Southeast Environmental Research Center
FLORIDA INTERNATIONAL UNIVERSITY

Evaluation of Vegetation Response to Changes in Hydrologic Parameters within Cape Sable Seaside Sparrow Habitat, Everglades National Park, Florida

Annual report - 2017

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Executive Summary

Cape Sable seaside sparrow (CSSS), a federally endangered species, and vegetation within its habitat are highly sensitive to changes in hydrologic regimes. In the Everglades, the CSSS has remained at the center of the water management strategies primarily because a decline in sparrow population in the early 1990s was attributed in part to management-induced alterations in hydrologic regimes. Guided by the 1999 CSSS Biological Opinion, a number of changes in water management activities have been implemented since early 2000s. The question is whether the water management activities aimed at mitigating damage to Everglades ecosystems caused by past management would affect the CSSS habitat, and how the impact on vegetation structure and composition would vary spatially and temporally in relation to the preferred CSSS habitat conditions. The results of hydrologic modelling associated with Everglades Restoration Transition Plan (ERTP) and Central Everglades Planning Project (CEPP) have suggested an improvement in habitat condition to the east of sub-population A, while areas in the western portion of sub-population B and E may become wetter and thus less suitable for the sparrows. Thus, the objectives of our study were to establish baseline vegetation data, at both fine and broad scales, in newly identified sensitive areas, and to assess the changes in vegetation condition in previously surveyed part of the sub-population A.

In 2017, 184 sites, including 69 transect and 115 census sites were sampled. The transect sites included 26 sites on Transect A established in 2003, 19 new sites on newly established transect (TAS) in the southeastern portion of the subpopulation A, and 24 sites east of sub-population E. The census sites included 105 sites established and first time sampled during 2003-2005 survey, and 10 new sites. Most of census sites were in two distinct areas (hN and hS) identified as improved potential future CSSS habitat. Vegetation sampling was done following the method described in Ross et al. (2006). Vegetation change analysis included calculation of changes in vegetation-inferred hydroperiod, and use of trajectory analysis. 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. In trajectory analysis, two statistics (delta and slope) were calculated to quantify the magnitude and rate of change in vegetation composition along the hydrologic gradient, and were based on the shift in position of sites along hydrologic vector within non-metric multidimensional scaling (NMDS) ordination space.

The hydrologic condition of the vegetation survey sites sampled in 2017 showed a distinct spatio-temporal pattern. While both four-year average hydroperiod and annual mean water depth, when averaged over all the 2017 census sites, did not differ significantly among sampling periods, they did vary spatially. In 2017, the vegetation sites in hN area were much drier than the sites in hS and western portions of the sub-population A, and they were also drier in 2017 than the previous sampling periods. Both vegetation-inferred hydroperiod and trajectory analysis results revealed that vegetation composition at several transect and census sites in the northeastern portion (hN area) of sub-population A has shifted towards the composition that was indicative of relatively dry conditions. Several sites in this area changed from marsh to wet prairie type. These sites had not only the shorter hydroperiod than other sites in recent years, but also had lowest four-year mean and minimum dry season water level. In contrast to the northeastern portion of sub-population A, majority of the vegetation sites in the southern and western portion of this sub-population either

did not show significant change in species composition or experienced a vegetation change towards wetter type in response to more hydric conditions in recent years, suggesting a continued deterioration of CSSS habitat in these areas. For instance, more than two thirds of sites sampled in hS area showed an increase in vegetation-inferred hydroperiod. Likewise, most of the sites that showed a significant shift in trajectory toward increasing wetness were in this region. Since the hS area has also been identified as potential future improved habitat, regular monitoring of sites will ascertain the direction of vegetation change in response to change in hydrologic conditions due to future restoration activities associated with Central Everglades Project plan (CEPP) and other components of CERP.

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General Background

The Cape Sable seaside sparrow (CSSS) as well as the vegetation within its range are highly sensitive to natural and management-caused changes in both hydrologic and fire regimes. With a broad goal of assessing the response of marl prairie ecosystems to Everglades restoration efforts, a study intended to characterize marl prairie vegetation and monitor its responses to hydrologic alterations and fire within CSSS habitat was conducted between 2003 and 2010 with funding from U.S. Army Corps of Engineers (USACE). In the first three years of the project (2003-2005), we completed a detailed account of vegetation composition and structure within occupied sparrow habitat (Ross et al. 2006). Subsequently, during 2006-2010, subsets of sites in six sparrow sub-populations (A-F) were re-visited annually to assess vegetation dynamics over space and time. The subset sampled each year included both unburned and burned sites (Sah et al. 2007, 2011). After a three-year interruption, the vegetation study was resumed in FY 2014 with funding from Everglades National Park (ENP). In FY 2014, the focus of the study was to assess the impact of the fire-hydrology interaction on vegetation along a wide range of hydrologic conditions (Sah et. al. 2015).

The hydrologic modelling carried out using the Regional Simulation Model (RSM) tool to evaluate the potential impact of Everglades Restoration Transition Project (ERTP) predicts that habitat in the eastern portion of CSSS sub-population A will be relatively dry (USCACE 2011, 2014; USFWS 2016) in comparison to 1990s and existing hydrologic conditions. Likewise, under CEPP-ALT 4R2, the recommended restoration alternative for Central Everglades Planning Project (CEPP), the CSSS habitat suitability index (HIS), calculated using habitat suitability modeling approach, suggests that some additional areas northeast of currently occupied habitat in sub-population A will exhibit improved hydrologic condition that is more suitable than without restoration (Pearlstine et al. 2016). In addition, the areas to the east of sub-population E are also projected to improve. Thus, a vegetation study focusing on these most sensitive areas within the marl prairie landscape was conducted in FY2017 with the funding from Everglades National Park (Task Agreement # P13AC01271, Cooperative Agreement # H5000-06-0104), and US Army Corps of Engineers – Engineer Research and Development Center (USACE-ERDC CA # W912HZ-17-2-0003). When vegetation sampling was done under these two separate funding sources, we ensured that the sites to be sampled under each were complementary, but not duplicative. However, when we were in the field, and the sites to be sampled under these projects were within the same vicinity, we sampled them together in-group so that federal resources allocated for field research in both projects were utilized with maximum efficiency. This report includes a comprehensive assessment of the vegetation structure and composition from all sites, sampled together in FY 2017 under both projects.

The major activities in FY2017 included site establishment and vegetation survey on two new transects, one in the southeastern portion of sub-population A and the other east of sub-population E. In addition, a subset of existing transect and census sites also was sampled within sub-population A. Vegetation sampling was done in spring 2017, followed by water depth measurement at the new sites in the wet season of the same year. The report describes temporal changes in vegetation structure and composition in relation to hydrologic conditions at the previously sampled sites, and characterization of vegetation pattern at the new transect sites in sub-population A and east of sub-population E.

1. Introduction

In the Everglades, the Cape Sable seaside sparrow (CSSS), a federally endangered species, is a pivot point for water management operations primarily because a decline in sparrow population in the early 1990s was attributed in part to management-induced alterations in hydrologic regimes. In general, the sparrow populations respond to changes in both hydrology and fire regime, either directly through their nesting success or failure (Pimm et al. 2002; Baiser et al. 2008), or indirectly, mediated through vegetation change in their habitat (Nott et al. 1998). Human influence on both these factors is pervasive, through the management of the extensive south Florida canal system, and through the fire management policies or plans of Everglades National Park (ENP) and Big Cypress National Preserve (BCNP). The question today is whether the water management activities aimed at mitigating damage to Everglades ecosystems caused by past management will affect the CSSS habitat, and how the impact on vegetation structure and composition will vary spatially and temporally in relation to the preferred CSSS habitat conditions.

The Cape Sable seaside sparrow (CSSS), originally described from brackish coastal marsh habitat, currently inhabits freshwater short hydroperiod marl prairies present on both flanks of the Shark River and Taylor Sloughs. The marl prairie habitat has gone through many transitions in hydrologic and fire regime due to management-induced changes in water flow pattern in the southern Everglades. Such changes in habitat conditions during the 1980s and 1990s resulted in an unexpected decline in sparrow numbers in four of six sub-populations. Guided by the 1999 CSSS Biological Opinion, recent water management activities have impacted occupied and adjacent potential CSSS habitat which had deteriorated due to extreme water conditions before the late 1990s. For instance, regulatory schedules for the S-12 structures along Tamiami Trail - followed under the operational objectives of Interim Structural and Operation Plan (ISOP)/Interim Operational Plan (IOP) (USACE 1999; USFWS 2002) - have caused consistently low water levels at NP-205 and nearby areas, resulting in vegetation characteristic of drier conditions in the northeastern part of sub-population A (Sah et al. 2011, 2016). In contrast, in the eastern marl prairies, operated under Interim Operation Plan (IOP) to provide protection for the adjacent CSSS habitat (USFWS 2002), the S332B and S332C pump structures deliver water from the L31N canal into a series of inter-connected detention ponds. In these areas, both the overflow above a fixed-crest weir and subsurface seepage from the pond to adjacent marl prairies in ENP have helped to control seepage back to the canal and to protect the sparrow habitat from further deterioration (USACE 2007). Accordingly, vegetation in areas adjacent to the canal has shifted towards a more mesic type (Sah et al. 2011, 2016, 2017), possibly improving the CSSS habitat, as these areas were considered over-drained followed frequent fires that adversely impacted the habitat resulting in reduced sparrow numbers (Pimm et al. 2002). These vegetation shifts are subject to change due to future restoration activities associated with Comprehensive Everglades Restoration Plan (CERP) and its recently outlined components, such as Everglades Restoration Transition Plan (ERTP) and Central Everglades Planning Project (CEPP) (USACE 2011; USACE 2014; USFWS 2016).

During CEPP planning, the Refined Recommended Plan (i.e. Alternative 4R2) has been considered the best alternative in comparison to the existing condition baseline (ALT EC) (USACE 2014). Modeled under these two scenarios, CEPP-ALT EC and CEPP-ALT 4R2, the CSSS habitat suitability index suggests that under the latter, some areas of sparrow habitat within both western (sub-population A) and eastern (B, E and F) sub-populations will become wetter, and thus possibly less suitable than at present (Pearlstine et al. 2014). Specifically, conditions along the western edge of sub-population E, one of the two largest and most persistent sub-populations, will be wetter than the sparrow prefers (Pearlstine et al. 2016), in association with increased water flow through the Blue Shanty area as well as Northeast Shark Slough (USACE 2014). In contrast, the model also predicts that some additional suitable habitat may become available outside the recent range of CSSS occurrence. In particular, adjoining areas to the northeast of currently occupied habitat boundary of sub-population A are expected to exhibit improved condition (Pearlstine et al. 2014, 2016). The results of hydrologic modelling associated with Everglades Restoration Transition Plan (ERTP) and Central Everglades Planning Project (CEPP) have also suggested an improvement in habitat condition east of sub-population A (USACE 2011, 2014).

Habitat conditions in some sensitive areas likely to be impacted by future water management were regularly monitored between 2003 and 2010 (Ross et al. 2006; Sah et al. 2011). Consequently, these areas contain an established network of monitoring sites at both fine (sites at 100 m along the transects) and broad landscape scales (sites 1 km apart in a gridded layout). In 2016, a number of vegetation monitoring sites were added in areas identified by modeling as potential suitable habitat southeast of sub-population A or to be adversely impacted by the water management activities western portion of sub-population E. However, the existing monitoring network did not include sites in the area to the northeast of occupied habitat in sub-population A. Likewise, to the east of sub-population E, where the area is expected to improve, there was a need to establish new sites. Thus, the objectives of the study we undertook in 2017 were to establish baseline vegetation data, at both fine and broad scales, in newly identified sensitive areas, and to assess the changes in vegetation condition in the existing habitat of sub-population A.

2. Methodology

2.1 Data Collection

2.1.1 Study Area:

The study area included the portion of existing and future potential CSSS habitat within the marl prairie landscape. Between 2003 and 2006, we established a network of 906 vegetation-monitoring sites in the marl prairies, most of which were congruent with sparrow census sites. While the vegetation-sampling network was widespread and covered almost all the recent range of CSSS habitat (Figure 1), it did not include all sparrow census sites established in 1981/1992 or added later. Specifically, the sparrow census sites not included in the vegetation survey were mostly in the northeast portion of sub-population A (NE-A), and the 55 sites in other populations, including 17 sites in the western portion of sub-population E (West-E). Thus, in 2016, we extended the existing Transect A eastward for 3 km to capture potential CSSS habitat and Transect E westward for 4 km up to the transition with the ridge-and-slough landscape. In 2017 we also established 19 and 24 sampling sites along new transects in the sub-population A and east of sub-population E, respectively. These additional sites were expected to capture fine scale changes in habitat conditions in southeastern portion of sub-population A and east of sub-population E that will possibly be impacted by the hydrological changes caused by ongoing and planned restoration activities (USCACE 2014; USFWS 2016).

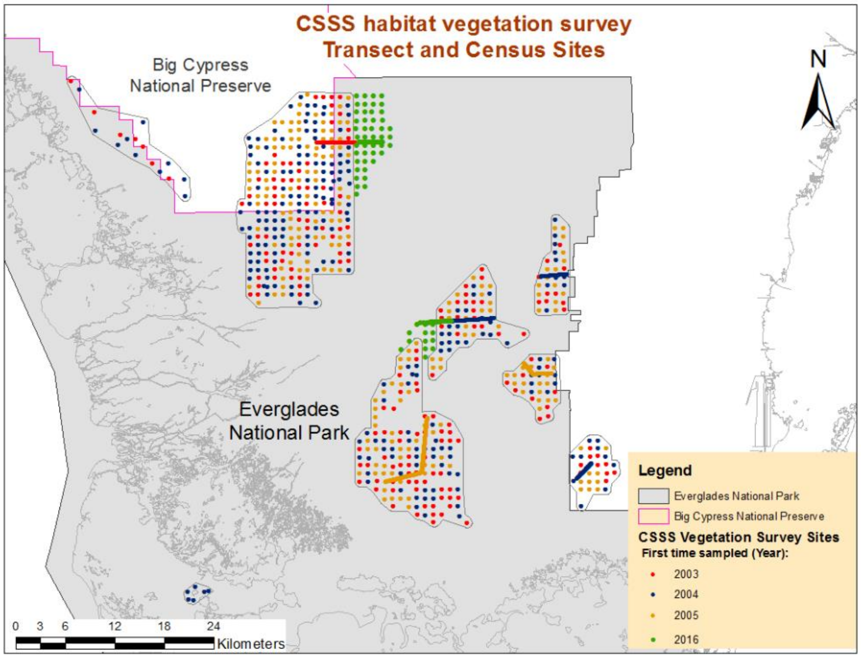

Figure 1: A network of vegetation monitoring sites. In the beginning of vegetation monitoring within the CSSS habitat, 906 sites (293 transect and 613 census sites) were established over three years (2003-2005), and were sampled at least twice in 8-year period (2003-2009). In 2016, additional 103 sites (45 transect and 58 census sites) were established and first time sampled.

