Final Report

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Elevation Change, Submergence, and Soil Toxicity in the Quinnipiac Tidal Marshes

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Introduction

Tidal marshes are key components of the coastal landscape, and play several valuable roles: habitat for wading birds, juvenile fish, and invertebrates; sites of high primary production and nutrient processing; buffers for removal of land-derived pollutants; and flood protection. These vital ecosystems have been legally protected from direct anthropogenic impacts (dredge and fill), but several sites, including the Quinnipiac, are experiencing unexplained "submergence," characterized by an increase in wetness, loss of vegetation, and conversion to mudflat.

Healthy marshes can avoid drowning by accreting sediment (organic and inorganic) at rates that allow the marsh to "keep up" with relative sea level rise (SLR). The reasons that submerging marshes are unable to do this are presently unclear.

The Quinnipiac River's extensive tidal marshes (brackish and salt) provide a unique ecological and recreational resource. This area is habitat to numerous birds and aquatic organisms and provides a biogeochemical filter for the waters of the river, as well as being a popular site for birding and boating. Submergence threatens those values.

In this project, we examined the processes determining the stability of the Quinnipiac marshes. In particular, our proposal identified 3 objectives:
1. Monitor 9 long term plots in spring 2015.
2. Monitor 3 of the plots in fall 2015.
3. Establish a marsh organ experiment and use it to assess the role of sediment toxicity in marsh production.

Our efforts and results in addressing these objectives are described below.

Accretion and elevation change (objectives 1 and 2)

Methods

In April 2015, we measured both accretion and elevation change at each of our previously-established Sediment Elevation Table – Marker Horizon (SET-MH) plots (Figure 1) using established methods (Cahoon et al. 2002). Specifically, we sampled triplicate plots in each of 3 vegetation types: *Typha glauca* near the drowning area ("degrading Typha"), *Phragmites australis* near the drowning area ("degrading Phragmites"), and Phragmites away from the drowning area ("healthy Phragmites"). We have previously determined that at the Phragmites sites, sampling more than once per year results in unacceptable damage to vegetation, so we sampled those sites only in April 2015 (before new shoots reached the elevation of our sampling platform). The Typha site is less susceptible to vegetation damage, so we had proposed sampling there in both April and November, but we concluded that the vegetation damage was not worth the additional information to be gained, so we did not sample at any of our sites in the fall.

