NCNERR SWMP tier 2 Emergent Marsh Biomonitoring
Final Report

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Reserve: North Carolina

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Background Information: The North Carolina National Estuarine Research Reserve (NCNERR) is a multicomponent reserve, made up of four components. These components span the entire coastline of North Carolina (N.C.), covering two biogeographic provinces (Virginian and Carolinian) and a range of tidal regime from essentially zero astronomical influence at Currituck Banks to almost 2m diurnal tides for our southern components Masonboro Island and Zeke's Island (Figure 1). This sets NCNERR up as an ideal location to conduct long term monitoring as the habitats and ecological settings of our Reserve components represent the range found in N.C. and are analogous to those found in many other east and gulf coast states. Thus, results learned in North Carolina have broad transferability.

The NCNERR components are all coastal barriers with front sides that face the Atlantic Ocean and backsides that transition through marsh habitat to estuarine bodies of water (Fear et al. 2008). Each component has dune and beach features, scrub shrub habitat, maritime forest, and large expanses of marsh habitats (Fear et al. 2008). Currituck Banks is unique from the other three in that its backside marshes are freshwater in nature, due to the influence of an oligohaline estuary. The other three components contain estuarine saltmarsh primarily inhabited by *Spartina alterniflora* in the low marsh areas and border meso to polyhaline estuaries.

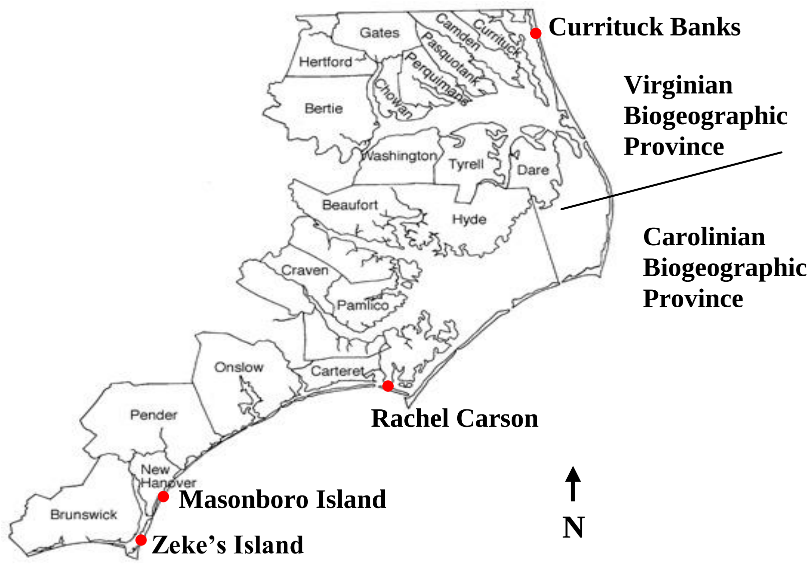

Figure 1: NCNERR components relative to the coastal counties of North Carolina, and associated biogeographic provinces.

Spartina alterniflora marshes are some of the most productive and most vulnerable wetland habitats. They provide a multitude of ecosystem services including coastal shore protection from erosion and storms, serve as nutrient and sediment traps, and provide critical habitat for marine and avian fauna (Hackney and Cleary 1987; Short et al. 2000; Currin et al. 2007). They sit at the interface between land and water and are susceptible to impacts from both the land and water. Thus, they are ideal sentinels to monitor how the land-water margin is changing. By observing the ecological condition and health of these marshes through time, one can predict whether the coastal margin in the general area is stable, eroding, or accreting.

Understanding how the coastal margin is changing is one of the most pressing issues in coastal management today. The continued increase in coastal populations further drives the need to understand these systems. More population means more infrastructure, more investment, and ultimately more risk exposure. The scientific community has consensus that sea levels are rising (IPCC, 2007). Previous work in North Carolina clearly demonstrates that our state is extremely vulnerable to sea level rise and episodic erosion from storm impacts (Riggs et al. 2008). Given these issues, it is clear that long-term monitoring of North Carolina's saltmarsh habitats is critical to understanding how to best manage these systems for all intended uses. The NCNERR components are ideal locations to conduct this monitoring since the land is guaranteed to be held in perpetuity in a natural state and as previously mentioned, represent the range of coastal ecological conditions found in North Carolina and many other east and gulf coast states.

NOAA's sentinel sites initiative is designed to integrate geodetic and tidal data with environmental habitiat monitoring efforts in order to establish effective tools for the understanding and potential mitigation of climate change impacts as they occur. The addition of the infrastructure associated with this project will advance this nationwide effort within North Carolina.

Project Description: Through previous efforts by NCNERR and partners, our Rachel Carson component was already being monitored as a sentinel site. The specific portion of the Rachel Carson Reserve involved in this monitoring is the Middle Marsh (MM) region. This included tier 2 emergent marsh biomonitoring. The biomonitoring transects and Sediment Elevation Tables (SETs) from this effort are shown in Figure 2. Both Middle Marsh and Rachel Carson will be used synonymously in this report to describe this component. This project provided Coastal Zone Management Act Section 315 funds through the National Estuarine Research Reserve System to continue the emergent marsh biomonitoring at the Rachel Carson component and initiate emergent marsh biomonitoring and install sentinel site infrastructure (SETs, groundwater wells, and vertical control) at our Masonboro Island (MI) and Zeke's Island (ZI) reserve components. This combined with the previous work at Rachel Carson brings three of the four NCNERR components online as sentinel sites. This report details the activities at these three components from 2010 to 2011 based on the following two project objectives.

Objective 1: Add annual emergent vegetation biomonitoring at Masonboro Island and Zeke's Island components to complement the existing emergent biomonitoring occurring at our Rachel Carson component.

Objective 2: Add SETS, groundwater wells, and vertical control at Masonboro Island and Zeke's Island to complement existing sentinel site infrastructure already in place at Rachel Carson.

It is our hypothesis that the saltmarsh habitats at Masonboro and Zekes Islands will respond much faster to forcings than those at our Rachel Carson component.

Figure 2: Existing Rachel Carson vegetation monitoring location (green oval), transects (black lines) and SETS (diamonds). The blue dot is the Middle Marsh SWMP-like water quality station.

Figure 3: Masonboro Island monitoring location (green oval). The large blue dot is the Loosin Creek SWMP station. The enlarged view depicts vegetation transects (yellow lines), SETs (green dots), and groundwater wells (blue dots) inside the green oval.