In 2017, we sampled 184 sites, including 69 transect and 115 census sites (Figure 2). The transect sites included 26 sites on Transect A that were established in 2003 and sampled in 2003, 2006 and 2010. In addition, we established a 5 km transect in the southeastern portion of the subpopulation A. On this transect, namely ‘Transect TAS’, 19 sites were sampled every 200 m. except in the areas covered by tree island and woody vegetation. An additional 24 sites were sampled on the extended portion of Transect E. The original Transect E, which runs roughly between two stage recorders CR2 and CR3, was extended for 4 km westward in 2016 (Figure 1). In 2017, we extended the transect eastward for 3.2 km, where it reached the western end of Taylor Slough Transect T5, which is regularly monitored by the Everglades National Park (ENP). On this transect, we sampled 24 sites spaced every 100 m, except a section of 800m in the middle where the area has dense cover of woody vegetation.

Census sites sampled in 2017 included 10 new sites and a subset of 105 sites from the previously sampled sites in subpopulation A. Most of census sites were in the eastern portion of CSSS sub-population A and the areas adjacent to it, where two distinct areas (hN and hS) have been identified as improved potential future CSSS habitat (USCACE 2014; USFWS 2016). All the new sites were established within hN and hS, especially in the gaps between existing vegetation survey sites in the CSSS monitoring network. In total, we sampled 34 census and 23 transect sites within hN, and 41 census and 19 transect sites within hS (Figure 2). The transect sites sampled within the hN habitat area were established in 2003 and sampled three times (2003, 2006 and 2010) prior to 2017 sampling, while all transect sites within hS were established and sampled for the first time in 2017.

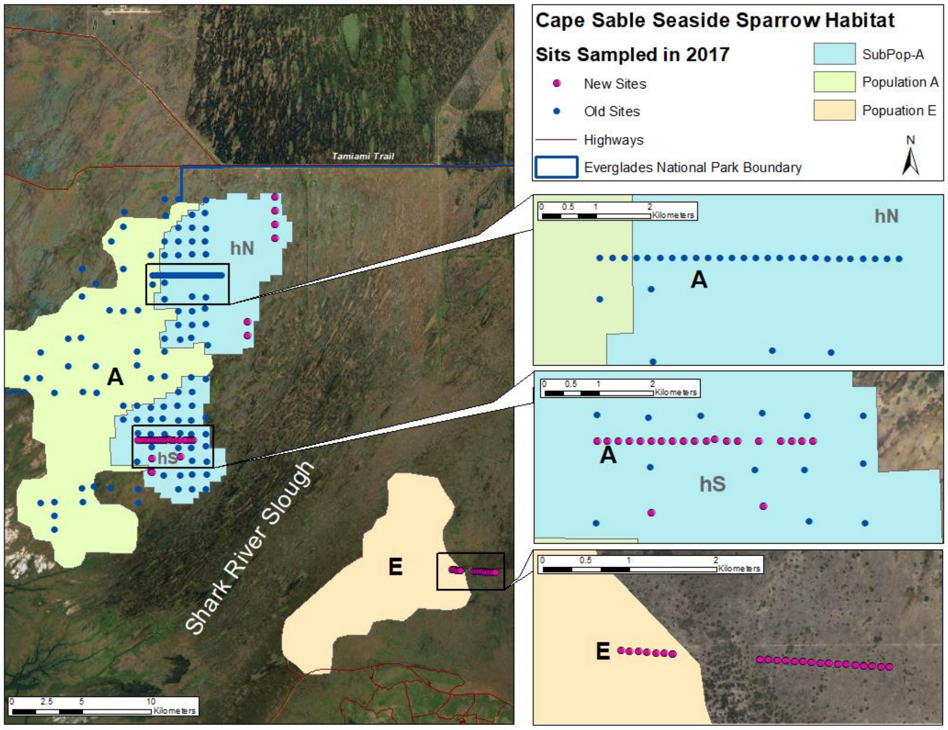

Figure 2: CSSS Vegetation Survey sites (69 transect and 115 census sites) sampled in 2017. The sites sampled in 2017 included both ENP and USACE-funded sites - 84 (blue) and 100 (pink) sites, respectively.

2.1.2 Vegetation sampling

At each sampling site, vegetation was sampled in a N-S oriented, 1 x 60 m rectangular plot beginning 3 m south of a rebar established to permanently mark the sampling site, following the methods described in Ross et al. (2006). Nested within the plots were ten 0.25 m^2 (0.5 x 0.5 m) subplots (compositional sub-plots), arrayed at 6-meter intervals along the baseline (east side) beginning at Meter 5. In each subplot, we recorded our ocular estimate of cover (live + dead) of each species. We also noted any additional species present in the 1 x 60 m plot, and assigned these species a mean cover of 0.01% for the plot as a whole. In addition, a suite of structural parameters was recorded in 30 0.25 m^2 (0.5 x 0.5 m) subplots (structural sub-plots) arrayed every two meters beginning at Meter 1. Structural sampling included three attributes: 1) Canopy height, i.e., the tallest vegetation present within a cylinder of ~5 cm width, measured at 4 points in each quadrat; 2) Total vegetative cover, in percent; and 3) live vegetation, expressed as a percent of total cover. In the compositional sub-plots of the new sites, we also measured soil depth at 4 points in each quadrant by probing to bedrock with a 1-cm diameter aluminum rod.

2.1.3 Hydrology

Hydrological variables used in this study were based on elevations determined from either topographic surveys (for transect sites) or water depths measured in the field (for census sites). If there was standing water at the time of sampling, we measured water depth in compositional sub-plots within each 1x 60 m plot. At the new census sites where there was no standing water in Spring 2017, we measured water depth at 3-5 locations within the 1x 60 m plot under flooded conditions during the wet season. However, at the new transect sites we measured water depth only near the re-bar, which served as reference benchmark for determining elevation of the compositional sub-plots, as the relative elevation of the plots with reference to the re-bar had been previously determined using an autolevel at the time of vegetation sampling.

Later, using the water surface elevations provided by Everglades Depth Estimation Network (EDEN) for the specific date, we calculated ground elevation for each plot. EDEN daily water surface elevation data (http://sofia.usgs.gov/eden/models/watersurfacemod_download.php) were then used to calculate annual mean daily water depth and hydroperiod for each site. Hydroperiod of each year was defined as the discontinuous number of days in a year when water level was above the ground surface. In addition, we also computed mean wet and dry season water depths, as these variables are also considered to have a significant relationship with vegetation structure and composition in the wetland marshes, especially in the ridge and slough landscape (Hotaling et al. 2009; Zweig and Kitchens 2008).

2.2 Data Analysis

2.2.1 Vegetation Classification

In this study, 53 sites were sampled for the first time in 2017. We used cluster analysis to classify the sites, examine the spatial distribution of vegetation types, and note any change in vegetation types at previously-established sites. However, to keep the vegetation type identified at those sites in coherence with the classification adapted for the marl prairie vegetation encompassing all the subpopulations, the analysis also included vegetation data collected at 608 census sites sampled in 2003-2005 within both historical (Cape Sable) and recent range (six subpopulations) of CSSS habitat. We followed the procedure, described in Ross et al. (2006), i.e., we eliminated species that were present in less than 12 sites, and relativized the species data by plot total. We then used the 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). Dendrograms were cut to arrive at the same ten vegetation groups that had been initially recognized based on data only from the 608 census sites (Ross et al. 2006).

2.2.2 Vegetation-environment relationships

To examine the relationship between vegetation composition and existing hydrological conditions, vegetation data were first summarized by a non-metric multidimensional scaling (NMDS) ordination, in which cover data were relativized by site total. The hydrology vector was derived by calculating plot level hydroperiod, using mean plot elevation obtained using field measurements of water depths and EDEN daily water surface elevation data. In ordination space, the vectors for the hydrologic gradient were defined by the vector fitting technique in DECODA (Minchin 1998). In this method, a gradient is defined in the direction through the ordination that produces maximum correlation between the measured environmental attribute and the scores of the sampling units along the vector. The statistical significance of such correlations is tested using a Monte-Carlo permutation test with 1,000 random permutations, as samples in the given ordination space are not independent (Minchin 1998). The orientation of the ordination is then rotated so that hydroperiod has a perfect correlation ($r = 1.0$) with axis-1, the ordination's principal axis.

2.2.3 Change in vegetation composition

Vegetation change analysis included calculation of vegetation-inferred hydroperiod, the hydroperiod for a site indicated from its vegetation composition using a Weighted Averaging Partial Least Square (WAPLS) regression model (Armentano et al. 2006; Ross et al. 2006; Sah et al. 2011). A change in vegetation-inferred hydroperiod between successive surveys reflects the amount and direction of change in vegetation, expressed in units of days (0-365) along a gradient in hydroperiod.

Additionally, vegetation response to hydrologic change was also analyzed with trajectory analysis (Minchin et al. 2005; Sah et al. 2014), which uses a change in community composition along a vector representing hydrologic condition. Trajectory analysis was used for the sites that were sampled for three times or more. In 2017, 26 transect sites were sampled for the 4th time, whereas99 census sites were sampled for the third time since the initial survey in 2003-2005.

For trajectory analysis, the vegetation data was first summarized using a non-metric multidimensional scaling (NMDS) ordination. Prior to NMDS, species composition data was standardized by species' maximum abundance i.e., all abundance values for a species were divided by the maximum abundance attained by that species. In ordination space, the reference vector for the hydrologic gradient was defined by a vector fitting technique in which a gradient is defined in the direction through ordination that produces maximum correlation between the measured environmental attribute and the scores of the sampling units along the vector (Minchin 1998). The orientation of the ordination was then rotated so that annual mean daily water depth had a perfect correlation ($r = 1.0$) with axis-1, the ordination's principal axis. In trajectory analysis, two statistics (delta (Δ) and slope) were calculated to quantify the degree and rate of change in vegetation composition along the hydrology vector (Minchin et al. 2005; Sah et al. 2014). In this analysis, the slope was calculated as the linear regression coefficient of projected scores on the target vector in sampling years. The statistical significance of both delta (Δ) and slope was tested using Monte Carlo simulations with 10,000 permutations.

2.2.4 Species richness, evenness and biomass

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 = Total crown cover (%), and Ht = Mean crown height (cm).

Friedman-ANOVA (Non-parametric test for multiple dependent variables) was used to test differences in cover of major species among the three sampling events. To account for the variability caused by the repeated measurement of vegetation structural variables (vegetation height, cover and biomass) and vegetation-inferred hydroperiod, Linear Mixed Models were used. General Liner Mixed Models were used to examine differences in structural variables between WP and M sites and among sampling years, whereas Generalized Linear Mixed Models (GLMMs) were used to examine differences in species richness, a count variable. Biomass and vegetation inferred hydroperiod data were log-transformed to approximate normality. Models were run in R v.3.5.0 (R core team, 2018) using the *lmer* (for general linear mixed model) and *glmer* (for generalized linear mixed model) functions in the ‘lme4’ package (Bates, 2014). Sites (PlotID) were treated as a random variable. We treated sampling event (Sampyear) as a fixed effect to examine the differences in cover, biomass and species richness among sampling years that was done in posthoc test using *glht* function implemented in ‘multicomp’ package.

3. Results

3.1 Hydrologic conditions

In the western marl prairie, which is the habitat of CSSS sub-population A, overall hydrologic condition has not changed much over the one and a half decades between 2003 and 2017. EDEN hydrologic summary, as shown on Cape Sable seaside sparrow (CSSS) viewer (https://sofia.usgs.gov/eden/csss/), reveals that four-year mean discontinuous hydroperiods in 2016 (295 days) and 2017 (307 days) were either same or slightly (15 days) higher than the mean hydroperiod for the three-year period (2003-2005; mean = 292 days), when the current vegetation survey sites were established and first time sampled (Figure 3). However, within the sub-population, hydrologic condition varied spatially. For instance, the northeastern and eastern portion of sub-population A (AX: hN and hS) that are identified as improved potential future CSSS habitat (USCACE 2014; USFWS 2016) had a four-year mean hydroperiod 20 days shorter than the overall average of sub-population A.

The hydrologic condition of the vegetation survey sites sampled in 2017 showed a distinct spatial and temporal pattern. The four-year average hydroperiod and annual mean daily water depth for the majority of vegetation survey sites (82.6%) were calculated using ground elevation derived from the field measurements of water depth and EDEN daily water surface elevation data. At the census sites sampled in 2017, the four-year average hydroperiod (WY 2013-2016: water year – May 1st to April 30th - ending in the year prior to vegetation sampling) ranged between 47 and 351 days, with a mean (± SD) of 239 (± 76) days and a median of 251 days. The median four-year average hydroperiod at these sites in 2017 was 12 and 23 days higher than 2003/2005 and 2006/2009 sampling events, respectively. However, the difference in mean hydroperiod was not statistically significant (Kruskal-Wallis Test: p = 0.203) (Figure 4).

