**Indicator: Oysters in the Great Bay Estuary**

<u>Question</u>

How many adult oysters are in the Great Bay Estuary and how has it changed over time?

<u>Short Answer</u>

The number of adult oysters decreased from over 25 million in 1993 to 1.2 million in 2000. Since 2012, the population has averaged 2.1 million oysters, which is 28% of the PREP goal for oyster recovery by 2020. This shows a decline from the previous reporting period (2009-2011) which averaged just over 2.8 million oysters.

<u>PREP Goal</u>

Increase the abundance of adult oysters at the six documented beds in the Great Bay Estuary to 10 million oysters by 2020 (from the PREP Comprehensive Conservation and Management Plan, PREP 2010).

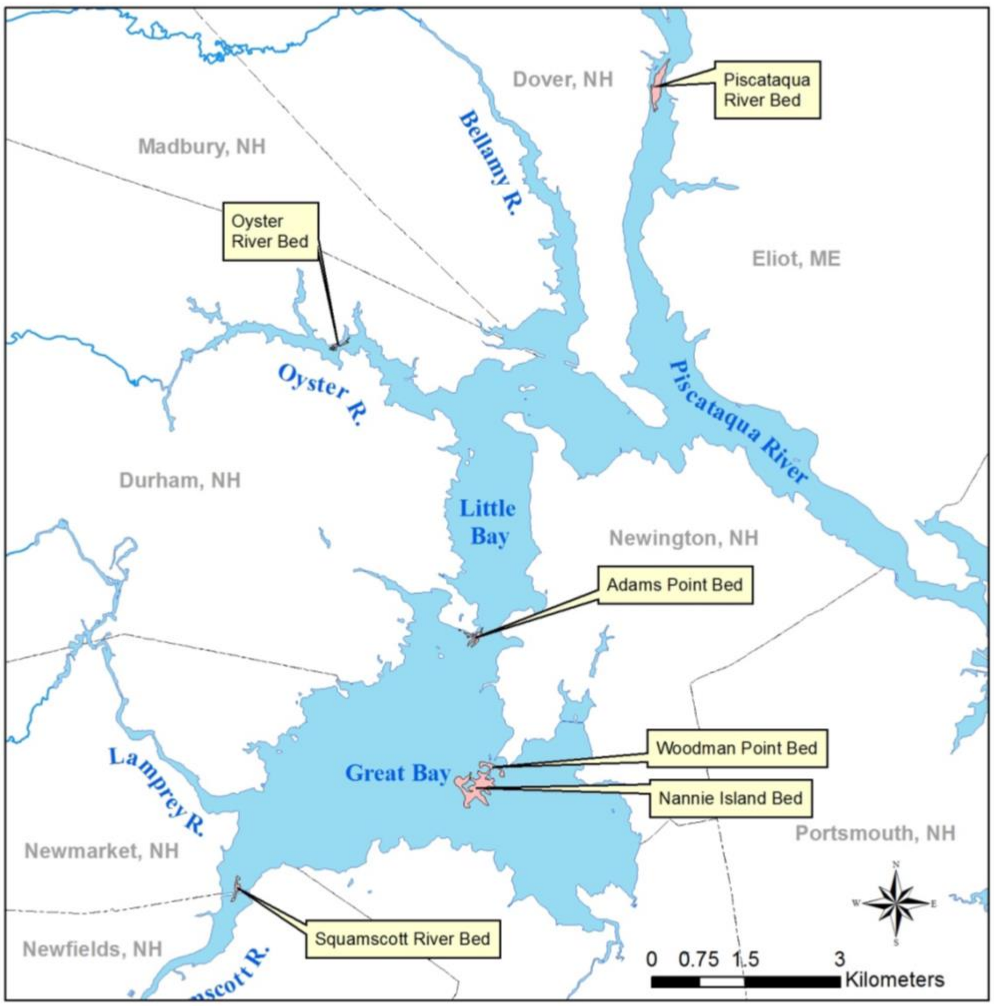


**Figure O-1. Map showing the locations of the six major oyster beds in the Great Bay Estuary.**

Why This Matters

Filter-feeding oysters are both a fisheries resource and a provider of key ecosystem services and functions. For example, they can reduce phytoplankton biomass and other suspended particles; this increases the ability for light to penetrate through the water which helps benthic plants, like eelgrass, to grow. They also provide important habitat for many invertebrate species and enhance biodiversity. Since the early 1990's as oyster populations in the Great Bay Estuary have declined, it is likely these important functions and services that oysters provide, may have also declined.

