4-2017

Influence of Nutrient Availability and Sediment Supply on Productivity of Spartina patens

Shannon Matzke

Recommended Citation

Matzke, Shannon, "Influence of Nutrient Availability and Sediment Supply on Productivity of Spartina patens" (2017). *Honors Theses*. 998.
https://repository.lsu.edu/honors_etd/998

Influence of Nutrient Availability and Sediment Supply on Productivity of *Spartina patens*

by

Shannon Matzke

Undergraduate honors thesis under the direction of

Dr. Tracy Quirk

Department of Oceanography and Coastal Sciences

Submitted to the LSU Roger Hadfield Ogden Honors College in partial fulfillment of
the Upper Division Honors Program.

April, 2017

Louisiana State University
& Agricultural and Mechanical College
Baton Rouge, Louisiana

Abstract

Coastal salt marshes are productive ecosystems that provide ecological services such as wave attenuation and carbon sequestration and are a nursery for estuarine animals. However, sea-level rise, subsidence, and erosion are contributing to the loss of salt marshes in many areas of the world. Approximately half of the original wetlands in the United States have been lost in the last 200 years. Along low-lying deltaic coasts, human management of river channels such as the installation of levees have changed the natural magnitudes and rates of coastal processes, such as flooding and sedimentation. In one of the largest deltaic systems in the world, the Mississippi River delta, wetland loss from subsidence and sea-level rise has been accelerated and is associated with human impacts to the river and surrounding marshes. One of the proposed restoration strategies to mitigate wetland loss is the implementation of river diversions to introduce both freshwater and sediment to subsiding marshes. A concern is that diversions will also introduce high nutrient loads to the marshes, which may alter rates of plant productivity, and ultimately marsh accretion rates. Here, we performed a greenhouse experiment to determine the effects of nutrient enrichment, sedimentation, and their interaction on above- and belowground productivity of the marsh grass, *Spartina patens*. Cores of *S. patens* roots were collected at Bayou Sauvage National Wildlife Refuge and transferred to the LSU greenhouses where a closed tidal system was used to create a split-plot design testing the effects of the treatments listed above. *Spartina patens* exhibited nearly double the height, stem density, and aboveground biomass in nutrient treatments compared to controls. Belowground biomass was also stimulated by nutrient additions. Live belowground biomass consisting of stem bases, rhizomes, and large roots, was greater in response to nutrients at almost every depth interval. Nutrient enrichment enhanced the growth of roots outside of the pot by two to six times that of controls. Sedimentation did not affect above- or belowground productivity. These results suggest that under these experimental conditions, not unlike those that would be experienced with a sediment diversion from the Mississippi River, *S. patens* above- and belowground productivity increased in response to nutrient enrichment.

1. Introduction

1.1. Louisiana salt marshes

Saline marshes are one of the most productive ecosystems per unit area on the planet, rivaling the productivity of tropical rainforests (Long and Mason, 1983). Much of the annual productivity of marsh vegetation is belowground in the form of roots and rhizomes (Rasse et al., 2005). As roots and rhizomes die, the organic matter serves as an electron donor for microbial activity, fueling nutrient cycling, and if not decomposed readily, accumulates in the soil as stored carbon, contributing to marsh accretion and potentially elevation change (Anisfeld et al., 1999; Bricker-Urso et al., 1989; Callaway et al., 1997; Chmura and Hung, 2004; Hatton et al., 1983; Huxham et al., 2010; McCaffrey and Thomson, 1980; Nyman et al., 1993; Nyman et al., 2006; Ouyang et al., 2016; Turner et al., 2000). Louisiana has approximately 15,000 km^2 of coastal marsh, which accounts for 40% of coastal marsh area in the United States. However, this vast area of marshland has been reduced from approximately 19,500 km^2 (Couvillion et al., 2011) due to both to rising sea level and land subsidence, exacerbated by human activities, which have reduced river input of freshwater and sediment. It has been predicted that unless allochthonous sediment is re-introduced to the coast, an additional 10,000-13,500 km^2 will be submerged by year 2100 (Blum and Roberts, 2009). Historically, the Mississippi River delta has changed location over thousands of years with the natural switching of the river course and delta lobe formation, but since the creation of levees to protect residents from flooding, the river has been confined to one path that has created the “Birdsfoot Delta.” This action has deprived other coastal areas from the sediment that is vital to the health of marshes. One strategy for coastal restoration is to increase sediment supply to coastal systems by diverting sediments from the Mississippi and Atchafalaya rivers into degrading marshes. However, as the Mississippi watershed drains approximately 33% of the United States including productive agricultural areas, sediment diversions will also introduce nutrient-laden freshwater into vulnerable coastal salt marsh systems. While nutrients are necessary for maintenance and growth of all organisms, there is concern because of the importance of belowground plant productivity to soil organic matter and accretion and the potential for plants to reduce their root growth when supplied with abundant nutrients (Grime, 1977). In addition, nutrient input to coastal ecosystems has increased as fertilizer use has become more widespread to support the growing human population. This could become a problem for marshes as eutrophication may lead to altered community structure and decreased biodiversity (Johnson et al., 2016).

1.2. Effects of nutrients on salt marsh productivity

Nutrients are essential to salt marsh productivity, and the aboveground productivity of many salt marsh species is limited primarily by nitrogen and secondarily by phosphorous availability (Caffrey et al., 2007; Sundareshwar et al., 2003; Tobias et al., 2014; Wijnen and Bakker, 1999). An increase in nutrients may be beneficial to plant productivity aboveground (Delaune et al., 2005; Valiela et al., 1976; Wigand et al., 2004); however, the effect of nutrients on belowground biomass is less clear (Anisfeld and Hill, 2012; Darby and Turner, 2008a; Deegan et al., 2012; Haines and Dunn, 1976). In addition, most fertilization studies have been conducted in the low marsh zone, dominated by *Spartina alterniflora*. For example, Deegan et al. (2012) found that belowground biomass of *Spartina alterniflora* along the creekbank averaged 387 g/m^2 when nutrients were added to tidal water as opposed to 579 g/m^2 for plants with no added nutrients. However, Anisfeld and Hill (2012) applied fertilizer during the ebb portion of neap tides to allow time for the fertilizer to dissolve, and neither nitrogen nor phosphorous fertilization led to a decrease in belowground biomass. In a Louisiana marsh, nitrogen additions were shown to have no effect on belowground biomass when compared to controls, but the addition of phosphorous led to a decrease in live belowground biomass (Darby and Turner, 2008a). In a controlled environment, seedlings of *S. alterniflora* that collected along a sandy beach and transplanted with sand to a greenhouse had higher shoot-to-root ratios but lower shoot-to-rhizome weight ratios compared to controls (Haines and Dunn, 1976), and the favorable allocation of resources to rhizomes as opposed to roots as nutrient levels increase may allow for greater carbohydrate storage and vegetative propagation but decreases plants biomass at deeper depths in the soil which is where structurally important roots are found. Although the consequence of nutrient enrichment on marsh plant productivity is not fully understood, one study has shown that nutrient loading reduces geomorphic stability leading to wider creeks and more unvegetated mud along the creekbank (Deegan et al., 2012).