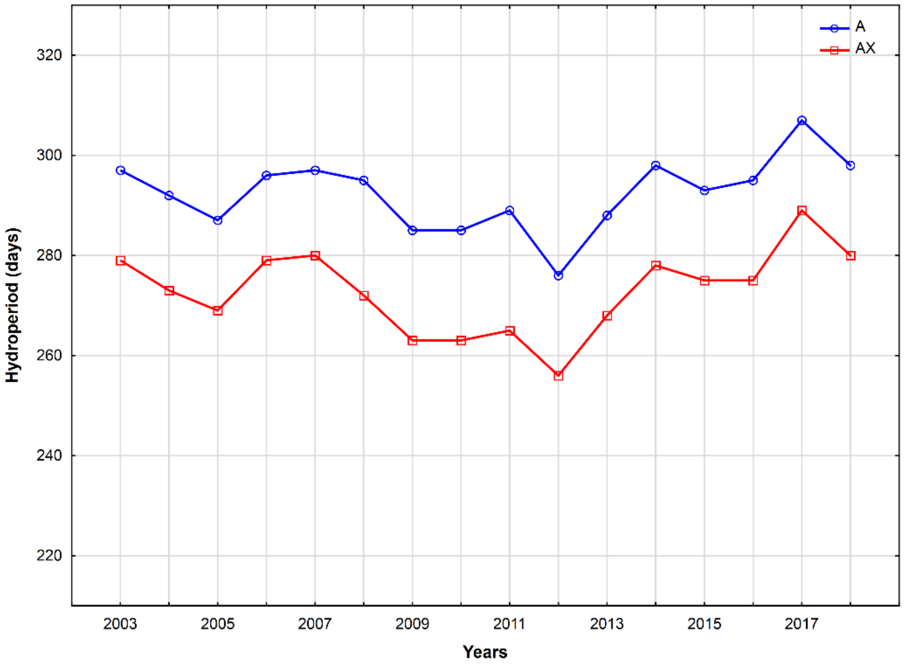

Figure 3: Four-year mean discontinuous hydroperiod in CSSS sub-population A. AX = northeastern and eastern portion of the sub-population A that are identified as improved potential future CSSS habitat. (Source: https://sofia.usgs.gov/eden/csss/)

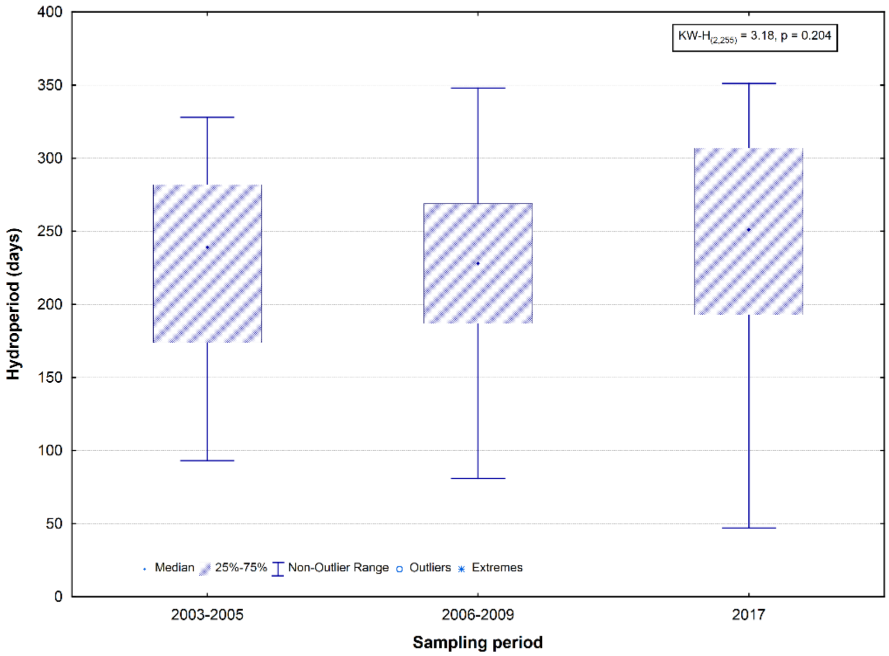

Figure 4: Box-plot showing median (box = 25% and whisker = 75% quartiles) four-year average hydroperiod at a subset of sites sampled in 2017 that had field measurements of water depth. The sites were sampled three times: during 2003-2005 and 2006-2009 sampling periods and in 2017.

At the census sites sampled in 2017, the four-year average (WY 2013-2016) annual mean daily water depth ranged between -18.7 and 33.0 cm with the mean (± SD) of 5.8 (±12.0) cm and median of 5.2 cm. The median four-year average annual mean daily water depth at these sites in 2017 was 1.5 and 1.7 cm higher than the previous sampling events (2003/2005 and 2006/2009), but the difference was not statistically significant (Kruskal-Wallis Test: p = 0.792) (Figure 5).

While both four-year average hydroperiod and annual mean water depth, when averaged over all the 2017 census sites, did not differ significantly among sampling periods, they did vary spatially. In 2017, the vegetation sites in the northeastern portion of the sub-population A (hN) were much drier than the sites in other portions of the sub-population A (Figure 6). In the hN area, the mean four-year average hydroperiod was 141 ± 67 days (median = 133 days), and water depth was -8.7± 6.6 cm (median = -7.8 cm). In contrast, the hS and western portion of the sub-population had the mean hydroperiod of 232 ± 57 and 281 ± 53 days, and the mean annual water depths of 4.7 ± 9.3 and 11.9 ± 10.4 cm, respectively (Table 1). Moreover, the hydrologic condition at many sites in hN area was drier in 2017 than the previous sampling periods, whereas the sites in the western and southern portion (hS) of sub-population A had become wetter over one and a half decades (2003-2017). For instance, mean hydroperiod at the sites in hN area in 2017 was 20 days shorter than the hydroperiod during the first survey (Table 1). In contrast, the hydroperiods in hS and western portion of sub-population A were 18 and 17 days longer in 2017 than one and a half decades earlier (Table 1).

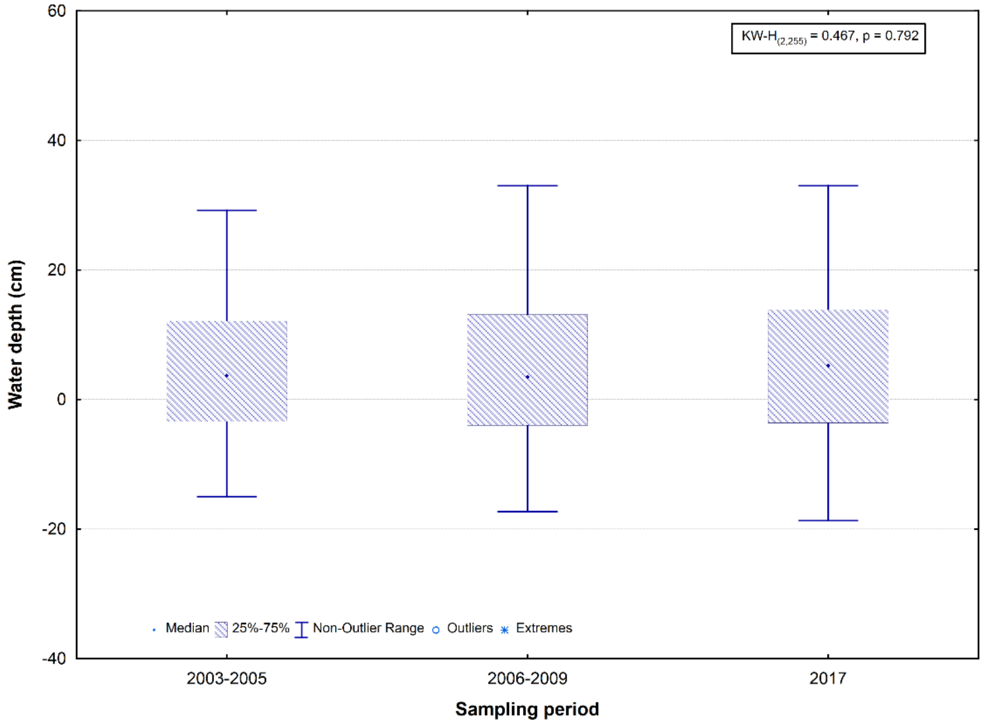

Figure 5: Box-plot showing median (box = 25% and whisker = 75% quartiles) four-year average annual mean daily water depth at a sub-set of sites sampled in 2017 that had field measurements of water depth. The sites were sampled three times, during 2003-2005 and 2006-2009 sampling periods and in 2017.

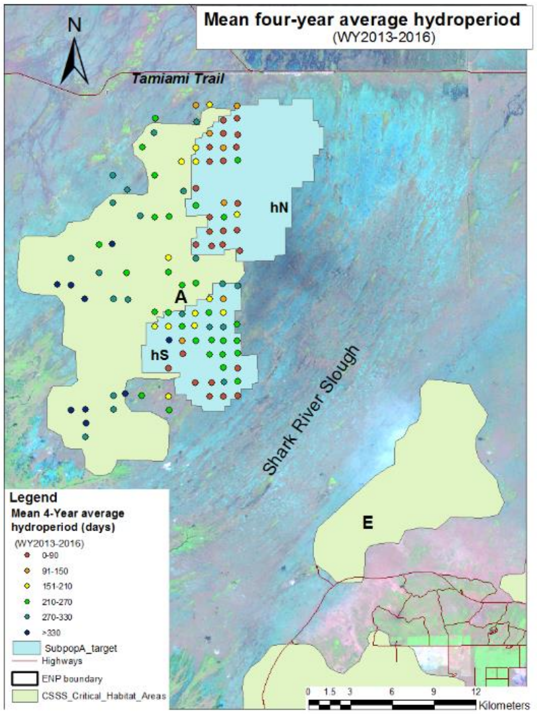

Figure 6: Four-year mean discontinuous hydroperiod at 2017 vegetation survey sites sub-population A. The values were calculated only for those sites for which field measurements of water depth were available, and the sites were sampled during both 2003-2005 and 2017 surveys.

Table 1: Four-year mean discontinuous hydroperiod and annual mean daily water depth at 2017 vegetation survey sites in different regions of CSSS sub-population A. The values were calculated only for those sites for which field measurements of water depth were available, and the sites were sampled during both 2003-2005 and 2017 surveys. The hydroperiod and daily water depth values were calculated using the ground elevation derived from the field measurements of water depth and EDEN daily water surface elevation data.

Sub-popA Region	**4-year average hydroperiod (days)**				**4-year annual mean daily water depth (cm)**			
	2003-2005		2017		2003-2005		2017	
	mean (±sd)	median	mean (±sd)	median	mean (±sd)	median	mean (±sd)	median
hN (n=15)	161 (± 51)	145	141 (± 57)	133	-5.9 (± 6.0)	-7.5	-8.7 (± 6.6)	-7.8
hS (n=29)	214 (± 55)	225	232 (± 67)	240	1.9 (± 9.4)	2.3	4.7 (± 9.3)	5.7
Western (n=41)	264 (± 47)	276	281 (± 53)	298	10.5(± 9.5)	11.3	11.9 (±10.5)	10.7

In 2017, 43 new transect sites – 19 sites in hS area of sub-populations A (TAS) and 24 sites on the eastward extension of existing Transect E – were established. The hydrologic conditions on these two transects were much different. While mean 4-year average hydroperiods on TAS (249 ± 58 days) and TE (242 ± 42 days) were not much different, annual mean daily water depth was significantly different. The mean ((± 12.9) water depth on Transect TAS was 8.4 (± 12.9) cm, but it was -0.6 (± 8.4) on TE, suggesting that when water level recedes below ground in these two areas, even though that may remain below ground for the same period, the water level at sites on Transect E drops far below the ground in comparison to the sites on Transect TAS. Likewise, those areas are flooded, the water depth at western sites are much deeper than the eastern transect sites.

3.2 Vegetation composition and structure

In general, the same nine vegetation types were observed in 2017 that were previously recorded within the marl prairie landscape. However, some sites that were resampled in 2017 were of a different vegetation type than what was present at that particular site 15 years earlier, suggesting a shift in species composition in response hydrologic changes over that period at those sites.

In 2017, all the resampled sites (105 census and 26 transect sites) were in sub-population A, and two-thirds (66.4%) of them were either in hN or hS areas. Distribution of vegetation types among the resampled sites within the subpopulation were not uniform (Figure 7). The western portion of the subpopulation and hS area had a disproportionately high percentage (81.8% and 63.9%, respectively) of sites with marsh vegetation. In hS, most (65%) were *Cladium* Marsh, and the remaining one-third of sites were *Cladium-Rhynchospora* Marsh, whereas in western-A, 30% of sites had either beakrush (*Rhynchospora) or* spikerush (*Eleocharis*)-dominated vegetation types. In contrast, in hN, two-third of the sites had prairie vegetation, and among them 50% the sites had *Schizachyrium* WP and 32% *Cladium* WP. The *Schoenus* WP type was present at three transect and one census sites

At the newly established transect sites, vegetation composition differed between sub-population A and eastern sub-population E. In the southern portion of sub-population A, where all new sites were within hS, a majority (83%) of 23 new sites had marsh vegetation, including *Cladium* Marsh, *Cladium-Rhynchospora* Marsh and *Rhynchospora-Cladium* Marsh (Figure 7). In contrast, on the extended part of Transect E, half of the new sites had wet prairie vegetation, mainly *Cladium* WP and *Schizachyrium* WP (Figure 7). Most of the other sites were *Cladium* Marsh.

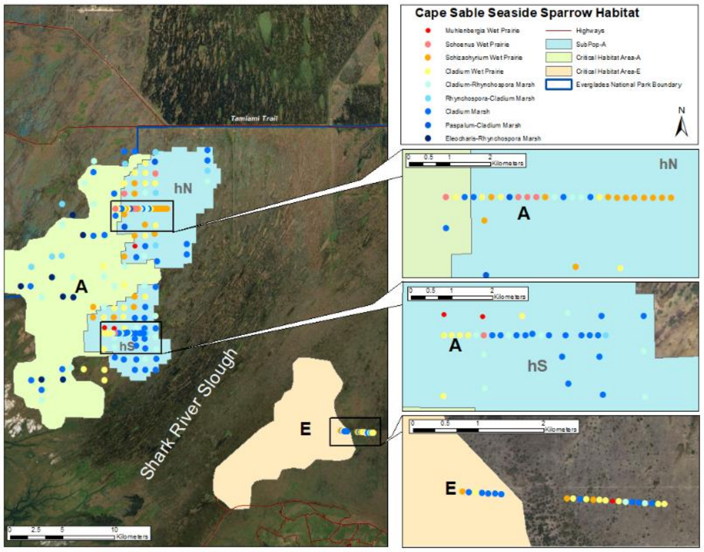

Figure 7: Spatial distribution of vegetation types at the 2017 sampling sites in (a) sub-population A (b) eastern portion of sub-population E (East-E). Vegetation type at each site was identified through cluster analysis of species cover values at these sites plus 608 census sites sampled in three years (2003-05). In the cluster analysis, cluster diagram was cut in the way so that the same 10 vegetation types identified in Ross et al. (2006) were obtained. Vegetation types represent from the dry (red) to wet (dark blue) community types

3.3 Vegetation change in sub-population A

In 2017, 26 transect sites and 105 census sites were re-sampled in sub-population A. Most of those sites were within the areas that are projected to be improved habitat. Before 2017 sampling, the transect sites had been sampled three times, 2003, 2006 and 2010, whereas the census sites were sampled only two times, during 2003-2005 and 2006-2009 sampling events. In general, vegetation composition at both transect and census sites in 2017 were significantly different (ANOSIM: p<0.01) from the composition present during previous samplings.

Transect A:

Transect A extends east (2 km) and west (3 km) from NP-205, and the temporal change in vegetation along this transect represents the hydrologic conditions within the sub-region. Vegetation composition on this transect differed significantly between the four sampling years (ANOSIM: Global R = 0.232, p-value <0.001), and the difference in composition between 2003 and subsequent surveys increased over time. For instance, the differences in composition were stronger between 2003 and 2017 (R = 0.313) than between any other pair of sampling years (Table 2).