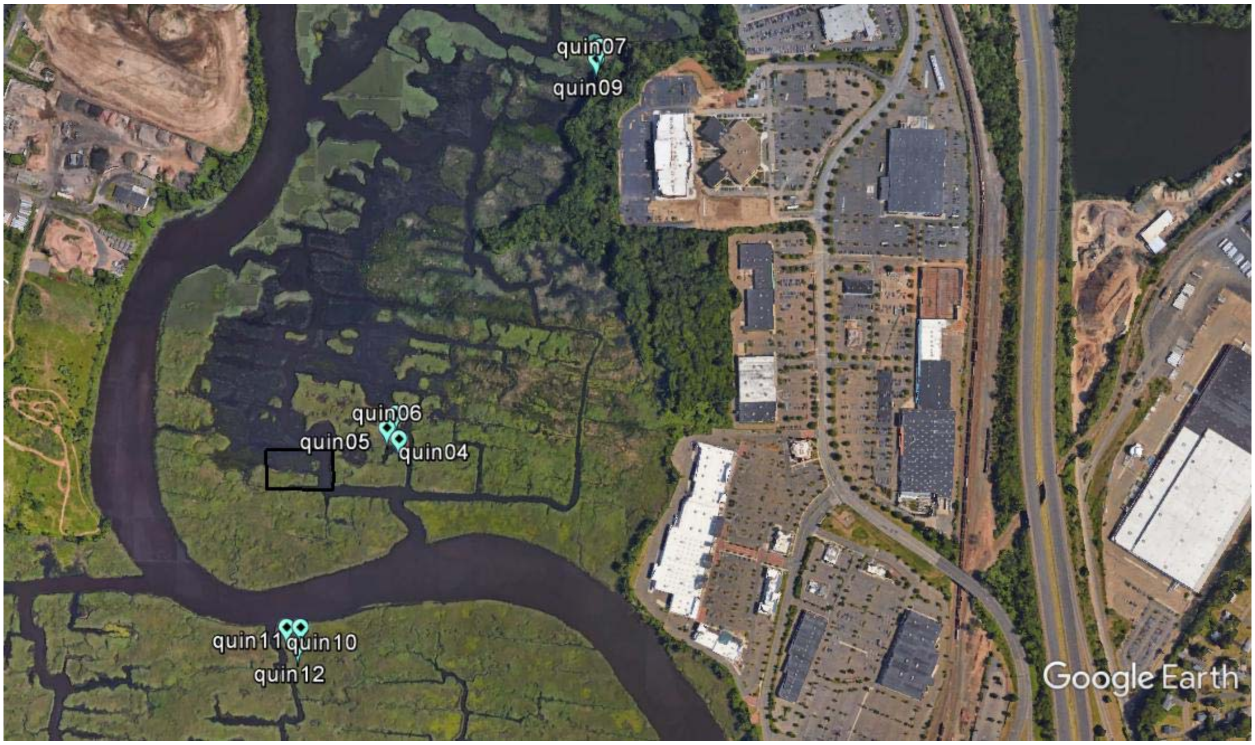

Figure 1. Sampling locations in the Quinnipiac marshes (Google Earth image). Blue markers indicate SET plots (triplicate plots at each site). Sites from north to south are: degrading Typha, degrading Phragmites, healthy Phragmites. The black rectangle (near degrading Phragmites plots) indicates the area where the organ experiment was carried out, shown in more detail in Figure 4.

For accretion, sampling involved collection of a small cryo-core using a liquid nitrogen system, followed by measurement of the depth of sediment on top of the feldspar marker horizons (established in 2006). This deposited sediment was also retained and analyzed for organic matter by Loss on Ignition (LOI). For elevation change, sampling involved deploying the sediment elevation table at each plot and collecting readings from 9 pins in each of 4 directions. These measurements were then compared to the initial readings; differences correspond to increases or decreases in sediment elevation.

Results

The two Phragmites sites showed similar patterns of accretion over time (Figure 2, top), with both sites accreting sediment at just over 3 mm yr^{-1}, roughly the regional rate of SLR. The two sites differed, however, in their elevation change (Figure 2, bottom), with the healthy site showing a considerably higher rate.