Figure 4: Zekes Island monitoring location (green oval). The large blue dot is the Zekes Basin SWMP station. The enlarged view depicts vegetation transects (yellow lines), SETs (green dots), and groundwater wells (blue dots) inside the green oval.

Methods: All vegetation monitoring methods used followed the protocols outlined in Moore et al. (2009). For the new monitoring transects at Masonboro and Zekes, individual transects were chosen at random covered the distance from the marsh-water interface to the marsh-upland transition. Seven transects were installed at Masonboro and seven were installed at Zekes (Figures 3 and 4). Vegetation assessments were made once annually during the peak of biomass (July-Sept for N.C.). Plant harvesting was conducted in 2011 from 0.625m2 quadrats to calculate standing aboveground biomass for the marshes (see below).

Methods for SET installation and reading followed standard USGS methods as outlined in Cahoon et al. (2002). Two SETS were installed at Masonboro and two at Zekes Island. The SETS at Masonboro Island were installed between transects 5 and 6 (Figure 3), and between transects 1 and 2 (Figure 4) at Zeke's Island. At Masonboro 11 rods at each SET were needed before refusal was reached providing a total rod depth of 13.2 m. At Zeke's, 12 rods at each SET were needed to reach refusal, providing a total rod depth of 14.4 m.

The groundwater wells were installed at Masonboro and Zeke's following the methods of Wiley Reah (pers. comm.). Each marsh had three groundwater wells, one in the low marsh zone within 2 m of the marsh/water transition, one in the upper marsh zone at the upland transition, and one half-way between these two endpoints. The wells were constructed of 1.25 in diameter PVC pipe that extended 1 m below the surface of the marsh. The holes for the groundwater wells were created using a ratcheting 4 in hand auger. Well holes were drilled to ~ 1.05 m. The PVC pipe was then placed in the hole and backfilled with clean sand. The wells had open slits along the entire distance from 18cm to 1m below the marsh surface, thus they represent an average of the groundwater along this entire depth gradient. The wells extended 1m above the marsh surface with solid PVC pipe and were sealed at the marsh surface with hydraulic cement and bentonite clay. This prevented surface water (rain and tidal) from infiltrating the well so long as the seal remained functional. The top of the wells were capped with loose fitting tops to allow air exchange and prevent rainwater intrusion. The tops of these wells were never topped by tidal waters (Figure 5).

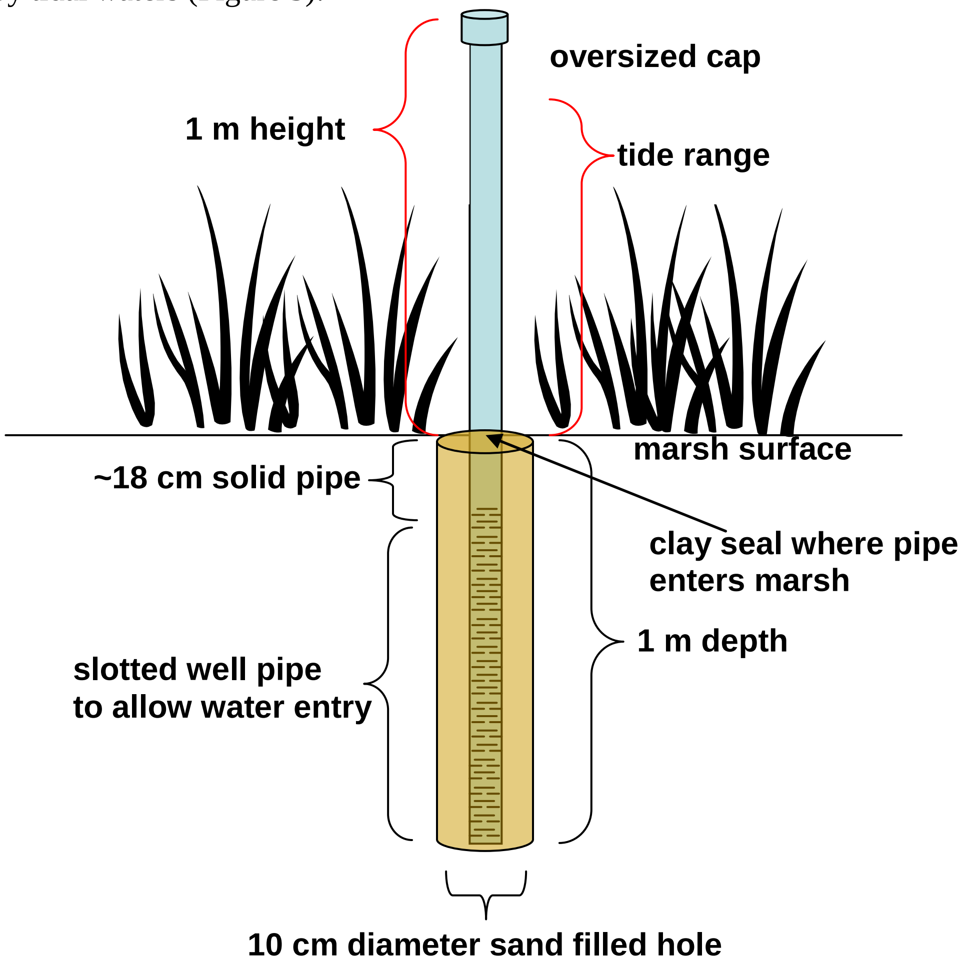

Figure 5: Groundwater well design. Instruments placed inside well pipe measure temperature, salinity, and water level.

Salinity and temperature of the water in the groundwater wells at Rachel Carson were obtained every three months by dropping a YSI 85 into the well at low tide. Grab samples from these wells were also occasionally obtained via a portable peristaltic pump. These samples were evaluated for salinity using a handheld refractometer as a backup to the YSI method. The Rachel Carson wells were also used to deploy *In-situ aquatrolls* for 2-3 week continuous deployments. The aquatrolls obtained a temperature, salinity and vented water level datapoint every 30min while deployed. After deployments the data from the aquatrolls was entered into an excel database and used to calculate inundation times. The Masonboro Island and Zeke's Island wells were not installed until November 2011 so no data has been obtained from them prior to this report.

The harvested *Spartina alterniflora* samples for above ground biomass were returned to the lab. Each stem was washed, measured for height and then dried at 60 °C for 72 hours. Once dry each stem was weighed to the nearest milligram using a standard laboratory balance. Stem height versus dry weight was then plotted and a regression line interpreted through the data. The resulting equation from the regression was used to calculate dry weights for measured stem heights. A separate regression line was calculated for each sampled marsh. The calculated dry weight was then scaled up by multiplying by the stem count from the sampled meter squared quadrats.

