

Running head: Cape Sable seaside-sparrow habitat change

Hydrological changes and Cape Sable seaside-sparrow (*Ammodramus maritimus mirabilis*) habitat.

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Abstract

The endangered Cape Sable Seaside-Sparrow (*Ammodramus maritimus mirabilis*) is restricted to freshwater prairies within Everglades National Park (ENP). Although first discovered in *Spartina* marshes, this subspecies now inhabits mostly *Muhlenbergia* prairies, and the distribution of *Spartina* marsh is greatly reduced. Water management structures have greatly altered the hydrologic patterns within ENP, and have affected the sparrow's habitat. We collected vegetation data from three distinct subpopulations of the sparrow, each with different sparrow densities and water levels. We demonstrate that a few structural and floristic characteristics can be used to assess the suitability of habitat for sparrows. These vegetation characteristics also serve as indicators of habitat degradation caused by changes in the hydrologic regime.

Key words: Cape Sable seaside-sparrow, habitat, hydrology, Everglades National Park

Key phrases: habitat change of the Cape Sable seaside-sparrow, hydrology and freshwater marl prairies, habitat indicators, conservation and water management for Everglades National Park

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Introduction

The Cape Sable seaside-sparrow (*Ammodramus maritimus mirabilis*) is an endangered subspecies that inhabits the interior, freshwater marl prairies of Everglades National Park (ENP). This subspecies is restricted to several isolated prairies dominated by *Muhlenbergia filipes* or sparse *Cladium jamaicense*, although early research found the sparrow in *Spartina* sp. marshes (Howell 1919, Semple 1936, Dietrich 1938, Nicholson 1938, Anderson 1942, Stimson 1944, 1948, 1956). All other seaside sparrows use coastal saltmarshes, although the extinct Dusky seaside-sparrow used freshwater prairies dominated by cordgrass (*Spartina bakeri*) (Post and Greenlaw 1994). Declines in all subspecies of seaside sparrow are correlated with increasing habitat loss, as urban development along the Atlantic and Gulf coasts destroys saltmarshes and increases fragmentation between populations (U.S. Fish and Wildlife Service 1987, Greenlaw 1992).

Cape Sable seaside-sparrows, like other grassland sparrows, may use floristic cues to establish and defend territories, but use structural characteristics at larger scales (Wiens 1973, Rotenberry 1985, Orians and Wittenberger 1991). Dependence on one plant species may be the result of a unique structural feature that species provides. Species, such as the grasshopper sparrow (*Ammodramus savannarum*) and Baird's sparrow (*Ammodramus bairdii*), can use introduced species that provide the necessary vegetative structure they require (Rising 1996). These sparrows may be better able to adapt to human-altered landscapes. The saltmarsh and seaside sparrows (*Ammodramus caudacutus*, *A. nelsoni*, and *A. maritimus*) have not demonstrated this plasticity in their habitat utilization. We do not know if Cape Sable seaside-sparrows can adapt to current habitat changes across its entire distribution.

For almost 25 years, researchers have been investigating what habitat cues Cape Sable seaside-sparrows use in locating suitable breeding grounds (Werner 1975, Werner and Woolfenden 1983, Kushlan and Bass 1983, O'Meara and Marion 1985, Curnutt et al 1998, Nott et al 1998). In 1983, Kushlan and Bass identified two freshwater prairie communities that sparrows occupy. The first is often called muhly prairie, as it consists mostly of *Muhlenbergia filipes*, blacktop sedge (*Schoenus nigricans*) and sawgrass (*Cladium jamaicense*). The second they termed mixed prairie. It consists largely of

Rhynchospora sp. and *Panicum sp.* Werner and Woolfenden (1983) found four habitat types that were suitable for sparrows: clumped *Spartina bakeri* prairie, unclumped *Spartina* prairie, sparse *Cladium* prairie, and *Muhlenbergia* prairie. They found most sparrows in muhly prairies, while some occupied sites in the other three prairie types. These past surveys of sparrow habitat may have been too general to discern the specific vegetation characteristics that sparrows require. The helicopter surveys covered the sparrow's entire distribution, but limited vegetation data to those estimates an observer could make in ten minutes at each drop site (Kushlan and Bass 1983). Werner (1975) collected detailed vegetation data, similar to the methods we employ, but surveyed only one site. Our study is the first intensive plant survey across the entire distribution of the sparrow.

