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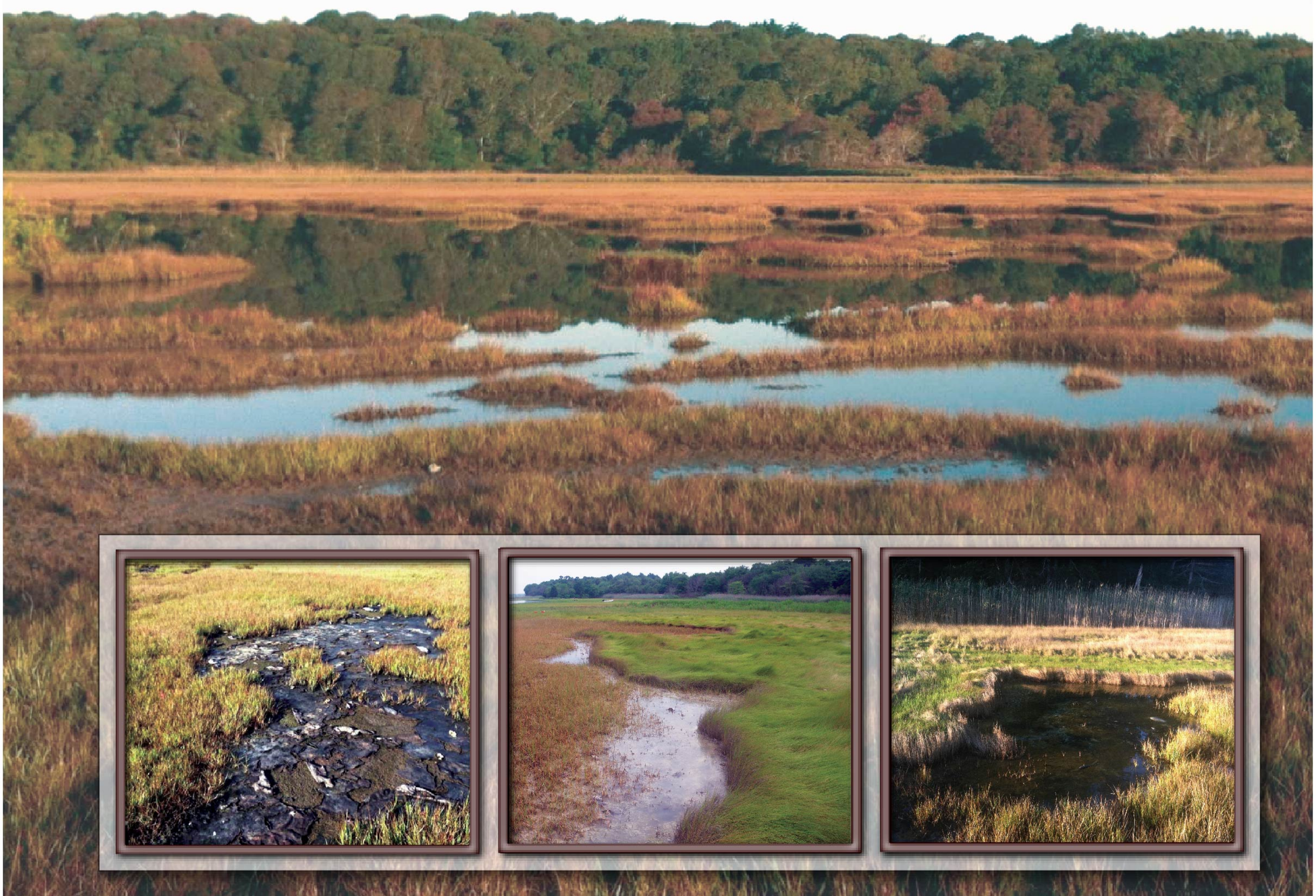
Pettaquamscutt Cove Salt Marsh

Environmental Conditions and Historical Ecological Change



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Photographs on front cover
Background: Sunrise at high tide showing salt marsh pools, 7 Oct 2013, Pettaquamscutt Cove salt marsh.
Bottom left: Peeling biofilm on unvegetated marsh, 7 Oct 2013, Pettaquamscutt Cove salt marsh.
Bottle middle: Interface between short-form *Spartina alterniflora* and *Spartina patens* at Pettaquamscutt Cove.
Bottom right: Salt marsh pool at Pettaquamscutt Cove.
All photos by E.B. Watson

Pettaquamscutt Cove Salt Marsh
Environmental Conditions and Historical Ecological Change

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NOTICE

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CONTENTS

BACKGROUND

The Narrow River Restoration Committee, consisting of mostly federal and state agencies including the U.S. Environmental Protection Agency, is charged with identifying restoration priorities for the Pettaquamscutt Estuary, located in Rhode Island with a focus on U.S. Fish and Wildlife Service (USFWS) refuge lands. Committee members envision that a mosaic of estuarine communities of historic significance will be supported by overall restoration and enhancement actions, which include shellfish and seagrass beds, fisheries habitat, and salt marsh plant communities. At present, committee members are principally concerned with the degradation of salt marsh habitat, resiliency of salt marsh to current and future rates of sea level rise, and loss of associated services.

The formation of pools in areas of poor drainage has occurred over the past century at Narrow River. These pools fluctuate in water level over spring-neap tidal cycles, and inter-annually, as depressions support greater or less amounts of stunted short form *Spartina alterniflora*. While pools are a natural and ecologically valuable component of salt marsh landscapes (Adamowicz and Roman 2005), this loss of high salt marsh habitat has implications for a bird species of concern, the salt marsh sparrow (*Ammodramus caudacutus*), which prefers the high salt marsh species, *Spartina patens*, for nesting. *Spartina patens*, also known as salt marsh hay, is a thin grass that grows 20–70 cm in height. The thin blades of *S. patens* blow over, creating a mosaic of tufts and cowlicks, which provide habitat for sparrow nesting. Restoration actions under consideration include options designed to protect and promote the expansion of high marsh habitat through hydrological and elevation enhancements.

Investigations of salt marsh at Pettaquamscutt Cove were undertaken by the U.S. Environmental Protection Agency (EPA) scientists as part of their activities designed to elucidate the impacts of multiple anthropogenic stressors (i.e., climatic change and high nutrient loads) on coastal habitats. As part of planning restoration activities, the Narrow River Restoration Committee and the U.S. Fish and Wildlife Service have been requesting a summation of research findings from active special use (i.e., research) permit holders. This report is designed to summate research findings in a way that is most useful for restoration planning purposes.