Results

Vegetation:

Table 1 shows the species richness by year for all the sampled marshes together and then for each of the sampled marshes individually. Seven species were recorded in total: *Spartina alterniflora, Spartina patens, Salicornia spp., Borrichia frutescens, Distichlis spicata, Limonium spp.*, and *Juncus roemerianus.* The species richness did not vary between the 2010 and 2011 sampling years.

Figure 6 shows the percent cover of each marsh species by year and sampling location. All three marshes were dominated by *Spartina alterniflora.* Middle Marsh was a *Spartina alterniflora* monoculture. No significant differences in percent cover were observed between sampling year 2010 and 2011. There were statistical differences in percent cover among the sampling locations for some of the plant species. The Middle Marsh percent cover for *Spartina patens* was significantly lower than the other two marshes ($p < 0.05$). The percent cover of *Salicornia sp*. at Masonboro was significantly greater than the other two sampling sites ($p < 0.01$). The percent cover of *Borrichia frutescens* was significantly greater at Zeke's compared to the other two marshes ($p < 0.01$). Of interest, there was no statistical difference in the percent cover of *Spartina alterniflora* among the three sampling locations (Figure 6).

Figure 7 shows the measured height of the marsh based on two different methods by sampling year. The red bars show the average height of 10 random *Spartina alterniflora* stems. The blue bars show the average height of the three tallest stems in the plots of the most dominant species. As such the red bars only represent *Spartina alterniflora* data while the blue bars include both *Spartina alterniflora* data as well as other species. Year 2010 was statistically higher than 2011 for the height of the 10 random *Spartina alterniflora* stems ($p = 0.03$). No statistical difference was observed between the sampling years for the average height of the three tallest members of the dominant species but the same pattern of lower heights in 2011 compared to 2010 noted above for the 10 random *Spartina alterniflora* stems was observed.

Figure 8 shows the average marsh height for both methods by sampling location. There was no difference noted for the 10 random *Spartina alterniflora* stems among the marshes. For the average of the three tallest dominant species, the plants at Middle Marsh were statistically shorter than those at the other two marshes ($p < 0.01$).

Figures 9 and 10 show the plant density by year and sampling location respectively. The plots include both live and dead stem counts. Statistically no significant differences in either metric were observed comparing 2010 data to 2011 data. The average live stem count at Zeke's

Island was significantly higher than the other two marshes ($p < 0.01$). The average dead stem count at Zeke's was significantly lower than that at Masonboro Island ($p = 0.001$).

Table 1: Species richness by year for all sampled marshes.		
All Marshes	2010	2011
Spartina alterniflora	X	X
Spartina patens	X	X
Salicornia spp.	X	X
Borrichia frutescens	X	X
Distichlis spicata	X	X
Limonium spp.	X	X
Juncus roemerianus	X	X
Total species count	7	7
Masonboro Island only		
Spartina alterniflora	X	X
Spartina patens	X	X
Salicornia spp.	X	X
Borrichia frutescens	X	X
Distichlis spicata	X	X
Limonium spp.	X	X
Juncus roemerianus		
Total species count	6	6
Zeke's Island only		
Spartina alterniflora	X	X
Spartina patens	X	X
Salicornia spp.	X	X
Borrichia frutescens	X	X
Distichlis spicata		
Limonium spp.		
Juncus roemerianus	X	X
Total species count	5	5
Middle Marsh only	2010	2011
Spartina alterniflora	X	X
Total species count	1	1
X indicates that a species was present.		

Figures 11 and 12 show the calculated biomass data for above ground *Spartina alterniflora* by year and sampling location respectively. Data for these figures was based on the height versus dry weight regressions. The regressions used to calculate above ground biomass are included in Table 2 where y = the calculated above ground dry weight, and x = the average measured stem height. The biomass in 2010 was significantly higher than that from 2011 ($p = 0.02$). No significant differences were noted when the three marshes were compared to each other.

