Southeast Environmental Research Center
FLORIDA INTERNATIONAL UNIVERSITY

Landscape Pattern – Marl Prairie/Slough Gradient: Decadal Vegetation Change in Shark River Slough and adjacent Marl Prairies

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General Background

Established to track the ecological effects of Everglades restoration, the Monitoring and Assessment Program (MAP) provides the data and analytical support necessary to implement adaptive management. In the Everglades, marsh vegetation in both marl prairie and ridge and slough landscapes is sensitive to large-scale restoration activities associated with the Comprehensive Everglades Restoration Plan (CERP) authorized by the Water Resources Development Act (WRDA) of 2000. More specifically, changes in hydrologic regimes at both local and landscape scales are likely to affect vegetation composition in the transition zone between these two landscapes, resulting in a shift in boundary between plant communities. In order to track these dynamics, Florida International University (Dr Michael Ross, Project Leader) has undertaken a study of vegetation structure and composition in relation to physical and biological processes along the marl prairie-slough gradient.

Vegetation monitoring transects in the Shark Slough basin, funded by US Army Corps of Engineers (USACOE) under RECOVER-MAP, capture the full range of marl prairie and slough plant communities, and address Performance Measure (PM): GE-15 (Landscape Pattern – Marl Prairie/Slough gradient), by "… detecting spatio-temporal change in vegetation structure and composition in response to natural and restoration-induced hydrologic changes...". Monitoring of vegetation along the marl prairie/slough gradients addresses a working hypothesis that 'Spatial patterning and topographic relief of ridges and sloughs are directly related to the volume, timing and distribution of sheet flow and related water depth patterns', identified in the hypothesis cluster "Landscape Patterns of Ridge and Slough Peatlands and Adjacent Marl Prairies in Relation to Sheet Flow, Water Depth Patterns and Eutrophication" (RECOVER 2009). The study also addresses the hypothesis that resumption of historical flow and related patterns of hydroperiod, water depth, and fire with the implementation of CERP will cause a noticeable change in plant community composition and structure in the ecotonal zone between marl prairie and peat-dominated ridge and sloughs.

Initiated in 2005 as an expansion on Shark Slough study transects that had been established and sampled in 1998-2000 with funding from DOI's Critical Ecosystems Study Initiative (CESI), the current study concluded its third sampling cycle in spring 2014. This document therefore summarizes vegetation dynamics and vegetation:environment relationships along the whole marl prairie-slough gradient, covering the period since 1998-2000 in Shark Slough (4 cycles) and the period since 2005-2006 (3 cycles) in the marl prairie, using identical sampling protocols.

Executive Summary

In the southern Everglades, vegetation in both the marl prairie and ridge and slough landscapes is sensitive to large-scale restoration activities associated with the Comprehensive Everglades Restoration Plan (CERP) authorized by the Water Resources Development Act (WRDA) 2000 to restore the south Florida ecosystem. More specifically, changes in hydrologic regimes at both local and landscape scales are likely to affect vegetation composition along the marl prairie-slough gradient, resulting in a shift in boundary between plant communities in these landscapes. To strengthen our ability to assess how vegetation would respond to changes in underlying ecosystem drivers along the gradient, it is important to have an improved understanding of reference conditions of plant community structure and function, and their responses to major stressors. In this regard, a study of vegetation structure and composition in relation to physical and biological processes along the marl prairie-slough gradient was initiated in 2005, and has continued through 2014 with funding from US Army Corps of Engineers (USACOE) (Cooperative Agreement # W912HZ-09-2-0018). This study addresses the hypothesis with respect to RECOVER-MAP monitoring item 3.1.3.5 – "Marl Prairie/Slough Gradients; patterns and trends in Shark Slough marshes and associated marl prairies".

The study design includes field sampling along five transects, namely MAP transects M1-M5, with the total length of 86.6 km. The Shark Slough portions of four MAP transects (M1-M4) overlap with the Shark Slough study transects that were established and sampled in 1998-2000, with funding from the Department of Interior's Critical Ecosystems Study Initiative (CESI). These sites were resampled three times between 2005 and 2013. The other sites in both marl prairie and Shark Slough landscapes were sampled three times between 2005 and 2014. Data analysis focused on the characterization of vegetation composition in relation to hydrology and soil characteristics along the entire transects, and an assessment of temporal changes in vegetation composition on the Shark Slough portion of transects sampled 1999 and 2013, and on the marl prairie portion of transects sampled between 2005 and 2014. We first summarized vegetation data using non- metric multidimensional scaling (NMDS) ordination and examined the vegetation:environment relationship by fitting environmental vectors in ordination space. To assess vegetation change at the Shark River Slough sites sampled four times between 1999 and 2013, we used trajectory analysis and examined the time trajectory of each site along the vector representing the hydrologic gradient. However, for the marl prairie sites, sampled only three times between 2005 and 2014, we used an alternate approach in which we first calculated vegetation-inferred hydroperiod using weighted averaging (WA) regression model, and assessed the change in vegetation-inferred hydroperiod. A change in vegetation-inferred hydroperiod between successive samplings indicates the amount and direction of change in vegetation, expressed in units of days per year (0-365) along a gradient in hydroperiod.

Species composition on the transects representing the marl prairie-slough gradient was strongly influenced by hydrology at the scale of the entire study area. However, in both marl prairies and Shark River Slough portions of the transects, within-landscape variation in vegetation response was also noticeable, suggesting that both local and regional scale hydrologic variation is important in determining spatio-temporal variation in species composition. In concurrence with the overall trend in hydrologic regimes that characterized the period 1999-2013, many sites in the Shark River Slough portion of the transects showed a shift towards vegetation associated with drier conditions. However, the direction and rate of such a shift in vegetation composition varied in space and time. While the shift towards dry vegetation on all four transects was most pronounced between 1999 and 2007, the vegetation change pattern thereafter varied among transects. During 2007-2012, the drying trend decreased from north (Transect M1) to south (Transect M4), i.e., Transect M1 had the highest percentage of sites showing a significant trajectory towards a drier condition over the period, while some portions of Transect M4 exhibited a change toward wetter condition. In general, species richness along the MP-S gradient is inversely proportional to degree of wetness, but on the wettest (slough) sites, the 13- year trend toward drier vegetation had little effect on species richness. In contrast to the slough sites, the vegetation change pattern in marl prairie portions differed among transects. Transect M1, located in Northeast Shark Slough showed a drying trend whereas southern Transects, M4 and M5 exhibited a wetting trend. The central and longest transect, M3 that includes marl prairies on both sides of Shark Slough, showed spatially differentiation in vegetation change mainly due to differences in management related hydrologic changes. Sites located west of the slough showed a drying trend whereas sites east of the slough exhibited a wetting trend. In Shark River Slough, the shift in vegetation composition towards drier type was augmented by an increase in abundance of sawgrass (*Cladium jamaicense*) that could be a step towards succession toward woody vegetation, especially when it occurs on elevated ground like ridges and far tail region of tree islands that experiences prolonged dry conditions.

In summary, hydrologic conditions had a strong influence on vegetation composition along the marl prairie-slough gradient, but vegetation response was not uniform in the marl prairie or slough portions of the gradient. In concurrence with the spatio-temporal variation in hydrologic regimes that characterized the period 1999-2014, many sites in the slough portion of the transects showed a shift towards drier vegetation. However, the direction and rate of such a shift in vegetation composition varied both temporally and spatially. The regional differences in spatio-temporal variation in hydrologic regimes have resulted in such a spatially differentiated shift in vegetation composition within both marl prairie and ridge and slough landscapes. Thus, in addition to monitoring of vegetation solely at the transition zones between marl prairie and slough landscapes, an assessment of vegetation composition coupled with the position and attributes of boundary between plant communities within each of these two landscapes also will help in adaptive management of southern Everglades ecosystems.

1. Introduction

Plant communities arranged along environmental gradients are manifestations of ecosystem functional processes associated with underlying physico-chemical drivers that vary in space and time. Along such gradients, different sets of key ecosystem processes operating at distinct spatial scales, along with a characteristic distribution of available resources, create identifiable plant communities separated by transition zones. Depending on the level of spatio-temporal variation in underlying drivers, the transition between two adjacent communities may be abrupt or gradual (Walker et al. 2003; Henneberg et al. 2005; Boughton et al. 2006). In general, the position and bio-physical attributes of a transition zone, as well as its persistence over time, depend on changes in underlying drivers, their effects on structure and function of the adjacent communities, and feedbacks between community and environment. Hence, determining the responses to spatio-temporal changes in key environmental drivers of plant assemblages along gradients, and the boundaries between them, is important for conservation and ecosystem restoration.

In the Southern Everglades, the landscape in both Shark River and Taylor Slough basins includes long hydroperiod sloughs, flanked by short hydroperiod marl prairies. Particularly in the Shark River Slough (SRS) basin, vegetation structure and composition change gradually along an elevation and water depth gradient, from short-hydroperiod marl prairies to ridge and slough, which are characteristic features of the landscape of central SRS (Olmsted and Loope 1984; Olmsted and Armentano 1997; Ross et al. 2003). I n the past century, changes in the amount and flow patterns of water, resulting from the construction and operation of a series of canals, levees and water structures (Light and Dineen 1994, McVoy et al. 2011), have altered the proportions of prairie and slough vegetation in the region. Furthermore, changes in water management associated with the ongoing Comprehensive Everglades Restoration Plan (CERP 2000) are likely to affect vegetation composition in the transition zone between these ecosystems, resulting in a shift in the boundary between marl prairie and slough communities. It is therefore important to understand how restoration impacts the dynamics of prairie and slough landscapes and the boundaries between the two. This study examines the changes in vegetation along the marl prairie-slough (MP-S) gradient extending across Shark Slough and into the edges of the marl prairie to the east and west.

Hydrology is one of the major drivers of species differences between marl prairie and ridge-and-slough landscapes of the Everglades. Hence, alterations in hydrologic conditions usually cause a shift in vegetation structure and composition within each landscape; extreme changes can lead to even dominance of hydric vegetation in marl prairie or various levels of degradation of landforms in the ridge and slough (R&S) landscape. Historically, such changes in hydrologic conditions were mainly driven by annual or decadal variation in the precipitation. However, in recent years, hydrologic modifications through the operations of water structures have dramatically impacted vegetation composition in both marl prairies and ridge-and-slough landscapes (McVoy et al. 2011). Since the vegetation communities along the gradient are sensitive to hydrologic changes, prolonged and extreme dry or wet events may also affect the boundary between these two communities. As described for floodplains exposed to prolonged flooding (e.g., Thomaz et al. 2007), ecological processes in marl prairie and adjacent lower elevation areas may tend to be alike, resulting in an increase in similarity between plant communities. For instance, continued flooding for 3-4 years resulted in an increase in abundance of sawgrass and other hydric species in the marl prairies west of SRS (Nott et al. 1998) and in Taylor Slough basin (Armentano et al. 2006; Sah et al. 2013). Prolonged flooding of the marl prairies may also enhance peat deposition, resulting in a regime shift in vegetation community. McVoy et al. (2011) pointed out that during the pre-drainage era, large portions of the present marl prairies were covered by a shallow layer of peat that supported tall and dense sawgrass, similar to that on the ridges in the interior peatlands. Indeed, the combination of prolonged dry conditions and subsequent consumption of the shallow organic surface soils in fire seem to have resulted in a large portions of the present rockland habitat (Davis 1943; Robertson 1953), and has been cited as the cause of the expansion of muhly grass-dominated vegetation in rockland marl prairies (Werner 1975; Olmsted et al. 1980). Moreover, frequent and prolonged drying of R&S landscape may cause the plant communities therein to follow different trajectories, thus affecting the boundaries between communities within the landscape, as well as along the boundary between SRS and adjacent marl prairies.

Changes in an environmental driver may slowly erode community resilience, causing them to change in a particular direction until a threshold is reached, followed by an abrupt change in community characteristics (Folke et al. 2004; Hagerthey et al. 2008). Along the marl prairie-slough gradient, vegetation in the marl prairie portion of the gradient is likely to respond to hydrologic changes more rapidly than vegetation in the slough portion. Armentano et al. (2006) also argued that the transition from one vegetation type to another (e.g., prairie to marsh) in response to hydrology may take place in as little as 3 to 4 years. However, the transition from marsh to prairie may take longer. In the southern Everglades, recent water management efforts have been directed towards ameliorating the adverse effects caused of previous water management activities. In this respect, a series of water detention ponds have been brought into operation along the eastern boundary of the park to mitigate the wet-season water reversals that were prevalent in this region due to the loss of water from the rocky glades to the canal (Van Lent et al. 1999). In contrast, strategic regulation of water deliveries through the S12 structures along US 41 has been in place since 2002 to reverse the damage that were caused by the extended wet conditions that resulted from both high water deliveries and rains in the mid-to-late -1990s. These modifications in water management activities, along with those planned under Central Everglades Planning Project (CEPP), including construction and operation of Tamiami Bridges, have affected, and are likely to influence water conditions within the Park, resulting in changes in vegetation communities and ecological processes.

In 2005, we initiated a long-term study of vegetation dynamics in relation to changes in underlying environmental drivers, especially hydrology, along the MP-S gradient. The broader goal of the study is to assess the impact of Everglades restoration activities on plant communities along the gradient, and to detect any shift in position and attributes of boundaries between those communities. The study is conducted on five transects that extend across SRS into adjacent marl prairies. Shark Slough portions of the transects overlap transects that were established and sampled under different sponsorship in 1998-2000, providing the prospect of assessing long-term temporal change in vegetation in those areas. The climatological records and hydrologic data from the SRS region suggest that water levels during most of the last decade of the 20th century were well above the 30-year average. In contrast, the annual mean water level was more variable and relatively low during last 14 years (2001-2014) (**Figure 1**). Such a difference in water conditions has provided an opportunity to assess the response of vegetation to drier conditions between 1999 and 2014.

In this study, our specific objectives were, i) to characterize recent vegetation composition along the marl prairie-slough gradient, and ii) to assess changes in vegetation in both the Shark Slough and marl prairie portions of the transects over a fifteen-year period (1999-2014). We hypothesized that variation in vegetation composition along the MP-S gradient is mainly driven by hydrology, i.e. duration and depth of flooding. We also hypothesized that Shark River Slough vegetation follows the temporal trend in hydrologic regimes, and over the last fifteen years has changed in species composition toward assemblages more indicative of relatively dry conditions. In addition, in compliance with the differential water management goals on both sides of SRS, we hypothesized that marl prairie vegetation follows the spatially differentiated temporal trend in hydrologic regimes, and over the nine years (2005-2014) vegetation in eastern portion of marl will change toward a wetter character while vegetation in the western marl prairies would shift toward a drier type.

2. Methods

2.1 Study Area

The study area is located within Everglades National Park (ENP), and comprises a diverse landscape including SRS, adjacent marl prairies, and a section of coastal zone in the southeastern corner of SRS (**Figure 2**). Shark River Slough, the main path of the surface water drainage in ENP, is centrally located and is greatly impacted by alterations in surface water flow. The construction of US Highway 41 together with the construction and operations of a network of canals and levees resulted in compartmentalization of the central Everglades north of the highway and reduction in the volume of surface water flow within the Park (Light and Dineen 1994). During the 1980s and 1990s, the goal of increasing water flow within the park was achieved by implementing several modifications in water management operations. However, a consistent pattern throughout the period was the diversion of water toward the western part of the slough, i.e. away from its primary flow-way through Northeast Shark Slough (NESS) (Light and Dineen 1994; McVoy et al. 2011).

Flanking both sides of SRS are the elevated, short-hydroperiod marl prairies, which are characterized by thin calcitic marl soils with frequent exposures of limestone bedrock, and species-rich plant communities consisting of grasses and sedges (Olmsted and Loope 1984). Soils in the marl prairie west of SRS are higher in quartz sand than those in the eastern prairies. In recent decades, the eastern marl prairies have experienced shortened hydroperiod and wet-season water-level reversals (Van Lent et al. 1999), whereas the western marl prairies have been impacted by varying water management strategies that included regulated water deliveries through the S12 structures along US 41, resulting in extended hydroperiod and drying pattern reversals (Kotun et al. 2009). Since 2000, changes have been made in water management strategies to reverse the damage done to the marl prairies on both sides of the slough. These changes in strategy included the construction and operations of a series of water retention ponds along the eastern levee and strict regulation of water deliveries through the S12s during the dry season (Kotun et al. 2009).

2.2 Data Acquisition

The study design includes field sampling along five transects, specifically MAP Transects M1 to M5, with a total length of 86.6 km. Three transects, M1, M3 and M4 extend across the Shark River Slough to adjacent short-hydroperiod marl prairie habitat (**Figure 2**). Transect M1, located in Northeastern Shark Slough (NESS), extends to marl prairie on the east of the slough only. M3 and M4 extend to prairie on both sides of the slough. Transect M2 covers an area restricted to SRS, extending on both sides of L-67S canal. Transect M5 covers an area in the coastal ecotone between fresh to brackish water ecosystems in the southeastern corner of SRS, extending to the east into fresh water marl prairies located on both sides of the main Park road. Moreover, 29.3 km of Transects M1, M2, M3 and M4 are in slough, and overlap with Shark Slough Transects, 1, 2, 3 and 5, respectively, that were established and sampled between 1998-2000 (hereafter identified as SS transects sampled in 1999), with funding from the DOI Critical Ecosystems Study Initiative program (CESI) (Ross et al. 2001; Ross et al. 2003). The 1999 sampling event at those sites is considered as the initial sampling (E0) in the analysis reported here.

Vegetation monitoring on the MAP transects began in the Fall 2005, and the transects were sampled every three years thereafter. On these transects, vegetation structure and composition were quantitatively studied in a set of plots at discontinuous, moderately-spaced (200-500 m) locations. **Table 1** summarizes the years and numbers of sites sampled on the transects. The slough portion of the MAP transects was sampled in the wet season (July to November), accessing the sites by airboat or helicopter, depending on permitting requirements and the water level in the field. Marl prairie portions of the transects were sampled in the dry season (Dec. to May) and were accessed by helicopter for drop off and pickup, and on foot for sampling.

Table 1: Sites sampled on five MAP transects M1-M5 between 2005 and 2012.

Transect	Sampling Event	Sites Sampled			
		Prairie sites		Slough sites	
		Year	Number of Sites	Year	Number of Sites
M1	E1	2006	11	2005	20
	E2	2009	11	2008	20
	E3	2012	11	2011	20
M2	E1			2005	25
	E2			2008	26
	E3			2011	25
M3	E1	2007	72	2006	37
	E2	2010	72	2009	37
	E3			2012	37
M4	E1	2008	32	2007	55
	E2	2011	32	2010	55
	E3	2014	32	2013	55
M5	E1	2008	31		
	E2	2011	31		
	E3	2014	31		

2.2.1 Vegetation sampling

Vegetation was sampled in a nested-plot design that allowed for efficient sampling of the range of plant growth forms (herbs, shrubs and trees) present along the transects. On each of five transects, the vegetation sampling plots were established at 200 to 500 m intervals. In the marl prairie section of the transects, the plots were established at 300 m intervals, and in the SRS portion of the transects, the plot density varied between 2 to 4 plots per km (250-500 meter intervals). Higher intensity sampling occurred in areas accessible by airboat, and was based on the contention that increased sampling intensity would enable us to make a more meaningful comparison of current vegetation with that present on the same transects in 1999 (Ross et al. 2001; Ross et al. 2003). In addition, eight additional plots, one each on M1 and M2, two on M3, and four on M4 were sampled, increasing density locally up to 6 plots per km. These additional sites had been sampled in 2000, when they exhibited the signature of sawgrass dieback that had occurred prior to sampling (Ross et al. 2001).

At each sampling site, a PVC tube marked the SE corner of a 10 x 10 m tree plot. Nested within each tree plot, a 5 x 5 m herb/shrub plot was laid out, leaving a 1-m buffer strip along the southern and eastern border of the tree plot. In the 10 x 10 m tree plots, we measured the DBH and crown length and width of any woody individual ≥ 5 cm DBH, then calculated species cover assuming horizontally-flattened elliptical crown form. Within each 5 x 5 m herb/shrub plot, we estimated the cover class of each species of shrub (woody stems >1m height and < 5cm DBH) and woody vines, using the following categories: < 1%, 1-4%, 4-16%, 16-33%, 33-66%, and > 66%. We estimated the cover % of herb layer species (all herbs, and woody plants <1m height) in five 1-m^2 subplots located at the four corners (NE, NW, SE and SW) and the center (CN) of the 5 x 5 m plot. Species present in the 5 x 5 m plot but not found in any of the 1 m^2 subplots was assigned a mean cover of 0.01%. In addition, a suite of structural parameters was recorded in a 0.25 m^2 quadrat in the SW corner of each of the 5 subplots. Structural measurements included the following attributes: 1) The height and species of the tallest plant in the plot; 2) Canopy height, i.e., the tallest vegetation present within a cylinder of ~5 cm width, measured at 4 points in each 0.25 m^2 quadrat; 3) Total vegetative cover, in %, and 4) live vegetation percent cover, expressed as a % of total cover.

2.2.2 Soil and water depth measurements

Soil depth was measured in each sub-plot by driving a 1-cm diameter probe to the bedrock. Soil depth measurements were taken only during the first cycle of sampling (2005-2008). However, in the slough portion of MAP transects M1, M2 and M4 that overlap with the SS-transects, soil depth measurements were not measured during 2005-2008 sampling, as the soil depths at those sites were inferred from measurements taken during the 1998-2000 study.

On each visit, water depth was measured at the PVC, the marker of the plot, and in the center of five vegetation sub-plots in a 5 x 5 m plot. In the marl prairie section, vegetation was sampled in the dry season when there was frequently no standing water, so water depth measurement was a problem. At those sites, we measured water depth once when there was standing water in the Fall of 2008. In addition, a Promark 3 GPS unit was also used to measure elevation on marl prairie sites with no standing water.

2.2.3 Fire frequency and Time since last fire

Fire geodatabase in which the records of fire events are catalogued from 1948 to 2012 was obtained from Everglades National Park (ENP). The shape files for 2013 and 2014 fires were also obtained from the Park, and were later added to the geodatabase. The database contains shape files of fires with other attributes such as type of fire (Natural, RX, incendiary, etc.), date of incidence, etc. The data were used to calculate fire frequency and time since last fire (TSLF) for vegetation monitoring sites along the MP-S gradient using ArcGIS 10.2.

2.3 Data Analysis

2.3.1 Hydroperiod and daily water depth estimation

We used field water depth-derived elevation and EDEN (Everglades Depth Estimation Network, http://sofia.usgs.gov/eden) water surface elevation data to estimate the hydrologic conditions at each sampling site. We calculated the ground elevation of each plot using mean water depth for the plot and EDEN estimates of water surface elevation at the plot center for the same sampling date. Daily water levels for each plot were estimated based on ground elevation and the time series of water surface elevation extracted from the EDEN database. We then calculated hydroperiod, the number of days per year when the location had water depth >0 cm, and mean annual water depth for each plot. Previous studies have found that prairie and marsh vegetation composition are well-predicted by the previous 3-5 years of hydrologic conditions (Armentano et al. 2006; Ross et al. 2006; Zweig and Kitchens 2009). In this study, we averaged hydroperiod and mean annual water depth for the four water years (May 1st – April 30th) prior to each sampling event to examine the relationships between hydrologic parameters and vegetation composition.

2.3.2 Vegetation classification and ordination

We summarized species data by calculating the importance value (IV) of each species present in herb and shrub layers in each plot. We calculated species' importance value as: IV = (relative cover + relative frequency)/2. For calculating IV of the species that did not occur in any of 5 subplots but occurred in 5 x 5 m^2 plot, a frequency of 4% was assigned. The assumption was that the species would have occurred in at least one subplot, had all 25 1 x 1 m^2 subplots within a plot sampled. Preliminary examination of the data suggested that four sites, one on M2 and three on M3 were forested, with species assemblages very different from all other sites. Outlier analysis also distinguished these sites on the basis of average distance (Bray-Curtis) from other sites (their average distance was more than 2 standard deviations from the mean). Another two sites had <10% total vegetation cover. We eliminated these six sites and classified the remaining sites. An hierarchical agglomerative cluster analysis was used to define vegetation types at all sites that were surveyed along the five transects between 2005 and 2008. We used Bray-Curtis dissimilarity as our distance measure, and the flexible beta method to calculate relatedness among groups and/or individual sites (McCune and Grace 2002). The SIMPER (Similarity Percentage) analysis included in the PRIMER Software (Clark and Warwick 2001; Clark and Gorley 2006) was used to identify which species contribute most to within group similarities.

We used non-metric multidimensional scaling (NMDS) ordination to visualize relationships among sites based on their similarities in vegetation composition. We performed NMDS on a matrix of Bray-Curtis dissimilarities among sampling units, with species' importance value first standardized by species' maximum. We then examined the relationship between vegetation composition and environment along a reference vector representing the hydrologic gradient. In NMDS, the community characteristics and environmental vectors, including one for mean annual water depth, were defined through a vector fitting technique in DECODA (Kantvilas and Minchin 1989; Minchin 1998). In the vector-fitting method, a vector is defined in the ordination in the direction that produces the maximum correlation between the measured community and environmental attribute and the scores of the sampling units. The statistical significance of such correlations was tested using a Monte-Carlo permutation test with 10,000 random permutations (Faith and Norris 1989).

2.3.3 Biomass estimation

For the sites in the marl prairie portion of the gradient, vegetation structural measurements were summarized for each plot, and mean canopy height and total vegetative cover were used to estimate above ground plant biomass, using the allometric equation developed by Sah et al. (2007) for marl prairie vegetation within CSSS habitat. The equation for calculating biomass was as follows:

$$\sqrt{Biomass} = 6.708 + 15.607*\text{arcsine}\ \sqrt{Cover/100} + 0.095*\text{Ht}$$

where Biomass = Total plant biomass (g/m^2), Cover = Crown cover (%), and Ht = Mean crown height (cm).

2.3.3 Trajectory analysis

At the slough sites on Transects M1-M4, where we had vegetation data from four complete cycles, we were able to use trajectory analysis (Minchin et al. 2005) to test hypotheses about rates and directions of community change more explicitly than would be effective with the shorter-term (3-cycle) marl prairie data. In this analysis, the direction of vegetation change was examined from the first sampling of SS sites in 1999-2000 through 2013. In the NMDS ordination performed for trajectory analysis, we included vegetation data for prairie sites collected during the first sampling cycle (2005-2008), and for SS sites the data collected between 1999 and 2013. Prairies sites were included in this analysis to better define the full range of hydrologic conditions on the transects, though we could not test their temporal trajectories directly. The environmental vectors were defined in ordination space as described above.

To quantify the degree and rate of change in vegetation composition along the reference vector, two statistics, delta (Δ) and slope were calculated (Minchin et al. 2005). Delta measures the total amount of change in the target direction. It was calculated as the difference between the projected score at the final time step and the initial time. Slope measures the mean rate of change in community composition along the target vector. The statistical significance of both delta (Δ) and slope was tested using Monte Carlo simulations with 10,000 permutations of the cover scores of species among sampling times within each trajectory, with the NMDS ordination and calculation of trajectory statistics repeated on each permuted data matrix.

2.3.4 Weighted averaging and Vegetation-inferred hydroperiod

Vegetation change analysis, especially in the marl prairie portion of the gradient, included calculation of vegetation-inferred hydroperiod, i.e., the hydroperiod for a site indicated from its vegetation composition using a weighted averaging partial least-square (WA-PLS) regression model. The training-data set with which we developed the WA-PLS regression model was the species cover data plus hydroperiod estimates from 291 plots on six topographically-surveyed transects within the Cape Sable seaside sparrow habitat (Ross et al. 2006). In developing the WA-PLS models, species cover were fourth square root transformed, which down-weights the influence of very dominant species. Mean hydroperiod was calculated across different time periods (i.e., years preceding vegetation sampling). The performance of the models was judged by the improvement in R^2 value and RMSEP (root mean square error of prediction). RMSEP was estimated by a leave-one-out (jackknife) cross-validation procedure, in which a vegetation-hydroperiod model is developed from all samples except one, and consequently applied to predict the hydroperiod of the left-out point on the basis of its vegetation. We used the C2 program of Juggins (2003) to develop the WA-PLS model.

Finally, the best WA-PLS model was applied to the calibration data set, here the MP-S gradient data that included vegetation data at 148 sites during three separate sampling periods. The predicted hydroperiods for those sites were termed ‘vegetation-inferred hydroperiod’. A change in vegetation-inferred hydroperiod between successive samplings reflects the amount and direction of change in vegetation, expressed in units of days (0-365) along a gradient in hydroperiod.

3. Results

3.1 Marl Prairie-Slough gradient

3.1.1 Physical environments: Hydrology, Soil depth & Fire

Hydrology: Marl prairie-slough gradient transects represented a wide range of hydrologic conditions present in the prairies and marshes in Everglades National Park. **Table 2** summarizes long-term hydroperiod and mean annual water depth averaged over 24 years (1991-2014), the period for which the daily EDEN water surface elevation data were available.

The MP-S gradient transects differed in both hydroperiod (Krusal-Wallis test: $\text{KW-H}_{4,277} = 61.2$, $p < 0.001$) and mean annual water depth (Krusal-Wallis test: $\text{KW-H}_{4,277} = 77.0$, $p < 0.001$) (**Figure 3**). Transect M3, the longest transect (35.8 km) extending from marl prairie near the eastern border of the ENP to the west of SRS, had the widest range of hydrologic conditions (**Figure 3 & 4**). On this transect, mean hydroperiod ranged from 92 to 364 days, and mean annual water depth from -24.6 to 54.7 cm (**Table 2**). The variation in hydroperiod (Standard deviation = 65 days) on M3 was greatest among all transects. Transect M2, restricted to the SRS landscape, had the longest mean hydroperiod (344 ± 17 days) with minimum variation. In contrast, M5 had the sites that were relatively dry. Its mean hydroperiod was shortest (258 ± 27 days) and mean annual water depth was the lowest of all transects (4.5 ± 5.8 cm). Transects M1 and M4 both had short-hydroperiod prairie as well as long- hydroperiod slough sites, and therefore moderate variation in hydrologic conditions (**Table 2**).