FOCUS AREA

Geographical Extent. EPA conducted a series of investigations at Pettaquamscutt Cove salt marsh at the Little Neck Cove during the summer of 2012 (Figure 1). The purpose of these investigations was to learn more about Pettaquamscutt Cove salt marshes and identify any perceived changes in vegetation, ecology, and sustaining processes over time. Using historic air photos and US coast survey maps, historic vegetation changes at Pettaquamscutt Cove over the past 180+ years were identified. Marsh elevation and plant surveys were conducted and compared with other salt marshes in Rhode Island and neighboring states. Water levels within a salt marsh tidal channel at Pettaquamscutt Cove were measured and used to develop an elevation/inundation frequency diagram. By analyzing dated and undated salt marsh sediment cores, accumulation rates, soil composition, and historic nitrogen sources were also reported. These data are intended to provide information useful for ongoing restoration planning.

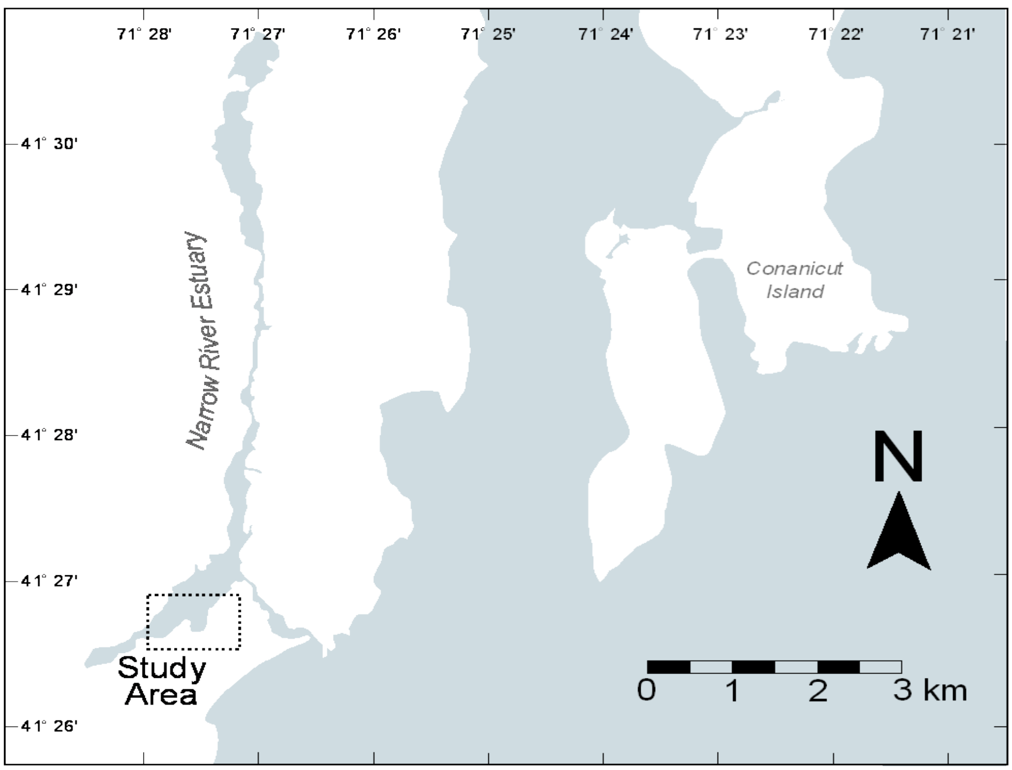

Figure 1. The Narrow River Estuary, with area of investigation delineated.

HISTORICAL VEGETATION CHANGE

Trends in Salt Marsh Areal Extent. To establish trends in salt marsh extent, marsh area (Civco et al. 1986; Smith 2009) at Little Neck Cove was digitized using an historic survey map (USCS 1869) and air photographs (Figure 2). Digitization used spatially referenced imagery available via mapserver from the Rhode Island State Geographic Information System Database and was conducted using ArcGIS, version10.

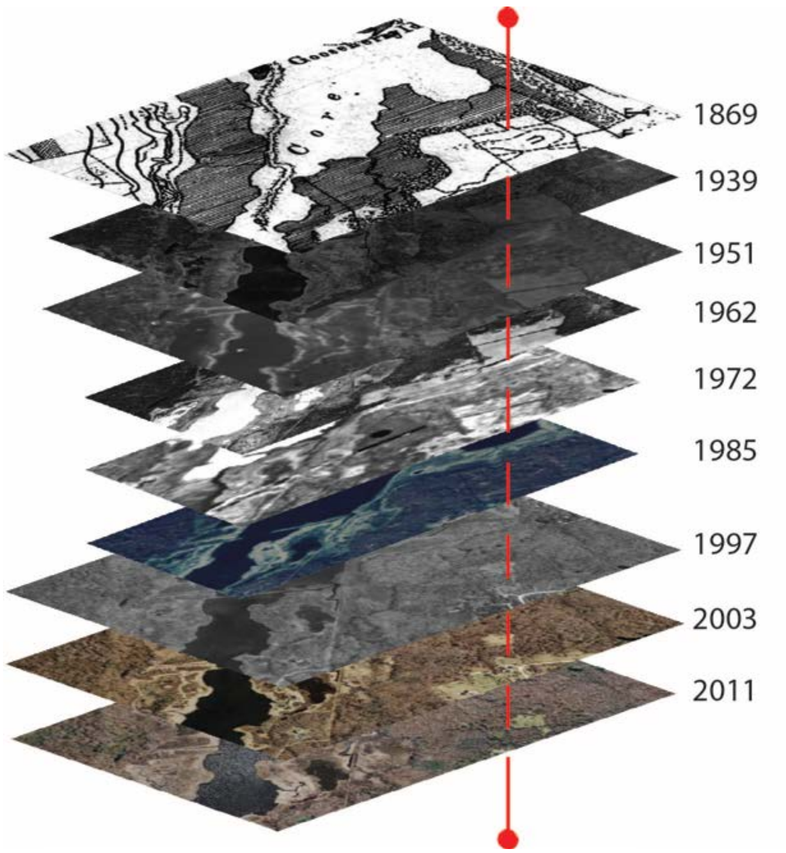

Figure 2. Data layers used for digitizing marsh extent over time for Little Neck Cove, Narrow River. These data sources document the shift from a nearly completely vegetated salt marsh to a ponded marsh.

