QUANTIFYING THE ECOLOGICAL SIGNIFICANCE OF MARSH SHADING: THE IMPACT OF PRIVATE RECREATIONAL DOCKS IN COASTAL GEORGIA

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EXECUTIVE SUMMARY

As population pressure increases along the Georgia coast, coastal managers require more and better data regarding coastal resources and human impacts to these resources to carry out their mission, particularly in the expansive and productive salt marshes. Understanding the impact of private recreational docks on saltmarsh ecosystems is considered by many to be a critical need, given that these structures shade the marsh and that their numbers are increasing rapidly with little understanding of their cumulative effects.

Until recently, no systematic study had been carried out examining this issue in the southeastern US, with the exception of one local study in SC (Sanger and Holland 2002). To address this data need, the Georgia Coastal Zone Management Program supported a study of dock proliferation and shading impacts on Wilmington Island, GA in Chatham County (Alexander and Robinson, 2004). The results of that study document a 90% increase in total dock area and a 73% increase in number of docks from 1970 to 2000. Approximately half of the total dock area in 2000 was constructed above, and thus overshadowing, the ubiquitous *Spartina alterniflora* saltmarsh vegetation. The shading effect created on average a 56% decrease in vegetation stem density beneath docks when compared to areas adjacent to docks. This stem density reduction represents a potentially important and previously unquantified term in the carbon budget of the marsh, which provides food and critical habitat for many commercially important species.

The present study quantifies the stem density, biomass and carbon produced in the *Spartina* marsh at sites shaded by private recreational docks and at sites adjacent to those under-dock sites. Plots were sampled by clipping all the grass in 0.25 m^2 quadrats and separating the vegetation into dead and living groups. The living group was further sorted into short and tall

subgroups. All vegetation was dried and weighed to determine the biomass within each group. An average of 87% of the biomass in each plot was contained within the living, tall stem group. Similar to the previous study, stem density was reduced under docks an average of 50%. Living aboveground biomass was 154 – 825 g/m^2 and total aboveground biomass was 249 – 1226 g/m^2, similar to other studies from the southeastern US and the average carbon production was 167 gC/m^2. Detailed height measurements demonstrated that tall vegetation was taller beneath the dock than in control sites, probably as a result of etoliation in response to shading. These detailed height data were used to calculate the average weight per stem and weight per linear centimeter, allowing us to address the issue of plant robustness at dock versus control sites. Lower stem densities of tall plants were associated with higher average biomass per stem. Although tall vegetation under the dock was taller and contained more mass per stem than those in the control sites, the decrease in stem density was significant enough to offset this increase in individual stem mass.

The 50% stem density reduction results in a consequent reduction between 21-37% of biomass and carbon produced per meter square under a dock structure. Applying the present results to the Alexander and Robinson (2004) study of Wilmington Island, the organic carbon reductions predict that the unrealized organic carbon contribution to the saltmarsh ecosystem under the average modern dock (123 m^2) would be between $4.3\text{-}7.6 \times 10^3$ gC per dock per year. By applying this 21-37% decrease to all docks on Wilmington Island to assess impact on an island-wide basis, dock footprints over vegetation are presently reducing the available organic carbon between $0.84\text{-}1.5 \times 10^6$ gC/y. Using State-wide data for dock numbers and sizes, these reductions suggest that private recreational docks are reducing organic carbon input between $1.0\text{-}1.7 \times 10^7$ gC/y. The Kneib (2003) trophic model shows that the 21-37% decrease in biomass equates to reductions of 0.5-0.9 g dw nekton/m^2 in total annual primary nekton production. For migrant nekton (i.e., penaeid shrimp and finfish), which make up 33% of the total nekton, primary nekton reductions are between 1.8-3.2 x 10^4 g ww nekton around Wilmington Island and between 0.6-1.2 x 10^6 g ww State-wide. Carrying this analysis further to determine the potential loss of harvestable-size, migrant nekton awaits species-specific biological data. This assessment of dock shading impacts should be refined by further research and points to the importance of assessing cumulative impacts of human activity in the coastal zone as these impacts are concentrated in critical nursery areas for commercial species.

INTRODUCTION

Estuaries in Georgia and throughout the country experience anthropogenic stresses which may alter the integrity of the natural ecological system. These transition zones between land and sea serve as some of the most biologically productive areas on earth and their significance merits an in-depth understanding of the ways habitat loss and alteration may degrade biotic communities (Kennish, 2002). Rapid development of coastal property in Georgia and the rapid increase in associated structures has revealed a need for research that both assesses and

Figure 1. Betz Creek area, Wilmington Island, Georgia.

quantifies the impacts of these structures, predominantly recreational docks, on surrounding habitats (Figure 1). With this information, managers can more effectively balance the needs of the States' valuable saltmarsh resource with development pressures by incorporating a science-based, quantitative understanding of these impacts into management decisions.

Property owners in Georgia with marshfront lands are able to apply for revocable permits to construct private recreational docks. In order to meet the private recreational dock requirements of the state, the dock must be non-commercial, on pilings over marsh grass and not interfere with tidal flow. In addition, the dock must extend from property with at least 50 ft of marsh frontage and has, or is capable of having, a single family residence. Two types of permit may be applied for: a fast-track permit or an individual dock permit. The waterway the dock will access, the width of the walkway, area of the fixed pier, hoist, and floating dock determine which type of permit is appropriate (GADNR, 2002). Ownership of land and marsh, subject to the ebb and flow of the tide and extending to the mean high water line, is claimed by the State of Georgia, although a few areas of privately owned marsh exist, traceable to valid King's Grants. Following the Public Trust Doctrine, all saltmarsh habitat is to be held in trust for the benefit of the State's citizens (Kundell et al., 1988; GADNR, 2004). Without exception, private dock structures are built above saltmarsh habitat protected by the State Coastal Marshlands Protection Act, although these private structures are not regulated under the Act (Kundell et al., 1988). Without sound, science-based data it is difficult to determine a balance between protecting the States' natural resources while also respecting property owners' desire to construct a dock. Throughout the country, coastal managers and regulatory agencies responsible for issuing dock permits have very little data on which to base dock permitting policy (Kelty and Bliven, 2003).

Several types of habitat alteration that could potentially degrade habitat function must be considered with respect to these structures' overall impact including: shade effect of the dock walkway on vegetation; impact of floating docks on benthic activity; role of the dock structure in disturbing natural removal of marsh detritus; and associated boating activity impacts. This report is focused on the first of these issues. Subsequent reports will address these other issues.

Spartina alterniflora (saltmarsh cordgrass) is the dominant vascular plant occurring in Southeastern salt marshes. The abundance and highly productive nature of *Spartina alterniflora* establish it as the most important primary producer of energy for saltmarsh ecosystems. Another principal energy producer, benthic algae, produces approximately 25% of the biomass generated by *Spartina alterniflora* or 10% of the total biomass (Pomeroy et. al., 1981). The energy contributions from *Spartina alterniflora* and benthic algae form the basis for several food webs and nutrient cycles (Adam, 1990; Teal 1962, Teal and Teal 1969; Weigert, Pomeroy and Weibe, 1981; Weinstein, 1996). When examining the quantity of biomass contributed to the saltmarsh system by *Spartina alterniflora* along the East Coast, it is important to note that productivity varies both spatially and temporally and is controlled by many factors including: temperature, light, soil water movement, soil water chemistry, and soil oxygen concentrations (Dame, 1989, Gross et al., 1991; Odum and Fanning, 1973; Valiela et al., 1978). The structure and distribution of living and dead vegetation on the marsh surface directly affects the availability of light, soil temperature, and water flow (Windham, 2001).

Previous studies conducted in the eastern U.S. have evaluated dock impact on saltmarsh vegetation by comparing plant stem densities below the dock with stem densities adjacent to the dock (Kearney, Segal, and Lefor, 1983; McGuire, 1990; Sanger and Holland, 2002; Alexander and Robinson, 2004). These studies all indicate that the dock walkway structure creates a significant reduction in plant stem density beneath the dock compared with adjacent sampling sites (Figure 2). *Spartina alterniflora* is the most sensitive of the common saltmarsh vegetation to shading impacts (Kearney, Segal, and Lefor, 1983). Stem density comparisons quantify physical alterations to the marsh community structure and work well for this type of analysis since they generate reliable data with minimal collection time. However, extension of stem

Figure 2. Reduced plant growth beneath dock.

density measurements to saltmarsh productivity is not straight-forward given the potential variability in plant heights and stem diameters. For example, it is possible that areas of saltmarsh under docks, where low stem densities are observed, may contain larger and more robust plants than in adjacent areas. A better assessment of marsh function should include factors such as above- and below-ground biomass, canopy architecture and species diversity. These types of analyses will lead to a much more accurate measure of how dock structures are affecting marsh productivity in terms of carbon input to the nutrient cycle (Thursby et al., 2002; Callaway et al., 2001). Several studies suggest that biomass measurements are central to attaining an accurate understanding of how salt marsh productivity is affected by docks (Kearney, Segal, and Lefor, 1983; Struck et al., 2002).

Given that the carbon content of *Spartina alterniflora* tissue is known, biomass measurements additionally allow an estimate of the impact on total organic carbon contributed to the saltmarsh nutrient budget (Keefe, 1972; Gallagher, 1975; Craft, Broome and Seneca 1986, 1991; Osgood and Zieman, 1993; Tyler, 1997; Callaway et al., 2001). This study seeks to establish if a relationship exists between stem density and aboveground biomass and if so, to determine the character and significance of this relationship for organic matter input to the marsh. Using these methods, we seek to constrain the impact of private recreational dock structures on basic parameters of saltmarsh productivity.

METHODS

Vegetation was harvested from below dock walkways and from areas 5 meters adjacent to the docks to measure the dry weight of plant material. These weights were used to estimate the amount of organic material the saltmarsh vegetation could potentially contribute to the estuarine food cycle. Samples were collected from study locations surrounding Wilmington Island, Georgia (Figure 3). The recreational docks around the island represent a broad range of dock sizes, dock ages, and marsh conditions from which to sample. A previous study (Alexander and Robinson, 2004) examined the stem density reduction associated with Wilmington Island docks as well as proliferation patterns of docks between 1970 and 2000. Data from that 2004 study, combined with biomass measurements, will establish a much more detailed description of recreational dock impacts on estuarine habitat.

Sampling areas were located beneath (hence termed “dock” samples) and adjacent (hence termed “control” samples) to 25 docks surrounding Wilmington Island, Georgia. Depending on marsh width or access logistics, these paired data were collected either 10 meters from the upland (“A” sites), 10 meters from the creek vegetation edge (“B” sites), or at both locations (“A” and “B” sites), for a total of 35 pairs of data   (13 “A” sites, 22 “B” sites).

