Mapping groundwater salinity and sampling for nitrogen loading in a *Phragmites*-invaded coastal wetland in Douglas Manor, Queens, NY

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Summary

We are reporting on a program of groundwater sampling to map salinity gradients and detect anthropogenic nitrogen loading in a 2-acre parcel of invasive *Phragmites australis*-covered coastal wetland in Udall's Cove in Douglas Manor, Queens, NY (referred to as the "Big Rock" wetland). This ongoing investigation was commenced in 2015 at the request of the Douglas Manor Environmental Association (DMEA) to provide documentation of the environmental history and physical parameters of the site essential to planning a restoration of the wetland to a native species assemblage. A key goal of this phase of the study is the delineation of physical parameters that may be acting as controls on the high-density growth of *Phragmites australis* in the wetland. Results to date show that the groundwater beneath the wetland is predominantly fresh and that there is a sharp freshwater-saltwater interface along the eastern margin of the wetland the corresponds to the transition from a *Phragmites* to *Spartina* marsh. Sampling for nitrogen in the groundwater revealed elevated levels of ammonia and nitrate associated with the freshwater discharge coming from the Douglas Manor community upgradient of the wetland.

Background

In the fall of 2015 the Douglas Manor Environmental Association (DMEA) begin seeking partners for an investigation of the tidal wetlands surrounding the Douglas Manor peninsula. Of particular interest was a 2-acre parcel of tidal wetland on the east side of the peninsula adjacent to Udall's Cove, a small embayment off of Little Neck Bay on the southwestern end of Long Island Sound along the Queens-Nassau County border (Figure 1). Initial studies focused on the analysis of sediment cores to investigate the environmental history of the wetland (Weaver et al. 2016, Bennington et al. 2017, Munn and Bennington 2018) In the summer and fall of 2018 Hofstra University partnered with the environmental consulting firm retained by the DMEA, GEI Consultants, to assist in a program of groundwater sampling to map salinity and measure nitrogen input into the Big Rock wetland to determine how these parameters might be controlling the invasion of the wetland by *Phragmites australis*.

Figure 1. Location of Big Rock tidal wetland in Douglas Manor on west side of Udall's Cove along the Queens-Nassau County border in northwestern Long Island.

The DMEA is concerned about the long-term management of the Big Rock wetland given the presence of dense stands of invasive *Phragmites australis*, a tall perennial grass that, although native to the eastern United States, is now dominated by a European genetic variant that has been overspreading both inland marshes and coastal wetlands for over a century (Lombard, Tomassi, and Ebersole 2012). *Phragmites* has been dominant in the Big Rock wetland for an indeterminate amount of time, although some residents have memories of cows being grazed in the wetland on 'salt hay" which is a common name for *Spartina patens*, the saltmarsh cordgrass that is currently growing along the bay margin of the wetland adjacent to the *Phragmites* (Figure 2). This suggests that the wetland may have been dominated by *Spartina* in the recent past. Available historical aerial images are difficult to interpret because they are low resolution and taken at different times of day and during different seasons. Although the *Phragmites* spreading in monocultures throughout wetlands in the eastern United States has been shown to be a non-native European Haplotype M (Meadows and Saltonstall 2007) there is controversy surrounding what actions should be taken in response to the long unfolding invasion.

Figure 2. Aerial view of the Big Rock wetland showing dense growth of *Phragmites* and fringing growth of *Spartina patens* (image courtesy of Jon McGillick).

Ecological studies have documented a variety of structural and functional impacts of the displacement of native vegetation by *Phragmites* on marsh ecosystems, including reduced use of marsh habitat by native birds, reduced recruitment of fish larvae, and reduced plant diversity (see Table 1 in Burdick and Konisky 2003). However, potential benefits of *Phragmites* in coastal marshes include enhanced accretion of marsh sediments in the face of sea level rise and increased protection of the shoreline from waves and storm surge (Burdick and Konisky 2003). Inevitably, any decision as to how to manage a wetland that has been disrupted by human activity and invaded by a new species comes down to a compromise that takes into account scientific knowledge, economic feasibility, and human value judgments (Ludwig et al. 2003).