1.3. Sedimentation in salt marshes

While many marshes have been subject to higher nutrient loading over the last 50 – 100 years, sediment loads from coastal rivers have also been altered. Human management activities (e.g. levees and dams) can prevent sediment from reaching marshes, which with sea level rise, require regular sediment supply. In the United States, 25 out of 61 rivers that drain to the Atlantic and Gulf coasts have experienced a decline in suspended sediment concentrations (Weston, 2014), and recent declines in wetland extent can be attributed to this lack of sediment supply. Sediments are necessary for marshes to keep pace with sea level rise and to provide a substrate in which plants can grow and thrive (Slocum et al., 2005; Kirwan and Megonigal, 2013). Mineral sediments are also beneficial to both plant canopy cover and aboveground biomass production because soil mineral matter increases soil fertility and marsh elevation, thereby alleviating nutrient deficiency, soil fertility, and sulfide stress from sea water (Mendelssohn and Kuhn, 2003). The effect of sedimentation on belowground biomass productivity is not well established. In a study of marsh plants treated with excess sediments, treated plants had similar belowground productivity and biomass as plants in natural treatments without the addition of sediment (Wigand et al., 2016). In areas with limited sediment supply in particular, marsh elevation can be directly influenced by belowground productivity contributing to peat and organic matter accumulation. When compared with natural marshes, marshes at an elevation 2-11 cm above mean sea level treated with a sediment slurry addition were more resilient even 15 years after restoration (Stagg and Mendelssohn, 2011). While sediment additions will likely allow for favorable plant growth, there is a threshold beyond which increased sediment supply is no longer beneficial. An 11 cm elevation above mean sea level has been shown to be the limit above which marsh stability begins to decrease due to dry conditions caused by lack of flooding (Mendelssohn and Kuhn, 2003). With the addition of mineral sediment may also come the ability of coastal marshes to accumulate more carbon, as Unger et al. 2016 found a correlation between increased mineral sedimentation and increased carbon accumulation.

Marsh subsidence and loss has prompted restoration strategies such as the beneficial use of dredged material and sediment diversions from leveed rivers (Peyronnin et al., 2013). Along the Gulf Coast of Louisiana, between 1932 and 2010, 5000 km^2 of marsh area was lost, equaling an annual rate of 43 km^2 per year (Couvillion et al., 2011). In response to the loss of marsh area, a large effort is underway to increase sediment availability to subsiding marshes. Sediment diversions will supply coastal marshes with mineral sediments, but it is unclear how the combined effect of both high nutrient and sediment loads will affect marsh plant productivity.

1.4. *Spartina patens*

Spartina patens is a perennial mid-high elevation salt marsh macrophyte. Above- and belowground biomass of *S. patens* is greatest with minimal inundation, 5.8-3.3 % of the time, positioned at 49-64 cm (North American Vertical Datum), and decreases exponentially with increased flood duration (Snedden et al., 2015). With its dense aboveground growth and branching root system, *S. patens* is a species that has become increasingly popular for use in restoration; however, it is vastly understudied compared to the low marsh species, *Spartina alterniflora*. More research is needed to understand how *S. patens* responds to human related impacts such as high nutrient loading and sediment additions. Because nutrient uptake is tightly regulated by redox conditions (Bandyopadhyay et al., 1993), and sediment deposition may increase the redox potential in surface sediments, plant response to nutrient addition may also be influenced by sediment availability. To examine the effect of nutrients and sediment availability on above- and belowground production of *S. patens*, a controlled greenhouse study was implemented. To test the hypothesis that plants receiving both nutrient and sediment additions are more productive than those receiving only one or neither treatment, aboveground height and stem density were monitored weekly and above- and belowground biomass was measured following a five-month study period.

2. Methods

2.1 Field Collection

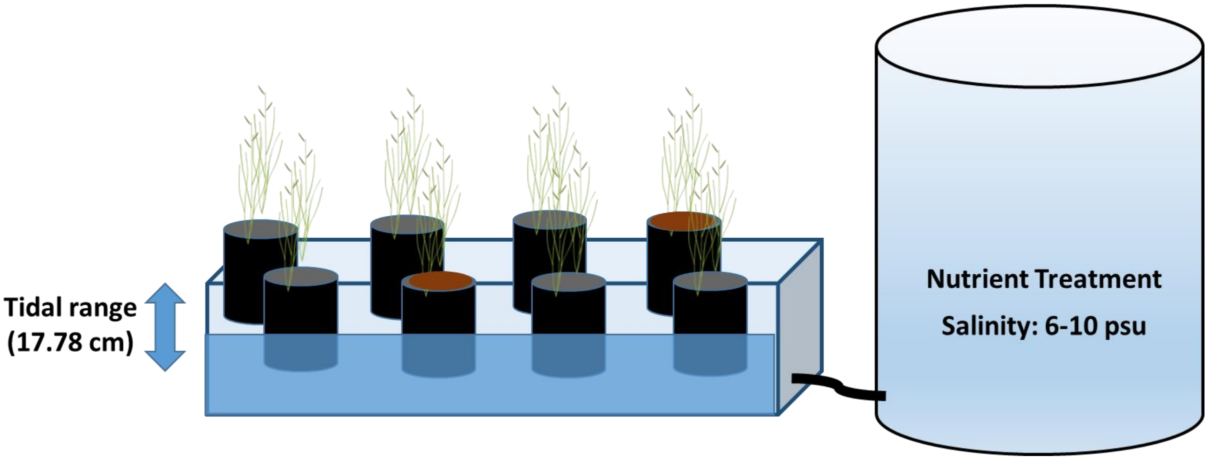
Plant collection occurred at Bayou Sauvage National Wildlife Refuge, New Orleans, Louisiana. The largest urban refuge in the United States, the Refuge, established in 1990, was formed by the abandoned St. Bernard delta of the Mississippi River and consists of silt and sediments deposited by the River (USFWS, 2015). The refuge has approximately 4,500 hectares of brackish marsh, where we collected cores of *Spartina patens* on three dates: 16 February 2016, 16 April 2016 and 24 June 2016. Forty cores (7.5 cm width x 10 cm depth) were collected in total using an aluminum core barrel with a sharpened bottom edge. The location of each core was randomly chosen within *S. patens* dominated areas. Sediments were collected from the bottom of an adjacent waterway during each collection. Cores were then potted in 897.26 cm^3 pots in-filled with sediment collected in tidal channels adjacent to the plant collection area. All aboveground biomass was clipped at the sediment surface.