Figure 3. Sampling locations around Wilmington Island, Georgia.

All live and standing dead *Spartina alterniflora* vegetation was clipped at ground level and collected from within a 0.25 m^2 quadrat below the dock and at a location 5 meters adjacent to the dock sample location (from the right side of the dock when facing channelward). A GPS location was taken above each quadrat to record location and digital pictures were taken before and after clipping (Figure 4). Samples were collected during late October and early November to quantify the biomass present at the end of the growing season.

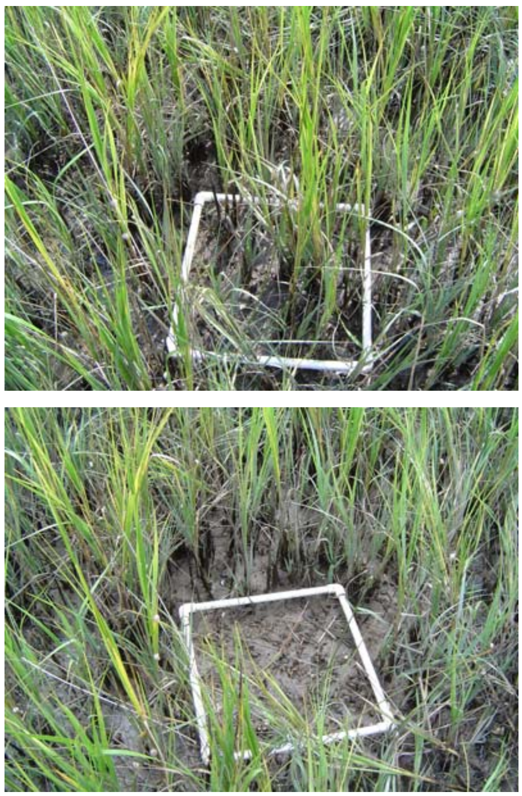

Figure 4. 0.25 m^2 quadrat before and after vegetation collection.

To test for differences between tall and short growth forms of *Spartina alterniflora*, samples were rinsed to remove mud and sorted into 3 categories (Figure 5): live-short (0-40 cm), live-tall (>40 cm), and dead (Valiela et al., 1978; Mooring et al., 1971; Shea et al., 1975). The total length for all live stems, short and tall, was measured and recorded. Each sorted sample was placed into a pre-weighed aluminum foil pouch (live-short, live-tall, and dead) and dried in an oven at 80 degrees C for 48 hours or to a constant weight (Cramer et al., 1981; Gross et al., 1991; Kirby and Gosselink, 1976).

Dead Short Tall

Figure 5. Stem groups separated prior to drying.

From these measurements we expanded the values to per m^2 and compared the stem density, the constant dry weight of live plants short and tall, standing dead plants, and total dry weight, below the dock versus the control areas. Data were also compared between “A” sites and “B” sites. The number of stems per unit area was compared with the weight of plant material for total, short, and tall. Recorded data is presented in eight categories; SAD – <u>s</u>hort grass, <u>A</u> location, under <u>d</u>ock; SAC – <u>s</u>hort grass, <u>A</u> location, <u>c</u>ontrol; TAD – <u>t</u>all grass, <u>A</u> location, under <u>d</u>ock; TAC – <u>t</u>all grass, <u>A</u> location, <u>c</u>ontrol; SBD – <u>s</u>hort grass, <u>B</u> location, under dock; SBC – short grass, B location, control; TBD – tall grass, B location, under dock; TBC – tall grass, B location, control. Data recorded for standing dead material was useful in calculating the total biomass residing in a quadrat for that particular collection time; however this data was not used in further analyses as this study is focused on the decrease in new organic material associated with dock structures.

Samples were collected from "A" site and "B" site locations to evaluate if differences exist in the manner a saltmarsh responds to recreational dock structures near the upland as opposed to near the waterway. "A" sites are located 10 meters from the marsh-upland boundary and "B" sites are located 10 meters from the marsh-creekside boundary. The selection of a 10 meter buffer was intended to exclude the luxuriant, tall plant growth near the marsh levee at "B" sites and to exclude obvious, direct upland influences (e.g., marsh wrack impacts, bulkheaded shorelines, pollutant runoff) at "A" sites. Significance was determined at the 95% confidence level.

RESULTS

Stem density measurements show an average reduction of 50% between dock samples and control samples (% decrease = ((control – dock / control) x 100)). "A" sites were reduced by an average of 46% and "B" sites were reduced by an average 52% (Figure 6, individual site data in Appendix 1). These values are similar to those recently documented for southeastern marshes by Alexander and Robinson (2004) and Sanger and Holland (2002) where they found a 56% and 71% decrease, respectively (Table 1). Stem densities below docks are significantly different from stem densities in control areas for all sites, for short vegetation, and tall vegetation using paired t-tests and the Wilcoxon signed rank test ($p < 0.001$; Fig. 7).

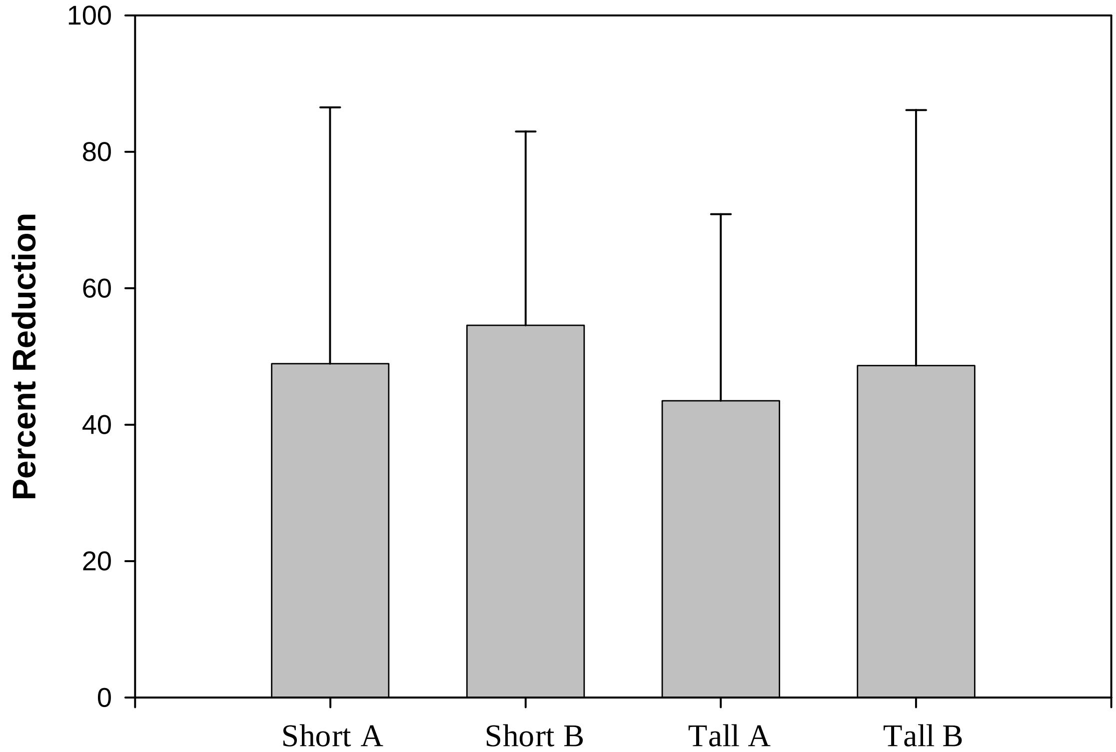

Figure 6. Comparison of percent reduction in stem density between dock and control (mean ± standard deviation).

Table 1. Comparison of stem density reduction associated with docks in studies from the Southeast.

State	Average Stem Density Reduction	Source
Georgia	50%	Alexander and Robinson (this study)
Georgia	56%	Alexander and Robinson (2004)
South Carolina	71%	Sanger and Holland (2002)
Virginia	65%	McGuire (1990)

All sites demonstrated a similar composition in the ratio of short to tall stems with short stems making up the majority of each sample (Figure 8). The number of stems from all samples

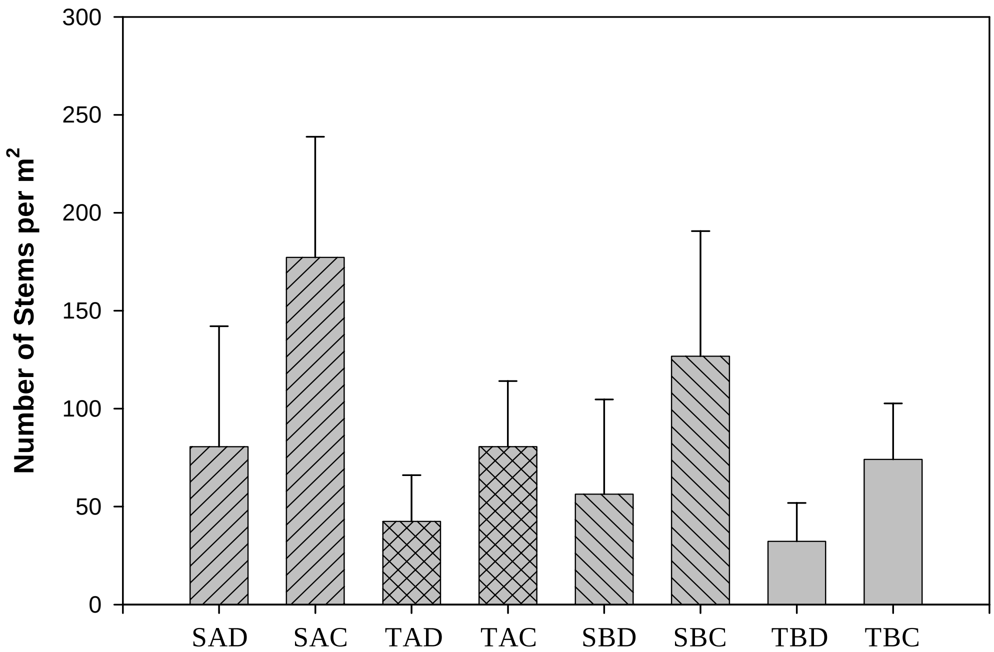

Figure 7. Comparison of stem densities for "A" and "B" sites, tall and short vegetation and dock and control sites (mean + standard deviation). Bars with identical patterns represent paired data used in statistical tests (see text).

