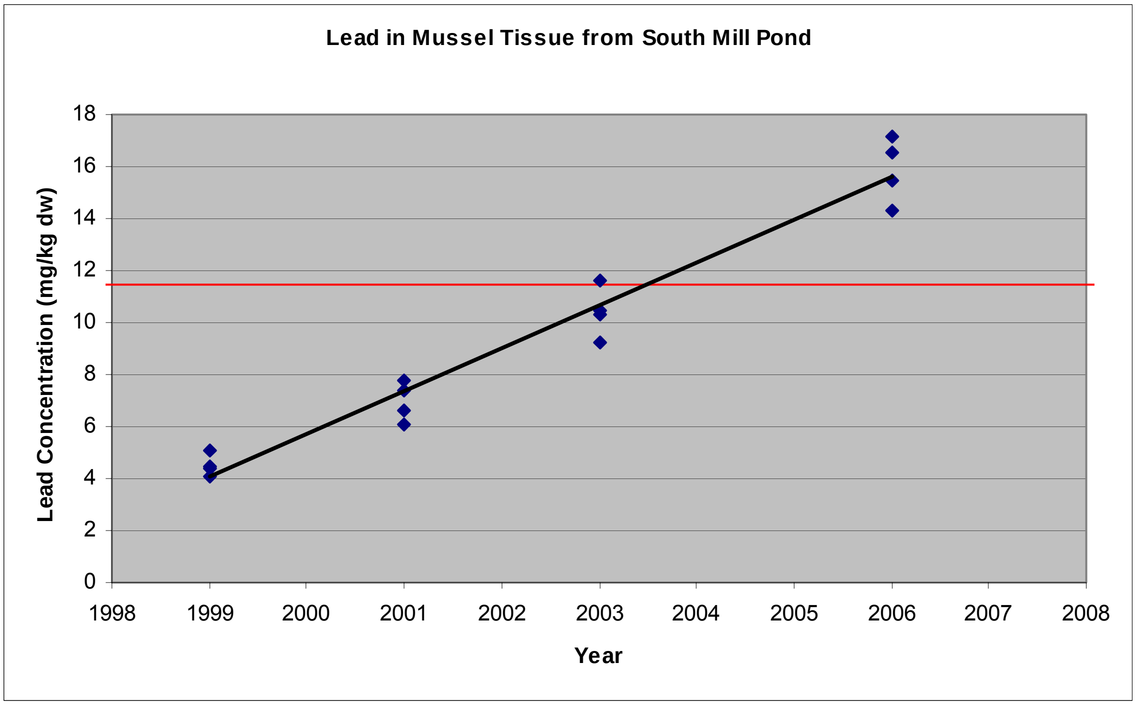

EXHIBIT 50 (AR K.27)

Indicator: TOX8. Finfish and Lobster Edible Tissue Contaminant Concentrations Relative to Risk Based Standards

PREP Goal: The goal is for the average concentrations of mercury and PCBs in the edible tissues of winter flounder and lobster to be significantly less than risk based consumption limits.

Why This Is Important: Toxic contaminants accumulate in the tissues of estuarine biota. Fish consumption is a pathway by which people can be exposed to these contaminants.

Monitoring Question: Are shellfish, lobsters, finfish, and other seafood species from NH coastal waters fit for human consumption?

Answer: Current guidelines advise avoiding and/or limiting consumption of certain types of saltwater fish and shellfish, especially for populations most susceptible to contaminant risk. The limited data available on fish and lobster tissue concentrations are consistent with these guidelines.

Explanation
During the sampling seasons in 2003 through 2006, a total of 27 lobsters and winter flounder were collected for edible fish tissue analysis. The fish were collected at many different locations throughout the estuary using a randomized sampling design. The average concentrations of mercury and total PCBs in each fish type are shown in Table TOX8-1. The mean concentrations of mercury in lobster and winter flounder were 0.126 and 0.038 ug/g, respectively, which are well below the FDA Action Level of 1 ug/g. The mean concentrations of PCBs in these species were similarly well below the FDA Action Level for PCBs. No trends were evident in the concentrations over the sampling period (Figures TOX8-1 and TOX8-2). The power to detect trends was expected to be low because fish were caught in different areas of the estuary each year.

DES has issued fish consumption guidelines for salt water fish, shellfish, and commercially available fish (see http://des.nh.gov/organization/divisions/air/pehb/ehs/ehp/documents/fish_advisory.pdf for guidelines issued in May 2009). The limited data presented in this indicator are consistent with these guidelines. Many factors and additional information are considered when setting a fish consumption advisory. This indicator should in no way be considered a replacement for the official advisories issued by state and federal agencies.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan with the following exceptions:
1. FDA Action Levels were used as the reference concentration for this analysis.
2. Statistical tests comparing the measured concentrations to the FDA Action Levels were not performed because concentrations were so far below action levels.

Table TOX8-1: Mean concentrations of mercury and PCBs in edible tissue of lobster and winter flounder

Species	Parameter	Units	n	Mean	SD	Goal
Lobster	Mercury	ug/g	17	0.126	0.050	1.0
Winter Flounder	Mercury	ug/g	10	0.038	0.034	1.0
Lobster	PCBs	ng/g	17	8.76	11.24	2000
Winter Flounder	PCBs	ng/g	10	6.31	8.66	2000

Note: All units are wet-weight basis.

EXHIBIT 50 (AR K.27)

Figure TOX8-1: Mercury concentrations in edible tissues of lobster and winter flounder

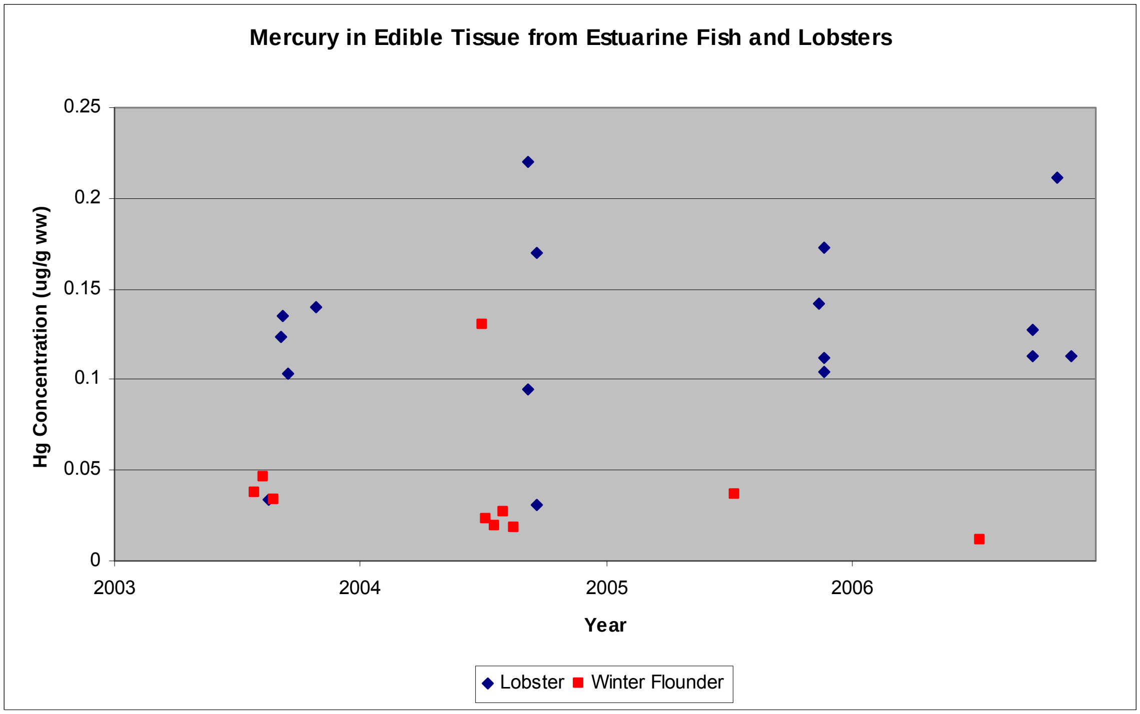

Figure TOX8-2: Total PCB concentrations in edible tissues of lobster and winter flounder

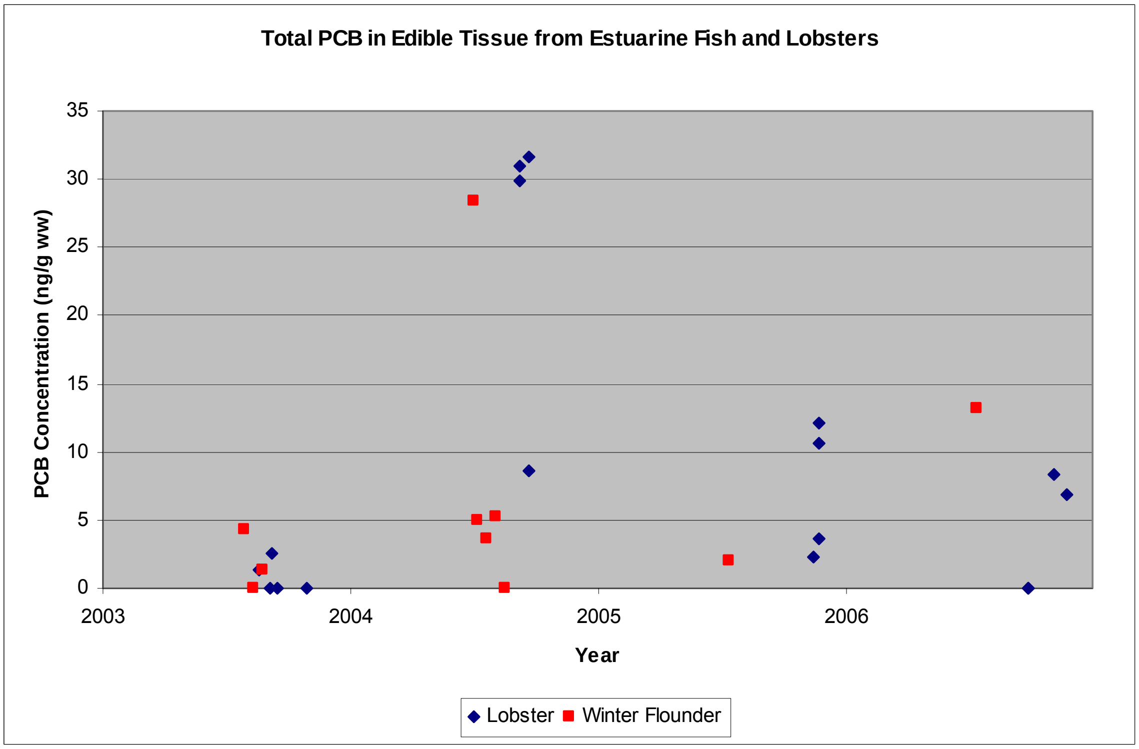

EXHIBIT 50 (AR K.27)

Indicator: TOX3. Trends in Shellfish Tissue Contaminant Concentrations

PREP Goal: The goal is to have no increasing trends for any toxic contaminants.

Why This Is Important: Mussels, clams, and oysters accumulate toxic contaminants from polluted water in their tissues. In addition to being a public health risk, the contaminant level in shellfish tissue is a long-term indicator of water quality in the estuaries.

Monitoring Question: Have concentrations of toxic contaminants in the tissues of shellfish changed over time?

Answer: Yes. The concentrations of polycyclic aromatic hydrocarbons, a component of petroleum products, have increased in the Piscataqua River and Portsmouth Harbor over the past 16 years. For other contaminants, the trends show declining concentrations.

Explanation
For the period between 1993 and 2008, mussel tissue has been analyzed 16, 12, and 12 years in Portsmouth Harbor, Dover Point and Hampton-Seabrook Harbor, respectively. Statistically significant linear trends were apparent at one or more stations for polycyclic aromatic hydrocarbons (PAHs), the pesticide DDT, and polychlorinated biphenyls (PCBs). There were also statistically significant trends for several metals. The significant trends are listed on Table TOX3-1.

The only increasing trends for a toxic contaminant are for PAHs at the stations in Portsmouth Harbor (MECC) and at Dover Point (NHDP). PAHs are components of petroleum products and may be introduced to the environment through fuel spills and combustion of fuels. In Portsmouth Harbor, the trend is uneven but generally follows a gradual linear increase of 51% over the time series. The PAH compounds detected at MECC are predominantly high molecular weight compounds, which indicate combustion sources or remobilization of weathered PAHs. In contrast, at Dover Point, the trend is non-linear and driven by much higher concentrations in 2005 and 2007. The 2005 spike was associated with high molecular weight PAH compounds and was probably the result of mobilization of coal tar during a dredging operation in the Cocheco River. In contrast, the peak in 2007 was associated with low molecular weight PAH compounds (phenathrene especially) and a predominance of alkylated compounds. This finding is consistent with the observation of a small fuel spill in the vicinity of site NHDP several weeks before the mussel samples were collected.

All of the other statistically significant trends for toxic contaminants were decreasing. The declining trends for PCBs, DDT, and lead are shown in Figures TOX3-3 through TOX3-8. PCB concentrations have decreased by 52 to 57%. DDT concentrations have declined by 36 to 50%. And, lead concentrations fell by 29 to 38 percent. These trends reflect the decreased usage of these contaminants due to product bans and pollution prevention programs.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan with the following exceptions:
1. In 2008, the Gulfwatch program changed the sample design from collecting four replicates at each station to collecting three replicates plus one composite of the three replicates. The results from the three true replicates were used in the regressions.

EXHIBIT 50 (AR K.27)

Table TOX3-1: Trends in contaminant concentrations in mussel tissue in Portsmouth Harbor ("MECC"), Dover Point ("NHDP") and Hampton-Seabrook Harbor ("NHHS"), 1993-2008

Station	Parameter	Trend for 1993-2008	Regression Equation	Percent Change
MECC	ALUMINUM	**Increasing**	[AL] = 9.63*YEAR - 18963	61%
	CADMIUM	No significant trend		
	CHROMIUM	**Decreasing**	[CR] = -0.053*YEAR + 109	-22%
	COPPER	No significant trend		
	IRON	No significant trend		
	LEAD	**Decreasing**	[PB] = -0.153*YEAR + 311	-38%
	MERCURY	No significant trend		
	NICKEL	No significant trend		
	SILVER	No significant trend		
	ZINC	No significant trend		
	DDT, TOTAL	**Decreasing**	[DDT] = -0.379*YEAR + 767	-50%
	PAH, TOTAL	**Increasing**	[PAH] = 4.96*YEAR - 9738	51%
	PCB, TOTAL	**Decreasing**	[PCB] = -1.85*YEAR + 3739	-52%
NHDP	ALUMINUM	No significant trend		
	CADMIUM	**Decreasing**	[CD] = -0.035*YEAR + 72.7	-18%
	CHROMIUM	No significant trend		
	COPPER	No significant trend		
	IRON	No significant trend		
	LEAD	**Decreasing**	[PB] = -0.079*YEAR + 161	-29%
	MERCURY	**Decreasing**	[HG] = -0.016*YEAR + 32.2	-40%
	NICKEL	No significant trend		
	SILVER	**Decreasing**	[AG] = -0.008*YEAR + 16.06	-59%
	ZINC	**Decreasing**	[ZN] = -2.08*YEAR + 4281	-23%
	DDT, TOTAL	**Decreasing**	[DDT] = -0.283*YEAR + 576	-36%
	PAH, TOTAL	**Increasing**	[PAH] = 18.8*YEAR - 37317	218%
	PCB, TOTAL	No significant trend		
NHHS	ALUMINUM	**Increasing**	[AL] = 13.2*YEAR - 26226	172%
	CADMIUM	No significant trend		
	CHROMIUM	**Decreasing**	[CR] = -0.035*YEAR + 70.9	-46%
	COPPER	**Decreasing**	[CU] = -0.072*YEAR +150.7	-15%
	IRON	No significant trend		
	LEAD	No significant trend		
	MERCURY	No significant trend		
	NICKEL	**Decreasing**	[NI] = -0.026*YEAR + 54.2	-16%
	SILVER	No significant trend		
	ZINC	**Decreasing**	[ZN] = -1.482*YEAR + 3079	-18%
	DDT, TOTAL	No significant trend		
	PAH, TOTAL	No significant trend		
	PCB, TOTAL	**Decreasing**	[PCB] = -0.626*YEAR + 1264	-57%

Source: NH Gulfwatch Program

1. Trends for silver and mercury are for 2003-2008.

EXHIBIT 50 (AR K.27)

Figure TOX3-1: Total PAH concentrations in mussel tissue at station MECC in Portsmouth Harbor

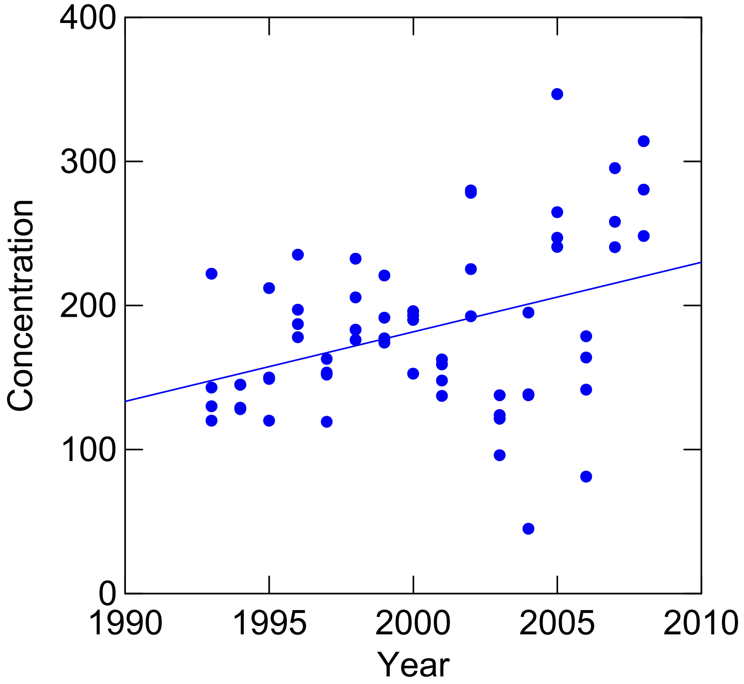

Figure TOX3-2: Total PAH concentrations in mussel tissue at station NHDP at Dover Point

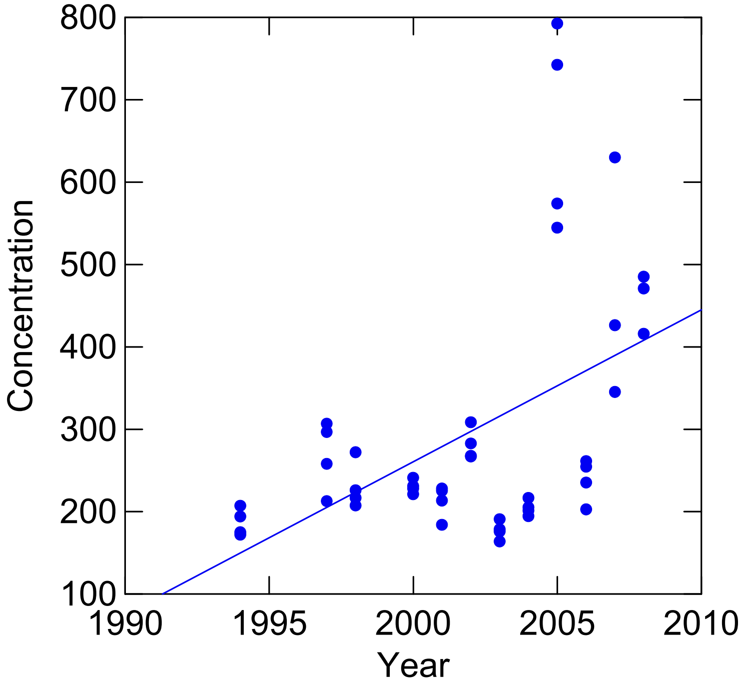

EXHIBIT 50 (AR K.27)

Figure TOX3-3: Total PCB concentrations in mussel tissue at station MECC in Portsmouth Harbor

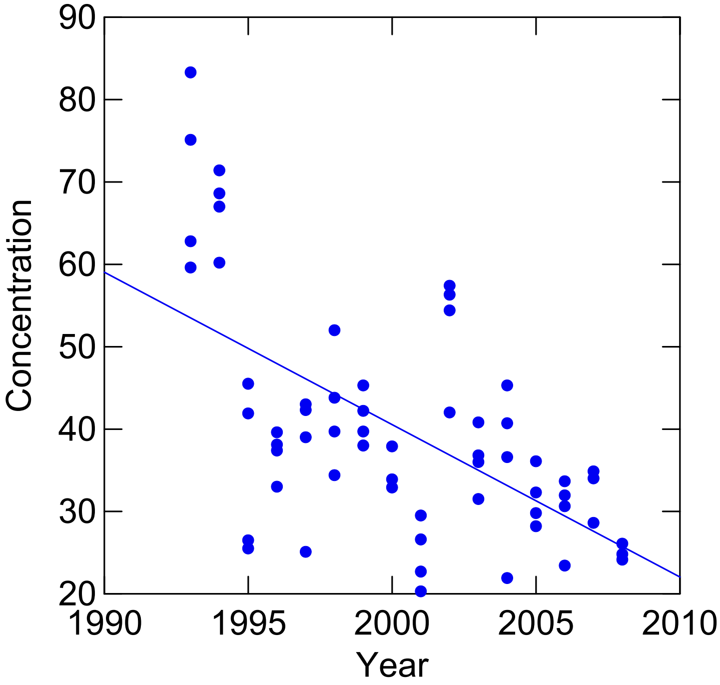

Figure TOX3-4: Total PCB concentrations in mussel tissue at station NHHS in Hampton Harbor

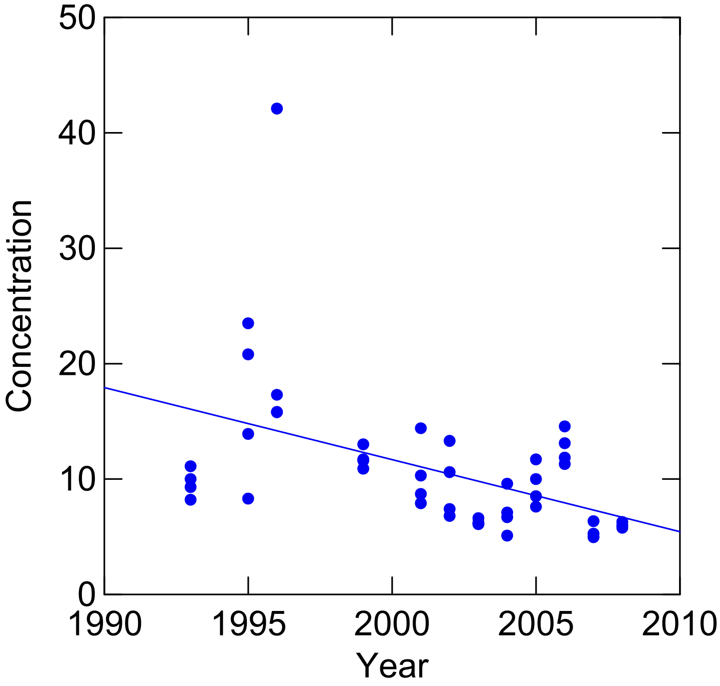

EXHIBIT 50 (AR K.27)

Figure TOX3-5: Total DDT concentrations in mussel tissue at station MECC in Portsmouth Harbor

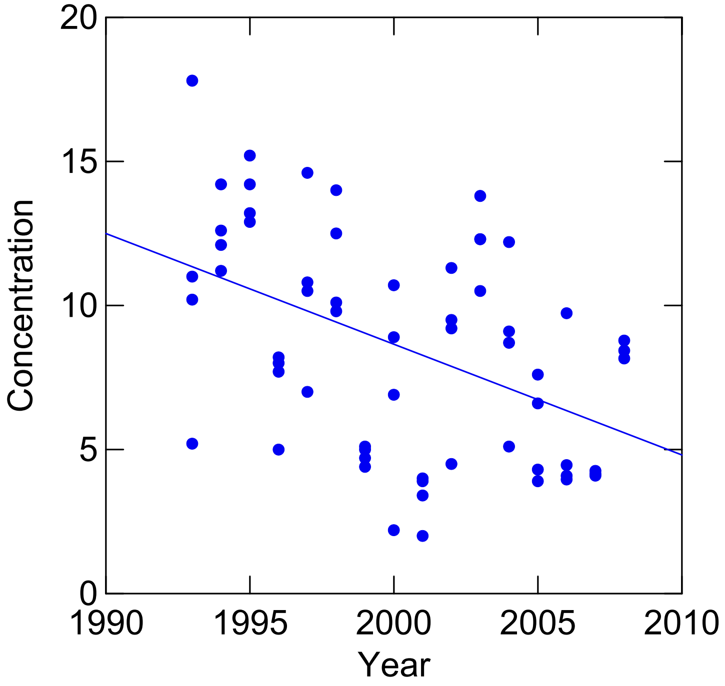

Figure TOX3-6: Total DDT concentrations in mussel tissue at station NHDP at Dover Point

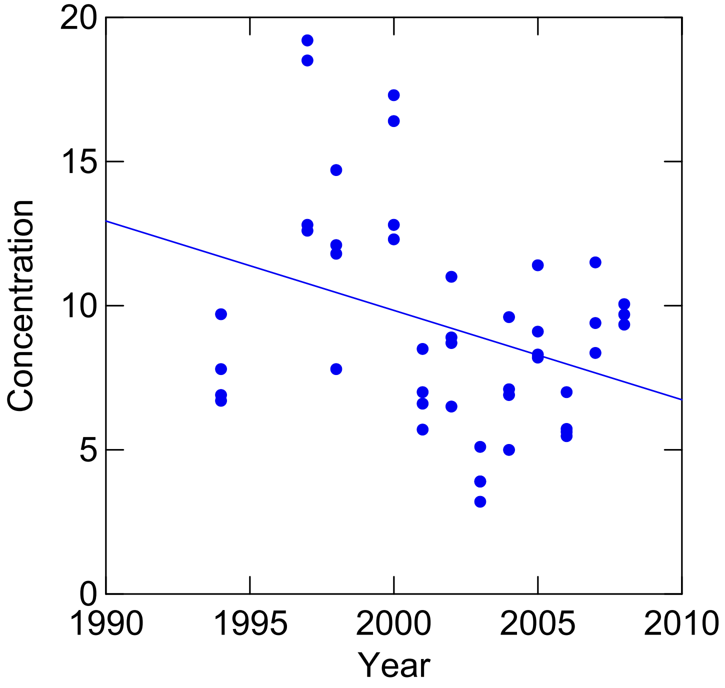

EXHIBIT 50 (AR K.27)

Figure TOX3-7: Lead concentrations in mussel tissue at station MECC in Portsmouth Harbor

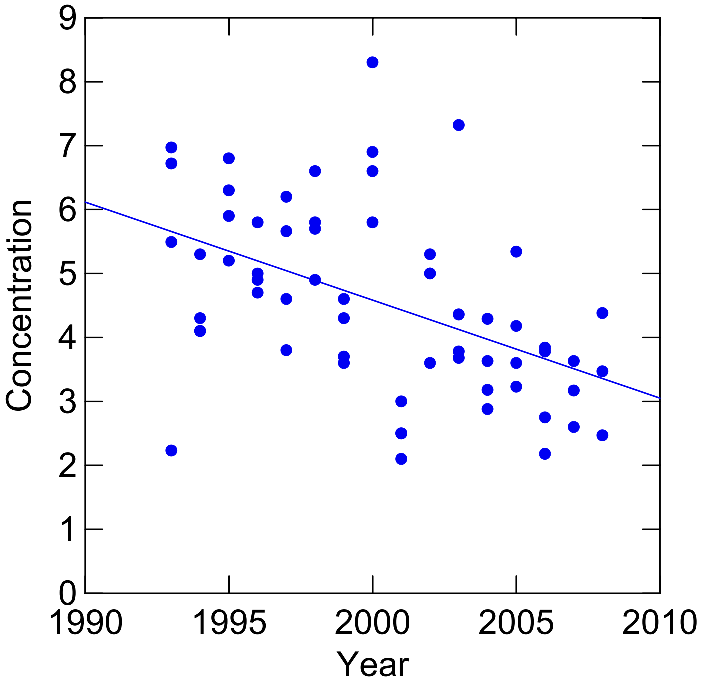

Figure TOX3-8: Lead concentrations in mussel tissue at station NHDP at Dover Point

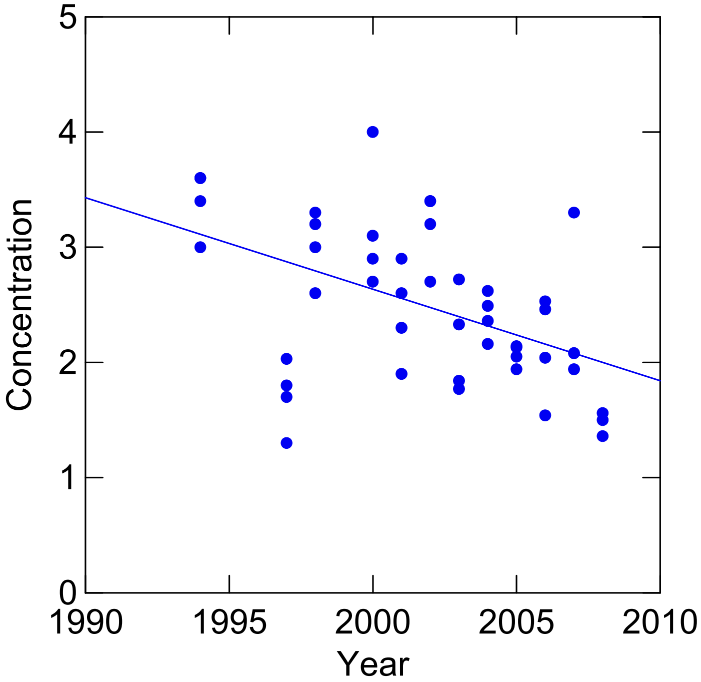

EXHIBIT 50 (AR K.27)

Indicator: TOX5. Sediment Contaminant Concentrations Relative to NOAA Guidelines

PREP Goal: The goal is for zero percent of estuarine area to have sediments containing one or more compounds higher than Probable Effect Concentrations (PEC) or 5 times Threshold Effect Concentrations (TEC) as defined in the DES Sediment Policy.

Why This Is Important: Toxic contaminants accumulate in estuarine sediments, and therefore organisms living in the sediments are especially at risk of being impacted by these pollutants. Furthermore, toxic contaminant concentrations in sediments can provide information on both historical and current pollution in the estuaries.

Monitoring Question: Do sediments in the estuaries contain toxic contaminants that might harm benthic organisms?

Answer: Yes. Twenty-four percent of the sediments in the estuary are above screening values that are used to identify potential impacts to benthic organisms.

Explanation

The percent of estuarine sediments with toxic contaminant concentrations above screening values from 2002-2005 is shown in Table TOX5-1 and Figure TOX5-1. Overall, elevated levels of contamination occur in only 24 percent of the sediments, mainly in the tidal rivers. Therefore, the PREP goal of having zero percent of the estuary affected by sediment contamination was not attained.

The sites with the highest chemical concentrations relative to screening values (a “hazard index”) are in the Cocheco River, at the most upstream sites in the Lamprey River, and the Piscataqua River. The chemicals that have concentrations greater than PECs or five times TECs are: chromium, copper, mercury, lead, PAHs, PCBs, DDT (and its metabolites), lindane, and dieldrin. Of these compounds, PAHs are the most common contaminant. PAH compounds were above screening values at 14 of the 75 stations monitored in 2002-2005. The distribution of PAH compounds at these sites shows mostly higher molecular weight compounds. Fluoranthene, pyrene, and benzo(b)fluoranthene are the most common PAH compounds. The higher molecular weight compounds indicate that the source of the PAHs is not recent fuel spills, but rather fuel combustion or historic contamination.

The locations of contamination varied with the compound; however, in general, the degree of sediment contamination was greater in the tidal rivers than in the open bays and harbors (Figure TOX5-2). The highest concentrations of PAHs were found in the Cocheco River, Lamprey River, Upper Piscataqua River, and Spruce Creek. Lead concentrations only exceeded screening values in North Mill Pond. PCBs and dieldrin concentrations were above screening values at one site in the Lower Piscataqua River. The only contaminant exceeding screening values in Hampton-Seabrook Harbor was lindane.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan with the following exceptions:

1. The Monitoring Plan indicates that non-detect results will not be compared to screening values to avoid “false positives”. In fact, the non-detected results were included in the analysis but were assigned a value of zero.

EXHIBIT 50 (AR K.27)

Table TOX5-1: Percent of estuarine sediments with and without toxic contaminants above screening values

Number of Contaminants Above Screening Values	Percent of Estuarine Area	Error (+/-)
0	65.86%	10.26%
1	8.46%	6.02%
Greater than 1	15.64%	7.86%
Missing Data	10.03%	6.50%

Figure TOX5-1: Percent of estuarine sediments with and without toxic contaminants above screening values

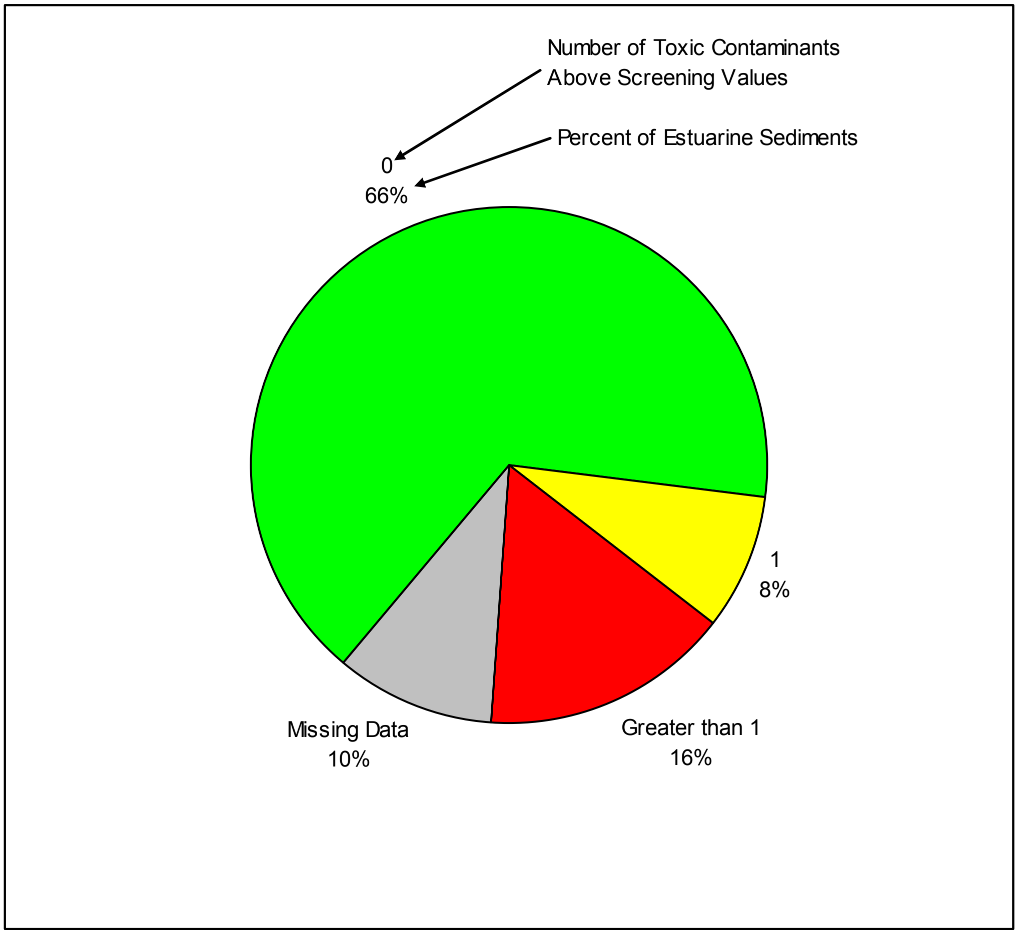

EXHIBIT 50 (AR K.27)

Figure TOX5-2: Locations of toxic contaminants in sediments

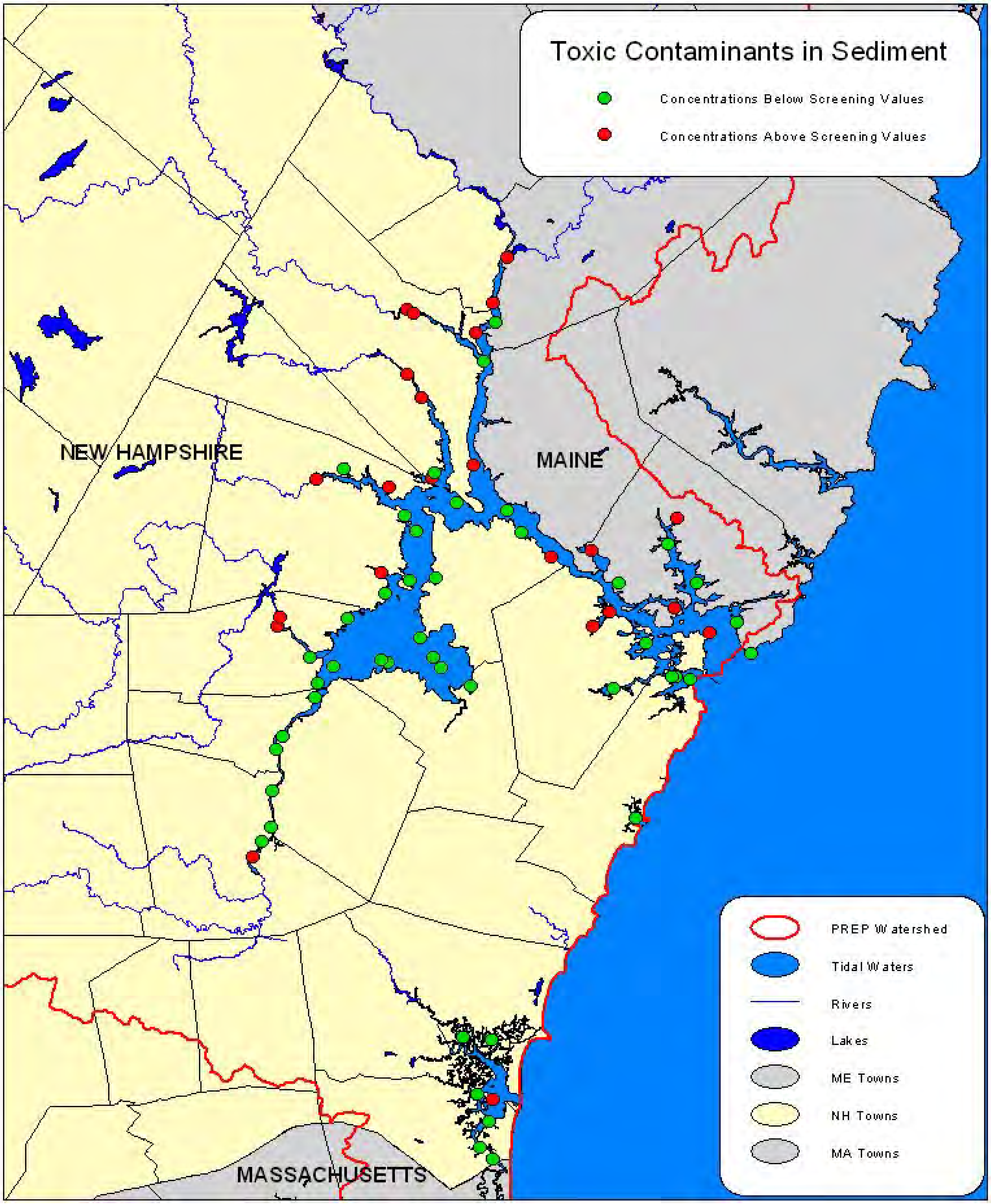

EXHIBIT 50 (AR K.27)

Indicator: TOX6. Trends in Sediment Contaminant Concentrations

PREP Goal: The goal is to have no increasing trends for any toxic contaminants.

Why This Is Important: Toxic contaminants accumulate in estuarine sediments, and therefore organisms living in the sediments are especially at risk of being impacted by these pollutants. Furthermore, toxic contaminant concentrations in sediments can provide information on both historical and current pollution in the estuaries.

Monitoring Question: Have the concentrations of toxic contaminants in sediment significantly changed over time?

Answer: No. The percent of the estuary with sediment contamination did not change significantly between surveys in 2000-2001 and 2002-2005.

Explanation
Indicator TOX5 shows the most recent data on toxic contaminant concentrations in estuarine sediments from the 2002-2005 survey. The concentrations of toxic contaminants in estuarine sediments had been surveyed once before in 2000-2001. The results from the 2000-2001 survey are compared to the results from the 2002-2005 survey in Figure TOX6-1. The percent of the estuary with sediment concentrations above screening values increased from 12% in 2000-2001 to 24% in 2002-2005. However, the uncertainty in the percentages is 8-10%, so this difference is not statistically significant. Therefore, the PREP goal of having no significantly increasing trends is being met.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan with the following exceptions:
1. The Monitoring Plan indicates that non-detect results will not be compared to screening values to avoid “false positives”. In fact, the non-detected results were included in the analysis but were assigned a value of zero.

EXHIBIT 50 (AR K.27)

Figure TOX6-1: Percent of estuarine sediments with and without toxic contaminants above screening values in 2000-2001 and 2002-2005

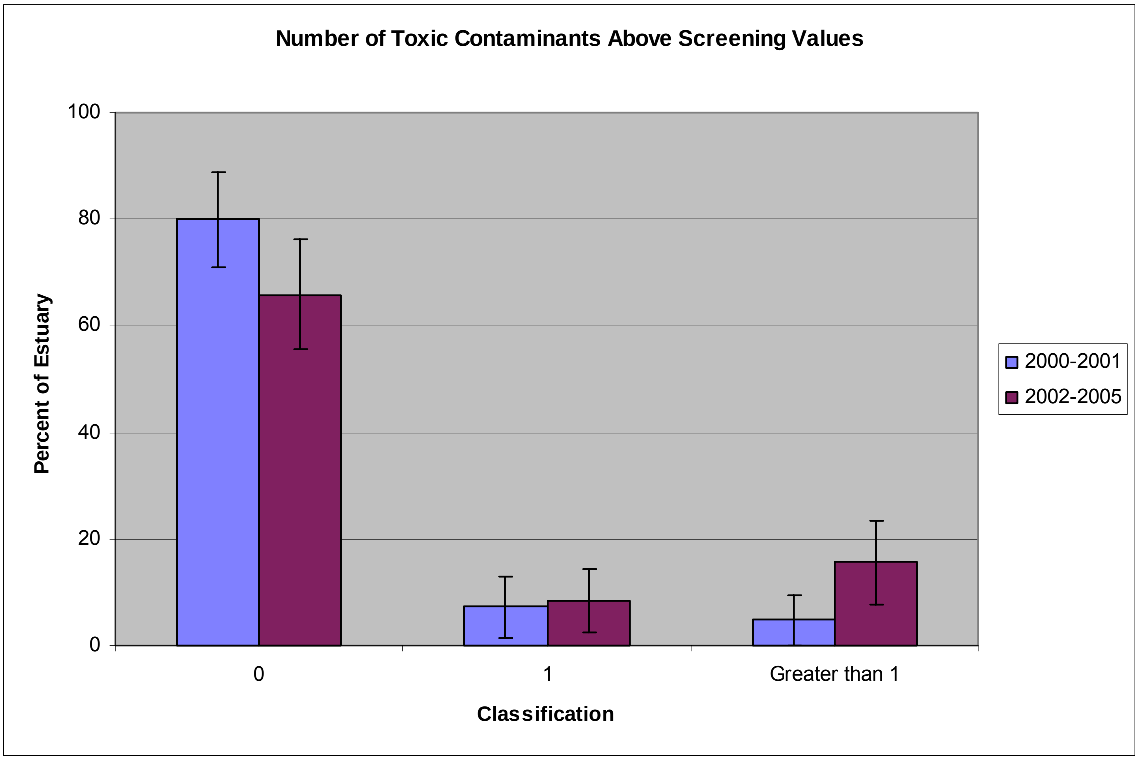

EXHIBIT 50 (AR K.27)

Indicator: TOX7. Benthic Community Impacts due to Sediment Contamination

PREP Goal: The goal is for 0% of estuarine area to have apparent impacts to the benthic community due to sediment contamination.

Why This Is Important: Toxic contaminants accumulate in estuarine sediments, and therefore organisms living in the sediments are especially at risk of being impacted by these pollutants. Furthermore, toxic contaminant concentrations in sediments can provide information on both historical and current pollution in the estuaries.

Monitoring Question: Do sediments in the estuaries contain toxic contaminants that might harm benthic organisms?

Answer: Yes, but rarely. Organisms living in the sediments might be adversely affected by toxic contaminants in only 2.8 percent of the estuaries.

Explanation
Benthic community conditions relative to toxic contaminants in 2002-2005 are shown in Table TOX7-1 and Figures TOX7-1 and TOX7-2. Only four locations stations comprising 2.8% of the estuary were classified as “poor”. The uncertainty in this percentage is 3.6% so the result is not statistically different from zero and the PREP goal is being met. The stations with poor conditions were located in the Squamscott River, Lamprey River, Spruce Creek, and Hampton-Seabrook Harbor. Sediment contamination with PAHs was the cause for the impairments in the Lamprey River, Squamscott River, and Spruce Creek. The impairment in Hampton-Seabrook Harbor was due to lindane (a pesticide).

The benthic community condition had been surveyed once before in 2000-2001. The results from the 2000-2001 survey are compared to the results from the 2002-2005 survey in Figure TOX7-3. The percent of the estuary in fair or poor condition for the benthic community increased from 0.3% in 2000-2001 to 2.8% in 2002-2005. However, the uncertainty in the percentages is 1.2-3.6%, so this difference is not statistically significant.

The absence of apparent effects on the benthic infauna community does not necessarily mean that there are no effects on all aquatic species. Benthic infauna are just one of many possible aquatic species groups. For bioaccumulative compounds, such as mercury and PCBs, species in higher trophic levels could be at risk.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

EXHIBIT 50 (AR K.27)

Table TOX7-1: Percent of estuarine sediments for different benthic community condition categories

Benthic Community Condition Relative to Toxic Contaminants	Percent of Estuarine Area	Error (+/-)
Good	78.70%	8.86%
Fair	8.48%	6.03%
Poor	2.78%	3.56%
Missing Data	10.03%	6.50%

Figure TOX7-1: Percent of estuarine sediments for different benthic community condition categories

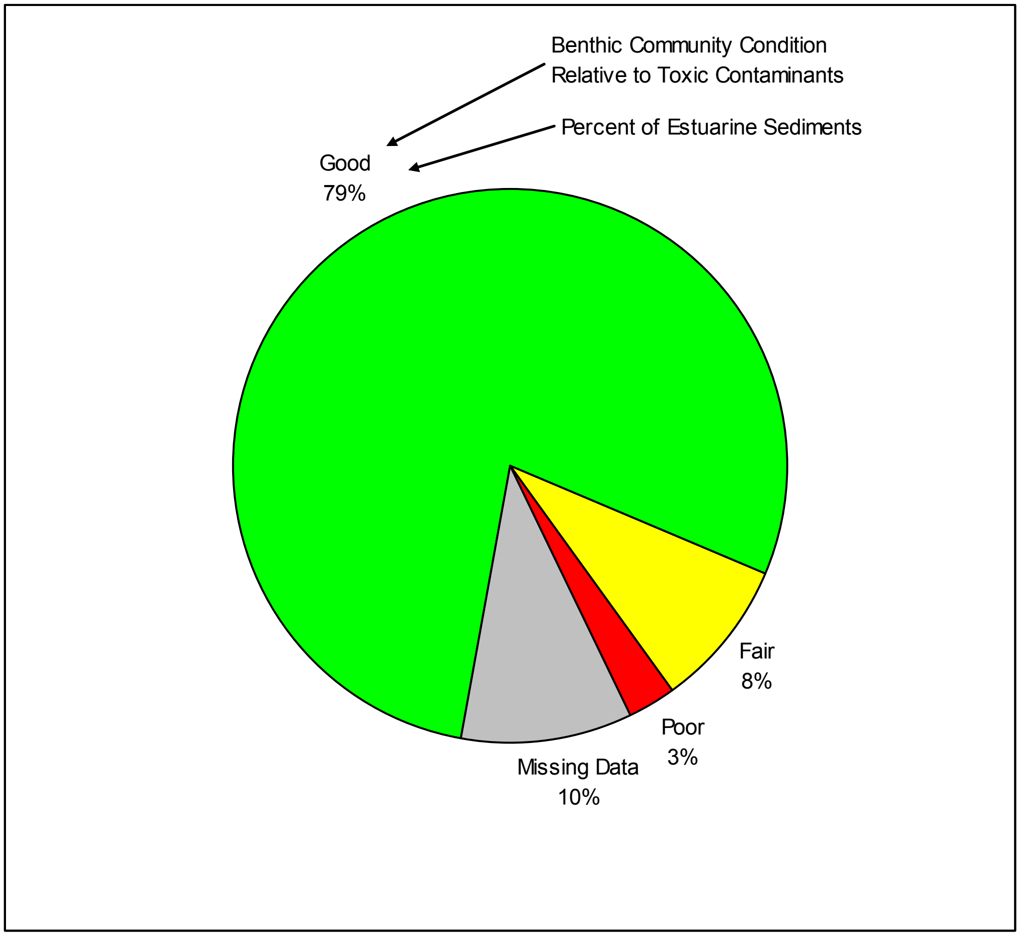

EXHIBIT 50 (AR K.27)

Figure TOX7-2: Locations with different benthic community condition categories

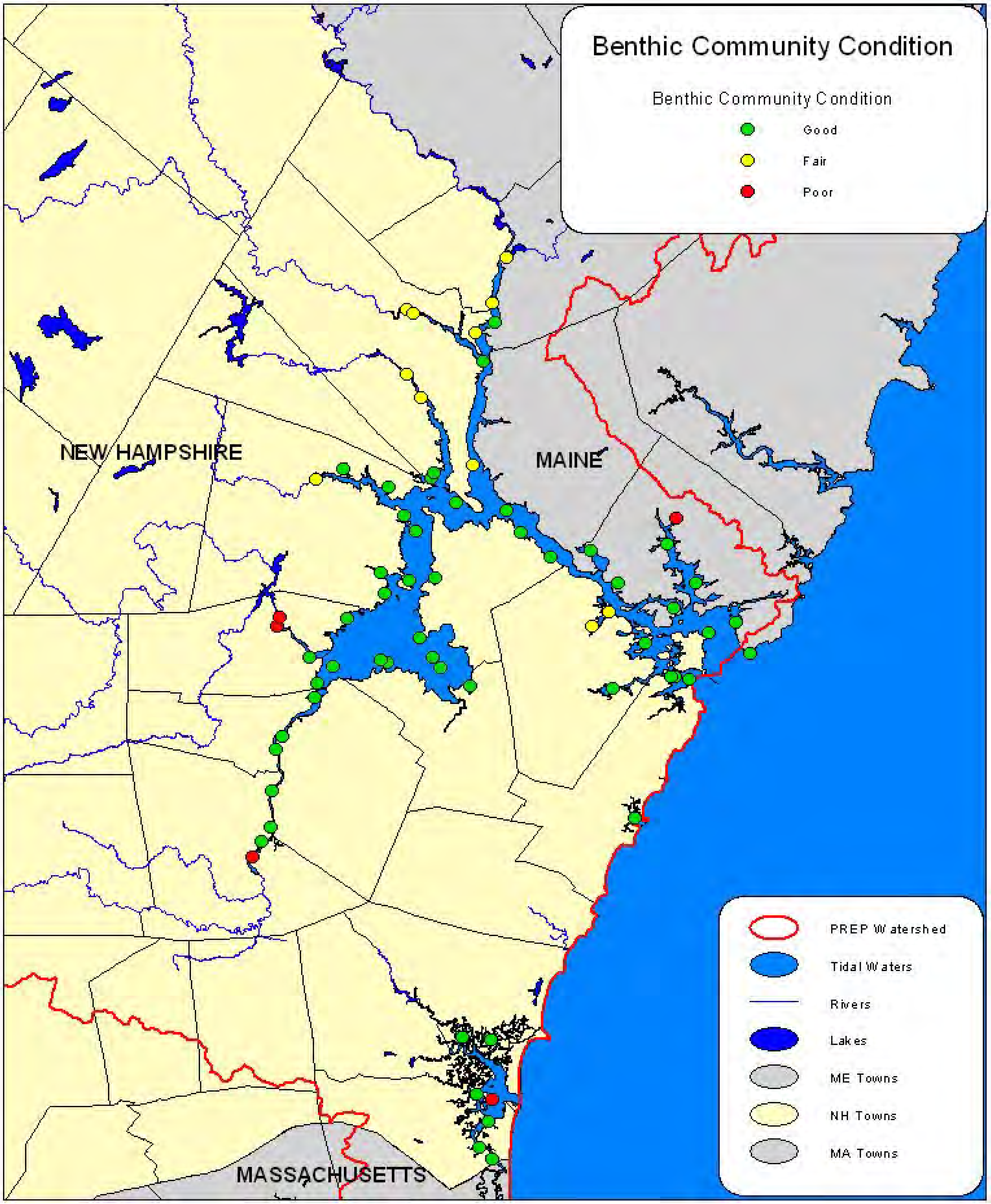

EXHIBIT 50 (AR K.27)

Figure TOX7-3: Percent of estuarine sediments for different benthic community condition categories in 2000-2001 and 2002-2005

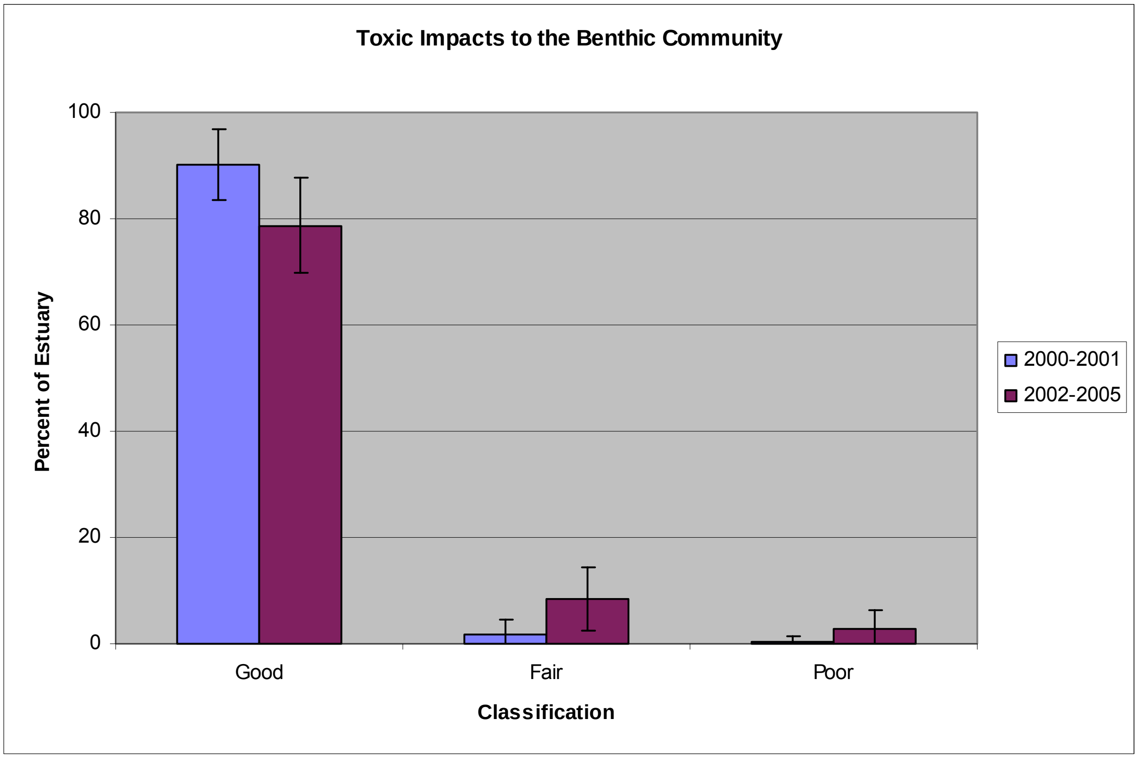

EXHIBIT 50 (AR K.27)

Indicator: NUT1. Annual Load of Nitrogen to the Great Bay Estuary

PREP Goal: The goal is for annual loads of total nitrogen to the Great Bay Estuary to be less than or equal to the estimated loading from 2002-2004 (1,097 tons/yr).

Why This Is Important: Excessive nitrogen can cause algae blooms, eliminate eelgrass beds, and change species composition of important habitats. Furthermore, decomposition of algae can deplete coastal waters of dissolved oxygen. Both of these effects will impair estuarine functions. In 2009, the New Hampshire Department of Environmental Services developed numeric criteria for nitrogen for the Great Bay Estuary.

Monitoring Question: Has the total nitrogen load to the Great Bay Estuary significantly changed over time?

Answer: Yes. The total nitrogen load to the Great Bay Estuary increased by 42 percent from 1,097 tons per year in 2002-2004 to 1,558 tons per year in 2006-2008.

Explanation
The Great Bay Estuary watershed, the major tributaries, and wastewater treatment facilities (WWTFs) are shown on Figure NUT1-1.

The total nitrogen loads from the 18 WWTFs in the Great Bay Estuary watershed are shown in Table NUT1-1 and Figure NUT1-2. The WWTF with the largest nitrogen load was Rochester followed by Portsmouth and Dover. These three WWTFs account for 69% of the nitrogen discharged by all WWTFs in the watershed. The nitrogen loads from WWTFs were measured monthly by PREP in 2008 (NHEP, 2008).