Prior to the late 1970's, most of the sparrow's range was significantly drier than it is today. Lower water levels in the middle of this century may have promoted the eventual disappearance of *Spartina* marshes and the spread of *Muhlenbergia* prairies (Olmsted et al. 1980, Werner and Woolfenden 1983). Although Davis (1943) reported *Muhlenbergia* in Big Cypress National Preserve, *Muhlenbergia* is not mentioned in any other early vegetation reports (Egler 1952, Robertson 1955, and Craighead 1971). *Muhlenbergia* might have begun its invasion of the freshwater prairies as late as 40 years ago. In the mid to late 1960's, the water management agencies increased water deliveries to ENP to aid declining species, such as the American alligator (*Alligator mississippiensis*, Mazzotti and Brandt 1994, Light and Dineen 1994). However, these deliveries were not uniform throughout ENP, with more water delivered to the western half. Curnutt et al. (1998) and Nott et al (1998) suggest that these hydrological changes have increased the sparrow's probability of extinction, as high water levels have flooded the western subpopulations, and low water levels have encouraged shrub invasion and frequent fires in eastern subpopulations. Specific information on how these prairies may change as water management alters delivery schedules to the Park is essential to this subspecies' chances for survival (O'Meara and Marion 1985).

In our study, we examined the specific habitat indicators that these sparrows may use to choose breeding habitat, and how hydrological changes may affect these indicators. We compare vegetation patterns at two scales, which increased our chances of detecting critical structural features that may be provided by one or a few plant species (Orians and Wittenberger 1991). First, we examine differences in vegetation between areas within sparrow territories to areas further away. We then compare general habitat characteristics between sites which differ in sparrow density and hydrology. We compare our results with

those found by earlier researchers, and demonstrate that hydrological changes profoundly alter the structure and species composition in these prairies. These vegetation changes render areas unsuitable for Cape Sable sparrows, and have clear implications for management of the sparrow's habitat.

Study Sites

We conducted our research from March to May 1997, on six sites within Everglades National Park (Figure 1). These sites differed in the number of sparrows supported and hydrological conditions. To calculate sparrow density, we averaged the number of adult sparrows found on each site and divided by the site's area. Each study area had boundaries which were either permanent PVC poles at the site's corners, or natural boundaries such as a pineland ecotone. On the five plots that supported sparrows, we took UTM locations of all sparrow territories in 1996 through 1998.

Shark Valley: This site is roughly 20 km south-southeast of the Shark Valley Tower at the north end of Everglades National Park. Vegetation surveys in the 1980's found moderate amounts of *Muhlenbergia* and sawgrass, and a fairly high density of sparrows. This site is 41 ha, and is within subpopulation A, which was one of two "core" subpopulations before 1992. This subpopulation experienced an 80% reduction after the 1992 breeding season, and has yet to recover. Olmsted and Armentano (1997) and Nott et al. (1998) have demonstrated that water levels in Shark Valley have been too high in wet years, too low in dry years, and have changed the plant communities in this area. At the time of this study, the site held approximately .44 sparrows per hectare, densities similar to those on North Mahogany (Pimm et al. 1998). For this area, we used hydrological data from the NP205 gauging station.

Subpopulation B: Four of our sites were within the largest "core" population of sparrows in the Park. Extensive helicopter surveys over the sparrow's range have found relatively stable sparrow numbers in this population since 1981. Two of the plots (Alligator Hammock and Dogleg) are along Main Park Road, are about 20 hectares, and support approximately 1 sparrow per hectare annually. North Mahogany is also in this area, but typically supports only .4 sparrows per hectare, and is 29 hectares. Old Ingraham Highway South is similar to Alligator Hammock and Dogleg in sparrow density but is south of these two sites, at the end of Old Ingraham Highway. (subpopulation B, see Figure 1). The P67 gauge provided us with water levels in this subpopulation.

Taylor Slough: The sixth plot, in subpopulation C, supported a large number of sparrows in 1981, but surveys since 1990 have failed to locate any sparrows here (Werner 1975, Pimm et al. 1998). We concentrated our plant transects within a 41 ha area, divided by the Main Park Road. This site is at the edge of the slough near the Park's boundaries, and directly downstream from a pumping station (S-332), activated in 1979. Since Werner's 1975 survey, S-332 is primarily responsible for a general increase in water levels on this site, and the reduction in seasonal variation of these levels. This site is very close to the TSB water gauging station.

Methods

We used hydrologic data from three water gauges near our study areas to determine differences in water levels between our sites (Figure 2). The three gauges demonstrated significantly different water levels (in cm above Mean Sea Level-MSL) in a Student t-test (P67 and TSB $t=-30.41$, $P=.000$, $df=82$, P67 and NP205 $t=-64.40$, $P=.000$, $df=82$, TSB and NP205 $t=-44.92$, $P=.000$, $df=83$). Subpopulation B was consistently driest (P67 gauge). Our Taylor Slough site (subpopulation C, TSB gauge) was much wetter than B, but drier than our Shark Valley site (subpopulation A, NP205 gauge). Water levels in Shark Valley rose dramatically between 1977 and 1979, and except for 1989 through 1992, levels have remained above all other sites, even during the spring dry-down periods. Taylor Slough had water levels comparable to those in our subpopulation B sites in 1970 to 1977, but levels have increased since then, remaining at its highest levels since 1992.