Early coast survey maps (USCS 1839) show the location and extent of salt marsh for Narrow River depicting sinuous tidal channels. Salt marsh tidal channels depicted on later series maps (USCS 1869; USCS 1871) also include numerous linear channels, presumably recirculation ditches. The 1871 series map also shows a road and bridge traversing Pettaquamscutt Cove, and Pettaquamscutt Cove salt marsh, and the position and general width of subtidal channels for Pettaquamscutt Cove. The salt marsh extent was not digitized in 1839 and 1871.

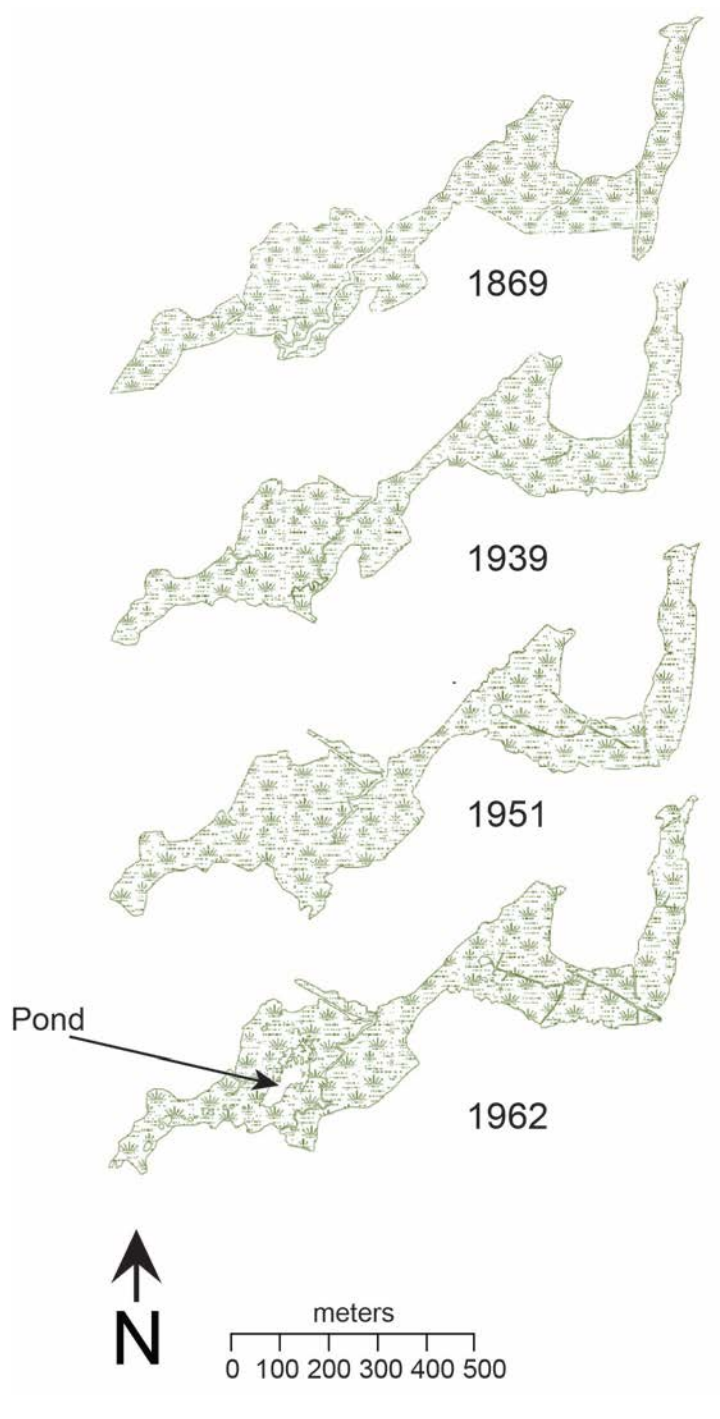

Figure 3a. Historical salt marsh landscape change for the Little Neck Cove portion of Pettaquamscutt Cove. Wetland hatching delineates areas of vegetated wetlands. Ponding first appears in this region on 1962 air photos, although the 1951 series photos show ponding at other locations. For Little Neck Cove, ponding makes up less than 10% of the landscape; however, for other portions of the estuary, ponds are larger and dominate the landscape.

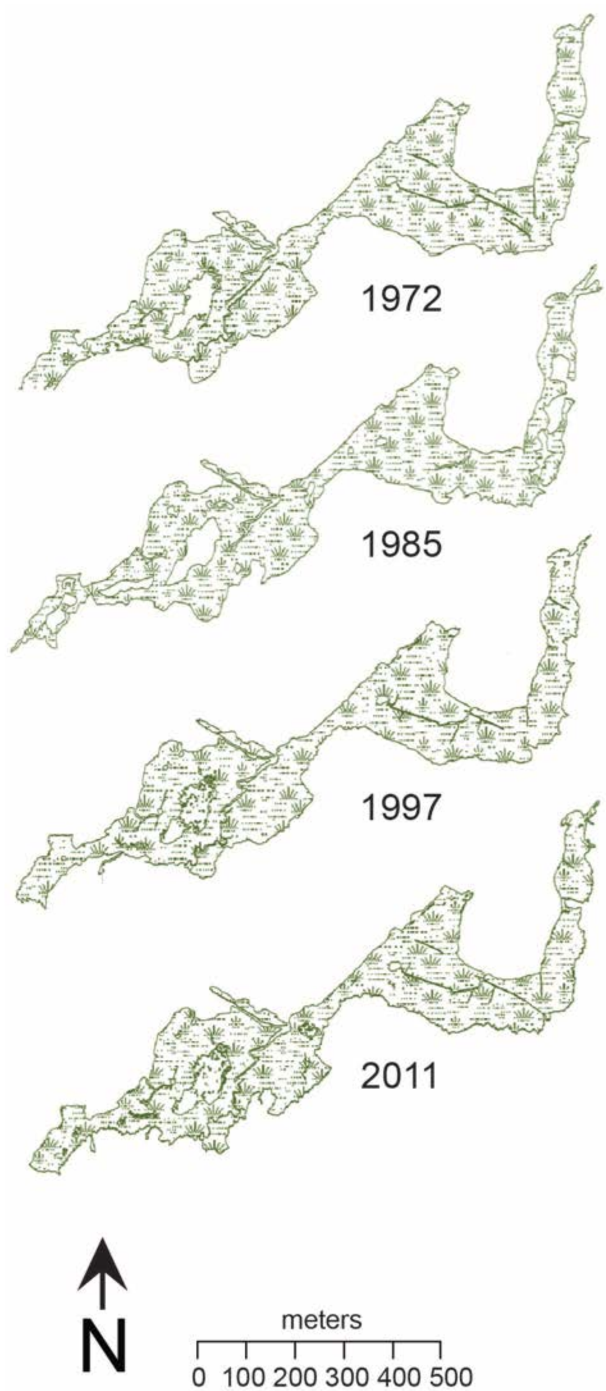

Figure 3b. Historical salt marsh landscape change for the Little Neck Cove portion of Pettaquamscutt Cove. From 1869–2011, area of marsh vegetation for this region has declined 18%; loss rates analyzed using linear regression suggests that the loss rate is linear and sums to 1.5% per decade (R^2=0.81; p<0.01). Loss is from a combination of ponding and edge loss. For the upper portion of the cove, ponds are ephemeral.