Eight WWTFs discharge to freshwater rivers upstream of the estuary. Some of the nitrogen discharged by these WWTFs will be lost through denitrification and other processes in the river before it reaches the estuary (Van Breeman et al., 2002). PREP estimated these losses using the approach from the USGS SPARROW model which is a first order exponential model based on the travel time in the river (Moore et al., 2004). Travel time was calculated using the river distance between the outfall and the estuary and the mean velocity from the New England SPARROW reaches. The attenuation coefficient depends on the size of the river, with the greatest losses occurring in small streams (Smith et al., 1997; Moore et al., 2004). The mean stream flows in all the river reaches with discharges were greater than 100 cfs and greater than 200 cfs in all but two of the reaches. Therefore, the attenuation coefficients for medium streams (200-1000 cfs) from the National and Chesapeake SPARROW models were the most appropriate (average coefficient: 0.343 days^{-1}) (Smith et al., 1997; Preston and Brakebill, 1999). The first order exponential equation predicted attenuation losses of nitrogen from 1% to 38% for travel times 0.03 to 1.37 days. For the eight WWTFs with upstream discharges these attenuation losses were subtracted from the WWTF loads to estimate the delivered load to the estuary (Table NUT1-1). No attenuation was assumed for WWTFs that discharge directly to estuarine waters.

The total nitrogen loads from the 8 major tributaries are shown in Table NUT1-2 and Figure NUT1-3. The Cocheco River produced the highest annual load. The loads from the Salmon Falls and Lamprey rivers were slightly lower. The remaining five rivers delivered considerably less nitrogen. In Table NUT1-2, the LOADEST model statistics for each river are shown. Overall, the models fit the data satisfactorily. The R-squared statistic for all the models was greater than 0.9.

The tributary nitrogen loads were partitioned into WWTF and non-point source components (Table NUT1-3, Figure NUT1-3). The WWTF component was calculated using the attenuation factors described earlier. The non-point source load was calculated by difference between the measured total load at the watershed outlet and the delivered load from upstream WWTFs. In order to compare the different size rivers, the WWTF and non-point source loads were converted to yields by dividing by the watershed drainage area (Figure NUT1-4). Only the Cocheco River had a significant WWTF nitrogen yield, which amounted to 60% of the total load. The highest non-point source yields occurred in the Exeter and Winnicut Rivers (1.5 tons/year/sq.mi.). Low non-point source yields were observed for the Cocheco and Great Works Rivers. While the low yield is credible for the Great Works River because of sparse development, the low yield for the Cocheco River is questionable. Even with attenuation factors applied, point sources account for the majority of the total nitrogen load from the Cocheco River watershed. A small uncertainty in the attenuation calculation for this watershed will have a big effect on the estimated non-point source yield. The other watersheds are less sensitive to the attenuation estimates because the upstream WWTFs account for less than 10% of the total load at the outlet station.

In Figure NUT1-5, the non-point source yield has been plotted against the percent of land in each watershed that was classified as developed or agricultural in 2006 (NOAA C-CAP imagery). The non-point source yield from the Cocheco River was excluded from this regression for the reasons discussed in the previous paragraph. The statistically significant relationship was used to estimate the non-point source loads from the drainage areas around the Great Bay, Upper Piscataqua River, and Lower Piscataqua River. The predicted values for these drainage areas are shown on the figure.

The groundwater nitrogen load to the Great Bay and Little Bay was determined to be 19.3 tons/year in 2001 by Ballestero et al., (2004). Ballestero et al. (2004b) found that the groundwater that was monitored in 2001 was 23 years old on average and, therefore, representative of pollution sources and conditions in 1978. The change in population density in the Great Bay drainage area was used as a surrogate for changes in groundwater nitrogen sources over time. In 1978, there were 0.645 people per acre in the Great Bay drainage area. The population density in this area grew 10.7% to 0.714 people per acre by 1984, which corresponds to the mean age of groundwater expected to have discharged to the bay in 2007. Therefore, as a first order approximation, the groundwater nitrogen load to Great Bay and Little Bay in 2007 was assumed to be 10.7% higher than the measured load from 2001. The population density values were calculated using town-level population densities in 1970, 1980, and 1990 applied to the fraction of each town in the Great Bay drainage area. The values for 1978 and 1984 were estimated using linear interpolation between the decadal values.

The groundwater load for the Upper Piscataqua drainage area was estimated from the Great Bay groundwater loads using area transposition. The percent of land that is developed or used for agriculture in the Upper Piscataqua drainage area (34%) is similar to the Great Bay drainage area (31%). The population densities for these two areas in 2000 were also similar (0.74 and 0.84 people/acre, respectively). Therefore, it was assumed that the groundwater load per square mile of the Upper Piscataqua drainage area would be similar to the measured value for the Great Bay from Ballestero et al. (2004). The ratio of the land areas in the Upper Piscataqua drainage area and the Great Bay drainage area (46%) was used to convert the groundwater loads for the Great Bay to the Upper Piscataqua drainage area.

Nitrogen loading from atmospheric deposition was not changed from the estimate in the 2006 report. There were no apparent trends for inorganic nitrogen deposition from the National Atmospheric Deposition Program stations near Great Bay. Therefore, the atmospheric deposition rate of 6.12 kg/year/ha for the Great Bay Estuary from Ollinger et al. (1993) was still considered valid.

The results from all the loading estimates are combined in Table NUT1-4. The total nitrogen loads to the Great Bay and the Upper Piscataqua River Estuary were 739 and 819 tons per year, respectively (1,558 tons per year combined). WWTF point sources contributed 19% of the total load to the Great Bay (Figure NUT1-6), while these sources were responsible for 42% of the load to the Upper Piscataqua River Estuary (Figure NUT1-7). For both systems combined, WWTFs were responsible for 31% of the total load (Figure NUT1-8). The largest source of nitrogen was non-point source runoff from the major tributaries and surrounding land area (65%). Finally, direct atmospheric deposition and groundwater were only responsible for 4% of the total load.

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Fear et al. (2007) also found groundwater inputs to be a small component of nitrogen loads in the Neuse River Estuary. Following the methodology in the PREP Monitoring Plan, one-half of the nitrogen loads from WWTFs discharging to the Lower Piscataqua River was assumed to enter the Great Bay and Upper Piscataqua River estuaries.

The total nitrogen load to the Great Bay and Upper Piscataqua River estuaries in 2002-2004 was estimated to be 1,097 tons per year (NHEP, 2006). Therefore, the nitrogen loads to the estuary have increased by 42% to 1,558 tons per year by 2006-2008. The majority of this increase can be attributed to increased non-point source runoff. The nitrogen load from the tributaries and drainage areas increased by 50% from 678 tons per year to 1,014 tons per year between the two periods. In 2002-2004, the average flow from the eight major tributaries was 1,231 cfs. Due to increased rainfall, the runoff from these eight tributaries was 2,187 cfs in 2006-2008. This increase in flows resulted in a higher average non-point source yield for nitrogen in 2006-2008 (1.12 tons/year/sq.mi.) compared to 2002-2004 (0.78 tons/year/sq.mi.). This observation suggests that non-point sources of nitrogen are limited by the amount of runoff available to carry the nitrogen to the rivers and estuaries, not the amount of nitrogen in the watersheds. In addition to the tributaries, flows also increased for the WWTFs in 2006-2008. The total flow from the 18 WWTFs increased by 30% from 17.6 MGD in 2002 to 22.9 MGD in 2008.

Nitrogen loads from non-point source runoff to the Lower Piscataqua River (Figure NUT1-1) were not included in the loading estimates provided above. Through stormwater runoff, this highly developed area of the watershed likely yields higher per acre nutrient loads to the estuary system than less developed areas of the watershed. For incoming tides nitrogen loads from direct discharge to this portion of the river could be carried into to the upper portions of the estuary. Using the relationship in Figure NUT1-5, it is possible to estimate the non-point source load from this area to be 67 tons per year, which would be 4% of the total load. This value is included to provide an order of magnitude estimate for non-point source nitrogen loads from the Lower Piscataqua drainage area. However, the uncertainty in this value is too great to include in the total loading tables and graphs. Additional research is needed to refine this estimate. Moreover, the import of nitrogen to the Lower Piscataqua River from the Gulf of Maine on incoming tides has not been considered.

It is important to note that the atmospheric deposition term only reflects deposition to the estuary surface. Estuary loading of nitrogen deposited to the land surface has been captured by the tributary and direct nonpoint source categories.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan with the following exceptions:

1. The data sources for point source loads from WWTFs were total nitrogen concentration measurements from NHEP (2008) and municipal NPDES permit monitoring. It was not necessary to use datasets containing total dissolved nitrogen and accompanying assumptions. For the WWTFs without nitrogen data, the average nitrogen concentration from NHEP (2008) was used.
2. Tributary loads from the Great Works River were based on measurements from only two years (2007-2008) of data because the monitoring began at station 02-GWR in 2007.
3. Flows at station 02-WNC were taken from a USGS stream gage installed at the station rather than using area transposition from gage 01073000 as planned.
4. In the Monitoring Plan, the non-point source load from the Great Bay and Upper Piscataqua drainage areas was to be calculated from the average non-point source nitrogen yield from the four tributaries which do not have WWTFs upstream of the monitoring station (09-EXT, 05-BLM, 05-OYS, and 02-WNC). That method was used for the 2006 nitrogen loading estimates. Instead, for this report, a regression was developed between the non-point source yield and the percent of developed and agricultural lands in the watersheds. The method was changed because the drainage areas around the Great Bay and Upper Piscataqua River were more developed than the rest of the watershed. Average non-point source yields would likely underestimate non-point source yields from these areas.

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5. The atmospheric deposition rate was assumed to be 6.12 kg/ha/yr, which is the same value used for the 2002-2004 nitrogen load estimate. The ClimCalc model from UNH has not been updated. There were no apparent trends in nitrogen deposition from NADP trend monitoring stations in New Hampshire, Southern Maine, and Northern Massachusetts.
6. Groundwater loads were assumed to have increased from 2001 at the same rate as population growth. The mean age of groundwater discharges was assumed to be 23 years (Ballestero et al. 2004b). The groundwater load for the Upper Piscataqua drainage area was estimated based on the ratio of the drainage areas for Great Bay and the Upper Piscataqua River. Groundwater loads to the Upper Piscataqua River were not included in the 2006 nitrogen load estimate. However, this source in the current estimate amounts to only 9.9 tons per year, which is only 0.6% of the total load.

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Figure NUT1-1: Watershed draining to the Great Bay Estuary

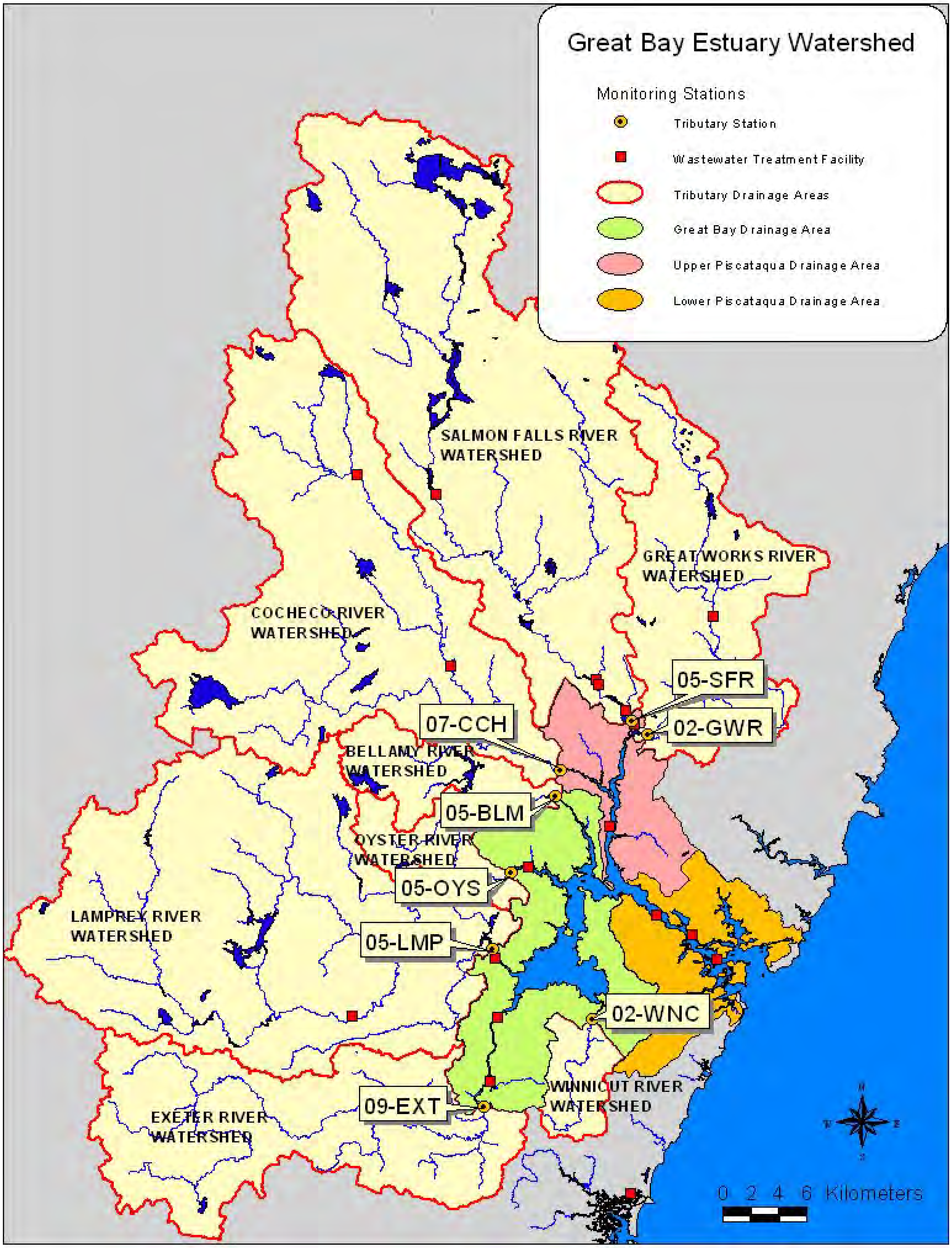

EXHIBIT 50 (AR K.27)

Table NUT1-1: Estimated total nitrogen loads from wastewater treatment facilities in 2008

WWTF	Treatment Type	Discharge Location	Ave. [TN] (mg N/L)	Data Source[1]	Annual Ave. Flow (MGD)[2]	TN Load in 2008 (lb/day)	TN Load in 2008 (tons/yr)	Atten-uation Loss[3] (%)	Delivered Load (tons/yr)
Durham	Secondary	Oyster River (tidal)	7.63	NHEP (2008)	1.080	68.65	12.53	0.00%	12.53
Exeter	Secondary	Exeter River (tidal)	14.43	NHEP (2008)	1.983	238.40	43.51	0.00%	43.51
Newfields	Secondary	Exeter River (tidal)	17.78	Estimated	0.098	14.45	2.64	0.00%	2.64
Newmarket	Secondary	Lamprey River (tidal)	30.10	NHEP (2008)	0.689	172.61	31.50	0.00%	31.50
Dover	Secondary	Upper Piscataqua River (tidal)	22.33	NHEP (2008)	3.152	586.21	106.98	0.00%	106.98
South Berwick	Secondary	Salmon Falls River (tidal)	9.95	Municipality	0.392	32.48	5.93	0.00%	5.93
Kittery	Secondary	Lower Piscataqua River	15.99	NHEP (2008)	1.262	168.06	30.67	0.00%	30.67
Newington	Secondary	Lower Piscataqua River	17.78	Estimated	0.152	22.51	4.11	0.00%	4.11
Portsmouth	Advanced Primary	Lower Piscataqua River	13.34	Municipality	5.982	664.70	121.31	0.00%	121.31
Pease ITP	Secondary	Lower Piscataqua River	8.74	Municipality	0.677	49.30	9.00	0.00%	9.00
Farmington	Secondary	Cocheco River	12.97	Municipality	0.407	43.96	8.02	37.60%	5.01
Rochester	Advanced	Cocheco River	30.11	NHEP (2008)	4.177	1,047.51	191.17	17.32%	158.05
Epping	Secondary	Lamprey River	17.78	Estimated	0.307	45.49	8.30	29.75%	5.83
Berwick	Advanced	Salmon Falls River	16.68	NHEP (2008)	0.384	53.40	9.75	3.87%	9.37
Milton	Secondary	Salmon Falls River	17.78	Estimated	0.088	13.01	2.37	28.80%	1.69
Rollinsford	Secondary	Salmon Falls River	17.78	Estimated	0.116	17.24	3.15	0.95%	3.12
Somersworth	Secondary	Salmon Falls River	4.95	NHEP (2008)	1.818	74.99	13.69	3.76%	13.17
North Berwick	Secondary	Great Works River	17.78	Estimated	0.134	19.88	3.63	23.63%	2.77
Total					22.898	3,332.85	608.25		567.18

1. For "NHEP (2008)", the concentration is the average of 10 grab samples collected during 2008. For "Municipality", the concentration is the average of samples collected by the municipality during 2008. For "Estimated", no data were available for this WWTF. The average TN concentration from NHEP (2008) was assumed.

2. The flows in this table are annual averages for 2008. The monthly average flows from NPDES discharge monitoring reports were averaged.

3. Attenuation loss estimated using the travel time for water between the WWTF outfall and the estuary and a first order loss coefficient of 0.343 days^{-1}.

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Table NUT1-2: Estimated total nitrogen loads from major tributaries in 2006-2008

Tributary	Station	TN Load (tons/yr)	Standard Error (tons/yr)	R^2	PPCC	Model
Exeter River	09-EXT	166.99	20.44	0.907	0.908	1
Cocheco River	07-CCH	271.38	18.07	0.925	0.980	9
Lamprey River	05-LMP	221.01	18.98	0.976	0.983	9
Salmon Falls River	05-SFR	264.44	25.55	0.950	0.954	9
Bellamy River	05-BLM	33.26	3.10	0.937	0.932	4
Oyster River	05-OYS	24.68	2.21	0.954	0.940	6
Winnicut River	02-WNC	21.74	1.87	0.972	0.980	9
Great Works River	02-GWR	66.31	7.79	0.949	0.989	6
Total		1069.80				

1. TN loads estimated using USGS software "LOADEST" with water quality data from the PREP Tidal Tributary Monitoring Program and streamflow data from USGS.

2. R^2 is a measure of the quality of the model (0=worst, 1=best)

3. PPCC is a measure of the normality of the residuals (0=worst, 1=best)

4. The model number refers to the specific model chosen. The models are defined in the LOADEST users manual (Runkel et al, 2004).

Table NUT1-3: WWTF and non-point source nitrogen yields from Great Bay watersheds 2006-2008

Tributary	Station	TN Load[1] (tons/yr)	Upstream WWTF TN Load[2,3] (tons/yr)	NPS TN Load (tons/yr)	Area (mi^2)	WWTF TN Yield (tons/yr/mi^2)	NPS TN Yield (tons/yr/mi^2)
Exeter River	09-EXT	166.99	0.00	166.99	106.92	0.00	1.56
Cocheco River	07-CCH	271.38	163.06	108.32	175.23	0.93	0.62
Lamprey River	05-LMP	221.01	5.83	215.18	211.56	0.03	1.02
Salmon Falls River	05-SFR	264.44	27.35	237.10	235.00	0.12	1.01
Bellamy River	05-BLM	33.26	0.00	33.26	27.30	0.00	1.22
Oyster River	05-OYS	24.68	0.00	24.68	19.83	0.00	1.24
Winnicut River	02-WNC	21.74	0.00	21.74	14.24	0.00	1.53
Great Works River	02-GWR	66.31	2.77	63.54	86.70	0.03	0.73
Average						0.14	1.12

1. TN loads estimated using USGS software "LOADEST" with water quality data from the PREP Tidal Tributary Monitoring Program and streamflow data from USGS.

2. The following WWTFs are located upstream of the tributary monitoring stations. The Epping WWTF is upstream of 05-LMP on the Lamprey River. The Rochester and Farmington WWTFs are upstream of 07-CCH on the Cocheco River. The Milton, Berwick, Somersworth and Rollinsford WWTFs are upstream of 05-SFR on the Salmon Falls River. The North Berwick WWTF is upstream of 02-GWR on the Great Works River.

3. Upstream WWTF loads were reduced using an attenuation loss model to estimate the delivered load to the estuary.

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Table NUT1-4: Summary of total nitrogen loads to the Great Bay and Upper Piscataqua River estuaries

SourceType	Source	TN Load (tons/yr)	Comments
Great Bay			
Non-Point Source	Lamprey River	215.18	Note 1
Non-Point Source	Bellamy River	33.26	
Non-Point Source	Exeter River	166.99	
Non-Point Source	Oyster River	24.68	
Non-Point Source	Winnicut River	21.74	
Non-Point Source	Direct Discharge Runoff	98.39	
Non-Point Source	Groundwater Discharge	21.36	Note 3
Non-Point Source	Atmospheric Deposition	19.81	
Point Source	Durham WWTF	12.53	
Point Source	Exeter WWTF	43.51	
Point Source	Newfields WWTF	2.64	
Point Source	Newmarket WWTF	31.50	
Point Source	Epping WWTF	5.83	
Point Source	Portsmouth WWTF	30.33	Note 2
Point Source	Pease ITP	2.25	Note 2
Point Source	Kittery WWTF	7.67	Note 2
Point Source	Newington WWTF	1.03	Note 2
Subtotal Point Sources (WWTFs)		*137.28*	(18.6%)
Subtotal Non-Point Sources		*601.40*	(81.4%)
Total		*738.68*	
Upper Piscataqua River Estuary			
Non-Point Source	Cocheco River	108.32	Note 1
Non-Point Source	Salmon Falls River	237.10	Note 1
Non-Point Source	Great Works River	63.54	Note 1
Non-Point Source	Direct Discharge Runoff	44.82	
Non-Point Source	Groundwater Discharge	9.92	Note 3
Non-Point Source	Atmospheric deposition	8.11	
Point Source	Dover WWTF	106.98	
Point Source	So. Berwick WWTF	5.93	
Point Source	Rochester WWTF	158.05	
Point Source	Farmington WWTF	5.01	
Point Source	Milton WWTF	1.69	
Point Source	Berwick WWTF	9.37	
Point Source	Somersworth WWTF	13.17	
Point Source	Rollinsford WWTF	3.12	
Point Source	North Berwick WWTF	2.77	
Point Source	Portsmouth WWTF	30.33	Note 2
Point Source	Pease ITP	2.25	Note 2
Point Source	Kittery WWTF	7.67	Note 2
Point Source	Newington WWTF	1.03	Note 2
Subtotal Point Sources (WWTFs)		*347.36*	(42.4%)
Subtotal Non-Point Sources		*471.80*	(57.6%)
Total		*819.16*	
Great Bay and Upper Piscataqua River Combined			
Subtotal Point Sources (WWTFs)		*484.64*	(31.1%)
Subtotal Non-Point Sources		*1073.20*	(68.9%)
Total		*1557.84*	

1. Non-point source load from this tributary. Delivered loads from upstream WWTF were subtracted from the tributary load.

2. 50% of the nitrogen loads from WWTFs in the Lower Piscataqua River were assumed to get into the Great Bay and Upper Piscataqua River Estuaries. The amount entering each of these estuaries was assumed to be equal. Therefore, 25% of the loads from WWTFs in the Lower Piscataqua River were assumed to enter the Great Bay and 25% of the loads from WWTFs in the Lower Piscataqua River were assumed to enter the Upper Piscataqua River.

3. The estimate of nitrogen loads from groundwater to the Great Bay is based on Ballestero et al. (2004).

EXHIBIT 50 (AR K.27)

Figure NUT1-2: Estimated total nitrogen loads from wastewater treatment facilities in 2008

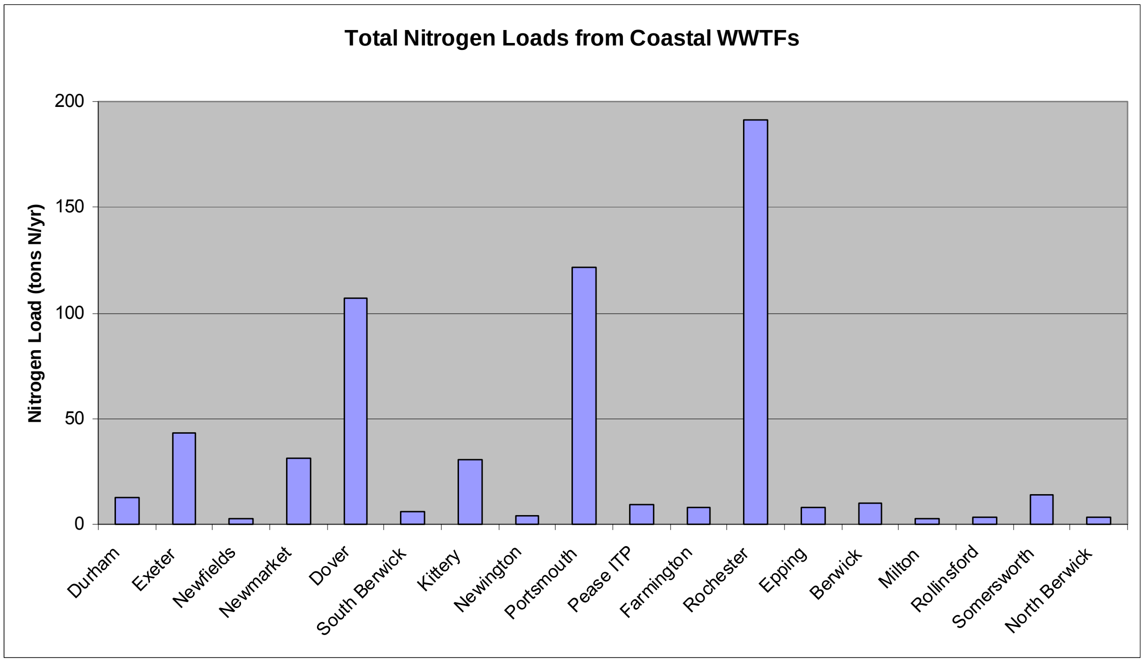

Figure NUT1-3: Estimated total nitrogen loads from major tributaries in 2006-2008

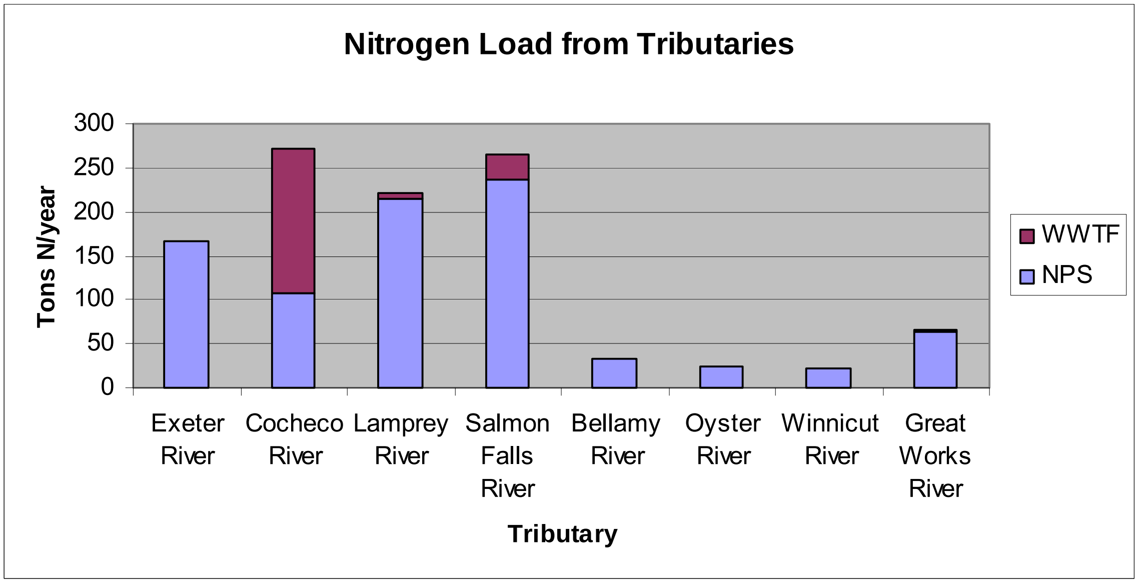

EXHIBIT 50 (AR K.27)

Figure NUT1-4: WWTF and non-point source nitrogen yields from major tributaries in 2006-2008

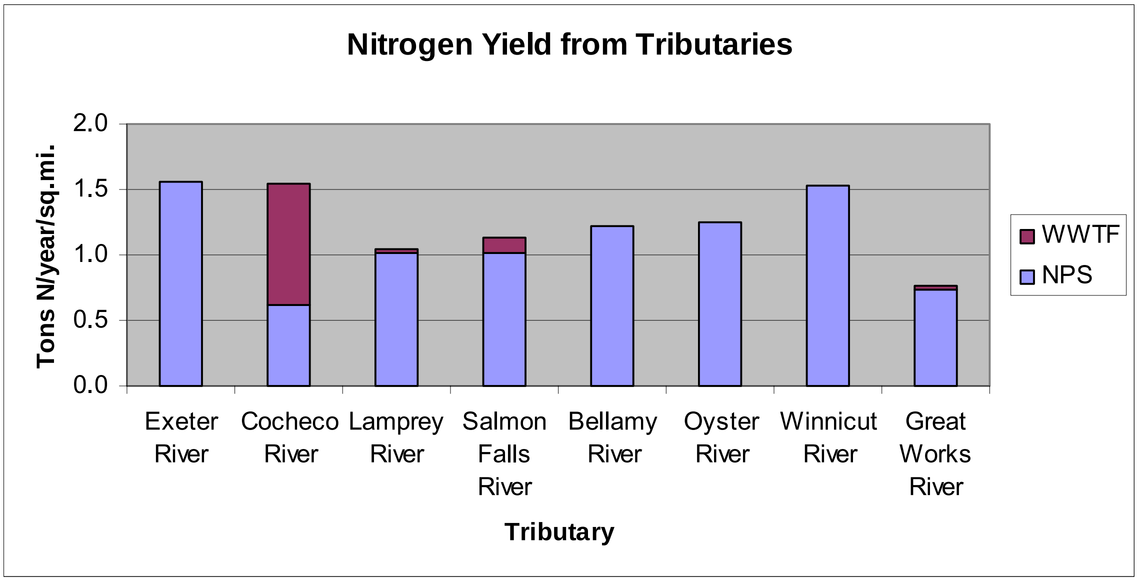

Figure NUT1-5: Relationship between non-point source nitrogen yields and land use

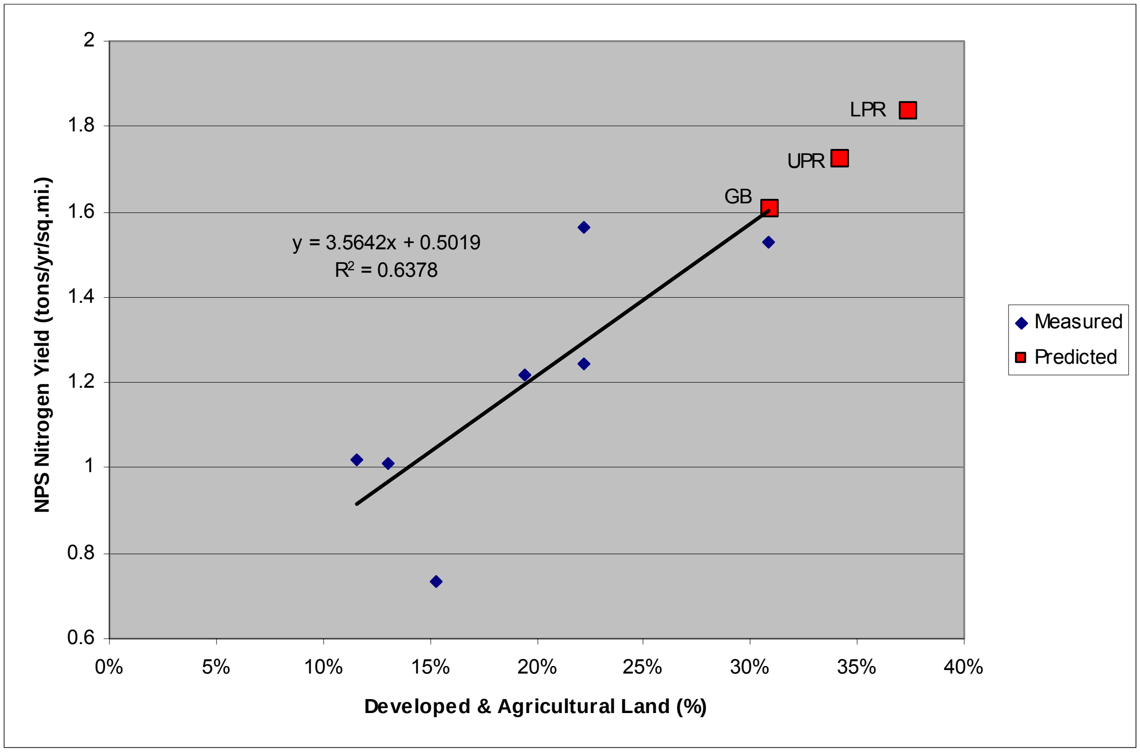

EXHIBIT 50 (AR K.27)

Figure NUT1-6: Total nitrogen loads to the Great Bay from different sources in 2006-2008

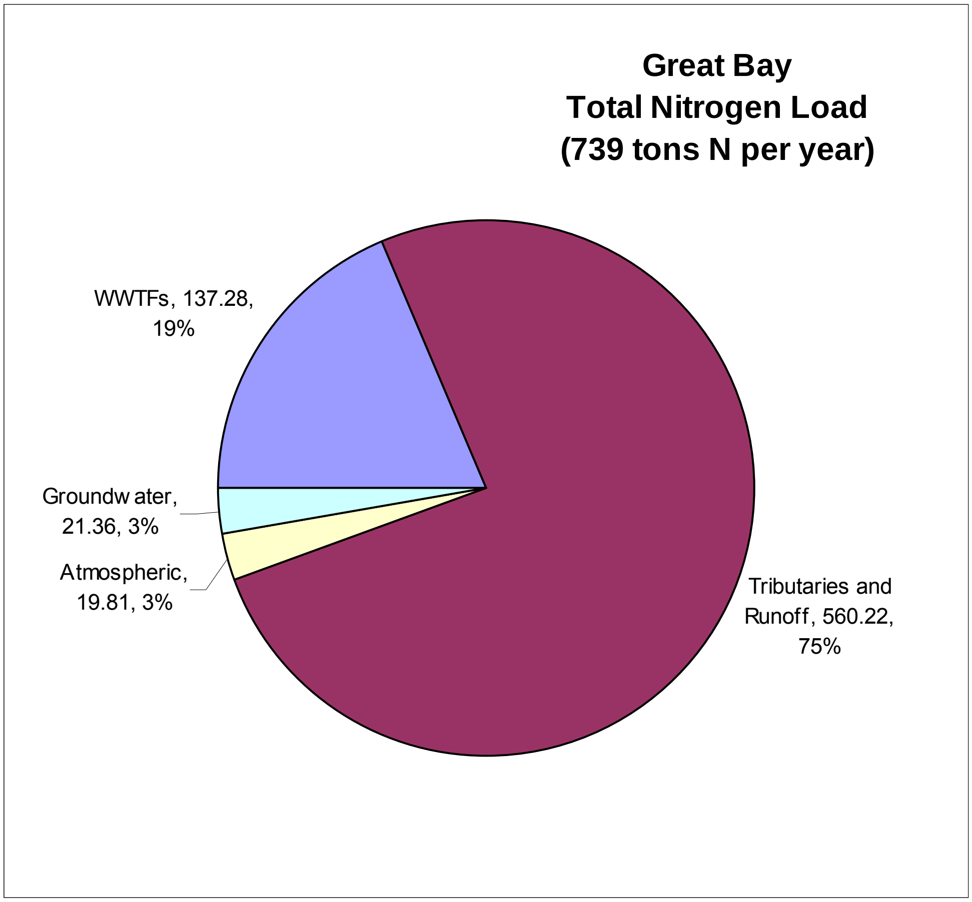

EXHIBIT 50 (AR K.27)

Figure NUT1-7: Total nitrogen loads to the Upper Piscataqua River from different sources in 2006-2008

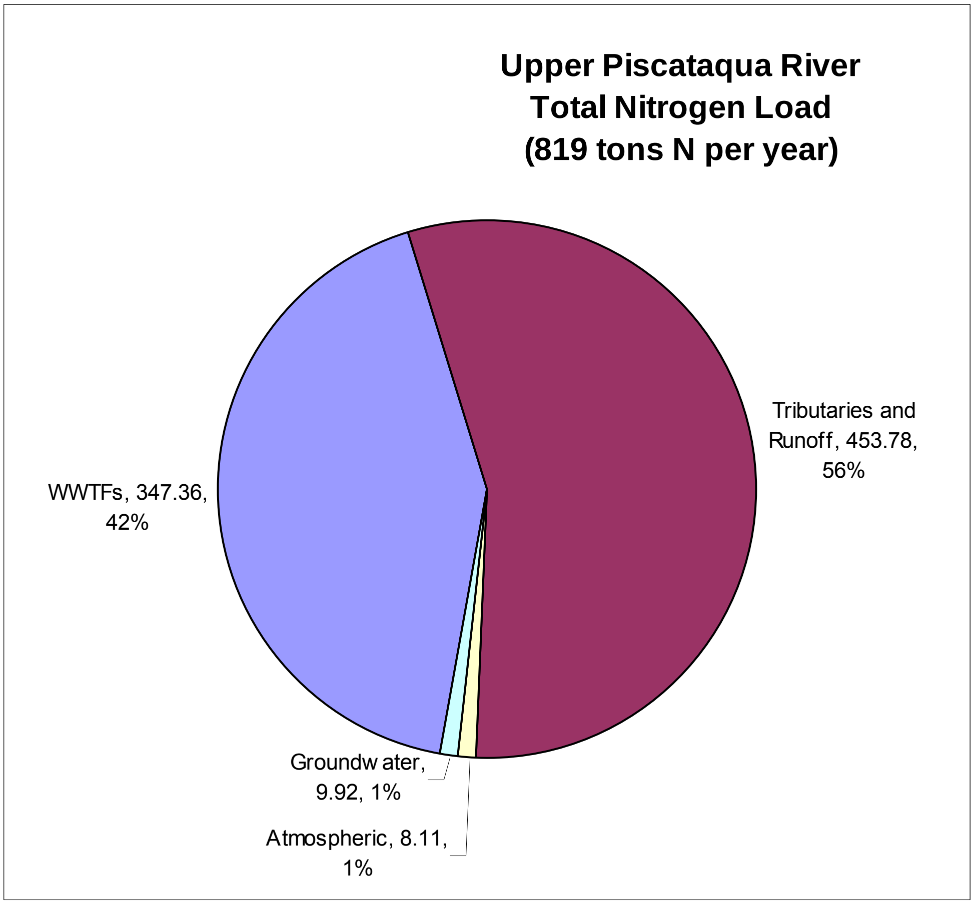

EXHIBIT 50 (AR K.27)

Figure NUT1-8: Total nitrogen loads to the Great Bay and the Upper Piscataqua River from different sources in 2006-2008

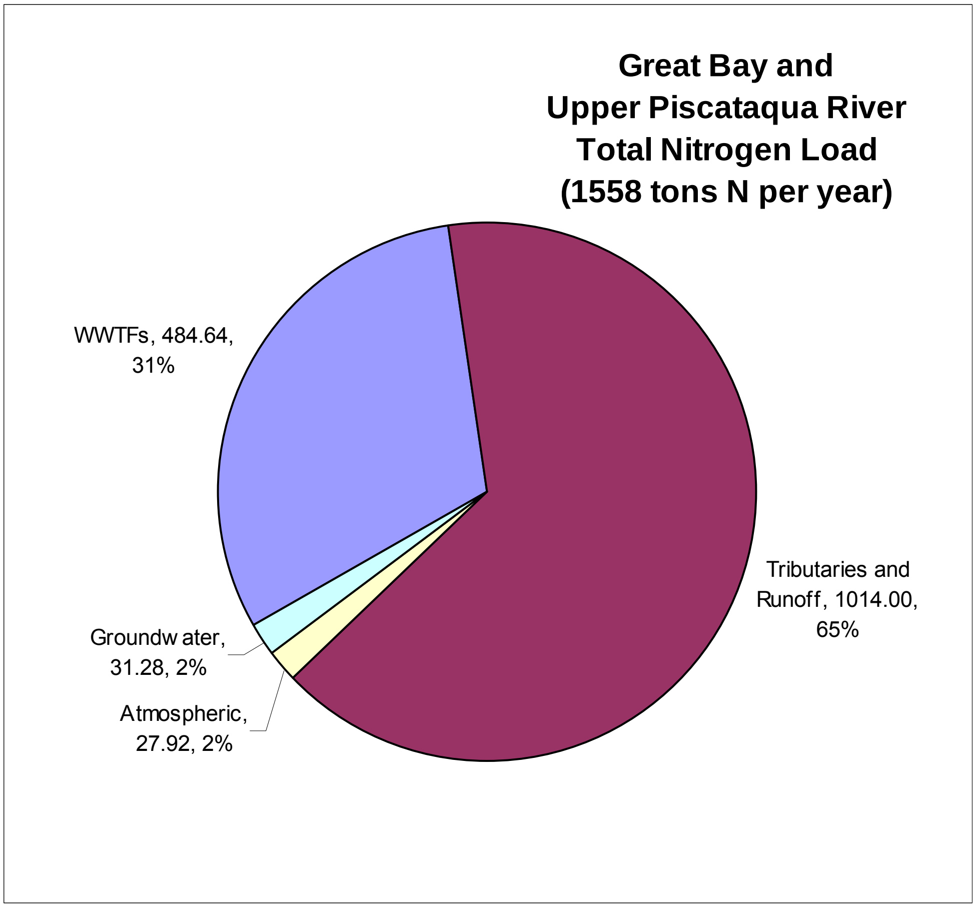

EXHIBIT 50 (AR K.27)

Indicator: NUT2. Trends in Estuarine Nutrient Concentrations

PREP Goal: The goal is to have no increasing trends for any nitrogen or phosphorus species.

Why This Is Important: Excessive nitrogen can cause algae blooms and change species composition of important habitats. Furthermore, decomposition of algae can deplete coastal waters of dissolved oxygen. Both of these effects will impair estuarine functions.

Monitoring Question: Have levels of dissolved and particulate nitrogen and phosphorus significantly changed over time?

Answer: Yes. Total nitrogen concentration in Great Bay increased by 24 percent between 2003 and 2008. Dissolved inorganic nitrogen concentrations have increased in Great Bay by 44 percent in the past 28 years.

Explanation

The locations of trend stations that were evaluated for this indicator are shown on Figure NUT2-1.

The trends for the nitrogen and phosphorus species at Adams Point in Great Bay are shown in Figures NUT2-2 through NUT2-6. Nitrate+nitrite and total nitrogen concentrations at this station have both increased significantly. Nitrate+nitrite concentrations grew by 57% between 1991 and 2008. Total nitrogen concentrations increased by 24% in the six years between 2003 and 2008. There were no significant trends in the concentrations of ammonia, dissolved inorganic nitrogen, or orthophosphate.

Statistically significant trends were also evident at other long-term stations. These trends are listed on Table NUT2-1. In particular, total nitrogen concentrations at station GRBCML in Portsmouth Harbor increased 47% between 2003 and 2008 (Figure NUT2-7). The rates of increase of total nitrogen concentrations at Adams Point and in Portsmouth Harbor were similar (17 ug/L and 22 ug/L, respectively). Ammonia and orthophosphate declined in the Lamprey River (Figures NUT2-9 and NUT2-10) and the Squamscott River (Figures NUT2-11 and NUT2-12). Orthophosphate also declined at station GRBGB in the middle of Great Bay (Figure NUT2-8).

By using historical datasets, it is possible to investigate whether nitrogen or phosphorus concentrations have changed over a longer period. Box and whisker plots of the ammonia, nitrate+nitrite, dissolved inorganic nitrogen, and orthophosphate concentrations between 1973-1981 and 2001-2008 are shown in Figures NUT2-13 through Figure NUT2-16. There has been a statistically significant ($p<0.05$ for linear regression and Kruskall-Wallis tests) increase in ammonia and dissolved inorganic nitrogen concentrations. The average concentration of dissolved inorganic nitrogen increased by 44% from 0.105 mg/L to 0.152 mg/L over approximately 28 years. There were no significant trends for nitrate+nitrite and orthophosphate.

The results of this historical analysis provide clear evidence that dissolved inorganic nitrogen concentrations have increased in the estuary in the past quarter century. Increasing trends of nitrogen concentrations were even detected by more current monitoring programs. Therefore, the goal to have no statistically significant increasing trends for nutrient concentrations is not being met.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan with the following exceptions:

1. For linear regressions with data since 1988, non detected results were included with the reporting detection limit substituted as the value. This approach was justified because less than 15% of the results were censored.
2. Rather than plotting time series of all parameters at all stations, the time series for all parameters at Adams Point and any other statistically significant trends were plotted.

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Table NUT2-1: Statistically significant linear trends (p<0.05) for nutrients at stations in the Great Bay Estuary

Station	Parameter	Trend	Slope	Units	Period	%Change
GRBAP	Nitrogen, Nitrate+Nitrite as N	Increasing	0.0023	mg/L/yr	1991-2008	57%
GRBAP	Nitrogen, Total	Increasing	0.0171	mg/L/yr	2003-2008	24%
GRBCML	Nitrogen, Total	Increasing	0.0221	mg/L/yr	2003-2008	47%
GRBGB	Phosphorus as Orthophosphate	Decreasing	-0.0016	mg/L/yr	2001-2008	-37%
GRBLR	Nitrogen, Ammonia as N	Decreasing	-0.0024	mg/L/yr	1992-2008	-49%
GRBLR	Phosphorus as Orthophosphate	Decreasing	-0.0006	mg/L/yr	1992-2008	-60%
GRBSQ	Nitrogen, Ammonia as N	Decreasing	-0.0088	mg/L/yr	2001-2008	-42%
GRBSQ	Phosphorus as Orthophosphate	Decreasing	-0.0052	mg/L/yr	2001-2008	-62%

Table NUT2-2: Long-term trends for dissolved nutrient species at low tide at Adams Point

Period	Statistic	Ammonia (mg N/L)	Nitrate+Nitrite (mg N/L)	Dissolved Inorganic Nitrogen (mg N/L)	Orthophosphate (mg N/L)
1974-1981	n	91	91	87	92
	Mean	0.034	0.073	0.105	0.027
	SD	0.029	0.061	0.081	0.013
1993-2000	n	92	95	92	95
	Mean	0.079	0.088	0.168	0.022
	SD	0.081	0.066	0.114	0.010
2001-2008	n	67	77	66	73
	Mean	0.058	0.090	0.152	0.023
	SD	0.041	0.075	0.088	0.011
T-test		Significant (p<0.05)	Not Significant	Significant (p<0.05)	Not Significant
Kruskall-Wallis test		Significant (p<0.05)	Not Significant	Significant (p<0.05)	Not Significant
Percent Change		71.79%		44.25%	

** T-test, Kruskall-Wallis test, and percent change calculated using 1974-1981 and 2001-2008 data*

EXHIBIT 50 (AR K.27)

Figure NUT2-1: Trend stations for nutrient indicators

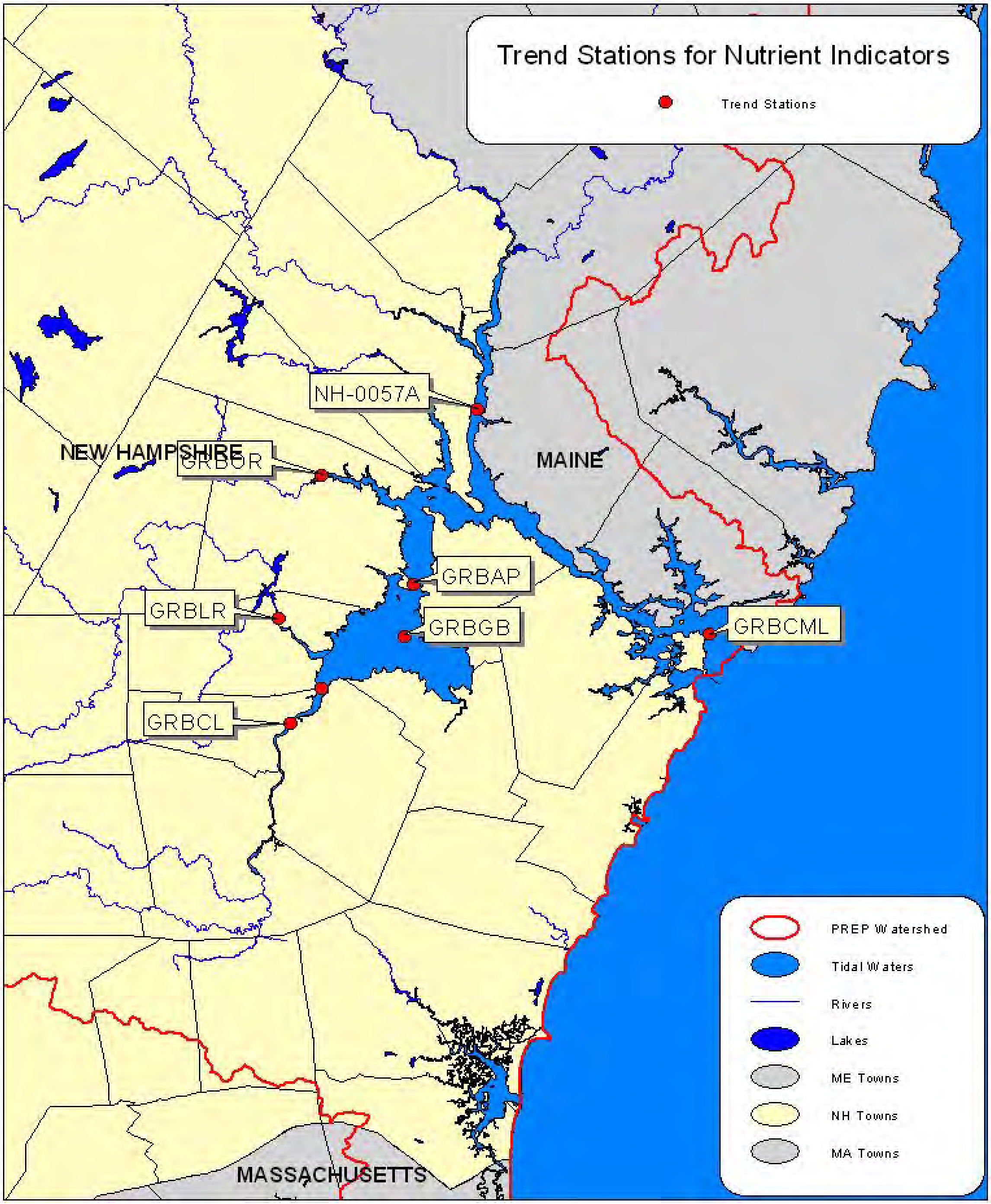

EXHIBIT 50 (AR K.27)

Figure NUT2-2: Long-term trends for ammonia concentrations measured monthly at Adams Point in Great Bay

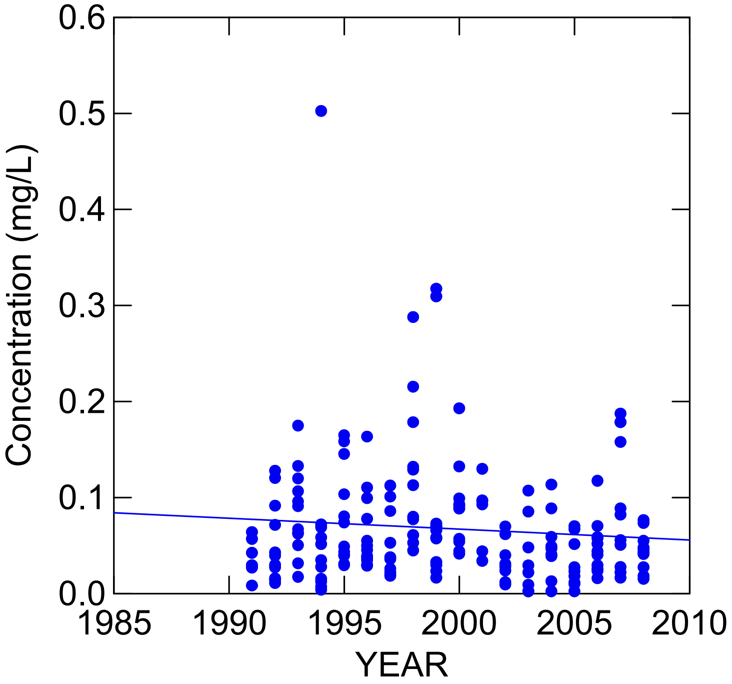

EXHIBIT 50 (AR K.27)

Figure NUT2-3: Long-term trends for nitrate+nitrite concentrations measured monthly at Adams Point in Great Bay

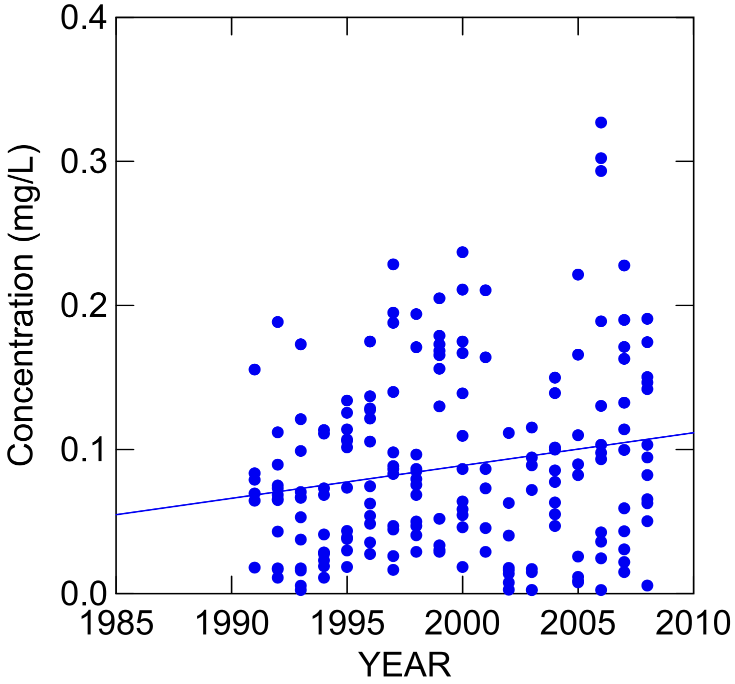

Figure NUT2-4: Long-term trends for dissolved inorganic nitrogen concentrations measured monthly at Adams Point in Great Bay

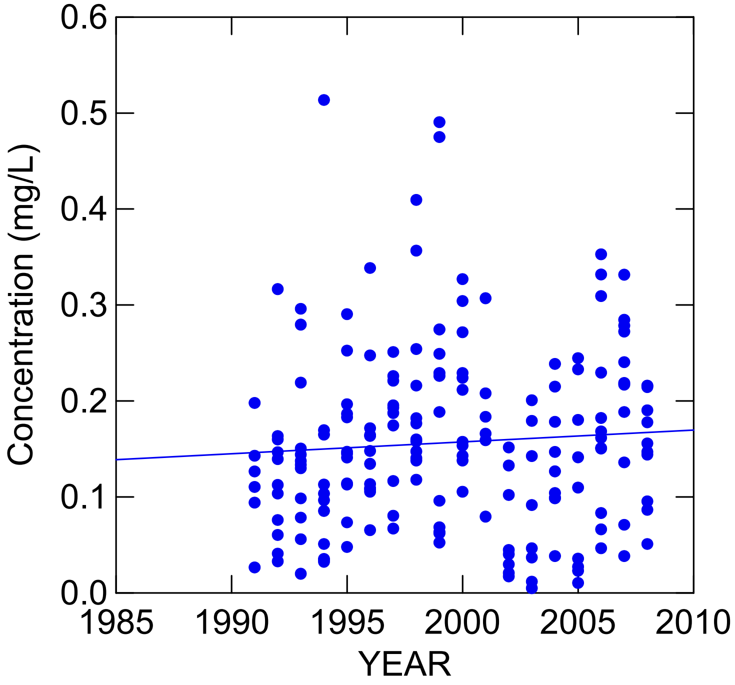

EXHIBIT 50 (AR K.27)

Figure NUT2-5: Long-term trends for total nitrogen concentrations measured monthly at Adams Point in Great Bay

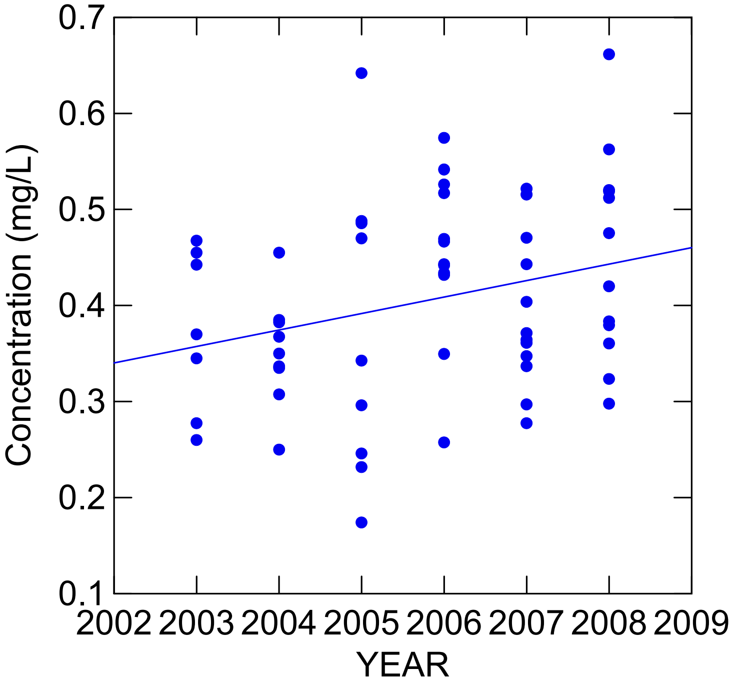

Figure NUT2-6: Long-term trends for orthophosphate concentrations measured monthly at Adams Point in Great Bay