Any attempt to manage and / or restore the Big Rock wetland will require understanding the physical controls on the presence and distribution of the invasive *Phragmites*. *Phragmites* thrives best in freshwater habitats but has been shown to be tolerant of salinity stress in field and laboratory studies (Burdick and Konisky 2003). Potential controls on the presence and success of *Phragmites* in the Big Rock marsh include frequency of tidal inundation and salinity of the shallow groundwater bathing the root mat, which extends from the surface to as much as 30 cm depth. The Big Rock wetland lies at the margin of a peninsula of land occupied by a suburban community of 600 homes whose wastewater is discharged to cesspools. Cesspools can be a locally-concentrated source of organic nitrogen, which in saltwater systems is a limiting nutrient.

Research shows that Phragmites may be able to colonize wetlands where the existing plant community has been disrupted by enriched nitrogen concentrations (Burdick and Konisky 2003). Evidence for abundant groundwater discharge from the peninsula to the Big Rock wetland can be observed in the constant seepage of groundwater along sections of Douglas Road which borders the wetland to the west. Groundwater discharge into the Big Rock wetland may be enhancing *Phragmites* growth by supplying both freshwater and nitrogen nutrients to the habitat.

Methods

Transects: Two shoreline perpendicular elevation transects were surveyed from Douglas Road bordering the west side of the wetland to the shoreline using a tape measure, leveling rod, and handheld sight with level. Major changes in vegetation type were noted on the transects. Transect elevations were measured from the elevation of the road determined from Google Earth.

Salinity: Groundwater samples were collected from the subsurface of the Big Rock wetland using a PushPoint sampling apparatus. The PushPoint is a thin stainless steel tube that is perforated at the pointed end. It can be inserted into the subsurface to extract groundwater samples up to 2 meters below the surface. Groundwater samples were collected and salinity measurements were taken in the field using an Oakton SALT 6+ handheld salinity meter with probe calibrated with standards prior to each field excursion and checked once midway through each sampling program. Groundwater samples were also taken from four piezometer wells installed by GEI along the shoreline perpendicular transects and screened at depth (Figure 3).

Figure 3. Location of the four piezometer wells installed by GEI in the Big Rock wetland. West wells are located in the *Phragmites* zone and that the east wells are located in the *Spartina* zone.

Salinity measurements were also taken from water samples collected from the bay and from the water seeping out and pooling along Douglas Road.

Nitrogen: 500 ml samples of water collected by PushPoint, from wells, and surface samples from the bay and road seepage were put on ice and sent by courier to TestAmerica to be assayed for NO_3^- (nitrate) and NH_3 (ammonia). Time of collection was recorded for all samples.

Results

Transects: There is a steep drop off from the road down to the surface of the wetland that is likely an artifact of fill and leveling of the roadbed during construction. The surface of the wetland that hosts the dense stand of *Phragmites* is at approximately 5 ft elevation. Where the wetland surface drops below 5 ft *Phragmites* become less dense and transitions to a *Spartina patens* dominated flora (Figure 4a,b). Invasive *Phragmites* has been shown in studies to be extremely salinity tolerant (Burdick and Konisky 2003, Meadows and Saltonstall 2007), however its relative absence in the Big Rock wetland at elevations below 5 ft suggests that frequent inundation by seawater is exerting a control on its spread into the low marsh environment.

