Effect of Hydrologic Restoration on the Habitat of The Cape Sable Seaside Sparrow

Annual Report of 2003-2004

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Summary

Following on our previous year's work on 'Effect of hydrologic restoration on the habitat of the Cape Sable seaside sparrow (CSSS)', we presented first year results at the Cape Sable seaside sparrow – fire planning workshop at Everglades National Park in December 2003. Later, with almost the same set of crews as in the previous year, we started field work in the first week of January and continued till May 26, 2004. Protocols for sampling topography and vegetation in 2004 were identical to the previous year. In the early season, we completed topographic surveys along two remaining transects, B and E (~16.5 km), and vegetation surveys along three transects, D, E and F (~10.8 km), leaving only the vegetation sampling on transects B and C to be completed in 2005. During April and May, vegetation sampling was completed at 230 census sites, making the total of 409 CSSS census sites for which we have complete vegetation data. We updated data sets from both 2003 and 2004, and analyzed them together using cluster analysis, ordination, weighted-averaging regression and analysis of variance, as we had in 2003. Additionally, we used logistic regression to examine the effect of vegetation structural parameters on the recent occurrence of CSSS. We also analyzed vegetation observations recorded by the sparrow census team in 1981 and annually between 1992 and 2004 to assess historical patterns of vegetation change in CSSS habitat.

In 2004, 28 species were added to the existing plant species list, bringing the total number species recorded from CSSS habitat to 167. The cluster analysis based on species cover data gathered at 409 sites yielded ten vegetation assemblages, including the same eight that had been recognized in the Year-1 data set, and two additional groups: *Eleocharis-Rhynchospora* marsh and *Paspalum-Schizachyrium-Cladium* wet prairie. Those assemblages were broadly grouped into two broad categories: 'wet-prairie' and 'marsh'. In general, wet prairies had shorter inferred hydroperiod, higher species richness and shallower soil depth than marshes. This generalization also applied to the two new groups. *Paspalum-Schizachyrium-Cladium* wet prairie had shorter (<240 days) hydroperiod and higher species richness (~22.0) than *Eleocharis-Rhynchospora* marsh. *Spartina*-dominated community in Cape Sable had the tallest canopy height (>1m), highest cover (~50%), and deepest (>1.5m) soil, but were poorest in species richness (~8.0). Structural variables were not significant in determining the bird occurrence. However, inferred hydroperiod proved to be a strong predictor of CSSS occurrence. In sites with hydroperiod ranging between 150 and 240 days, CSSS occupancy was >40%, while at longer hydroperiods occupancy was <20%. Many of same sites, currently with long hydroperiods (>240 days), had high occupancy in 1981 and early in the 1990's. At those sites, however, CSSS occupancy declined after 1993, owing to change in hydrological conditions followed by vegetation change. During 1992 to 1997, many sites in Areas A, C and D changed from prairies to marsh, probably in response to water management changes at the S-12 and S-332 structures. The more detailed analysis of the compete data sets, including the ones to be collected in next two years of the project, will be required for a more complete understanding of vegetation changes, and the response of CSSS populations to them.

1. Introduction

This document summarizes the progress that was made during the second year of the research project "Effect of hydrologic restoration on the habitat of the Cape Sable Seaside Sparrow (*Ammodramus maritimus mirabilis*)", a four-year collaborative effort among the Army Corps of Engineers, Everglades National Park, Florida International University, and the US Geological Service (Biological Resources Division).

2. Methods

2.1 Presentations and field work

Due to problems associated with transferring funds early in the fiscal year, a short hiatus in funding was experienced between Oct 2003 and mid-January 2004. In the interim, a number of activities were continued, including analysis of data and limited sampling along transects that could be reached by foot. The most significant activity during this period was a presentation that Jay Sah and Mike Ross made at the Cape Sable seaside sparrow - fire planning workshop at ENP on December 2-3. In this presentation, we described much of the work reported on in the 2002-03 Annual Report, plus an analysis of vegetation data in areas of ENP burned during the last 10 years. Fire effects are outside the current SOW, but observations on fire effects in several census plots are discussed in the context of vegetation:hydrology results (Section 3.4), and the figures from our December 2003 presentation are included as an Appendix. In July, Jay Sah presented a new version of his talk, updated to include the results of the 2004 sampling, at the International Association of Vegetation Science annual meeting.

The logistics of the field work in 2004 differed slightly from the previous year. As in 2003, Biscayne Helicopter provided transportation during the census portion of the field season (March-May), but transportation for much of the transect work (January-March) was contracted from Big Cypress National Preserve (Bill Evans, Pilot). Both Biscayne Helicopter and BCNP provided excellent service. Consistency in our vegetation sampling was also greatly benefited by retaining most of the sampling personnel over the first two years of the project. As in 2002-03, FIU personnel were Michael Ross, Project Leader; Jay Sah, Post-doctoral Research Associate; Pablo Ruiz, GIS Specialist; David Jones, Lead Botanist; and Hillary Cooley, Graduate Research Assistant. Susanna Stoffella joined the sampling team midway through the season. We were also assisted by the staff of Evelyn Gaiser's Periphyton Research Group, including also Serge Thomas, Rafael Travieso, and Franco Tobias. The USGS participants included Jim Snyder, Project Leader, and his assistant, Sara Robinson, who replaced Curt Schaeffer.

Protocols for sampling topography and vegetation in 2004 were identical to the previous year (Ross et al. 2003). Transect surveys were completed early in the season. Vegetation surveys were completed along Transects D, E, and F. Topographic surveys were completed for Transects B, and E as well, leaving only the vegetation sampling on Transects B (~11 km) and C (~5 km) to be completed in 2005. Census sampling in 2004 began on March 9, when we sampled a set of 10 census plots in Population A in anticipation of a planned prescribed fire. Weather conditions did not permit burning as anticipated. Census sampling was re-initiated on April 2. Due to exceptionally good weather condition during the remainder of the spring, we were able to sample a total of 230 plots before ending for the season on May 26. With the 179 plots we visited in 2003, we now have complete vegetation data for 409 of the sparrow census plots. We have also completed two annual follow-up surveys at three plots burned in a 2003 prescribed fire in Population B.

2.2 Analytical methods

Data treatment described in this Report include several analyses similar in kind to those done in 2003 (ordination and classification, weighted averaging regression), but updated to include the entire 2003-2004 data set. In addition, we present for the first time analysis and display of landscape-scale CSSS habitat occupancy, as well as historical change in vegetation based on CSSS census observers.

Classification and ordination: We used agglomerative cluster analysis to define grouping of all 409 sites sampled in 2003 and 2004. We 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). We performed non-metric multidimensional scaling (NMS) ordination to visualize relationships among plant communities among census sites. We first removed the species present in less than 5 sites, resulting in a matrix of 409 sites & 109 species. The site-by-site dissimilarity matrix was based on species cover data that was first relativized by plot total. Four *Spartina*-dominated plots from the Cape Sable area were identified as outliers, and were eliminated from the ordination. The cluster analysis and NMS ordination were done using PC-ORD software (McCune and Mefford 1999).

Weighted averaging regression and calibration: The training data set with which we developed the updated (from 2003) WA model was the species cover data and hydroperiod estimates from 134 plots on Transects A, E and F. Vegetation in Transect A was sampled in 2003 and Transects E & F were sampled in 2004. Hydroperiod estimates for Transects A and F were arrived at from topographic surveys in conjunction with water level records at NP205 and RG2, respectively. For sites on Transect E, we used water level records from two recorders, CR2 and A13, located near the eastern and western ends of the transect, respectively. The estimate of mean water level at each plot on Transect E was calculated on the basis of a distance-weighted average of stage at the recorders at each end of the 5-km transect. Thus, for a given day, water level at a point 100 meters west of CR2 was calculated as 98% of stage recorded at CR2 plus 2% of stage at A13, at the west end of the transect. In this way, water level at meter 2500 in the middle of the transect was influenced equally by both recorders.

In developing the WA models, hydroperiod was calculated across different time periods (i.e., years preceding vegetation sampling). When mean annual values of the 1 to 6 year periods preceding sampling were evaluated, the four-year period yielded the best model. Thus, for Transect A, sampled in 2003, we used hydroperiod for 1999-2002, while hydroperiod for 2000-2003 was used for Transects E and F, sampled in 2004. The best model was one in which species' impact was not weighted on the basis of tolerance (i.e., the width of its realized hydrologic niche), and in which the inverse method of de-shrinking the site estimates was employed (Birks et al. 1990). We used the C2 program of Juggins (2003) to develop WA model. The best WA model was applied to the calibration data set that included the vegetation data from 409 census plots, of which 179 were surveyed in 2003 and 230 were surveyed in 2004.

Logistic regression: Logistic regression was used to examine the effect of vegetation structural parameters on the recent occurrence of Cape Sable seaside sparrow (CSSS). The analysis was applied only to sites at which the bird census was conducted each year during the three-year period preceding the year of vegetation sampling (2003 or 2004). The dependent variable in the analysis was the occurrence (Presence/absence) of at least one bird during any of the three years, and the independent variables tested were vegetation-inferred hydroperiod, crown height, crown closure, total cover and % live cover in the plots.

Vegetation change, 1981-2004: Vegetation observations recorded by the sparrow census team in 1981 and annually from 1992 to 2004 were used to assess historical patterns of vegetation change in CSSS habitat. Vegetation observers recorded, in order of importance, the dominant species or species groups (1-4 per observation) in the vicinity of the helicopter landing site. We categorized these observations into four broad categories – marsh, wet-prairies, woody and Spartina-dominated. "Marsh" included sites at which *Bacopa, Eleocharis, Juncus*, Lily, *Rhynchospora,* or *Sagittaria* were the first dominant. Sites at which *Muhlenbergia* or *Schizachyrium* were the first dominant were classified as "wet-prairie". Sites where *Cladium, Panicum* or *Schoenus* were the first dominants were grouped as Marsh or Wet-prairie depending on the nature of the co-dominant species. For example, when *Cladium* was the first dominant and *Rhynchospora, Eleocharis, Schoenus* or *Cypress* were second (i.e., SG+RC, SG+EL, SG+BT, SG+CY), the sites was classified as marsh, whereas Cladium-dominated sites with second-dominants characteristic of prairies, e.g., *Muhlenbergia, Schizachyrium* or Mixed-prairie (SG+MU, SG+SZ, SG+MP) were classified as Wet-prairie. Sites with trees as the first-dominant component of vegetation were grouped as "Woody". *Spartina*-dominated sites were grouped separately. Our analysis of change among the four conglomerate vegetation categories was restricted to 335 sites for which vegetation observations were available for most years.

We evaluated the adequacy of the historical vegetation observations and our procedures in summarizing them by comparing sites classified as described above in 2003 or 2004 with classifications based on quantitative data collected at the same sites and in the same year by the FIU/USGS vegetation survey crews. We used a χ^2 test to compare vegetation groupings arrived at by the two methods. We also used one-way analysis of variance to compare mean inferred hydroperiod (based on the detailed FIU/USGS data) for sites classified as "marsh" and "wet-prairie" in 2003 or 2004 by the CSSS census team.

Finally, we used the historical vegetation observations to evaluate change from marsh to prairie vegetation, or vice versa, during the periods 1981-1992, 1992-1997, 1997-2000, and 2000-2004. In conjunction with documentation of hydrologic conditions during these periods, such analyses may provide evidence of the sensitivity of the plant communities to water management, and the time frame in which vegetation responses are expressed.

3. Results

3.1 Vegetation

The locations of the six transects, as well as the census points sampled in 2003 and 2004 are detailed in **Figure 1**. While the intensity of our sample will increase with the inclusion of 2005 data, our current sampling network is well-distributed and presumably representative of the short-hydroperiod grasslands peripheral to Shark and Taylor Sloughs.

During the course of the 2004 field season, we identified 28 new plant species within or adjacent to the vegetation plots, bringing our composite species list to 167 (**Appendix 1**). Many of the new species occurred in our single day of sampling in Cape Sable (Population G). 29 other taxa were collected this year but could not be identified to species.

The cluster analysis based on the composite 2003-2004 set of 409 census plots identified the same eight groups that had been recognized in the smaller Year 1 data set, plus two additional groups: *Eleocharis-Rhynchospora* marsh and *Paspalum-Schizachyrium-Cladium* wet-prairie (**Figure 2**). The NMS ordination of the same data (**Figure 3**) clarifies the position of these two newly-defined types within the CSSS habitat matrix. Four outliers were removed in order to reduce stress in the ordination. The resulting stress was reasonably low (16.0) suggesting that the 2-axis solution provides a good representation of site relationships. As in the ordination based on 2003 data alone (Ross et al. 2003), a 'V' shaped pattern is evident, with the mono-dominant *Cladium* marsh at the fulcrum of the 'V' and prairie and marsh types aligned along the left and right arms, respectively. Within this alignment, *Eleocharis-Rhynchospora* marsh is arrayed at the extreme end of the marsh arm, and *Paspalum-Schizachyrium-Cladium* wet-prairie is loosely distributed between the two arms. The description of vegetation results that follows focuses on these two types.

The distinctive composition of the two newly identified communities is evident in **Table 1**, which summarizes, by vegetation type, the mean cover of the 25 most abundant plant species in CSSS grasslands. The leading plant species in *Paspalum-Schizachyrium-Cladium* wet-prairie is *Paspalum monostachyum*, which is absent or a minor component in the other nine units. Similarly, *Eleocharis cellulosa* is the dominant species in *Eleocharis-Rhynchospora* marsh. *E. cellulosa* is common in several other types (*Spartina* marsh, *Cladium-Rhynchospora* marsh, *Rhynchospora-Cladium* marsh), but it is never the most abundant species in those types.

Table 2 lists mean values for three measures of diversity --- mean species richness, the Shannon-Weaver diversity index (H'), and evenness (E) (Shannon & Weaver 1949) --- in the 10 vegetation types. In the Everglades, wet prairies are more diverse plant communities than marshes. Among the prairie types, *Paspalum-Schizachyrium-Cladium* wet-prairie has the highest H', due primarily to high evenness among species. Like the other marsh communities, *Eleocharis-Rhynchospora* marsh has low species richness, resulting in low H'.