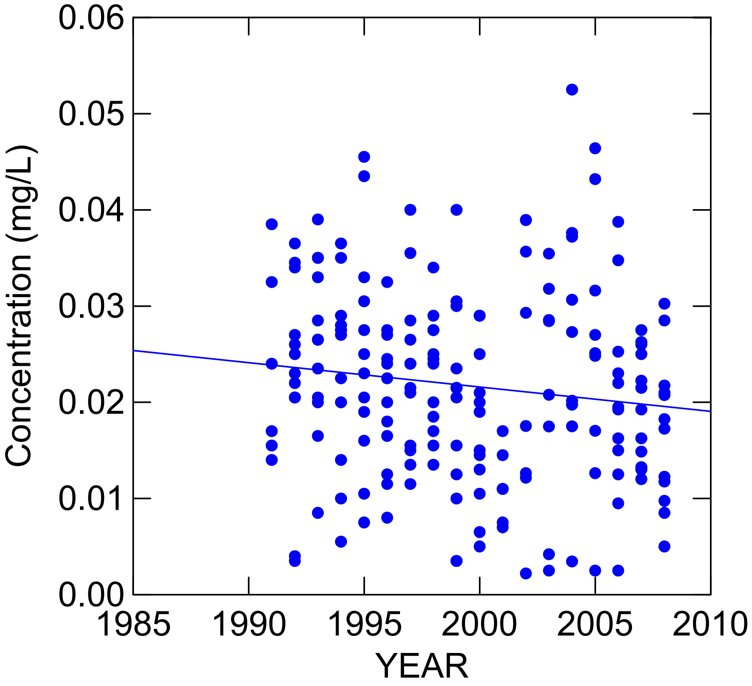

EXHIBIT 50 (AR K.27)

Figure NUT2-7: Long-term trends for total nitrogen concentrations measured monthly at the Coastal Marine Laboratory in Portsmouth Harbor

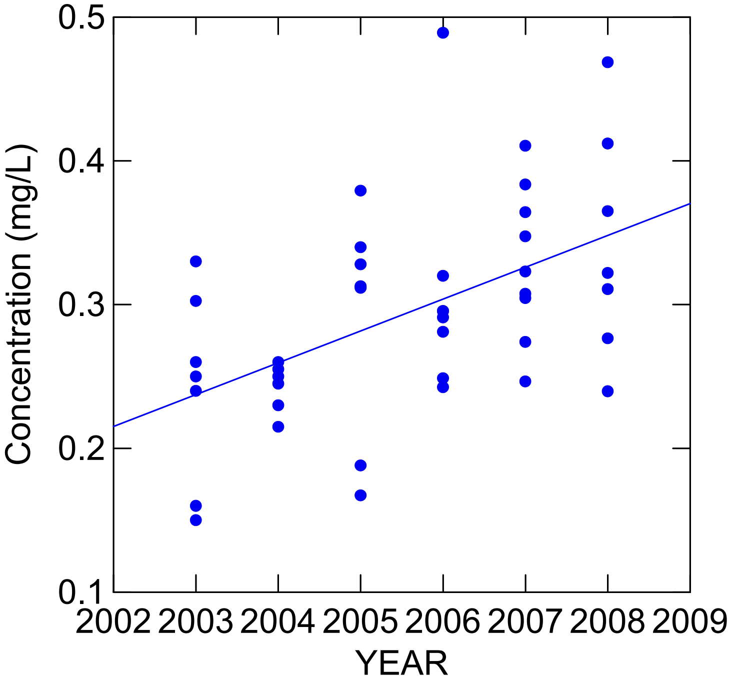

Figure NUT2-8: Long-term trends for orthophosphate concentrations measured monthly at station GRBGB in Great Bay

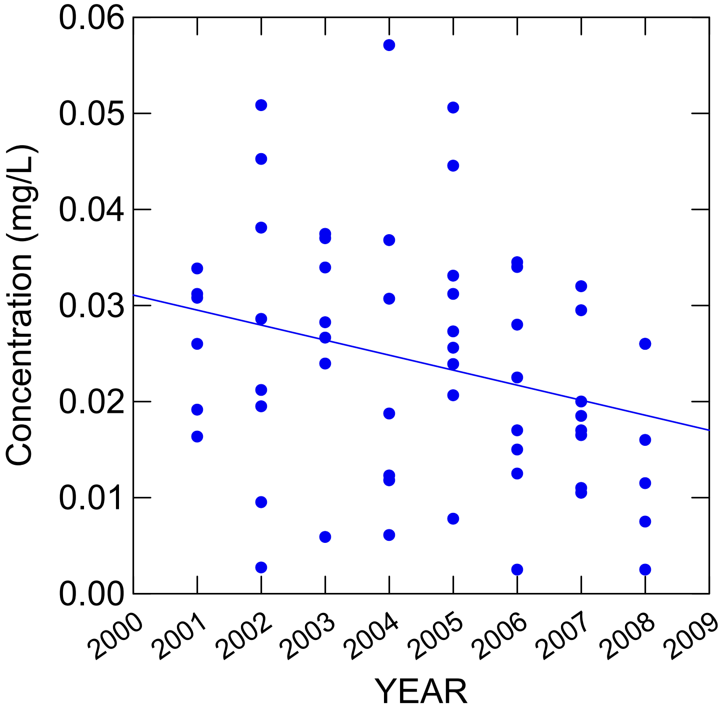

EXHIBIT 50 (AR K.27)

Figure NUT2-9: Long-term trends for ammonia concentrations measured monthly at station GRBLR in the Lamprey River

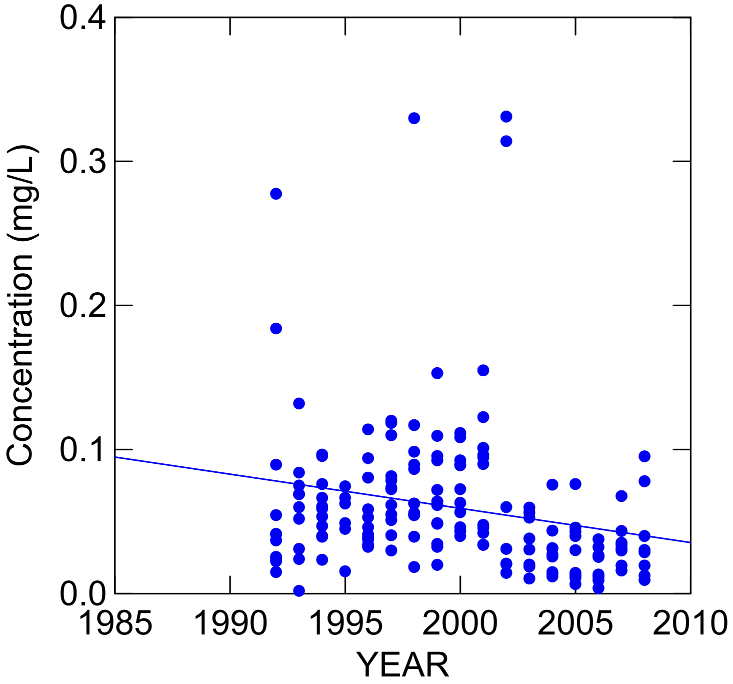

Figure NUT2-10: Long-term trends for orthophosphate concentrations measured monthly at station GRBLR in the Lamprey River

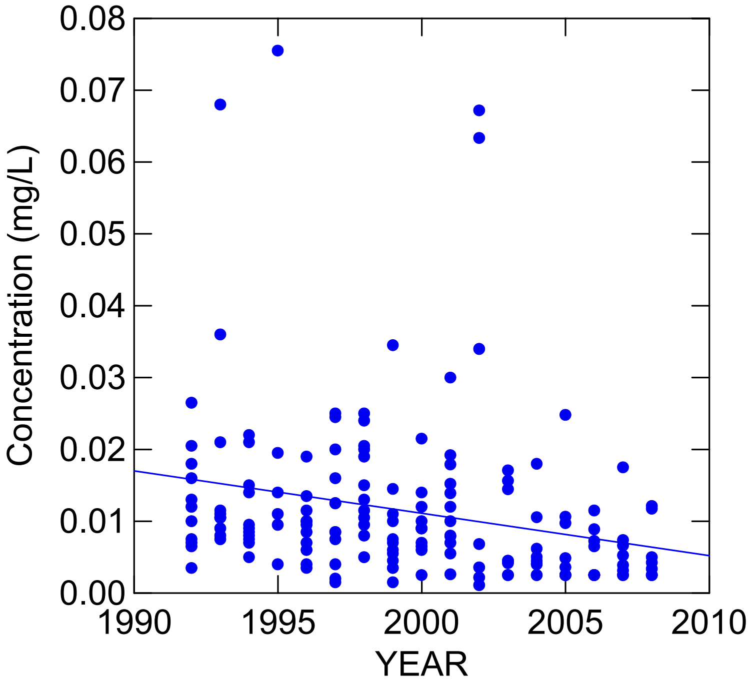

EXHIBIT 50 (AR K.27)

Figure NUT2-11: Long-term trends for ammonia concentrations measured monthly at station GRBSQ in the Squamscott River

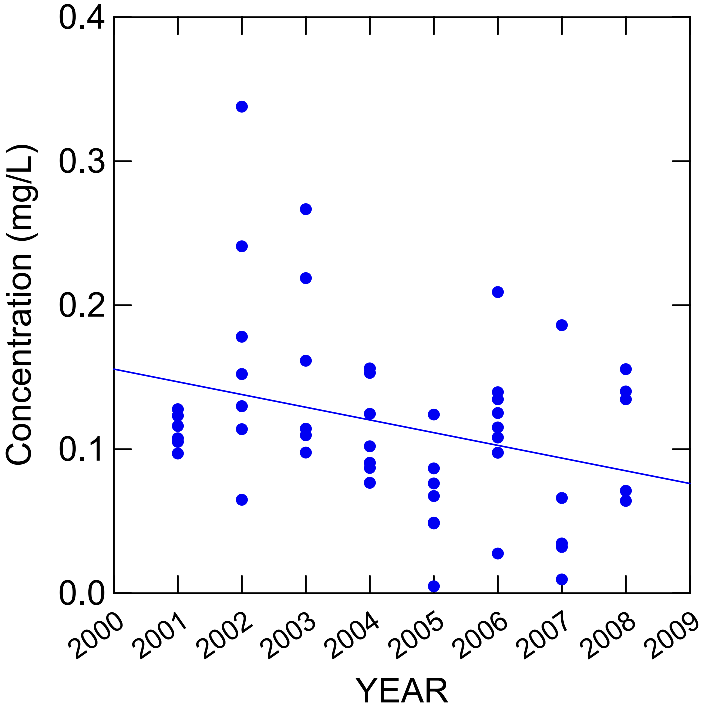

Figure NUT2-12: Long-term trends for orthophosphate concentrations measured monthly at station GRBSQ in the Squamscott River

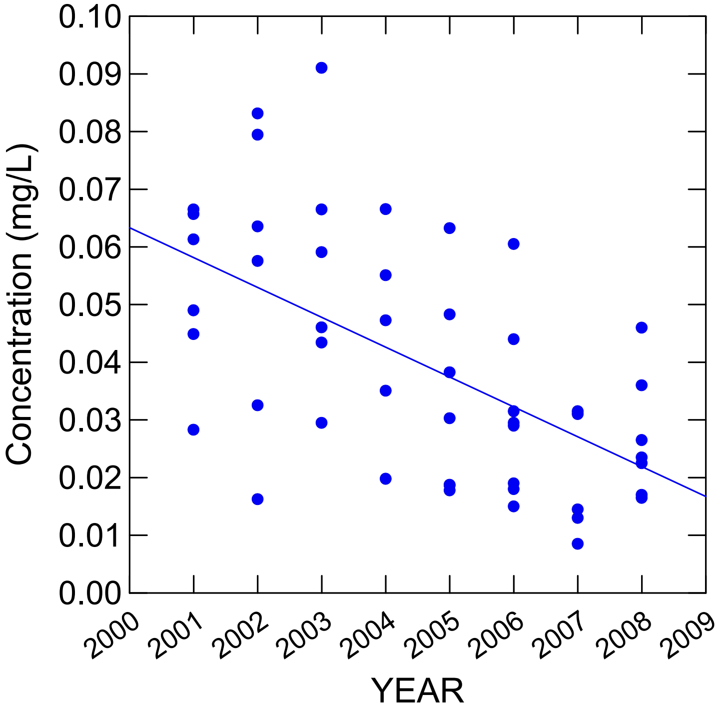

EXHIBIT 50 (AR K.27)

Figure NUT2-13: Box and whisker plots of ammonia concentrations in 1973-1981, 1993-2000, and 2001-2008 at Adams Point in Great Bay

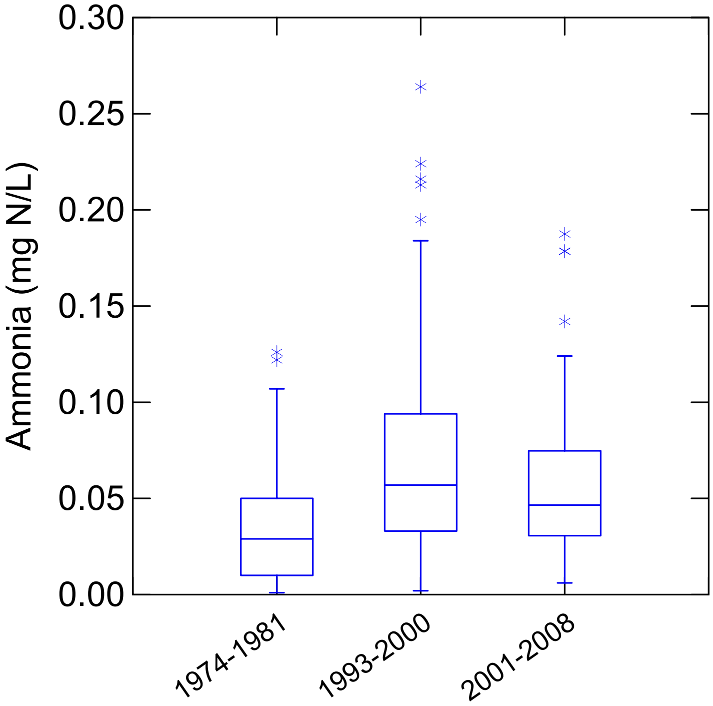

Figure NUT2-14: Box and whisker plots of nitrate+nitrite concentrations in 1973-1981, 1993-2000, and 2001-2008 at Adams Point in Great Bay

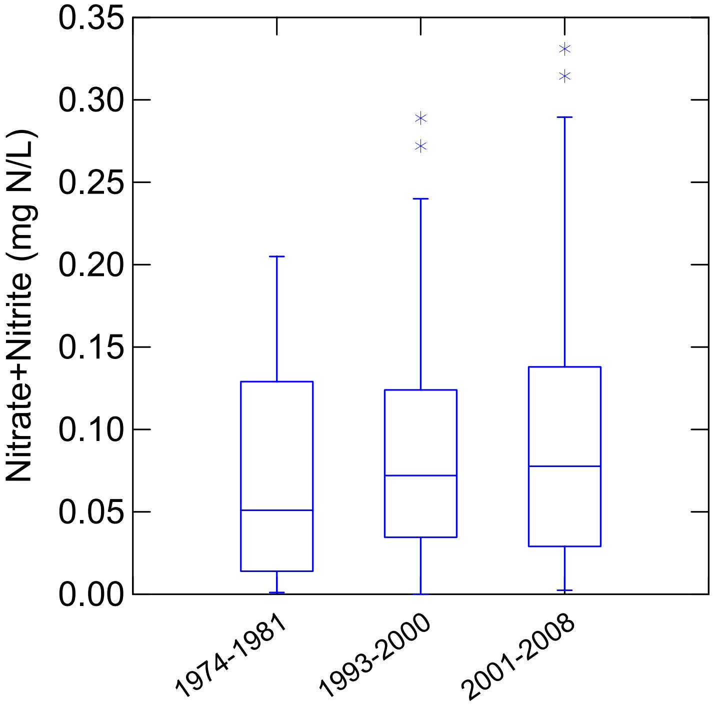

EXHIBIT 50 (AR K.27)

Figure NUT2-15: Box and whisker plots of dissolved inorganic nitrogen concentrations in 1973-1981, 1993-2000, and 2001-2008 at Adams Point in Great Bay

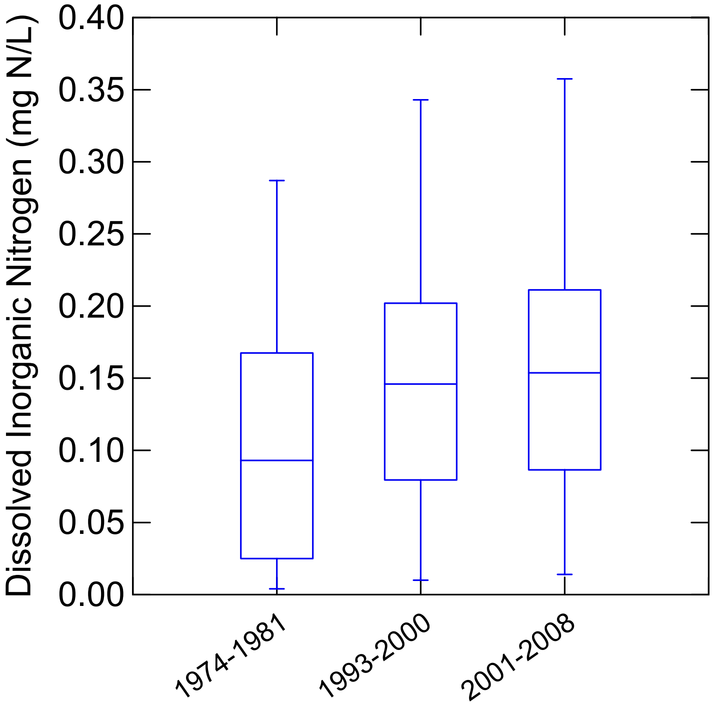

Figure NUT2-16: Box and whisker plots of orthophosphate concentrations in 1973-1981, 1993-2000, and 2001-2008 at Adams Point in Great Bay

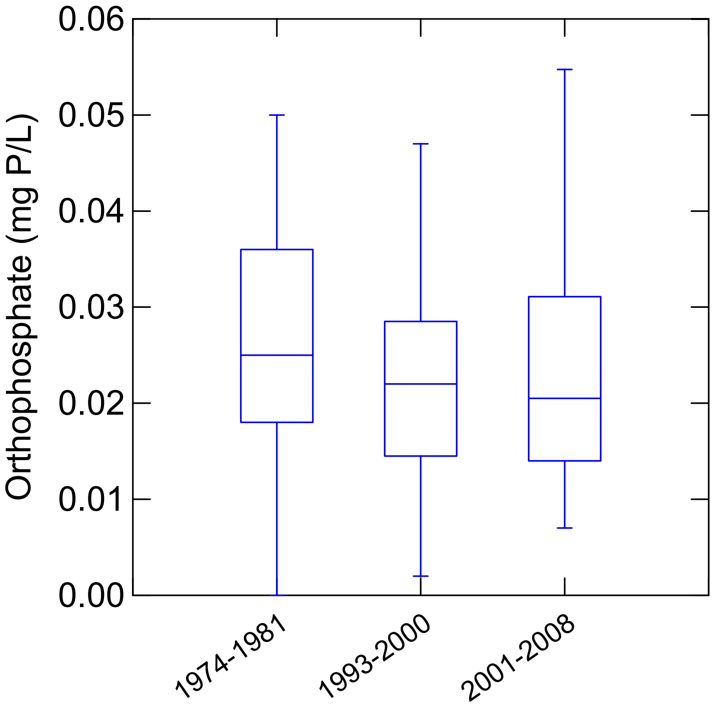

EXHIBIT 50 (AR K.27)

Indicator: NUT3. Trends in Estuarine Particulate Concentrations

PREP Goal: The goal is to have no increasing trends for chlorophyll-a or total suspended solids concentrations.

Why This Is Important: Suspended particles in the water column affect the clarity of the water. Water clarity is critical for the survival of eelgrass beds. The main sources of suspended particles are phytoplankton blooms in the estuary and erosion from the developed landscape.

Monitoring Question: Have phytoplankton and suspended solids levels significantly changed over time?

Answer: Yes. Chlorophyll-a and suspended solids concentrations have increased in Great Bay by 28% and 123%, respectively, in the past 28 years.

Explanation
The trends for chlorophyll-a and suspended solids concentrations at Adams Point in Great Bay are shown in Figures NUT3-1 and NUT3-2. The concentrations of both parameters at this station have increased significantly. Chlorophyll-a concentrations grew by 106% between 1988 and 2008. Suspended solids concentrations increased by 86% during the same period.

Statistically significant trends were also evident at other long-term stations. These trends are listed on Table NUT3-1. In particular, chlorophyll-a concentrations at station GRBSQ in the Squamscott River increased 150% between 2001 and 2008. Suspended solids concentrations increased in the Lamprey River by 65%.

By using historical datasets, it is possible to investigate whether particulate concentrations have changed over a longer period. Box and whisker plots of the chlorophyll-a and suspended solids concentrations between 1973-1981 and 2001-2008 are shown in Figures NUT3-5 and NUT3-6. There has been a statistically significant ($p<0.05$ for linear regression and Kruskall-Wallis tests) increase in both parameters. The average concentration of chlorophyll-a increased by 28% from 3.6 ug/L to 4.6 ug/L over approximately 28 years. The average suspended solids concentration increased by 123% during this same period.

The rate of increase for the suspended solids concentration has been consistent between the recent dataset and the historical dataset (~0.4 mg/L/yr). In contrast, the rate of increase for chlorophyll-a in the recent dataset is much faster than the increase over the 28 year period from the historical dataset.

The results of this historical analysis provide clear evidence that chlorophyll-a and suspended solids concentrations have increased in the estuary in the past quarter century. Increasing trends of particulates were even detected by more current monitoring programs. Therefore, the goal to have no statistically significant increasing trends for particulate concentrations is not being met.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan with the following exceptions:
1. For linear regressions with data since 1988, non detected results were included with the reporting detection limit substituted as the value. This approach was justified because less than 15% of the results were censored.
2. Rather than plotting time series of all parameters at all stations, the time series for all parameters at Adams Point and any other statistically significant trends were plotted.

EXHIBIT 50 (AR K.27)

Table NUT3-1: Statistically significant linear trends ($p<0.05$) for chlorophyll-a and suspended solids at stations in the Great Bay Estuary

Station	Parameter	Trend	Slope	Units	Period	%Change
GRBAP	Chlorophyll-a	Increasing	0.1135	ug/L/yr	1988-2008	106%
GRBAP	Suspended Solids	Increasing	0.4143	mg/L/yr	1988-2008	88%
GRBLR	Suspended Solids	Increasing	0.1298	mg/L/yr	1992-2008	65%
GRBSQ	Chlorophyll-a	Increasing	0.8635	ug/L/yr	2001-2008	150%

Table NUT3-2: Long-term trends for chlorophyll-a and suspended solids at low tide at Adams Point

Period	Statistic	Chlorophyll-a (ug/L)	Suspended Solids (mg/L)
1974-1981	n	88	65
	Mean	3.573	8.825
	SD	2.925	10.822
1993-2000	n	96	94
	Mean	3.512	10.185
	SD	4.144	5.687
2001-2008	n	76	73
	Mean	4.564	19.705
	SD	2.932	13.799
T-test		Significant ($p<0.05$)	Significant ($p<0.05$)
Kruskall-Wallis test		Significant ($p<0.05$)	Significant ($p<0.05$)
Percent Change		27.75%	123.28%

** T-test, Kruskall-Wallis test, and percent change calculated using 1974-1981 and 2001-2008 data*

EXHIBIT 50 (AR K.27)

Figure NUT3-1: Long-term trends for chlorophyll-a concentrations measured monthly at Adams Point in Great Bay

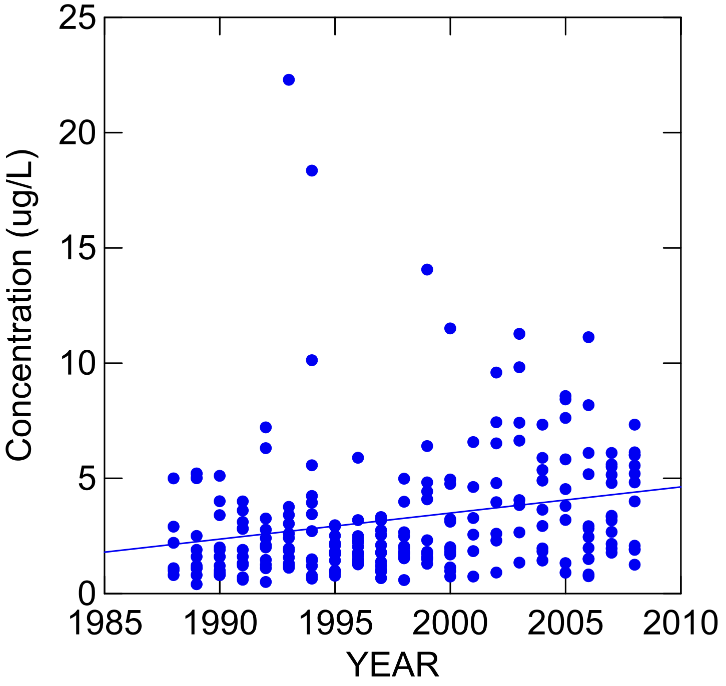

Figure NUT3-2: Long-term trends for suspended solids concentrations measured monthly at Adams Point in Great Bay

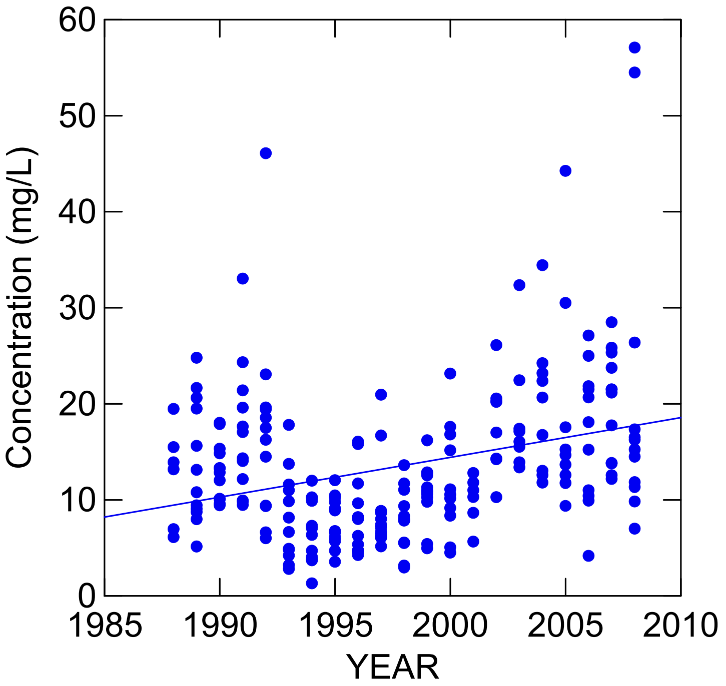

EXHIBIT 50 (AR K.27)

Figure NUT3-3: Long-term trends for suspended solids concentrations measured monthly in the Lamprey River

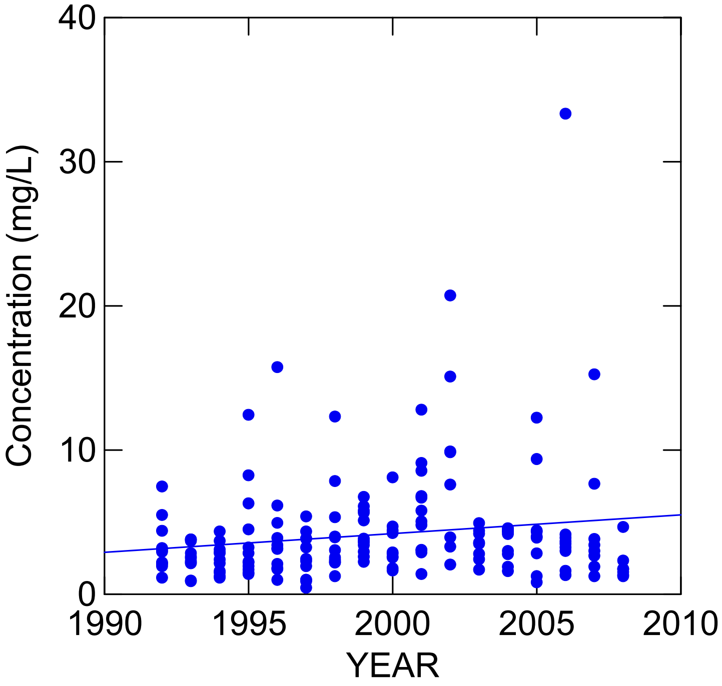

Figure NUT3-4: Long-term trends for chlorophyll-a concentrations measured monthly in the Squamscott River

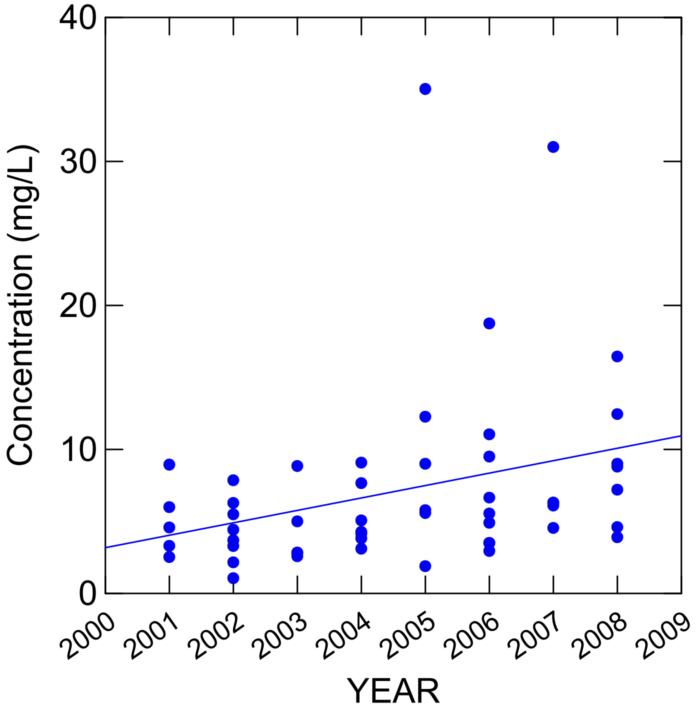

EXHIBIT 50 (AR K.27)

Figure NUT3-5: Box and whisker plots of chlorophyll-a concentrations in 1973-1981, 1993-2000, and 2001-2008 at Adams Point in Great Bay

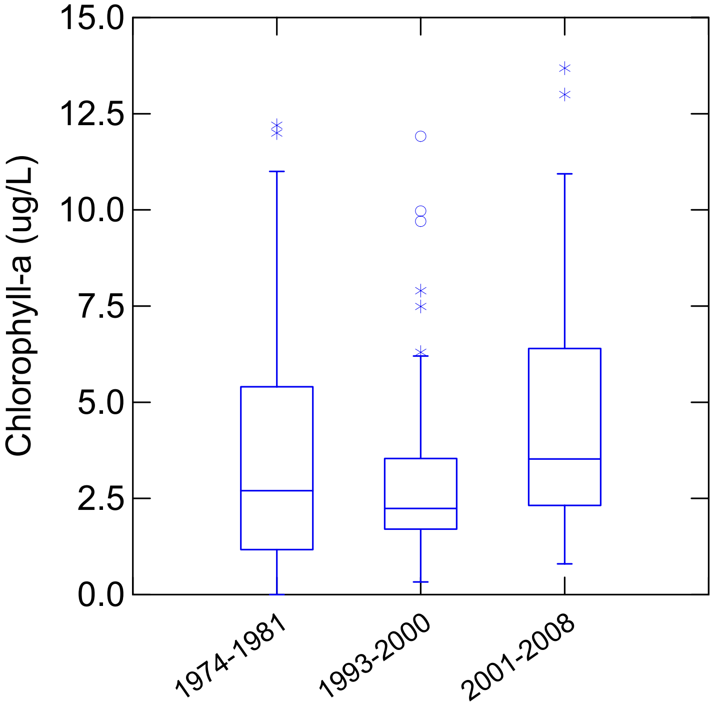

Figure NUT3-6: Box and whisker plots of suspended solids concentrations in 1973-1981, 1993-2000, and 2001-2008 at Adams Point in Great Bay

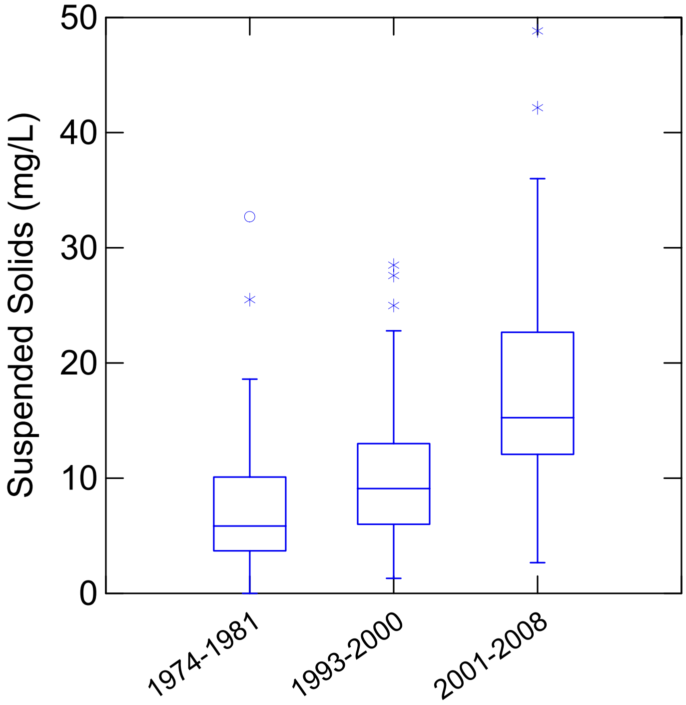

EXHIBIT 50 (AR K.27)

Indicator: NUT5. Exceedences of Instantaneous Dissolved Oxygen Standard

PREP Goal: The goal is to have zero days with exceedences of the instantaneous standard.

Why This Is Important: Fish and many other aquatic organisms need dissolved oxygen in the water to survive. Prolonged periods of low dissolved oxygen can alter aquatic ecosystems.

Monitoring Question: How often do dissolved oxygen levels in the Great Bay Estuary fall below state standards?

Answer: Rarely in the bays and harbors, but often in the tidal rivers.

Explanation
The exceedences of the dissolved oxygen instantaneous standard during the summer months at each station are summarized in Table NUT5-1. Trends over time in the percentage of days with exceedences are shown in Figure NUT5-1 and NUT5-2. The locations of the datasonde stations are shown in Figure NUT5-3.

In Great Bay (GRBAP) and Portsmouth Harbor (GRBCML), the dissolved oxygen concentrations in the summer never fell below 5 mg/L between 2000 and 2008. Therefore, the PREP goal of zero exceedences is essentially being met for the well mixed areas of Great Bay and Portsmouth Harbor.

In contrast to the open bays, there were persistent exceedences of the standard at the stations in the tidal tributaries. The percent of summer days with violations varied over time at the stations (Figure NUT5-1). On average, the violations were most persistent in the Lamprey River (GRBLR) and the Squamscott River (GRBSQ). Figure NUT5-2 shows that the number of violations in 2006-2008 was less than half of the number observed in 2002-2005. Based on these data, the tidal tributaries do not meet the goal of having zero days with dissolved oxygen less than 5 mg/l.

While the 5 mg/L water quality standard for DO provides an objective reference point by which to judge measurements in the estuary, there are questions about whether the standard correctly identifies impairments of the aquatic life in tidal waters. Excursions of DO concentrations below 5 mg/L may be natural in tidal rivers and creeks. Pennock (2005) studied dissolved oxygen in the Lamprey River and found that, in some cases, the episodes of low dissolved oxygen were caused by a salinity stratification that set up in the bottom waters.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan with the following exceptions:
1. The analysis for this indicator was not limited to days with complete datasonde records for dissolved oxygen. Instead, all dissolved oxygen results in July, August, and September were used. The objective of the indicator is to identify days with minimum dissolved oxygen below state standards. It is not important to have a complete datasonde record to detect a value lower than 5 mg/L.
2. Histograms of the duration of “low dissolved oxygen episodes” were not completed.

EXHIBIT 50 (AR K.27)

Table NUT5-1: Measurements of dissolved oxygen concentrations less than 5 mg/L at in-situ datasondes in the estuary

Station	Year	Number of Summer Days with Valid DO Data	Number of Summer Days with Minimum DO <5 mg/L	Percent
GRBCML	2002	16	0	0.0%
GRBCML	2003	20	0	0.0%
GRBCML	2004	21	0	0.0%
GRBCML	2005	49	0	0.0%
GRBCML	2006	51	0	0.0%
GRBCML	2007	15	0	0.0%
GRBCML	2008	92	0	0.0%
GRBGB	2000	9	0	0.0%
GRBGB	2001	20	0	0.0%
GRBGB	2002	29	0	0.0%
GRBGB	2003	24	0	0.0%
GRBGB	2004	20	0	0.0%
GRBGB	2005	47	0	0.0%
GRBGB	2006	59	0	0.0%
GRBGB	2007	92	0	0.0%
GRBGB	2008	92	0	0.0%
GRBLR	2000	7	0	0.0%
GRBLR	2001	20	3	15.0%
GRBLR	2002	25	21	84.0%
GRBLR	2003	15	9	60.0%
GRBLR	2004	52	33	63.5%
GRBLR	2005	44	10	22.7%
GRBLR	2006	55	1	1.8%
GRBLR	2007	92	49	53.3%
GRBLR	2008	92	12	13.0%
GRBOR	2002	25	9	36.0%
GRBOR	2003	19	1	5.3%
GRBOR	2004	52	21	40.4%
GRBOR	2005	35	2	5.7%
GRBOR	2006	30	1	3.3%
GRBOR	2007	92	4	4.3%
GRBOR	2008	53	7	13.2%
GRBSF	2002	10	0	0.0%
GRBSF	2003	17	6	35.3%
GRBSF	2004	60	12	20.0%
GRBSF	2005	10	1	10.0%
GRBSF	2006	28	0	0.0%
GRBSF	2007	15	1	6.7%
GRBSF	2008	41	2	4.9%

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EXHIBIT 50 (AR K.27)

Table NUT5-1 (cont.)

Station	Year	Number of Summer Days with Valid DO Data	Number of Summer Days with Minimum DO <5 mg/L	Percent
GRBSQ	2000	15	4	26.7%
GRBSQ	2001	20	0	0.0%
GRBSQ	2002	20	8	40.0%
GRBSQ	2003	18	8	44.4%
GRBSQ	2004	92	19	20.7%
GRBSQ	2005	37	4	10.8%
GRBSQ	2006	73	12	16.4%
GRBSQ	2007	92	7	7.6%
GRBSQ	2008	88	14	15.9%

Note: Summer days are defined as days in the months of July, August, and September.

EXHIBIT 50 (AR K.27)

Figure NUT5-1: Trends in the percent of summer days with minimum dissolved oxygen less than 5 mg/L at each datasonde station

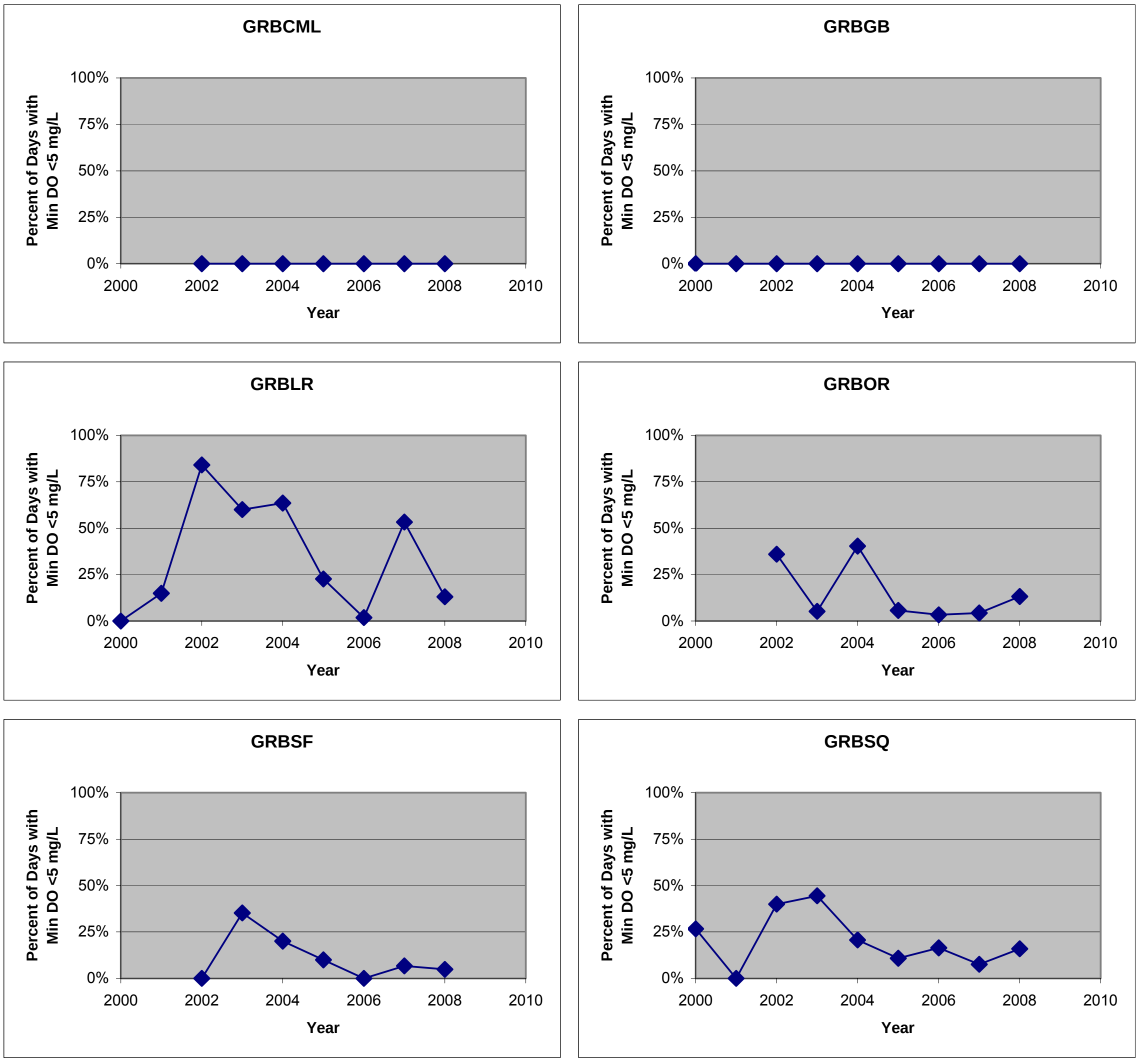

EXHIBIT 50 (AR K.27)

Figure NUT5-2: Median values of the percent of summer days with minimum dissolved oxygen less than 5 mg/L at each datasonde station for the periods 2002-2005 and 2006-2008

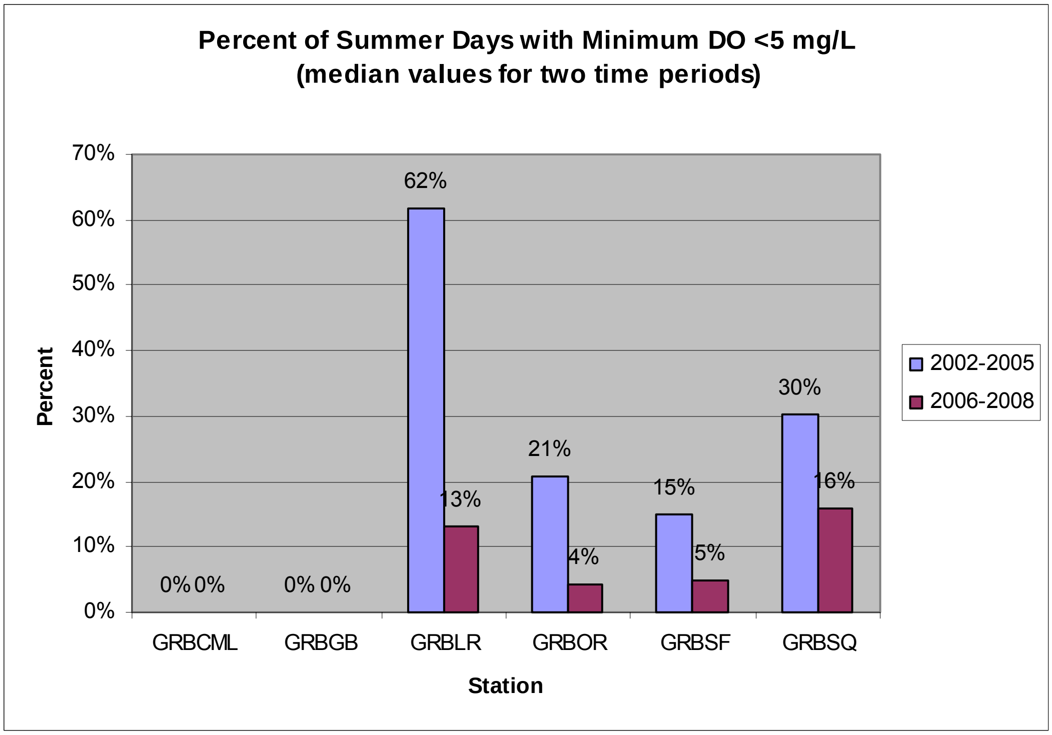

EXHIBIT 50 (AR K.27)

Figure NUT5-2: Datasonde stations

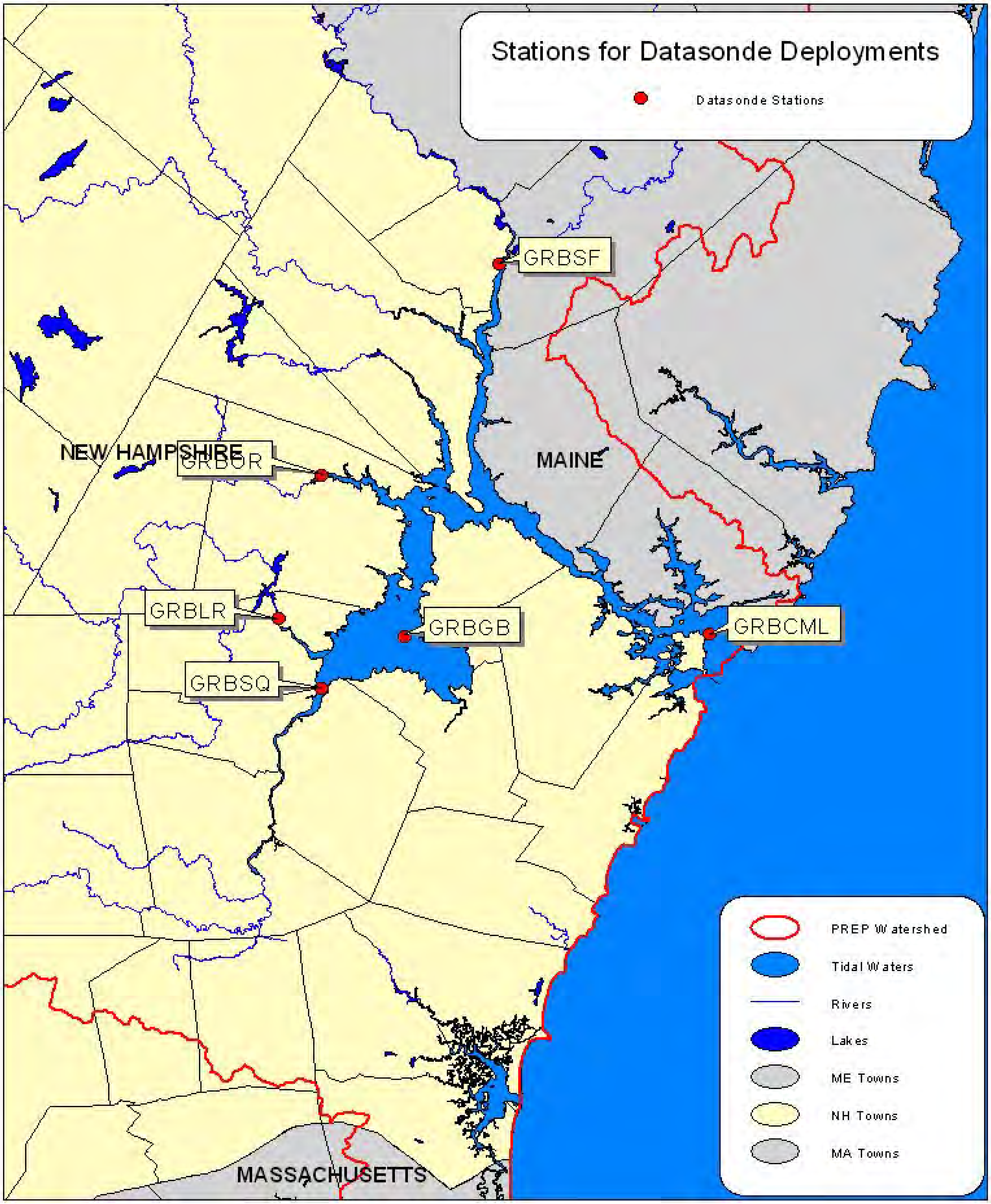

EXHIBIT 50 (AR K.27)

Indicator: NUT6. Exceedences of the Daily Average Dissolved Oxygen Standard

PREP Goal: The goal is to have zero days with violations of the daily average standard.

Why This Is Important: Fish and many other aquatic organisms need dissolved oxygen in the water to survive. Prolonged periods of low dissolved oxygen can alter aquatic ecosystems.

Monitoring Question: How often do dissolved oxygen levels in the Great Bay Estuary fall below state standards?

Answer: Rarely in the bays and harbors, but often in the tidal rivers.

Explanation
Table NUT6-1 summarizes the number of exceedences of the daily average dissolved oxygen standard at the different datasondes. Trends in the frequency of occurrence for the exceedences are shown in Figure NUT6-1 and Figure NUT6-2.

The results for this indicator are similar to those for NUT5. The dissolved oxygen concentrations in the Great Bay and Portsmouth Harbor consistently meet the 75% saturation standard, while exceedences of the standard have been observed in the tidal tributaries. The most exceedences have been observed in the Lamprey River (51% of the time on average in 2002-2005). Relatively few exceedences of the standard have been observed in the Squamscott River, despite the fact that the dissolved oxygen concentration often falls below 5 mg/L at this station (see NUT5). These results indicate large diurnal swings of dissolved oxygen in the Squamscott River system. In general, there were fewer violations in 2006-2008 than during 2002-2005 (Figure NUT6-2).

The data sources and methods used for this indicator are described in the PREP Monitoring Plan with the following exceptions:
1. Starting in 2007, some of the datasondes recorded measurements every 15 minutes. Therefore, for the 2007 and 2008 datasets, days with complete data for DO were required to have 96 valid measurements.

EXHIBIT 50 (AR K.27)

Table NUT6-1: Measurements of daily average dissolved oxygen saturation less than 75% at in-situ datasondes in the estuary

Station	Year	Number of Summer Days with Complete DO Data	Number of Summer Days with Average DOsat <75%	Percent
GRBCML	2002	9	0	0.0%
GRBCML	2003	12	0	0.0%
GRBCML	2004	16	0	0.0%
GRBCML	2005	46	0	0.0%
GRBCML	2006	45	0	0.0%
GRBCML	2007	6	0	0.0%
GRBCML	2008	91	0	0.0%
GRBGB	2000	5	0	0.0%
GRBGB	2001	12	0	0.0%
GRBGB	2002	18	0	0.0%
GRBGB	2003	15	0	0.0%
GRBGB	2004	18	0	0.0%
GRBGB	2005	42	0	0.0%
GRBGB	2006	57	0	0.0%
GRBGB	2007	92	0	0.0%
GRBGB	2008	90	0	0.0%
GRBLR	2000	4	1	25.0%
GRBLR	2001	11	0	0.0%
GRBLR	2002	15	6	40.0%
GRBLR	2003	9	6	66.7%
GRBLR	2004	50	31	62.0%
GRBLR	2005	30	3	10.0%
GRBLR	2006	53	7	13.2%
GRBLR	2007	78	23	29.5%
GRBLR	2008	91	2	2.2%
GRBOR	2002	13	2	15.4%
GRBOR	2003	6	0	0.0%
GRBOR	2004	46	13	28.3%
GRBOR	2005	29	0	0.0%
GRBOR	2006	25	2	8.0%
GRBOR	2007	90	1	1.1%
GRBOR	2008	48	6	12.5%
GRBSF	2002	6	0	0.0%
GRBSF	2003	9	2	22.2%
GRBSF	2004	55	6	10.9%
GRBSF	2005	6	0	0.0%
GRBSF	2006	24	0	0.0%
GRBSF	2007	9	0	0.0%
GRBSF	2008	39	2	5.1%

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EXHIBIT 50 (AR K.27)

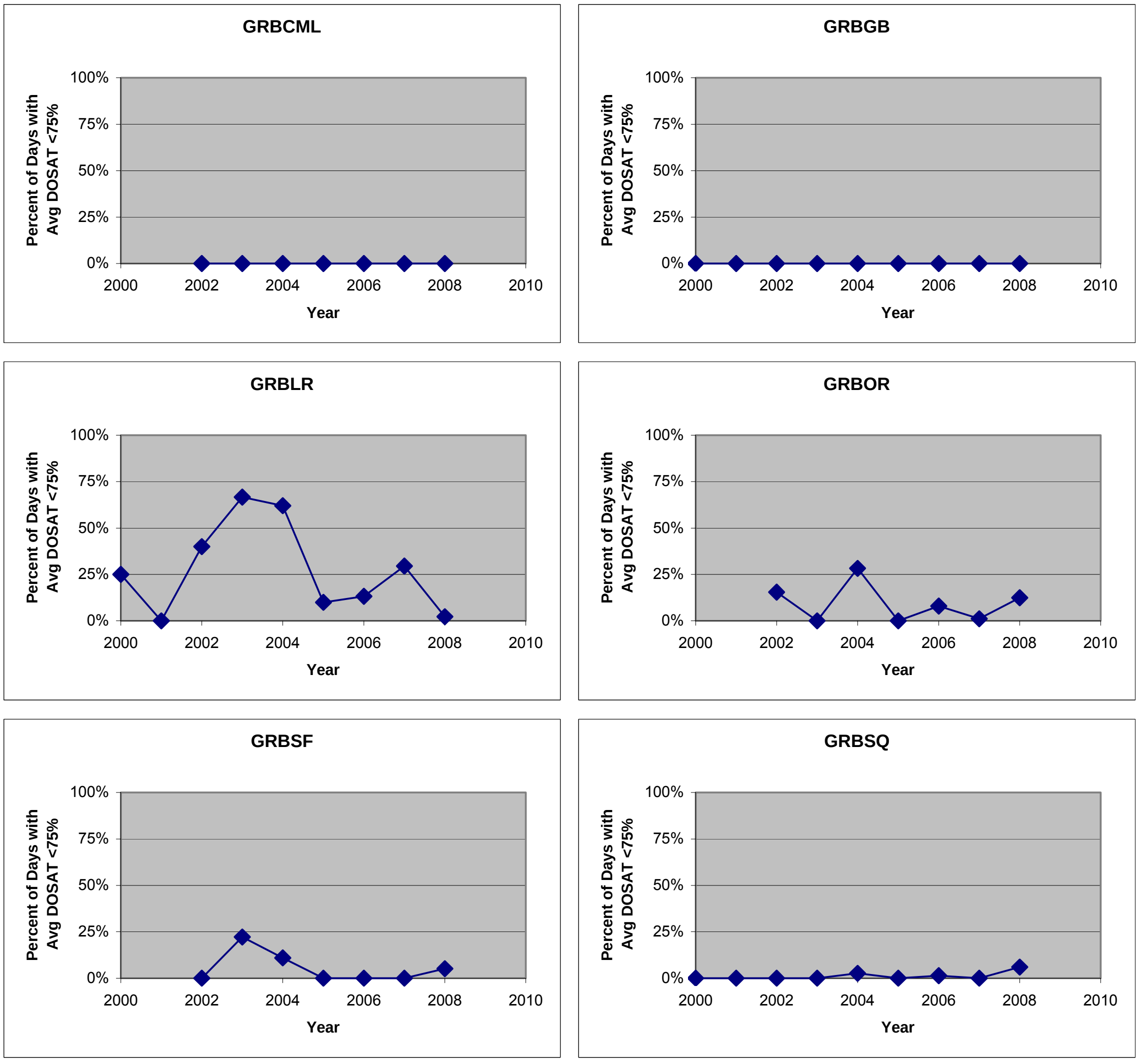
Table NUT6-1 (cont.)

