2-14-2017

Monitoring Macroalgae in the Great Bay Estuary for 2015

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Monitoring Macroalgae in the Great Bay Estuary for 2015

A Report to
The Piscataqua Region Estuaries Partnership

submitted by
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February 14, 2017

This report was funded by a grant from the Piscataqua Region Estuaries Partnership, as authorized by the U.S. Environmental Protection Agency pursuant to Section 320 of the Clean Water Act, and in part, by NOAA’s Office for Coastal Management under the Coastal Zone Management Act in conjunction with the NH Department of Environmental Services Coastal Program.
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Cite as:
Burdick, D.M., A.C. Mathieson, S. Nick and C.R. Peter. 2017 Monitoring Macroalgae in the
Executive Summary

In 2015, five of the eight locations with fixed intertidal transects were sampled as part of the long-term effort to monitor macroalgae in the Great Bay Estuary. With the completion of the third year of the project, all eight locations have been sampled at least once, two years of data have been collected for four locations, and three years of data have been collected for one location. Monitoring results from 2015 show high levels of cover of nuisance green or red algae (Ulva and Gracilaria, respectively) at all sites sampled. Nuisance algae is characterized as fast-growing; it can interfere with human use of a system, and can result in dramatic impacts to valuable ecological components by smothering and causing anoxic episodes. Based upon this short-term data set we found significant cover and biomass of nuisance algae, some known as introduced, invasive species. Visual examination of our intertidal transect data along with anecdotal observations suggest that algal populations are changing, but long-term collections will be needed to determine whether significant differences in intertidal macroalgal populations are occurring over time.
Monitoring Macroalgae in the
Great Bay Estuary for 2015

Introduction

Tracking changes in macroalgae, or seaweed populations in the Great Bay Estuary is important for our understanding of how changes in environmental conditions affect the structure, function and biodiversity of the Estuary. Monitoring of eelgrass, one of the critical habitats in the Estuary, has shown significant declines over the past fifteen years (Beem and Short 2009, Short 2014). The loss in eelgrass has concerned resource managers and the public (Trowbridge 2006). Human population growth and climate change can influence nutrient loading and cycling, sediment input, resuspension, and suitability of various estuarine habitats for supporting the growth of macroalgae. Fluctuations in environmental conditions can favor different native species at different times, as well as creating opportunities for non-native invasive species to establish populations in the Estuary. Mats of macroalgae can also smother other benthic species, alter sediment redox and intercept the sunlight needed by eelgrass to maintain their growth, altering the habitat structure and food web of the Bay.

Standardized, repeatable sampling of macroalgae has occurred in the Estuary from time to time. Macroalgae typically grows in intertidal and shallow subtidal areas. Typically, intertidal areas are accessed by land whereas subtidal macroalgae are assessed by vessel and observers using either snorkel or SCUBA. Our program uses an array of fixed sample points at locations that provide good intertidal exposure and are accessible by vehicle and on foot. These long-term sample sites are sampled using a 0.25m² quadrat at set tidal elevations (0.0 m, 0.5 m, etc. above Mean Low Water). The best historical data that have been archived were collected from intertidal sampling grids at fixed locations as part of graduate student projects conducted under the direction of Arthur Mathieson: in 1978 (Hardwick-Whitman and Mathieson, 1983) and 2008-2010 (Nettleton et al. 2011). Most recently, Cianciola and Burdick (2014) reoccupied several historically assessed sites and used previous project results to develop a modified protocol for macroalgal monitoring that was used in 2013 and 2014 (Burdick et al. 2016).
**Project Goals and Objectives**

The long-term fixed station sampling array was begun in 2013 and completed in 2014. The strategy for maintaining eight sites in a variety of estuarine areas and shoreline exposures was to facilitate sampling of the entire fixed array every other year, with three sites sampled in alternate years and two others sampled every year. Sampling in 2015 was performed at five sites for cover and biomass in late August/early September. The Quality Assurance Project Plan (Matso 2016) can be found on the PREP website.

