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Status of Vegetation Structure and Composition within the Habitat of Cape Sable seaside sparrow Subpopulation D

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Executive Summary

Cape Sable seaside sparrow (CSSS), a federally-listed endangered species, as well as vegetation within its habitat are highly sensitive to changes in hydrologic regimes. Thus, to ensure that the impacts of Everglades restoration projects do not impede the survival and continued existence of sparrows in their habitat, the C-111 Spreader Canal Western project embraces regular monitoring of the sparrow population and the status of its habitat. As per requirements stated in Biological Opinion issued by the US Fish and Wildlife Service, baseline conditions of the CSSS sub-population D and its habitat were studied in 2011. With funding support from SFWMD (PO # 4500079149), the present study examined any vegetation shift that might have occurred since the 2011 baseline survey.

The sampling design was the same used in 2011, and included two groups of sites: (1) sparse vegetation sampling sites (SS sites), and (2) concentrated vegetation sampling sites (CS sites). The 44 SS sites were 500 m to 1 km apart, whereas the 36 CS sites were at the corners of each 250 x 250 m grid cell in an area of 1.25 km x 1.25 km. At each site, vegetation was sampled using a nested design: a 5 m x 5 m shrub plot was nested within a 10 m x 10 m tree plot. Within shrub plots, cover of shrubs and vines were estimated. Herbaceous plants were surveyed within five 1-m^2 subplots located within each shrub plot. In addition to species cover, a suite of structural parameters was recorded in a 0.25 m^2 quadrat in the southeast corner of each subplot. Ground elevation of the plots was calculated using the field measurements of water depth in combination with Water Depth Assessment Tools (WDAT) and Everglades Depth Estimation Network (EDEN) water surface elevation data. However, only EDEN data was used to calculate annual mean daily water depth and hydroperiod for the plots. Vegetation change analysis included Analysis of Similarity (ANOSIM), and Weighted Averaging Regression, a method used to calculate vegetation-inferred hydroperiod, i.e., the hydroperiod for a site predicted from vegetation composition. Changes in vegetation-inferred hydroperiod between successive samplings are indicative of changes in response to hydrology of the period. Paired t-tests were used to test the differences in vegetation structural variables, biomass, species richness and vegetation-inferred hydroperiod between two samplings.

Marl prairie vegetation within the habitat of sub-population D included vegetation assemblages arranged along the full hydrologic gradient. Vegetation change over three years, since the base line survey in 2011, was marked by an increase in wetness of some sites and a consequent shift in species composition toward a vegetation type characteristic of wetter conditions. Even though our findings showed that vegetation shifted towards wetter types, the vegetation response to relatively long hydroperiod during the Project period (2011-2014) was somewhat slowed due to the lag-time involved. However, the results confirmed that even a small change in hydrologic condition near the upper limits of hydrologic conditions suitable for wet prairie vegetation and sparrow occurrence can present rapid deterioration of habitat quality. Our findings suggest that the shrinking trend of suitable sparrow habitat detected by Virzi et al. (2013) was likely due to a shift in vegetation composition and structure. However, it is not yet fully understood whether the shift in habitat conditions are due to project activities or natural annual variability in hydrologic conditions, or both. Thus, within the sub-population D habitat where the hydrologic conditions are likely to be impacted by the project activities, only the continued monitoring of the vegetation as well as sparrow population can provide a conclusive assessment of the future course of the sparrow population and its habitat.

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Background

Cape Sable seaside sparrow (CSSS) and its habitat have been at the pivot of several water management activities for the last two decades, affecting both sides of the Shark River Slough in the Everglades. The reason rests on the fact that CSSS is a federally-listed endangered species endemic to the short-hydroperiod marl prairies of the Everglades, and both the sparrow and vegetation that structures its habitat are highly sensitive to changes in hydrologic regime. Unusually high water conditions during the sparrow breeding period can cause sharp decline of the sparrow population, either directly by inflicting mortality or impairing breeding success, or indirectly through destruction of its habitat (Pimm et al. 2002; Jenkins et al. 2003). Flooding that inordinately extends hydroperiod causes the short-hydroperiod marl prairie to change to long-hydroperiod sawgrass marsh as quickly as within 3-4 years (Armentano et al. 2006; Sah et al. 2014), causing the habitat to be unsuitable for sparrows (Nott et al. 1998; Jenkins et al. 2003). Thus, to ensure that impacts of Everglades restoration projects to sparrow habitat do not impede the survival and continued existence of sparrows, several water management projects in the Southern Everglades include regular monitoring of the sparrow population and its habitat as integral components.

The C-111 Spreader Canal Western project is designed to restore the quantity, timing, and distribution of water delivered to Florida Bay via Taylor Slough and to improve hydroperiod and hydro-pattern in the area south of the C-111 canal, known as the Southern Glades and Model Lands. To ensure that the project impacts to Cape Sable seaside sparrow (CSSS) Designated Critical Habitat Units 2 and 3 (also referred to as subpopulations C and D, respectively) do not exceed the impacts recognized in the United States Fish and Wildlife Service (USFWS's) Incidental Take Statement (ITS), the SFWMD is required to conduct CSSS habitat monitoring, and to document and track vegetation conditions in subpopulation D. As per the requirements stated in Term and Condition #6 of ITS, baseline conditions of the Cape Sable seaside sparrow (CSSS) sub-population D and its habitat were studied with funding support from South Florida Water Management District (SFWMD) in 2011, before project implementation. The study concluded that the population had declined from a peak of 400 birds in 1981 to few pairs of birds in the mid-2000s (Virzi et al. 2011), which corresponded with a change in vegetation from short-hydroperiod prairie to the long-hydroperiod sawgrass marsh during that period (Ross et al. 2004). The baseline study also emphasized that the population had recently (2007-2010) begun to show signs of improvement that corresponded with an improvement in habitat conditions resulting from a drying trend in the late 2000s (Virzi et al. 2011). However, it was expected that this trend would be disrupted upon project implementation, as computer simulation modeling results indicated that operations would result in an increased hydroperiod, and thus adversely affect the habitat conditions within the CSSS subpopulation D critical habitat (USFWS 2009).

An examination of daily stage data at EVER4, located in the center of the CSSS sub-population D habitat, revealed that the three year period (May 1, 2011 – April 30, 2014) following the 2011 baseline survey (Project period) were slightly wetter than during the three years (May 1, 2008 –

April 30, 2011) before the survey (Pre-project period). The mean daily water depth was 3 cm higher during the project period than the pre-project period. Near EVER4, the inundation period was 96% and 93% during the project and pre-project period, respectively. During the project period, the sparrow subpopulation was still persisting (Virzi and Davis 2013). However, the response of vegetation to project operations was still unknown in 2013. With funding support from SFWMD (PO # 4500079149), we studied the current status of sparrow subpopulation D habitat. The specific objective of this study was to document vegetation structure and composition within the habitat of CSSS sub-population D, and to analyze any vegetation change that might have occurred since baseline survey was performed.

Methods

Study design

The study area was within the critical habitat of CSSS sub-population D (**Figure 1**). The study was designed to incorporate sufficient spatial and temporal resolution in the vegetation monitoring that the impact of project operations on hydrology-mediated changes in vegetation structure and composition could be assessed. The sampling design was the same used in the 2011 baseline survey, and included two groups of sites, (1) sparse vegetation sampling sites (SS sites), and (2) concentrated vegetation sampling sites (CS sites). Together there were 44 SS and 36 CS sites for a total of 80 sites (Appendix 1). The SS sites included 17 previously sampled vegetation census sites located at the corners of 1 km x 1 km grid cells (Ross et al. 2006), and an additional 27 sites that were established in 2011 either at the corners of additional grid cells included in the critical habitat boundary of Unit-3 (subpopulation D), or at the centers of the aforementioned grid cells. The CS sites were at the corners of each 250 x 250 m grid cell within a 1.25 km x 1.25 km area that included a set of occupied CSSS territories that had been delineated by Dr. Thomas Virzi (Rutgers University) and group (Virzi et al. 2011; Virzi and Davis 2013) at the time of project initiation.