Station	Year	Number of Summer Days with Complete DO Data	Number of Summer Days with Average DOsat <75%	Percent
GRBSQ	2000	8	0	0.0%
GRBSQ	2001	12	0	0.0%
GRBSQ	2002	12	0	0.0%
GRBSQ	2003	10	0	0.0%
GRBSQ	2004	76	2	2.6%
GRBSQ	2005	31	0	0.0%
GRBSQ	2006	71	1	1.4%
GRBSQ	2007	92	0	0.0%
GRBSQ	2008	50	3	6.0%

Note: Summer days are defined as days in the months of July, August, and September.

EXHIBIT 50 (AR K.27)

Figure NUT6-1: Trends in the percent of summer days with daily average dissolved oxygen saturation less than 75% at each datasonde station



GRBCML

GRBGB

GRBLR

GRBOR

GRBSF

GRBSQ

EXHIBIT 50 (AR K.27)

Figure NUT6-2: Median values of the percent of summer days with daily average dissolved oxygen saturation less than 75% at each datasonde station for the periods 2002-2005 and 2006-2008

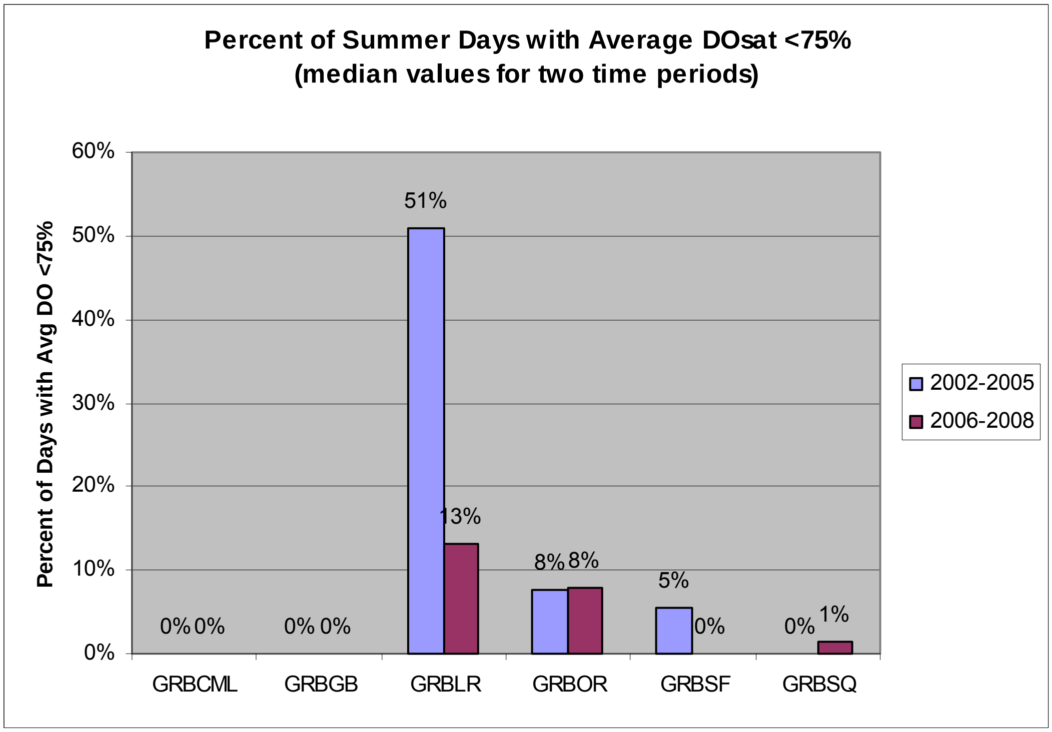


EXHIBIT 50 (AR K.27)

Indicator: NUT7. Trends in Biological Oxygen Demand Loading to Great Bay

PREP Goal: The goal is for no WWTF to have significantly increasing trends in BOD loading.

Why This Is Important: Discharges of organic matter from wastewater treatment facilities to the estuary can cause dissolved oxygen to be depleted. Fish and many other aquatic organisms need dissolved oxygen to survive.

Monitoring Question: Do any surface tidal or freshwaters show a significant change in biological oxygen demand?

Answer: BOD loading has increased for a few of the wastewater treatment facilities that discharge to the estuary. However, the discharge volume has increased for nearly all facilities.

Explanation
The statistically significant trends for flow and BOD loading are shown in Table NUT7-1 and Table NUT7-2, respectively. For nearly all of the WWTFs, flows have increased by approximately 31% over the period of record. The one exception was Kittery WWTF, which has reduced its flow by 10%.

Despite the increasing flows, the BOD load was actually reduced at the Durham, Newfields, Newington WWTFs. BOD loading from the Dover WWTF increased but at a slower rate than flow (Figure NUT7-1). However, at the Newmarket, and South Berwick WWTFs the rate of BOD loading increased faster than flow (Figure NUT7-2 and NUT7-3).

The PREP goal for this indicator is for no WWTF to have statistically significant, increasing trends. This goal is not being met. However, without a water quality model, it is not possible to determine the effect of the increased BOD loads on dissolved oxygen concentrations in the estuary.

Linear trend lines were not shown on these figures because the trends were evaluated using the Seasonal Kendall Test.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

EXHIBIT 50 (AR K.27)

Table NUT7-1: Trends in flow from wastewater treatment facilities discharging to estuarine waters

Facility	Flow (MGD)*	Period of Record	Trend	Percent Change
Dover WWTF	3.11	6/91 to 12/08	Increasing	43%
Durham WWTF	1.01	1/89 to 12/08	No significant trend	
Exeter WWTF	1.95	1/89 to 12/08	Increasing	20%
Kittery WWTF	1.21	1/93 to 12/08	Decreasing	-10%
Newfields WWTF	0.13	7/96 to 12/08	Increasing	14%
Newington WWTF	0.15	9/93 to 12/08	Increasing	10%
Newmarket WWTF	0.65	1/89 to 12/08	Increasing	25%
Pease ITF	0.73	10/00 to 12/08	Increasing	106%
Portsmouth WWTF	5.57	1/89 to 12/08	Increasing	43%
South Berwick WWTF	0.38	1/93 to 12/08	Increasing	63%

** Average for 2006-2008*

Source: NPDES Discharge Monitoring Reports

Table NUT7-2: Trends in biological oxygen demand (BOD) loading from wastewater treatment facilities discharging to estuarine waters

Facility	BOD Load (lb/day)*	Period of Record	Trend	Percent Change
Dover WWTF	312	4/92 to 12/08	Increasing	32%
Durham WWTF	56	8/89 to 12/08	Decreasing	-58%
Exeter WWTF	218	2/89 to 12/08	No significant trend	
Kittery WWTF	105	3/98 to 12/08	No significant trend	
Newfields WWTF	6	7/96 to 12/08	Decreasing	-33%
Newington WWTF	10	9/93 to 12/08	Decreasing	-55%
Newmarket WWTF	116	10/89 to 12/08	Increasing	84%
Pease ITF	48	10/00 to 12/08	Increasing	172%
Portsmouth WWTF	3,483	1/89 to 12/08	No significant trend	
South Berwick WWTF	12	1/98 to 12/08	Increasing	178%

** Average for 2006-2008*

Source: NPDES Discharge Monitoring Reports

EXHIBIT 50 (AR K.27)

Figure NUT7-1: Trend in BOD loading from the Dover WWTF

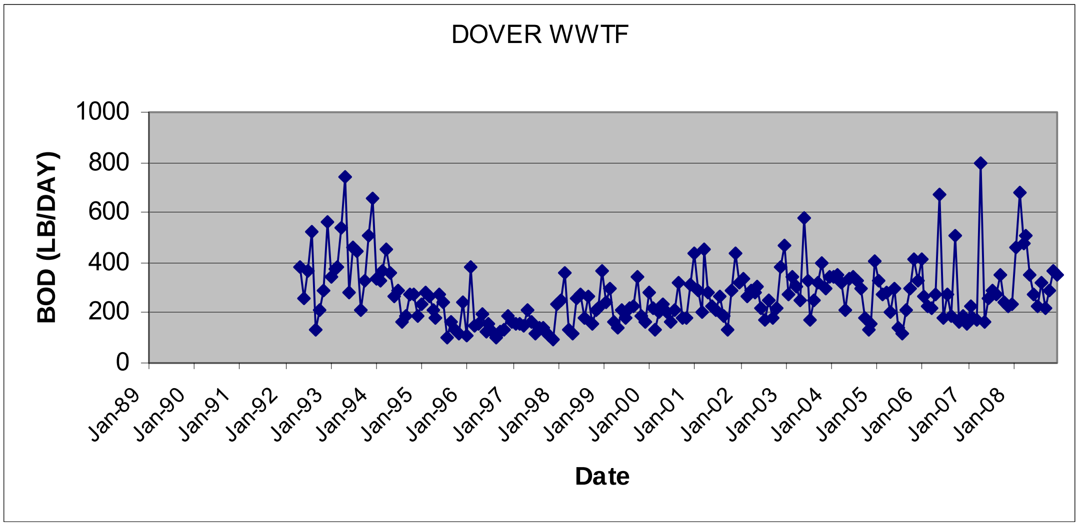


Figure NUT7-2: Trend in BOD loading from the Newmarket WWTF

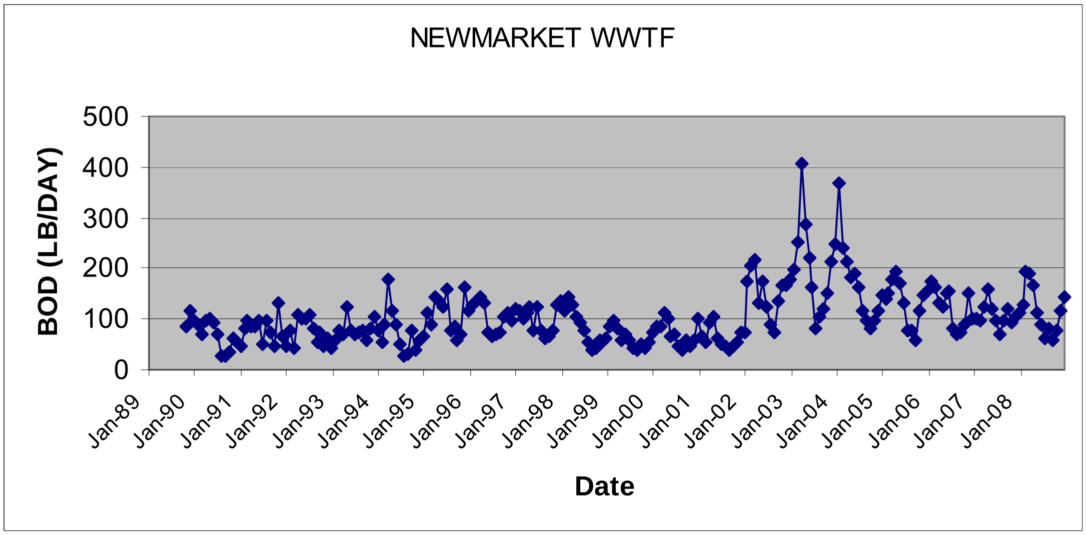


Figure NUT7-3: Trend in BOD loading from the South Berwick WWTF

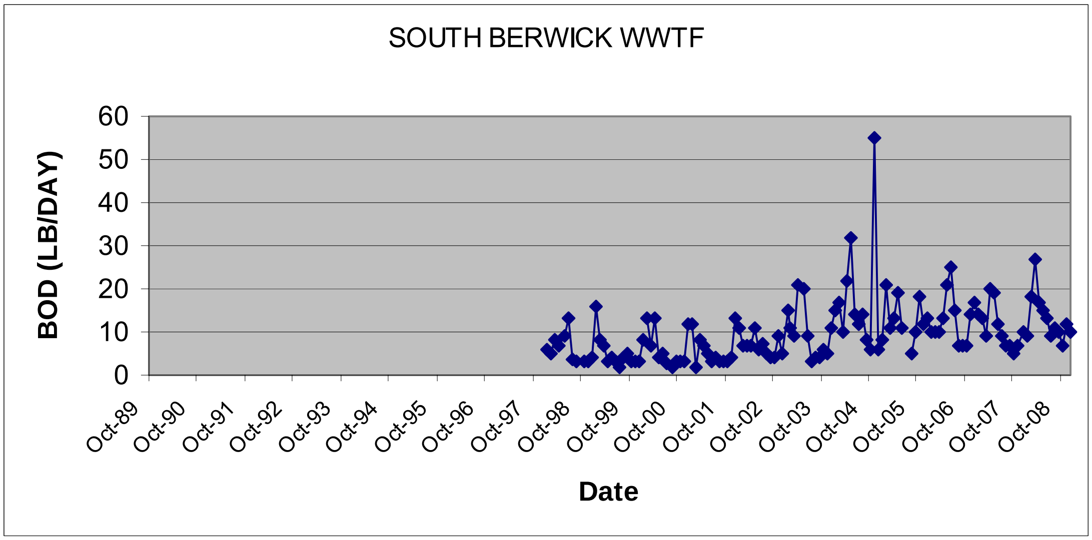


EXHIBIT 50 (AR K.27)

Indicator: NUT8. Percent of the Estuary with Chlorophyll-a Concentrations greater than State Criteria

PREP Goal: The goal for this indicator is for 0% of estuarine waters to be listed in State §305(b) reports as impaired for swimming due to elevated chlorophyll-a concentrations (i.e., >20 ug/L).

Why This Is Important: Chlorophyll-a concentrations are a measure of phytoplankton blooms, which is a measure of eutrophication of the estuary.

Monitoring Question: Do any surface waters exhibit chlorophyll-a levels that do not support swimming standards?

Answer: Chlorophyll-a concentrations are greater than 20 ug/L in a small percentage of the estuary.

Explanation
This indicator is based on results from a probabilistic survey. In effect, a probabilistic monitoring program is a “poll” of water quality the estuary. In a typical public opinion poll, a subset of the population is chosen at random and then asked questions about a topic. The responses of this group are taken to be representative of the overall public opinion within a known margin of error. The same general process was followed for the probabilistic monitoring program in estuaries. Out of the all the possible sampling locations in the estuaries, a subset of stations were chosen randomly. Since the stations were chosen at random, it was assumed that the water quality at the chosen stations was representative of water quality in the entire estuary. A margin of error was assigned when the results were extrapolated to the entire estuary.

The probabilistic survey in 2006-2007 revealed that 98% of the estuarine area was expected to have chlorophyll-a concentrations less than 20 ug/L (Figure NUT8-1). In contrast, 2% of the estuarine area was expected to have concentrations greater than 20 ug/L, which is the threshold that NHDES uses to determine impairments in the estuary. The error bars on the estimate show that the result is not significantly different from zero. Therefore, the goal is currently being met.

The results from the 2002-2003 and 2004-2005 surveys are provided in Table NUT8-1. The results from the three surveys have been consistent.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

Table NUT8-1: Percent of estuarine waters with chlorophyll-a concentrations greater than 20 ug/L

Survey	Chlorophyll-a >20 ug/L	Chlorophyll-a <=20 ug/L	Not Sampled	Error
2002-2003	1.8%	90.8%	7.5%	3.1%
2004-2005	0.5%	99.3%	0.1%	1.6%
2006-2007	2.0%	98.0%	0.0%	3.9%

Figure NUT8-1: Percent of estuarine waters with chlorophyll-a concentrations greater than 20 ug/L

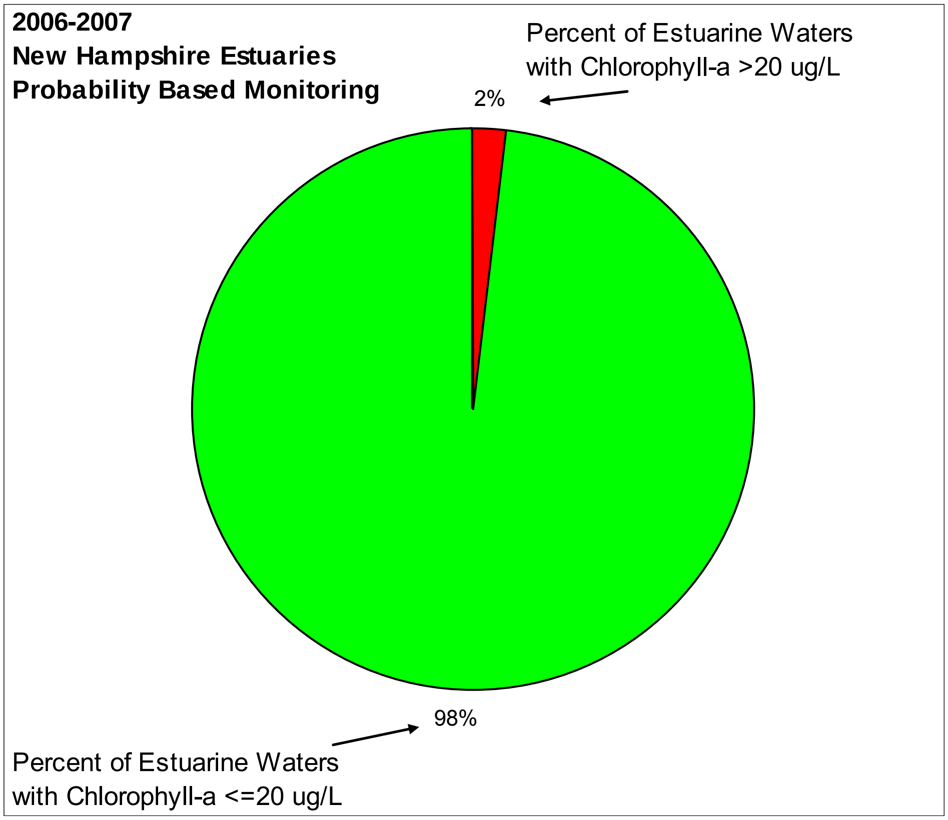


EXHIBIT 50 (AR K.27)

Environmental Indicators

B. Biological Indicators

EXHIBIT 50 (AR K.27)

Indicator: SHL1. Area of Oyster Beds in the Great Bay Estuary

PREP Goal: The goal is for each bed to at least maintain its 1997 area (64.2 acres) as reported in Langan (1997).

Why This Is Important: Oysters are excellent indicators of estuarine condition because they are relatively long-lived, stationary filter feeders that play important roles in nutrient cycling and water clarity. They also provide food and habitat for other species in the estuary. They are economically important because they support valuable recreational fisheries and have potential as an aquacultural species.

Monitoring Question: Has the area of oyster beds in the Great Bay Estuary decreased from the 1997 level?

Answer: No. The total area of oyster beds in the Great Bay Estuary in 2001-2003 was 61 acres, which is not significantly different from the area mapped in 1997.

Explanation
The six main oyster beds in the Great Bay Estuary were mapped in 1997 by Langan (1997). In 2001, New Hampshire Fish and Game (NHF&G) and the University of new Hampshire (UNH), with funding support from PREP, completed a new set of maps for four oyster beds using a method that combined information from acoustic sonar, videography, and diver surveys (NHF&G, 2002). The remaining two oyster beds were mapped by UNH in 2003 using videography techniques (Grizzle, 2004). Table SHL1-1 contains the oyster bed areas as measured in 1997, 2001 and 2003.

The total area of oyster beds in Great Bay has not changed significantly since 1997; therefore the PREP goal is being met. In 1997, the six oyster beds covered 64 acres in total. In 2001 and 2003, the bed areas summed to 61 acres. The difference between these two estimates is less than the uncertainty in either of the values. To estimate the uncertainty, each bed area estimate was assumed to be accurate to +/-10%. The root mean square of the uncertainties in each bed area resulted in errors of +/- 4 acres and +/- 3 acres for the 1997 and 2001/2003 totals, respectively. For individual beds, the size of the Nannie Island and Adams Point beds decreased and increased, respectively. These discrepancies may be the result of changes in the mapping methods or how these beds were defined. In the future, the oyster beds will be mapped using the same methods as were employed in 2001and 2003 for comparability.

The general locations of the six oyster beds that are being tracked by PREP are shown in Figure SHL1-1. Maps of the individual beds, showing the outlines from 1997 compared to the 2001 and 2003 boundaries are provided in Figures SHL1-2 through Figure SHL1-6. The recently mapped Sturgeon Creek bed is not part of this analysis.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

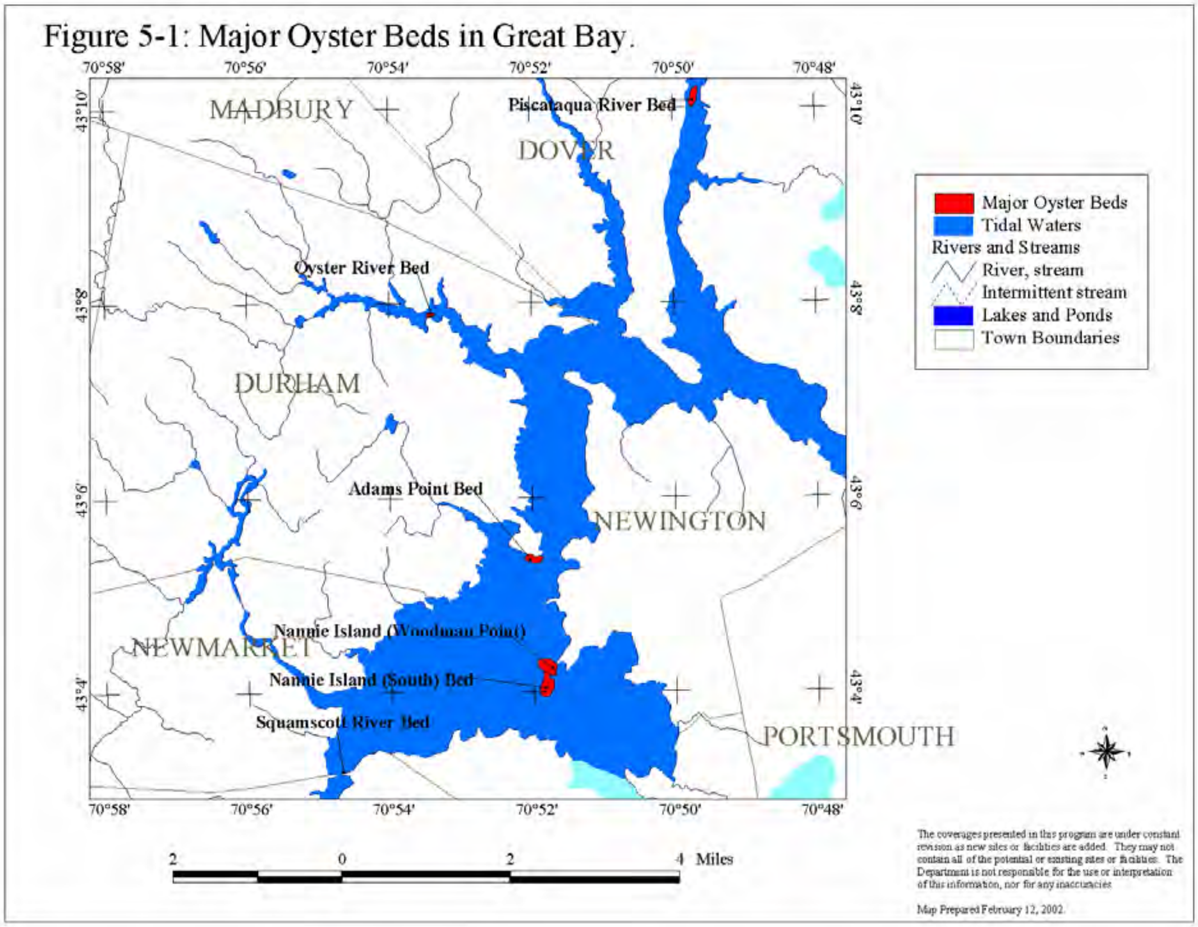
EXHIBIT 50 (AR K.27)

Table SHL1-1: Area (in acres) of the major oyster beds in the Great Bay Estuary

Oyster Bed	Size in 1997[1] (acres)	Size in 2001-3[2] (acres)	Change (acres, %)
Nannie Island	37.3	24.7	12.6, -41%
Woodman Point	6.6	7.3	0.7, 10%
Piscataqua River	12.8	12.5	-0.3, -2%
Adams Point	4.0	13.1	9.1, 106%
Oyster River	1.8	1.7	-0.1, -6%
Squamscott River	1.7	1.9	0.2, 11%
TOTAL	**64 +/- 4**	**61 +/- 3**	**-3, -5%**

1. Areas from Langan (1997)
2. Areas from NHF&G (2002) and Grizzle (2004). For the Piscataqua and Squamscott beds, the area shown is for "high density" oysters (>50% coverage of bottom by oyster shell).

Figure SHL1-1: Major oyster beds in the Great Bay Estuary

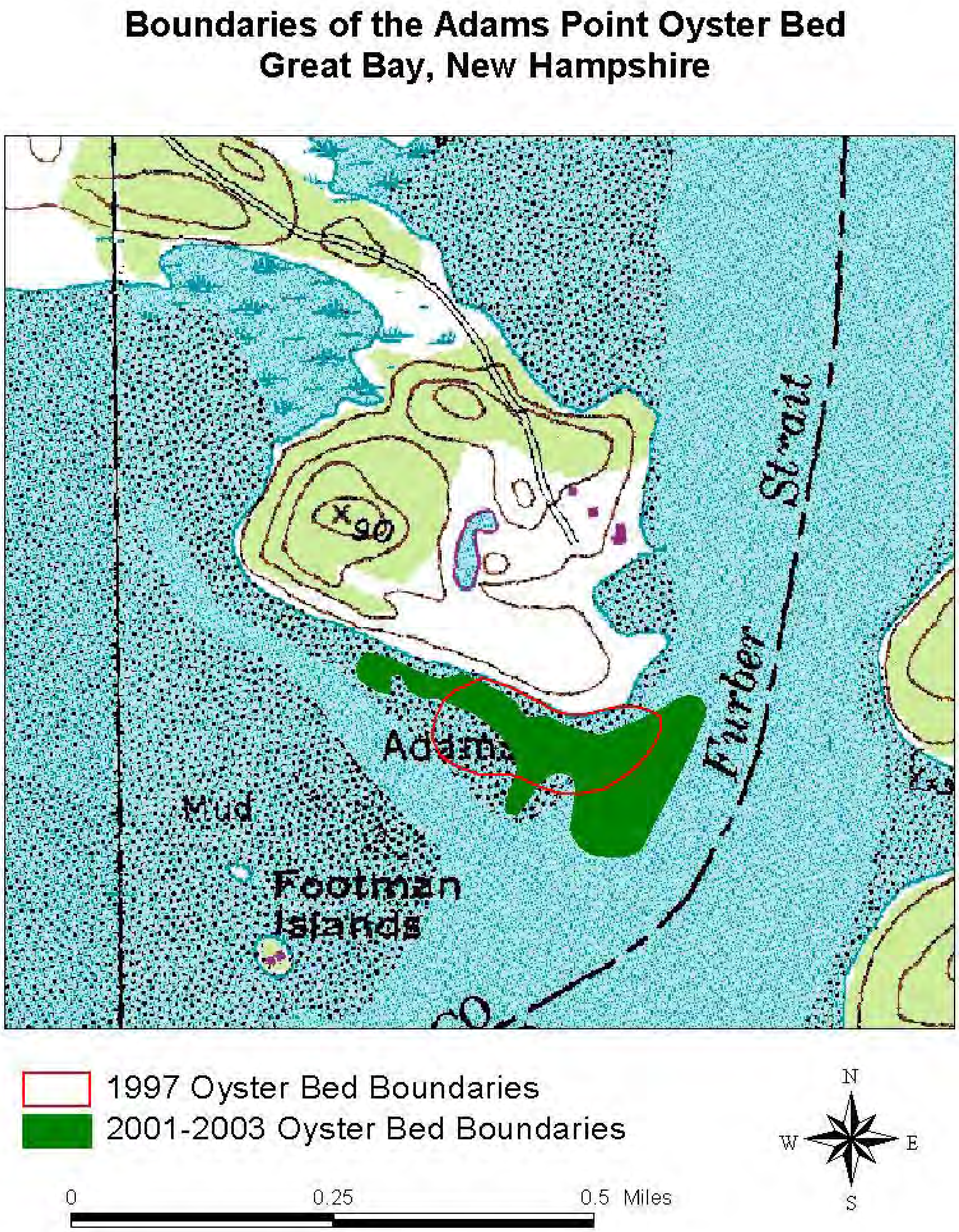


The coverages presented in this program are under constant revision as new sites or facilities are added. They may not contain all of the potential or existing sites or facilities. The Department is not responsible for the use or interpretation of this information, nor for any inaccuracies.

Map Prepared February 12, 2002.

EXHIBIT 50 (AR K.27)

Figure SHL1-2: Boundaries of the Adams Point oyster bed



Boundaries of the Adams Point Oyster Bed
Great Bay, New Hampshire

EXHIBIT 50 (AR K.27)

Figure SHL1-3: Boundaries of the Nannie Island and Woodman Point oyster beds

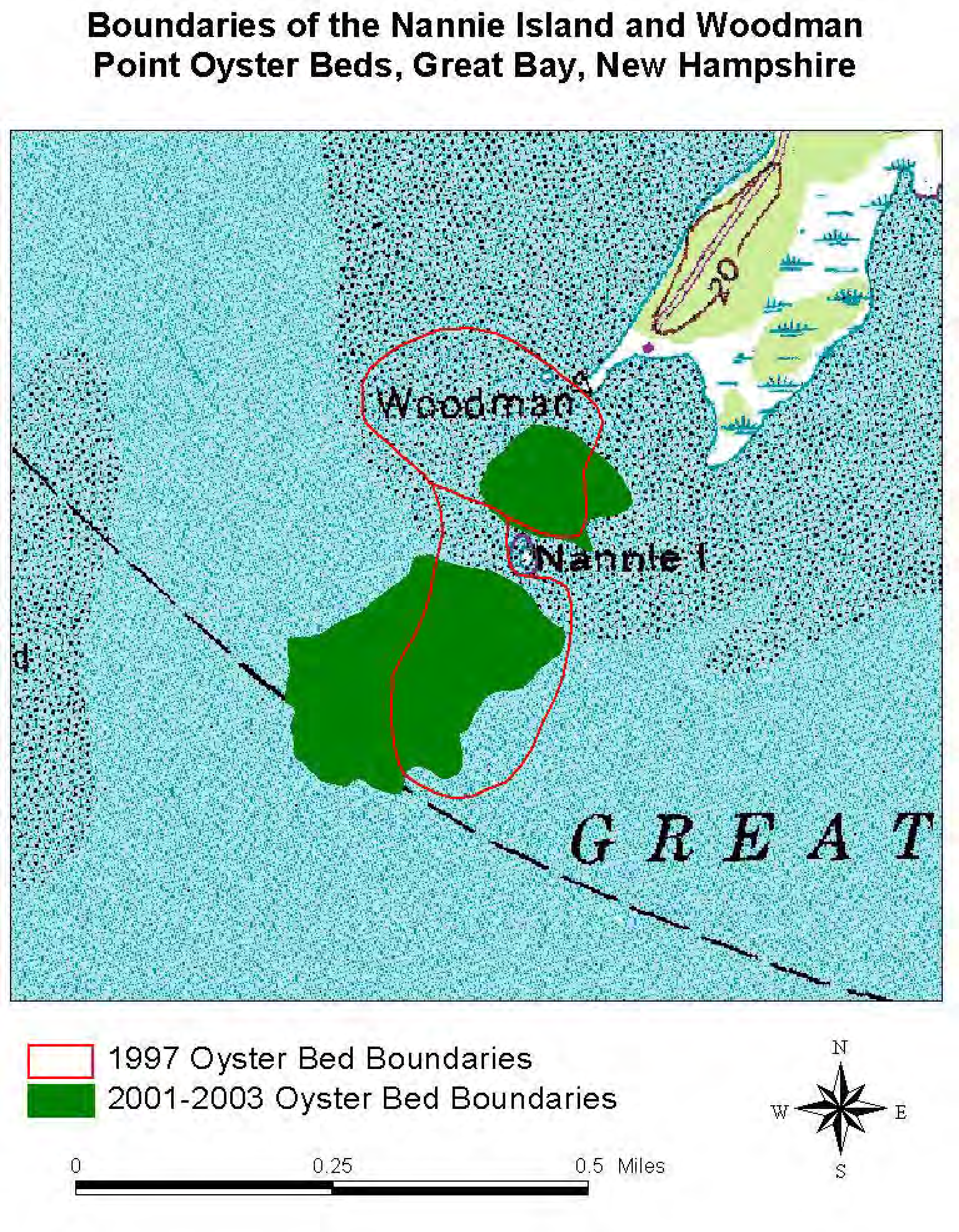


EXHIBIT 50 (AR K.27)

Figure SHL1-4: Boundaries of the Squamscott River oyster bed

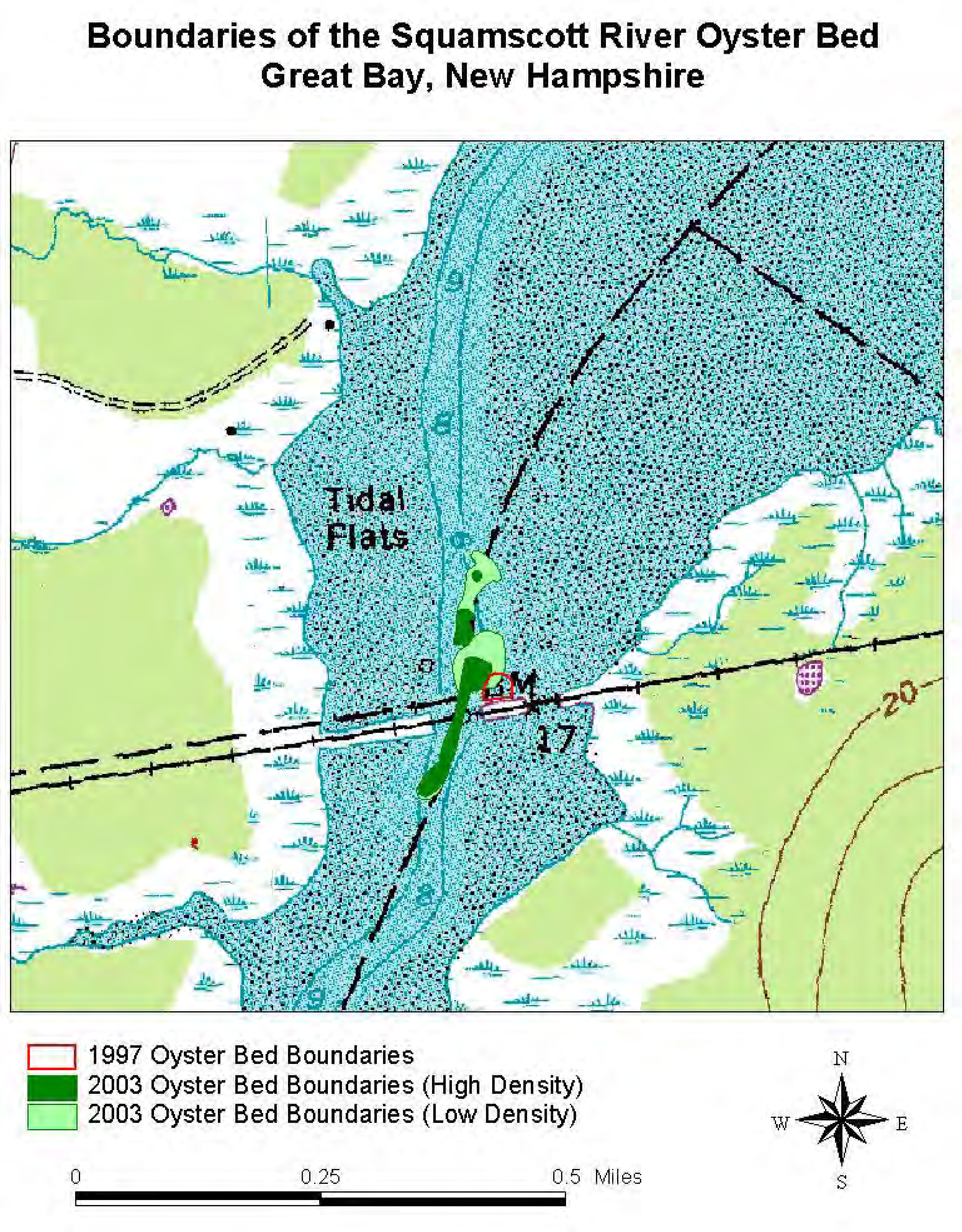


EXHIBIT 50 (AR K.27)

Figure SHL1-5: Boundaries of the Oyster River oyster bed

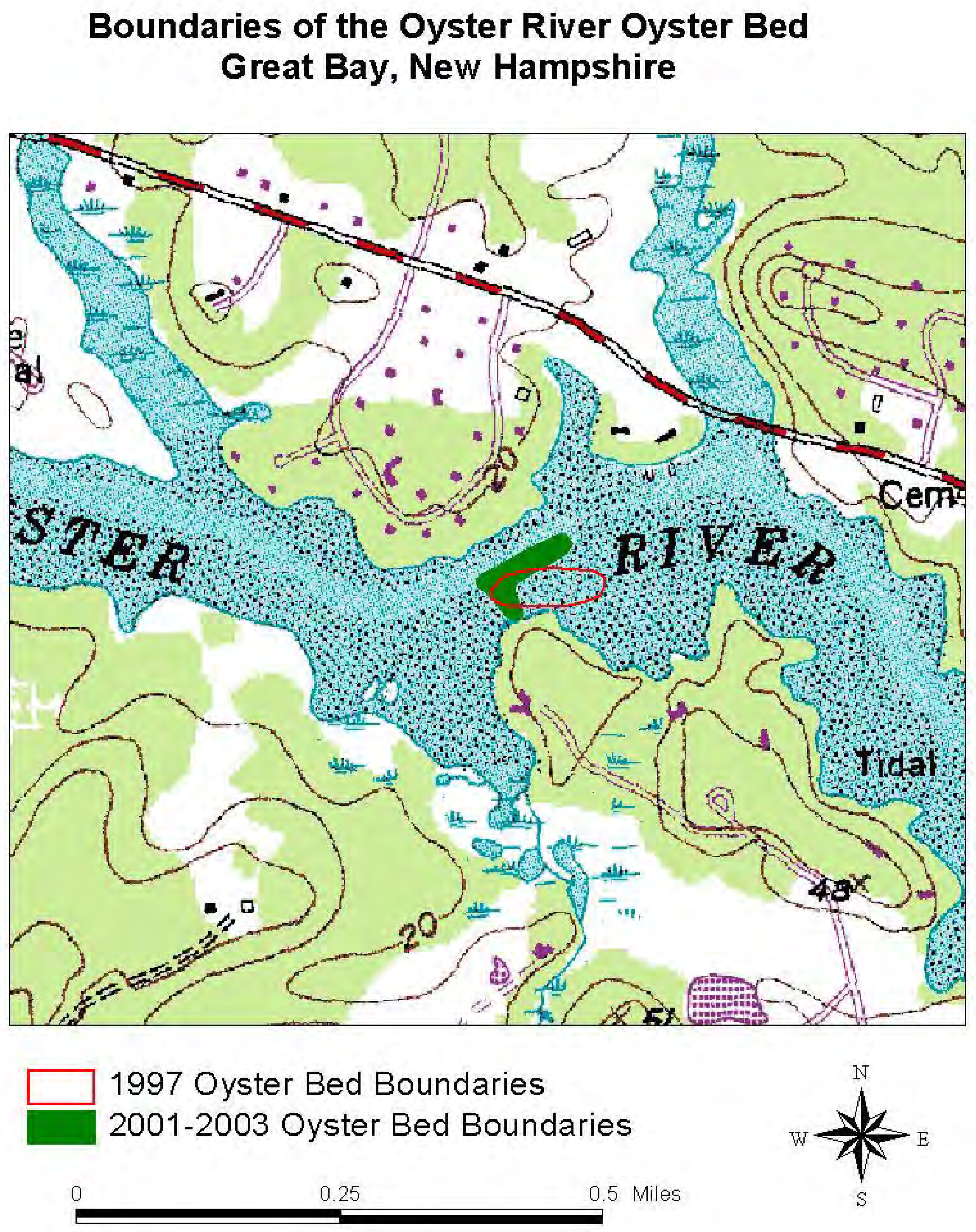


EXHIBIT 50 (AR K.27)

Figure SHL1-6: Boundaries of the Piscataqua River oyster bed

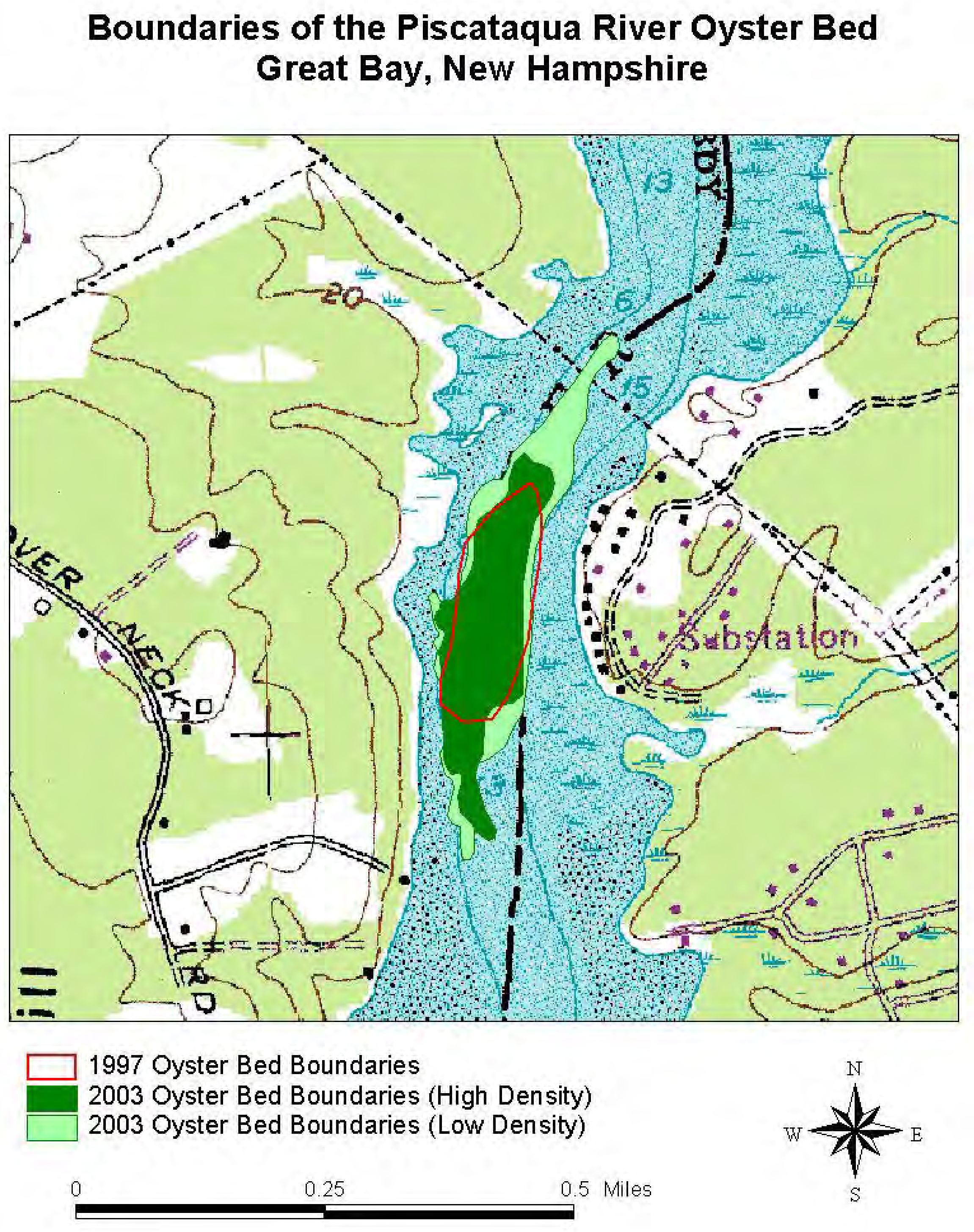


EXHIBIT 50 (AR K.27)

Indicator: SHL2. Density of Harvestable Oysters at Great Bay Estuary Beds

PREP Goal: The goal is for each bed to maintain its 1997 density (for >80mm) as reported in Langan (1997).

Why This Is Important: Oysters are excellent indicators of estuarine condition because they are relatively long-lived, stationary filter feeders that play important roles in nutrient cycling and water clarity. They also provide food and habitat for other species in the estuary. They are economically important because they support valuable recreational fisheries and have potential as an aquacultural species.

Monitoring Question: Has the density of harvestable-size oysters in Great Bay beds decreased from 1997 levels?

Answer: Yes. The density of harvestable size oysters has declined by 80-100% at the largest oyster beds; however, the density has increased significantly at some of the smaller beds in the rivers.

Explanation

Oysters have suffered a significant decline in recent years at most beds but are increasing at the Oyster River and Squamscott River beds. Table SHL2-1 illustrates that densities are well below (80-100 percent) the PREP goal of 1997 levels for the Adams Point, Nannie Island, Woodman Island, and Piscataqua River beds. The cause for the decline largely has been attributed to the protozoan pathogens MSX and Dermo. In contrast, there have been statistically significant increases in harvestable size oyster densities in the Oyster River and the Squamscott River. The mean densities of harvestable oysters from 1993 to 2008 are presented in Figure SHL2-1.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

EXHIBIT 50 (AR K.27)

Table SHL2-1: Average density (in # per m2) of harvestable size oysters at Great Bay beds

Year	Adams Point	Nannie Is.	Oyster River	Piscataqua R	Squamscott R	Woodman Pt
1993	120.0	119.3	109.5			66.4
1995		48.0	46.7			34.3
1996	52.7	67.0	40.8			39.0
1997	38.0	50.0	29.0	20.0		63.0
1998	27.5	28.7	26.0	5.1	9.3	28.7
1999		13.6	10.4	0.0		22.4
2000	5.3	4.8	12.0	1.3		4.0
2001	7.0	13.3	17.6	1.0	8.0	8.6
2002	2.8	3.2	9.6	0.8		6.4
2003	13.6	7.2	10.4	0.8		10.4
2004	7.2	2.7	24.8	0.0		12.0
2005	33.6	4.0	28.8	4.0	161.3	8.8
2006	26.4	0.0	29.6	4.8		29.6
2007	8.8	5.6	40.8	20.0		4.0
2008	7.2	3.2	79.2	0.0	44.0	8.8

Source: NHF&G except 1997 which is from Langan (1997)

1. Green cells are the PREP Management Goals for harvestable oyster density from Langan (1997). The density at the Squamscott River bed was not measured in 1997 so the 1998 value from NHF&G is the goal for this bed.
2. Yellow cells are statistically significant ($p<0.05$) decreases below management goals using a one sample, two-sided t-test.

* Value for Woodman Pt in 1993 is from NHF&G summary reports. Raw data from quadrats were not available for this survey.

Figure SHL2-1: Average density of harvestable size oysters in Great Bay beds

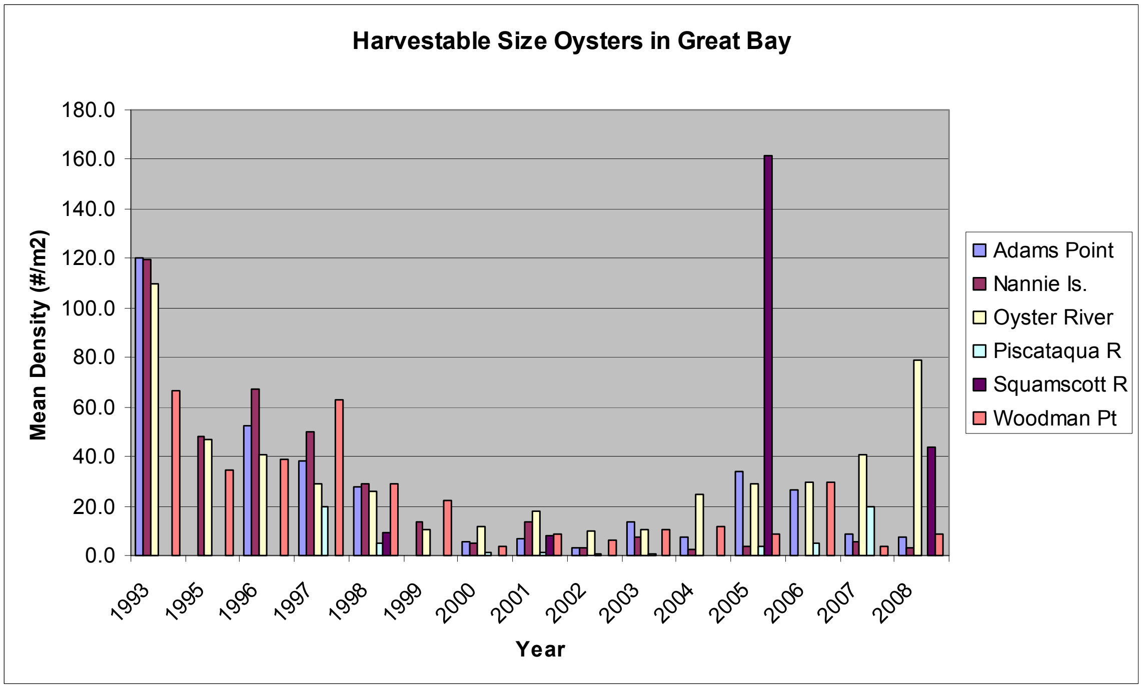


EXHIBIT 50 (AR K.27)

Indicator: SHL3. Density of Harvestable Clams at Hampton-Seabrook Harbor Flats

PREP Goal: The goal is for each flat to at least maintain the 10-year average density for clams of harvestable size (>50mm shell length) that was recorded between 1990 and 1999.

Why This Is Important: Soft shell clams are an important economic, recreational, cultural, and natural resource for the Seacoast region. Recreational shellfishing in Hampton-Seabrook Harbor is estimated to contribute more than $3 million a year to the State economy (NHEP, 2000).

Monitoring Question: Has the density of harvestable-size clams in Hampton-Seabrook Harbor decreased from the historical average?

Answer: Yes. The densities of harvestable size clams are 62% below the PREP goal and 40% below the longer term averages for Hampton-Seabrook Harbor.

Explanation
Table SHL3-1 shows that densities in 2008 were 62% below the PREP goal (10 year average 1990-1999) for all three flats. The 2008 densities were also 40% lower than the longer-term baseline densities recorded between 1974 and 1989.

Table SHL3-1 and Figure SHL3-1 illustrate the trends in harvestable clam populations over the last 30 years. The densities have followed a cyclical pattern with a period of approximately 12 years. For instance, at Common Island, peak densities between 35.5 and 59.9 clams per square meter were observed in 1972, 1983, and 1997. Between these peaks, the harvestable clam density fell to 1-2 clams per square meter. All the flats were closed to harvesting due to bacterial pollution in 1989. The Common Island, Confluence, and Middle Ground flats were reopened in 1994, 1995, and 1998, respectively. The high clam densities in the 1990s occurred during this period. However, densities have decreased since their peak in 1997 even though the harvest from the flats has been relatively low since 1998. The average density grew slightly between 2004 and 2006 and then fell again in 2007 and 2008.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

EXHIBIT 50 (AR K.27)

Table SHL3-1: Yearly average density (in # per m2) of harvestable size clams in Hampton-Seabrook Harbor

Year	Common Island Flat	Confluence Flat	Middle Ground Flat
1971	22.6	40.9	30.1
1972	35.5	15.1	24.8
1973	14.0	11.8	6.5
1974	22.6	14.0	18.3
1975	11.8	5.4	4.3
1976	3.2	1.1	1.1
1977	2.2	1.1	1.1
1978	1.1	2.2	1.1
1979	1.1	2.2	6.5
1980	18.3	23.7	34.4
1981	39.8	9.7	24.8
1982	30.1	9.7	23.7
1983	45.2	58.1	10.8
1984	36.6	18.3	9.7
1985	17.2	5.4	6.5
1986	7.5	3.2	2.2
1987	2.2	1.1	2.2
1988	2.2	1.1	4.3
1989	4.3	1.1	7.5
1990	8.6	1.1	27.9
1991	13.1	2.4	51.9
1992	18.1	5.8	47.2
1993	17.4	3.2	30.9
1994	13.7	4.2	34.1
1995	12.6	16.0	37.1
1996	28.5	38.8	46.3
1997	59.9	19.9	72.9
1998	21.3	10.0	22.5
1999	20.1	8.4	14.8
2000	9.8	18.1	7.7
2001	5.2	9.6	6.0
2002	3.0	5.3	7.5
2003	3.0	4.0	7.0
2004	5.1	2.7	3.9
2005	3.7	3.2	6.0
2006	15.9	6.6	9.0
2007	14.5	3.6	9.3
2008	12.3	4.9	4.9
10-Year Average (1990-1999)	21.3	11.0	38.6
Longer-Term Baseline (1974-1989) ave	15.3	9.8	9.9

Source: Seabrook Station Environmental Monitoring Program

EXHIBIT 50 (AR K.27)

Figure SHL3-1: Average density of harvestable size clams in Hampton-Seabrook Harbor

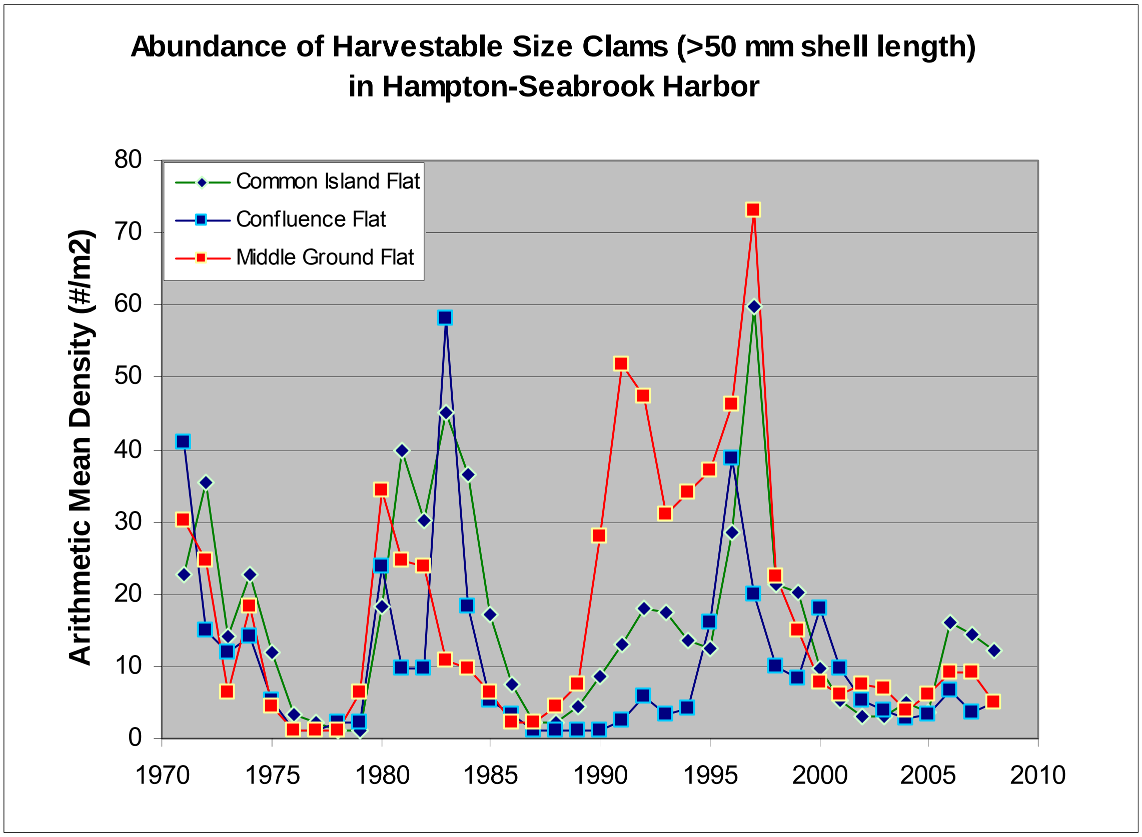


EXHIBIT 50 (AR K.27)

Indicator: SHL4. Area of Clam Flats in Hampton-Seabrook Harbor

PREP Goal: No goal

Why This Is Important: Soft shell clams are an important economic, recreational, cultural, and natural resource for the Seacoast region. Recreational shellfishing in Hampton-Seabrook Harbor is estimated to contribute more than $3 million a year to the State economy (NHEP, 2000).

Monitoring Question: Has the area of clam flats in Hampton-Seabrook Harbor changed over time?

Answer: There is no evidence that significant areas of clam flats have been lost from Hampton-Seabrook Harbor.