Explanation (from 2018 State of Our Estuaries Report)

From 2012 to 2016, the average standing stock of adult oysters (greater than 80 mm in shell height) at the six largest oyster habitat sites (Figure O-1) was just over 2.1 million oysters. This shows a decline from the previous reporting period (2009- 2011) which averaged just over 2.8 million oysters (Figure O-2). In 2016, there were 2,766,314 oysters, a decrease of 89% from 1993, when 25,729,204 adult oysters were present. The 2016 oyster population is approximately 28% of the PREP goal.

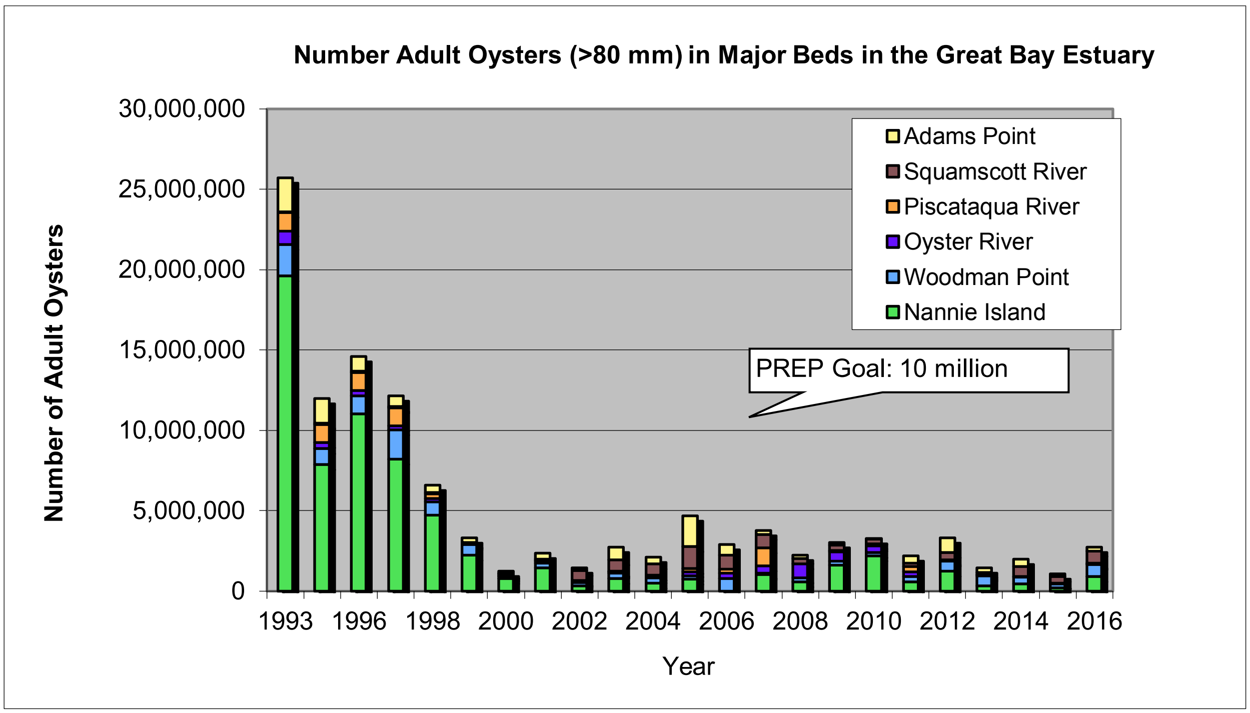


**Figure O-2. Standing stock of adult (>80 mm shell height) oysters in the Great Bay Estuary. Standing stock is estimated by multiplying adult densities by estimates of the acreage at each site. Data Source: Oyster density data from NH Fish and Game; site acreages from UNH Jackson Estuarine Laboratory.**

A primary limitation on oyster health is disease, caused by two microscopic parasitic organisms, Dermo (*Parkinsus marinus*) and MSX (*Haplosporidium nelsoni*). Figure O-3 shows that Dermo, a warmer water organism, has become more prevalent over time. The prevalence of both diseases increases with salinity (Ewart and Ford 1993). Figure O-3 also indicates that oysters no longer grow above 115 mm in shell height, which suggests that oysters are only living four or five years, rather than 10+ years as they did in the early 1990s.