Table 1: Mean species cover (%) in herb stratum of ten vegetation types, as defined in Figure 2. Means are based on 409 census plots sampled in 2003 and 2004. Species listed are the 25 most abundant across all sites.

Species	Vegetation type									
	***Paspalum-Schizachyrium -Cladium* WP**	***Schizachyrium* WP**	***Muhlenbergia* WP**	***Schoenus* WP**	***Cladium* WP**	***Cladium* Marsh**	***Cladium-Rhynchospora* Marsh**	***Rhynchospora -Cladium* Marsh**	***Eleocharis-Rhynchospora* Marsh**	***Spartina* WP**
Cladium jamaicense	4.14	13.95	9.76	10.87	22.83	34.71	13.29	5.92	2.50	2.11
Schizachyrium rhizomatum	4.42	17.57	5.50	3.06	4.42	0.14	0.18			0.09
Muhlenbergia filipes	1.30	3.63	16.90	2.87	4.46	0.47	0.04	0.01		
Rhynchospora tracyi	1.00	0.44	0.30	0.22	0.35	0.85	2.51	9.74	2.77	0.73
Eleocharis cellulosa	0.30	0.01	0.07	0.00	0.13	0.34	2.25	2.74	6.61	8.87
Schoenus nigricans	0.00	0.28	1.35	16.21	0.46	0.48	0.00			
Bacopa caroliniana	0.13	0.02	0.00	0.00	0.10	0.32	1.47	2.63	2.25	
Spartina bakeri	0.53		0.04			0.07	0.00	0.05	0.01	32.69
Paspalum monostachyum	7.65	0.70	0.51		0.29	0.05	0.38	0.05	0.01	0.01
Panicum tenerum	0.19	0.54	0.20	0.16	0.43	0.27	0.93	0.46	0.37	
Centella asiatica	1.33	0.82	0.47	0.31	0.88	0.09	0.03	0.02	0.00	0.04
Panicum virgatum	1.24	0.81	0.16	0.06	0.46	0.23	0.38	0.11	0.17	0.09
Rhynchospora microcarpa	1.02	0.38	0.26	0.34	0.37	0.17	0.22	0.34	0.02	0.03
Pluchea rosea	0.56	0.49	0.18	0.02	0.35	0.30	0.28	0.13	0.01	0.00
Crinum americanum	0.38	0.12	0.04	0.01	0.05	0.21	0.43	0.61	0.65	0.01
Cassytha filiformis	0.16	0.64	0.36	0.46	0.18	0.20	0.13	0.01	0.01	
Sagittaria lancifolia	0.03	0.00	0.03	0.08	0.06	0.13	0.20	0.33	0.96	
Panicum hemitomon		0.00	0.01		0.02	0.04	0.18	0.37	1.37	
Hymenocallis palmeri	0.12	0.15	0.17	0.15	0.06	0.08	0.14	0.42	0.43	0.00
Rhynchospora divergens	0.02	0.11	0.37	0.27	0.12	0.02	0.01	0.00		
Pontederia cordata					0.00	0.12	0.29		0.03	
Rhynchospora inundata	0.00				0.01	0.09	0.01	0.22	0.36	
Aristida purpurascens		0.17	0.34	0.08	0.10	0.01	0.00			
Utricularia purpurea	0.00				0.00	0.01	0.05	0.01	0.73	
Leersia hexandra	0.05	0.06			0.02	0.04	0.08	0.18	0.18	

Mean values for five structural variables are presented by vegetation type in **Figure 4**. *Paspalum-Schizachyrium-Cladium* wet-prairie is similar in height characteristics to the other wet-prairie types, with mean maximum height of 90 cm and mean canopy height of ~55 cm. Among the wet-prairie communities, it has a comparatively open canopy structure (mean cover only 30%). Dead leaves do not typically build up in this community as they do in other wet prairies (live leaves >50% of total). *Eleocharis-Rhynchospora* marsh is most similar to *Rhynchospora-Cladium* marsh in its low stature (maximum height 80 cm, canopy height 40 cm), and open canopy (cover <25%, mean closure height ~2 cm). With >60% live leaves (the highest of the ten communities), the canopy of *Eleocharis-Rhynchospora* marsh likewise does not accumulate much dead material, at least as judged from our sampling period in late spring.

Table 2: Mean species richness, evenness, and diversity in herb stratum of eight vegetation types. Means are based on 409 census plots sampled in 2003 & 2004. Number of plots per type is presented in Figure 2. S = number of species per plot. H' = Shannon's diversity (Shannon and Weaver 1949), and E = H'/$\log_n$(S).

Vegetation type	Species richness	Shannon's diversity index (H')	Evenness (E)
Eleocharis-Rhynchospora marsh	12.1	1.648	0.667
Rhynchospora-Cladium marsh	14.7	1.639	0.620
Cladium-Rhynchospora marsh	15.7	1.457	0.538
Cladium marsh	15.3	0.679	0.251
Spartina marsh	8.6	0.700	0.361
Cladium wet prairie	24.7	1.358	0.426
Schoenus wet prairie	21.5	1.488	0.484
Muhlenbergia wet prairie	24.4	1.597	0.505
Schizachyrium wet prairie	24.2	1.513	0.476
Paspalum-Schizachyrium-Cladium wet prairie	22.2	2.048	0.675

Now that our census data set has increased to 409 points, the spatial distribution of vegetation types within this sampling network (**Figure 5**) begins to take on more meaning. Wet-prairies vegetation is concentrated in the eastern half of the study area, while marsh communities are prevalent in the western and southeastern areas (Areas A & D). We sampled *Eleocharis-Rhynchospora* marsh in the western half of Area A, the Stair-step area in the far western portion of the study area (Area H), and along the coastal fringes of Area B. Based on our surveys so far, *Paspalum-Schizachyrium-Cladium* wet-prairie is a fairly common type along the central ridge in Area A, and is sparsely distributed in Areas B, C, and H.

3.2 Soils

Soil depth is a variable that seems to distinguish prairie and marsh sites in CSSS habitat. **Figure 6** overlays and contours mean soil depths on the NMS site ordination. Prairie vegetation occurs almost exclusively where soil depth is 40 cm or less, while marsh vegetation is typically found on soils deeper than 30 cm. The deepest soils were observed on Cape Sable, where soil depth exceeded 1.5 meters at all sites sampled.

3.3 Topography

The topographic surveys for Transects A, C, D, and F were presented in the 2002-03 Report. This year we completed the surveys of single transects in CSSS sub-population B & E (**Figure 7)**. Transect E drops by about 50 centimeters from east to west. The sharp highs and lows in the data are indicative of the very rough surface in this portion of the Rocky Glades. Transect B is 11 km long, running south and then southwest from its origin in western Long Pine Key. The northern one-third of the transect is relatively flat, but elevation drops by about 50 cm between Meter 3500 and the end of the transect near State Road 9336. Transect B is lower in elevation than Transect E, and its surface roughness appears to be less as well, at least as viewed at a scale of 100 meters. We plan to examine variation in surface roughness at a smaller scale (i.e., 6 meters) when all of the plot data is complete.

3.4 Vegetation-hydrology relationships

In some cases, animals may respond to vegetation at a variety of scales, perhaps in a hierarchical fashion. For instance, changes in vegetation in a large area may cause certain animal species to abandon it entirely, despite the presence of smaller patches of suitable habitat that remain. Once it chooses its broader landscape, the same species may utilize habitat in a fine-scale manner, concentrating its activities on specific micro-sites while avoiding others. One of our objectives in the current study is to understand the effects of scale on vegetation pattern, and how the CSSS may respond to this hierarchy of scales. **Figure 8** illustrates variation in vegetation and hydrology at a smaller scale than that presented in **Figure 5**, i.e., at 100-meter intervals along Transects D, E & F. Along these transects, vegetation type was resolved one plot at a time by inserting a row representing plot species abundances into the species cover data from 409 census plots, and determining which unit it grouped with in the cluster analysis.

Vegetation types along Transect D & F were relatively uniform (**Figure 8**). Along Transect D, marshes were dominant, while most of the vegetation on Transect F was wet prairie. Vegetation on Transect E was more heterogeneous. Prairies were dominant in most locations, but marshes were present at the low elevation sites evident in **Figure 7**. Mean total cover was also lower along Transect E than Transects D or F, though recent fire in Transect D left a few sites sparsely vegetated.

Combining the vegetation and hydrology information collected along Transect A, E and F, we used weighted averaging methods to determine species optima and tolerances for hydroperiod. 94 species occurred in at least two plots (**Table 3**). Calculated optimal hydroperiods ranged from 94 days for *Mecardonia acuminata* var. *peninsularis* to 264 days for *Dicanthelium dicotomum*.

We used the same data to determine which weighting procedure (tolerance-weighted or not), deshrinking method (classical or inverse), and hydrologic lag period (hydroperiod means based on stage records of 1-6 years prior to sampling) provided the best weighted averaging model. The best model was one which applied a 4-year hydrologic record prior to

Table 3: Species hydroperiod optima and tolerances, as estimated by weighted averaging regression, based on species cover collected along Transects A, E, and F.

S. No.	Species	Species code	Occurrence (n)	Estimated hydroperiod	
				Optimum	Tolerance
1	*Aeschynomene pratensis* var. *pratensis*	AESPRA	17	201	59
2	*Agalinis linifolia*	AGALIN	12	237	14
3	*Aletris bracteata*	ALEBRA	4	139	52
4	*Andropogon virginicus* var. *virginicus*	ANDVIR	52	169	64
5	*Angadenia berterii*	ANGBER	11	153	45
6	*Annona glabra*	ANNGLA	28	170	63
7	*Aristida purpurascens*	ARIPUR	64	170	47
8	*Asclepias lanceolata*	ASCLAN	9	208	42
9	*Asclepias longifolia*	ASCLON	13	200	51
10	*Aster adnatus*	ASTADN	2	157	51
11	*Aster bracei*	ASTBRA	89	213	46
12	*Aster dumosus*	ASTDUM	56	204	55
13	*Bacopa caroliniana*	BACCAR	91	248	31
14	*Cassytha filiformis*	CASFIL	74	206	60
15	*Casuarina glauca*	CASGLA	2	214	24
16	*Centella asiatica*	CENASI	105	176	49
17	*Chiococca parvifolia*	CHIPAR	7	118	40
18	*Cirsium horridulum*	CIRHOR	8	146	38
19	*Cladium jamaicense*	CLAJAM	134	221	42
20	*Crinum americanum*	CRIAME	33	250	24
21	*Cyperus haspan*	CYPHAS	5	194	74
22	*Dichanthelium aciculare*	DICACI	5	173	15
23	*Dichromena colorata*	DICCOL	15	190	43
24	*Dichanthelium dichotomum*	DICDIC	2	264	42
25	*Eleocharis cellulosa*	ELECEL	47	250	16
26	*Eleocharis geniculata*	ELEGEN	8	198	27
27	*Eragrostis elliottii*	ERAELL	90	208	63
28	*Erianthus giganteus*	ERIGIG	30	240	24
29	*Erigeron quercifolius*	ERIQUE	4	159	30
30	*Eupatorium leptophyllum*	EUPLEP	27	179	38
31	*Eupatorium mikanioides*	EUPMIK	32	188	50
32	*Evolvulus sericeus*	EVOSER	2	136	14
33	*Flaveria linearis*	FLALIN	7	111	41
34	*Fuirena breviseta*	FUIBRE	24	195	42
35	*Helenium pinnatifidum*	HELPIN	34	178	52
36	*Heliotropium polyphyllum*	HELPOL	11	169	34
37	*Hymenocallis palmeri*	HYMPAL	77	183	53
38	*Hyptis alata*	HYPALA	14	214	49
39	*Ipomoea sagittata*	IPOSAG	45	212	40
40	*Iva microcephala*	IVAMIC	13	141	41
41	*Justicia angusta*	JUSANG	37	201	60
42	*Leersia hexandra*	LEEHEX	45	236	45
43	*Linum medium* var. *texanum*	LINMED	4	162	57
44	*Lobelia glandulosa*	LOBGLA	6	196	32
45	*Ludwigia microcarpa*	LUDMIC	42	174	72
46	*Ludwigia repens*	LUDREP	13	238	22

S. No.	Species	Species code	Occurrence (n)	Estimated hydroperiod	
				Optimum	Tolerance
47	*Magnolia virginiana*	MAGVIR	2	154	30
48	*Mecardonia acuminata* var. *peninsularis*	MECACU	5	94	47
49	*Mikania scandens*	MIKSCA	46	203	49
50	*Mitreola sessilifolia*	MITSES	29	209	57
51	*Muhlenbergia filipes*	MUHFIL	77	188	38
52	*Myrica cerifera*	MYRCER	15	202	51
53	*Nymphoides aquatica*	NYMAQU	5	173	59
54	*Oxypolis filiformis*	OXYFIL	50	224	34
55	*Panicum dichotomiflorum*	PANDIC	20	208	81
56	*Panicum hemitomon*	PANHEM	31	244	34
57	*Panicum rigidulum*	PANRIG	15	221	53
58	*Panicum tenerum*	PANTEN	133	229	40
59	*Panicum virgatum*	PANVIR	89	217	46
60	*Paspalidium geminatum* var. *geminatum*	PASGEM	14	232	26
61	*Paspalum monostachyum*	PASMON	49	169	52
62	*Peltandra virginica*	PELVIR	22	243	35
63	*Phyla nodiflora*	PHYNOD	20	176	49
64	*Piriqueta caroliniana*	PIRCAR	8	139	39
65	*Pluchea rosea*	PLUROS	114	212	42
66	*Polygala grandiflora* var. *leiodes*	POLGRA	14	187	44
67	*Polygonum hydropiperoides*	POLHYD	3	256	9
68	*Pontederia cordata* var. *lanciifolia*	PONCOR	6	250	16
69	*Proserpinaca palustris*	PROPAL	29	221	55
70	*Rhynchospora divergens*	RHYDIV	53	161	47
71	*Rhynchospora inundata*	RHYINU	10	233	49
72	*Rhynchospora microcarpa*	RHYMIC	107	204	50
73	*Rhynchospora tracyi*	RHYTRA	127	220	42
74	*Sabatia grandiflora*	SABGRA	2	95	48
75	*Sabal palmetto*	SABPAL	5	219	34
76	*Sagittaria lancifolia* var. *lancifolia*	SAGLAN	46	231	45
77	*Samolus ebracteatus*	SAMEBR	3	187	16
78	*Schoenolirion albiflorum*	SCHALB	6	238	47
79	*Schoenus nigricans*	SCHNIG	40	224	36
80	*Schizachyrium rhizomatum*	SCHRHI	98	186	45
81	*Scleria verticillata*	SCLVER	2	95	48
82	*Setaria geniculata*	SETGEN	2	190	49
83	*Solidago stricta*	SOLSTR	48	182	39
84	*Spermacoce terminalis*	SPETER	2	141	2
85	*Spiranthes spp.*	SPISPP	2	240	22
86	*Teucrium canadense*	TEUCAN	6	183	57
87	*Thalia geniculata*	THAGEN	3	244	1
88	*Typha domingensis*	TYPDOM	2	245	1
89	*Utricularia cornuta*	UTRCOR	8	215	25
90	*Utricularia foliosa*	UTRFOL	5	230	25
91	*Utricularia purpurea*	UTRPUR	15	259	29
92	*Utricularia radiata*	UTRRAD	2	208	40
93	*Utricularia subulata*	UTRSUB	30	204	31
94	*Vernonia blodgettii*	VERBLO	15	149	36

sampling, in which species impact was not weighted on the basis of tolerance, and in which the inverse method of deshrinking the site estimates was employed (**Figure 9**).
The root mean squared error (33.2) and R^2 (0.65) indicated that the model is useful in predicting hydroperiod from known vegetation composition at sites whose hydrology was unknown. Nevertheless, caution must be used in interpreting such predictions. Examination of the calibration model (**Figure 9**) indicated that estimates of hydroperiod for Transect F were unbiased, but model estimates tended to slightly underpredict and overpredict flooding duration on Transects E and A, respectively. This is to be expected, as flooding is only one of several variables that influence plant species composition.