Explanation

Table SHL4-1 and Figure SHL4-1 show the acreages of the three major clam flats mapped during 7 surveys. The latest available data on flat areas are from 2002. These data do not indicate any long-term trends in clam flat areas. However, in 2004-2005, the U.S. Army Corps of Engineers completed a large dredging operation in Hampton Harbor. The operation filled in a channel between the Middle Ground flat and Seabrook, reinforced the edge where the Blackwater River passes by the Middle Ground flat and dredged a channel through the northern edge of the Middle Ground flat. It is important to note that sand flats that are exposed during low tide do not guarantee the presence of clams. Clams may colonize only a portion of this habitat.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

Table SHL4-1: Area (in acres) of major clam flats in Hampton-Seabrook Harbor

Year	Common Island Flat	Confluence Flat	Middle Ground Flat	Total
1977	54.9	27.2	49.7	131.8
1979	54.8	26.7	53.5	135.0
1981	54	24.7	50.8	129.5
1983	52.7	26.4	49.9	129.0
1984	50	21.7	47.9	119.6
1995	45.7	26.4	47.3	119.4
2002	36.9	23.4	57.8	118.1

Source: Seabrook Station Environmental Monitoring Program

EXHIBIT 50 (AR K.27)

Figure SHL4-1: Area of clam flats in Hampton-Seabrook Harbor

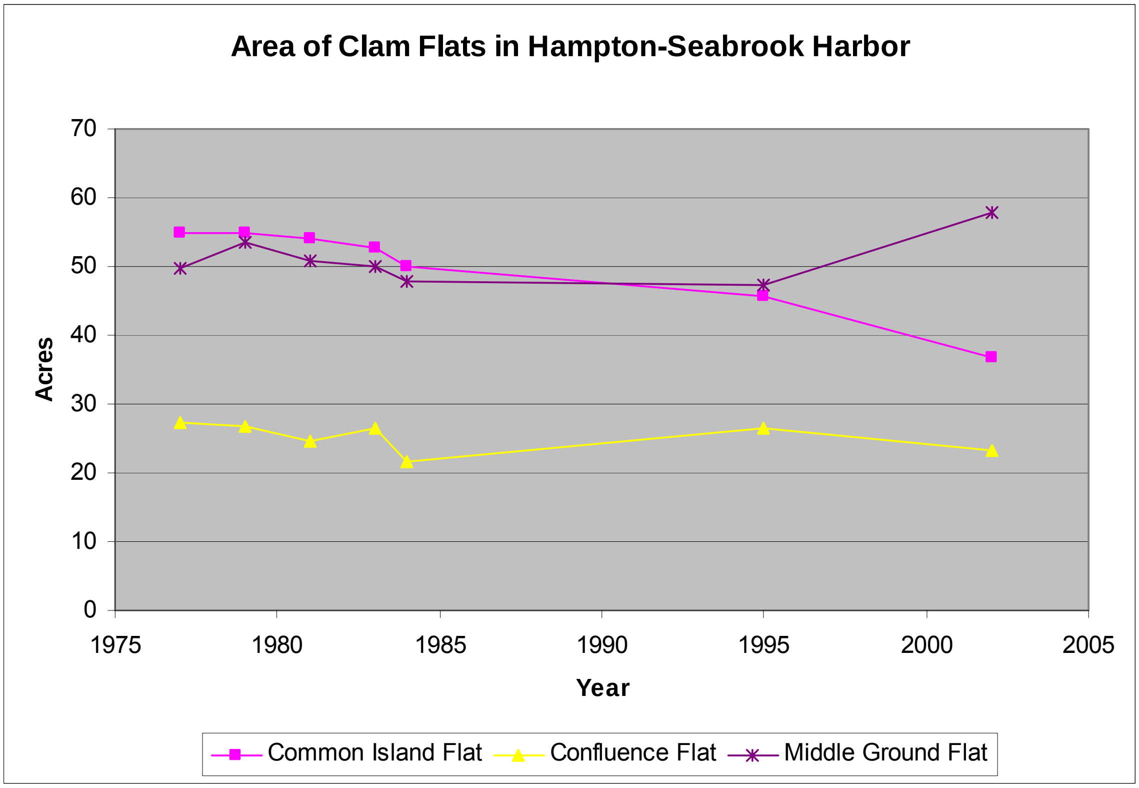


EXHIBIT 50 (AR K.27)

Indicator: SHL5. Standing Stock of Harvestable Oysters in the Great Bay Estuary

PREP Goal: The goal for this indicator is 50,000 bushels of harvestable size oyster in the major beds of the Great Bay Estuary.

Why This Is Important: Oysters are excellent indicators of estuarine condition because they are relatively long-lived, stationary filter feeders that play important roles in nutrient cycling and water clarity. They also provide food and habitat for other species in the estuary. They are economically important because they support valuable recreational fisheries and have potential as an aquacultural species.

Monitoring Question: Has the number of harvestable oysters tripled from 1999 levels to 50,000 bushels?

Answer: No. The standing stock of harvestable size oysters is 20% of the PREP goal of 50,000 bushels.

Explanation

Data from 1993 to 2008 illustrate that the oyster fishery in Great Bay has suffered a considerable decline. The 2008 standing stock of adult oysters (>80 mm) is approximately 20% of the management goal of 50,000 bushels of harvestable oysters. The trends over time for oyster standing stock are shown in Table SHL5-1 and Figure SHL5-1. There was a precipitous fall from over 125,000 bushels in 1993 to 6,174 bushels in 2000. The major cause of this decline is thought to be the protozoan pathogens MSX and Dermo which have caused similar declines in oyster fisheries in the Chesapeake and other mid-Atlantic estuaries.

Since 2000, the adult oyster standing stock has grown slightly to 10,044 bushels with varying trends in the six major beds (Figure SHL5-2). The standing stock of adult oysters in the Nannie Island bed has continued to decline. This bed contained the majority of the oysters in Great Bay in 2000 and earlier, but by 2008 only accounted for 17% of the standing stock. The standing stock in the Squamscott and Oyster River beds has grown slowly between 2000 and 2008. These two beds contained 48% of the standing stock in 2008, compared to 13% in 2000. Harvest is not permitted from the Squamscott and Oyster River beds because of poor water quality. It is possible that the increasing stock in these beds is related to the absence of harvest pressure. The harvestable size oyster populations at Adams Point and Woodman Point beds have fluctuated but have typically represented 35% of the total standing stock. The contribution of the Piscataqua River bed has been variable with large numbers adult oysters in 2007 and none in 2008.

It is expected that the adult oyster populations will increase starting in 2009. In 2006, there was a large oyster spat set (see indicator SHL8). This was followed the next year with another good set. Figure SHL5-3 shows that these spat set have resulted in an increase in the density of juvenile oysters on beds in the Great Bay Estuary. These juvenile oysters may approach the harvestable size (>80 mm) for the 2009 survey. The 2006 spat set is already contributing to increased numbers of spawning oysters greater than 60 mm in size (Figure SHL5-4).

The data sources and methods used for this indicator are described in the PREP Monitoring Plan with the following exceptions:

1. The density of juvenile oysters and the standing stock of oysters >60 mm were added to illustrate the effects of the spatfall in 2006 on oyster spawning stock.

EXHIBIT 50 (AR K.27)

Table SHL5-1: Standing stock (in bushels) of adult oysters (>80 mm) in the Great Bay Estuary

Year	Adams Point	Nannie Island	Oyster River	Piscataqua River	Squamscott River	Woodman Point	Total - open beds	Total - all beds
1993	10,577	98,081	4,341	5,641	350	9,657	118,314	128,646
1995	7,609	39,451	1,851	5,641	350	4,986	52,047	59,889
1996	4,642	55,068	1,618	5,641	350	5,672	65,382	72,990
1997	3,349	41,095	1,150	5,641	350	9,162	53,607	60,748
1998	2,424	23,622	1,031	1,451	350	4,169	30,215	33,046
1999	1,447	11,178	412	0	325	3,258	15,883	16,620
2000	470	3,945	476	376	325	582	4,997	6,174
2001	2,021	7,257	659	282	300	1,379	10,656	11,897
2002	808	1,742	360	226	3,172	1,029	3,579	7,336
2003	3,926	3,919	390	220	3,545	1,673	9,517	13,672
2004	2,078	1,451	929	0	3,545	1,930	5,460	9,934
2005	9,699	2,177	1,079	1,102	6,754	1,416	13,292	22,227
2006	7,621	0	1,109	1,322	4,298	4,761	12,382	19,111
2007	2,540	3,048	1,528	5,509	4,298	643	6,231	17,567
2008	2,078	1,742	2,967	0	1,842	1,416	5,236	10,044

Sources: Langan (1997) for 1997 values and NHF&G for all other years.

Most of the values on this table are approximate because the oyster density and oyster bed boundary were not measured in the same year. In 1997, the density and boundary were mapped by Langan (1997) for all the beds except for the Squamscott River bed. In 2001, the density and boundary were mapped for the Adams Point, Nannie Island, Oyster River, and Woodman Point beds. In 2003, only the boundaries were mapped for the Piscataqua River and Squamscott River beds. Boundaries from 1997 were used up until the year that the beds were remapped (2003 for the Squamscott and Piscataqua beds and 2001 for all others). This simplification requires the assumption that the bed sizes have not changed over 4-6 years, which may not be justified. Area estimates from 2001 (and 2003 for Squamscott and Piscataqua beds) were used to estimate the standing stock in 2001 through 2008. The average harvestable oyster density for Woodman Point in 1993 was taken from NHF&G reports because raw data were not available to calculate this value independently.

Yellow cells indicate that an assumption regarding the density of oysters was needed to calculate the standing stock because density measurements were not taken at that bed in that year. Either the closest standing stock calculation from another year or an average of two bracketing standing stocks was used.

Open beds include Adams Point, Nannie Island, and Woodman Point. Closed beds are: Oyster River, Piscataqua River, and Squamscott River.

EXHIBIT 50 (AR K.27)

Figure SHL5-1: Standing stock of adult oysters (>80 mm) in the Great Bay Estuary

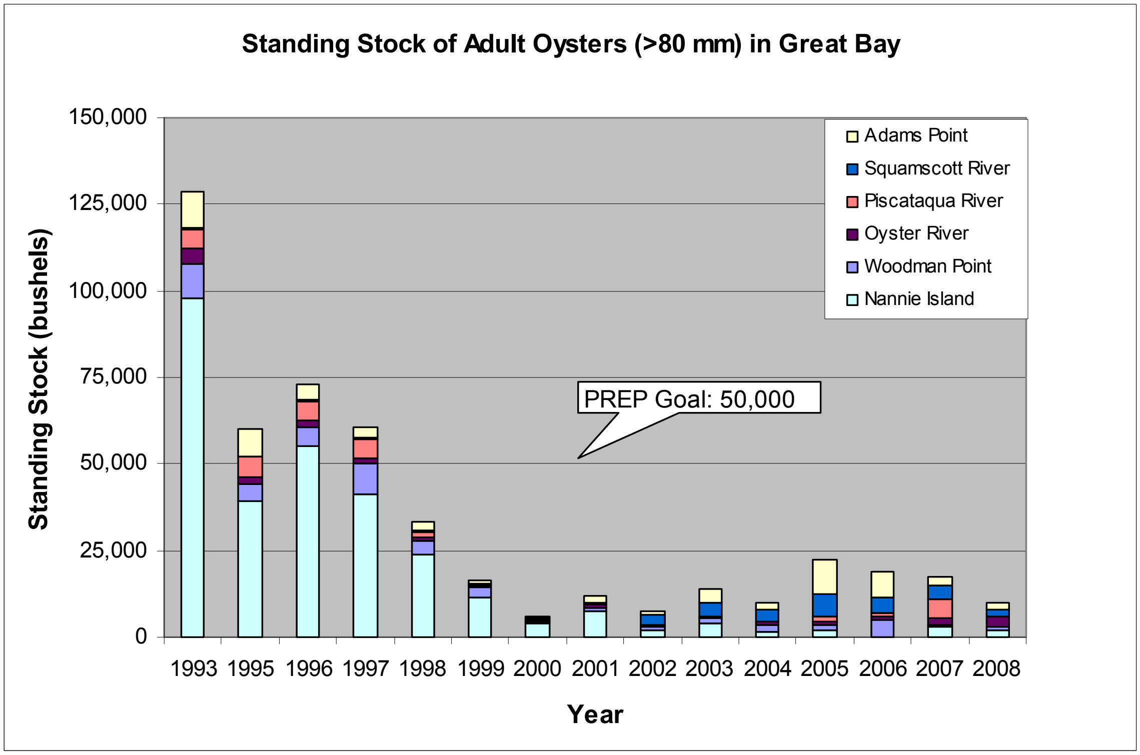


Figure SHL5-2: Standing stock of adult oysters (>80 mm) in the Great Bay Estuary since 2000

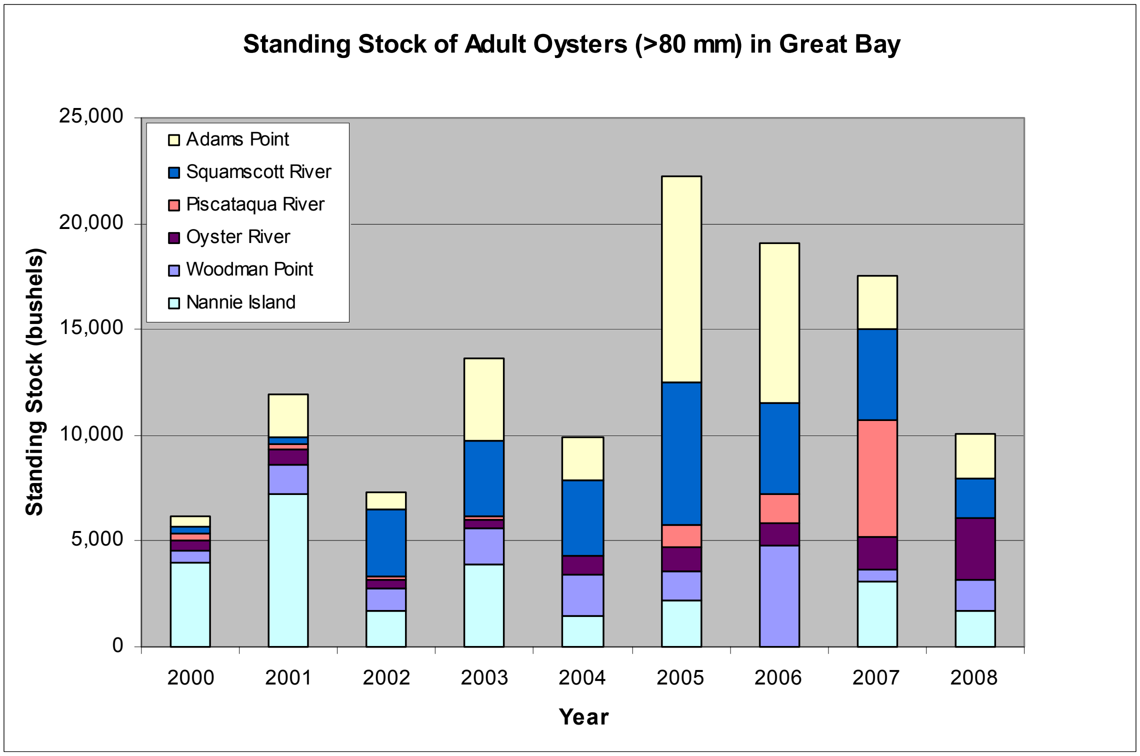


EXHIBIT 50 (AR K.27)

Figure SHL5-3: Density of juvenile oysters (20-80 mm) in the Great Bay Estuary

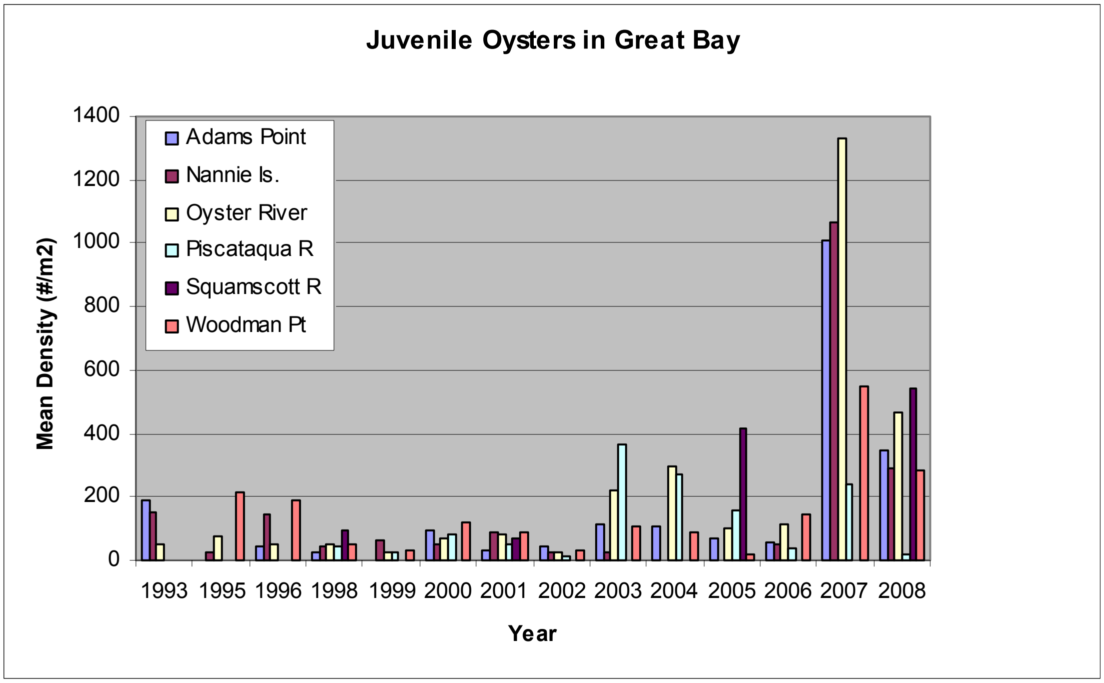


Figure SHL5-4: Standing stock of spawning oysters (>60 mm) in the Great Bay Estuary

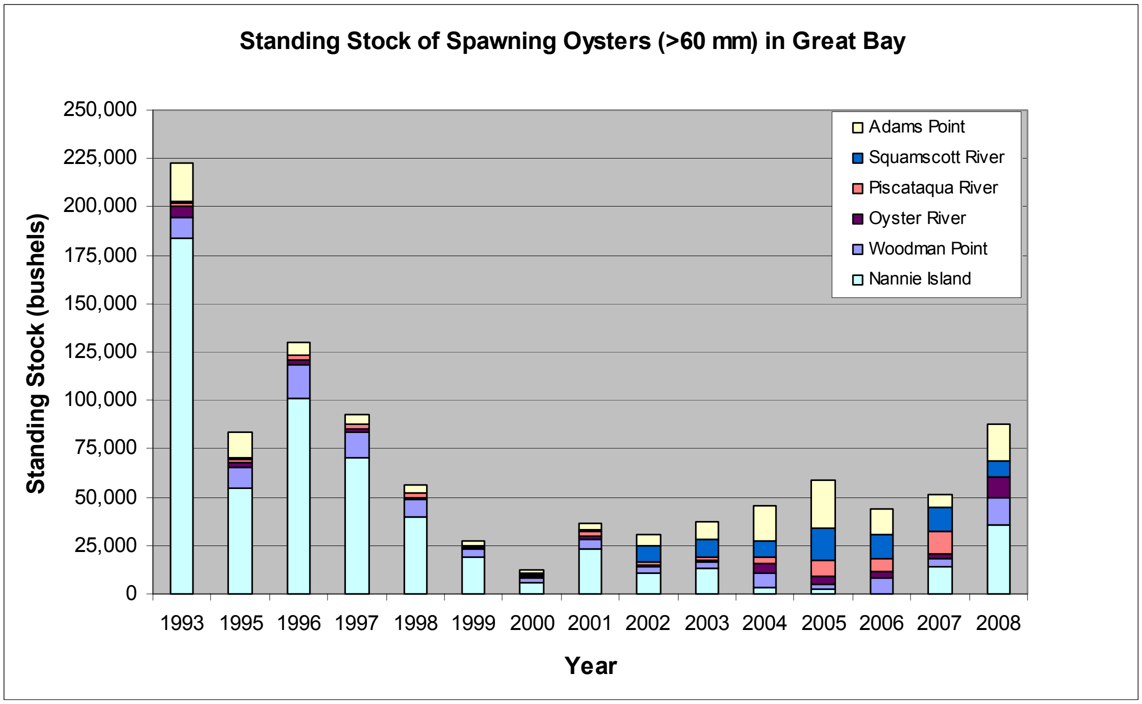


EXHIBIT 50 (AR K.27)

Indicator: SHL6. Standing Stock of Harvestable Clams in Hampton-Seabrook Harbor

PREP Goal: The goal for this indicator is 8,500 bushels of harvestable size clams in Hampton-Seabrook Harbor.

Why This Is Important: Soft shell clams are an important economic, recreational, cultural, and natural resource for the Seacoast region. Recreational shellfishing in Hampton-Seabrook Harbor is estimated to contribute more than $3 million a year to the State economy (NHEP, 2000).

Monitoring Question: Has the number of harvestable clams tripled from 1999 levels to 8,500 bushels?

Answer: No. The standing stock of clams in Hampton-Seabrook Harbor in 2008 was 5,432 bushels (64% of the goal).

Explanation
Table SHL6-1 and Figure SHL6-1 show the history of harvestable clam standing stock over the past 36 years. The standing stock has undergone several 12-15 year cycles of growth and decline. Peak standing stocks of approximately 23,000, 13,000, and 27,000 bushels occurred in 1967, 1983, and 1997, respectively. Between the peaks, there have been crashes of the fishery in 1978 and 1987, with standing stock less than 1,000 bushels. From 1997 to 2004, the standing stock dropped once again to 2,600 bushels. In the last three years, however, the population has rebounded to 5,432 bushes (64% of the goal).

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

EXHIBIT 50 (AR K.27)

Table SHL6-1: Standing stock of harvestable size clams in Hampton-Seabrook Harbor

Year	Standing Stock (bushels)
1967	23,400
1968	no data
1969	15,840
1970	no data
1971	13,020
1972	8,920
1973	6,310
1974	8,690
1975	4,945
1976	1,350
1977	1,060
1978	940
1979	1,400
1980	8,890
1981	12,400
1982	9,200
1983	13,019
1984	8,821
1985	4,615
1986	2,793
1987	976
1988	1,137
1989	2,295
1990	6,752
1991	8,462
1992	14,942
1993	12,161
1994	13,440
1995	11,701
1996	16,001
1997	26,606
1998	11,992
1999	11,756
2000	8,765
2001	5,539
2002	3,688
2003	3,276
2004	2,634
2005	2,669
2006	6,188
2007	6,519
2008	5,432

Figure SHL6-1: Standing stock of harvestable size clams in Hampton-Seabrook Harbor

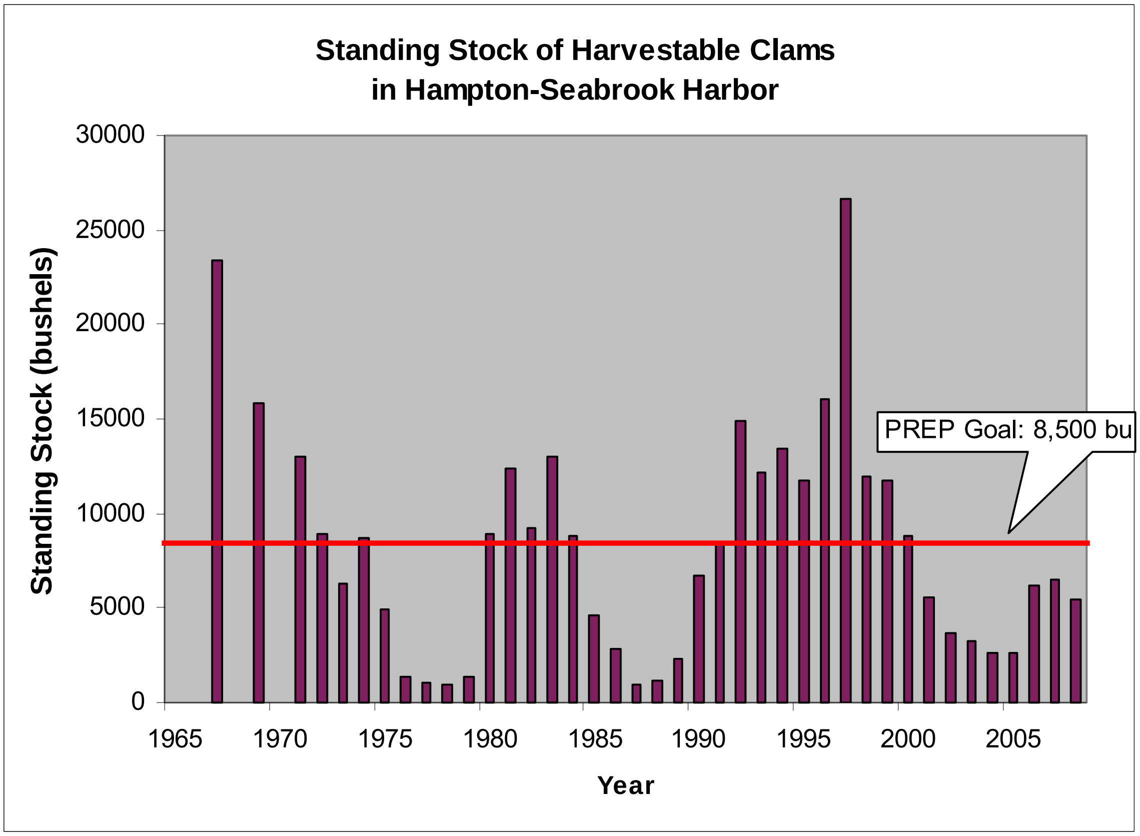


EXHIBIT 50 (AR K.27)

Indicator: SHL7. Abundance of Shellfish Predators

PREP Goal: No goal

Why This Is Important: Beal (2006) determined that predation by green crabs is a major factor limiting the population of harvestable size clams in Hampton-Seabrook Harbor.

Monitoring Question: Are NH shellfish healthy, growing, and reproducing at sustainable levels?

Answer: There are no statistically significant trends in green crab populations in Hampton-Seabrook Harbor but fluctuations in this population appear to influence juvenile clam populations.

Explanation
The green crab is an invasive species which was introduced from Europe and currently exists along the Atlantic coast from Nova Scotia to Delaware. Time series data on green crab abundance in Hampton-Seabrook Harbor are shown in Figure SHL7-1. There is no statistically significant trend in the abundance values over time. Green crabs prey on juvenile clams. Figure SHL7-2 shows that juvenile clam populations are low during years with high crab abundance and rebound when the crab abundance drops. Therefore, predation by green crabs may limit the abundance of adult clams.

The New Hampshire Coastal Program is funding research on the potential predatory impact that green crabs have on shellfish populations in both the Hampton-Seabrook Estuary and the Great Bay Estuary.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

EXHIBIT 50 (AR K.27)

Figure SHL7-1: Green crab abundance in Hampton-Seabrook Harbor

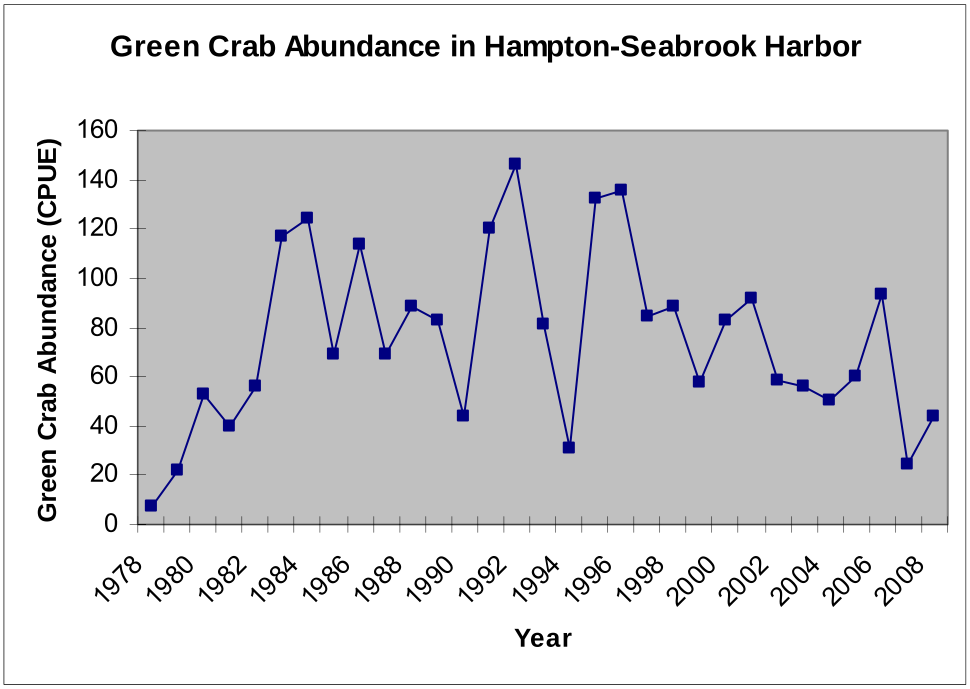


Figure SHL7-2: Green crab and juvenile clam abundance in Hampton-Seabrook Harbor

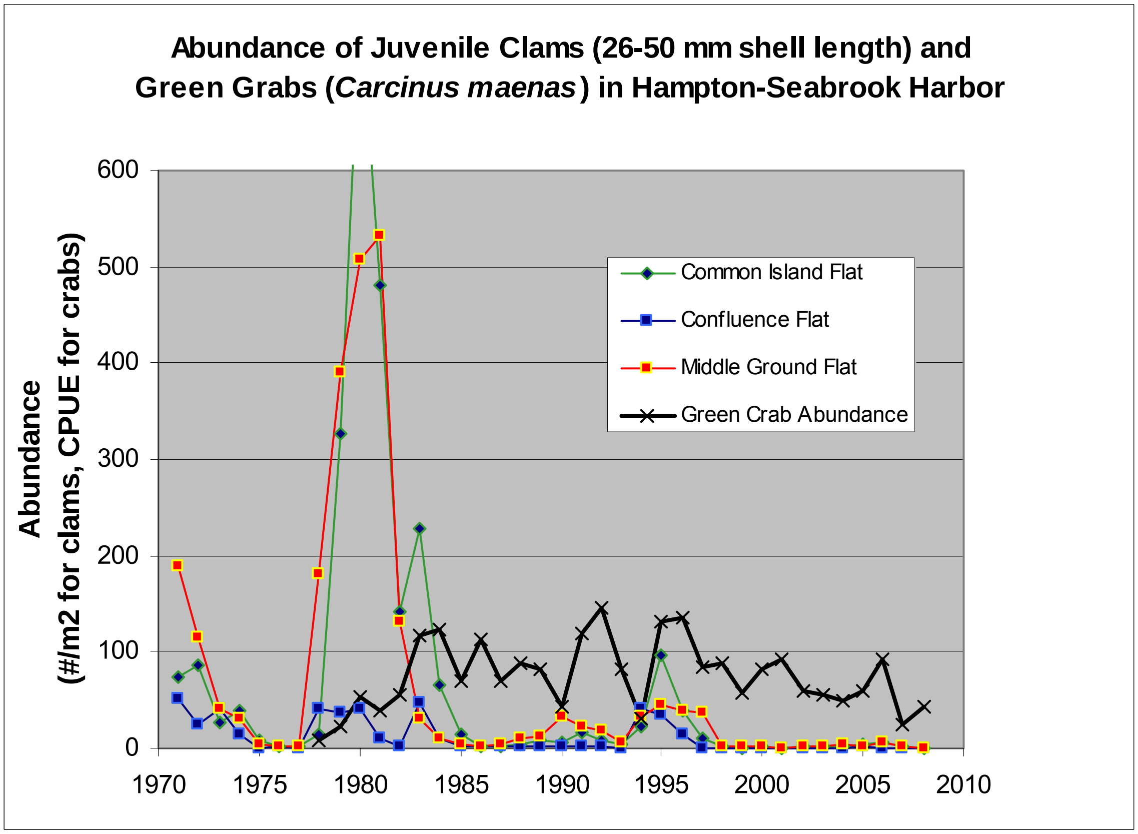


EXHIBIT 50 (AR K.27)

Indicator: SHL8. Clam and Oyster Spatfall

PREP Goal: No goal

Why This Is Important: Spat populations are a good indicator of shellfish recruitment and a harbinger of future harvestable size clams and oysters.

Monitoring Question: Are NH shellfish healthy, growing, and reproducing at sustainable levels?

Answer: Spatfall for clams and oysters has been variable, with good sets in recent years for both species.

Explanation
Figure SHL8-1 shows that there was a very large oyster spat set at almost all of the Great Bay Estuary oyster beds in 2006. The last significant spat set before 2006 in was in 2002; however, the spat density during this year was much lower than in 2006. The spat set in 2007 was above average but, in 2008 there was very little spat. Indicator SHL5 shows that the 2006 year class has matured into juveniles and will likely approach harvestable size (>80 mm) in 2009.

Figure SHL8-2 illustrates that clam spatfall has fluctuated on approximately four year intervals over the past 30 years. Very large spatfalls occurred in the late 1970s and early 1980s. After an unusually low spatfall in 2006, the spatfall in 2008 rebounded to one of the highest on record.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

EXHIBIT 50 (AR K.27)

Figure SHL8-1: Average oyster spat density in the Great Bay Estuary

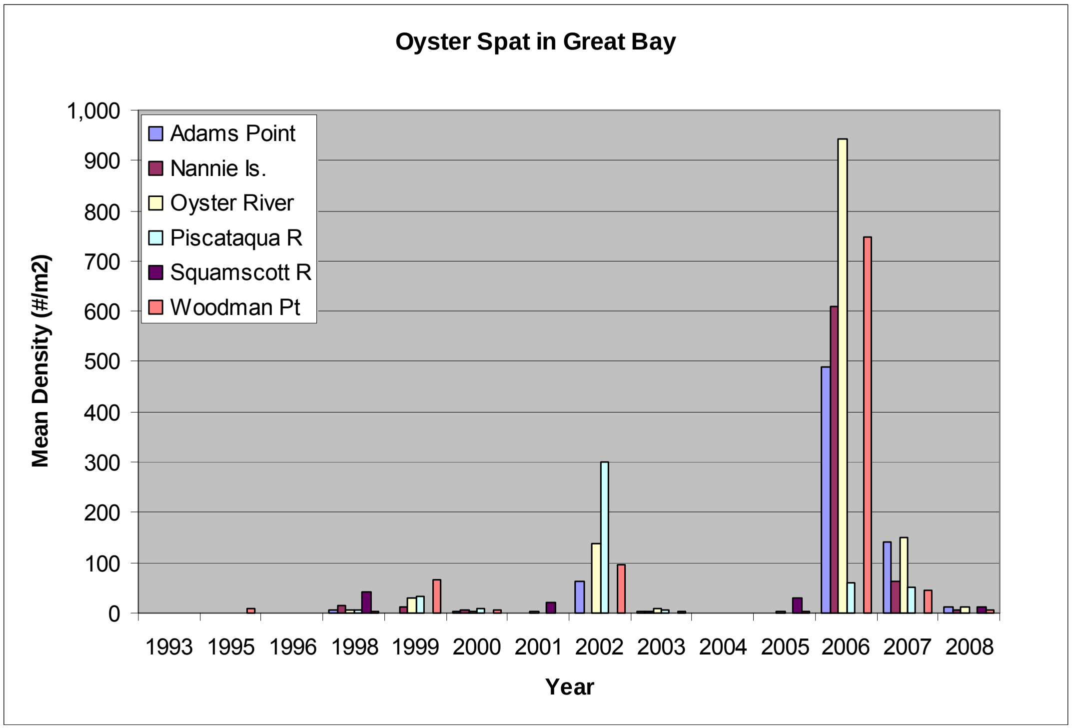


Figure SHL8-2: Average clam spat density in Hampton-Seabrook Harbor

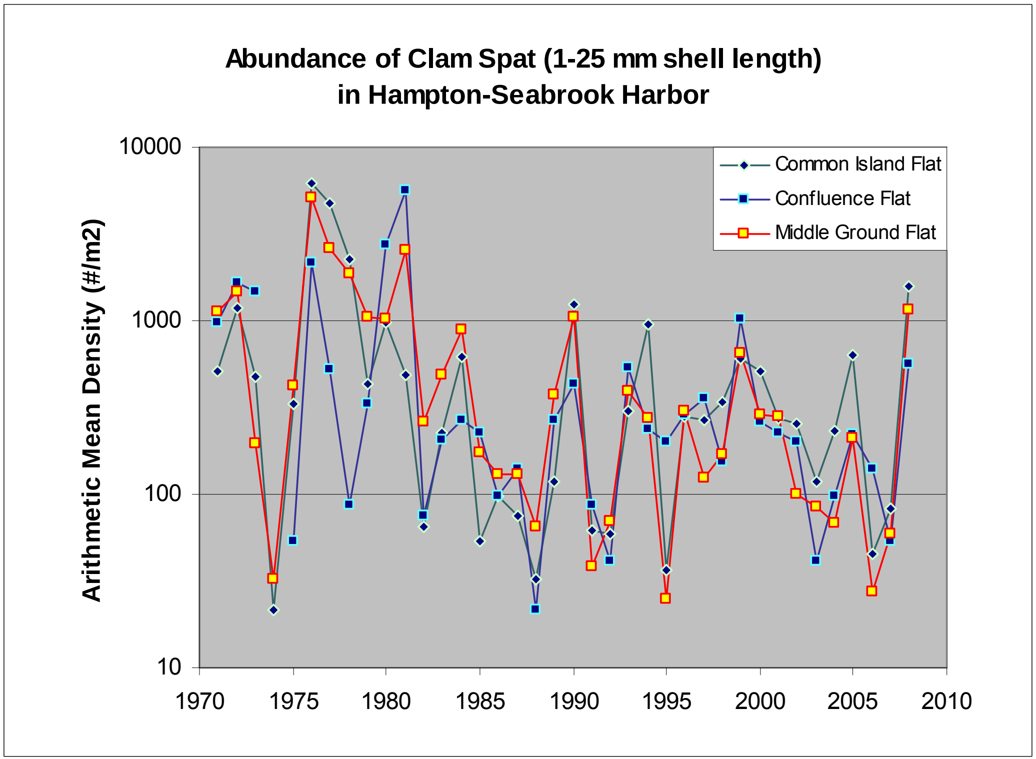


EXHIBIT 50 (AR K.27)

Indicator: SHL9. Recreational Harvest of Oysters

PREP Goal: No goal

Why This Is Important: The recreational harvest of oysters is one factor that can limit the oyster population and prevent attainment of the PREP goal of 50,000 bushels of harvestable size oysters.

Monitoring Question: Are NH shellfish being harvested at sustainable levels?

Answer: Yes. The harvest pressure on oysters in Great Bay is low and has been declining for 25 years.

Explanation
In Table SHL9-1, the historical record of recreational harvest license sales has been combined with the available estimates of oyster harvest. For the years when estimates of oyster harvest were made, the results have been compared to oyster standing stock estimates from indicator SHL-5.

The limited available data indicate a progressive decline in license sales and a proportional decline in total harvest. License sales fell 90% between 1981 and 2008 (Figure SHL9-1). In 1996, the total harvest amounted to approximately 4% of the standing stock. Only 221 oyster harvesting licenses were sold in 2008. The declining trend in license sales is assumed to reflect declining harvest as well. However, there is no recent information on actual harvest to confirm this assumption.

In 2008, the New Hampshire Fish and Game Department reduced the daily limit for recreational harvest of oysters from one bushel to one-half bushel.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

EXHIBIT 50 (AR K.27)

Table SHL9-1: Recreational oyster harvest license sales and harvest estimates

Year	License Sales*	Harvest (bushels)	Standing Stock (bu)	Harvest as a Percent of Standing Stock
1975	1532			
1976	1460			
1977	1479			
1978	1440			
1979	1553			
1980	1961			
1981	2109			
1982	1522			
1983	1426			
1984	1373			
1985	1582			
1986	1358			
1987	1285			
1988	1157			
1989	992	>4,000	128,646 (1)	3.1%
1990	932			
1991	1001			
1992	907			
1993	847			
1994	1009			
1995	971			
1996	661	2,727	72,990 (2)	3.7%
1997	582			
1998	579			
1999	545			
2000	506			
2001	406			
2002	344			
2003	253			
2004	262			
2005	270			
2006	293			
2007	325			
2008	221			

Source: Oyster harvest license sales provided by NHF&G

(1) Using earliest standing stock estimate (1993) from indicator SHL-5 to represent the "late 1980s". Harvest estimate is from Manalo et al. (1991).
(2) Using standing stock estimate for 1996 from indicator SHL-5. Harvest estimate is from NHF&G (1997).

EXHIBIT 50 (AR K.27)

Figure SHL9-1: Recreational oyster harvest license sales

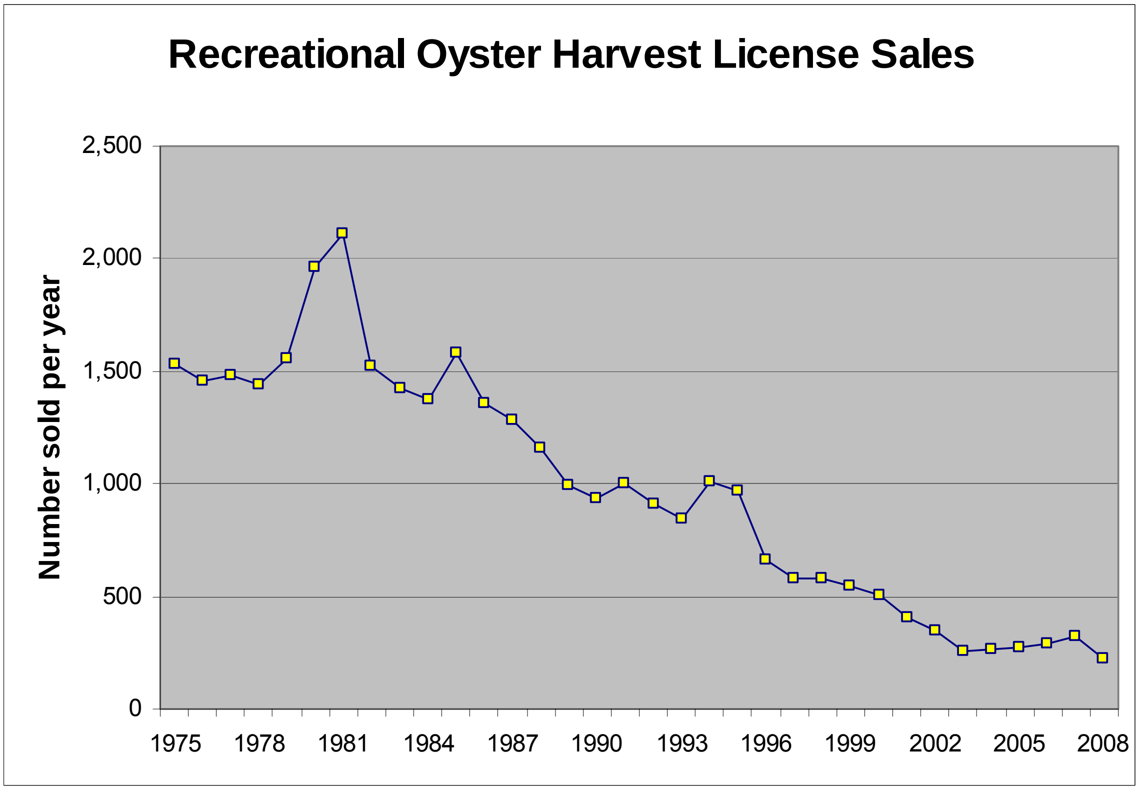


EXHIBIT 50 (AR K.27)

Indicator: SHL10. Recreational Harvest of Clams

PREP Goal: No goal

Why This Is Important: The recreational harvest of clams is one factor that can limit the clam population and prevent attainment of the PREP goal of 8,500 bushels of harvestable size clams.

Monitoring Question: Are NH shellfish being harvested at sustainable levels?

Answer: In the past, recreational clam harvest appears to have limited the clam populations. Under the current level of harvest pressure, clam populations have increased.

Explanation
Figure SHL10-1 shows that clam harvest license sales have ranged from peak values >9,000 in 1975 and 1981 to <320 in 1990-1993. The oscillations in license sales generally follow similar patterns in the clam standing stock (Figure SHL10-2). This relationship indicates that recreational clam harvesting has been high enough to limit clam populations. For example, the number of license sales reached peak values >9,000 before the two major crashes of the fishery in the late 1970s and late 1980s. Clam populations rebounded during the period from 1989 to 1994 when harvest was prohibited because of water quality concerns. The number of license sales in 2003-2008 has stabilized at approximately 1,100. At this level of harvest pressure, the clam standing stock has grown.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan with the following exceptions:
1. The clam harvest license sales were used as the indicator of harvest pressure. The regression equation between actual harvest and license sales was developed between 1980 and 2002 when digging was allowed on Fridays and Saturdays. Starting in 2003, the regulations changed such that digging was only allowed on Saturdays. Therefore, the regression equation may not be accurate for the more recent years and was not used.

EXHIBIT 50 (AR K.27)

Figure SHL10-1: Clam harvest license sales in New Hampshire

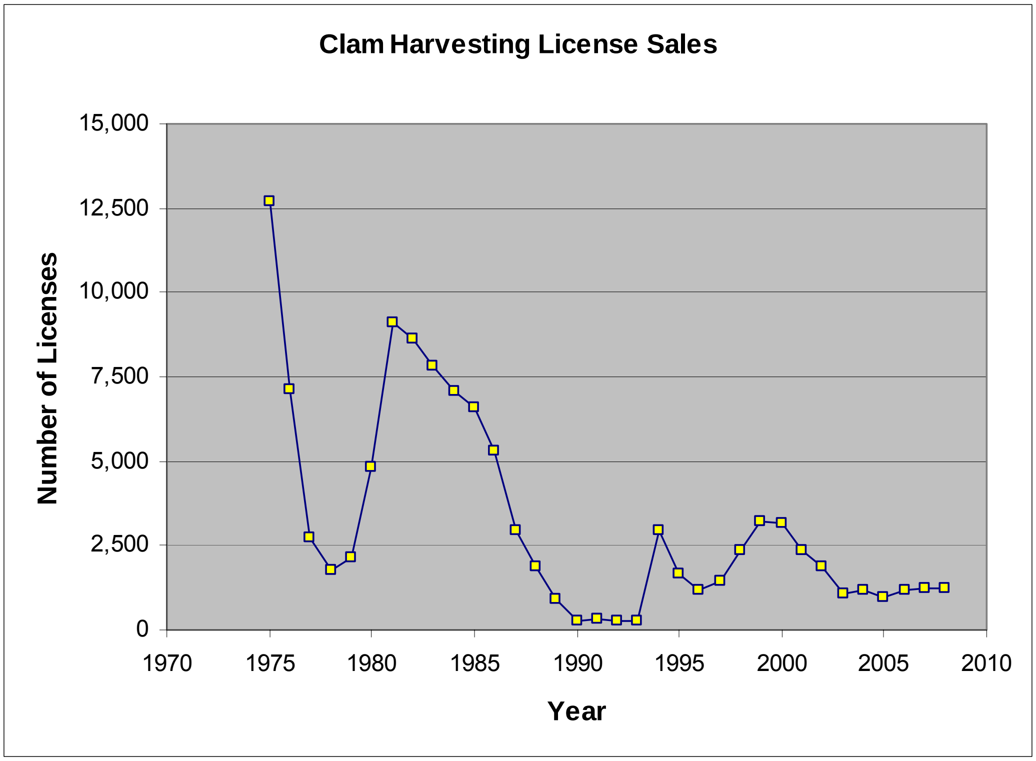


Figure SHL10-2: Clam standing stock in Hampton-Seabrook Harbor and harvest license sales in New Hampshire

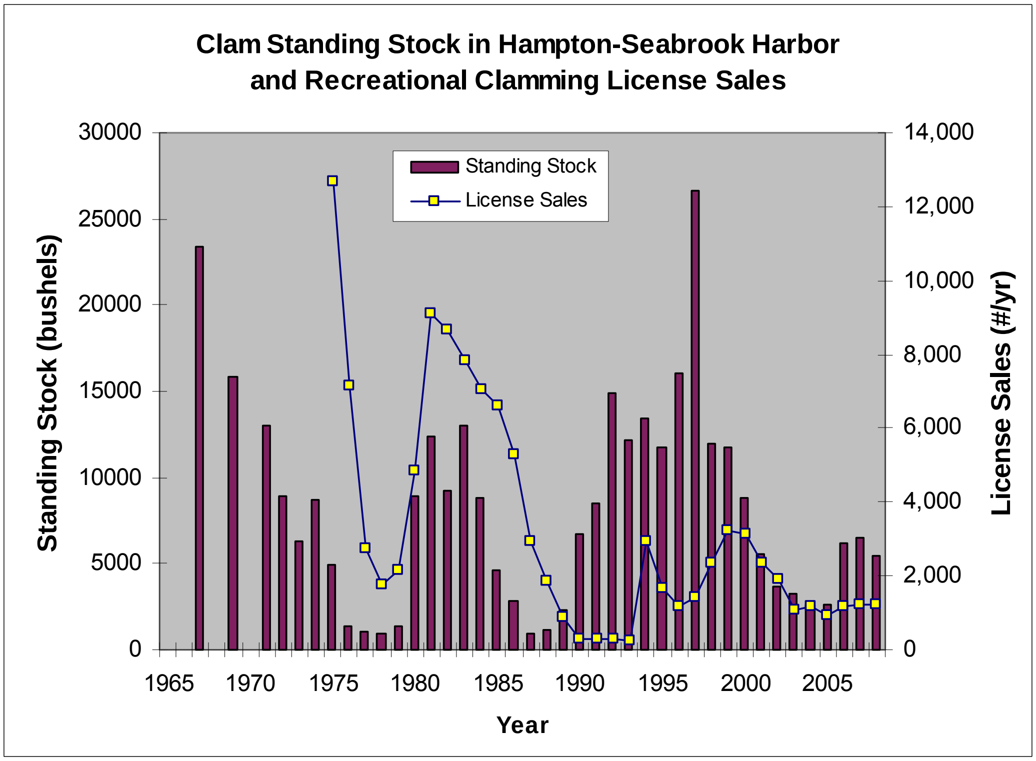


EXHIBIT 50 (AR K.27)

Indicator: SHL11. Prevalence of Oyster Disease

PREP Goal: No goal

Why This Is Important: Oyster disease is a major factor controlling oyster populations in the Great Bay Estuary.

Monitoring Question: Has the incidence of shellfish diseases changed significantly over time?

Answer: Yes. The average infection prevalence for Dermo has increased significantly from zero to greater than 60 percent since 2001. The infection prevalence for MSX has not changed and is approximately 33 percent.

Explanation

The disease MSX was first detected in Delaware Bay in 1957 and since then has spread throughout the Atlantic coast. The protozoa that causes MSX (*Haplosporidium nelsoni*) is mainly controlled by salinity. The protozoa cannot survive in low salinity water (<10 ppt), has limited virulence at salinities between 10 and 20 ppt, and is fully infectious at salinities >20 ppt (Haskin and Ford, 1982). Therefore, droughts tend to increase the prevalence of MSX infections and allow for expansion of the protozoa's range.

Unspeciated haplosporidian plasmodia were observed in the Piscataqua River as early as 1979 by Maine Department of Marine Resources. The presence of MSX in Great Bay was first conclusively determined in 1983. However the first oyster mortality from the disease was observed in 1995 following a severe drought (Barber et al., 1997).

The NH Fish and Game Department has monitored the prevalence of MSX in oysters from the Great Bay every year since 1995. There is no apparent trend in MSX infection rates since the disease was first detected (Table SHL11-1, Figures SHL11-1 and SHL11-2) Approximately 27% of the oysters in Great Bay were infected with MSX at some level in 2008. The rate of systemic infection (5% on average in 2008) is also important because systemic infection is a portent of imminent death, whereas oysters with low grade infections will often survive for at least another year. There has been no significant trend in average MSX infection prevalence since 1996.

The other major oyster disease present in Great Bay is Dermo which is caused by the protozoa *Perkinsus marinus*. The NH Fish and Game Department has monitored the prevalence of Dermo in oysters from the Great Bay every year since 1996. The infection prevalence of Great Bay oysters by Dermo has been less severe than MSX until recently. In 1997, only 10% of oysters from any bed were infected with the disease. Between 1998 and 2001, Dermo was not found in New Hampshire waters except at the Salmon Falls River bed (not shown). In 2002, oysters from Adams Point, Nannie Island, and the Salmon Falls River were found to be infected with Dermo again. By 2004, the prevalence of Dermo infection was approximately 60% in the Nannie Island and Adams Point oyster beds (NHF&G, 2005). Between 2005 and 2008, the average prevalence of infection has ranged from 63% to 74% with 8% to 27% of the oysters heavily infected. The average infection prevalence for Dermo has increased significantly since 1996 based on a Mann-Kendall test with a significance level of $p<0.05$.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

EXHIBIT 50 (AR K.27)

Table SHL11-1: MSX infection prevalence in Great Bay oysters

Date	Year	Location	Number Tested	Percent Infected	Percent with Systemic Infection	Notes
11/06/95	1995	Adams Point	20	40%	15%	(3)
05/27/96	1996	Adams Point	10	0%	0%	
11/17/97	1997	Adams Point	25	40%	20%	
12/09/98	1998	Adams Point	25	28%	8%	
11/04/00	2000	Adams Point	20	35%	25%	
11/04/01	2001	Adams Point	20	25%	20%	
10/14/02	2002	Adams Point	20	45%	0%	
10/14/02	2002	Adams Point	20	45%	0%	
11/19/04	2004	Adams Point	19	11%	5%	
11/14/2005	2005	Adams Point	20	35%	10%	
11/22/2006	2006	Adams Point	20	5%	0%	
12/7/2007	2007	Adams Point	20	25%	5%	
10/8/2008	2008	Adams Point	20	5%	0%	
11/06/95	1995	Nannie Island	20	15%	5%	(3)
05/27/96	1996	Nannie Island	40	8%	0%	(1)
11/17/97	1997	Nannie Island	25	52%	28%	
12/09/98	1998	Nannie Island	25	44%	8%	
10/21/99	1999	Nannie Island	20	35%	30%	
11/04/00	2000	Nannie Island	20	30%	25%	
10/10/01	2001	Nannie Island	24	21%	17%	
10/31/02	2002	Nannie Island	24	37%	17%	
10/31/02	2002	Nannie Island	24	37%	17%	
10/28/03	2003	Nannie Island	26	8%	0%	
11/18/04	2004	Nannie Island	17	29%	6%	
12/7/2006	2006	Nannie Island	20	20%	0%	
11/21/2007	2007	Nannie Island	20	25%	5%	
10/22/2008	2008	Nannie Island	20	15%	5%	
12/18/95	1995	Oyster River	20	50%	30%	(3)
11/17/97	1997	Oyster River	25	36%	8%	
11/15/00	2000	Oyster River	20	35%	10%	
11/04/01	2001	Oyster River	20	25%	20%	
10/14/02	2002	Oyster River	20	45%	5%	
10/14/02	2002	Oyster River	20	45%	5%	
10/27/04	2004	Oyster River	24	25%	4%	
11/6/2005	2005	Oyster River	20	35%	5%	
11/1/2006	2006	Oyster River	20	40%	5%	
10/23/2007	2007	Oyster River	20	35%	15%	
10/10/2008	2008	Oyster River	20	40%	10%	
10/27/95	1995	Piscataqua River	45	71%	33%	(2) (3)
11/17/97	1997	Piscataqua River	25	60%	20%	
12/09/98	1998	Piscataqua River	18	39%	17%	
11/04/00	2000	Piscataqua River	20	30%	15%	
10/31/2006	2006	Piscataqua River	20	55%	10%	
10/16/2007	2007	Piscataqua River	20	35%	5%	
10/23/2008	2008	Piscataqua River	10	50%	0%	
09/08/97	1997	Squamscott River	25	44%	20%	
12/09/98	1998	Squamscott River	25	68%	28%	
11/17/2005	2005	Squamscott River	20	30%	15%	
11/7/2006	2006	Squamscott River	40	60%	15%	
10/27/2008	2008	Squamscott River	10	30%	0%	
11/16/2005	2005	Woodman Point	20	10%	0%	
11/2/2006	2006	Woodman Point	20	30%	5%	
10/24/2007	2007	Woodman Point	20	25%	15%	
10/9/2008	2008	Woodman Point	20	20%	15%	

Source: NHF&G except where noted

(1) Combination of 30 samples taken 4/12/96 and 10 samples taken 5/27/96

(2) Combination of 25 oysters tested on 9/5/95 and 20 oysters tested on 10/27/95. Samples taken at "summer bed".