Table 2: Summary of hydrologic conditions, hydroperiod (days) and annual water depth (cm), averaged over 24 years (1991-2014) at sites on five marl prairie-slough gradient transects in Everglades National Park. * = Hydrologic parameters for two sites on M4 and 6 sites on M5 were not calculated.

Transect	**N**	**Hydroperiod (days)**					**Annual Water Depth (cm)**				
		Mean	**SD**	**Min**	**Max**	**CV**	**Mean**	**SD**	**Min**	**Max**	**CV**
M1	32	310	38	207	349	0.123	23.2	11.3	-2.5	38.3	0.486
M2	26	344	17	292	360	0.049	35.1	8.6	14.7	50.6	0.243
M3	109	271	65	92	364	0.240	13.5	17.4	-24.6	54.7	1.294
M4	85*	318	46	183	364	0.143	26.6	13.5	-3.3	46.8	0.506
M5	25*	258	27	212	307	0.103	4.5	5.8	-4.2	15.9	1.272

Soil depth: Soil depth varied greatly among and within MAP transects. Mean (±SD) soil depth was lower on M3 and M5 (30.8 ± 22.1 and 31.0 ± 11.3 cm, respectively) than on other transects. However, these two transects differed notably in within-transect variability (**Table 3**). M3 had much greater variation in soil depth than M5, which had the lowest variation among all transects. Mean soil depth was highest on Transect M2 (74.9 ± 50.6 cm), primarily because the transect does not include any sites in the marl prairie landscape, where soils are relatively shallow. On this transect, however, soil depth varied greatly, and the soils were deeper in the central portion than the distal portions of the transect (**Figure 5**). Transects M1 and M4 also had great variation in soil depth, ranging from 0.4 cm to 150 cm. Mean (± SD) soil depth on these transects were 37.8 (± 23.3) and 49.1 (± 31.2), respectively (**Table 3; Figure 5**).

Table 3: Summary of soil depth measured on five marl prairie-slough gradient transects in southern Everglades.

Transect	**N**	**Mean**	**SD**	**Min**	**Max**	**CV**
M1	32	37.8	23.3	1.4	85.4	0.617
M2	26	74.9	50.6	9.8	170.1	0.675
M3	109	30.8	22.1	4.2	105.1	0.717
M4	87	49.1	31.2	0.4	150.0	0.636
M5	31	31.0	11.3	10.7	53.2	0.364

Fire: Fire is an integral component of the both marl prairie and R&S landscapes in the Everglades. Several sites on the MP-S gradient transects have burned frequently in the past**.** The fire-frequency on these transects over 67 years (1948-2014) for which fire data available from ENP records is summarized in **Figure 6**. Fire was more frequent, up to 1.2 fires per decade, in northern transects than the southern ones where fire frequency was as low as 0.1 fires per decade. Moreover, across all transects there was no significant difference in fire frequency between prairie and slough sites. However, the results could have been confounded due to prairie-dominated as well as mangrove encroached Transect 5 located in the south with less frequent fire and frequently-burned Transect 2 in the north with only slough sites. On three transects (M1, M3 and M4), that have both prairie and slough sites, the fire frequency was higher (One-way ANOVA: $F_{1,226} = 6.26$; $p = 0.031$) in the marl prairie sites than the slough portion of the transects (**Figure 7**). Between 1990 and 2005, the period that included vegetation sampling (1999/2000) at the slough sites, there was little fire. Only a few prairie sites burned (maximum 4 sites in a year), and not a single site in the slough section of the transects burned. Nevertheless, since 2005, when vegetation monitoring began at regular interval on all these transects, several prairie and slough sites on Transects M1, M2 and M3 burned due to either prescribed burns (Rx), human-caused fire or wild fires (**Table 4**). Time elapsed between the burned-year and sampling events, defined as time since last fire (TSLF), might have impacted vegetation composition observed at these sites.

Table 4: Vegetation sampling sites burned over the sampling period (2005-2014). The fire attributes were obtained from the Fire database of Everglades National Park.

Fire Name	Year	M1	M2	M3	M4	M5
L67 Rx	2005	0	1	0	0	0
Airboat	2006	18	4	7	0	0
U Road Rx	2007	0	10	0	0	0
Coptic	2007	1	0	0	0	0
West L67 WFU	2007	0	1	0	0	0
Mustang Corner	2008	11	1	44	0	0
Shark Valley Tram Rx	2009	0	0	1	0	0
ROG NE Rx	2012	0	12	31	0	0
EE 1 Rx	2012	18	13	0	0	0

3.1.2 Vegetation Composition

Plant communities arranged along the MP-S gradient varied in species composition. The single most dominant species was sawgrass (*Cladium mariscus* ssp. *jamaicense*). Within a data set that included the first-cycle (2005-2008) sampling of a full set of sites on all five transects, 14 vegetation types were identified through the classification procedure (**Appendix 1**). The distinctive composition of 12 vegetation types is evident in **Table 5**, which summarizes the mean importance value (IV) of the 25 plant species that were identified in the SIMPER analysis as characteristic (cumulative contribution of ≥95% to the group similarity) of one or more vegetation assemblages. These characteristic species represented a range of hydrologic conditions along which the vegetation types were differentiated, as evidenced in the increasing importance of species, arranged by their optimum water depth, from the upper-left to lower-right side of the table. Species composition of three vegetation types, *Schizachyrium* WP, *Muhlenbergia* WP and *Cladium* WP overlapped somewhat. These types were distinguished based on differences in the relative abundances of their dominant species, *Schizchyrium rhizomatum, Muhlenbergia capillaris, and C. jamaicense*, while subordinate species were reasonably constant. Two vegetation types, *Schoenus* WP and *Paspalum-Cladium* WP, each of which had only one site, were not included in the SIMPER analysis or in **Table 5**.

Table 5; Mean importance value (IV) of species identified as the characteristic species (cumulative contribution to ≥ 95% to mean group similarity) within each vegetation types. The vegetation types with at least two sites are included. Species (except *Rhizophora mangle*) are sorted by their optimum water depth and vegetation types (except RHIMAN) by mean annual water depth for four years prior to vegetation sampling. SCWP =*Schizachyrim* Wet Prairie (WP); MWP = *Muhlenbergia* WP; CWP = *Cladium* WP; RCM = *Rhynchospora-Cladium* Marsh: CMM = *Cladium* Mixed Marsh; CM = *Cladium* Marsh; CEM = *Cladium-Eleocharis* Marsh; ECM = *Eleocharis-Cladium* Marsh, EM = *Eleocharis* Marsh; TCM = *Typha-Cladium* Marsh*; Nymphaea* Open Marsh; RHIMAN = Red mangrove. The IV values of species identified as the characteristic species of the vegetation type in SIMPER analysis are in bold.

Species	**SPCODE**	SCWP	MWP	CWP	RCM	CMM	CM	CEM	ECM	EM	TCM	NOM	RHI-MAN
Schizachyrium rhizomatum	**SCHRHI**	**32.70**	**3.77**	**4.58**	0.03								
Muhlenbergia capillaris var. filipes	**MUHCAP**	**7.43**	**25.26**	**8.13**		1.27		0.09					
Symphyotrichum dumosum	**ASTDUM**	0.82	0.61	**1.15**	0.62			0.08					
Centella asiatica	**CENASI**	**4.73**	**4.75**	**3.15**		0.78							
Cassytha filiformis	**CASFIL**	**3.98**	2.59	**2.74**			0.46						
Phyla nodiflora	**PHYNOD**	2.03	**3.39**	**3.27**		**2.03**	0.02						
Ipomoea sagittata	**IPOSAG**	0.28	**1.85**	0.94		0.35	0.27						
Panicum virgatum	**PANVIR**	**2.85**	**3.03**	**4.43**	0.97	1.34	0.08	0.09					
Mikania scandens	**MIKSCA**		0.40	**1.23**		0.83							
Pluchea rosea	**PLUROS**	**3.56**	**5.04**	**4.79**	0.10	**3.27**	0.12	0.02	0.04				
Rhynchospora microcarpa	**RHYMIC**	**2.66**	**1.99**	**5.30**	0.70	0.91	0.13	0.10					
Panicum tenerum	**PANTEN**	**3.10**	**3.55**	**3.40**	0.74	**3.95**	0.02	0.16	0.25				
Hymenocallis palmeri	**HYMPAL**	**2.40**	1.18	**1.10**	0.10		0.33	0.29		0.49			
Ludwigia repens	**LUDREP**	0.20	0.25	0.43		**1.55**	0.22	0.14					
Rhynchospora tracyi	**RHYTRA**	**2.50**	**2.71**	**5.37**	**27.60**	**2.22**	0.27	2.60	4.31	**3.99**		0.95	
Rhynchospora inundata	**RHYINU**	0.25	0.28	1.00	**5.55**	**2.48**	0.17	0.55	0.03	0.55			
Cladium mariscus ssp. *jamaicense*	**CLAJAM**	**15.67**	**20.85**	**28.59**	**19.67**	**54.30**	**70.39**	**46.52**	**23.13**	**4.40**	**29.49**	**10.10**	**26.85**
Justicia angusta	**JUSANG**	0.26	0.62	0.36	0.39	**1.52**	2.54	0.49	0.98	0.02			
Bacopa caroliniana	**BACCAR**	0.23		**1.90**	**10.45**	**2.40**	2.05	**5.68**	**5.21**	**6.24**		1.76	
Eleocharis cellulosa	**ELECEL**	0.36		1.20	**9.37**	**2.19**	**5.30**	**24.51**	**37.60**	**36.99**	2.31	**10.68**	**6.75**
Panicum hemitomon	**PANHEM**	0.36	0.28	0.35	**5.30**	0.90	1.21	1.58	3.42	**6.15**		**4.36**	
Typha domingensis	**TYPDOM**				0.31	0.44	0.82	0.30		0.04	**63.38**		
Utricularia purpurea	**UTRPUR**				3.57	0.32	2.39	**9.02**	**17.41**	**28.99**		**35.65**	2.95
Nymphaea odorata	**NYMODO**				0.03		0.26	0.06	0.04	0.47		**21.54**	
Rhizophora mangle	**RHIMAN**						0.04	0.11		0.05			**60.17**

The spatial distribution of vegetation types along transects provides a view of the status of vegetation composition along the MP-S gradient. While Marl Wet Prairie (WP) types are dominant within marl prairie landscape, long-hydroperiod Marsh vegetation types were common in SRS section of transects. However, some sites with relatively wet vegetation types were also present throughout the marl prairie portion of the transects (**Figure 8; Appendix 1**). The most dominant vegetation type in prairie and slough portions of transects were *Cladium* Wet Prairie and *Cladium* Marsh, respectively. Spikerush Marsh was dominant on Transect M4 (**Figure 8**).

In the transition zones of Transects M1, M3 and M4, the vegetation composition was of mixed types, i.e. species composition at those sites were dominated by sawgrass, but also included a number of species that were characteristic in both WP and Marsh vegetation groups. Red mangroves were present at 4 sites in the western portion of Transect M5, which occupies the transition between brackish and fresh water vegetation.

Variation in species composition in relation to environmental gradients was effectively summarized by a NMDS ordination (3-D: stress = 0.15) that was rotated to align with the hydrologic gradient (**Figure 9**). The first axis, which was aligned to parallel the fitted vector of mean annual water depth in rotated ordination space, separates the SS sites from most of the MP sites, suggesting that species composition along the gradient is primarily influenced by hydrology (hydroperiod - $r = 0.88$, $p < 0.001$; mean annual water depth $r = 0.87$, $p < 0.001$) (**Table 6**). However, the overlap between prairie and slough sites in ordination space is noticeable. Some sites within the MP landscape had species composition similar to that of long-hydroperiod SS sites, as previously noted for the spatial distribution of vegetation types along transects (**Figure 8**). The distribution of species along the gradient is shown in **Figure 10**. The characteristic species of short hydroperiod marl prairie sites are confined to the left side in the ordination space. These include muhly grass (*Muhlenbergia capillaris* ssp. *filipes*), little bluestem (*Schizachyrium rhizomatum*), back-top sedge (*Schoenus nigricans*), spadeleaf (*Centella asiatica*), rosy camphorweed (*Pluchea rosea*), among others. The characteristic species of long hydroperiod sites, in both MP and SRS landscapes, included spikerush (*Eleocharis* sp.), bladderwort (*Utricularia* sp.), arrowhead (*Sagittaria lancifolia*), maidencane (*Panicum hemitomon*), pickerelweed (*Pontederia cordata*), and others (**Figure 10**). Sawgrass (*Cladium*), which has the most ubiquitous distribution in Everglades due to its wide range of hydrologic tolerance, occupied an intermediate position in the ordination.

Table 6: Maximum correlations (r) of significant environmental and community characteristic vectors fitted in NMDS ordination space for plant species' importance value (IV) data on five transects. Probabilities (P) were calculated using 10000 random permutations.

Variable	N	r	p-value
Soil Depth (SoilDep) (cm)	285	0.47	<0.001
Hydroperiod	277	0.88	<0.001
Annual Water Depth (WaterDep)	277	0.87	<0.001
Species Richness (SppRich)	285	0.88	<0.001
Total Cover (TotCov)	285	0.29	<0.001
Shannon's Diversity (ShanDiv)	285	0.80	<0.001
Simpson Evenness (SimpEven)	285	0.46	<0.001
Time since last fire (TSLF)	285	0.18	ns

The NMDS ordination also revealed within-landscape variation in species composition. In both MP and SRS landscapes, the species composition varied among sites along the second axis that was aligned to soil depth vector in rotated ordination space (**Figure 8**). When considering only MP landscapes from both sides of the SRS, species composition differed between eastern and western sites. This difference was significant (ANOSIM: $R = 0.475$, $p = 0.01$), particularly on Transect M3. The location (UTM Easting coordinate) of MP sites on this transect was also strongly correlated ($r = 0.66$, $p < 0.01$) with the second axis (**Figure 11**), suggesting that regional differences in species composition are driven by differences in underlying environmental drivers between the two regions. The vegetation east of SRS was mostly dominated by muhly grass and sawgrass, whereas muhly grass had very low cover west of the SRS. On the west side of SRS, *S. rhizomatum*, *S. nigricans* and *Paspalum monostachyum* were more common than muhly. The vegetation composition within the SRS landscape also varied from relatively open vegetation dominated by spikerush and bladderworts to denser, sawgrass vegetation to mixed vegetation with some woody components. Across both landscapes, sawgrass cover was strongly correlated ($r = 0.74$, $p < 0.001$) with the second axis that was also aligned with soil depth. However, time since last fire (TSLF) did not show significant correlation with species composition (**Table 6**).

3.1.3 Species richness and Biomass:

Species richness ranged between 1 and 27 species/plot, and differed significantly (ANOVA: $F_{4,280} = 9.8$, $p < 0.001$) among transects (**Table 7**). Transects M1 and M2 that included all or mostly SS sites had significantly lower species richness than other transects. Transect M3 had the highest mean species richness (11.7 species plot^{-1}). Across all transects, species richness was negatively correlated (Generalized Linear Model: df = 275; log-likelihood = -769.2, Deviance = 441, $p<0.001$) with hydroperiod (**Figure 12**), suggesting that raising water level in marl prairie regions will have negative impact on plant species richness. On each of three transects that included substantial areas of both marl prairie and slough, short hydroperiod MP sites had higher number of species than SRS sites (**Figure 13**).

Table 7: Plant species richness on five marl prairie-slough gradient transects in southern Everglades.

Transect	N	Mean	SD	Min	Max	CV
M1	32	6.1	3.5	1	14	0.568
M2	26	6.7	4.3	3	24	0.642
M3	109	11.7	5.9	1	26	0.509
M4	87	9.4	5.0	2	27	0.529
M5	31	9.7	5.5	2	22	0.565

During the first cycle of sampling (2005-2008), above ground plant biomass on the marl prairie portions of four transects (M1, M3, M4 and M5) ranged between 0.20 and 2.53 kg m^{-2}, and the biomass differed among transects (**Table 8**). Transect M5, which has prairie sites on both sides of the Park road, had lower biomass than other transects. Moreover, on each of two transects, M3 and M4 that includes substantial areas of marl prairie on both sides of SRS, biomass differed between two sides of the slough. On Transect M3, biomass is higher in the eastern prairie (783 ± 341 g m-2) than west of the slough (551± 211 g m-2), whereas an opposite pattern was observed on Transect M4. On this transect, biomass was 2.5 times higher in the western prairie than eastern prairie

Table 8: Above ground plant biomass (g m^{-2}) on the marl prairie portion of five transects in southern Everglades. Transects M3 and M4 have prairie sites on both sides (E & W) of Shark River Slough, and Transect M5 have the sites on both east and west of the Park road. On the western portion of Transect 5, four mangrove sites were excluded from analysis.

Transect	Prairie	N	Mean	SD	Min	Max	CV
M1		11	582	659	195	2355	1.13
M3	**E**	41	783	341	281	1659	0.44
	W	31	551	211	263	1218	0.38
M4	**E**	20	504	248	275	1437	0.49
	W	12	1287	681	491	2530	0.53
M5	**E**	16	442	150	298	795	0.34
	W	11	463	193	271	1008	0.42

3.2 Decadal Vegetation Change Pattern in Shark River Slough

Shark River Slough hydrology (1999-2013)

In concurrence with a general trend in hydrologic conditions during the late 1990s and 2000s, the mean hydroperiod and annual water depth averaged over four years prior to vegetation sampling in SRS showed a decreasing trend (**Figure 14**). In the late 1990s, i.e. before the 1999/2000 vegetation sampling, mean hydroperiod on all four transects (M1-M4) were >360 days, and mean annual water depths were >40 cm at all transects except Transect M1. During that period, water depths on M1 which is primarily in NESS were lower than on the other transects, suggesting a regional difference in water depth within SRS landscape. In addition to spatial variation in hydrologic conditions, mean hydroperiod and annual water depth were lower during each of the subsequent sampling events than before 1999, and the differences in mean hydroperiod and water depth between two successive sampling periods were significant (Paired t-Test) on almost all transects, except on M2 and M4 (**Figure 14**). In recent years, i.e. before 2013-2014 sampling, hydroperiod was 23-60 days shorter and mean water depth 17-18 cm less than before the 1999 sampling. The drying trend observed at sites in SRS was not identical throughout the region. The drop in water level on M2 and M4 was less pronounced than on M1 and M3. For instance, in the southern SRS, represented by M4, mean water depth was even significantly higher (Paired t-Test: $n = 36$, $t = 54.5$, $p < 0.001$) before the last sampling (E3) i.e. between 2010 and 2013 than the intervals preceding earlier sampling periods, suggesting that differences in spatio-temporal pattern of water regimes in the Everglades are possibly in response to regional water management activities.

Shark River Slough vegetation change (1999-2013)

Between 1999 and 2013, marsh vegetation showed a shift in relative abundance of species indicative of sensitivity to the increasing dryness in SRS across the period. In general, trajectory analysis revealed that in the slough portion of four MAP transects (M1-M4) sampled at 3-6 year intervals between 1999 and 2013, species composition primarily shifted towards drier vegetation types (**Figures 15-18; Appendix 2**). However, the percentage of sites that showed a drying trend varied among the four transects. The percent of sites with a significant shift towards dry vegetation was the highest (45.6%) on M1. On M4 in the far south, the percent of sites showing a shift towards drier vegetation (27.8%) was much less than on the other three transects. On this transect, many sites even showed a wetting trend (**Figure 17**). On M2 and M3, the percent of sites with significant time trajectories indicating a shift towards dry vegetation were 33.3% and 39.3%, respectively.

On the SRS portion of the transects, the direction and rate of vegetation change varied temporally and spatially. On all four transects, the shift towards drier vegetation was greatest between the first two sampling events, E0 and E1. However, during the following sampling periods, the vegetation change pattern was spatially differentiated. Between E1 and E2, the shift towards dry vegetation continued on only two transects, M1 and M3 (**Figures 15, 17**). In contrast, on M2 and M4, sites showed a slight shift toward wetter vegetation during that period (**Figures 16, 18**). A shift in vegetation composition towards a relatively wet type was also observed at several sites on M1 and M3 during the last sampling period, between 2008 and 2012.

The sites showing a significant shift in vegetation composition along hydrology vector in ordination spaces were not uniformly distributed on individual transects (**Figure 19**). For instance, while a drying trend was observed at most of sites on M2 and M3, the shift in vegetation composition was significant mostly in the western portion of the transects. In contrast, eastern sites on Transect M4 showed a shift towards dry vegetation, but many sites on the western portion of the transect showed a shift towards wet vegetation.

The change in vegetation composition observed over fourteen years on four transects also resulted in changes in species richness. While mean species richness was significantly higher (Pairwise t-Test) on Transect M3 and M4 in later sampling events than in 1999, the mean richness on M2 did not differ among sampling years (**Figure 20**). Contrary to expectation, species richness on Transect M1was significantly lower in the last sampling event (2011) than in the previous three sampling events.

Between 1999 and 2012, total plant cover did not differ among years. However, among the most abundant (Importance Value > 2.0) species, the relative abundance of sawgrass (*Cladium mariscus* ssp. *jamaicense*) and spikerush (*Eleocharis cellulosa*), averaged over all transects, increased significantly after 1999 (**Figure 21**). In contrast, the abundance of the bladderworts (*Utricularia* sp.), which are indicators of relatively wet conditions and are commonly found in *Nymphaea odorata*, *E. cellulosa*, and/or *Panicum hemitomon*-dominated sloughs, significantly decreased in SRS. The mean abundance of two other species, *Bacopa caroliniana* and *P. hemitomon* did not show a significant change over the years. However, several other species of more restricted distribution on the transects (e.g., *Eleocharis elongata* and *Potamogeton illinoensis* on M4, *Justicia angusta* on M1, M2 and M3, and *Sagittaria lancifolia* on M2 and M3) decreased, and some others (e.g. *Pluchea rosea* on M2 and M3, and *Rhynchospora microcarpa* on M3) increased in abundance over the years (**Appendix 3**).

3.3 Vegetation Change in Marl Prairie

Marl prairie hydrology (2005-2014)

Hydrologic conditions in the marl prairie portion of the MP-S gradient varied among transects over the period 2005-2014. Mean hydroperiod, averaged over four years before vegetation sampling, showed different trends on the northern and southern transects. On M1 and M3, the 4-year period before E2 census was much drier than in the years before E1, followed by slightly wetter conditions between E2 and E3 (**Figure 22**). The difference in mean hydroperiod between E2 and E3 sampling events on Transect M1 was not statistically significant, but mean hydroperiod on Transect M3 significantly increased by 28 days during the same period. Contrary to the trend observed on M1 and M3, hydrologic conditions at the marl prairie sties on M4 and M5 were relatively wet during the successive sampling periods (**Figure 22**). The differences in hydrologic conditions among transects were mostly due to extreme events. The prolonged dry period between 2006 and 2008, i.e. the period before the 2nd census (E2), saw water levels dip far below the ground level, while similarly low water levels defined the hydrologic condition before the 1st census (E1) on Transect 4 and 5.

On Transects M3 and M4, marl prairies are present on both sides of Shark River Slough. Over the sampling period, the hydrologic conditions were not the same in eastern and western prairies. While western prairies on M4 had 30 days longer hydroperiod than their eastern counterparts, eastern and western portions of M3 varied independently over time. On this transect, the hydrologic conditions during E1 were similar on both sides of the slough, but during E3, the eastern prairie became wetter while western prairie sites remained relatively dry (**Figure 22**). On Transect 5, which gradually transition to the mangroves in the west, prairie sites west of the Park road were much wetter than sites east of the road. However, the sites on both sides of the road became wetter during E2 and E3 samplings.

Marl Prairie vegetation change (2005-2014)

Vegetation composition in the marl prairie portion of the MP-S gradient tracked the spatio-temporal variation in hydrologic conditions. A shift in vegetation composition over time in response to hydrologic changes is represented by the change in vegetation-inferred hydroperiod between successive samplings. The magnitude and direction of change in inferred hydroperiod reflects the amount and direction of change in vegetation composition, expressed in units of days per year (0-365) along a gradient in hydroperiod.

Six years after vegetation was first sampled in 2006 at marl prairie sites on M1, species composition had shifted toward a drier type (**Figure 23**). About 50% of sites showed that vegetation-inferred hydroperiod decreased by more than 30 days which was very much in compliance with the trend in observed mean hydroperiod that also decreased by 40 days over the same period (**Figure 22**). The drying trend on this transect resulted in an increase in abundance (IV) of several species (*Muhlenbergia capillaris* var. *fillipes*, *Rhynchospora microcarpa*, *Centella asiatica*, *Symphyotrichum tenuifolium*) that are characteristic of the marl prairie environment (Pairwise t-Test: $p<0.05$). In contrast, the abundance of hydric species, *Bacopa caroliniana*, *Utricularia purpurea* and others decreased by 2-3 fold (**Appendix 4a**). On

M3, which has marl prairie sites located both sides of SRS, vegetation change pattern differed between eastern and western prairies. While species composition in western prairies shifted towards a drier type, as evidenced in an increase in the abundance of *Schoenus nigricans* and *Paspalum monostachyum* accompanied by a decrease in abundance of *B. caroliniana, Eleocharis cellulosa* and *Rhynchospora tracyi*, the direction of change in vegetation composition in eastern prairie sites showed a mixed pattern (**Appendix 4a**). Several sites at the distal portions of the transect, especially close to the eastern Park boundary, exhibited an increase in inferred-hydroperiod, suggesting that species composition at these sites shifted toward a wetter type between 2007 and 2013 (**Figure 24**). Surprisingly, the abundance of representatives of both prairie and hydric species were observed to decrease on this section of the transect. However, not all major species decreased in cover; the abundance of *E. cellulosa* did not change during the period, and *R. tracyi* increased significantly.

In contrary to the drying trend observed on the northern-most transect, the two southern transects, M4 and M5, experienced a wetting trend. On M4, the 2008-14 shift in species composition towards a wetter type at the eastern sites was more variable than at the western locations (**Figure 25**). However, at about 40% of sites on both sides of the slough, the increase in inferred hydroperiod exceeded 20 days, and at 25% of sites in the eastern prairie, the increase was >40 days. Mean changes in EDEN-based calculated hydroperiod on this transect were also 23 and 46 days in the western and eastern prairies sites, respectively. On both sections of this transect, the abundance of several hydric species including *Bacopa caroliniana, Eleocharis cellulosa* and *Rhynchospora inundata* significantly decreased (**Appendix 4b**). Transect M5, on which prairie vegetation composition differs sharply on opposite sides of the main Park road, species composition shifted toward a wetter type throughout the transect (**Figure 26**). However, the shift was greater west of the road than east of it.

The shift in vegetation composition observed over nine years at the marl prairie portion on four transects also resulted in changes in species richness and plant biomass. Mean species richness increased significantly (Pairwise t-test) on M1 and the eastern portion of M3, where a drying trend was observed (**Figure 27**). In contrast, on the western portion of M3, both sections of M4, and the western portion of M5, species richness was significantly lower during the E3 sampling period than in E1. On the eastern portion of M5, mean species richness did not differ between E1 and E3 events, though the mean number of species on this transect was lower in the 2nd sampling event than during the other two periods.

Mean plant biomass did not change on M1 (**Figure 28**). A major change in biomass was on the eastern portion of M3 where all but three plots burned in Mustang Fire in 2008. Biomass during the 2nd sampling (E2), 2 years after the fire, was only half of what it was during E1. Mean (± SD) above ground biomass during E1 and E2 was 768 and 403 g m^{-1}, respectively. In this portion of M3, biomass recovered in three years, but at the time of E3, it was still only two-thirds of the initial biomass. In contrast, the western prairie on M3 showed an increase in biomass over time. Among the southern transects, biomass on M4 did not change over time, whereas it significantly increased on M5, especially west of the Park road.

4. Discussion

Marl prairie-slough gradient

The strong relationship between species composition and hydrologic conditions observed along the marl prairie-slough gradient reinforces the primacy of hydrology as the leading driver of structure and composition of plant communities in the southern Everglades. Species composition in the Shark River Slough portion of the gradient differs sharply from composition at the majority of marl prairies sites. However, within-landscape variation as well as some overlap in species composition between these two landscapes was also evident, suggesting that cross-scale hydrologic variability is important in determining spatial and temporal variation in species composition.

