**Indicator: Eelgrass habitat in the Great Bay Estuary**

Question

How many acres of eelgrass are currently present in the Great Bay Estuary and how has it changed over time?

Short Answer

The Great Bay Estuary, which includes seven tidal tributary rivers, the Piscataqua River and Portsmouth Harbor, had 1,625 acres of eelgrass in 2016, which is 54% of the PREP goal of 2900 acres. In Great Bay proper, there were 1,490 acres of eelgrass, which is a 31% reduction from 1981, the first year that data was collected. Over time, eelgrass habitat indicates a diminishing ability to recover from periodic disturbances, such as stress from extreme storms.

PREP Goal

Increase the aerial extent of eelgrass cover to 2,900 acres and restore connectivity of eelgrass beds throughout the Great Bay Estuary by 2020 (from the PREP Comprehensive Conservation and Management Plan, PREP 2010).

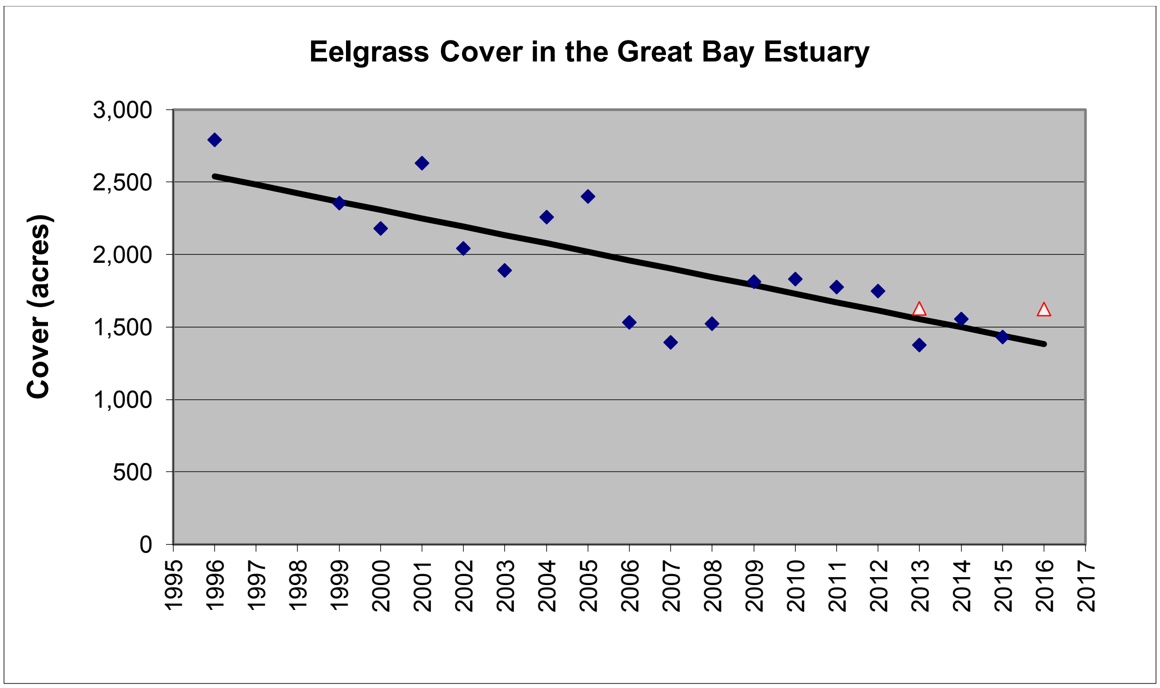


**Figure E-1. Eelgrass cover in the Great Bay Estuary. Diamonds indicate UNH Jackson Laboratory as data source; triangles indicate Kappa Mapping, Inc. Data in 2013 were averaged for regression analysis.**

Why This Matters

The long leaves of eelgrass (*Zostera marina*) slow the flow of water, encouraging suspended materials to settle, thereby promoting water clarity. Eelgrass roots stabilize sediments and both the roots and leaves take up nutrients from sediments and the water. Eelgrass provides habitat for fish and shellfish, and it produces significant amounts of organic matter for the larger food web.