Moisture relationships associated with the range of CSSS vegetation types are explored in **Figure 10**, which superimposes and contours inferred hydroperiod on the site ordination introduced in **Figure 3**. Sites range in inferred hydroperiod from more than 330 days per year to less than 120 days. Hydroperiods in marsh sites generally exceed 7-8 months per year, while the annual flooding period in prairie vegetation types is shorter. This generalization applies equally to the two new types *Eleocharis-Rhynchospora* marsh (flooding period >240 days) and *Paspalum-Schizachyrium-Cladium* wet-prairie (flooding period <240 days).

Figure 11 displays vegetation-inferred hydroperiod throughout the census plot network. Potential CSSS habitat with current inferred hydroperiods less than 7 months are concentrated in mid-Area B, on the periphery of Long Pine Key, in the East Everglades, and in a narrow strip along the axis of Area A. As our sampling density increases, we will get an increasingly detailed view of this distribution. When these data are complete, we plan to compare the distribution of inferred hydroperiods with the distribution achieved by applying hydrologic surfaces derived from the Everglades' water monitoring network onto the USGS topographic surveys. The use of vegetation to estimate hydrologic conditions in areas with sparse water monitoring networks may have particular application in wetlands less intensively studied than the Everglades.

3.5 Current CSSS habitat usage

Our efforts to assess the potential effects of hydrologic or vegetation change on CSSS populations begin with an analysis of the current distribution of sparrows with respect to these two variables. **Figure 12** is based on 2003 and 2004 vegetation sampling plots, and whether individuals of *A. maritimus mirabilis* were observed at least once during the 2000-2002 or 2001-2003 censuses, respectively. Percentage occupancy was calculated for 30-day ranges of vegetation-inferred hydroperiod, with the ranges of the 10 vegetation classes displayed above the histogram. In sites with hydroperiod ranging between 150 and 240 days, CSSS occupancy was >40%, while at shorter and longer hydroperiods occupancy was 20% or less. Application of logistic regression to the same data (**Figure 13**) revealed that CSSS was significantly more likely to occur in shorter-hydroperiod wetlands than more persistently flooded ones. Of course, because hydroperiod and vegetation change in tandem, one might just as easily say that CSSS were more likely to be present in prairie vegetation than marsh (e.g., **Figure 14**). To directly test the influence of wetland structure on habitat use by CSSS, logistic regression was employed again on the entire 409-site data set. Four variables (maximum height, canopy height, canopy cover, and crown closure) were independent variables in a multiple regression model, but none proved significant (**Table 4**). We suspect that these results might have been different had we analyzed the data within broad wetland groups, e.g., prairies and marshes, or within finer subdivisions within these groups, i.e., vegetation types. We have deferred a more detailed analysis of this topic until the census plot vegetation data set is complete and representation within subsets of the data is more robust, i.e., after the 2005 sampling season.

Table 4: Logistic regression of relationships between vegetation structural variables and sparrow occurrence at CSSS census sites sampled in 2003 and 2004.

Structural variables	B	S.E.	Wald	Sig.	Exp(B)
Constant	2.644	1.186	4.969	0.026	14.076
Maximum height	-0.021	0.015	2.047	0.152	0.979
Crown height	-0.014	0.017	0.670	0.413	0.986
Crown closure	0.053	0.054	0.955	0.328	1.055
Total Cover	-0.010	0.014	0.537	0.464	0.990

3.6 Historical CSSS habitat usage

Table 5 presents the data displayed in **Figure 12** in tabular form, with information included on the sampling intensity in the nine vegetation types (*Spartina* marsh were not surveyed). The table makes clear that while sparrow occupancy decreases with hydroperiod (as inferred from current vegetation), sampling intensity in current prairie and marsh are roughly the same. Using available data, we attempted to address the following questions: 1) Were CSSS always sparsely distributed in areas that are now characterized by marsh vegetation and a long period of inundation? and 2) Was vegetation cover in those areas always marsh? We used CSSS census data from 1981-2004 to address Question 1, and vegetation observations made by the CSSS observers during the same censuses to address Question 2.

Table 5: Number of census sites, in which CSSS were surveyed and birds were present at least once during 2001-2004. Data are based on 409 sites in which vegetation was sampled in 2003 & 2004.

Vegetation type	Mean Inferred hydroperiod	# of sites surveyed for birds	% of sites with birds
Muhlenbergia wet prairie	167	32	56.3
Schizachyrium wet prairie	174	41	43.9
Paspalum-Schizachyrium-Cladium wet prairie	174	10	20.0
Cladium wet prairie	209	71	40.8
Schoenus wet prairie	220	15	66.7
Cladium marsh	246	75	18.7
Cladium-Rhynchospora marsh	257	46	10.9
Rhynchospora-Cladium marsh	270	32	3.1
Eragrostis-Rhynchospora marsh	303	9	11.1

Figures 14 and **15** examine the history of CSSS occupancy between 1981 and the present. In **Figure 14**, sites are arranged into 30-day "inferred hydroperiod" groups, and the occupancy data are smoothed by averaging over 3-year periods. In three short-hydroperiod groups (150-180, 180-210, and 210-240 days) occupancy was relatively high (35-55%) and constant throughout the period. Occupancy in one long-hydroperiod group was initially very high, decreased after 1993, and finally declined to zero at present. Occupancy in three other long-hydroperiod groups and one infrequently flooded group was initially moderate (20-35%), decreasing sharply after 1993, and then fluctuating at low levels (0-25%) through the present. In **Figure 15** the same data are broken down by current vegetation type. CSSS occupancy varied among sites categorized as wet-prairie, with *Schoenus* wet-prairie exhibiting the highest occupancy (70-80%) throughout. More pertinently, current wet-prairie sites experienced little or no long-term change in CSSS occupancy over the 1981-2004 period. In contrast, current marsh sites all decreased from higher levels at the beginning of the period of record than at present, with most change occurring during the early 1990's.

3.7 Vegetation dynamics in CSSS habitat

During the 14 CSSS censuses conducted since 1981, more than 200 different combinations of species and/or community types have been used to characterize the vegetation present at the sampling locations. In order to calibrate these qualitative observations against our own, we compared our observations with those of the ENP census team at sites sampled by both crews in 2003 or 2004; sites characterized by the CSSS team as woody plant-dominated were excluded from analysis. In order to make the comparison between data sets, it was necessary to merge vegetation types used by both groups into broader categories. After several steps of reducing the number of vegetation classes in both data sets, a classification based on two broad categories – wet-prairie and marsh – showed a high degree of resemblance (χ^2 = 101.9, p = <0.001), with more than 80% of sites classified similarly by the two groups (**Table 6**). Inferred hydroperiod (from FIU composition data) for sites classified as "wet-prairie" by the CSSS team (mean=199 days) were significantly shorter (ANOVA; $F_{1, 271}$ = 142.4, p = <0.001) than for sites classified as "marsh" (mean = 246 days) (**Figure 16).** Thus it seems that the qualitative vegetation observations made in association with the CSSS census should be sufficient to track ecologically meaningful trends in vegetation over 1981-2004, when those changes are widespread and reasonably consistent.

Table 6: Number (and %) of sites classified as wet-prairie and marsh based on vegetation data in both bird survey and vegetation survey during 2003 and 2004.

	Vegetation type	CSSS survey 03-04	
		Wet Prairie	**Marsh**
Vegetation survey 03-04	Wet-prairie	133 (81.1 %)	21 (19.3%)
	Marsh	31 (18.9%)	88 (80.7%)

We therefore used the CSSS census vegetation data to summarize changes in vegetation type in 7 sub-regions between 1981 and 2004. Included among these is sub-population G, in which the census was not conducted after 1997. Analyses are based on sites which were sampled in most years, with few or no missing entries. Vegetation was classified into four types: the predominant marsh and wet-prairie categories, plus woody- and *Spartina*-dominated classes, which we felt might be of additional interest. The data are presented in **Figure 17**. Several sub-regions show an increase in marsh vegetation at the expense of prairie, beginning in the early 1990's. The most prominent of these are Areas A and D, though Areas B and E also show a slight increase over the 1992 condition. Area D was almost completely prairie in 1981, but is almost completely marsh today. No consistent change in the number of sites dominated by woody plants was detected, and the trend for *Spartina* marsh on Cape Sable is difficult to interpret. Some noise in the data may be attributed to year-to-year differences in the specific points of observation, which until recently were not permanently fixed and may have varied by 100 meters or more in some cases.

The changes from prairie to marsh illustrated in **Figure 17** take on a spatial perspective when comparing **Figure 18**, which depicts the distribution of types within the sampling network in 1981, to **Figure 5**, which illustrates vegetation within this network today. The loss of prairie vegetation in Areas A and D are particularly noticeable. While today's CSSS landscape can be described in many places as islands of prairie vegetation enclosed by marsh, the two broad types were more evenly co-distributed in 1981.

Figure 19 provides a more detailed view of the temporal sequence of vegetation changes illustrated in **Figures 5, 17,** and **18**. Sites are classified as unchanged marsh or prairie, changed from wet-prairie to marsh, or changed from marsh to wet-prairie during four periods: 1981 to 1992, 1992 to 1997, 1997 to 2000 and 2000 to 2004. 1981-1992 was characterized by a drying trend, with many sites throughout the region changing from marsh to prairie. Very strong drought conditions during 1989-1991 may have played a role. Examples of opposite changes, i.e., from prairie to marsh were primarily found in Area D and western Area A. During 1992-97, changes from prairie to marsh were widespread throughout Area A as well as in the eastern portion of Area C. These trends may have been related to water management changes at the S-12 and S-332 structures. During the most recent periods, 1997-2000 and 2000-2004, marsh-prairie and prairie-marsh changes have been well-balanced, with no outstanding regional trends obvious to the eye.

3.7 Overview of CSSS habitat dynamics

The analyses described in this Report highlight vegetation changes that appear to have been brought about by water management or inter-annual climatic variation, especially in the early 1990's. However, in the Everglades, hydrology inevitably influences plant response both directly and indirectly, through its effects on resource variables (e.g., nutrient availability), stressors (e.g., salinity), or disturbance (e.g., fire). For instance, **Figure 20** illustrates vegetation recovery in two census plots sampled before an April 2003 prescribed fire, and then twice afterwards. Vegetation reappeared almost immediately after the fire, but after 14 months canopy cover had not yet approached its pre-fire level, and dead fuel buildup had not yet begun. Populations of many bird species, including grassland specialists, appear to be sensitive to structural rather than compositional variation in vegetation (MacArthur and MacArthur 1961; Rotenberry and Wiens 1980). A more complete understanding of vegetation changes both among and within units in the Everglades prairie-marsh mosaic, and the response of CSSS populations to them, will require more complex models of community development in this ecosystem, based on long-term, quantitative data sets.