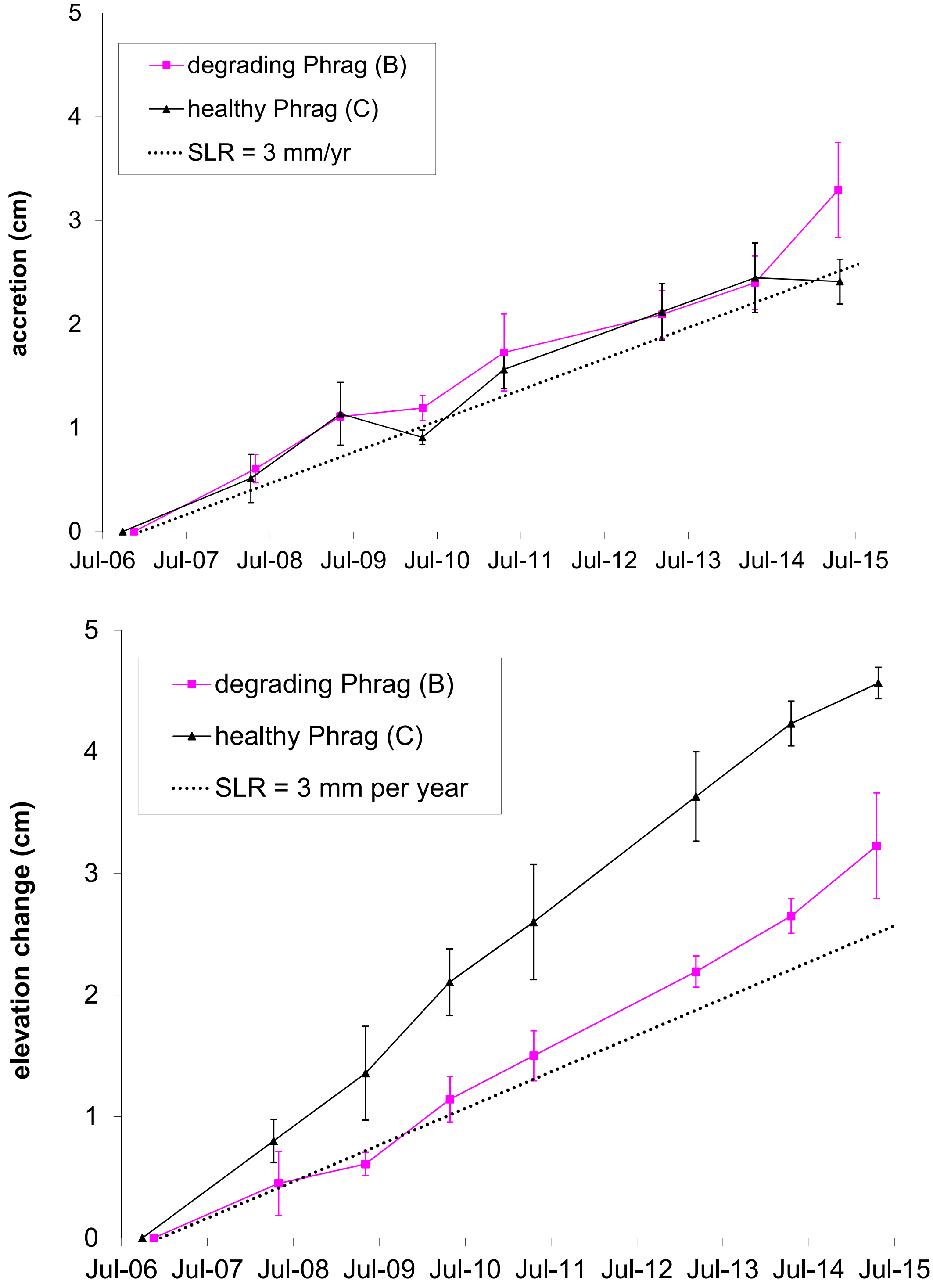

Figure 2. Accretion (top) and elevation change (bottom) at the two SET-MH Phragmites sites (mean and standard error of triplicate plots at each site). Dashed line shows a constant SLR of 3 mm yr^{-1}.

Our sampling at the Typha site showed that, despite its proximity to the mudflat, this site is both accreting and gaining elevation at rates well in excess of 3 mm yr^{-1}, though with a great deal of inter-plot variability (Figure 3).