Explanation (from 2018 State of Our Estuaries Report)

In 2016, there were 1,625 acres of eelgrass in the Great Bay Estuary. Figure E-1 (above) shows a statistically significant decreasing trend in eelgrass acreage since 1996 when the data became available for the entire estuary. The year 1996 also represents the highest amount of eelgrass on record for the Great Bay Estuary (see Table E-1); this must be considered when evaluating the trend. Figure E-2 compares 2016 eelgrass coverage with the acreage of eelgrass in 1996.

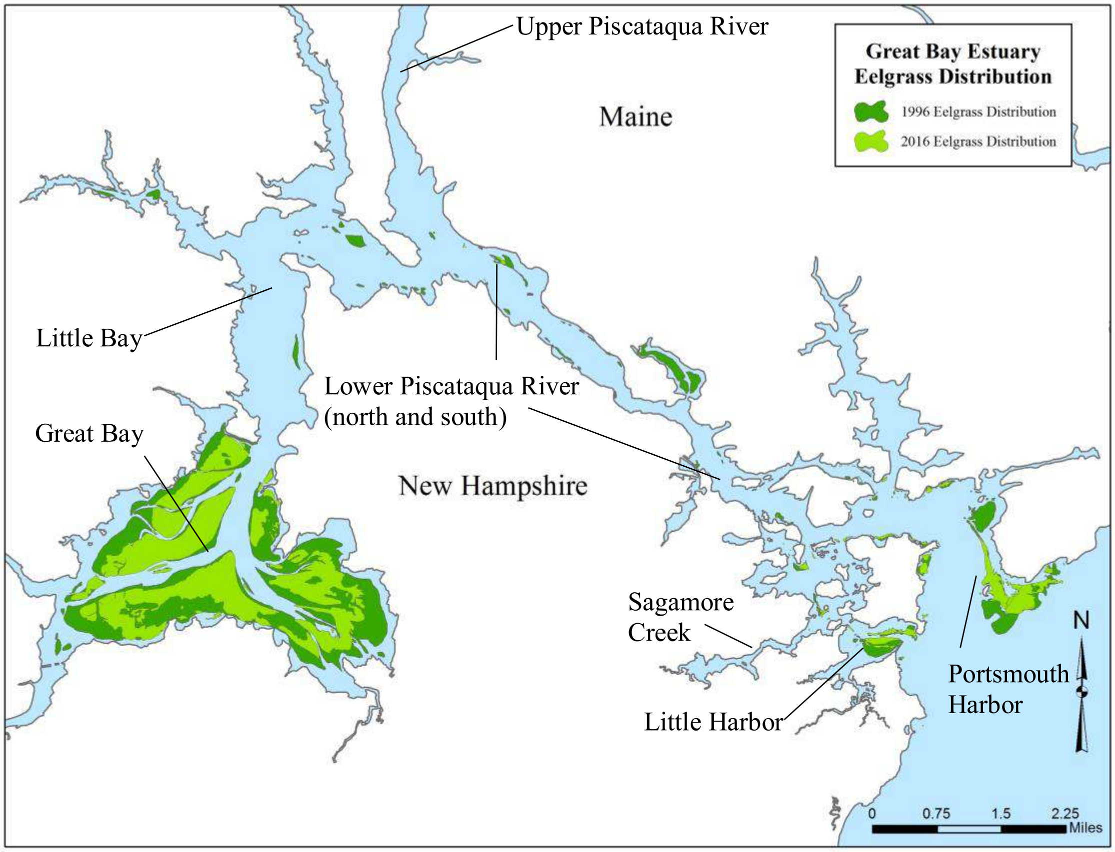


**Figure E-2. Map of eelgrass cover for 1996 and 2016. Map based on 2016 data from Kappa Mapping, Inc., and 1996 data provided by UNH Jackson Estuarine Laboratory. To be counted as present, eelgrass must cover at least 10% of a given area. Therefore, this map does not distinguish between areas with dense versus sparse cover. With negligible exceptions, the 2016 areas also existed in 1996; the darker shade of green therefore represents areas that have been lost since 1996.**

For Great Bay only, in contrast, data exists going back to 1981 (see Figure E-3). In 2016, there were 1,490 acres of eelgrass in Great Bay. The trend is not statistically significant; however, there is broad scientific consensus that eelgrass in the Great Bay shows a consistent pattern of being less and less able to rebound from episodic stresses. Current levels of eelgrass in the Great Bay are 31% reduced from 1981 levels. Connectivity of the remaining eelgrass habitat in the Great Bay Estuary is critical for habitat health and expansion. See Figure E-2 for 2016 eelgrass distribution.

