2006

New Hampshire Estuaries Project

Environmental Indicator Report: Critical Habitats and Species

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March 2006

ENVIRONMENTAL INDICATOR REPORT

CRITICAL HABITATS AND SPECIES

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This report was funded in part by the U.S. Environmental Protection Agency National Estuary Program through an agreement with the New Hampshire Estuaries Project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENTS

This report was peer-reviewed by the NHEP Technical Advisory Committee. The members of this committee deserve thanks for their time and thoughtful input.

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INTRODUCTION

The New Hampshire Estuaries Project (NHEP) 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. The NHEP is funded by the EPA and is administered by the University of New Hampshire.

The NHEP's Comprehensive Conservation and Management Plan for New Hampshire's estuaries was completed in 2000 and implementation is ongoing. The Management Plan outlines key issues related to management of New Hampshire's estuaries and proposes strategies (Action Plans) that are expected to preserve, protect, and enhance the State's estuarine resources. The NHEP's priorities were established by local stakeholders and include water quality improvements, shellfish resources, land protection, and habitat restoration. Projects addressing these priorities are undertaken throughout NH's coastal watershed, which includes 42 communities.

Every three years, the NHEP 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 the NHEP, 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, the NHEP publishes four technical data reports ("indicator reports") that illustrate the status and trends of the complete collection of indicators tracked by the NHEP. Each report focuses on a different suite of indicators: Shellfish, Water Quality, Land Use and Development, and Critical Habitats and Species. All of the indicators are presented to the NHEP Technical Advisory Committee, which selects a subset of indicators to be presented to the NHEP 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 2006 Critical Habitats and Species Indicator Report is the second NHEP indicator report on this subject. Data from this report will be used in the 2006 State of the Estuaries report.

The following sections contain the most recent data for the 10 habitat and species indicators tracked by the NHEP. In some cases the NHEP 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 NHEP Monitoring Plan (NHEP, 2004).

The results and interpretations for the indicators presented in this report have been peer reviewed by the NHEP 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 New Hampshire's estuaries.

HAB1 - SALT MARSH EXTENT AND CONDITION

Monitoring Objective

The objective of this indicator is to report on the total area of the coastal watershed covered by salt marshes as well the area of salt marshes that are degraded due to invasive species or tidal restrictions. This indicator answers the following monitoring questions:

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

Has the acreage of invasive species (phragmites, purple loosestrife) in NH salt marshes and wetlands significantly changed over time?

Measurable Goal

The goal for this indicator is to have the total area of salt marsh in the coastal watershed greater than or equal to 6,200 acres.

Data Analysis and Statistical Methods

Salt marshes were mapped in 2004 by Normandeau Associations under contract to the NH Coastal Program. The 1:24,000 maps were derived from color infrared imagery (CIR) flown during the spring of 2004. Under the Cowardin classification system, salt marshes were classified as Estuarine-Intertidal-Emergent (Class "E2EM"). ArcView/ArcInfo software was used to calculate the total acreage covered by E2EM wetlands in the coastal watershed. This total was compared to the goal of 6,200 acres. In addition, the areas of degraded salt marshes due to invasive species (phragmites, purple loosestrife) were summarized. The results were reported for the coastal watershed as a whole as well as for three sub-areas: Hampton/Seabrook Harbor, Atlantic coast and Portsmouth Harbor, and Great Bay and its tributaries. A rigorous statistical test was not possible for this indicator because the uncertainty for the salt marsh mapping process was unknown.

Results

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 1). The majority of the salt marsh acreage was in Hampton/Seabrook Harbor (60.8%) (Figure 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 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 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 1).

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

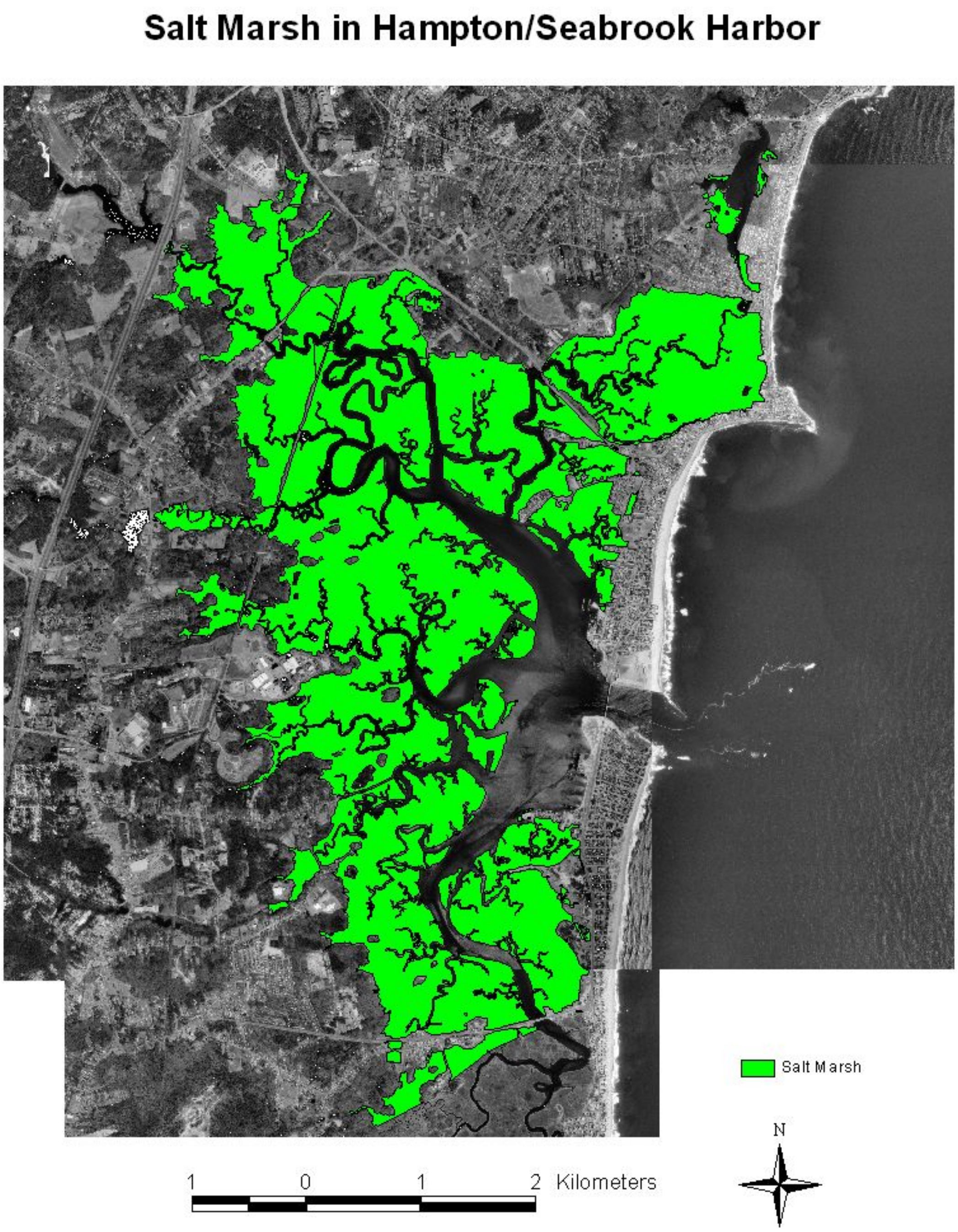
Wetland Type	Total Coverage (acres)	Number of Unique Stands	Average Size of Stands (acres)
Salt marsh	5,554	Not applicable	Not applicable
Phragmites	133	351	0.38
Purple loosestrife	6	14	0.45
Cattail	202	122	1.65
Combination of phragmites, loosestrife or cattail	31	19	1.63

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 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)

Figure 1: Salt marsh extent in Hampton/Seabrook Harbor



HAB2 - EELGRASS DISTRIBUTION

Monitoring Objective

The objective of this supporting variable is to track the area of eelgrass present in the Great Bay Estuary and its tributaries. Water clarity is one of the main factors affecting the distribution of eelgrass. However, eelgrass can be affected by other factors such as disease on a rapid temporal scale. This indicator provides information relevant to the following question:

Has eelgrass habitat in Great Bay changed over time?

Measurable Goal

Eelgrass distribution is a supporting variable so a measurable goal has not been established.

Data Analysis and Statistical Methods

The method for eelgrass mapping in the Great Bay Estuary generally followed the standardized "C-CAP" protocol for mapping submerged aquatic vegetation (Coastal Change Analysis Program, NOAA). The aerial photographs were taken at both 3,000 ft and at 600 ft at low spring tide with roughly 60% overlap on a calm day without preceding rain events and when the sun was at a low angle to minimize reflection (between 7 and 10 am). The photographs were near-verticals, taken with a hand-held 35mm camera, which deviates from C-CAP's protocol, but follows a published method (Short and Burdick, 1996). Photographs were taken in late summer, usually late August or early September, depending on tides and weather, to capture the time of maximum annual eelgrass biomass. Ground truthing was done from a small boat at the same season as the photographs were taken. Observations were made at low tide. Samples were collected with an eelgrass sampling hook. Positions were determined using GPS. The ground truth surveys assessed ten to twenty percent of the eelgrass beds in the estuary. The photographs, in the form of 35mm slides or digital computer images, were projected on a screen and the eelgrass images were transferred to a base map. Each eelgrass bed was assigned a density based on visual observation: partial (10-30% cover), half (30-60% cover), some bottom (60-90% cover) and dense (90-100% cover). These maps were then digitized and verified using the ground truth data by placing the GPS points onto the digital image in ArcInfo.

For data analysis, ArcView/ArcInfo software was used to calculate the area of eelgrass coverage in each year in the different sections of the Great Bay Estuary (Table 3). For the purposes of calculating acreage totals, all areas mapped as being eelgrass by UNH were included equally in the total regardless of the eelgrass density. The total areas of eelgrass in different density classes in Great Bay were also tracked over time.

Table 3: Eelgrass assessment zones

Area	Zone of eelgrass quantification
Squamscott and Lamprey Rivers	upstream of a line connecting Sandy Point and Moody's Point
Oyster River	upstream of a line across the mouth of the Oyster River
Bellamy River	upstream of the Bellamy River Bridge
Great Bay	from boundary of Squamscott/Lamprey Rivers to Adams Point
Little Bay	from Adams Point to Gen. Sullivan Bridge minus Oyster and Bellamy Rivers
Piscataqua River	from I-95 bridge to Gen. Sullivan Bridge and up the Piscataqua River
Portsmouth/Little Harbor	from I-95 bridge across the Piscataqua to the Atlantic Ocean

The yearly eelgrass coverages between 1990 and 2003 were overlayed to evaluate the frequency of occurrence of eelgrass at specific locations. Spatial Analyst, an extension to ArcInfo, was used to split the eelgrass polygons into unique grids. One grid was created for each year. A final coverage was calculated by adding the grids together, resulting in a single coverage that show total years of eelgrass presence. Summary files were created that documented the presence of eelgrass of any density and the presence of dense (greater than 90% cover) eelgrass. Eelgrass in Great Bay has been mapped yearly since 1986 (and annually since 1990 with consistent density classifications). In contrast, Little Bay and the Piscataqua River have only been mapped six times since 1996. Therefore, the frequency of occurrence calculations were conducted separately for Great Bay and for Little Bay/Piscataqua River.

Results

Eelgrass (*Zostera marina*) is an essential habitat for the estuary because it provides food for wintering waterfowl and habitat for juvenile fish (Thayer et al. 1984, Short 1992). Eelgrass filters estuarine water and stabilizes sediments. Eelgrass detritus is part of the estuarine food chain (Thayer et al. 1984). The UNH Seagrass Ecology Group has mapped the distribution of eelgrass every year from 1986 to 2003 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 2003. Table 4 summarizes the acres of eelgrass in each assessment zone from 1986-2003. Figure 2 and Figure 3 show the trend in eelgrass cover in various locations over time.

Total eelgrass cover in Great Bay has been relatively constant for the past 14 years at approximately 2,000 acres. In 1989, there was a dramatic crash of the eelgrass beds 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 greatest extent of eelgrass was observed in 1996 (2,421 acres) following several years of good water quality (Fred Short, pers. comm.). The current (2003) extent of eelgrass in Great Bay is 1,592 acres, which is substantially less than the maximum extent observed in 1996. Between 1998 and 2003, the eelgrass coverage declined, except for one good year in 2001.

Trends are harder to discern in areas other than Great Bay, except in the Piscataqua River where there has been a decline since 1996 (Figure 3). The eelgrass extent in Portsmouth Harbor has remained relatively constant. The acreage of eelgrass in Little Bay is small. Likewise, eelgrass acreage in the Bellamy and Oyster Rivers is erratic and often zero.

Frequency of occurrence mapping showed that eelgrass typically grows in the same places year after year (Figure 9, Figure 11, Figure 13). In Great Bay, 68% of the area where eelgrass was observed had eelgrass for 10 or more years out of 14 years (Figure 7). The areas where eelgrass is more transient tend to be on the edges of the persistent beds and in the tributaries. In contrast, the dense eelgrass coverage appears to be emphemeral in most areas (Figure 10, Figure 12, Figure 14). In 70% of the areas where dense eelgrass has been mapped, the dense eelgrass persisted for 5 or less years out of 14 years (Figure 7). Therefore, eelgrass often recurs in the same location in the Great Bay but the locations of dense eelgrass change.

The eelgrass cover in Great Bay in each different density class are shown in Table 5 and Figure 4. The acreage of dense eelgrass (90-100% cover) was low in 1990 and 1991 at the tail end of the wasting disease event, shot up to a plateau of 1,500 acres for the majority of the years between 1992 and 1996, and then steadily declined. In 1995, the dense eelgrass area dropped sharply to 365 acres during a short wasting disease event in which large holes were observed in formerly dense eelgrass beds (Fred Short, pers. comm.). The area of eelgrass in the other density classes has remained relatively constant.

The biomass of eelgrass in Great Bay was calculated for each year by assuming a shoot density for each density class (see Table 5). The trends in eelgrass biomass are shown in Figure 5 and Figure 6. In 1990, 1992, and 1995, the biomass was low due to wasting disease events. Superimposed on these rapid events, there has been a statistically significant ($p<0.05$), decreasing trend between 1992 and 2003. The biomass declined by 71% during this period, at an average rate of 100 metric tons per year (Figure 6). In 2003, there were only 579 metric tons of eelgrass biomass in the Great Bay.

The trend of declining eelgrass biomass in Great Bay is a concern. Eelgrass is an essential habitat for the estuary, the loss of which would fundamentally alter the ecosystem of the bay. The specific cause of the decline is uncertain. Eelgrass is sensitive to water quality, specifically water clarity. The observed changes in eelgrass cannot be linked directly to a water quality trend, although increasing concentrations of suspended solids have been observed at Adams Point (NHEP, 2006). Given the nonlinear nature of the ecosystem, it may not be realistic to expect a direct linkage between eelgrass and water quality. Eelgrass can also be affected by wasting disease. The effects of the disease are typically dramatic and only last for one or two years. Therefore, a gradual decline over 10 years is not consistent with a wasting disease event. Another possible factor is nuisance macroalgae. There have been anecdotal reports of increasing populations of nuisance macroalgae in the bay. Macroalgae compete with and sometimes smother eelgrass (Fred Short, pers. comm.).