2.2 Greenhouse Study

The greenhouse was located on the Louisiana State University campus in Baton Rouge, LA. The greenhouse had a series of eight tanks where a tidal control system created a consistent semi-diurnal tide with a 17.78 cm tidal range. The soil surface of every pot was stationed 3.36 cm below the high tide and 14.5 cm above the low tide, and thus plants were flooded every tide (12 hrs). Pot rims were situated 2.9 cm above soil surface. Nyman et al. (2009) found that in Louisiana coastal brackish marshes dominated by *Spartina patens*, water depth is, on average, 11 cm below the marsh surface, with daily high water averaging near the marsh surface. Thus our treatments were placed at an elevation below that of the average *S. patens* marsh in order to simulate a suboptimal growth condition that would be found in a subsiding marsh (water depth was on average 9 cm below sediment surface). To create a brackish salinity of ~6 psu, 11,400 g of salt (Instant Ocean™) was added to 1,900 L of water in each tank. Water was added periodically to counter loss through evapo-transpiration.

2.2.1. Treatments

A split-plot design was used for two experimental treatments of elevated nutrients and sediment addition. Nutrients were added to four of the eight tidal tanks while four tanks received no nutrient additions and were considered control tanks (whole-plot factor). Each tank-carboy unit was a closed system in which water flowed to and from the tank with the flood and ebb of the tide. Sediment was added to a subset of pots within each nutrient (n = 10) or control treatment (n = 14) (sub-plot factor).



Nutrients - Four of the eight tidal tanks received nutrient additions, while four tanks were maintained as controls. Rather than adding fertilizer pellets to the soil surface of the plants, slow release fertilizer was ground for faster release and added to the tanks with 1,900 L of water. This was done to provide a natural flow path for nutrient enrichment, from the water to autotrophs (e.g., algae in the water and soil surface) and to plants. Analysis of fertilizer before application showed that this fertilizer contained 59.10 mg/L NH_4^+. On 28 September 2016, we added Green-Gro™ fertilizer with an N-P-K of 33-0-0 (30.4 g) and 8-24-24 (7.6 g). This level of fertilization was effective in increasing nutrient concentrations in the water (Table 1).

Sediment - Sediment additions (2 cm/pot = 352.25g) of sterile river silt were applied monthly for four months (n=24). To account for pot space, when sediment was added, pot rims (approximately 2.95 cm) were added to the sediment addition pots. Average soil surfaces ranged from 3.36 cm below high tide and 14.5 cm above low tide for control pots and 0.01 cm below high tide and 17.85 cm above low tide for sediment additions. Rim height was below high tide for control pots, but the additions of rims on pots with added sediment brought the rim height to about 2.49 cm above high tide. However, soil height was still below high tide, and plants were flooded at high tide due to openings in the pots.

February plants received sediment additions on 6 March, 6 April, 8 June, and 25 October 2016. April plants received additions on 8 June, 25 October, and 1 and 28 December 2016. June plants received additions on 25 October, 1 and 28 December 2016, and 31 January 2017.

2.2.2. Measurements

Nutrient concentration – Water column nutrients was tested one time 3 weeks after fertilizer application. Water (60 mL) was filtered through a 0.45 µm glass fiber filter, and frozen prior to analysis of nitrate, ammonium and phosphate. Nitrate, ammonium and phosphate were analyzed using an autoanalyzer (OI Analytical Flow Solutions IV).

Plant height- Shoot height of all stems in each pot was measured weekly over the 20-week study period by measuring height from the soil surface to the tip of the tallest leaf of each stem. No plants flowered during experiment. For stems that had received additions of sediment, the total height (cm) of added sediment was added to the height observed during stem measurement.

Stem density - Stem density (# stems/pot) was collected once per week over the 20-week study period.

Aboveground shoot growth rates- Small stems (n=2 per pot when applicable) were flagged in order to monitor growth rates of individual stems. Growth rate of stems was monitored weekly for 15 weeks. As with measurements described above in *Plant Height,* height of added sediment was added to observed height for sediment treated plants. To account for differences in initial stem height, relative growth rates were calculated for each stem by dividing by subsequent heights as well as the change in height by the initial height.

Plant senescence- To examine the potential effect of elevated nutrients, sediment addition, and their combination on the degree of senescence, the number of dead stems was monitored weekly, from 4 November 2016 – 20 February 2017.

Biomass- All plants were harvested between 20 and 24 February 2017.

Aboveground biomass was clipped at the soil surface. Final shoot height and density were determined and all live and dead biomass was dried at 60°C to a constant weight. Based on the area of each pot, biomass was converted to a square-meter basis. Again, height of added sediment was added to heights of stems under sediment treatment, as stem bases were covered as sediment was added.

For belowground biomass measurement, remaining soil was cut into 2-cm depth segments and stored in a refrigerator until processed. Excess roots, defined as root material protruding from each pot, were collected, dried and weighed for biomass determination. Each 2-cm soil depth segment was placed into stacked sieves of 2 and 0.71 mm, rinsed, and belowground biomass was further sorted into three categories: live rhizomes, large roots, coarse dead roots and organic matter, and fine roots (live and dead) and organic matter. Live rhizomes and roots were differentiated by sight, coarse dead and coarse organic was anything trapped on the 2 mm sieve, and fine roots and organic matter was anything trapped on the 0.71 mm sieve. Biomass was dried at 60°C for two days and weighed.

Soil - For soil carbon and nitrogen analysis, a 2.1 cm^2 core was collected from each pot and divided into 5-cm depth intervals. Each segment was bagged and kept in a refrigerator until CN analyses were conducted on a COSTECH CHN analyzer. Each 5 cm interval was weighed while wet, dried at 60°C and weighed again, ground until homogeneous. Soil samples were then weighed out to approximately 1 g, burned at 550°C for 6 hours, and weighed again for loss on ignition (LOI; percent organic matter) determination.

2.3 Statistical Analysis

Data were analyzed using JMP SAS (V8). A 3-way split plot Analysis of Variance (ANOVA) was used with nutrients as the whole plot factor and sediment additions as the sub-plot factor. Nutrients and sediment additions were considered main effects, nutrients were nested within tanks and a random effect. The main effects and interaction between nutrient treatment and sediment addition was tested on dependent variables of shoot height, aboveground biomass, root:shoot ratio, belowground biomass (composite, at different depths, and different types of biomass), and LOI. Data were tested for normality using Shapiro-Wilk test and were transformed to meet the assumptions of ANOVA. The only aboveground data that were found to be normal were stem height, all other data were transformed for statistical analyses. A logit transformation was performed on LOI data. Data from each collection were analyzed separately unless the ANOVA showed that there were no statistically significant differences.