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Appendix 1: List of species identified within or adjacent ot census or transect plots and added to the list from first year of sampling. Reference Codes: (1) Godfrey and Wooten 1979, 1981; (2) Long and Lakela 1976; (3) Wunderlin 1998; (4) Correll & Correll 1982; (5) Lellinger 1985

CLASS	FAMILY	SCIENTIFIC NAME	AUTHOR CITATION	REF	SPCODE	ALTERNATE NAME
PTERIDOPHYTE	PTERIDACEAE	*Acrostichum aureum*	L.	5	ACRAUR	
PTERIDOPHYTE	PTERIDACEAE	*Acrostichum danaeifolium*	Langsd. & Fisch.	5	ACRDAN	
DICOT	SCROPHULARIACEAE	*Agalinis maritima*	(Raf.) Raf.	1	AGAMAR	
DICOT	SCROPHULARIACEAE	*Bacopa monnieri*	(L.) Pennell	1	BACMON	
PTERIDOPHYTE	BLECHNACEAE	*Blechnum serrulatum*	L.C. Rich.	5	BLESER	
DICOT	CASUARINACEAE	*Casuarina glauca*	Sieber ex Spreng.	2	CASGLA	
MONOCOT	CYPERACEAE	*Cyperus polystachyos*	Rottb.	1	CYPPOL	
MONOCOT	POACEAE	*Dichanthelium aciculare*	(Desv. ex Poir.) Gould & C.A. Clark	3	DICACI	
MONOCOT	POACEAE	*Digitaria villosa*	(Walter) Pers.	2	DIGVIL	3 *D. filiformis* (L.) Koeler var. *filiformis*
MONOCOT	CYPERACEAE	*Eleocharis geniculata*	(L.) Roem. & Schult.	1	ELEGEN	2 *E. caribaea* (Rottb.) S.F. Blake
MONOCOT	ERIOCAULACEAE	*Eriocaulon* sp.			ERISP1	
DICOT	MALVACEAE	*Hibiscus grandiflorus*	Michx.	1	HIBGRA	
DICOT	MALVACEAE	*Kosteletzkya virginica*	(L.) Presl.	1	KOSVIR	
DICOT	COMBRETACEAE	*Laguncularia racemosa*	(L.) C.F. Gaertn.	1	LAGRAC	
PTERIDOPHYTE	SCHIZAEACEAE	*Lygodium microphyllum*	(Cav.) R. Br.	5	LYGMIC	
DICOT	MYRSINACEAE	*Myrsine floridana*	A. DC.	4	MYRFLO	1,2 *M. guianensis* (Aubl.) Kuntze; 3 *Rapanea punctata* (Lam.) Lund.
MONOCOT	POACEAE	*Paspalum blodgettii*	Chapm.	2	PASBLO	1 *P. caespitosum* Flugge
DICOT	ASTERACEAE	*Pluchea odorata*	(L.) Cass.	1	PLUODO	
DICOT	SALICACEAE	*Salix caroliniana*	Michx.	1	SALCAR	
DICOT	APOCYNACEAE	*Sarcostemma clausum*	(Jacq.) Roem. & Schult.	1	SARCLA	
DICOT	SAURURACEAE	*Saururus cernuus*	L.	1	SAUCER	
DICOT	AIZOACEAE	*Sesuvium portulacastrum*	(L.) L.	1	SESPOR	
MONOCOT	MARANTACEAE	*Thalia geniculata*	L.	1	THAGEN	
MONOCOT	TYPHACEAE	*Typha domingensis*	Pers.	1	TYPDOM	
DICOT	LENTIBULARIACEAE	*Utricularia radiata*	Small	1	UTRRAD	
DICOT	LENTIBULARIACEAE	*Utricularia subulata*	L.	1	UTRSUB	
DICOT	FABACEAE	*Vicia acutifolia*	Elliott	1	VICACU	
DICOT	VITACEAE	*Vitis rotundifolia*	Michx.	1	VITROT	

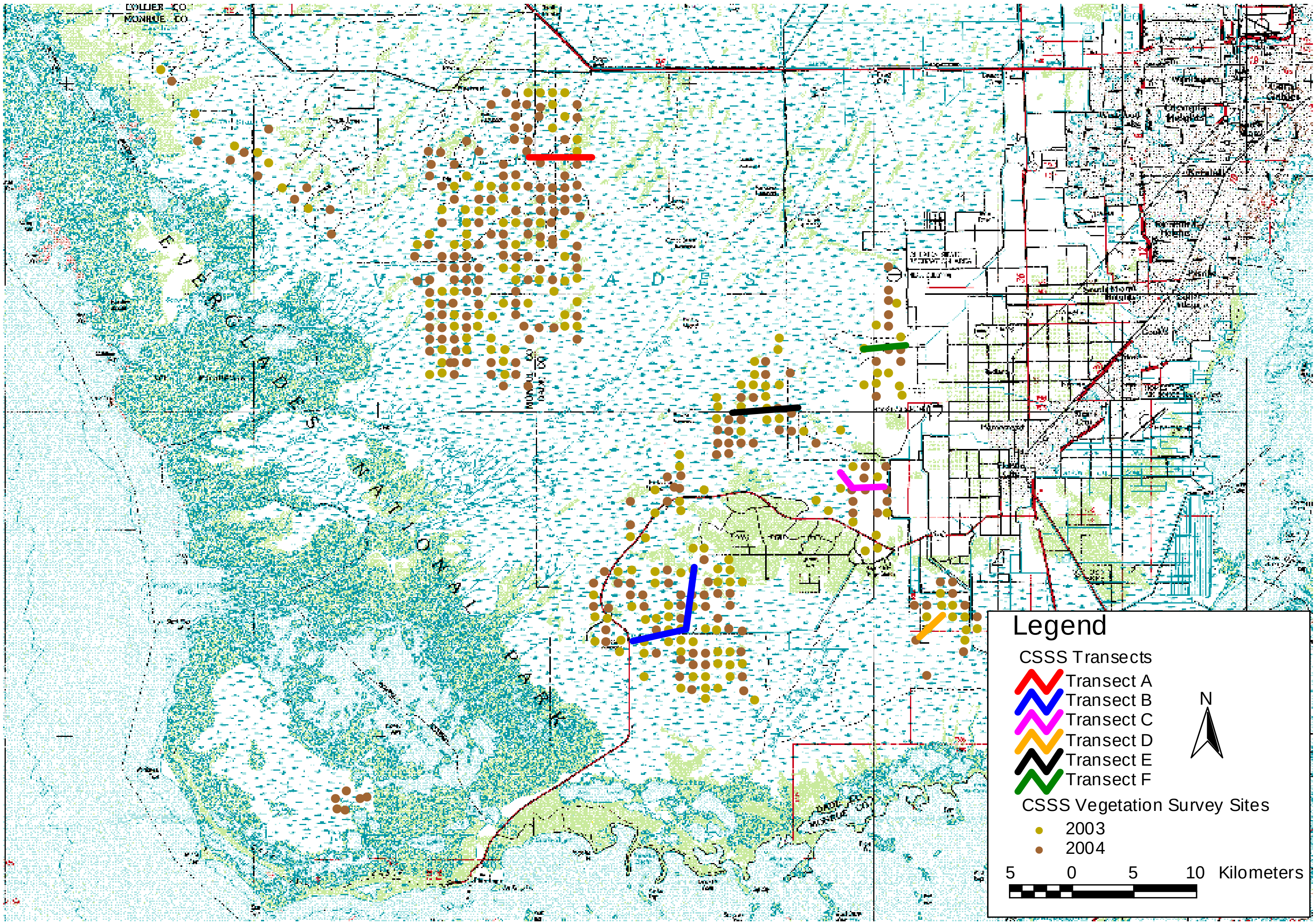

Figure 1: Location of CSSS vegetation survey sites and transects

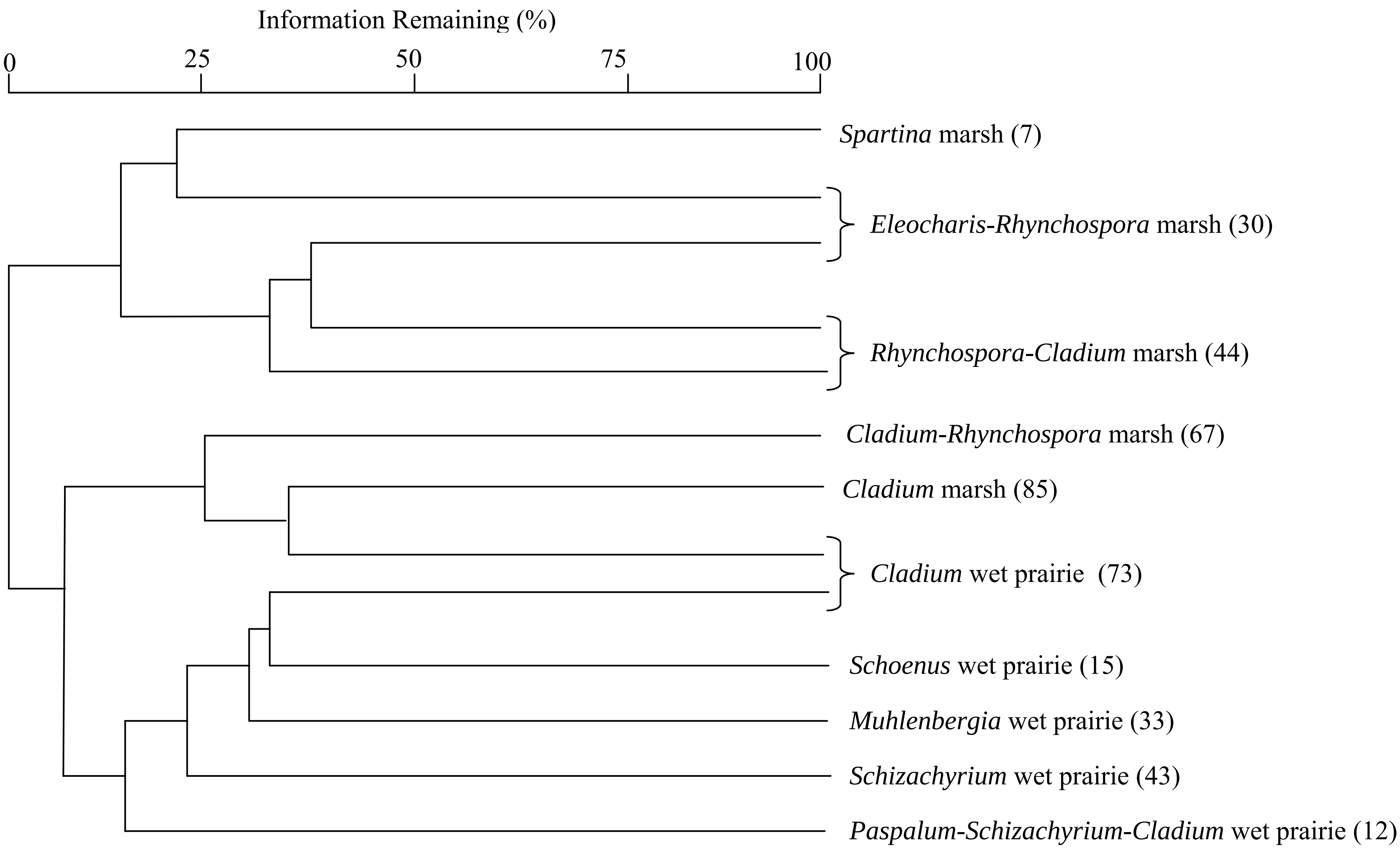

Figure 2: Vegetation types identified through cluster analysis of species cover values at 409 census plots sampled in 2003 & 2004. Numbers in parentheses are number of sites sampled in each type. Information remaining (%) is based on Wishart's objective function, following McCune and Grace (2002)

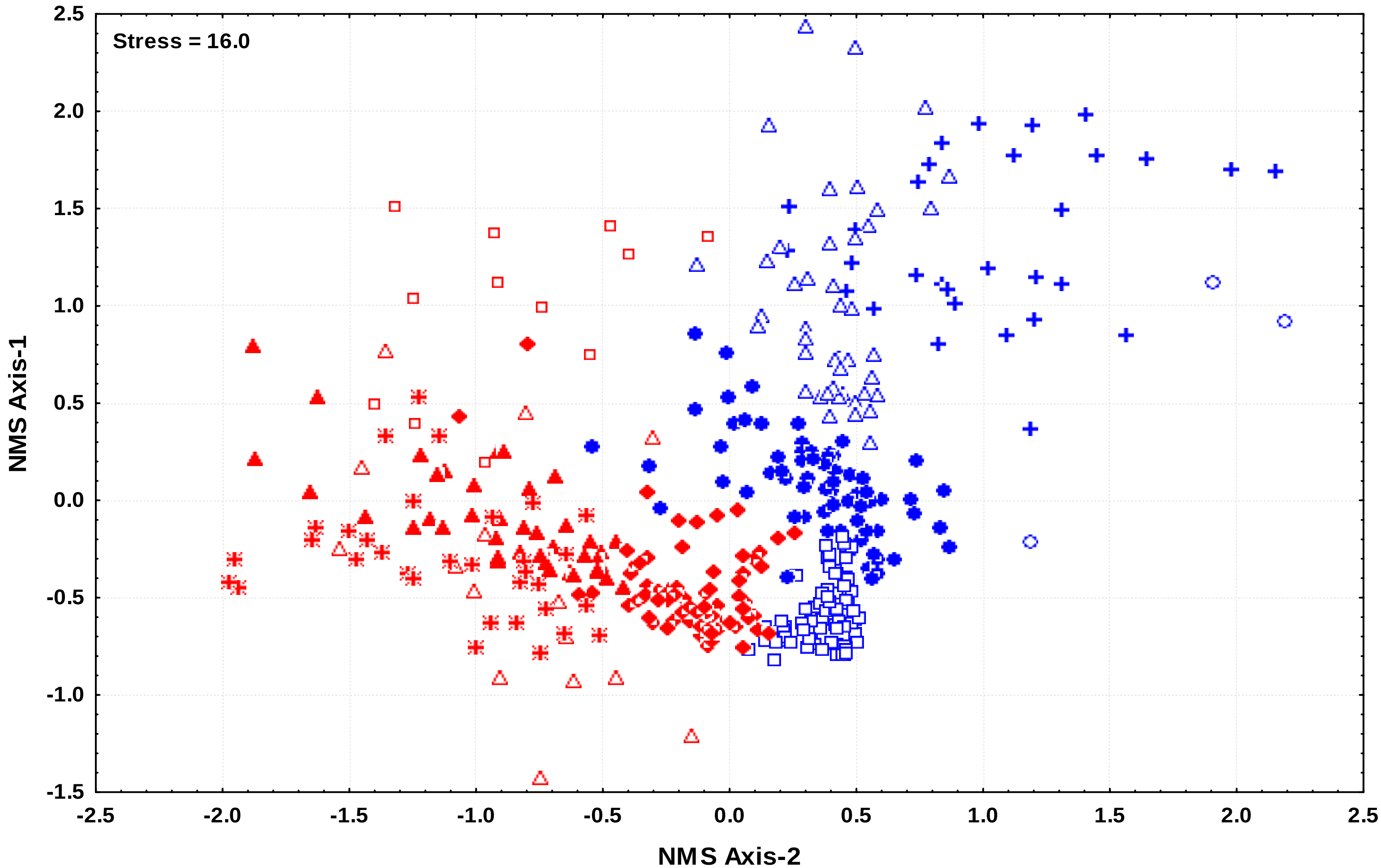

Figure 03: Site scores from 2-axis non-metric multidimensional scaling (NMS) ordination, based on relative cover at 409 census plots sampled in 2003 and 2004. ✚ *Eleocharis-Rhynchospora* marsh △ *Rhynchospora-Cladium* marsh ● *Cladium-Rhynchospora* marsh □ *Cladium* marsh ○ *Spartina* marsh ◆ *Cladium* wet prairie (WP) △ *Schoenus* WP ✱ *Muhlenbergia* WP ▲ *Schizachyrium* WP □ *Paspalum-Schizachyrium-Cladium* WP