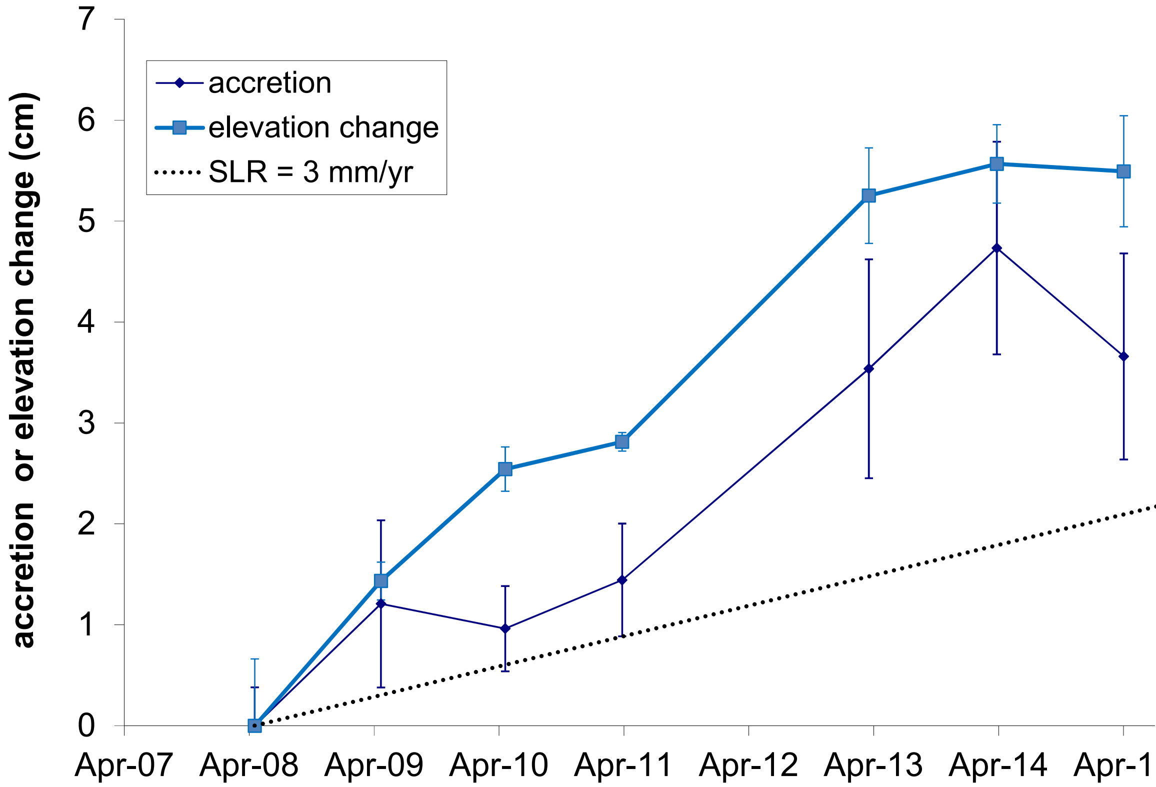

Figure 3. Accretion and elevation change at the SET-MH Typha site (mean and standard error of triplicate plots). Dashed line shows a constant SLR of 3 mm yr^{-1}. Only spring data are shown.

Organ experiment (objective 3)

Methods

Our goal was to determine the effect of two parameters – elevation and sediment metal concentrations – on the productivity of *Phragmites australis*.

For the elevation parameter, we used two treatments – low and high, where "low" represented the current mudflat elevation and "high" represented the current vegetated-area elevation. In order to determine these elevations, we carried out preliminary surveying at our site (Figure 4) using a TOPCON DL transit.

For the metal parameter, we wanted to ensure that potential differences in productivity were due to metal levels, rather than other factors (e.g., other toxicants, nutrients, etc). In order to do this, we used three metal treatments:

- “Quinnipiac”: This was in-situ sediment from the Quinnipiac mudflat where the experiment was carried out. However, we returned it to the lab before use to homogenize and to ensure that it was treated similarly to the other treatments.
- “control”: This was sediment obtained from Hoadley Creek in Guilford, expected to be relatively low in contaminants.
- “metal”: This was Hoadley sediment to which Ag, Cd, Cr, Cu, Ni, Pb, and Zn were added at levels meant to approximate concentrations in the Quinnipiac sediment.

To compensate for the addition of Cl^- and NO_3^- as counter-ions in the “metal” treatment, equal amounts of these ions were added to the other treatments. The pH of all treatments was adjusted to circum-neutral.