3. Results

3.1 Aboveground

3.1.1. Height

Spartina patens stems responded positively to nutrient treatments throughout the experiment, and treated stems had a larger rate of growth than controls (Fig. 1a). At the conclusion of the study, stems were an average of 87.7±3.4 cm when grown with elevated nutrient concentrations compared to 6±4.5 cm when plants received no nutrient addition (Fig. 2). Addition of sediment did not have an effect on plant height, nor did they negate the effect of nutrients.

3.1.2. Density

Plants treated with nutrients had faster rates of density (stems per pot) increase over the study than controls for both live stems and total (live + dead stems). Total density was driven by rate of live stem density increase. Total and live density exhibited similar trends, so only total density is plotted here (Fig. 1). At the end of the study, there were 45±5.8 stems per pot in the nutrient enriched compared to 14±1.43 stems per pot in control tanks (Figs. 3 a,b). Plants that received sediment additions had an average of 26±5.3 live stems per pot compared to 33±5.63 stems per pot for controls that received no addition of sediment (Fig. 4). There was no significant interaction between nutrients and sediment on live stem density.

3.1.3. Biomass

For both live and total (live + dead) aboveground biomass, nutrients had a significant effect compared to controls (Figs. 5 a,b). Nutrient treated plants had an average of 24.24±2.97 g of live biomass and 27.68±3.24 g of total biomass per pot compared to controls with 6.83±1.11 g of live and 11.8±1.69 g of total biomass per pot. Sediments did not affect aboveground biomass.

3.2. Belowground

3.2.1. Composite Biomass

At the end of the study, total belowground biomass was greater in the nutrient treatment than in controls with or without sediments added for both April and June collections (Fig. 6 a,b).

3.2.2. Live Biomass by Depth

When compared to controls, nutrient treated plants had more live biomass at all but the 8-10 cm depth interval (Fig. 7 a,b). Nutrient treated plants had live roots growing out of the pot such that this biomass was nearly six times greater than that from plants without nutrient enrichment.

3.2.3. Biomass in Added Sediment

New root growth into sediment added during the experiment was stimulated by nutrients in both April and June collections (Fig. 8 a,b). The combined treatment (sediments + nutrients) promoted higher total biomass compared controls, suggesting that *S. patens* was better able to utilize new sediment supply when nutrients are added.

3.3. Soil Organic Matter

Percent organic matter (LOI) with depth did not differ significantly among treatments.

4. Discussion

4.1. Relationship between nutrients and *Spartina patens* productivity

Spartina patens responded positively to nutrient enrichment at the levels used in this study, both above- and belowground. While many studies have found the stimulation of aboveground productivity by increasing nutrient availability, the effect of nutrient enrichment on belowground biomass is unclear. Some of the factors that may have led to our results include the mechanism by which we created a nutrient treatment, the amount of nutrients added, and the greenhouse method compared to a standing crop method. Specifically, we ground up slow release fertilizer and added it to water in a tidal system, which allowed the nutrients to dissolve and distribute evenly throughout the water column, as would be seen in a natural environment. This may allow for nutrient uptake by algae in the water column and on the soil surface, thereby transferring inorganic nutrients to the organic pools, where it can then be slowly mineralized. It is possible that mode of transport of nutrients is an important factor in plant uptake, so previous studies that created enriched conditions using dry fertilizer sprinkled on the surface of the marsh may not accurately portray how salt marshes respond to nutrient additions (Darby and Turner, 2008a; Darby and Turner 2008b; Gallagher, 1975; Graham and Mendelssohn, 2014; Graham and Mendelssohn, 2016; Haines, 1979; Valiela et al., 1976; Wigand et al., 2004).

The amount of fertilizer that we used to create our nutrient treatment was 5.6 mg/L nitrogen (in the form of NH_4^+) and 0.96 mg/L phosphorous (in the form of PO_4^{3-}). Many studies use nutrient levels that are much higher than what would be seen in a realistic setting, and their results have shown that nutrient addition can cause belowground biomass loss. These studies show that there is a threshold nutrient level beyond which belowground plant productivity declines. Our results indicate that the concentrations used in this study (Table 1) are not above this threshold. Our findings show that nutrients that would enter coastal marshes as a result of sediment diversions will increase plant productivity above- and belowground, but it is important to note that extreme nutrient input, as seen in previous studies, is not an acceptable strategy for marsh recovery.

Most previous studies have used the standing crop method by which established marshes were fertilized (Anisfeld and Hill, 2012; Darby and Turner, 2008a; Darby Turner 2008b; Deegan et al., 2012; Gallagher, 1975; Graham and Mendelssohn, 2014; Graham and Mendelssohn, 2016; Haines, 1979; Hunter et al., 2008; Langely et al., 2009; Morris and Bradley, 1999; Nelson and Zavaleta, 2012; Valiela, 1976; Wigand et al., 2004); however, here we planted each collected core in unvegetated sediment. This provides plant roots and rhizomes more space to grow and spread and is representative of created marshes or sediment diversion sites in which new sediment is supplied, allowing marsh grasses ample space to utilize any nutrients that may be present.

We are aware of no other studies that have examine nutrient and sediment availability and their interaction on marsh plant productivity.

4.2. Conditions under which sediment affect productivity

Although sediment addition did not play a role in productivity of *Spartina patens* in this study, it is expected that marsh grasses in the field will be stimulated by the addition of mineral sediments. Excess sediments will raise the marsh surface, reducing the stresses of flooding and anoxia on vegetation. In our greenhouse experiment, *S. patens* plants had mechanisms to escape stresses of low redox potential so that their low elevation was not a limiting factor to growth. Upon harvesting the plants, roots were consistently concentrated along the edges of each pot. More long term field studies should be done to assess how marsh grasses respond to excess sediment while undergoing the stresses found in a natural environment. This pattern of root growth could also be responsible for the lack of differences in the LOI data. The cores used for LOI analysis were taken between the center and the edge of each pot. It is possible that insufficient root biomass was present in this location for representative organic matter analyses.

5. Conclusion

Aboveground growth (height, stem density, and biomass) of *Spartina patens* was stimulated by the addition of nutrients, but sediment addition had no effect on aboveground productivity. Preliminary data show that belowground live biomass was also stimulated by nutrient additions, even at deeper depths. Below 10 cm depth, nutrient treated plants had live biomass that was double to six times the amount found in control plants with no nutrients added. We believe that this is due both to the realistic nutrient concentrations that were used to treat the plants and also to the dissolved nutrient approach that would be seen in nature rather than distributing fertilizer pellets on the soil surface. Importantly, nutrients played a role in the added sediments where there was greater fine biomass, signifying new root growth, when plants were in nutrient-enriched tanks. These results suggest that the additions of nutrients to coastal wetlands through sediment diversions will not only allow for more root growth at deeper depths providing structure to marshes, but also that they will help plants to utilize the added sediment for new root growth. Although the belowground data are preliminary, we predict that similar trends will exist upon the completion of processing and statistical analyses. We predict that these results are applicable to coastal salt marsh species other than *S. patens*, but that *S. patens* specifically will be a beneficial species to coastal restoration projects such as sediment diversions.