ELEVATION AND VEGETATION SURVEYS

Dispersion of Plant Species. Vegetation and elevation surveys were performed at 201 points along 10 transects at Little Neck Cove, with measures performed every 5 m along transects. Vegetation was described using the point intercept method (as described by Roman et al. 2001) using a 25 point/sq m grid. Nomenclature follows treatment in the Flora of North America. Topographic surveys were performed using a CST/Berger Self-Leveling Exterior Rotary Laser, with reported accuracy of ±1.5 mm at 30 m and a range of up to 800 m. To convert relative elevations to orthometric heights, 2–4 hour static post-processed GPS surveys were performed at three temporary benchmarks using a Trimble 4700 survey-grade GPS receiver (Figure 4). To produce elevation solutions, GPS data was post-processed using OPUS (Online Positioning User Service, National Geodetic Survey). Surveys were conducted to minimize elevation uncertainties by surveying under two separate satellite configurations, away from potential sources of multipath errors, during clear conditions free of magnetic disturbances, and using a fixed height antenna.

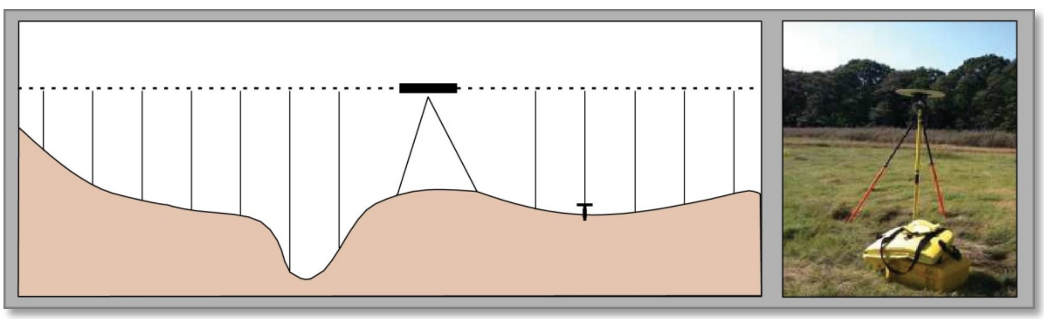

Figure 4. Topographic surveys were performed by differential leveling. Temporary benchmarks were established; orthometric heights for these marks were measured using a survey grade GPS receiver, post-processed using data from the National Geodetic Survey CORS network.

We found that *Spartina patens* was not associated with significantly higher elevations than short form *Spartina alterniflora*, which was an unexpected result (Figure 5). For other Narragansett Bay salt marshes for which we have data, *S. patens* is located in the upper marsh (Watson, unpublished data). For instance, we have found that *S. patens*, on average, grows at marsh elevations 18.7 cm higher than *S. alterniflora* at Hundred Acre Cove (Barrington, RI), and at 11.7 cm higher in elevation at Mary Donovan Marsh (Little Compton, RI). This suggests that the primary control on *S. patens* distribution at Narrow River is not elevation. Examination of air photos taken during the growing season shows areas of light green reflected light, presumably *S. patens*, found adjacent to the shoreline and tidal channels, suggesting that drainage may instead determine distribution of this species at Narrow River. To test this hypothesis, we computed for our survey stations,

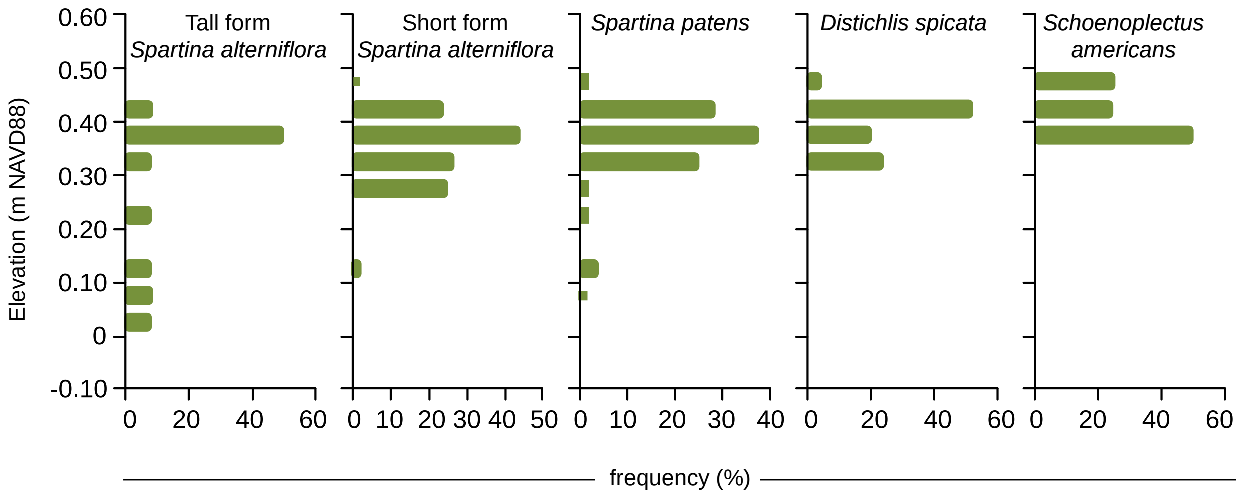

Figure 5. Distribution of salt marsh plant species relative to elevation at Little Neck Cove, Narrow River. Elevations are relative to the NAVD88 datum, GEOID12A. Surveys were conducted in 2012.

a metric of weighted channel proximity (Sanderson et al. 2001), where the cumulative inverse squared distance (*CISD*) function was calculated for each point q:

$$CISD\ (q) = \Sigma(w_0 * d^{-2})$$

where q is a particular location in the salt marsh, d is the distance from the location to a potentially influential channel that is less than 50 m away, and w_0 is a weighting factor (1, 10, and 100 in this example) based on channel size. The *CISD* was then used as an input in a logistic regression model to predict *S. patens* presence. The model was significant (χ^2=14.3, df=1, p=1.57 x 10^{-4}), and plotting the *CISD* for locations where *S.patens* was found to be present and absent demonstrates that channel proximity, and presumably drainage, significantly influences distribution of *S. patens* (Figure 6).