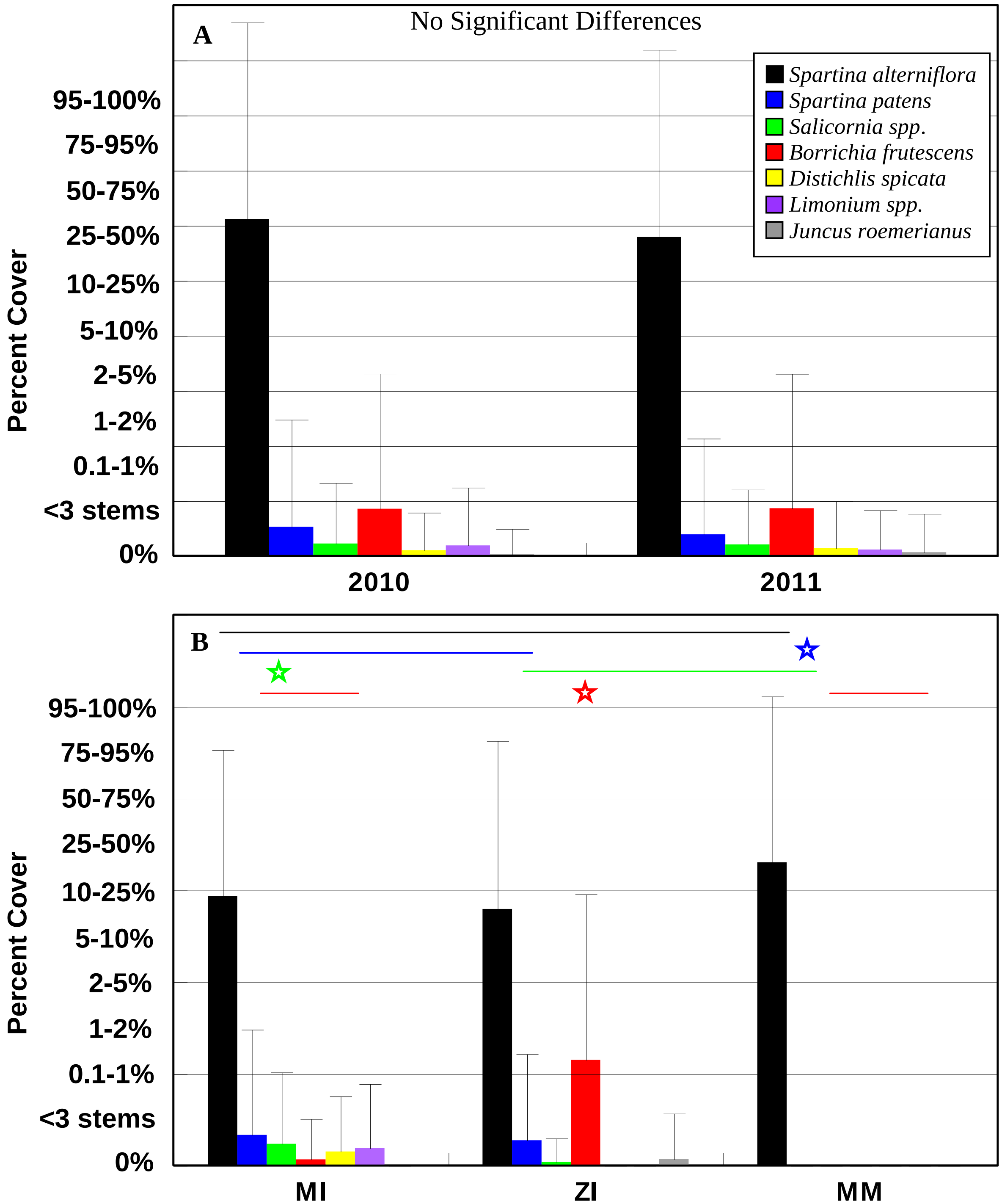

Figure 6: Percent cover by year (panel A) and by marsh (panel B). Error bars represent one standard deviation. No significant differences were observed in percent cover between 2010 and 2011 for any plant species. Color coded stars and lines depict significant differences for the four most dominant species (bonferroni).

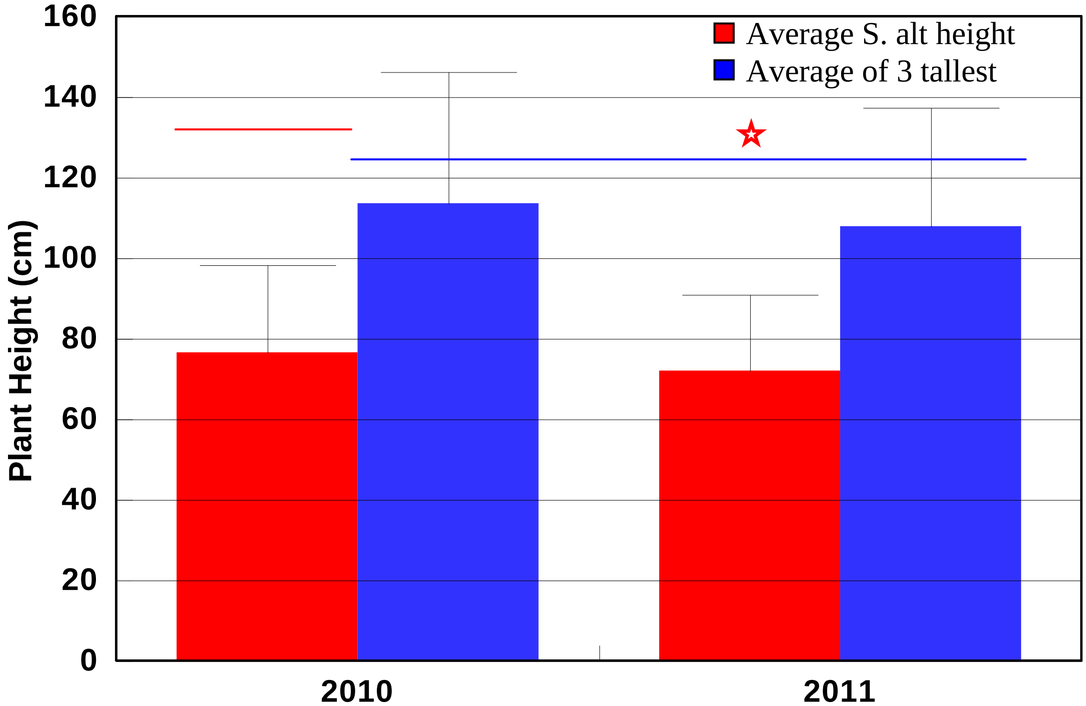

Figure 7: Average plant height by year. Error bars represent 1 standard deviation. Significant differences are noted by the color coded stars and lines (ANOVA).

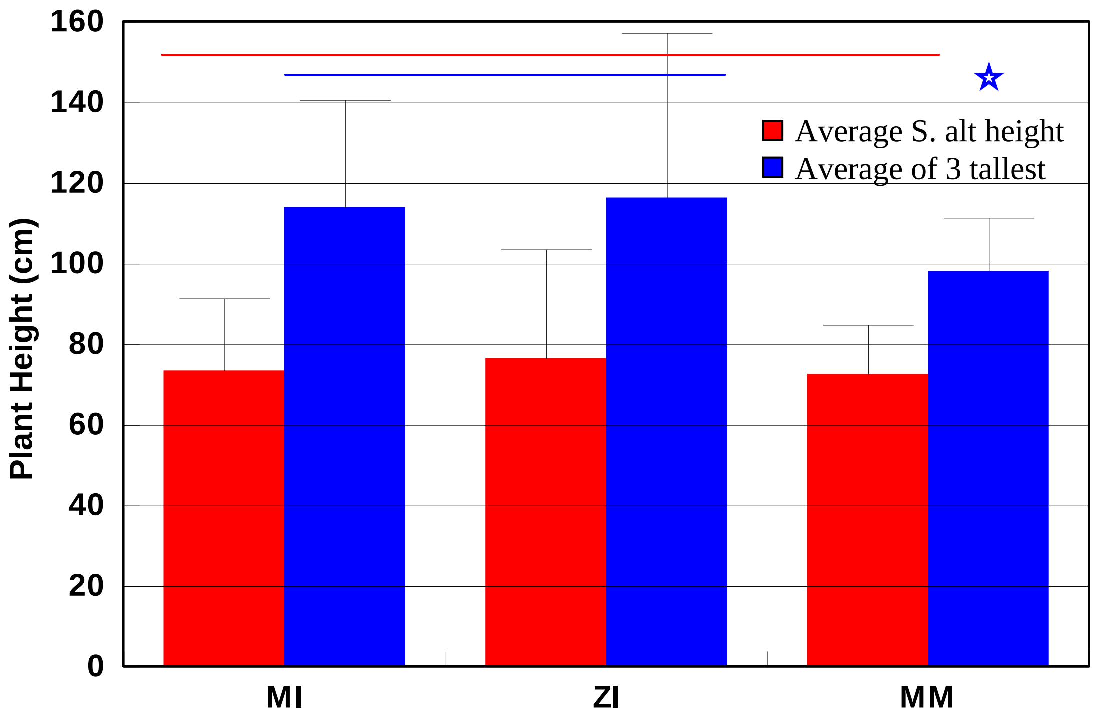

Figure 8: Average plant height by marsh. Error bars represent 1 standard deviation of the mean. Significant differences are noted by the color coded stars and lines.