Crossing the 2 elevation treatments with the 3 metal treatments led to 6 treatments, each of which was replicated 5 times, for a total of 30 plots. Each plot consisted of 4-inch PVC pipe which was sunk into the sediment and leveled to the desired elevation, and then filled with the appropriate sediment. Each plot received one Phragmites seedling collected from the nearby Phragmites stand. The plots were encircled with orange fencing (visible in Figure 4) in order to protect them from herbivory.

Figure 4. Location of the organ experiment. The black line indicates the Phragmites survey transect used to determine the elevation of the “high” elevation treatment. The orange rectangle in the mudflat encircles the 30 plots.

<u>Results</u>

Surveying revealed that the mudflat was lower than the nearby vegetated area by ~20 cm (Figure 5), so the “high” treatment was elevated by 20 cm relative to the “low” treatment. Sediment analysis revealed that the Quinnipiac sediment had metal concentrations that were 2 to 10 times as high as the Hoadley sediment (Figure 6), so the "metal" treatment was prepared accordingly.

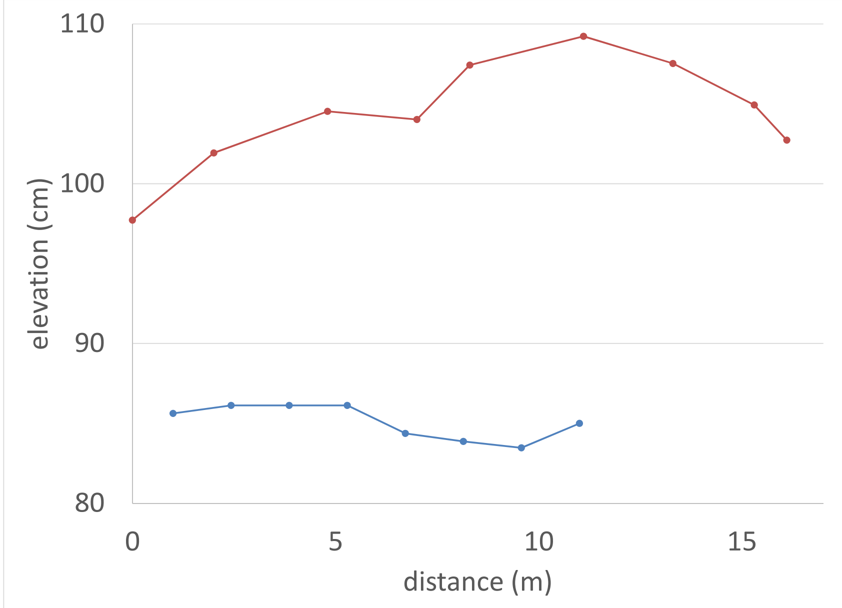

Figure 5. Elevation along transects in mudflat (bottom) and a Phragmites stand (top). Distances (x-axis) are approximate; elevations (y-axis) are relative to an arbitrary datum.