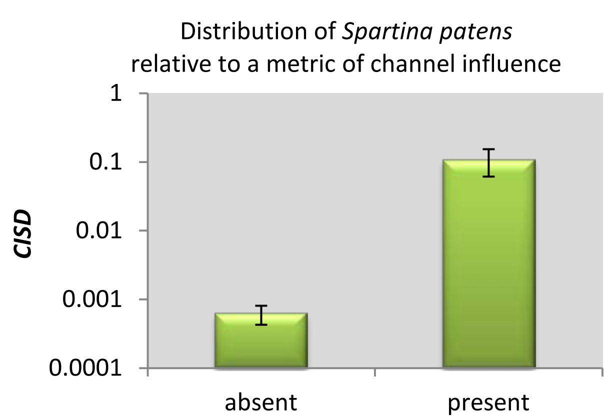

Figure 6. Air photo on left (July 2008) taken during the growing season shows dispersion of *Spartina patens* (light green) relative to tidal channels for Narrow River. On right, the *CISD* metric for locations where *Spartina patens* is present and absent for survey stations.

Elevation. The concept of elevation capital has been used by Reed (2002) and Cahoon and Guntenspergen (2010) to describe the elevation of a salt marsh relative to its potential range, with high elevation salt marshes possessing more elevation capital than a marsh situated lower in the inter-tidal range. To determine the elevation capital of Narrow River salt marshes, we compared heights to other sites in Rhode Island for which we have geodetic survey data, and to 38 other sites in Rhode Island and bordering states (Long Island, Connecticut, and southern Massachusetts) where we derive elevation from digital elevation models. Finally, we compare our geodetic survey heights to LiDAR (Light Detection And Ranging) elevations at Narrow River (after converting to the appropriate geoid model) to test cross-comparability (Figures 7 and 8).

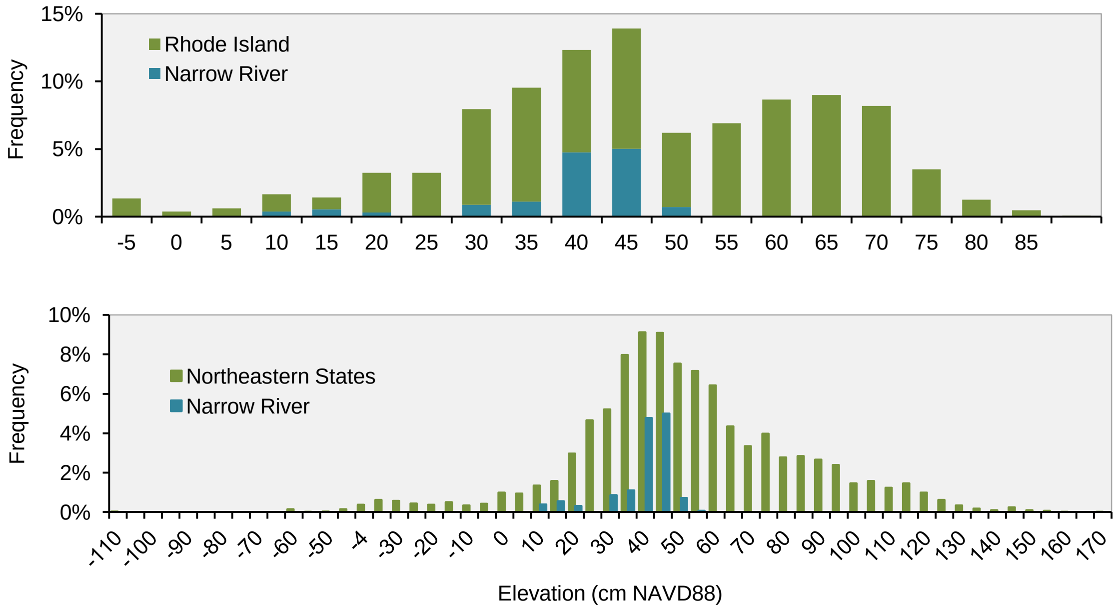

Figure 7. Comparison of salt marsh elevations for Narrow River to other locations in Rhode Island for which we have data, and for other locations in the northeastern US, suggests that Narrow River salt marshes are found at the low-mid part of the distribution. Mean heights for Narrow River are 31.7 cm; the mean height for all of Rhode Island (for which we have data) is 41.2 cm, and the mean height for the northeast is 52.3 cm NAVD88.

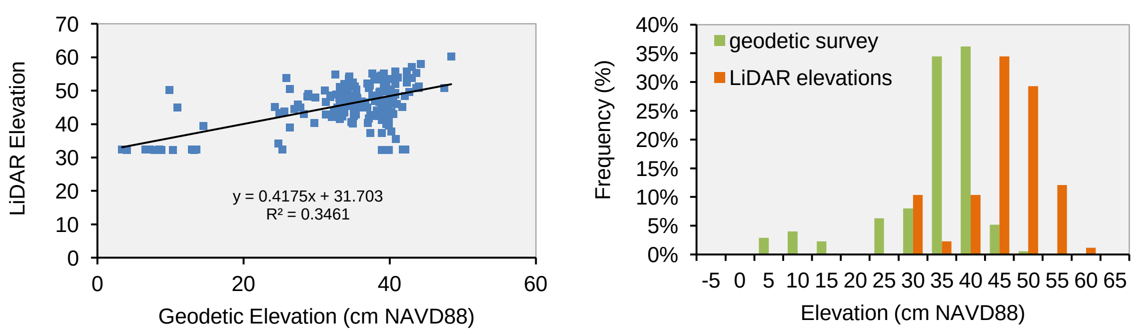

Figure 8. Comparison of geodetic survey elevations with LiDAR survey elevations shows that plot level correlations are fair for Narrow River (R^2 = 0.35). However, LiDAR elevations are overestimates (by ~10 cm), and under-report elevations below 32 cm, showing that LiDAR did not penetrate water at this location.