Field Sampling

At each sampling site, a 3-ft tall PVC pole marked the SE corner of a 10 m x 10 m tree plot. Nested within each tree plot, a 5 m 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 (**Figure 2**). In the tree plots, we measured the DBH and crown length and width of any woody individuals of ≥ 5 cm DBH. Within each 5 m 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%. Herbaceous plants were surveyed within five 1-m^2 subplots located at the four corners and center of each herb/shrub plot. In 1-m^2 subplots, we estimated the cover % of each vascular plant species, using the same categories as we used for shrub cover. If an herbaceous species was present in the 5 m x 5 m herb/shrub plot but not found in any of the subplots, it 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 southeast corner of each subplot. Structural sampling included the following attributes: 1) 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; 2) The height and species of the tallest plant in the quadrat; 3) Total vegetative cover, in %; and 4) live vegetation, expressed as a % of total cover. The number of woody individuals (height $\leq$ 1 m) present in the subplots was also recorded. In addition, if there was standing water in the herb/shrub plots, we also measured water depth at three locations in each plot. **Figure 3** shows photo of research team members taking vegetation structural and compositional measurements in the field.

Analytical method

During the 2014 field survey, almost all sites were dry and did not have standing water. Thus, we calculated hydrological variables based on elevations determined from water depths measured in 2011. In the wet season of 2011, when sites in the region were inundated with standing water, we measured water depth at three locations within each 5 m x 5 m plot: 44 and 36 plots on Aug 31st and Sept 9th, respectively. Using the water surface elevations provided by available empirical models (e.g., SFWMD's Water Depth Assessment Tool (WDAT) and USGS's Everglades Depth Estimation Network (EDEN)) for the specific date, we calculated ground elevation for each plot. The EDEN water surface elevation data were not available for 10 sites east of the C111canal, and at the time of field measurement of water depth, standing water was not present at one site. Thus, the analysis of hydrology data was mainly based on the 69 sites. Across all the sites (n = 69), ground elevations based on both the WDAT and EDEV water surface data were strongly correlated (r = 0.89), though the WDAT-based mean ground elevation was 2.12 cm higher than the EDEN-based elevation (**Figure 4**). The WDAT time series water surface elevation data for the survey sites were not readily available. We, therefore, used only EDEN data (http://sofia.usgs.gov/eden/models/watersurfacemod_download.php) to calculate annual mean daily water depth and hydroperiod for each of the 69 plots. Hydroperiod was defined as the discontinuous number of days in a year when water level was above the ground surface.

The vegetation data was summarized using a non-metric multidimensional scaling (NMDS) ordination. Analysis of Similarity (ANOSIM), a nonparametric multivariate analytical procedure, was used to examine the overall change in vegetation composition since the baseline survey (McCune and Grace 2002). Vegetation change analysis also included calculation of vegetation-inferred hydroperiod, the hydroperiod for a site indicated from its vegetation composition using a Weighted Averaging regression model (see Armentano et al. 2006 for details). 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.

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).

Paired t-tests were used to test for differences in vegetation structural variables, biomass, species richness and vegetation-inferred hydroperiod between two samplings. Spatio-temporal variation in hydrological and vegetation structural parameters was illustrated on the map using ArcGIS 10.2.

Results and Discussion

Marl prairie vegetation within the habitat of sub-population D includes vegetation assemblages arranged along the hydrologic gradient, broadly categorized into two groups, 'wet prairies' and 'marsh'. Wet prairie (WP) vegetation, grasslands with mixed dominance of muhly grass (*Muhlenbergia capillaris* ssp. *filipes*), sawgrass (*Cladium mariscus* ssp. *jamaicense*) and/or black-top sedge (*Schoenus nigricans*), were prevalent at the CS sites, in the vicinity of recently occupied portion of sparrow habitat (**Figure 5**). Marsh (M) sites had hydroperiods generally greater than 210 days, and the vegetation assemblages at the sites were mainly sawgrass (*C. marsiscus* ssp. *jamaicense*) and sawgrass-beakrush sedge (*Cladium-Rhynchospora*) marsh. Two other marsh vegetation types were Beakrush sedge-sawgrass (*Rhynchospora-Claidum*) and spkirush-beakrush sedge (*Eleocharis-Rhynchospora*) Marsh. Vegetation change over three years, since the base line survey in 2011, was marked by an increase in wetness of some sites and a consequent shift in species composition toward the wetter type.

In this study, analysis of hydrologic conditions of the vegetation survey sites revealed that the sites were slightly wetter during the Project period (2011-2014) than the Pre-project period (2008-2011) (**Figure 6**). During the Project period, the mean hydroperiod was 22 days longer, and mean annual water depth was 3.4 cm higher than the Pre-project period. In response, the species composition showed significant change (ANOSIM: R = 0.097; p-value = 0.001) between 2011 and 2014. Observed- and vegetation-inferred hydroperiods were well correlated in both years (**Figure 7**). In concurrence with the higher hydroperiod during the Project period than Pre-project period, the mean vegetation-inferred hydroperiod was also slightly (only 7 days), but significantly (Paired t-Test: t = 3.6, df = 79, p = 0.001) higher in 2014 than in 2011 (**Figure 8**), suggesting that a prevalence of wet conditions during the Project period has caused a shift in species composition toward a more hydric type within the short, 3-year period.

Vegetation change between two surveys was marked also by a decline in mean vegetation cover and species richness and an increase in vegetation height (**Figure 9**). Mean (±SD) vegetation cover was significantly lower in 2014 (32.6 ± 12.7%) than in 2011 (39.3 ± 17.2%). The cover value of major characteristic species of marl wet prairie sites significantly declined, whereas the difference in cover of beakrush sedge (*Rhynchospora tracyi*) and spikerush (*Eleocharis cellulosa*), which are most abundant at the wet end of the marl prairie gradient (Ross et al. 2006; Sah et al. 2011), was not statistically significant (**Table 1**). Mean plant species richness was also significantly lower in 2014 (8.4 ± 3.3 species/plot) than in 2011 (9.6 ± 3.9). In the marl prairies, species richness is negatively correlated with hydroperiod (Ross et al. 2006), and thus a decline in plant species richness corresponding with the shift in vegetation toward a wetter type was not a surprise. In comparison to reduced cover and species richness, vegetation height increased in three years, and the mean vegetation height was significantly higher in 2014 (57.1 ± 11.0 cm) than in 2011 (52.9 ± 14.1 cm). In contrast, the aboveground biomass was relatively low in 2014, but the difference between two surveys was not statistically significant (**Figure 9**). The observed changes in vegetation structure between two surveys were not the same in both wet prairie and marsh sites throughout the study area (Appendices 2, 3). The differences in vegetation cover and height as well as species richness were significant only in the wet prairie group of sites, whereas those differences at the marsh sites were not statistically significant (**Table 2**).

Table 1: Mean (± 1 S.D.) value of percent cover of major species averaged over all sites (n = 80) surveyed in 2011 and 2014 within the CSSS sub-population D habitat region.

Plant species	Sampling years		Paired t-test (df = 79)	
	2011	2014	t	p-value
Cladium mariscus ssp. *jamaicense*	33.3±18.9	21.9±14.0	6.06	<0.001
Schoenus nigricans	11.1±17.8	6.0±10.5	4.13	<0.001
Muhlenbergia capillaris ssp. *filipes*	3.2±6.9	1.7±2.7	2.50	0.015
Rhynchospora microcarpa	3.3±5.0	1.5±1.9	3.62	0.001
Rhynchospora trayci	4.5±6.5	3.5±3.7	1.50	0.138
Eleocharis cellulosa	3.2±10.0	2.3±7.0	1.66	0.101

Table 2: Mean (± 1 S.D.) value of vegetation structural measurements and species richness for two groups of sites, wet prairie (WP) vs marsh (M) surveyed in 2011 and 2014 within the CSSS sub-population D habitat region. Grouping of sites as WP and M is based on the 2011 site classification.