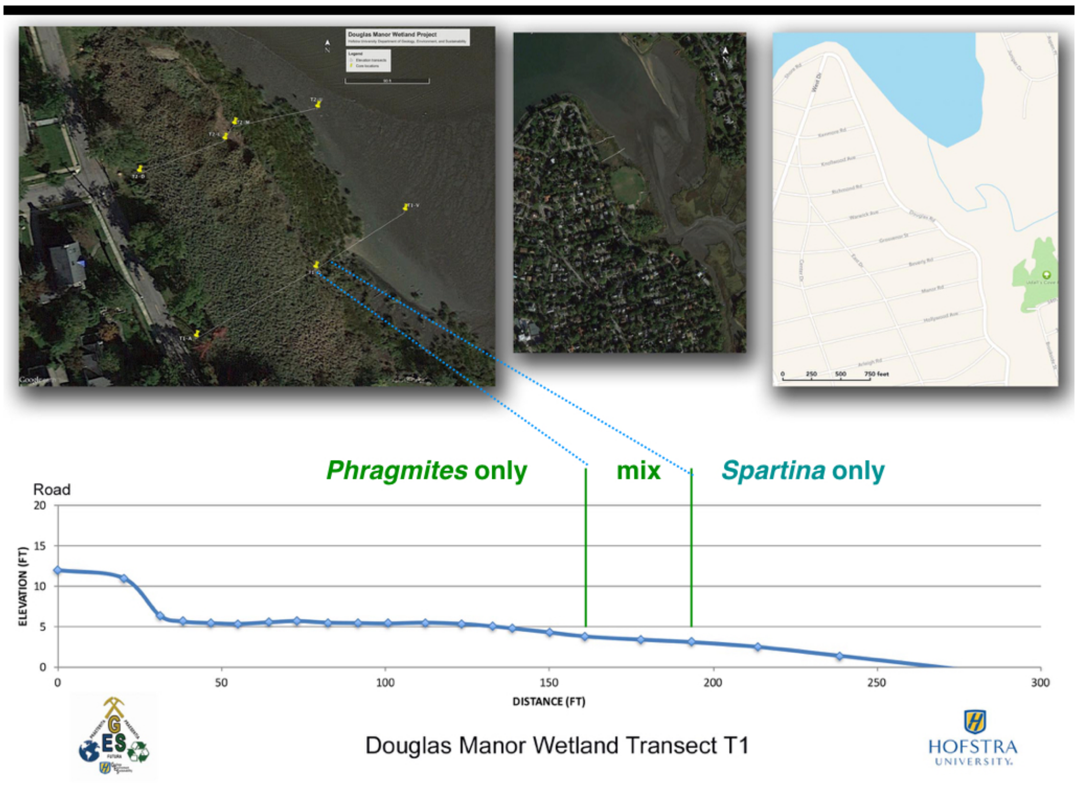

Figure 4a. Southern profile across the Big Rock wetland showing changes in vegetation relative to elevation.

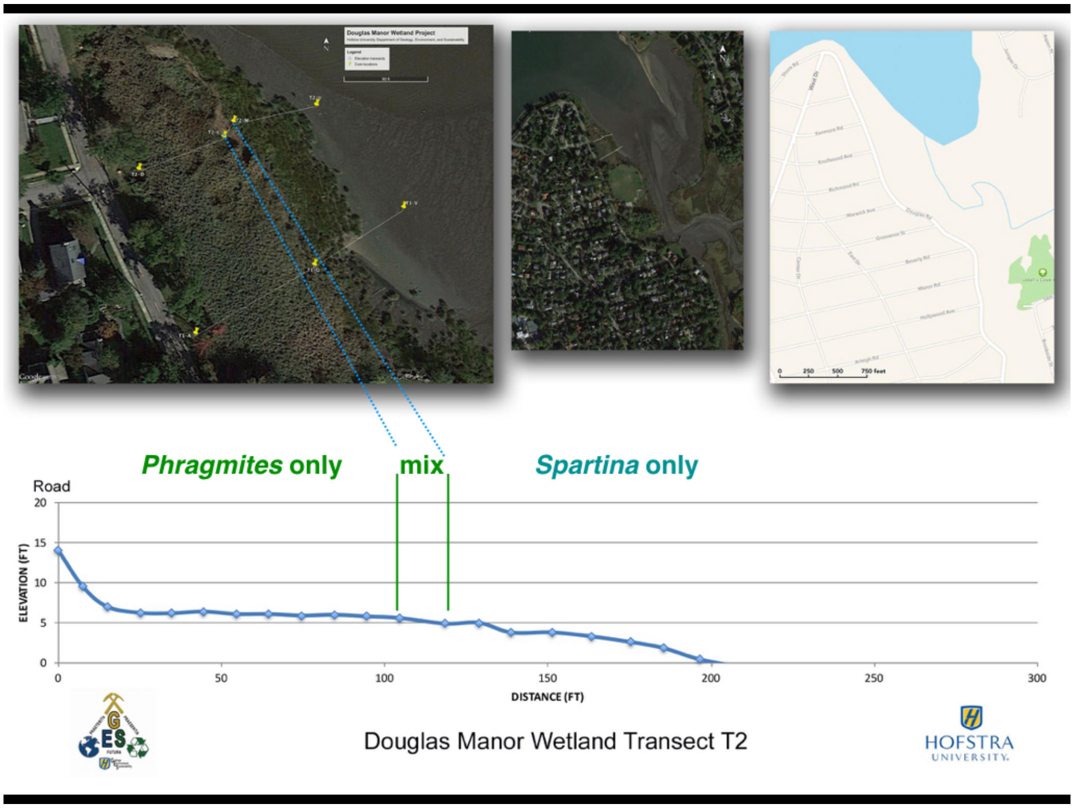

Figure 4a. Northern profile across the Big Rock wetland showing changes in vegetation relative to elevation.