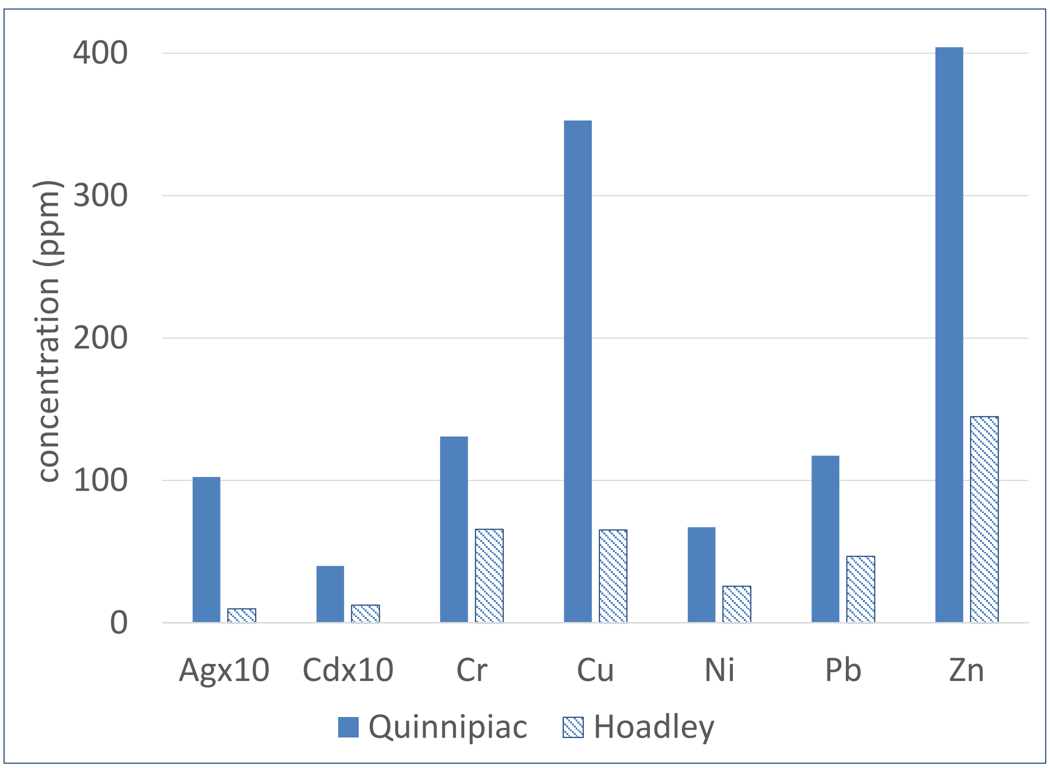

Figure 6. Metal concentrations in sediment from mudflats in the Quinnipiac marsh and Hoadley Creek marsh. Values shown are the mean and standard error (n=4 for each site). Values for Ag and Cd are multiplied by 10 for visibility.

Monitoring of our plots over summer 2015 revealed several flaws with the study:

- For the first several weeks of the study, salinity levels in the Hoadley Creek sediment were higher than in the Quinnipiac sediment. This is perhaps unsurprising, as Hoadley is a salt marsh and the Quinnipiac is brackish.
- The sediment in the PVC tubes shrank away from the sides, creating a somewhat desiccated micro-environment, especially at high tide. In hindsight, the tubes were too small for this experiment.
- In the first few weeks of the experiment, most of the transplanted seedlings withered and died (Figure 7), probably as a result of transplant shock, compounded by the issues mentioned above.

Figure 7. An example of dying Phragmites stems, about two weeks after transplantation.

We were thus not able to test our original hypothesis. However, we did accidentally discover a very interesting result: Over the course of the summer, the entire enclosed area filled in with vegetation (primarily Phragmites with minor amounts of *Pluchea purpurascens*), while the surrounding mudflat remained unvegetated, as shown in Figure 8. We harvested the vegetation in a 40x40 cm quadrat and found a dry weight of 620 g m^{-2}, an impressive value. We believe that the enclosure provided protection from herbivory, leading to germination and growth of seed stock in the mud.

Figure 8. Photo from September 22, 2015, showing that the area protected by the orange fencing was highly vegetated, while the surrounding mudflat remained mostly unvegetated.

Conclusions

Our long-term monitoring of accretion and elevation change (objectives 1 and 2) continues to suggest that vegetated areas of the marsh – even areas that are adjacent to the expanding mudflat – are keeping up with sea-level rise. This may indicate that the marsh-destroying processes have not yet reached our plots. Nonetheless, the difference in elevation change between the healthy and degrading Phragmites plots (Figure 2, bottom) is large and growing, and suggests that there is a fundamental difference between the two areas in their resilience to sea-level rise.

Our organ experiment (objective 3) did not succeed in its original objective, but did reveal an unexpected and potentially ground-breaking result: Recovery of vegetation in the mudflat appears to be limited by herbivory, perhaps by the Canada geese (*Branta canadensis*) often seen on the site. This suggests that more widespread protection from herbivory might allow the marsh to recover.

Acknowledgments

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