Vegetation structural variables		Sampling years		Paired t-test		
		2011	2014	t	df	p-value
Vegetation cover (%)	WP	38.9±16.0	32.4±12.1	2.70	51	0.009
	M	40.0±19.4	33.0±14.0	2.00	27	0.056
Vegetation height (cm)	WP	51.5±13.1	58.0±11.0	-2.87	51	0.006
	M	55.6±15.8	55.6±11.2	0.01	27	0.994
Species richness (species/plot)	WP	11.4±3.0	9.8±2.4	3.87	51	<0.001
	M	6.1±3.1	5.9±3.3	0.66	27	0.515
Aboveground plant biomass (g m^{-1})	WP	509±150	483±133	1.03	51	0.310
	M	542±218	476±145	1.76	27	0.090

In the Everglades, the marl prairie is a dynamic landscape system where hydrology and fire are important drivers. In this system, vegetation responses to hydrologic alterations may occur rapidly (Armentano et al. 2006), consequently affecting the quality of CSSS habitat and the sparrow population (Nott et al. 1999; Jenkins et al. 2003). Within the habitat of sub-population D, vegetation has gone through different episodes of change over the past three decades, primarily in response to the natural and anthropogenic alterations in hydrologic regimes. In 1981, the vegetation was mostly the marl wet-prairie type, and the sparrow population at the time was about 400 individuals (Pimm et al. 2002). During the early 1990s, however, the vegetation changed to a sawgrass-dominated marsh type in response to prolonged hydroperiod and high water conditions in the area. These conditions resulted from both high rainfall during the mid-1990s and an increased water delivery into Taylor Slough since 1993 (Ross et al. 2004). Consequently, the sparrow population sharply declined (Pimm et al. 2002). Marsh vegetation prevailed till the early 2000s, and the sparrow population dropped from sight, as no sparrow was recorded for three consecutive years (2002-2004). Later, in the second half of the last decade (2005-2010), the vegetation within the region showed a drying trend, primarily in response to several drought years (Sah et al. 2011). Consequently, the wet prairie vegetation was more widely spread in 2011 than it was during the period of 2003-2006 when a detailed systematic vegetation survey was first conducted at a network of sites located 1 km apart (Ross et al. 2006; Sah et al. 2011). Since the baseline survey in 2011, vegetation composition has shifted back toward a wetter type, and trajectory that might have implications on sparrow occupancy within the area.

A shift in marl prairie vegetation towards wetter type is perceived as the deterioration in the available sparrow habitat quality. The foundation for this belief lies in the fact that sparrow occurrence is usually highest in muhly-dominated wet prairie with hydroperiods ranging between 90 and 180 days; concurrently, CSSS occurrence is less frequent in wetter vegetation types ranging from sawgrass-dominated prairie and marsh to beakrush sedge (*Rhyncospora tracyi*) and spikerush (*Eleocharis* sp.) marsh (Ross et al. 2006; **Figure 10**). In sub-population A, west of Shark River Slough, researchers have also attributed a sharp decline in sparrow population to severe and prolonged flooding in the mid-1990s and the consequent change in vegetation to sawgrass marsh (Nott et al. 1998; Pimm et al. 2002; Jenkins et al. 2003). In Sub-population D too, sparrow population has sharply declined since the 1980s, probably for the same reason (Pimm et al. 2002). However, within this sub-population, a small breeding population of sparrows has consistently been recorded since 2006 by Julie Lockwood (2006-2010) and Tom Virzi (2011-2013) from Rutgers University (Lockwood et al. 2006, 2010; Virzi et al. 2011; Virzi and Davis 2013). The bird nests were generally found within an area of high ground in northwest-central region of subpopulation D (Virzi et al. 2011; Virzi and Davis 2013), where WP vegetation was dominant in 2011 (Sah et al. 2011). Later, Virzi and Davis (2013) found that the total extent of occupied habitat has been shrinking each year, and wondered if the decline was in response to changes in vegetation conditions. Since WP sites are the suitable sparrow habitat, and most sparrows in sub-population-D were confined to the area of CS sites, we re-analyzed the vegetation inferred-hydroperiod data, dividing the sites into sub-groups, WP vs M sites, and CS vs SS sites. The increase in mean vegetation-inferred hydroperiod between 2011 and 2014 was disproportionately higher at WP or CS sites than the M or SS sites. At the WP and CS sites, inferred hydroperiod increased by 11 and 13 days, respectively. In contrast, inferred hydroperiod increased by only 1-3 days at the M or SS sites, and the difference in inferred hydroperiod at the M or SS sites between two sampling years was not statistically significant (**Table 3**). Our findings showed that vegetation shifted towards wetter types mainly at the existing WP or CS sites, likely causing the sites to be less suitable CSSS habitat, though the level of change in suitability was not clear and needs additional assessment.

Table 3: Mean (± SD) vegetation inferred hydroperiod for two groups of sites, wet prairie (WP) vs marsh (M), and concentrated (CS) vs sparse (SS) sites. Grouping of sites as WP and M is based on the 2011 site classification. CS and SS groupings were based on the spatial distribution of sites in the field (See the Methodology for details). P-value is from paired t-test between two sampling years, 2011 and 2014.

Site type	n	Sampling years		t	p-value
		2011	2014		
Wet prairie (WP)	52	184 ± 26	195 ± 27	-5.09	<0.001
Marsh (M)	28	257 ± 40	259 ± 44	-0.24	0.809
Concentrated Sites (CS)	36	185 ± 25	198 ± 24	-4.48	< 0.001
Sparse sites (SS)	44	229 ± 52	232 ± 53	-1.06	0.293

The degree of change in inferred-hydroperiod (12 days) between Pre-project and Project period was small in comparison to that in calculated hydroperiod (22 days), and one might wonder whether such a small scale change in hydroperiod would have any significant impact on the sparrow habitat. First, the smaller change in vegetation-inferred hydroperiod than in actual hydroperiod could be the result of a lag in vegetation responses to the alterations in hydrologic condition. Though the hydrology-mediated change in vegetation composition can be visible in 3-4 years, the lag time could be longer depending on the intensity of hydrologic changes. In sub-population D, the wide spread of WP sites in 2011 was the result of several drought years prior to the 2011 sampling (Sah et al. 2011). Some effects of these drought conditions on vegetation might still persist, causing vegetation in 2014 to not completely reflect the wet condition of the Project period. Even within that three-year period, not all years were consistently wet. Instead, 2011 was a dry year (**Figure 6**), and that might have slowed the rate of change in vegetation toward a wetter type. Second, in considering whether the changes in vegetation were enough to adversely impact on sparrow occurrence, results should be assessed in reference to the range of optimum hydroperiod for sparrow occurrence. If the upper limit of the optimum range of sparrow occurrence (>25% frequency) is considered to be 240 days (**Figure 10**), the mean hydroperiod at 48% of WP sites had exceeded this threshold three years later. Similarly, among sites that experienced 210 days or less of annual flooding during the Pre-project period, 90% of them exceeded that level in 2014. Thus, our findings suggest that the decrease in suitable sparrow habitat detected by Virzi and Davis (2013) was likely due to a shift in vegetation composition observed in this study. However, whether such a shift in habitat conditions is the result of project activities or simply a response to natural variability in hydrologic conditions is unclear, and can only be referenced from a comparative parallel study in the non-project area. Currently, parallel results from another area are not available, though the preliminary analysis of stage (RG2) data from the sub-population F showed that on average the three years from 2011 to 2014 were wetter than the previous three years. The mean daily water level was 5.1 cm higher during the project period than the pre-project period, and near the stage (RG2), the inundation period was 40 and 31% during the project and pre-project period, respectively. A study of the impact of hydrology on vegetation in that part of marl prairie habitat is underway (Marl Prairie-Slough Gradient, a RECOVER monitoring project: Sah et al. *in preparation*). Moreover, within the sub-population D habitat where the hydrologic conditions are likely to be impacted by project activities, only continued monitoring of the vegetation as well as sparrow population dynamics can provide a conclusive assessment of the future fate of the existing CSSS population and its habitat.

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Virzi, T. and Davis, M. J. (2013) C-111 Project and Cape Sable seaside sparrow subpopulation D. Annual Report – 2013. Submitted to South Florida Water Management District, West Palm Beach, FL. 38 pp.

