CONTINUED MONITORING OF THE BUCKTOWN CREATED MARSH:

2008 VEGETATIVE AND EDAPHIC CHARACTERIZATION AND EFFECTS OF THE 2008 BONNET CARRE OPENING ON NUTRIENT STATUS OF SEDIMENT AND PLANT TISSUE

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INTRODUCTION

This report describes current soil and vegetation conditions in the Bucktown area mitigation marsh and integrates these findings with previously collected data. Continued monitoring over time is enabling us to evaluate the restoration trajectory and provide insights into the primary driving forces, such as local hydrology and herbivore grazing intensity. Additionally, this report contains a preliminary analysis of the effects of the Bonnet Carre opening on the nutrient status of marsh soils and leaf tissue of the dominant vegetation.

As described in previous reports the Bucktown area mitigation marsh (3.5 acres in area) was constructed outside the Lake Pontchartrain levee immediately adjacent to the “Bucktown” area of greater New Orleans. Marsh substrate was obtained through hydraulic dredging of the nearby Bucktown Harbor in the summer of 2000 with a target elevation of 1.5 to 2.0 NGVD (Burke and Kleinpeter 2001). The planting of 1,030 trade gallons and 8,000 vegetative plugs of salt-hardened *Spartina alterniflora* (Vermillion accession) was completed by August 2, 2003, with the anticipation that other wetland vegetation would also rapidly colonize the marsh (Burke and Kleinpeter 2001). The surrounding areas (adjacent land, water, and the Lake Pontchartrain levee) are subject to frequent recreational use by the general public (Mark Hester pers. obs.). More general information and documentation on the Bucktown Created Marsh can be found at SaveOurLake.org (see the coastal program webpage).

METHODS

Long-Term Monitoring

Study Implementation

Twenty, 1.0-m^2 permanent plots were established on June 30, 2006 throughout the Bucktown created marsh site, with 5 replicate plots being established in each of four habitat types described in a previous assessment completed prior to Hurricane Katrina (Hester et al. 2005). Habitat types are delineated as follows: Western Low Marsh, High Marsh, Scrub Shrub, and Eastern Low Marsh. Two sediment elevation tables (SETs), one in the Western Low Marsh habitat type and one in the Scrub Shrub habitat type, were also established at this time. A continuous-recording water-level gauge was also installed in the low marsh habitat type at this time.

Variables Measured

Visual estimation of plant community composition has been assessed in the summer and fall of each year since the inception of the monitoring project. Soil bulk density, soil moisture content, and soil organic matter content have been determined annually each summer. Soil cores were collected to a depth of 15 cm using a 5-cm diameter thin-wall aluminum corer for the determination of soil bulk density. Soil samples were then dried at 65º C until a constant weight was reached. Thereafter, soil samples were homogenized using a mortar and pestle and a subsample was combusted at 500 ºC for 5 hours to determine organic matter content through the loss-on-ignition method. Change in marsh surface elevation was determined using two sediment elevation tables (SET) in conjunction with feldspar markers (see Cahoon et al. 2002 for details on SET installation and protocols).

Statistical Analyses
Total vegetative cover was analyzed in a repeated measures one-way ANOVA RBD (Analysis of Variance Randomized Block Design) framework using the GLM model procedures of SAS 9.1. All data collected at only one point in time were subjected to univariate one-way ANOVA analysis using the GLM procedures of SAS 9.1. Vegetative communities of permanent plots in all years were evaluated for differences through the Multiple Response Permutation Procedures of PC-ORD 4.0. Also, community composition was assessed for the presence of environmental gradients using nonmetric multidimensional scaling analysis (nMDS), performed using PC-ORD 4.0. For this analysis the Sorensen distance matrix wax employed, with initial dimensionality of 6 axes and stepwise reduction of a single dimension until optimal stress reduction was achieved. Stability criterion was set to 0.00010 and the number of model runs was 40 for real data and 50 for randomized data. See Clarke (1993) for discussion of Multiple Response Permutation Procedure and nonmetric multidimensional scaling.

Bonnet Carre Nutrient Impacts

Study approach
Soils and aboveground plant tissue were collected from each plot in Fall of 2008 to assess potential impacts on nutrient status resulting from the opening of the Bonnet Carre spillway. Soils were dried to a constant weight at 65º C and then subjected to a 1:2 (w:v) extraction with deionized water following the methods of Soil and Plant Analysis (1999). Water extracts were then sent to the Microbiology Testing Laboratory at Southeastern Louisiana University for determination of ammonium. Archived soil samples from each plot that was previously collected during our 2007 summer sampling were subjected to the same extraction and analysis procedure for comparison purposes. Aboveground plant tissue was dried, homogenized using a Wiley Mill, and then sent to the Soil Testing and Plant Analysis Lab at Louisiana State University for determination of total nitrogen, phosphorus, and potassium content.

RESULTS

Long-Term Monitoring

Vegetative composition
A significant effect of both time and the interaction of time with vegetative zone was detected in total cover (**Figure 1**, F= 10.147, p<0.001, and F= 5.550, p< 0.001, respectively). As expected, MRPP revealed significant differences among habitat types within the Summer 2007, Fall 2007, Summer 2008, and Fall 2008 sampling periods (**Figure 2**, T= 4.90, P< 0.001; **Figure 3**, T= -7.03, P< 0.001; **Figure 4**, T= -4.39, P=0.001; **Figure 5**, T= -4.032, P< 0.001, respectively), suggesting that these habitats are maintaining distinct species assemblages. In the case of the both the Eastern and Western Low Marsh zones, which have been dominated by *Spartina alterniflora*, this is driven by the occurrence of other species within the Western Low Marsh, whereas the Eastern Low Marsh continues to exist primarily as monospecific *S. alterniflora* stands. The High Marsh zone, as expected, continues to have lower coverage of *S. alterniflora*, but relatively high cover of other species typical of high marsh habitats in Louisiana, and is thus differentiated from the other marsh zones. The Scrub Shrub zone remains dominated by *Iva frutescens* and, importantly, the extent of coverage by this species has been steadily increasing

over time. The existence of two gradients based on nMDS of vegetative community composition in the summer 2007 sampling period was corroborated by detection of these gradients again in summer of 2008 (**Figure 6**, p=0.0196). These gradients can be interpreted similarly to our previous analysis (2007 annual report), with axis 1 being inversely correlated with *Iva frutescens* (r = -0.930) and axis 2 being positively correlated with *Spartina alterniflora* cover (r = 0.779) and inversely correlated with *Schoenoplectus americanus* (r = -0.718). Also, the two environmental gradients detected in Fall of 2007 appear to have been maintained in Fall of 2008 (**Figure 7**, p=0.0196). As with previous analyses, *Spartina alterniflora* and *Iva frutescens* are the primary species representing these gradients. *Spartina alterniflora* is inversely correlated with axis 2 (r = -0.815) whereas *Iva frutescens* is positively correlated with axis 1 (r = -0.843).

Edaphic variables and elevation
A significant effect of vegetative zone was detected for both soil organic matter and soil moisture (**Figure 8**, F= 6.43, p= 0.0162, F= 5.23 p= 0.0174, respectively). Overall, elevation changes in the Western Low Marsh and the Scrub Shrub zones were minimal (< 2.5 mm), although a significant difference was detected in elevation change between these two zones (**Figure 9**, F= 8.19, p <0.001); the Western Low Marsh lost about 1 mm of elevation while the Scrub Shrub zone gained about 2 mm of elevation. Water level data indicates that flooding duration has tended to be greater in the Western Low Marsh than other vegetative zones assessed in this study (**Figures 10** and **11**).

Potential Effects of Bonnet Carre Opening

Soil Nutrient Status
Surficial soils (upper 15 cm) collected in the summer of 2008 (after the Bonnet Carre opening) had significantly greater ammonium content than surficial soils collected in summer of 2006 (Fig 13; F= 7.45, p= 0.0149). It is important to note that a) no significant interaction of time by vegetative zone was discerned, nor b) were significant effects of zone detected within the 2006 and 2008 sampling season, thereby indicating that the increase in surficial ammonium in 2008 is a consistent effect that was detected across all marsh zones.