In the spring of 1997, we conducted plant surveys using a strip transect/1 m² quadrat method. In each study site, we used a stratified random sampling technique to place twenty 50m-strip transects. All transects have associated UTM coordinates. We determined the direction of the transect by throwing a small plastic stake. With ten quadrats per transect, this scheme yields 200 1m²- quadrats of data per site. This satisfies Mueller-Dombois and Ellenberg's (1974) minimum sample area requirement for their "dry- grassland" and "hay meadow" habitat categories (the closest in structure to marl prairies) of 50-100 m².

In each 1 m² quadrat at every 5m interval along the transect, we collected the following data:

- Cover – We used a Braun- Blanquet method (Phillips 1959, Mueller-Dombois and Ellenberg 1974): from 1 (0 to 1.0%) to 6 (75-100%).

- Dead matter cover – Using the same scale as above, we estimated the cover of dead matter in each quadrat. We counted dead leaves attached to living plants as "dead matter", along with debris on the ground.
- Periphyton cover – Again using the same cover scale, we estimated the abundance of the periphyton mat, which is a critical component of the marl prairies. Periphyton is a microalgal community that forms a thick mat above the soil. It is an extremely important primary producer in the Everglades, and can profoundly affect water chemistry, sediment production, and hence plant communities (Browder et al. 1994). Hydrology and water quality directly affects periphyton diversity, cover and thickness.
- Species composition – We took presence/absence data, along with the above two estimates, for every species in each quadrat. We made every attempt to identify all plants to species, but when this was impossible, we resolved the taxa to genus. We cross-checked each species identification with samples in the Everglades National Park Museum and in the vegetation crew office. We also estimated the cover for each species, although here we only report the cover data for the four dominant graminoids: *Cladium jamaicense*, *Muhlenbergia filipes*, *Rhynchospora* sp., and *Schizachyrium rhizomatum*. Most *Rhynchospora* was *R. microcarpa*, and although we did find small amounts of *R. tracyi*, we combined measurements for the two in this analysis.
- Stem density – For each plant species, we counted the number of stems per quadrat. Pimm et al (1996) conducted preliminary plant surveys, in which they counted stem densities of all species in a 1m² area. They removed and weighed (dry biomass) all plant matter, and found a linear relationship between stem density and biomass. We used this relationship in this year's data to indirectly measure biomass in each quadrat.
- Maximum vegetation height – Especially critical to determine available perches, we measured the highest plant in the quadrat in centimeters.
- Effective height (Wiens 1969) – Using a field notebook, we recorded the maximum height (in centimeters) at which 90% of the side of the notebook was obscured by vegetation. Werner (1975) used a similar measurement, which he called "vertical obscurity profile". While this is a crude measurement, it allows us to quantify an aspect of the habitat that may be important to the sparrow for predator evasion, thermal regulation and nest sites.
- Distance to nearest Cape Sable Seaside-Sparrow territory – for each transect, we calculated the distance between each transect and the nearest territory (from years 1996 to 1998), using GPS coordinates and computer-generated maps. We used the closest part of each transect to determine this distance measure. By using three years of sparrow territory, we were better able to determine areas within the study sites that are

consistently used by sparrows, and those areas that are never used. These distances have an error of 5 to 30 m associated with them, due to inaccuracies of our GPS unit. We divided these transects into three groups: 0-50m from a territory, 50-100m, and 100+m. Differences between our 0-50m group and 100+m group may be more statistically sound than those comparisons made to the intermediate group (50-100m).

We tested all continuous variables (maximum vegetation height, effective height, species richness, and biomass) for normality and homogeneity of variance before using an ANOVA. If the variables satisfied these criteria, we then tested each distance group with a post hoc Bonferroni test for significant differences between means. We judged significant results at a $P=.05$ level. If the variables did not satisfy the criteria, we entered them with the ordinal cover variables in a nonparametric Kruskal-Wallis H test. If any of the variables showed significance in this test, we further examined differences between distance group means with Wilcoxon sign-rank tests. When making pairwise comparisons of vegetation characteristics between areas with differences in hydrology, we used a nonparametric Mann-Whitney U test. To test the degree of correlation between two vegetation characteristics, we used Kendall's tau-b nonparametric correlation test. We conducted all tests using SPSS 8.0 for Windows (SPSS Inc.).