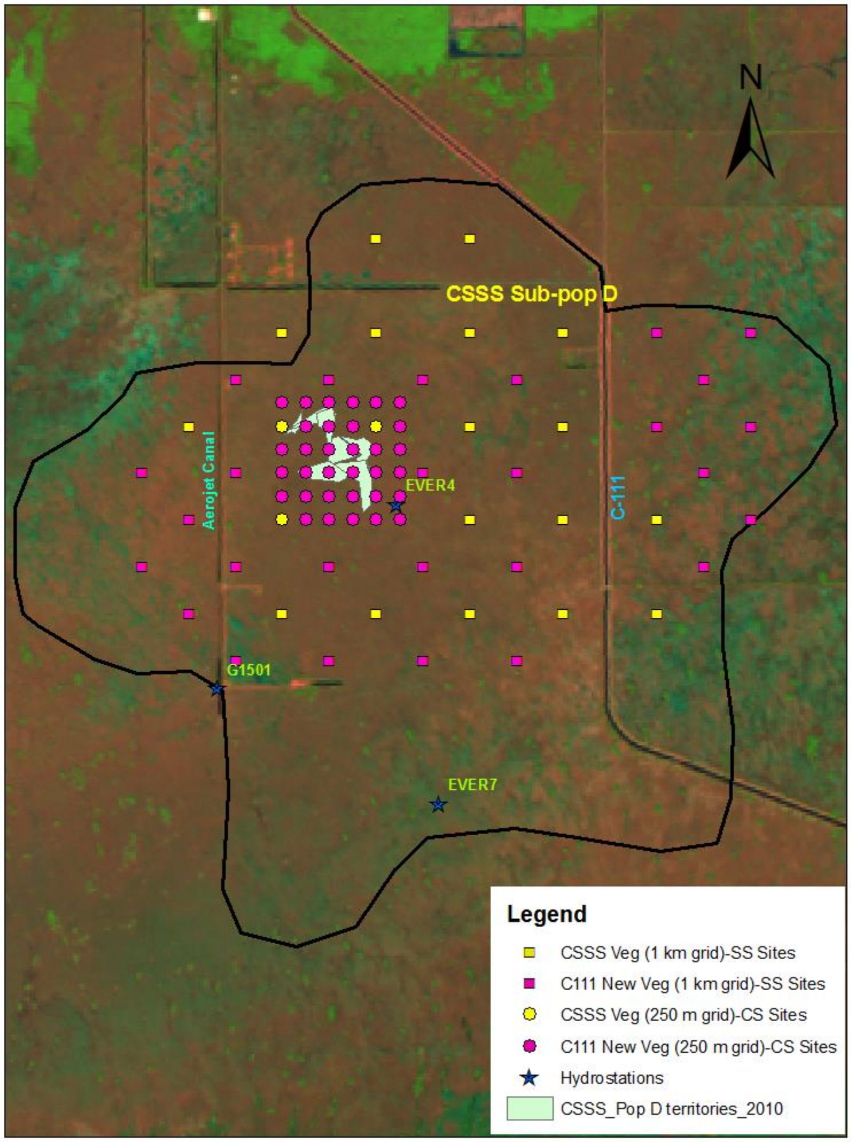


Figure 1: Vegetation survey sites within C111 Spreader Canal Western Project – CSSS Sub population D area.

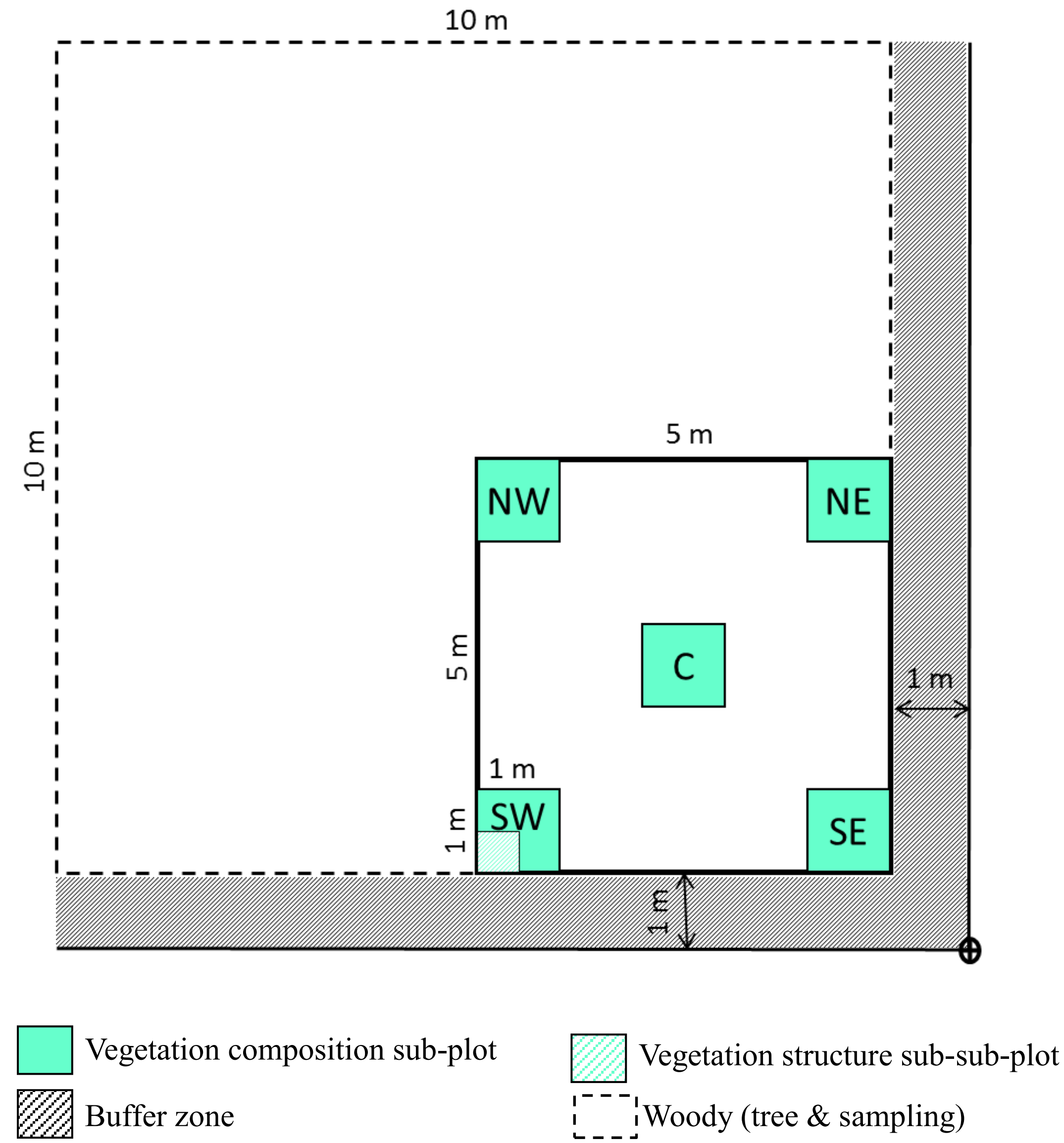


Figure 2: Vegetation sampling design at each of 80 sites sampled in 2014 to document status of vegetation structure and composition in the habitat of CSSS sub-population D within C111-Spreader Canal Project Area.

Figure 3: Vegetation sampling. (A) Field crews taking vegetation measurements in the field, (B) 1 m x 1 m quadrat used for herbaceous species cover estimation within the plot.