Table 2: Global R and p-values from analysis of similarity (ANOSIM) testing for among-year differences in vegetation composition on Transect A sampled in 2003, 2006, 2010 and 2017. n=51 during 2003, 2006 and 2010 samplings, and n = 26 in 2017.

	Sampling years		
	2003	**2006**	**2010**
2006	0.137***		
2010	0.244***	0.261***	
2017	0.314***	0.277***	0.238***

p-value: * <0.05, ** <0.01, *** <0.001

On transect A, the vegetation composition change between 2003 and 2006 was not limited to species that are indicative of wetter or drier environments, as the difference in median vegetation-inferred hydroperiod between 2003 and 2006 was not statistically significant (Figure 8). In contrast, median vegetation-inferred hydroperiod was significantly lower in 2010 and 2017 than in both the 2003 and 2006 samples. However, the difference in median vegetation-inferred hydroperiod between 2010 and 2017 was not significant. The median vegetation-inferred hydroperid in 2003, 2006, 2010 and 2017 were 247, 243, 218 and 212 days, respectively. The change in vegetation-inferred hydroperiod on transect A over the complete study period paralleled changes in hydroperiod referenced to stage level at NP-205 (Figure 8).

The change in vegetation-inferred hydroperiod was corroborated with the trajectory of vegetation shift revealed in the trajectory analysis. During the first three surveys, 51 sites, located at every 100m on Transect A, were sampled each year, whereas in 2017, only 26 sites, located at every 200m, were sampled. Between the first sampling year (2003) and the most recent ones (2010 or 2017), 94% of the sites on Transect-A took an opposite trajectory along the vector of increasing hydroperiod, suggesting a trend from wetter to drier conditions (Appendix A2). Among the sites that showed a shift in vegetation composition toward drier type, the magnitude (delta) and rate (slope) of trajectory shift was statistically significant at 40% of the sites. However, at those sites, the mean change towards drier vegetation, represented by a shift along X-axis in NMDS ordination (Figure 9), was more prominent between 2006 and 2010 than between 2003 and 2006 or between 2010 and 2017.

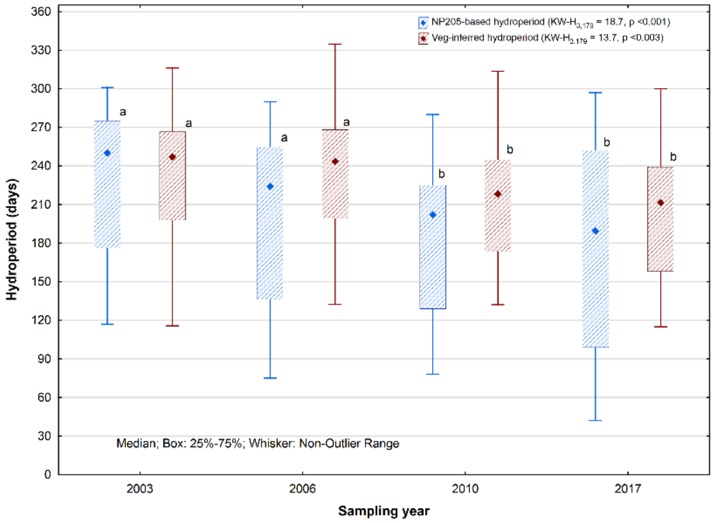

Figure 8: Box-plot showing median (box = 25% and whisker = 75% quartiles) hydroperiod (NP-205 based) and vegetation-inferred hydroperiod (days) at the sites on Transect A sampled in 2003, 2006, 2010 and 2017. In first three samplings, n = 51, whereas in 2017 sampling, n = 26.

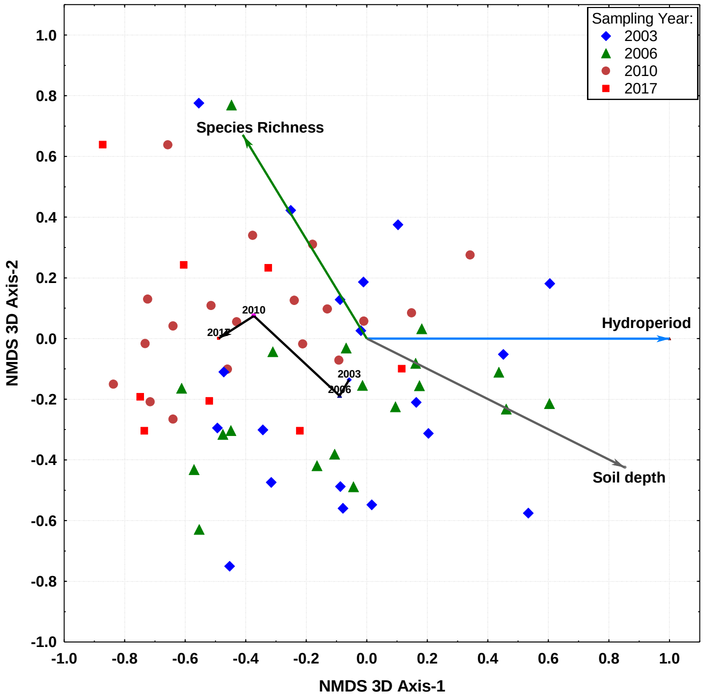

Figure 9: NMDS ordination bi-plots of site scores, the environmental vectors fitted in the ordination space, and the trajectory of centroid. The ordination is based on species abundance data collected at CSSS Transect A sites, sampled in 2003, 2006, 2010 and 2017. Only the sites that showed significant ($p \leq 0.1$) rate of change in species composition along the hydrology gradient are shown. Initial point and the end of the trajectory represent the 2003 and 2010 or2017 sampling event, respectively

On Transect A, the mean cover of *Bacopa caroliniana* and *Panicum virgatum*, both prevalent in wetter portion of marl prairies (Ross et al. 2006), significantly decreased between 2003 and 2017 (Table 2). Mean cover of two other species with a relatively wide range of hydrologic tolerances, *Cladium jamaicense* and *Rhynchospora tracyii*, also decreased from 13.2% and 1.36% in 2003 to 10.8% and 0.24% in 2010, respectively. However, their mean cover again increased to 12.9% and 1.21% in next 7 years, between 2010 and 2017. In contrast, mean cover of *S. rhiozomatum*, a dominant species in short-hydroperiod prairies, increased from 3.69% in 2003 to 7.7% in 2010, and remained at 6.6% in 2017. Other species whose mean cover significantly (pair-wise t-test; $p<0.5$) increased between 2003 and 2017 were *Centella asiatica*, and *Crinum americanum*.

Table 2: Mean cover (%) of major species on Transect A in 2003, 2006, 2010 and 2017. Different superscript letters indicate significant difference (Pair-wise t-test; p-value <0.05) in species' cover between years. During the first three sampling years (2003, 2006 & 2010), 51 sites were sampled each year, whereas in 2017, only 26 sites were sampled.

Species	**2003**	**2006**	**2010**	**2017**
Bacopa caroliniana	0.36^{a}	0.87^{b}	0.20^{c}	0.04^{d}
Centella asiatica	0.27^{a}	0.18^{b}	1.45^{c}	0.53^{d}
Cladium jamaicense	13.20^{a}	10.18^{b}	10.83^{bc}	12.96^{ac}
Crinum americanum	0.18^{a}	0.35^{b}	0.63^{c}	0.43^{bc}
Panicum tenerum	1.38^{a}	0.28^{b}	1.86^{a}	0.31^{b}
Panicum virgatum	1.15^{a}	1.07^{ac}	2.28^{b}	0.99^{c}
Paspalum monostachyum	2.83^{ac}	2.02^{b}	3.63^{c}	1.84^{ab}
Rhynchospora tracyi	1.36^{a}	2.57^{b}	0.24^{c}	1.21^{a}
Schoenus nigricans	3.98^{a}	2.03^{b}	2.01^{b}	2.91^{ab}
Schizachyrium rhizomatum	3.69^{a}	4.18^{a}	7.73^{b}	6.59^{ab}

Census sites:

In 2017, a subset of 105 census sites was resampled in sub-population A. Most of them (94%) were sampled for the third time since initial sampling during 2003-2005. Mean (±SD) vegetation-inferred hydroperiods at those sites were 253 (±46), 259 (±49) and 251 (±45) days in 2003-2005, 2006-2009 and 2017 sampling events, respectively, and the mean hydroperiods did not differ among three sampling events (Figure 10). Nevertheless, the direction of change in inferred hydroperiod varied spatially. Most of the sites in hN had shorter vegetation-inferred hydroperiod in 2017 than during the 2003-2005 survey (Figure 11). In contrast, vegetation-inferred hydroperiod at the two-third of sites in hS was higher in 2017 than previous survey years. Within this area, 23 new sites (4 census and 19 transect sites) were sampled for the first time in 2017. The inferred hydroperiod at those sites ranged between 200 and 318 days. Surprisingly, the sites in the western portion of sub-population showed mixed results, though, more than half (55%) had higher vegetation-inferred hydroperiod than before.

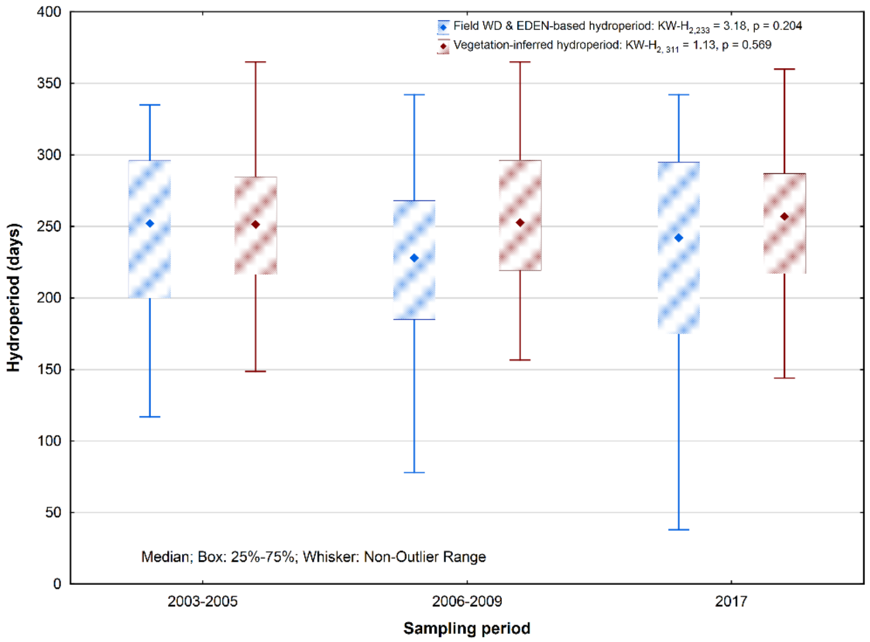

Figure 10: Box-plot showing median (box = 25% and whisker = 75% quartiles) field water-depth & EDEN-based hydroperiod and vegetation-inferred hydroperiod (days) averaged over 105 census sites sampled during 2003/2005 and 2006/2009 periods and in 2017.

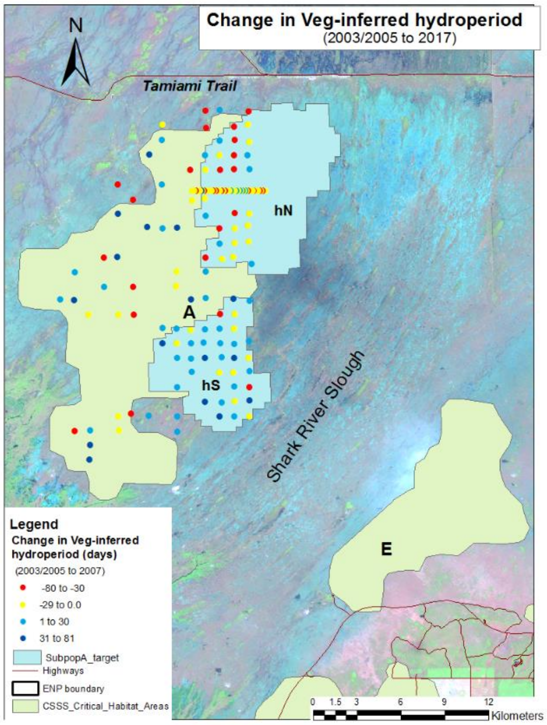

Figure 11: Map showing the spatial variation in a change in vegetation-inferred hydroperiod between 2003/2005 and 2017 samplings at the sites sampled in 2017 in sub-population A.

In agreement with the spatially differentiated change in vegetation-inferred hydroperiod, trajectory analysis results also revealed that the direction of shift in vegetation composition spatially varied. In contrast to 90% transect sites showing drying trend, only slightly more than half (52.4%) of sampled census sites showed a shift in vegetation composition toward drier type. Among those sites, the magnitude (delta) and rate (slope) of trajectory shift was statistically significant at 35% of the sites. Most of these sites were hN and its adjacent areas. Among the sites (47.6%), that showed wetting trend, the amount of trajectory shift was statistically significant at only 30% of the sites. These sites were mostly in hS area (Figure 12)

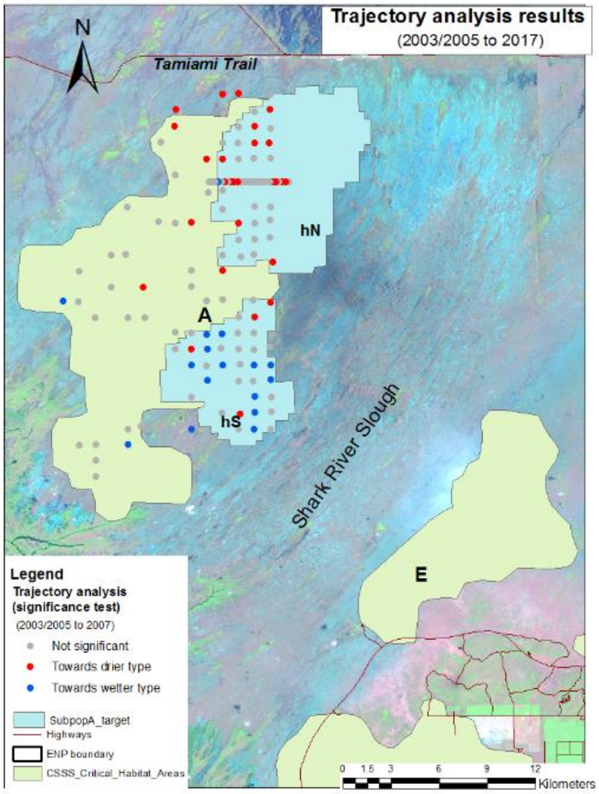

Figure 12: Sites showing a significant shift in vegetation composition between 2003/2005 and 2017 samplings in sub-population A. Significance of site trajectory was obtained by trajectory analysis.