Additional research is needed to understand the reason for the eelgrass biomass decline. In order to improve the accuracy of future biomass estimates, the eelgrass mapping program should be enhanced to collect information on shoot density at mapped eelgrass beds. Turbidity data from the in-situ datasonde in Great Bay should be analyzed for changes in water clarity and correlations with suspended solids concentrations. The eelgrass beds should be investigated for evidence of wasting

Table 4: Eelgrass coverage in the Great Bay Estuary

Year	Great Bay	Little Bay	Portsmouth and Little Harbors	Piscataqua River	Squamscott and Lamprey Rivers	Oyster River	Bellamy River
1986	1,989				29		
1987	1,681				7		
1988	1,123				64		
1989	313				0		
1990	1,999				13		
1991	2,230				17		
1992	2,275				50		
1993	2,353				83		
1994	2,349				76		
1995	2,172				42		
1996	2,421	33	327	76	65	14	0
1997	2,285				3		
1998	2,318				61		
1999	2,041	26	300	66	63	0	0
2000	1,873	7	329	63	72	0	0
2001	2,330	11	332	69	53	0	0
2002	1,721	4	342	39	55	0	0
2003	1,592	14	335	47	21	0	0

Blank cells indicate no data collected
Source: UNH Seagrass Ecology Group

Figure 2: Eelgrass coverage in Great Bay, Little Bay and Portsmouth Harbor

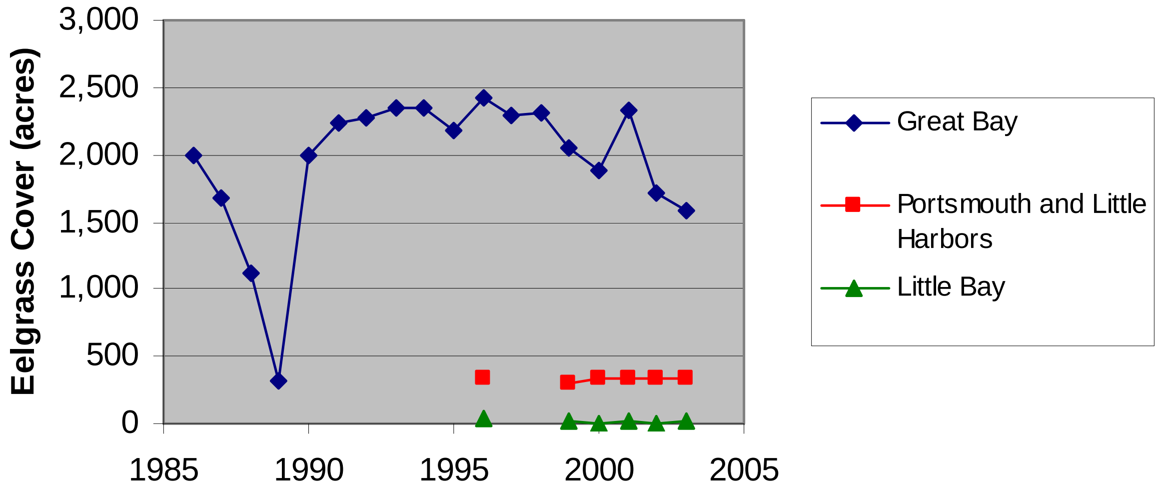


Figure 3: Eelgrass coverage in tidal rivers

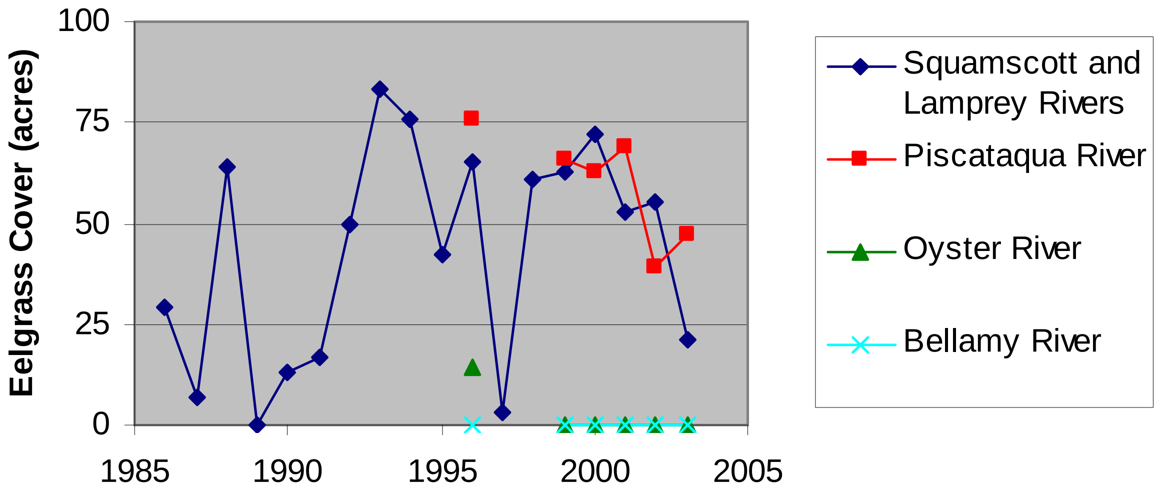


Table 5: Area of eelgrass in each density class and total eelgrass biomass in Great Bay

Year	Area in Each Density Class (acres)					Biomass (metric tons)
	90-100%	60-90%	30-60%	10-30%	Total	
1990	675	376	587	360	1,999	979
1991	605	546	795	284	2,230	1,006
1992	1,471	55	465	283	2,275	1,640
1993	1,533	220	165	435	2,353	1,708
1994	1,307	386	175	481	2,349	1,543
1995	365	375	529	902	2,172	708
1996	1,397	290	134	599	2,421	1,604
1997	739	582	627	338	2,285	1,121
1998	558	613	439	708	2,318	945
1999	447	270	815	509	2,041	778
2000	126	551	642	553	1,873	516
2001	575	640	788	328	2,330	1,010
2002	39	498	987	197	1,721	450
2003	203	690	544	156	1,592	579

Biomass calculated from eelgrass areas using the following shoot density values:

Eelgrass cover	Shoot density (g/m2)
10-30%	25
30-60%	55
60-90%	85
90-100%	250

Source: UNH Seagrass Ecology Group

Figure 4: Area of eelgrass in Great Bay in each density class

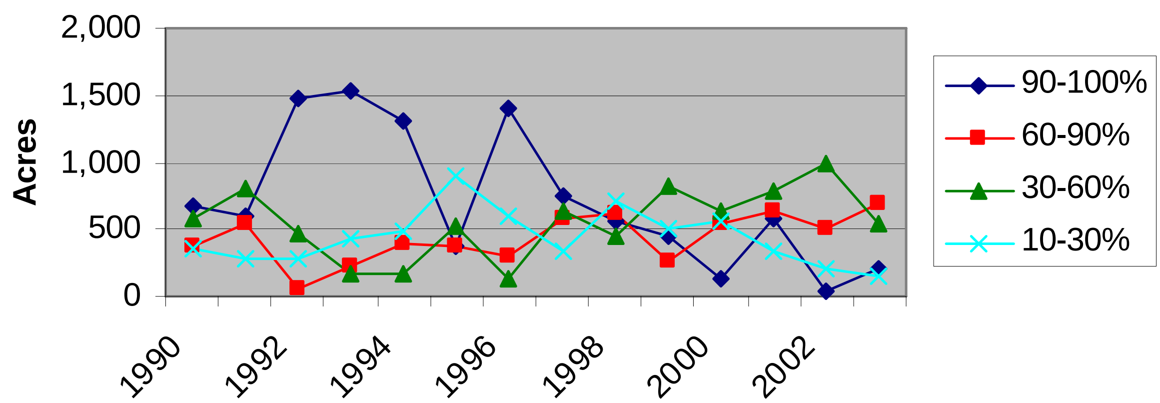


Figure 5: Eelgrass biomass in Great Bay (1990-2003)

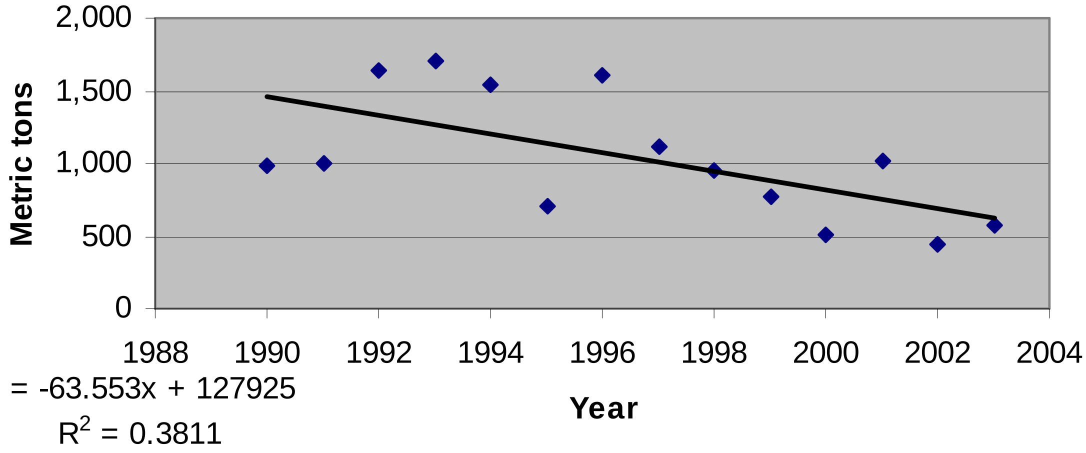


Figure 6: Eelgrass biomass in Great Bay (1992-2003)

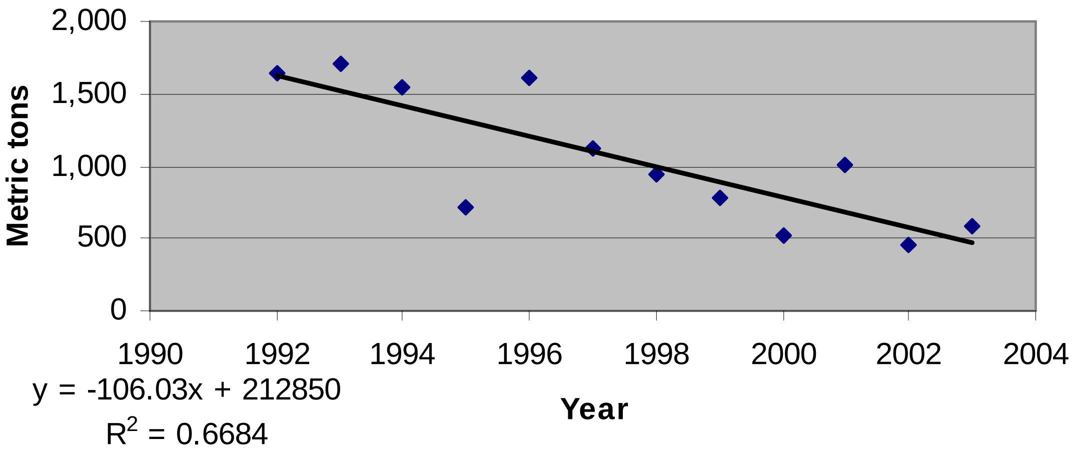


Figure 7: Frequency of occurrence of eelgrass cover in Great Bay and its tributaries between 1990 and 2003

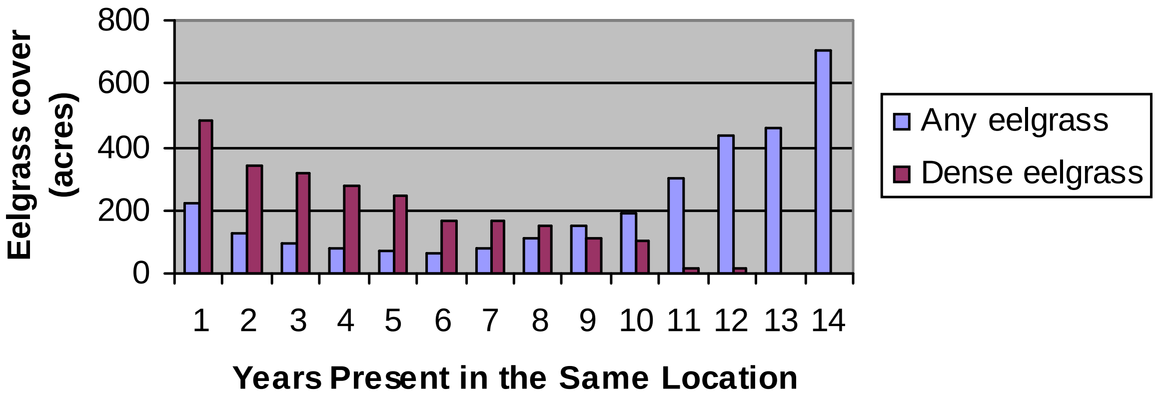


Figure 8: Frequency of occurrence of eelgrass cover in Little Bay and the Piscataqua River in 1996 and 1999-2003

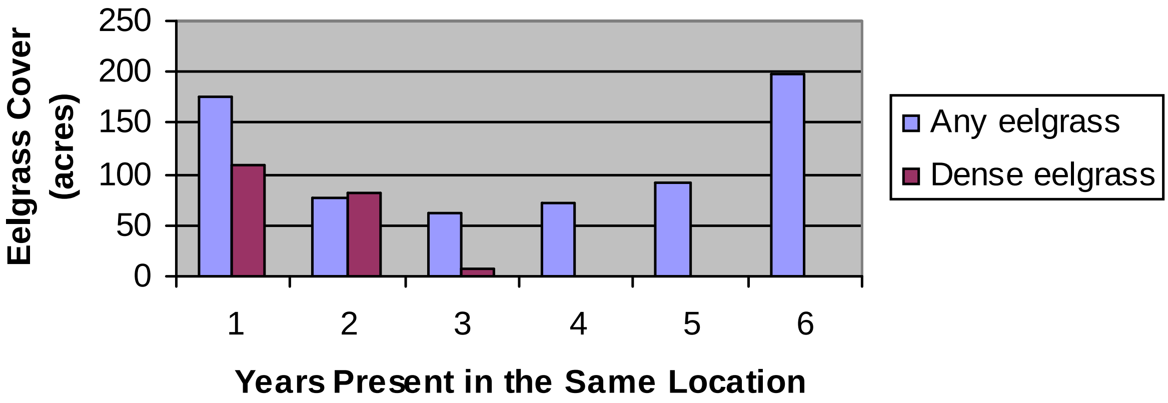


Figure 9: Frequency of occurrence of eelgrass in the Great Bay between 1990 and 2003