**Methods**

Each location with fixed array sampling transects was set up with three transects (random distance apart but no closer than 10 m) along a 100 m length of shoreline. Sampling points were established at MLLW and every 0.5 m above until the shoreline was reached where no benthic plants occurred. Elevations were found relative to the low tide line or high tide line (where low tide could not be reached, e.g., Lubberland Creek). Biennial sites monitored this year included: Cedar Point in Dover, Wagon Hill Farm in Durham, and Lubberland Creek in Newmarket Table 1). The two annually monitored sites were Adams Point in Durham and Depot Road in Stratham. All locations are shown in Figure 1 and specific sample transects/plots are shown in Figure 2.

Table 1. Macroalgae intertidal collection sites for fixed array sampling.

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Town</th>
<th>Location</th>
<th>Elevations (m above MLW)</th>
<th>Sample Schedule</th>
<th>Years Sampled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Four Tree Island</td>
<td>Portsmouth</td>
<td>43.07536N 070.74701W</td>
<td>0.0, 0.5, 1.0, 1.5, 2.0, 2.5</td>
<td>Even</td>
<td>2014</td>
</tr>
<tr>
<td>Hilton Point</td>
<td>Dover</td>
<td>43.12292N 070.82786W</td>
<td>0.0, 0.5, 1.0, 1.5, 2.0</td>
<td>Even</td>
<td>2014</td>
</tr>
<tr>
<td>Cedar Point</td>
<td>Dover</td>
<td>43.12934N 070.85283W</td>
<td>0.0, 0.5, 1.0, 1.5</td>
<td>Odd</td>
<td>2013, 2015</td>
</tr>
<tr>
<td>Wagon Hill Farm</td>
<td>Durham</td>
<td>43.12457N 070.87260W</td>
<td>0.0, 0.5, 1.0, 1.5</td>
<td>Odd</td>
<td>2013, 2015</td>
</tr>
<tr>
<td>Adams Point</td>
<td>Durham</td>
<td>43.09019N 070.86735W</td>
<td>0.0, 0.5, 1.0, 1.5</td>
<td>All</td>
<td>2014, 2015</td>
</tr>
<tr>
<td>Lubberland Creek</td>
<td>Newmarket</td>
<td>43.07427N 070.90339W</td>
<td>0.5, 1.0, 1.5</td>
<td>Odd</td>
<td>2013, 2015</td>
</tr>
<tr>
<td>Depot Road</td>
<td>Greenland</td>
<td>43.05611N 070.89682W</td>
<td>0.5, 1.0, 1.5</td>
<td>All</td>
<td>2013-15</td>
</tr>
<tr>
<td>Sunset Hill Farm</td>
<td>Newington</td>
<td>43.05751N 070.83443W</td>
<td>0.75, 1.0, 1.5</td>
<td>Even</td>
<td>2014</td>
</tr>
</tbody>
</table>
Figure 1. Eight macroalgae intertidal collection sites for fixed array sampling of the Great Bay Estuary.

Cover data for macroalgae and vascular plants were collected at the five previously established monitoring sites in late summer (August/September). Transects and plot locations were found using a handheld Garmin Geographic Positioning System (GPS) and pvc markers. Visual estimates of percent cover were made by species or genus in a 0.25 m$^2$ quadrat centered landward of each sampling point on each transect. A photograph was taken and archived for each plot sampled. Macroalgal biomass samples were collected by placing a 0.0625 m$^2$ quadrat two meters to the right of each cover sampling point on each transect, as determined when facing the shore. Percentage cover was estimated in the quadrat and a photograph was taken before collecting all live material in the quadrat and placing it in labeled plastic bags. In the lab, biomass samples were cleaned of sediment and detritus and sorted by species/genus. Algal material was placed in marked foil envelopes and dried at 60°C in a drying oven for five days before weighing to 0.01g.
Figure 2. The eight sampling sites for intertidal macroalgae in the Great Bay estuary. Locations were plotted with positions determined by GPS with the exception of one sample site in Sunset Hill Farm (SHF) as indicated by the black triangle. This site location will be confirmed and recorded by GPS in 2016.
Species identifications were authenticated by Dr. Arthur Mathieson and nomenclature generally followed Villalard-Bohnsack (2003), with updates from Mathieson and Dawes (2016). Thus, some taxonomic changes were included. (These changes were not due to mistakes but to changes in taxonomic naming protocols.) For example, the green alga *Enteromorpha intestinalis* was transferred to *Ulva intestinalis*, while the invasive red alga “*Heterosiphonia*” *japonica* was redesignated as *Dasysiphonia japonica*.