Change in vegetation types on Transect A and Census sites:

In concurrence with a significant difference in overall species composition among sampling years at both census and transect sites, the vegetation type also changed at almost half (48%) of the sites in fifteen years. However, majority (75%) of them showed minimal shift in vegetation composition, resulting them to be in the same two broad categories of vegetation type; marsh or wet prairie vegetation, as recorded before. Nevertheless, while 21% of sites changed from marsh to wet prairie type, suggesting a drying trend in some areas of sub-population A, only few sites (4%) changed from wet prairie to marsh vegetation type (Figure 13). Majority of sites that changed from marsh (M) to wet prairie type (WP) were in hN suggesting the drying trend in northeastern part of the sub-population A.

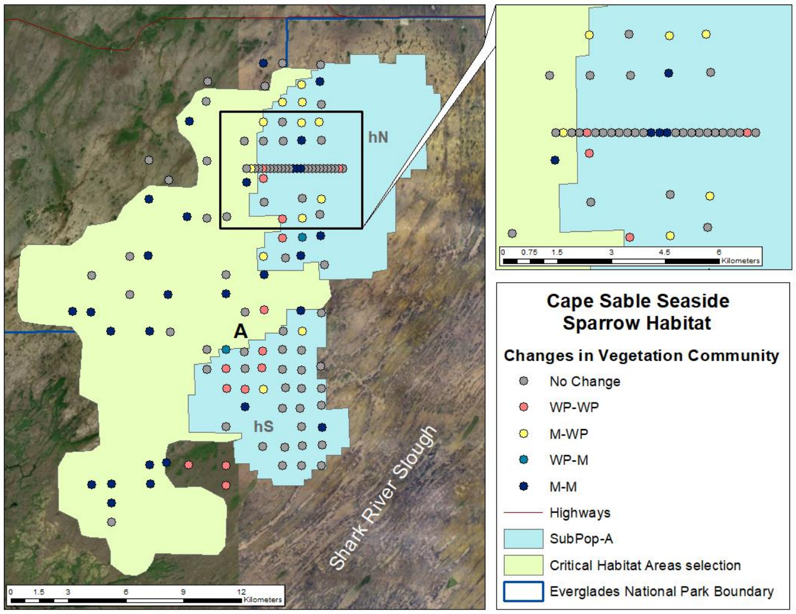

Figure 13: Change in vegetation types at the census and transect sites in sub-population A between first sampling (2003-2005) and 2017 sampling.

Hydrologic conditions at the sites that showed either no change or a change in vegetation type differ significantly. Before 2017 sampling, the mean four-year average hydroperiod was greater than 250 days at the marsh sites that showed no change or a change from one marsh type to another. Similarly, mean hydroperiod was 263 days at the sites that changed from wet prairie to marsh type. In contrast, the sites that remained wet prairie or changed from one wet prairie type to another, the mean hydroperiods were 172 ± 53 and 215 ± 55 days, respectively. The hydrologic condition was much drier at the sites that changed from marsh type to a prairie type. The mean hydroperiod and water depth at those sites were 147 ± 68 days and -7.8 ± 7.0 cm. Over the study period, mean hydroperiod decreased only at the sites that showed either a change from marsh to wet prairie type or the wet prairie sites that did not change in vegetation type. In contrast, mean hydroperiod increased for all other groups of sites, including those that changed from one prairie type to another.

The magnitude and rate of change in vegetation composition, represented by delta and slope in trajectory analysis, were positively correlated with hydrological variables. While the correlation between delta or slope and four-year average hydroperiod and annual mean daily water depth was not so strong ($r <= 0.21$, $p = 0.05$ to 0.1) (Figure 14), both delta and slope were significantly correlated with dry season hydrologic variables, mean ($r = 0.23$, $p = 0.03$) and minimum ($r = 0.31$, $p = 0.004$) water depths (Figure 15). Most of sites that changed from marsh to prairie had four-year mean dry season water level of 10-15 cm (Figure 15a, b) below the ground. At many of those sites, the dry season minimum was <-60 cm (Figure 15c,d), suggesting that dry season water level has important implication on the marl prairie vegetation dynamics.

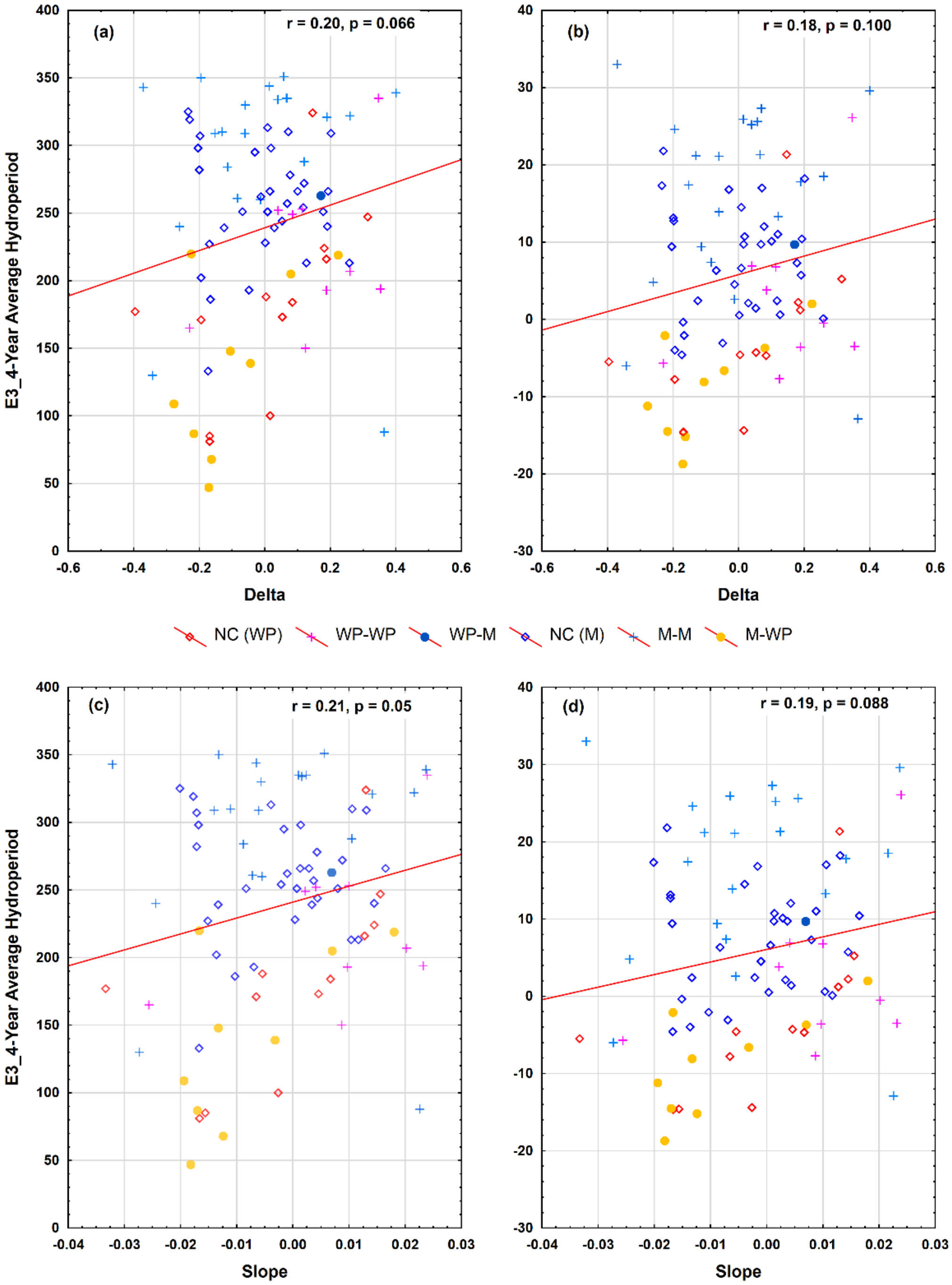

Figure 14: Relationship between 2017 (E3 = Survey 3) dry season hydrologic conditions (4-year mean hydroperiod and water depth) and magnitude (delta) and rate (slope) of vegetation change. Both delta and slope are the statistics obtained in trajectory analysis, representing the shift in position of sites along the defined vector (hydrology) within ordination space. NC = No change; M = Marsh; WP = Wet prairie.

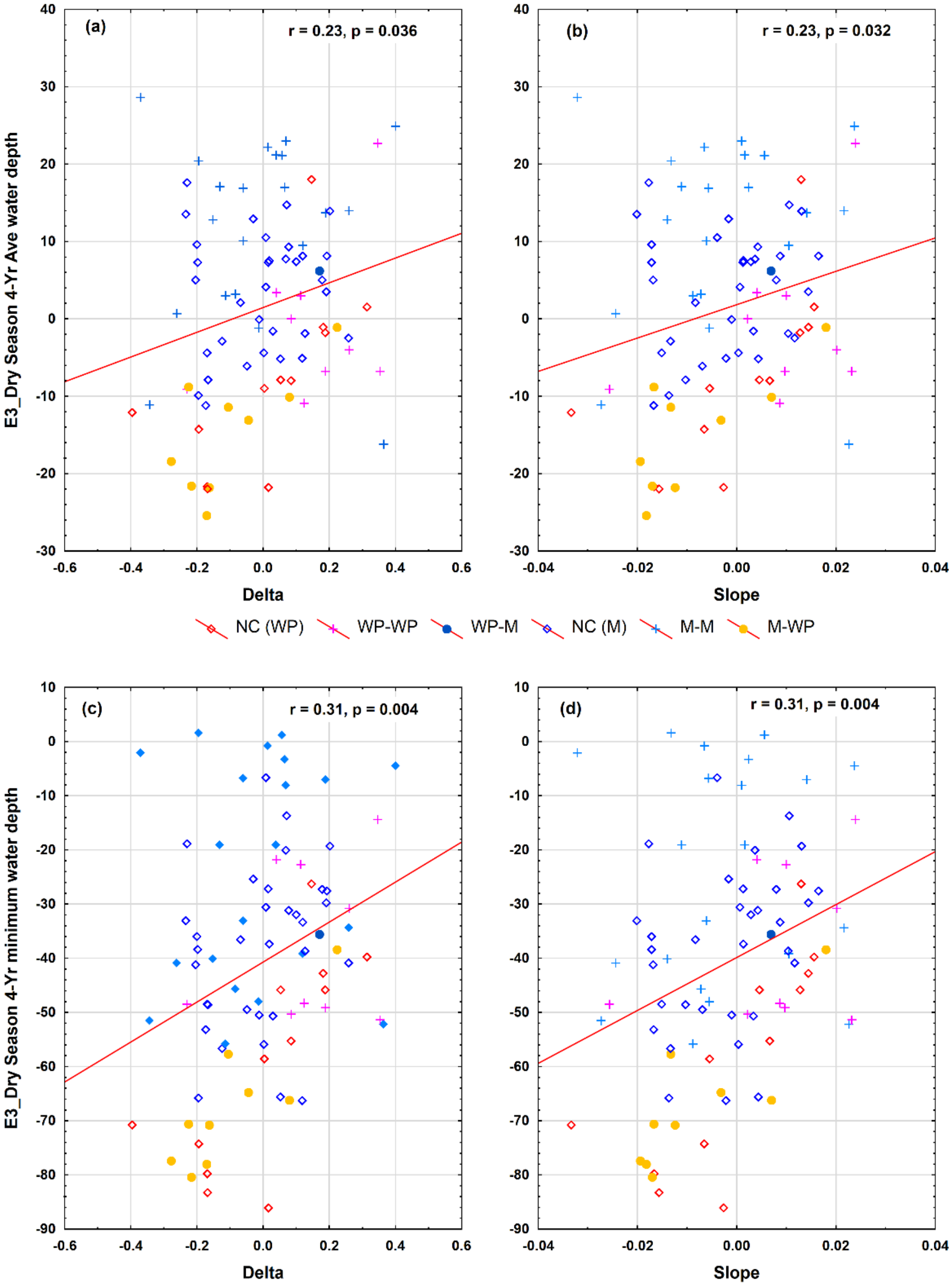

Figure 15: Relationship between 2017 (E3 = Survey 3) dry season hydrologic conditions (4-year dry season mean and minimum water depth) and magnitude (delta) and rate (slope) of vegetation change. Both delta and slope are the statistics obtained in trajectory analysis, representing the shift in position of sites along the defined vector (hydrology) within ordination space. NC = No change; M = Marsh; WP = Wet prairie.

4. Discussion

In the southern Everglades marl prairies, particularly west of Shark River Slough in CSSS sub-population A, hydrologic conditions have changed over one and a half decades (2003-2017), mainly due to changes in water management activities. Such alterations in hydrologic regime have resulted in a shift in vegetation composition that, in harmony with hydrologic change, showed distinct spatial pattern.

Hydrologic alterations are a major cause of habitat degradation in wetlands, including floodplains and other wetland types (Toth et al. 1998; Dudgeon 2000; Acreman et al. 2007). Thus, restoration activities that result in modification of hydrologic characteristics are considered a crucial step in habitat restoration (Acreman et al. 2007). In the Everglades, where preferred habitat of threatened or endangered species were lost or degraded by extreme or multi-decadal practice of hydrologic alteration (Nott et al. 1998; Jenkins et al. 2003; Bennetts et al. 2002), several restoration activities were initiated in 2000 (USACE 1999). These restoration efforts, which involve adaptive water management activities, have already shown improvements in habitat conditions in some regions, and are expected to continue to do so throughout the landscape, especially with the implementation of several projects conceived under Comprehensive Everglades Restoration Plan (CERP) and its recently outlined components, such as Everglades Restoration Transition Plan (ERTP) and Central Everglades Planning Project (CEPP) (USACE 2011; USACE 2014). Even before the implementation, of CERP, guided by the 1999 CSSS Biological Opinion (USACE 1999, USFWS 2002), several water management activities under Interim Operation Plan (IOP) were directed towards improving CSSS habitat that had deteriorated due to extreme water conditions earlier in the1990s. The result was that since 2002, regulatory schedules have been imposed on water deliveries through the S-12s structures. These regulations caused consistently low water levels at NP-205 and nearby areas for several years, resulting in a less hydric vegetation type in the northeastern part of sub-population A (Sah et al. 2011; 2016). In this portion of sub-population A, the trend in vegetation shift towards a drier type, first confirmed in 2010 (Sah et al. 2011), has continued in recent years. Such changes in the vegetation composition was probably the primary reason that sparrows have continued to occupy that part of sub-population A in recent years, though still in low numbers. The trend in improvement in marl prairie habitat conditions is expected to continue under the planned management activities described in CEPP. During CEPP planning, the Refined Recommended Plan (i.e. Alternative 4R2) has been considered the best alternative in comparison to the existing condition baseline (ALT EC) (USACE 2014). In this scenario, flow connectivity between Water Conservation Areas 3A and 3B will be restored and water will be allowed to flow eastward and southward to the Park (USACE 2014), potentially resulting in less water in the prairies west of Shark River Slough. Under that management scenario, the recently observed trend of vegetation change towards a drier type in this part of the CSSS range may be expected to continue.