WATER LEVELS

Tidal Range. Water levels were measured in a salt marsh tidal channel at Little Neck Cove (41.44288°, -71.45775°) from 19 July 2012 to 15 October 2012 at five-minute intervals using a Solonist Model 3001 Levelogger Edge. Values were barometrically compensated using pressure measures from a Solonist Barologger. Tidal datums were estimated using the modified-range-ratio method (Table 1), with Newport, RI, as the control station. Such a conversion is associated with accuracy on the order of 2–3 cm (Swanson 1974; NOAA 2003). Water levels were converted to the NAVD88 datum using measures of water level height made on monthly sampling trips relative to field mesocosms, which were themselves part of elevations surveys (Figure 9).

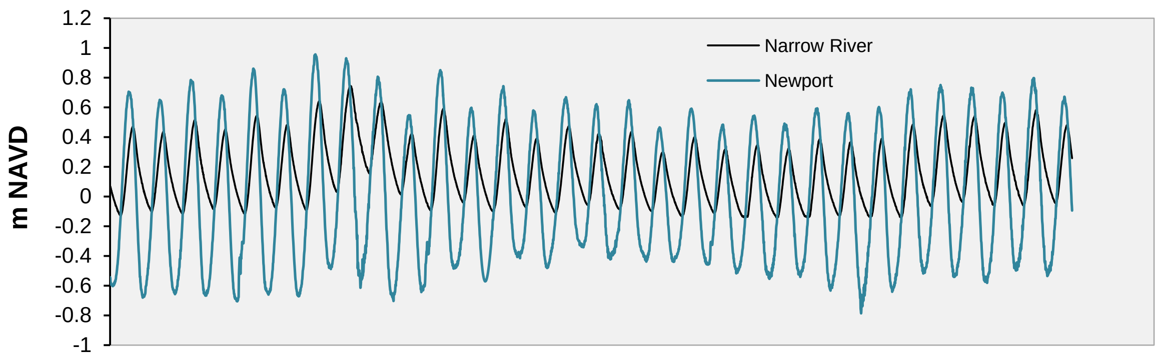

Figure 9. Water levels measured for the second two weeks of September, 2012, at the Narrow River salt marsh channel and at the Newport NOAA tide station.

Table 1. Tidal datums during the calibration period, and preliminary computed values for the National Tidal Datum Epoch (1983–2001) reported in meters relative to the NAVD88 datum. MHW refers to mean high water, MLW to mean low water, MTL to mean tide level, or the arithmetic mean of MHW and MLW, and MN to mean range of tide, or the difference in height between mean high water and mean low water.

	Narrow River	Newport
MHW 7/19/2012-10/15/2012	0.396	0.619
MLW 7/19/2012-10/15/2012	-0.102	-0.477
MTL 7/19/2012-10/15/2012	0.147	0.071
MN 7/19/2012-10/15/2012	0.497	1.097
MHW 1983-2001	0.232	0.477
MLW 1983-2001	-0.302	-0.699
MTL 1983-2001	-0.035	-0.111
MN 1983-2001	0.534	1.176

Using water level data, we plotted a frequency-inundation curve for the inter-tidal zone at Narrow River (Figure 10). To further focus on the range of salt marsh elevations measured along transects, we plot mean percent inundation for 5cm intervals where salt marsh vegetation was found (Figure 11).

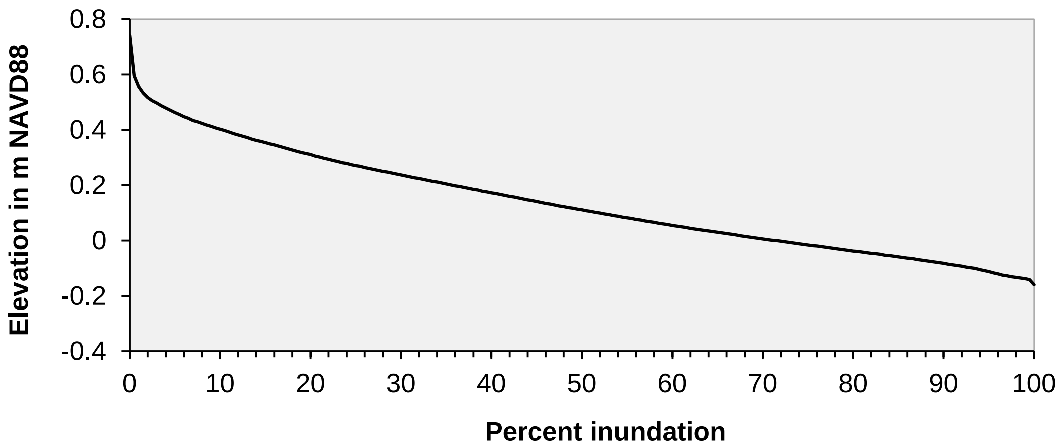

Figure 10. Estimates for intertidal inundation at Little Neck Cove as function of elevation for mid- and late summer of 2012.

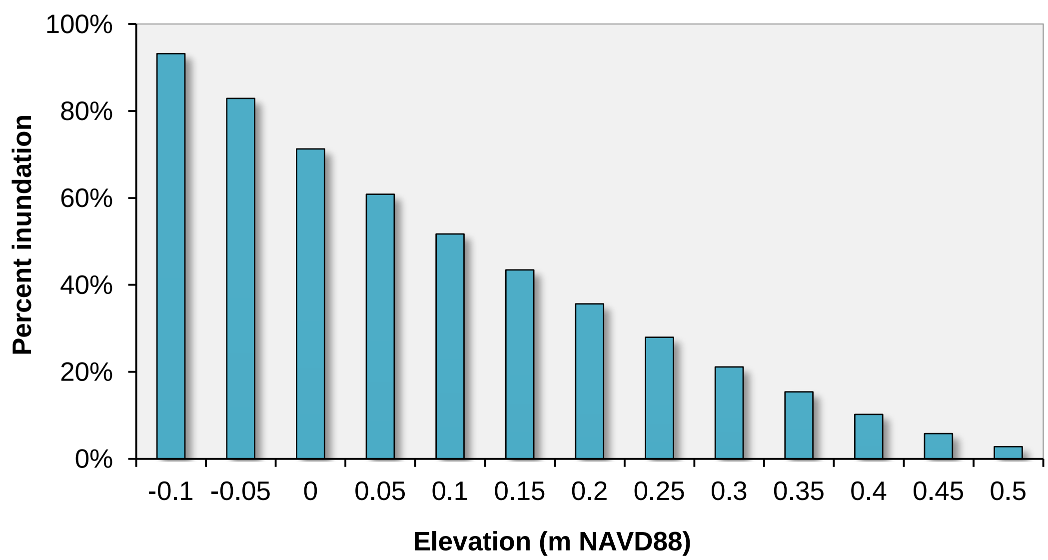

Figure 11. Estimates of inundation for the range of elevations found for salt marsh at Little Neck Cove, Narrow River. The elevation mode (~40 cm NAVD88) for salt marsh elevation is associated with an inundation figure of 10.2%. Elevations of 25 cm were inundated 27.9% of the time, elevations of 30 cm were inundated 21.1% of the time, elevations of 35 cm were inundated 15.4% of the time, and elevations of 45 cm were inundated 5.8% of the time.