(3) Source: Barber et al. (1997)

EXHIBIT 50 (AR K.27)

Table SHL11-2: Dermo infection prevalence in Great Bay oysters

Date	Year	Location	Number Tested	Percent Infected	Percent Heavily Infected	Source	Notes
11/17/97	1997	Adams Point	50	10%	0%	NHF&G	
12/09/98	1998	Adams Point	25	0%	0%	NHF&G	
11/04/00	2000	Adams Point	20	0%	0%	NHF&G	(1)
11/04/01	2001	Adams Point	20	0%	0%	NHF&G	(1)
10/14/02	2002	Adams Point	20	15%	0%	NHF&G	(1)
11/19/04	2004	Adams Point	20	65%	20%	NHF&G	(1)
11/14/05	2005	Adams Point	20	90%	10%	NHF&G	
11/22/06	2006	Adams Point	20	100%	30%	NHF&G	
12/07/07	2007	Adams Point	20	55%	20%	NHF&G	
10/08/08	2008	Adams Point	20	80%	30%	NHF&G	
12/16/96	1996	Nannie Island	25	4%	0%	NHF&G	
11/17/97	1997	Nannie Island	50	2%	0%	NHF&G	
12/09/98	1998	Nannie Island	25	0%	0%	NHF&G	
10/21/99	1999	Nannie Island	20	0%	0%	NHF&G	
11/04/00	2000	Nannie Island	20	0%	0%	NHF&G	
10/10/01	2001	Nannie Island	25	0%	0%	NHF&G	
10/31/02	2002	Nannie Island	24	8%	0%	NHF&G	
10/28/03	2003	Nannie Island	25	20%	8%	NHF&G	
11/18/04	2004	Nannie Island	17	59%	6%	NHF&G	
12/07/06	2006	Nannie Island	20	60%	5%	NHF&G	
11/21/07	2007	Nannie Island	20	35%	10%	NHF&G	
10/22/08	2008	Nannie Island	20	40%	10%	NHF&G	
11/17/97	1997	Oyster River	50	2%	0%	NHF&G	
11/15/00	2000	Oyster River	20	0%	0%	NHF&G	
11/04/01	2001	Oyster River	20	0%	0%	NHF&G	
10/14/02	2002	Oyster River	20	0%	0%	NHF&G	
10/27/04	2004	Oyster River	25	16%	0%	NHF&G	
11/06/05	2005	Oyster River	20	65%	10%	NHF&G	
11/01/06	2006	Oyster River	20	80%	30%	NHF&G	
10/23/07	2007	Oyster River	20	100%	35%	NHF&G	
10/10/08	2008	Oyster River	20	85%	15%	NHF&G	
11/17/97	1997	Piscataqua River	50	10%	2%	NHF&G	
12/09/98	1998	Piscataqua River	18	0%	0%	NHF&G	
11/04/00	2000	Piscataqua River	20	0%	0%	NHF&G	
10/31/06	2006	Piscataqua River	20	75%	20%	NHF&G	
10/16/07	2007	Piscataqua River	20	90%	30%	NHF&G	
10/23/08	2008	Piscataqua River	10	30%	0%	NHF&G	
09/08/97	1997	Squamscott River	25	4%	0%	NHF&G	
12/09/98	1998	Squamscott River	25	0%	0%	NHF&G	
11/17/05	2005	Squamscott River	20	5%	0%	NHF&G	
11/07/06	2006	Squamscott River	39	13%	0%	NHF&G	
10/27/08	2008	Squamscott River	10	50%	10%	NHF&G	
11/16/05	2005	Woodman Point	20	90%	10%	NHF&G	
11/02/06	2006	Woodman Point	20	100%	5%	NHF&G	
10/24/07	2007	Woodman Point	20	90%	40%	NHF&G	
10/09/08	2008	Woodman Point	20	95%	35%	NHF&G	

(1) Combination of 25 oysters taken 8/14/97 and 25 oysters taken 11/17/97

EXHIBIT 50 (AR K.27)

Figure SHL11-1: MSX infection prevalence in Great Bay Oysters

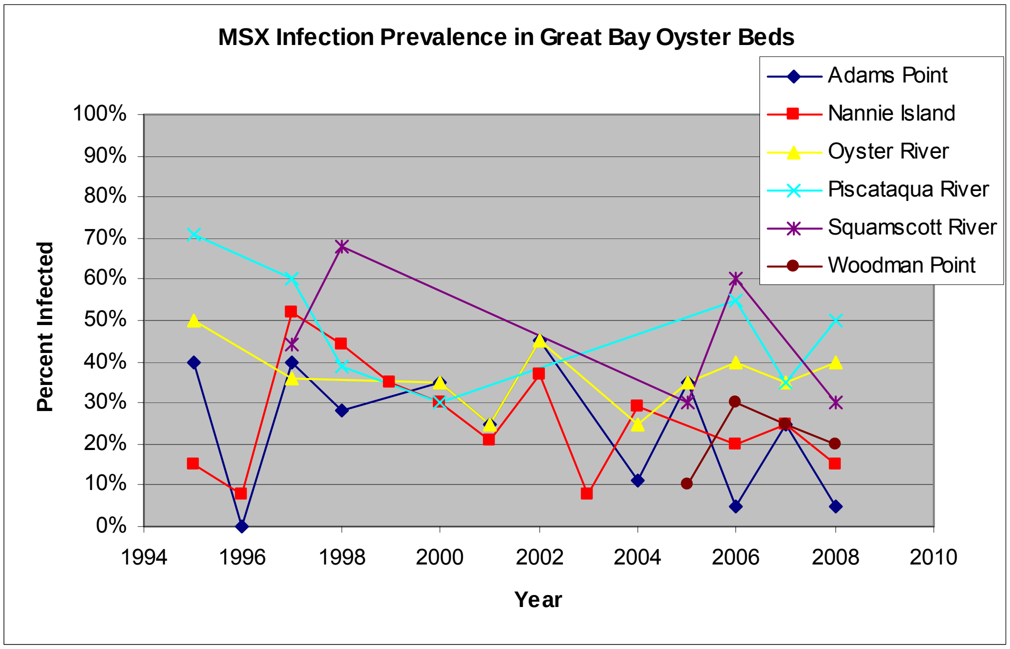


Figure SHL11-2: MSX systemic infection prevalence in Great Bay oysters

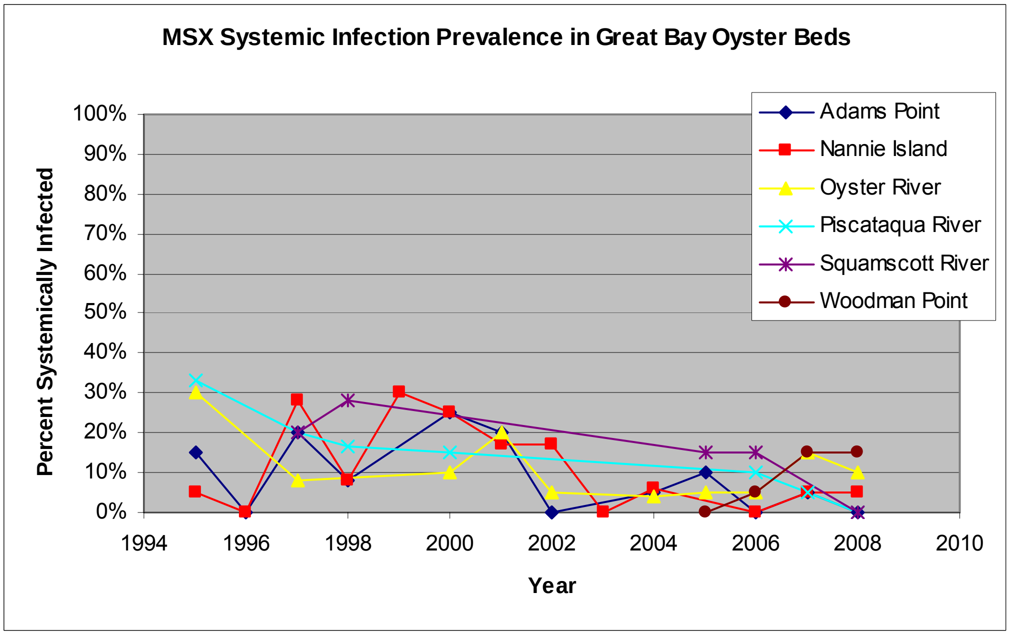


Figure SHL11-3: Dermo infection prevalence in Great Bay oysters

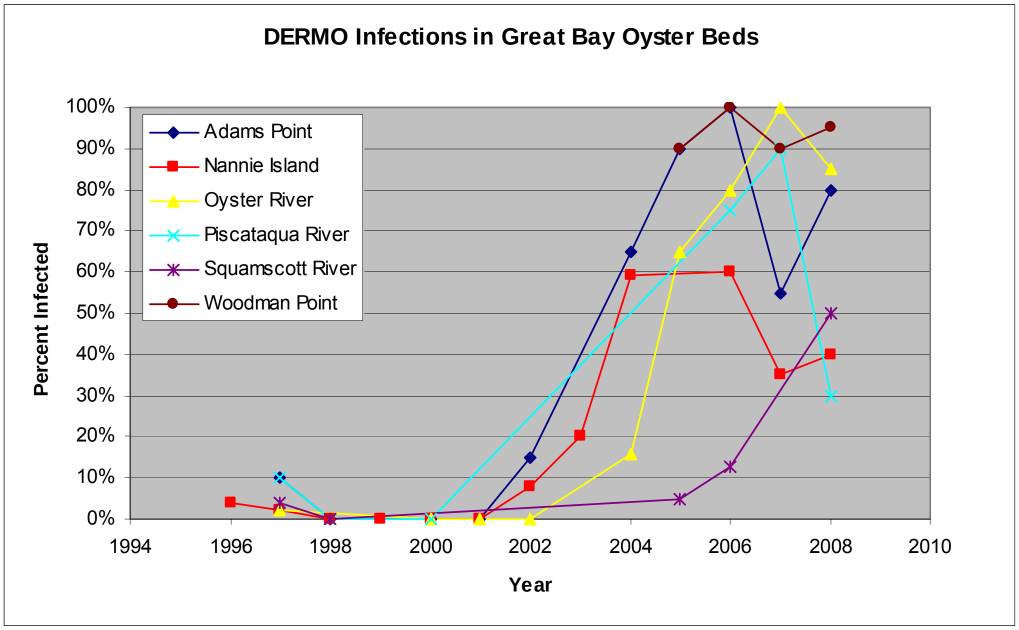


Figure SHL11-4: Dermo heavy infections in Great Bay oysters

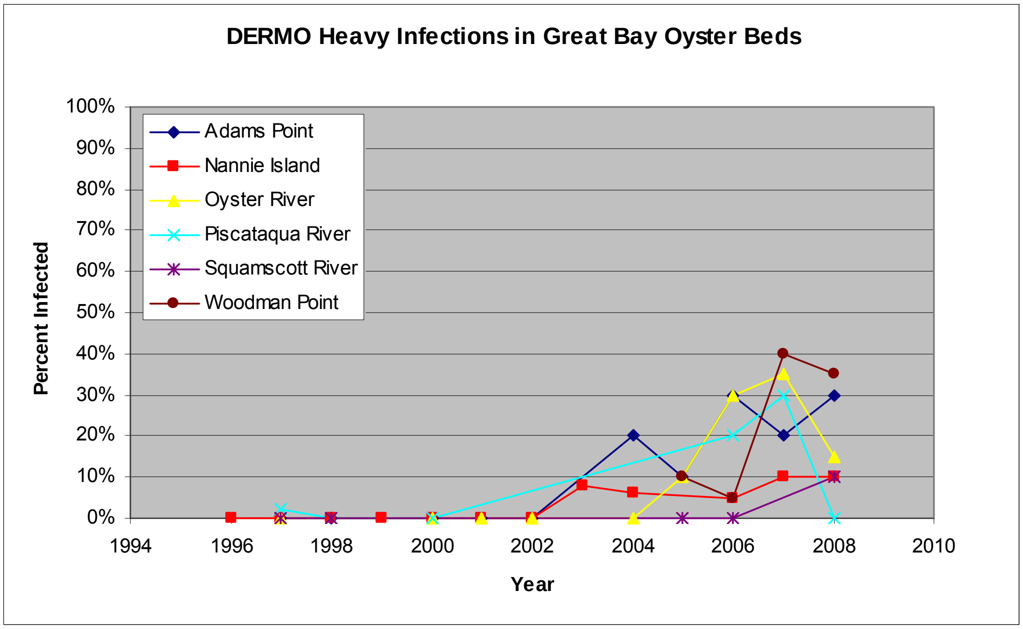


EXHIBIT 50 (AR K.27)

Indicator: SHL12. Prevalence of Clam Disease

PREP Goal: No goal

Why This Is Important: Disease is a factor that limits clam populations from reaching the PREP goal of 8,500 bushels of harvestable size clams in Hampton-Seabrook Harbor.

Monitoring Question: Has the incidence of shellfish diseases changed significantly over time?

Answer: No trends in the prevalence for clam neoplasia are apparent.

Explanation
Sarcomatous neoplasia (neoplasia) is a lethal form of leukemia in soft-shell clams. In 1986, neoplasia was first discovered in clams from Hampton-Seabrook Harbor. By 1989, 80% of the clams from the Confluence flat had neoplastic cells (FPL, 2004). A consistent monitoring program for neoplasia was put in place by Seabrook Station starting in 2002. Between 2002 and 2008, the prevalence of any neoplasia infection typically ranged from 50 to 75% of clams (Figure SHL12-1). Infection here is defined as clams having anywhere from 1 to 100% neoplastic cells. No trend in the prevalence rate is apparent. The disease is normally fatal in clams, although some lightly infected clams can recover (Brousseau and Baglivo, 1991). Clams with a high degree of infection (90-100% neoplastic cells) are expected to have a 92% mortality rate (Farley, 1989).

The data sources and methods used for this indicator are described in the PREP Monitoring Plan with the following exceptions:
1. Data for this indicator were taken from surveys completed by Seabrook Station in 2002-2008.

Figure SHL12-1: Average prevalence of neoplasia infection in clams from Hampton-Seabrook Harbor

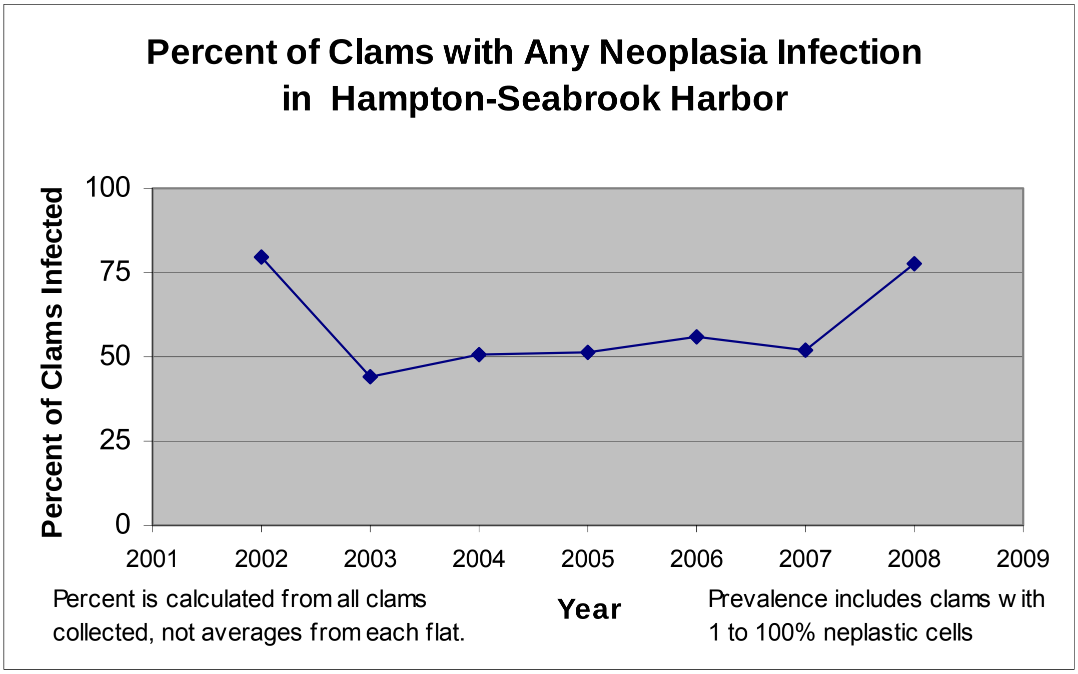


EXHIBIT 50 (AR K.27)

Indicator: HAB1. Salt Marsh Extent and Condition

PREP Goal: The goal for this indicator is to have to the total area of salt marsh in the NH Seacoast greater than or equal to 6,200 acres.

Why This Is Important: Salt marsh is a critical habitat for estuarine systems. Loss of salt marsh affects wildlife populations and water quality. Salt marsh also play an important role in buffering storm surges.

Monitoring Question: Has there been any significant net loss or degradation of tidal wetlands in NH?

Answer: In 2004, there were 5,554 acres of salt marsh in NH, which is less than the goal; however, due to differences in mapping techniques, this difference may not be significant.

Explanation

The total area of salt marsh in the coastal watershed in 2004 was 5,554 acres, which is less than the NHEP goal of 6,200 acres (Table HAB1-1). The majority of the salt marsh acreage was in Hampton/Seabrook Harbor (60.8%) (Figure HAB1-1). The remainder was spread out along the Atlantic Coast and Great Bay shorelines.

For historical comparison, it is possible to use the National Wetlands Inventory (1991) and salt marsh maps created by UNH (1990-1992). The National Wetland Inventory (NWI) represents “baseline” conditions for wetlands covering greater than 3 acres as published in 1991 using pre-1991 imagery. The total area of salt marsh wetlands included in the NWI in 1991 was 5,620 acres. Additional tidal wetland mapping around Great Bay and its tributaries was completed by the UNH Jackson Estuarine Laboratory under contract with NH Office of State Planning. Wetlands were mapped on aerial photograph enlargements (1:2,400) collected between 1990 and1992. The UNH mapping project was completed on a larger scale than the NWI so it identified salt marshes which were not included in the NWI. After the NWI and the UNH maps were merged, the total area of salt marsh mapped in the 1990-1992 coverages was 6,452 acres.

The merged 1990-1992 salt marsh coverage was compared to the 2004 coverage to identify changes between the periods (Table HAB1-2). There were a total of 1,578 acres of salt marsh in the 1990-1992 coverage that were not included in the 2004 coverage. Conversely, 681 acres of salt marsh were mapped in 2004 which did not appear on the 1990-1992 maps. Most of the discrepancies were smaller than 1 acre in size and occurred around the edges of salt marsh stands. However, it is unclear if these small discrepancies represent actual changes in salt marsh extent or the result of irreducible error in the mapping method. The larger discrepancies appeared to be created by different mapping protocols. For example, the 2004 coverage mapped the presence of phragmites and cattails in salt marshes while the older maps did not.

Overall, there were more salt marshes mapped in 1990-1992 than in 2004. However, due to the difference in the mapping techniques, it is not appropriate to draw conclusions about changes in the salt marsh acreage between these two periods. The two datasets should be studied in detail to understand the reasons for the discrepancies.

Phragmites stands covered 133 acres of salt marsh habitat in 2004 (Table HAB1-1). There were a total of 351 unique phragmites stands. The average size of a stand was 0.38 acres. These numbers do not include the large phragmites stands in the Great Bog, which were mapped in 2004 even though they are not salt marshes. The distribution of phragmites was similar to the distribution of salt marshes with one exception. There was relatively more phragmites along the Atlantic coast and Portsmouth Harbor than other areas (see footnotes 3 and 4 in Table HAB1-1).

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

EXHIBIT 50 (AR K.27)

Table HAB1-1: Summary of salt marsh extent and condition in coastal New Hampshire

Wetland Type	Total Coverage (acres)	Number of Unique Stands	Average Size of Stands (acres)
Salt marsh	5,554	Not applicable	Not applicable
Phragmites	133	351	0.38
Purple loosestrife	6	14	0.45
Cattail	202	122	1.65
Combination of phragmites, loosestrife or cattail	31	19	1.63

1. Totals based on summation of the following Cowardin classes
-Salt marsh: E2 EM1, EM/5, EM/PSS1
-Phragmites: P, EM/P, P/5
-Loosestrife: L
-Cattail: T, EM/T
-Combination: L/T, L/T/5, T/L/P, T/P
2. Data provided by NH Coastal Program, contracted to Normandeau Associates
3. The salt marsh total acreages in different parts of coastal NH are:
-Hampton/Seabrook Harbor: 3,379 (60.8%)
-Atlantic Coast and Portsmouth Harbor: 978 (17.6%)
-Great Bay and Tributaries: 1,197 (21.6%)
4. The phragmites total acreages in different parts of coastal NH are:
-Hampton/Seabrook Harbor: 59.1 (44.5%)
-Atlantic Coast and Portsmouth Harbor: 42.0 (31.7%)
-Great Bay and Tributaries: 31.6 (23.8%)

Table HAB1-2: Comparison of salt marsh coverages from 1990-1992 and 2004

Statistic	Result
Area of salt marsh (2004)	5,554 ac
Area of salt marsh (1990-1992)	6,452 ac
Salt marsh in both 2004 and 1990-1992	4,874 ac
Salt marsh in 2004 but not 1990-1992	681 ac
- in features <1 ac	376 ac (n=3332, ave=0.1 ac)
- in features 1-10 ac	294 ac (n=149, ave=2.0 ac)
- in features >10 ac	11 ac (n=1)
Salt marsh in 1990-1992 but not 2004	1,578 ac
- in features <1 ac	666 ac (n=7067, ave=0.1 ac)
- in features 1-10 ac	793 ac (n=324, ave=2.4 ac)
- in features >10 ac	119 ac (n=8, ave=14.9 ac)

EXHIBIT 50 (AR K.27)

Figure HAB1-1: Salt marsh extent in Hampton-Seabrook Harbor

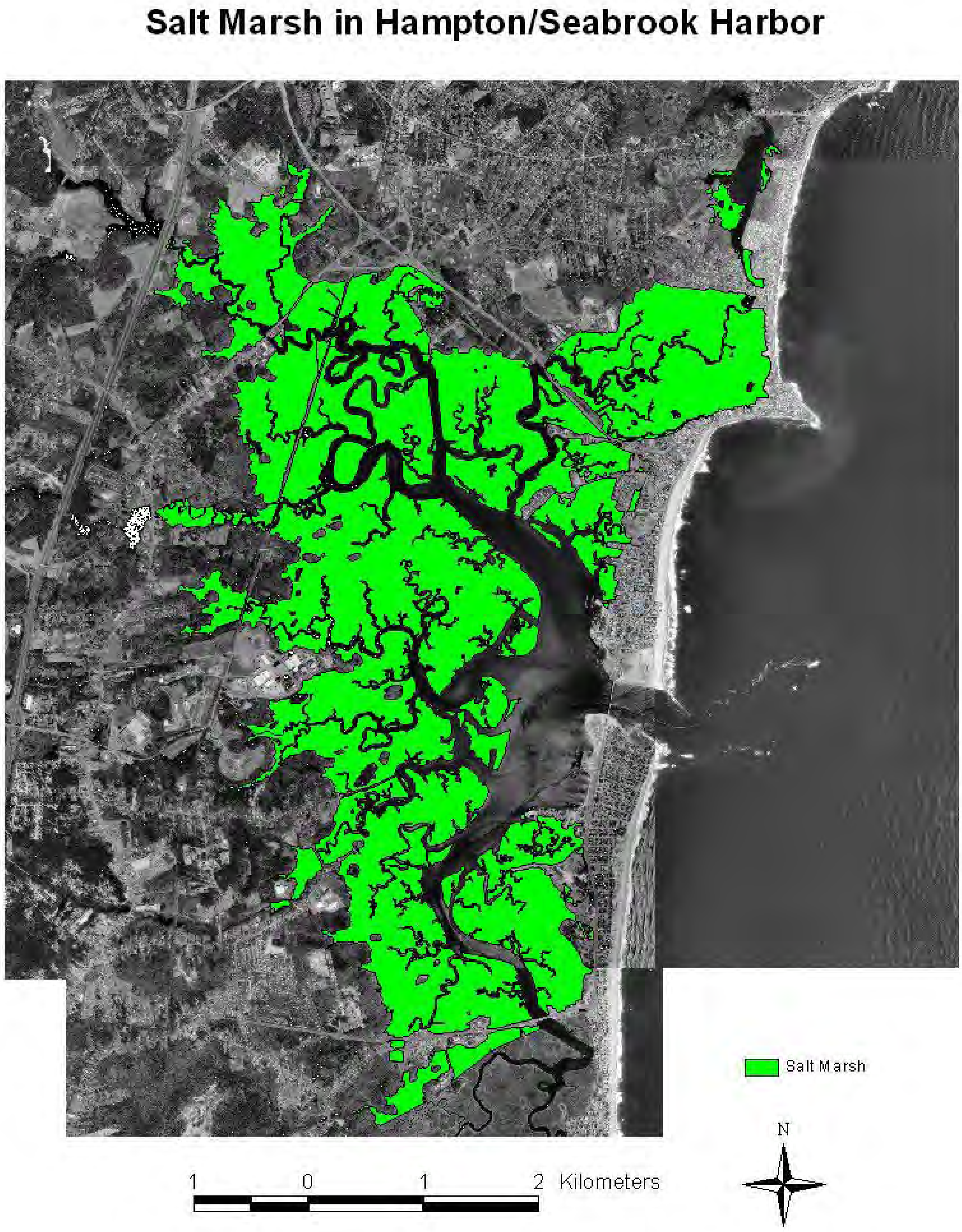


EXHIBIT 50 (AR K.27)

Indicator: HAB2. Eelgrass Distribution

PREP Goal: No goal

Why This Is Important: Eelgrass (*Zostera marina*) is essential to estuarine ecology because it filters nutrients and suspended particles from water, stabilizes sediments, provides food for wintering waterfowl, and provides habitat for juvenile fish and shellfish, as well as being the basis of an important estuarine food web. Healthy eelgrass both depends on and contributes to good water quality.

Monitoring Question: Has eelgrass habitat in the Great Bay Estuary changed over time?

Answer: Yes. Eelgrass cover in the Great Bay itself has declined by 37 percent between 1990 and 2008 and has completely disappeared from the tidal rivers, Little Bay, and the Piscataqua River.

Explanation

The UNH Seagrass Ecology Group has mapped the distribution of eelgrass every year from 1986 to 2008 in the Great Bay. The entire Great Bay Estuary (Great Bay, Little Bay, tidal tributaries, Piscataqua River, Little Harbor, and Portsmouth Harbor) was mapped by these researchers in 1996 and from 1999 through 2008. Table HAB2-1 summarizes the acres of eelgrass in each assessment zone from 1986-2008. Figure HAB2-1 shows the trends in eelgrass cover in various locations over time. The most recent (2008) eelgrass coverage in the Great Bay Estuary is shown in Figure HAB2-2.

In 1989, there was a dramatic crash of the eelgrass beds in the Great Bay itself down to 300 acres (15% of normal levels). The cause of this crash was an infestation of a slime mold, *Labryrinthula zosterae*, commonly called “wasting disease” (Muehlstein et al., 1991). The eelgrass beds recovered following the infestation but have experienced a slow, steady decline since their recovery. Between 1990 and 2008, the eelgrass in Great Bay and Little Bay has declined by 37 and 87 percent, respectively. In 2007 and 2008, no eelgrass was found in Little Bay. All of the eelgrass in the Winnicut River was lost between 1990 and 2008. Eelgrass has only been occasionally detected at low levels in the other tributaries to Great Bay and Little Bay. However, historical maps indicate that eelgrass formerly existed in these rivers (DES, 2008).

Another very troubling finding is that eelgrass cover in both Portsmouth Harbor and Little Harbor is also declining. The water quality in these areas is generally considered to be the best within the estuary. Nevertheless, the area of eelgrass beds in Portsmouth Harbor and Little Harbor has declined by 24-30 percent between 1996 and 2008.

The eelgrass populations in the upper and lower reaches of the Piscataqua River have also declined to nearly zero in 2008. The remaining beds are all near the mouth of the river, south of the Memorial Bridge (Route 1), near Seavey Island. Although high variability precludes the detection of statistically significant trends, the nearly complete loss of eelgrass from all the assessment zones in the Piscataqua River clearly indicates a declining trend for this area.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan with the following exceptions:

1. The assessment zones for eelgrass used in this report are different than those used in past reports. The assessment zones were changed to match the zones used for the DES nutrient criteria assessment.
2. Percent change for statistically significant trends ($p<0.05$) was calculated using the value of the trend line from the first and last year of the timeseries.

EXHIBIT 50 (AR K.27)

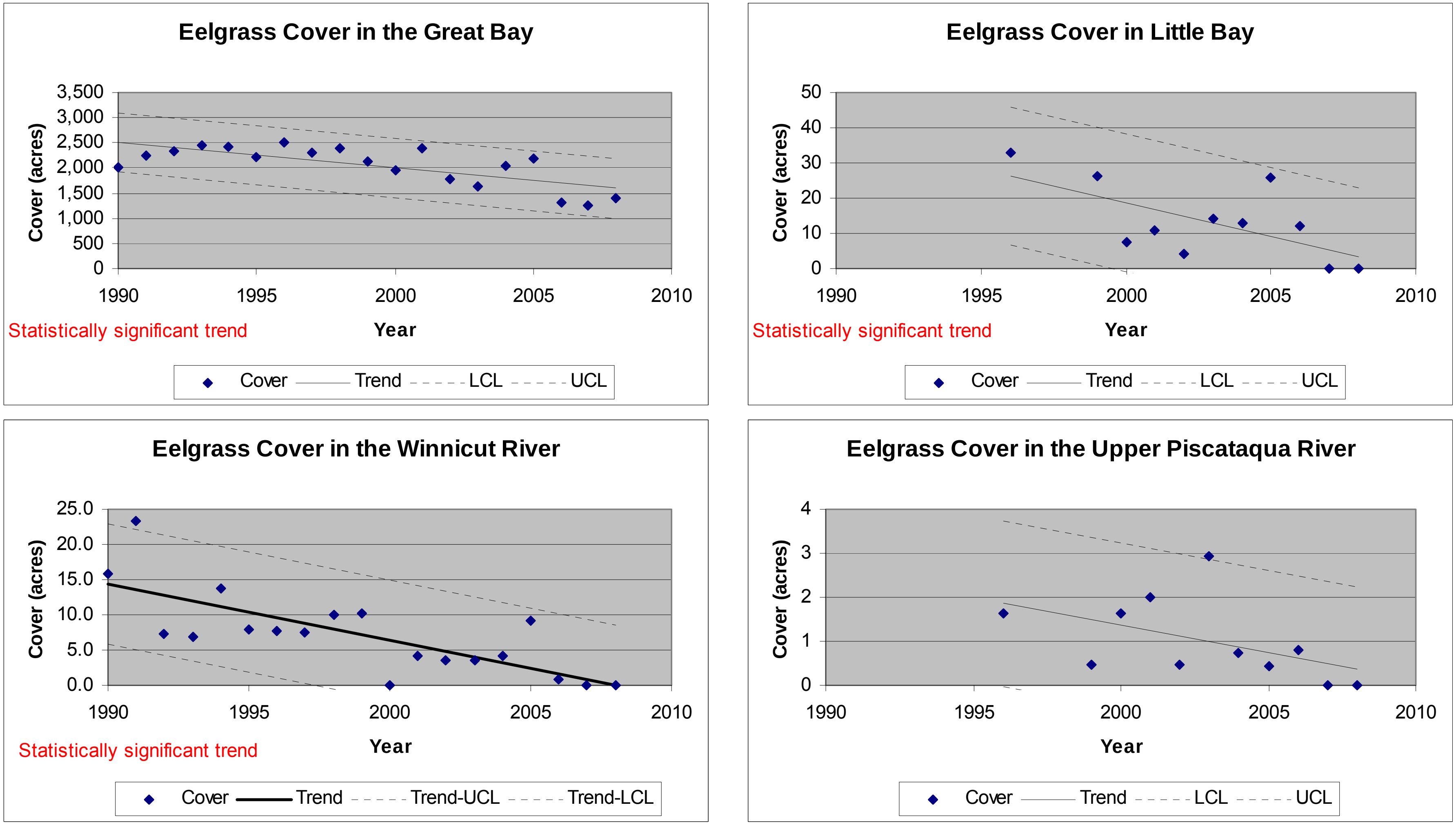
Table HAB2-1: Eelgrass coverage in the Great Bay Estuary

Year	Winnicut River	Squamscott River	Lamprey River	Oyster River	Bellamy River	Great Bay	Little Bay	Upper Piscataqua River*	Lower Piscataqua River North*	Lower Piscataqua River South*	Portsmouth Harbor*	Little Harbor	Sagamore Creek
1986	2.2	0.0	0.0	a	a	2015.2	a	a	a	a	a	a	a
1987	2.2	0.0	0.0	a	a	1685.7	a	a	a	a	a	a	a
1988	0.0	0.0	0.0	a	a	1187.5	a	a	a	a	a	a	a
1989	0.0	0.0	0.0	a	a	312.6	a	a	a	a	a	a	a
1990	15.9	0.0	0.0	a	a	2024.2	a	a	a	a	a	a	a
1991	23.4	0.0	0.0	a	a	2255.8	a	a	a	a	a	a	a
1992	7.3	0.0	0.0	a	a	2334.4	a	a	a	a	a	a	a
1993	6.9	0.0	0.0	a	a	2444.9	a	a	a	a	a	a	a
1994	13.8	0.0	0.0	a	a	2434.3	a	a	a	a	a	a	a
1995	7.8	0.0	0.0	a	a	2224.9	a	a	a	a	a	a	a
1996	7.6	0.0	0.0	14.0	0.0	2495.4	32.7	1.6	20.9	10.2	245.6	70.1	1.8
1997	7.5	0.0	0.0	a	a	2297.8	a	a	a	a	a	a	a
1998	10.0	0.0	0.0	a	a	2387.8	a	a	a	a	a	a	a
1999	10.2	0.0	0.0	0.0	0.0	2119.5	26.2	0.5	7.4	4.0	244.0	50.1	3.0
2000	0.0	0.0	0.0	0.0	0.0	1944.5	7.5	1.6	3.8	7.6	260.5	60.9	0.9
2001	4.1	0.0	0.0	0.0	0.0	2388.2	10.9	2.0	9.7	10.7	274.2	45.3	2.2
2002	3.5	0.0	0.0	0.0	0.0	1791.8	4.3	0.5	8.0	9.3	268.9	63.1	2.3
2003	3.5	0.0	2.2	0.0	0.0	1620.9	14.2	2.9	22.9	9.2	270.1	54.7	2.2
2004	4.2	0.0	0.0	0.0	0.8	2043.3	12.8	0.7	13.6	6.5	225.2	65.9	2.5
2005	9.2	0.0	0.0	0.0	0.0	2201.2	25.8	0.4	14.6	9.6	232.5	50.8	6.1
2006	0.8	0.0	0.0	0.0	0.0	1320.7	12.2	0.8	10.8	11.6	217.6	52.1	0.9
2007	0.0	0.0	0.0	0.0	0.0	1246.1	0.1	0.0	0.4	5.6	201.3	42.7	0.6
2008	0.0	0.0	0.0	0.0	0.0	1395.1	0.0	0.0	0.0	3.9	183.8	41.4	2.3

Units = Acres a = not mapped Total coverage includes all mapped eelgrass of all densities
* The acreages for 1996-2008 include beds from both the NH and ME sides of the Piscataqua River but not the tidal creeks along the Maine shore.

EXHIBIT 50 (AR K.27)

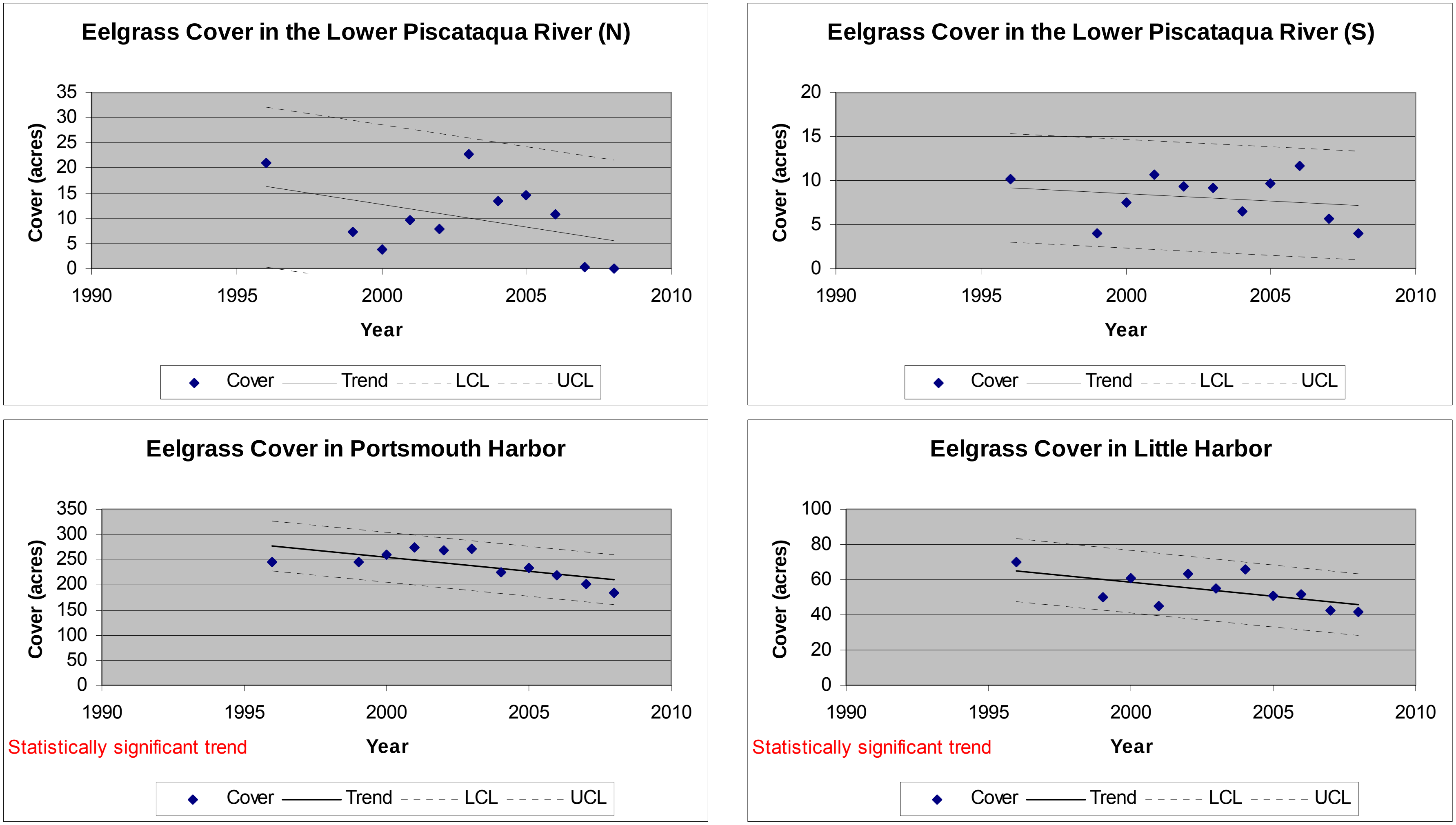
Figure HAB2-1: Eelgrass coverage in segments of the Great Bay Estuary



* Trend UCL and Trend LCL refer to the upper and lower confidence limits (95th percentile) of the trend line

EXHIBIT 50 (AR K.27)

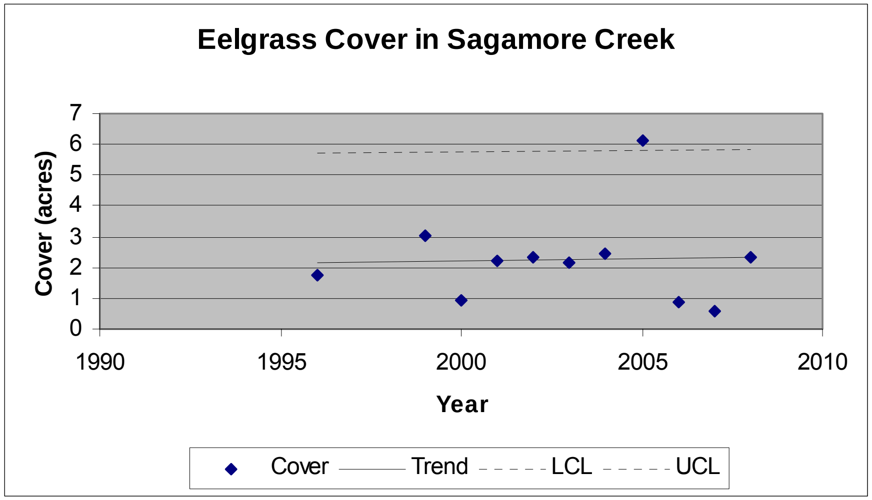
Figure HAB2-1: Eelgrass coverage in segments of the Great Bay Estuary (cont.)



* Trend UCL and Trend LCL refer to the upper and lower confidence limits (95th percentile) of the trend line

EXHIBIT 50 (AR K.27)

Figure HAB2-1: Eelgrass coverage in segments of the Great Bay Estuary (cont.)



* Trend UCL and Trend LCL refer to the upper and lower confidence limits (95th percentile) of the trend line

EXHIBIT 50 (AR K.27)

Figure HAB2-2: Eelgrass coverage in the Great Bay Estuary in 2008

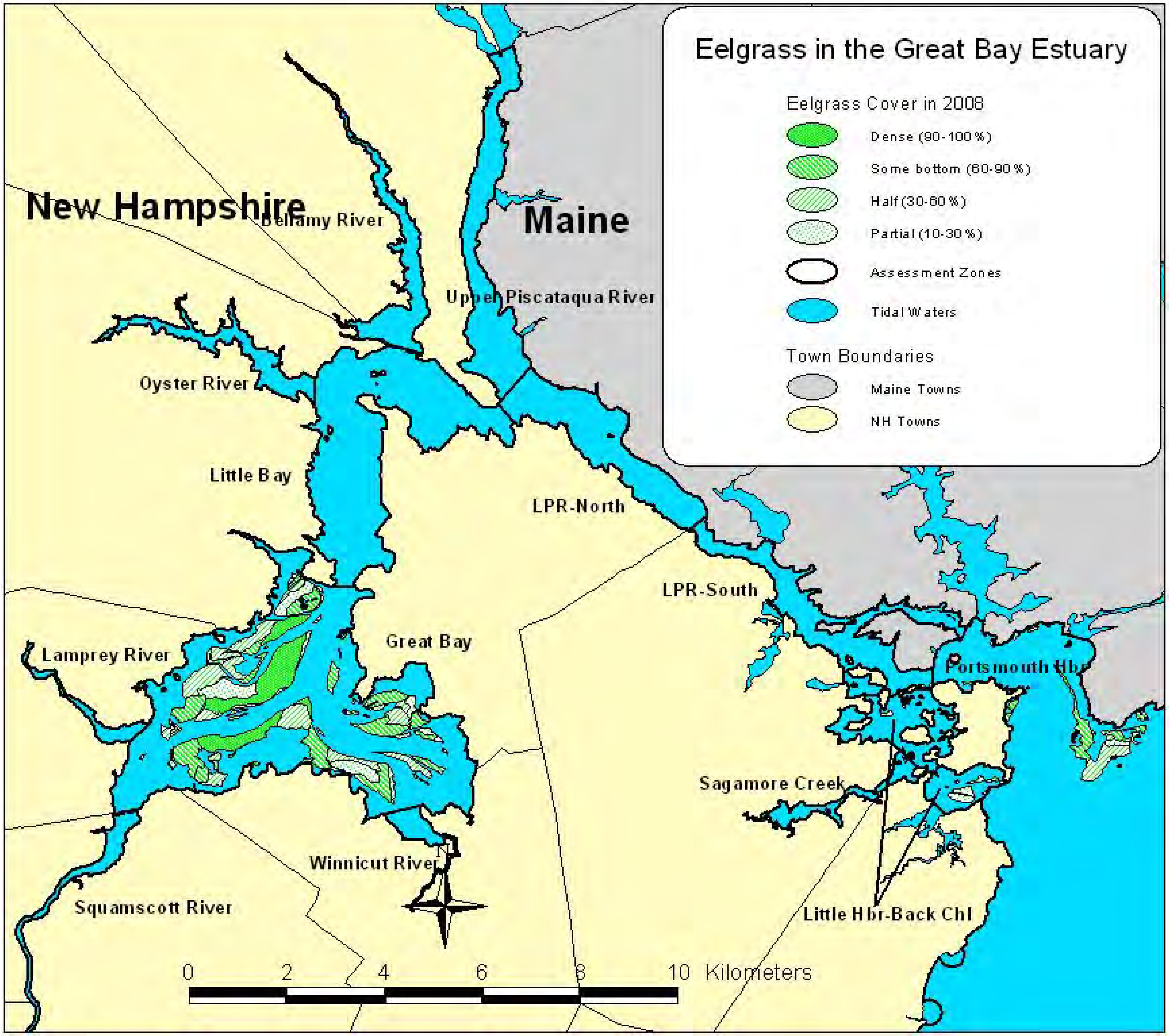


EXHIBIT 50 (AR K.27)

Indicator: HAB12. Eelgrass Biomass

PREP Goal: No goal

Why This Is Important: Eelgrass (*Zostera marina*) is essential to estuarine ecology because it filters water, stabilizes sediments, provides food for wintering waterfowl, and provides habitat for juvenile fish and shellfish. Healthy eelgrass both depends on and contributes to good water quality.

Monitoring Question: Has eelgrass habitat in the Great Bay Estuary changed over time?

Answer: Yes. Eelgrass biomass in the Great Bay has declined by 64 percent between 1990 and 2008.

Explanation
The UNH Seagrass Ecology Group has mapped the distribution of eelgrass every year from 1986 to 2008 in the Great Bay. The entire Great Bay Estuary system (Great Bay, Little Bay, tidal tributaries, Piscataqua River, and Portsmouth Harbor) was mapped in 1996 and from 1999 through 2008. Based on the density of the eelgrass beds, it is possible to estimate the total biomass of eelgrass (i.e., the total mass of plants) in different sections of the estuary. Table HAB12-1 summarizes the biomass of eelgrass in each assessment zone from 1990-2008. (Note: While eelgrass mapping began in 1986, the density of the beds was first mapped in 1990). Figure HAB12-1 shows the trends in eelgrass biomass in various locations over time.

Between 1990 and 2008, the eelgrass in Great Bay and Little Bay has declined by 64 and 100 percent, respectively. One hundred percent of the eelgrass biomass in the Winnicut River has been lost over this same period. Eelgrass has only been occasionally detected in the other tributaries to Great Bay and Little Bay. However, historical maps indicate that eelgrass formerly existed in these rivers (DES, 2008). Eelgrass populations in the upper and lower reaches of the Piscataqua River and Portsmouth Harbor appear to be declining but there is too much variability for the trend to be statistically significant. Finally, 75 percent of the eelgrass biomass has been lost from Little Harbor where the water quality is thought to be better than in most of the estuary.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan with the following exceptions:
1. The assessment zones for eelgrass used in this report are different than those used in past reports. The assessment zones were changed to match the zones used for the DES nutrient criteria assessment.
2. Percent change for statistically significant trends ($p<0.05$) was calculated using the mean of the trend line from the first and last year of the timeseries.

EXHIBIT 50 (AR K.27)

Table HAB12-1: Eelgrass biomass in the Great Bay Estuary

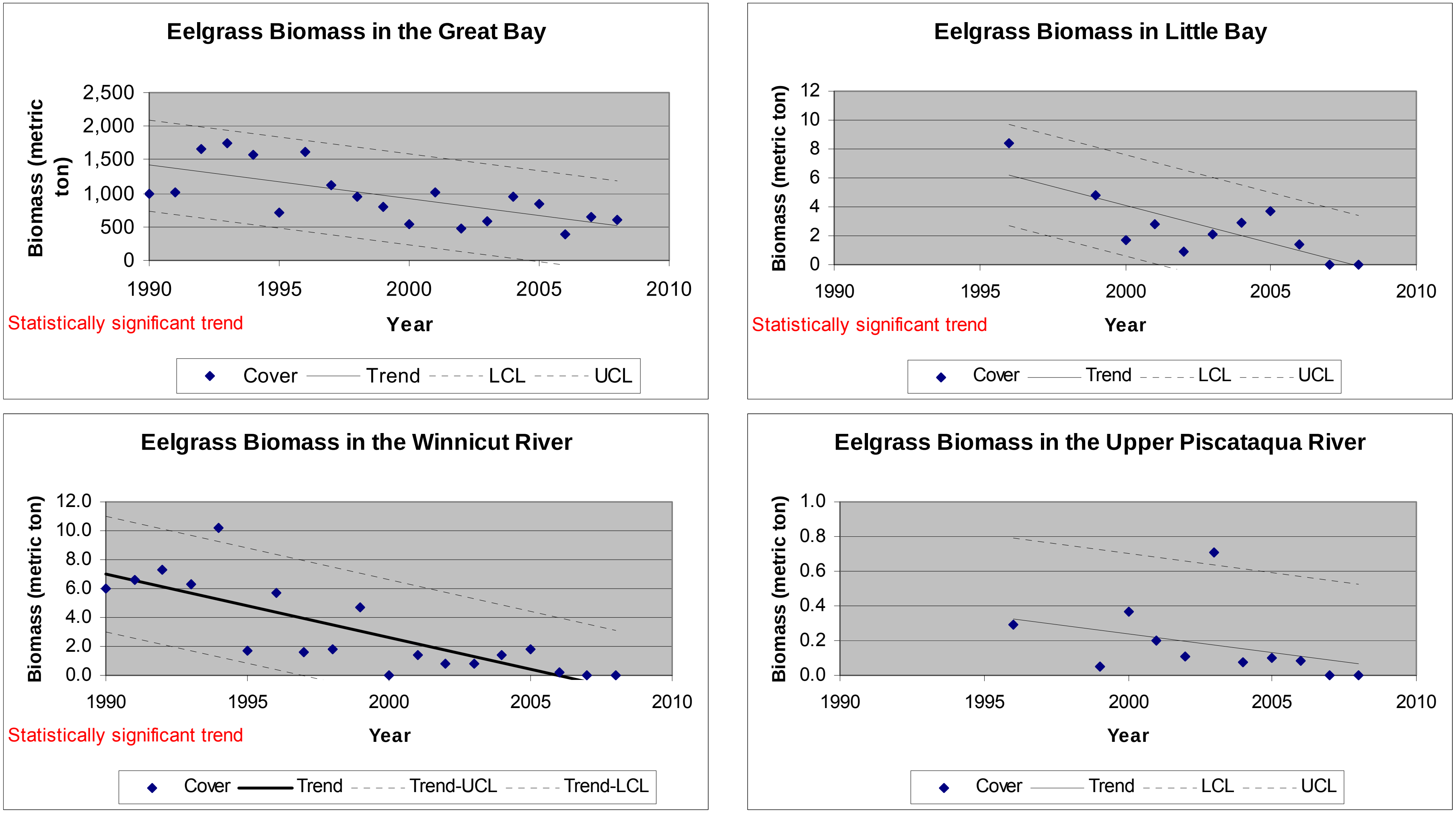
Year	Winnicut River	Squamscott River	Lamprey River	Oyster River	Bellamy River	Great Bay	Little Bay	Upper Piscataqua River*	Lower Piscataqua River North*	Lower Piscataqua River South*	Portsmouth Harbor*	Little Harbor	Sagamore Creek
1990	6.0	0.0	0.0	a	a	996.6	a	a	a	a	a	a	a
1991	6.6	0.0	0.0	a	a	1013.8	a	a	a	a	a	a	a
1992	7.3	0.0	0.0	a	a	1669.1	a	a	a	a	a	a	a
1993	6.3	0.0	0.0	a	a	1756.2	a	a	a	a	a	a	a
1994	10.2	0.0	0.0	a	a	1573.0	a	a	a	a	a	a	a
1995	1.7	0.0	0.0	a	a	717.2	a	a	a	a	a	a	a
1996	5.7	0.0	0.0	2.0	0.0	1624.3	8.4	0.3	4.6	4.7	131.0	24.9	0.7
1997	1.6	0.0	0.0	a	a	1121.6	a	a	a	a	a	a	a
1998	1.8	0.0	0.0	a	a	952.2	a	a	a	a	a	a	a
1999	4.7	0.0	0.0	0.0	0.0	794.5	4.8	0.0	1.6	1.7	83.3	23.2	0.8
2000	0.0	0.0	0.0	0.0	0.0	531.1	1.7	0.4	1.4	3.0	151.4	16.1	0.1
2001	1.4	0.0	0.0	0.0	0.0	1019.0	2.8	0.2	5.1	3.7	89.4	12.9	0.5
2002	0.8	0.0	0.0	0.0	0.0	463.8	0.9	0.1	2.6	1.7	97.8	20.6	0.7
2003	0.8	0.0	0.6	0.0	0.0	586.0	2.1	0.7	14.1	2.5	89.0	11.0	0.6
2004	1.4	0.0	0.0	0.0	0.1	958.8	2.9	0.1	8.5	3.1	161.2	12.2	0.6
2005	1.8	0.0	0.0	0.0	0.0	832.9	3.7	0.1	6.1	3.0	192.3	11.3	1.5
2006	0.2	0.0	0.0	0.0	0.0	394.3	1.4	0.1	3.1	5.1	149.3	11.2	0.2
2007	0.0	0.0	0.0	0.0	0.0	652.2	0.0	0.0	0.1	1.9	101.2	6.3	0.1
2008	0.0	0.0	0.0	0.0	0.0	609.1	0.0	0.0	0.0	1.1	55.0	6.3	0.4

Units = Metric tons (1 metric ton = 1000 kg) a = not mapped

* The biomass estimates for 1996-2008 include beds from both the NH and ME sides of the Piscataqua River but not the tidal creeks along the Maine shore.

EXHIBIT 50 (AR K.27)

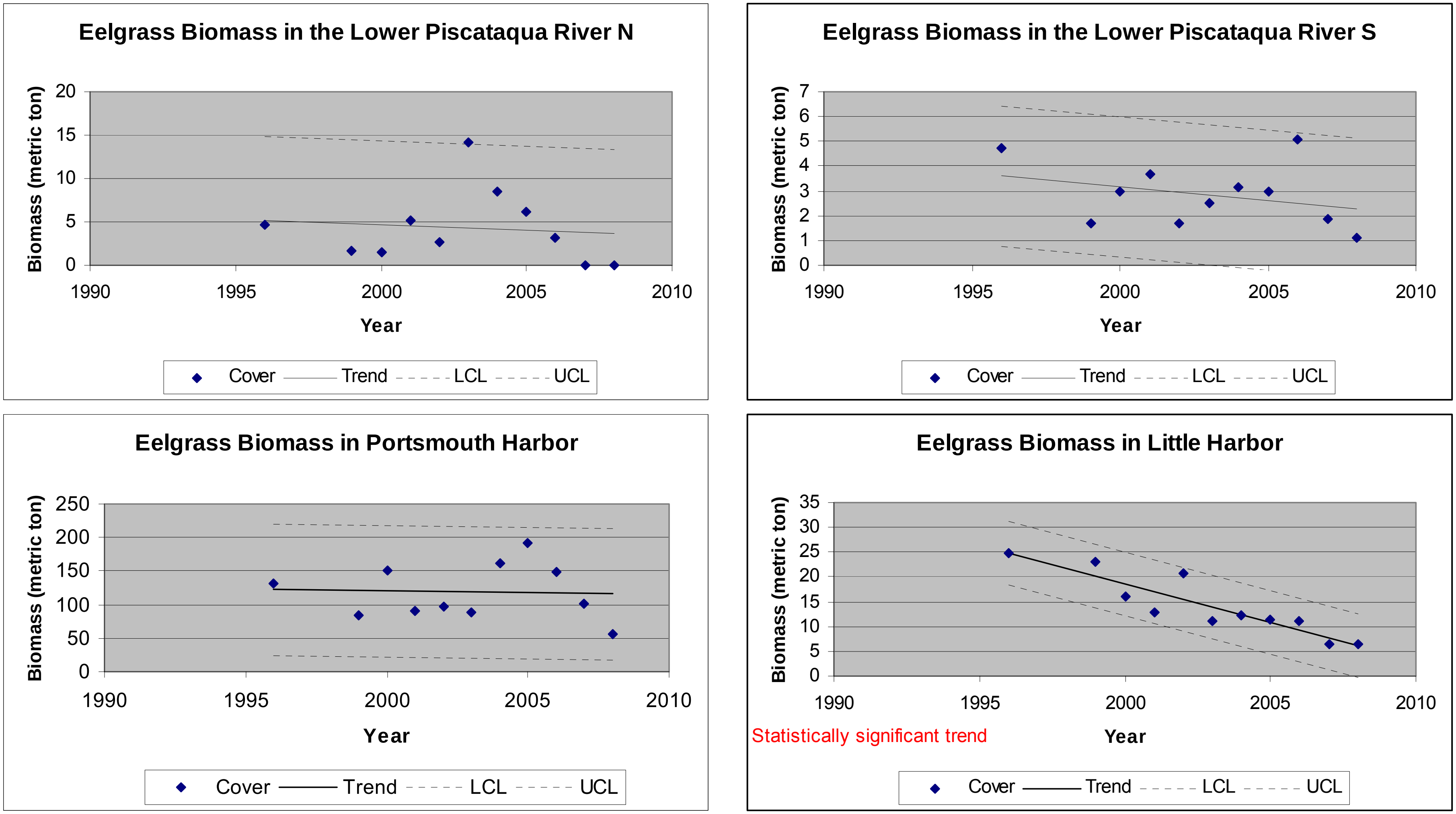
Figure HAB12-1: Eelgrass biomass in segments of the Great Bay Estuary



* Trend UCL and Trend LCL refer to the upper and lower confidence limits (95th percentile) of the trend line

EXHIBIT 50 (AR K.27)

Figure HAB2-1: Eelgrass coverage in segments of the Great Bay Estuary (cont.)



Eelgrass Biomass in the Lower Piscataqua River N

Eelgrass Biomass in the Lower Piscataqua River S

Eelgrass Biomass in Portsmouth Harbor

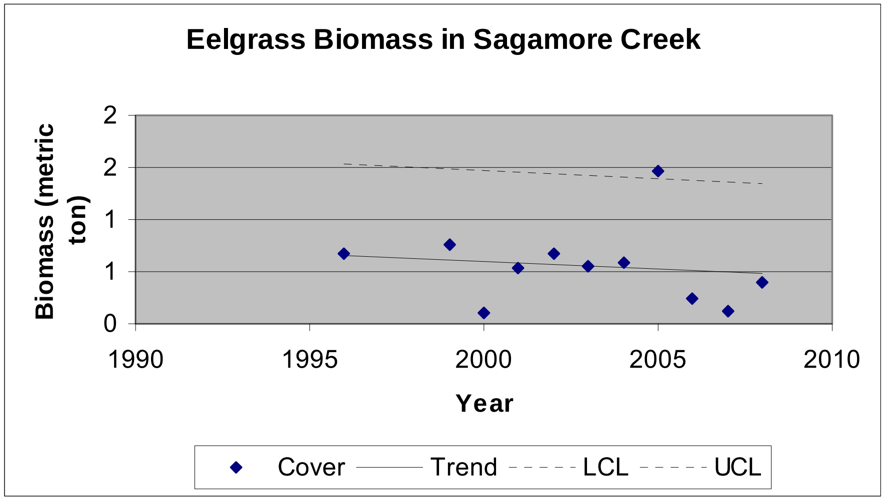
Eelgrass Biomass in Little Harbor

Statistically significant trend

* Trend UCL and Trend LCL refer to the upper and lower confidence limits (95th percentile) of the trend line

EXHIBIT 50 (AR K.27)

Figure HAB2-1: Eelgrass coverage in segments of the Great Bay Estuary (cont.)