Short-hydroperiod marl prairies in the Everglades are flooded annually for a varying period, and they remain dry for part of the year. Generally, in seasonally flooded ecosystems like the Everglades marl prairies, species present in the vegetation mosaic are adapted to tolerate the alternating wet/dry conditions that are characteristic of any flood-pulsed environment (Junk and Piedade 1997). 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 are usually the basis for variation in plant species composition. Marl prairie species differ in their hydroperiod optima and tolerances (Ross et al. 2006); hence, any change in duration of periodic inundation is likely to affect their abundance. This is what we observed in sub-population A: a change in water regime that coincided with a change in the relative cover of constituent plant species. However, the resulting change in vegetation was not only a minimal shift in composition, but rather a radical shift in vegetation type from marsh to wet prairie type, and *vice versa*. For instance, in the north-eastern and eastern part of the sub-population, where duration of annual dry-down increased, possibly owing to reduced deliveries through the S12 water structures, a two-fold increase in cover of blue-stem *Schizachyrium rhizomatum* was observed. *S. rhizomatum* has relatively short hydroperiod optimum and is a dominant species of short-hydroperiod marl prairies (Ross et al. 2006). In contrast, the relative cover of species like *Bacopa caroliniana*, *Panicum virgatum*, *Cladium jamaicense*, and *Rhynchospora tracyii*, which are characteristic of relatively long hydroperiod marl prairies, decreased substantially. These species remained dominant or their cover increased in the western portion of sub-population A where hydroperiod has increased in recent years. Depending on the relative contribution of individual species that differ in their optimum hydrologic tolerances, such a shift in species composition in response to hydrologic change was clearly expressed in similar changes in vegetation-inferred hydroperiod. For instance, on Transect A, the vegetation-inferred hydroperiods were significantly shorter in 2010 and 2017 than in 2003 and 2006.

In contrast to the northeastern portion of sub-population A, the areas in the southern and western portion of this sub-population experienced a wetter hydrologic regime than eight years earlier. In this area, vegetation change towards a wetter type in response to more hydric conditions in recent years is indicative of continued deterioration of sparrow habitat. Interestingly, it continued despite achievement of the mandated regulation water levels at NP-205, which resulted in an improved habitat in northeastern and eastern portions of sub-population A. The continued wetting trend in the western portion of sub-population A is partly due to increased runoff from WCA-3A through Big Cypress National Preserve resulting in an increase in flows through the culvert and bridges on Tamiami Trail and 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, apparently contributing to high water levels in the western part of sub-population A. Vegetation in coastal Florida, including the southwestern part of sup-population A, is also influenced by the sea level rise, but the extent of that influence is uncertain. A thorough investigation using species indicators of sea level rise along transects in this portion of CSSS habitat can only help to answer this question.

The more hydric condition than previous sampling events in southeastern portion, hS, was unexpected. More than two thirds of sites sampled in this area showed an increase in vegetation-inferred hydroperiod. Likewise, most of the sites that showed a significant shift in trajectory in the ordination toward increasing wetness were in this region. Since this region has been identified as potential future improved habitat, regular monitoring of sites will ascertain the direction of vegetation change in response to change in hydrologic conditions due to future restoration activities associated with CEPP and other components of CERP (USCACE 2014; USFWS 2016).

Finally, in the western marl prairies, spatially differentiated trends in habitat characteristics observed in this study suggest that the limited numbers of sparrows that remain in sub-population A will continue to be restricted to the northeastern and eastern portion of the habitat. In the given scenarios, that increasing sea level and restoration activities aimed at increasing the water delivery into the Park through Northeast Shark River Slough would adversely affect the western and southeastern portions of the sub-population A, the management may have little option except assisted improvement of habitat quality in the northeastern and central-eastern portion of this sub-population. However, if increasing sparrow populations west of Shark River Slough is the objective, then ideally, the strategies that achieve desirable sparrow habitat conditions throughout the region while satisfying the broader ecosystem restoration goals of the Comprehensive Everglades Restoration Plan (CERP) should be considered.

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Appendices

Appendix A1: List of vegetation survey sites sampled in 2017.

Sub pop.	C_T	Year established	Site ID	X_NAD83	Y_NAD83	Funding Source
A	Census	2003	A-01-02	513139.0	2846878.0	ENP
A	Census	2003	A-01-03	514119.0	2846904.0	ENP
A	Census	2003	A-01-06	515125.0	2844858.0	USACE
A	Census	2003	A-01-07	514102.0	2843847.0	ENP
A	Census	2003	A-01-08	516146.0	2842899.0	ENP
A	Census	2003	A-03-02	513155.0	2834079.0	ENP
A	Census	2003	A-03-04	515132.0	2832965.0	ENP
A	Census	2003	A-03-05	516090.0	2831118.0	ENP
A	Census	2003	A-03-06	515089.0	2830946.0	USACE
A	Census	2003	A-03-07	513029.0	2831037.0	USACE
A	Census	2003	A-03-08	511174.0	2831001.0	USACE
A	Census	2003	A-03-09	511168.0	2831996.0	USACE
A	Census	2003	A-03-10	510182.0	2832018.0	ENP
A	Census	2003	A-04-02	512186.0	2829011.0	USACE
A	Census	2003	A-04-03	514251.0	2830027.0	ENP
A	Census	2003	A-04-04	516131.0	2829091.0	USACE
A	Census	2003	A-04-05	515117.0	2828015.0	USACE
A	Census	2003	A-04-06	515133.0	2827012.0	ENP
A	Census	2003	A-04-07	516163.0	2827057.0	USACE
A	Census	2006	A-04-08	515108.0	2825981.0	USACE
A	Census	2006	A-04-09	514123.0	2825976.0	USACE
A	Census	2003	A-05-02	505216.0	2823052.0	ENP
A	Census	2003	A-05-03	505226.0	2824020.0	ENP
A	Census	2003	A-05-04	505225.0	2825013.0	ENP
A	Census	2003	A-05-05	507234.0	2825015.0	ENP
A	Census	2003	A-06-06	507215.0	2826006.0	ENP
A	Census	2003	A-06-10	509227.0	2826008.0	ENP
A	Census	2004	A-07-07	507216.0	2832954.0	ENP
A	Census	2003	A-08-01	503198.0	2833998.0	ENP
A	Census	2003	A-08-08	507113.0	2836904.0	ENP
A	Census	2003	A-09-02	507173.0	2839844.0	ENP
A	Census	2003	A-09-04	509143.0	2838908.0	ENP
A	Census	2003	A-09-08	511185.0	2835905.0	ENP
A	Census	2003	A-09-09	511196.0	2838896.0	ENP
A	Census	2003	A-09-10	513152.0	2835885.0	ENP
A	Census	2004	A-10-01	511203.0	2829990.0	USACE
A	Census	2004	A-10-02	512167.0	2831000.0	ENP
A	Census	2004	A-10-03	513091.0	2831909.0	ENP

Sub pop.	C_T	Year established	Site ID	X_NAD83	Y_NAD83	Funding Source
A	Census	2004	A-10-04	514126.0	2830961.0	USACE
A	Census	2004	A-10-07	516154.0	2833899.0	USACE
A	Census	2004	A-11-02	514273.0	2836753.0	USACE
A	Census	2004	A-11-03	515074.0	2836883.0	USACE
A	Census	2004	A-11-04	516286.0	2836395.0	USACE
A	Census	2004	A-11-05	516105.0	2837908.0	USACE
A	Census	2004	A-11-06	515127.0	2837851.0	USACE
A	Census	2004	A-11-07	514118.0	2837794.0	USACE
A	Census	2004	A-11-08	514123.0	2838811.0	USACE
A	Census	2004	A-12-05	511187.0	2827984.0	USACE
A	Census	2004	A-12-07	513083.0	2826972.0	USACE
A	Census	2004	A-12-08	514248.0	2826938.0	USACE
A	Census	2004	A-12-09	516129.0	2825994.0	USACE
A	Census	2004	A-12-10	516163.0	2827975.0	USACE
A	Census	2004	A-13-01	504181.0	2824977.0	ENP
A	Census	2004	A-15-02	504153.0	2833951.0	ENP
A	Census	2004	A-15-04	505171.0	2832943.0	ENP
A	Census	2004	A-17-03	510174.0	2838837.0	ENP
A	Census	2004	A-17-08	513139.0	2836852.0	USACE
A	Census	2004	A-19-03	512122.0	2842830.0	ENP
A	Census	2004	A-19-04	515100.0	2842892.0	USACE
A	Census	2004	A-19-06	513112.0	2840887.0	USACE
A	Census	2004	A-19-08	515144.0	2839865.0	ENP
A	Census	2004	A-19-09	515136.0	2838845.0	ENP
A	Census	2004	A-19-10	516073.0	2839044.0	USACE
A	Census	2004	A-20-05	513181.0	2845696.0	ENP
A	Census	2004	A-20-06	516073.0	2845920.0	USACE
A	Census	2004	A-20-07	516149.0	2844757.0	USACE
A	Census	2005	A-21-02	510218.0	2845943.0	ENP
A	Census	2005	A-21-03	510151.0	2844890.0	ENP
A	Census	2005	A-21-05	509283.0	2843872.0	ENP
A	Census	2005	A-22-01	516104.0	2846819.0	ENP
A	Census	2005	A-22-02	515118.0	2845783.0	USACE
A	Census	2005	A-22-03	514116.0	2844847.0	USACE
A	Census	2005	A-22-04	513113.0	2843822.0	USACE
A	Census	2005	A-22-05	513134.0	2842827.0	USACE
A	Census	2005	A-22-08	514134.0	2842821.0	ENP
A	Census	2005	A-22-09	515116.0	2843812.0	USACE
A	Census	2005	A-22-10	516024.0	2843849.0	USACE
A	Census	2005	A-23-01	510168.0	2841826.0	ENP
A	Census	2005	A-23-04	512252.0	2840716.0	ENP

Sub pop.	C_T	Year established	Site ID	X_NAD83	Y_NAD83	Funding Source
A	Census	2005	A-23-08	513149.0	2839676.0	ENP
A	Census	2005	A-23-10	516135.0	2839836.0	USACE
A	Census	2005	A-24-02	507169.0	2841834.0	ENP
A	Census	2005	A-24-05	508190.0	2840801.0	ENP
A	Census	2005	A-25-04	504188.0	2835849.0	ENP
A	Census	2005	A-25-07	506180.0	2836853.0	ENP
A	Census	2005	A-26-02	506190.0	2834854.0	ENP
A	Census	2005	A-26-03	508179.0	2834854.0	ENP
A	Census	2005	A-26-05	511172.0	2834890.0	ENP
A	Census	2005	A-27-01	512150.0	2833964.0	ENP
A	Census	2005	A-27-02	512145.0	2831869.0	USACE
A	Census	2005	A-27-04	514096.0	2831997.0	USACE
A	Census	2005	A-27-05	515104.0	2831980.0	USACE
A	Census	2005	A-27-06	514137.0	2832972.0	USACE
A	Census	2005	A-27-07	515060.0	2834026.0	USACE
A	Census	2005	A-28-10	508265.0	2832912.0	ENP
A	Census	2005	A-29-07	508062.0	2826150.0	ENP
A	Census	2005	A-29-09	511189.0	2825973.0	ENP
A	Census	2005	A-29-10	511192.0	2824959.0	ENP
A	Census	2005	A-30-01	510186.0	2830972.0	ENP
A	Census	2005	A-30-04	512152.0	2829941.0	USACE
A	Census	2005	A-30-05	513124.0	2829962.0	ENP
A	Census	2005	A-30-06	515090.0	2829964.0	ENP
A	Census	2005	A-30-07	516118.0	2829970.0	USACE
A	Census	2005	A-30-08	515041.0	2828959.0	USACE
A	Census	2005	A-30-09	514119.0	2828965.0	ENP
A	Transect	2003	TA-0000	517265.0	2841401.0	ENP
A	Transect	2003	TA-0200	517065.0	2841401.0	ENP
A	Transect	2003	TA-0400	516865.0	2841401.0	ENP
A	Transect	2003	TA-0600	516665.0	2841401.0	ENP
A	Transect	2003	TA-0800	516446.0	2841401.0	ENP
A	Transect	2003	TA-1000	516265.0	2841401.0	ENP
A	Transect	2003	TA-1200	516065.0	2841401.0	ENP
A	Transect	2003	TA-1400	515865.0	2841401.0	ENP
A	Transect	2003	TA-1600	515665.0	2841401.0	ENP
A	Transect	2003	TA-1800	515465.0	2841401.0	ENP
A	Transect	2003	TA-2000	515265.0	2841401.0	ENP
A	Transect	2003	TA-2200	515065.0	2841401.0	ENP
A	Transect	2003	TA-2380	514865.0	2841401.0	ENP
A	Transect	2003	TA-2600	514665.0	2841401.0	ENP
A	Transect	2003	TA-2800	514465.0	2841401.0	ENP