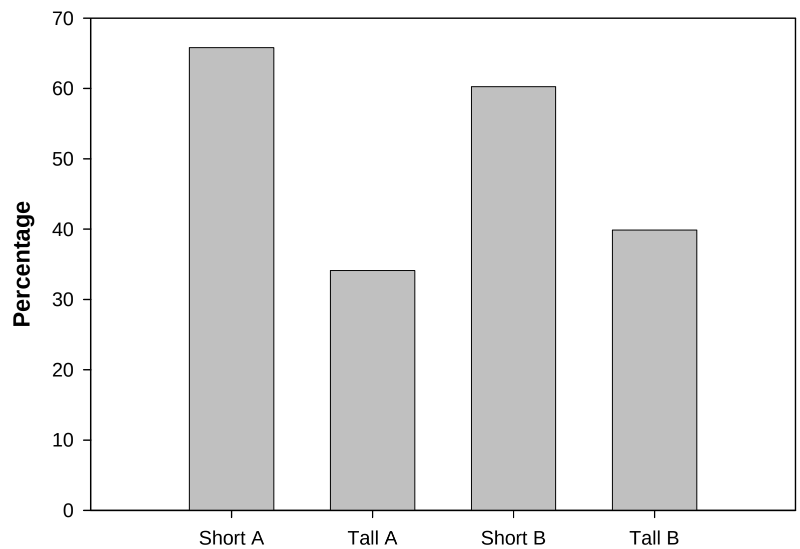

Figure 8. Stem height class percentages by site.

averaged 62% short and 38% tall, “A” site stems averaged 65% short and 35% tall, and “B” site stems averaged 60% short and 40% tall, (n = 2833 stems).

Average stem heights were greater for tall vegetation below the dock than for tall vegetation in control sites at both “A” and “B” locations (Figure 9, individual data in appendix 2). “B” location tall stems are taller than “A” location tall stems. Average stem heights at “B”

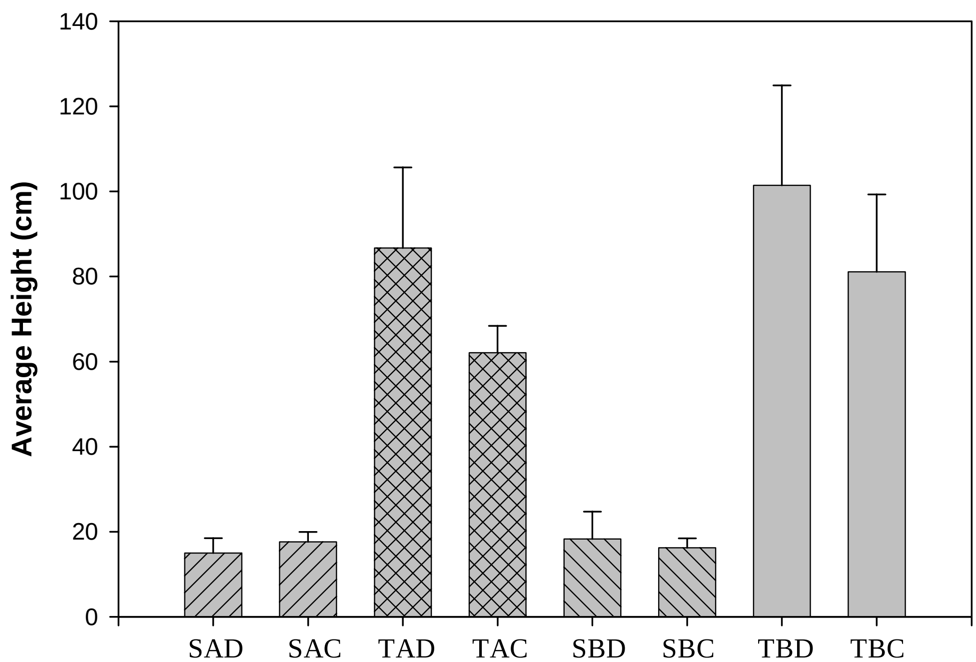

Figure 9. Comparison of average stem heights by category (mean $\pm$ standard deviation). Bars with identical patterns represent paired data used in statistical tests (see text).

locations were statistically different for tall stems below dock compared to tall stems from the control area using a paired t-test ($t = 3.992$, $df = 21$, $p < 0.001$). “B” location short stem heights were not statistically different between dock and control using a paired t-test ($t = 1.324$, $df = 21$, $p = 0.20$). Average stem heights at “A” locations were statistically different for both tall ($t = 4.834$, $df = 14$, $p < 0.001$) and short stems using paired t-tests ($t = -2.383$, $df = 14$, $p = 0.032$). Tall plants were not significantly different between “A” and “B” locations below dock using a t-test ($t = 1.797$, $df = 35$, $p = 0.081$) but were significantly different in the control locations using a Mann-Whitney Rank Sum Test ($t = 179$, n(small) = 15, n(big) = 22, $p = 0.001$). Variation between “A” and “B” sites may be the result of many variables and will be discussed in a later section of this report. Fundamentally, plants growing near creek edges are exposed to different nutrient, temperature, salinity, and moisture conditions than plants found in higher parts of the marsh.

The mean weights of total (living plus dead) aboveground biomass, or organic matter, in this study was comparable to that observed in similar environments (Table 2). The mean weight of aboveground living biomass for each category sampled was higher in the control sites (average value for all control sites 379 g/m^2) than in the dock sites except for tall plants at “A” locations (Table 3, individual data in appendix 3). Average percentage of living biomass reduction was 33% for short stems in “A” locations, 45% for short stems in “B” locations, and 31% for tall stems in “B” locations. An average increase in live weight of 23% was observed for tall stems in “A” locations.

Table 2. Comparison of total and living aboveground biomass measurements.

Source	**State**	**Living Biomass (g/m^2)**	**Total Biomass (g/m^2)**
Alexander and Robinson (this study)	Georgia	154 - 825	249 - 1226
Hardisky (1980)	Georgia	444 - 717	
Reidenbaugh (1983)	Virginia	318 - 1082	
McIntire and Dunstan (1975)	Georgia		275 - 1922
Williams and Murdoch (1966)	North Carolina		250 - 2100
Stroud and Cooper (1969)	North Carolina		259 - 1320
Tyler (1997)	Virginia		274 - 977

Table 3. Summary of mean values for stem density, aboveground living biomass, plant height, weight per stem, and weight per linear cm from each category.

Category	Mean Stem Density (m^2)	Mean Aboveground Biomass (g/m^2)	Mean Plant Height (cm)	Mean Weight per Stem (g)	Mean Weight per Linear cm (g)
SAD	82	28	15	0.28	0.019
SAC	183	50	18	0.31	0.018
TAD	43	196	88	4.30	0.050
TAC	79	175	62	2.28	0.037
SBD	56	24	18	0.51	0.028
SBC	127	47	16	0.41	0.026
TBD	32	257	101	8.65	0.082
TBC	74	410	81	5.90	0.071

Changes in total aboveground living biomass are significant using paired t-tests when comparing under dock and control sites at "B" locations ($t = -4.642$, $df = 21$, $p < 0.001$), and when combining "A" and "B" sites together ($t = -3.917$, $df = 36$, $p < 0.001$); no significance was observed looking at "A" locations alone ($t = -0.949$, $df = 14$, $p = 0.36$). "B" location data was significantly different between dock and control for both short and tall stems using paired t-tests (short: $t = - 4.382$, $df = 18$, $p < 0.001$, tall: $t = - 3.925$, $df = 18$, $p < 0.001$) and "A" location data was significantly different for short stems ($t = - 2.512$, $df = 11$, $p = 0.029$) but not significant for tall stems ($t = - 0.323$, $df = 11$, $p = 0.75$; Figure 10, individual data in appendix 3).

Because 44% of the plant biomass is organic carbon (Table 4) the percent reduction in carbon input between dock and control is the same as the percent reduction in biomass for every

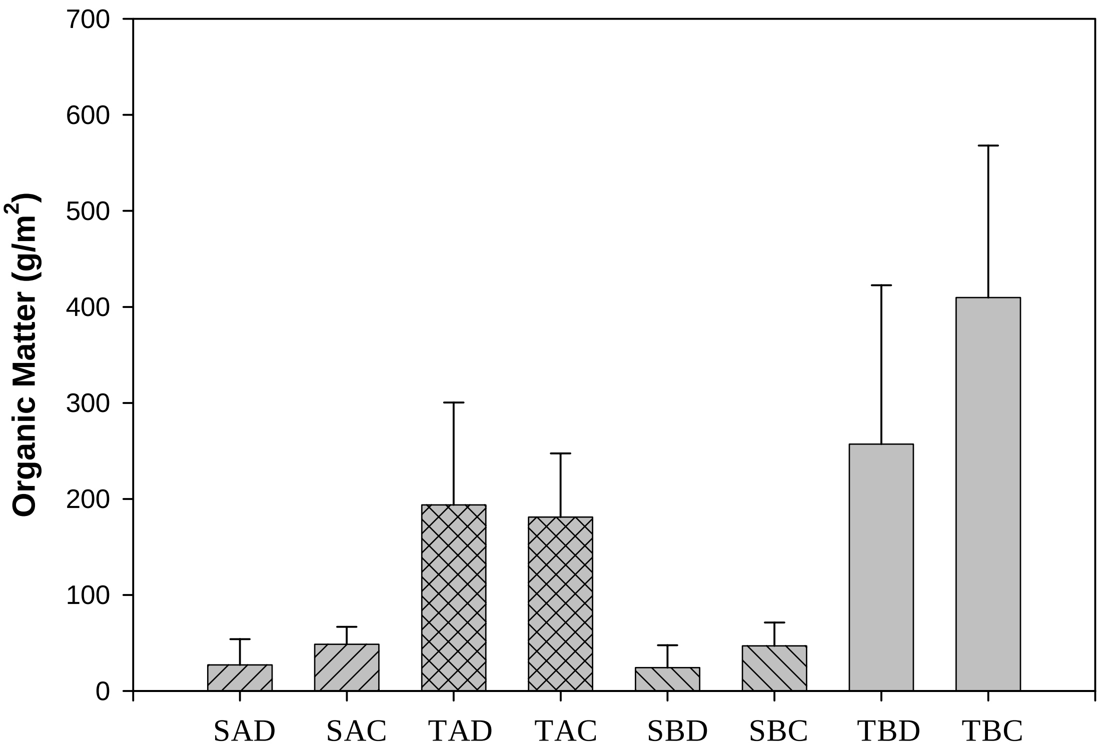

Figure 10. Aboveground biomass comparison by category (mean ± standard deviation). Bars with identical patterns represent paired data used in statistical tests (see text).

Table 4. Comparison of organic carbon values measured from *Spartina alterniflora* tissue samples.