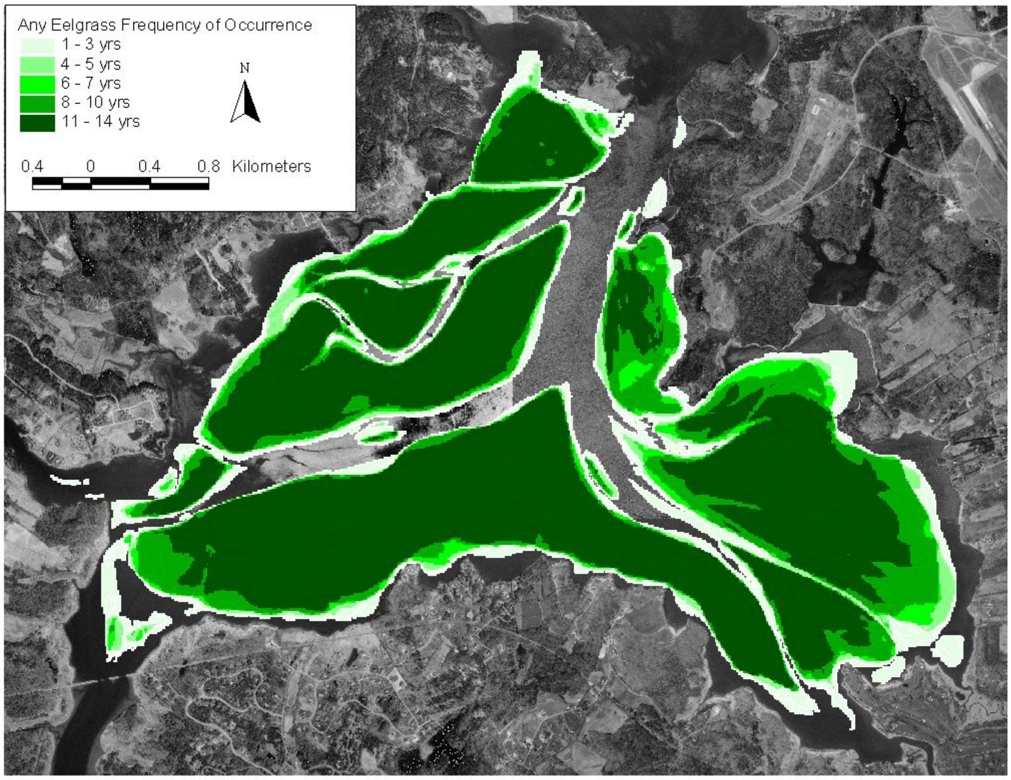


Figure 10: Frequency of occurrence of dense eelgrass in the Great Bay between 1990 and 2003

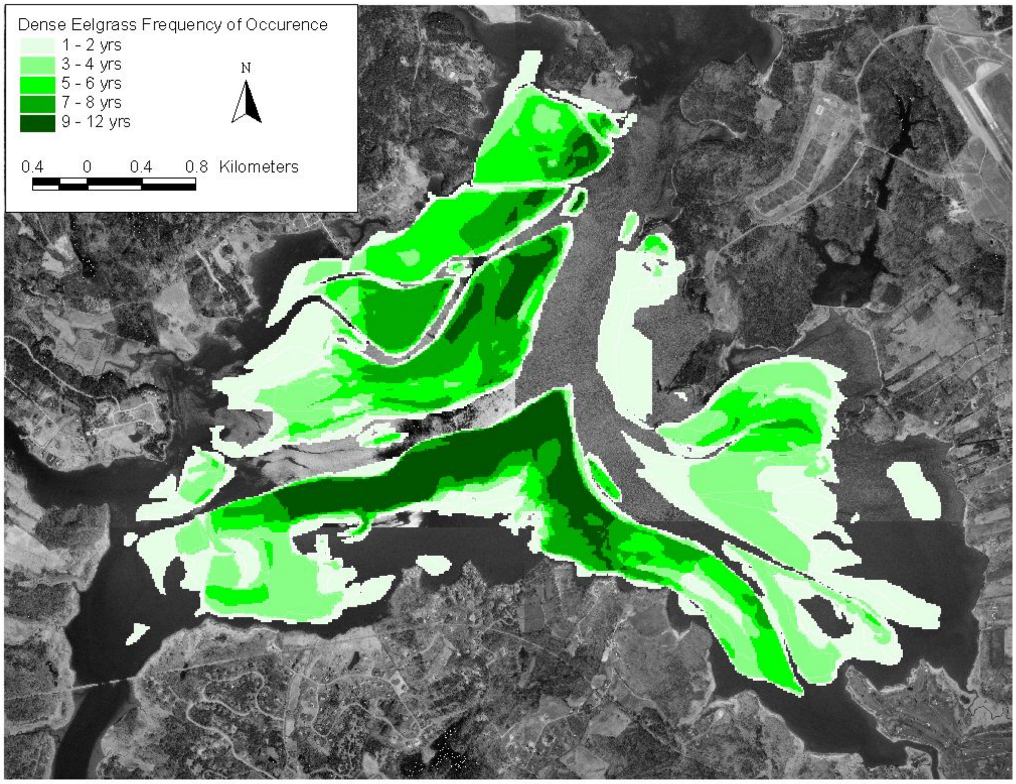


Figure 11: Frequency of occurrence of eelgrass in Little Bay in 1996 and 1999-2003

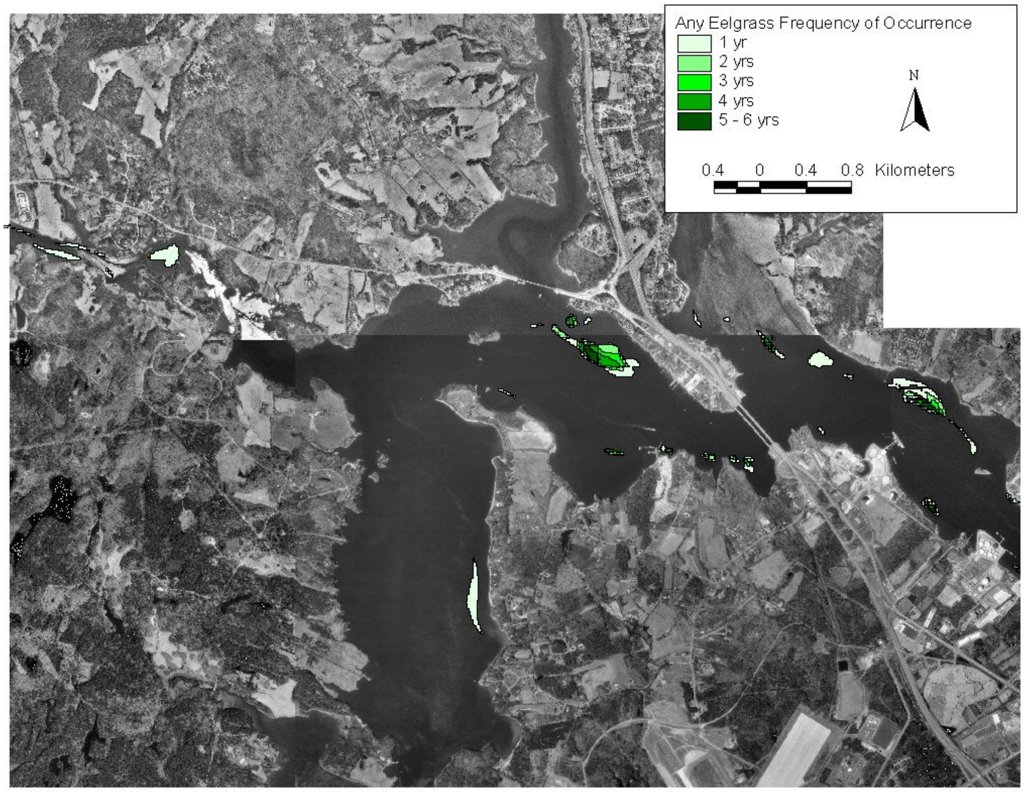


Figure 12: Frequency of occurrence of dense eelgrass in Little Bay in 1996 and 1999-2003

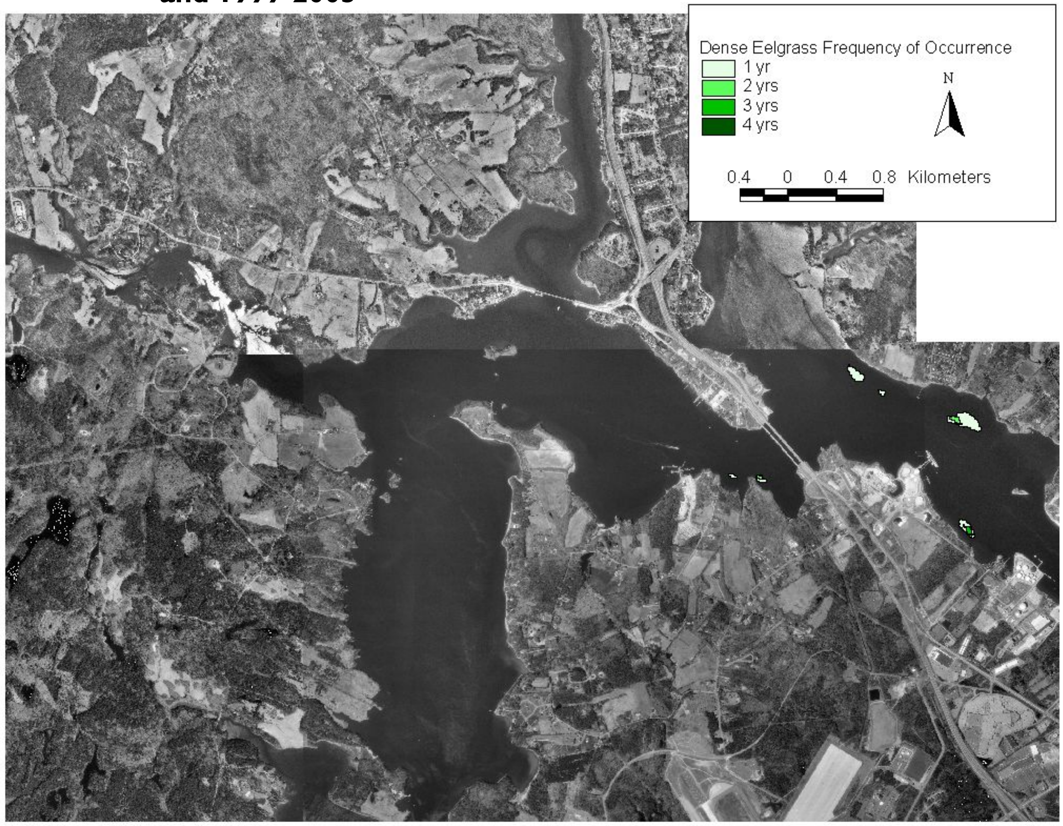


Figure 13: Frequency of occurrence of eelgrass in Portsmouth Harbor in 1996 and 1999-2003

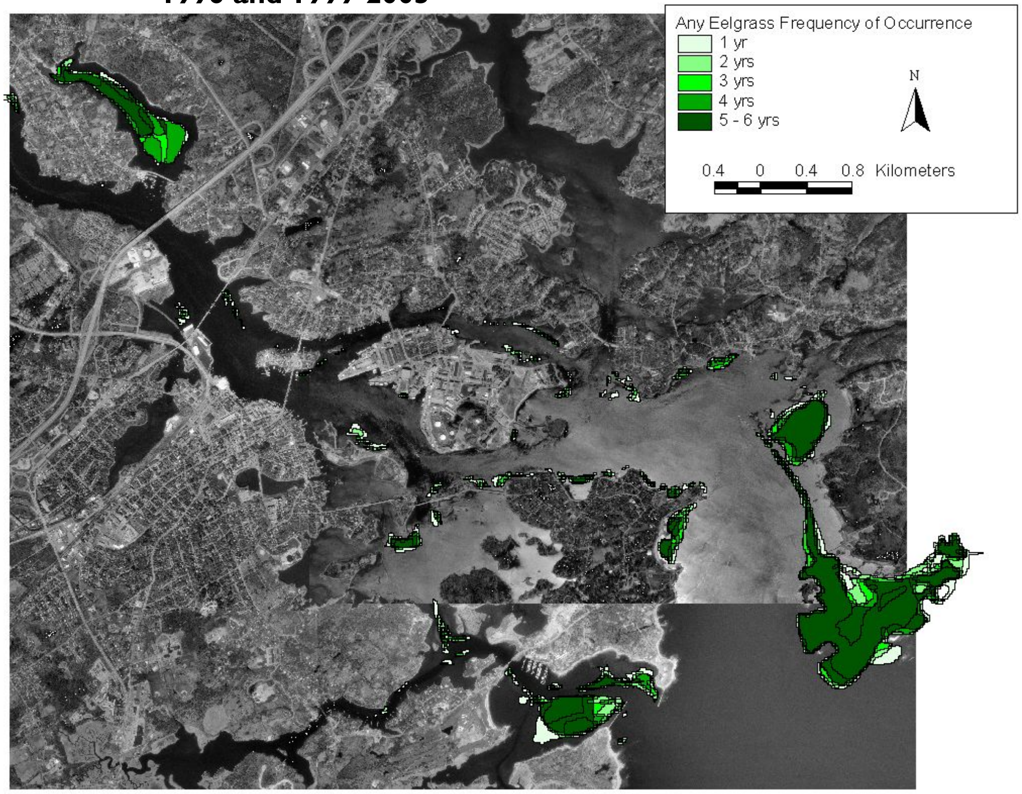
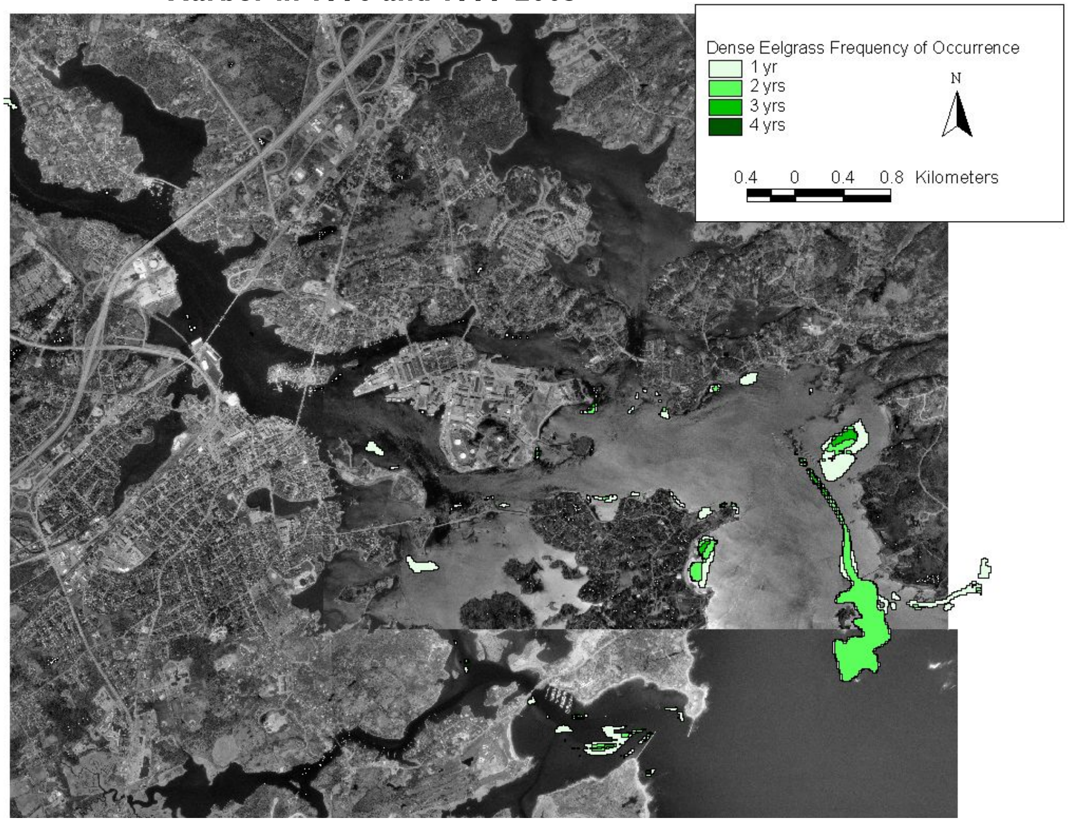


Figure 14: Frequency of occurrence of dense eelgrass in Portsmouth Harbor in 1996 and 1999-2003



HAB11 - UNFRAGMENTED FOREST BLOCKS

Monitoring Objective

The objective of this indicator is to report on the total acreage of large, unfragmented forest blocks in the coastal watershed. This indicator answers the following monitoring question:

Has the acreage of large, unfragmented forest blocks in the coastal watershed changed over time?