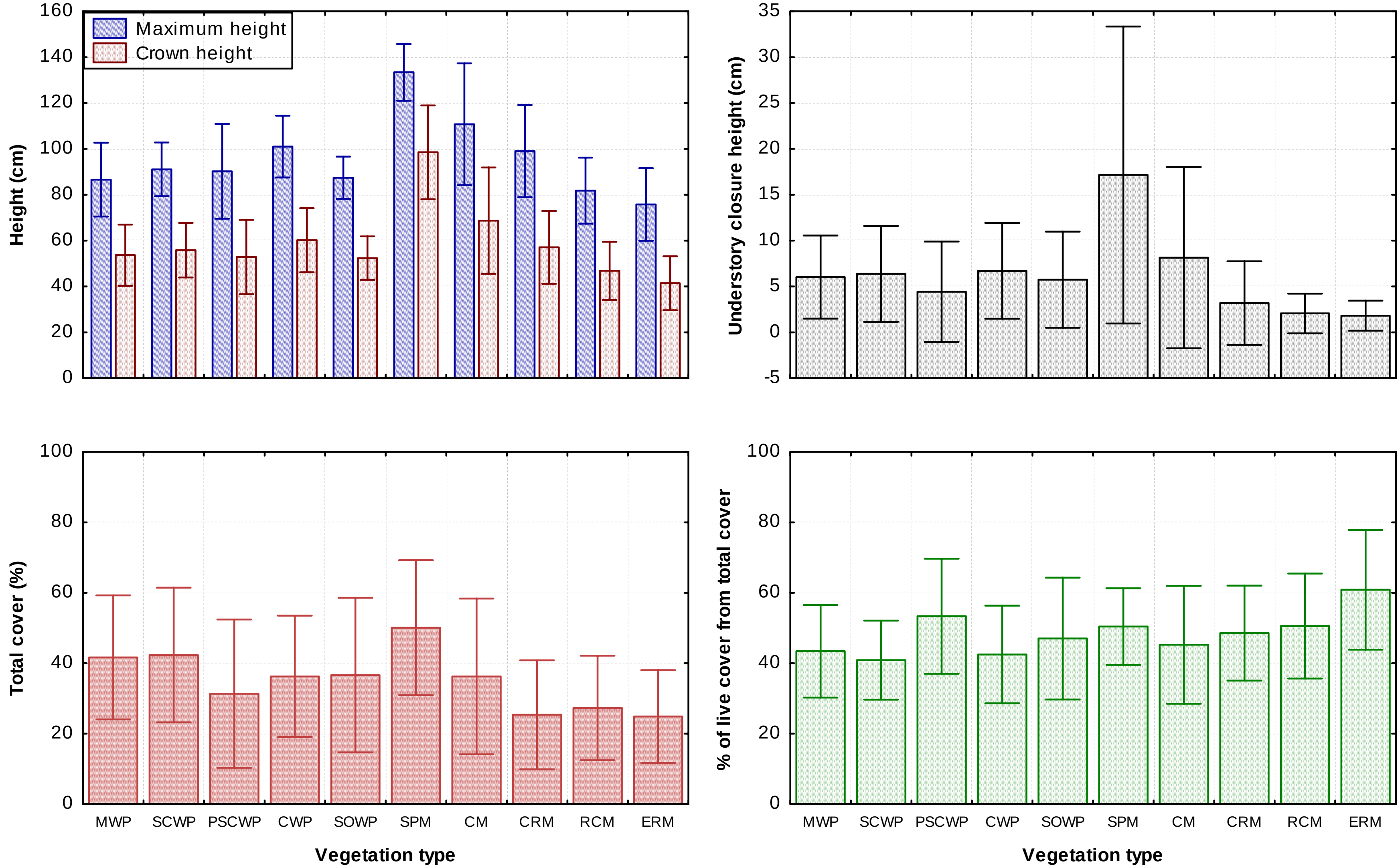

Figure 4: Mean (±1 S.E.) for five important structural variables in herb stratum of ten vegetation types, based on 409 census plots sampled in 2003 & 2004. MWP = *Muhlenbergia* wet prairie; SCWP = *Schizachyrium* wet prairie; PSCWP = *Paspalum-Schizachyrium-Cladium* wet prairie; CWP = *Cladium* wet prairie; SOWP = *Schoenus* wet prairie; SPM = *Spartina* marsh; CM = *Cladium* marsh; CRM = *Cladium-Rhynchospora* marsh; RCM = *Rhynchospora -Cladium* marsh; ERM = *Eleocharis-Rhynchospora* marsh

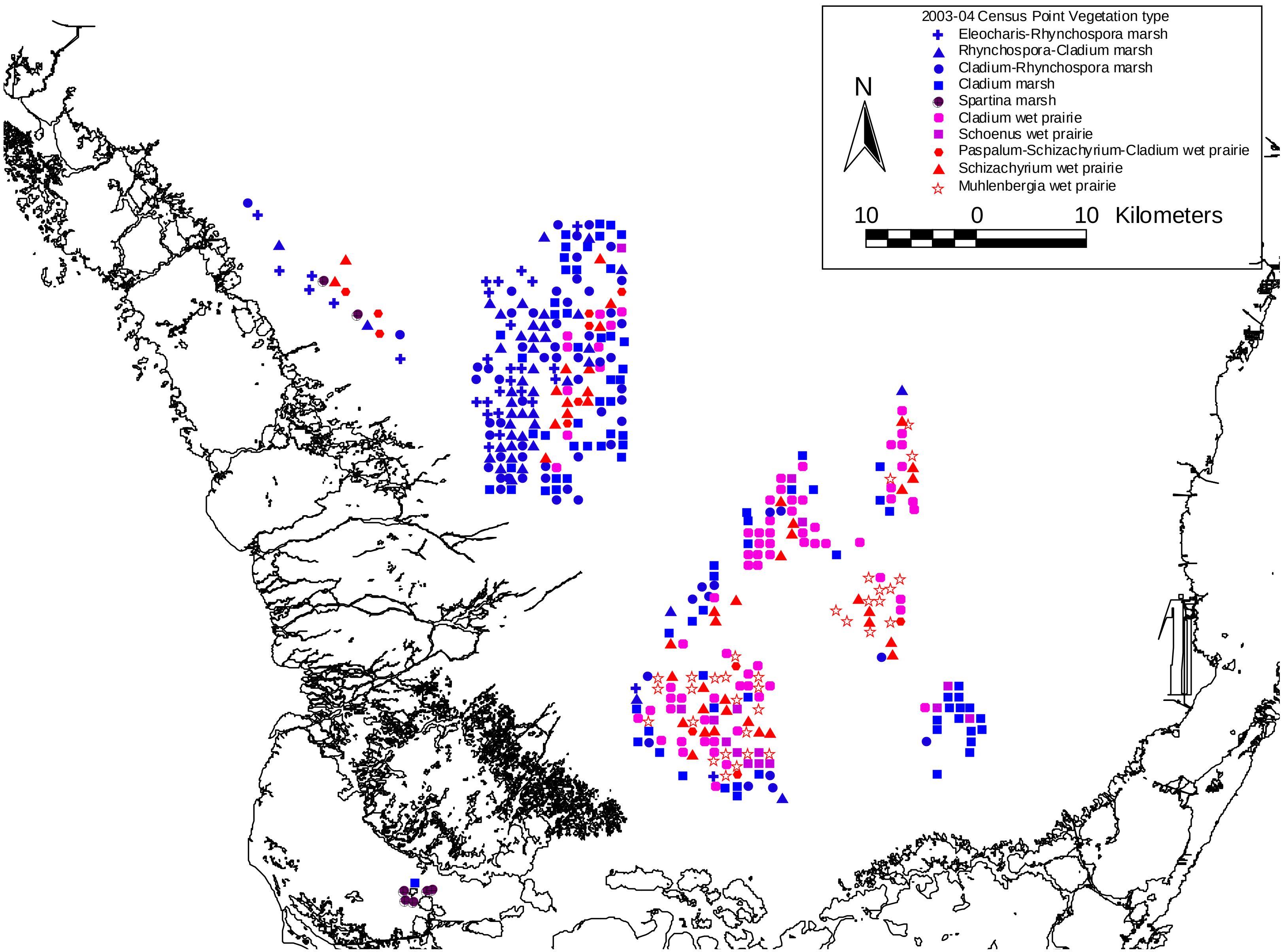

Figure 5: Distribution of vegetation types within recent range of CSSS, based on census plots sampled in 2003 & 2004.

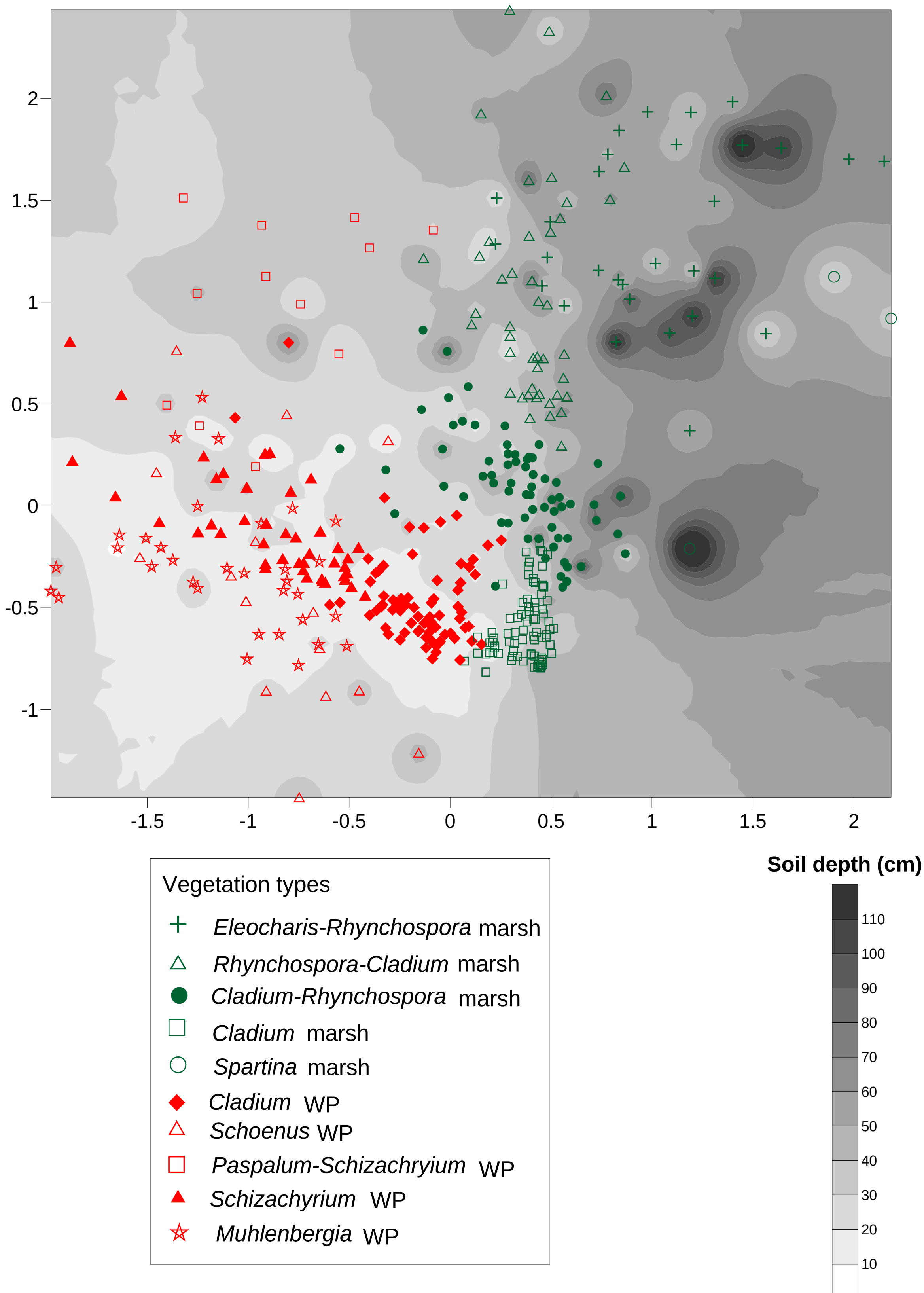

Figure 6: Relationship of vegetation type to soil depth in CSSS landscape, as indicated by their covariation in NMS ordination space