Results

We report our results in four sections. We first determined which vegetation characteristics were correlated. Floristic measures that are strongly correlated with structural ones, may indicate that these species are responsible for this characteristic. Then, we look at the difference between vegetation within and outside sparrow territories. Next, we compare differences in vegetation between subpopulations in different areas of ENP, that support different densities of sparrows and have been exposed to different water levels in the recent past. Finally, we describe changes that have occurred in one site over time as water levels have increased.

Correlated vegetation characteristics

Many of our vegetation measures were correlated, but no two variables displayed the same relationship with all measures (Table 1). Among the structural characteristics, live cover, dead cover, and maximum vegetation height were positively correlated with each other, while periphyton cover was negatively correlated with them. Effective height decreased with increasing periphyton cover, and increased with live cover and biomass. Several of the floristic characteristics demonstrated correlations as well. *Cladium* was negatively

correlated with species richness, *Muhlenbergia* and *Rhynchospora*, while these three variables were all positively correlated with each other. *Muhlenbergia* was positively associated with *Schizachyrium*. Between structural and floristic characteristics, *Cladium* was positively correlated with maximum vegetation height and biomass, and negatively associated with effective height. *Muhlenbergia* cover increased with effective height and live cover, but decreased with increased periphyton cover. Live cover, *Muhlenbergia*, and *Schizachyrium* were all positively correlated.

Table 1. Kendall's tau-b bivariate correlation matrix between vegetation characteristics

	Cover	MVH	EH	Dead	Perip h	SpRh	Biom	Clad	Muhl	Rhyn	Schiz
Cover		++	++	++	--		++		++	--	++
MVH	0.18			++	--	-		++		--	--
EH	0.23	-0.02		+	--	++	+	-	++	++	
Dead	0.22	0.40	0.15		--					-	
Perip h	-0.41	-0.27	-0.35	-0.54					--		
SppR	0.14	-0.14	0.29	-0.04	-0.10			--	++	++	
Biom	0.23	0.11	0.14	-0.07	0.06	-0.02		++			
Clad	0.02	0.39	-0.17	0.13	0.05	-0.25	0.37		--	--	
Muhl	0.21	-0.10	0.35	0.07	-0.24	0.20	-0.01	-0.22			++
Rhyn	-0.17	-0.25	0.26	-0.14	0.13	0.40	-0.12	-0.24	0.09		
Schiz	0.16	-0.18	0.11	-0.06	-0.10	-0.05	0.06	-0.13	0.19	-0.13	

+, -: correlation significant at the .05 level (2-tailed)

++, --: correlation significant at the .01 level (2-tailed)

Habitat and proximity to a sparrow territory:

Four variables increased with distance from a sparrow territory: maximum vegetation height, percent cover *Cladium jamaicense* and *Rhynchospora* sp., and periphyton cover. On Dogleg, mean maximum vegetation height was lowest in areas closest to territories ($P=0.051$, $x_{0-50m} = 89.91\text{cm}$, $sd=5.27$, $x_{100+m} = 93.11\text{cm}$, $sd=6.70$). On the three "high occupancy" sites, maximum vegetation height increased with distance from a territory ($P=0.051$, $x_{0-50m} = 89.71\text{cm}$, $sd=11.16$, $x_{100+m} = 95.70\text{cm}$, $sd=12.75$), as did percent cover of *Cladium* ($P=0.041$ for ANOVA, means of distance groups not significantly

different). When we combined all sites, percent cover of *Rhynchospora* sp. also increased with distance ($P=0.028$, $x_{50-100m} = .8222$, $sd=0.30$, $x_{100+m} = 1.2708$, $sd=0.27$). On the two "moderate occupancy" sites, periphyton cover increased with distance from a territory ($P=0.023$, $x_{0-50m} = 4.69$, $sd=0.34$, $x_{50-100m} = 4.83$, $sd=0.17$, and $x_{100+m} = 4.95$, $sd=0.12$).

With increasing distance from a territory, all five occupied sites demonstrated a decrease in percent cover of *Muhlenbergia* ($x_{0-100m} = 1.67$, $sd=0.72$, $x_{100+m} = 0.73$, $sd=0.71$), and *Schizachyrium* ($x_{0-100m} = 1.07$, $sd=0.53$, $x_{100+m} = 0.75$, $sd=0.51$, Figure 3). Dead matter cover decreased on North Mahogany with distance from a territory ($P=0.043$, $x_{0-50m} = 1.97$, $sd=0.62$, $x_{50-100m} = 1.85$, $sd=0.35$, $x_{100+m} = 1.45$, $sd=0.23$). On the two "moderate occupancy" sites, dead cover decreased with distance ($P=0.007$, $x_{0-50m} = 1.83$, $sd=0.57$, $x_{100+m} = 1.34$, $sd=0.30$). On North Mahogany, biomass peaked in areas 50-100m from a territory ($P=0.012$, $x_{0-50m} = 1544.01g$, $sd=$ $x_{50-100m} = 2059.39g$, and $x_{100+m} = 1406.72g$). This pattern was not significant on any other site, and may be a result of a unique fire history or soil composition. Figure 3 combines all significant results and plots the percent deviation of the characteristic from the mean of all occupied sites.