Leaf tissue nutrient status
Analysis of dominant vegetation leaf tissue nitrogen in 2008 revealed a significant effect of zone, reflecting higher leaf nitrogen content of *Iva frutescens* in the Scrub Shrub zone than the *Spartina alterniflora* in the three marsh zones (**Figure 12**; Contrast F= 24.246, P < 0.001). Average 2008 leaf tissue phosphorus concentration in *Spartina alterniflora* was 0.94 mg g^{-1}. *Spartina alterniflora* leaf tissue potassium concentration in 2008 averaged 3.80 mg g^{-1}. It is important to note that no previous leaf tissue data had been collected at this Bucktown Marsh site for direct (within site) comparisons over time (see Discussion for appropriate comparisons to other leaf tissue data).

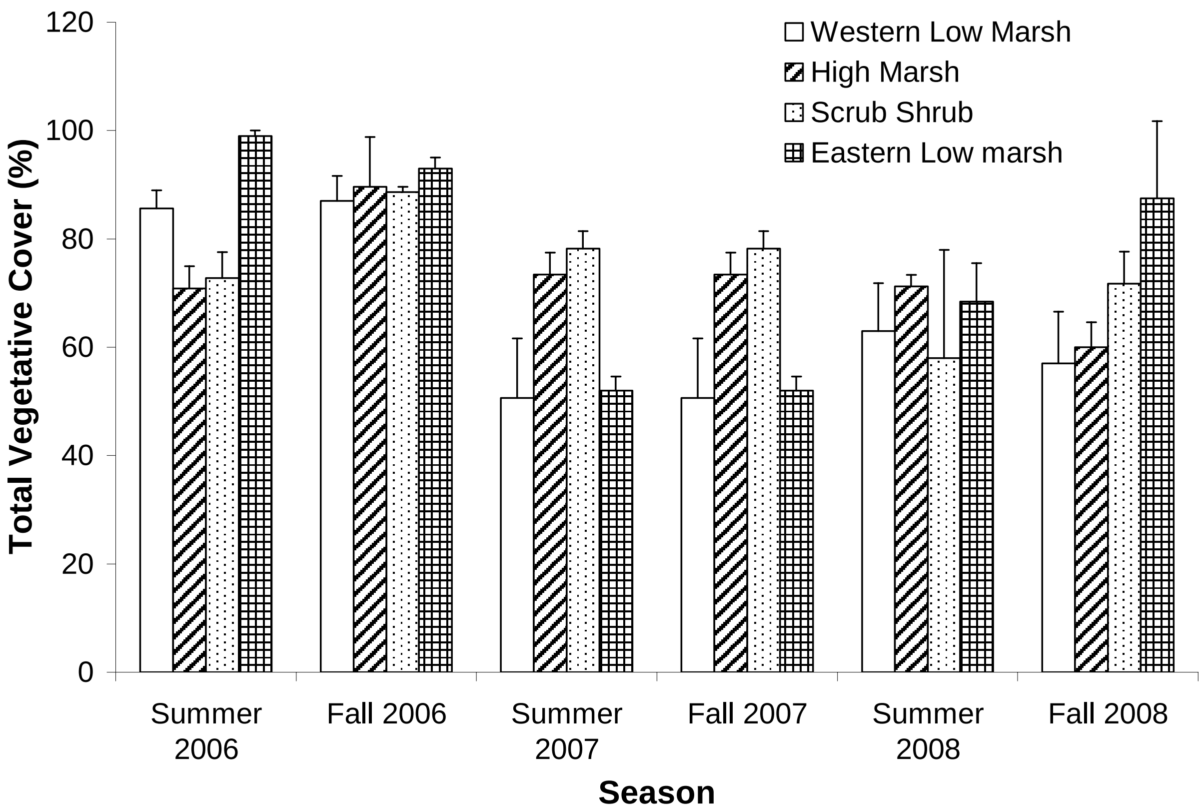

Figure 1. Effect of time on vegetative species composition in the four Bucktown marsh habitat zones.

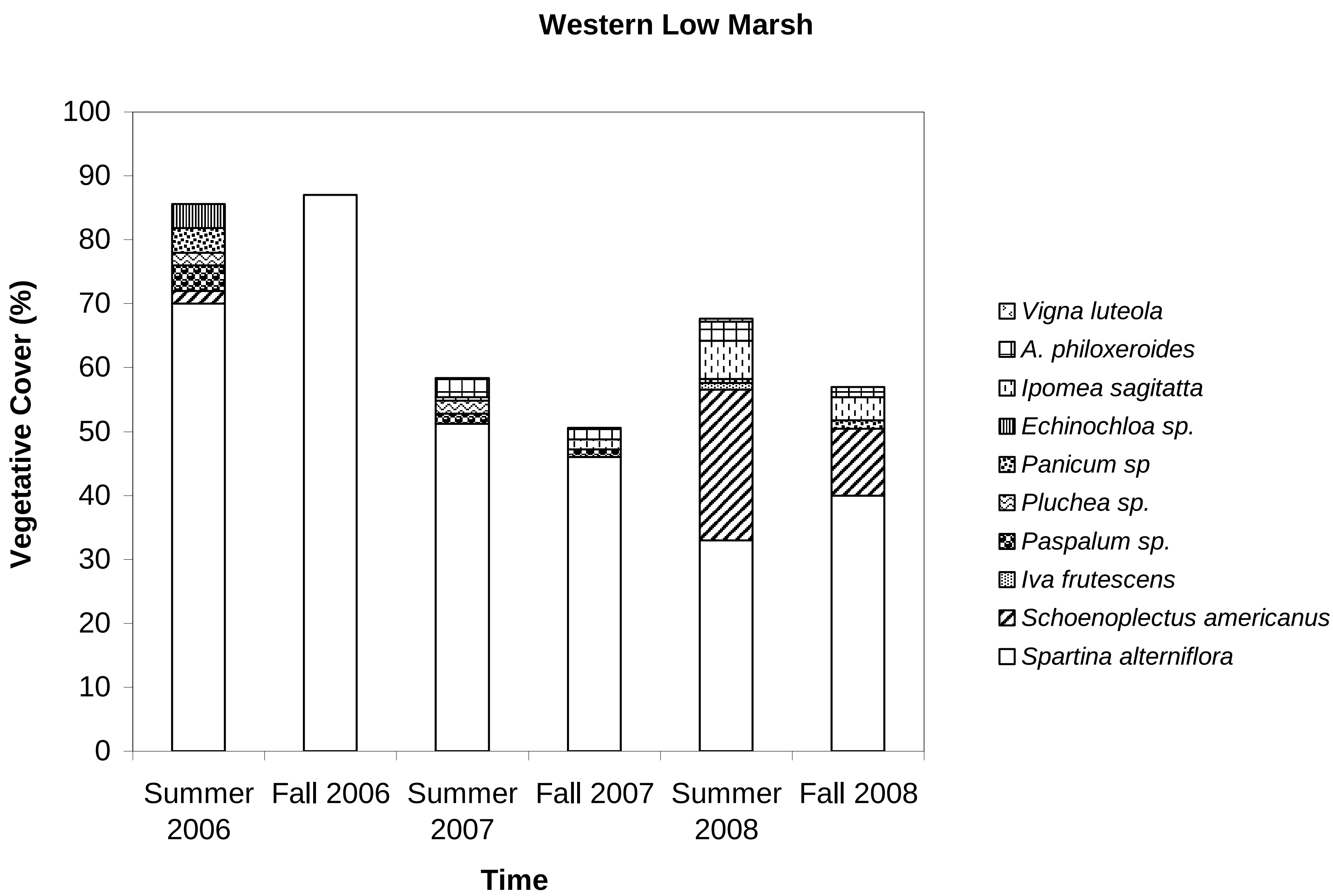

Figure 2. Effect of time on vegetative species composition and abundance in the Western Low Marsh zone.