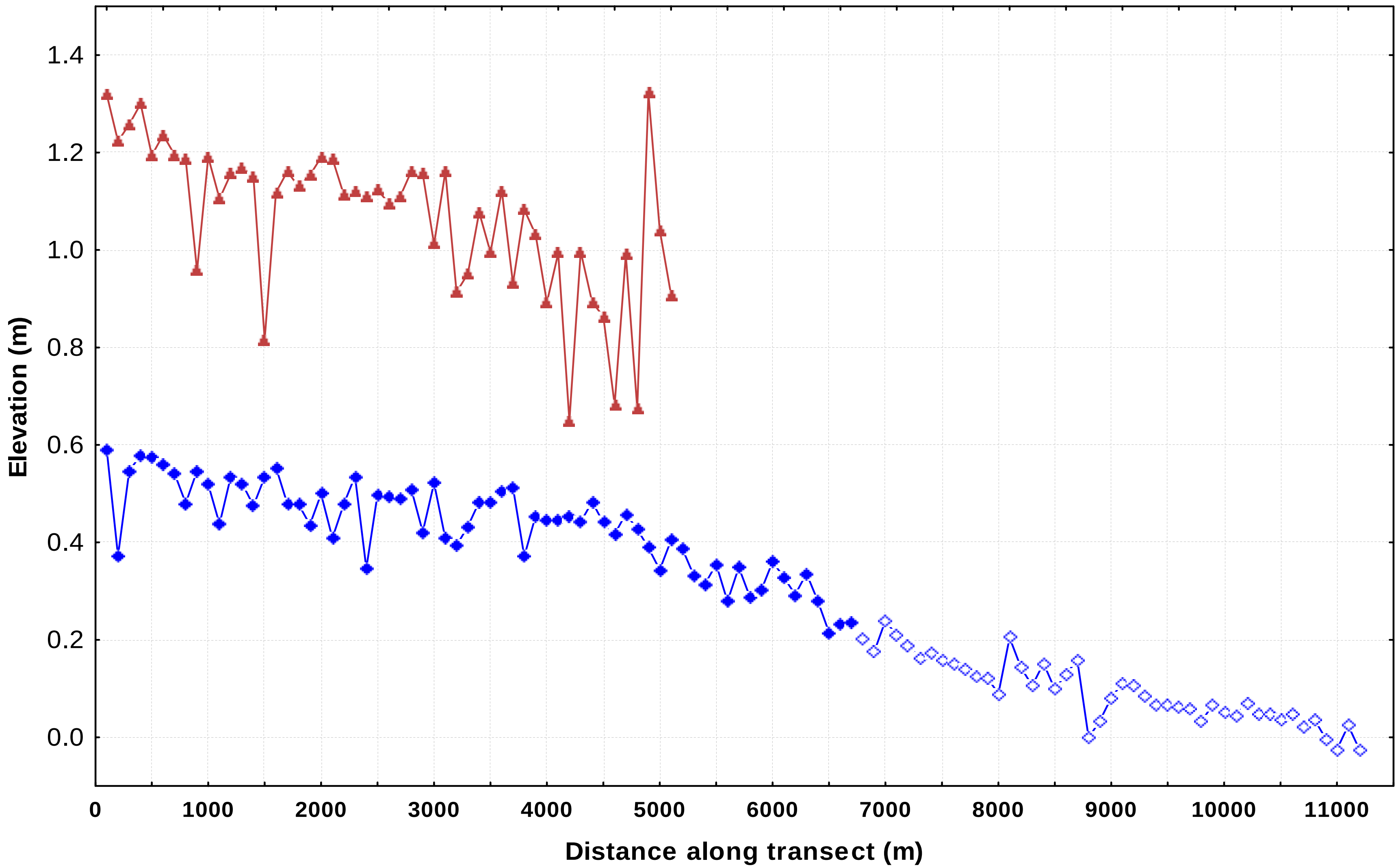

Figure 7: Ground elevation (based on NGVD 88) at the 100 m sample points along the transect in subpopulations B & E. Transect in subpopulation E ( ) runs east to west. In subpopulation B, the transect has two parts, the first section B ( ) runs north to south, and the second section ( ) runs northeast to southwest.

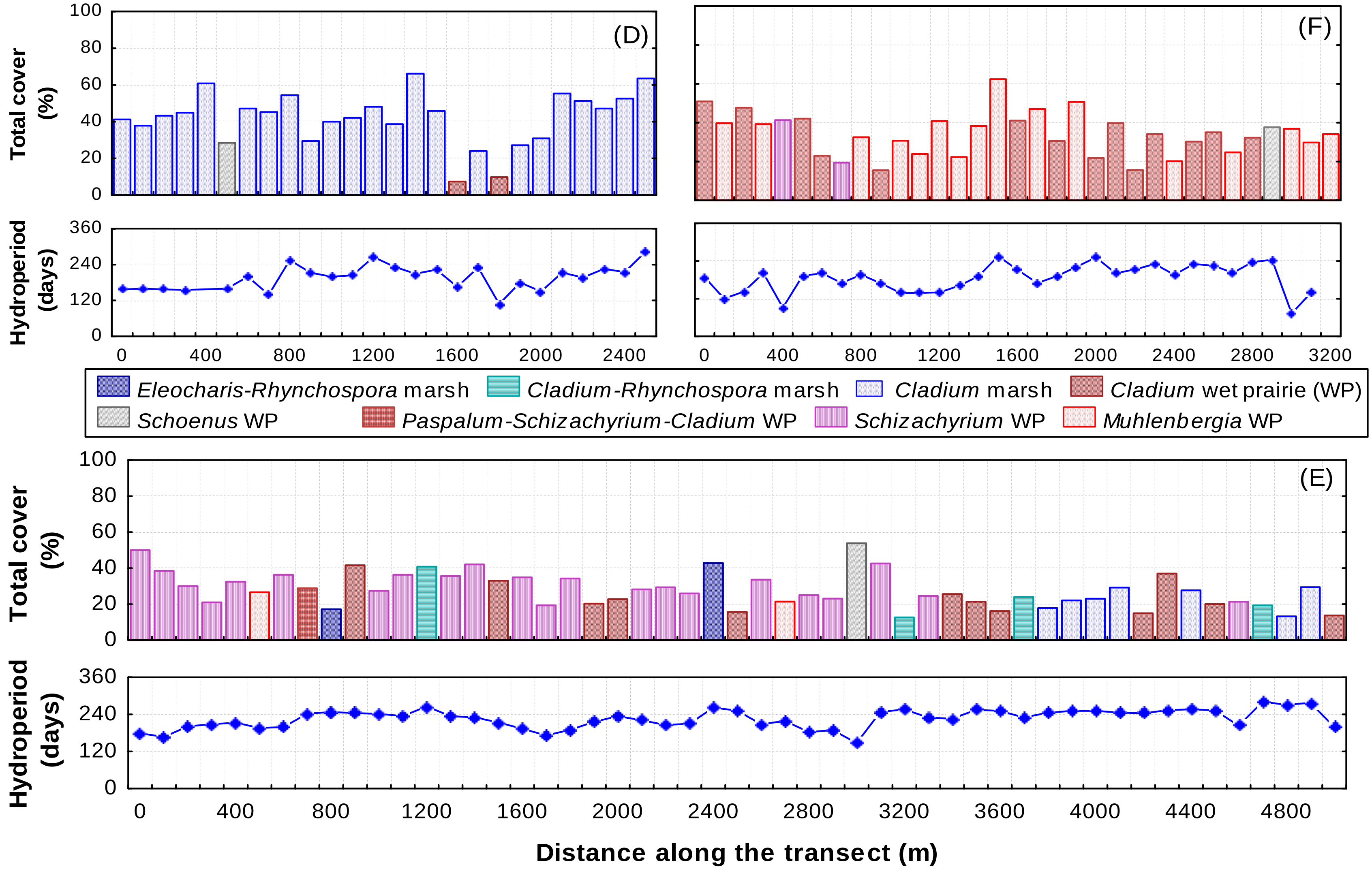

Figure 8: Vegetation type and total herb stratum vegetation cover, in relation to hydroperiod along Transect D, E, and F. Hydroperiods are calculated from mean elevation of 10 compositional sub-plots, and respective stage recorders (see text).

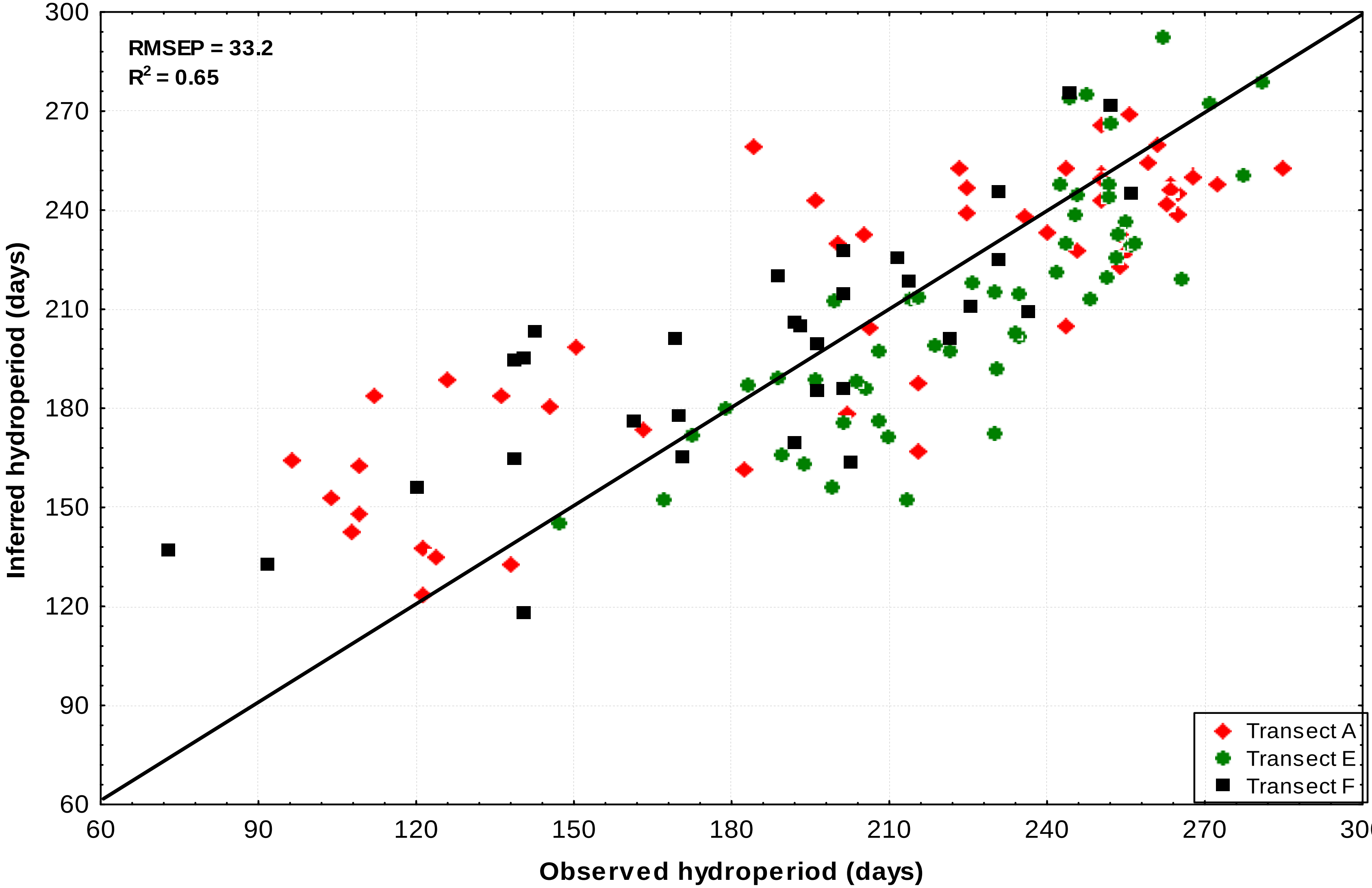

Figure 9: Observed vs inferred hydroperiods at 134 locations along Transects A, E, and F. Inerrred values are derived from bootstrapping procedure (100 runs) in WA regression, C^2 program (Juggins 2003)

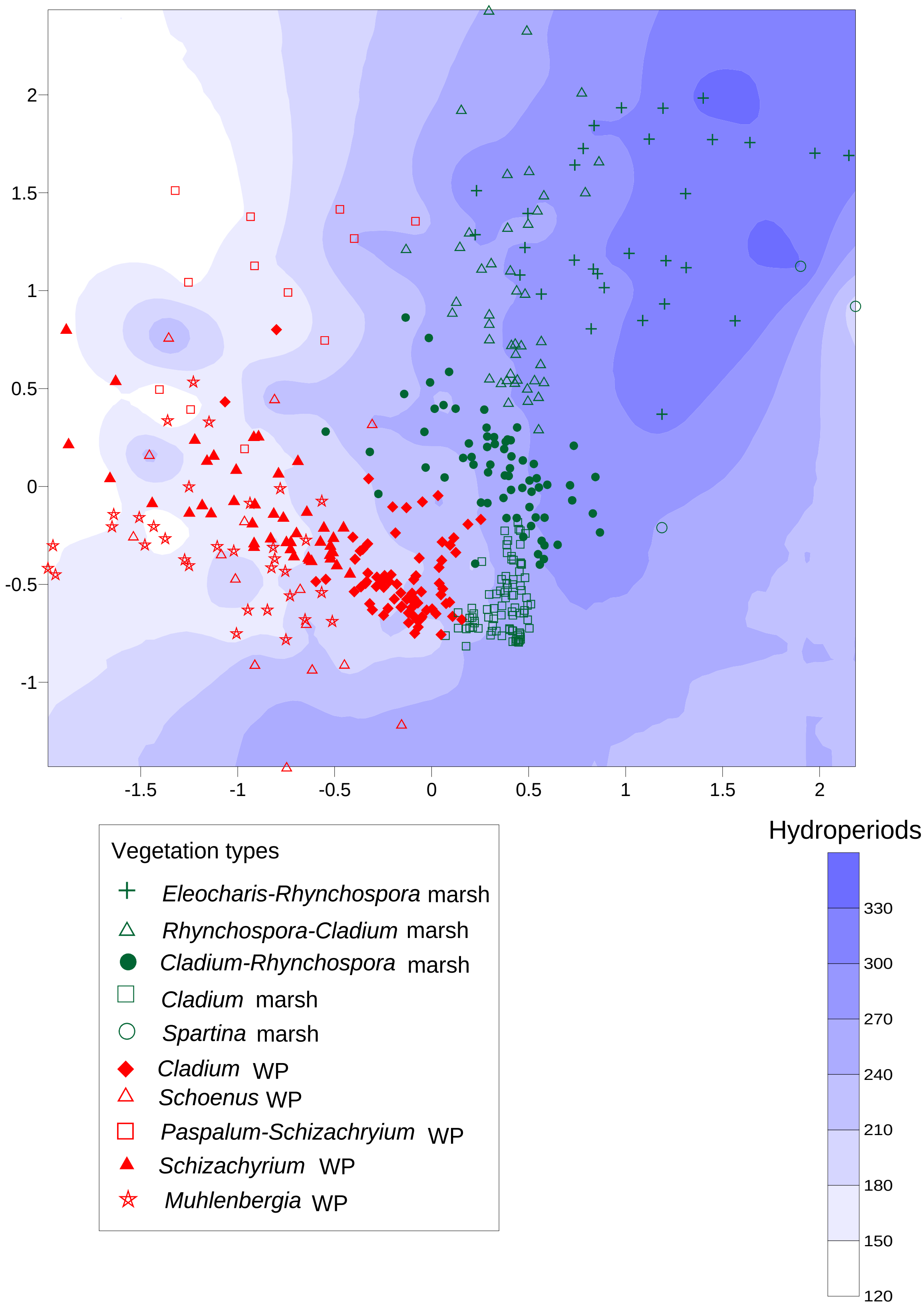

Figure 10: Relationships of vegetation type to inferred hydroperiod in the CSSS landscape, as indicated by their co-variation in NMS ordination space