Shark River Slough and adjoining marl prairies are hydrologically connected. Vegetation composition and dynamics observed along the Everglades gradient are perhaps most analogous to those occurring in shallow river channels and floodplains. As such, marl prairies are the floodplain in both the Shark River and Taylor Slough basins in the southern Everglades. As in many other river floodplains, variation in plant community structure and composition on the marl prairie portions of the gradient could conceivably result from ecological processes linked to the dry and wet phases of the systems described in the flood pulse concept, first proposed for Amazon floodplain by Junk et al. (1989), and applied to other floodplains (Bayley 1995; Benke et al. 2000; Toth and van der Valk 2012). In the Shark Slough basin, when surface water recedes into the central slough during the dry season, and water level in the prairies drops below the ground, many terrestrial plants grow well in the prairies. Luxuriant growth of long hydroperiod-adapted wetland species is confined to depressions and sinkholes. With the onset of rising water in the slough in the wet season, resulting from natural rainfall and/or water management activities, water gradually spreads over the adjoining marl prairies. The dry season terrestrial species die and decompose, releasing nutrients into the water, where they are rapidly taken up by growing aquatic species. This effect is accentuated, by the rehydration of periphyton that is abundant and highly productive in marl prairie habitat (Thomas et al. 2006; Ewe et al. 2006). Both between and within landscape variation in vegetation composition observed in this study is probably due to evolutionarily fixed, physiological adaptations to such fluctuations in water level by species occupying different positions along the gradient. For instance, the relative proportion of C_4 and C_3 species varies from prairie to slough. While C_4 graminoids such as muhly grass and bluestem are dominant in the drier end of the prairies, their proportions decrease toward wetter environments (Sah et al. *manuscript in preparation*). Moreover, floodplain behavior in the marl prairie has changed in the last century, mainly due to anthropogenic interventions, and vegetation patterns of the present day reflect recent hydrologic connections between the slough and its floodplain. For instance, in the pre-drainage era, hydrologic differences between SRS covered with deep peat and the marl prairies covered with shallow peat was much less than it is in recent years (McVoy et al. 2011). Past presence of organic soils would imply that surface water flowing through the region as sheet flow covered a larger portion of the marl prairies for more extended periods than in recent decades when water levels are largely controlled by regional water management activities. As a result, the differences in plant community composition along the gradient are probably now more distinct than during the pre-drainage period.

Regional differences in vegetation composition observed in this study in similar landscapes, e.g. in marl prairies on both sides of the slough, are driven by both topographic differences and the effects of water management. For instance, shortened hydroperiod and increased drought severity that are prevalent on eastern marl prairies (Van Lent et al 1999) have resulted in vegetation dominated by short hydroperiod-adapted species. In contrast, in the mid-1990s, marl prairies west of SRS experienced high water conditions and extended flooding due to water deliveries from the Water Conservation Area (WCA) north of Tamiami Trail, coupled with high precipitation during the period (Kotun et al. 2009). These high water conditions resulted in sawgrass-dominated vegetation in most areas (Nott et al. 1998). The muhly grass-dominated community that was once common in the western prairies in the 1980s and early 1990s (Ross et al. 2004) was practically absent during the three-year extensive survey of vegetation in mid 2000s in those areas (Ross et al. 2006). In subsequent years, in concurrence with the restrictions on water deliveries through the S12 structures at Tamiami Trail practiced since 2000, a drying trend was observed in some western marl prairies (Sah et al. 2011). However, vegetation has not reverted to the composition present in that region before the mid-1990s, and which currently characterizes the eastern marl prairies. Differences in fire frequency over the 25 year period 1980-2005 between eastern and western prairies, with the former burning much more frequently (Ross et al. 2006, Sah et al. 2007), also might have contributed to the differences in vegetation composition observed in this study.

Within individual regions, vegetation composition is affected by small scale variation in major environmental drivers. Topography is very uneven, and depressions and sinkholes are widespread within the marl prairie landscape. Even though the shallow peat layer laid down over marl soils has disappeared from a large portion of marl prairies east and west of SRS, peat is still found in depressions and solution holes occupied by dense sawgrass and occasionally spikerush communities similar to those found in SRS (McVoy et al. 2011). Moreover, marl prairie landscape is traversed by numerous longitudinal shallow drainages that also influence the spatial continuity of vegetation in the area. The nature and origin of such drainages have not so far been described in detail. In other floodplains, researchers have associated the floodplain geomorphic features to sources of flood water, stage and frequency of floods, and associated fluvial processes (Hupp and Osterkamp 1985; Hupp 2000). In addition to geological processes, the role of regular flood pulses as well as extreme flooding events is also important. In the pre-drainage era, when there was gradual deposition of peat in the main channel of the Everglades, the extent of flooding and duration of water retention on the adjoining floodplains might have progressively increased. In such circumstances, flash floods would have been more likely to cause erosion and gully formation on the floodplains. However, only a focused research effort could ascertain the processes of formation and/or maintenance of those drainages.

Within the ridge-and-slough portion of the MP-S gradient, the variations in vegetation composition observed in this study are due to differences in both local and regional processes. In general, the marsh landscape in SRS consists of elevated ridges with tall sawgrass- dominated vegetation and sloughs with more open water and/or spikerush dominated vegetation (Ross et al. 2003). In a healthy R&S landscape, a sharp distinction in elevation and hydrologic regimes, represented in their bimodal distribution across the landscape (Watts et al. 2010), exist between ridge and slough. However, in SRS the R&S landscape have been degraded by early 20thcentury drainage and subsequent water management activities (Ross et al. 2013). Although hydrologic differences among different communities within the landscape still exist, these differences become fuzzy when considered across the region. For instance, Ross et al. (2003) pointed out that while a difference in hydrology existed between tall sawgrass and spikerush communities in the same region, tall sawgrass had a longer hydroperiod in northern SRS than spikerush-dominated vegetation in any other region of the Park. This explains why slough communities were not well separated on NMDS Axis 1 that represented the water depth along marl prairie slough gradient (**Figure 9a**).

The marl prairie portions of the transects had much higher species richness than the sloughs. Local species richness varies along disturbance and environmental stress gradients (Grime 1973; Connell 1978), and the mechanisms involved may include competitive exclusion (Grime 1973) and/or facilitation among species (Michalet et al. 2006). Whether it is through competition, positive interactions, or both, the role of spatial heterogeneity in available resources is important, though the relationship between habitat heterogeneity and species richness also depends on the scale considered (Auerbach and Shmida 1987). Marl prairies with high variability in topography and soil characteristics are likely to have high heterogeneity in water and soil nutrient availability, resulting in relatively high species richness. Fire is also known to create habitat heterogeneity in forests as well as grasslands (Collins 1992; Turner et al. 1994). Our analysis of available fire data for six and half decades showed that fire frequency was relatively high in dry portions of the marl prairies (**Figure 6 & 7**), and thus might have enhanced habitat heterogeneity resulting in higher species richness in prairies than marshes. Moreover, within the relatively wet conditions, highly productive environments with dense canopies of tall sawgrass had low species richness, perhaps due to limitation of light resources by the competitive dominant, whereas flooding stress that limited the regeneration and growth of many species may be responsible for the low species richness in the wettest, spikerush-dominated environments in which total vascular plant cover was also low.

Shark Slough vegetation change (1999-2013)

In the Greater Everglades, the relationship between hydrologic regime and vegetation distribution is dynamic. In Shark Slough, spatial variation in vegetation composition dynamics observed in this study is not surprising. The reason for such variation probably involves the fact that the water is not evenly distributed in the slough mainly due to spatial differences in water flow from Water Conservation Areas north of the Park. Northeast Shark Slough (NESS), a pathway for the historic northeast-southwest flow of water, has been kept relatively dry throughout the 1980s and 1990s (Van Lent et al. 1999). Even though the partial filling of L67S extension to homogenize the water distribution by reconnecting NESS to the rest of SRS was completed during the last decade, the effects of this structure continued in the 2000s. Northeast Shark Slough was therefore drier in recent years than it was in the mid to late 1990s when the water levels were relatively high throughout the region due to unusually high rainfall, resulting in a shift in vegetation composition towards drier type on Transect M1. In Northern Shark Slough (NSS), the region west of the L-67 levee and the location of most of slough portions of Transects M2 and M3, the drying trend was also obvious (**Figure 19**). It was possibly due to both lower precipitation and regulated deliveries through the S12s connecting ENP to the Water Conservation Area. In contrast, in the south where there may be less impact of spatial variation in water delivery, the vegetation change pattern might have reflected mostly natural variation in water regime that in the present study involved drier condition in recent years (2005-2013) than during the mid-1990s, resulting in vegetation characteristic of these drier conditions on several sites on the slough portion of Transect M4.

Together with a general trend of drying out of the slough over 14 years, vegetation shift on individual transects was also influenced by annual variation in water conditions (**Figure 1**), possibly caused by both rainfall and water management activities. For instance, while water level was above the thirty year average for continuous three years prior to 2005 sampling in northern SRS, water level was at or below the 30-year benchmark during the next four years. Moreover, in subsequent years, including the 2011 drought, mean annual water level varied greatly. Since not all transects were sampled in the same year, the annual variation in water conditions resulted in different trends in vegetation change on these transects. The sensitivity of vegetation change patterns to year-to-year variations such as these supports earlier findings that in sloughs, discernible change in species composition can occur in periods as short as 3-4 years (Armentano et al. 2006; Zweig and Kitchens 2008; Sah et al. 2013).

Vegetation dynamics in the ridge and slough landscape, including SRS, is also affected by the events of 'sawgrass die-off', a pronounced, spatially extensive, and episodic decadence. Such areas were observed in mono-dominant stands of sawgrass at several sites in 1999-2000 on Shark Slough transects (Ross et al. 2001). In the present study, we have not thoroughly investigated the cause of sawgrass die-off. However, a mixture of factors, including reduced fire frequency, nutritional imbalance, fungal infection, boring larvae (*Scirpophaga perstrialis*), hurricane-caused periphyton deposition (Hofstetter and Parson 1975; Wade et al. 1980; Alexander and Cook 1984; Clark et al. 2009) and extreme flooding in the mid-1990s (Olmsted and Armentano 1997) may be involved. In areas of sawgrass die-off, plant succession may start within months (Alexander 1967), but years may pass before full vegetation recovery is achieved. In parts of our study transects where open water sites due to sawgrass die-off prevailed in 1999-2000, sawgrass was still sparse (<50 %) after 10 to 12 years. While these areas of sawgrass die-off seem to have partially recovered, periodic sawgrass die-off events within the ridge-slough landscape have important implications, including the diminished viability of the ridge-slough mosaic through shrinkage of the elevation difference between these two important features (Clark et al. 2009).

In Everglades peatlands, surface microtopography that affects local hydrologic conditions is the result of a balance between soil accretion and degradation. Fire is another important factor affecting surface microtopography. Fires that occur in peat-dominated wetlands, i.e. *peat fires*, may consume a substantial amount of the organic soils, thereby altering the microtopography and ultimately affecting the hydrology and vegetation of the peatland (Loveless 1959; McVoy et al. 2011).   In Shark River Slough, historical fires have probably affected the distribution of plant communities directly by consuming biomass, and indirectly by destroying upper, dry peat layers, lowering the ground surface, and altering hydrologic regimes. However, the extent to which fires burn peat layers depends on the position of the water table relative to the surface and the moisture of the surface peat during the fire. Within the study area, the Mustang Corner fire that occurred in May 2008, following almost two years of drought and at a time when water level was 65 cm below the surface (Ruiz et al. 2013), may have consumed significant amounts of peat on SRS portion of Transect M1. The vegetation at five burned sites on M1, where the mean cover was 66% in 1999, is currently very sparse (cover 17.5%) and comprised mostly of hydric species. Fire- induced elevation loss may also have contributed to compositional shift toward wetter vegetation at several locations along this Transect (**Figure 14**).

An overall increase in sawgrass and spikerush cover in response to relatively dry conditions in last thirteen years in SRS supports the longer-term dynamics described for the post-drainage era in the Everglades by Bernhardt and Willard (2009). Other researchers also have reported an expansion of sawgrass and other emergent species, such as spikerush, in the R&S landscape, primarily due to decreased water levels (Busch et al., 1998; Zweig and Kitchens, 2008 2009, Nungesser 2011) and flow velocities (Larsen et al. 2011). Such expansion may occur within 3-4 years, especially when a minimum water level is maintained in the sloughs beneath the peat surface for three consecutive dry seasons (Zweig and Kitchens 2009). While the extensive expansion of sawgrass could be a step towards succession toward woody vegetation, especially when it occurs on elevated ground that experiences prolonged dry conditions, the extended wet seasons that occur intermittently in some years or a severe fire that burns the peat layer would reverse the process. The deviation in trajectories of vegetation shift observed on each transect may have been the result of such fluctuations in water conditions and fire occurrence. In the present study, fire also affected species richness. In general, plant species richness is inversely related to wetness, and thus the richness was expected to increase with drying of the sites. However, while such a trend was observed on Transects M3 and M4, species richness at the slough sites on Transects M1 and M2 decreased. Several sites on these two transects burned in 2006 and 2007, respectively, and affected the number of species present in subsequent samplings after 2005.

Marl Prairie vegetation change (2006-2014)

The marl prairie landscape, which is currently the only habitat of the Cape Sable seaside sparrow (CSSS) is highly dynamic, and vegetation composition within this landscape is the manifestation of hydrology, fire and their interactions. Short-hydroperiod marl prairies in the Everglades are flooded annually for varying periods, while remaining dry for extended portions of the year. Generally, in seasonally-flooded ecosystems similar to the Everglades marl prairies, species present in the vegetation mosaic are adapted to tolerate the alternating wet/dry conditions that are part of any flood-pulsed environment (Junk and Piedade 1997; Middleton 1999). However, the inherent ability of plants to survive and grow under various hydrologic regimes varies among species, and the differences in species' optimum flooding tolerances usually form the basis for variation in vegetation composition in these ecosystems. In marl prairies, species differences in hydroperiod optima and tolerances have been well-documented (Ross et al. 2006). Hence, any change in duration of inundation would affect the abundance of various species. These dynamics are reflected in changes we observed in relative cover of constituent species, resulting in shifts in vegetation composition towards either wetter or drier types.

Northeast Shark Slough, the site of Transect M1, has been kept relatively dry throughout the 1980s and 1990s (Van Lent et al. 1999) and this condition has changed little during recent years. Thus, the observed vegetation shift toward a drier type was not a surprise, especially considering that most years after the E1 sampling event in spring 2006 were relatively dry. Moreover, the discrepancy in the vegetation change pattern observed in the eastern and western prairies on M3 was primarily management-driven. Water conditions in the prairies west of SRS are influenced by regulatory schedules for the S-12 structures along Tamiami Trail implemented under the operational objectives of Interim Structural and Operation Plan (ISOP)/Interim Operational Plan (IOP). In concurrence with management efforts to regulate water deliveries from the S-12 structures, a consistently low water level has been maintained at NP-205. This has caused the vegetation composition to shift toward a drier type in recent years. In contrast, vegetation on the eastern portion of Transect M3 shifted toward a wetter character. In this region, water pump structures at S332B and S332C, constructed under Interim Operation Plan (IOP) to provide protection for the adjacent CSSS habitat, deliver water from the L31N canal into a series of inter-connected detention ponds. These ponds have a large fixed-crest weir on the western levee that allows water from the pond to enter ENP marl prairies. In addition, water may also be entering ENP through subsurface flow. The purpose of operating pump stations along the L-31N canal includes lowering canal and groundwater levels and creating a continuous hydraulic ridge to control seepage back to the canal while protecting the marl prairie (sparrow habitat) from further deterioration (USACOE 2006). Pumping through S332B and S332C serves the management goal of re-hydrating the marl prairies of the Rocky Glades. Thus, a shift in vegetation towards the wetter types indicates that the management goal is being achieved, at least in part.

In addition to a positive outcome of the operations of water pumps and detention ponds along eastern boarder of the Park, impact of such management efforts on prairie vegetation needs to be interpreted cautiously, because water flow from detention ponds towards prairies in the Park may have adverse consequences as well. For instance, periphyton near inflow structures had elevated phosphorus in comparison to adjacent marl prairie sites to the west, suggesting an increase in P-loading due to long-term exposure of the canal-side sites to seepage (Gaiser et al. 2008; 2014). Sah et al. (2014) also concluded that vegetation in upper Taylor Slough basin showed significant trajectory along the vector representing the phosphorus gradient, possibly due to influence of seepage water from the detention ponds. In this study, we did not work on the possible impact of nutrient on vegetation change. However, if water from the detention ponds continues to influence the vegetation in prairies, the water quality issue also needs to be addressed in future so that vegetation in the prairie adjacent to the ponds does not shift to another stable state adapted to P-enriched soil (Hagerthey et al. 2008) due to canal water that is pumped in to the ponds.

Contrary to management-induced changes in water conditions followed by a shift in vegetation composition observed on Transect M3, the hydrologic changes together with the vegetation shift on southern Transects M4 and M5 are more likely rain-driven. In the prairie portion of these transects, vegetation was first sampled in spring 2008, an extremely dry year, and similar conditions had prevailed during the previous two years. Subsequently, water conditions varied, though the mean annual water level was above 30-year average for four of the next six years, probably causing vegetation on these transects to shift toward a wetter type. Despite prevalence of more nature-driven hydrologic condition, an influence of water management activities on these transects, especially on the western section of M4, cannot be ruled out. In the western part of the prairie west of Shark Slough, relatively high water level has persisted in recent years, mainly because the hydrologic conditions in this area are influenced by flows through the culvert and bridges on Tamiami Trail and the Loop Road. In an analysis of the flow data in relation to rainfall, Kotun et al. (2009) showed that mean annual runoff per unit rainfall in the FMB-Monroe sub-basin increased by a factor of two during 1992-2008 in comparison to three earlier periods (1941-1952, 1953-1963 and 1964-1991). They attributed the increased runoff to high stage level in WCA-3A, which resulted in a backwater effect in Mullet Slough, causing water to flow southwest towards Big Cypress National Preserve, and ultimately ending up in increased flow across the Tamiami Trail. Moreover, the increase in flow was much greater at the easternmost bridges, close to the L28 (Kotun et al. 2009). These flows appear to have contributed to high water levels near stage recorder P34 in the southwestern marl prairies, and thus the western portions of Transect M4 might also have been influenced.

In summary, at the broader scale, vegetation composition varies along the environmental gradient from short hydroperiod marl prairie to the sloughs that remain inundated for most of the year. This variation in species composition is evident at both local and regional scales. Regional differences in hydrologic regimes resulting from alternative management strategies have caused variation in species composition within individual landscapes, and have also brought on temporal change in vegetation composition in Shark River Slough and adjacent marl prairies. The occurrence of these changes coincided with changes in hydrologic regimes during the past fourteen years. The temporal changes in vegetation composition across the gradient are likely to have affected the position and attributes of transition zones in ways not yet fully understood. Our results provide feedback for the adaptive management of Everglades wetland ecosystems along the marl prairie-slough gradient.

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Figures

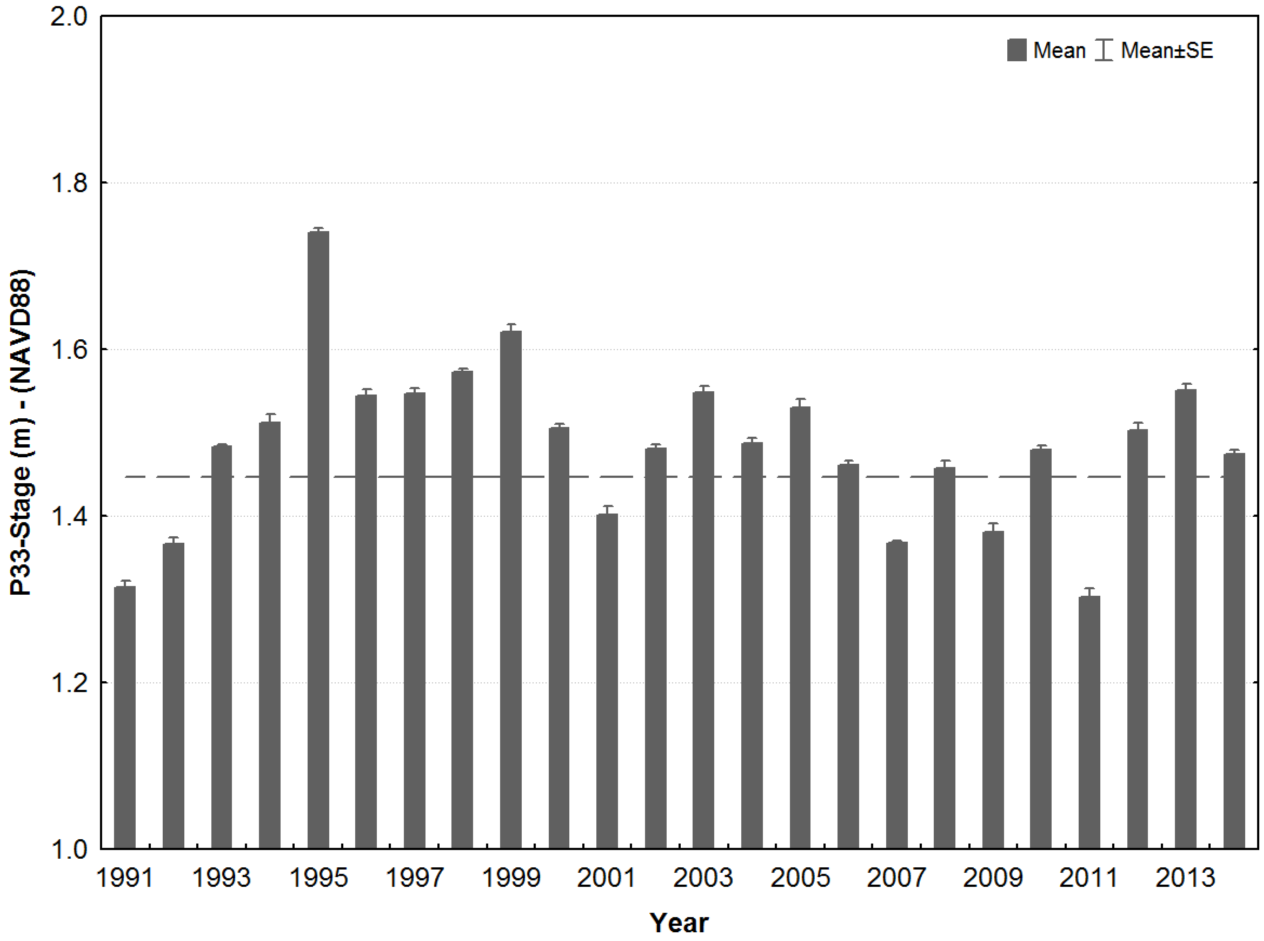

Figure 1: Mean (± S.E.) annual and 30-Yr (1981-2010) average water level at the stage recorder P-33 located in Shark River Slough within the Everglades National Park.

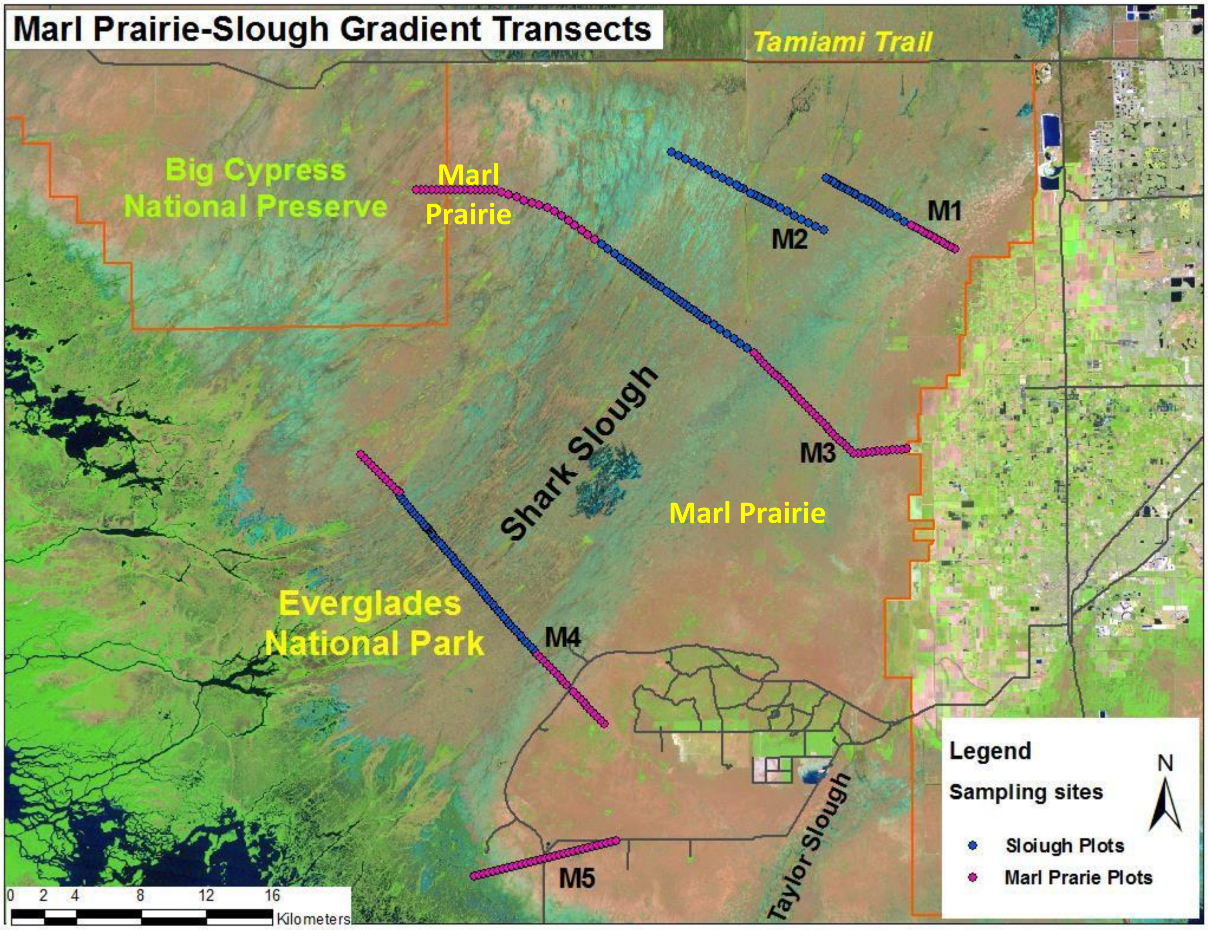

Figure 2: Location map of Marl prairie-Slough Gradient Study plots on Transects M1-M5. Slough plots represent long hydroperiod and marl prairie plots represent short hydroperiod sites.

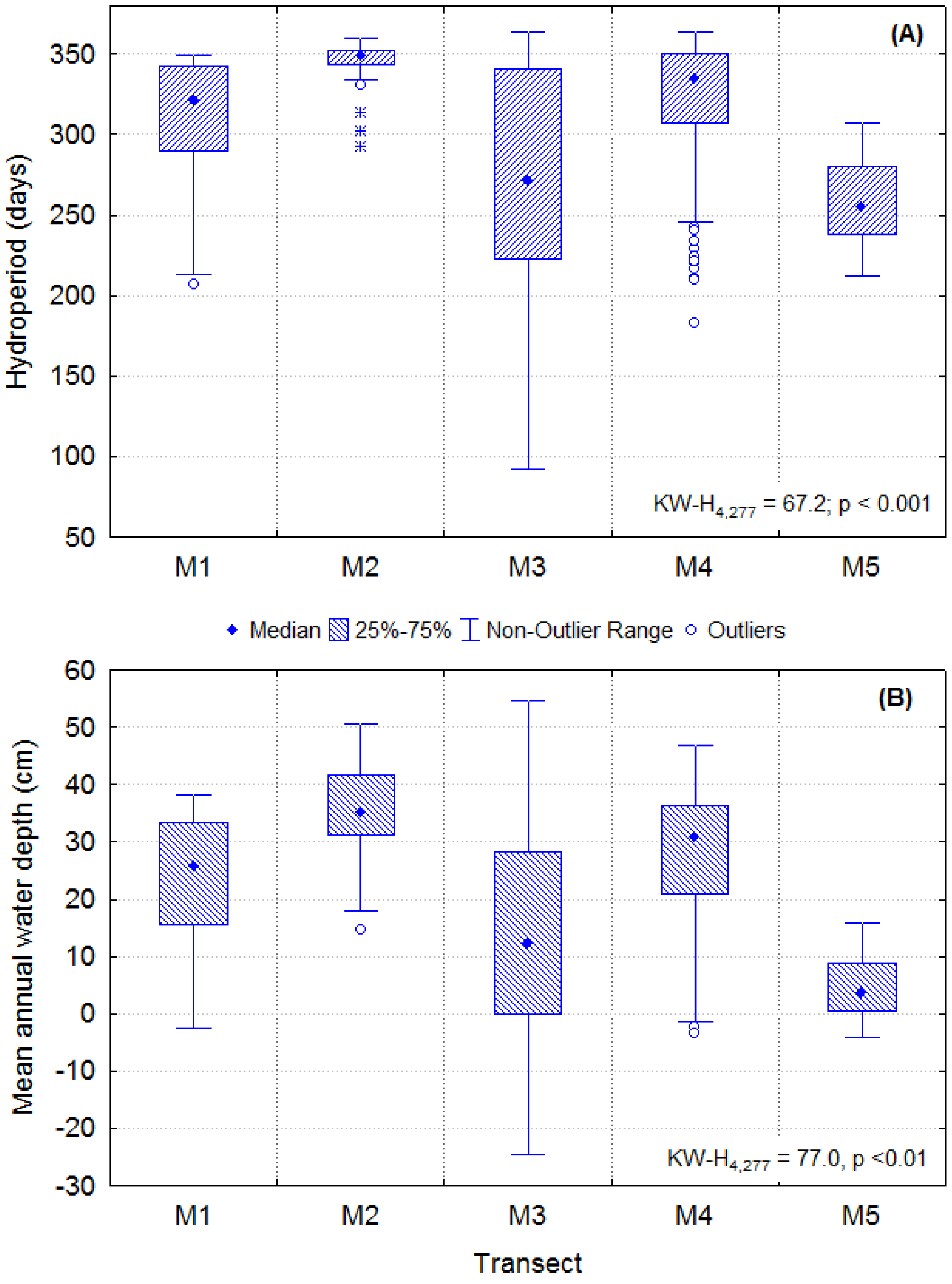

Figure 3: Box Plots showing (A) hydroperiod and (B) mean annual water depth averaged over twenty four years (1991-2014).