The research team compiled the field percent cover estimates and the laboratory biomass data from the August/September sampling period in an electronic spreadsheet. Data were reduced to arithmetic means for elevations within sites and over all sites for taxa and by major taxonomic groups of plants (benthic algae and vascular marsh species). Biomass sample percentage covers were regressed against plant weights after all zero cover/weight samples were removed. Predictive equations of biomass from percentage cover were forced through zero and strength of the relationship is reported as the r coefficient obtained from Pearson’s correlations.

**Results and Discussion**

**Macroalgae Cover**

In late August and early September, we collected percent cover and biomass data by seaweed taxon at five sites around the Great Bay Estuary: Cedar Point, Dover; Wagon Hill Farm and Adams Point, Durham; Lubberland Creek, Newmarket; and Depot Road, Stratham. Cover of macroalgae ranged from 0 to 100% for individual plots. Two groups of nuisance algae are noteworthy: *Gracilaria*, (a genus of red algae comprised mainly of one native and one invasive species) averaging 5.1% cover and *Ulva* (a genus of diverse tubular and foliose green algae, but dominated by *U. lactuca*, sea lettuce) averaging 5.2% cover. Raw cover data is available in tabular form in Appendix A.

When categorized by major color types (red, green and brown) and compared across sites, the brown algae (primarily long-lived fucoids) dominated Adams Point (Figure 3). Algal cover at Cedar Point, Wagon Hill Farm and Adams Point were dominated by greens and brown fucoid algae. The two stations in the south of Great Bay, Lubberland Creek and Depot Road, showed fairly even mixes of reds, (predominately *Gracilaria* spp.), greens (predominately *Ulva* spp.) and
browns (predominately fucoids). Similar to the two previous years, the greatest cover of nuisance algae was found at Depot Road (Figures 3-5).

Figure 3. Cover of macroalgae averaged over sampling depths at the five sites sampled in 2015.
Figure 4. Cover of macroalgae averaged over sampling depths and three seasonal collection periods at the five sites sampled in 2014.
The general pattern observed in the intertidal seaweeds by major color groups and position in the estuary was perhaps clearest in 2014, showing a steady increase in reds (mostly *Gracilaria* spp.) from the coast (Four Tree Island) to Great Bay (Depot Road and Sunset Hill Farms). The contribution of green seaweeds (mostly *Ulva* spp.) was greatest in the Piscataqua River at Hilton Park and also high at Adams Point and Depot Road in Great Bay (Figure 4). The brown algae, composed largely of the long lived fucoids, were greatest at Four Tree Island and Adams Point (roughly 15 to 20% cover). The spatial trend of higher contribution of red alga in Great Bay was seen for all three years, with substantial greens in Little and Great Bays as well. In 2015 brown algae contributed more to the macroalgal cover than the other two years, with very high cover at Adams Point (50%) and greater cover when compared with the other four stations that were sampled in 2013.
When the data are presented showing cover by elevation for each of the three years, different patterns emerge (Figure 6). First, the browns were dominant at both Four Tree Island, near the mouth of the Piscataqua River, and Adams Point, on the northern shore of Great Bay. Browns were also commonly found at the mid elevations of Cedar Point and Wagon Hill Farm (Little Bay) and upper elevation of Depot Road (Great Bay). At these sites there are rocks that provide attachment sites for their holdfasts. The relatively long-lived fucoid algae are not nuisance algae and have been a feature of the Estuary’s rocky shores for years (Short 1992). Where multiple years of data exist, the cover of browns was relatively greater in 2015 (Figure 6), perhaps due to the mild winter (less damage from ice, which can remove these algae from the rocks; Mathieson et al. 1982).

Red algae, primarily the Asiatic nuisance alga *Gracilaria vermiculophylla*, were mostly found in Great Bay where they accumulate at lower elevations (mudflats). At Depot Road where there are three years of data, reds became more prevalent at the 1 m elevation and less prevalent at the 0.5 meter elevation (Figure 6). The temporal trends in the red algae are interesting, but we are unable to assign a cause or mechanism for these changes.