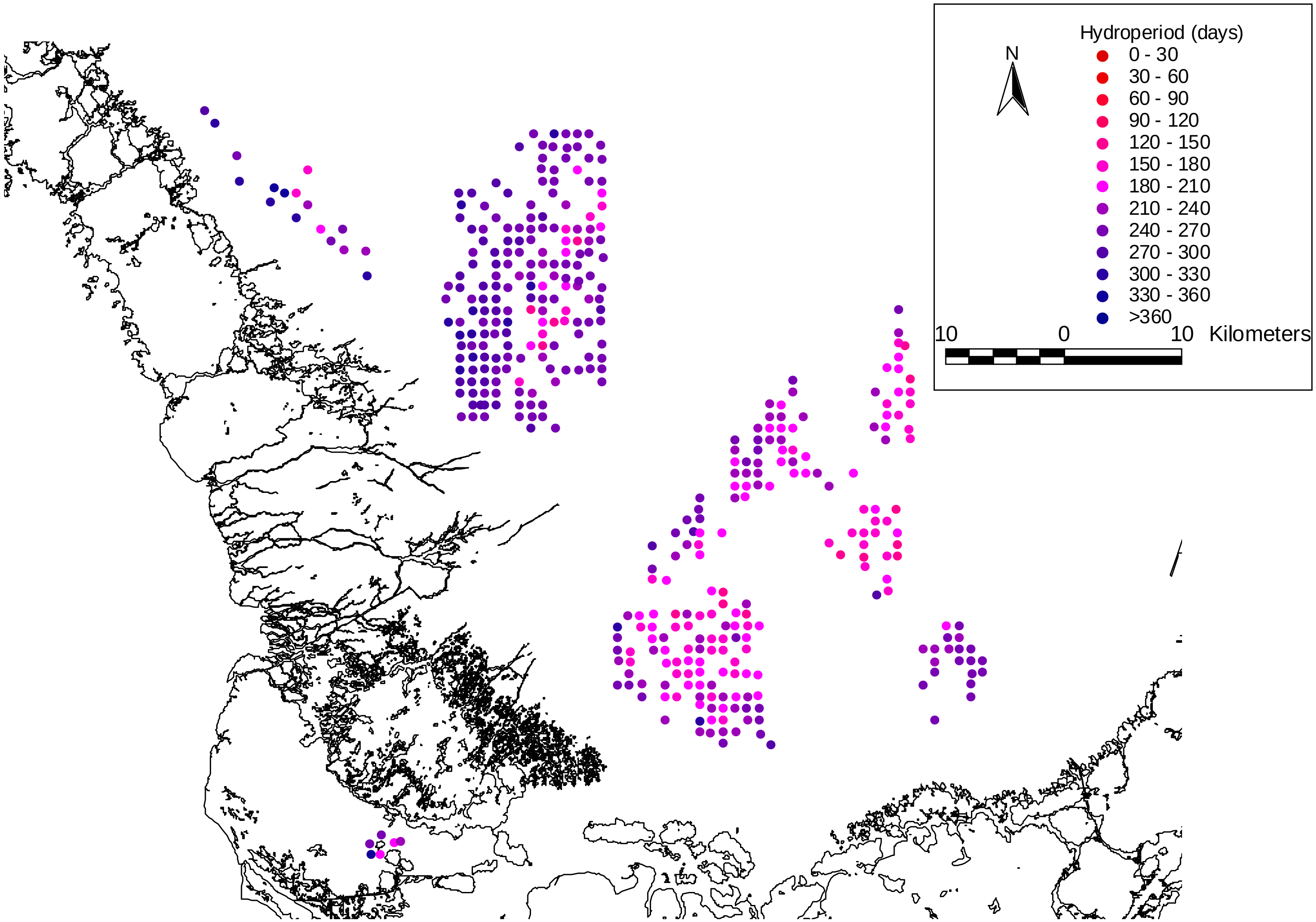

Figure 11: Distribution of inferred hydroperiods within recent range of CSSS, based on census plots sampled in 2003 & 2004.

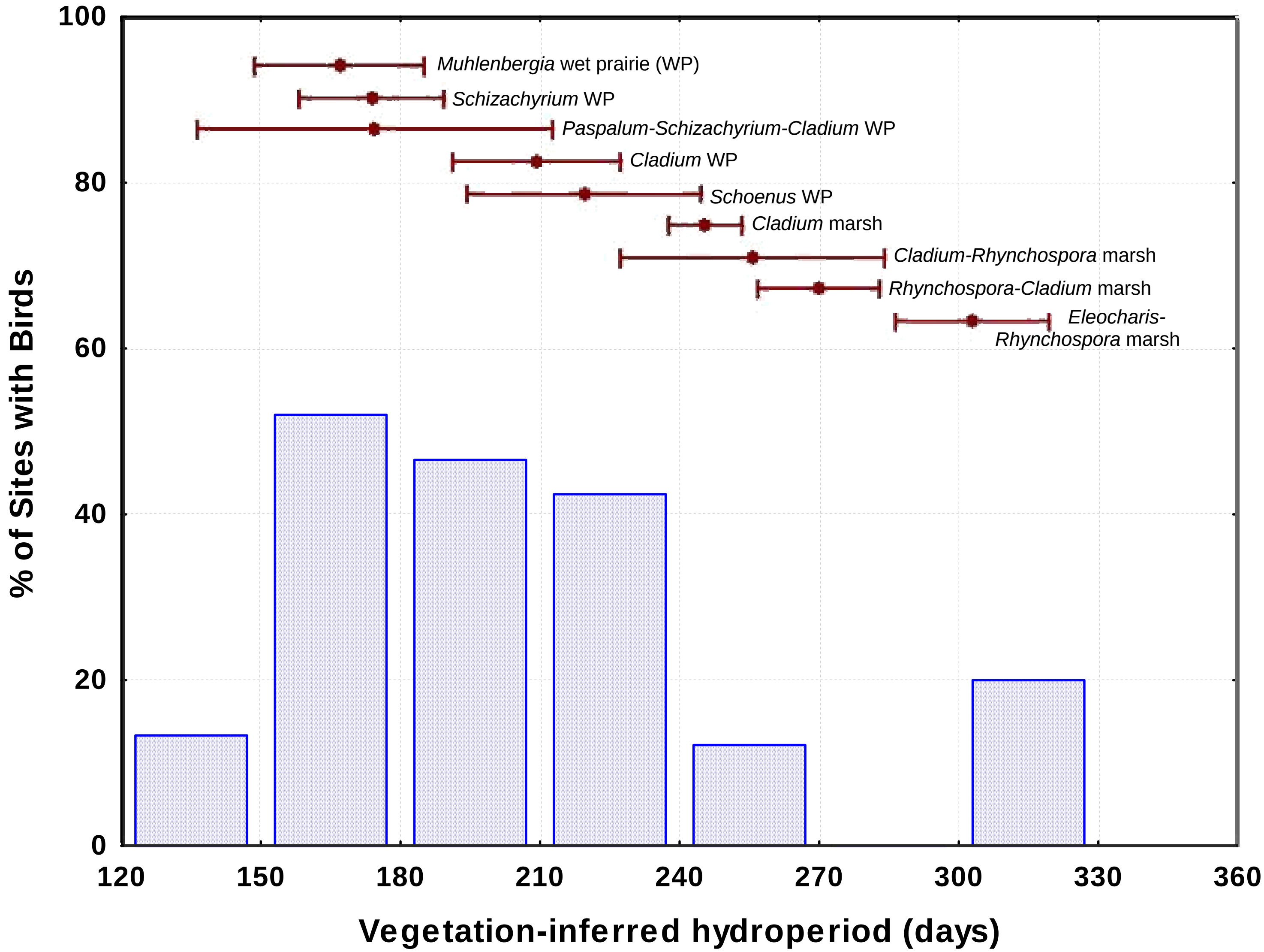

Figure 12: Percentage of census locations, subdivided into 30-day increments of inferred hydroperiod, in which CSSS were observed at least once during 2002-2004. Data are based on 409 sites sampled in 2003 & 2004. Mean (±1 S.E.) inferred hydroperiod for nine vegetation types among 2003-04 vegetation census plots are superimposed.

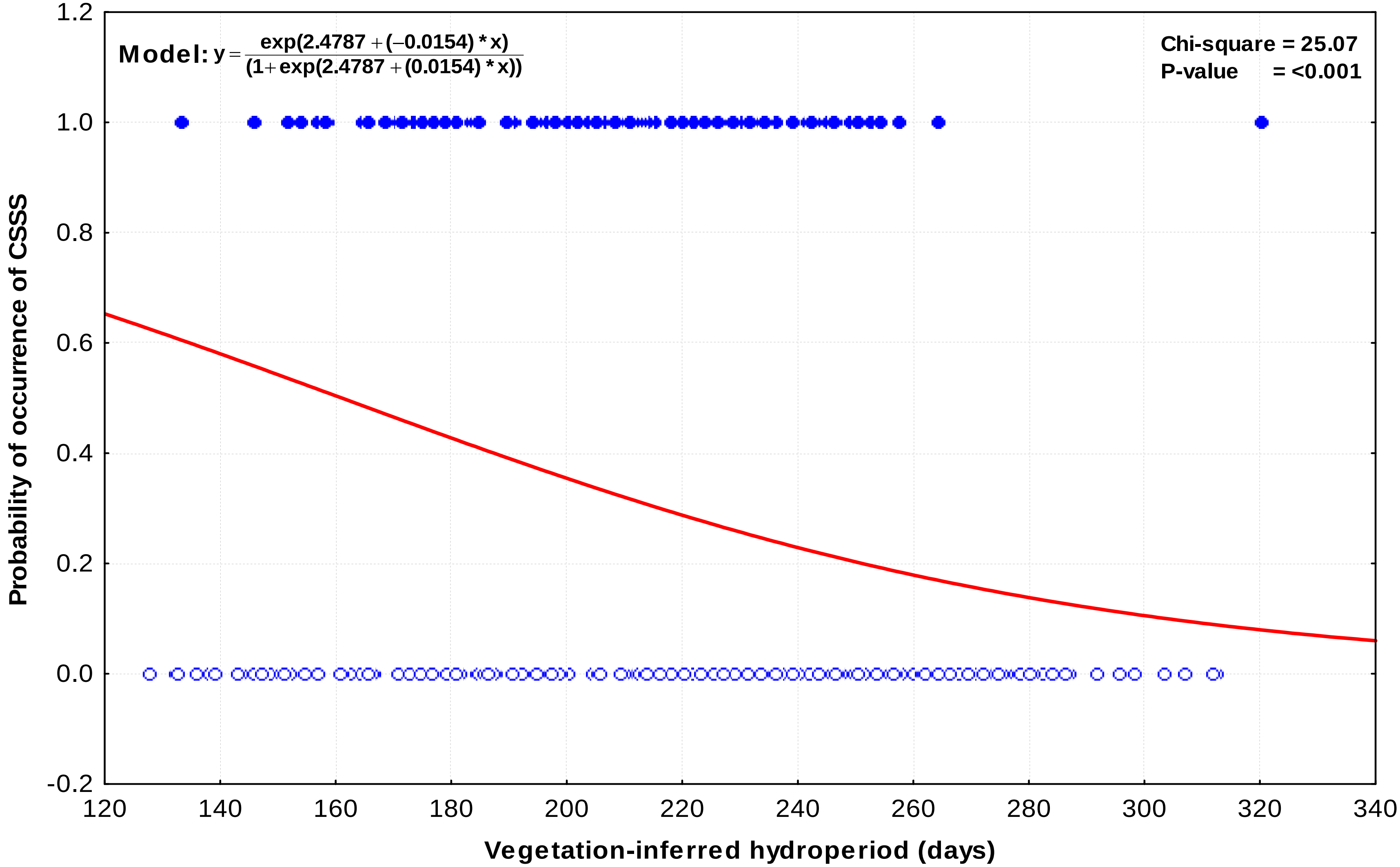

Figure 13: Logistic regression of relationships between vegetation-inferred hydroperiod and occurrence of Cape Sable seaside sparrow at the CSSS census sites surveyed in 2003 and 2004. Regression line is based on inferred hydroperiod at sites with (●) and without ( ) birds.