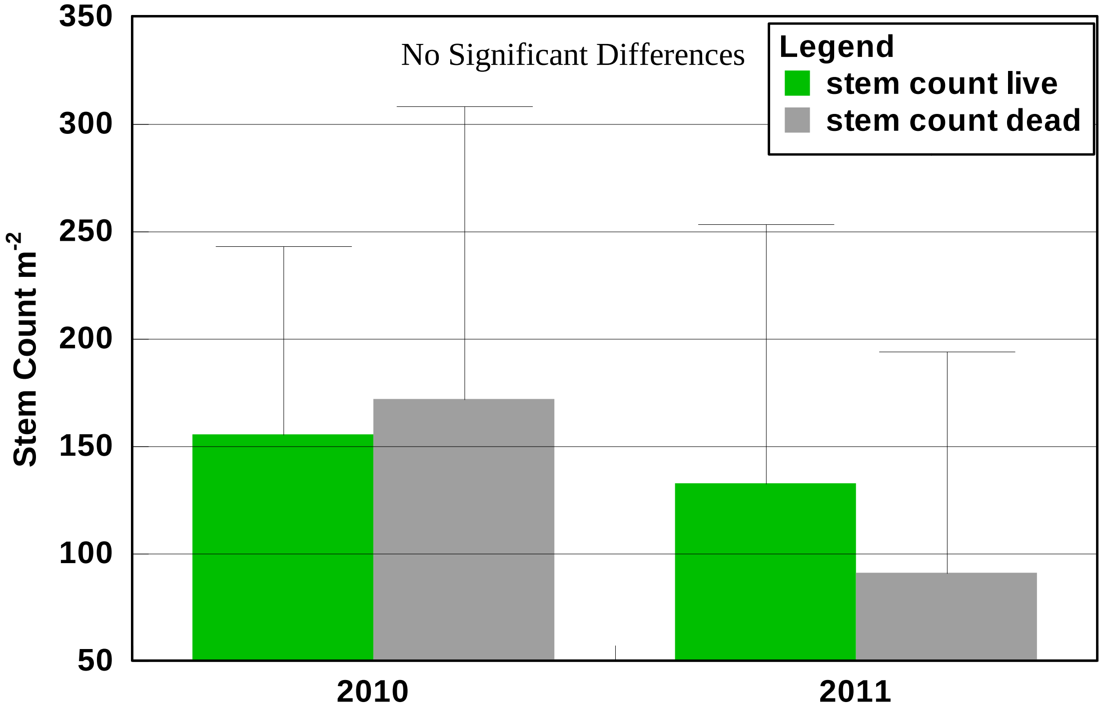

Figure 9: Average plant density by year. Error bars represent 1 standard deviation.

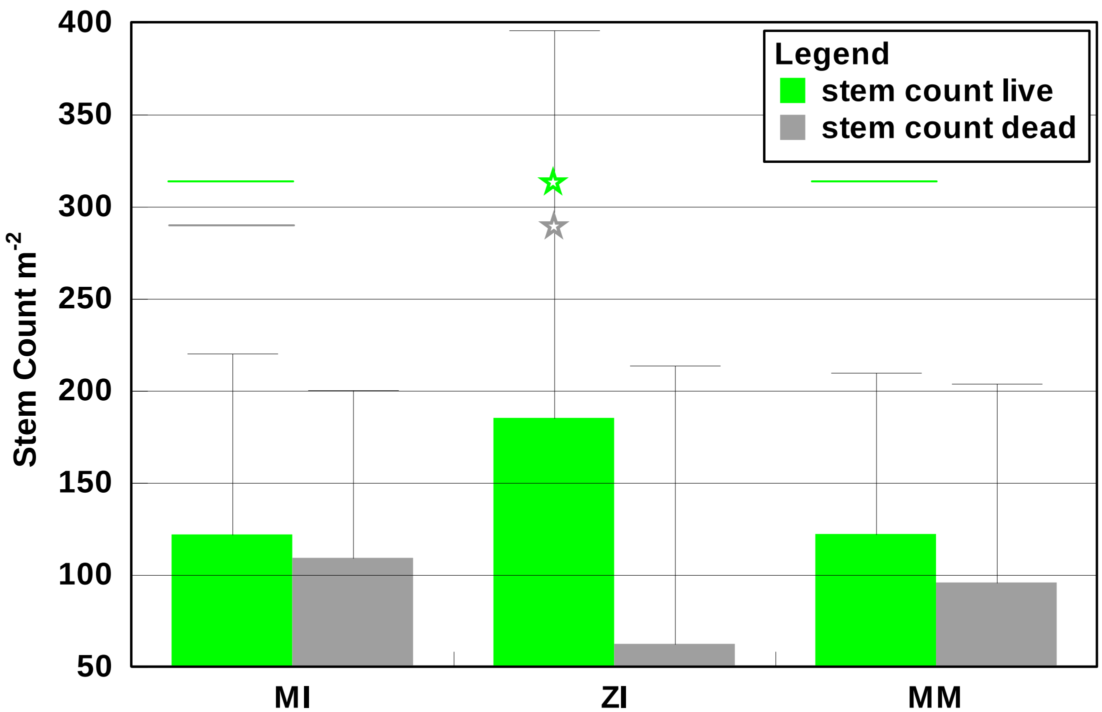

Figure 10: Plant density by marsh. Error bars represent 1 standard deviation of the mean. Significant differences are noted by the color coded stars and lines.