Oyster habitat in the Great Bay Estuary also faces challenges due to available substrate for oyster larvae to settle. Oysters themselves can provide this substrate, but less and less oyster habitat diminishes the available substrate. This can be offset by planting recycled oyster shell material—for example, from restaurants and other sources—in key locations in the estuary. (See "Oyster Restoration" Indicator).

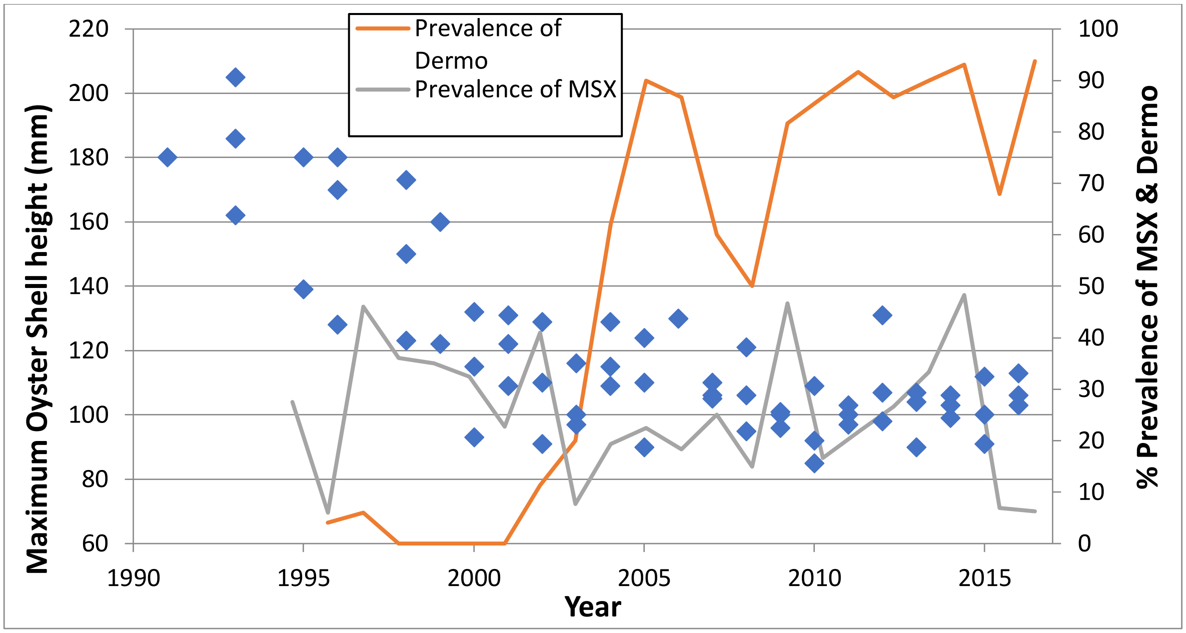


**Figure 0-3: Blue diamonds indicate maximum shell height of oysters from the Adams Point, Nannie Island and Woodman Point reefs. Updated from the original graph, published in Eckert (2016). Data Source: NH Fish and Game.**

Sedimentation is another stressor on oysters and it relates to the issue of available substrate. Sediments occur in the watershed from run-off, from stream and river erosion, and they get resuspended from the substrate in the estuary. With eelgrass and oyster habitats decreased from historic levels, sediments may be more easily resuspended following storms and high-flow periods. Oyster restoration monitoring has indicated that young reefs can easily be smothered by sediment.

Recreational harvesting of oysters may also be stressing the population. However, studies from other areas have shown that some restricted harvesting can provide benefit, through the removal of sediment.