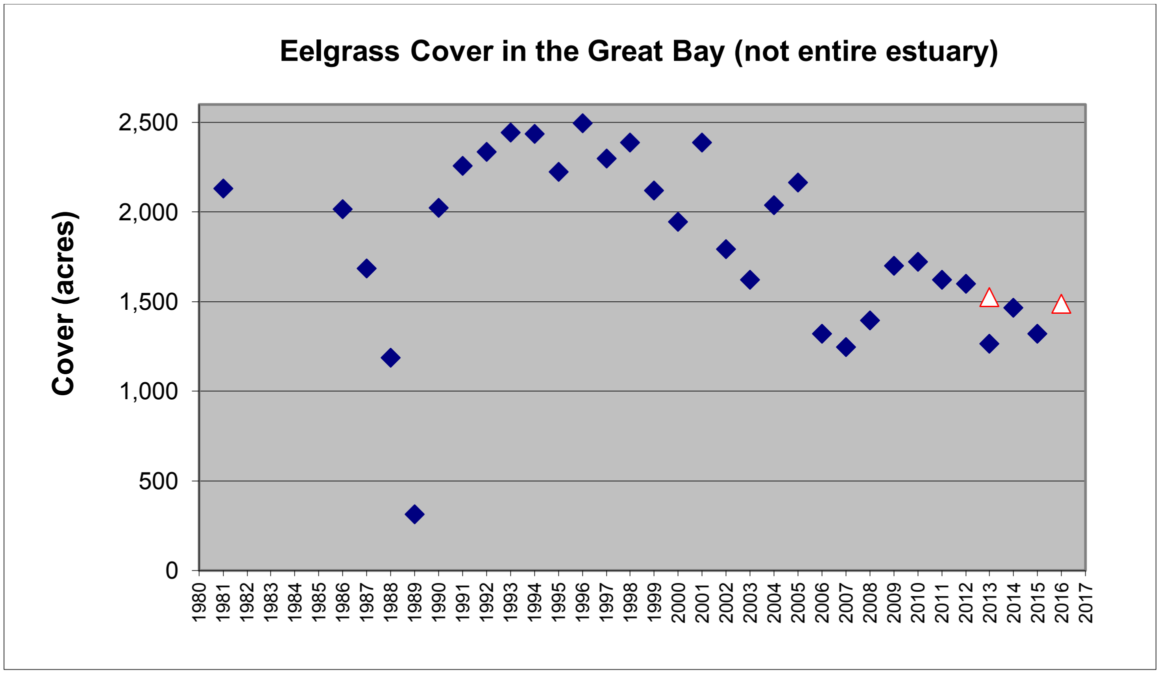


**Figure E-3. Eelgrass cover in the Great Bay only. Missing data for years 1982-1985. Years 1988 and 1989 show very low values due to eelgrass "wasting disease" event. These data, however, are still included in linear regression calculations. Diamonds indicate UNH Jackson Laboratory as data source; triangles indicate Kappa Mapping, Inc. Data in 2013 were averaged for regression analysis.**