We then analyzed vegetation differences between areas with different sparrow densities. We grouped three of the sites with densities around 1 sparrow per hectare into a "high density" category, grouped two sites (with density near .5 sparrows per hectare) into a "moderate density", and used Taylor Slough as an unoccupied site. Several variables showed no pattern with distance from a territory, but were correlated with sparrow density (Figure 4). Plant cover, effective height, and biomass all decreased with sparrow density, while maximum vegetation height, percent cover of *Cladium* and *Rhynchospora*, and periphyton cover increased (Mann-Whitney U, $P<0.02$ for all variables). However, note that we found much more *Rhynchospora* than *Muhlenbergia* on Shark Valley, one of our two "moderate density" sites.

Sparrow habitat and hydrology:

Several of the vegetation characteristics found to differ with sparrow proximity and density demonstrated similar trends with water levels as well (Table 2). Effective height and percent cover of *Muhlenbergia* were lower on areas with higher water, as they were further from sparrow territories (not significantly for effective height) and in lower-density areas. Maximum vegetation height and percent cover of *Cladium* demonstrated an opposite trend. We found no *Muhlenbergia* on our site in subpopulation A, although Pimm et al. (1996) recorded its presence during their helicopter surveys until 1994. Percent cover of

Rhynchospora sp. was higher on our subpopulation A site, although this characteristic was lower on our higher density sites. Subpopulation A also had much lower percent cover of *Schizachyrium rhizomatum* than our other two sites, and we found this species cover to be higher in areas with higher sparrow densities. Periphyton cover was lowest within territories and high density areas, and generally decreased with water levels. Plant cover, dead matter cover, species richness, and percent cover of *Schizachyrium rhizomatum* did not display a pattern with water level, although all three areas differed significantly in these characteristics. Taylor Slough had the highest mean cover, dead cover, and percent cover of *Schizachyrium rhizomatum*, but the lowest species diversity.

Table 2. Mean differences between subpopulations, from wettest to driest			
	Subpopn A	Subpopn C	Subpopn B
Cover ^{a,b,c}	1.72	2.20	1.85
Max Veg Height ^{a,b,c}	102.64	111.63	94.44
Effective Height ^{a,b}	0.87	1.99	2.39
Dead cover ^{a,b,c}	1.37	2.27	1.65
Periphyton cover ^{a,b,c}	4.94	4.19	4.73
Spp. Richness ^{b,c}	8.04	6.90	7.91
% cover <i>Cladium</i> ^{a,b}	2.26	2.13	1.98
% cover <i>Muhlenbergia</i> ^{a,b,c}	0	1.00	1.30
% cover <i>Rhynchospora</i> ^{a,b,c}	1.64	0.01	1.24
% cover <i>Schizachyrium</i> ^{a,c}	0.44	1.37	1.16

- a. significantly different between A and B, $P < 0.05$
- b. significantly different between B and C, $P < 0.05$
- c. significantly different between A and C, $P < 0.05$

Taylor Slough: Past and present

Werner (1975) measured some of the same vegetation characteristics we did. He maximum vegetation height and effective height, the dominance (number of quadrats a species dominated) of *Cladium jamaicense*, *Muhlenbergia filipes*, and *Schizachyrium rhizomatum*, and the frequency (number of quadrates in which a species was found) for *Rhynchospora microcarpa* (*R. tracyi* was not present in 1975 or in 1997) and *Spartina bakeri*. When our results are compared to those that Werner (1975) found on his five Taylor Slough plots (one of which was unoccupied), we see the same vegetation patterns occur over time as we do over space (between subpopulations) (Table 3). Maximum vegetation height, effective

height, and *Cladium* and *Muhlenbergia* dominance have all changed as conditions have gotten wetter. Since 1975, mean maximum vegetation height has increased on Taylor Slough by more than 10 cm. The mean effective height on Werner's unoccupied plots was substantially higher than on any of our transects in 1997. *Muhlenbergia* and *Rhynchospora* decreased, and *Spartina* disappeared. *Schizachyrium* has remained relatively constant to Werner's unoccupied plot, but is much greater than in his occupied plots. *Cladium* has increased overall, which probably also accounts for the increase in maximum vegetation height.