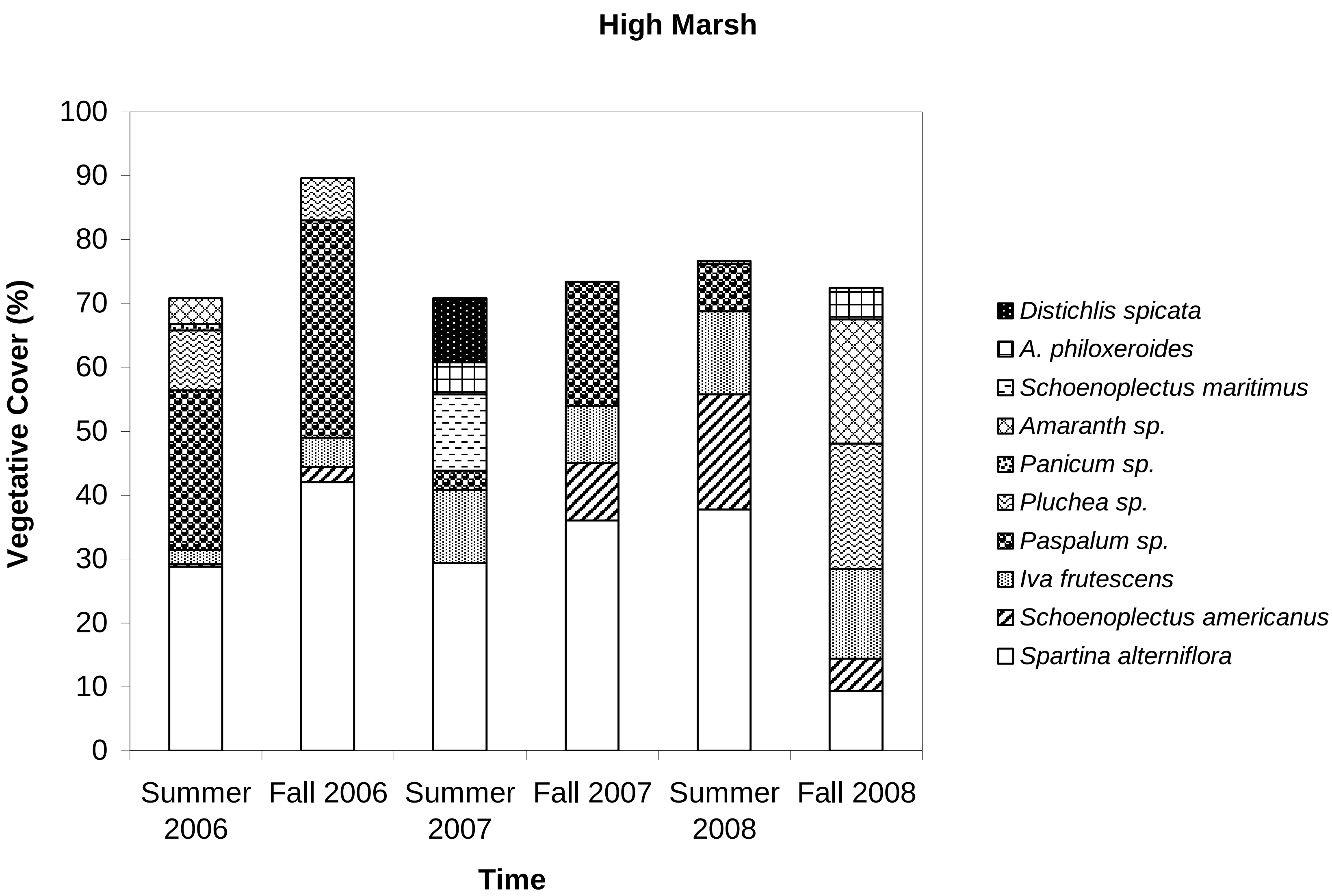

Figure 3. Effect of time on vegetative species composition and abundance in the High Marsh zone.

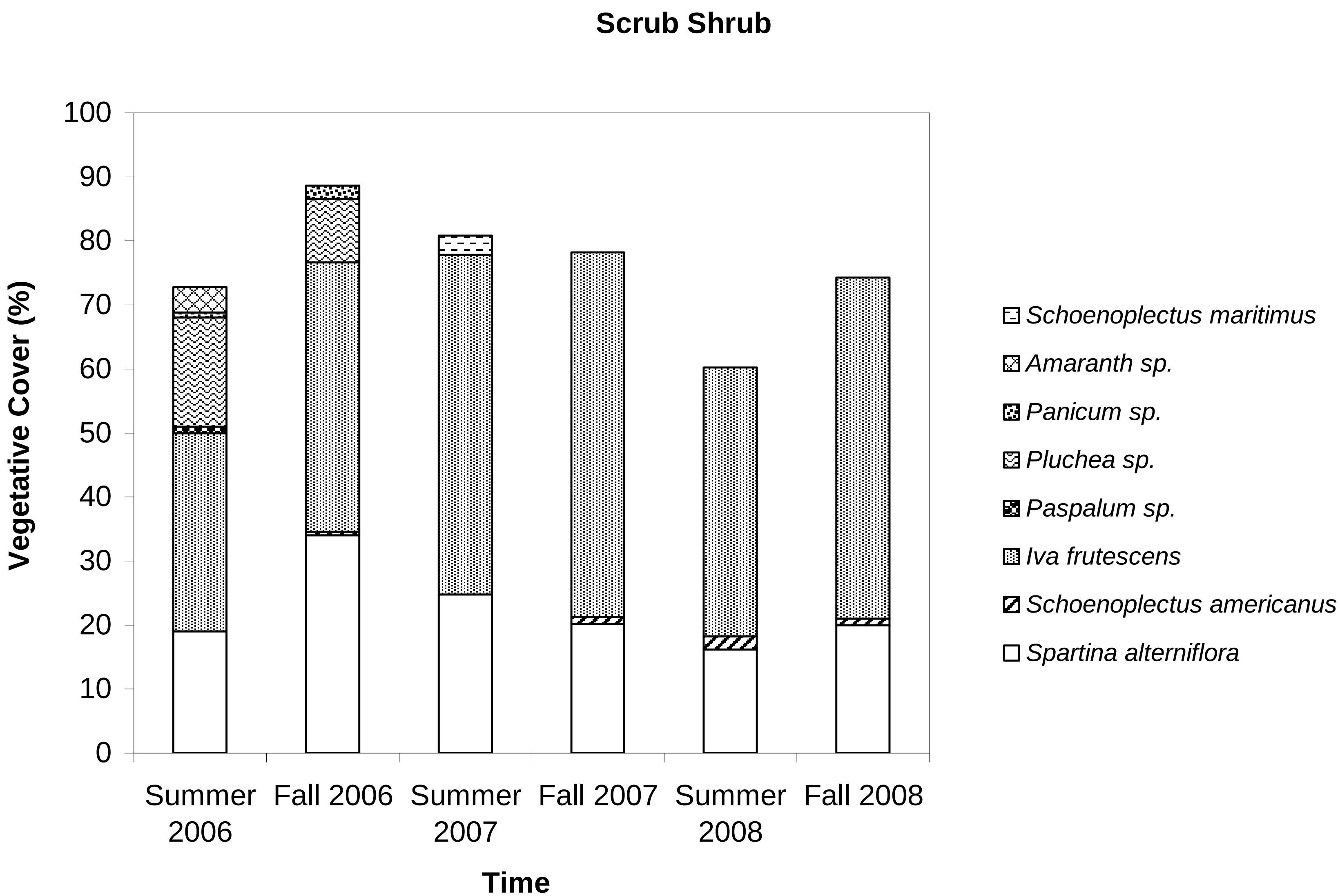

Figure 4. Effect of time on vegetative species composition and abundance in the Scrub Shrub zone.