<u>Methods and Data Sources</u>

For each of the major oyster beds, the average density of adult oysters (>80 mm shell height) was calculated and compared to 1997 levels (Langan 1997). For each oyster bed in each year, the mean of the number of oysters per quadrat with >80mm shell height was calculated. Only quadrats where oysters were found were included in the average density calculation. The number of adult oysters in each bed was estimated by multiplying the average density of oysters for each bed by the most recent estimate of the bed size. If data on density or area was missing for a bed for a particular year, the closest other available data for that bed was used in the calculation. The number of adult oysters was summed for beds in areas open for harvesting and for all beds.

*Data Sources*

Baseline data from 1997 on the six major oyster beds in Great Bay was provided in Langan (1997). The baseline data were compared to more recent mapping (Grizzle and Ward 2013). The monitoring programs for this indicator should have an accuracy of ± 10% in the area estimate for each bed.

The NHF&G Oyster Resource Monitoring Program conducts a survey of the major oyster beds in the Great Bay Estuary every year to measure oyster density with quadrats and to collect samples for disease testing.

Maps of open and closed areas for shellfishing were provided by the DES Shellfish Program.

Technical Advisory Committee (TAC) Discussion Highlights

As part of the January 2017 TAC meeting, participants discussed some of the most salient stressors on oyster habitats (PREP 2017c). Complete notes are available at: http://prepestuaries.org/prep-technical-advisory-committee/

**Table O-1. TAC participants collaboratively rated salient stressors on oyster habitat in terms of the impact of the stressor as well as the ability of managers to affect the situation. Choices were "high," "medium," and "low." * indicates that the rating was unanimous. ** indicates that the rating was close to unanimous (2 or less opposing.) *** indicates that there was a majority but the feedback was mixed.**

| Stressor | Impact on Oysters | Ability to Manage |
|---|---|---|
| Disease | High* | Low** |
| Available Substrate | High* | High** |
| Sedimentation | High* | ?? |
| Harvest | Medium*** | High* |

The four stressors in Table O-1 are discussed in greater detail below. Other stressors discussed in the notes (PREP 2017c) include spawning stock biomass and predation from green crabs and other animals.

*Disease and Natural Resistance*
The TAC was in agreement regarding the impacts of disease (MSX and Dermo) on oyster habitat (Figure O-3). However, there was some disagreement about the potential to improve the situation through selective breeding. While some members felt that using disease-resistant oysters holds promise, others were less supportive of this idea, noting that results have not been extremely impressive in other locations, and asserted that research indicates that the natural adaptation of oysters to disease holds more promise, although this is a very slow process.

*Available Substrate*
It was agreed that there is significant unrealized potential to add available substrate by expanding past/current activities, such as working with local restaurants to collect oyster shell and then placing that shell in the estuary. However, several participants cautioned that decisions regarding the placement of shell need to be made very strategically. Recent research on oyster larvae settling patterns in the Great Bay Estuary (Eckert 2016) indicate that there is more recruitment—settling of larvae onto available substrate—on restored reefs that are close to native reefs.

Finally, there was agreement that increased understanding of larval transport in the estuary would be helpful to ensure that resources spent on adding additional substrate were most effective.

*Sedimentation*
Most participants agreed that sedimentation—the movement and settling of sediment within the estuary—has a negative impact on native and restored reefs. Monitoring efforts (e.g., Grizzle and Ward 2016) indicate that young oysters are often covered by sediment. There was also general agreement that sediments are more mobile now than in the past, at least partially due to the loss of oyster and eelgrass habitat, both of which baffle water and encourage the settlling of sediments. A more thorough sediment budget was proposed as a research need to better understand where sediments are coming from—i.e., how much is coming from internal sources and how much is being supplied from the tributaries—and how sediments are transported within the system.

*Harvest*
There was disagreement about whether current recreational harvesting levels are adding stress to oyster habitat. Current regulations allow recreational harvesters to take a half bushel of unshucked oysters using either hands, rakes or tongs. Some participants felt that rakes and tongs are harmful to reefs, especially as these reefs try to build up a vertical profile to defend against sedimentation. Other participants asserted that current harvest levels have a negligible negative impact.