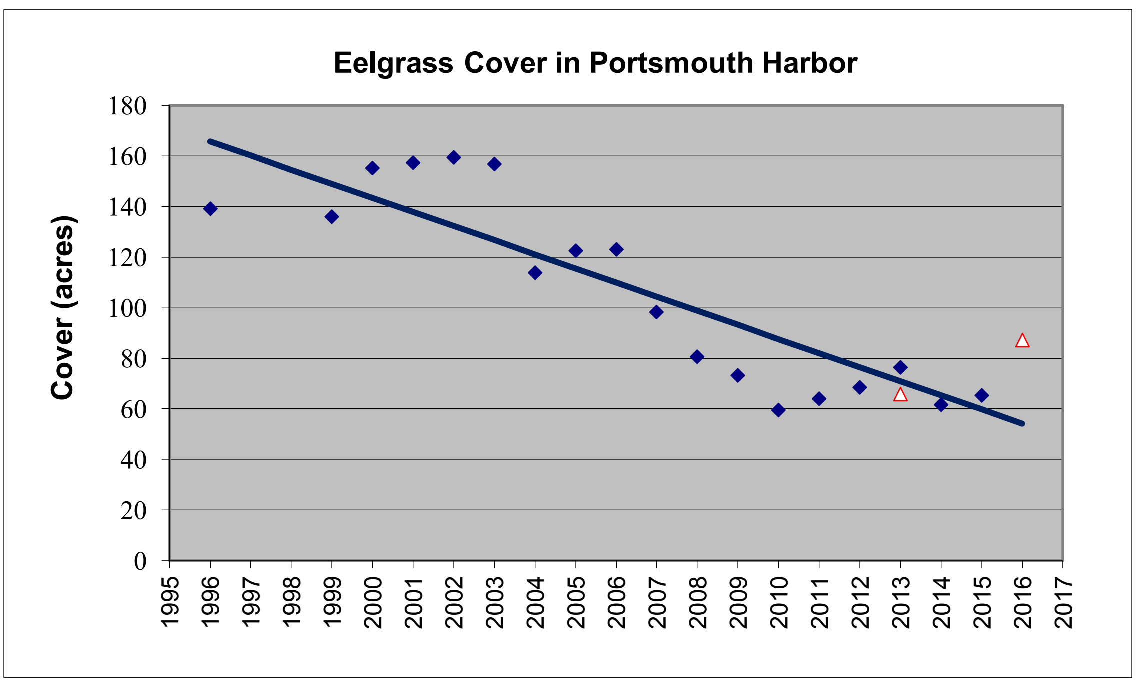


**Figure E-4. Eelgrass cover in Portsmouth Harbor. Diamonds indicate UNH Jackson Laboratory as data source; triangles indicate Kappa Mapping, Inc. Data in 2013 were averaged for regression analysis.**

In Portsmouth Harbor (Figure E-4), there were 87.4 acres of eelgrass in 2016. The entire time series (1996-2016) shows a statistically significant decreasing trend. On a positive note, the number of acres in 2016 was higher than the previous 8 years.

The causes of eelgrass decline in the Great Bay continue to be the subject of great interest. Worldwide, the main causes of temperate (between the tropics and the polar regions) seagrass loss are nutrient loading, sediment deposition, sea-level rise, high temperature, introduced species, biological disturbance (e.g., from crabs and geese), and wasting disease (Orth et al. 2006). Toxic contaminants such as herbicides that are used on land can also stress eelgrass (Unsworth et al. 2015). All of these causes are plausible in the Great Bay Estuary and many magnify each other to stress eelgrass and make habitats less resilient. Proactive actions to increase resilience for eelgrass habitat are critical as climate science predicts an increase of stressful events, such as extreme storms with increased rains and higher winds. Since the 1930’s there have been three 100-year storms recorded by measurements of the river discharge at the Lamprey River – two of those storms occurred in 2006 and 2007, the third was in 1987. Increased rainfall during these events causes a large quantity of waterflow to enter the estuary delivering increased sediments and nutrients as well as resuspending sediments throughout the water column. Since eelgrass relies on clear water to grow these events are important to note.

Research and discussions continue to focus on the type of recovery the Great Bay Estuary can expect for eelgrass. In some cases, recovery requires only a decrease in the stressors that caused the problem. In other cases, conditions for recovery have to be better than conditions before the habitat loss began to occur (Kenworthy et al. 2013; Unsworth et al. 2015). Figure E-3 shows that eelgrass recovered after the wasting disease event of 1988-1989. After a drop in 2002-2003, eelgrass rebounded but not quite to previous levels. Another three-year downturn during 2006-2008 was followed by a weaker recovery.

<u>Methods and Data Sources</u>

For the Great Bay (only)—as opposed to the whole estuary—maps from the UNH Jackson Estuarine Laboratory (JEL) from 1986 to 2015 were used. Maps for the entire Great Bay Estuary (Great Bay, Little Bay, tidal tributaries, Piscataqua River, Little Harbor, and Portsmouth Harbor) were used from JEL from the year 1996, the first year JEL mapped the entire estuary, through 2015.

The assessment of 1981 coverage was also made by JEL, using imagery from the USDA and field verification from NH Fish & Game (Short 2009). Note that the 1981 values most likely underestimate actual eelgrass habitat in 1981, because the 1981 dataset was incomplete. Eelgrass in some portions of the estuary could not be mapped because the imagery had glare in some areas. The interference affected mapping in the Oyster River, Lower Piscataqua River, Portsmouth Harbor and Little Harbor (Short 2009).