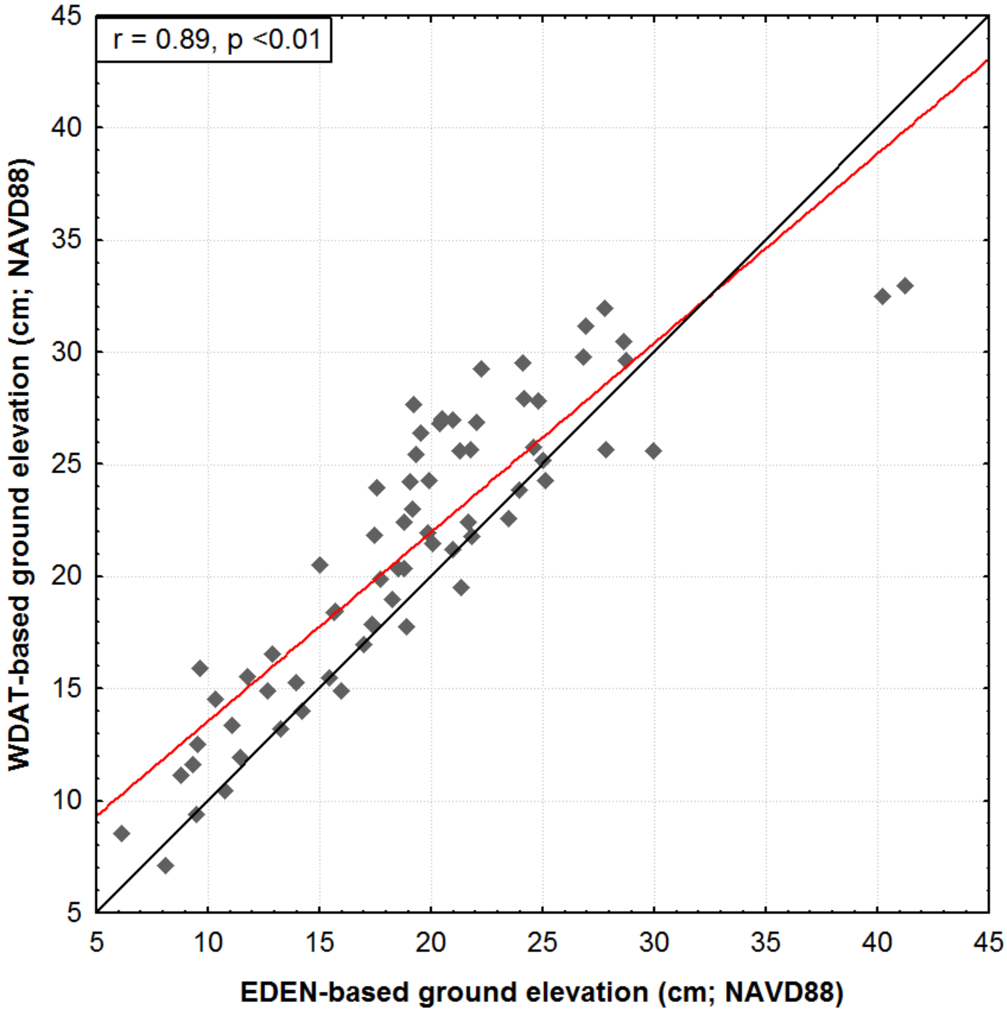


Figure 4: Scatterplot showing the relationship between EDEN (Everglades Depth Estimation Network)- and WDAT (Water Depth Assessment Tools)-based ground elevation of 69 vegetation survey sites within the habitat of CSSS sub-population D.

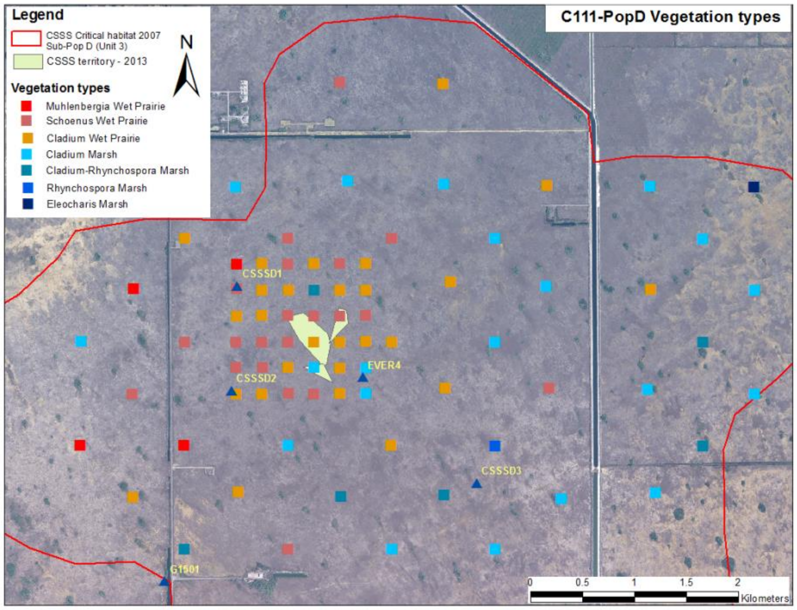


Figure 5a: Vegetation types at 80 sites based on 2011 species composition data collected to document baseline vegetation condition in the habitat of CSSS sub-population D within C111-Spreader Canal Project Area. Vegetation type at each site was identified through cluster analysis of species cover values at 688 sites, including 608 census sites sampled in three years (2003-05). Vegetation types represent from the the dry (red) to wet (dark blue) community types.

Figure 5b: Black-top sedge (*Schoenus nigricans*)-dominated vegetation at the site D-05-02.

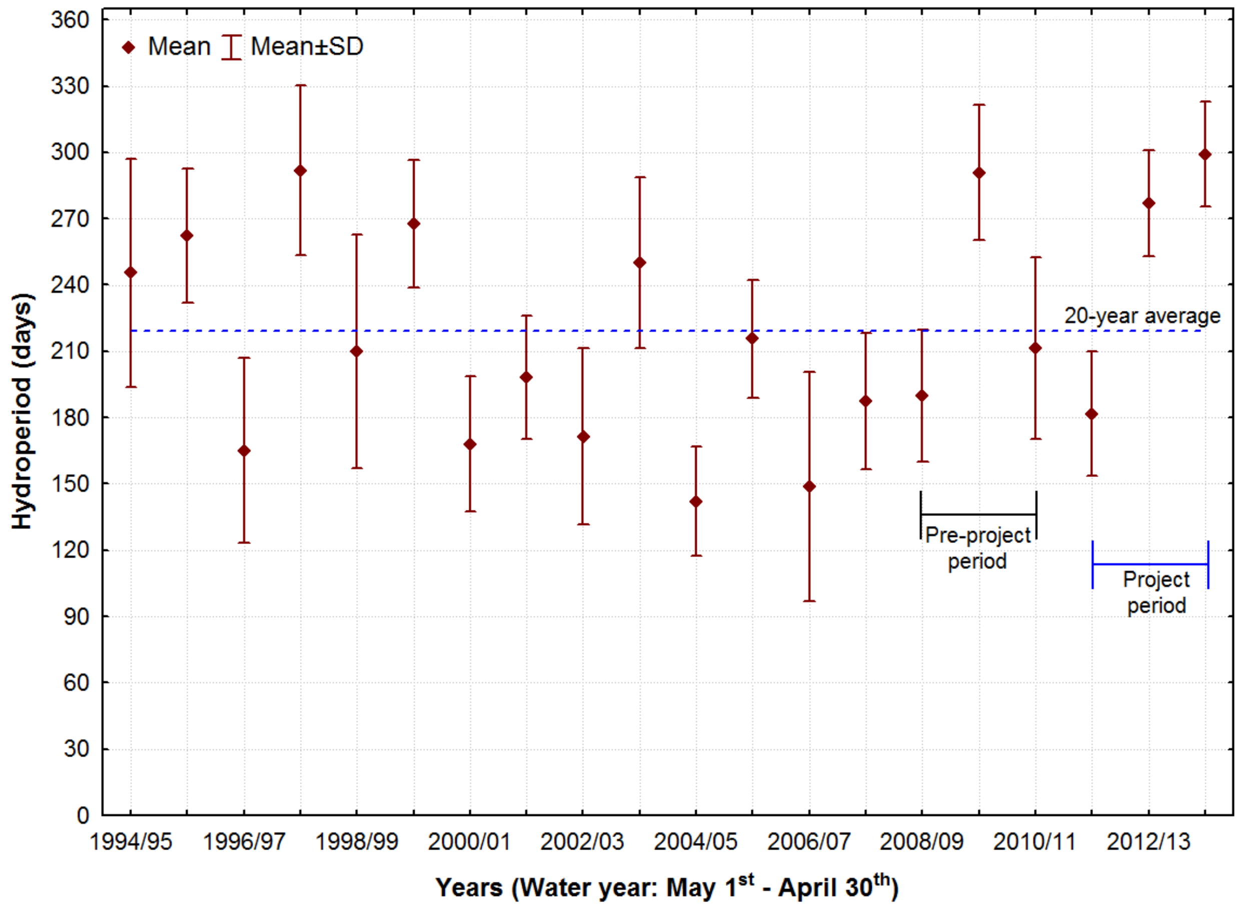


Figure 6: Annual mean hydroperiod at the vegetation survey sites (n = 69) for 20 years (water year: May 1st – April 30th). Dashed line is the 20-year average value. Hydroperiod for each site was calculated using field water depth-based ground elevation and EDEN water surface time series data.