Green algae, composed primarily of the nuisance *Ulva* species, were the most common type of macroalgae in the mid-estuary (Hilton Park, Cedar Point and Wagon Hill Farm). Greens were also important at lower elevation sampling points in Great Bay (Adams Point, Lubberland Creek, and Depot Road). No temporal trends were observed in the green algae over the last three years.

From 2013 to 2015 we have not observed dramatic increases in macroalgae in the Estuary. However, anecdotal observations show red algae persisting through the winter as dominant cover in many intertidal embayments along tidal tributaries like the Oyster River and then being rapidly covered by the green alga *Ulva* the following summer (personal observations, DB and ACM, 2016).
Figure 6. Cover of macroalgae at all sites sampled during three years and shown for each elevation, averaged over the three transects. Lowest sample elevation at Sunset Hill Farms was actually 0.75 m (not 0.5 m) above MLLW.

**Paired Cover and Biomass**

Following the collection protocol, a 0.0625 m$^2$ quadrat was placed two meters to the right of each sampling site (facing shoreward) and after estimation of cover and photographing the plot, all algae within the plot were collected and processed to determine biomass. We have accumulated significant numbers of data points for four taxa of algae: blade-forming *Ulva* (green), *Gracilaria* spp. (red) and the two species of brown fucoid algae: *Ascophyllum nodosum* and *Fucus vesiculosus*. The 2013-14 data were combined with new data collected in 2015 to generate correlations (Figure 7).

We used the Quartile Robust Fit method in JMP statistical software to identify and justify removal of some outliers (greater weight than expected for the amount of cover). Although the correlation coefficients ($r = 0.63$ to 0.89) indicate fairly good correspondence, there is still quite
a bit of variability in the data even after removing some outliers. One of our ultimate goals is to develop cover-biomass relationships to create regressions of algal cover data that can be used to estimate algal biomass at the various collection sites.

Figure 7. Correlations of percentage visual cover (x-axes) and biomass (y-axes) from the 0.0625 m² quadrats for the 2013, 2014 and 2015 combined data. Best fit lines and 90% confidence intervals are shown. Outliers were excluded from Gracilaria (6 outliers excluded), Ulva (8), Ascophyllum (5) and Fucus (5) using Quartile Robust Fit method (JMP 2015).

**Summary and Conclusions**

Monitoring results from 2015 show increasing cover of the long-lived brown algae species, *Fucus vesiculosus* and *Ascophyllum nodosum*, perhaps due to relatively mild winters. High levels of cover of nuisance green or red algae (*Ulva* and *Gracilaria*, respectively) were found at all sites during 2015. Biomass collections in 2015 increased sample size and strengthened our ability to predict biomass from cover data. Anecdotal observations suggest that intertidal macroalgal populations appear to be increasing over time, but developing a statistically significant pattern of increase using standardized protocols will require a longer time series. It is also recognized
that this report does not cover subtidal macroalgae; however, changes in subtidal macroalgae are very important to understand, and should therefore be added to future monitoring efforts.

Acknowledgements
The authors thank Molly McGovern, an undergraduate student at UNH, for assistance in the field and laboratory. We also thank Kalle Matso, Rachel Rouillard and Jean Brochi for support of the project. This project was funded in part by a grant from the Piscataqua Region Estuaries Partnership as authorized by the U.S. Environmental Protection Agency’s National Estuary Program, and helps implement the Management Plan for the Region’s Estuaries. The project was funded, in part, by NOAA’s Office for Coastal Management under the Coastal Zone Management Act in conjunction with the NH Department of Environmental Services Coastal Program.

References


Appendices

Appendix A: Data Tables: Cover and biomass
Appendix B: Quadrat Photographs
Appendix C: Site Descriptions
Appendix A: Data Tables: Percentage of Cover and Biomass (See “Methods” section for details on units, etc.)