Measurable Goal

Since unfragmented forest blocks is a supporting variable that will not be used to answer a management question, no goal has been set.

Data Analysis and Statistical Methods

Unfragmented lands data was obtained from the Society for the Protection of New Hampshire Forests (SPNHF). SPNHF had processed 2001 land cover data from GRANIT using USGS digital line graphs of roads and NHDOT's G_roads datalayer to identify blocks of unfragmented lands in southeastern New Hampshire. The methodology and assumptions used by SPNHF to process the data are included below.

Natural land cover types were extracted from the GRANIT land cover data for the study area as a precursor to generating an unfragmented blocks datalayer. These land cover types included: all forest cover types except Alpine (440), forested and non-forested wetlands, and tidal wetlands; and bedrock/vegetated, sand dunes, and cleared or disturbed land covers. Active agriculture was excluded.

A special roads datalayer was generated for use as a fragmenting feature; only traveled roadways were included. The USGS-based datalayer and the NHDOT datalayer were merged after selecting out all jeep trails, Cl 6 roads, and other non-traveled roadways; private roads in the NHDOT datalayer were included in the merged dataset even though some function only as occasional use access roads.

Note that the influence of urban land uses and transportation land cover types as fragmenting features was automatically accounted for in the selection of natural land cover types above, but the transportation land cover type was found to be insufficient within the GRANIT land cover mapping due to tree cover occluding many road segments. Furthermore, frontage development could not be accounted for in the GRANIT land cover mapping, so a 300' buffer was created from the merged road datalayers.

NHDES clipped the unfragmented data layer from SPNHF to the coastal watershed boundary (HUC8 01060003) and then selected only those blocks that covered greater than 250 acres inside the watershed.

Results

As of 2001, there were 282 unfragmented blocks greater than 250 acres in the coastal watershed. The majority of the blocks are less than 1000 acres in size. There are only

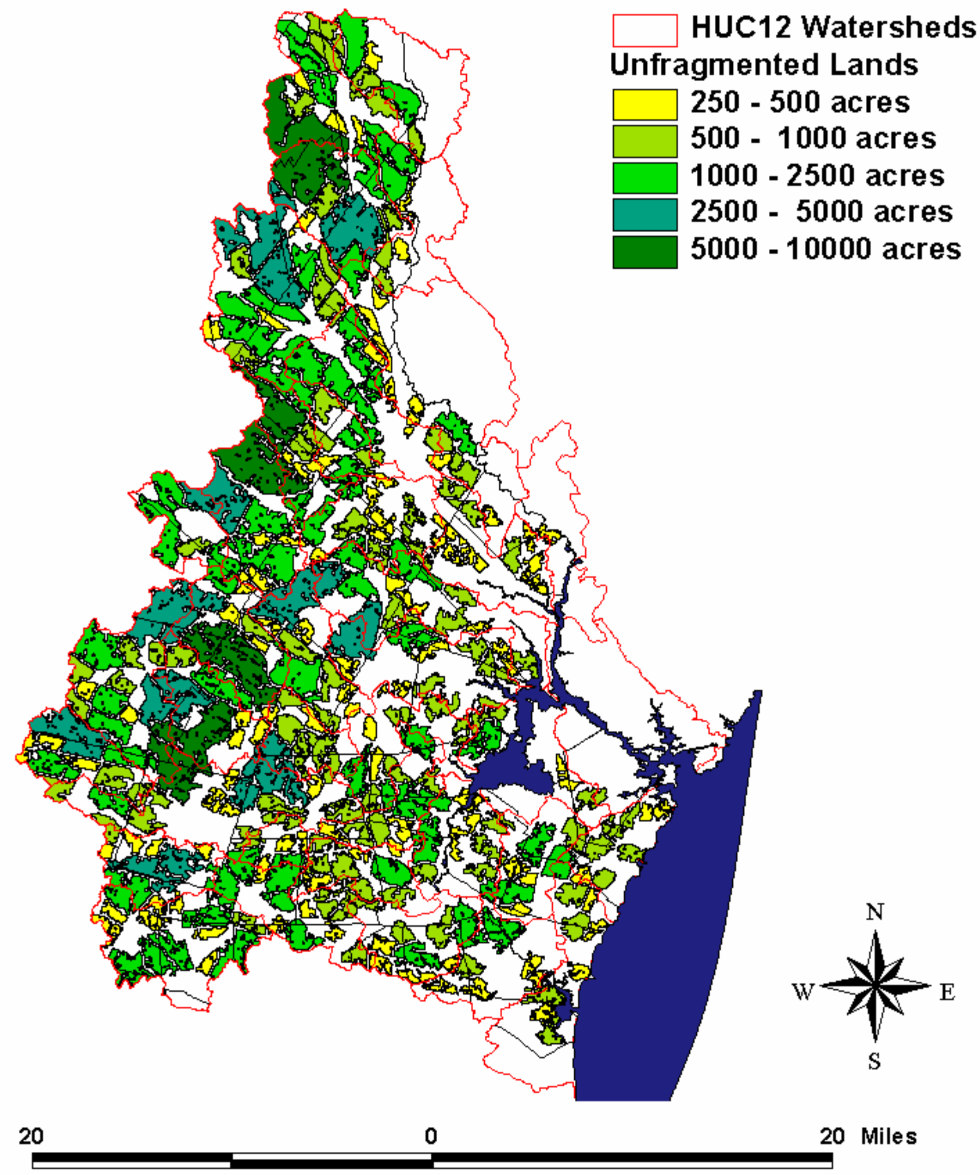
4 blocks greater than 5000 acres (Table 6). Figure 15 shows the locations of the unfragmented blocks in the coastal watershed. The larger blocks are in the northern and western sections of the watershed. The total area in blocks greater than 250 acres constituted 51% of the total land area in NH's coastal watershed.

Table 6: Number and acreage of large, unfragmented forest blocks in the coastal watershed

	UNFRAGMENTED BLOCK SIZE (ACRES)					
	250 to 500	500 to 1000	1000 to 2500	2500 to 5000	5000 to 10000	Total
Number of unfragmented blocks	112	95	60	11	4	282
Acres of unfragmented blocks	40,486	65,629	87,751	40,202	28,019	262,087

Data Source: 2001 land cover from GRANIT processed by SPNHF

Figure 15: Unfragmented forest blocks in the coastal watershed



HAB7 - ABUNDANCE OF JUVENILE FINFISH

Monitoring Objective

Juvenile finfish are sensitive to estuarine conditions. Many juvenile fish species spend significant portions of their life in the estuary, and are an important source of food to other species. Since juvenile finfish occupy a lower niche in the food web, population dynamics are less complicated and more predictable. The objective of this supporting variable is to illustrate year to year trends in the abundance and diversity of juvenile finfish in the estuary. It addresses the following monitoring question related to Land Use Goal #6:

Has the population of finfish in the estuary changed over time?

Measurable Goal

Since juvenile finfish is a supporting variable that will not be used to answer a management question, no goal has been set.

Data Analysis and Statistical Methods

Data on juvenile fish abundance was provided by fish counts from standardized beach seine hauls conducted by NHF&G for the Atlantic Coastal Fisheries Cooperative Management Act (NHF&G, 2005a). The data were analyzed several ways.

First, the average catch per unit effort (CPUE) for the most abundant species was calculated and compared to the range of observations from previous years. The geometric mean CPUE for all months combined for the selected species was taken from the annual reports by NHF&G. Results from Great Bay/Little Bay, the Piscataqua River, Little Harbor and Hampton/Seabrook Harbor were averaged separately because these areas have different environments with different fish assemblages. The average CPUE for each species in each area was compared to the range of all the previous observations in a time series. The species for which time series were presented were:

- Killifish (Fundulus spp.)
- Flounder, winter (Pleuronectes americanus)
- Silverside, Atlantic (Menidia menidia)
- Herring, Atlantic (Clupea harengus)
- Herring, blueback (Alosa aestivalis)
- Smelt, rainbow (Osmerus mordax)

These species were selected by querying data from 2000 for finfish species which reproduce in the estuary with an abundance of at least 1% of the total CPUE. Cumulatively, these species accounted for greater than 90% of the total CPUE of finfish (crabs and lobsters were removed from the dataset).

Second, the Simpson diversity index (D) was calculated based on the counts of all juvenile fish species caught during the season. The equation for the Simpson index (Simpson, 1949) is:

$$D = \sum_i p_i^{\ 2} = \frac{\sum_i n_i(n_i - 1)}{N(N-1)}$$

where p_i is the proportion of each species *i* in the community, n_i is the number of fish collected for species *i* and *N* is the total number of fish collected. The CPUE values reported by NHF&G were multiplied by the effort required to capture one fish of the least abundant species and then rounded to the closest integer to transform the data into a format compatible with this equation.

Third, the species richness index (S) was calculated. The species richness index is simply the number of species observed each year.

Results

The average CPUE for the dominant species are shown in Table 7 and Figure 16 through Figure 21. Table 8/Figure 22 and Table 9/Figure 23 contain the values of the Simpson diversity index (D) and the species richness index (S), respectively.

There were distinct differences in the juvenile fish composition in the four survey areas. In all areas, the most abundant juvenile fish was the Atlantic silverside but the second most abundant species changed between areas. In Great Bay/Little Bay, Atlantic silversides were more than 35 times more abundant than any other species on average. The next most abundant species in Great Bay/Little Bay was the killifish. In the Piscataqua River, Atlantic Silversides were the most abundant species by a factor of 9 and rainbow smelt was the next most abundant species. In Little Harbor and Hampton/ Seabrook Harbor, Atlantic silversides were 2-3 times more abundant than winter flounder.

The values of the Simpson diversity index (D) reflect the dominance of the one or two species (Figure 22). Values of D have hovered between 0.3 and 0.8 for all areas of the estuary. In 2004, the values for D for all areas were clustered near 0.54. D is a measure of the probability of selecting a pair of individuals of the same species from a single random sample of the community. Therefore, there is a 54% chance that any two juvenile fish selected from the estuary at random will be the same species. The species richness index (Figure 23) shows that there are slightly more juvenile fish species present in the Great Bay/Little Bay and Piscataqua River (19 species) than in the coastal harbors (9-16 species).

In general, the abundance of the species in recent years was within the range of previous observations. Time series graphs of abundance for each species are shown in Figure 16 through Figure 21. Only seven years of data are available on juvenile fish populations so the range of previous observations is not expected to represent "baseline" conditions or to define the full range of possible outcomes. However, by making comparisons to previous data, the results from the latest year can be viewed in the context of what has been seen before.

Table 7: Average catch per unit effort (CPUE) for selected juvenile finfish, 1998-2004

(a) Results sorted by species

Species	Location	1998	1999	2000	2001	2002	2003	2004	Grand Total
Flounder, winter	Great/Little Bay	1.07	0.38	4.32	1.70	3.11	2.07	0.66	1.90
	Hampton Harbor	1.99	1.07	3.51	2.18	4.70	3.35	2.52	2.76
	Little Harbor	5.57	1.74	7.26	2.95	12.39	8.86	3.39	6.02
	Piscataqua River	1.11	1.19	3.18	1.12	1.63	1.28	0.94	1.49
Herring, atlantic	Great/Little Bay	0.61	1.21	0.76	0.46	0.43	0.19	0.35	0.57
	Hampton Harbor	0.00	1.44	0.00	0.00	0.09	0.26	0.00	0.26
	Little Harbor	0.07	0.00	0.45	0.00	0.04	0.04	0.13	0.10
	Piscataqua River	0.00	2.32	0.92	0.00	0.65	1.65	0.00	0.79
Herring, blueback	Great/Little Bay	1.47	1.62	2.33	0.99	0.56	1.59	0.19	1.25
	Hampton Harbor	0.00	0.37	0.17	0.84	0.00	0.08	0.25	0.24
	Little Harbor	0.34	0.04	0.12	1.91	0.04	0.62	0.24	0.47
	Piscataqua River	1.46	7.86	3.50	1.29	0.76	3.57	0.36	2.69
Killifish	Great/Little Bay	1.13	4.71	2.09	3.92	6.52	5.45	2.19	3.72
	Hampton Harbor	0.01	0.00	0.00	0.06	0.00	0.27	0.00	0.05
	Little Harbor	0.02	0.28	0.09	0.30	0.10	0.13	0.25	0.17
	Piscataqua River	0.30	2.93	2.32	0.92	1.00	5.21	3.74	2.35
Silverside, atlantic	Great/Little Bay	45.66	238.10	134.37	95.01	192.38	159.74	52.73	131.14
	Hampton Harbor	3.53	14.93	12.38	11.53	5.25	6.21	9.16	9.00
	Little Harbor	2.28	36.42	14.77	12.22	9.38	6.94	10.28	13.18
	Piscataqua River	8.87	285.53	119.84	54.28	58.97	45.89	70.97	92.05
Smelt, rainbow	Great/Little Bay	2.50	0.36	3.79	4.17	1.32	4.21	3.22	2.80
	Hampton Harbor	0.50	0.05	0.25	0.06	0.00	0.06	0.41	0.19
	Little Harbor	0.17	0.45	0.58	0.12	0.16	0.19	0.08	0.25
	Piscataqua River	4.11	2.83	32.43	16.62	4.68	9.12	4.48	10.61