Report	Organic Carbon Content
Gallagher (1975; Georgia)	44%
Craft, Broome, and Seneca (1986; North Carolina)	43%
Osgood and Zieman (1993; Virginia)	40% - 42%
Tyler (1997; Virginia)	41% - 44%

site. Average reduction of biomass and organic carbon was 21% when looking at all sites, -3% when looking at "A" sites alone, and 37% when looking at "B" sites alone (Figure 11). Positive biomass reductions were observed in all site comparisons except those for tall vegetation at A sites (Figure 12).

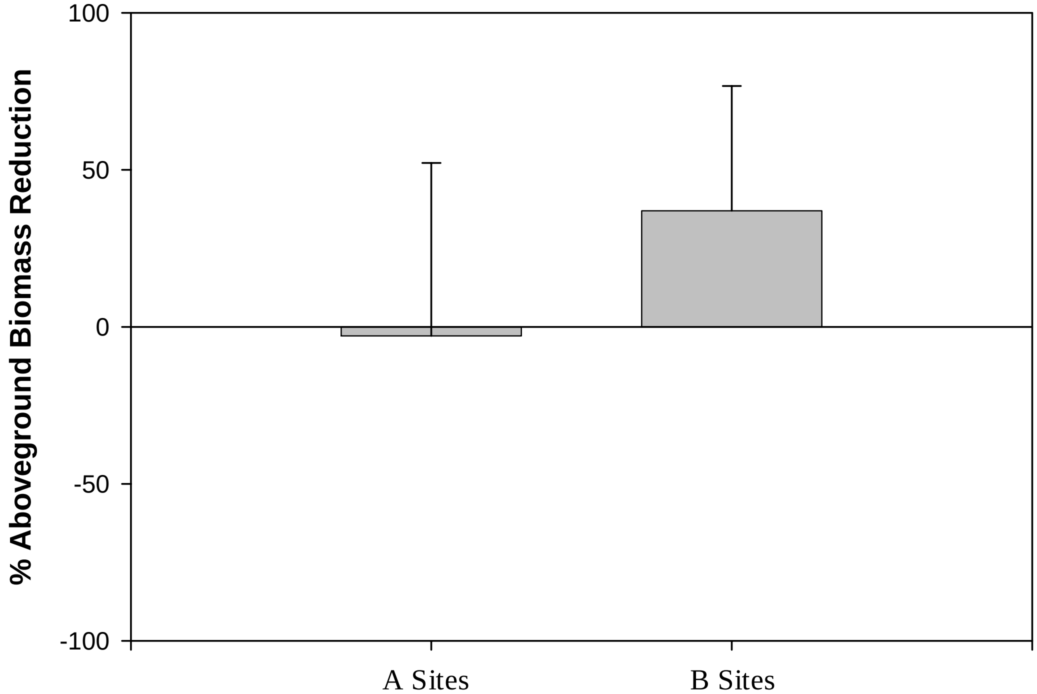

Figure 11. Percent biomass reduction between dock and control locations (mean + standard deviation).

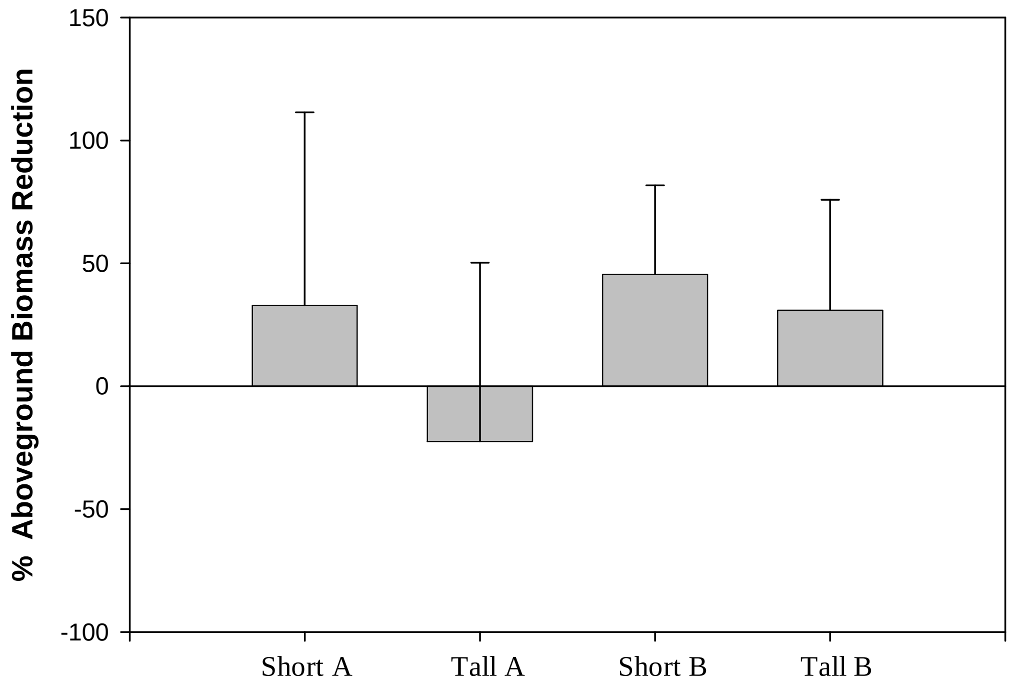

Figure 12. Percent biomass reduction by site (mean + standard deviation).

By dividing the mass in each stem category by the corresponding number of stems, we can calculate that the average weight per stem from all samples is 2.4 g, the average weight per stem of short stems is 0.4 g, and the average weight per stem of tall stems is 5.9 g. Short stems average 13% and tall stems average 87% of total living aboveground biomass. The weight per stem by category is given in Table 3 and shown in Figure 13.

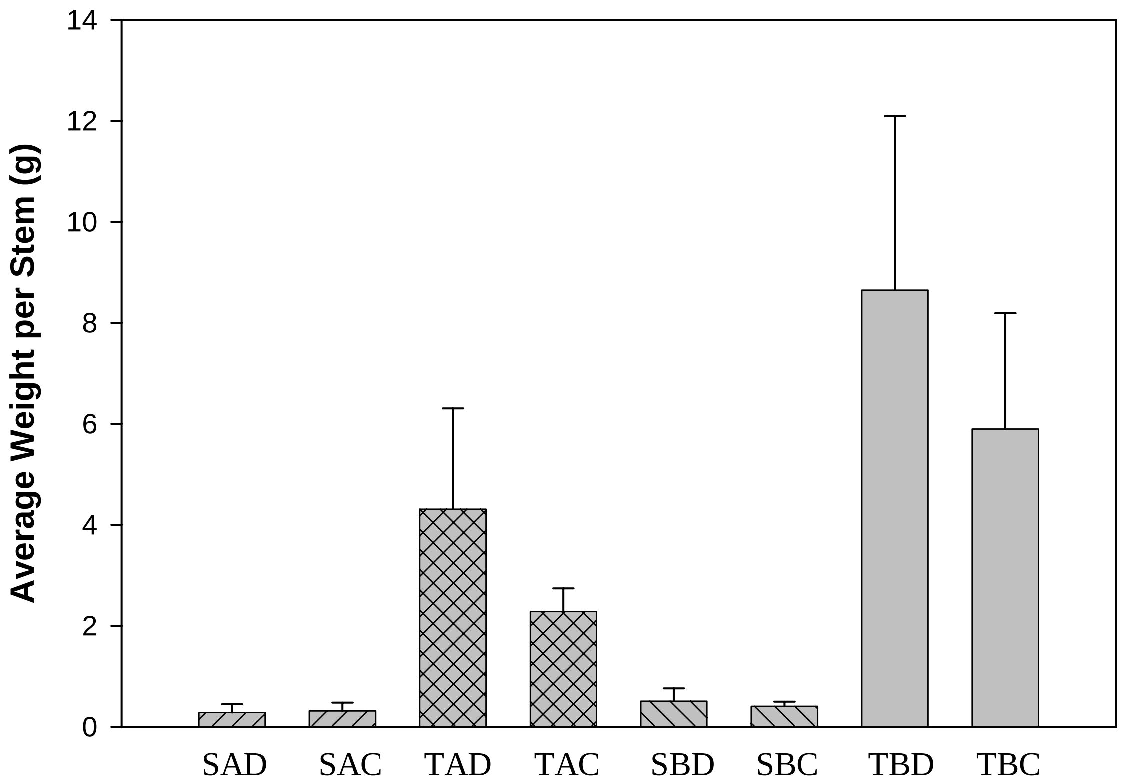

Figure 13. Comparison of average weight per stem by category (mean ± standard deviation). Bars with identical patterns represent paired data used in statistical tests (see text).

Living plant biomass was averaged by the number of stems and the stem heights in each category to estimate an average weight per linear cm. There was no significant difference between short stems at dock versus control sites at either "A" or "B" locations using paired t-tests (A: $t = 0.746$, $df = 11$, $p = 0.47$, B: $t = 0.775$, $df = 18$, $p = 0.45$). Tall stems were significantly different under dock versus control at both "A" and "B" locations (A: $t = 4.429$, $df = 11$, $p = 0.001$, B: $t = 2.098$, $df = 18$, $p = 0.05$). The weight per linear cm by category is given in Table 3 and shown in Figure 14.

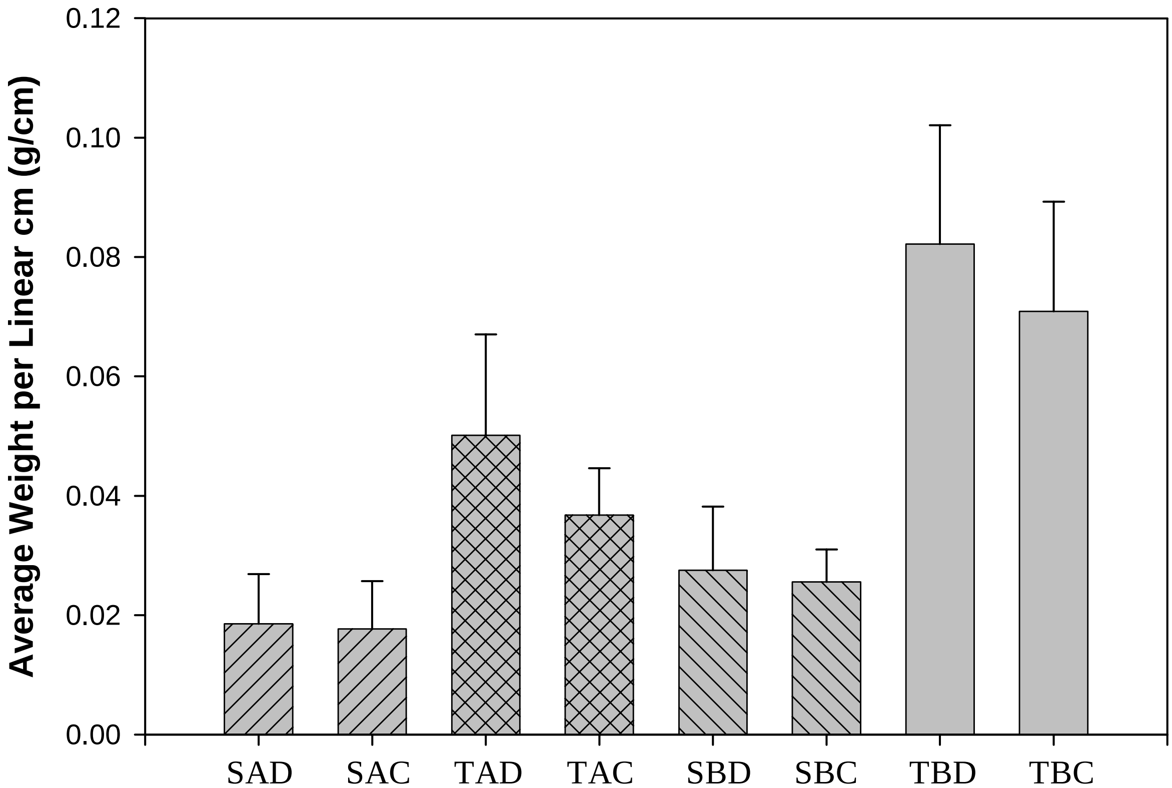

Figure 14. Comparison of average weight per linear cm by category (mean $\pm$ standard deviation). Bars with identical patterns represent paired data used in statistical tests (see text).