In 2013, mapping was conducted by both JEL and Kappa Mapping, Inc. (now Cornerstone Energy Services), and an accuracy assessment for both approaches was implemented. The results of those assessments can be found at scholars.unh.edu (Wood 2014; Wood 2015). In 2016, the eelgrass mapping was performed by Kappa Mapping, Inc. only. Quality Assurance Project Plans (QAPPs) can be found at scholars.unh.edu. QAPPs were issued for JEL work in year 2003 (Short and Trowbridge 2003), and 2010 (Short and Trowbridge 2010). The QAPP for Kappa Mapping, Inc. was issued in 2013 (Trowbridge 2013). In addition, year by year reports on eelgrass distribution and mapping can also be found at scholars.unh.edu. Finally, NH DES created a user-friendly GIS application focused on eelgrass, which can be accessed at: http://nhdes.maps.arcgis.com/apps/webappviewer/index.html?id=2792e57da2704867b164c17ae e2dc43e

The area of eelgrass in each assessment zone of the estuary was calculated using the GIS files provided by JEL or Kappa Mapping, Inc. and the ArcGIS Identity tool. Trends in the area of eelgrass cover in each assessment zone versus year were identified using linear regression with $p<0.05$ defined as the level of significance.

Additional Results (Beyond What Was Reported in the SOOE)
Results for the entire Great Bay Estuary, the Great Bay and Portsmouth Harbor were reported earlier in this section (Figures E-1, E-3 and E-4). Below, six other components of the estuary are discussed. See Table E-1 and Figure E-5 for more information.

Four of the six zones discussed below indicate significantly decreasing trends. As noted earlier, the dataset begins at a period of time (1996) known to be a peak year for the system, which impacts the results of the regression. Three of the six zones (Sagamore Creek, Little Harbor, and Lower Piscataqua River - North), have shown slow but consistently increasing levels of eelgrass over the most recent reporting period (2012 to 2016).

**Sagamore Creek** (no significant trend since 1996): A very slow and consistent increase in acreage is evident since 2013 (from 0.3 acres to 1.9 acres.) Maximum acres of eelgrass on record was in the year 2005 (6.1 acres).

**Little Harbor** (significant decreasing trend since 1996): A very slow and consistent increase since 2014 to 39.2 acres. Maximum acres of eelgrass on record was in the year 2004 (65.8 acres).

**Lower Piscataqua River (south)** (significant decreasing trend since 1996): Little change during the 2012 to 2016 period. 2016 acreage = 3.6 acres. Maximum acres of eelgrass on record was in the year 2006 (11.6 acres).

**Lower Piscataqua River (north)** (significant decreasing trend since 1996): No eelgrass detected between 2008 and 2011. Since 2012, slight and consistent increases. 2016 acreage = 3.0 acres. Maximum acres of eelgrass on record was in the year 2003 (22.9 acres).

**Upper Piscataqua River** (significant decreasing trend since 1996): No eelgrass detected since 2007. Maximum acres of eelgrass on record was in the year 2003 (2.9 acres).

**Little Bay** (no significant trend since 1996): No eelgrass detected in the years 2008, 2009, 2014 and 2016. In 2011 and 2012, over 30 acres were present. Since 2012, acreage has not exceeded 1.7 acres. Maximum acres of eelgrass on record was in the year 2011 (48.2 acres).

Technical Advisory Committee (TAC) Discussion Highlights
*Biomass*
Previous PREP Data Reports (PREP 2012) as well as eelgrass distribution reports (e.g., Short 2016) have gone beyond the discussion of eelgrass cover—that is, the number of acres covered where there is at least 10% cover of eelgrass—to discuss eelgrass biomass. Biomass refers to the actual weight, in this case, of the aboveground (not including roots below the surface) eelgrass material.

At a TAC meeting in October 2017, the rationale for including biomass was discussed at length. For a primer and extensive notes on the discussion, see Matso (2016) and PREP (2016). Existing data (Short et al. 1993; Trowbridge 2006; Short 2016; Short 2017b) suggest that eelgrass in the Great Bay Estuary has decreased since the late 1990s in terms of acreage AND also in terms of density, which in turn decreases estimates of biomass. However, based on the discussion, there were many questions about how biomass is assessed and how error in the measurement is captured and articulated. Until PREP has the opportunity to better understand and assess the reliability of the measurement, biomass will not be included in the State of Our Estuaries reporting.