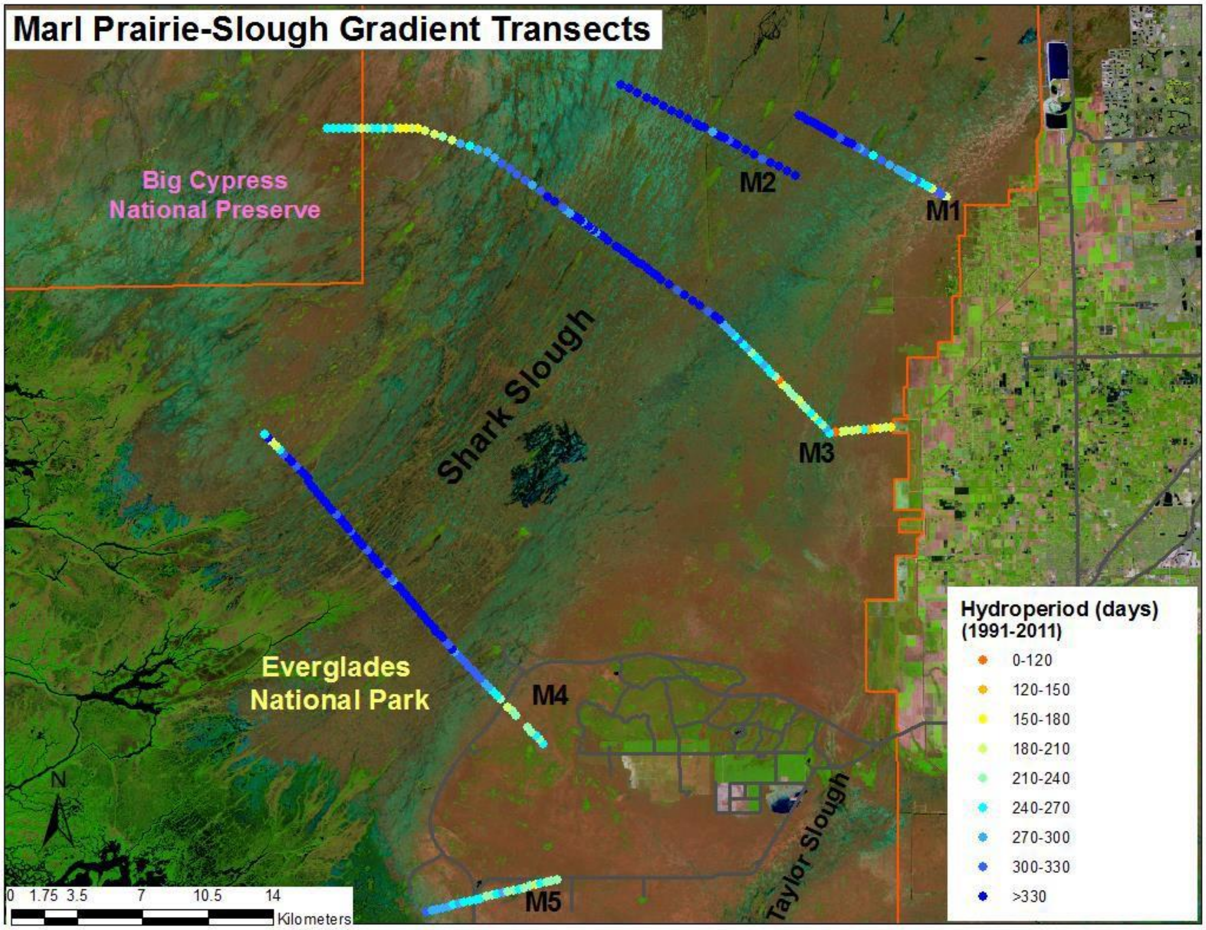

Figure 4: Long-term hydroperiod (days) averaged over 21 years (1991-2011) at the vegetation sampling sites on Transects M1-M5 along marl-prairie slough gradient.

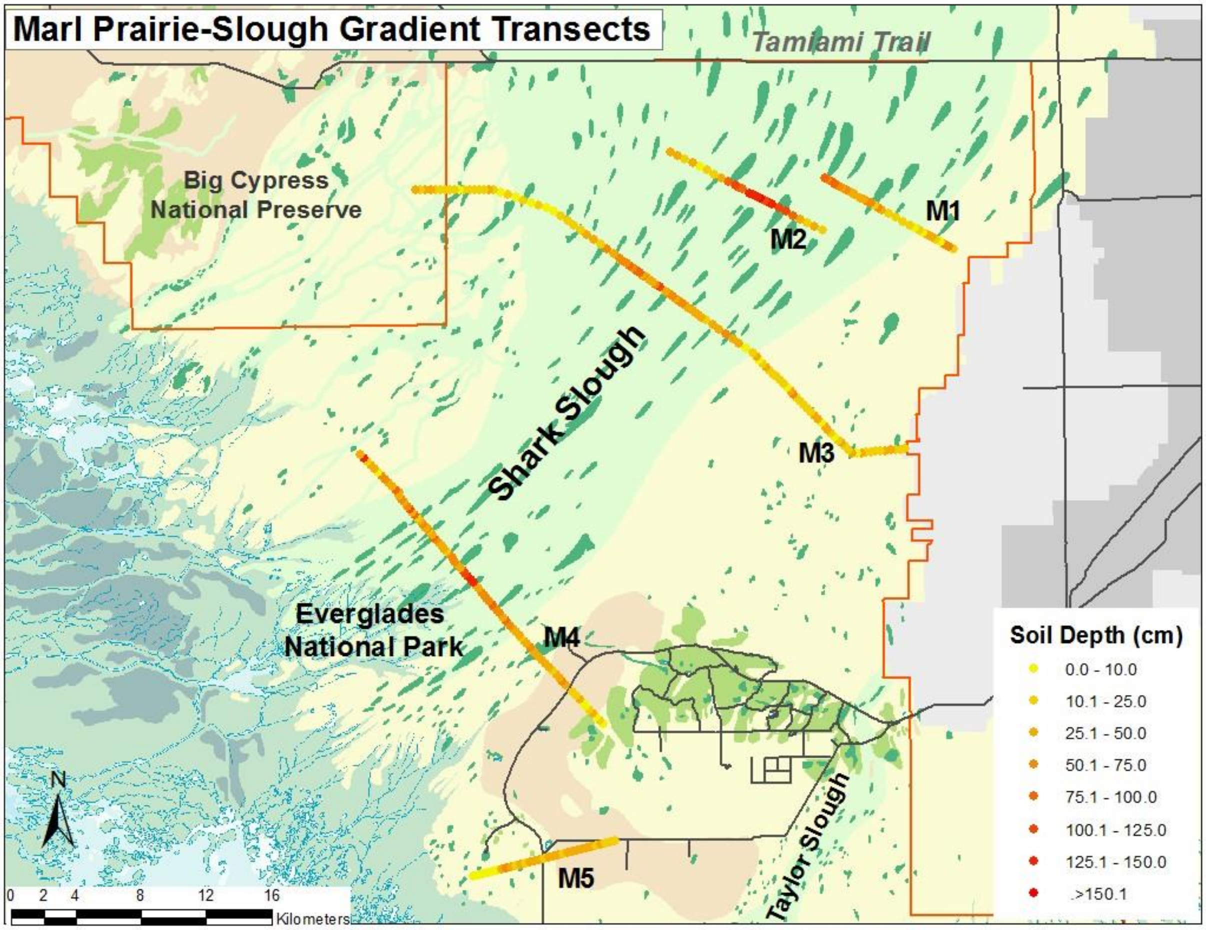

Figure 5: Soil depth (cm) at the vegetation sampling sites on Transects M1-M5.

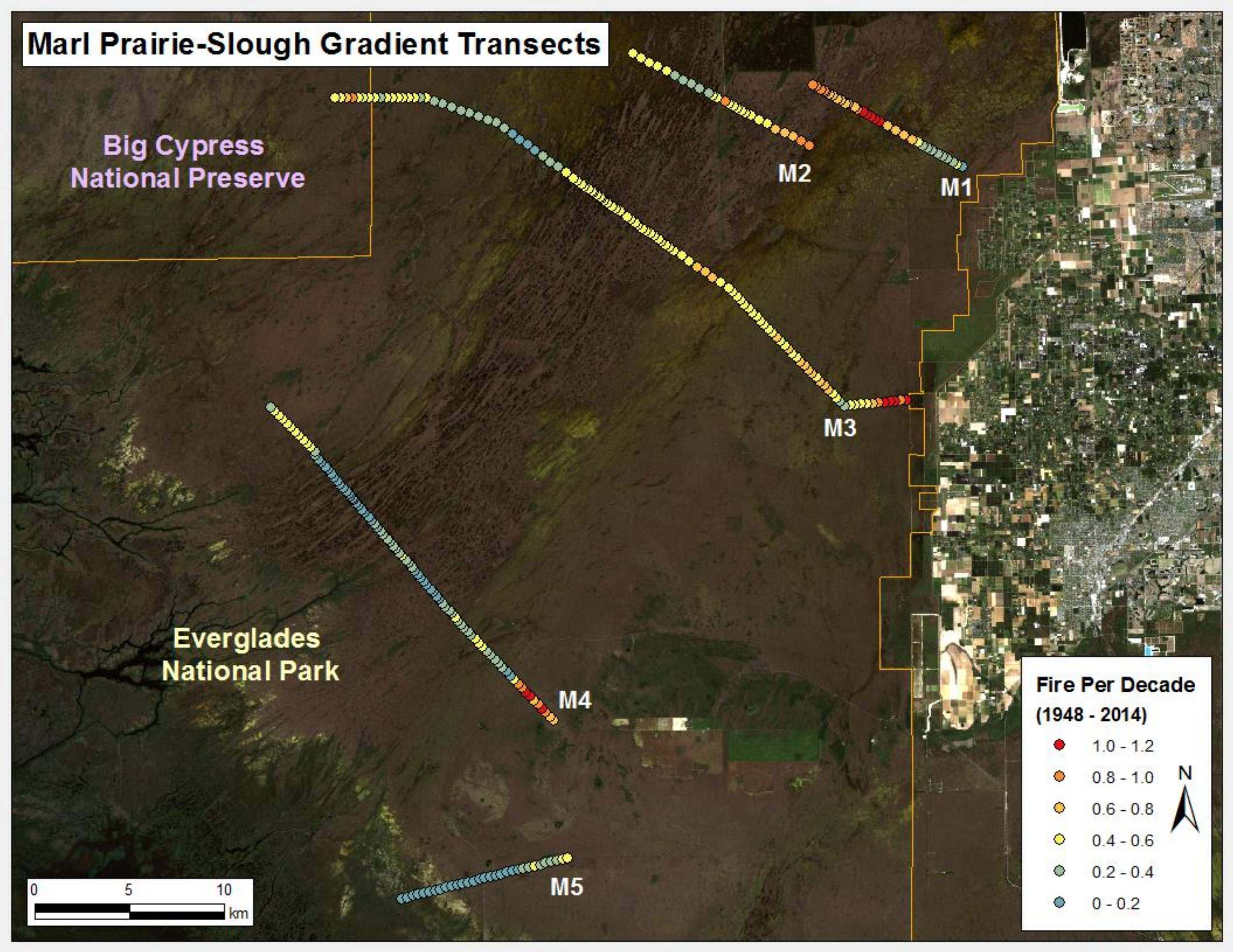

Figure 6: Fire frequency (number of fires/decade) at the vegetation sampling sites on Transect M1-M5. Fire frequency was calculated over 67 years (1948-2014) for which the fire shape files were available in Everglades National Park Fire database.

Figure 7: Box plots showing mean (SE & 95% CI) fire frequency (number of fires/decade) at the vegetation sampling sites in two different landscapes, marl prairie and ridge-and-slough. Fire frequency was calculated over 67 years (1948-2014) for three Transects M1, M3 and M4 which have the both marl prairie and slough sites.

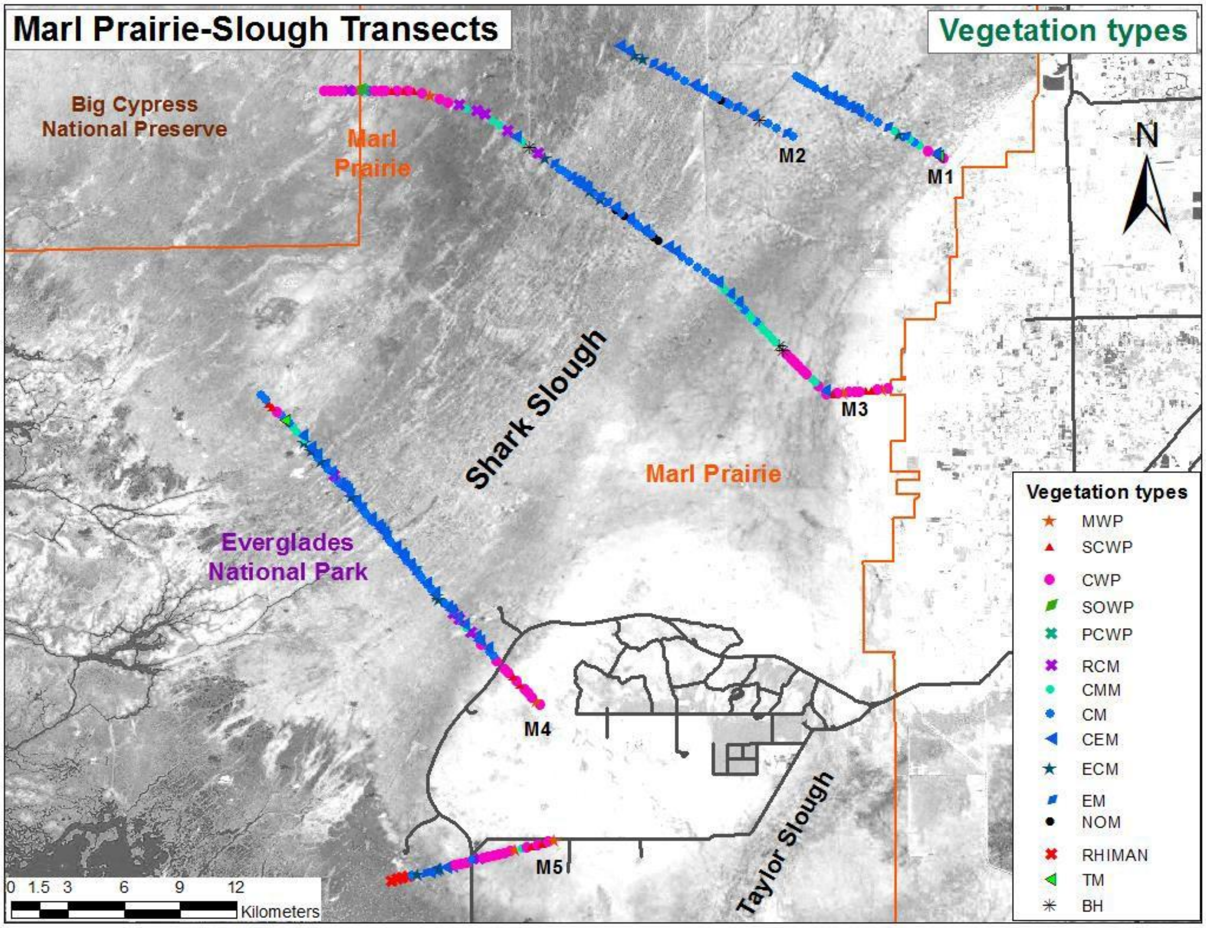

Figure 8: Vegetation types at the vegetation sampling sites on Transects M1-M5 (***See also Appendix 1***). SCWP =*Schizachyrium* Wet Prairie (WP); MWP = *Muhlenbergia* WP; CWP = *Cladium* WP; SOWP = *Schoenus* WP; PCWP = *Paspalum-Cladium* WP; RCM = *Rhynchospora-Cladium* Marsh: CMM = *Cladium* Mixed Marsh; CM = *Cladium* Marsh; CEM = *Cladium-Eleocharis* Marsh; ECM = *Eleocharis-Cladium* Marsh, EM = *Eleocharis* Marsh; TCM = *Typha-Cladium* Marsh*; Nymphaea* Open Marsh; RHIMAN = Red mangrove.

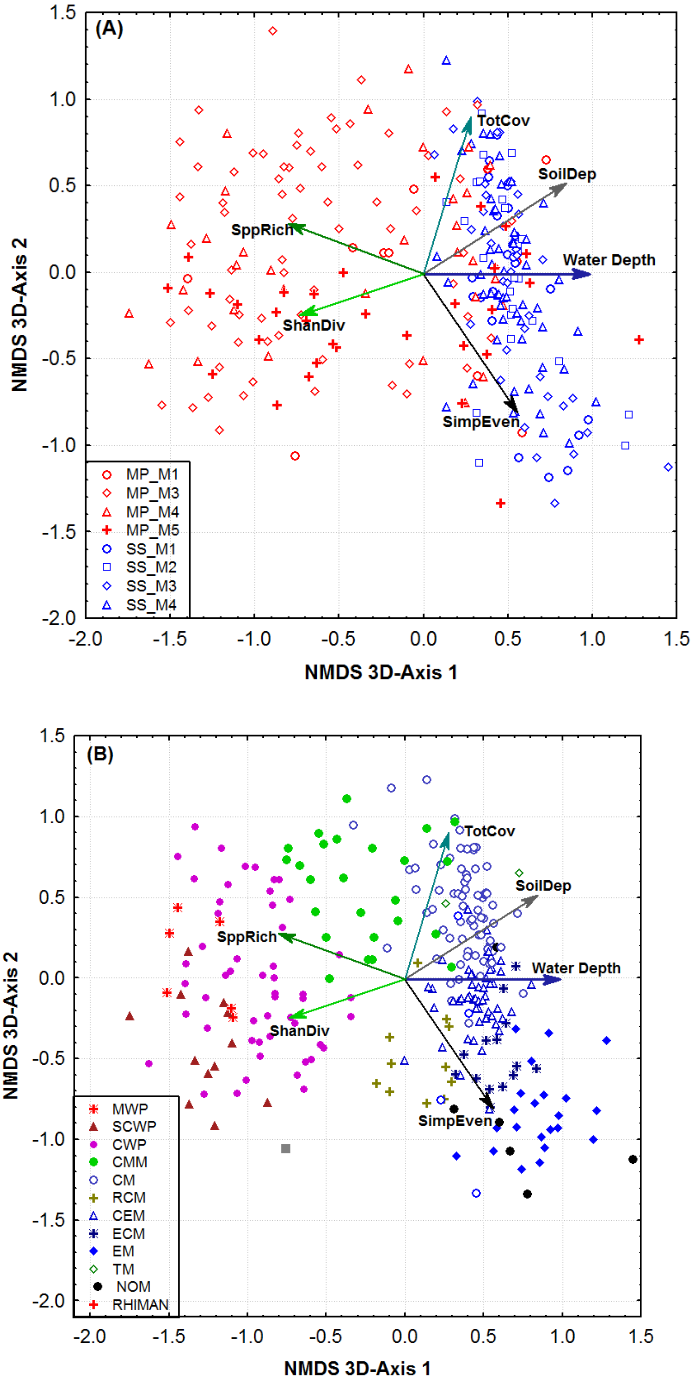

Figure 9: Bi-plots of site from three-dimensional non-metric multidimensional scaling (NMDS) ordination based on species abundance data collected at sites in both marl prairie (MP) and Shark Slough (SS) portions of five transects during the 2005-2008 period. Environmental and community characteristic vectors fitted in the ordination spaces represent the direction of their maximum correlation with ordination configuration. Codes for vector variables are as in Table 5. Sites are grouped by (A) Transects, and (B) Vegetation types. Codes for the vegetation types are as in Figure 8.

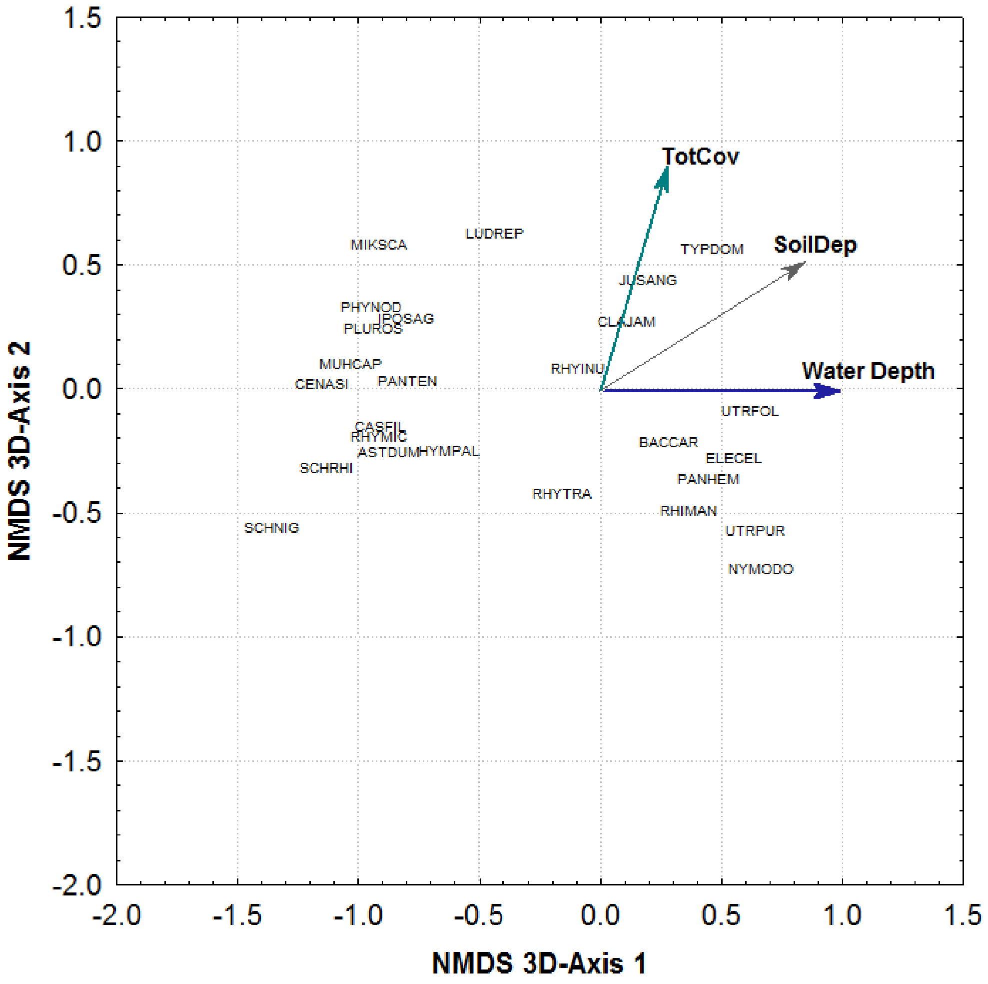

Figure 10: Bi-plots of major species' axis scores from three-dimensional non-metric multidimensional scaling (NMDS) ordination based on species abundance data collected at the sites on five marl prairie-slough gradient Full name of species are given in Table 5 Environmental and community characteristic vectors fitted in the ordination spaces represent the direction of their maximum correlation with ordination configuration.

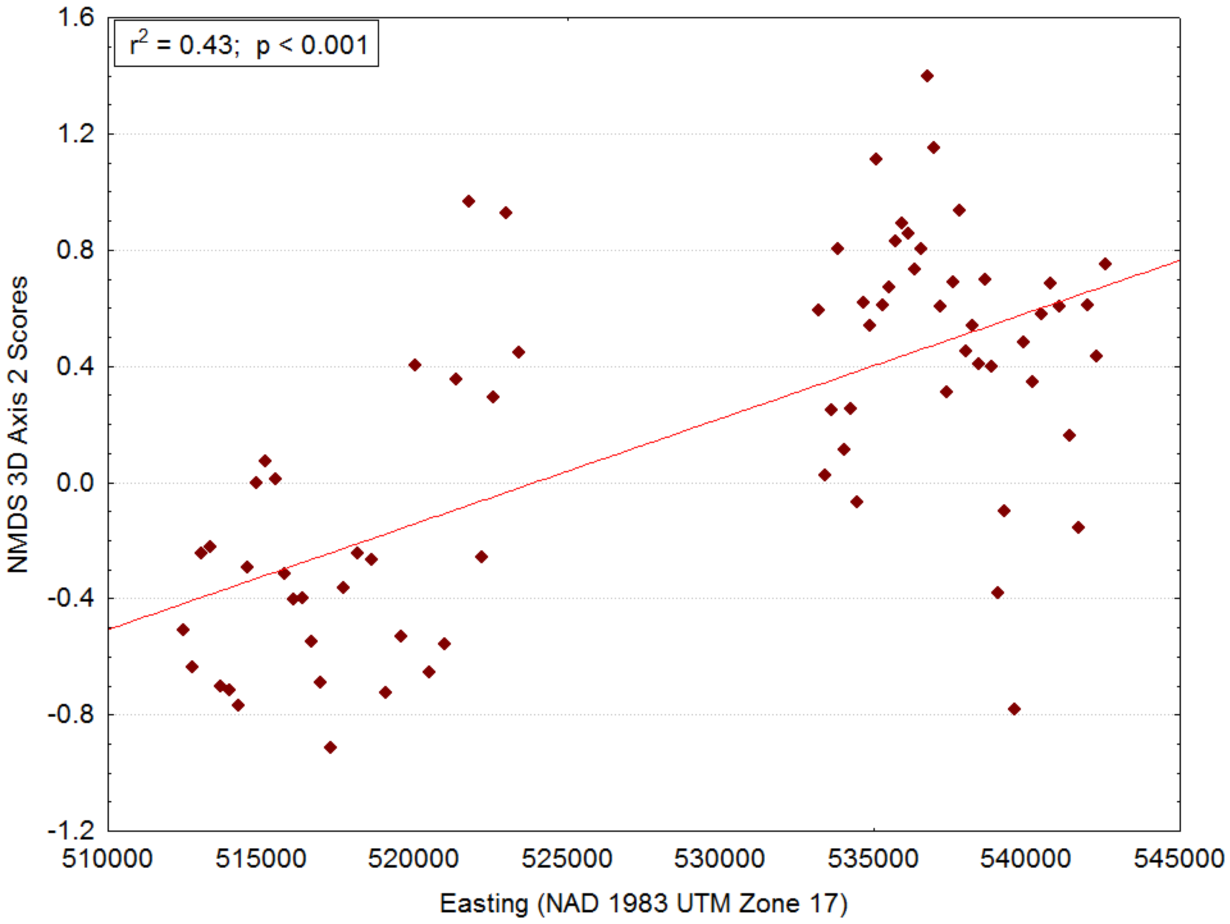

Figure 11: Scatter plot showing the relationship between location of sites in the marl prairie portions of the Transect M3 and Axis scores from three-dimensional non-metric multidimensional scaling (NMDS) ordination based on species abundance data collected at the sites on Transects M1-M5 during the 2005-2008 period.

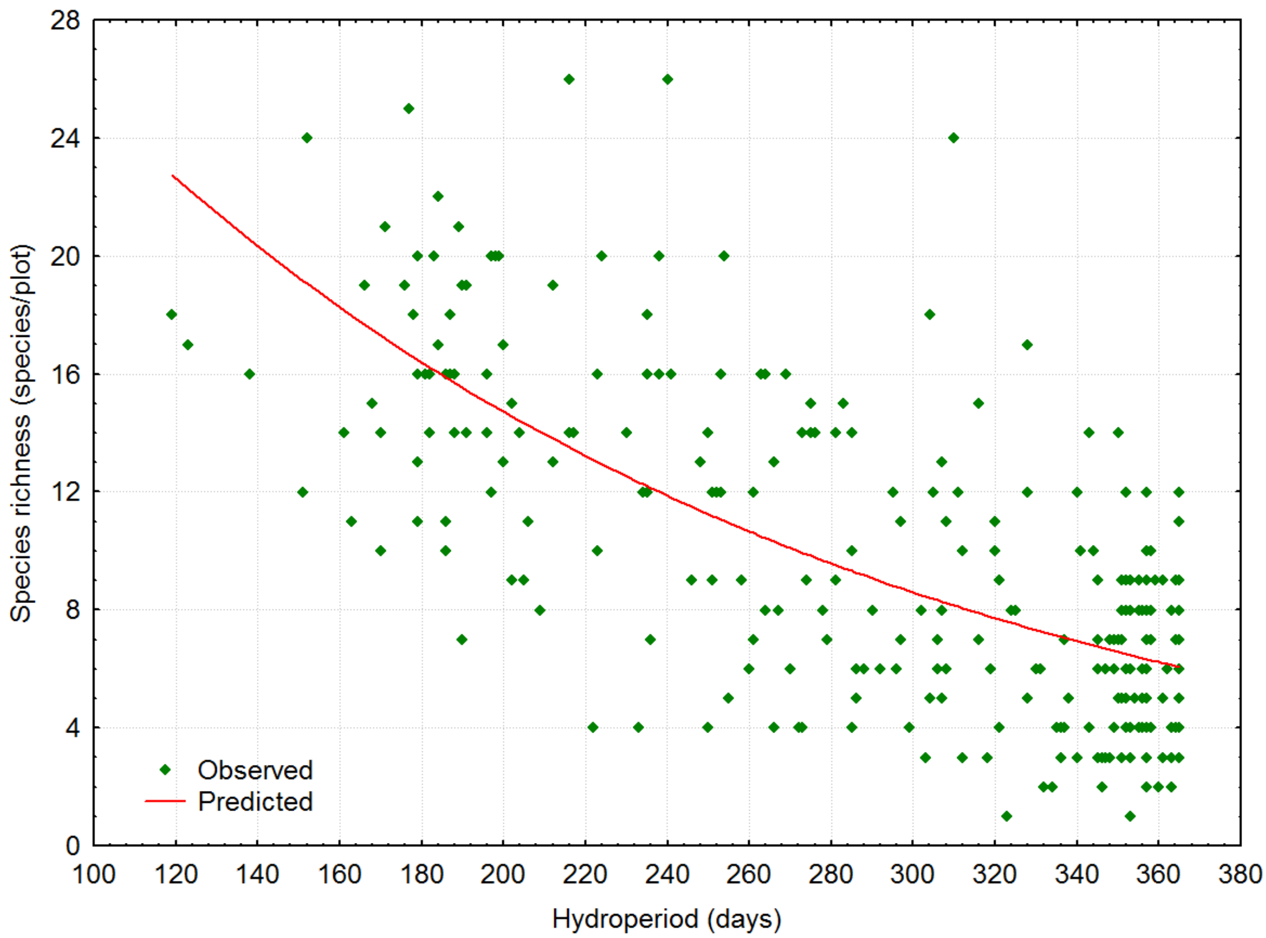

Figure 12: Scatterplot showing the relationship between hydroperiod and species richness. The trend line represents the predicted value obtained in Generalized Linear Model with Poisson distribution and long-link function.