Percentage of Cover:

| Date   | Year | Month | Site     | Transect | D isplacement in show km | Sample Site | Shade | Tube Site | Gracilicaesp | Acrop. | F. reniforme | P. reniforme | P. reniforme | C. reniforme | S. pustulata | A. parvidens | L. naufragi | A. potida | V. corallina | W. rodeo | Encrusting algae | Balanus | Other Zostera |
|--------|------|-------|----------|----------|--------------------------|-------------|-------|-----------|-------------|---------|--------------|--------------|--------------|--------------|-------------|--------------|------------|---------|---------|-------------|--------|----------------|---------|--------------|
| 8/30/15 | 2015 | AUGUST | ADAMS POINT A | 0.0 - 0.25 m² | 25 | 0 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/30/15 | 2015 | AUGUST | ADAMS POINT B | 0.0 - 0.25 m² | 30 | 0 | 70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/30/15 | 2015 | AUGUST | ADAMS POINT C | 0.0 - 0.25 m² | 35 | 0 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/30/15 | 2015 | AUGUST | ADAMS POINT D | 0.0 - 0.25 m² | 40 | 0 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/30/15 | 2015 | AUGUST | ADAMS POINT E | 0.0 - 0.25 m² | 45 | 0 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/30/15 | 2015 | AUGUST | ADAMS POINT F | 0.0 - 0.25 m² | 50 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/30/15 | 2015 | AUGUST | ADAMS POINT G | 0.0 - 0.25 m² | 55 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/30/15 | 2015 | AUGUST | ADAMS POINT H | 0.0 - 0.25 m² | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/30/15 | 2015 | AUGUST | ADAMS POINT I | 0.0 - 0.25 m² | 65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/30/15 | 2015 | AUGUST | ADAMS POINT J | 0.0 - 0.25 m² | 70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/30/15 | 2015 | AUGUST | ADAMS POINT K | 0.0 - 0.25 m² | 75 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/30/15 | 2015 | AUGUST | ADAMS POINT L | 0.0 - 0.25 m² | 80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/30/15 | 2015 | AUGUST | ADAMS POINT M | 0.0 - 0.25 m² | 85 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/30/15 | 2015 | AUGUST | ADAMS POINT N | 0.0 - 0.25 m² | 90 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/30/15 | 2015 | AUGUST | ADAMS POINT O | 0.0 - 0.25 m² | 95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

(See “Methods” section for details on units, etc.)
### Percentage Cover (%) and Biomass (g):

<table>
<thead>
<tr>
<th>Species</th>
<th>Length</th>
<th>Width</th>
<th>Height</th>
<th>Morphology</th>
<th>Cover %</th>
<th>Biomass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Natural Herb</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Timothy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Brome Grass</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Kentucky Blue</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bentgrass</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Rye Grass</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Fescue</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>Lolium</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **Calamagrostis canadensis** | 0.5 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| **Carex** | 0.5 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| **Other Grass** | 0.5 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |

| **Total** | 0.5 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |

### Notes:
- NA: Not applicable
- Data represents average ± standard deviation
Appendix B: Adam’s Point: Photos from August, 2015. (Note: Some photos are taller than others. This is due to an error in the camera setting.)

Adam’s Point; Site View, Photo 1

Adam’s Point; Site View, Photo 2
Adam’s Point; Transect A; Elevation = 0; Quad Size = 0.250m²

Adam’s Point; Transect A; Elevation = 0; Quad Size = 0.0625m²
Adam’s Point; Transect A; Elevation = 1; Quad Size = 0.250m²

Adam’s Point; Transect A; Elevation = 1; Quad Size = 0.0625m²
Adam’s Point; Transect B; Elevation = 0; Quad Size = 0.250m²
Adam’s Point; Transect B; Elevation = 1.5; Quad Size = 0.250m²

Adam’s Point; Transect B; Elevation = 1.5; Quad Size = 0.0625m²
Adam’s Point; Transect C; Elevation = 0; Quad Size = 0.250m²

Adam’s Point; Transect C; Elevation = 0; Quad Size = 0.0625m²
Adam’s Point; Transect C; Elevation = 0.5; Quad Size = 0.250m²
Adam’s Point; Transect C; Elevation = 0.5; Quad Size = 0.0625m²
Adam’s Point; Transect C; Elevation = 1; Quad Size = 0.250m²
Adam’s Point; Transect C; Elevation = 1; Quad Size = 0.0625m²
Adam’s Point; Transect C; Elevation = 1.5; Quad Size = 0.250m2
Adam’s Point; Transect C; Elevation = 1.5; Quad Size = 0.0625m²
Appendix B: Cedar Point: Photos from August, 2015. (Note: Some photos are taller than others. This is due to an error in the camera setting.)