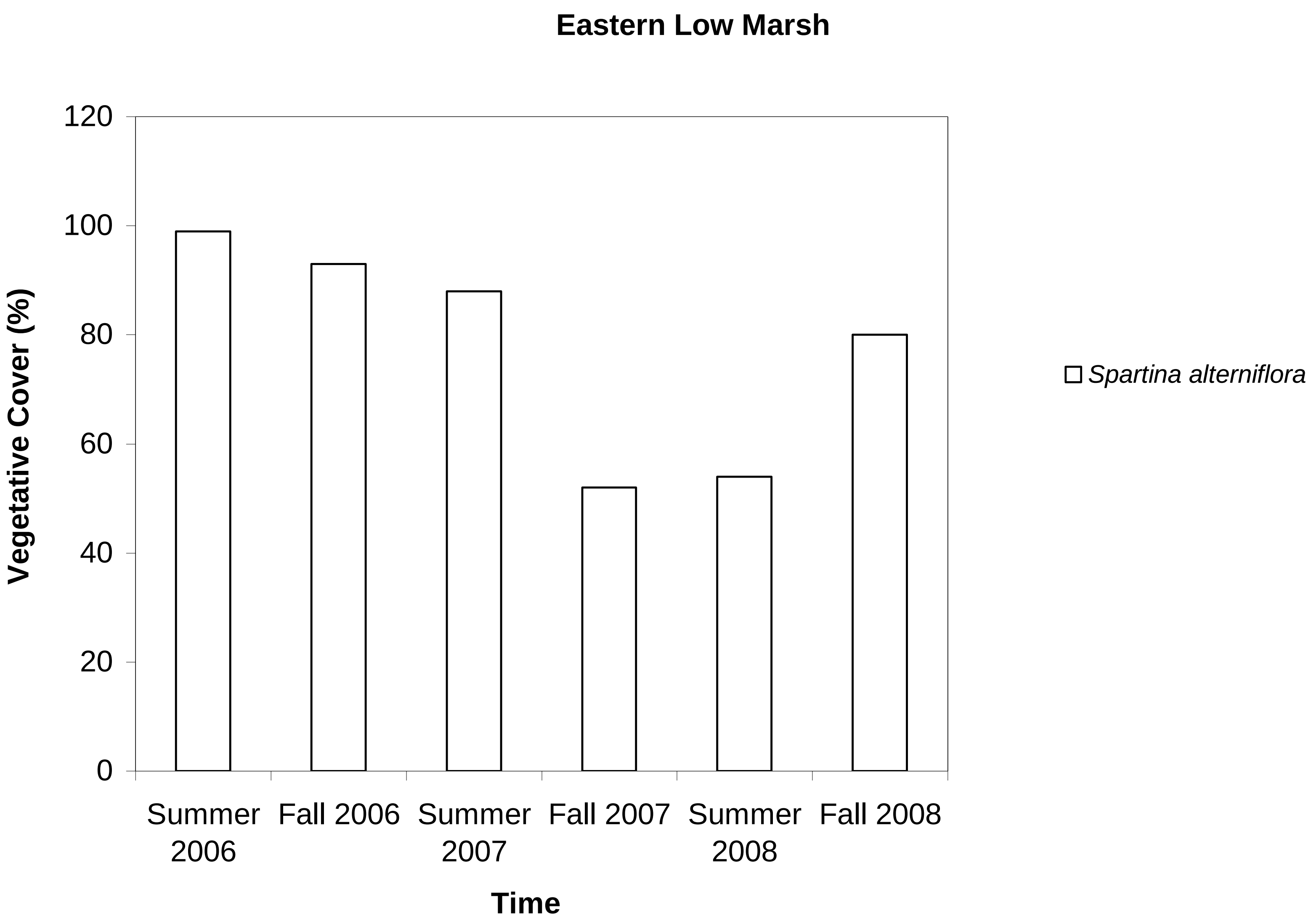

Figure 5. Effect of time on vegetative species composition and abundance in the Eastern Low Marsh zone.

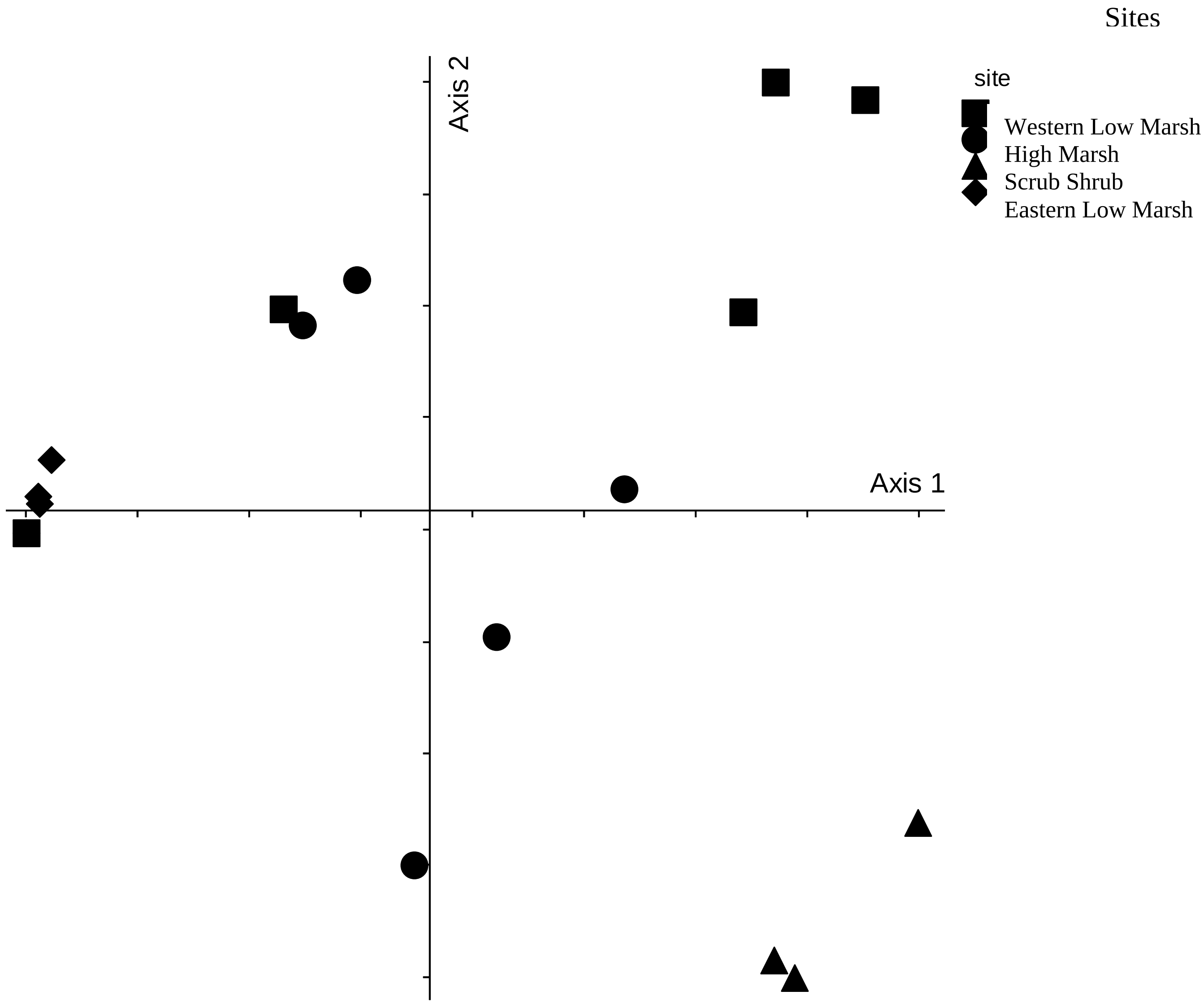

Figure 6. Similarity of permanent plots and vegetative zones for Summer 2008 as determined by nonmetric multidimensional scaling. The X axis inversely correlates with *Iva frutescens* cover; the Y axis correlates with *Spartina alterniflora* cover.