*Wasting Disease*
"Wasting Disease" is caused by a pathogenic slime mold, *Labyrinthula zosterae*, and can have a significant negative impact on eelgrass health and distribution (Groner et al. 2016). In the Great Bay Estuary, two wasting disease events had a particularly devastating impact: the first in the early 1930s and the second in the late 1980s (Muehlstein et al. 1991). For further published information specific to wasting disease in the Great Bay Estuary, see "Eelgrass Distribution" reports from years 2002, 2003 and 2004, as well as Trowbridge (2006) at scholars.unh.edu.

These reports and other published research (e.g., Kaldy 2014; Groner et al. 2016) indicate that wasting disease is always present in the eelgrass population, and its effects become more or less noticeable in response to other environmental conditions. For example, increased salinity may favor wasting disease (Burdick et al. 1993) as well as warming waters and high nitrate conditions (Kaldy 2014).

During PREP TAC discussions, some participants proposed that any year with a report of wasting disease be eliminated from regression analyses (PREP 2017), including various years in the 1990s and early 2000's. Also, in the past, PREP has eliminated the years 1988 and 1989 from regressions due to the significant losses of eelgrass to wasting disease in those two years. However, in this latest State of Our Estuaries Report, PREP has included all years in regression analyses for two reasons: 1) there has not been any clear criteria set for how much wasting disease constitutes a wasting disease "event," and 2) research clearly shows that the virulence of wasting disease is increased by other environmental factors. Until these factors are clearly separated, eliminating any years due to particularly significant losses runs counter to the entire point of monitoring eelgrass health over many years and regressing changing levels against the factor of time.

*Stressors on Eelgrass*
This topic was discussed as part of two consecutive TAC meetings on May 9-10, 2017; notes and presentations are available (PREP 2017). Many stressors were discussed, from ice scour and geese to warming waters to factors affecting the amount of light that reaches eelgrass blades. The three external advisors to the TAC advocated that all light-attenuating components (e.g., seaweeds, TSS, colored dissolved organic matter (CDOM) and phytoplankton) be considered together, not separately, because these components act in an additive fashion. This approach to considering light attenuating substances and broader considerations relating to management options for increasing the resilience of the Great Bay Estuary are articulated more fully in the "Stress and Resilience" section of the 2018 State of Our Estuaries Report (PREP 2017b) as well as the "Statement Regarding Eelgrass Stressors" (Kenworthy et al. 2017).