Cedar Point; Site View

Cedar Point; Transect A; Elevation = 0; Quad Size = 0.250m2
Cedar Point; Transect A; Elevation = 0.5; Quad Size = 0.0625m2
Cedar Point; Transect A; Elevation = 1; Quad Size = 0.250m2
Cedar Point; Transect A; Elevation = 1; Quad Size = 0.0625m²
Cedar Point; Transect A; Elevation = 1.5; Quad Size = 0.250m2
Cedar Point; Transect A; Elevation = 1.5; Quad Size = 0.0625m²
Cedar Point; Transect B; Elevation = 0; Quad Size = 0.250m^2
Cedar Point; Transect B; Elevation = 0; Quad Size = 0.0625m²
Cedar Point; Transect B; Elevation = 0.5; Quad Size = 0.250m2
Cedar Point; Transect B; Elevation = 0.5; Quad Size = 0.0625m²
Cedar Point; Transect B; Elevation = 1; Quad Size = 0.250m2
Cedar Point; Transect B; Elevation = 1.5; Quad Size = 0.250m²
Cedar Point; Transect B; Elevation = 1.5; Quad Size = 0.0625m²
Cedar Point; Transect C; Elevation = 0; Quad Size = 0.250m²
Cedar Point; Transect C; Elevation = 0; Quad Size = 0.0625m²
Cedar Point; Transect C; Elevation = 0.5; Quad Size = 0.250m²
Cedar Point; Transect C; Elevation = 0.5; Quad Size = 0.0625m²
Cedar Point; Transect C; Elevation = 1; Quad Size = 0.250m²
Cedar Point; Transect C; Elevation = 1.5; Quad Size = 0.250m²
Cedar Point; Transect C; Elevation = 1.5; Quad Size = 0.0625m2
Appendix B: Depot Road: Photos from August, 2015. (Note: Some photos are taller than others. This is due to an error in the camera setting.)

Depot Road; Site View, Photo 1

Depot Road; Site View, Photo 2
Depot Road; Transect A; Elevation = 1; Quad Size = 0.0625m2
Depot Road; Transect A; Elevation = 1.5; Quad Size = 0.250m2
Depot Road; Transect A; Elevation = 1.5; Quad Size = 0.0625m2
Depot Road; Transect B; Elevation = 0.5; Quad Size = 0.250m2
Depot Road; Transect B; Elevation = 0.5; Quad Size = 0.0625m²

Depot Road; Transect B; Elevation = 1; Quad Size = 0.250m²
Depot Road; Transect B; Elevation = 1; Quad Size = 0.0625m²

Depot Road; Transect B; Elevation = 1.5; Quad Size = 0.250m²
Depot Road; Transect B; Elevation = 1.5; Quad Size = 0.0625m2
Depot Road; Transect C; Elevation = 0.5; Quad Size = 0.250m²

Depot Road; Transect C; Elevation = 0.5; Quad Size = 0.0625m²
Depot Road; Transect C; Elevation = 1; Quad Size = 0.0625m²
Depot Road; Transect C; Elevation = 1.5; Quad Size = 0.250m²
Depot Road; Transect C; Elevation = 1.5; Quad Size = 0.0625m²
Appendix B: Lubberland Creek: Photos from August, 2015. (Note: Some photos are taller than others. This is due to an error in the camera setting.)