(b) Results sorted by area

Location	Species	1998	1999	2000	2001	2002	2003	2004	Grand Total
Great/Little Bay	Silverside, atlantic	45.66	238.10	134.37	95.01	192.38	159.74	52.73	131.14
	Killifish	1.13	4.71	2.09	3.92	6.52	5.45	2.19	3.72
	Flounder, winter	1.07	0.38	4.32	1.70	3.11	2.07	0.66	1.90
	Herring, atlantic	0.61	1.21	0.76	0.46	0.43	0.19	0.35	0.57
	Herring, blueback	1.47	1.62	2.33	0.99	0.56	1.59	0.19	1.25
	Smelt, rainbow	2.50	0.36	3.79	4.17	1.32	4.21	3.22	2.80
Hampton Harbor	Silverside, atlantic	3.53	14.93	12.38	11.53	5.25	6.21	9.16	9.00
	Killifish	0.01	0.00	0.00	0.06	0.00	0.27	0.00	0.05
	Flounder, winter	1.99	1.07	3.51	2.18	4.70	3.35	2.52	2.76
	Herring, atlantic	0.00	1.44	0.00	0.00	0.09	0.26	0.00	0.26
	Herring, blueback	0.00	0.37	0.17	0.84	0.00	0.08	0.25	0.24
	Smelt, rainbow	0.50	0.05	0.25	0.06	0.00	0.06	0.41	0.19
Little Harbor	Silverside, atlantic	2.28	36.42	14.77	12.22	9.38	6.94	10.28	13.18
	Killifish	0.02	0.28	0.09	0.30	0.10	0.13	0.25	0.17
	Flounder, winter	5.57	1.74	7.26	2.95	12.39	8.86	3.39	6.02
	Herring, atlantic	0.07	0.00	0.45	0.00	0.04	0.04	0.13	0.10
	Herring, blueback	0.34	0.04	0.12	1.91	0.04	0.62	0.24	0.47
	Smelt, rainbow	0.17	0.45	0.58	0.12	0.16	0.19	0.08	0.25
Piscataqua River	Silverside, atlantic	8.87	285.53	119.84	54.28	58.97	45.89	70.97	92.05
	Killifish	0.30	2.93	2.32	0.92	1.00	5.21	3.74	2.35
	Flounder, winter	1.11	1.19	3.18	1.12	1.63	1.28	0.94	1.49
	Herring, atlantic	0.00	2.32	0.92	0.00	0.65	1.65	0.00	0.79
	Herring, blueback	1.46	7.86	3.50	1.29	0.76	3.57	0.36	2.69
	Smelt, rainbow	4.11	2.83	32.43	16.62	4.68	9.12	4.48	10.61

Data Source: NHF&G ACFCMA Reports

Figure 16: Average catch per unit effort (CPUE) for winter flounder in 1998-2004

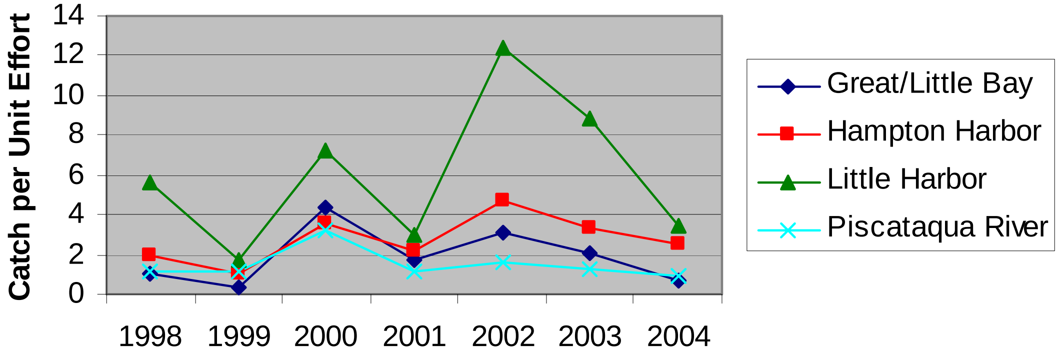


Figure 17: Average catch per unit effort (CPUE) for Atlantic herring in 1998-2004

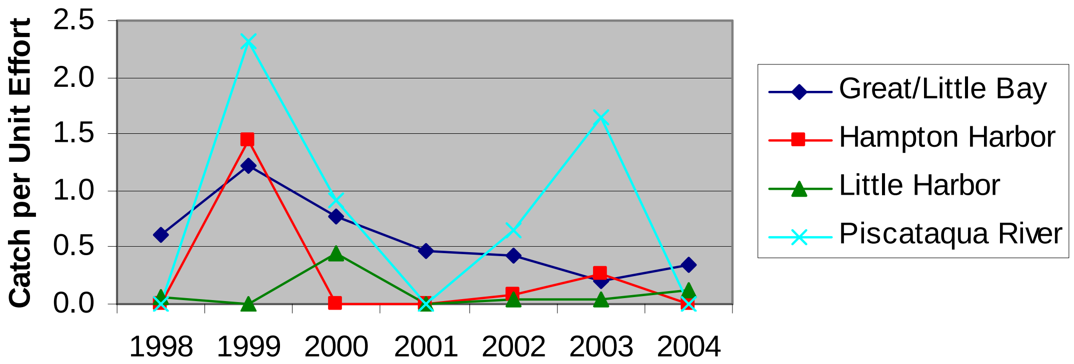


Figure 18: Average catch per unit effort (CPUE) for blueback herring in 1998-2004

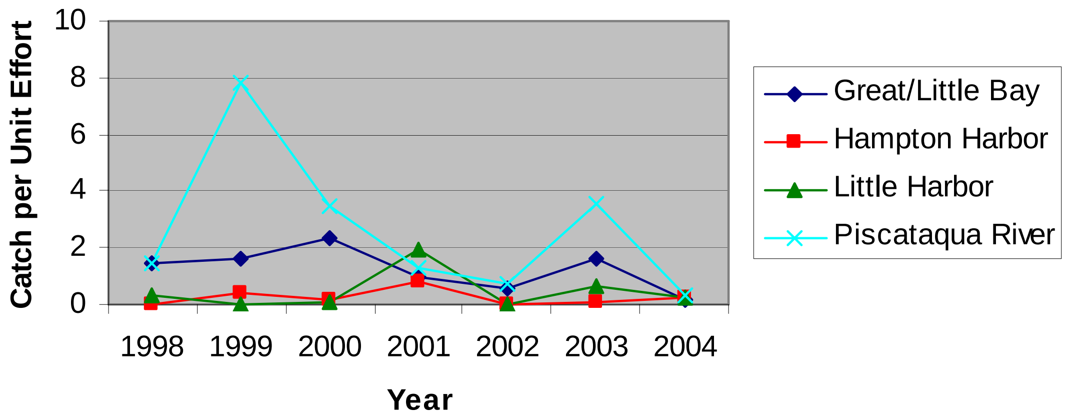


Figure 19: Average catch per unit effort (CPUE) for killifish in 1998-2004

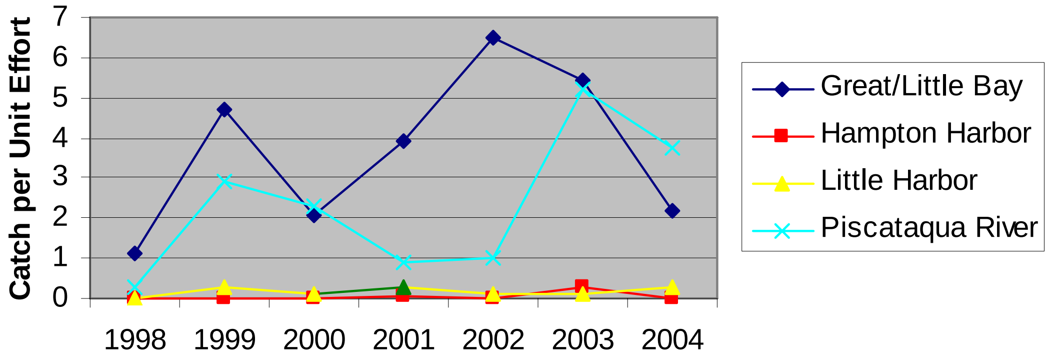


Figure 20: Average catch per unit effort (CPUE) for Atlantic silverside in 1998-2004

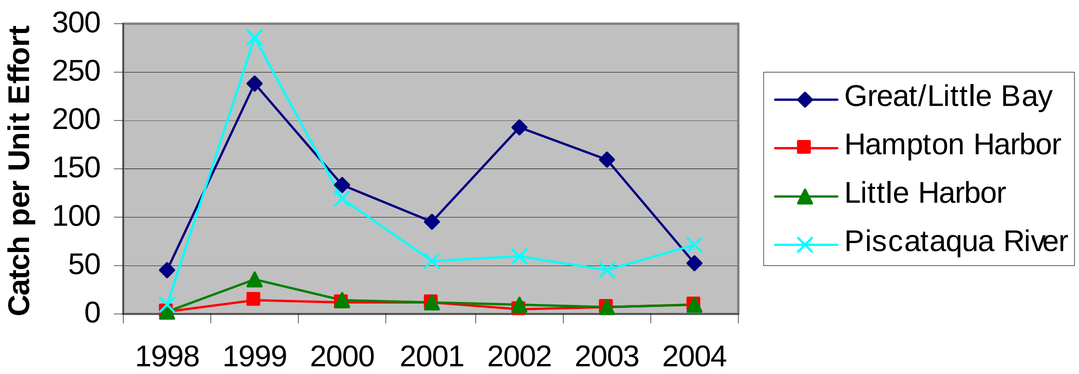


Figure 21: Average catch per unit effort (CPUE) for rainbow smelt in 1998-2004

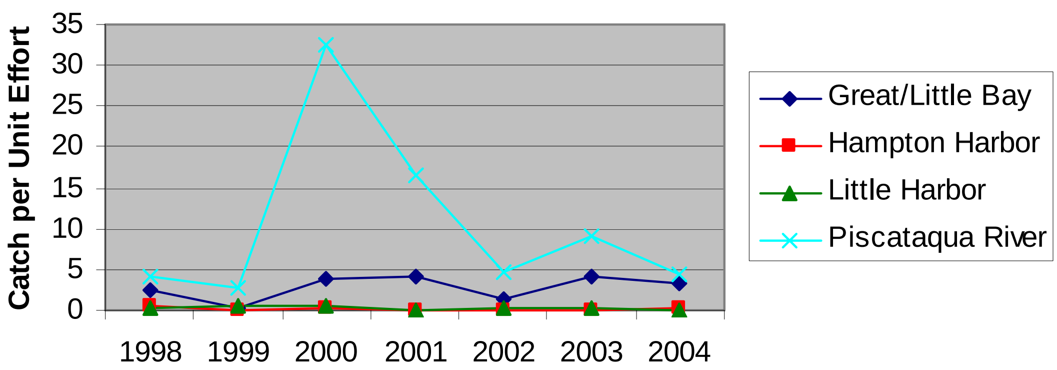


Table 8: Simpson's diversity index (D) for juvenile finfish diversity in NH's estuaries

Year	Little Harbor	Hampton Harbor	Piscataqua River	Great/Little Bays
1998	0.396	0.406	0.308	0.624
1999	0.776	0.604	0.817	0.803
2000	0.454	0.456	0.472	0.697
2001	0.451	0.588	0.518	0.675
2002	0.405	0.390	0.503	0.792
2003	0.377	0.335	0.294	0.717
2004	0.490	0.503	0.622	0.556

Data Source: NHF&G ACFCMA Reports

Figure 22: Simpson's diversity index (D) for juvenile finfish diversity in NH's estuaries

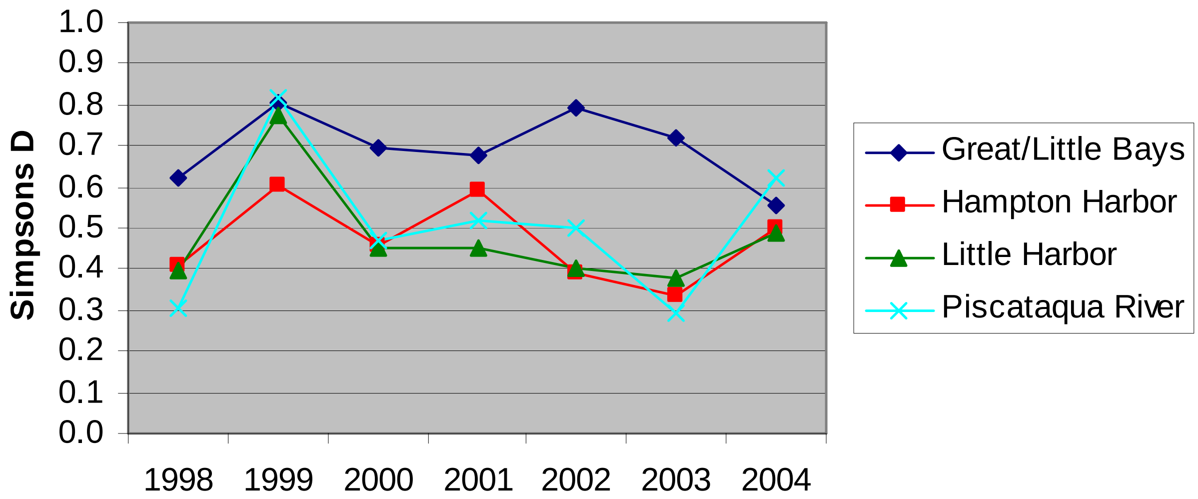
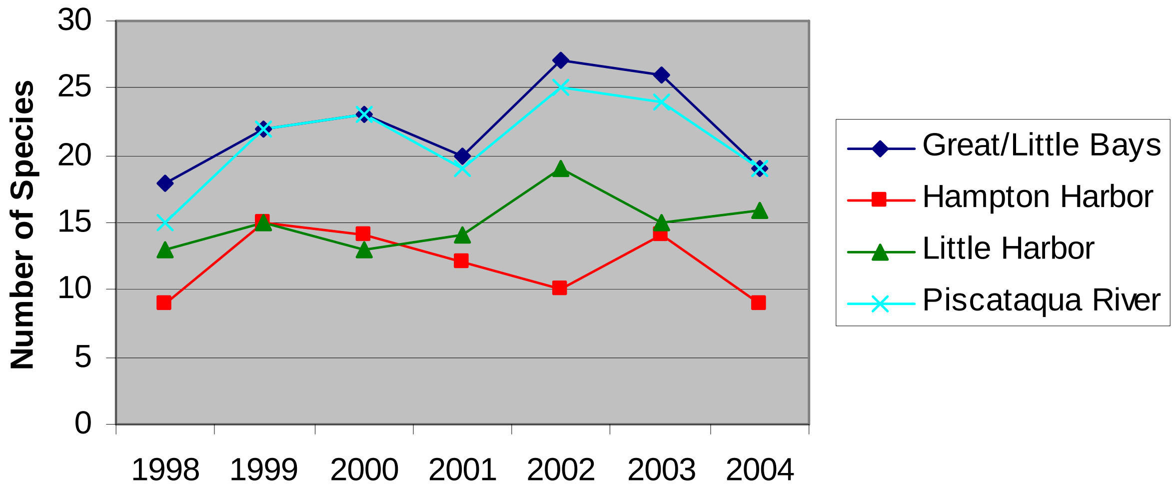


Table 9: Species richness index (S) for juvenile fish in NH's estuaries

Year	Little Harbor	Hampton Harbor	Piscataqua River	Great/Little Bays
1998	13	9	15	18
1999	15	15	22	22
2000	13	14	23	23
2001	14	12	19	20
2002	19	10	25	27
2003	15	14	24	26
2004	16	9	19	19

Data Source: NHF&G ACFCMA Reports

Figure 23: Species richness index (S) for juvenile fish in NH's estuaries



HAB8 - ANADROMOUS FISH RETURNS

Monitoring Objective

As a subset of the adult finfish, anadromous fish returns are indicative of conditions in the upper watershed. The juvenile fish need suitable habitat in the rivers and streams to thrive, adults need passage through dams and suitable upstream habitat to spawn. Therefore, changes in the anadromous fish returns could be due to many factors. The TAC felt that, despite the complexity of this indicator, tracking the returns of river herrings and smelt would be a useful indicator of ecological conditions in the coastal watershed as long as consideration was given to other factors that might affect fish returns (e.g., efficiency of the fish ladders, amount and quality of spawning habitat, predation levels, harvest pressure, stock enhancement). The objective of this supporting variable is to illustrate year to year trends in the abundance of anadromous finfish in the estuary. It addresses the following monitoring question related to Land Use Goal #6:

Has the number of anadromous fish returning to NH's coastal rivers changed over time?