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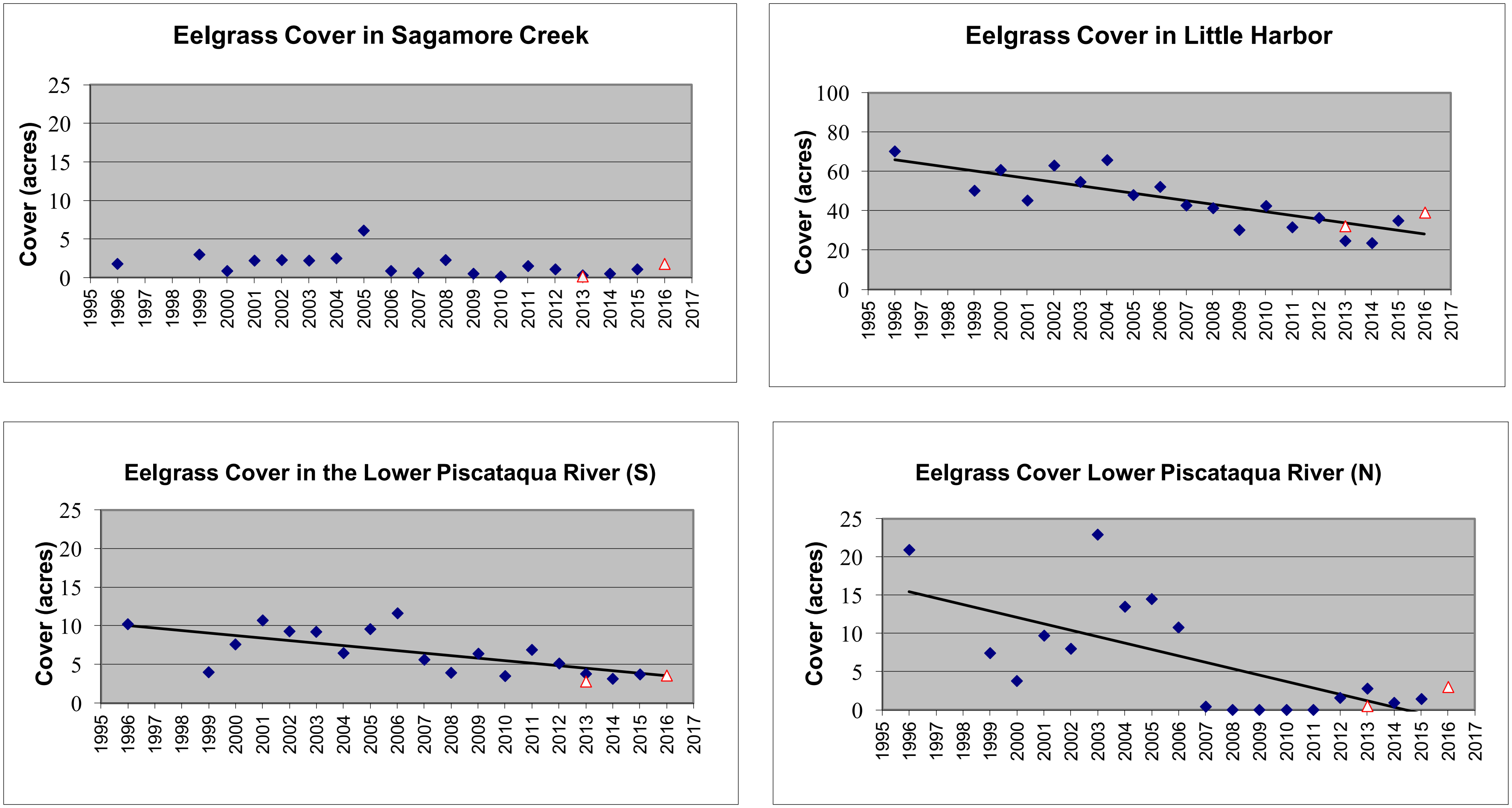
**Table E-1: Eelgrass coverage in the Great Bay Estuary.** Units = Acres; a = not mapped. * The acreages for 1981,1996-2008 include beds from both the NH and ME sides of the Piscataqua River but not the tidal creeks along the Maine shore.