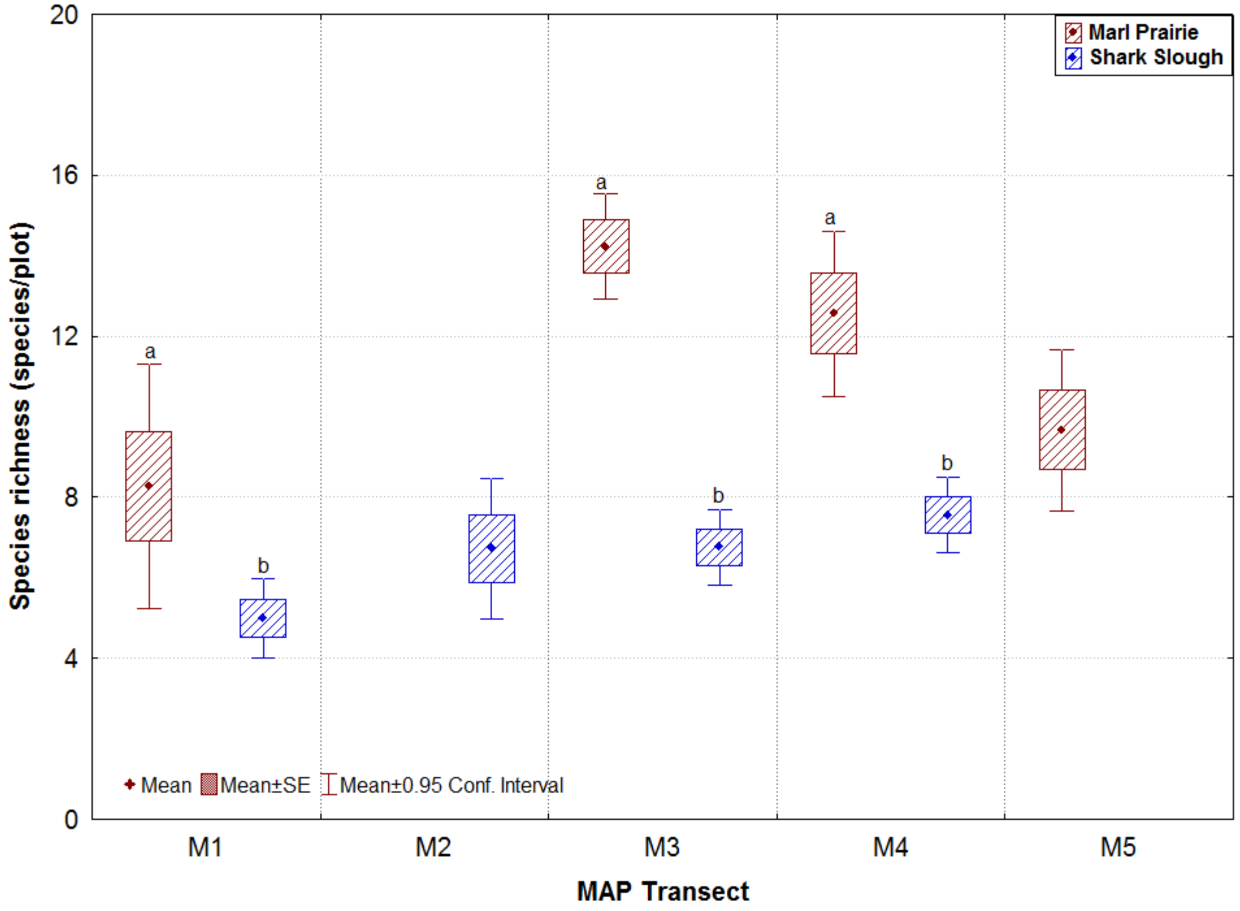

Figure 13: Box Plots showing species richness in marl prairie and slough portions of MAP transects sampled between 2005 and 2008. Different letters indicate significant difference (ANOVA: $p < 0.05$) in mean species richness between two landscapes on the same transect.

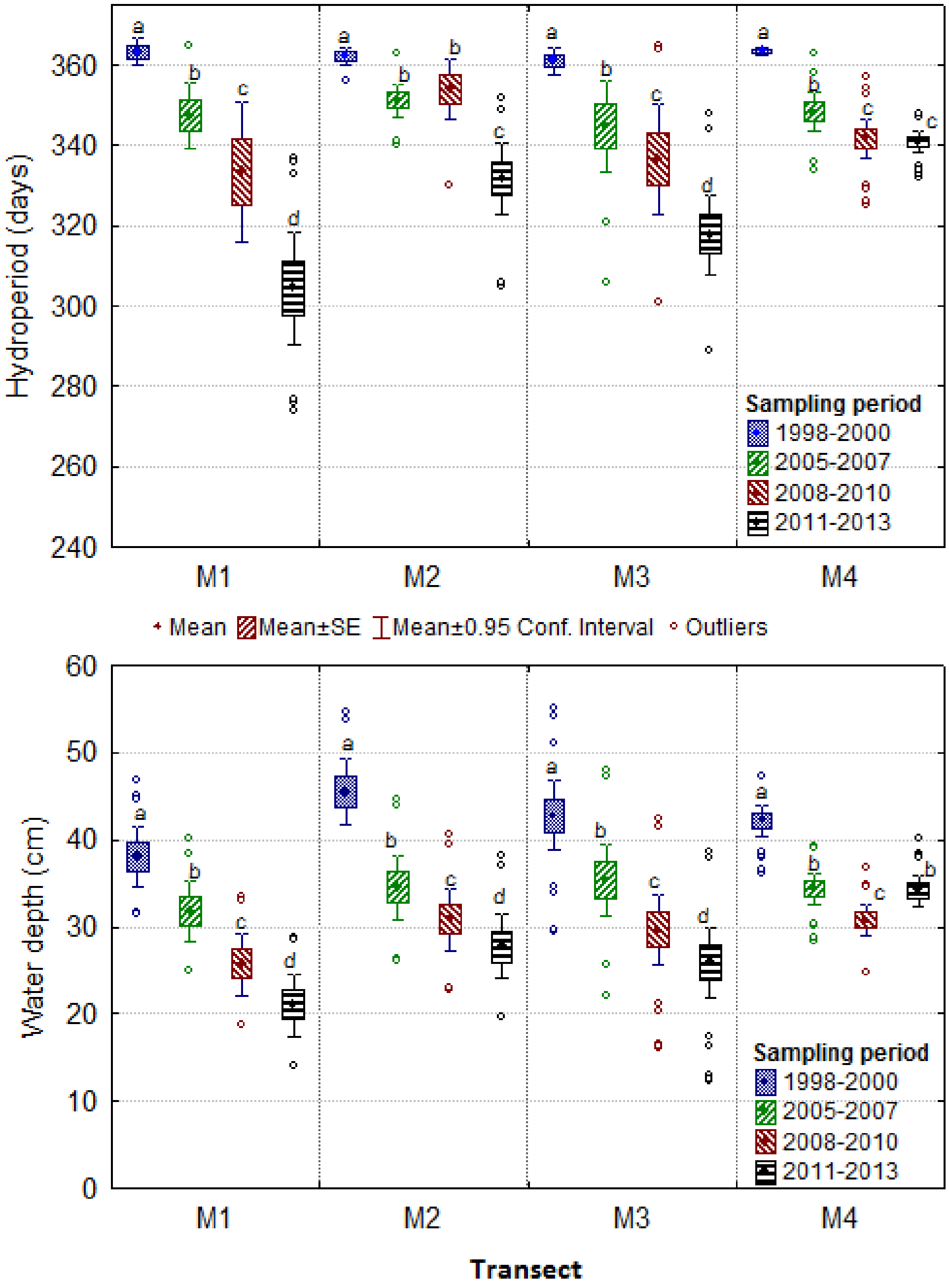

Figure 14: Box Plots showing (A) hydroperiod and (B) mean annual water depth averaged over four years prior to vegetation sampling in the Shark Slough portions of MAP transects sampled between 1998 and 2013. Different letters represent significant (pair-wise t-test; $p < 0.05$) difference in (A) hydroperiod, and (B) mean annual water depth among years on individual transects.

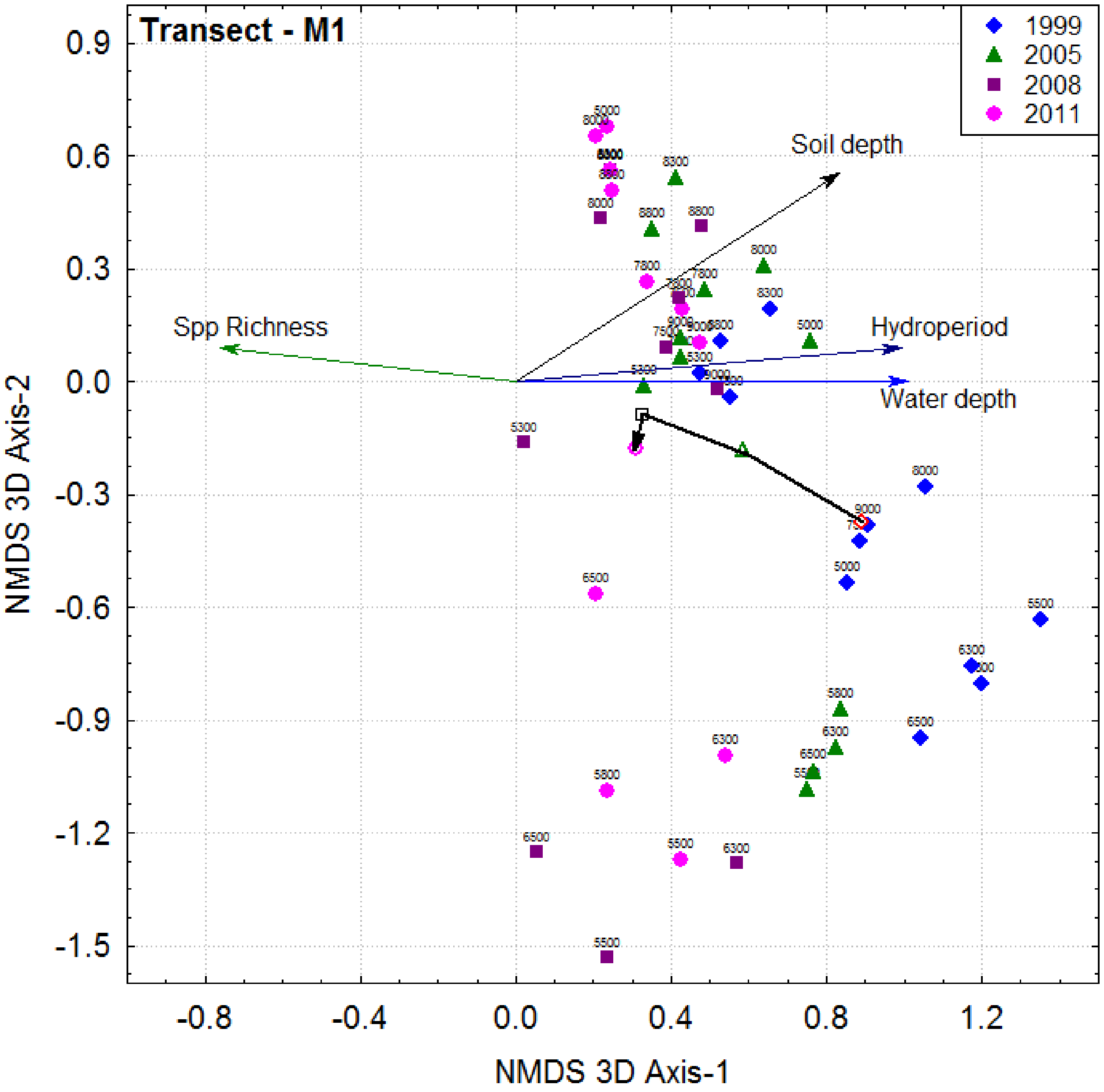

Figure 15: NMDS ordination bi-plots of site scores, the environmental vectors fitted in the ordination space, and the trajectory of centroid. The ordination is based on species abundance data collected four times between 1999 and 2012 in the Shark Slough portion of the Transect M1. Only the sites that showed significant (p≤0.1) rate of change in species composition along the hydrology gradient are shown. Initial point and the end of the trajectory represent the 1999 and 2011 sampling event, respectively.

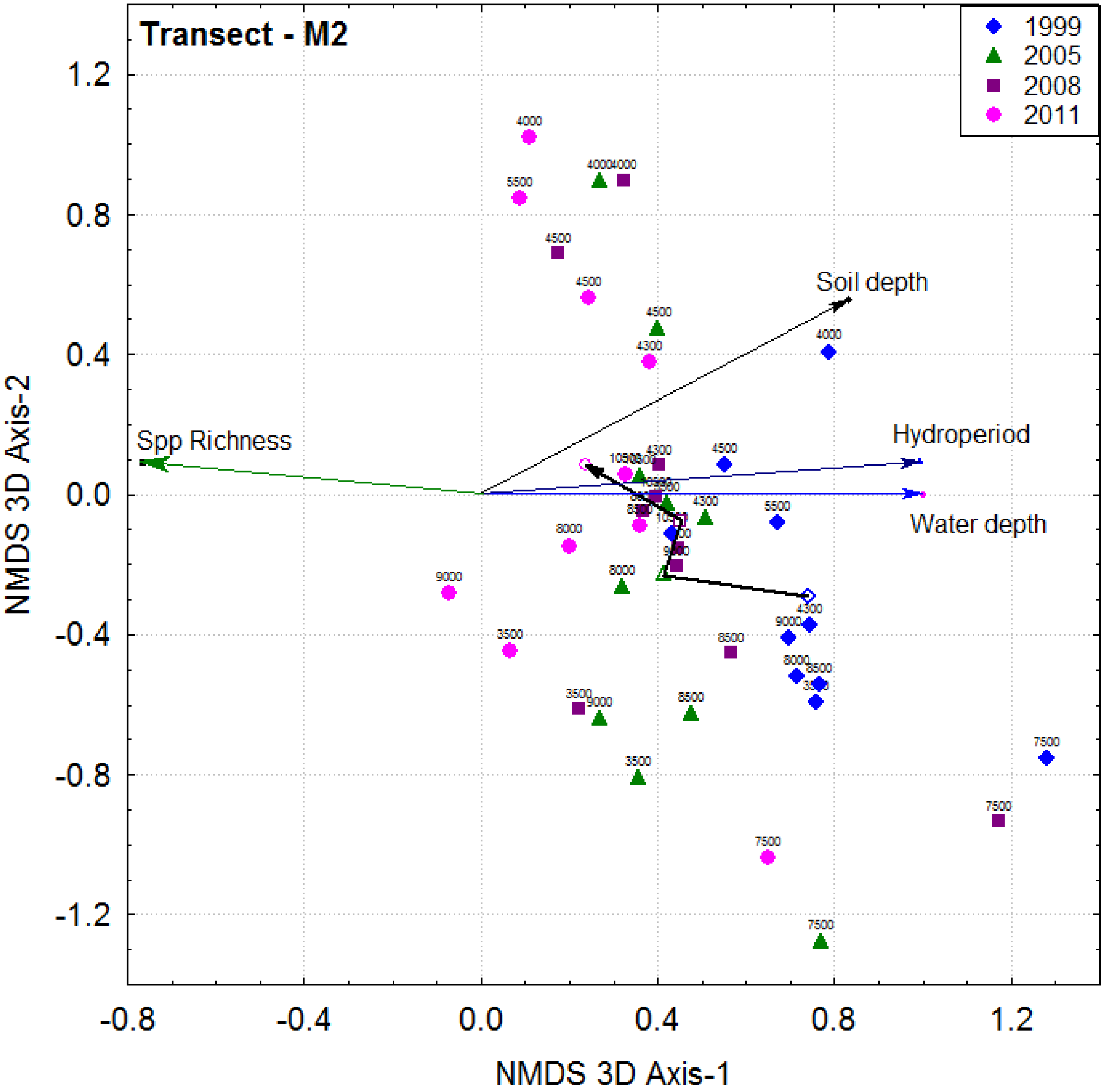

Figure 16: NMDS ordination bi-plots of site scores, the environmental vectors fitted in the ordination space, and the trajectory of centroid. The ordination is based on species abundance data collected four times between 1999 and 2012 in the Shark Slough portion of the Transect M2. Only the sites that showed significant (p≤0.1) rate of change in species composition along the hydrology gradient are shown. Initial point and the end of the trajectory represent the 1999 and 2011 sampling event, respectively.

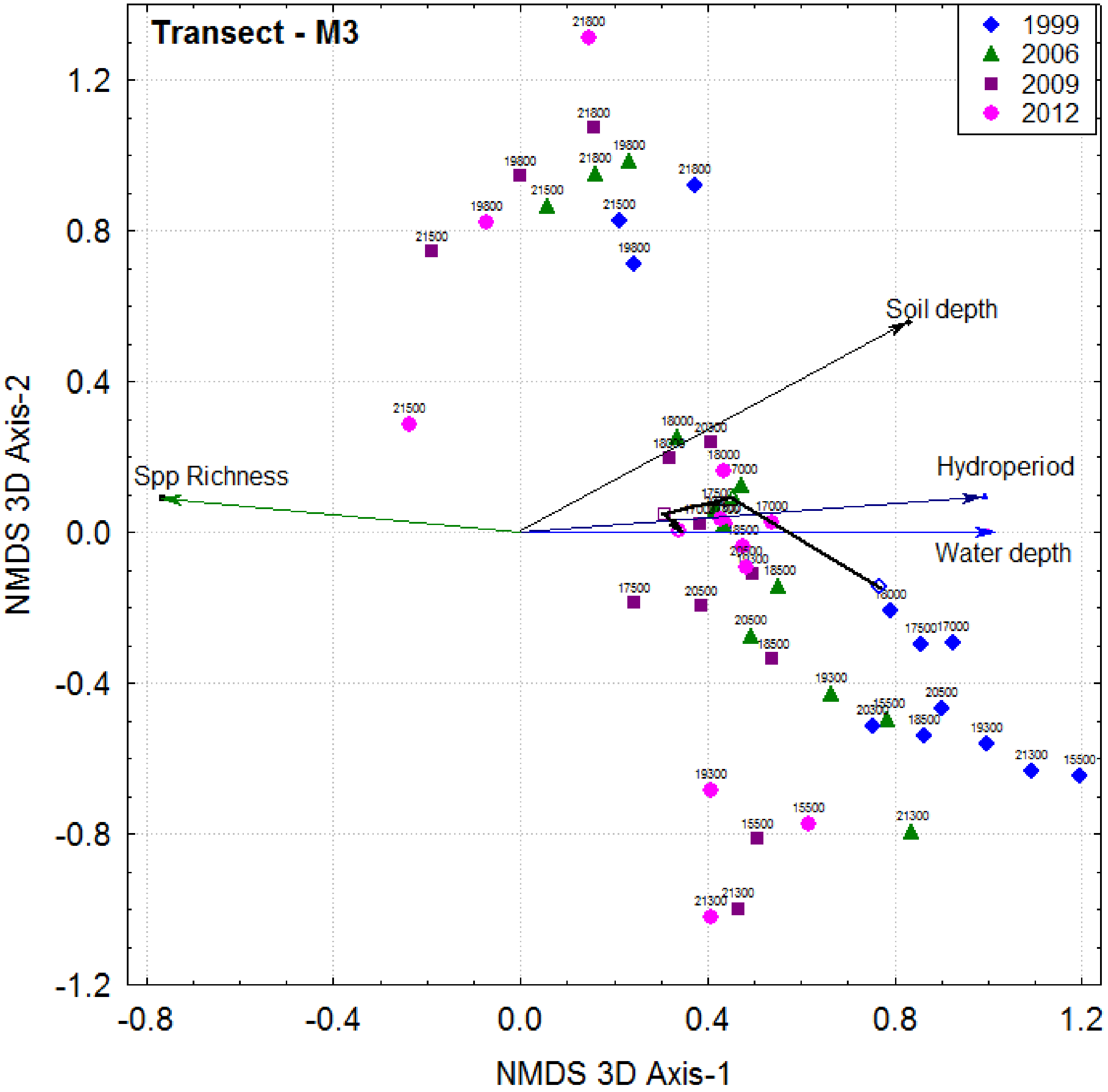

Figure 17: NMDS ordination bi-plots of site scores, the environmental vectors fitted in the ordination space, and the trajectory of centroid. The ordination is based on species abundance data collected four times between 1999 and 2012 in the Shark Slough portion of the Transect M3. Only the sites that showed significant (p≤0.1) rate of change in species composition along the hydrology gradient are shown. Initial point and the end of the trajectory represent the 1999 and 2012 sampling event, respectively.

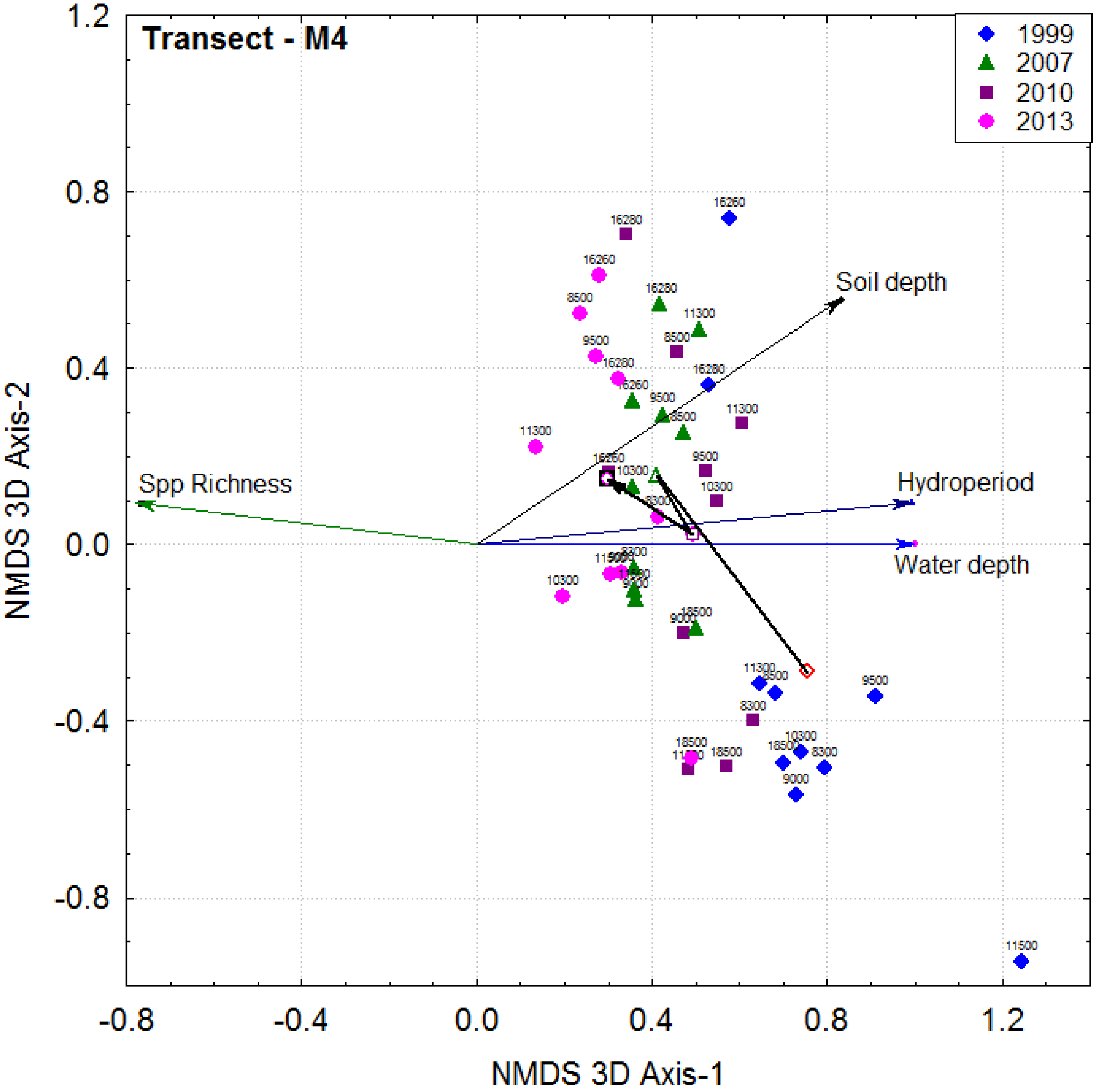

Figure 18: NMDS ordination bi-plots of site scores, the environmental vectors fitted in the ordination space, and the trajectory of centroid. The ordination is based on species abundance data collected three times between 1999 and 2013 in the Shark Slough portion of the Transect M4. Only the sites that showed significant ($p \leq 0.1$) rate of change in species composition along the hydrology gradient are shown. Initial point and the end of the trajectory represent the 1999 and 2013 sampling event, respectively.

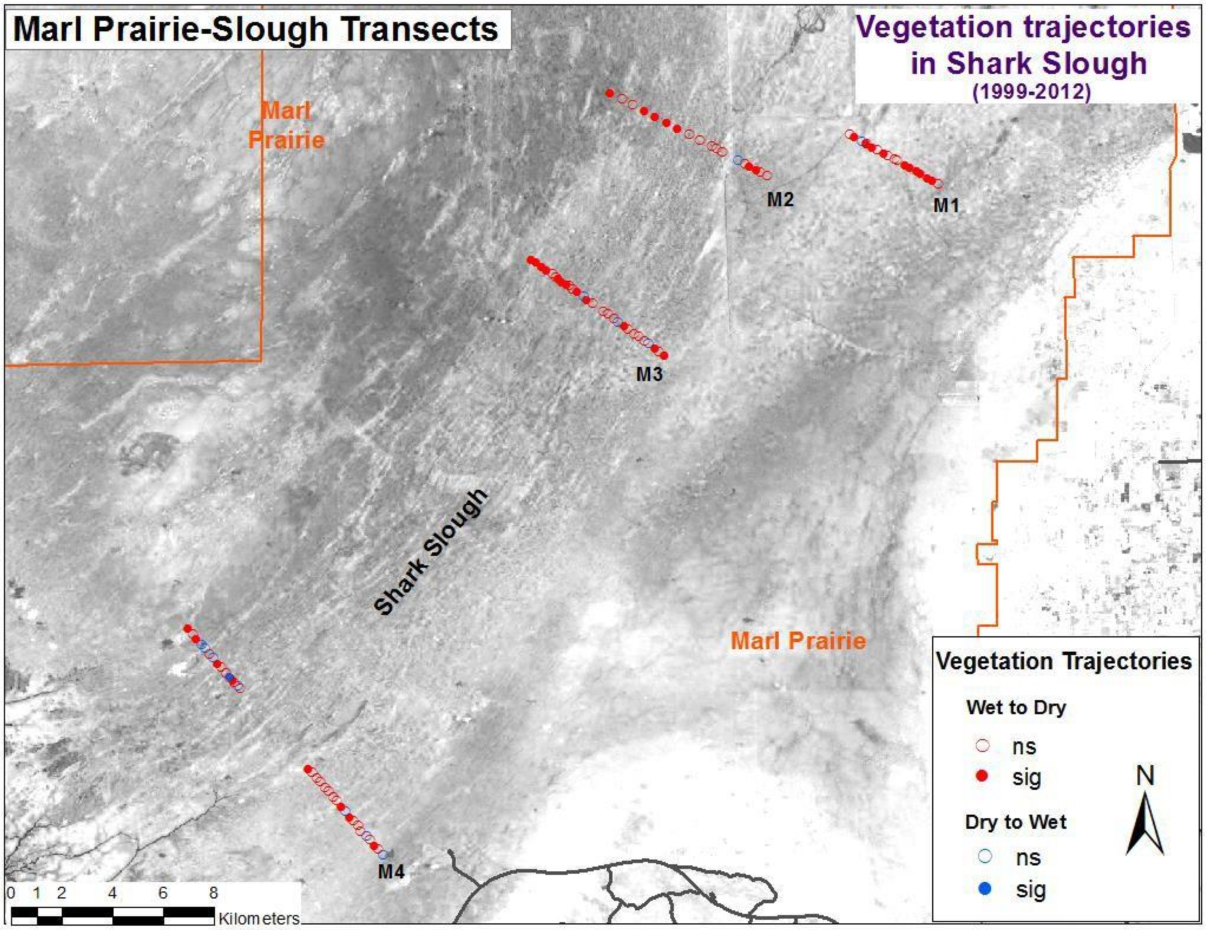

Figure 19: Sites in the Shark Slough portion of four transects showing the vegetation trajectory trend that was determined using trajectory analysis on vegetation data collected four times between 1999 and 2013. ns – not significant; sig = significant.