Lubberland Creek; Site View, Photo 1

Lubberland Creek; Site View, Photo 2
Lubberland Creek; Transect A; Elevation = 0.5; Quad Size = 0.250m²

Lubberland Creek; Transect A; Elevation = 0.5; Quad Size = 0.0625m²
Lubberland Creek; Transect A; Elevation = 1; Quad Size = 0.250m²

Lubberland Creek; Transect A; Elevation = 1; Quad Size = 0.0625m²
Lubberland Creek; Transect A; Elevation = 1.5; Quad Size = 0.250m2
Lubberland Creek; Transect A; Elevation = 1.5; Quad Size = 0.0625m²
Lubberland Creek; Transect B; Elevation = 0.5; Quad Size = 0.250m²

Lubberland Creek; Transect B; Elevation = 0.5; Quad Size = 0.0625m²
Lubberland Creek; Transect B; Elevation = 1; Quad Size = 0.250m²

Lubberland Creek; Transect B; Elevation = 1; Quad Size = 0.0625m²
Lubberland Creek; Transect B; Elevation = 1.5; Quad Size = 0.250m2
Lubberland Creek; Transect B; Elevation = 1.5; Quad Size = 0.0625m²

Lubberland Creek; Transect C; Elevation = 0.5; Quad Size = 0.250m²
Lubberland Creek; Transect C; Elevation = 0.5; Quad Size = 0.0625m²

Lubberland Creek; Transect C; Elevation = 1; Quad Size = 0.250m²
Lubberland Creek; Transect C; Elevation = 1; Quad Size = 0.0625m²

Lubberland Creek; Transect C; Elevation = 1.5; Quad Size = 0.250m²
Lubberland Creek; Transect C; Elevation = 1.5; Quad Size = 0.0625m²
Appendix B: Wagon Hill Farm: Photos from August, 2015. (Note: Some photos are taller than others. This is due to an error in the camera setting.)

Wagon Hill Farm; Transect A; Elevation = 0; Quad Size = 0.250m²

Wagon Hill Farm; Transect A; Elevation = 0; Quad Size = 0.0625m²
Wagon Hill Farm; Transect A; Elevation = 1; Quad Size = 0.250m²

Wagon Hill Farm; Transect A; Elevation = 1; Quad Size = 0.0625m²
Wagon Hill Farm; Transect A; Elevation = 1.5; Quad Size = 0.250m²

Wagon Hill Farm; Transect A; Elevation = 1.5; Quad Size = 0.0625m²
Wagon Hill Farm; Transect B; Elevation = 0; Quad Size = 0.250m²

Wagon Hill Farm; Transect B; Elevation = 0; Quad Size = 0.0625m²
Wagon Hill Farm; Transect B; Elevation = 0.5; Quad Size = 0.250m²

Wagon Hill Farm; Transect B; Elevation = 0.5; Quad Size = 0.0625m²
Wagon Hill Farm; Transect B; Elevation = 1; Quad Size = 0.250m²
Wagon Hill Farm; Transect B; Elevation = 1.5; Quad Size = 0.250m2
Wagon Hill Farm; Transect B; Elevation = 1.5; Quad Size = 0.0625m²

Wagon Hill Farm; Transect C; Elevation = 0; Quad Size = 0.250m²
Wagon Hill Farm; Transect C; Elevation = 0; Quad Size = 0.0625m²

Wagon Hill Farm; Transect C; Elevation = 0.5; Quad Size = 0.250m²
Wagon Hill Farm; Transect C; Elevation = 1.5; Quad Size = 0.0625m²
Appendix C. Site Descriptions

The macroalgal sampling site at Four Tree Island lies east of the causeway between boulder fields on the island and a point on Peirce Island to the east. Access is provided by the adjacent parking lot. The water depth shallows above mean lower low water (MLLW, 0.0 m elevation) into a broad mudflat with coarsening sediments as elevations rise above 0.5 m elevation and flats begin to grade into a low marsh with *Spartina alterniflora* at 1.0 m. Low marsh dominated the next two elevation at 1.5 and 2.0 m, and then high marsh dominated by *Spartina patens* (2.5 m) occurred at the uppermost samples.

The sampling area at Dover Point lies on the northeast side of the point on the Piscataqua River, approximately 200 meters north of the boat launch about 50 meters north of the northernmost portion of Hilton Park and its parking area. The shore is characterized by subtidal boulders (0.0 m) grading into a narrow intertidal mudflat (0.5 and 1.0 m) with scattered rocks before a short step (at 1.5 m) up to low marsh (sampled at 2.0 m). Since trees shade out the uppermost portion of a fringing marsh that adjoins vertical rocky outcrop, only unvegetated areas were evident at 2.5 m and so this elevation was not sampled.