Stem density of *Spartina* was compared with several variables in order to assess its effectiveness for describing marsh productivity. Stem density in each category compared with living aboveground biomass in each category demonstrated positive linear relationships (SAD, $r^2 = 0.83$, $p = 0.0002$; SAC, $r^2 = 0.39$, $p = 0.054$; TAD, $r^2 = 0.48$, $p = 0.026$; TAC, $r^2 = 0.84$, $p = 0.0002$; SBD, $r^2 = 0.72$, $p < 0.0001$; SBC, $r^2 = 0.72$, $p < 0.0001$; TBD, $r^2 = 0.65$, $p < 0.0001$; TBC, $r^2 = 0.11$, $p = 0.17$). Stem density compared with mean plant height, weight per stem, and weight per linear cm was poorly correlated and showed weak negative relationships for tall plants. Stem density of tall plants from dock and control sites compared with total living aboveground biomass also produced positive relationships (TAD, $r^2 = 0.55$, $p = 0.014$; TAC, $r^2 = 0.80$, $p = 0.0005$; TBD, $r^2 = 0.62$, $p < 0.0001$; TBC, $r^2 = 0.12$, $p = 0.15$). Comparing stem density percentage reduction for tall plants with the percent organic carbon reduction gave similar estimates, as the organic carbon content of the organic matter is a constant proportion (i.e., 44%). Measurements from “A” locations showed a strong relationship between tall stem density reduction and organic carbon reduction ($r^2 = 0.69$, $p = 0.0004$), “B” locations expressed a weaker, although statistically significant, relationship ($r^2 = 0.34$, $p = 0.005$, Figure 15).

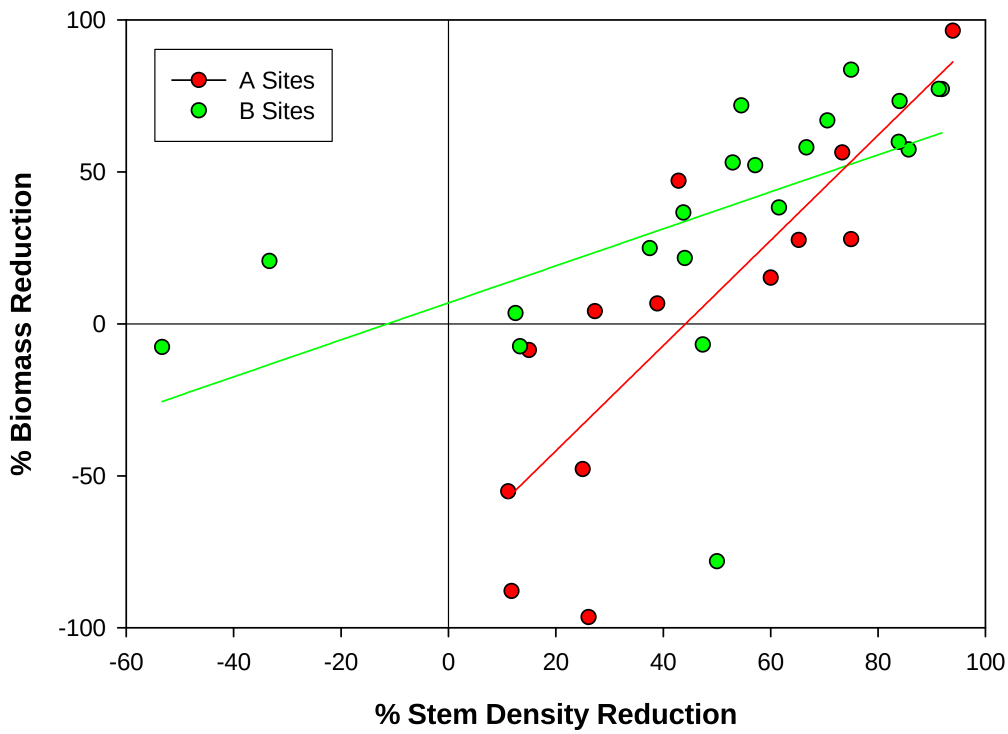

Figure 15. Comparison of stem density reduction versus biomass reduction at “A” and “B” sites.

As the salt marsh is a biological system that is growing and actively producing biomass, one would expect the two parameters of stem density reduction and biomass reduction to positively covary (i.e., a decrease in stem density should be accompanied by a decrease in biomass). Thus, the data would be expected to fall, and to a great extent does, within the upper right quadrant in Figure 15, suggesting that data in other quadrants of the graph may be outliers from non-steady-state conditions in the marsh (see Discussion).

Looking at only the data in the upper right quadrant of Figure 15, a graph using both the “A” and “B” location data shows a significant correlation between stem density and biomass reduction ($r^2 = 0.63$, $p < 0.0001$) and an x-intercept at 13.3% along the stem density reduction axis from the origin (Figure 16). In contrast, “B” location data alone exhibit a more robust significant relationship ($r^2 = 0.74$, $p < 0.0001$) and the regression through these data exhibits an

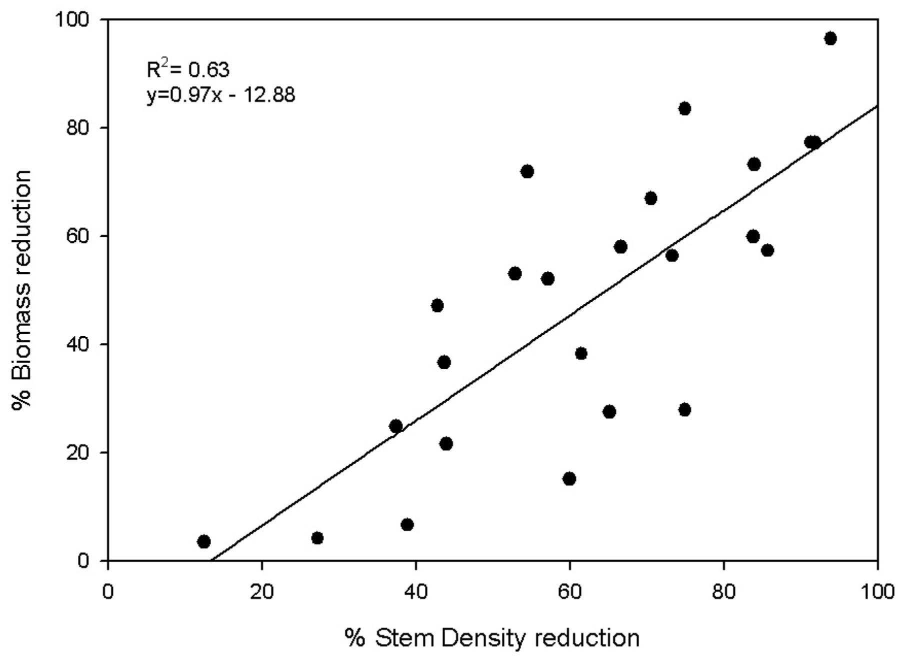

Figure 16. Biomass reduction vs. stem density reduction using all positive “A” and “B” site data. Note that the intercept on the stem density reduction axis (13.3%) is significantly offset from the origin, suggesting a resiliency in the system to accommodate this magnitude of reduction without a significant reduction of biomass.

x-intercept at only 2.9% on the stem density reduction axis (Figure 17). “A” location data alone exhibit a weaker significant relationship ($r^2 = 0.58$, $p = 0.027$) and the regression through these data exhibits the large x-intercept at 26.7% on the stem density reduction axis (Figure 18).

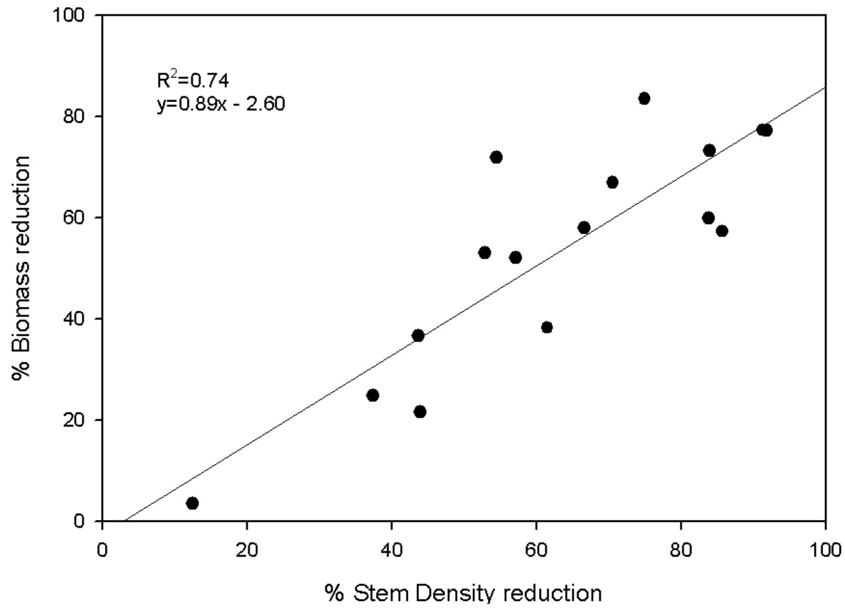

Figure 17. Biomass reduction vs. stem density reduction using the positive values for "B" sites only, a subset of the data in Fig. 15. Note that the intercept on the stem density reduction axis (2.9%) is close to the origin.