Salinity: Samples collected from open water in Udall's Cove show that salinity in the cove fluctuates with the tide from around 22 ppt with the incoming waters from Long Island sound to as low as 7 ppt for waters being carried by the outgoing tide (Figure 5). The Long Island Sound Study website (http://longislandsoundstudy.net/about-the-sound/by-the-numbers/) reports a salinity value for western Long Island Sound of 23 ppt, which agrees with the incoming tide values we observed in Udall's Cove. The drop in salinity observed during the outgoing tide is most likely caused by the discharge of fresh groundwater into the cove during ebb tidal cycle.

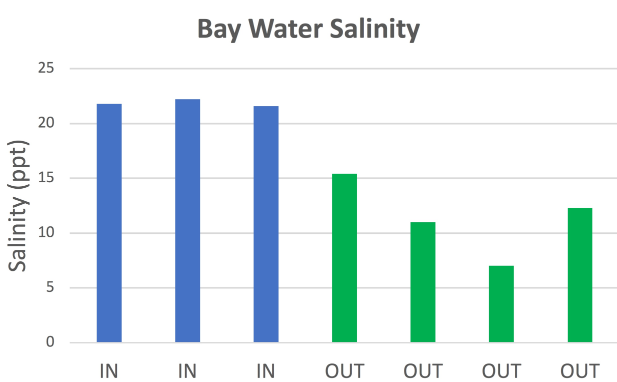

Figure 5. Salinity values recorded from bay samples during incoming and outgoing tides.

Groundwater samples from the two eastern piezometer wells have salinity levels approaching those observed for the bay and clearly indicate that the eastern wells are located seaward of the freshwater-saltwater interface (Figure 6). Samples from the western two wells show salinity values close to zero ppt and are sampling groundwater landward of the interface. Salinity values measured from the wells fluctuate somewhat, but there does not appear to be a correlation between salinity and tide level in the deeper groundwater sampled by the wells.

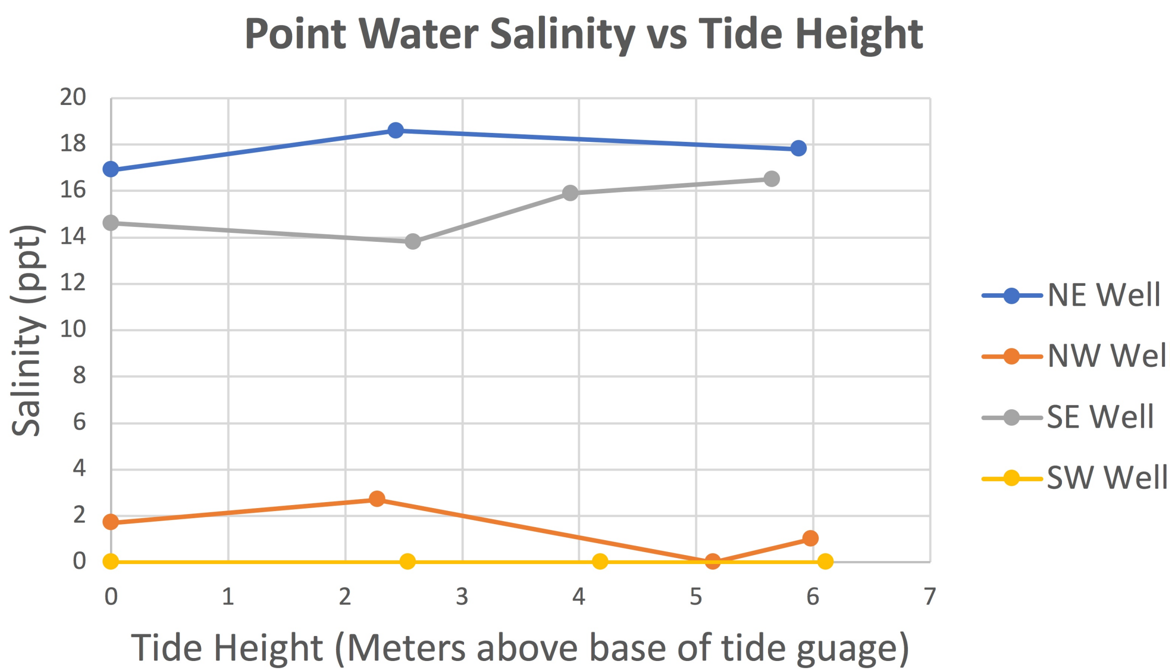

Figure 6. Salinity values recorded from point water in four piezometer wells installed in the Big Rock wetland. The NE and SE wells are proximal to the bay shoreline in the *Spartina* zone of the wetland and the NW and SW wells are located away from the bay in the *Phragmites* zone (see Figure 3).