Table 3. Vegetation changes on Taylor Slough between 1975 (Werner 1975) and 1997.

	1975 occupied	1975 unoccupied	1997 (unoccupied)
Max. Veg. Ht. (cm)	96.9	93.7	111.6
Effective Ht. (cm)	12.9	4.0	.99
<i>Muhlenbergia</i> dominance	87%	40%	25%
<i>Cladium</i> dominance	8%	26%	45%
<i>Schizachyrium</i> dominance	4%	34%	29%
<i>Rhynchospora</i> frequency	36%	10%	2%
<i>Spartina</i> frequency	4%	6%	0

Discussion

Our results define several vegetation characteristics that can help identify sparrow habitat. Sparrows avoid areas with mean stand heights of 100cm or taller (Table 1). This includes large stands of tall *Cladium jamaicense*, which typically grows taller than any other graminoid in the prairie. Maximum vegetation height was an important habitat indicator at the territory and subpopulation scales, and was positively correlated with percent cover of *Cladium*. Periphyton cover was higher in areas with less plant cover, maximum vegetation height, effective height, dead cover, and *Muhlenbergia*. Sparrows may avoid areas with higher periphyton, since these areas tend to be more open. The sparrow spends a considerable amount of time foraging and traveling on the ground (Post and Greenlaw 1994), and these areas may expose the sparrows to more predators, or offer fewer food and nest resources.

Sparrows appear to choose areas with high mean effective height, dominance of *Muhlenbergia filipes* or *Rhynchospora* sp., and possibly dead cover for breeding habitat

and nest sites (Lockwood et al. in prep). Effective height and percent cover of *Muhlenbergia* were positively correlated, and were higher in areas with higher sparrow density and lower water levels. Sparrows may need an overall mean effective height of at least 1-2cm in their habitat, although Lockwood et al. (in prep) found mean effective height at nest sites of 3.4cm. *Muhlenbergia* and *Rhynchospora* sp., along with dead matter, may provide the bulk of this effective height characteristic. In the past, *Spartina bakeri* provided these low, dense clumps, but we found no *Spartina* on any of our sites. Live cover, biomass, and *Schizachyrium rhizomatum* cover were also higher in areas within sparrow territory or higher sparrow densities, and may offer more protection and resources.

This study is not the first to indicate that recent hydrological changes have affected the Everglades vegetation (Loveless 1959, McPherson 1973, Goodrick 1974, Volk et al. 1974, Alexander and Crook 1984, Davis et al. 1994), but it is one of few to quantify these changes. High water levels were positively associated with several of the vegetative characteristics that sparrows seem to avoid. In wetter areas (Shark Valley) and as water levels increased over time (Taylor Slough), the amount of *Cladium* increased, consistent with several other studies (Werner 1975, Oldmsted et al. 1980, Alexander and Crook 1984). In these areas, maximum vegetation height exceeded 1m. Percent cover of *Muhlenbergia* decreased, lowering the average height of clumps to less than 1cm. On Taylor Slough, we did not observe an increase in *Spartina*, *Rhynchospora*, or *Schizachyrium* to compensate for the loss in effective height. If high water persists in Shark Valley, we would expect the vegetation changes to mimic those on Taylor Slough. Maximum height and *Cladium* cover will increase, as effective height decreases. If *Rhynchospora* sp. cover also decreases as it has on Taylor Slough, and no other plant species that can provide effective height replaces it, this site may eventually become unsuitable for sparrows.

Nott et al. (1998) suggested a mechanism by which high water levels directly impact relative dominance among the plant species, and the vegetative structure. Increased hydroperiod (higher water levels persisting for a longer period of time) may increase the thickness and height of the floating periphyton mat. This mat then selectively crushes soft-leaved vegetation (such as *Muhlenbergia filipes*) during dry-down, while stiffer vegetation (such as *Cladium jamaicense*) punches through. Our results give credence to this hypothesis. Shark Valley and Taylor Slough had considerably higher periphyton and *Cladium* cover than our areas in subpopulation B. High periphyton cover was negatively

correlated with live and dead vegetation cover, and may crush these structural attributes as well.

The disappearance of other suitable habitat types (sparse and clumped *Spartina* marshes) has left only two habitat types for the sparrows, *Muhlenbergia* prairies and the marginal sparse *Cladium* prairies. Now, higher water levels may be primarily responsible for the decrease in *Muhlenbergia* prairies, with no indication that other suitable habitat types are taking their place. As a consequence, the sparrow may be increasingly restricted to *Muhlenbergia* in areas, such as subpopulation B, where hydrologic patterns remain stable. We do not know how fast, or how well, the sparrow may adapt to these changing habitat conditions. The disappearing act of the sparrow in its past, along with its reappearance in well-traveled areas (such as our study areas along the Main Park Road), may indicate that the sparrow can change its habitat preferences within limits. Areas that are not now suitable for sparrows may become so in the near future. These freshwater prairies exhibit highly dynamic patterns in structure and species composition in response to hydrological changes. The sparrow may require a much larger area for its "critical habitat" than just those areas we find them in now. Water levels and a few vegetation variables (maximum vegetation height, effective height, and percent cover of *Cladium* and *Muhlenbergia*) may be the most useful predictors of present and future suitable sparrow habitat. These same variables may also be the most affected by dramatic hydrological changes.