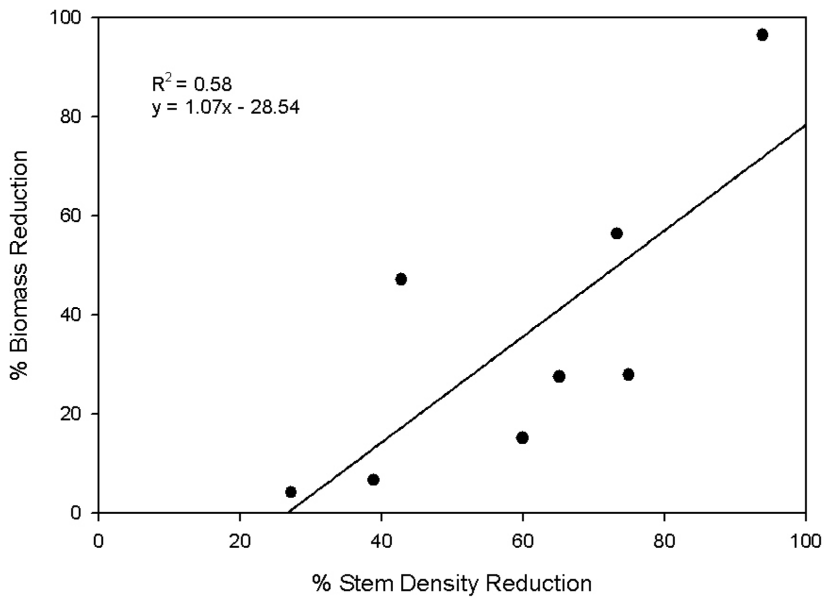

Figure 18. Biomass reduction vs. stem density reduction using the positive values for "A" sites only, a subset of the data in Fig. 15. Note that the intercept on the stem density reduction axis (26.7%) exhibits a much greater offset from the origin than do “B” sites.

DISCUSSION

The results produced in this study document that clip plots of marsh grass for aboveground biomass measurements is a viable technique that works well for examining recreational dock impacts. The methods employed in this study provide data on both stem density and biomass for short and tall vegetation at upland as well as creek-side locations. The broad natural variation in saltmarsh habitat and its response to perturbations necessitates sampling in a large number of areas to minimize the error inherent in sampling biological systems.

Several previous studies have demonstrated how dock structures cause physical and biological alteration to saltmarsh habitat through the thinning of the vegetated canopy (see Merkey et al., 2005 and references therein). This thinning increases predation risk to juvenile inhabitants sheltering and feeding in the marsh, causes habitat fragmentation and decreases food availability in the form of detritus and algae. The physical habitat is changed as well, as decreased stem density correlates to less baffling of current and wave energy, which causes less sediment to be deposited on the marsh and increases the erosion potential of the surface. These habitat changes can be expected to be associated with the decrease in stem density documented in this study. Analysis of stem density data from this study produced similar results to previous work on dock impacts to marsh vegetation in the southeastern US.

Clip harvesting samples from the marsh allowed for accurate height measurements. By classifying vegetation into short and tall groups, we were able to establish that the composition of habitat based on the ratio of short to tall grass was similar for both upland and creekside locations. Detailed height measurements demonstrated that tall vegetation was taller beneath the dock than in control sites for both upland and creekside locations, probably as a result of etoliation in response to shading (Kearney, Segal, and Lefor, 1983; McGuire, 1990). As has been previously documented from numerous sites, control creekside tall plants were taller than upland tall plants (Table 3). These detailed height data were used to calculate the average weight per stem and weight per linear centimeter, allowing us to address the issue of plant robustness at dock versus control sites. In both “A” and “B” locations lower stem densities of tall plants were associated with higher average biomass per stem. Although samples below the docks contained more mass per stem and per linear cm, the decrease in stem density was still significant enough to easily offset this increase in mass. Dock-site stems may grow more robustly due to reduced competition for nutrients and space beneath the dock; however, these characteristics were not assessed in this study.

As the stem density increases so does the total biomass in all locations. Note that significant positively covarying relationships were observed between stem density and biomass with total stems, tall stems and organic carbon, suggesting that stem density is a useful method for assessing these parameters. Tall grass biomass increases with stem density at a much faster rate than does short grass biomass and creekside locations increase faster than upland locations. The live biomass was lower beneath the dock than adjacent to the dock for each category except tall grass at upland locations. Biomass of short grass was reduced 33% at “A” locations and reduced 45% at “B” locations. Biomass of tall grass was reduced 31% at “B” locations whereas it was increased by 23% at “A” locations. The variation in tall biomass between “A” and “B” locations and the greater variability in the data from the “A” sites suggests that there may be physical differences distinguishing the two locations and altering the tall grass’ productivity.

In all zones of the marsh there are areas of spatial heterogeneity and fragmentation caused by changes in the structural composition of the marsh (e.g., vegetation size, stem density, proximity to small creeks and drainages, canopy, and presence of marsh wrack). As a result of these natural variations, both "A" and "B" locations demonstrated a broad range of values for many of the parameters being measured. However, in this study we consistently found the marsh to be more variable in the region represented by "A" locations and more homogeneous in the region represented by "B" locations. Several distinct differences are evident between "A" type and "B" type sites. Although "A" sites were located in areas of monotypic *Spartina alterniflora*, they were more closely located to other species of high marsh and marsh border vegetation. "B" sites were consistently in areas of broad, dense *Spartina* vegetation. Vegetation at "A" and "B" sites experience a different duration of inundation. The "A" sites' proximity to the upland results in coarser sediment grain size, higher pore water salinity, greater potential for marsh wrack accumulation, greater impact from upland runoff and greater use by upland fauna when compared to "B" sites. Plant height from control samples show that "B" site vegetation is taller, averaging 81 cm, whereas "A" site vegetation averages 63 cm tall. In addition, the tall vegetation in "B" sites has a greater average weight per linear cm than vegetation at "A" sites (Table 3). In all cases, the "A" sites are potentially more influenced by adjacent and unlike environments whereas "B" sites represent the bulk of Georgia salt marshes which are removed from upland interactions. For these reasons, we feel that the data for "B" sites is more representative of the saltmarsh as a whole than are the data for "A" sites.

Interestingly, the biomass reduction versus stem density reduction data presented in Figures 16-18 may suggest that some parts of the marsh are more resilient to shading impacts. The offset between the origin of the graphs in Figures 16-18 at 0,0 and where the regression line actually crosses the stem density reduction axis implies that there may be some amount of stem density reduction that can be accommodated by the system without a commensurate decrease in biomass. The combined “A” and “B” site data show a 13.3% offset from the origin along the stem density reduction axis, suggesting resiliency in the system as a whole, such that a decrease in stem density of 13.3% can be accommodated without any decrease in biomass (Figure 16). However, looking at the “A” and “B” data separately documents that the dominant factor in the offset derives from the “A” site data alone, which exhibit a 26.7% offset (Figure 18). The true magnitude of the offset is actually masked by the small offset of the “B” site data (2.9%) when the two are plotted together (Figure 17). The “B” location data also suggest that the bulk of the salt marshes of Georgia, which we suggest earlier are represented by “B” locations, is more sensitive to shading and cannot accommodate large decreases in stem density without significant decreases in biomass. Thus, in terms of impact to the marsh, shorter docks are preferable to longer docks because shorter docks cross proportionally more of the resilient marsh environment (i.e., “A” sites) and less of the comparatively sensitive marsh environments (i.e., “B” sites). These observations are worth additional examination given the small number of observations in the present “A” site dataset.

The mass of potential organic carbon production that is not realized each year because of shading was estimated based on the biomass of the samples and the carbon content of *Spartina*. The average reduction in organic carbon for all samples at all locations was 21% beneath the dock versus adjacent to the dock. “A” locations encompassed a wide range of values (-96% to 96%) and demonstrate a slight increase in organic carbon weight beneath the dock. The values beneath the dock were not found to be significantly different than those found adjacent. “B” location values show a 37% decrease beneath the dock and values were found to be significantly different from adjacent values.

Assessing Cumulative Impacts

The data in this report can be combined with an extensive dataset of dock information for Wilmington Island, GA, to quantify the impact of this decrease in carbon. From the present study, the average mass of organic carbon per square meter of marsh calculated from all control sites is 167 g/m^2. Using area measurements from the Alexander and Robinson (2004) dock study on Wilmington Island, the average area of dock walkway constructed over vegetation between 1990 and 2000 was 123 m^2. Assuming that these most recently constructed docks are typical of modern construction sizes, 20,541 g of carbon could be produced in the footprint of one of these docks (167 g/m^2 * 123 m^2). Using the organic carbon reduction of all sites and "B" sites (21% and 37% respectively), then the unrealized organic carbon contribution to the saltmarsh ecosystem under the footprint of the dock would be between 4.3-7.6 x 10^3 g per dock per year (Table 5). Cumulative measurements of all docks constructed in the study area in 2000 measured 24,021 m^2 of dock area over vegetation. Based on these values, the year 2000 dock footprint over vegetation is presently reducing the available organic carbon between 8.4-1.5 x 10^6 g per year.

Table 5. Possible carbon reductions based on measured reductions in biomass.

Organic Carbon % of Live Aboveground Biomass	Average Control Site Annual Organic Carbon Production	Annual Reduction of Organic Carbon Per Dock (21% reduction)	Annual Reduction of Organic Carbon Per Dock (37% reduction)
44%	167 g dw/m^2	4,313 g dw	7,600 g dw

The 2000 dock data from Wilmington Island documented 301 recreational docks existing around the island. Parcel data from 2000 demonstrated that there were 609 (or in other words, an additional 308) parcels with riparian rights that could potentially be permitted to build docks. Based on these numbers and without further subdivision of parcels, cumulative annual reduction of organic carbon to the saltmarsh nutrient budget would be 2.2-3.8 x 10^6 grams per year around Wilmington Island. The area of marsh directly surrounding Wilmington Island from the upland out to the first 9 m wide creek is 4.8 x 10^6 m^2. The annual production of organic carbon for this area is approximately 8.0 x 10^8 g. Maximum buildout of docks on Wilmington, assuming 609 parcels, could reduce the available organic carbon by 0.3% to 0.5% (Table 6). It is reasonable to assume that some subdivision of the remaining 308 riparian parcels will occur and therefore the actual amount of carbon reduction would be greater.

Table 6. Potential reduction of organic carbon based on conditions as of 2000, and in a maximum build-out scenario.