MARSH SOILS AND ACCUMULATION RATES

Sedimentation. A shallow sediment core (10cm diameter by 30 cm in length) was removed from Little Neck Cove (41.44217° -71.45689°) in August of 2012. Gamma activity for ^{214}Pb, ^{210}Pb, and ^{137}Cs was measured on homogenized and sieved sediment sub-samples (roots removed) to determine accretion rates. The depth associated with peak concentrations of radiocesium (a product of nuclear testing) was assigned an age of 1962. ^{210}Pb is a naturally produced decay product of the ^{238}U decay series, has a half-life of 22 years, and is removed from the atmosphere by precipitation. ^{214}Pb is a parent of ^{210}Pb in the ^{238}U decay series; ^{214}Pb decay ultimately produces the radon that decays into ^{210}Pb. Measuring ^{214}Pb activity for each sample allows specific sample-by-sample estimates of supported and unsupported ^{210}Pb activity.

Accretion rates were estimated from profiles of excess ^{210}Pb (Figure 12) following the Constant Flux: Constant Sedimentation model (Nittrouer et al. 1979; Wheatcroft and Sommerfield 2005). In the following equation, *A* represents excess ^{210}Pb activity, *z* is depth, and lambda is the ^{210}Pb decay constant of 0.0311 yr^{-1}. To calculate *w*, an unweighted least squares regression was fit to the log transformed activity data, where depth was the independent variable. To calculate the average accretion rate, the ^{210}Pb decay constant (0.0311) was divided by *w*. Confidence intervals (95%) were calculated for this accretion rate by calculating the uncertainty of the slope estimate.

$$\mathrm{Ln}A_z = \mathrm{Ln}A_0 - \lambda / w * z$$

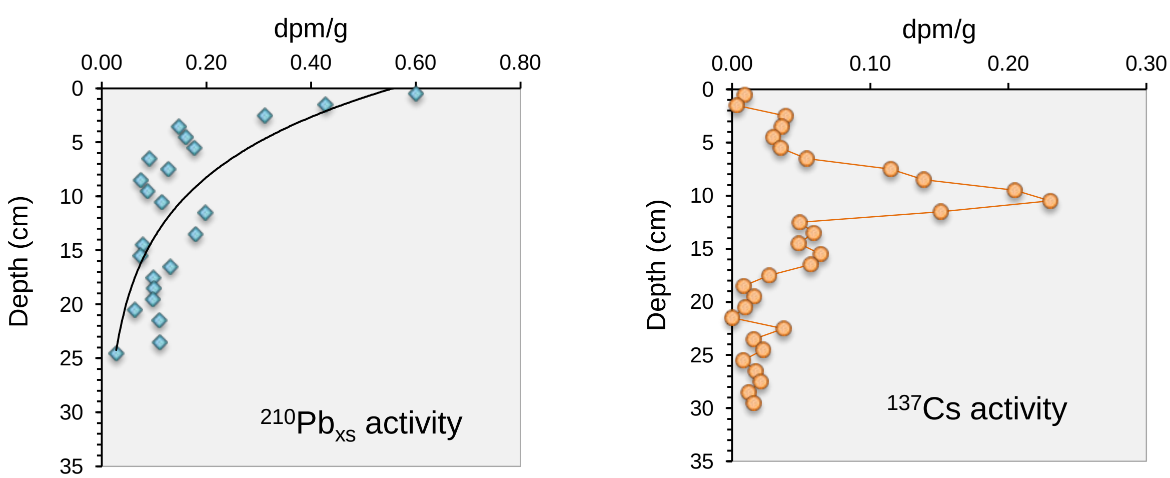

Figure 12. Downcore profiles of excess ^{210}Pb and ^{137}Cs activity in disintegrations per minute per gram. Based on the ^{210}Pb profiles, sediment accumulation rates have averaged 0.17 cm/yr (95% CI: 0.13–0.27) at Narrow River for the past 180 years. Based on the ^{137}Cs peak, accretion rates have averaged 2.1 mm/yr since the 1960s.

This shallow sediment core and three additional undated sediments cores collected from two high marsh and one low marsh locations around Little Neck Cove were sub-sampled and analyzed for sediment organic content and bulk density (Figure 13) using loss on ignition methods (Dean 1974; Heiri et al. 2001). Sediment lithic particle size distribution was also measured for these three undated sediment cores. Samples were pretreated with concentrated hydrogen peroxide to remove organic particulates (Gray et al. 2010), dispersed with a deflocculant, and analyzed using a Malvern Mastersizer 2000S laser granulometer (Figure 14).