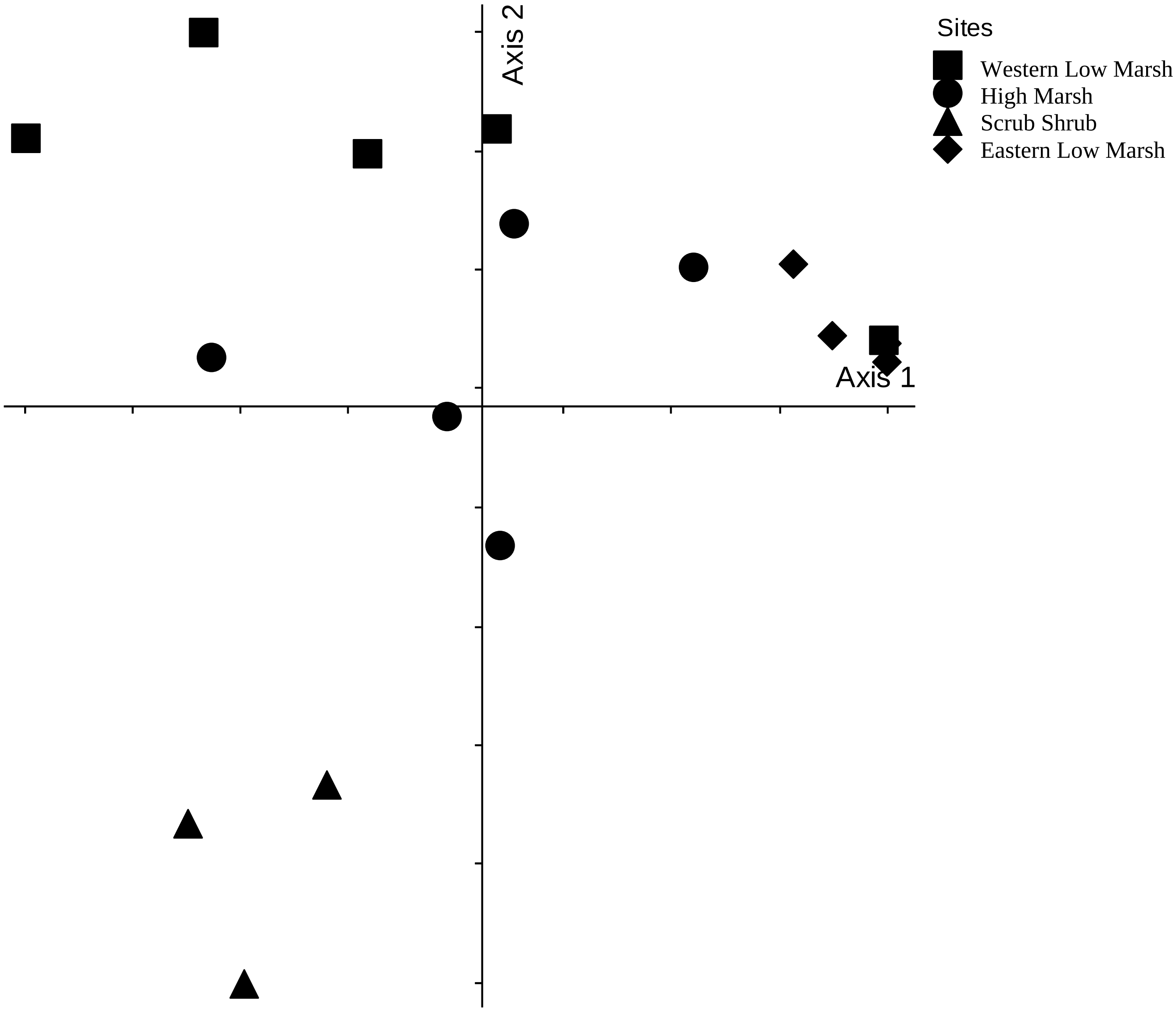

Figure 7. Similarity of permanent plots and vegetative zones for Fall 2008 as determined by nonmetric multidimensional scaling. The X axis correlates with *Iva frutescens* cover; the Y axis inversely correlates with *Spartina alterniflora* cover.

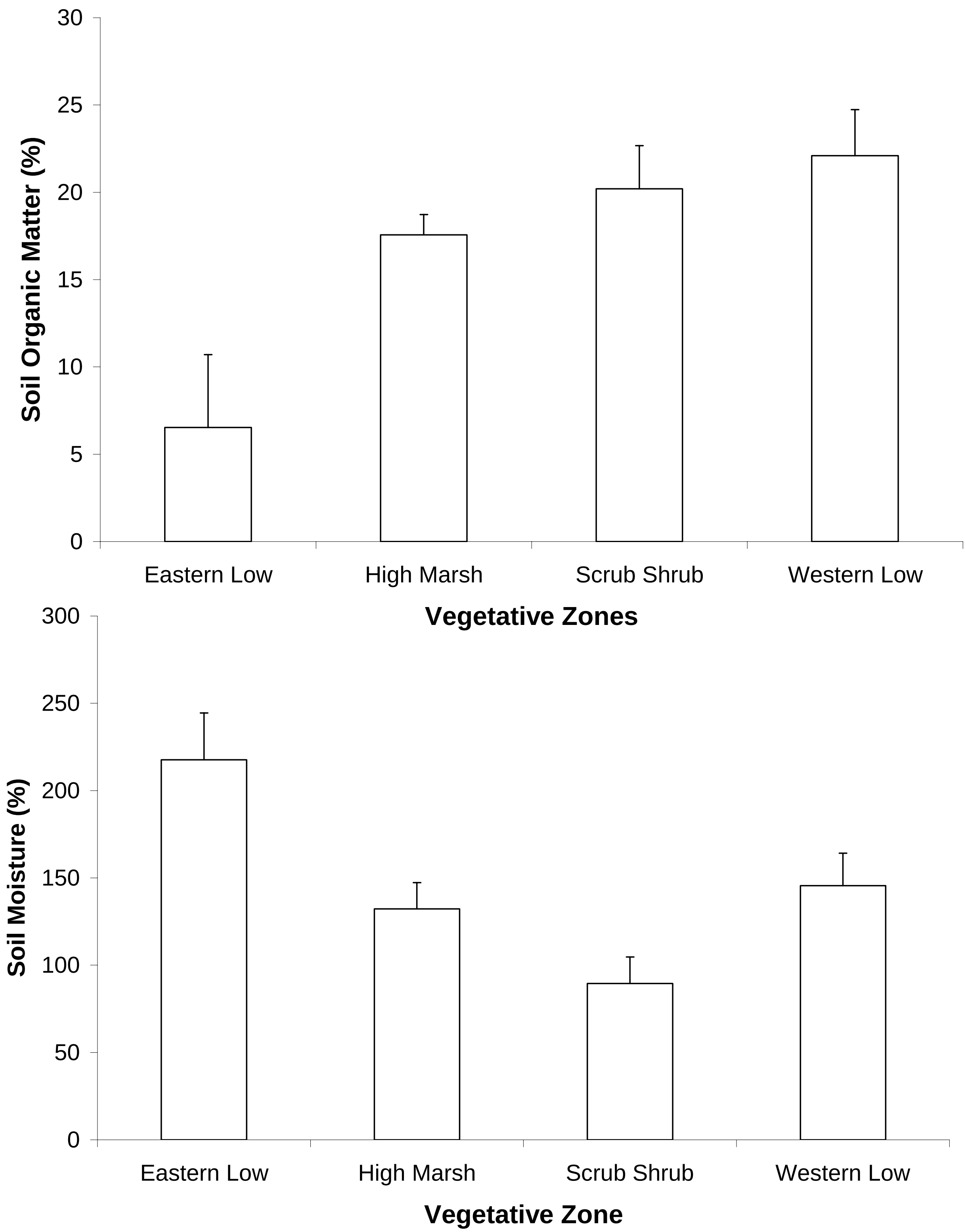

Figure 8. Top Panel: Effect of vegetative zone on soil organic matter in summer 2008 (%; mean +/- se). Bottom Panel: Effect of vegetative zone on soil moisture content (dry weight basis) in summer 2008 (%; mean +/- se).