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**Table O-2: Area (in acres) of the major oyster beds in the Great Bay Estuary.**

| Year | Bed Area (acres) | | | | | | | Source | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | Adams Point | Nannie Island | Oyster River | Piscataqua River | Squamscott River | Woodman Point | Total area | | |
| 1997 | 4 | 37.3 | 1.8 | 12.8 | 1.7 | 6.6 | 64.2 | Langan (1997) | |
| 2001 | 13.1 | 24.7 | 1.7 | | | 7.3 | 61.2 | NHF&G (2002) | Total calculated using 2003 areas for the PR & SR |
| 2003 | | | | 12.5 | 1.9 | | | Grizzle and Brodeur (2004) - high density area | |
| 2004 | | 41.8 | | | | 6.1 | | Grizzle et al. (2008) | |
| 2006 | 5.7 | | 2.5 | | | | 70.5 | Grizzle et al. (2008) | Total calculated using 2003 areas for PR & SR, 2004 areas for NI & WP |
| 2012 | 15.9 | 32.4 | 1.4 | 7 | 7.7 | 15.4 | 79.8 | Grizzle and Ward (2013) | |
| Difference | 11.9 | -4.9 | -0.4 | -5.8 | 6 | 8.8 | 15.6 | Acreage change 1997 to 2012 | |
| | 298% | -13% | -22% | -45% | 12% | 353% | 24% | % change 1997 to 2012 | |

*** Note that changes in acreages can be caused by actual changes in bed area as well as changes in mapping approaches. In some cases, newer mapping efforts extended the area mapped and new habitat was found (Grizzle and Ward 2013). No mapping of natural oyster reefs has occurred since the report by Grizzle and Ward (2013).**

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**Table O-3: Average density (# per m$^2$) of adult oysters (>80 mm shell height) in the major Great Bay Estuary beds.**

| Year | Adams Point | Nannie Island | Oyster River | Piscataqua River | Squamscott River | Woodman Point | Source |
|---|---|---|---|---|---|---|---|
| 1993 | 120.0 | 119.3 | 109.5 | | | 66.4* | NHF&G |
| 1995 | | 48.0 | 46.7 | | | 34.3 | NHF&G |
| 1996 | 52.7 | 67.0 | 40.8 | | | 39.0 | NHF&G |
| 1997 | 38.0 | 50.0 | 29.0 | 20.0 | | 63.0 | Langan (1997) |
| 1998 | 27.5 | 28.7 | 26.0 | 5.1 | 9.3 | 28.7 | NHF&G |
| 1999 | | 13.6 | 10.4 | 0.0 | | 22.4 | NHF&G |
| 2000 | 5.3 | 4.8 | 12.0 | 1.3 | | 4.0 | NHF&G |
| 2001 | 7.0 | 13.3 | 17.6 | 1.0 | 8.0 | 8.6 | NHF&G |
| 2002 | 2.8 | 3.2 | 9.6 | 0.8 | | 6.4 | NHF&G |
| 2003 | 13.6 | 7.2 | 10.4 | 0.8 | | 10.4 | NHF&G |
| 2004 | 7.2 | 2.7 | 24.8 | 0.0 | | 12.0 | NHF&G |
| 2005 | 33.6 | 4.0 | 28.8 | 4.0 | **161.3** | 8.8 | NHF&G |
| 2006 | 26.4 | 0.0 | **29.6** | 4.8 | | 29.6 | NHF&G |
| 2007 | 8.8 | 5.6 | **40.8** | 20.0 | | 4.0 | NHF&G |
| 2008 | 7.2 | 3.2 | **79.2** | 0.0 | **44.0** | 8.8 | NHF&G |
| 2009 | 7.2 | 8.8 | **56.0** | | | 8.8 | NHF&G |
| 2010 | 1.6 | 12.0 | **36.0*** | 2.4 | **32.0** | 8.0 | NHF&G |
| 2011 | 18.4 | 3.2 | 23.2 | 6.0 | **24.8** | 12.8 | NHF&G |
| 2012 | 12.8 | 8.8 | 17.6 | 0.0 | **13.6** | 8.8 | NHF&G |
| 2013 | 4.0 | 2.4 | 16.0 | 4.0 | | 8.8 | NHF&G |
| 2014 | 6.4 | 3.2 | 6.4 | 0.0 | **18.4** | 6.4 | NHF&G |
| 2015 | 2.0 | 1.6 | 2.4 | 0.8 | **12.8** | 3.2 | NHF&G |
| 2016 | 4.0 | 6.4 | 7.2 | 0.8 | **21.6** | 11.2 | NHF&G |

1. Green cells are the PREP Management Goals for adult 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. Bold values indicate an increase above 1997 density

* Value for Woodman Pt in 1993 is from NHF&G summary reports. Raw data from quadrats were not available for this survey. Value for Oyster River in 2009 was measured using tongs, not quadrats.