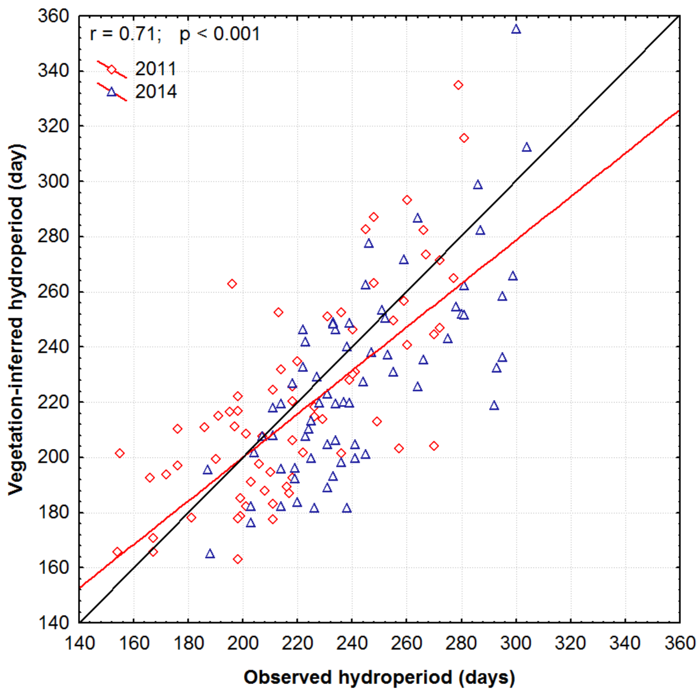


Figure 7: Observed vs vegetation-inferred hydroperiod at the 69 sites within the habitat of CSSS sub-population D. The hydroperiod was averaged over 4 years prior to the vegetation sampling. Vegetation-inferred hydroperiod values were predicted from vegetation composition using Weighted Averaging regression model developed from the vegetation and hydrology data from CSSS vegetation transect D (Ross et al. 2006).

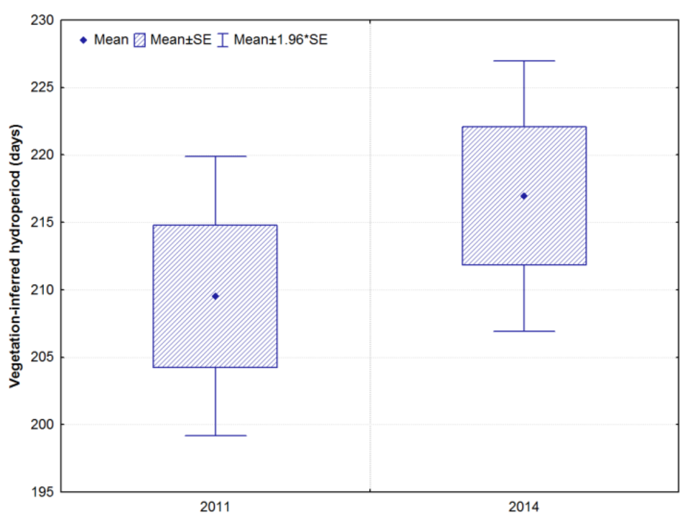


Figure 8: Box-plots (Mean, SE, and mean±1.96*SE) showing vegetation-inferred hydroperiod at the 69 sites within the habitat of CSSS sub-population D. Vegeation-inferred hydroperiod values were the same as in Figure 6.

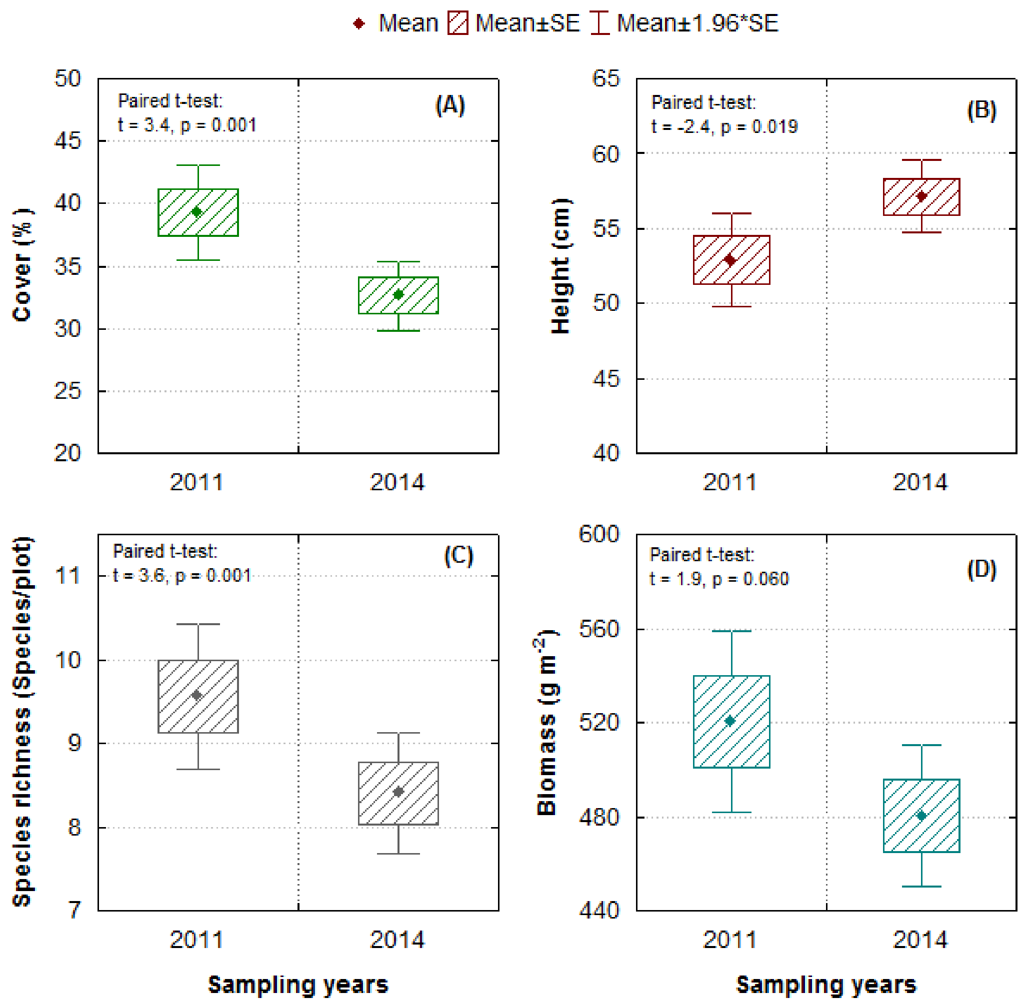


Figure 9: Box-plots (mean, SE, 95% CI) showing the vegetation structure, (A) vegetation cover, (B) vegetation height, (C) species richness, and (D) aboveground biomass in both 2011 and 2014 sampling years (n = 80).