Sub pop.	**C_T**	**Year established**	**Site ID**	**X_NAD83**	**Y_NAD83**	**Funding Source**
A	Transect	2003	TA-3000	514264.0	2841401.0	ENP
A	Transect	2003	TA-3200	514065.0	2841401.0	ENP
A	Transect	2003	TA-3400	513865.0	2841401.0	ENP
A	Transect	2003	TA-3600	513665.0	2841401.0	ENP
A	Transect	2003	TA-3800	513465.0	2841401.0	ENP
A	Transect	2003	TA-4000	513265.0	2841401.0	ENP
A	Transect	2003	TA-4200	513064.0	2841401.0	ENP
A	Transect	2003	TA-4400	512865.0	2841401.0	ENP
A	Transect	2003	TA-4600	512665.0	2841401.0	ENP
A	Transect	2003	TA-4800	512465.0	2841401.0	ENP
A	Transect	2003	TA-5000	512265.0	2841401.0	ENP
A	Census	2017	A-35-06	521110.0	2847017.0	USACE
A	Census	2017	A-35-07	521109.0	2846017.0	USACE
A	Census	2017	A-35-08	521109.0	2845017.0	USACE
A	Census	2017	A-35-09	521109.0	2844017.0	USACE
A	Census	2017	A-35-10	519084.0	2838044.0	USACE
A	Census	2017	A-36-01	519084.0	2837044.0	USACE
A	Census	2017	A-36-02	514268.0	2828296.0	USACE
A	Census	2017	A-36-03	512172.0	2827242.0	USACE
A	Census	2017	A-36-04	512207.0	2828170.0	USACE
A	Census	2017	A-36-05	512207.0	2827170.0	USACE
A	Transect	2017	TAS-1000	515195.0	2829486.0	USACE
A	Transect	2017	TAS-1200	514995.0	2829486.0	USACE
A	Transect	2017	TAS-1400	514795.0	2829486.0	USACE
A	Transect	2017	TAS-1600	514595.0	2829486.0	USACE
A	Transect	2017	TAS-2000	514195.0	2829486.0	USACE
A	Transect	2017	TAS-2400	513795.0	2829486.0	USACE
A	Transect	2017	TAS-2600	513595.0	2829486.0	USACE
A	Transect	2017	TAS-2800	513377.0	2829523.0	USACE
A	Transect	2017	TAS-3000	513213.0	2829491.0	USACE
A	Transect	2017	TAS-3200	512995.0	2829486.0	USACE
A	Transect	2017	TAS-3400	512795.0	2829486.0	USACE
A	Transect	2017	TAS-3600	512595.0	2829486.0	USACE
A	Transect	2017	TAS-3800	512395.0	2829486.0	USACE
A	Transect	2017	TAS-4000	512195.0	2829486.0	USACE
A	Transect	2017	TAS-4200	511995.0	2829486.0	USACE
A	Transect	2017	TAS-4400	511795.0	2829486.0	USACE
A	Transect	2017	TAS-4600	511595.0	2829486.0	USACE
A	Transect	2017	TAS-4800	511395.0	2829486.0	USACE
A	Transect	2017	TAS-5000	511195.0	2829486.0	USACE
E	Transect	2017	TE-90100	533865.4	2820122.4	USACE

Sub pop.	C_T	Year established	Site ID	X_NAD83	Y_NAD83	Funding Source
E	Transect	2017	TE-90200	533965.2	2820116.3	USACE
E	Transect	2017	TE-90300	534065.0	2820110.1	USACE
E	Transect	2017	TE-90400	534164.8	2820103.9	USACE
E	Transect	2017	TE-90500	534264.6	2820097.8	USACE
E	Transect	2017	TE-90600	534364.4	2820091.6	USACE
E	Transect	2017	TE-90700	534464.2	2820085.5	USACE
E	Transect	2018	TE-90800	534464.0	2820079.4	USACE
E	Transect	2017	TE-91700	535462.3	2820023.9	USACE
E	Transect	2017	TE-91800	535562.1	2820017.7	USACE
E	Transect	2017	TE-91900	535662.0	2820011.6	USACE
E	Transect	2017	TE-92000	535761.8	2820005.4	USACE
E	Transect	2017	TE-92100	535861.6	2819999.3	USACE
E	Transect	2017	TE-92200	535961.4	2819993.1	USACE
E	Transect	2017	TE-92300	536061.2	2819987.0	USACE
E	Transect	2017	TE-92400	536161.0	2819980.8	USACE
E	Transect	2017	TE-92500	536260.8	2819974.7	USACE
E	Transect	2017	TE-92600	536360.6	2819968.5	USACE
E	Transect	2017	TE-92700	536460.4	2819962.3	USACE
E	Transect	2017	TE-92800	536560.2	2819956.2	USACE
E	Transect	2017	TE-92900	536660.1	2819950.0	USACE
E	Transect	2017	TE-93000	536759.9	2819943.9	USACE
E	Transect	2017	TE-93100	536859.7	2819937.7	USACE
E	Transect	2017	TE-93200	536959.5	2819931.6	USACE

Appendix A2: Vegetation type for all sites, and delta and slope (amount and rate of change in the target direction, respectively) for sites sampled at least three times between 2003 and 2017. Vegetation types were determined using the cluster analysis. Delta and Slope were calculated using trajectory analysis, in which the base year for change in vegetation was the 1st year of sampling, and the hydrology vector represent the increasing wetness in the non-metric multidimensional scaling (NMDS) ordination. Statistical significance ($p \leq 0.1$) of delta and slope was tested using Monte Carlo's simulations with 10,000 permutations.

Sub-pop.	C_T	Year estd.	Field ID	Vegetation type-1 (2003-2005)	Vegetation type-2 (2007)	Delta	Prob	Slope	Prob
A	Census	2003	A-01-02	*Cladium-Rhynchospora* Marsh	*Cladium* Marsh	-0.343	**0.003**	-0.027	**0.001**
A	Census	2003	A-01-03	*Cladium* Marsh	*Cladium* Marsh	-0.166	**0.054**	-0.010	**0.061**
A	Census	2003	A-01-06	*Cladium-Rhynchospora* Marsh	*Cladium* Wet Prairie	-0.171	0.133	-0.018	**0.044**
A	Census	2003	A-01-07	*Schizachyrium Wet Prairie*	*Schizachyrium Wet Prairie*	-0.168	0.253	-0.017	0.158
A	Census	2003	A-01-08	*Rhynchospora-Cladium* Marsh	*Rhynchospora-Cladium* Marsh	0.118	0.272	-0.002	0.433
A	Census	2003	A-03-02	*Schizachyrium Wet Prairie*	*Cladium* Wet Prairie	0.085	0.314	0.002	0.424
A	Census	2003	A-03-04	*Cladium* Marsh	*Cladium* Wet Prairie	-0.106	0.237	-0.013	**0.093**
A	Census	2003	A-03-05	*Cladium-Rhynchospora* Marsh	*Cladium-Rhynchospora* Marsh	0.101	0.308	0.003	0.367
A	Census	2003	A-03-06	*Cladium* Marsh	*Cladium* Marsh	0.078	0.109	0.004	0.157
A	Census	2003	A-03-07	*Schizachyrium Wet Prairie*	*Cladium* Wet Prairie	0.188	0.107	0.010	0.182
A	Census	2003	A-03-08	*Schizachyrium Wet Prairie*	*Cladium* Wet Prairie	-0.230	0.152	-0.026	**0.045**
A	Census	2003	A-03-09	*Cladium* Wet Prairie	*Cladium-Rhynchospora* Marsh	0.171	0.142	0.007	0.277
A	Census	2003	A-03-10	*Schizachyrium Wet Prairie*	*Schizachyrium Wet Prairie*	0.315	0.107	0.016	0.183
A	Census	2003	A-04-02	*Cladium* Marsh	*Cladium-Rhynchospora* Marsh	0.364	**0.007**	0.023	**0.013**
A	Census	2003	A-04-03	*Cladium-Rhynchospora* Marsh	*Cladium-Rhynchospora* Marsh	0.259	**0.043**	0.012	0.122
A	Census	2003	A-04-04	*Cladium-Rhynchospora* Marsh	*Cladium-Rhynchospora* Marsh	0.191	0.121	0.015	**0.077**
A	Census	2003	A-04-05	*Cladium* Marsh	*Cladium* Marsh	0.179	**0.011**	0.008	**0.061**
A	Census	2003	A-04-06	*Cladium-Rhynchospora* Marsh	*Cladium-Rhynchospora* Marsh	0.072	0.275	0.011	**0.064**
A	Census	2003	A-04-07	*Cladium* Marsh	*Cladium* Marsh	0.069	**0.066**	0.004	0.106
A	Census	2006	A-04-08	*Cladium* Marsh	*Cladium* Marsh	0.048	**0.059**	0.004	**0.059**
A	Census	2006	A-04-09	*Cladium* Marsh	*Cladium* Marsh	-0.049	0.360	-0.005	0.360
A	Census	2003	A-05-02	*Cladium-Rhynchospora* Marsh	*Cladium-Rhynchospora* Marsh	0.009	0.507	-0.004	0.362
A	Census	2003	A-05-03	*Cladium-Rhynchospora* Marsh	*Cladium* Marsh	-0.195	0.145	-0.013	0.121
A	Census	2003	A-05-04	*Cladium-Rhynchospora* Marsh	*Eleocharis-Rhynchospora* Marsh	0.066	0.381	0.002	0.439
A	Census	2003	A-05-05	*Rhynchospora-Cladium* Marsh	*Eleocharis-Rhynchospora* Marsh	0.189	**0.081**	0.014	**0.056**

Sub-pop.	C_T	Year estd.	Field ID	Vegetation type-1 (2003-2005)	Vegetation type-2 (2007)	Delta	Prob	Slope	Prob
A	Census	2003	A-06-06	*Cladium-Rhynchospora* Marsh	*Cladium* Marsh	-0.060	0.280	-0.006	0.186
A	Census	2003	A-06-10	*Schizachyrium Wet Prairie*	*Cladium* Wet Prairie	0.114	0.268	0.010	0.189
A	Census	2004	A-07-07	*Rhynchospora-Cladium* Marsh	*Eleocharis-Rhynchospora* Marsh	-0.130	0.156	-0.011	0.125
A	Census	2003	A-08-01	*Cladium-Rhynchospora* Marsh	*Eleocharis-Rhynchospora* Marsh	0.400	**0.023**	0.024	**0.040**
A	Census	2003	A-08-08	*Cladium-Rhynchospora* Marsh	*Rhynchospora-Cladium* Marsh	0.039	0.401	0.002	0.448
A	Census	2003	A-09-02	*Rhynchospora-Cladium* Marsh	*Cladium-Rhynchospora* Marsh	-0.060	0.291	-0.006	0.203
A	Census	2003	A-09-04	*Cladium-Rhynchospora* Marsh	*Eleocharis-Rhynchospora* Marsh	0.260	0.255	0.022	0.243
A	Census	2003	A-09-08	*Cladium* Wet Prairie	*Cladium* Wet Prairie	0.004	0.498	-0.005	0.272
A	Census	2003	A-09-09	*Cladium* Marsh	*Cladium* Marsh	-0.124	0.131	-0.013	**0.033**
A	Census	2003	A-09-10	*Rhynchospora-Cladium* Marsh	*Cladium-Rhynchospora* Marsh	-0.152	0.180	-0.014	**0.092**
A	Census	2004	A-10-01	*Schizachyrium Wet Prairie*	*Muhlenbergia* Wet Prairie	0.347	**0.063**	0.024	**0.080**
A	Census	2004	A-10-02	*Schizachyrium Wet Prairie*	*Schizachyrium Wet Prairie*	0.182	**0.094**	0.015	**0.083**
A	Census	2004	A-10-03	*Schizachyrium Wet Prairie*	*Cladium* Wet Prairie	0.353	**0.019**	0.023	**0.043**
A	Census	2004	A-10-04	*Cladium* Marsh	*Cladium* Marsh	0.120	0.183	0.009	0.186
A	Census	2004	A-10-07	*Cladium* Marsh	*Cladium* Marsh	-0.199	0.109	-0.017	**0.074**
A	Census	2004	A-11-02	*Cladium* Marsh	*Cladium* Marsh	-0.245	**0.066**	-0.015	0.104
A	Census	2004	A-11-03	*Cladium* Marsh	*Cladium-Rhynchospora* Marsh	-0.145	0.139	-0.011	0.151
A	Census	2004	A-11-04	*Cladium* Marsh	*Cladium* Marsh	-0.225	**0.025**	-0.015	**0.047**
A	Census	2004	A-11-05	*Cladium-Rhynchospora* Marsh	*Rhynchospora-Cladium* Marsh	-0.025	0.462	0.001	0.480
A	Census	2004	A-11-06	*Cladium* Wet Prairie	*Cladium* Marsh	-0.159	0.178	-0.014	0.122
A	Census	2004	A-11-07	*Schizachyrium Wet Prairie*	*Muhlenbergia* Wet Prairie	0.090	0.382	0.009	0.334
A	Census	2004	A-11-08	*Cladium* Wet Prairie	*Schizachyrium Wet Prairie*	-0.428	**0.003**	-0.034	**0.002**
A	Census	2004	A-12-05	*Cladium* Wet Prairie	*Cladium* Wet Prairie	-0.006	0.476	-0.001	0.435
A	Census	2004	A-12-07	*Cladium* Marsh	*Cladium* Marsh	0.093	0.243	0.005	0.299
A	Census	2004	A-12-08	*Cladium* Marsh	*Cladium* Marsh	-0.208	**0.062**	-0.015	**0.073**
A	Census	2004	A-12-09	*Cladium* Marsh	*Cladium* Marsh	0.106	0.108	0.007	0.111
A	Census	2004	A-12-10	*Cladium* Marsh	*Cladium-Rhynchospora* Marsh	0.041	0.386	0.003	0.365
A	Census	2004	A-13-01	*Cladium-Rhynchospora* Marsh	*Cladium* Marsh	0.058	0.363	0.006	0.305
A	Census	2004	A-15-02	*Cladium-Rhynchospora* Marsh	*Cladium* Marsh	-0.371	0.120	-0.032	0.103