Shallow groundwater samples in the wetland show a range of values from zero to 19.1 ppt, with shallow groundwater in the *Phragmites* zone mostly fresh to slightly brackish (0-2.5 ppt) and groundwater in the *Spartina* zone showing higher salinities from 7-19 ppt. Along the boundary of the *Phragmites* zone salinity values range from 4.8-6.2 ppt where the *Phragmites* tends to be less tall and dense than farther landward. We have not yet collected enough measurements to determine how much the salinity of the shallow groundwater fluctuates with the tide, however it seems likely that some of the variability in observed shallow groundwater salinity between closely spaced samples is being driven by changes in tide height and inundation of the marsh surface during high tide.

Samples collected from pools of standing water along Douglas Road were all fresh water.

Figure 7. Map of salinity values (ppt) for shallow groundwater samples in the Big Rock wetland.

Nitrogen: Elevated levels of nitrogen in the form of ammonia and nitrate were detected in a number of groundwater samples from the Big Rock wetland and in samples of groundwater discharging along Douglas Road (Figure 8, Table 1). Two samples (R1, R4) of standing water along the road taken on different days show elevated levels of both ammonia and nitrate. Samples of groundwater taken from wells tend to show elevated levels of ammonia with the highest values observed in the eastern (shoreline proximal) wells. Two out of five shallow groundwater samples (PP2, PP5) had nitrate in excess of 5 mg/L and one (PP4) had ammonia above 8 mg/L. Most bay samples (B1-B4) show comparably low levels of both ammonia and nitrate (<1 mg/L). The two bay samples (B5, B6) that show somewhat elevated levels of nitrate (1.6-2.3 mg/L) were both collected at close to low tide, suggesting that the nitrate in these samples may have come from fresh groundwater discharging into the bay.

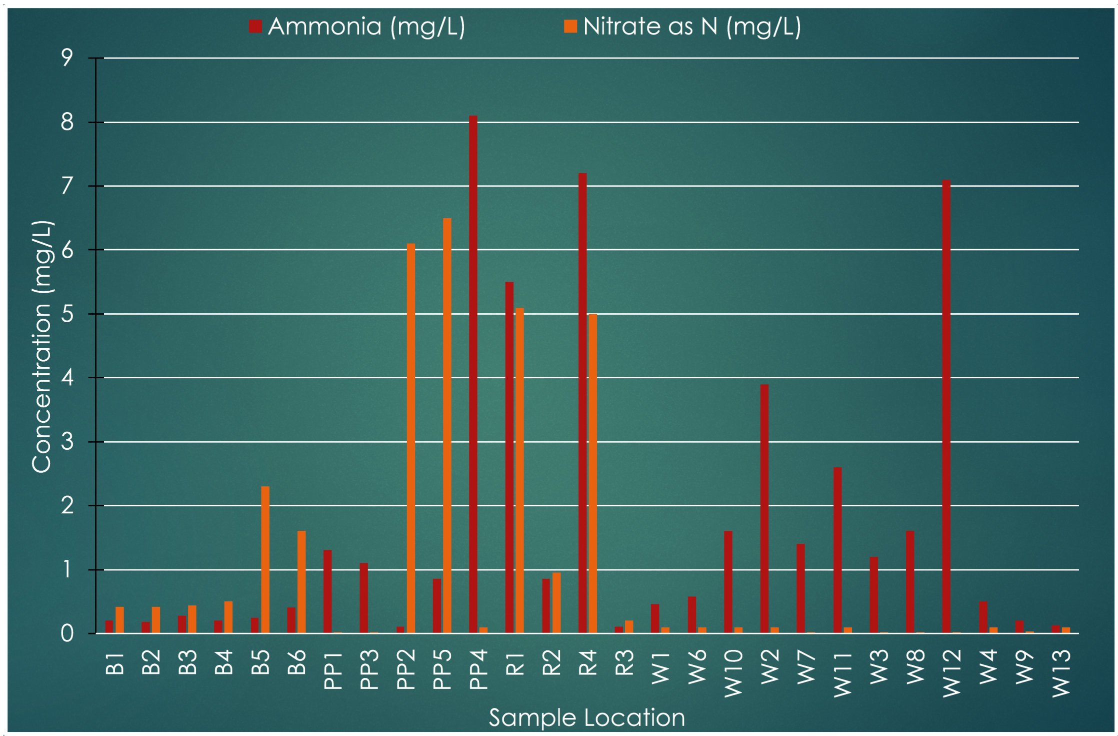

Figure 8. Results of ammonia and nitrate assays for water samples from the Big Rock wetland.