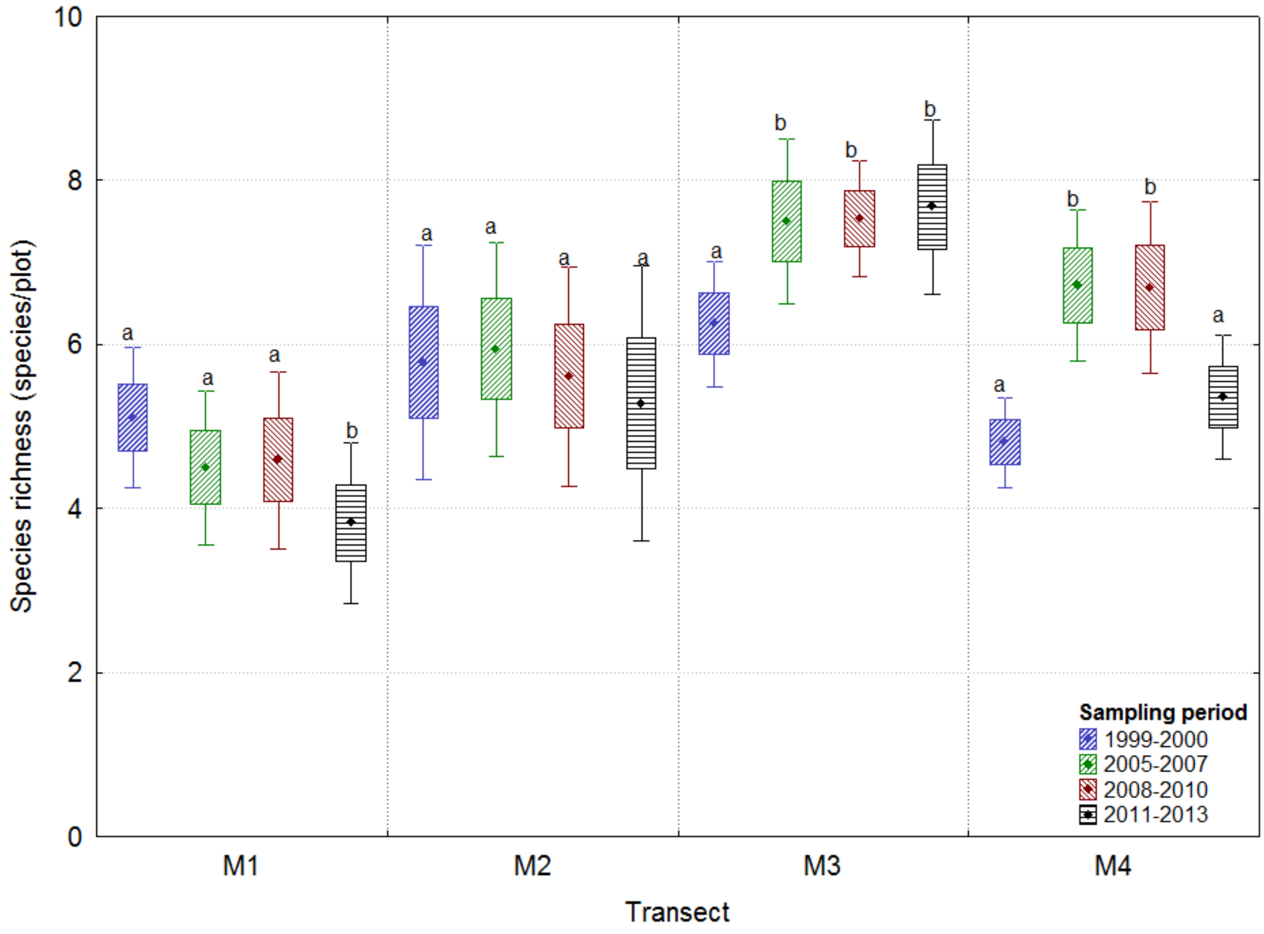

Figure 20: Box Plots showing species richness in Shark Slough portion of MAP transects sampled multiple times between 1999 and 2013. Different letters represent significant (pair-wise t-test; $p < 0.05$) difference in mean species richness among years on individual transects.

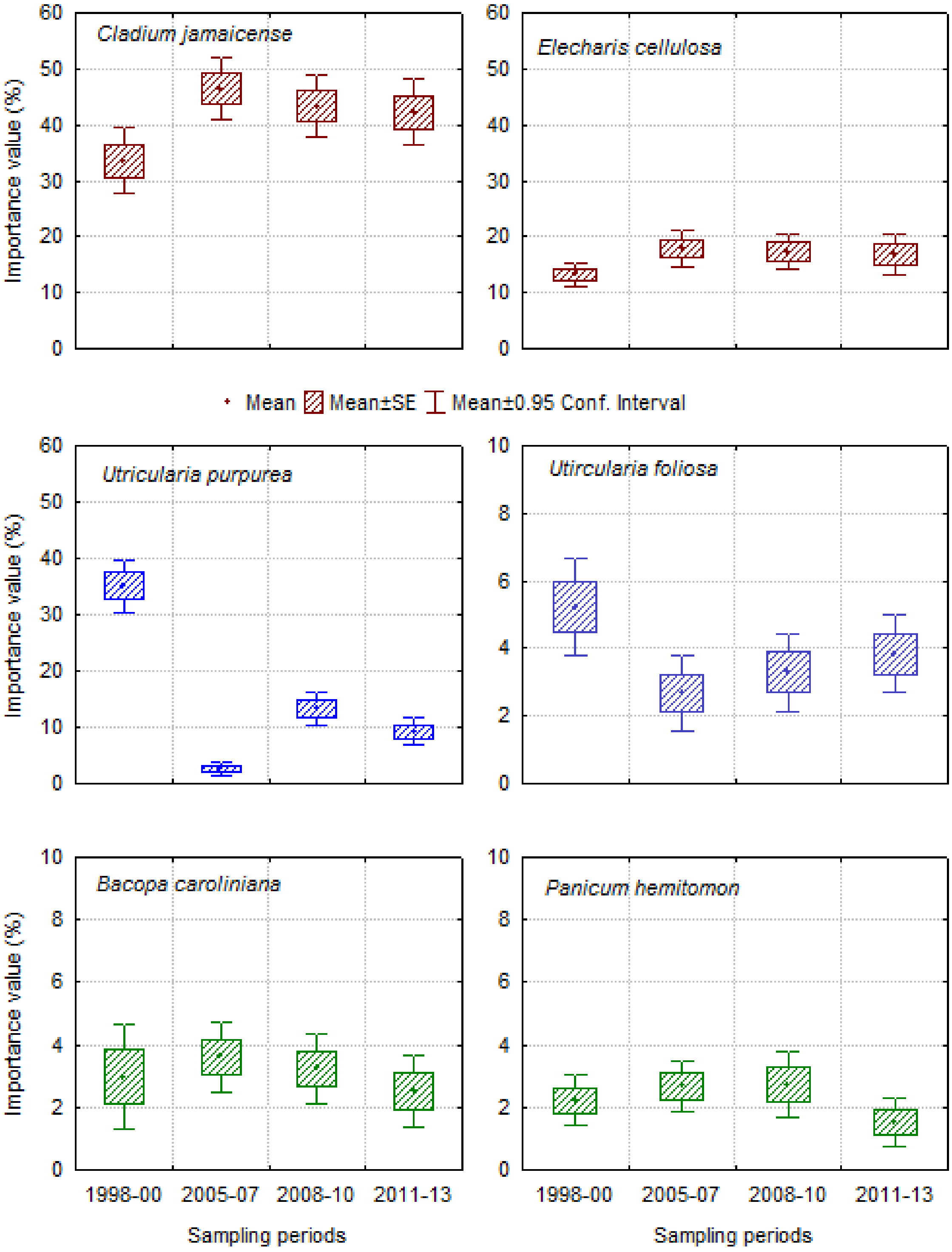

Figure 21: Box-plots of major species' importance value (IV) averaged across all transects for each sampling period.

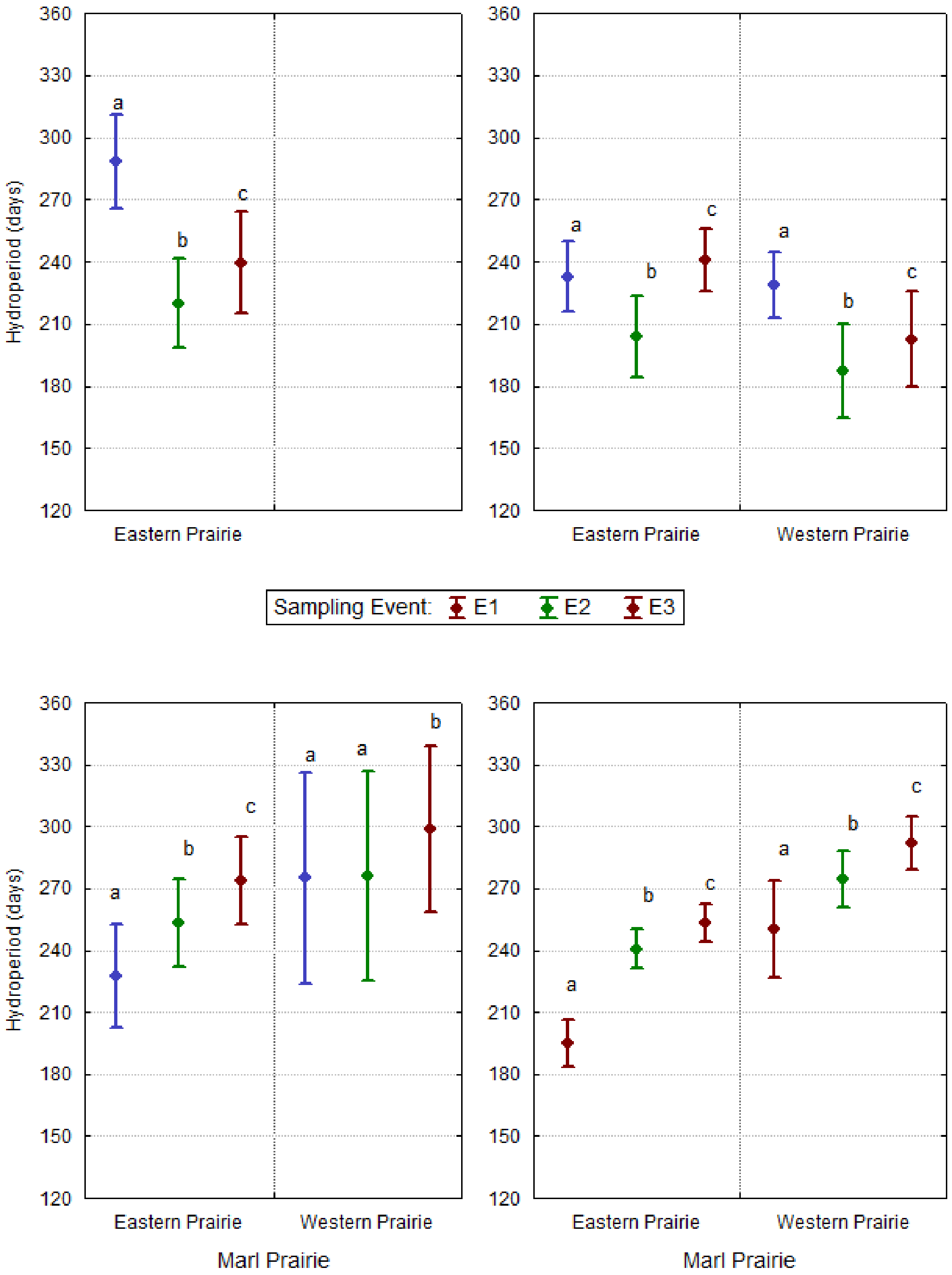

Figure 22: Mean (±95% CI) hydroperiod averaged over four years prior to vegetation sampling in the marl prairie portions of MAP transects sampled between 2005 and 2014. Transect M3 and M4 have marl prairies both sides (East & West) of Shark Slough, and Transect M5 has the sites on both sides of Park Road. Different letters represent significant (pair-wise t-test; $p < 0.05$) difference in hydroperiod between sampling period on individual transects.

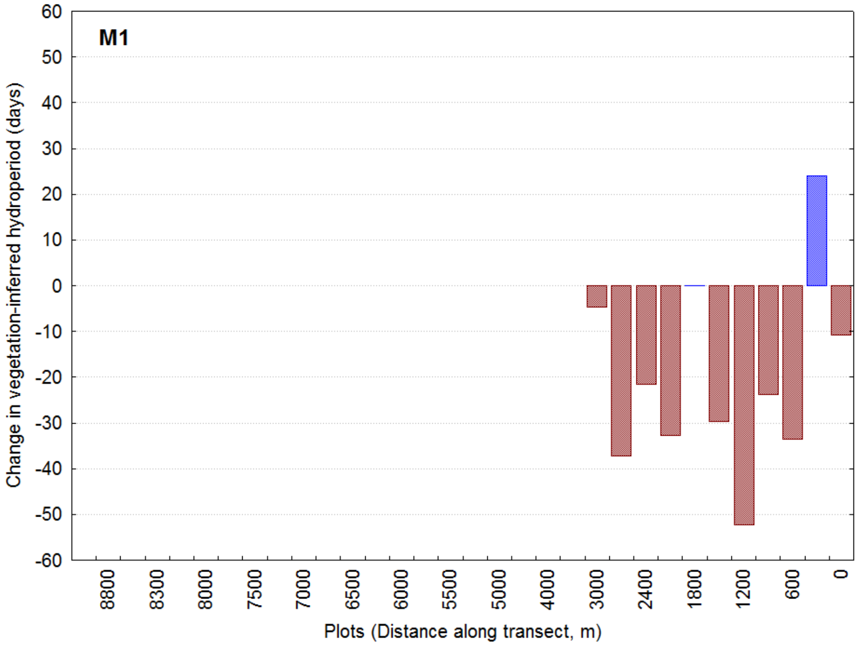

Figure 23: Change in vegetation-inferred hydroperiod between 1st sampling, E1 (2006) and the 3rd sampling, E3 (2012) at the vegetation monitoring plots on the marl prairie portion of the Transect M1.

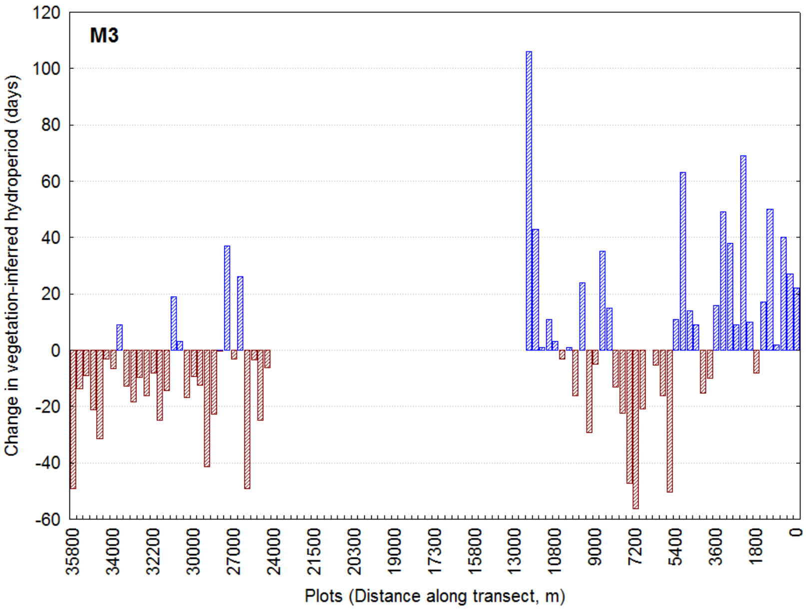

Figure 24: Change in vegetation-inferred hydroperiod between 1st sampling, E1 (2007) and the 3rd sampling, E3 (2013) at the vegetation monitoring plots on the marl prairie portion of the Transect M3.

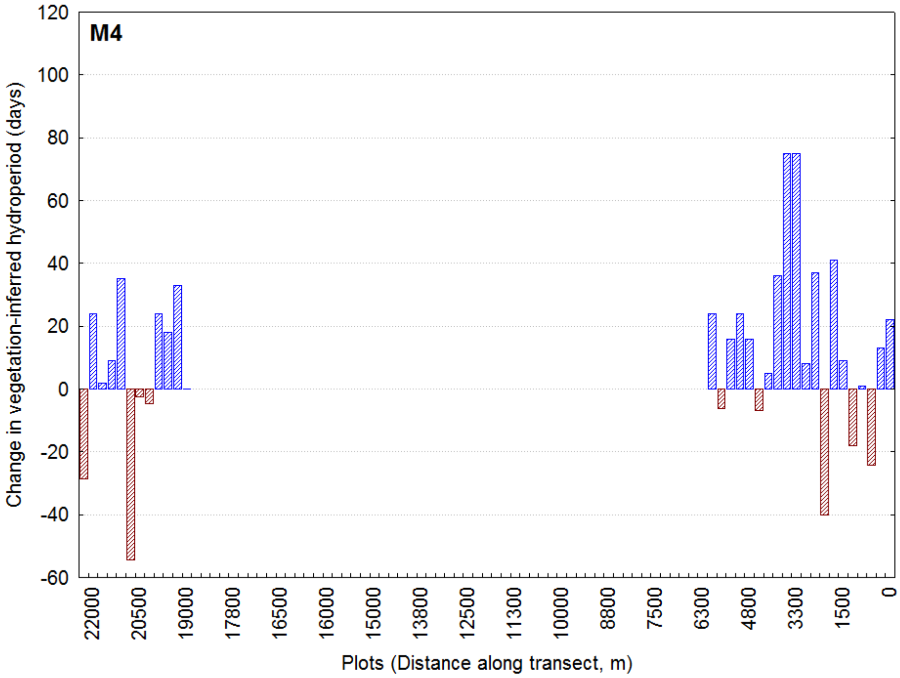

Figure 25: Change in vegetation-inferred hydroperiod between 1st sampling, E1 (2008) and the 3rd sampling, E3 (2014) at the vegetation monitoring plots on the marl prairie portion of the Transect M4.

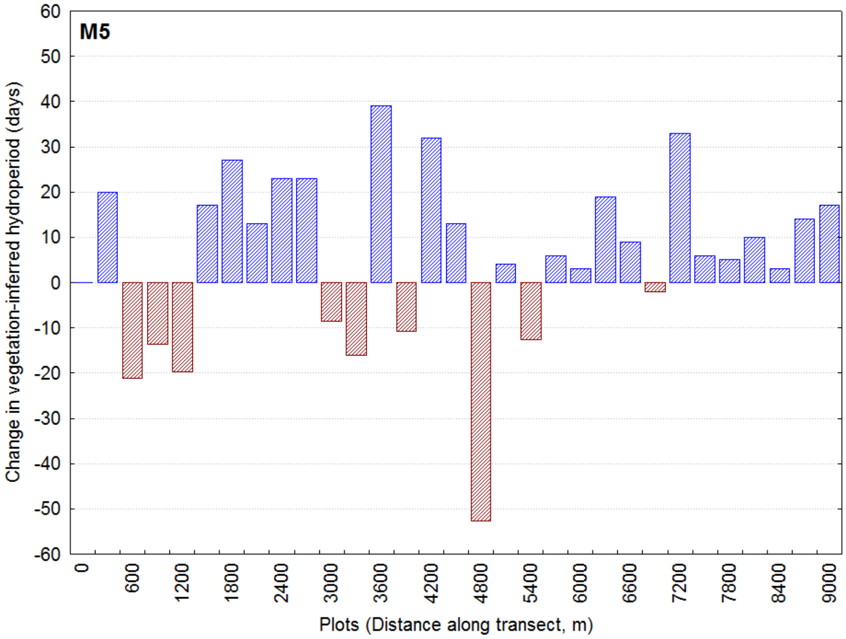

Figure 26: Change in vegetation-inferred hydroperiod between 1st sampling, E1 (2008) and the 3rd sampling, E3 (2014) at the vegetation monitoring plots on the marl prairie portion of the Transect M5.

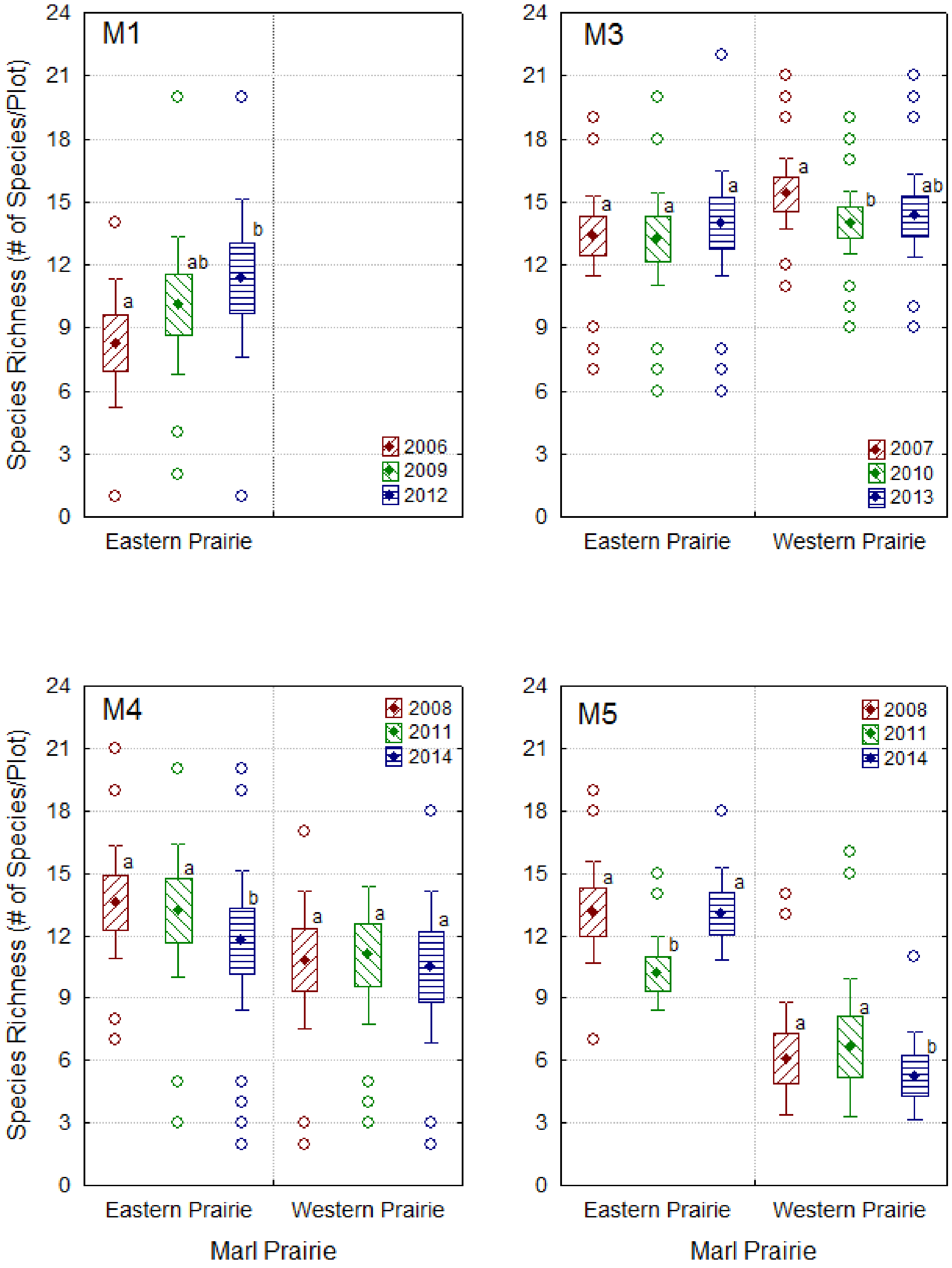

Figure 27: Box Plots showing mean (± SE, 95% CI, and outliers) species richness in marl prairie portion of MP-S gradient transects sampled three times between 2006 and 2014. Different letters represent significant (pair-wise t-test; $p < 0.05$) difference in mean species richness among years on individual transects.

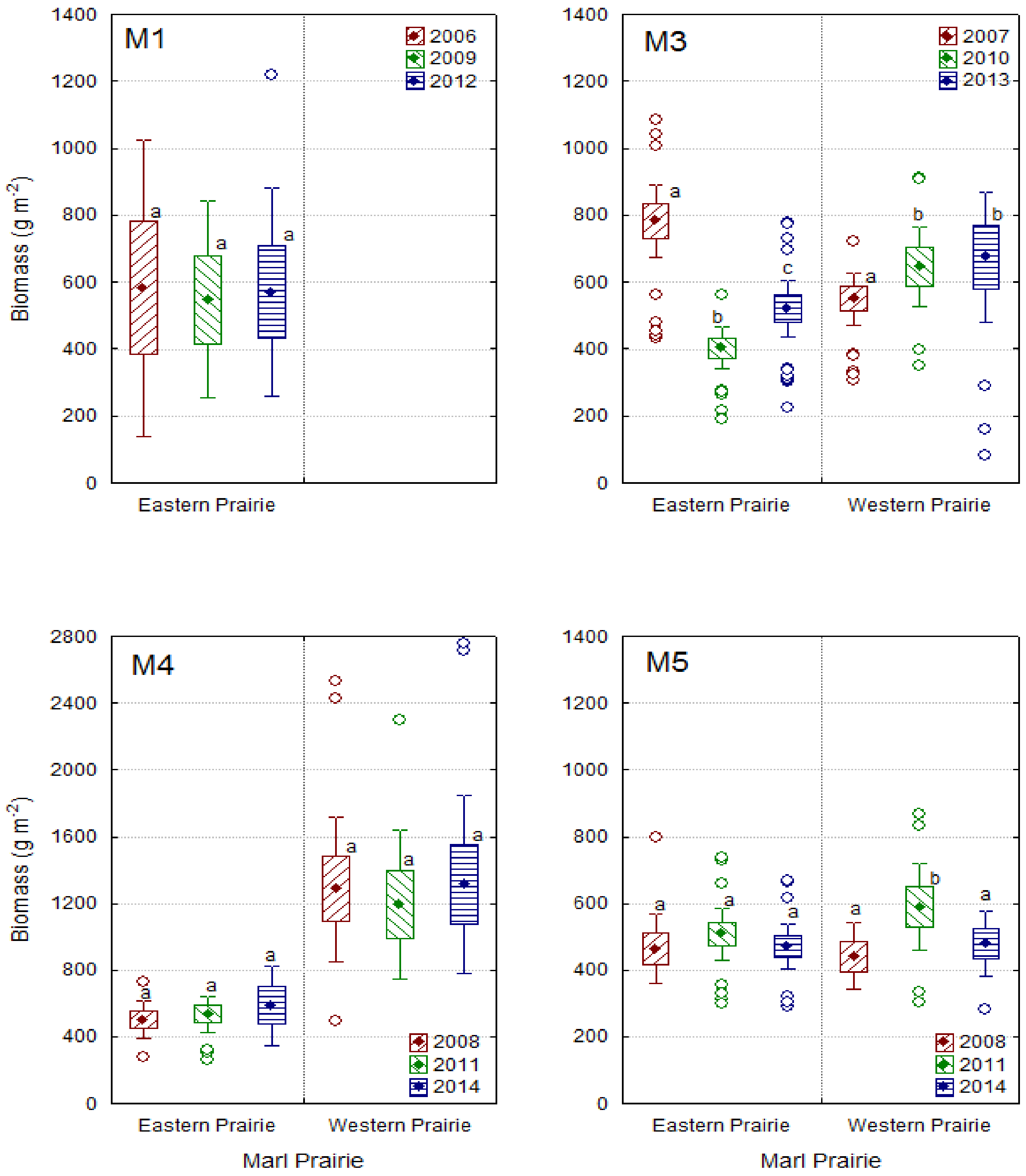

Figure 28: Box Plots showing mean (± SE, 95% CI, and outliers) above ground biomass in marl prairie portion of MP-S gradient transects sampled three times between 2006 and 2014. Different letters represent significant (pair-wise t-test; $p < 0.05$) difference in mean above ground biomass among sampling years on individual transects.

Appendices

Appendix 1: Vegetation types at the vegetation sampling sites on Transects M1-M5. Vegetation types at the sites that were surveyed along the five transects between 2005 and 2008 were identified using an hierarchical agglomerative cluster analysis with Bray-Curtis dissimilarity as distance measure and flexible beta as linkage method.