Measurable Goal

Since anadromous fish is a supporting variable that will not be used to answer a management question, no goal has been set.

Data Analysis and Statistical Methods

Measurements of abundance for five anadromous fish species were compiled for each year using data collected by NHF&G (NHF&G 2005b). For most anadromous fish, the measurements were counts of fish passing through fish ladders. The following table lists the species that were analyzed for this indicator.

SPECIES	ABUNDANCE MEASURE	LOCATION	SOURCE
Herring (Alosa pseudoharengus and Alosa aestivalis)	Passage through fish ladders (# of fish/yr)	Exeter, Lamprey, Oyster, Cocheco, Winnicut, and Taylor rivers	NHF&G F-61-R reports
Shad (Alosa sapidissima)	Passage through fish ladders (# of fish/yr)	Exeter, Lamprey, and Cocheco rivers	NHF&G F-61-R reports
Salmon (Salmo salar)	Passage through fish ladders (# of fish/yr)	Lamprey and Cocheco rivers	NHF&G F-61-R reports
Smelt, rainbow (Osmerus mordax)	CPUE (catch per angler hour)	Great Bay Ice Fishery	NHF&G F-61-R reports
Lamprey (Petromyzon marinus)	Passage through fish ladders (# of fish/yr)	Cocheco river	NHF&G records

Results

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 not possible.

Data on river herring returns are shown in Table 10 and Figure 24. In the Cocheco River, herring returns have been generally increasing since the late 1989. Returns to the Exeter River have been erratic and fell to historically low levels in the past two years. NHF&G considers low dissolved oxygen in the upstream impoundment, impediments to downstream migration and harvest pressure to be possible causes of the decline (NHF&G 2005b). Herring passage in the Oyster River fish ladder was low until 1985, after which fish returns rose sharply. However, returns to this river decreased over the past five years. In the Lamprey River, herring passage appears to follow a sinusoidal pattern with a period of approximately 20 years. A new record number of fish passing the Lamprey River fish ladder was reached in 2004. In the late 1970s, as many as 450,000 herring returns were reported for the Taylor River. There has been a steady decline in returns at this fish ladder over the past 30 years. In 2004, only 1,055 herring passed through the ladder, the lowest passage on record. In 1997, the fish ladder on the Winnicut River was reconfigured to improve passage. Returns have steadily increased over the years to a record value of 8,044 fish in 2004.

Returns of American shad are shown in Table 11 and Figure 25. Shad returns to the Exeter River have been decreasing for the past four years, following two good years in 1999 and 2000. There has been a slow increase for shad returns to the Cocheco River. The recent trend in the Lamprey River is improving.

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 returns by year and location are shown in Table 12 and Figure 26.

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 27). The smelt survey was not performed in 2002, which may have been another peak abundance year.

Table 14 and Figure 28 contain records of 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 for their products. The number of returning fish was depressed following this harvest. The abundance graph indicates that the lamprey population has been slowly rebounding since 1988.

Table 10: Numbers of river herring returning to fishways on coastal NH rivers

Year	Cocheco River	Exeter River	Oyster River	Lamprey River	Taylor River	Winnicut River	Notes
1972				2,528			
1973				1,380			
1974				1,627			
1975		2,639		2,882			
1976	9,500		11,777	3,951	450,000		
1977	29,500		359	11,256		2,700	
1978	1,925	205	419	20,461	168,256	3,229	
1979	586	186	496	23,747	375,302	3,410	
1980	7,713	2,516	2,921	26,512	205,420	4,393	
1981	6,559	15,626	5,099	50,226	94,060	2,316	
1982	4,129	542	6,563	66,189	126,182	2,500	
1983	968	1	8,866	54,546	151,100		
1984	477		5,179	40,213	45,600		
1985	974		4,116	54,365	108,201		
1986	2,612	1,125	93,024	46,623	117,000	1,000	
1987	3,557	220	57,745	45,895	63,514		
1988	3,915		73,866	31,897	30,297		
1989	18,455		38,925	26,149	41,395		
1990	31,697		154,588	25,457	27,210		
1991	25,753	313	151,975	29,871	46,392		
1992	72,491	537	157,024	16,511	49,108		
1993	40,372	278	73,788	25,289	84,859		
1994	33,140		91,974	14,119	42,164		(1)
1995	79,385	592	82,895	15,904	14,757		
1996	32,767	248	82,362	11,200	10,113		
1997	31,182	1,302	57,920	13,788	20,420		(2)
1998	25,277	392	85,116	15,947	11,979	219	
1999	16,679	2,821	88,063	20,067	25,197	305	
2000	30,938	533	70,873	25,678	44,010	525	
2001	46,590	6,703	66,989	39,330	7,065	1,118	
2002	62,472	3,341	58,179	58,605	5,829	7,041	
2003	71,199	71	51,536	64,486	1,397	5,427	
2004	47,934	83	52,934	66,333	1,055	8,044	

(1) Exeter fish trap was damaged in 1994 allowing fish to pass without being counted.

(2) Winnicut dam modified to allow fish passage. All previous returns were from hand-passing over the dam.

(3) Data Source: NHF&G F61R Reports

Figure 24: Returns of river herring to NH coastal tributaries

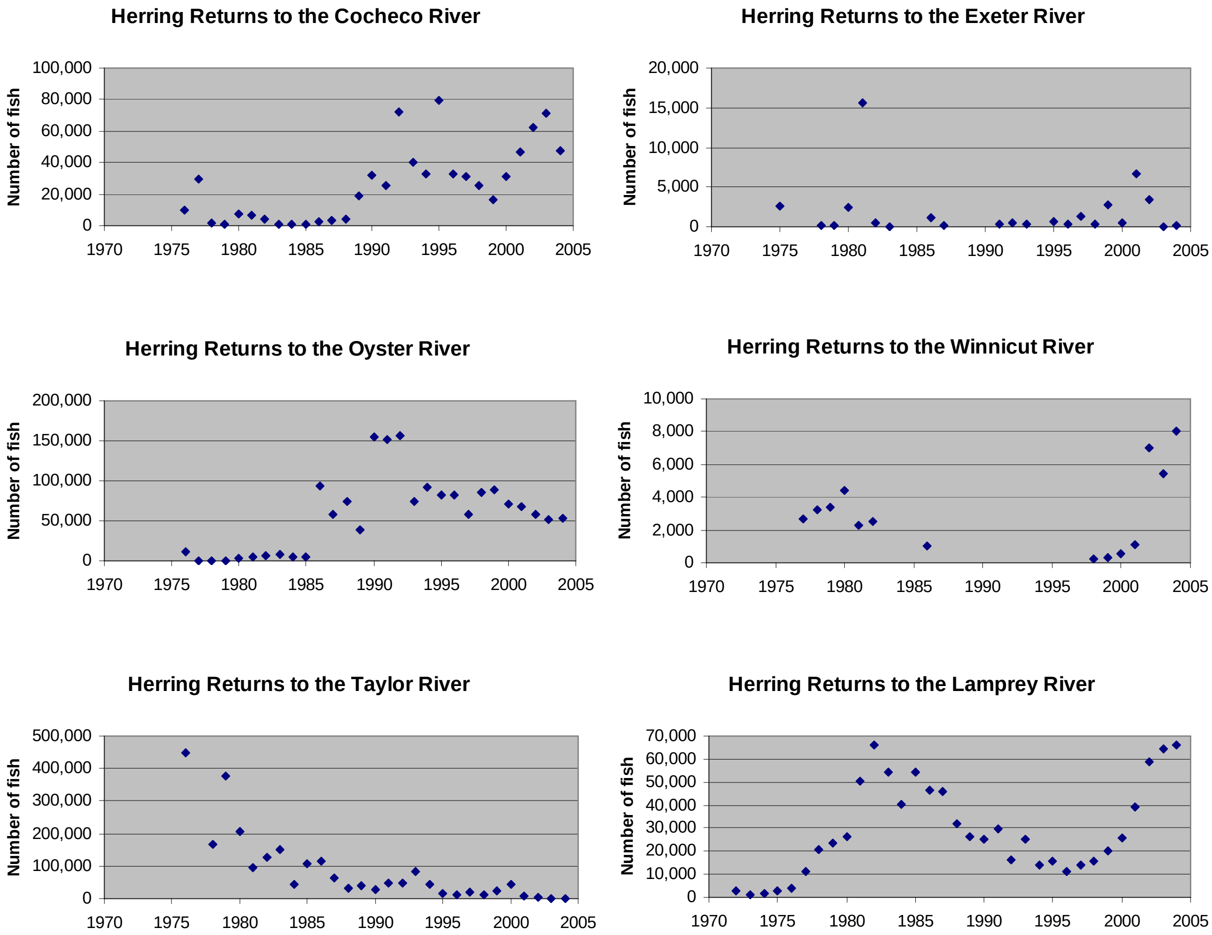


Table 11: American shad returns to New Hampshire coastal fishways

Year	Exeter River	Lamprey River	Cocheco River	Comments
1983			3	
1984				
1985		2	1	
1986		39	1	
1987				
1988			4	1
1989			8	1
1990			3	1
1991	12	2	6	
1992	22	5	24	
1993	21	200	17	2
1994		13	9	2, 3
1995	18	14	8	2
1996	58	2	5	2
1997	30	4	11	2
1998	33	3	6	2
1999	129	3	2	2
2000	163	7	14	2
2001	42	6	6	2
2002	41	4	4	2
2003	33	26	6	2
2004	22	33	12	2

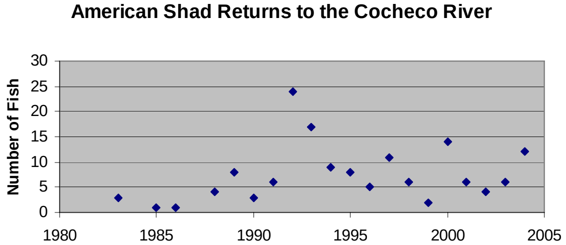
1 - No counts at Exeter or Lamprey rivers because ladder was operated as a swim through.

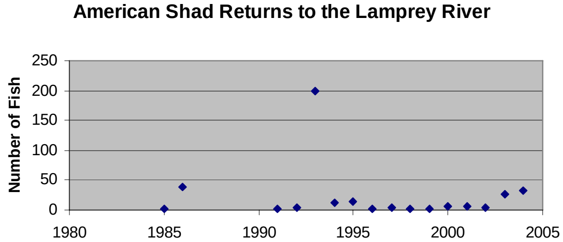
2 - Minimum counts for Lamprey River - ladder operated as swim through until late May.

3 - No counts at Exeter River because ladder was operated as a swim through.

Blank cells indicate no data

Figure 25: American shad returns to Great Bay tributaries





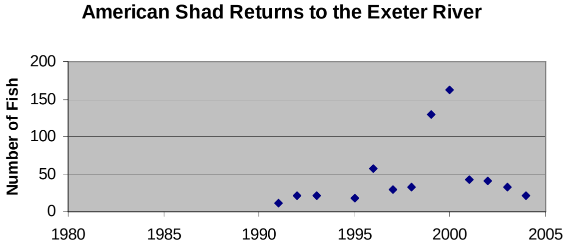


Table 12: Number of recorded salmon returns

Year	Cocheco River	Lamprey River	Total Salmon
1992	1	2	3
1993	4	8	12
1994	0	3	3
1995	1	1	2
1996	2	1	3
1997	0	0	0
1998	0	0	0
1999	3	6	9
2000	2	4	6
2001	0	0	0
2002	0	0	0
2003	4	2	6
		Total	**44**

Data Source: NHF&G F61R Reports
Salmon stocking and monitoring were discontinued in 2004

Figure 26: Salmon returns to Great Bay tributaries

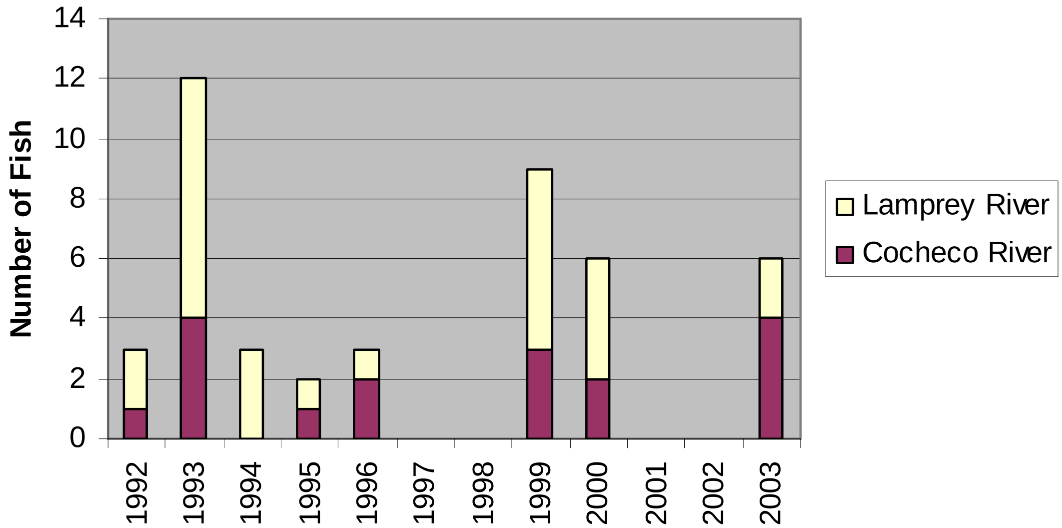


Table 13: Catch per unit effort of rainbow smelt in the Great Bay ice fishery

Year	Catch per unit effort (fish/angler hour)	Comments
1978	11.4	
1979	6.8	
1980	1.1	
1981	5.9	
1982	1.3	
1983		No survey
1984		No survey
1985		No survey
1986		No survey
1987	5.8	
1988	5.3	
1989	10.2	
1990	5.7	
1991	2.3	
1992	1.5	
1993	3.6	
1994	2.9	
1995	9.7	
1996	4.9	
1997	2.6	
1998	2	
1999	2.5	
2000	4	
2001	5.6	
2002		No survey
2003	5	
2004	4.3	