* Trend UCL and Trend LCL refer to the upper and lower confidence limits (95th percentile) of the trend line

EXHIBIT 50 (AR K.27)

Indicator: HAB8. Anadromous Fish Returns

PREP Goal: No goal

Why This Is Important: Anadromous fish migrate from the ocean to fresh water to spawn. These species need suitable spawning and rearing habitat in the rivers and streams to thrive, and both upstream and downstream passage past dams. Therefore, anadromous fish returns are dependent on environmental conditions of watershed streams and barriers to both upstream and downstream migration.

Monitoring Question: Has the number of anadromous fish returning to NH’s coastal rivers changed over time?

Answer: While each fish species and river system is unique, the overall weight of evidence is that returning anadromous fish populations have reached the carrying capacity of the currently available habitat and are limited by various annual environmental factors including water quality, dam passage, and flooding.

Explanation
Many factors influence the returns of anadromous fish. Each species has its own life cycle history and has different habitat needs as larvae, juvenile and adults. The following comments are simply summaries of the reported data. More in-depth analysis of the data is difficult and convoluted.

Data on river herring returns are shown in Figure HAB8-1. One of the most important observations regarding river herring returns is that high water conditions during the spawning runs affect fish ladder efficiency thereby dramatically reducing the number of returns as noted in all rivers from 2005 through 2007. Once the river herring population in the Cocheco River became established after construction of a fish ladder, herring returns have improved but are subjected to lows likely due to high water conditions and sporadic availability of downstream passage over dams. Following the construction of a fish ladder construction in the Exeter River, the herring runs have been relatively low due to sea lamprey inundation, harvest pressure, inadequate downstream passage over dams, and water quality issues such as low dissolved oxygen in the upstream impoundment (NHF&G 2005). Once the herring population was established after ladder construction in the Oyster River, a carrying capacity population of above ~50,000 fish has been noted. Recent lows in returns to the Oyster River are likely due degraded water quality conditions and, as noted above, flood conditions. In the Lamprey River, herring passage appears to follow a sinusoidal pattern with a period of approximately 20 years. The Taylor River, in Hampton-Seabrook Harbor, has had the highest recorded returns of herring. However, this population has declined dramatically due to issues such as water quality degradation and harvesting. River herring returns to the rivers of the Great Bay Estuary have been combined in Figure HAB8-2. This figure illustrates growth of the returns during the 1970s and 1980s with the installation of and improvements in fish ladders, followed by a period of relative stability in the 1990s. There has been a general decline in river herring returns in recent years. This decline is due to a combination of natural fluctuations in populations, realization of a river’s carrying capacity, fish passage inefficiencies, possible overharvest, water quality degradation, and high water conditions. Returns can be improved through ladder improvements as shown in the Exeter and Winnicut (2001) however those improvements do not compensate for poor water quality within upstream impoundments.

Returns of American shad are shown in Figure HAB8-3. Shad returns to the Exeter River have been decreasing since 2001. Similar to river herring, the declines in shad returns are likely due to flood waters, impoundment water quality degradation and lack of downstream passage. Returns to the Lamprey and Cocheco Rivers have been minimal as well, largely due to fact that restoration efforts have focused on the Exeter River, leaving only a small residual spawning stock.

EXHIBIT 50 (AR K.27)

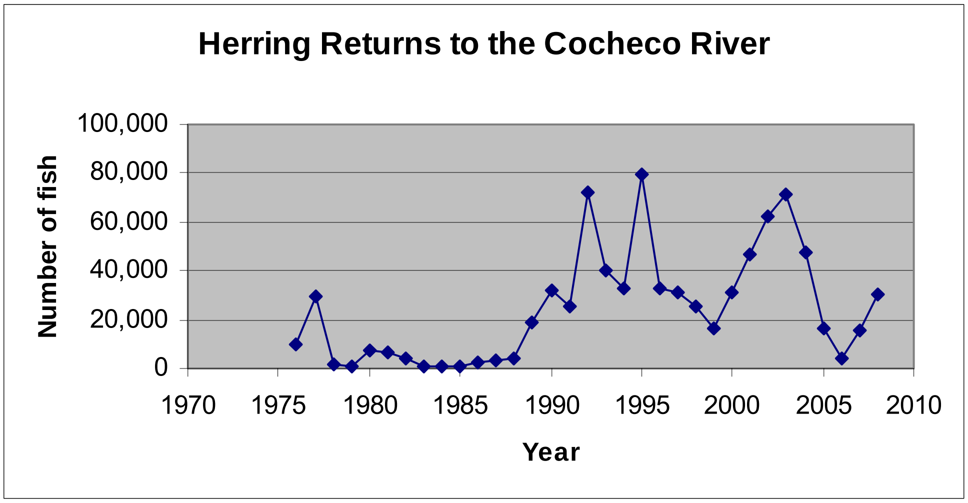
Rainbow smelt abundance has followed a moderate cyclical pattern of increasing and decreasing values with a period of 5-6 years. Peak abundance in recent years was in 1989 and 1995 (Figure HAB8-4).

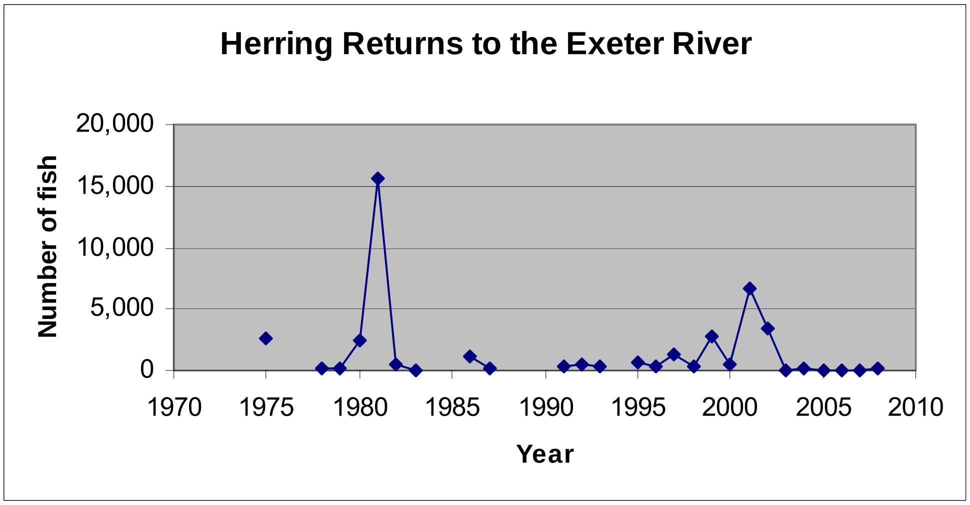
Figure HAB8-5 contains records of sea lamprey returns to the Cocheco River. Although lampreys have been sporadically recorded at other fish ladders, the records are best and most consistent at the Cocheco River ladder. From 1978 to 1988, a biological supply company harvested lampreys from the Exeter, Lamprey, and Cocheco rivers. The number of returning fish was depressed following this harvest. The abundance graph indicates that the lamprey population has been slowly rebounding since 1988.

Very few salmon have returned to NH's rivers. Between 1992 and 2003, only 44 fish were recorded in fish ladders. NHF&G discontinued salmon stocking and monitoring programs in 2004.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

Figure HAB8-1: Returns of river herring to fish ladders on NH coastal tributaries.





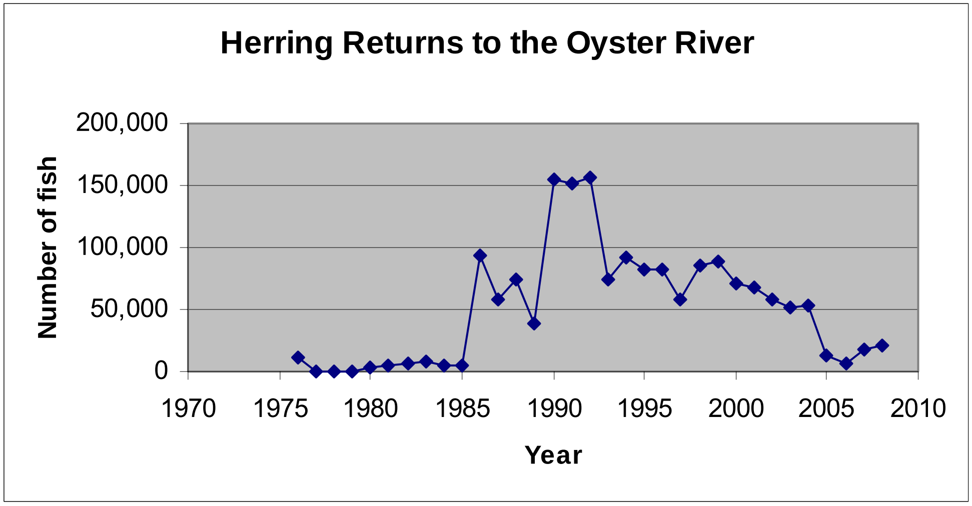
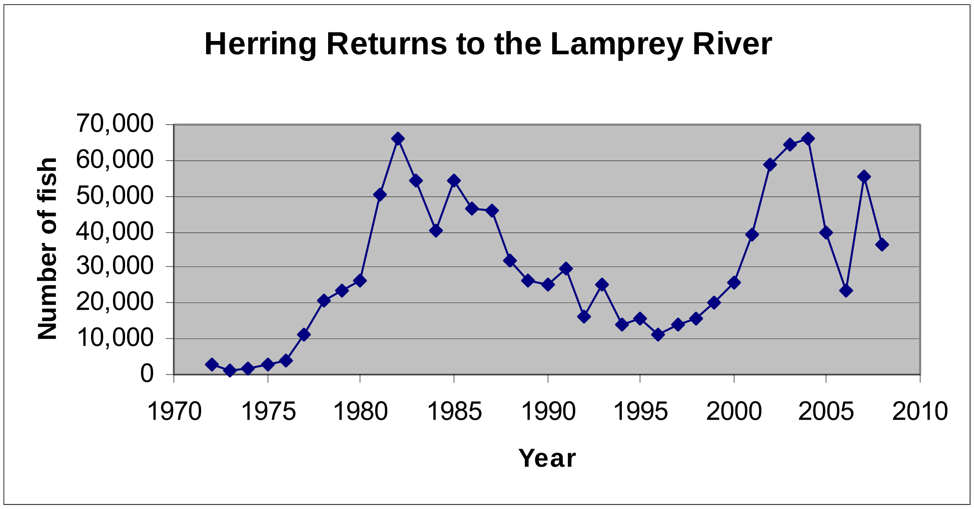
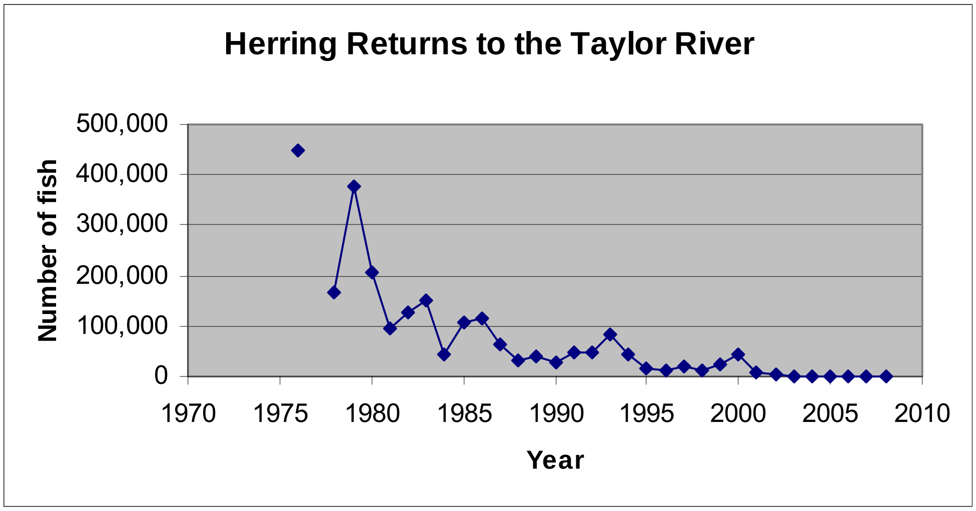


Figure HAB8-1: Returns of river herring to fish ladders on NH coastal tributaries (cont.)





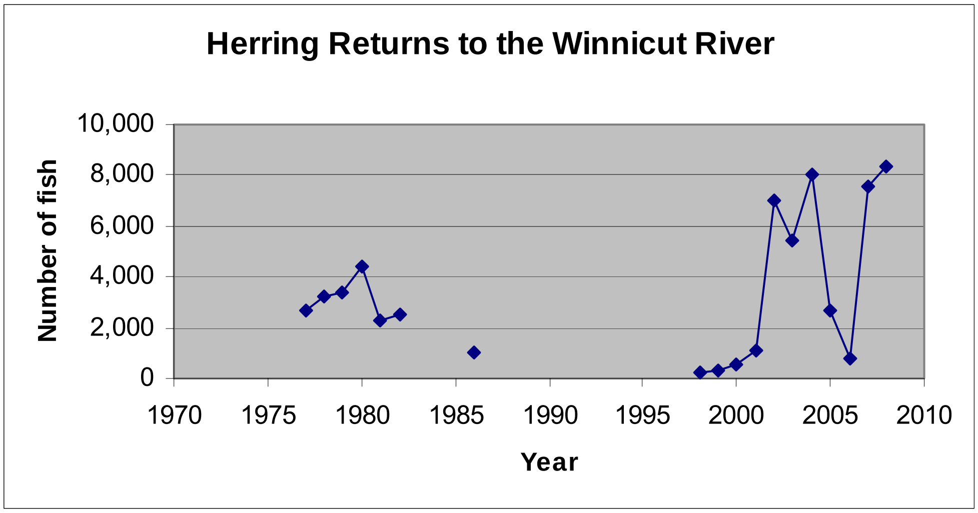


EXHIBIT 50 (AR K.27)

Figure HAB8-2: Returns of river herring to fish ladders in the Great Bay Estuary

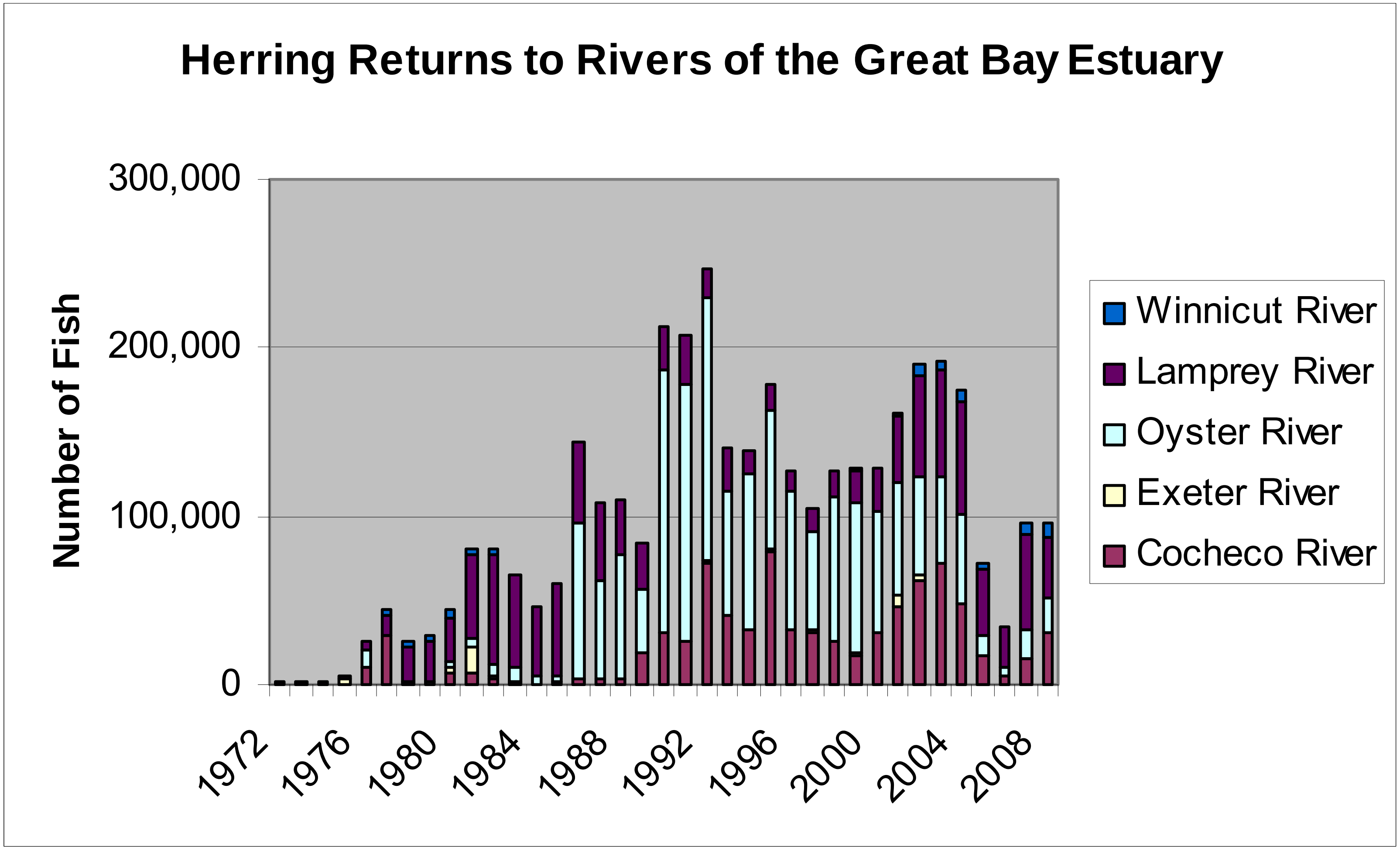


EXHIBIT 50 (AR K.27)

Figure HAB8-3: American shad returns to fish ladders on Great Bay tributaries.

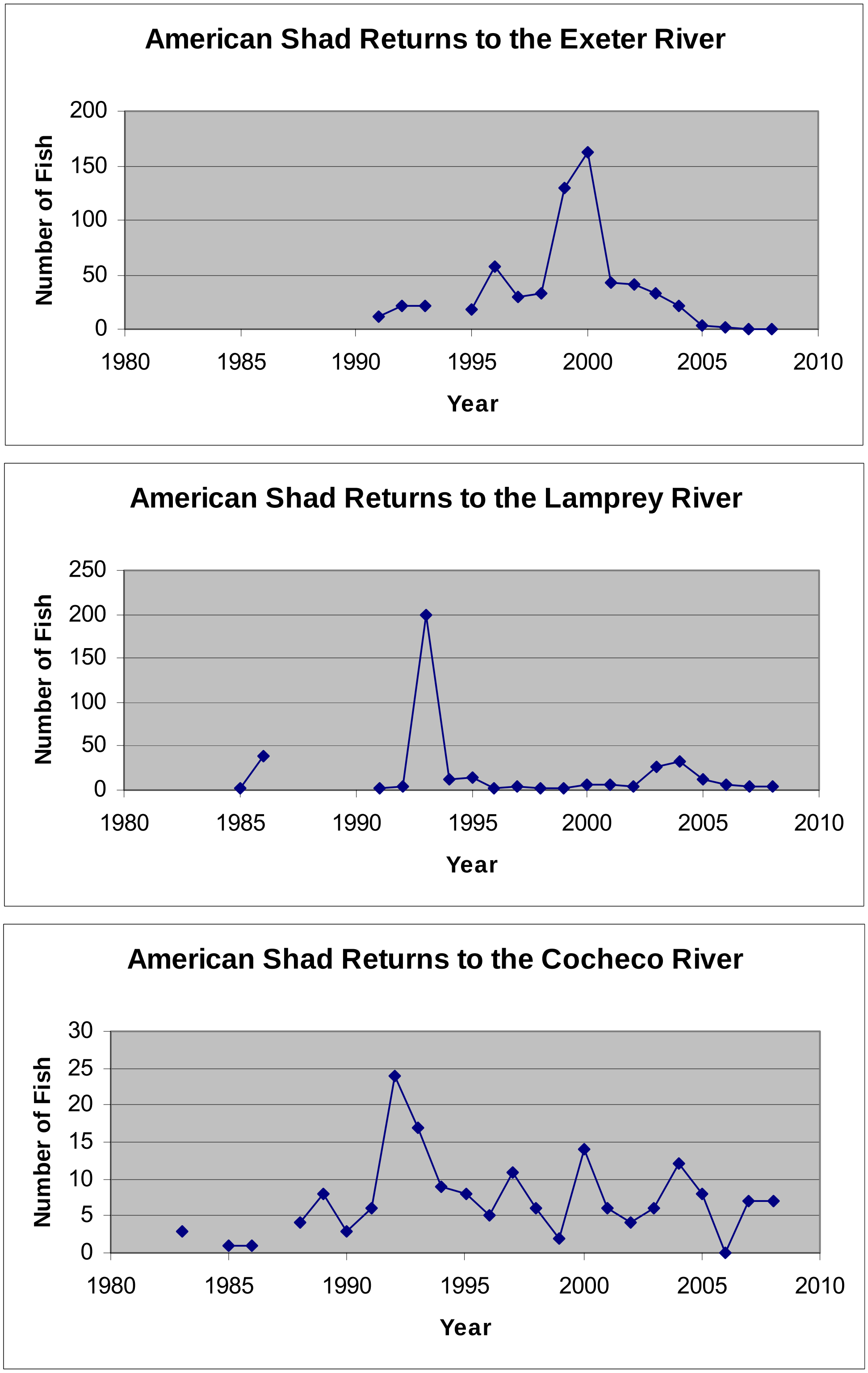


EXHIBIT 50 (AR K.27)

Figure HAB8-4: Abundance of rainbow smelt in the Great Bay ice fishery.

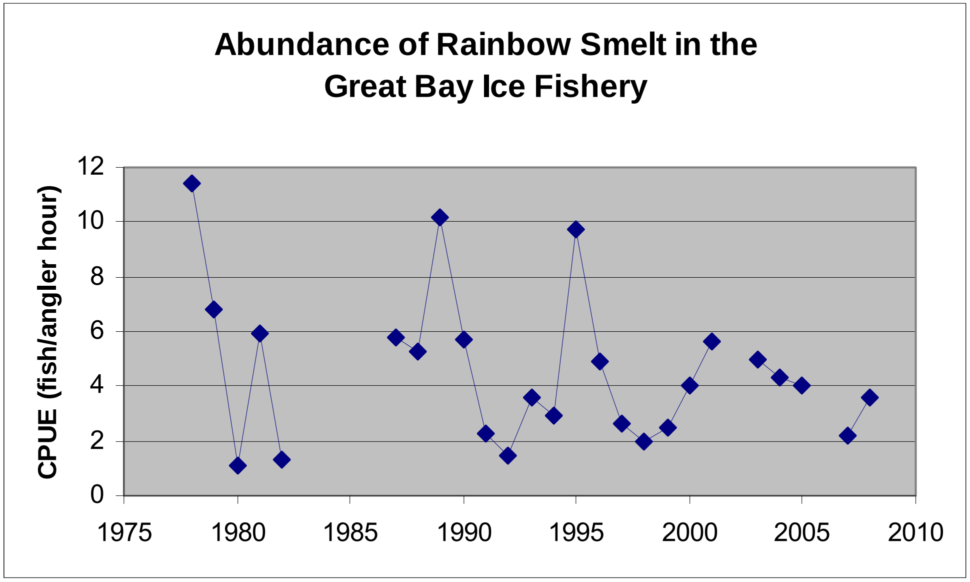


Figure HAB8-5: Number of sea lamprey returns to the Cocheco River fish ladder.

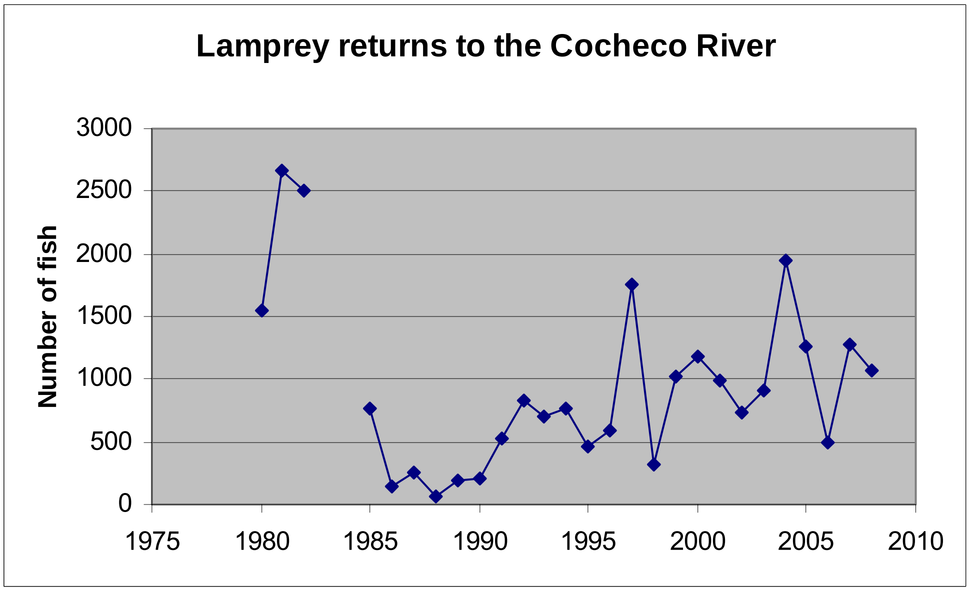


EXHIBIT 50 (AR K.27)

Indicator: HAB10. Abundance of Wintering Waterfowl

PREP Goal: No goal

Why This Is Important: Approximately 75% of all the waterfowl that winter in New Hampshire do so in the seacoast region, mainly in the Great Bay or Hampton-Seabrook Harbor (NHF&G, 1995). Wintering waterfowl depend on habitat provided by salt marshes, tidal flats, and eelgrass for survival. Therefore, the wintering waterfowl population in the estuary is an indicator of the health of these habitats. However, the population wintering over in any particular estuary along the Atlantic Flyway depends on multiple factors including the local climatic conditions and the total number of birds in the migration.

Monitoring Question: Has the population of wintering waterfowl on the NH coast changed over time?

Answer: There are no apparent trends in wintering waterfowl populations related to conditions in the estuary.Wintering waterfowl populations are controlled by many factors.

Explanation
Bird counts in the NH coast and the Atlantic Flyway are shown in Table HAB10-1 and Figure HAB10-1.

The most abundant waterfowl in both the NH coast and the Atlantic Flyway is the Canada goose, which constitutes approximately half of the birds counted. The next most abundant species are scaup in the Flyway and black duck on the NH coast. In 2009, 4,890 wintering waterfowl of the target species were observed on the NH coast, which is higher than the 10-year average of 4,735 birds observed. There were relatively fewer Canada geese and more scaup in NH in 2009 compared to observations during the previous 10 years, even though there were less scaup and equal numbers of Canada geese in the Flyway.

The birds stopping in the NH coast are just a fraction of the nearly 1.5 million waterfowl that migrate along the Atlantic Flyway. Over the past 50 years, the number of Canada geese in the Flyway has increased from 400,000 to 1,000,000 (Figure HAB10-2). The Canada goose population is important for eelgrass in the Great Bay because geese graze on the meristems of eelgrass plants, which kills the plant (Fred Short, *pers. comm.*).

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

Table HAB10-1: Wintering waterfowl in NH and the Atlantic Flyway

Species	New Hampshire Coast			Atlantic Flyway		
	2009	1999-2008 Average		2009	1999-2008 Average	
	Bird Counts	Bird Counts	Relative Percent	Bird Counts	Bird Counts	Relative Percent
Mallard (Anas platyrhynchos)	429	501	11%	139,335	145,222	9%
Black Duck (Anas rubripes)	905	785	17%	186,864	222,435	14%
Scaup (Aythya marila/affinis)	1,592	738	16%	263,712	351,420	21%
Canada Goose (Branta canadensis)	1,964	2,712	57%	915,951	919,517	56%
Total	4,890	4,735	100%	1,505,862	1,638,594	100%

EXHIBIT 50 (AR K.27)

Figure HAB10-1: Wintering waterfowl on the NH coast

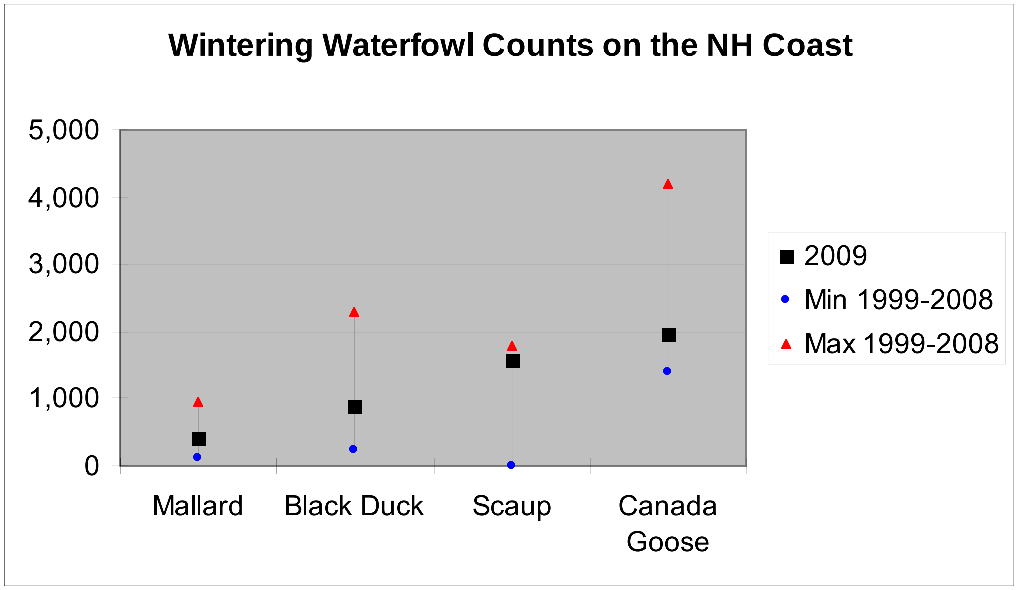


Figure HAB10-2: Wintering waterfowl in the Atlantic Flyway

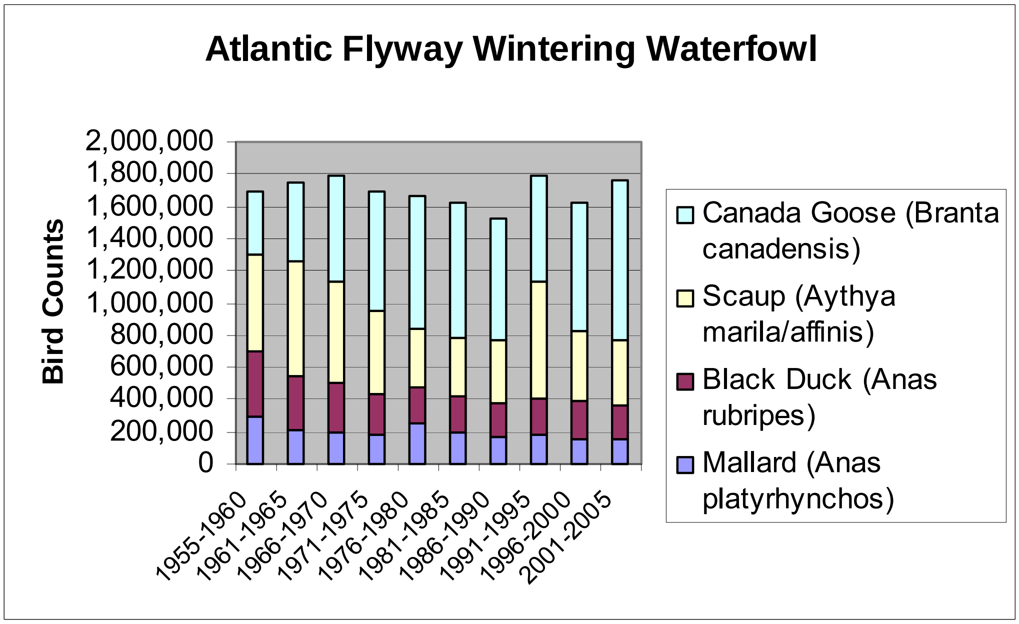


EXHIBIT 50 (AR K.27)

Environmental Indicators

C. Conservation, Restoration, and Development Indicators

EXHIBIT 50 (AR K.27)

Indicator: HAB6. Protected Conservation Lands

PREP Goal: Increase the acres of protected private and public lands from baseline levels to 15% of the land area of Piscataqua region watersheds and 15% of the land area of the coastal communities by 2010.

Why This Is Important: Development of land for residential, commercial, industrial, and other uses can eliminate or disrupt habitats and increase stormwater runoff and other sources of water pollution. Permanently protecting key areas from development will maintain the ecosystem benefits provided by healthy, natural landscapes.

Monitoring Question: How much of the coastal watershed is protected from development?

Answer: At the end of 2008, 76,269 acres in the Piscataqua Region watershed were protected, which amounted to 11.3 percent of the land area.

Explanation

Table HAB6-1 summarizes the acres of conservation lands in the Piscataqua Region watershed in both New Hampshire and Maine. By the end of 2008, there were 76,269 acres of protected land in the watershed. This amount is equivalent to 11.3% of the land area, which is still below the PREP goal of 15%. Eighty-five percent of the conservation lands have permanent protection status. The remaining lands are “unofficial” conservation lands, water supply lands, or recreational parks and fields. Parcels in Maine and New Hampshire make up 11.6 and 88.4% of the total conservation lands, respectively.

There are 22 municipalities in the PREP study area which have tidal shorelines, 17 in New Hampshire and 5 in Maine (Table HAB6-2). In these coastal communities, there was a total of 43,067 acres of conservation land in 2008 (16.9% of the total land area in these towns). This amount exceeds the PREP goal of 15%. However, only 73% of these conservation lands have permanent protection.

The conservation lands database for 2008 was updated by Wells National Estuarine Research Reserve for the Maine towns and The Nature Conservancy for the New Hampshire towns. The combination of these two datasets provides the first watershed-wide information on conservation lands for the Piscataqua Region. Therefore, it is not possible to evaluate changes over time for conservation lands for the whole watershed. However, in the New Hampshire portion of the watershed, the total amount of conservation lands has grown from 42,585 in 2002 (8.4%) to 54,622 in 2005 (10.7%) to 67,463 in 2008 (13.2%). The rate of growth of conservation lands in New Hampshire has been approximately 4,000 acres per year. In order to reach the PREP goal of protecting 15% of the entire Piscataqua Region watershed by 2010, an additional 24,676 acres of conservation lands are still needed.

The percentage of land area that is protected in each PREP municipality is shown in Table HAB6-2 and on Figure HAB6-1. Figure HAB6-1 illustrates that great progress toward the PREP goals has been made in the towns around Great Bay, near the coast, in the vicinity of the Bear Brook and Pawtuckaway State Parks, and in the Mt. Agamenticus to the Sea area. In contrast, there is a lower percentage of protected land in the Salmon Falls River and Cocheco River watersheds.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan with the following exceptions:

1. Some of the conservation lands in Maine overlapped with tidal waters. These conservation lands were clipped to the land area before calculating totals.
2. Conservation lands were grouped into “permanent”, “unofficial”, and “recreational” categories using the protection level fields from NH GRANIT and Wells NERR. Permanent conservation lands were Level 1 in both databases. Unofficial conservation lands were Levels 2 and 3 in both databases. Recreational lands (e.g., parks, fields) were Level 4 in both databases.

EXHIBIT 50 (AR K.27)

Table HAB6-1: Conservation lands in the Piscataqua Region watershed in 2008

Type	New Hampshire	Maine	Total	% of Total
Permanent	57,549	7,331	64,880	85.07%
Unofficial	9,269	1,475	10,743	14.09%
Recreational	645	0	645	0.85%
Total	67,463	8,806	76,269	100.00%
% of Total	88.45%	11.55%	100.00%	

Table HAB6-2: Conservation lands in PREP municipalities in 2002, 2005 and 2008

Town Name (*=coastal community)	Conservation Lands - 2002 (ac)	Conservation Lands - 2005 (ac)	Conservation Lands - 2008 (ac)	Percent Conservation - 2008
BARRINGTON, NH	2,551	2,734	3,157	10.6%
BRENTWOOD, NH	460	1,474	2,571	23.9%
BROOKFIELD, NH	1,813	1,845	2,461	16.9%
CANDIA, NH	1,891	2,046	2,110	10.9%
CHESTER, NH	1,320	1,312	1,311	7.9%
DANVILLE, NH	458	557	567	7.6%
DEERFIELD, NH	5,332	5,582	6,034	18.5%
DOVER, NH*	1,589	1,529	2,259	13.2%
DURHAM, NH*	3,401	4,326	5,010	35.0%
EAST KINGSTON, NH	156	670	847	13.4%
EPPING, NH	498	1,367	1,441	8.8%
EXETER, NH*	2,447	3,496	3,689	29.4%
FARMINGTON, NH	1,146	1,242	1,574	6.8%
FREMONT, NH	209	231	574	5.2%
GREENLAND, NH*	727	899	1,328	19.6%
HAMPTON, NH*	631	630	763	9.2%
HAMPTON FALLS, NH*	483	633	664	8.6%
KENSINGTON, NH	626	1,548	1,549	20.3%
KINGSTON, NH	1,067	1,376	1,473	11.8%
LEE, NH	1,239	2,340	2,336	18.4%
MADBURY, NH*	1,641	1,328	1,390	18.8%
MIDDLETON, NH	398	488	2,316	20.0%
MILTON, NH	2,568	2,553	2,672	12.7%
NEW CASTLE, NH*	106	106	106	21.0%
NEW DURHAM, NH	1,754	1,753	1,753	6.7%
NEWFIELDS, NH*	394	784	784	17.3%
NEWINGTON, NH*	1,216	1,307	1,307	25.1%
NEWMARKET, NH*	761	1,330	1,512	18.7%
NORTH HAMPTON, NH*	481	718	903	10.2%
NORTHWOOD, NH	2,150	2,381	2,476	13.8%
NOTTINGHAM, NH	5,676	5,860	8,112	27.1%
PORTSMOUTH, NH*	1,107	1,103	1,117	11.2%
RAYMOND, NH	1,075	1,017	1,247	6.8%
ROCHESTER, NH	436	436	1,013	3.6%

EXHIBIT 50 (AR K.27)

Town Name (*=coastal community)	Conservation Lands - 2002 (ac)	Conservation Lands - 2005 (ac)	Conservation Lands - 2008 (ac)	Percent Conservation - 2008
ROLLINSFORD, NH*	411	409	633	13.5%
RYE, NH*	1,246	1,495	1,532	19.2%
SANDOWN, NH	336	591	591	6.6%
SEABROOK, NH*	285	451	451	8.0%
SOMERSWORTH, NH	221	221	299	4.8%
STRAFFORD, NH	3,646	5,261	6,275	20.1%
STRATHAM, NH*	671	1,025	1,098	11.3%
WAKEFIELD, NH	284	397	691	2.7%
ACTON, ME	NA	NA	432	1.8%
BERWICK, ME	NA	NA	944	3.9%
ELIOT, ME*	NA	NA	583	4.6%
KITTERY, ME*	NA	NA	1,567	13.8%
LEBANON, ME	NA	NA	923	2.6%
NORTH BERWICK, ME	NA	NA	635	2.6%
SANFORD, ME	NA	NA	2,587	8.5%
SOUTH BERWICK, ME*	NA	NA	3,475	16.9%
WELLS, ME*	NA	NA	5,266	14.5%
YORK, ME*	NA	NA	7,631	21.9%
TOTAL:	**54,909**	**66,852**	**104,038**	**12.4%**
TOTAL Coastal Communities:	**17,598**	**21,570**	**43,069**	**16.9%**

(1) Data source for conservation lands in 2008: The Nature Conservancy (NH towns), Wells NERR (ME towns)

(2) Results are for the whole town. PREP also reports on conservation lands in the Piscataqua Region watershed. Some towns are only partially in the watershed.Therefore, there are some discrepancies between the totals on this table and the totals for the whole watershed.

(3) The dates of conservation lands are approximate and reflect the date when the parcel was reported with sufficient metadata, not the date of an easement or other instrument.

EXHIBIT 50 (AR K.27)

Figure HAB6-1: Percent of land area that is protected in each PREP municipality in 2008

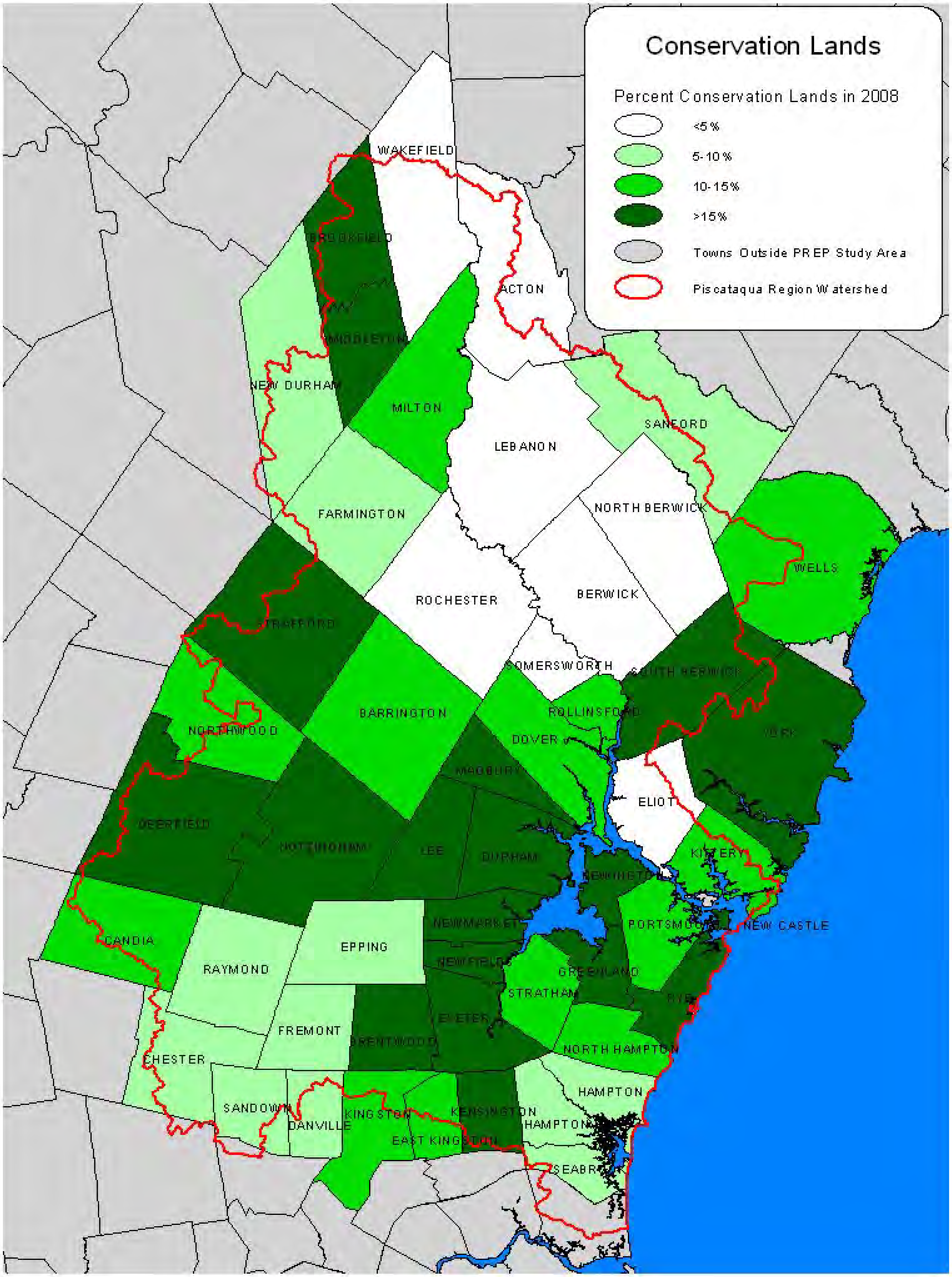


EXHIBIT 50 (AR K.27)

Indicator: HAB5. Protected Conservation Focus Areas in the Piscataqua Region Watersheds

This indicator was updated on 7/31/09 to include information on the conservation focus areas in Maine.

PREP Goal: No Goal

Why This Is Important: The Land Conservation Plan for New Hampshire's Coastal Watersheds (TNC, 2006) identified 75 Conservation Focus Areas in the New Hampshire portion of the Piscataqua Region watershed. Fifteen conservation focus areas have been delineated in the Maine side. These focus areas are priorities for conservation because of their high habitat values.

Monitoring Question: How much of the conservation focus areas in the coastal watershed are protected from development?

Answer: In 2008, 25 percent of the core areas in all conservation focus areas in New Hampshire and Maine were conserved.

Explanation

The updated database of conservation lands was merged with the locations of conservation focus areas in the Piscataqua Region watershed to determine how much of each focus area was protected from development. Table HAB5-1 shows the total area of conservation land in all of the focus areas. Overall, 42,046 acres of conservation land fall within the core focus areas, which amounts to 25% of the combined area of the focus areas.

The percent of conservation lands varies across the focus areas. Thirty of the 90 focus areas have less than 10% of the core land area protected. In contrast, there are 11 focus areas with greater than 50% coverage by conservation lands. The percentage of conservation lands in each focus area is shown in Tables HAB5-2 and HAB5-3 and on Figure HAB5-1.

In general, there is a higher percentage of conservation lands in conservation focus areas than in the watershed as a whole. Indicator HAB6 showed that 11.3% of the Piscataqua Region watershed was protected from development. In contrast, 57 of the 90 focus areas have at least 12% coverage by conservation lands and cumulatively 25% of the focus areas are covered by conservation lands.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan with the following exceptions:

1. Only core areas for conservation focus areas were used for this analysis.
2. Conservation lands were grouped into "permanent", "unofficial", and "recreational" categories using the protection level fields from NH GRANIT and Wells NERR. Permanent conservation lands were Level 1 in both databases. Unofficial conservation lands were Levels 2 and 3 in both databases. Recreational lands (e.g., parks, fields) were Level 4 in both databases.

EXHIBIT 50 (AR K.27)

Table HAB5-1: Conservation lands in all conservation focus areas in the Piscataqua Region watershed in 2008

Type	New Hampshire	Maine	Total	% of Total
Permanent	34,916.39	3,576.95	38,493.34	91.55%
Unofficial	2,664.73	723.15	3,387.88	8.06%
Recreational	164.80	0.00	164.80	0.39%
Total	37,745.92	4,300.09	42,046.01	100.00%
% of Total	89.77%	10.23%	100.00%	

Table HAB5-2: Conservation lands in individual conservation focus areas in New Hampshire in 2008

Focus Area	Area of Core CFA (acres)	Permanent Conservation Land (acres)	Unofficial Conservation Land (acres)	Active Recreational Land (acres)	Total Conservation Lands (acres)	Percent of Core CFA Area
Awcomin Marsh	885.02	335.71	0.00	0.00	335.71	37.9%
Bailey Brook	564.20	86.77	28.96	0.00	115.73	20.5%
Bayside Point	333.12	126.38	0.00	0.00	126.38	37.9%
Bellamy River	796.04	458.65	0.00	0.00	458.65	57.6%
Birch Hill Road Lowlands	57.74	0.00	0.00	0.00	0.00	0.0%
Bloody and Dudley Brooks	552.78	363.15	0.00	0.00	363.15	65.7%
Blue Hills	16,905.78	2,745.03	46.53	0.00	2,791.56	16.5%
Bumfagging Hill	2,361.07	314.97	0.00	0.00	314.97	13.3%
Candia Road	549.16	0.00	0.00	0.00	0.00	0.0%
Cocheco Headwaters	1,693.73	173.54	0.00	0.00	173.54	10.2%
Coldrain Pond	911.01	61.25	0.00	0.00	61.25	6.7%
Cooper Cedar Woods	379.52	130.91	0.00	0.00	130.91	34.5%
Creek Pond Marsh	671.19	590.36	0.00	0.00	590.36	88.0%
Crommet and Lubberland Creeks	3,798.67	2,114.57	0.00	3.11	2,117.68	55.7%
Davis and Oak Hill	1,337.32	38.77	0.00	0.00	38.77	2.9%
Dogtown Swamp	164.06	36.89	0.00	0.00	36.89	22.5%
Dumplingtown Hill	364.87	113.89	0.00	4.83	118.72	32.5%
Exeter River	620.35	390.87	4.50	0.00	395.37	63.7%
Fabyan Point	1,071.65	787.63	0.00	10.18	797.81	74.4%
Fordway Brook Headwaters	943.91	14.07	0.00	0.00	14.07	1.5%
Fresh Creek	325.92	0.00	0.00	0.00	0.00	0.0%
Garvin Brook	82.76	36.33	0.00	0.00	36.33	43.9%
Great Bog	989.22	390.17	0.00	0.00	390.17	39.4%
Great Meadows	1,400.24	139.93	674.87	0.00	814.80	58.2%
Hampton Marsh	7,488.42	569.91	69.47	25.61	664.99	8.9%
Hart Brook / Mt. Tenneriffe	3,502.97	393.36	335.43	0.00	728.79	20.8%
Johnson and Bunker Creeks	747.57	175.00	0.00	0.00	175.00	23.4%
Kennard Hill	1,294.60	0.00	0.00	0.00	0.00	0.0%
Lamprey River	1,722.17	385.89	0.00	0.00	385.89	22.4%
Langley and Cyrus Ponds	1,027.81	0.00	0.00	0.00	0.00	0.0%
LaRoche and Woodman Brooks	444.12	41.87	233.60	0.00	275.47	62.0%
Lower Berry's Brook	270.18	58.44	0.00	0.00	58.44	21.6%

EXHIBIT 50 (AR K.27)

Focus Area	Area of Core CFA (acres)	Permanent Conservation Land (acres)	Unofficial Conservation Land (acres)	Active Recreational Land (acres)	Total Conservation Lands (acres)	Percent of Core CFA Area
Lower Cocheco River	485.50	42.61	0.00	0.00	42.61	8.8%
Lower Fordway Brook	1,679.11	201.50	0.00	0.00	201.50	12.0%
Lower Isinglass River	1,260.85	102.94	16.85	0.00	119.79	9.5%
Lower Lamprey River	1,228.13	227.49	181.51	0.00	409.00	33.3%
Lower Little River	195.85	76.75	0.00	0.00	76.75	39.2%
Lower Lubberland Creek	239.13	177.34	0.00	0.00	177.34	74.2%
Lower Piscassic River	3,027.24	524.24	9.62	23.28	557.14	18.4%
Lower Winnicut River	229.02	55.62	0.00	5.74	61.36	26.8%
Middle Isinglass River	504.35	0.00	0.00	0.00	0.00	0.0%
Middle Little River	595.16	9.21	86.28	0.00	95.49	16.0%
Middle Piscassic River	2,281.30	1,189.93	0.00	14.85	1,204.78	52.8%
Middle Winnicut River	163.91	36.77	0.00	0.00	36.77	22.4%
Moose Mountains	8,799.04	3,573.69	81.68	0.00	3,655.37	41.5%
Muddy Pond	156.29	17.39	44.04	0.00	61.43	39.3%
North River / Rollins Brook	813.86	0.00	3.76	0.00	3.76	0.5%
Northeast Pond	1,803.31	707.37	0.00	0.00	707.37	39.2%
Oyster River	2,691.08	140.43	533.06	0.00	673.49	25.0%
Packer Bog	815.15	374.12	0.00	0.00	374.12	45.9%
Parkman Brook	547.25	45.27	0.00	0.00	45.27	8.3%
Pawtuckaway Mountains	23,142.56	10,041.14	0.00	0.00	10,041.14	43.4%
Pawtuckaway River	748.99	119.85	0.00	0.00	119.85	16.0%
Pike Brook	2,343.73	30.64	0.00	26.82	57.46	2.5%
Preston Pond	342.52	0.00	0.00	0.00	0.00	0.0%
Rochester Heath Bog	1,024.04	49.15	0.00	0.00	49.15	4.8%
Rochester Neck	1,605.23	136.30	0.00	0.00	136.30	8.5%
Saddleback Mountain	3,605.43	1,369.73	259.02	0.00	1,628.75	45.2%
Seavey Creek / Fairhill Swamp	636.65	440.54	0.00	0.00	440.54	69.2%
Spruce Swamp	1,854.54	427.13	11.23	14.47	452.83	24.4%
Squamscott River	2,023.57	605.36	3.41	0.00	608.77	30.1%
Stonehouse Brook	726.48	0.00	0.00	0.00	0.00	0.0%
Taylor River and The Cove	2,421.89	538.67	0.00	0.00	538.67	22.2%
Thurston Pond / Hartford Brook	2,865.47	553.12	0.00	0.00	553.12	19.3%
Union Meadows	985.90	43.93	0.00	0.00	43.93	4.5%
Upper Berry's Brook	1,460.65	296.15	23.13	0.00	319.28	21.9%
Upper Exeter River	3,012.47	220.54	0.00	35.91	256.45	8.5%
Upper Great Brook	543.55	186.30	0.00	0.00	186.30	34.3%
Upper Isinglass River	853.75	140.74	0.00	0.00	140.74	16.5%
Upper Little River	326.56	87.28	0.00	0.00	87.28	26.7%
Upper North Branch River	2,885.64	743.15	0.00	0.00	743.15	25.8%
Upper Taylor River	438.99	105.85	0.00	0.00	105.85	24.1%
Upper Winnicut River	289.58	44.89	0.00	0.00	44.89	15.5%
Wallis Marsh	310.88	113.93	12.41	0.00	126.34	40.6%
Winnicut River / Cornelius Brook	329.43	45.02	5.37	0.00	50.39	15.3%
Total	136,551.17	34,916.39	2,664.73	164.80	37,745.92	27.6%

EXHIBIT 50 (AR K.27)

Table HAB5-3: Conservation lands in individual conservation focus areas in Maine in 2008

Focus Area	Area of Core CFA (acres)	Permanent Conservation Land (acres)	Unofficial Conservation Land (acres)	Active Recreational Land (acres)	Total Conservation Lands (acres)	Percent of Core CFA Area
Bauneg Beg Mountain	1,572.20	0.00	0.00	0.00	0.00	0.0%
Beaver Dam Heath	1,051.75	103.47	0.00	0.00	103.47	9.8%
Brave Boat Harbor and Gerrish Island	347.95	103.87	3.98	0.00	107.85	31.0%
Cranberry Meadow	426.70	169.69	0.00	0.00	169.69	39.8%
Gerrish Mountain	1,282.71	0.00	0.00	0.00	0.00	0.0%
Knights Pond	113.54	0.00	0.00	0.00	0.00	0.0%
Little River East	4,373.50	0.00	0.00	0.00	0.00	0.0%
Little River West	476.93	32.66	0.00	0.00	32.66	6.8%
Merriland River Wetlands	3,257.17	51.32	283.35	0.00	334.67	10.3%
Mount Agamenticus and York River Headwaters	6,851.18	2,732.93	245.84	0.00	2,978.77	43.5%
Sanford Ponds	907.76	26.87	71.50	0.00	98.36	10.8%
Shapleigh Pond	72.00	0.00	0.00	0.00	0.00	0.0%
South Acton Swamps	8,182.81	306.85	105.92	0.00	412.77	5.0%
Sturgeon Creek	295.97	49.30	0.00	0.00	49.30	16.7%
West Sanford Swamps	1,256.58	0.00	12.55	0.00	12.55	1.0%
Total	30,468.74	3,576.95	723.15	0.00	4,300.09	14.1%

EXHIBIT 50 (AR K.27)

Figure HAB5-1: Percent of land area that is protected in each core conservation focus area in 2008

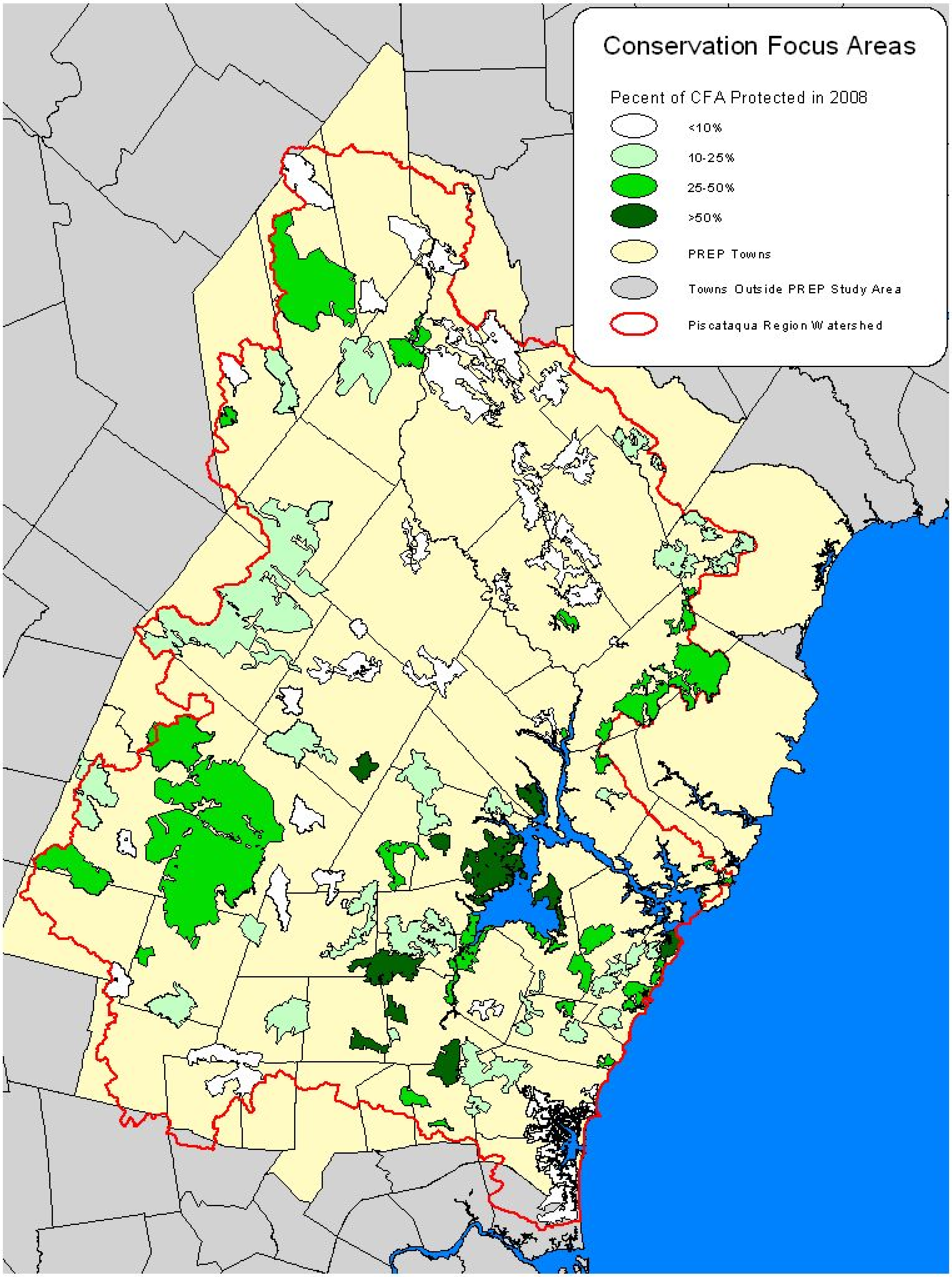


EXHIBIT 50 (AR K.27)

Indicator: RST1. Restored Salt Marsh

PREP Goal: The goal is to restore 300 acres of salt marsh by 2010.