**Table O-4: Standing stock 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 | 2,115,360 | 19,616,145 | 868,259 | 1,128,192 | 69,924 | 1,931,324 | 23,662,828 | 25,729,204 |
| 1995 | 1,521,884 | 7,890,293 | 370,188 | 1,128,192 | 69,924 | 997,241 | 10,409,418 | 11,977,722 |
| 1996 | 928,408 | 11,013,534 | 323,650 | 1,128,192 | 69,924 | 1,134,362 | 13,076,304 | 14,598,070 |
| 1997 | 669,864 | 8,219,055 | 230,045 | 1,128,192 | 69,924 | 1,832,431 | 10,721,350 | 12,149,511 |
| 1998 | 484,770 | 4,724,435 | 206,248 | 290,107 | 69,924 | 833,804 | 6,043,009 | 6,609,287 |
| 1999 | 289,393 | 2,235,583 | 82,499 | 0 | 64,930 | 651,531 | 3,176,507 | 3,323,936 |
| 2000 | 94,016 | 789,029 | 95,191 | 75,213 | 64,930 | 116,345 | 999,390 | 1,234,724 |
| 2001 | 404,122 | 1,451,372 | 131,857 | 56,410 | 59,935 | 275,752 | 2,131,246 | 2,379,448 |
| 2002 | 161,649 | 348,329 | 71,922 | 45,128 | 634,314 | 205,895 | 715,873 | 1,467,237 |
| 2003 | 785,151 | 783,741 | 77,916 | 44,070 | 708,939 | 334,579 | 1,903,471 | 2,734,397 |
| 2004 | 415,668 | 491,563 | 185,799 | 0 | 708,939 | 322,910 | 1,230,141 | 2,124,879 |
| 2005 | 1,939,785 | 737,344 | 215,767 | 220,350 | 1,350,892 | 236,800 | 2,913,930 | 4,700,939 |
| 2006 | 658,163 | 0 | 320,378 | 264,420 | 859,659 | 796,511 | 1,454,673 | 2,899,130 |
| 2007 | 219,388 | 1,032,282 | 441,603 | 1,101,750 | 859,659 | 107,637 | 1,359,306 | 3,762,317 |
| 2008 | 179,499 | 589,875 | 857,228 | 0 | 368,425 | 236,800 | 1,006,175 | 2,231,828 |
| 2009 | 179,499 | 1,622,157 | 606,121 | 66,105 | 318,185 | 236,800 | 2,038,456 | 3,028,868 |
| 2010 | 39,889 | 2,212,032 | 389,649 | 132,210 | 267,946 | 215,273 | 2,467,194 | 3,256,999 |
| 2011 | 458,719 | 589,875 | 251,107 | 330,525 | 207,658 | 344,437 | 1,393,032 | 2,182,322 |
| 2012 | 896,913 | 1,256,524 | 108,588 | 0 | 461,501 | 597,237 | 2,750,673 | 3,320,763 |
| 2013 | 280,285 | 342,688 | 98,717 | 123,396 | | 597,237 | 1,220,210 | 1,442,323 |
| 2014 | 448,456 | 456,918 | 39,487 | 0 | 624,384 | 434,354 | 1,339,728 | 2,003,598 |
| 2015 | 140,143 | 228,459 | 14,808 | 24,679 | 434,354 | 217,177 | 585,778 | 1,059,619 |
| 2016 | 280,285 | 913,836 | 44,423 | 24,679 | 732,972 | 760,119 | 1,954,240 | 2,756,314 |

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). For 2002 onwards, the most recent area for a bed was used starting with the year that the new map was made. This simplification requires the assumption that the bed sizes have not changed over 4-6 years, which may not be justified. The average adult 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 oyster density measurements were not taken at that bed in that year and an assumption regarding the density of oysters was needed for the calculation. Either the closest value from another year or an average of two bracketing years was used.

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

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