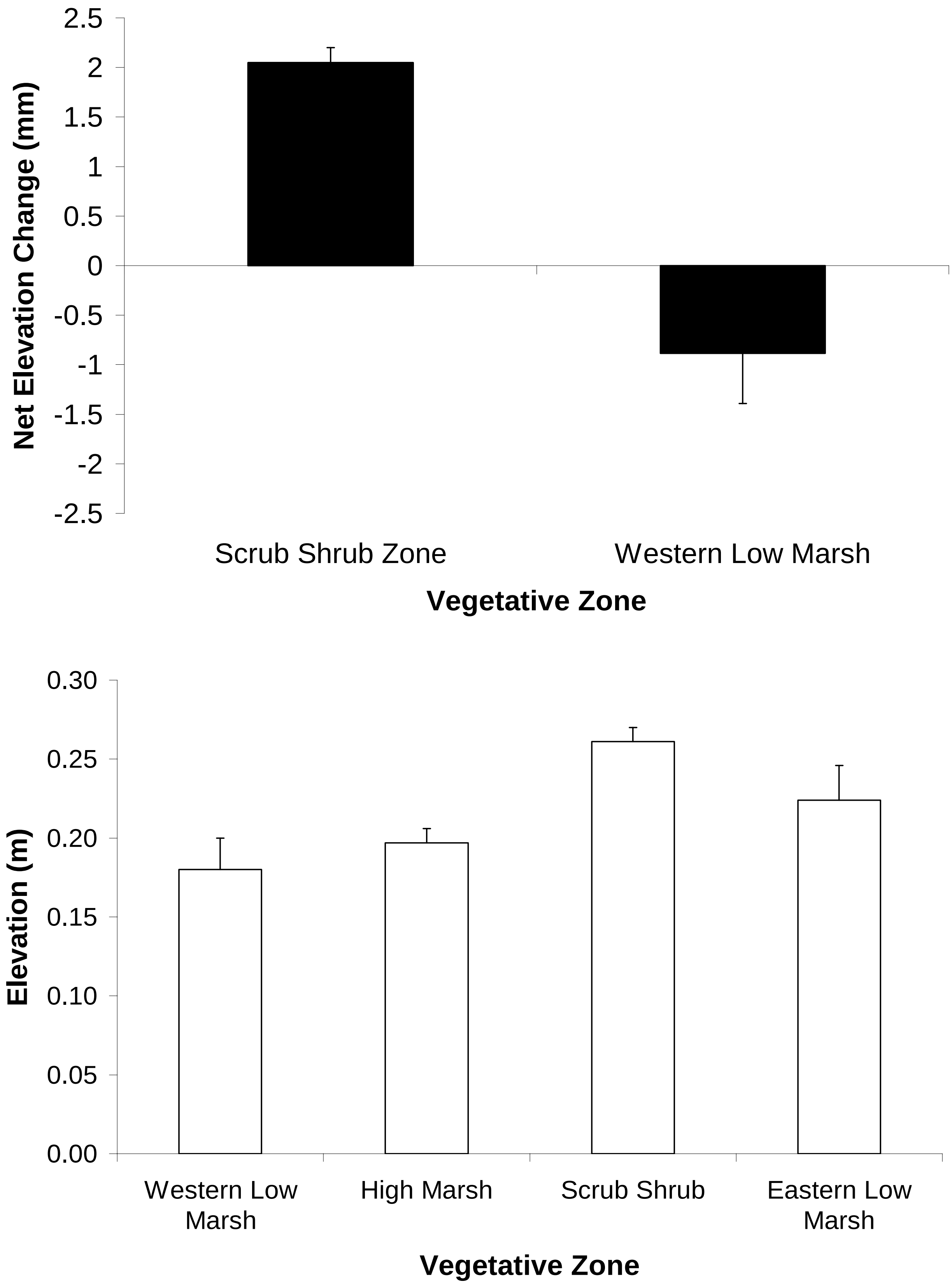

Figure 9. Top panel: Elevation change in the Scrub Shrub and Western Marsh Zone from Winter 2008 to Summer 2008 (mean +/- se). Bottom panel: Summer 2008 relative survey elevation corrected to the lowest plot elevation (mean +/- se).

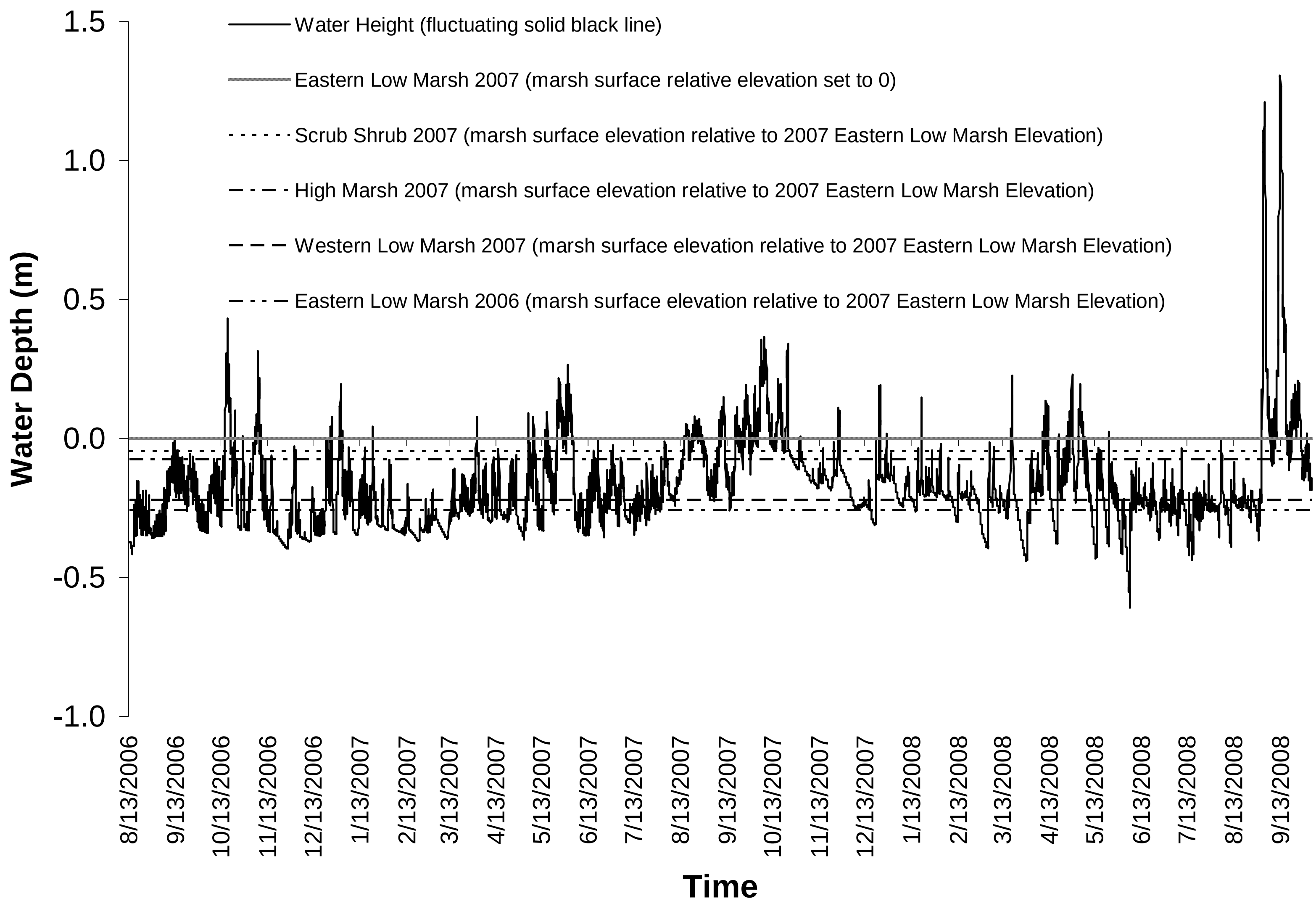

Figure 10. Flooding depth to the soil surface in 2 hour increments for each habitat zone of the Bucktown marsh over time (8/13/2006 to 8/13/2008). The Eastern Low Marsh zone received an input of sediment in 2007 that is believed to be due to nearby anthropogenic dredge and fill operations. Therefore baseline relative elevations of this zone (2006) is provided in addition to the 2008 (post sediment deposition) elevation.