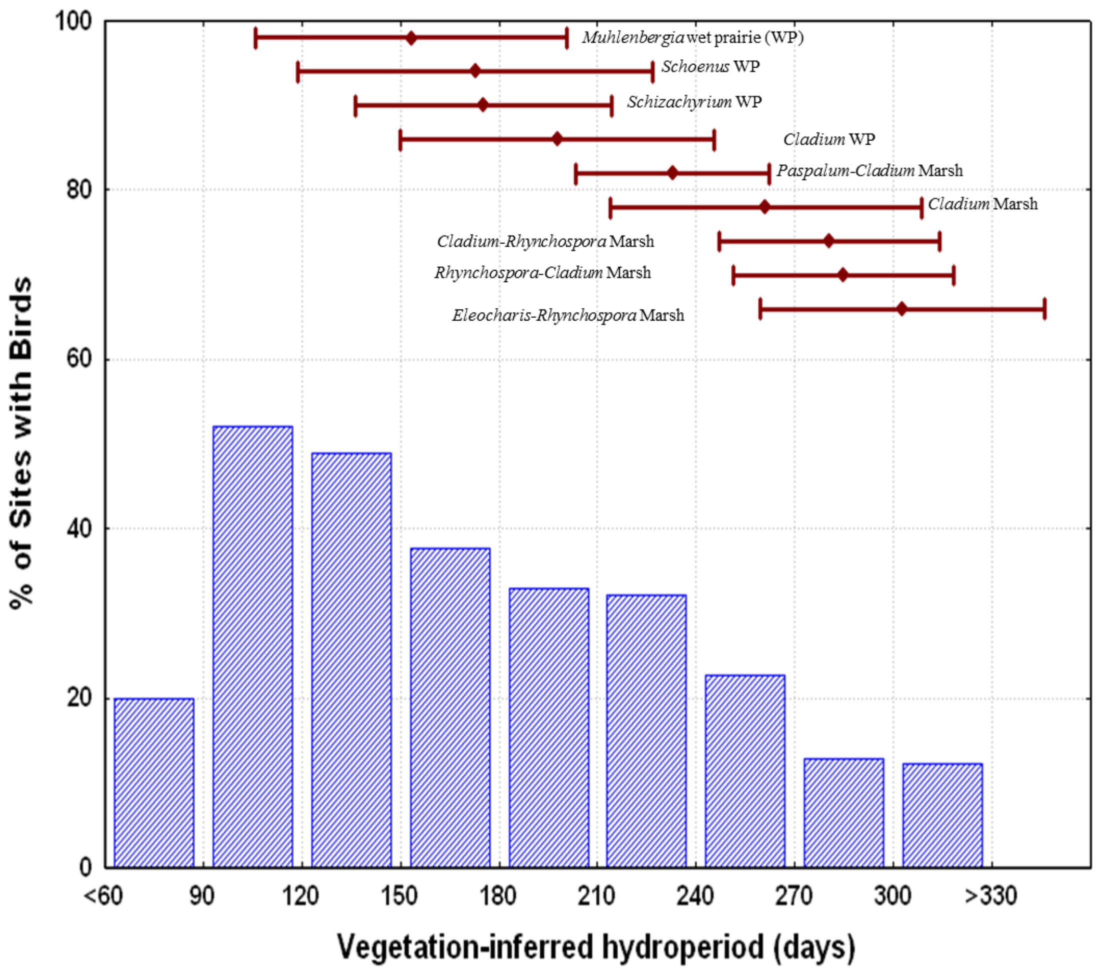
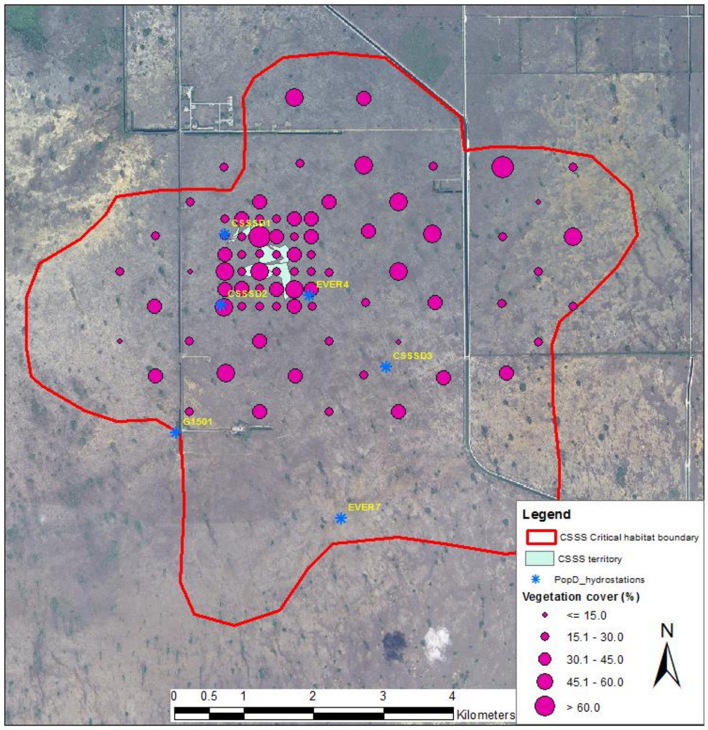


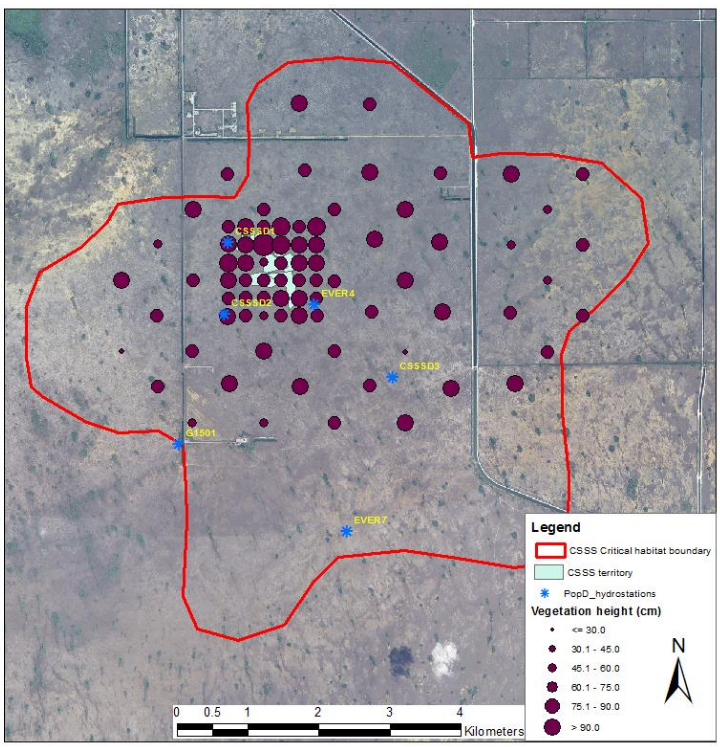
Figure 10: Percentage of census locations, subdivided into 30-day increments of vegetation-inferred hydroperiod, in which CSSS were observed at least once during 3 years prior to vegetation sampling. Data are based on 608 sites sampled in three years (2003-05). Mean (± 1 SD) inferred hydroperiod for nine vegetation types among 2003-05 vegetation census plots are superimposed. (**Source**: Ross et al. 2006)

Appendix 1: List of CSSS sub-population D habitat vegetation monitoring sites sampled in 2014. Vegetation types are based on 2011 species composition data collected to document baseline vegetation condition. Vegetation type at each site was identified through cluster analysis of species cover values at 688 sites, including 608 census sites sampled in three years (2003-05). MWP = *Muhlenbergia* Wet Prairie; SOWP = *Schoenus* Wet Prairie; COWP = *Cladium* Wet Prairie; CM = *Cladium* Marsh; CRM = *Cladium-Rhynchospora* Marsh; RCM = *Rhynchospora-Cladium* Marsh; ERM = *Eleocharis-Rhynchospora* Marsh.