Literature Cited

Anisfeld, S.C., Tobin, G.B., 1999. Sedimentation rates in flow-restricted and restored salt marshes in Long Island Sound. Estuaries. 22, 231-244.

Anisfeld, S.C., Hill, T.D., 2012. Fertilization effects on elevation change and belowground carbon balance in a long island sound tidal marsh. Estuaries and Coasts. 35, 201-211.

Bandyopadhyay, B.K, Pezeshki, S.R., Delaune, R.D., Lindau, C.W., 1993. Influence of soil oxidation-reduction potential and salinity on nutrition, N-15 uptake and growth of Spartina patens. Wetlands. 13, 10-15.

Blum, M.D., Roberts, H.H., 2009. Drowning of the Mississippi Delta due to insufficient sediment supply and global sea-level rise. Nature Geoscience. 2, 488-491.

Bricker-Urso, S., Nixon, S.W., Cochran, J.K., Hirschberg, D.J., Hunt, C., 1989. Accretion rates and sediment accumulation in Rhode Island salt marshes. Estuaries. 12, 300-317.

Caffrey, J.M., Murrell, M.C., Wigand, C., McKinney, R., 2007. Effect of nutrient loading on biogeochemical and microbial processes in a New England salt marsh. Biogeochemistry. 82, 251-254.

Callaway, J.C., DeLaune, R.D., Patrick Jr., W.H., 1997. Sediment accretion rates from four coastal wetlands along the Gulf of Mexico. Journal of Coastal Research. 13, 181-1997.

Chmura, G.L., Hung, G.A., 2004. Controls on salt marsh accretion: a test in salt marshes of Eastern Canada. Estuaries. 27, 70-81.

Couvillion, B.R., Barras, J.A., Steyer, G.D., Sleavin, W., Fischer, M., Beck, H., Trahan, N., Griffin, B., Heckman, D., 2011. Land area change in coastal Louisiana from 1932 to 2010: U.S. Geological Survey Scientific Investigations Map 3164, scale 1:265,000, p. 12. pamphlet.

Darby, F.A., Turner, R.E., 2008a. Below- and Aboveground Biomass of *Spartina alterniflora:* Response to Nutrient Addition in a Louisiana Salt Marsh. Estuaries and Coasts. 31(2), 326-334.

Darby, F.A., Turner, R.E., 2008b. Effects of eutrophication on salt marsh root and rhizomes biomass accumulation. Marine Ecology Process Series. 363, 63-70.

DeLaune, R.D., Pezeshki, S.R., Jugsujinda, A., 2005. Impact of Mississippi River freshwater reintroduction on *Spartina patens* marshes: responses to nutrient input and lowering of salinity. Wetlands. 25, 155–161.

Deegan, L., Johnson, D.S., Warren, R.S., Peterson, B.J., Fleeger, J.W., Fagherazzi, S., Wollheim, W.M., 2012. Coastal eutrophication as a driver of salt marsh loss. Nature. 490, 388–392.

Gallagher, J.L., 1975. Effect of an ammonium-nitrate pulse on growth and elemental composition of natural stands of *Spartina alterniflora* and *Juncus roemerianus.* American Journal of Botany. 62, 644-648.

Graham, S.A., Mendelssohn, I.A., 2014. Coastal wetland stability maintained through counterbalancing accretionary responses to chronic nutrient enrichment. Ecology. 95, 3271-3283.

Graham, S.A., Mendelssohn, I.A., 2016. Contrasting effects of nutrient enrichment on below-ground biomass in coastal wetlands. Journal of Ecology. 104, 249-260.

Grime, J.P., 1977. Evidence for the Existence of Three Primary Strategies in Plants and Its Relevance to Ecological and Evolutionary Theory. The American Naturalist. 111(982), 1169-1194.

Haines, B.L., 1979. Growth dynamics of cordgrass, *Spartina alterniflora* Loisel, on control and sewage sludge fertilized plots in a Georgia salt marsh. Estuaries. 2, 50-53.

Haines, B.L., Dunn, E.L., 1976. Growth and resource allocation responses of *Spartina alterniflora loisel* to three levels of NH4-N, Fe and NaCl in solution culture. Botanical Gazette. 137, 224–230.

Hatton, R.S., DeLaune, R.D., Patrick Jr., W.H., 1983. Sedimentation, accretion, and subsidence in marshes of Barataria Basin, Louisiana. Limnology and Oceanography. 28, 494-502.

Hunter, A., Moris, N.M.B., Lafabrie, C., Cobrian, J., 2008. Effects of nutrient enrichment on *Distichlis spicata* and *Salicornia bigelovii* in a marsh salt pan. Wetlands. 28, 760-775.

Huxham, M., Langat, J., Tamooh, F., Kennedy, H., Mencuccini, M., Skov, M.W., Kairo, J., 2010. Decomposition of mangrove roots: Effects of location, nutrients, species identity and mix in a Kenyan forest. Estuarine, Coastal and Shelf Science. 88(1), 135-142.

Johnson, D.S., Warren, R.S., Deegan, L.A., Mozdzer, T.J., 2016. Saltmarsh plant responses to eutrophication. Ecological Applications. 26(8), 2649-2661.

Kirwan, M.L., Megonigal, J.P., 2013. Tidal wetland stability in the face of human impacts and sea-level rise. Nature. 504, 53-60

Langley, J.A., McKee, K.L., Cahoon, D.R., Cherry, J.A., Megonigal, J.P., 2009. Elevated CO_2 stimulates marsh elevation gain, counterbalancing sea-level rise. Proceedings of the National Academy of Sciences of the United States of America. 106, 6182-6186.

Long, S.P., Mason, C.F., 1983. Saltmarsh ecology. Blackie & Son Ltd, Glasgow, p.125.

McCaffrey, R.J., Thomson, J., 1980. A record of the accumulation of sediment and trace metals in a Connecticut salt marsh. Advances in Geophysics. 22, 165-236.

Mendelssohn, I.A., Kuhn, N.L., 2003. Sediment subsidy: effects on soil-plant responses in a rapidly submerging coastal salt marsh. Ecological Engineering. 21(2-3), 115-128.

Morris, J.T., Bradley, P.M., 1999. Effects of nutrient loading on the carbon balance of coastal wetland sediments. Limnology and Oceanography. 44, 699-702.