Dock Buildout Scenario	**Number of Recreational Docks**	**Annual Reduction of Organic Carbon (21% reduction)**	**Annual Reduction of Organic Carbon (37% reduction)**
2000 Actual	301	842,416 g	1,484,258 g
2000 Parcel data	609	2,171,008 g	3,825,110 g

This analysis can be carried further using a State-wide dataset of private recreational docks in Georgia. This dataset, acquired from the Georgia Department of Natural Resources, Coastal Resource Division (2006), documents permits for 3,183 private docks issued between 1974 and May 2006. The DNR has size data for 73% of these docks, which provides an average area of 174 m^2 per dock. Based on the 2000 footprint of all docks around Wilmington Island, on average 51% of total dock area is built over marsh vegetation. Assuming that these sizes (from the DNR dataset) and marsh-coverage statistics (from Alexander and Robinson, 2004) are representative of all docks in the State built after 1974, the average area of a private dock over vegetation in Georgia is 89 m^2 (0.51 * 174 m^2) and the total post-1974 permitted dock footprints cover 283,287 m^2 of vegetated marsh. Based on these numbers, private recreational docks are decreasing the input of carbon into the Georgia estuarine environment by 1.0-1.8 x 10^7 gC/y (283,287 m^2 * 167 gC/m^2 * 0.21 or 0.37). However, these values should be considered minimum estimates because the data do not include any docks constructed prior to 1974, which could be substantial in number. Alexander and Robinson (2004) document that 58% of individual docks and 52% of total dock area existing on Wilmington Island in 2000 existed prior to 1970, suggesting that State-wide data for docks may be underestimating dock numbers by approximately 50%.

Application to Biological Resources

The previous discussion has provided data demonstrating the physical changes and fundamental biological impacts that are manifest in salt marsh habitat under existing private recreational docks. One approach to using these data to further assess the biological impacts of these physical changes is to use biomass data to quantify the reduction in productivity of the saltmarsh ecosystem because of decreased primary productivity. Primary production, in this instance, is defined as the rate of photosynthetic energy accumulation within the saltmarsh system, leading to an increase of biomass. Beyond acting as an indicator of marsh performance, this biomass provides the energy source necessary for all subsequent trophic interactions (Callaway et al. 2001). For the intertidal marshes of Georgia, vascular plants and benthic algae are the two main sources of primary production and thus biomass. Kneib (2003) has developed a productivity model that uses the aboveground biomass of living *Spartina* to estimate the biomass production of both resident (killifish, grass shrimp) and migrant (sciaenid fishes, penaeid shrimp) nekton, which includes juveniles of many commercial species from Georgia waters. Figure 19 illustrates the application of the Kneib (2003) model to the dataset from the present study. Insects and other herbivores graze directly on the *Spartina* and have a 10% trophic transfer efficiency, 20% which is available to aquatic predators and the rest assigned to terrestrial food webs (i.e., spiders). Remaining *Spartina* production (90% of the total) enters a detrital pathway initiated by fungi with a trophic transfer efficiency of 55%. Invertebrate consumers capture 33% of the available production with a 10% trophic transfer efficiency. The remaining 67% of detrital production passes on to the bacterial community with a 10% trophic transfer efficiency and this bacterial biomass is available to invertebrate consumers with a 10% trophic transfer efficiency as well. This model assumes a benthic algae contribution 25% that of *Spartina* (Pomeroy et. al., 1981). Benthic algae is directly available for consumption by invertebrates with a 10% trophic transfer efficiency. The model assumes that 90% of the invertebrate production is available with a 10% trophic transfer efficiency to nekton. Total nekton production is approximately 67% resident species and 33% migrant species based on field data. Finally, the resident nekton are available as prey for the migrant nekton with a 10% trophic transfer efficiency.

Using an average living *Spartina* biomass of 379 g dw/m^2 as derived from the present study from control locations, nekton production would be 2.3 g dw/m^2 (Figure 19). Carrying the 21% decrease in biomass averaged over all study locations through the model results in a 21% reduction in nekton productivity and carrying a 37% decrease in biomass representative of “B”

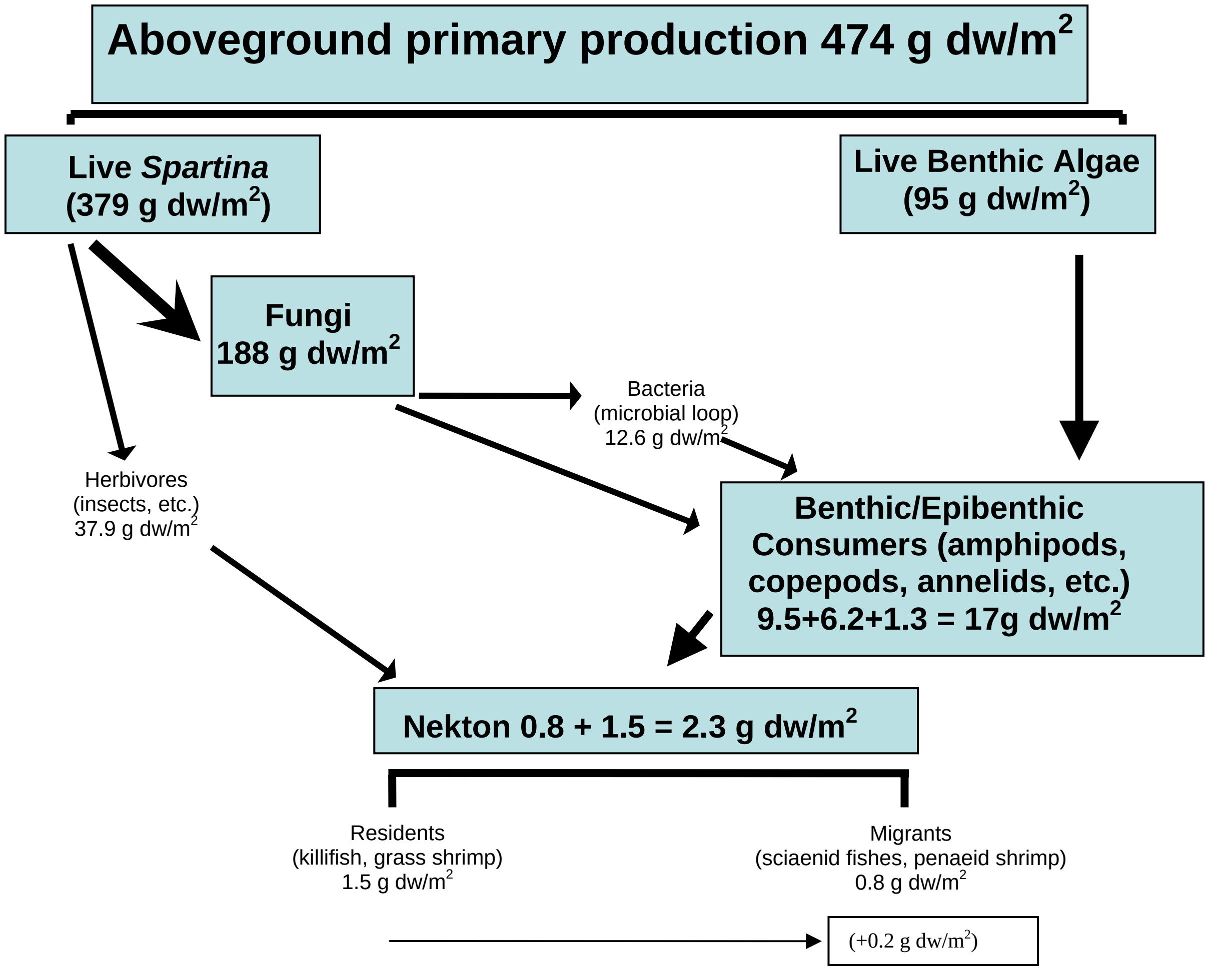

Figure 19. Model of trophic transfer from Kneib (2003) used to show the decrease in nekton production resulting from dock shading.

locations through the model results in a 37% reduction in nekton productivity under the footprint of each dock. Thus, shading from each individual dock decreases the production of nekton under the footprint of the dock by 0.5 g dw/m^2 using data averaged over all sites, or 0.9 g dw/m^2, if "B" sites are more representative of the saltmarsh as a whole as described earlier. A critical point to understand is that this loss of nekton production would be primary nekton production (e.g., the youngest juvenile shrimp and finfish), all of which would gain considerable mass while resident in the marshes. Scaling these nekton productivity data up to an island-wide basis with the data from Wilmington Island, and converting the dry weight to wet weight (ww=dw/0.22; see Table 3 in Kneib 2003) for comparison to living biomass, the 301 existing docks are presently decreasing primary nekton production between 5.5-9.8 x 10^4 g ww (121-216 lbs ww) annually and dock buildout from 2000 parcel data would decrease primary nekton production between 1.4-2.5 x 10^5 g ww (309-551 lbs ww) annually. Total primary nekton reduction from all permitted docks in the State would be between 0.6-1.2 x 10^6 g ww (1411-2646 lbs ww) annually. Again, these values should be considered minimum estimates because the state-wide data do not include any docks constructed prior to 1974 and dock numbers may be underestimated by approximately 50%.

These results for reduction in primary nekton production could be further generalized to assess cumulative impacts to commercially harvested species, if the necessary biological data existed for species commercially harvested in Georgia estuaries. Some of the data necessary to make that evaluation exists. From field data collected to develop the Kneib (2003) model and reported therein, we know that the migrant nekton comprises approximately 33% of the total nekton. Thus, permitted private docks in Georgia are potentially reducing the migrant nekton between 2.1-3.6 x 10^5 g ww (463-794 lbs ww) annually, or 33% of the total nekton decrease calculated in the paragraph above.   Further extension of these data to individual species would require knowledge of species-specific habitat utilization and growth parameters as well as predation and escapement rates. Currently, only some of these data are known for commercial species in Georgia estuaries.

Additional Research Needs

The cumulative effects of docks on salt marshes result not just from the direct effects in productivity, but from the indirect effects on habitat quality, suitability and structure. Several data needs exist at the confluence of physical and biological issues that illustrate the complex nature of salt marsh ecosystems and the need for a holistic approach to their study, as salt marsh vegetation not only provides a tremendous food resource for marine organisms through the primary production of biomass but additionally provides critical habitat in which to feed, grow and avoid predation. Measurement of the reduced *Spartina* stem density and subsequent loss in biomass from beneath the footprint of the dock structure, as reported here, is a first step in quantifying these impacts and facilitates estimates of consequent reduction in available nekton. However, these values are based specifically on the area of vegetated salt marsh directly beneath the footprint of the dock, and do not consider other secondary impacts (i.e., far-field shading, change in habitat structure) that where not the subject of this study and at present remain unquantified. We know that there is a direct shading effect under the footprint of the dock, but how far does it extend to either side of the structure? What is the effective footprint of impact from this and other processes?