Acknowledgements

Funding from the National Park Service and United States Army Corps of Engineers made this research possible. Cary Sharp provided statistical support, and Julie Lockwood, Phil Nott, and John Curnutt provided valuable comments to earlier versions of this draft. I'd also like to thank Hilliary Cooley and Mike Rugge, from the AmeriCorps program, for helping me with plant identification, and George Schardt from the National Park Service, Everglades National Park, for hydrology data.

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Figure 1. Everglades National Park, study areas, and gauging stations.

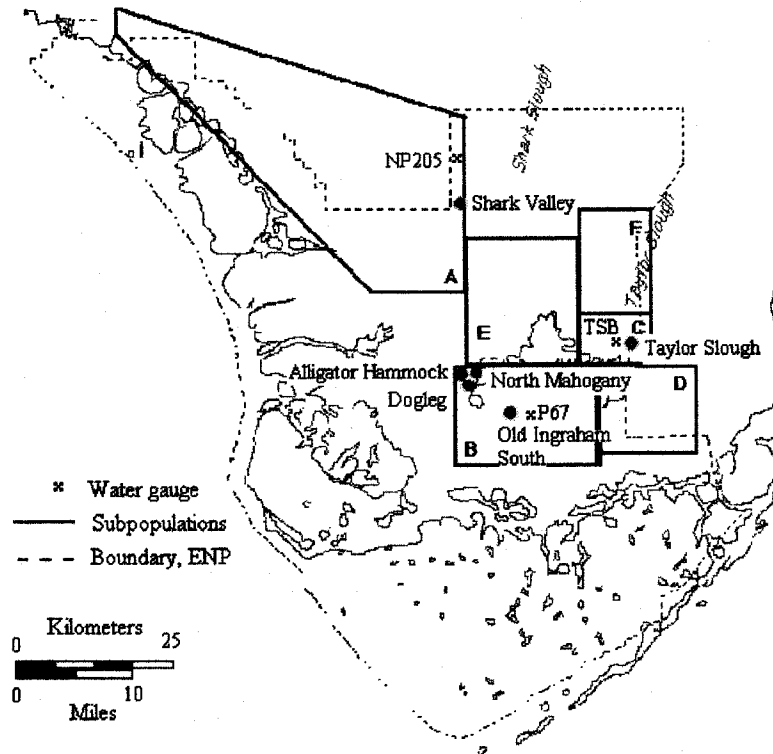


Figure 2. Water levels at three gauging stations, 1970-1998

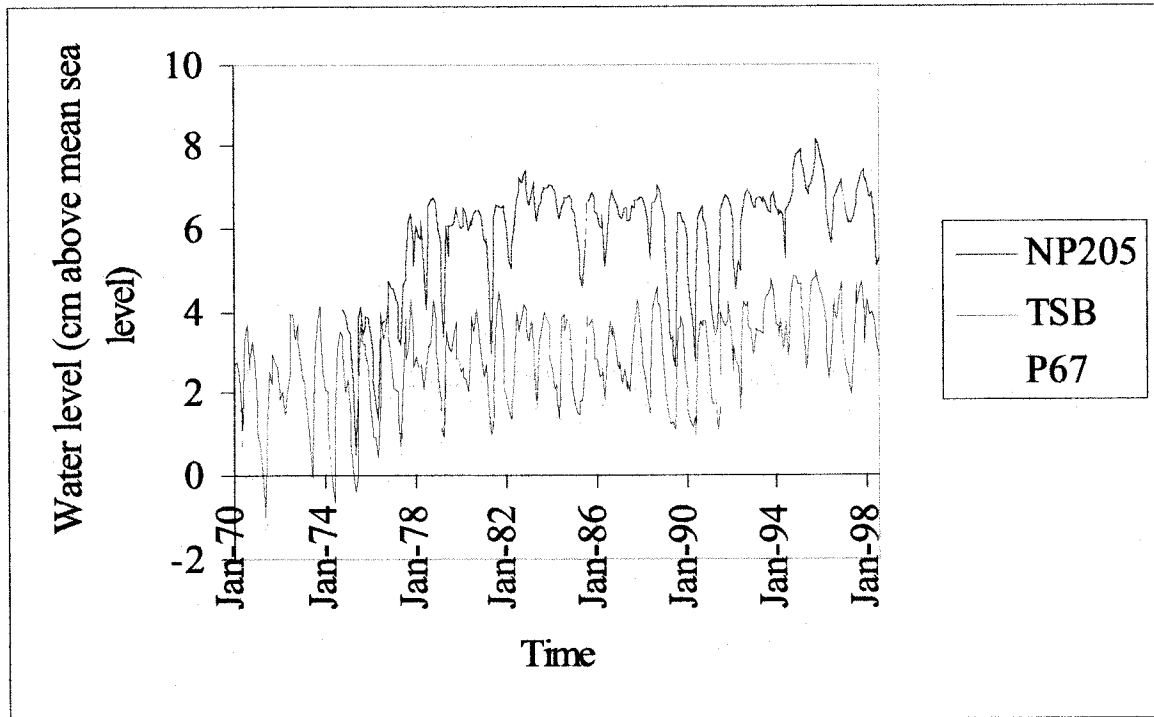


Figure 3. Distance from a sparrow territory and vegetation change, significant results only ($P < .05$)

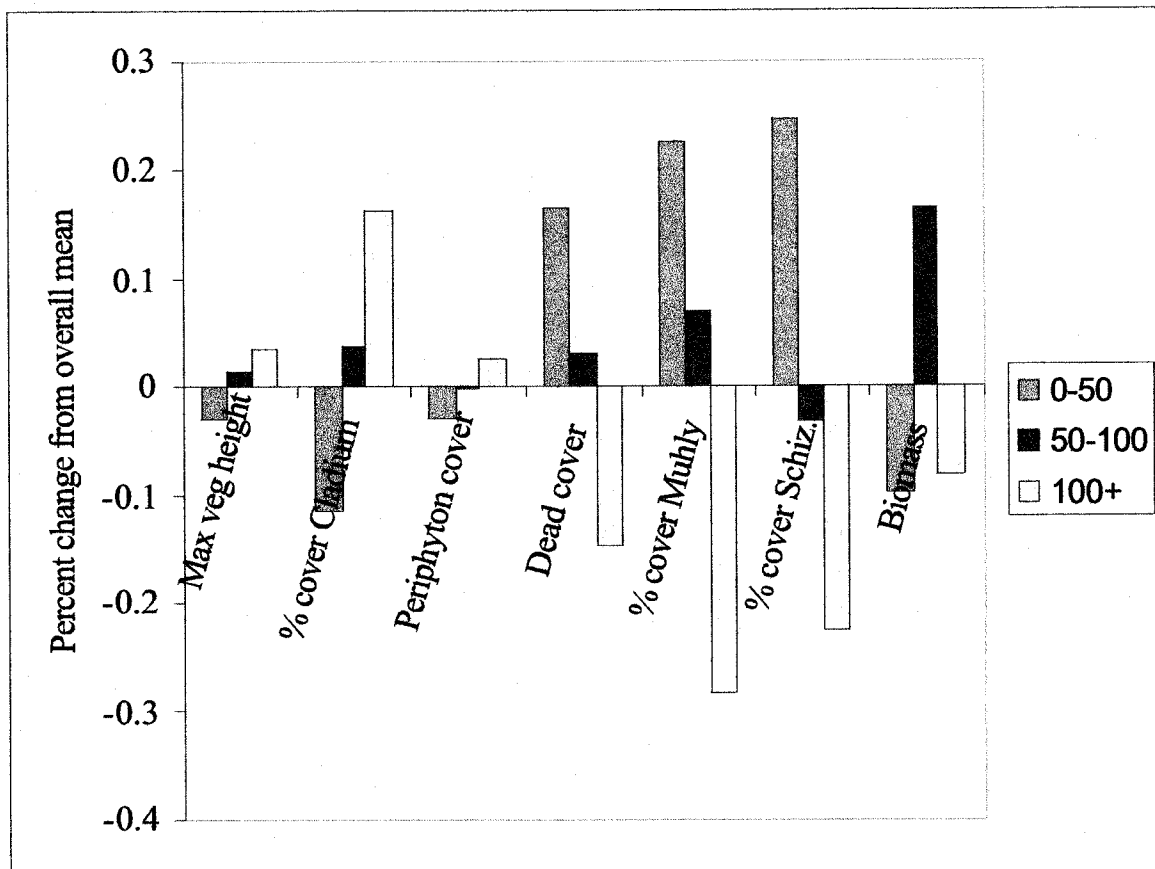


Figure 4. Sparrow density and differences in vegetation, significant results only ($P < .05$)