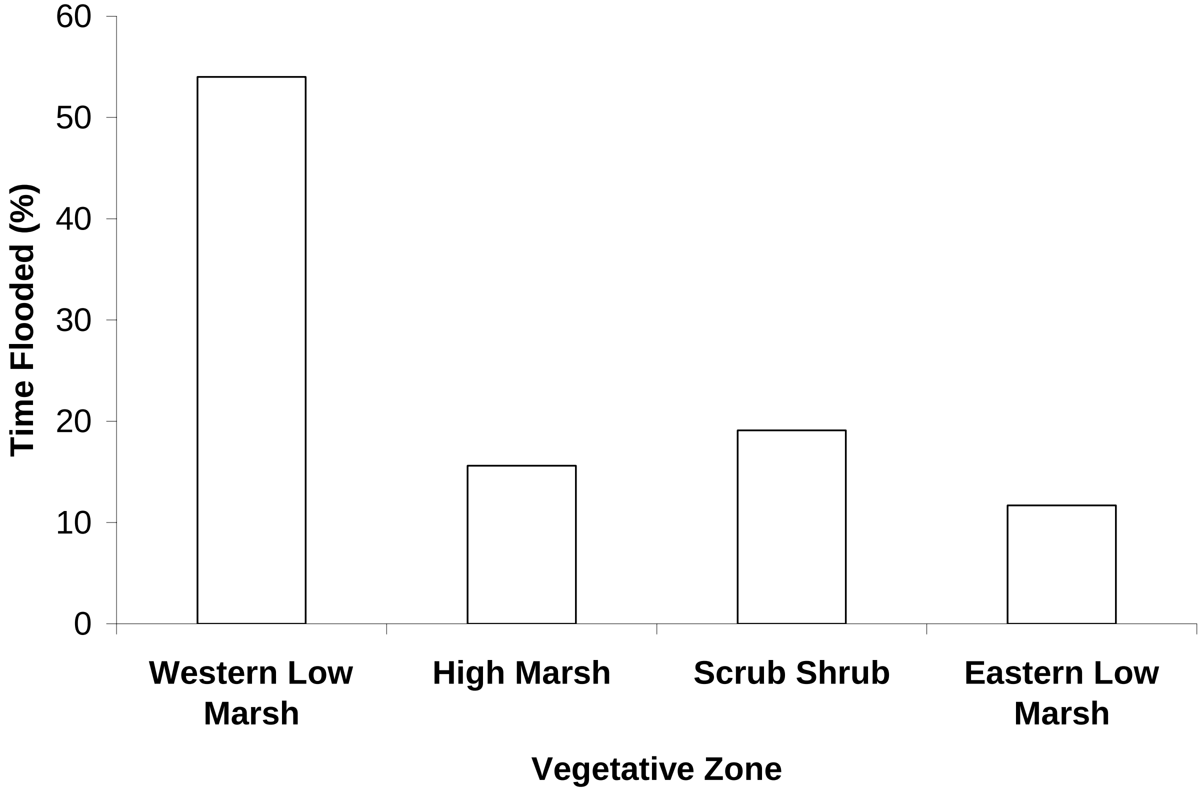

Figure 11. Effect of habitat zone on percentage of time flooded from August 2006 through August 2008.

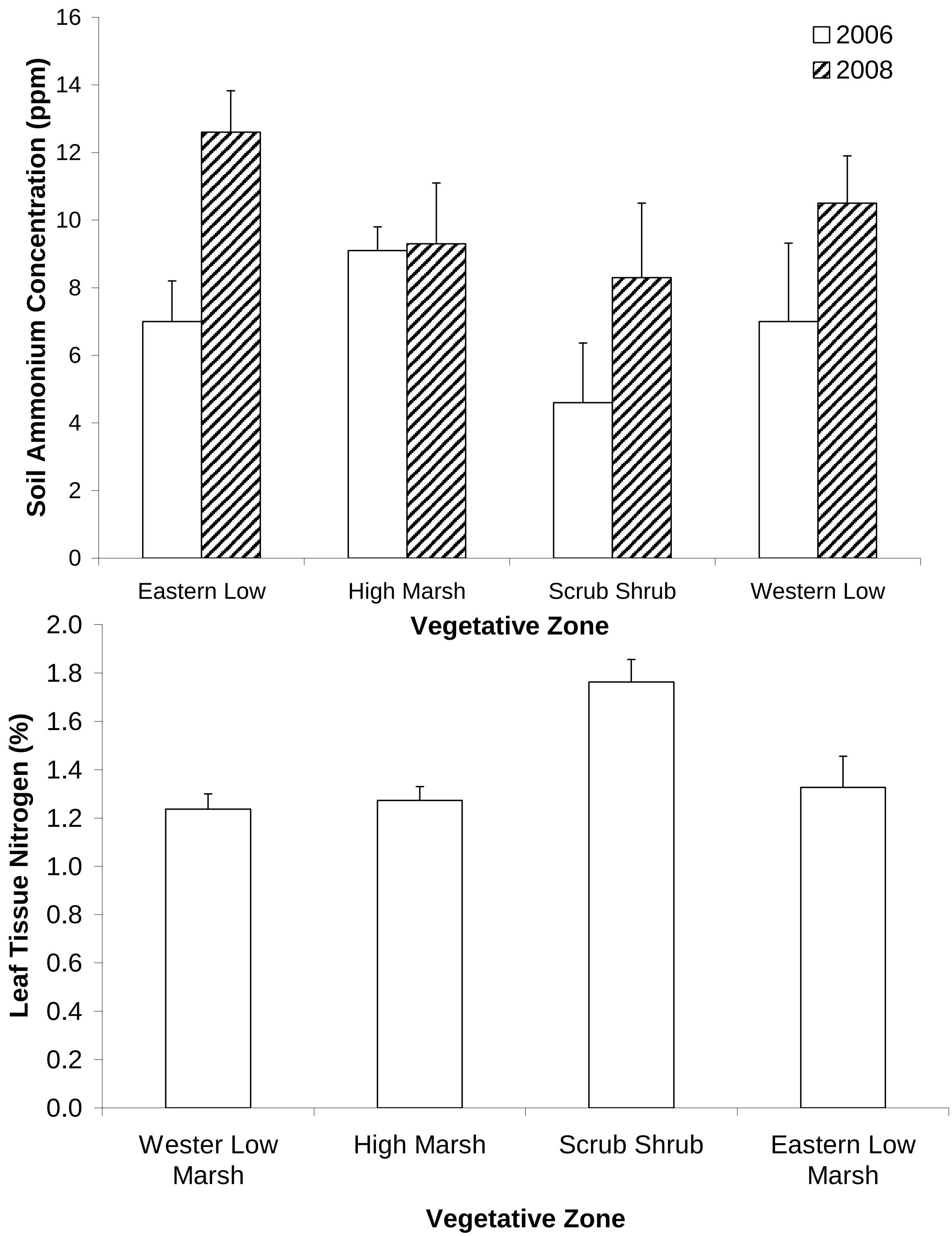

Figure 12. Top Panel: Effect of year and vegetative zone on soil ammonium concentration (ppm, mean+/- se). Bottom Panel: Effect of vegetative zone on leaf tissue nitrogen in summer of 2008 (µg/g, mean+/- se).