Nelson, J.L, Zavaleta, E.S., 2012. Salt marsh as a coastal filter for the oceans; changes in function with experimental increases in nitrogen loading and sea-level rise. PLoS ONE. 7, e38558.

Nyman, J.A., DeLaune, R.D., Roberts, H.H., Patrick Jr., W.H., 1993. Relationship between vegetation and soil formation in a rapidly submerging coastal marsh. Marine Ecology Progress Series. 98, 269-279.

Nyman, J.A., La Peyre, M.K., Caldwell, A., Piazza, S., Thom, C., Winslow, C., 2009. Defining restoration targets for water depth and salinity in wind-dominated *Spartina patens* (Ait.) Muhl. coastal marshes. Journal of Hydrology. 676(3-4), 327-336.

Nyman, J.A., Walters, R.J., Delaune, R.D., Patrick Jr., W.H., 2006. Marsh vertical accretion via vegetative growth. Estuarine, Coastal and Shelf Science. 69(3-4), 370-380.

Ouyang, X., Yip Lee, S., Connolly, R.M., 2017. The role of root decomposition in global mangrove and saltmarsh carbon budgets. Earth-Science Reviews. 166, 53-63.

Rasse, D.P., Rumpel, C., Dignac, M-F., 2005. Is soil carbon mostly root carbon? Mechanisms for specific stabilization. Plant and Soil. 269(1), 341-356.

Peyronnin, N.S., Green, M., Richards, C.P., Owens, A., Reed, D., Groves, D., Chamberlain, J., Rhinehart, K., Belhadjali, K., 2013. Louisiana’s 2012 coastal master plan: overview of a science-based and publicly-informed decisionmaking process. Journal of Coastal Research Special Issue. 67, 1–15

Snedden, G.A., Cretini, K., Patton, B., 2015. Inundation and salinity impacts to above- and belowground productivity in *Spartina patens* and *Spartina alterniflora* in the Mississippi River deltaic plain: Implications for using river diversions as restoration tools. Ecological Engineering 81, 133-139.

Stagg, C.L., Mendelssohn, I.A., 2011. Controls on resilience and stability in a sediment-subsidized salt marsh. Ecological Applications. 21(5), 1731-1744.

Sundareshwar, P.V., Morris, J.T., Koepfler, E.K., Fornwalt, B., 2003. Phosphorus limitation of coastal ecosystem processes. Science. 299, 563-565.

Tobias, V.D., Williamson, M.F., Nyman, J.A., 2014. A Comparison of the Elemental Composition of Leaf Tissue of *Spartina Patens* and *Spartina Alternifora* in Louisiana’s Coastal Marshes. Journal of Plant Nutrition. 37, 1327-1344.

Turner, R.E., Swenson, E.M., Milan, C.S., 2000. Organic and inorganic contribution to vertical accretion in salt marsh sediments. Weinstein, M.P., Kreeger, D.A. (Eds.), Concepts and Controversies in Tidal Marsh Ecology, Kluwer Academic Publishers, Boston, 583-595.

Turner, R.E., 2010. Beneath the Salt Marsh Canopy: Loss of Soil Strength with Increasing Nutrient Loads. Estuaries and Coasts. 34(5), 1084-1093.

Unger, V., Elsey-Quirk, T., Sommerfield, C., Velinsky, D., 2016. Stability of organic carbon accumulating in *Spartina alterniflora*-dominated salt marshes of the Mid-Atlantic U.S. Estuarine, Coastal and Shelf Science. 182, 179-189.

U.S. Fish & Wildlife Service. (2015). *Bayou Sauvage National Wildlife Refuge* [Fact Sheet].

Valiela, I., Teal, J.M., Persson, N.Y., 1976. Production and dynamics of experimentally enriched salt marsh vegetation: belowground biomass. Limnology and Oceanography. 21, 245–252.

van Wijnen, H J., Barrer, J.P., 1999. Nitrogen and phosphorus limitation in a coastal barrier salt marsh: the implications for vegetation succession. Journal of Ecology. 87, 265-272.

Weston, N.B., 2014. Declining Sediments and Rising Seas: an Unfortunate Convergence for Tidal Wetlands. Estuaries and Coasts. 37, 1-23

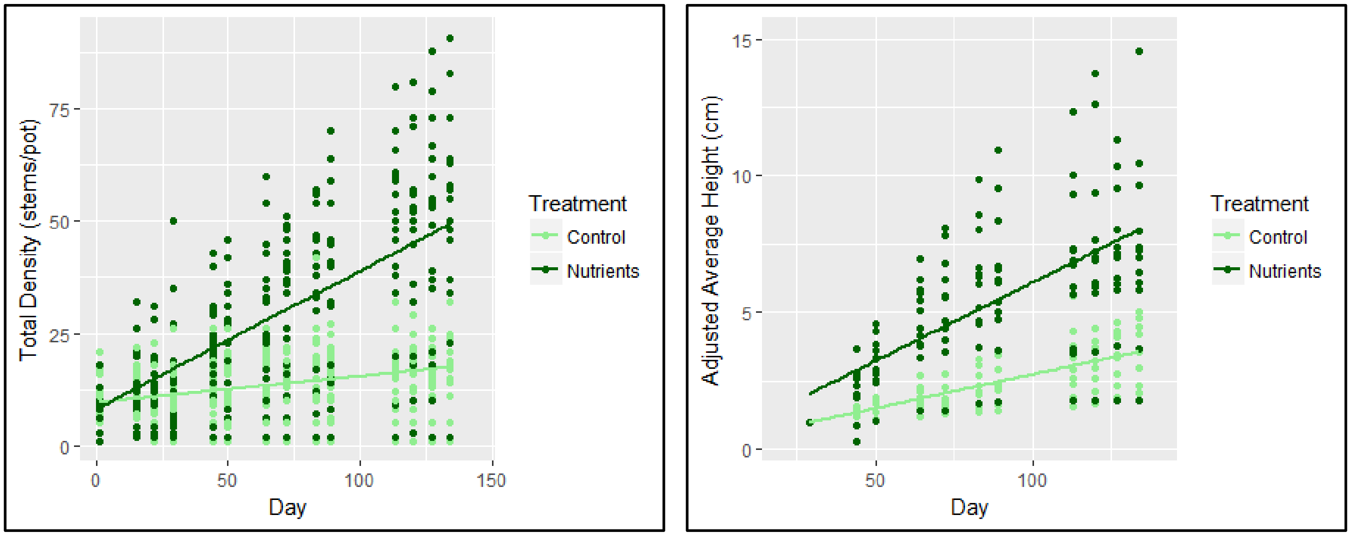
Wigand, C., Sundberg, K., Hanson, A., Davey, E., Johnson, R., Watson, E., Morris, J,. 2016. Varying Inundation Regimes Differentially Affect Natural and Sand-Amended Marsh Sediments. PLOS ONE. 11(10).