Sub-pop.	**C_T**	**Year estd.**	**Field ID**	**Vegetation type-1 (2003-2005)**	**Vegetation type-2 (2007)**	**Delta**	**Prob**	**Slope**	**Prob**
A	Census	2004	A-15-04	*Cladium* Marsh	*Cladium-Rhynchospora* Marsh	0.069	0.349	0.001	0.396
A	Census	2004	A-17-03	*Cladium* Marsh	*Cladium* Marsh	0.002	0.487	0.000	0.455
A	Census	2004	A-17-08	*Paspalum-Cladium* Marsh	*Schizachyrium Wet Prairie*	-0.226	0.181	-0.014	0.219
A	Census	2004	A-19-03	*Cladium* Marsh	*Cladium* Marsh	-0.194	**0.029**	-0.014	**0.049**
A	Census	2004	A-19-04	*Cladium* Marsh	*Cladium-Rhynchospora* Marsh	0.030	0.358	0.002	0.335
A	Census	2004	A-19-06	*Cladium* Wet Prairie	*Schizachyrium Wet Prairie*	-0.109	0.274	-0.004	0.355
A	Census	2004	A-19-08	*Schizachyrium Wet Prairie*	*Schizachyrium Wet Prairie*	0.017	0.461	-0.003	0.443
A	Census	2004	A-19-09	*Cladium-Rhynchospora* Marsh	*Cladium* Wet Prairie	-0.225	0.104	-0.017	0.107
A	Census	2004	A-19-10	*Schizachyrium Wet Prairie*	*Schizachyrium Wet Prairie*	-0.194	0.149	-0.007	0.354
A	Census	2004	A-20-05	*Rhynchospora-Cladium* Marsh	*Rhynchospora-Cladium* Marsh	-0.197	0.182	-0.017	0.130
A	Census	2004	A-20-06	*Cladium* Marsh	*Paspalum-Cladium* Marsh	-0.449	**0.001**	-0.035	**0.002**
A	Census	2004	A-20-07	*Schoenus* Wet Prairie	*Schoenus* Wet Prairie	-0.090	0.357	-0.004	0.422
A	Census	2005	A-21-02	*Cladium-Rhynchospora* Marsh	*Cladium-Rhynchospora* Marsh	-0.169	**0.010**	-0.015	**0.004**
A	Census	2005	A-21-03	*Cladium* Marsh	*Cladium* Marsh	-0.204	**0.011**	-0.017	**0.007**
A	Census	2005	A-21-05	*Cladium* Marsh	*Cladium-Rhynchospora* Marsh	-0.013	0.477	-0.006	0.261
A	Census	2005	A-22-01	*Rhynchospora-Cladium* Marsh	*Rhynchospora-Cladium* Marsh	-0.173	0.369	-0.017	0.325
A	Census	2005	A-22-02	*Cladium* Marsh	*Cladium* Wet Prairie	-0.163	0.127	-0.012	0.146
A	Census	2005	A-22-03	*Cladium* Marsh	*Cladium* Wet Prairie	-0.044	0.357	-0.003	0.344
A	Census	2005	A-22-04	*Cladium* Marsh	*Cladium* Wet Prairie	0.079	0.216	0.007	0.185
A	Census	2005	A-22-05	*Schoenus* Wet Prairie	*Schoenus* Wet Prairie	-0.395	**0.028**	-0.033	**0.029**
A	Census	2005	A-22-08	*Schizachyrium Wet Prairie*	*Schizachyrium Wet Prairie*	-0.168	0.166	-0.016	0.144
A	Census	2005	A-22-09	*Cladium* Marsh	*Cladium* Wet Prairie	-0.278	**0.022**	-0.019	**0.046**
A	Census	2005	A-22-10	*Cladium-Rhynchospora* Marsh	*Cladium* Wet Prairie	-0.217	**0.071**	-0.017	**0.086**
A	Census	2005	A-23-01	*Cladium-Rhynchospora* Marsh	*Cladium-Rhynchospora* Marsh	-0.012	0.408	-0.001	0.408
A	Census	2005	A-23-04	*Cladium-Rhynchospora* Marsh	*Cladium* Marsh	-0.114	0.165	-0.009	0.178
A	Census	2005	A-23-08	*Paspalum-Cladium* Marsh	*Paspalum-Cladium* Marsh	0.053	0.363	0.004	0.363
A	Census	2005	A-23-10	*Paspalum-Cladium* Marsh	*Cladium* Wet Prairie	-0.050	0.404	-0.005	0.372
A	Census	2005	A-24-02	*Rhynchospora-Cladium* Marsh	*Rhynchospora-Cladium* Marsh	0.019	0.447	0.001	0.479
A	Census	2005	A-24-05	*Eleocharis-Rhynchospora* Marsh	*Eleocharis-Rhynchospora* Marsh	-0.233	0.223	-0.020	0.221

Sub-pop.	**C_T**	**Year estd.**	**Field ID**	**Vegetation type-1 (2003-2005)**	**Vegetation type-2 (2007)**	**Delta**	**Prob**	**Slope**	**Prob**
A	Census	2005	A-25-04	*Rhynchospora-Cladium* Marsh	*Rhynchospora-Cladium* Marsh	0.203	0.153	0.013	0.214
A	Census	2005	A-25-07	*Rhynchospora-Cladium* Marsh	*Rhynchospora-Cladium* Marsh	-0.068	0.322	-0.008	0.286
A	Census	2005	A-26-02	*Eleocharis-Rhynchospora* Marsh	*Eleocharis-Rhynchospora* Marsh	-0.229	**0.063**	-0.018	0.101
A	Census	2005	A-26-03	*Rhynchospora-Cladium* Marsh	*Cladium-Rhynchospora* Marsh	-0.260	**0.016**	-0.024	**0.006**
A	Census	2005	A-26-05	*Cladium* Marsh	*Cladium-Rhynchospora* Marsh	-0.084	0.199	-0.007	0.188
A	Census	2005	A-27-01	*Cladium-Rhynchospora* Marsh	*Cladium-Rhynchospora* Marsh	0.030	0.366	0.003	0.338
A	Census	2005	A-27-02	*Cladium* Wet Prairie	*Cladium* Wet Prairie	0.147	**0.097**	0.013	**0.080**
A	Census	2005	A-27-04	*Schizachyrium Wet Prairie*	*Schizachyrium Wet Prairie*	0.188	**0.058**	0.013	0.105
A	Census	2005	A-27-05	*Cladium* Marsh	*Cladium* Marsh	-0.048	0.323	-0.007	0.226
A	Census	2005	A-27-06	*Schizachyrium Wet Prairie*	*Schizachyrium Wet Prairie*	0.085	0.265	0.007	0.255
A	Census	2005	A-27-07	*Cladium* Marsh	*Cladium-Rhynchospora* Marsh	0.120	0.216	0.011	0.186
A	Census	2005	A-28-10	*Eleocharis-Rhynchospora* Marsh	*Eleocharis-Rhynchospora* Marsh	-0.030	0.429	-0.002	0.455
A	Census	2005	A-29-07	*Cladium* Marsh	*Cladium-Rhynchospora* Marsh	0.014	0.478	-0.007	0.295
A	Census	2005	A-29-09	*Muhlenbergia* Wet Prairie	*Cladium* Wet Prairie	0.260	**0.062**	0.020	**0.080**
A	Census	2005	A-29-10	*Schizachyrium Wet Prairie*	*Cladium* Wet Prairie	0.040	0.416	0.004	0.406
A	Census	2005	A-30-01	*Schizachyrium Wet Prairie*	*Schizachyrium Wet Prairie*	0.054	0.360	0.005	0.366
A	Census	2005	A-30-04	*Cladium* Wet Prairie	*Muhlenbergia* Wet Prairie	0.124	0.176	0.009	0.216
A	Census	2005	A-30-05	*Cladium* Marsh	*Cladium* Wet Prairie	0.224	**0.054**	0.018	**0.050**
A	Census	2005	A-30-06	*Cladium* Marsh	*Cladium* Marsh	0.127	**0.083**	0.010	**0.088**
A	Census	2005	A-30-07	*Cladium* Marsh	*Cladium* Marsh	0.193	**0.022**	0.017	**0.021**
A	Census	2005	A-30-08	*Cladium* Marsh	*Cladium* Marsh	0.016	0.464	0.001	0.464
A	Census	2005	A-30-09	*Cladium* Marsh	*Cladium* Marsh	0.009	0.470	0.001	0.470
A	Transect	2003	TA-0000	*Schizachyrium Wet Prairie*	*Schizachyrium Wet Prairie*	0.170	0.219	0.010	0.258
A	Transect	2003	TA-0200	*Cladium* Wet Prairie	*Schizachyrium Wet Prairie*	0.516	**0.011**	0.041	**0.004**
A	Transect	2003	TA-0400	*Schizachyrium Wet Prairie*	*Schizachyrium Wet Prairie*	0.241	0.107	0.019	**0.086**
A	Transect	2003	TA-0600	*Schizachyrium Wet Prairie*	*Schizachyrium Wet Prairie*	0.034	0.430	0.010	0.219
A	Transect	2003	TA-0800	*Schizachyrium Wet Prairie*	*Schizachyrium Wet Prairie*	0.317	0.133	0.027	**0.074**
A	Transect	2003	TA-1000	*Schizachyrium Wet Prairie*	*Schizachyrium Wet Prairie*	0.440	**0.017**	0.028	**0.026**
A	Transect	2003	TA-1200	*Schizachyrium Wet Prairie*	*Schizachyrium Wet Prairie*	0.308	0.128	0.022	0.112

Sub-pop.	C_T	Year estd.	Field ID	Vegetation type-1 (2003-2005)	Vegetation type-2 (2007)	Delta	Prob	Slope	Prob
A	Transect	2003	TA-1400	*Schizachyrium Wet Prairie*	*Schizachyrium Wet Prairie*	0.163	0.295	0.012	0.280
A	Transect	2003	TA-1600	*Cladium* Wet Prairie	*Cladium* Wet Prairie	0.027	0.459	0.008	0.317
A	Transect	2003	TA-1800	*Cladium* Marsh	*Cladium* Marsh	0.068	0.367	0.010	0.191
A	Transect	2003	TA-2000	*Cladium-Rhynchospora* Marsh	*Cladium-Rhynchospora* Marsh	-0.064	0.449	-0.009	0.390
A	Transect	2003	TA-2200	*Cladium* Marsh	*Cladium-Rhynchospora* Marsh	0.161	0.240	0.011	0.235
A	Transect	2003	TA-2400	*Cladium-Rhynchospora* Marsh	*Cladium* Marsh	-0.098	0.347	0.001	0.485
A	Transect	2003	TA-2600	*Cladium* Marsh	*Cladium-Rhynchospora* Marsh	0.186	0.254	0.021	0.139
A	Transect	2003	TA-2800	*Schizachyrium Wet Prairie*	*Schizachyrium Wet Prairie*	0.045	0.466	0.001	0.504
A	Transect	2003	TA-3000	*Schoenus* Wet Prairie	*Schoenus* Wet Prairie	0.290	0.100	0.019	0.110
A	Transect	2003	TA-3200	*Schoenus* Wet Prairie	*Schoenus* Wet Prairie	0.294	**0.071**	0.020	**0.058**
A	Transect	2003	TA-3400	*Schoenus* Wet Prairie	*Schoenus* Wet Prairie	0.342	**0.083**	0.024	**0.075**
A	Transect	2003	TA-3600	*Paspalum-Cladium* Marsh	*Paspalum-Cladium* Marsh	0.419	**0.011**	0.033	**0.004**
A	Transect	2003	TA-3800	*Cladium* Wet Prairie	*Cladium* Wet Prairie	0.191	0.155	0.013	0.155
A	Transect	2003	TA-4000	*Schizachyrium Wet Prairie*	*Schizachyrium Wet Prairie*	0.209	**0.068**	0.014	**0.058**
A	Transect	2003	TA-4200	*Schoenus* Wet Prairie	*Cladium* Wet Prairie	-0.009	0.446	0.006	0.368
A	Transect	2003	TA-4400	*Cladium* Marsh	*Cladium* Marsh	-0.263	**0.049**	-0.013	0.100
A	Transect	2003	TA-4600	*Cladium* Marsh	*Cladium* Marsh	0.125	0.318	0.011	0.247
A	Transect	2003	TA-4800	*Cladium-Rhynchospora* Marsh	*Cladium* Wet Prairie	0.110	0.290	0.011	0.181
A	Transect	2003	TA-5000	*Schoenus* Wet Prairie	*Schoenus* Wet Prairie	0.025	0.444	0.003	0.426
A	Census	2017	A-35-06		*Cladium* Marsh				
A	Census	2017	A-35-07		*Cladium* Marsh				
A	Census	2017	A-35-08		*Rhynchospora-Cladium* Marsh				
A	Census	2017	A-35-09		*Cladium-Rhynchospora* Marsh				
A	Census	2017	A-35-10		*Cladium* Marsh				
A	Census	2017	A-36-01		*Cladium* Marsh				
A	Census	2017	A-36-02		*Cladium* Marsh				
A	Census	2017	A-36-03		*Cladium-Rhynchospora* Marsh				
A	Census	2017	A-36-04		*Cladium-Rhynchospora* Marsh				
A	Census	2017	A-36-05		*Cladium* Marsh				

Sub-pop.	C_T	Year estd.	Field ID	Vegetation type-1 (2003-2005)	Vegetation type-2 (2007)	Delta	Prob	Slope	Prob
A	Transect	2017	TAS-1000		*Rhynchospora-Cladium* Marsh				
A	Transect	2017	TAS-1200		*Cladium* Marsh				
A	Transect	2017	TAS-1400		*Cladium* Marsh				
A	Transect	2017	TAS-1600		*Cladium* Marsh				
A	Transect	2017	TAS-2000		*Cladium* Marsh				
A	Transect	2017	TAS-2400		*Cladium* Marsh				
A	Transect	2017	TAS-2600		*Cladium-Rhynchospora* Marsh				
A	Transect	2017	TAS-2800		*Cladium* Marsh				
A	Transect	2017	TAS-3000		*Cladium* Marsh				
A	Transect	2017	TAS-3200		*Cladium* Marsh				
A	Transect	2017	TAS-3400		*Cladium-Rhynchospora* Marsh				
A	Transect	2017	TAS-3600		*Cladium* Marsh				
A	Transect	2017	TAS-3800		*Cladium* Marsh				
A	Transect	2017	TAS-4000		*Schoenus* Wet Prairie				
A	Transect	2017	TAS-4200		*Cladium-Rhynchospora* Marsh				
A	Transect	2017	TAS-4400		*Cladium* Wet Prairie				
A	Transect	2017	TAS-4600		*Cladium* Wet Prairie				
A	Transect	2017	TAS-4800		*Cladium* Wet Prairie				
A	Transect	2017	TAS-5000		*Cladium* Wet Prairie				
E	Transect	2017	TE-90100		*Schizachyrium Wet Prairie*				
E	Transect	2017	TE-90200		*Cladium* Marsh				
E	Transect	2017	TE-90300		*Cladium* Wet Prairie				
E	Transect	2017	TE-90400		*Cladium* Marsh				
E	Transect	2017	TE-90500		*Cladium* Marsh				
E	Transect	2017	TE-90600		*Cladium* Marsh				
E	Transect	2017	TE-90700		*Cladium* Marsh				
E	Transect	2018	TE-90800		*Cladium* Marsh				
E	Transect	2017	TE-91700		*Schizachyrium Wet Prairie*				
E	Transect	2017	TE-91800		*Cladium* Wet Prairie				

Sub-pop.	C_T	Year estd.	Field ID	Vegetation type-1 (2003-2005)	Vegetation type-2 (2007)	Delta	Prob	Slope	Prob
E	Transect	2017	TE-91900		*Cladium* Marsh				
E	Transect	2017	TE-92000		*Cladium* Wet Prairie				
E	Transect	2017	TE-92100		*Schizachyrium Wet Prairie*				
E	Transect	2017	TE-92200		*Cladium* Wet Prairie				
E	Transect	2017	TE-92300		*Cladium* Wet Prairie				
E	Transect	2017	TE-92400		*Muhlenbergia* Wet Prairie				
E	Transect	2017	TE-92500		*Cladium* Wet Prairie				
E	Transect	2017	TE-92600		*Cladium-Rhynchospora* Marsh				
E	Transect	2017	TE-92700		*Cladium* Marsh				
E	Transect	2017	TE-92800		*Cladium* Marsh				
E	Transect	2017	TE-92900		*Cladium-Rhynchospora* Marsh				
E	Transect	2017	TE-93000		*Cladium* Marsh				
E	Transect	2017	TE-93100		*Cladium* Wet Prairie				
E	Transect	2017	TE-93200		*Cladium* Wet Prairie				