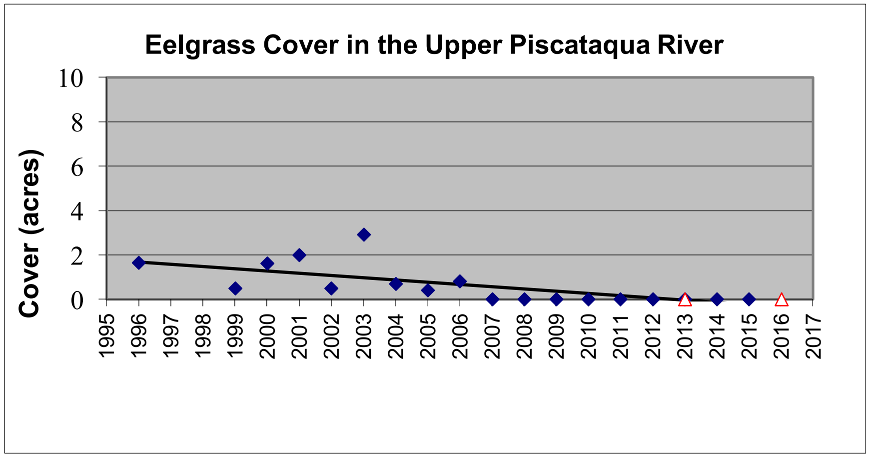
| Year | Winnicut River | Squamscott River | Lamprey River | Oyster River | Bellamy River | Great Bay | Little Bay | Upper Pisc River* | Lower Pisc River North* | Lower Pisc River South* | Portsmouth Harbor* | Little Harbor | Sagamore Creek | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1981 | 0.0 | 0.0 | 0.0 | a | 3.4 | 2130.7 | 252.0 | 0.5 | 60.1 | 5.1 | 227.7 | 68.8 | 4.1 | 2752.3 |
| 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 | 2900.0 |
| 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 | 2464.9 |
| 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 | 2287.3 |
| 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 | 2747.3 |
| 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 | 2151.7 |
| 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 | 2002.8 |
| 2004 | 4.2 | 0.0 | 0.0 | 0.0 | 0.8 | 2037.6 | 12.8 | 0.7 | 13.5 | 6.5 | 225.2 | 65.8 | 2.5 | 2369.8 |
| 2005 | 9.1 | 0.0 | 0.0 | 0.0 | 0.0 | 2165.7 | 25.8 | 0.4 | 14.5 | 9.6 | 232.5 | 47.9 | 6.1 | 2511.7 |
| 2006 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 1319.8 | 12.2 | 0.8 | 10.8 | 11.6 | 217.6 | 52.1 | 0.9 | 1626.5 |
| 2007 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1245.3 | 0.1 | 0.0 | 0.4 | 5.6 | 201.3 | 42.7 | 0.6 | 1496.0 |
| 2008 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1394.9 | 0.0 | 0.0 | 0.0 | 3.9 | 183.8 | 41.4 | 2.3 | 1626.4 |
| 2009 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 1700.6 | 0.0 | 0.0 | 0.0 | 6.4 | 155.0 | 30.2 | 0.5 | 1892.8 |
| 2010 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1722.2 | 0.3 | 0.0 | 0.0 | 3.5 | 128.0 | 42.5 | 0.2 | 1896.8 |
| 2011 | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 | 1623.2 | 48.2 | 0.0 | 0.0 | 6.9 | 178.8 | 31.6 | 1.5 | 1890.6 |
| 2012 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 1598.4 | 34.6 | 0.0 | 1.6 | 5.1 | 68.5 | 36.4 | 1.1 | 1817.1 |
| 2013 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1395.4 | 0.2 | 0.0 | 1.6 | 3.3 | 71.1 | 28.5 | 0.3 | 1566.7 |
| 2014 | 2.4 | 0.0 | 0.0 | 0.0 | 0.0 | 1464.0 | 0.0 | 0.0 | 0.9 | 3.1 | 61.8 | 23.7 | 0.5 | 1621.4 |
| 2015 | 0.0 | 0.0 | 0.0 | 2.4 | 0.0 | 1319.3 | 1.7 | 0.0 | 1.4 | 3.7 | 65.4 | 34.9 | 1.1 | 1497.5 |
| 2016 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1490.0 | 0.0 | 0.0 | 3.0 | 3.6 | 87.4 | 39.2 | 1.8 | 1689.1 |

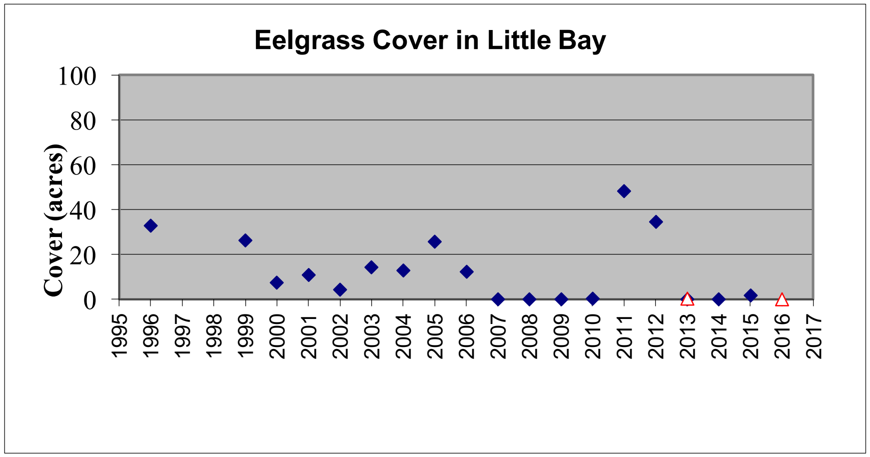
**Figure E-5: Eelgrass coverage in segments of the Great Bay Estuary.**




* Regression lines indicate a statistically significant trend. Diamonds are data collected by UNH-JEL; triangles indicate data from Kappa Mapping, Inc.

**Figure E-5 (cont'd): Eelgrass coverage in segments of the Great Bay Estuary.**




* Regression lines indicate a statistically significant trend. Diamonds are data collected by UNH-JEL; triangles indicate data from Kappa Mapping, Inc.