Table 1. Concentrations of macronutrients (N, P, K) in *Spartina alterniflora* leaf tissue from the Bucktown created marsh (summer 2008 following the spring opening of the Bonnet Carre Spillway) and from other published studies.

Macronutrient	Bucktown Marsh 2008	Other Published Studies	
Nitrogen	12.2 mg g^{-1}	18.3 mg g^{-1}	Pennings et al. 1998
Phosphorus	0.94 mg g^{-1}	1.3 mg g^{-1}	Turner 1993
Potassium	3.80 mg g^{-1}	1.23 mg g^{-1}	Ornes and Kaplan 1989

Discussion and Conclusions

Long-Term Monitoring

Monitoring data collected for the Bucktown marsh creation project over the previous three years indicate that the created area continues to successfully maintain the vegetative and soil characteristics of a healthy brackish marsh in coastal Louisiana. A high level of vegetative cover by native Louisiana wetland plant species has been found for the High Marsh and Scrub Shrub zones since the inception of the project. A substantial, likely anthropogenic, perturbation from an adjacent dredge/fill operation was found to have impacted the Eastern and, to some extent, Western Marsh zones in Fall of 2007, with the Eastern Low Marsh surface displaying a net increase in elevation (Hester et al. 2007). However, there appears to be a trend of plant community recovery, particularly in the Western Low Marsh zone, in 2008. This suggests that the Eastern and Western Marsh zones have already developed some degree of resilience, allowing them to partially recover from impacts within a single year. Importantly, evidence of substantial nutria grazing was observed in early 2009 for the Eastern Low Marsh zone (J. Lopez, pers. obs.). Thus, recovery of this zone may be experiencing additional hindrance due to nutria grazing immediately subsequent to the original anthropogenic perturbation.

A general trend of less *Spartina alterniflora* cover in the Western Low Marsh zone can be discerned, although total cover has been relatively unchanged in 2007 and 2008. Importantly, this reduction in *S. alterniflora* has occurred concomitantly with an increase in *Schoenoplectus americanus* a valuable and native wetland plant species in Louisiana. Similarly, the High Marsh zone demonstrated a reduction in *Spartina alterniflora* cover in fall of 2008, but no decrease in overall cover. The High Marsh Zone continues to have a high degree of species richness in comparison to other zones likely resulting from more hospitable conditions (e.g., little shading, lower soil water-logging intensity). The expansion of these native wetland plant species has maintained a high degree of vegetative cover in the high marsh zone in spite of the reduction in *S. alterniflora* cover. The extent of habitat that can be classified as Scrub Shrub appears to have increased since the inception of the study, likely due to the favorable hydrology of the area. Permanent plots within the Scrub Shrub zone indicate an increase in coverage by *Iva frutecens*. The increase in *I. frutescens* may be regarded as at least somewhat beneficial given the unique and critical habitat provided by woody species in these environments (Havens et al. 2002). With time, it will be interesting to note if subsidence of the created marsh surface may lead to a hydrologic regimes that eventually becomes less favorable for vigorous growth and expansion of *I. frutescens*. Thursby and Abdelrhman (2004) reported that *I. frutescens* in marshes along the Rhode Island coast became stunted as the hydrologic regime resulted in flooding of the marsh surface for 20% of the time. When flooded more than 30% of the time, *I. frutescens* has been reported to experience a substantial decline in growth and may be replaced by herbaceous species characteristic of that marsh type (Thursby and Abdelrhman 2004).

No additional exotic species beyond those previously noted, *Echinochloa crus-galli* and *Alternanthera philoxeroides*, which are not classified as noxious weeds in the state of Louisiana (USDA), were found. These species are generally considered normal species for Louisiana marshes and in the case of *Echinochloa crus-galli* are thought to act as a food source for native avifauna. Soil metrics (bulk density, organic matter, and moisture) continue to fall within the range expected for a healthy Louisiana brackish marsh (Edwards and Proffitt 2003; Baustian and

Turner 2006). Soil and vegetative characterizations thus far are greatly encouraging regarding the current health as well as the resilience of the Bucktown area mitigation marsh, although concerns remain regarding the apparent recent invasion by nutria. Otherwise however, this wetland has maintained a high degree of vegetative cover and appropriate levels of species richness. Further, some recovery by several vegetative communities exposed to an acute perturbation has been observed.

Potential Effects of Bonnet Carre Opening

Soil nutrient status

Following the opening of Bonnet Carre Spillway in spring 2008, soil ammonium levels were higher in 2008 soil samples than archived (2006) soil samples suggesting that the recent opening of the Bonnet Carre spillway did, in fact, result in increased soil ammonium concentrations at the Bucktown marsh. Although these findings are by definition correlative in nature, we are aware of no other potential sources for additional inputs of nitrogen to this site during this time period other than the opening of Bonnet Carre Spillway.

Leaf tissue nutrient status

Comparisons of our 2008 leaf tissue nutrients must be made relative to other published studies since we did not sample leaf tissue plant at the Bucktown marsh prior to our 2008 sampling. This inherently introduces the potential for site-specific differences in nutrient loading, which can be affected by a number of factors. Nonetheless, such comparisons are still useful since they provide a range of reported values. Pennings et al. (1998) in an investigation of plant palatability on Sapelo Island, Georgia, reported that average leaf tissue nitrogen content (mg g^{-1}) of *Iva frutescens* was 23.7 +/- 2.5 (sd), and *Spartina alterniflora* average leaf tissue nitrogen content (ppm) was 18.3 +/- 2.0 (sd). Based on this comparison, levels of plant tissue nitrogen at the Bucktown marsh are considerably lower for both species than at the Sapelo Island, Georgia, marsh more than a decade earlier. However, in an ongoing comparison of photosynthetic nutrient-use efficiency between *Spartina alterniflora* in Sapelo Island, Georgia, and Fourchon, Louisiana, Hester et al. (2008) reported leaf tissue N levels to be 16.6 mg g^{-1} +/- 6.2 (sd) for Sapelo Island and 13.2 mg g^{-1} +/-4.6 (sd) for Fourchon. Therefore, using more current estimates, the leaf tissue N of *Spartina alterniflora* at the Bucktown marsh site (approx. 0.94 mg g^{-1}) appears to be closer to the range of leaf nitrogen for Louisiana. Based on these values, the leaf tissue N of Louisiana *Spartina alterniflora*, in general, appears to be slightly lower than those reported in Georgia (which has a mesotidal and semi-diurnal hydrologic setting versus the microtidal and diurnal hydrologic setting of Louisiana). The average phosphorus concentration (0.94 mg g^{-1}) in *Spartina alterniflora* leaf tissue collected in the Bucktown marsh in 2008 was slightly lower than previously reported concentrations of phosphorus in *Spartina alterniflora* leaf tissue collected from coastal Louisiana (1.3 mg g^{-1}; Turner 1993). The average potassium concentration (3.80 mg g^{-1}) in *Spartina alterniflora* leaf tissue collected in the Bucktown marsh in 2008 was actually higher than previously reported concentrations of phosphorus in *Spartina alterniflora* leaf tissue collected from coastal South Carolina (1.23 mg g^{-1}; Ornes and Kaplan 1989).

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LPBF Lake Pontchartrain Basin Foundation website: http://www.saveourlake.org/

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USDA PLANTS database: *Echinochloa crus-galli*: http://plants.usda.gov/java/profile?symbol=ECCR

USDA PLANTS database: *Alternanthera philoxeroides*: http://plants.usda.gov/java/profile?symbol=ALPH