The transects at Cedar Point lie on the south side with their upper elevations close to the parking lot (southwest corner of the Scammel Bridge), which is above a steep bedrock embankment (access to the shore is provided by stairs). Subtidal mud bottom slopes steeply up to the edge of the intertidal at 0.0 m elevation MLLW and the mudflats continue at 0.5 and 1.0 elevations, where the sediments coarsen as a narrow band of low marsh is approached. The marsh is sampled at 1.5 meters in elevation. A rocky outcrop extends shore-normal between the second and third transects that is colonized by fucoid algae.

The sampling site at Wagon Hill Farm lies just north of the artificial beach created and maintained by the Town of Durham as part of the park. Access to the site from the main lot occurs by heading eastward across several fields to the shore. The transects run across a wide mudflat from intertidal elevations (0.0, 0.5 and 1.0 m MLLW) to a narrow fringing marsh (1.5 m) that is shaded by overhanging trees and shows strong signs of erosion. The third, northernmost, transects runs into a derelict pier characterized as a crib-construction and filled by cobble and larger rock, with fucoid algae attached to some of the exposed rock.

Along the southern shoreline of Adams Point lies the three sampling transects that extend south toward the Footman Islands. Access to the site is provided by state-maintained walking trails and wooden steps constructed along the steep embankment of shale bedrock. Fringing marsh is discontinuous at the site, occurring between coarse shale ‘beach’. The edge of the intertidal is characterized by small boulders and rocks (at 0.0 m elevation) that grade up into mudflat interspersed with rocks (0.5 and 1.0 m), often colonized by fucoid algae (primarily *Fucus vesiculosus*). At 1.5 m there can either be a fringing marsh or unconsolidated shale.

Land holdings of The Nature Conservancy (TNC) extend from the middle of Lubberland Creek north through the extensive salt marsh and several points and islands. The sampling location is accessed through a TNC trail that begins on the opposite side of Bay Road from their trail head parking lot. As the trail approaches the shoreline and salt marsh, strike off toward the shore and continue along the shore until a large mowed field extending to the marsh edge is reached. Three transects extend across the marsh into a
broad very flat mudflat that extends into the Bay between a point and island. One sample set is collected from the mudflat (0.5 m elevation), another just as the low marsh is reached (1.0 m), and a final set is located in the low marsh (1.5 m). An osprey platform with active nest is located in the adjacent upland field and so sampling should be restricted to mid-July or later to avoid disrupting any fledglings.

The Great Bay National Estuarine Research Reserve (GBNERR) has as its headquarters at the Sandy Point Discovery Center located on the southern shore of Great Bay. The transects are located from the GBNERR kayak launch extending westward and accessed by the adjacent parking lot. The mud flats are flat and broad and the 0.0 m elevation could not be accessed by walking across the mudflat (beyond 1 km), and so the three transects began at 0.05 m elevation where the mudflat began to slope upward. The 1.0 elevation was also in mudflat but within 10 meters of a fringing marsh and the 1.5 m elevation was in low marsh at the two western transects and on a rock pile adjacent to the launch for the eastern transect.

On the eastern shore of Great Bay, extensive mudflats grade into fringing salt marsh before the land rises into uplands that were historically farmed. One farm (Sunset Hill) in Newington has been set aside for conservation by the NH Fish and Game. This site has shorelines adjacent to mown fields and knobs of bedrock that show rocky outcrops along the shoreline. The private site is accessed by permission from NH Fish and Game and the first transect has its highest elevation near a derelict crib construction pier. The remaining two shore normal transects are found to the north. Similar to the Lubberland Creek and Depot Road sites, mean low water could not be reached on foot and the lowest elevation was chosen at 0.75 above MLLW, approximately 100 m seaward of the continuous edge of the low marsh (tiny marsh islands were common, but very few extended lower than 0.75 m elevation). The sampling sites at 1.0 m elevation were also in mudflat, but close to the continuous low marsh, where the 1.5 m samples were collected.