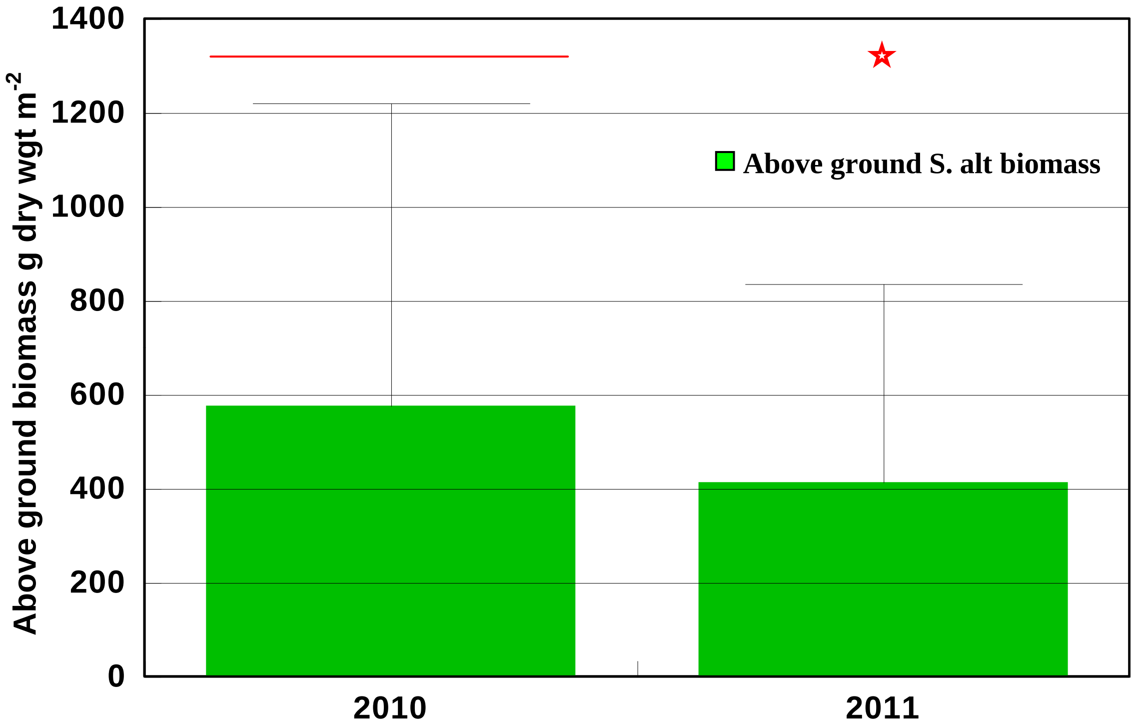

Figure 11: Calculated average above ground *Spartina alterniflora* biomass by year for all sampling locations. Error bars represent one standard deviation. 2010 was significantly different from 2011(ANOVA).

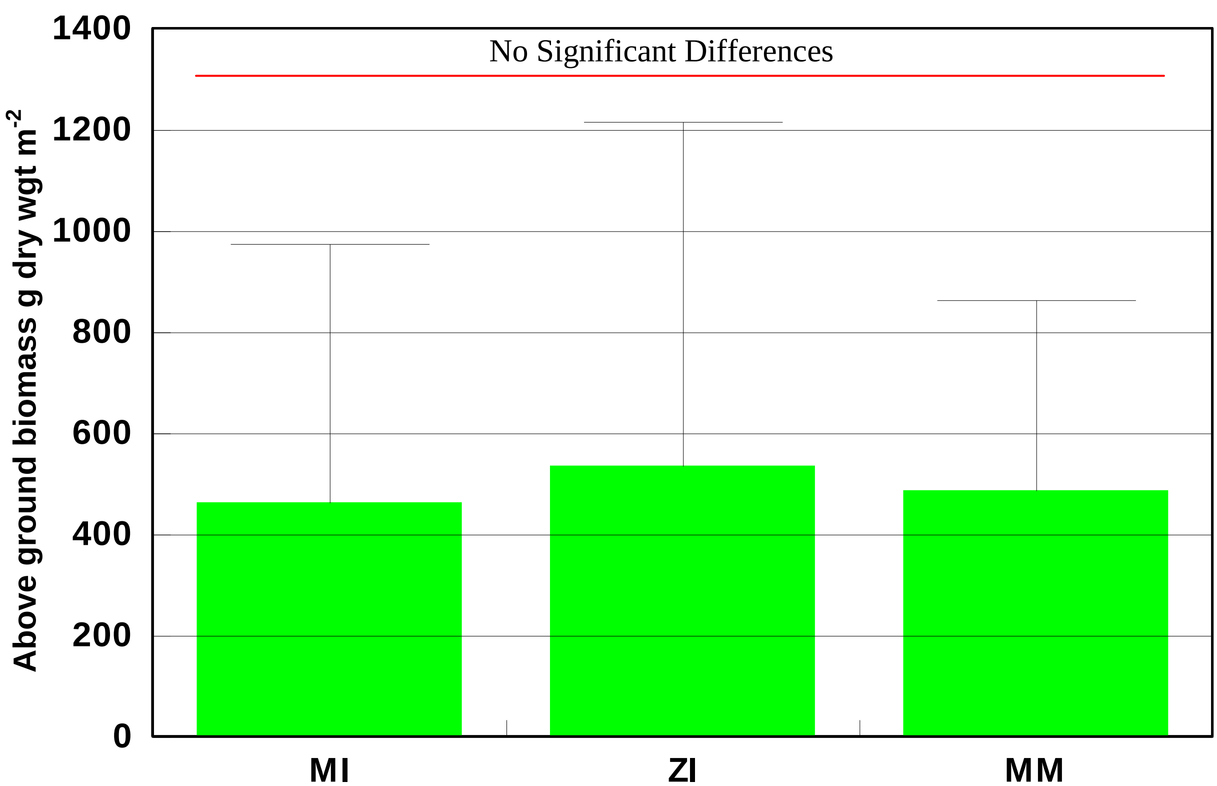

Figure 12: Calculated above ground *Spartina alterniflora* biomass by site. Error bars represent one standard deviation.

Table 2: Biomass model regressions.

	Regression Equation	r^2	# points in regression
Masonboro Island	$y = 0.000008x^3 - 0.0005x^2 + 0.0366x$	0.8765	167
Zekes Island	$y = -0.000002x^3 + 0.0006x^2 + 0.0022x$	0.8117	123
Middle Marsh*	$y = 0.000005x^3 + 0.0003x^2 + 0.0008x$	0.8871	492
* Middle Marsh data from Currin et al. 2010 (pers. comm.)			

Groundwater wells:

The groundwater wells were installed in November and December 2011 at Masonboro Island and Zeke's Island. Delays in the purchasing ability due to agency constraints pushed the installation date back. As such, no data has been obtained from these wells yet. However, *In-situ aquatrolls* are to be installed in Jan/Feb 2012 to provide water level data for these marshes.