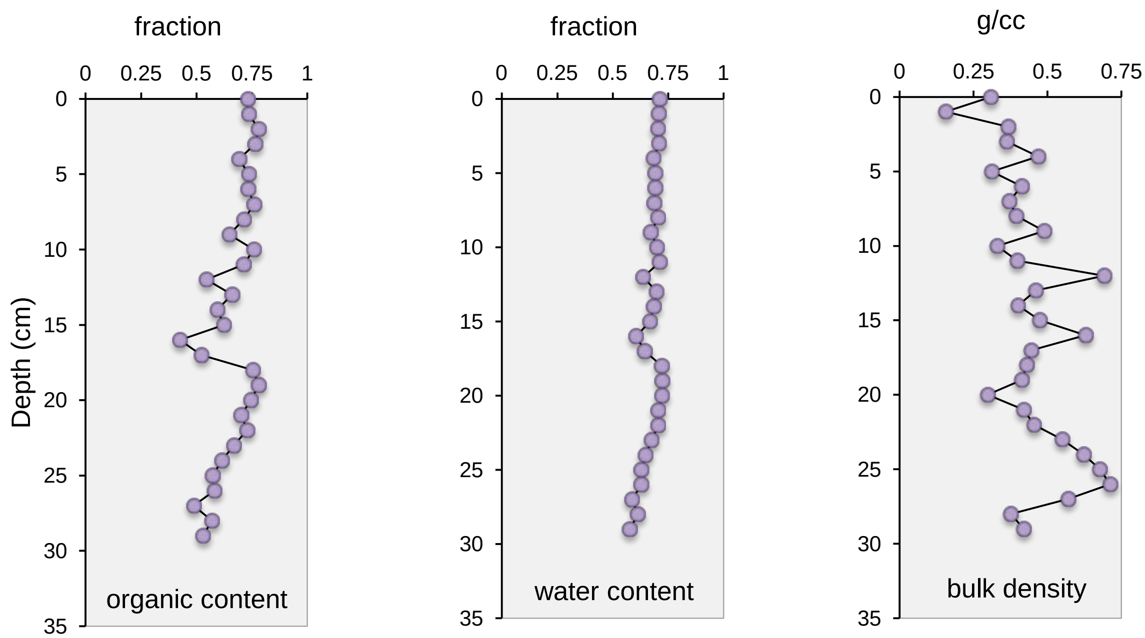

Figure 13. Downcore profiles of sediment organic content, water content, and density for bulk soils. Organic content ranges from 38–78%, with a mean of 72% of dry weight. Water content ranges from 58–72%, with a mean of 70%. Dry bulk density ranges from 0.16 to 0.71 g cc^{-1}, with a mean of 0.36. Supplemental cores average 50% organic, water content averages 82%, and average bulk density averages 0.20 g cc^{-1}.

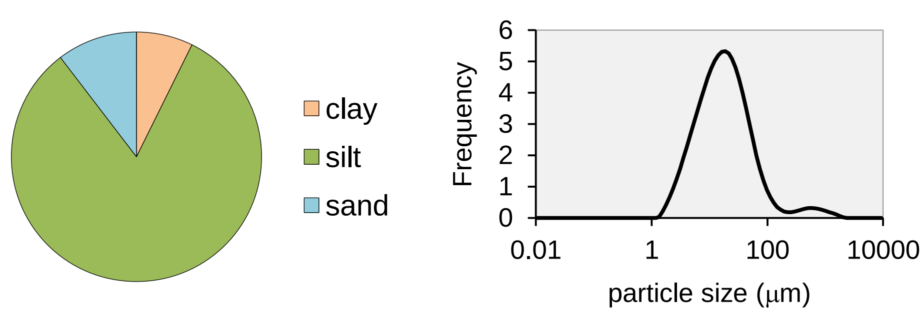

Figure 14. Particle size distribution for sediments from Little Neck Cove, Narrow River. Little variation is apparent with depth, or by location. Median particle size is 17.5 μm, mode is 18.7 μm. Using methods of Folk (1980), particle size distribution is classified as poorly sorted with a symmetrical distribution.

HISTORICAL CHANGES IN SALT MARSH NITROGEN SOURCES

Water Quality. Ground and surface waters at Narrow River are degraded by residential and commercial land use activities, with both nitrogen and coliform bacteria as known pollutants (RICRMC 1999). While nutrient inputs may have negative affects on salt marshes (Deegan et al. 2013), impacts may vary with geographic location, elevation, and soil matrix. Soil stable isotope values were used to help determine whether Narrow River salt marshes appear to be impacted by high nutrient loads.

Nitrogen occurs as two major stable isotopes (^{15}N and ^{14}N), which have slightly different physical properties. The ratio of these isotopes ($\delta^{15}N$) varies with nitrogen source (e.g., sewage effluent, groundwater, fertilizer) and can be used to help discriminate sources of nitrogen in estuarine water bodies. Locations where wastewater makes up a large proportion of dissolved inorganic nitrogen tend to have values for $\delta^{15}N$ in biota that are above 5–8‰ (Cole et al. 2004). By measuring $\delta^{15}N$ in soils from a dated sediment core collected from Little Neck Cove, we found low values of $\delta^{15}N$, both for recent time periods and historically (Figure 15).

Compared to sediments with known heavy nitrogen loads from wastewater (e.g., Nguyen and Peteet 2012; Wigand et al., 2014), these values are extremely low and indicate dilution of wastewater by tidal flushing. While preliminary, these results suggest that high nutrient loads are unlikely to be a primary stressor on Narrow River salt marsh.

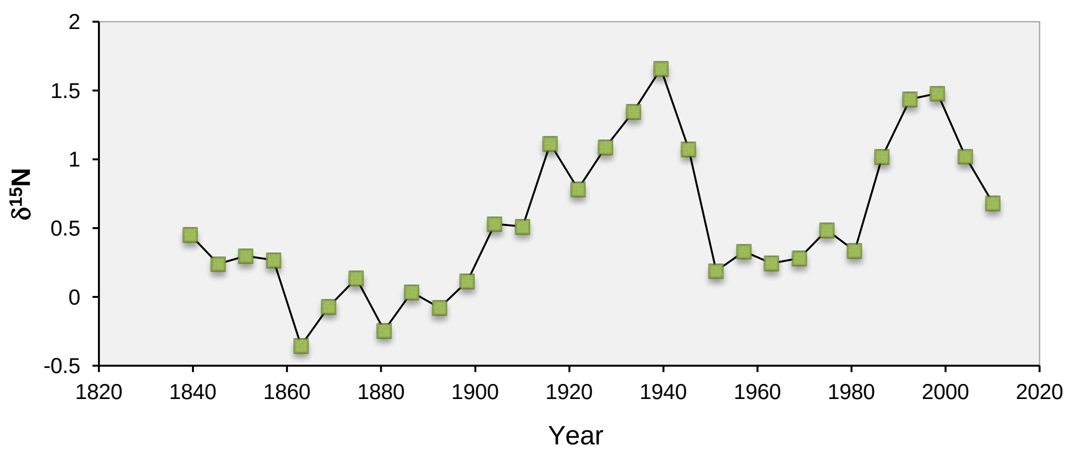

Figure 15. Nitrogen stable isotope ratios for soils over time for a sediment core collected at Little Neck Cove, Narrow River. Overall low values ($\delta^{15}N<5$) suggest that nitrogen source to salt marsh is primarily oceanic nitrogen, rather than anthropogenic nitrogen. Although nuances in the $\delta^{15}N$ curve are relatively small in magnitude, increases over time suggest enhanced wasterwater-N, with a potentially small recent drop reflecting a decrease in sewage inputs with sewering and storm drain remediation. The drop corresponding to 1940–1980 may reflect land use patterns or tidal flushing (a similar drop ca. 1938 was noted for salt marsh at Block Island; Thomas and Varekamp 2013)

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