Physical changes to the structure of the salt marsh habitat, resulting from reduced stem density and introduction of new structures into the marsh, is another variable which may influence overall dock impact. Lower vegetation densities can alter the dynamics of the predator–prey relationship within the marsh by providing better access into the marsh for predators and may enhance the effectiveness of larger predatory fish and crabs when feeding on the marsh surface (Minello et al., 1989). Also, the shade and structure that docks provide alters environmental parameters beneath the dock by changing the physical character, ambient light and temperature conditions in that area, thereby causing a change in the biological community structure from that which would naturally exist. In addition, observations throughout the study area show that walkway pilings across the marsh interfere with the natural processes of marsh detritus (e.g., wrack) accumulation and removal. Large rafts of decaying *Spartina* stems accumulate against these pilings during spring tides and onshore winds. Being unable to pass below the dock, these rafts persist and enlarge, compressing large areas of vegetated marsh, completely shading the underlying plants and leading eventually to a denuded mudflat.

Understanding how human activities and physical structures interact with the saltmarsh is a critical step towards informed management of the resource. Coastal resource managers, as part of their stewardship mandate, face the unique challenge of protecting this important habitat for all state residents while also respecting landowners' desire for access. Data from this study provide an estimate of biomass reduction resulting from private recreational docks per unit of area. Future research may provide more detailed insight into the complex web of trophic interactions and more accurately describe the relationship between primary production and available nekton. With this study it is now possible to objectively compare and evaluate dock shading impacts between structures of different size and shape. Quantifying the biomass reduction for an individual dock is critical information for evaluating the relative impacts of alternative dock designs, determining probable buildout scenarios and potentially identifying the need for and scope of mitigation efforts.

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Appendix 1. Stem density data for all sample locations. Sample identifiers (WIXXXX) are decoded as follows: WI – Wilmington Island, middle two numbers are the station number, final two letters are A or B designating "A" or "B" sites and D or C designating dock or control sites. Stem density reductions shown are calculated between adjacent dock and control sites at a single station.

Appendix 1		**All values are per 0.25 m^2**		
Sample ID	**Number of live stems**	**Number of short stems**	**Number of tall stems**	**Stem Density Reduction (%)**
WI01BD	10	7	3	85
WI01BC	66	54	12	
WI02BD	52	42	10	43
WI02BC	92	66	26	
WI03AD	11	8	3	84
WI03AC	67	55	12	
WI04AD	23	15	8	67
WI04AC	70	47	23	
WI05BD	27	14	13	29
WI05BC	38	23	15	
WI05AD	29	18	11	40
WI05AC	48	30	18	
WI06BD	53	39	14	18
WI06BC	65	40	25	
WI07AD	59	42	17	14
WI07AC	69	46	23	
WI08BD	56	42	14	20
WI08BC	70	54	16	
WI08AD	21	17	4	54
WI08AC	46	36	10	
WI09BD	8	3	5	78
WI09BC	36	25	11	
WI10BD	9	6	3	79
WI10BC	43	22	21	
WI11BD	30	20	10	29
WI11BC	42	23	19	
WI12BD	17	12	5	73
WI12BC	62	45	17	
WI13BD	15	12	3	85
WI13BC	100	61	37	
WI14BD	13	11	2	66
WI14BC	38	15	23	
WI15BD	30	21	9	38
WI15BC	48	32	16	
WI12AD	19	11	8	72
WI12AC	67	41	26	
WI16AD	16	7	9	24

WI16AC	21	9	12	
WI16BD	18	11	8	67
WI16BC	55	38	17	
WI17AD	52	32	20	47
WI17AC	99	62	35	
WI17BD	12	4	8	33
WI17BC	18	12	6	
WI18AD	44	28	16	24
WI18AC	58	40	18	
WI18BD	38	15	23	-12
WI18BC	34	19	15	
WI19BD	12	7	5	76
WI19BC	50	19	31	
WI19AD	39	24	15	43
WI19AC	68	51	17	
WI20AD	14	6	8	70
WI20AC	47	36	11	
WI20BD	12	8	4	83
WI20BC	69	44	25	
WI21AD	9	7	2	91
WI21AC	103	68	33	
WI21BD	11	3	8	63
WI21BC	30	18	12	
WI22BD	21	11	10	45
WI22BC	38	22	16	
WI22AD	12	4	8	86
WI22AC	87	57	30	
WI23AD	71	54	17	-22
WI23AC	58	39	20	
WI23BD	16	7	9	64
WI23BC	44	23	21	
WI24BD	21	14	7	34
WI24BC	32	18	14	
WI25BD	5	1	4	86
WI25BC	36	24	12	
WI25AD	37	25	12	54
WI25AC	80	65	15	

Appendix 2. Average plant heights of short and tall groups of stems from all sample locations. Station identifiers as described in Appendix 1.

Appendix 2		
Sample ID	**Average height short stems (cm)**	**Average height tall stems (cm)**
WI01BD	21	64
WI01BC	20	72
WI02BD	13	109
WI02BC	15	86
WI03AD	14	113
WI03AC	19	57
WI04AD	21	103
WI04AC	17	61
WI05BD	18	95
WI05BC	20	82
WI05AD	13	91
WI05AC	18	63
WI06BD	13	104
WI06BC	14	83
WI07AD	18	108
WI07AC	19	68
WI08BD	16	129
WI08BC	15	136
WI08AD	10	106
WI08AC	18	69
WI09BD	23	103
WI09BC	12	85
WI10BD	24	156
WI10BC	13	71
WI11BD	20	133
WI11BC	18	88
WI12BD	15	113
WI12BC	14	95
WI13BD	13	95
WI13BC	15	57
WI14BD	11	136
WI14BC	20	96
WI15BD	14	96
WI15BC	16	89
WI12AD	15	100
WI12AC	17	90
WI16AD	16	86
WI16AC	19	51
WI16BD	7	71
WI16BC	17	68
WI17AD	15	65

WI17AC	22	67
WI17BD	29	78
WI17BC	16	107
WI18AD	14	77
WI18AC	19	51
WI18BD	20	86
WI18BC	16	83
WI19BD	15	105
WI19BC	16	67
WI19AD	12	92
WI19AC	14	62
WI20AD	18	82
WI20AC	19	63
WI20BD	18	69
WI20BC	16	53
WI21AD	17	50
WI21AC	16	65
WI21BD	14	95
WI21BC	21	57
WI22BD	21	79
WI22BC	16	77
WI22AD	8	91
WI22AC	17	58
WI23AD	17	64
WI23AC	13	68
WI23BD	24	84
WI23BC	17	76
WI24BD	18	117
WI24BC	16	73
WI25BD	36	114
WI25BC	15	87
WI25AD	21	100
WI25AC	20	55

Appendix 3. Dry weight of living plant material in total, short, and tall categories for all sampling locations. Short and tall stems were not separated before drying and weighing at stations WI01-WI05. Station identifiers as described in Appendix 1.

Appendix 3	**All values are per 0.25 m^2**			
Sample ID	**Total live dry wt (g)**	**Dry weight of short stems (g)**	**Dry weight of tall stems (g)**	**Reduction in live weight (%)**
WI01BD	10.1	----	----	84
WI01BC	61.4	----	----	
WI02BD	80.3	----	----	38
WI02BC	130.0	----	----	
WI03AD	39.8	----	----	28
WI03AC	55.2	----	----	
WI04AD	61.0	----	----	28
WI04AC	84.1	----	----	
WI05BD	101.4	----	----	-7
WI05BC	94.4	----	----	
WI05AD	79.4	----	----	7
WI05AC	85.0	----	----	
WI06BD	93.2	9.8	83.5	22
WI06BC	119.0	11.2	107.8	
WI07AD	114.0	20.2	93.7	-96
WI07AC	58.0	9.3	48.7	
WI08BD	175.9	24.0	151.9	4
WI08BC	182.4	26.7	155.7	
WI08AD	32.7	3.4	29.3	15
WI08AC	38.5	10.3	28.2	
WI09BD	23.4	1.0	22.4	72
WI09BC	83.0	9.5	73.5	
WI10BD	40.8	3.0	37.8	57
WI10BC	95.5	8.1	87.4	
WI11BD	157.2	11.6	145.5	-7
WI11BC	147.1	11.1	136.0	
WI12BD	57.5	7.9	49.6	67
WI12BC	173.5	18.4	155.2	
WI13BD	23.0	3.7	19.3	77
WI13BC	100.9	16.2	84.8	
WI14BD	38.0	4.8	33.1	77
WI14BC	167.2	6.6	160.6	
WI15BD	90.4	15.6	74.8	37
WI15BC	142.6	17.3	125.3	
WI12AD	82.7	5.1	77.6	60
WI12AC	206.5	17.7	188.8	

WI16AD	57.8	2.4	55.4	-48
WI16AC	39.1	6.3	32.8	
WI16BD	45.3	1.2	44.1	53
WI16BC	96.4	19.7	76.7	
WI17AD	53.2	8.8	44.4	47
WI17AC	100.5	21.1	79.4	
WI17BD	38.1	4.0	34.1	21
WI17BC	48.0	5.1	42.8	
WI18AD	62.4	5.7	56.6	-55
WI18AC	40.2	10.6	29.7	
WI18BD	149.4	5.6	143.8	-8
WI18BC	138.8	9.0	129.7	
WI19BD	61.2	2.6	58.6	60
WI19BC	152.4	8.2	144.2	
WI19AD	89.2	5.7	83.5	-88
WI19AC	47.5	10.8	36.7	
WI20AD	47.6	3.6	44.1	4
WI20AC	49.7	17.4	32.3	
WI20BD	26.2	2.5	23.7	73
WI20BC	98.0	19.8	78.3	
WI21AD	2.8	0.8	2.0	96
WI21AC	77.2	15.7	61.6	
WI21BD	59.9	1.0	58.9	-26
WI21BC	47.6	9.1	38.5	
WI22BD	87.9	6.2	81.7	25
WI22BC	117.0	7.3	109.7	
WI22AD	28.0	0.2	27.7	56
WI22AC	64.1	11.7	52.4	
WI23AD	64.3	16.8	47.5	-9
WI23AC	59.1	8.1	51.0	
WI23BD	57.4	5.0	52.4	52
WI23BC	119.8	8.8	111.0	
WI24BD	70.1	5.0	65.1	-78
WI24BC	39.4	4.2	35.2	
WI25BD	42.3	1.1	41.2	58
WI25BC	100.8	6.9	93.9	
WI25AD	65.2	10.3	54.9	-48
WI25AC	44.0	16.6	27.4	