The groundwater wells for Middle Marsh were equipped with the aquatrolls in July 2010. This data was utilized along with the marsh surface elevation data obtained via laser leveling from known benchmarks (Figure 13) to calculate the amount of time that the marsh is underwater (Figure 14). From this plot it can be seen that the marsh surface at Middle Marsh is underwater between 30-40% of the time. Figure 13 shows that the marsh surface at Middle Marsh is essentially level. This makes sense as Middle Marsh is a platform marsh that sits atop a relict flood tide delta. There are not any uplands present in Middle Marsh.

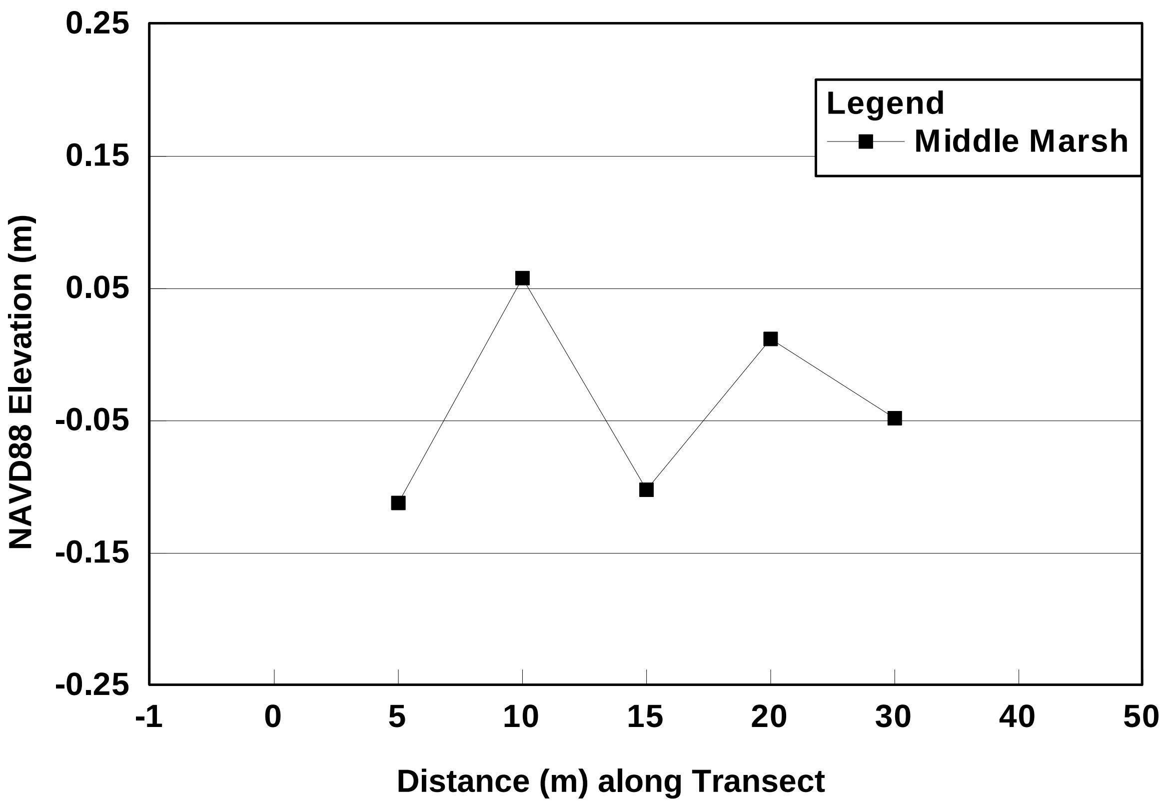

Figure 13: Elevation of primary transect in Middle Marsh relative to NAVD88 MSL. Zero represents water/marsh interface.

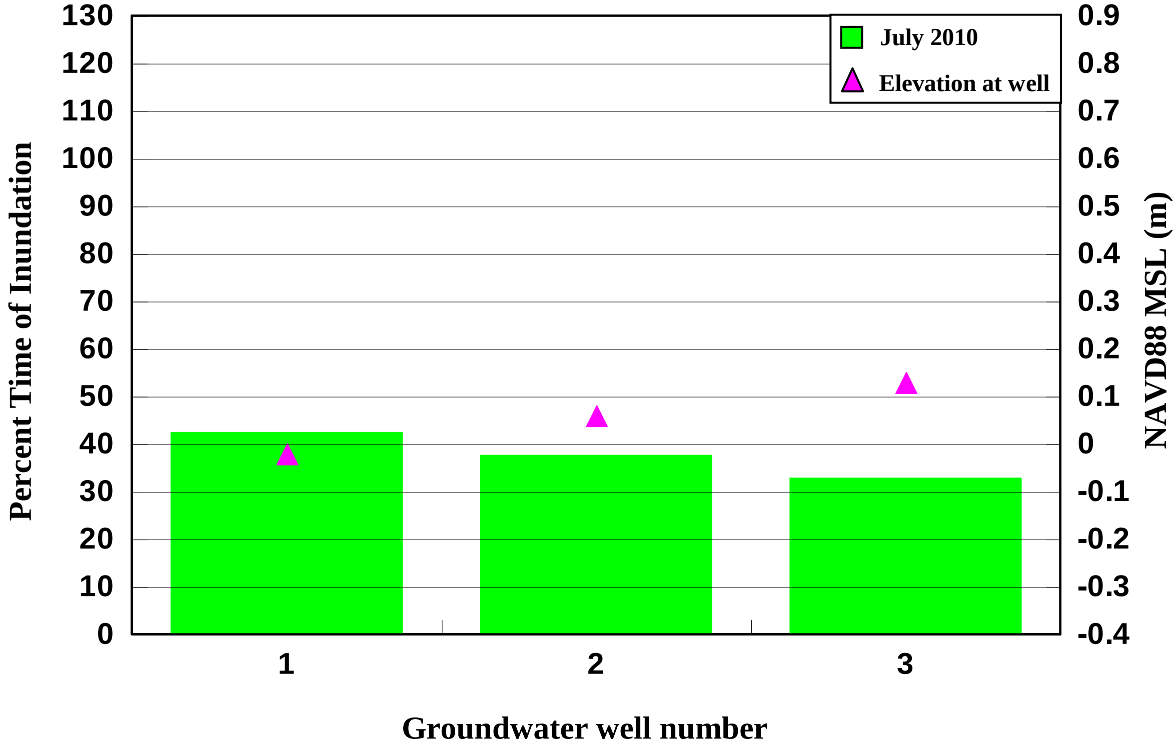

Figure 14: Middle Marsh inundation plot based on water level meters. Pink diamonds indicate marsh surface elevations at each groundwater well. Well 1 is nearest the water, well 3 is the farthest from the water.