Wigand, C., Thursby, G.B., McKinney, R.A., Santos, A.F., 2004. Response of *Sparina patens* to dissolved inorganic nutrient additions in the field. Journal of Coastal Research. 45, 134-149.

Figures and Tables:

Table 1: Molar concentrations of nutrients in water samples collected on 18 October 2016 after 30.4 g of N-P-K 33-0-0 and 7.6 g of N-P-K 8-24-24 was added on 28 September 2016.

	Tank	TN (µM)	TP (µM)
Control	T-1	8.13	2.75
Control	T-2	2.03	4.21
Nutrient	T-3	219.8	2.55
Nutrient	T-4	173.9	4.38
Control	T-5	1.1	3.5
Nutrient	T-6	409.9	3.96
Control	T-7	5.9	2.56
Nutrient	T-8	439.6	2.36



Figures 1 a,b: Live and dead stems per pot (Fig. 1a, left) and adjusted average height per pot (Fig. 1b, right) over 20-week study period for control and nutrient treated plants. Nutrient treated plants had significantly higher growth rates than controls (t = -6.09, p = 0.0011).

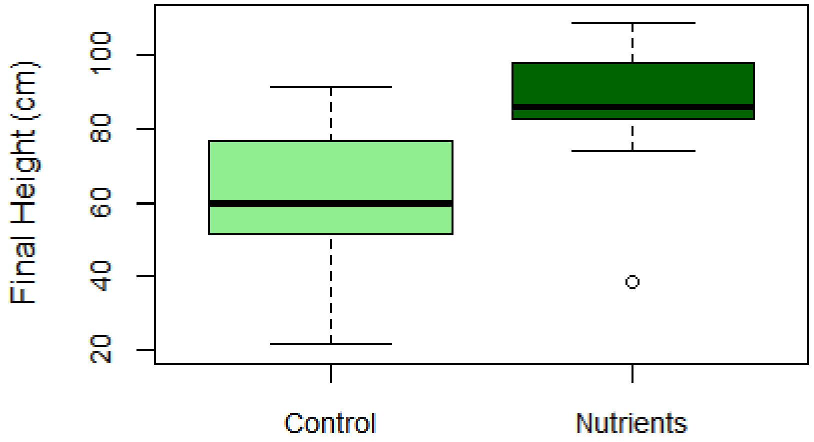
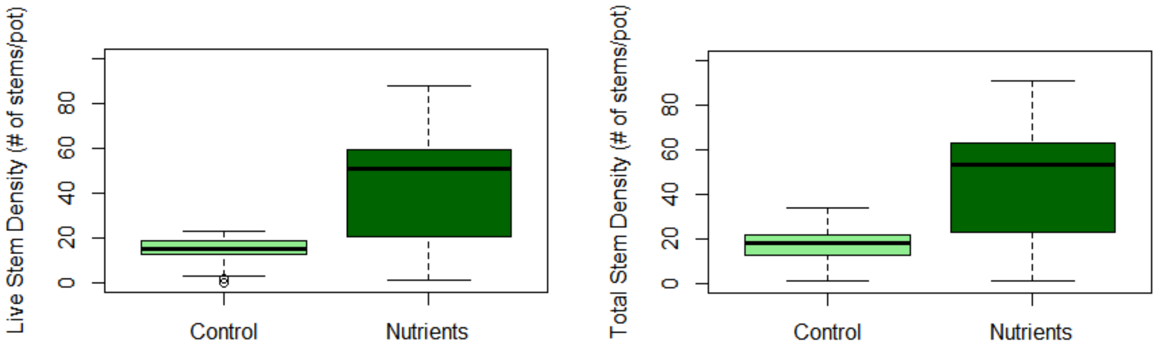


Figure 2: Average of 5 tallest stems at the time of final harvest for control plants with no nutrient additions and plants undergoing nutrient treatments. The nutrient treatment led to significantly taller stems than controls (t = -5.34, p = 0.048).



Figures 3 a,b: Stem density at time of harvest for live stems (Fig. 3a, left) and total stems (live + dead) (Fig. 3b, right). Plants had significantly more live stems in treatment versus control pots (t = -5.15, p = 0.0024) and more stems overall in treatment versus control pots (t = -4.74, p = 0.0037).

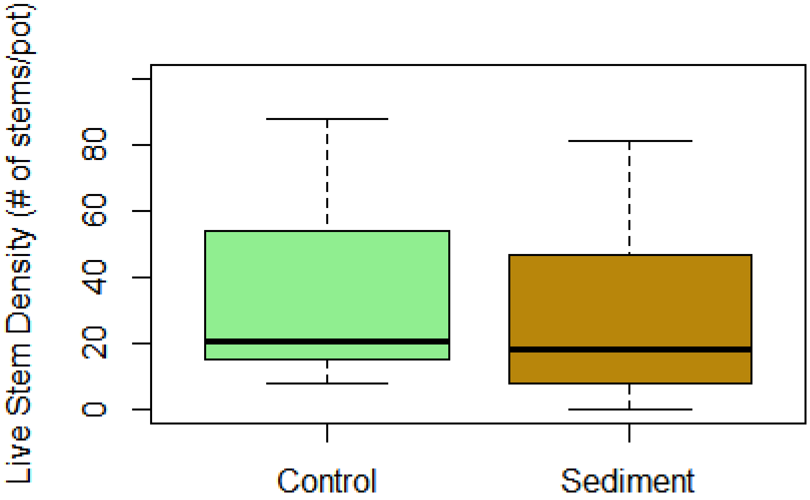
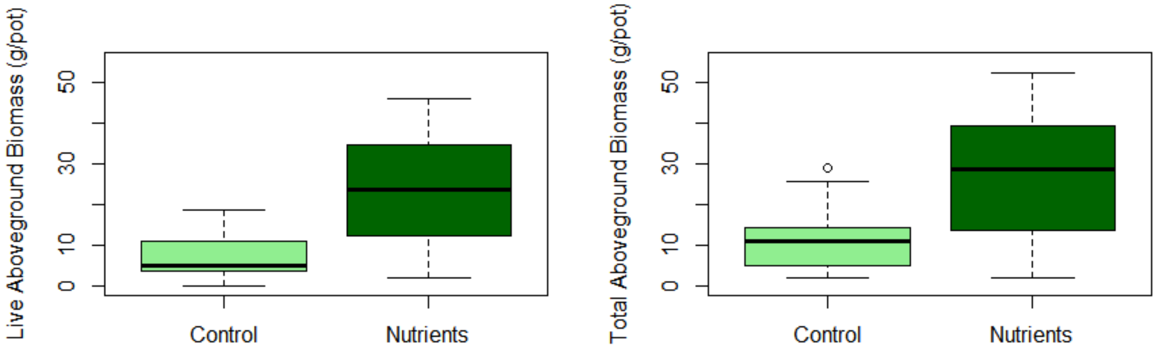
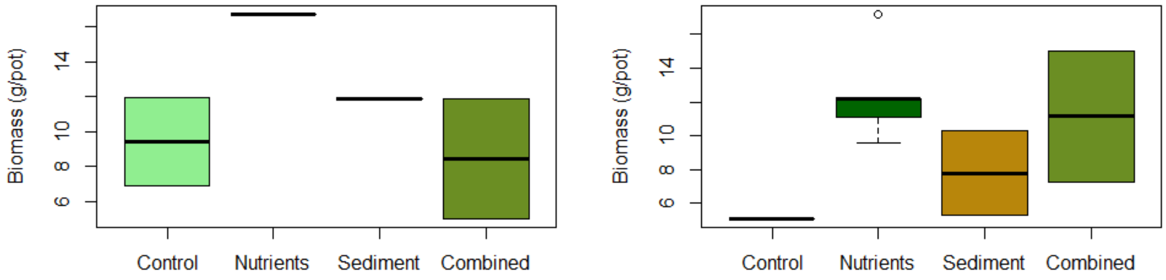