Data Source: NHF&G F61R Reports

Figure 27: Abundance of rainbow smelt in the Great Bay ice fishery

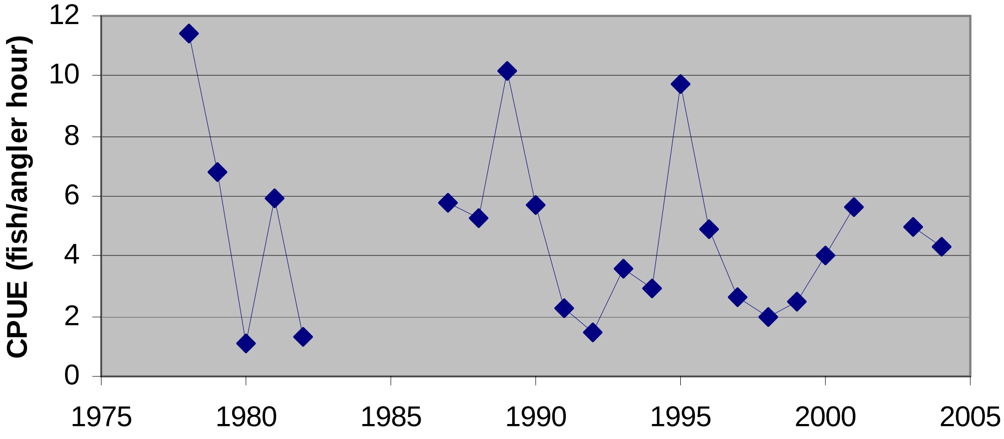


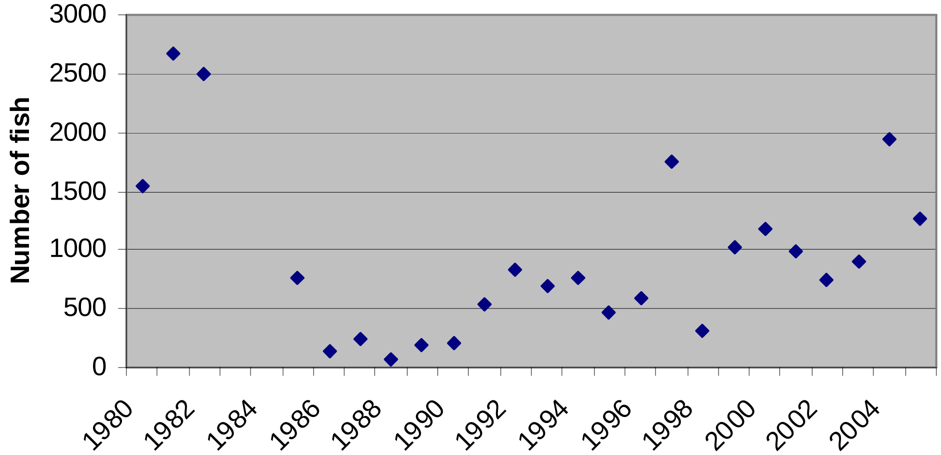
Table 14: Number of lamprey returns to tidal rivers

Year	Cocheco River	Squamscott River	Lamprey River
1980	1547	5540	1628
1981	2662	5954	1683
1982	2500	4288	959
1983			
1984			
1985	768		1
1986	146		6
1987	251	9	1
1988	62	100+	
1989	184	5	1
1990	201		0
1991	533	2	4
1992	824	1	8
1993	697	1	0
1994	761	trap broken	118
1995	469	5	166
1996	589	114	238
1997	1752	5	213
1998	313	11	292
1999	1020	13	253
2000	1175	96	1246
2001	993	2728	42
2002	739	361	37
2003	906	1139	116
2004	1945	418	10
2005	1261	16	131

(1) The numbers from 1980 to 1982 are from the annual report of M. L. Taylor, a biological supply company that collected lampreys from 1978 to 1988. The records for 1983 to 1986 were either lost or were never filed. The number of returning lampreys was severely reduced after these years of heavy collecting.

(2) NHF&G monitoring began in 1985

Figure 28: Number of lamprey returns to the Cocheco River



HAB9 - ABUNDANCE OF LOBSTERS

Monitoring Objective

The commercial fishery for lobster is the largest and most important fishery in New Hampshire. Although lobsters are not exclusively dependent on conditions in the estuary to survive, a crash in the lobster population would be a cause for concern both ecologically and commercially. The objective for this supporting variable is to track the overall abundance of lobsters (total and legal size) to illustrate any trends over time. It addresses the following monitoring question:

Has the population of lobsters changed over time?

Measurable Goal

Since lobster abundance is a supporting variable that will not be used to answer a management question, no goal has been set.

Data Analysis and Statistical Methods

Measurements of lobster abundance were tracked for each year using data from NHF&G (NHF&G, 2005c). Specifically, the average total catch per trap haul set over day (CTHSOD), marketable CTHSOD and marketable catch per trap haul (CTH) were calculated and plotted against year to illustrate trends over time. The statistics were calculated using data from the Piscataqua River, Isles of Shoals and North Coast areas collected during July through October. Only data from 2001-2004 were used in the analysis because these data were collected using consistent protocols.

Results

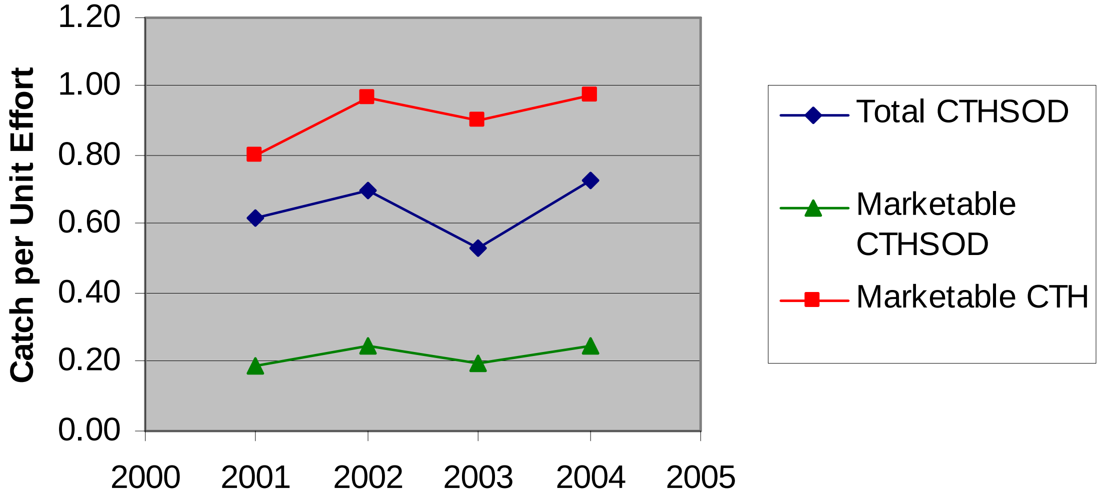
Over the past four years, the abundance of lobsters along the NH coast has been relatively constant. The expected total catch per trap haul set over a day (CTHSOD) was approximately 0.5 to 0.75, with marketable lobsters making up approximately one-third of this catch (marketable CTHSOD=0.20-0.25) (Table 15, Figure 29).

Table 15: Lobster abundance in NH coastal waters

Year	Total CTHSOD	Marketable CTHSOD	Marketable CTH	Comments
2001	0.62	0.19	0.80	
2002	0.70	0.25	0.97	
2003	0.53	0.20	0.90	
2004	0.73	0.25	0.98	

(1) Averages computed using data from the River, Shoals, and North Coast stations during July through October.
(2) Data source: NHF&G Lobster Sea Sampling reports
(3) CTHSOD=catch per trap haul set over day
CTH=catch per trap haul

Figure 29: Lobster abundance in NH coastal waters



HAB10 - ABUNDANCE OF WINTERING WATERFOWL

Monitoring Objective

Waterfowl are one of most important wildlife species in the estuary. 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). Eelgrass, open water and tidal flats provide winter forage for the birds (NHF&G, 1995). The population wintering over in any particular estuary along the Atlantic Flyway depends on multiple factors including the local and regional climatic conditions and the total number of birds in the migration (e.g., ice cover, weather patterns, amount of forage available, breeding success, mortality). These regional conditions are more important than local conditions in the estuary in terms of understanding changes in wintering waterfowl populations. The objective of this supporting variable is track the abundance of wintering waterfowl in Great Bay and the Atlantic Flyway to illustrate changes over time. Trends in waterfowl populations are used to understand changes in the ecosystem of the estuary, not as an indicator of water quality or the health or quality of the estuary. This supporting variable is used to answer the following question:

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

Measurable Goal

Since wintering waterfowl is a supporting variable that will not be used to answer a management question, no goal has been set.

Data Analysis and Statistical Methods

Each January, biologists from NHF&G use aircraft surveys to count the number and species of waterfowl present along the NH coast. Simultaneous surveys are conducted in other Atlantic Flyway states. Annual mid-winter waterfowl counts were compiled for the NH coastal region and the Atlantic Flyway. The latest year's results (2006) were compared to the 10-year average population for reference. The waterfowl species that were compiled were: mallard (*Anas platyrhynchos*), black duck (*Anas rubripes*), greater/lesser scaup (*Aythya marila/affinis*), and Canada goose (*Branta canadensis*).

Results

Bird counts in the NH coast and the Atlantic Flyway are shown in Table 16, Figure 30, Figure 31 and Figure 32.

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 2006, 5,859 wintering waterfowl of the target species were observed on the NH coast, which is higher than the 10-year average of 5,072 birds observed. There were relatively fewer black ducks and more scaup in 2006 compared to observations during the previous 10 years.

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. 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.).

Table 16: Wintering waterfowl in NH and the Atlantic Flyway

Species	New Hampshire Coast			Atlantic Flyway		
	2006	1996-2005 Average		2006	1996-2005 Average	
	Bird Counts	Bird Counts	Relative Percent	Bird Counts	Bird Counts	Relative Percent
Mallard (Anas platyrhynchos)	538	598	12%	116,148	152,419	9%
Black Duck (Anas rubripes)	408	1,191	23%	190,653	221,470	13%
Scaup (Aythya marila/affinis)	1,500	596	12%	249,075	412,678	24%
Canada Goose (Branta canadensis)	3,413	2,687	53%	880,478	898,583	53%
Total	5,859	5,072	100%	1,436,354	1,685,151	100%

Data provided from NHF&G Midwinter Waterfowl Survey

Figure 30: Wintering waterfowl on the NH coast

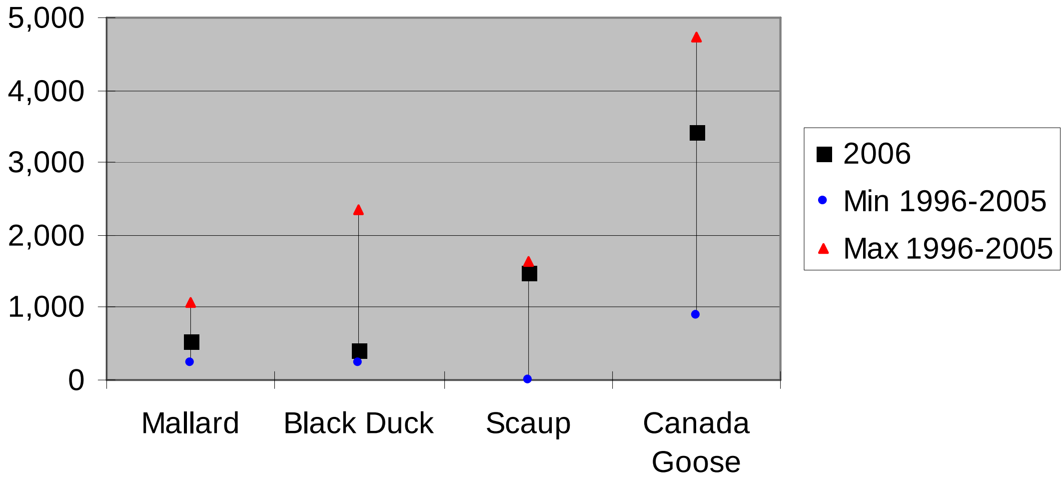


Figure 31: Wintering waterfowl in the Atlantic Flyway

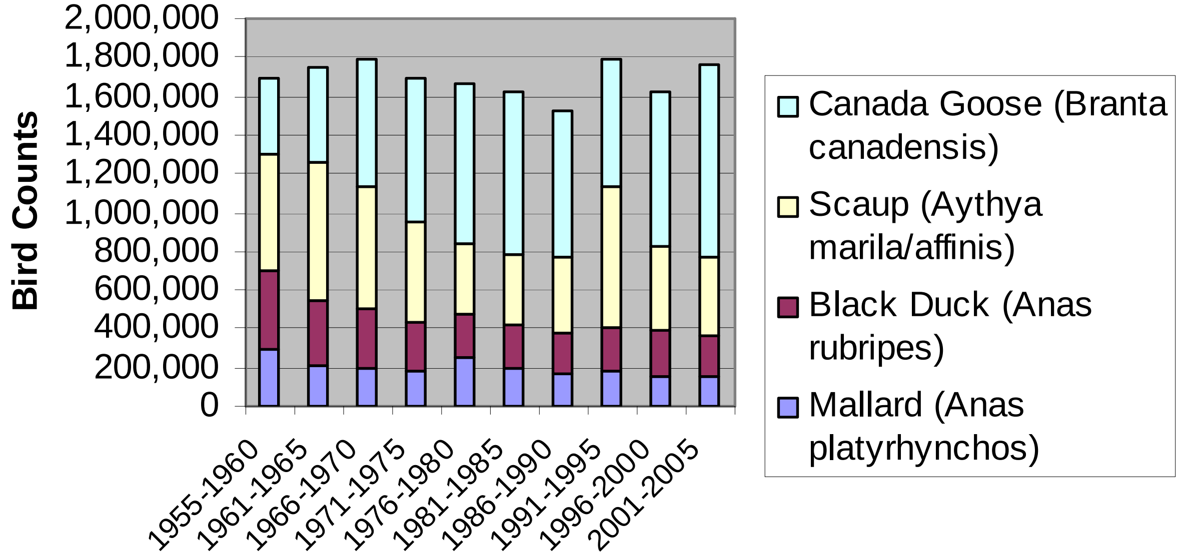
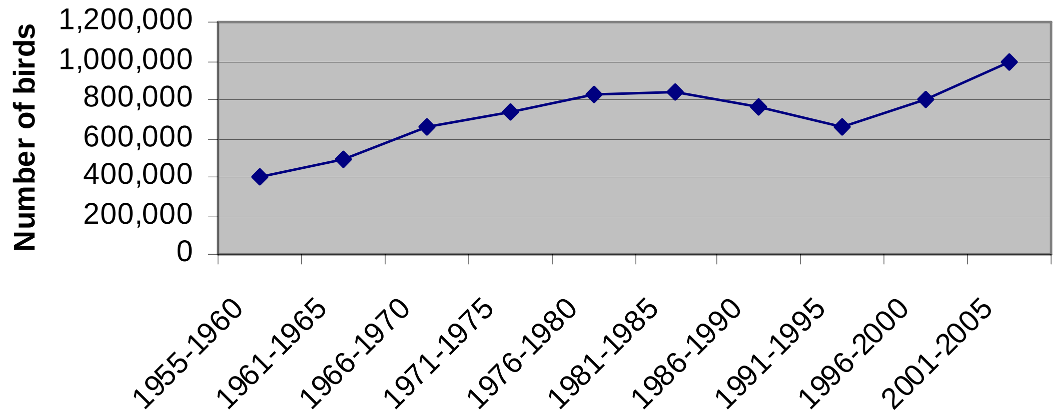


Figure 32: Fifty year trend in winter Canada goose abundance in the Atlantic Flyway



RST1 - RESTORED SALT MARSH

Monitoring Objective

The objective of this indicator is to track the cumulative acres of salt marsh with tidal restrictions that have been restored since NHEP implementation began (2000). This indicator partially answers the following monitoring question:

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

Measurable Goal

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

Data Analysis and Statistical Methods

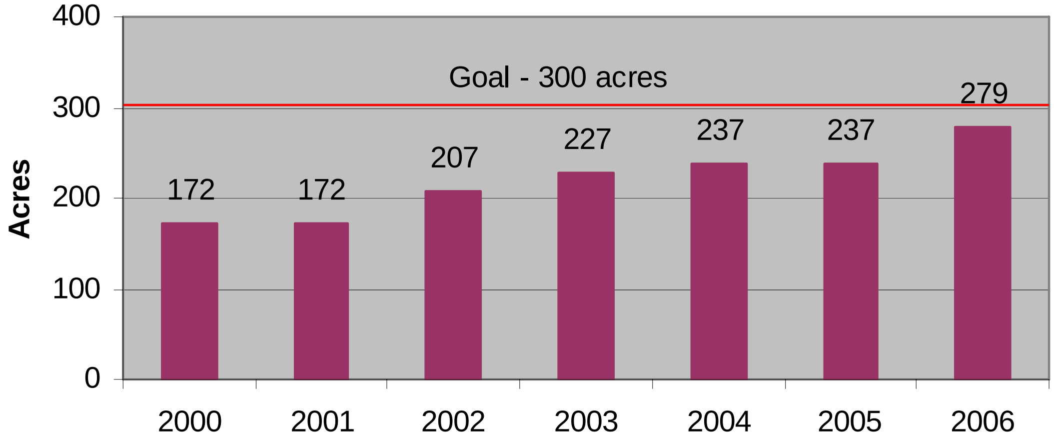
The total acres of salt marsh restorations that have occurred since January 1, 2000 were calculated and compared to the goal of 300 total acres. The salt marsh was considered "restored" at the conclusion of the restoration project. The total area of restored salt marsh was determined by the restoration project manager. No statistical tests were applied.