Site_ID	Transect	Plot	EASTNAD83	NORTHNAD83	Vegetation type
M1-00000	M1	0	545528	2837755	*Cladium* Wet Prairie
M1-00300	M1	300	545251	2837899	*Typha* Marsh
M1-00600	M1	600	545007	2838042	*Cladium-Eleocharis* Marsh
M1-00900	M1	900	544745	2838187	*Cladium* Wet Prairie
M1-01200	M1	1200	544482	2838330	Open Prairie
M1-01500	M1	1500	544220	2838476	*Cladium*-mixed Marsh
M1-01800	M1	1800	543954	2838617	*Cladium* Marsh
M1-02100	M1	2100	543691	2838766	*Cladium*-mixed Marsh
M1-02400	M1	2400	543428	2838908	*Eleocharis* Marsh
M1-02700	M1	2700	543164	2839051	*Eleocharis-Cladium* Marsh
M1-03000	M1	3000	542904	2839204	*Cladium*-mixed Marsh
M1-03500	M1	3500	542466	2839440	*Eleocharis* Marsh
M1-04000	M1	4000	542029	2839683	*Cladium* Marsh
M1-04500	M1	4500	541588	2839923	*Cladium* Marsh
M1-05000	M1	5000	541150	2840169	*Cladium* Marsh
M1-05300	M1	5300	540886	2840314	*Cladium-Eleocharis* Marsh
M1-05500	M1	5500	540711	2840411	*Eleocharis* Marsh
M1-05800	M1	5800	540448	2840557	*Eleocharis* Marsh
M1-06000	M1	6000	540274	2840652	*Cladium* Marsh
M1-06300	M1	6300	540011	2840798	*Eleocharis* Marsh
M1-06500	M1	6500	539836	2840894	*Eleocharis* Marsh
M1-06900	M1	6900	539487	2841088	*Cladium-Eleocharis* Marsh
M1-07000	M1	7000	539398	2841136	*Cladium* Marsh
M1-07300	M1	7300	539136	2841282	*Cladium* Marsh
M1-07500	M1	7500	538961	2841379	*Cladium-Eleocharis* Marsh
M1-07800	M1	7800	538699	2841524	*Cladium* Marsh
M1-08000	M1	8000	538523	2841620	*Cladium* Marsh
M1-08260	M1	8260	538297	2841747	*Cladium* Marsh
M1-08300	M1	8300	538262	2841767	*Cladium* Marsh
M1-08500	M1	8500	538087	2841863	*Cladium* Marsh
M1-08800	M1	8800	537824	2842008	*Cladium* Marsh
M1-09000	M1	9000	537647	2842105	*Cladium* Marsh
M2-00000	M2	0	537477	2838897	*Cladium* Marsh
M2-00500	M2	500	537030	2839126	*Eleocharis* Marsh

Site_ID	**Transect**	**Plot**	**EASTNAD83**	**NORTHNAD83**	**Vegetation type**
M2-01000	M2	1000	536584	2839356	*Cladium* Marsh
M2-01500	M2	1500	536142	2839586	*Cladium* Marsh
M2-02000	M2	2000	535705	2839782	Bayhead
M2-02500	M2	2500	535251	2840044	*Cladium-Eleocharis* Marsh
M2-03000	M2	3000	534806	2840275	*Cladium* Marsh
M2-03500	M2	3500	534362	2840506	*Eleocharis* Marsh
M2-03800	M2	3800	534096	2840643	*Cladium* Marsh
M2-04000	M2	4000	533918	2840738	*Cladium* Marsh
M2-04300	M2	4300	533651	2840876	*Nymphaea sp.* Marsh
M2-04500	M2	4500	533475	2840968	*Cladium* Marsh
M2-04800	M2	4800	533209	2841105	*Cladium* Marsh
M2-05000	M2	5000	533034	2841200	Open Marsh
M2-05500	M2	5500	532587	2841431	*Cladium-Eleocharis* Marsh
M2-05760	M2	5760	532358	2841552	*Cladium* Marsh
M2-06000	M2	6000	532144	2841662	*Cladium-Eleocharis* Marsh
M2-06500	M2	6500	531702	2841894	*Cladium* Marsh
M2-07000	M2	7000	531259	2842125	*Cladium* Marsh
M2-07500	M2	7500	530815	2842356	*Eleocharis* Marsh
M2-08000	M2	8000	530373	2842588	*Cladium-Eleocharis* Marsh
M2-08500	M2	8500	529929	2842820	*Eleocharis* Marsh
M2-09000	M2	9000	529485	2843050	*Eleocharis-Cladium* Marsh
M2-09500	M2	9500	529041	2843282	*Eleocharis-Cladium* Marsh
M2-10000	M2	10000	528599	2843515	*Cladium-Eleocharis* Marsh
M2-10500	M2	10500	528155	2843743	*Cladium-Eleocharis* Marsh
M3-00000	M3	0	542581	2825474	*Cladium* Wet Prairie
M3-00300	M3	300	542283	2825447	*Muhlenbergia* Wet Prairie
M3-00600	M3	600	541984	2825420	*Cladium* Wet Prairie
M3-00900	M3	900	541685	2825392	*Schizachyrium* Wet Prairie
M3-01200	M3	1200	541387	2825365	*Schizachyrium* Wet Prairie
M3-01500	M3	1500	541088	2825337	*Cladium* Wet Prairie
M3-01800	M3	1800	540789	2825310	*Cladium* Wet Prairie
M3-02100	M3	2100	540491	2825283	*Cladium* Wet Prairie
M3-02400	M3	2400	540192	2825256	*Muhlenbergia* Wet Prairie
M3-02700	M3	2700	539893	2825228	*Cladium* Wet Prairie
M3-03000	M3	3000	539594	2825201	*Schizachyrium* Wet Prairie
M3-03300	M3	3300	539295	2825173	*Cladium* Wet Prairie
M3-03600	M3	3600	539085	2825387	*Cladium-Eleocharis* Marsh
M3-03900	M3	3900	538875	2825601	*Cladium* Wet Prairie
M3-04200	M3	4200	538664	2825815	*Cladium*-mixed Marsh
M3-04500	M3	4500	538454	2826029	*Cladium*-mixed Marsh
M3-04800	M3	4800	538244	2826243	*Cladium* Wet Prairie
M3-05100	M3	5100	538034	2826457	*Cladium* Wet Prairie

Site_ID	**Transect**	**Plot**	**EASTNAD83**	**NORTHNAD83**	**Vegetation type**
M3-05400	M3	5400	537823	2826671	*Cladium* Wet Prairie
M3-05700	M3	5700	537613	2826885	*Cladium* Wet Prairie
M3-06000	M3	6000	537403	2827099	*Cladium* Wet Prairie
M3-06300	M3	6300	537192	2827313	*Cladium* Wet Prairie
M3-06600	M3	6600	536982	2827527	Bayhead
M3-06900	M3	6900	536772	2827741	Bayhead
M3-07200	M3	7200	536561	2827955	*Cladium*-mixed Marsh
M3-07500	M3	7500	536351	2828169	*Cladium*-mixed Marsh
M3-07800	M3	7800	536141	2828383	*Cladium*-mixed Marsh
M3-08100	M3	8100	535931	2828597	*Cladium*-mixed Marsh
M3-08400	M3	8400	535720	2828811	*Cladium*-mixed Marsh
M3-08700	M3	8700	535510	2829025	*Cladium* Marsh
M3-09000	M3	9000	535300	2829239	*Cladium*-mixed Marsh
M3-09300	M3	9300	535089	2829453	*Cladium*-mixed Marsh
M3-09600	M3	9600	534879	2829666	*Cladium* Marsh
M3-09900	M3	9900	534669	2829880	*Cladium*-mixed Marsh
M3-10200	M3	10200	534459	2830094	*Cladium-Eleocharis* Marsh
M3-10500	M3	10500	534248	2830308	*Cladium*-mixed Marsh
M3-10800	M3	10800	534038	2830522	*Cladium-Eleocharis* Marsh
M3-11100	M3	11100	533828	2830736	*Cladium*-mixed Marsh
M3-11400	M3	11400	533617	2830950	*Cladium*-mixed Marsh
M3-11700	M3	11700	533407	2831164	*Cladium-Eleocharis* Marsh
M3-12000	M3	12000	533197	2831378	*Cladium* Marsh
M3-12500	M3	12500	532785	2831661	*Cladium* Marsh
M3-13000	M3	13000	532372	2831944	*Cladium* Marsh
M3-13500	M3	13500	531960	2832227	*Cladium* Marsh
M3-14000	M3	14000	531548	2832510	*Cladium* Marsh
M3-14500	M3	14500	531136	2832793	*Cladium-Eleocharis* Marsh
M3-15000	M3	15000	530724	2833076	*Cladium-Eleocharis* Marsh
M3-15500	M3	15500	530301	2833366	*Nymphaea sp.* Marsh
M3-15800	M3	15800	530056	2833541	*Nymphaea sp.* Marsh
M3-16000	M3	16000	529896	2833659	*Cladium* Marsh
M3-16300	M3	16300	529653	2833834	*Cladium* Marsh
M3-16500	M3	16500	529490	2833952	*Cladium-Eleocharis* Marsh
M3-16800	M3	16800	529247	2834127	*Cladium* Marsh
M3-17000	M3	17000	529085	2834245	*Cladium* Marsh
M3-17300	M3	17300	528842	2834420	*Cladium* Marsh
M3-17500	M3	17500	528680	2834538	*Cladium-Eleocharis* Marsh
M3-17800	M3	17800	528437	2834713	*Nymphaea sp.* Marsh
M3-18000	M3	18000	528276	2834831	*Cladium* Marsh
M3-18300	M3	18300	528033	2835006	*Nymphaea sp.* Marsh
M3-18500	M3	18500	527870	2835124	*Cladium-Eleocharis* Marsh

Site_ID	Transect	Plot	EASTNAD83	NORTHNAD83	Vegetation type
M3-19000	M3	19000	527464	2835417	*Eleocharis* Marsh
M3-19300	M3	19300	527221	2835592	*Eleocharis-Cladium* Marsh
M3-19500	M3	19500	527060	2835710	*Eleocharis* Marsh
M3-19800	M3	19800	526816	2835885	*Cladium* Marsh
M3-20000	M3	20000	526654	2836003	*Eleocharis-Cladium* Marsh
M3-20200	M3	20200	526493	2836120	*Cladium* Marsh
M3-20300	M3	20300	526412	2836178	*Cladium-Eleocharis* Marsh
M3-20500	M3	20500	526249	2836296	*Cladium-Eleocharis* Marsh
M3-20700	M3	20700	526088	2836413	*Cladium* Marsh
M3-20800	M3	20800	526007	2836472	*Cladium-Eleocharis* Marsh
M3-21000	M3	21000	525845	2836589	*Eleocharis* Marsh
M3-21300	M3	21300	525601	2836765	*Eleocharis* Marsh
M3-21500	M3	21500	525440	2836882	*Cladium* Marsh
M3-21800	M3	21800	525197	2837058	*Cladium* Marsh
M3-22000	M3	22000	525035	2837175	*Cladium* Marsh
M3-22500	M3	22500	524630	2837469	*Eleocharis* Marsh
M3-23000	M3	23000	524225	2837762	*Eleocharis-Cladium* Marsh
M3-23500	M3	23500	523820	2838055	*Rhynchospora_Cladium* Marsh
M3-24000	M3	24000	523415	2838349	Bayhead
M3-24500	M3	24500	523010	2838642	*Cladium*-mixed Marsh
M3-25000	M3	25000	522605	2838935	*Cladium-Eleocharis* Marsh
M3-25500	M3	25500	522200	2839229	*Rhynchospora_Cladium* Marsh
M3-26000	M3	26000	521795	2839522	*Cladium*-mixed Marsh
M3-26500	M3	26500	521390	2839815	*Cladium*-mixed Marsh
M3-27000	M3	27000	520985	2840108	*Rhynchospora_Cladium* Marsh
M3-27500	M3	27500	520513	2840272	*Rhynchospora_Cladium* Marsh
M3-28000	M3	28000	520041	2840436	*Cladium*-mixed Marsh
M3-28500	M3	28500	519568	2840600	*Rhynchospora_Cladium* Marsh
M3-29000	M3	29000	519096	2840764	*Cladium* Wet Prairie
M3-29500	M3	29500	518624	2840928	*Cladium* Wet Prairie
M3-30000	M3	30000	518151	2841092	*Muhlenbergia* Wet Prairie
M3-30500	M3	30500	517679	2841256	*Cladium* Wet Prairie
M3-31000	M3	31000	517265	2841400	*Schizachyrium* Wet Prairie
M3-31300	M3	31300	516965	2841400	*Cladium* Wet Prairie
M3-31600	M3	31600	516665	2841400	*Schizachyrium* Wet Prairie
M3-31900	M3	31900	516365	2841400	*Cladium* Wet Prairie
M3-32200	M3	32200	516065	2841400	*Schizachyrium* Wet Prairie
M3-32500	M3	32500	515765	2841400	*Cladium* Wet Prairie
M3-32800	M3	32800	515465	2841400	*Cladium* Wet Prairie
M3-33100	M3	33100	515165	2841400	*Cladium* Wet Prairie
M3-33400	M3	33400	514865	2841400	*Cladium* Wet Prairie
M3-33700	M3	33700	514565	2841400	*Paspalum* Wet Prairie

Site_ID	**Transect**	**Plot**	**EASTNAD83**	**NORTHNAD83**	**Vegetation type**
M3-34000	M3	34000	514264	2841400	*Schoenus* Wet Prairie
M3-34300	M3	34300	513965	2841400	*Cladium* Wet Prairie
M3-34600	M3	34600	513665	2841400	*Rhynchospora_Cladium* Marsh
M3-34900	M3	34900	513365	2841400	*Cladium* Wet Prairie
M3-35200	M3	35200	513065	2841400	*Cladium* Wet Prairie
M3-35500	M3	35500	512765	2841400	*Cladium* Wet Prairie
M3-35800	M3	35800	512465	2841400	*Cladium* Wet Prairie
M4-00000	M4	0	523986	2808587	*Cladium* Wet Prairie
M4-00300	M4	300	523778	2808803	*Muhlenbergia* Wet Prairie
M4-00600	M4	600	523570	2809019	*Cladium* Wet Prairie
M4-00900	M4	900	523362	2809235	*Cladium* Wet Prairie
M4-01200	M4	1200	523153	2809450	*Cladium* Wet Prairie
M4-01500	M4	1500	522945	2809666	*Schizachyrium* Wet Prairie
M4-01800	M4	1800	522737	2809882	*Cladium* Wet Prairie
M4-02100	M4	2100	522529	2810098	*Schizachyrium* Wet Prairie
M4-02400	M4	2400	522320	2810314	*Cladium* Wet Prairie
M4-02700	M4	2700	522112	2810530	*Cladium* Wet Prairie
M4-03300	M4	3300	521695	2810962	*Cladium* Wet Prairie
M4-03600	M4	3600	521487	2811178	*Cladium* Marsh
M4-03900	M4	3900	521279	2811394	*Cladium* Marsh
M4-04200	M4	4200	521071	2811610	*Cladium-Eleocharis* Marsh
M4-04485	M4	4485	520870	2811817	*Cladium* Wet Prairie
M4-04800	M4	4800	520654	2812042	*Cladium-Eleocharis* Marsh
M4-05100	M4	5100	520446	2812258	*Cladium-Eleocharis* Marsh
M4-05400	M4	5400	520238	2812473	*Rhynchospora_Cladium* Marsh
M4-05700	M4	5700	520029	2812689	*Cladium*-mixed Marsh
M4-06000	M4	6000	519821	2812905	*Cladium-Eleocharis* Marsh
M4-06300	M4	6300	519613	2813121	*Rhynchospora_Cladium* Marsh
M4-06500	M4	6500	519474	2813265	*Cladium-Eleocharis* Marsh
M4-06800	M4	6800	519266	2813481	*Rhynchospora_Cladium* Marsh
M4-07000	M4	7000	519127	2813625	*Cladium-Eleocharis* Marsh
M4-07300	M4	7300	518932	2813850	*Cladium-Eleocharis* Marsh
M4-07500	M4	7500	518816	2814005	*Cladium* Marsh
M4-07800	M4	7800	518601	2814237	*Eleocharis-Cladium* Marsh
M4-08000	M4	8000	518470	2814380	*Eleocharis-Cladium* Marsh
M4-08300	M4	8300	518235	2814568	*Cladium-Eleocharis* Marsh
M4-08500	M4	8500	518146	2814763	*Cladium* Marsh
M4-08800	M4	8800	517951	2814986	*Cladium* Marsh
M4-09000	M4	9000	517827	2815131	*Cladium-Eleocharis* Marsh
M4-09300	M4	9300	517623	2815361	*Cladium* Marsh
M4-09500	M4	9500	517489	2815520	*Cladium* Marsh
M4-09800	M4	9800	517279	2815755	*Eleocharis* Marsh

Site_ID	Transect	Plot	EASTNAD83	NORTHNAD83	Vegetation type
M4-10000	M4	10000	517167	2815900	*Cladium* Marsh
M4-10300	M4	10300	516968	2816123	*Cladium-Eleocharis* Marsh
M4-10500	M4	10500	516842	2816276	*Cladium* Marsh
M4-10800	M4	10800	516647	2816503	*Cladium-Eleocharis* Marsh
M4-11000	M4	11000	516516	2816654	*Cladium-Eleocharis* Marsh
M4-11300	M4	11300	516328	2816887	*Cladium* Marsh
M4-11500	M4	11500	516190	2817032	*Cladium-Eleocharis* Marsh
M4-11800	M4	11800	515994	2817260	*Cladium* Marsh
M4-12000	M4	12000	515863	2817411	*Cladium* Marsh
M4-12300	M4	12300	515667	2817638	*Eleocharis* Marsh
M4-12500	M4	12500	515536	2817789	*Cladium-Eleocharis* Marsh
M4-12800	M4	12800	515340	2818017	*Cladium-Eleocharis* Marsh
M4-13000	M4	13000	515209	2818168	*Cladium-Eleocharis* Marsh
M4-13300	M4	13300	515013	2818395	*Cladium* Marsh
M4-13500	M4	13500	514883	2818546	*Cladium-Eleocharis* Marsh
M4-13800	M4	13800	514687	2818774	*Cladium* Marsh
M4-14000	M4	14000	514556	2818925	*Cladium* Marsh
M4-14300	M4	14300	514360	2819152	*Eleocharis* Marsh
M4-14500	M4	14500	514229	2819303	*Cladium* Marsh
M4-14800	M4	14800	514033	2819531	*Cladium-Eleocharis* Marsh
M4-15000	M4	15000	513903	2819682	*Eleocharis-Cladium* Marsh
M4-15300	M4	15300	513707	2819909	*Eleocharis* Marsh
M4-15500	M4	15500	513576	2820060	*Cladium-Eleocharis* Marsh
M4-15700	M4	15700	513450	2820219	*Cladium-Eleocharis* Marsh
M4-15800	M4	15800	513381	2820287	*Cladium-Eleocharis* Marsh
M4-16000	M4	16000	513248	2820444	*Eleocharis* Marsh
M4-16100	M4	16100	513189	2820519	*Cladium* Marsh
M4-16260	M4	16260	513076	2820636	*Cladium* Marsh
M4-16280	M4	16280	513063	2820651	*Cladium* Marsh
M4-16300	M4	16300	513049	2820666	*Cladium* Marsh
M4-16500	M4	16500	512922	2820822	*Rhynchospora_Cladium* Marsh
M4-16800	M4	16800	512725	2821052	*Cladium-Eleocharis* Marsh
M4-17000	M4	17000	512599	2821200	*Cladium* Marsh
M4-17300	M4	17300	512396	2821434	*Eleocharis* Marsh
M4-17500	M4	17500	512266	2821581	*Eleocharis-Cladium* Marsh
M4-17800	M4	17800	512082	2821805	*Cladium* Marsh
M4-18000	M4	18000	511949	2821956	*Cladium-Eleocharis* Marsh
M4-18300	M4	18300	511754	2822189	*Eleocharis-Cladium* Marsh
M4-18500	M4	18500	511618	2822337	*Cladium-Eleocharis* Marsh
M4-18800	M4	18800	511420	2822569	*Eleocharis-Cladium* Marsh
M4-19000	M4	19000	511410	2822766	*Cladium*-mixed Marsh
M4-19300	M4	19300	511198	2822978	*Cladium-Eleocharis* Marsh

Site_ID	**Transect**	**Plot**	**EASTNAD83**	**NORTHNAD83**	**Vegetation type**
M4-19600	M4	19600	510986	2823190	*Cladium*-mixed Marsh
M4-19900	M4	19900	510774	2823402	*Cladium*-mixed Marsh
M4-20200	M4	20200	510562	2823615	*Cladium* Marsh
M4-20500	M4	20500	510350	2823827	*Typha* Marsh
M4-20800	M4	20800	510138	2824039	*Cladium* Marsh
M4-21100	M4	21100	509926	2824251	*Cladium* Wet Prairie
M4-21400	M4	21400	509714	2824464	*Schizachyrium* Wet Prairie
M4-21700	M4	21700	509502	2824676	*Schizachyrium* Wet Prairie
M4-22000	M4	22000	509290	2824888	*Cladium* Marsh
M4-22300	M4	22300	509078	2825100	*Cladium* Marsh
M5-00000	M5	0	515992	2799188	*Rhizophora mangle* Mangrove
M5-00300	M5	300	516283	2799261	*Rhizophora mangle* Mangrove
M5-00600	M5	600	516575	2799333	*Rhizophora mangle* Mangrove
M5-00900	M5	900	516866	2799406	*Rhizophora mangle* Mangrove
M5-01200	M5	1200	517157	2799478	*Cladium* Marsh
M5-01500	M5	1500	517448	2799551	*Eleocharis-Cladium* Marsh
M5-01800	M5	1800	517740	2799623	*Eleocharis* Marsh
M5-02100	M5	2100	518031	2799696	*Cladium-Eleocharis* Marsh
M5-02400	M5	2400	518322	2799768	*Cladium-Eleocharis* Marsh
M5-02700	M5	2700	518613	2799841	*Eleocharis-Cladium* Marsh
M5-03000	M5	3000	518905	2799914	*Cladium-Eleocharis* Marsh
M5-03300	M5	3300	519196	2799986	*Cladium-Eleocharis* Marsh
M5-03600	M5	3600	519487	2800059	*Cladium* Wet Prairie
M5-03900	M5	3900	519778	2800131	*Cladium* Wet Prairie
M5-04200	M5	4200	520070	2800204	*Cladium* Wet Prairie
M5-04500	M5	4500	520361	2800276	*Cladium* Marsh
M5-04800	M5	4800	520652	2800349	*Rhynchospora_Cladium* Marsh
M5-05100	M5	5100	520943	2800421	*Cladium* Wet Prairie
M5-05400	M5	5400	521237	2800493	*Cladium* Wet Prairie
M5-05700	M5	5700	521526	2800564	*Cladium* Wet Prairie
M5-06000	M5	6000	521817	2800635	*Cladium* Wet Prairie
M5-06300	M5	6300	522111	2800706	*Cladium* Wet Prairie
M5-06600	M5	6600	522403	2800775	*Cladium* Wet Prairie
M5-06900	M5	6900	522693	2800848	*Muhlenbergia* Wet Prairie
M5-07200	M5	7200	522983	2800919	*Cladium*-mixed Marsh
M5-07500	M5	7500	523274	2800991	*Cladium* Wet Prairie
M5-07800	M5	7800	523567	2801064	*Schizachyrium* Wet Prairie
M5-08100	M5	8100	523858	2801134	*Cladium* Wet Prairie
M5-08400	M5	8400	524150	2801206	*Schizachyrium* Wet Prairie
M5-08700	M5	8700	524441	2801277	*Cladium* Wet Prairie
M5-09000	M5	9000	524733	2801349	*Muhlenbergia* Wet Prairie

Appendix 2: Results (delta and slope values) of trajectory analysis for sites on Shark Slough portions of transects M1, M2, M3 and M4 along hydroperiod vector for 1999-2012 period. N1 and N2 are the number of sampling years during Shark Slough transect and Marl prairie-Slough gradient study, respectively. P-values <0.1 are in bold.

Shark Slough Transect -ID	MAP Transect	Plot	N1	N2	Delta	p-value	Slope	p-value
T1_0	M1	5000	1	3	-0.718	0.867	-0.063	0.889
T1_300	M1	5300	1	2	-1.142	**0.996**	-0.101	**0.971**
T1_500	M1	5500	1	3	-1.414	**0.967**	-0.108	**0.960**
T1_800	M1	5800	1	2	-1.492	**1.000**	-0.124	**1.000**
T1_1000	M1	6000	1	3	-0.669	0.842	-0.065	0.889
T1_1300	M1	6300	1	3	-0.531	0.853	-0.044	0.863
T1_1500	M1	6500	1	3	-1.213	**0.952**	-0.134	**0.991**
T1_1900	M1	6900	1	3	-0.608	0.888	-0.050	0.882
T1_2000	M1	7000	1	3	-0.233	0.797	-0.022	0.847
T1_2300	M1	7300	1	3	0.079	0.420	0.006	0.411
T1_2500	M1	7500	1	3	-0.816	**0.987**	-0.070	**0.991**
T1_2800	M1	7800	1	3	-0.322	**0.933**	-0.027	**0.938**
T1_3000	M1	8000	1	3	-1.298	**0.986**	-0.118	**0.991**
T1_3260	M1	8260	1	3	0.221	0.301	0.020	0.306
T1_3300	M1	8300	1	3	-0.298	0.756	-0.026	0.768
T1_3500	M1	8500	1	3	0.154	0.178	0.012	0.180
T1_3800	M1	8800	1	3	-0.230	0.788	-0.020	0.804
T1_4000	M1	9000	1	3	-0.835	**0.977**	-0.060	**0.948**
T2_0	M2	3500	1	3	-0.710	0.856	-0.067	0.886
T2_300	M2	3800	1	3	-0.322	0.764	-0.031	0.769
T2_500	M2	4000	1	3	-0.825	**0.918**	-0.072	**0.917**
T2_800	M2	4300	1	3	-0.498	0.865	-0.048	0.890
T2_1000	M2	4500	1	3	-0.296	0.784	-0.031	0.804
T2_1300	M2	4800	1	3	0.212	0.311	0.023	0.272
T2_2000	M2	5500	1	3	-1.132	**0.998**	-0.083	**0.988**
T2_2260	M2	5760	1	3	-0.015	0.556	-0.001	0.520
T2_2500	M2	6000	1	3	-0.680	0.871	-0.046	0.801
T2_3000	M2	6500	1	3	-0.051	0.562	-0.001	0.513
T2_3500	M2	7000	1	3	-0.487	0.845	-0.020	0.694
T2_4000	M2	7500	1	3	-1.160	**1.000**	-0.084	**0.993**
T2_4500	M2	8000	1	3	-0.352	0.818	-0.033	0.841
T2_5000	M2	8500	1	3	-0.658	**0.988**	-0.048	**0.963**
T2_5500	M2	9000	1	3	-0.881	**0.953**	-0.074	**0.951**
T2_6000	M2	9500	1	3	-0.347	0.789	-0.026	0.748
T2_6500	M2	10000	1	3	-0.266	**0.996**	-0.025	**0.995**
T2_7000	M2	10500	1	3	-0.110	0.869	-0.006	0.761
T3_0	M3	15500	1	3	-0.768	**0.969**	-0.079	**0.996**
T3_300	M3	15800	1	3	-0.257	0.740	0.011	0.331
T3_500	M3	16000	1	3	-0.754	**0.942**	-0.062	**0.963**

Shark Slough Transect -ID	**MAP Transect**	**Plot**	**N1**	**N2**	**Delta**	**p-value**	**Slope**	**p-value**
T3_800	M3	16300	1	3	-0.143	0.664	-0.003	0.530
T3_1000	M3	16500	1	3	-0.261	0.789	-0.032	**0.905**
T3_1300	M3	16800	1	3	-0.224	0.673	-0.007	0.571
T3_1500	M3	17000	1	3	-0.430	0.822	-0.040	0.846
T3_1800	M3	17300	1	3	-0.421	0.756	-0.041	0.789
T3_2000	M3	17500	1	3	-0.635	**0.928**	-0.056	**0.940**
T3_2300	M3	17800	1	3	0.190	0.318	0.033	0.156
T3_2500	M3	18000	1	3	-0.461	0.849	-0.039	0.871
T3_2800	M3	18300	1	3	-0.170	0.740	-0.002	0.534
T3_3000	M3	18500	1	3	-0.571	**0.903**	-0.030	0.813
T3_3500	M3	19000	1	3	0.128	0.371	-0.011	0.723
T3_3800	M3	19300	1	3	-0.550	**0.904**	-0.034	0.871
T3_4000	M3	19500	1	3	0.239	0.279	0.025	0.235
T3_4300	M3	19800	1	3	-0.400	0.880	-0.029	**0.901**
T3_4500	M3	20000	1	3	-0.482	0.845	-0.045	**0.909**
T3_4700	M3	20200	1	3	0.340	0.221	0.010	0.396
T3_4800	M3	20300	1	3	-0.617	**0.975**	-0.053	**0.987**
T3_5000	M3	20500	1	3	-0.565	**0.924**	-0.049	**0.958**
T3_5200	M3	20700	1	3	-0.298	**0.971**	-0.019	**0.948**
T3_5300	M3	20800	1	3	0.316	0.185	0.003	0.452
T3_5500	M3	21000	1	3	0.007	0.508	-0.013	0.626
T3_5800	M3	21300	1	3	-0.290	0.706	-0.038	0.846
T3_6000	M3	21500	1	3	-0.634	**0.954**	-0.052	**0.970**
T3_6300	M3	21800	1	3	-0.636	**0.999**	-0.047	**0.997**
T3_6500	M3	22000	1	3	-0.221	0.642	-0.018	0.682
T5_0	M4	7000	1	3	0.258	0.273	0.023	0.189
T5_300	M4	7300	1	3	-0.157	0.640	-0.011	0.649
T5_500	M4	7500	1	3	-0.530	**0.970**	-0.041	**0.991**
T5_800	M4	7800	1	3	-0.247	0.668	-0.022	0.728
T5_1000	M4	8000	1	3	0.288	0.219	0.027	0.123
T5_1300	M4	8300	1	3	-0.587	**0.978**	-0.035	**0.958**
T5_1500	M4	8500	1	3	-0.559	0.832	-0.041	0.844
T5_1800	M4	8800	1	3	0.017	0.475	-0.003	0.550
T5_2000	M4	9000	1	3	-0.540	**0.943**	-0.039	**0.950**
T5_2300	M4	9300	1	3	-0.054	0.533	-0.002	0.495
T5_2500	M4	9500	1	3	-1.361	**0.998**	-0.099	**1.000**
T5_2800	M4	9800	1	3	0.387	0.211	0.025	0.224
T5_3000	M4	10000	1	3	0.238	0.163	0.015	0.182
T5_3300	M4	10300	1	3	-0.558	0.885	-0.039	0.876
T5_3500	M4	10500	1	3	-0.004	0.515	0.001	0.525
T5_3800	M4	10800	1	3	-0.258	0.719	-0.022	0.744
T5_4000	M4	11000	1	3	-0.319	0.786	-0.024	0.795