Description	Sample Location	Sampling Date	Salinity (ppt)	Ammonia (mg/L)			Nitrate as N (mg/L)		
				Result	Q	MDL	Result	Q	MDL
Bay	B1	11/9/2018	?	0.2		0.09	0.42		0.01
Bay	B2	11/9/2018	21.6	0.18	J	0.09	0.42		0.01
Bay	B3	11/16/2018	15.4	0.28		0.045	0.44		0.01
Bay	B4	11/16/2018	11	0.2		0.045	0.5		0.01
Bay	B5	11/30/2018	7	0.25		0.045	2.3		0.02
Bay	B6	11/30/2018	12.3	0.41		0.045	1.6		0.01
Pushpoint	PP1	11/16/2018	1.7	1.3		0.23	0.015	J	0.01
	PP3	11/30/2018	0	1.1		0.45	0.015	J	0.01
Pushpoint	PP2	11/16/2018	0	0.11	J	0.09	6.1		0.05
	PP5	11/30/2018	0	0.86	J	0.45	6.5		0.05
Pushpoint	PP4	11/30/2018	1.3	8.1		0.45	0.1	U	0.01
Road	R1	11/9/2018	0	5.5		0.23	5.1		0.05
	R2	11/16/2018	0	0.86		0.09	0.95		0.01
	R4	11/30/2018	0	7.2		0.23	5		0.05
Road	R3	11/16/2018	0	0.11	J	0.09	0.2		0.01
NW Well	W1	11/9/2018	1	0.46	J	0.23	0.1	U	0.01
	W6	11/16/2018	2.7	0.58		0.23	0.1	U H	0.01
	W10	11/30/2018	1.7	1.6		0.45	0.1	U	0.01
NE Well	W2	11/9/2018	17.8	3.9		0.23	0.1	U	0.01
	W7	11/16/2018	18.6	1.4		0.23	0.018	J	0.01
	W11	11/30/2018	16.9	2.6		0.45	0.1	U	0.01
SE Well	W3	11/9/2018	16.5	1.2		0.23	0.012	J	0.01
	W8	11/16/2018	13.8	1.6		0.23	0.014	J	0.01
	W12	11/30/2018	14.6	7.1		0.45	0.013	J	0.01
SW Well	W4	11/9/2018	0	0.5	U	0.23	0.1	U	0.01
	W9	11/16/2018	0	0.2	U	0.09	0.031	J	0.01
	W13	11/30/2018	0	0.13		0.045	0.1		0.01

Table 1. Results of ammonia and nitrate assays for water samples from the Big Rock wetland.

Discussion and Conclusions

The data amassed by this study of the Big Rock wetland supports both salinity and nitrogen loading as important environmental factors contributing to the invasion of the Big Rock wetland by *Phragmites australis*. PushPoint and well sampling of groundwater below the *Phragmites* root mat shows that the majority of the wetland is bathed in fresh groundwater discharging from the Douglas Manor peninsula, maintaining the *Phragmites* root mat in fresh to slightly brackish conditions. Approaching the freshwater-saltwater interface shallow groundwater salinity values begin to climb above 5 ppt and the *Phragmites* thin out. Shoreward of the interface where the groundwater is significantly brackish *Spartina* is the dominant plant. However, the *Phragmites-Spartina* transition zone also correlates with a drop in the elevation of the marsh, allowing for duration and frequency of tidal inundation to also contribute to establishing the limit of *Phragmites* growth. Sampling for nitrogen has established that there is a component of nitrogen loading in the groundwater coming off of the peninsula, most likely originating from septic systems. There is no evidence that nitrogen is being delivered to the wetland from the bay, rather, bay samples with elevated nitrate levels taken at low tide suggest instead that groundwater discharge is delivering excess nitrogen to the bay.

Acknowledgements

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