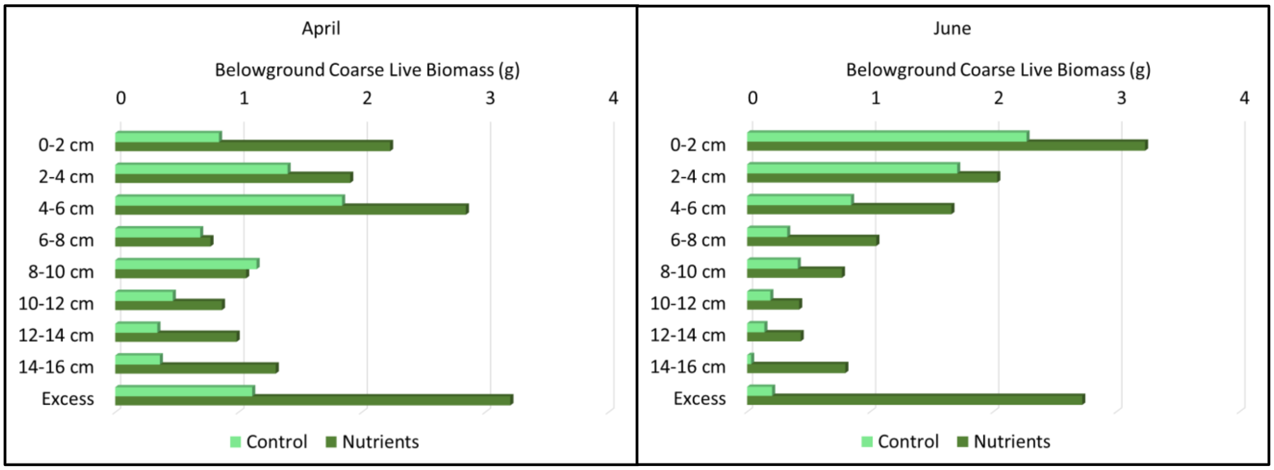
Figure 4: Live stem density at time of harvest was significantly less for plants that underwent sediment additions than for controls with no additions of sediment (t = -2.07, p = 0.0461).



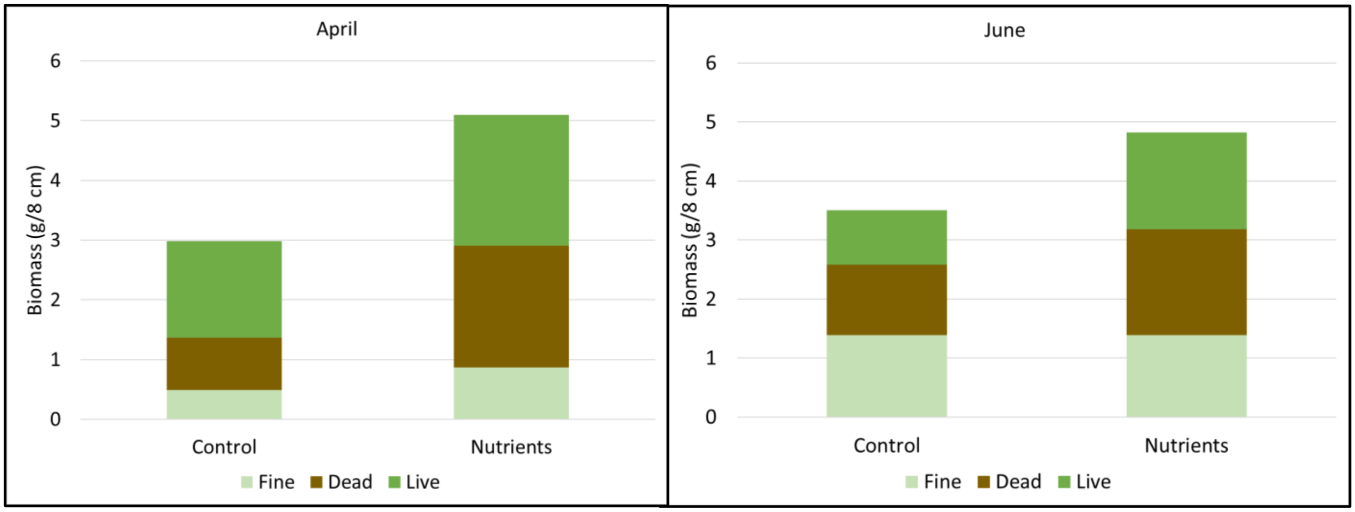
Figures 5 a,b: Nutrients had a significant treatment effect for both live (Fig. 5a, left) aboveground biomass (t = -5.78) and total (live and dead) (Fig. 5b, right) aboveground biomass (t = -3.99, p = 0.0074).



Figures 6 a,b: Fig. 6a (left) shows belowground biomass for the April collection and Fig. 6b shows belowground biomass for the June collection. Data are still being gathered, and statistics are not yet able to be run. These preliminary data suggest that nutrient treated plants will have higher belowground biomass overall than plants with no nutrient additions.



Figures 7 a,b: Belowground live biomass by depth for the April (Fig. 7a) and June (Fig. 7b) collections. These preliminary data suggest that nutrient treated plants have more belowground biomass than controls.



Figures 8 a,b: Biomass in the top 8 cm of sediment for a subsample of sediment treated pots. Sediment treated plants that were also in a treatment of added nutrients show more overall biomass in both the April (Fig. 8a) and June (Fig. 8b) collection.