Results

There has been significant progress toward the goal of restoring 300 acres between 2000 and 2006 (Figure 33). The current tally of salt marsh restoration projects by tidal restriction removal since January 1, 2000 is 279 acres (93% of goal). The NH Coastal Program is currently planning additional salt marsh restoration by tidal restriction removal, which, if completed, would surpass the NHEP 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.

Figure 33: Acres of salt marsh restoration through tidal restriction removal



RST2 - RESTORED EELGRASS BEDS

Monitoring Objective

The objective of this indicator is to track the cumulative acres of eelgrass beds that have been restored since NHEP implementation began (2000). This indicator partially answers the following monitoring question:

Have restoration efforts resulted in a significant increase in the acreage of eelgrass?

Measurable Goal

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

Data Analysis and Statistical Methods

The total acres of eelgrass restoration projects that have occurred since January 1, 2000 were calculated and compared to the goal. The eelgrass beds were considered "restored" at the conclusion of the restoration project. Only projects that actively planted eelgrass in areas were considered restoration projects. Expanded eelgrass coverage due to water quality improvement projects has not been observed, but would be considered part of the restoration total if it occurred. The total area of restored eelgrass bed was determined by the restoration project manager. No statistical tests were applied.

Results

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 m2/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 NHEP goal.

In 2005, eelgrass was transplanted to locations in the Bellamy River (1 ac.) and Portsmouth Harbor (0.25 ac.). Success of the two projects will be determined in 2006.

Therefore, since 2000, 1.75 acres of eelgrass restoration projects have been completed (3.5% 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.

RST3 - RESTORED OYSTER BEDS

Monitoring Objectives

The objective of this indicator is to track the cumulative acres of oyster beds that have been restored since NHEP implementation began (2000). This indicator partially answers the following monitoring question:

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

Measurable Goal

The goal is to restore 20 acres of oyster beds by 2010. This is roughly equivalent to the known losses in oyster habitat in the Great Bay Estuary and its tributaries over the past 20 years.

Data Analysis and Statistical Methods

The total acres of oyster restoration projects that have occurred since January 1, 2000 were calculated and compared to the goal. The oyster beds were considered "restored" at the conclusion of the restoration project. Only projects that actively transplanted oysters to reefs were considered restoration projects. Expanded oyster density due to water quality improvement projects has not been observed, but would be considered part of the restoration total if it occurred. The total area of each restored oyster bed was determined by the restoration project manager. No statistical tests were applied.

Results

Five oyster restoration projects have been implemented in the Great Bay Estuary. The locations of the five projects are shown in Figure 35 through Figure 39. As a result of these projects, a total of 3.18 acres of oyster bed has been restored (16% of goal) (Figure 34). 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 0.11 acres of the restoration sites. However, the restoration work still created oyster habitat by installing cultch or other materials on which spat could settle.

The NHEP has provided financial support for the Nannie Island and Bellamy River restoration projects. 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 infections in native oysters.

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.

Figure 34: Acres of oyster bed restoration

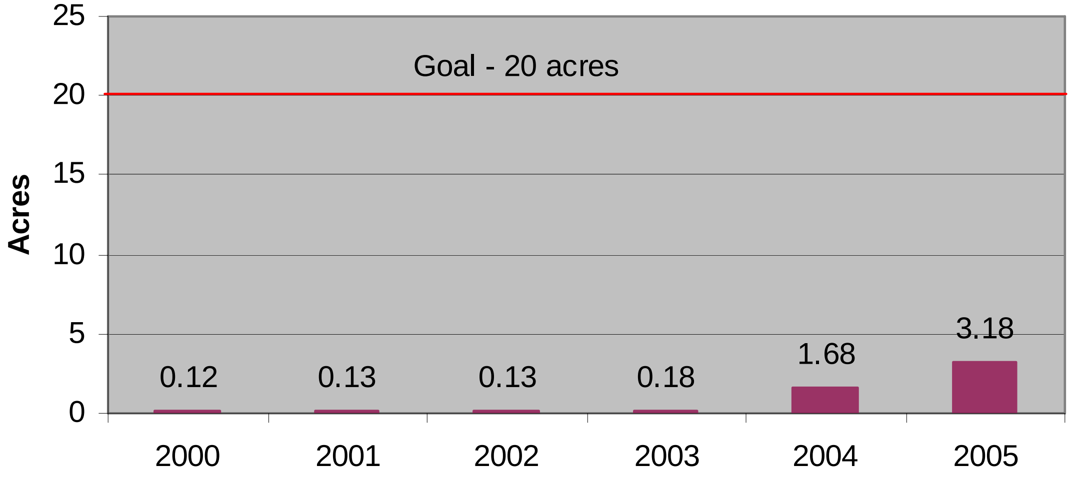
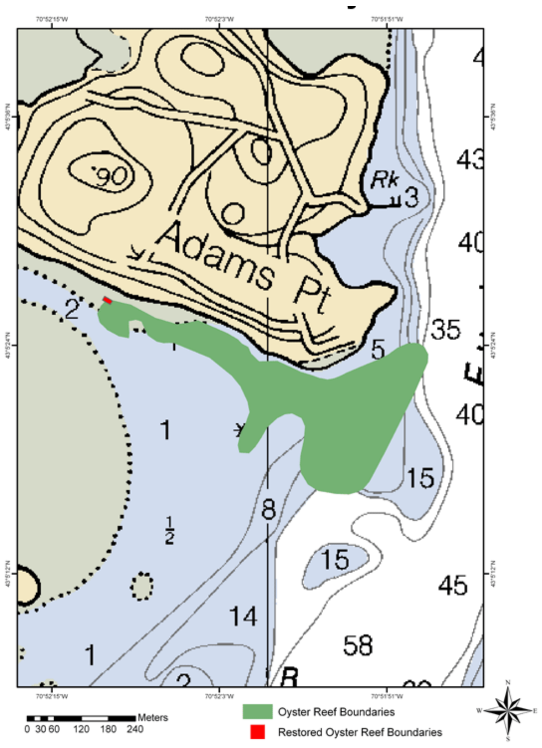
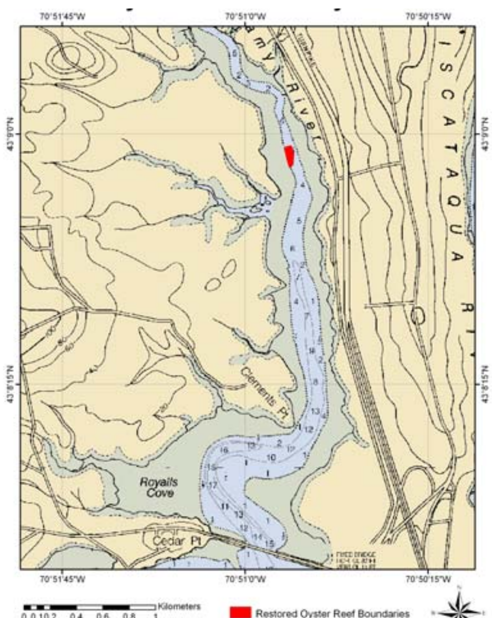


Figure 35: Oyster restoration site at Adams Point



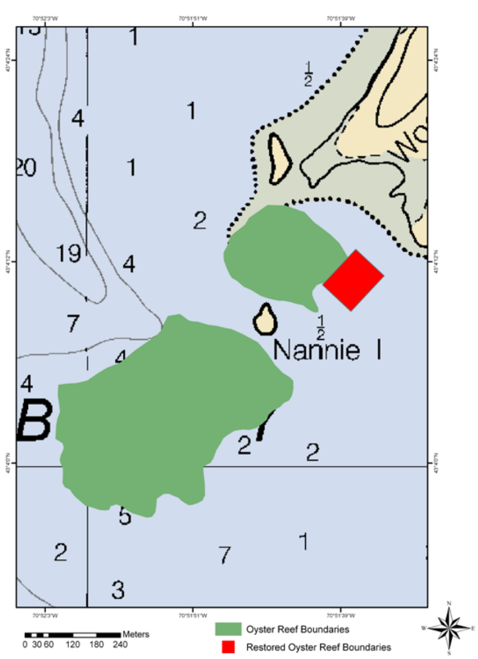
Source: UNH Benthic Ecology Lab

Figure 36: Oyster restoration site in the Bellamy River



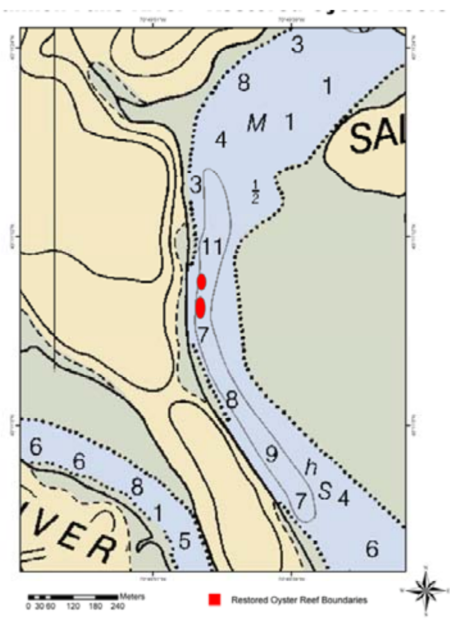
Source: UNH Benthic Ecology Lab

Figure 37: Oyster restoration site at Nannie Island



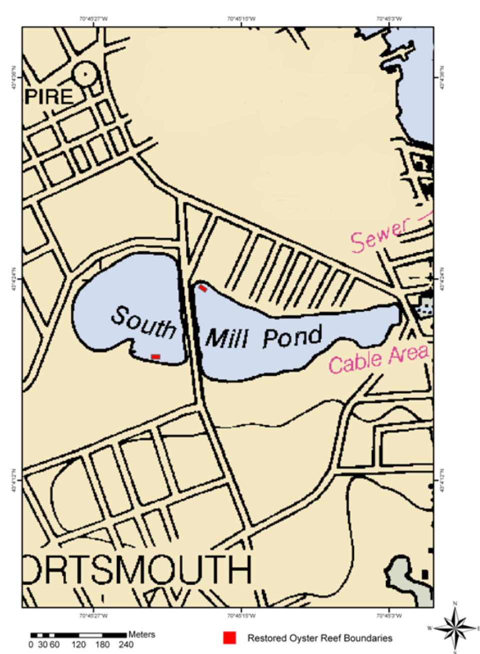
Source: UNH Benthic Ecology Lab

Figure 38: Oyster restoration site in the Salmon Falls River



Source: UNH Benthic Ecology Lab

Figure 39: Oyster restoration site in South Mill Pond



Source: UNH Benthic Ecology Lab

CONCLUSIONS

While it is hard to summarize overall conditions in the NHEP project area, the habitats and species indicators presented in this report show that:

- The extent of salt marsh mapped in 2004 (5,554 ac) was lower than the NHEP goal (6,200 ac) and the estimated extent in 1990-1992 (6,452 ac). However, without further study it is not possible to know whether these differences are due to real changes in salt marsh area or different mapping methods. The discrepancies between the two datasets should be investigated in detail. Phragmites covered 133 acres of salt marsh area in 2004. There were 351 individual phragmites stands with an average size of 0.4 acres.
- Eelgrass coverage in the Great Bay has been declining since 1996 except for one good year in 2001. The trend for eelgrass biomass is more troubling. Between 1992 and 2003, the eelgrass biomass in Great Bay declined by 71%. The cause of the decline is uncertain. Water clarity, disease and nuisance macroalgae are all possible factors. More research is needed to understand the reasons for the decline.
- Unfragmented forest blocks greater than 250 acres constituted 51% of the land area in NH's coastal watershed in 2001. Only four blocks greater than 5,000 acres remained as of 2001.
- The populations of critical species of juvenile finfish, anadromous fish, lobster and waterfowl remain similar to previous observations. The NHEP has not set management goals for these populations.
- Habitat restoration is proceeding at an uneven pace. Excellent progress is being made toward the goal of restoring 300 acres of salt marsh by 2010. The NH Coastal Program has managed 279 acres of salt marsh restorations since 2000 (93% of goal). Oyster and eelgrass restorations are proceeding more slowly. UNH has completed five oyster bed restoration projects totaling 3.18 acres (16% of the goal). UNH has also completed 1.75 acres of successful eelgrass restorations (3.5% of the goal), along with a 5.5 acre eelgrass transplant for mitigation.

RECOMMENDED CHANGES TO THE NHEP MONITORING PLAN

- Discrepancies between the 1990-1992 and 2004 salt marsh maps should be investigated to determine whether salt marshes have actually been lost and to understand the accuracy of aerial mapping methods. The NHEP Technical Advisory Committee (TAC) should consider setting a new goal for salt marsh extent (HAB1) based on the 2004 mapping methods and results.
- The TAC should consider setting a management goal of 2,000 to 2,500 acres for eelgrass coverage in Great Bay (HAB2). Shoot density sampling should be added to the annual eelgrass surveys to improve the accuracy of eelgrass biomass estimates. Turbidity trends, wasting disease and macroalgae populations should be researched to understand the cause of the eelgrass biomass decline.
- Habitat restoration sites should be qualitatively monitored periodically in order to report on the area of functionally restored habitat, as opposed to the area of completed restoration projects.

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