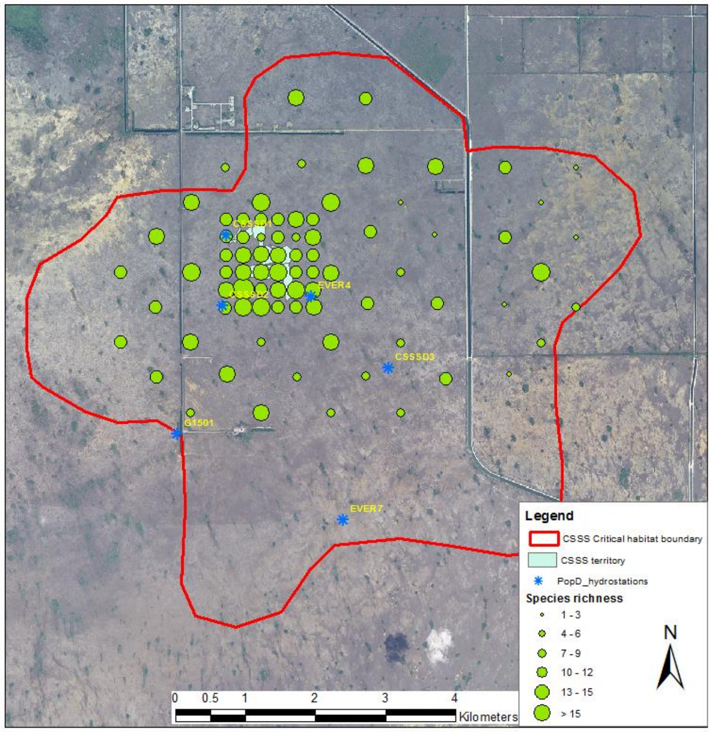
PLOT	X_UTM83	Y_UTM83	LAT_WGS84	LONG_WGS84	Vegetation type
D-01-02	544353	2801406	25.328592	-80.559292	CWP
D-01-03	545411	2804404	25.355633	-80.548679	CM
D-01-05	546405	2803430	25.346807	-80.538834	CWP
D-01-06	546354	2802406	25.337561	-80.539376	CWP
D-01-07	547357	2802410	25.337566	-80.529409	SOWP
D-01-08	547475	2801337	25.327872	-80.528274	CM
D-01-10	548377	2801401	25.328421	-80.519309	CM
D-02-01	545335	2805354	25.364214	-80.549403	SOWP
D-02-02	546327	2805342	25.364075	-80.539543	CWP
D-02-03	546334	2804375	25.355343	-80.539507	CM
D-02-04	543345	2803363	25.346294	-80.569245	MWP
D-02-06	547321	2803391	25.346426	-80.529732	CM
D-02-07	548307	2802395	25.337400	-80.519969	CM
D-03-01	547329	2804365	25.355221	-80.529619	CWP
D-03-02	544322	2804348	25.355160	-80.559504	CM
D-03-03	546337	2801375	25.328251	-80.539580	CRM
D-03-04	545343	2801363	25.328173	-80.549457	CRM
D-04-01	542834	2802855	25.341721	-80.574339	CM
D-04-02	542831	2801856	25.332700	-80.574401	MWP
D-04-03	543326	2802353	25.337173	-80.569466	SOWP
D-04-04	543338	2801354	25.328152	-80.569379	CWP
D-04-05	543835	2803855	25.350722	-80.564360	CWP
D-04-06	543835	2802853	25.341674	-80.564392	SOWP
D-04-07	543832	2801857	25.332680	-80.564454	MWP
D-04-08	543832	2800854	25.323622	-80.564486	CRM
D-04-09	544836	2803855	25.350693	-80.554412	SOWP
D-04-10	544832	2801855	25.332632	-80.554518	CM
D-05-01	544836	2800854	25.323592	-80.554511	SOWP
D-05-02	545835	2803854	25.350653	-80.544484	SOWP
D-05-03	545835	2802849	25.341578	-80.544518	CWP
D-05-04	545831	2801855	25.332602	-80.544591	CWP
D-05-05	545833	2800854	25.323562	-80.544605	CM
D-05-06	546832	2803854	25.350622	-80.534576	CM
D-05-07	546833	2802854	25.341592	-80.534600	CM
D-05-08	546830	2801851	25.332534	-80.534665	RCM
D-05-09	546834	2800850	25.323495	-80.534660	CM
D-06-01	548330	2804355	25.355099	-80.519671	CM
D-06-02	548333	2803356	25.346077	-80.519677	CWP

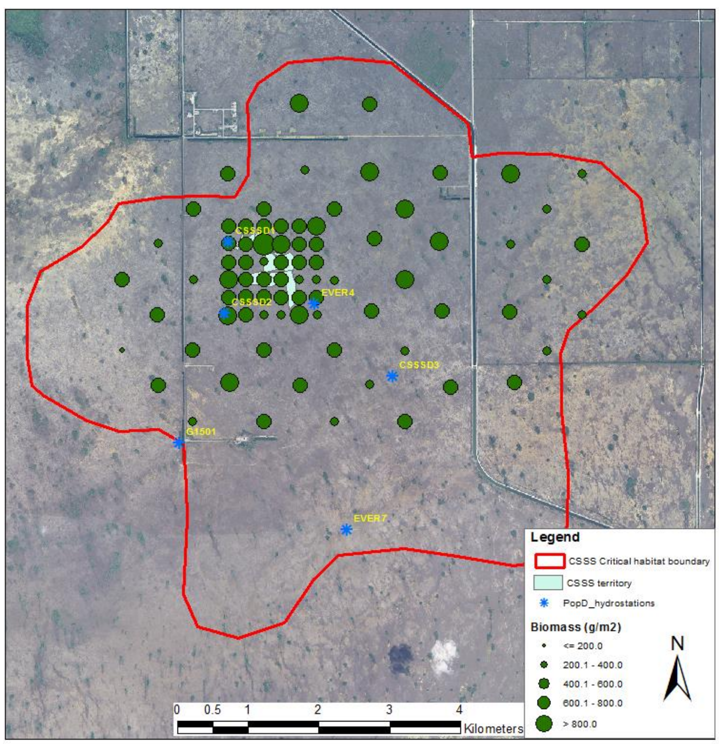
PLOT	X_UTM83	Y_UTM83	LAT_WGS84	LONG_WGS84	Vegetation type
D-06-03	548832	2803849	25.350513	-80.514700	CM
D-06-04	548834	2802850	25.341491	-80.514716	CRM
D-06-05	548834	2801851	25.332470	-80.514752	CRM
D-06-06	549331	2804349	25.355012	-80.509723	ERM
D-06-07	549336	2803354	25.346026	-80.509709	CM
D-06-08	549334	2802353	25.336987	-80.509766	CM
TD-01-01	544337	2803605	25.348450	-80.559379	MWP
TD-01-02	544583	2803606	25.348452	-80.556934	CWP
TD-01-03	544835	2803604	25.348426	-80.554430	SOWP
TD-01-04	545084	2803606	25.348436	-80.551955	CWP
TD-01-05	545333	2803606	25.348429	-80.549481	SOWP
TD-01-06	545582	2803607	25.348430	-80.547006	CWP
TD-02-01	544339	2803363	25.346264	-80.559367	SOWP
TD-02-02	544585	2803351	25.346149	-80.556923	CWP
TD-02-03	544837	2803353	25.346159	-80.554418	CWP
TD-02-04	545086	2803354	25.346161	-80.551944	CRM
TD-02-05	545337	2803351	25.346126	-80.549450	CWP
TD-02-06	545583	2803353	25.346137	-80.547005	CWP
TD-03-01	544337	2803104	25.343926	-80.559395	CWP
TD-03-02	544584	2803105	25.343927	-80.556941	CWP
TD-03-03	544834	2803107	25.343938	-80.554456	SOWP
TD-03-04	545084	2803104	25.343903	-80.551972	SOWP
TD-03-05	545332	2803104	25.343896	-80.549508	SOWP
TD-03-06	545584	2803105	25.343897	-80.547003	SOWP
TD-04-01	544335	2802852	25.341650	-80.559423	SOWP
TD-04-02	544585	2802853	25.341652	-80.556939	SOWP
TD-04-03	544835	2802853	25.341644	-80.554455	SOWP
TD-04-04	545085	2802853	25.341637	-80.551971	CWP
TD-04-05	545334	2802854	25.341638	-80.549496	CWP
TD-04-06	545584	2802856	25.341649	-80.547012	CWP
TD-05-01	544334	2802604	25.339411	-80.559442	SOWP
TD-05-02	544587	2802607	25.339430	-80.556927	SOWP
TD-05-03	544833	2802608	25.339432	-80.554483	CWP
TD-05-04	545085	2802605	25.339397	-80.551979	CM
TD-05-05	545332	2802603	25.339371	-80.549524	CWP
TD-05-06	545584	2802603	25.339364	-80.547020	CM
TD-06-01	544330	2802349	25.337108	-80.559490	CWP
TD-06-02	544585	2802352	25.337127	-80.556956	CWP
TD-06-03	544839	2802354	25.337138	-80.554432	SOWP
TD-06-04	545084	2802353	25.337121	-80.551997	SOWP
TD-06-05	545335	2802356	25.337141	-80.549503	CWP
TD-06-06	545585	2802355	25.337124	-80.547019	CM





Appendix 2: Mean total vegetation cover and height at 88 sites sampled in CSSS Sub-population D habitat within C111 SC Western Project area.





Appendix 3: Mean species richness and aboveground biomass at 88 sites sampled in CSSS Sub-population D habitat within C111 SC Western Project area.