Shark Slough Transect -ID	**MAP Transect**	**Plot**	**N1**	**N2**	**Delta**	**p-value**	**Slope**	**p-value**
T5_4300	M4	11300	1	3	-0.515	0.842	-0.029	0.820
T5_4500	M4	11500	1	3	-0.943	**0.924**	-0.065	**0.904**
T5_8700	M4	15700	1	3	-0.438	0.677	-0.025	0.652
T5_8800	M4	15800	1	3	0.711	**0.081**	0.065	**0.017**
T5_9000	M4	16000	1	3	0.065	0.439	0.003	0.460
T5_9100	M4	16100	1	3	0.096	0.375	0.003	0.492
T5_9260	M4	16260	1	3	-0.166	0.664	-0.011	0.666
T5_9280	M4	16280	1	3	0.125	0.311	0.005	0.377
T5_9300	M4	16300	1	3	0.253	0.249	0.025	0.155
T5_9500	M4	16500	1	3	1.174	0.267	0.063	0.318
T5_9800	M4	16800	1	3	-0.705	**0.956**	-0.051	**0.966**
T5_10000	M4	17000	1	3	-0.698	**0.960**	-0.051	**0.985**
T5_10300	M4	17300	1	3	1.160	**0.011**	0.074	**0.009**
T5_10500	M4	17500	1	3	-0.084	0.586	-0.011	0.673
T5_10800	M4	17800	1	3	0.243	0.240	0.012	0.312
T5_11000	M4	18000	1	3	0.228	0.344	0.024	0.237
T5_11300	M4	18300	1	3	-0.335	**0.906**	-0.027	**0.937**
T5_11500	M4	18500	1	3	-0.364	**0.965**	-0.022	**0.950**
T5_11800	M4	18800	1	3	-0.292	**0.904**	-0.026	**0.953**

Appendix 3: Importance value index (IV) of species present at the Shark Slough sites that were first sampled in 1998-2000, and then multiple times between 2005 and 2013

Species	**M1**				**M2**				**M3**				**M4**			
	1999	**2005**	**2008**	**2011**	**1999**	**2005**	**2008**	**2011**	**1999**	**2006**	**2009**	**2012**	**1999**	**2007**	**2010**	**2013**
Acrostichum danaeifolium							0.67	0.83								
Aeschynomene pratensis		0.16	0.36	0.39	0.19	0.41	0.40	0.22		0.34	0.57	0.48		0.67	0.37	0.13
Annona glabra								0.32		0.26	1.00	0.19		0.18	0.22	
Bacopa caroliniana	0.48	4.92	3.19	4.91	2.62	2.49	2.33	0.95	1.74	3.64	3.67	1.74	5.37	3.52	3.42	2.79
Blechnum serrulatum					0.79	0.66	0.86	0.62	0.33	0.24	0.13	0.25	0.54		0.89	
Boehmeria cylindrica								0.56								
Cephalanthus occidentalis					0.99	1.29	0.35	1.13	0.60	0.96	1.27	2.18	0.32	0.26	0.28	0.17
Chrysobalanus icaco							0.36	0.13	0.12							
Cladium mariscus ssp. *jamaicense*	33.12	52.89	59.99	62.38	37.17	49.48	47.87	61.22	27.82	4.85	39.79	31.94	36.63	45.91	35.87	31.2
Crinum americanum	2.72	1.90	2.46	1.43	2.37	1.89	2.85	2.78	1.53	1.40	0.97	1.76	0.46	0.51	0.52	0.89
Cynanchum							0.18									
Cyperus haspan												0.18			0.30	
Eleocharis cellulosa	11.79	11.85	15.56	14.78	15.91	24.80	15.79	17.46	1.19	14.25	2.62	17.64	14.96	2.47	16.66	16.8
Eleocharis elongata															1.97	
Fuirena breviseta										0.18				0.16	0.57	0.28
Funastrum clausum							0.18	1.18		0.15	0.64					
Hydrolea corymbosa	0.37															
Hymenocallis latifolia	0.49				0.49				0.27				0.20			
Hymenocallis palmeri		0.27				0.93	0.28	0.56				0.22		0.21	0.95	0.14
Hyptis alata										0.71						
Ipomoea sagittata								0.98	0.37	0.45	0.64	0.82	0.29		0.46	0.28
Iva microcephala			0.58													
Justicia angusta	0.79	0.57	0.96	0.94	1.21	2.18	3.12	2.26	1.53	3.72	3.46	4.53	1.28	1.15	1.13	0.29
Leersia hexandra			0.54		0.72	0.14	0.13			0.34	0.34	0.28		0.77	0.27	0.69
Ludwigia alata						0.99			0.33	0.33		0.19				
Ludwigia curtissii										0.37						

Species	**M1**				**M2**				**M3**				**M4**			
	1999	**2005**	**2008**	**2011**	**1999**	**2005**	**2008**	**2011**	**1999**	**2006**	**2009**	**2012**	**1999**	**2007**	**2010**	**2013**
Ludwigia microcarpa								0.18			0.22					
Ludwigia repens			0.78				0.18							0.15	0.39	
Magnolia virginiana									0.97	0.87		0.17				
Melaleuca quinquenervia	0.65	0.76	0.16	0.14												
Metastelma blodgettii					0.23											
Mitreola petiolata											0.22					
Morella cerifera				0.63				0.54								
Nymphaea odorata	1.88	0.86	0.57	0.92	0.57	2.11	1.66	0.75	2.83	3.63	6.29	3.77		0.36	0.84	0.28
Nymphoides aquatica				0.19			0.16		0.35	0.79	2.86	0.39	0.12	0.16	0.89	0.14
Oxypolis filiformis								0.22						0.37		
Panicum hemitomon	3.64	2.59	1.91	2.76	1.70	2.48	0.74	1.38	3.64	4.12	6.26	3.19	0.66	1.80	1.37	0.19
Panicum tenerum			0.32			0.16		0.25								
Panicum virgatum			0.58					0.25								
Paspalidium geminatum	1.24	1.95	0.94	0.86	0.66	0.31	0.13	0.18	1.66	0.68	1.26	1.39	1.36	0.56	0.49	0.84
Peltandra virginica	0.47	0.74	0.56	0.44	0.32	1.68	0.91	0.19	1.17	1.27	1.74	0.66	1.40	1.25	0.54	0.15
Persea borbonia								0.13		0.37	0.14					
Pluchea rosea								0.19			0.12	0.21				
Polygonum hydropiperoides				0.25				0.79				0.94				
Pontederia cordata		1.91	2.22		0.48	0.56	0.74	0.36	0.33	0.37	0.85		0.24	1.86	2.75	0.72
Potamogeton illinoensis													0.12	0.35	0.67	0.28
Proserpinaca palustris											0.27		0.12			
Rhynchospora inundata			0.25							0.16	0.75	0.26		1.14	1.26	0.56
Rhynchospora microcarpa		0.48					0.13			0.29	0.54	0.34				
Rhynchospora miliacea			0.58													
Rhynchospora tracyi		1.54	4.32	6.47	0.75	0.12	0.57	1.18	0.17	0.30	0.74	0.78	0.22	3.37	1.32	
Sagittaria lancifolia	0.59	1.24	2.30	0.75	0.23	0.81	1.33	1.62	0.22	0.75	1.17	0.87	0.14	0.54	0.33	0.32
Salix caroliniana											0.62	0.19	0.36			
Schoenoplectus tabernaemontani														0.50		

Species	**M1**				**M2**				**M3**				**M4**			
	1999	**2005**	**2008**	**2011**	**1999**	**2005**	**2008**	**2011**	**1999**	**2006**	**2009**	**2012**	**1999**	**2007**	**2010**	**2013**
Thelypteris interrupta								0.67								
Typha domingensis								0.59		0.37	0.61	0.76		0.78	1.43	2.94
Utricularia cornuta	0.47													0.14		
Utricularia foliosa	5.82	2.74		0.62	4.56	0.80	1.52	0.37	5.38	2.70	1.98	7.46	5.17	3.63	6.79	4.26
Utricularia gibba										0.33				0.11		
Utricularia purpurea	37.37	13.34	4.15	3.55	29.67	7.34	16.69	1.43	41.98	19.12	4.60	18.36	31.26	1.69	22.42	8.77

Appendix 4a: Importance value index (IV) of species present at the marl prairie sites of Transect M1 and M3 that were sampled three times between 2005 and 2013.

Species	M1			M3					
				M3E			M3W		
	2006	2009	2012	2007	2010	2013	2007	2010	2013
Aeschynomene pratensis	0.81	1.52	0.06		0.01		0.79	0.56	0.09
Agalinis linifolia		0.46			0.20	0.02	0.15	0.07	0.11
Agalinis sp.						0.00			
Aletris bracteata					0.02	0.01			
Andropogon glomeratus var. *glomeratus*				0.01					
Andropogon virginicus	0.69	1.05	2.43	0.02	0.46	0.37	0.34	0.46	0.02
Anemia adiantifolia				0.11					
Angadenia berteroi				0.10	0.05	0.00			
Annona glabra	0.42		0.18	0.08	0.06	0.06	3.58	1.96	0.60
Ardisia escallonioides					0.01	0.00			
Aristida purpurascens			0.38	0.04	0.95	0.74	0.02	0.13	0.56
Aristida stricta				0.02					
Asclepias lanceolata				0.16	0.07	0.00	0.03	0.16	0.08
Asclepias longifolia									0.04
Symphyotrichum bracei							0.33		
Symphyotrichum dumosum				0.01	0.08	0.02	0.64	2.23	0.32
Symphyotrichum subulatum				0.92					
Symphyotrichum tenuifolium	1.75	1.17	3.09		4.99	0.66	0.06	2.54	0.59
Aster sp.				0.08					
Bacopa caroliniana	3.94	1.14	1.50	2.27	1.95	0.95	4.64	4.43	1.37
Baccharis halimifolia		0.04		0.11		0.08			
Bacopa monnieri							0.04	0.48	
Blechnum serrulatum				0.59	0.10	0.30			
Buchnera americana				0.01					
Capraria biflora						0.00			
Cassytha filiformis				0.70	0.29	0.05	3.81	0.59	0.71
Centella asiatica	2.77	3.00	3.56	3.27	0.70	0.40	3.04	4.64	2.49
Cephalanthus occidentalis						0.00	0.01		0.00
Chiococca parvifolia				0.04					
Cirsium horridulum					0.05	0.00			
Cladium mariscus ssp. *jamaicense*	40.94	41.35	37.42	47.57	38.03	22.79	20.38	22.39	24.44
Coelorachis rugosa								0.01	
Conoclinium coelestinum					0.42				
Crinum americanum		0.31	0.54				1.72	1.03	0.53
Cyperus haspan			0.06	0.01	0.14	0.01			
Cyperus sp.					0.08				
Dichanthelium aciculare			0.04			0.03			

Species	M1			M3					
				M3E			M3W		
	2006	2009	2012	2007	2010	2013	2007	2010	2013
Dichanthelium dichotomum				1.11	1.64	0.01			
Diodia virginiana						0.00			
Dyschoriste angusta									0.07
Echinochloa sp.							0.01		
Eleocharis baldwinii			0.04			0.03			
Eleocharis cellulosa	9.88	13.72	9.91	3.25	4.94	3.59	2.35	2.08	1.28
Eleocharis elongata					0.08				
Eragrostis elliottii	0.27		0.84	0.87	0.81	0.03	0.20	0.32	0.15
Eriocaulon compressum								0.15	
Erigeron quercifolius				0.07	0.12	0.01	0.06		
Eugenia axillaris				0.08		0.00			
Eupatorium capillifolium		0.36	0.04	1.30					
Eupatorium leptophyllum					0.49	0.16			
Eupatorium mikanioides		0.29	0.04	0.18	0.11	0.00	0.16	0.24	0.08
Eustachys petraea				0.11		0.12			0.04
Flaveria linearis				0.36					
Fuirena breviseta	0.07		0.21	0.01	0.59	0.15	0.01		
Habenaria repens								0.07	
Helenium pinnatifidum								0.01	
Heliotropium polyphyllum				0.15	0.09	0.00			
Hibiscus grandiflorus				0.01			0.07	0.01	
Hydrolea corymbosa						0.00			
Hymenocallis palmeri				0.17	0.07	0.05	1.16	1.18	0.62
Hyptis alata				0.38	0.25	0.04	0.04	0.10	
Hypericum cistifolium					0.07				
Hypericum hypericoides						0.00			
Ipomoea sagittata		1.20	0.03	0.27	0.15	0.16	0.37	0.34	0.10
Iva microcephala			0.59	0.14	0.46	0.08			
Justicia angusta	0.90	0.96	1.33	0.27	1.02	0.08	0.96	1.56	0.47
Kosteletzkya virginica					0.03	0.10			0.02
Leersia hexandra	0.21	0.78	0.35		0.16		0.23	0.70	0.31
Linum medium				0.01	0.02				0.03
Lobelia glandulosa					0.03	0.01	0.14		
Ludwigia alata				0.03	0.34	0.10			0.00
Ludwigia microcarpa	0.22	0.06	0.93	0.19	0.63	0.11	0.06	0.80	0.07
Ludwigia repens		1.38		1.20	0.81	0.08	0.32	0.05	
Melaleuca quinquenervia		0.22							
Metopium toxiferum				0.20					
Mikania scandens	0.27		0.18	1.55	1.84	0.09	0.14	0.14	

Species	M1			M3					
				M3E			M3W		
	2006	2009	2012	2007	2010	2013	2007	2010	2013
Mitreola petiolata			0.23	0.71	0.08	0.00	0.81	0.28	0.18
Muhlenbergia capillaris var. filipes	2.46	5.42	4.32	7.49	7.74	3.55	0.61	0.39	0.18
Morella cerifera	0.12			0.62	0.01	0.30	0.06	0.17	0.03
Myrsine floridana				0.14					
Nymphoides aquatica				0.01	0.03		0.07	0.20	0.00
Nymphaea odorata								0.05	
Oxypolis filiformis	0.50	0.14	0.09	0.11	0.48	0.04	0.16	0.18	0.17
Panicum dichotomiflorum					1.57				
Panicum hemitomon	0.21		0.07	0.22	0.93	0.20	2.15	1.54	0.20
Panicum rigidulum				0.04	0.13	0.18	0.04	0.14	0.00
Panicum tenerum	4.38	4.35	5.74	3.05	5.43	2.22	3.37	6.77	1.75
Panicum virgatum		0.61	0.03	0.61	0.15	0.06	5.59	7.57	5.06
Panicum sp.					0.11				
Parthenocissus quinquefolia						0.00			
Paspalidium geminatum				0.05		0.11	0.14	0.61	0.02
Paspalum monostachyum					0.05	0.06	4.29	8.47	5.60
Passiflora suberosa					0.01	0.02			
Peltandra virginica	0.74	1.16	0.21	0.11	0.06	0.01	0.01		0.12
Persea borbonia				0.20	0.10	0.38	0.03	0.13	0.00
Phytolacca americana						0.01			
Phyllanthus caroliniensis				0.05					
Phyla nodiflora	1.39	0.51	0.44	3.77	0.89	0.58	0.10	0.09	
Phyla stoechadifolia		0.74	0.47	0.70	0.10	0.04			
Phyllanthus sp.									0.02
Pinguicula pumila				0.01					
Piriqueta cistoides ssp. caroliniana									0.02
Pluchea rosea	1.61	2.67	1.55	4.10	4.50	1.02	3.40	3.20	1.00
Polygala balduinii				0.01					
Polygala grandiflora				0.10	0.04	0.00			0.03
Polygonum hydropiperoides		0.79	0.75	0.31	0.15	0.06	0.17	0.09	0.02
Pontederia cordata	0.27	0.58	0.27		0.35	0.00	0.42	0.41	0.02
Proserpinaca palustris		0.72	0.19	0.75	0.54	0.19	0.30	0.06	0.00
Psychotria nervosa				0.35					
Pteridium aquilinum				0.58	0.34	0.25			
Randia aculeata				0.38	0.01	0.08			
Rhus copallinum						0.25			
Rhynchospora colorata				0.01	0.15	0.03	0.13	0.06	0.00
Rhynchospora divergens					0.85	0.86			
Rhynchospora inundata	0.25		1.12	0.12			4.66	1.70	0.53

Species	M1			M3					
				M3E			M3W		
	2006	2009	2012	2007	2010	2013	2007	2010	2013
Rhynchospora microcarpa	0.05		1.35	0.69	1.38	0.71	9.21	3.00	2.71
Rhynchospora miliacea		1.56							
Rhynchospora tracyi	11.80	9.08	13.12	0.61	4.54	1.08	10.18	4.70	4.93
Rhynchospora sp.				0.02					
Sabatia grandiflora				0.06	0.14		0.12		
Sabal palmetto				0.01	0.02		0.01		
Saccharum giganteum		0.18	0.22	0.18	0.06	0.01	0.01	0.07	0.00
Sagittaria lancifolia				0.61	0.59	0.12	0.77	1.04	0.15
Salix caroliniana	0.21	0.22	0.32	0.08		0.28	0.12		0.16
Samolus ebracteatus				0.37	0.23	0.05			
Funastrum clausum							0.18	0.38	
Schoenolirion albiflorum								0.19	0.05
Schoenus nigricans				0.01	0.01	0.05	1.24	1.73	2.80
Schizachyrium rhizomatum		0.15	0.24	2.97	2.72	1.85	4.64	5.71	4.17
Schinus terebinthifolius				0.08		0.01			
Scirpus sp.							0.09		
Setaria parviflora			0.69	0.74	0.08		0.01	0.22	
Sideroxylon salicifolium				0.01	0.05	0.00			
Smilax laurifolia				0.02					
Solidago fistulosa					0.16				
Solidago stricta		0.03	0.13	0.29	0.82	0.08	0.17		0.02
Taxodium distichum var. imbricrium							0.05		
Teucrium canadense					0.29	0.04		0.11	
Thalia geniculata					0.03		0.01	0.12	0.02
Thelypteris kunthii				0.01					
Toxicodendron radicans				0.39	0.06	0.21			
Trema micrantha					0.22	0.07			
Typha domingensis	6.34	0.94	1.84				0.35	0.67	1.17
Unknown grass							0.03		
Unknown sp01							0.06		
Unknown sp02						0.00	0.14		
Unknown sp03						0.00	0.04		
Unknown sp04							0.08		
Unknown sp06					0.10				
Utricularia cornuta									0.02
Utricularia foliosa	0.05	0.09	0.51	0.08	0.01	0.00		0.02	
Utricularia purpurea	6.49	1.04	2.36		0.09	1.43		0.42	
Utricularia subulata								0.01	
Utricularia sp.					0.01				

Species	**M1**			**M3**					
				M3E			**M3W**		
	2006	**2009**	**2012**	**2007**	**2010**	**2013**	**2007**	**2010**	**2013**
Vernonia blodgettii					0.16	0.00			
Vitis rotundifolia				0.16					

Appendix 4b: Importance value index (IV) of species present at the marl prairie sites of Transect M4 and M5 and mangrove sites of M5 that were sampled three times between 2005 and 2013.

Species	**M4**						**M5**								
	Eastern prairie			**Western prairie**			**Eastern prairie**			**Western prairie**			**Mangrove**		
	2008	**2011**	**2014**	**2008**	**2011**	**2014**	**2008**	**2011**	**2014**	**2008**	**2011**	**2014**	**2008**	**2011**	**2014**
Aeschynomene pratensis	0.24	0.21		2.88	1.77	1.29									
Agalinis linifolia	0.56	0.48	0.22		0.29										
Aletris bracteata		0.01	0.01												
Andropogon virginicus							0.02								
Anemia adiantifolia	0.01		0.05												
Angadenia berteroi	0.11	0.01	0.14												
Annona glabra	0.18			1.05		0.09	0.16								
Aristida purpurascens	0.15	0.20													
Asclepias lanceolata	0.02	0.01	0.17		0.14	0.02		0.23	0.55						
Asclepias longifolia		0.10													
Symphyotrichum bracei	1.19		1.88			0.14	0.34		1.53	0.46		0.42			
Symphyotrichum dumosum	0.99	1.20	0.65	0.48	0.76	0.72	2.12	3.68	2.04	0.66	0.27	0.32			
Symphyotrichum tenuifolium		1.88			0.51	0.34		1.10			1.90				
Bacopa caroliniana	2.44	3.61	3.16	5.11	4.10	7.13									
Bacopa monnieri		0.84			1.87										
Boehmeria cylindrica					0.11										
Cassytha filiformis	0.96	1.06	0.59	4.00	5.58	4.80	0.93		3.23	2.37	0.05	2.49			
Catopsis berteroniana													0.16		
Centella asiatica	0.39	0.10	0.31	1.49	1.84	1.03	0.87		0.02						
Cephalanthus occidentalis					0.35										
Chiococca parvifolia	0.07	0.10	0.20												
Cirsium horridulum		0.01	0.07												
Cladium mariscus ssp. *jamaicense*	32.77	31.01	31.74	44.82	35.27	41.15	29.10	26.66	22.84	44.30	34.48	32.84	26.85	27.38	21.94
Conocarpus erectus	2.70	0.51	1.14												

Species	M4						M5								
	Eastern prairie			Western prairie			Eastern prairie			Western prairie			Mangrove		
	2008	2011	2014	2008	2011	2014	2008	2011	2014	2008	2011	2014	2008	2011	2014
Crinum americanum				0.92	2.63	2.78	3.33	5.94	5.18	2.12	2.66	3.66			
Cyperus haspan				0.05		0.03									
Dichanthelium dichotomum	0.51	0.17	0.12												
Dyschoriste angusta	0.77	1.88	0.46												
Eleocharis cellulosa	6.24	12.10	11.50	2.62	4.44	5.79	2.47	4.22	5.11	31.62	38.66	43.71	6.75	7.97	2.50
Eragrostis elliottii		0.17	0.07	0.03	0.42			0.25			0.17				
Erigeron quercifolius								0.09							
Eupatorium mikanioides	0.19	0.24	0.23	0.02	0.33	0.11			0.21						
Evolvulus sericeus		0.07													
Ficus aurea				0.05											
Fuirena breviseta	0.26		0.05			0.03					0.24				
Fuirena scirpoidea		0.15													
Galactia volubilis				0.23											
Helenium pinnatifidum	0.38	0.33	0.36	0.22	0.05	0.12	0.67	2.03	1.12	0.35	0.18	0.03			
Heliotropium polyphyllum	0.40	0.38	0.60												
Hydrolea corymbosa				1.46	1.24	0.05									
Hymenocallis palmeri	0.23	0.90	0.47	0.51	0.31	0.40	2.81	4.16	4.12	1.05	0.07				
Hyptis alata	0.18	0.27	0.07	0.33	0.20		0.03		0.16						
Ilex cassine		0.25	0.07												
Ipomoea sagittata	0.52	0.30	0.75	0.71	0.36	1.80	2.53		3.01						
Iva microcephala	0.55	0.23	0.51				0.27		0.15						
Jacquemontia pentanthos			0.07												
Justicia angusta	0.02	0.34	0.49	1.49	2.67	1.77	0.13	0.49	0.13	0.31	0.48				
Kosteletzkya virginica				0.05											
Leersia hexandra	0.11	0.20		0.76	0.03	0.16	0.21		0.94						
Lobelia glandulosa							0.17		0.21			0.18			
Ludwigia alata				0.56	1.12			0.55							

Species	**M4**						**M5**								
	Eastern prairie			**Western prairie**			**Eastern prairie**			**Western prairie**			**Mangrove**		
	2008	**2011**	**2014**	**2008**	**2011**	**2014**	**2008**	**2011**	**2014**	**2008**	**2011**	**2014**	**2008**	**2011**	**2014**
Ludwigia microcarpa	0.09	0.39					0.11	0.20	0.29						
Ludwigia repens	0.24			1.31	3.48	0.80	0.41	0.37	0.79						
Ludwigia sp.						0.23									
Magnolia virginiana	0.04														
Melanthera nivea	0.11	0.70	0.17												
Mikania scandens	1.00	1.09	1.32			0.73	0.03		0.24						
Mitreola petiolata	0.24	0.14	0.02			0.11		0.33							
Muhlenbergia capillaris var. *filipes*	5.21	7.24	5.71			0.14	14.97	13.57	11.96	0.52	2.33				
Morella cerifera		0.06	0.18				0.01	0.12	0.18			0.39			
Myrsine floridana	0.16		0.13												
Nymphoides aquatica			0.10												
Nymphaea odorata	0.02				0.14										
Oxypolis filiformis	0.10	0.24	0.24			0.04	0.02	0.02	0.02	0.03	0.18	0.21			
Panicum hemitomon	0.45	0.46		1.68	2.37	0.90	0.46				0.13				
Panicum rigidulum	0.03														
Panicum tenerum	2.06	1.41	0.72	1.12	0.86	1.56	1.25	0.53	0.94	0.74	0.43	0.21			
Panicum virgatum	0.94	1.89	1.91	2.42	3.23	1.47	5.17	6.86	5.96	1.12	1.47	1.14			
Paspalidium geminatum			0.20				0.09	0.13	0.21						
Paspalum monostachyum	1.16	1.19	2.30	0.12			0.41	3.97	2.04						
Passiflora suberosa		0.01													
Peltandra virginica	0.11		0.27	0.28	0.04	0.27									
Persea borbonia	0.05	0.04					0.02								
Phragmites australis							0.12								
Phyla nodiflora	3.23	2.03	2.76	0.16			1.82	0.02	1.56	0.46					
Phyla stoechadifolia	0.59	0.14	0.18												
Phyllanthus sp.	0.13														
Piriqueta cistoides ssp. *caroliniana*		0.01					0.14		0.02						

Species	**M4**						**M5**								
	Eastern prairie			**Western prairie**			**Eastern prairie**			**Western prairie**			**Mangrove**		
	2008	**2011**	**2014**	**2008**	**2011**	**2014**	**2008**	**2011**	**2014**	**2008**	**2011**	**2014**	**2008**	**2011**	**2014**
Pluchea rosea	3.75	3.63	3.00	2.54	1.27	1.31	2.20	2.43	0.98		0.11				
Polygala grandiflora	0.15	0.07					0.01								
Polygonum hydropiperoides	0.02			0.37		0.33			0.08						
Pontederia cordata	0.53	0.15	0.05	0.51	2.35	1.47			0.02						
Proserpinaca palustris	0.13	0.62	0.05	0.21	0.74	0.98	0.37	0.79	0.30						
Rhizophora mangle							0.09			0.75	1.06	2.15	60.17	58.40	65.10
Rhynchospora colorata	0.01	0.07	0.07					0.19							
Rhynchospora divergens												0.18			
Rhynchospora inundata	0.34		0.62	0.46	1.53	1.25	0.62	0.58	0.95						
Rhynchospora microcarpa	0.73	1.67	1.41	0.62	0.39	0.65	1.24	2.74	2.99	0.35		2.47			
Rhynchospora tracyi	4.42	1.70	2.18	4.94	1.68	1.42	7.96	3.73	6.31	2.37	2.36	1.27			
Sabal palmetto		0.11	0.01												
Sagittaria lancifolia	0.90	1.17	0.56	0.68	0.82	0.81	0.11	0.23	0.12	3.24	2.94	0.56			
Samolus ebracteatus	0.06	0.01													
Funastrum clausum				0.05		0.06									
Schoenolirion albiflorum								0.02							
Schoenus nigricans				1.49	1.35	0.91	0.12	0.30							
Schizachyrium rhizomatum	4.59	3.70	3.78	3.47	3.60	4.28	13.19	12.39	10.48	6.24	5.55	5.15			
Setaria parviflora								0.02							
Solidago stricta	0.59	0.15	0.35				0.35		0.49	0.28	0.13	0.35			
Spartina bakeri	0.71	0.16	0.60				1.93	1.03	2.29						
Taxodium distichum var. *imbricrium*	9.57	5.00	13.08					0.02							
Teucrium canadense	0.06	1.09	0.91						0.09						
Thalia geniculata				0.42	1.75	3.37									
Tillandsia balbisiana													0.16		
Tillandsia flexuosa	0.02												1.77		
Tillandsia paucifolia	0.20	0.09											0.30	2.07	0.77

Species	**M4**						**M5**								
	Eastern prairie			**Western prairie**			**Eastern prairie**			**Western prairie**			**Mangrove**		
	2008	**2011**	**2014**	**2008**	**2011**	**2014**	**2008**	**2011**	**2014**	**2008**	**2011**	**2014**	**2008**	**2011**	**2014**
Tillandsia sp.															0.77
Tillandsia utriculata													0.88		
Typha domingensis				6.94	7.70	6.39									
Unknown sp09				0.11			0.15								
Unknown sp11		0.20													
Unknown sp12											0.35				
Unknown sp13											0.02				
Unknown sp14									0.13						
Unknown sp15			0.11												
Utricularia cornuta	0.20						0.48		0.05						
Utricularia foliosa		1.84	0.55	0.05	0.26	0.79					1.72			4.18	8.73
Utricularia gibba	2.08			0.02	0.05			0.02			0.66				
Utricularia purpurea	1.80	2.20	0.35	0.22						0.66	1.29	1.90	2.95		0.20
Utricularia resupinata											0.12	0.39			
Vitis shuttleworthii	0.02														