SETs:

The SETs at Masonboro and Zeke's were installed in November 2011. The SET installation was severely delayed due to the time it took to acquire the needed materials. The SETs need to settle for ~2 months after installation before the first datapoint is taken (Smith pers. comm.) so no data has been acquired yet. The first SET reading is scheduled for Jan 2012.

The SETs at Rachel Carson were read by one of our partners during the 2011 year. This reading was part of an ongoing monitoring program looking at the ability of coastal fringing saltmarshes to keep up with sea level rise. NCNERR will take over the reading of these SETs in 2012. Because our partner has not published their data yet, we have not included the 2011 values in this report. However, it will be available as NCNERR continues with this monitoring over the next few years.

Discussion:

The data available at this time limit the discussion to the vegetation parameters. This is only a partial picture of what is occurring at these marshes so these initial findings should be viewed with caution. As this effort continues and subsequent year's data including the elevation and water level data at Masonboro and Zeke's Islands, then the three marshes can be fully compared to each other. With only two years of data, it is not appropriate to discuss annual differences. The graphs and statistical analyses were only included for completeness.

Differences across years will not be discussed in this report. This type of analysis will be re-examined at the end of the five year planned sampling period.

The available data do provide a few interesting findings. Most of the significant findings reported in the percent cover between Middle Marsh and the other sampling locations are based on the fact that Middle Marsh is a *Spartina alterniflora* monoculture. As such, it is simply a presence absence factor that makes it different from the other marshes. The monoculture nature of Middle Marsh is due to the fact that there are not any uplands in Middle Marsh and thus no elevation gradient to support additional marsh species (Figure 13). Given this constraint, the only species that can be considered when computing vegetation comparisons among all three of our sample sites is *Spartina alterniflora.* Comparisons between Masonboro and Zeke's Islands can be considered for the other plant species present.

The two years of data collected to date indicated that the *Spartina alterniflora* at Middle Marsh occurs at similar coverage levels as at Masonboro and Zeke's (Figure 6). This was slightly surprising as we had hypothesized that the *Spartina alterniflora* coverage at Middle Marsh would be higher due to the lack of competition from other plant species. Although not statistically significant, the percent cover of *Spartina alterniflora* at Middle Marsh was slightly higher than the other two sampling locations. It will be interesting to see if this trend is supported in future sampling years. Masonboro Island had significantly more *Salicornia spp.* coverage than Zeke's Island, while Zeke's Island had significantly more *Borrichia frutescens* than Masonboro Island (Figure 6). While we don't yet have the elevation data to corroborate the following conjecture, visual assessment of the sites indicate that this finding is due to the transect layout that was utilized at Zeke's. A berm runs through the marsh at Zeke's. This berm was used as the back edge of all but one of the transects (Figure 4). The berm is primarily inhabited by *Borrichia frutescens.* The one transect at Zeke's that runs all the way back to the upland transition has similar species, including *Salicornia sp*., to the Masonboro transects. If all the Zeke's transects ran back to the upland transition, then we suspect the species percent coverage between Masonboro and Zeke's would be more similar.

The plant height data from the average of the three tallest stems of the dominant species support our hypothesis that the plants at Masonboro and Zeke's would be taller than those at Middle Marsh (Figure 8). This hypothesis was based on the difference in tidal amplitude that is present between the southern locations (1-1.5 m) compared to Middle Marsh (0.5-1.0 m). It should be noted that the average of the 10 random *Spartina alterniflora* stems did not show any statitistical differences among the sampling locations. While on the surface this seems contradictory to the results from the other height method, it really is just an artifact of what the two sampling methods are designed to capture. The three tallest stem method is designed to quantify maximum marsh canopy height. The 10 random stem method is designed to provide an overall average of marsh height. The impacts from the tallest stems get muted by both the random nature of the sampling and the averaging over the ten samples that occurs. Another contributing factor to the two methods providing different answers is that the 3 tallest method measures the 3 tallest stems of the dominant plant species. The 10 random sampling design only measures *Spartina alterniflora*.

Live stem density was statistically higher at Zeke's compared to the other two marshes (Figure 10). This is an interesting finding that at current time remains unexplained. Many things are unique about Zeke's that could be playing a role in this result. The salinity regime at Zeke's is lower than that at Masonboro and Middle Marsh. Zeke's is a lagoonal system that offer some protection to the *Spartina alterniflora* stems preventing uprooting. There may be less grazing pressure on the marsh at Zeke's. The decreased dead stem count observed at Zeke's (Figure 10) supports the idea that the *Spartina alterniflora* at Zeke's Island is less stressed than at the other two marsh locations. Zeke's is the only marsh sampled connected to the mainland. The other sites are island systems. As such there could be some connectivity issue providing a benefit to the *Spartina alterniflora* at Zeke's that is not present at the other two locations.

Zeke's is also the only Reserve component that receives water from a major river system. The other sites are located in proximity to tidal creeks and small coastal drainages. Data from our system wide monitoring program reveal that the nutrient levels in the water at Zeke's are much higher than those at Masonboro Island and Rachel Carson. These extra nutrients could be supporting the denser *Spartina alterniflora* at Zeke's. All these factors will be examined over the coming years.

The above ground *Spartina alterniflora* biomass data did not show a significant difference among the sampled marshes. The increased stem density that was observed at Zeke's did not translate into increased biomass. One explanation is that the plants at Zeke's while more dense are thinner. Initial examination of the harvested plants seems to support this, but more years of harvesting data will be needed to confirm this idea. Again the lagoonal nature of Zeke's may mean that the plants need less structural support than those at Masonboro and Middle Marsh.

Conclusions:

Many more years of data collection are required to fully understand the differences in marsh functions among the three marshes sampled as part of the NCNERR Biomonitoring effort. Initial indications suggest that Zeke's is behaving differently than the other two locations. Of high interest is the water level and inundation patterns at Zeke's compared to the other two locations. This work represents a great initial baseline that supports both the National Estuarine Research Reserve biological monitoring strategic committee proposal (Moore et al. 2010), and the newly created sentinel site concept (Dionne et al. 2010). NCNERR is committed to continuing this monitoring and will reassess the inter-marsh comparisons at the five year time horizon.

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