Why This Is Important: Historic data suggests that salt marshes, oyster beds, and eelgrass habitats in New Hampshire's estuaries have been degraded or destroyed over time. Restoration efforts attempt to restore the function of these critical habitats.

Monitoring Question: Have restoration efforts resulted in a significant increase in the acreage of salt marshes?

Answer: Yes. 280 acres of salt marsh have been restored since 2000.

Explanation
There has been significant progress toward the goal of restoring 300 acres between 2000 and 2008 (Figure RST1-1). The current tally of salt marsh restoration projects by tidal restriction removal since January 1, 2000 is 280 acres (93% of goal).

This indicator tracks restoration effort in terms of acres for which restoration was attempted. The area of functional habitat created by restoration projects may be lower.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

Figure RST1-1: Cumulative acres of salt marsh restoration through tidal restriction removal

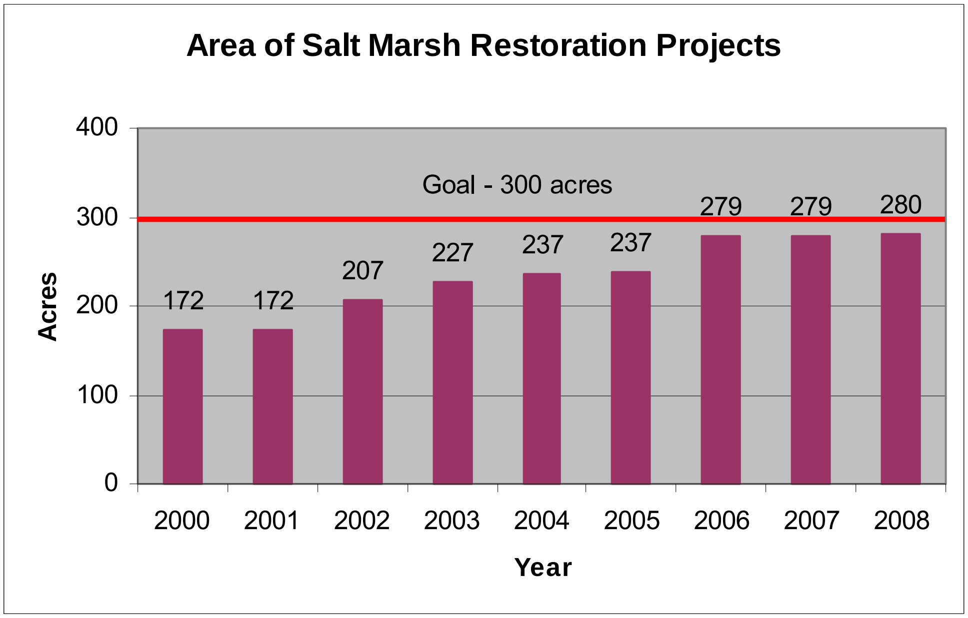


EXHIBIT 50 (AR K.27)

Indicator: RST2. Restored Eelgrass Beds

PREP Goal: The goal is to restore 50 acres of eelgrass beds by 2010.

Why This Is Important: Historic data suggests that salt marshes, oyster beds, and eelgrass habitats in New Hampshire's estuaries have been degraded or destroyed over time. Restoration efforts attempt to restore the function of these critical habitats.

Monitoring Question: Have restoration efforts resulted in a significant increase in the acreage of eelgrass beds?

Answer: 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.

Explanation
Three eelgrass planting projects have been completed since January 1, 2000. A small, community-based project was attempted in North Mill Pond in 2000. Eelgrass was transplanted in over twenty frames (0.25 m^2/frame). The total area covered by the project was 0.5 acres. None of the transplants survived due to inadequate water quality.

In 2001, an eelgrass mitigation project for the US Army Corps of Engineers was completed in Little Harbor. Eelgrass was transplanted over 5.5 acres. The restoration was monitored for one year following the transplant and found to be successful. However, because the impetus for this project was to replace eelgrass beds that were destroyed, it was not counted toward the PREP goal.

In 2005, eelgrass was transplanted to locations in the Bellamy River (1 ac.) and Portsmouth Harbor (0.25 ac.). In 2006-2008, a total of 6.8 acres of eelgrass have been restored in the Bellamy River. The project was funded by the Natural Resource Conservation Service. Therefore, since 2000, 8.05 acres of eelgrass restoration projects have been completed (16% of the goal). Prior to 2005, no state or federal money was available for eelgrass restoration. This indicator tracks restoration effort in terms of acres for which restoration was attempted. The area of functional habitat created by restoration projects may be lower.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

Figure RST2-1: Cumulative acres of eelgrass bed restoration

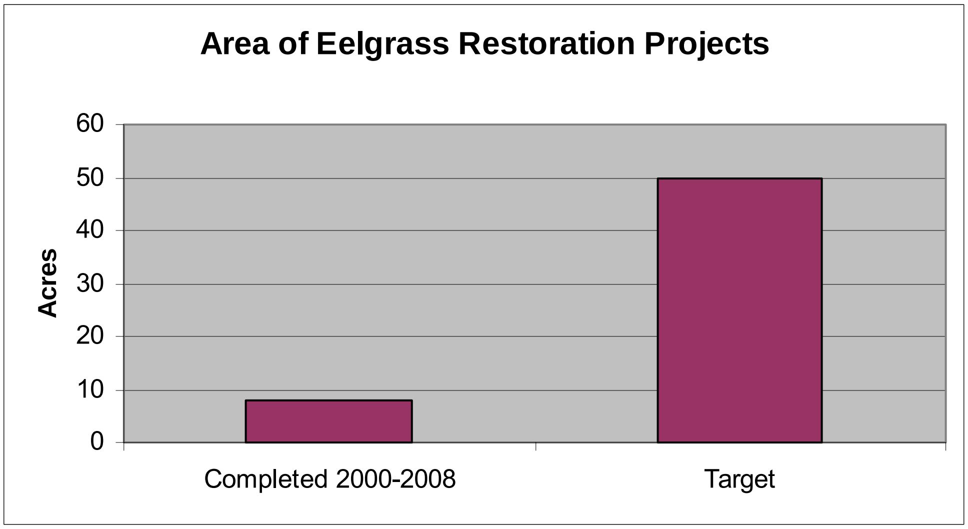


EXHIBIT 50 (AR K.27)

Indicator: RST3. Restored Oyster Beds

PREP Goal: The goal is to restore 20 acres of oyster beds by 2010.

Historic data suggests that salt marshes, oyster beds, and eelgrass habitats in New Hampshire's estuaries have been degraded or destroyed over time. Restoration efforts attempt to restore the function of these critical habitats.

Monitoring Question: Have restoration efforts resulted in a significant increase in the acreage of oyster beds?

Answer: A total of 6.58 acres of oyster beds have been created in the Great Bay Estuary, which is only 33% of the goal. Mortality due to oyster diseases is a major impediment to oyster restoration.

Explanation
Eight oyster restoration projects have been implemented in the Great Bay Estuary. As a result of these projects, a total of 6.58 acres of oyster bed has been restored (33% of goal) (Figure RST3-1). All of the projects involved remote setting of disease-resistant spat followed by introduction of the settled spat to an artificial reef. High mortality was reported for some of the restoration sites. However, the restoration work still created oyster habitat by installing cultch or other materials on which spat could settle. Additional information about oyster restorations in New Hampshire is available from www.oyster.unh.edu. A major impediment to oyster restoration efforts in the Great Bay is the ongoing oyster mortality due to MSX and Dermo infections in native oysters. Inconsistent year spatfall is another limiting factor.

This indicator tracks restoration effort in terms of acres for which restoration was attempted. The area of functional habitat created by restoration projects may be lower.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

Figure RST3-1: Cumulative acres of oyster bed restoration

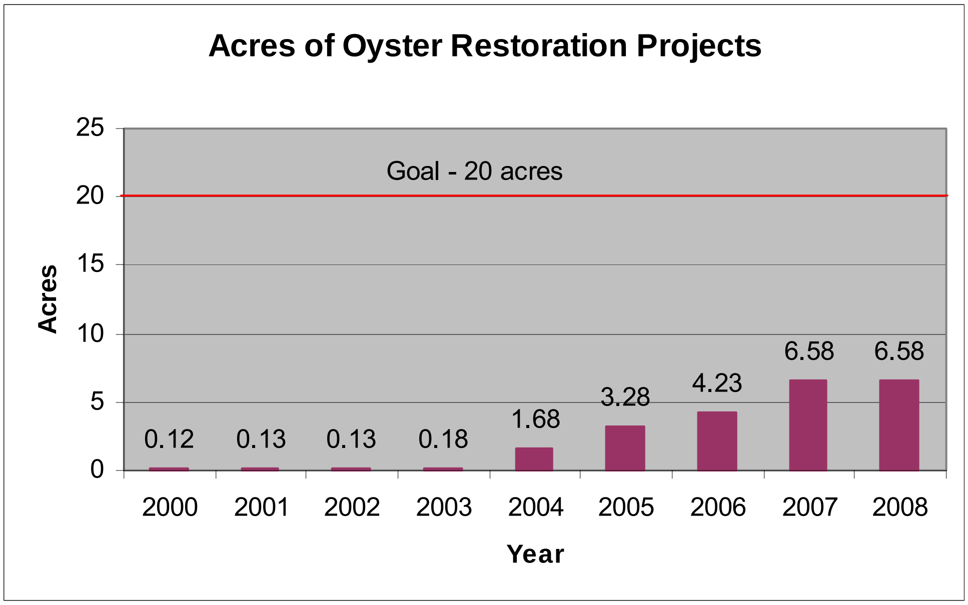


EXHIBIT 50 (AR K.27)

Indicator: LUD1. Impervious Surfaces in Coastal Subwatersheds

PREP Goal: The goal is to have none of the subwatersheds in the coastal watershed with impervious surfaces covering more than 10% of the watershed area. The original goal from the PREP Management Plan, which was set before the level of impervious surface cover was known, was to keep the percent impervious surfaces in all coastal watersheds less than 10%. Based on the monitoring results for 1990, 2000, and 2005, this goal is not being met, nor will the goal be met in the near future since impervious surfaces are unlikely to decline over time. As an interim goal, the PREP should work to slow the growth of impervious surfaces in those watersheds that are still less than 10% impervious so that the number of watersheds exceeding 10% impervious does not increase from the current number of 9.

Why This Is Important: Impervious surfaces such as paved parking lots, roadways, and building roofs increase the pollutant load, sediment load, volume, and velocity of stormwater flowing into the estuaries. Studies conducted in other regions of the country have demonstrated water quality deterioration where impervious surfaces cover greater than 10 percent of the watershed area (CWP, 2003). In 2005, a study in New Hampshire demonstrated the percent of urban land use in stream buffer zones and the percent of impervious surface in a watershed can be used as indicators of stream quality (Deacon et al., 2005).

Monitoring Question: How much of New Hampshire's coastal watershed is covered by impervious surfaces?

Answer: In 2005, 7.5 percent of the land area of the watershed was covered by impervious surfaces, and 9 subwatersheds had greater than 10 percent impervious surface cover.

Explanation
The percent impervious results for the 40 HUC12 watersheds and 52 municipalities in the coastal watershed are reported on Table LUD1-1 and Table LUD1-2. Overall, the area of impervious surfaces has grown from 28,710 acres in 1990 to 42,618 acres in 2000 to 50,351 acres in 2005. The number of watersheds with greater than 10% impervious surface cover was 2 in 1990, 8 in 2000, and 9 in 2005. The number of towns with greater than 10% impervious surface cover has grown similarly (Figure LUD1-1). On a percentage basis, the 4.3%, 6.3%, and 7.5% of the land area in the watershed was covered by impervious surfaces in 1990, 2000, and 2005, respectively (Figure LUD1-2). Between 1990 and 2000, 13,908 acres of impervious surfaces were added to the watershed (1,391 acres per year). Impervious surfaces were added at a slightly higher rate between 2000 and 2005 (1,547 acres per year). All of these summary statistics show that impervious surfaces continue to be added to the watershed at about the same rate. On average, 1,443 acres of impervious surfaces were added to the watershed each year for the 15-year period, which amounts to 0.2% of the land area in the watershed each year.

The percent of impervious surfaces in each coastal watershed in 2005 is shown in Figure LUD1-3. A similar map for the coastal municipalities is provided in Figure LUD1-4. The watersheds and municipalities which had greater than 10% impervious cover in 2005 were mostly along the Atlantic Coast and in the Cocheco River watershed.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan with the following exceptions:
1. In previous reports, a threshold of 10.7% was used to identify towns or watersheds exceeding the 10% impervious surface goal. The 0.7% was added to test for statistical significance because 0.7% was the estimated error in the percent impervious surface values. In this report, a threshold of 10% was used to reduce confusion and to harmonize the maps and tables.

EXHIBIT 50 (AR K.27)

Table LUD1-1: Impervious surface coverage in coastal watersheds

Watershed		Impervious Surfaces (acres)			Percent Imperviousness (%)				Meeting Goal	Comments
HUC10	HUC12	1990	2000	2005	1990	2000	2005	Goal		
Great Works River	Great Works River (1) at North Berwick	952.2	1,496.1	1,757.5	3.4%	5.3%	6.2%	10%	Yes	
Great Works River	Great Works River (2) at mouth	537.7	946.2	1,157.4	2.0%	3.6%	4.3%	10%	Yes	
Salmon Falls River	Upper Branch River-Lovell Lake	402.8	555.4	616.7	2.3%	3.2%	3.5%	10%	Yes	
Salmon Falls River	Junes Brook-Branch River	318.7	442.6	497.0	1.9%	2.6%	2.9%	10%	Yes	
Salmon Falls River	Headwaters-Great East Lake	267.4	410.8	475.3	1.8%	2.7%	3.1%	10%	Yes	(1)
Salmon Falls River	Milton Pond	285.9	422.9	509.2	2.0%	3.0%	3.6%	10%	Yes	(1)
Salmon Falls River	Little River	471.7	793.3	983.4	1.4%	2.3%	2.8%	10%	Yes	
Salmon Falls River	Middle Salmon Falls River	1,645.3	2,471.3	3,079.4	4.3%	6.5%	8.1%	10%	Yes	(1)
Salmon Falls River	Lower Salmon Falls River	670.4	1,001.8	1,204.2	5.0%	7.4%	8.9%	10%	Yes	(1)
Cocheco River	Upper Cocheco River	699.9	970.3	1,174.8	2.6%	3.6%	4.3%	10%	Yes	
Cocheco River	Axe Handle Brook	212.3	290.2	363.9	3.0%	4.1%	5.1%	10%	Yes	
Cocheco River	Middle Cocheco River	1,267.3	1,684.5	1,911.7	8.0%	10.6%	12.1%	10%	No	
Cocheco River	Bow Lake	121.0	184.7	216.7	1.5%	2.3%	2.7%	10%	Yes	
Cocheco River	Nippo Brook-Isinglass River	266.0	373.5	452.8	1.6%	2.2%	2.6%	10%	Yes	
Cocheco River	Long Pond	148.0	220.7	248.9	1.5%	2.2%	2.5%	10%	Yes	
Cocheco River	Lower Isinglass River	802.7	1,183.8	1,339.2	5.6%	8.3%	9.4%	10%	Yes	
Cocheco River	Lower Cocheco River	1,502.4	2,080.2	2,535.1	9.3%	12.9%	15.8%	10%	No	
Lamprey River	Headwaters-Lamprey River	371.6	593.2	726.9	1.7%	2.7%	3.3%	10%	Yes	
Lamprey River	North Branch River	255.0	392.7	459.4	2.3%	3.6%	4.2%	10%	Yes	
Lamprey River	Middle Lamprey River	1,232.4	1,879.7	2,217.0	4.8%	7.3%	8.6%	10%	Yes	
Lamprey River	Pawtuckaway Pond	111.6	171.0	193.9	0.9%	1.4%	1.6%	10%	Yes	
Lamprey River	Bean River	256.3	374.4	461.9	1.7%	2.5%	3.1%	10%	Yes	
Lamprey River	North River	155.8	255.7	320.6	1.8%	3.0%	3.7%	10%	Yes	
Lamprey River	Little River (Lamprey)	289.0	446.0	531.2	2.3%	3.5%	4.1%	10%	Yes	
Lamprey River	Piscassic River	513.6	885.0	1,091.0	3.6%	6.1%	7.6%	10%	Yes	
Lamprey River	Lower Lamprey River	521.4	767.8	831.1	4.0%	5.8%	6.3%	10%	Yes	
Exeter River	Watson Brook	330.5	531.5	642.3	3.2%	5.1%	6.1%	10%	Yes	
Exeter River	Towle Brook-Lily Pond	649.6	1,090.9	1,360.5	3.1%	5.2%	6.5%	10%	Yes	
Exeter River	Spruce Swamp-Little River	649.2	1,022.8	1,179.2	4.5%	7.1%	8.2%	10%	Yes	
Exeter River	Little River (Exeter)	563.0	823.0	1,001.0	5.7%	8.4%	10.2%	10%	No	
Exeter River	Great Brook-Exeter River	497.1	782.7	928.9	4.0%	6.4%	7.5%	10%	Yes	

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Watershed		Impervious Surfaces (acres)			Percent Imperviousness (%)				Meeting Goal	Comments
HUC10	HUC12	1990	2000	2005	1990	2000	2005	Goal		
Exeter River	Squamscott River	915.1	1,379.6	1,645.0	6.9%	10.4%	12.4%	10%	No	
Great Bay Drainage	Winnicut River	777.9	1,189.7	1,381.4	7.0%	10.7%	12.4%	10%	No	
Great Bay Drainage	Oyster River	969.3	1,480.3	1,664.1	4.9%	7.5%	8.4%	10%	Yes	
Great Bay Drainage	Bellamy River	1,147.9	1,707.9	2,028.4	5.4%	8.1%	9.6%	10%	Yes	
Great Bay Drainage	Great Bay	810.3	1,185.9	1,342.0	4.5%	6.5%	7.4%	10%	Yes	
Coastal Drainage	Portsmouth Harbor	3,593.0	4,984.1	5,743.6	12.8%	17.8%	20.5%	10%	No	(1)
Coastal Drainage	Berrys Brook-Rye Harbor	842.6	1,236.8	1,414.8	8.0%	11.8%	13.5%	10%	No	
Coastal Drainage	Taylor River-Hampton River	1,156.6	1,745.4	2,145.1	8.0%	12.1%	14.9%	10%	No	
Coastal Drainage	Hampton Harbor	1,529.2	2,163.3	2,518.5	10.8%	15.3%	17.8%	10%	No	(1)
TOTAL		**28,710**	**42,618**	**50,351**	**4.3%**	**6.3%**	**7.5%**			

(1) Includes both the NH and Maine or NH and Massachusetts portions of the watershed.
(2) Data Source: UNH Complex Systems Research Center
(3) The uncertainty for all the percent impervious values was assumed to be +/-0.7%. This value is the size of the error bar for an average watershed.
(4) Watersheds with >10% impervious cover are highlighted.

EXHIBIT 50 (AR K.27)

Table LUD1-2: Impervious surface coverage in coastal municipalities

Town	Mapped Area (acres)			Impervious Surface (acres)			Percent Imperviousness (%)				Meeting
Name	Total	Water	Land	1990	2000	2005	1990	2000	2005	Goal	Goal
BARRINGTON, NH	31,117	1,398	29,719	763.5	1,186.7	1,387.0	2.6%	4.0%	4.7%	10%	Yes
BRENTWOOD, NH	10,862	121	10,742	532.1	828.8	1,023.2	5.0%	7.7%	9.5%	10%	Yes
BROOKFIELD, NH	14,880	287	14,593	139.2	190.8	198.2	1.0%	1.3%	1.4%	10%	Yes
CANDIA, NH	19,557	215	19,342	531.4	794.0	930.9	2.7%	4.1%	4.8%	10%	Yes
CHESTER, NH	16,718	98	16,620	423.4	720.4	855.5	2.5%	4.3%	5.1%	10%	Yes
DANVILLE, NH	7,569	131	7,439	260.4	445.3	533.7	3.5%	6.0%	7.2%	10%	Yes
DEERFIELD, NH	33,349	762	32,587	492.0	768.0	969.0	1.5%	2.4%	3.0%	10%	Yes
DOVER, NH	18,592	1,498	17,094	1,872.6	2,626.4	3,171.6	11.0%	15.4%	18.6%	10%	No
DURHAM, NH	15,852	1,543	14,308	675.0	1,025.6	1,098.0	4.7%	7.2%	7.7%	10%	Yes
EAST KINGSTON, NH	6,381	62	6,319	221.5	335.2	439.3	3.5%	5.3%	7.0%	10%	Yes
EPPING, NH	16,776	308	16,468	657.8	1,070.8	1,291.8	4.0%	6.5%	7.8%	10%	Yes
EXETER, NH	12,814	261	12,553	937.4	1,375.8	1,559.3	7.5%	11.0%	12.4%	10%	No
FARMINGTON, NH	23,640	419	23,221	687.1	965.6	1,089.5	3.0%	4.2%	4.7%	10%	Yes
FREMONT, NH	11,143	107	11,036	329.3	537.9	654.3	3.0%	4.9%	5.9%	10%	Yes
GREENLAND, NH	8,524	1,744	6,780	455.0	712.6	844.9	6.7%	10.5%	12.5%	10%	No
HAMPTON, NH	9,071	754	8,317	1,179.3	1,605.5	1,717.1	14.2%	19.3%	20.6%	10%	No
HAMPTON FALLS, NH	8,077	358	7,719	341.8	536.1	698.7	4.4%	6.9%	9.1%	10%	Yes
KENSINGTON, NH	7,668	31	7,637	243.3	378.4	469.8	3.2%	5.0%	6.2%	10%	Yes
KINGSTON, NH	13,450	955	12,495	651.0	1,018.7	1,211.7	5.2%	8.2%	9.7%	10%	Yes
LEE, NH	12,928	248	12,680	467.6	740.5	840.6	3.7%	5.8%	6.6%	10%	Yes
MADBURY, NH	7,799	396	7,403	251.5	393.7	391.7	3.4%	5.3%	5.3%	10%	Yes
MIDDLETON, NH	11,843	283	11,560	204.5	284.2	350.4	1.8%	2.5%	3.0%	10%	Yes
MILTON, NH	21,935	836	21,099	597.4	838.8	985.3	2.8%	4.0%	4.7%	10%	Yes
NEW CASTLE, NH	1,348	843	504	108.1	155.0	170.9	21.4%	30.7%	33.9%	10%	No
NEW DURHAM, NH	28,054	1,707	26,347	458.3	627.9	727.2	1.7%	2.4%	2.8%	10%	Yes
NEWFIELDS, NH	4,647	105	4,542	141.6	250.6	307.5	3.1%	5.5%	6.8%	10%	Yes
NEWINGTON, NH	7,916	2,701	5,215	686.9	941.0	1,055.8	13.2%	18.0%	20.2%	10%	No
NEWMARKET, NH	9,080	1,007	8,073	479.7	706.6	818.8	5.9%	8.8%	10.1%	10%	No
NORTH HAMPTON, NH	8,922	57	8,865	647.5	957.6	1,100.2	7.3%	10.8%	12.4%	10%	No
NORTHWOOD, NH	19,356	1,380	17,976	424.1	610.1	716.7	2.4%	3.4%	4.0%	10%	Yes
NOTTINGHAM, NH	30,997	1,116	29,880	447.9	692.7	842.2	1.5%	2.3%	2.8%	10%	Yes

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Town	Mapped Area (acres)			Impervious Surface (acres)			Percent Imperviousness (%)				Meeting
Name	Total	Water	Land	1990	2000	2005	1990	2000	2005	Goal	Goal
PORTSMOUTH, NH	10,763	762	10,001	2,128.3	2,726.0	3,054.3	21.3%	27.3%	30.5%	10%	No
RAYMOND, NH	18,944	495	18,448	977.3	1,483.6	1,713.6	5.3%	8.0%	9.3%	10%	Yes
ROCHESTER, NH	29,081	750	28,331	2,395.2	3,304.5	3,942.3	8.5%	11.7%	13.9%	10%	No
ROLLINSFORD, NH	4,843	161	4,682	265.5	381.3	437.4	5.7%	8.1%	9.3%	10%	Yes
RYE, NH	8,424	426	7,997	586.5	877.9	1,026.3	7.3%	11.0%	12.8%	10%	No
SANDOWN, NH	9,232	343	8,889	337.2	544.2	701.3	3.8%	6.1%	7.9%	10%	Yes
SEABROOK, NH	6,160	491	5,669	801.6	1,206.1	1,538.7	14.1%	21.3%	27.1%	10%	No
SOMERSWORTH, NH	6,399	179	6,220	767.7	1,021.2	1,256.7	12.3%	16.4%	20.2%	10%	No
STRAFFORD, NH	32,779	1,626	31,153	434.0	637.9	726.6	1.4%	2.0%	2.3%	10%	Yes
STRATHAM, NH	9,901	228	9,672	628.3	979.2	1,245.7	6.5%	10.1%	12.9%	10%	No
WAKEFIELD, NH	28,716	3,452	25,264	877.9	1,224.8	1,407.1	3.5%	4.8%	5.6%	10%	Yes
ACTON, ME	26,408	2,146	24,262	374	597	693	1.5%	2.5%	2.9%	10%	Yes
BERWICK, ME	24,227	225	24,002	617	1,053	1,308	2.6%	4.4%	5.4%	10%	Yes
ELIOT, ME	13,650	1,041	12,609	522	937	1,158	4.1%	7.4%	9.2%	10%	Yes
KITTERY, ME	48,199	36,824	11,375	917	1,345	1,574	8.1%	11.8%	13.8%	10%	No
LEBANON, ME	35,633	600	35,033	627	1,065	1,304	1.8%	3.0%	3.7%	10%	Yes
NORTH BERWICK, ME	24,423	129	24,293	526	848	1,018	2.2%	3.5%	4.2%	10%	Yes
SANFORD, ME	31,205	621	30,584	1,780	2,745	3,068	5.8%	9.0%	10.0%	10%	No
SOUTH BERWICK, ME	20,891	330	20,561	482	795	965	2.3%	3.9%	4.7%	10%	Yes
WELLS, ME	46,857	10,427	36,430	1,377	2,188	2,703	3.8%	6.0%	7.4%	10%	Yes
YORK, ME	84,348	49,428	34,919	1,503	2,471	2,907	4.3%	7.1%	8.3%	10%	Yes
TOTAL	**971,947**	**132,416**	**839,531**	**35,233**	**52,751**	**62,199**	**4.2%**	**6.3%**	**7.4%**		

(1) Data Source: UNH Complex Systems Research Center
(2) The uncertainty for all the %impervious values was assumed to be +/-0.7%. This value is the size of the error bar for an average watershed.
(3) Towns with >10% impervious cover are highlighted.

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Figure LUD1-1: Number of watersheds and towns with greater than 10% impervious surface cover in 1990, 2000 and 2005

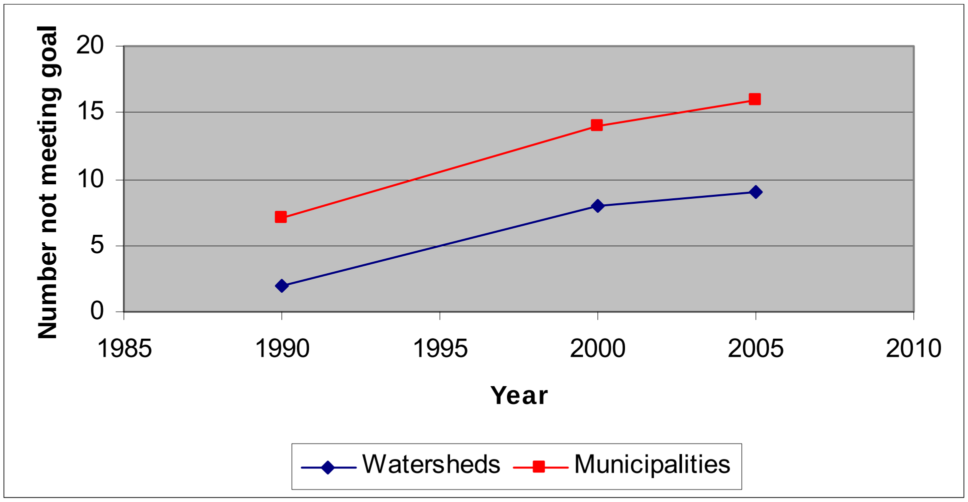

Figure LUD1-2: Impervious surface cover in the entire coastal watershed in 1990, 2000 and 2005

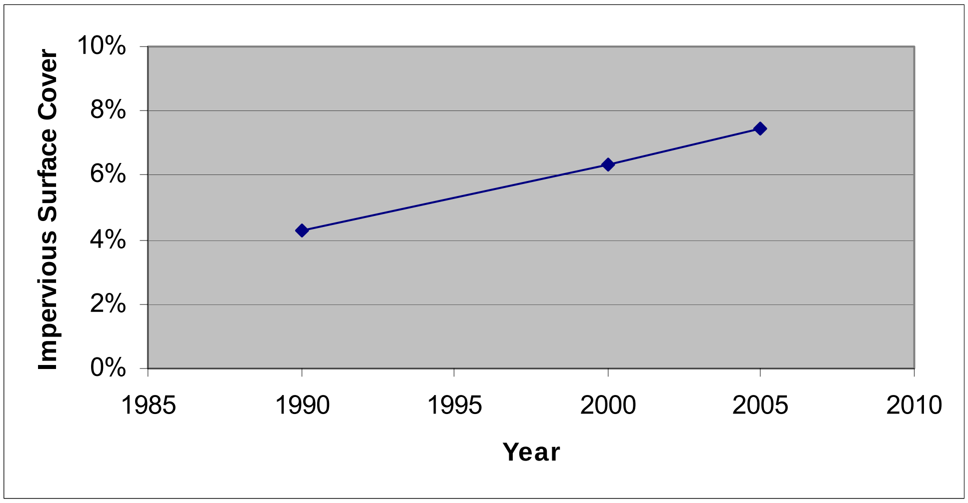

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Figure LUD1-3: Percent impervious surfaces in coastal watersheds in 2005

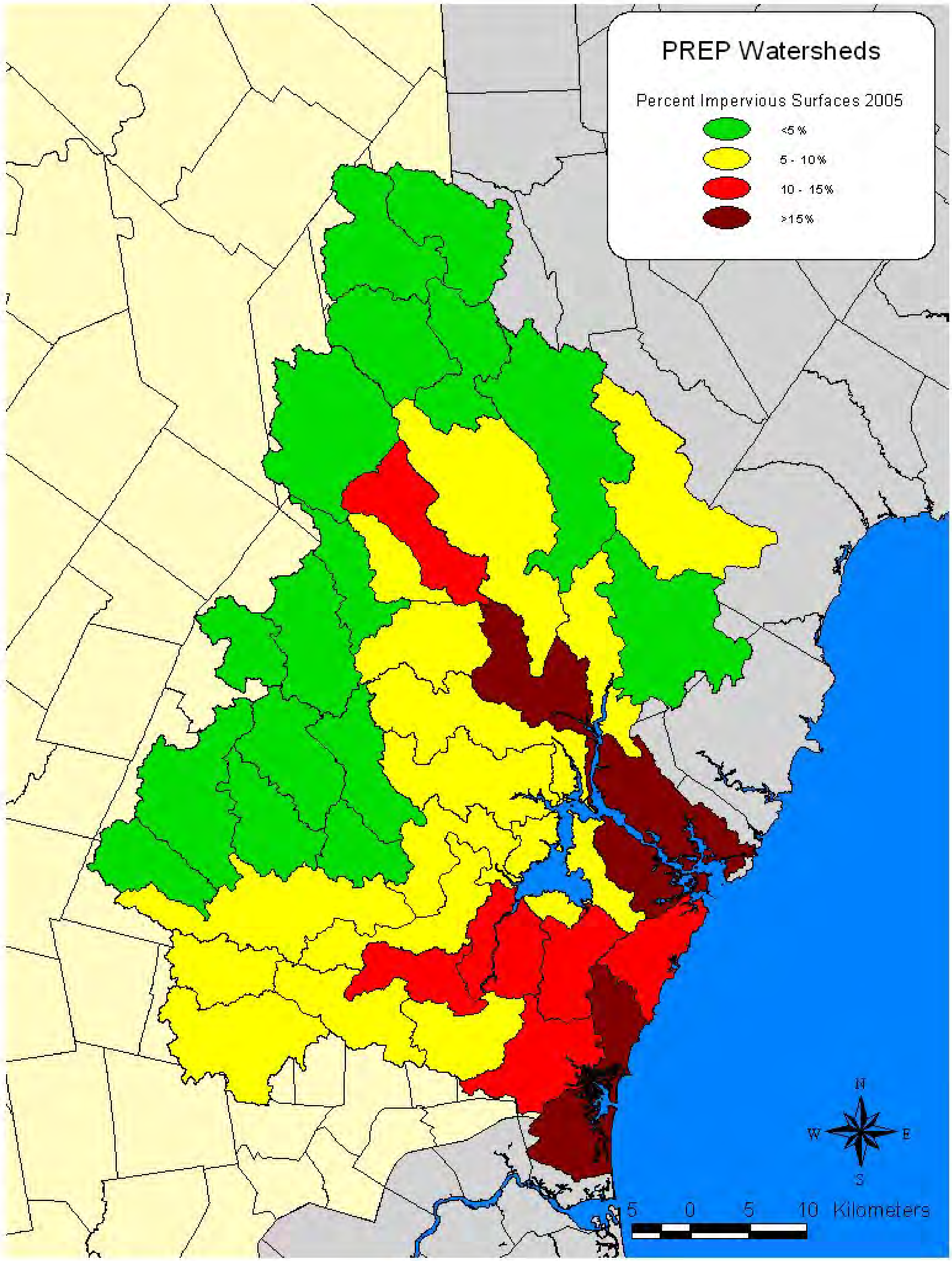

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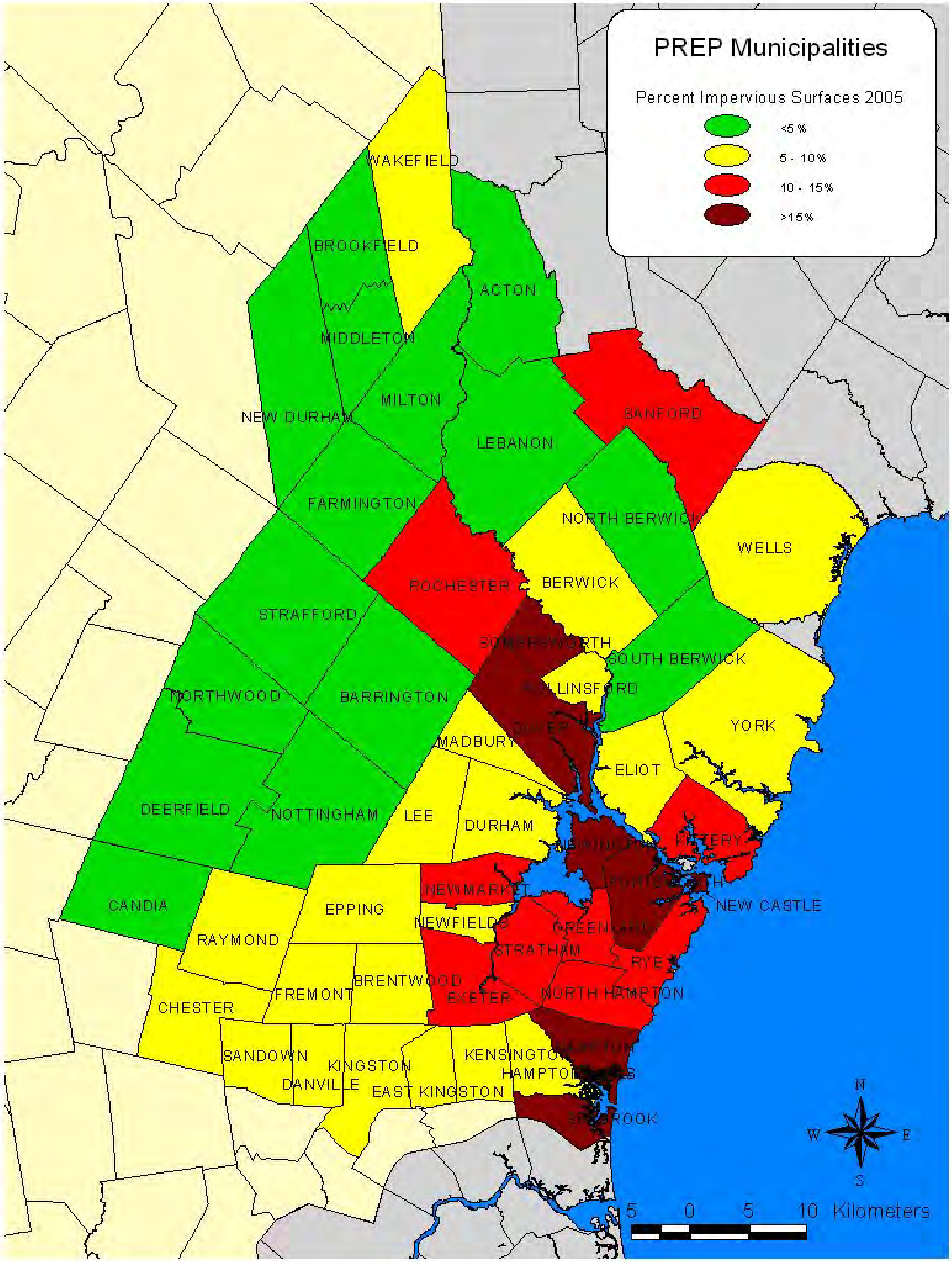
Figure LUD1-4: Percent impervious surfaces in coastal municipalities in 2005



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Indicator: LUD2. Rate of Sprawl – High Impact Development

PREP Goal: New development in coastal watershed towns between 2000 and 2010 should add no more than 0.1 acres of impervious surfaces per new resident.

Why This Is Important: Increasing rates of land consumption per person is an indicator of sprawl-type development. Undeveloped land is at a premium in the coastal watershed. Accelerated consumption of this land is a threat to the habitats, health, and aesthetic quality of the watershed. Sprawl is a regional issue of concern as population in the Seacoast region continues to increase. If development is poorly planned, it can result in creation of unnecessary impervious surface cover with impacts to water quality, wildlife, and other natural resources.

Monitoring Question: Is the coastal watershed experiencing “sprawl-type” development?

Answer: Yes. From 1990 to 2005, the rate of land consumption increased from 0.128 to 0.188 acres of impervious surface per person.

Explanation

Population totals, impervious surface acres, and the imperviousness per capita for each municipality in the coastal watershed in 1990, 2000, and 2005 are shown in Table LUD2-1. Overall, the median imperviousness per capita for the 52 municipalities grew from 0.128 acres per person in 1990 to 0.172 acres per person in 2000 to 0.188 acres per person in 2005. The median value for 2005 was higher than the median of the PREP goals for the individual towns (0.169 acres per person). These statistics are clear evidence that land consumption per person in the coastal watershed is still increasing.

While the average values indicate an overall problem with sprawling growth, the imperviousness per capita varied between municipalities. The imperviousness per capita in each municipality in 2005 is shown on Figure LUD2-1. Overall, there was a marked difference in the median imperviousness per capita between municipalities with <10,000 people (0.195 acres/person) and municipalities with >10,000 people (0.137 acres/person). It makes sense that as municipalities approach build out, population growth results in development of smaller lots and in multi-storied buildings which do not have as much of an impervious surface footprint as single family homes. The linear relationship between population and imperviousness may only be applicable to smaller towns with abundant undeveloped land.

The one municipality which is radically different from the rest is Newington. The imperviousness per capita for Newington was 1.33 acres per person in 2005, which is nearly seven times the median value for all the towns. Newington is an exception due to the presence of runways for the former Pease Air Force Base, extensive commercial development, and low population.

The PREP goals to reduce the imperviousness per capita for new construction have also not been met. Only 15 of the 52 municipalities met their PREP goals for imperviousness per capita in 2005. The goal for each town was set from the impervious cover in 2000 plus 0.1 acres for each new person added to the town population between 2000 and 2005. To classify a town as not meeting its goal, the impervious surface per capita value had to exceed the goal by more than 0.015 acres/person to account for the uncertainty in the estimate. Figure LUD2-2 shows the status of each town relative to its goal.

The data sources and methods used for this indicator are described in the PREP Monitoring Plan.

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Table LUD2-1: Imperviousness per capita in PREP municipalities in 1990, 2000, and 2005

Town	Impervious Surface (acres)			Population			Imperviousness per Capita (ac/person)				Meeting goal?
Name	1990	2000	2005	1990	2000	2005	1990	2000	2005	Goal	
BARRINGTON, NH	763.5	1,186.7	1,387.0	6,164	7,475	8,145	0.124	0.159	0.170	0.154	No
BRENTWOOD, NH	532.1	828.8	1,023.2	2,590	3,197	3,692	0.205	0.259	0.277	0.238	No
BROOKFIELD, NH	139.2	190.8	198.2	518	604	661	0.269	0.316	0.300	0.297	Yes
CANDIA, NH	531.4	794.0	930.9	3,557	3,911	4,154	0.149	0.203	0.224	0.197	No
CHESTER, NH	423.4	720.4	855.5	2,691	3,792	4,639	0.157	0.190	0.184	0.174	Yes
DANVILLE, NH	260.4	445.3	533.7	2,534	4,023	4,381	0.103	0.111	0.122	0.110	Yes
DEERFIELD, NH	492.0	768.0	969.0	3,124	3,678	4,103	0.157	0.209	0.236	0.198	No
DOVER, NH	1,872.6	2,626.4	3,171.6	25,042	26,884	28,383	0.075	0.098	0.112	0.098	Yes
DURHAM, NH	675.0	1,025.6	1,098.0	11,818	12,664	13,276	0.057	0.081	0.083	0.082	Yes
EAST KINGSTON, NH	221.5	335.2	439.3	1,352	1,784	2,225	0.164	0.188	0.197	0.170	No
EPPING, NH	657.8	1,070.8	1,291.8	5,162	5,476	6,072	0.127	0.196	0.213	0.186	No
EXETER, NH	937.4	1,375.8	1,559.3	12,481	14,058	14,665	0.075	0.098	0.106	0.098	Yes
FARMINGTON, NH	687.1	965.6	1,089.5	5,739	5,774	6,426	0.120	0.167	0.170	0.160	Yes
FREMONT, NH	329.3	537.9	654.3	2,576	3,510	3,975	0.128	0.153	0.165	0.147	No
GREENLAND, NH	455.0	712.6	844.9	2,768	3,208	3,373	0.164	0.222	0.250	0.216	No
HAMPTON, NH	1,179.3	1,605.5	1,717.1	12,278	14,937	15,394	0.096	0.107	0.112	0.107	Yes
HAMPTON FALLS, NH	341.8	536.1	698.7	1,503	1,880	2,026	0.227	0.285	0.345	0.272	No
KENSINGTON, NH	243.3	378.4	469.8	1,631	1,893	2,044	0.149	0.200	0.230	0.193	No
KINGSTON, NH	651.0	1,018.7	1,211.7	5,591	5,862	6,225	0.116	0.174	0.195	0.169	No
LEE, NH	467.6	740.5	840.6	3,729	4,145	4,405	0.125	0.179	0.191	0.174	No
MADBURY, NH	251.5	393.7	391.7	1,404	1,509	1,656	0.179	0.261	0.237	0.247	Yes
MIDDLETON, NH	204.5	284.2	350.4	1,183	1,440	1,686	0.173	0.197	0.208	0.183	No
MILTON, NH	597.4	838.8	985.3	3,691	3,910	4,344	0.162	0.215	0.227	0.203	No
NEW CASTLE, NH	108.1	155.0	170.9	840	1,010	1,031	0.129	0.153	0.166	0.152	Yes
NEW DURHAM, NH	458.3	627.9	727.2	1,974	2,220	2,449	0.232	0.283	0.297	0.266	No
NEWFIELDS, NH	141.6	250.6	307.5	888	1,551	1,584	0.160	0.162	0.194	0.160	No
NEWINGTON, NH	686.9	941.0	1,055.8	990	775	809	0.694	1.214	1.305	1.167	No
NEWMARKET, NH	479.7	706.6	818.8	7,157	8,027	9,153	0.067	0.088	0.089	0.089	Yes
NORTH HAMPTON, NH	647.5	957.6	1,100.2	3,637	4,259	4,570	0.178	0.225	0.241	0.216	No
NORTHWOOD, NH	424.1	610.1	716.7	3,124	3,640	3,969	0.136	0.168	0.181	0.162	No

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Town	Impervious Surface (acres)			Population			Imperviousness per Capita (ac/person)				Meeting goal?
Name	1990	2000	2005	1990	2000	2005	1990	2000	2005	Goal	
NOTTINGHAM, NH	447.9	692.7	842.2	2,939	3,701	4,360	0.152	0.187	0.193	0.174	No
PORTSMOUTH, NH	2,128.3	2,726.0	3,054.3	25,925	20,784	20,620	0.082	0.131	0.148	0.131	No
RAYMOND, NH	977.3	1,483.6	1,713.6	8,713	9,674	10,096	0.112	0.153	0.170	0.151	No
ROCHESTER, NH	2,395.2	3,304.5	3,942.3	26,630	28,461	29,945	0.090	0.116	0.132	0.115	No
ROLLINSFORD, NH	265.5	381.3	437.4	2,645	2,648	2,616	0.100	0.144	0.167	0.145	No
RYE, NH	586.5	877.9	1,026.3	4,612	5,182	5,225	0.127	0.169	0.196	0.169	No
SANDOWN, NH	337.2	544.2	701.3	4,060	5,143	5,701	0.083	0.106	0.123	0.105	No
SEABROOK, NH	801.6	1,206.1	1,538.7	6,503	7,934	8,411	0.123	0.152	0.183	0.149	No
SOMERSWORTH, NH	767.7	1,021.2	1,256.7	11,249	11,477	11,696	0.068	0.089	0.107	0.089	No
STRAFFORD, NH	434.0	637.9	726.6	2,965	3,626	3,971	0.146	0.176	0.183	0.169	Yes
STRATHAM, NH	628.3	979.2	1,245.7	4,955	6,355	7,080	0.127	0.154	0.176	0.149	No
WAKEFIELD, NH	877.9	1,224.8	1,407.1	3,057	4,252	4,654	0.287	0.288	0.302	0.272	No
ACTON, ME	374	597	693	1,727	2,145	2,269	0.217	0.278	0.305	0.269	No
BERWICK, ME	617	1,053	1,308	5,995	6,353	7,337	0.103	0.166	0.178	0.157	No
ELIOT, ME	522	937	1,158	5,329	5,954	6,404	0.098	0.157	0.181	0.153	No
KITTERY, ME	917	1,345	1,574	9,372	9,543	10,447	0.098	0.141	0.151	0.137	Yes
LEBANON, ME	627	1,065	1,304	4,263	5,083	5,552	0.147	0.210	0.235	0.200	No
NORTH BERWICK, ME	526	848	1,018	3,793	4,293	4,795	0.139	0.198	0.212	0.187	No
SANFORD, ME	1,780	2,745	3,068	20,463	20,806	21,673	0.087	0.132	0.142	0.131	Yes
SOUTH BERWICK, ME	482	795	965	5,877	6,671	7,291	0.082	0.119	0.132	0.117	Yes
WELLS, ME	1,377	2,188	2,703	7,778	9,400	10,073	0.177	0.233	0.268	0.224	No
YORK, ME	1,503	2,471	2,907	9,818	12,854	13,409	0.153	0.192	0.217	0.188	No
MEDIAN							**0.128**	**0.172**	**0.188**	**0.169**	

(1) Data source for population: U.S. Census

(2) Data source for impervious surfaces: UNH Complex Systems Research Center

(3) The uncertainty for imperviousness per capita values was assumed to be +/-0.015 ac/person. This value is the size of the error bar for an average town.

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Figure LUD2-1: Impervious surfaces per capita in PREP municipalities in 2005

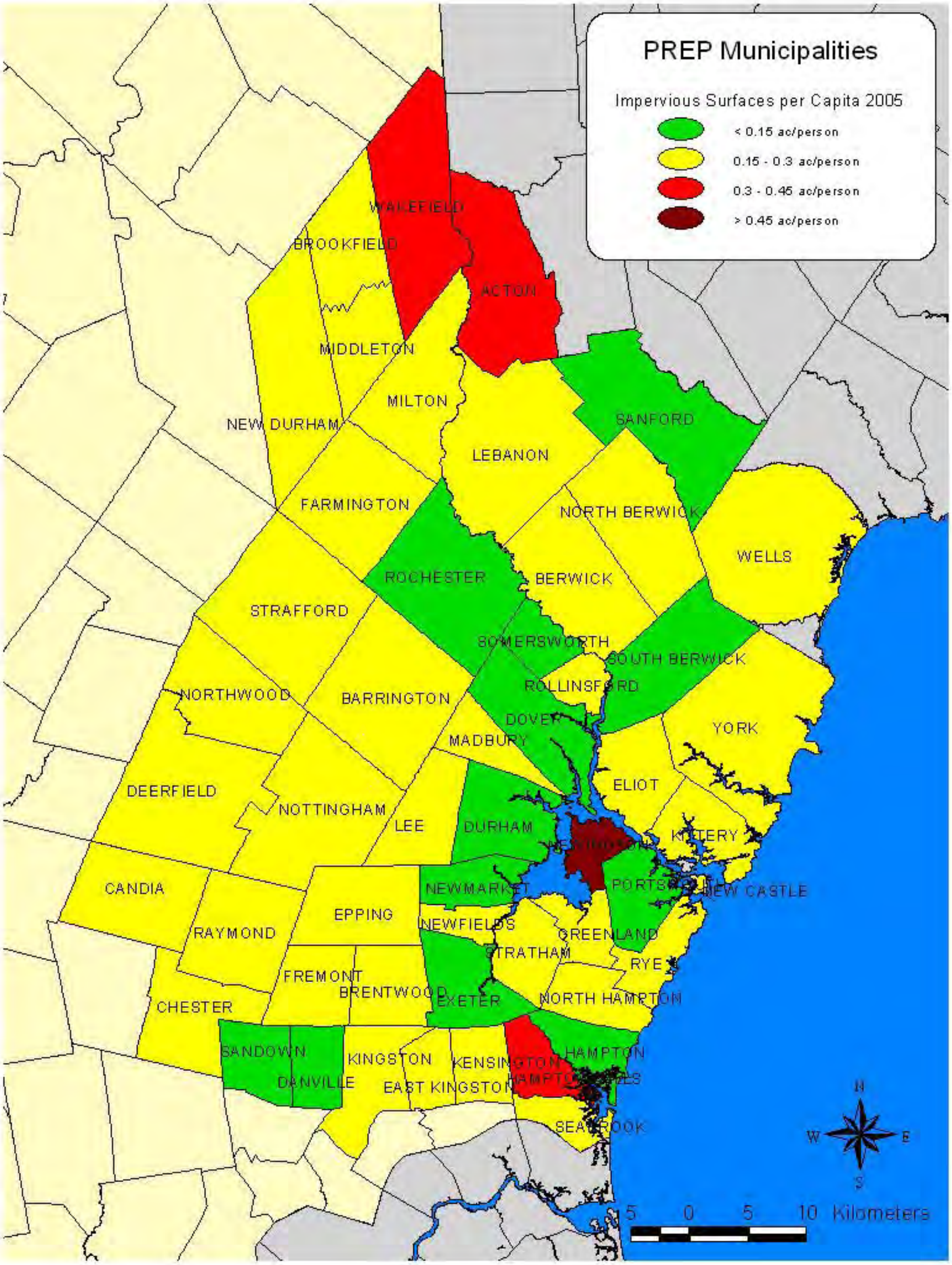

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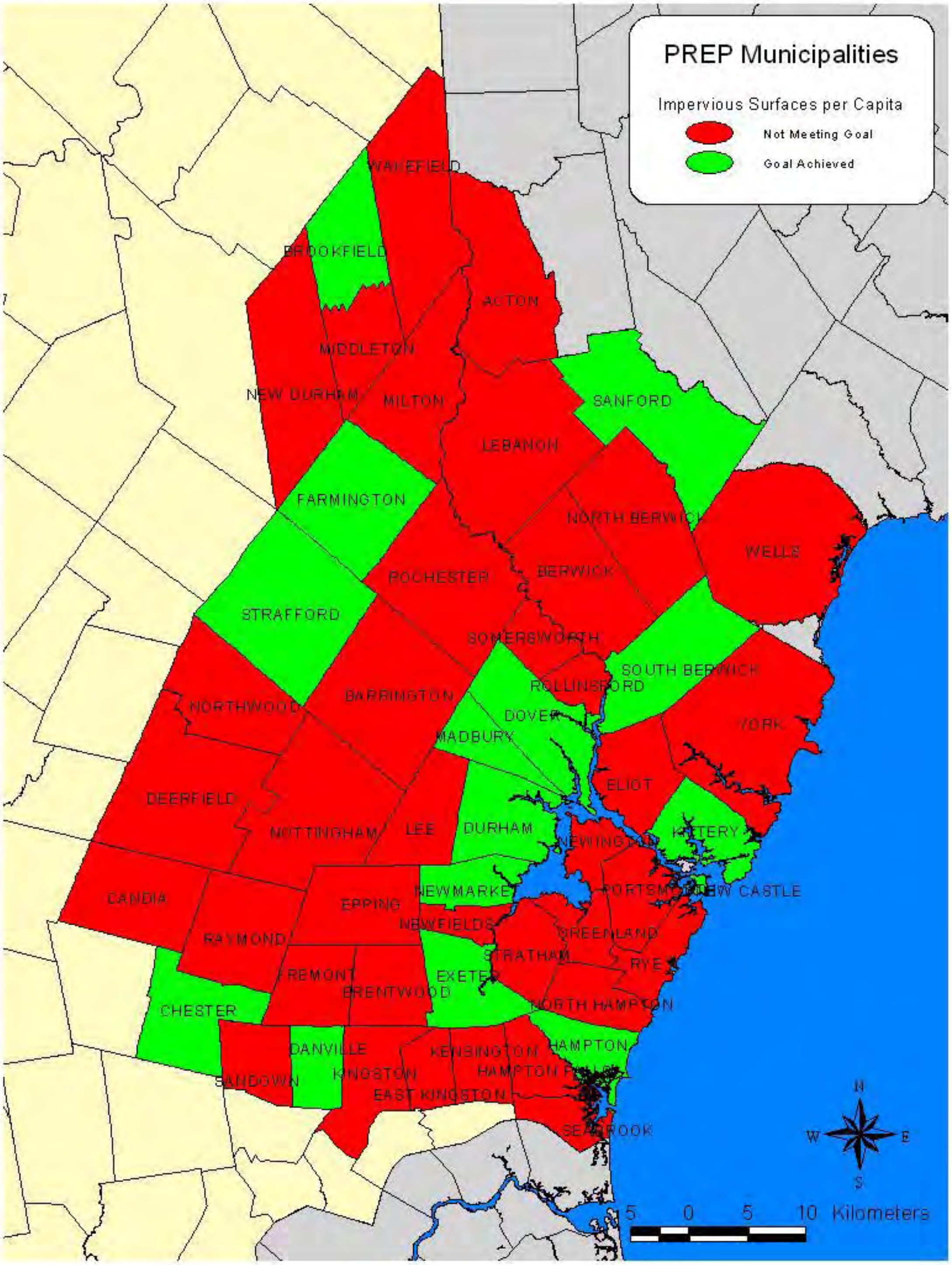
Figure LUD2-2: PREP municipalities classified relative to impervious surface per capita goals in 2005



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