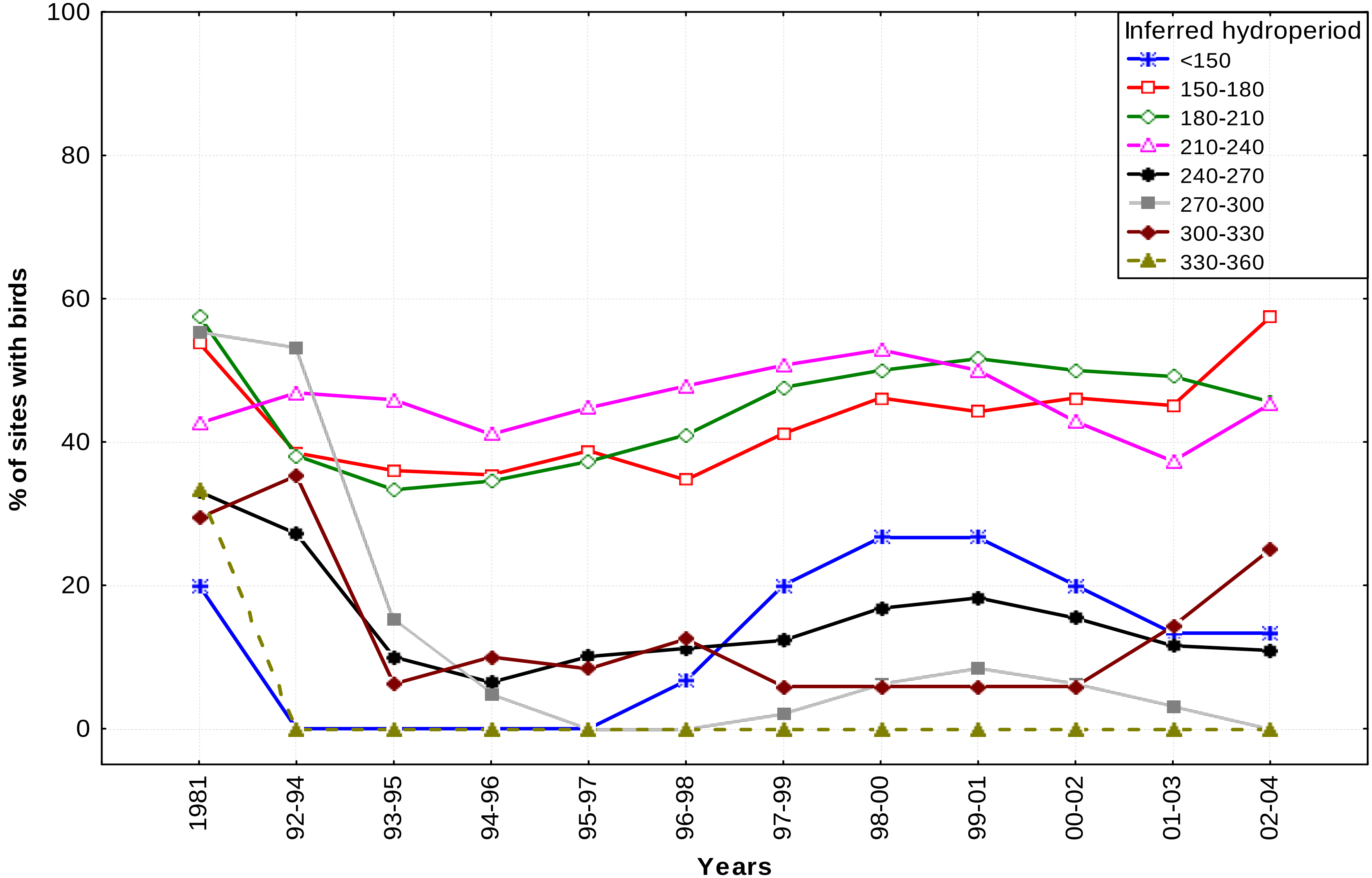

Figure 14: Percentage of census sites in which CSSS were observed in 1981 and at least once during overlapping 3-year spans between 1992 and 2004. Inferred hydroperiods are derived from vegetation at 409 CSSS census sites sampled in 2003 & 2004.

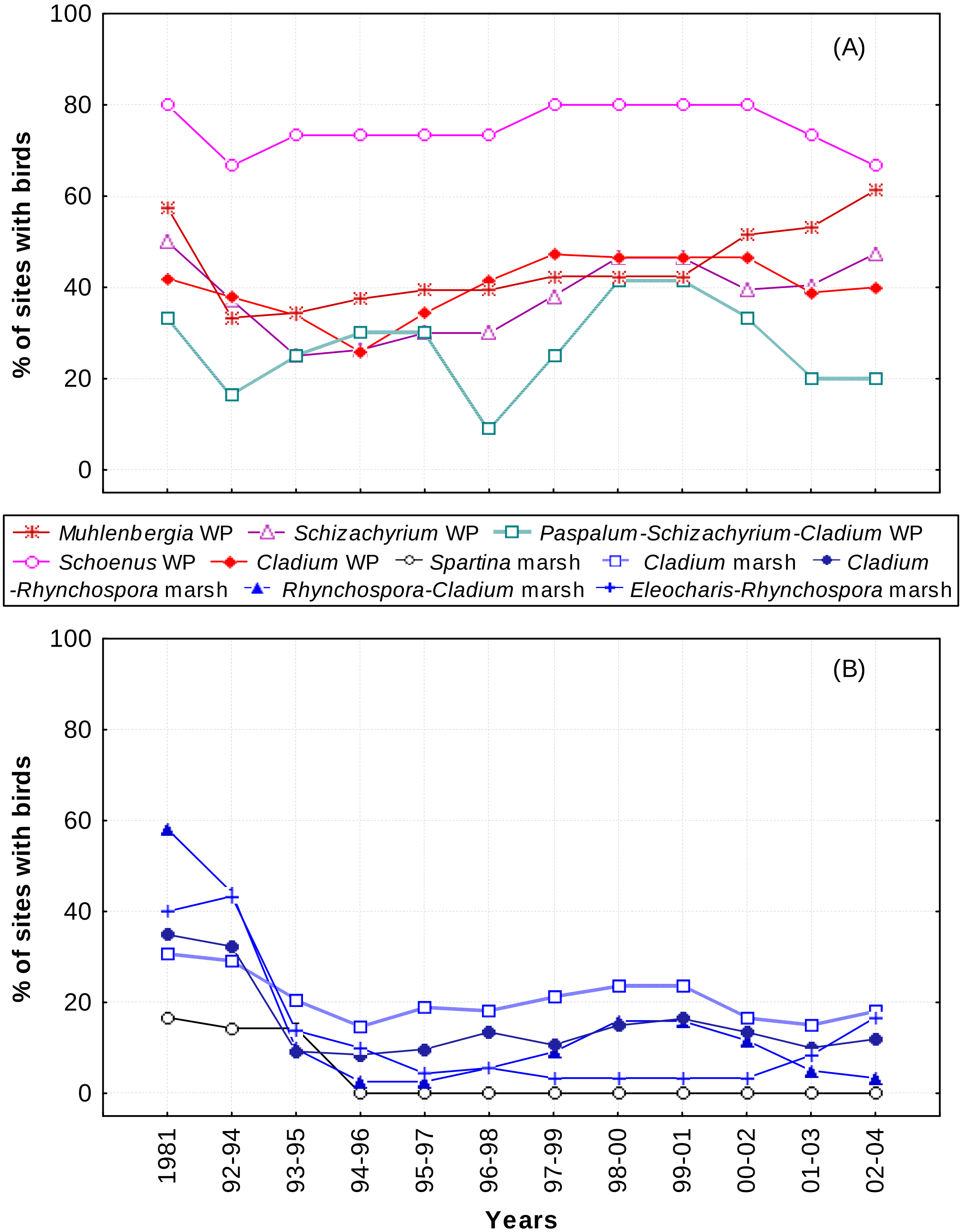

Figure 15: Percentage of census sites, in which CSSS were observed in 1981 and at least once during overlapping 3-year spans between 1992 and 2004. Vegetation types are based on species cover data at 409 sites sampled in 2003 & 2004. (A) Wet prairies (B) Marsh sites

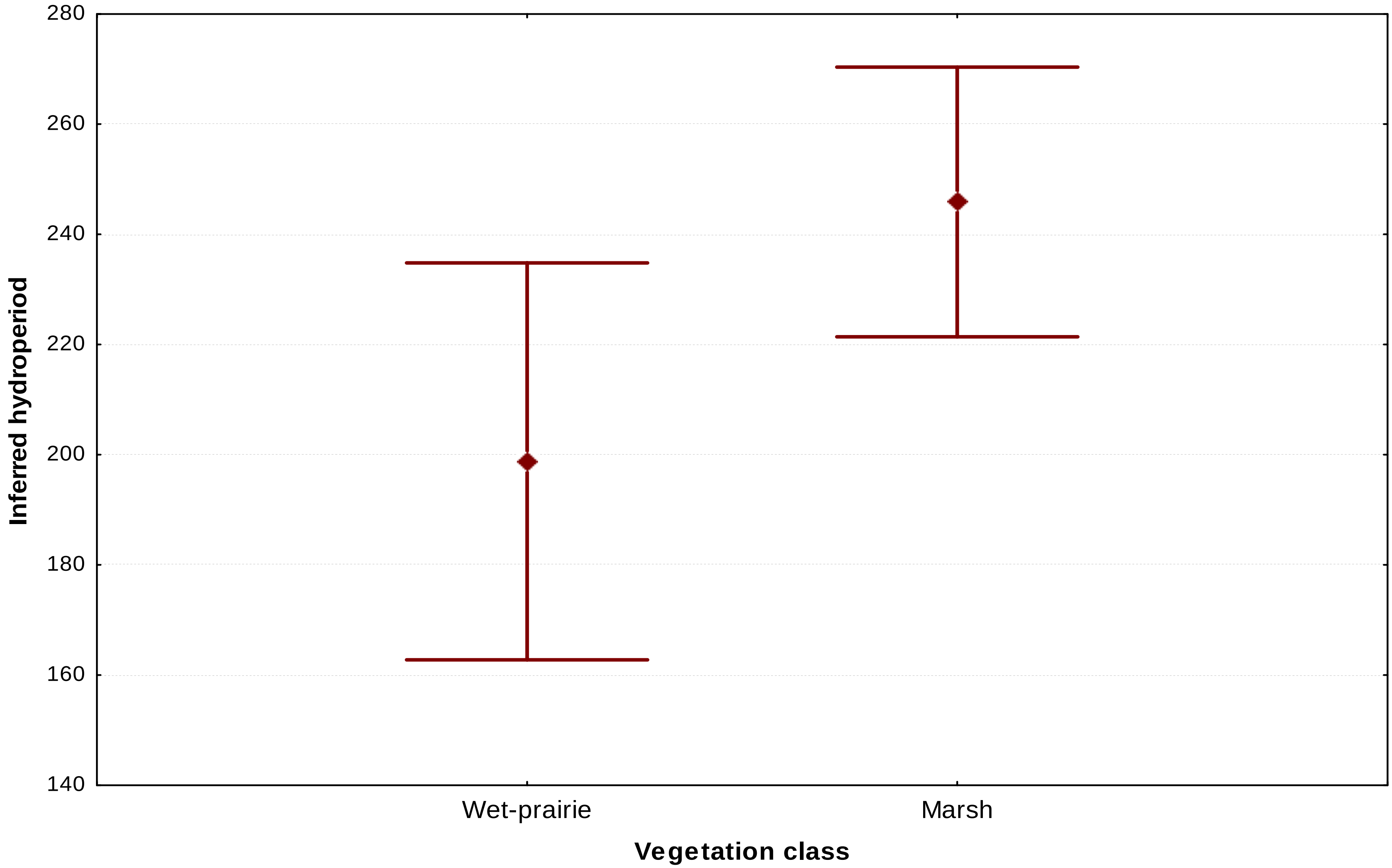

Figure 16: Mean inferred hydroperiod for CSSS census sites grouped into two classes, wet-prairie and marsh, based on qualitative vegetation observations recorded during sparrow census in 2003 & 2004. Inferred hydropeiods are based on vegetation data at 409 sites sampled in 2003 & 2004.

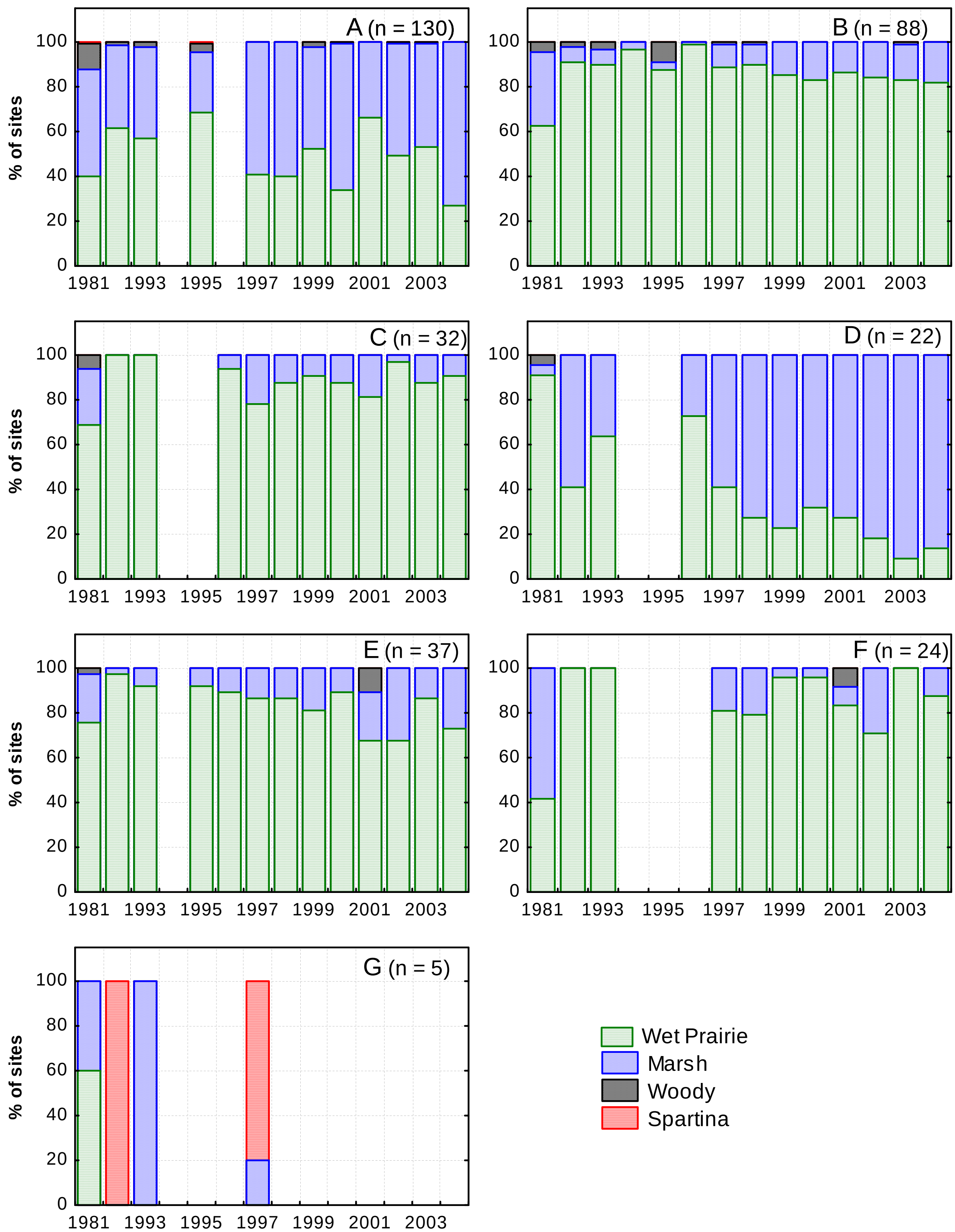

Figure 17: Percentage of sites categorized in four different vegetation types at CSSS census sites between 1981-2004. Vegetation types are based on qualitative vegetation observations recorded during CSSS survey.

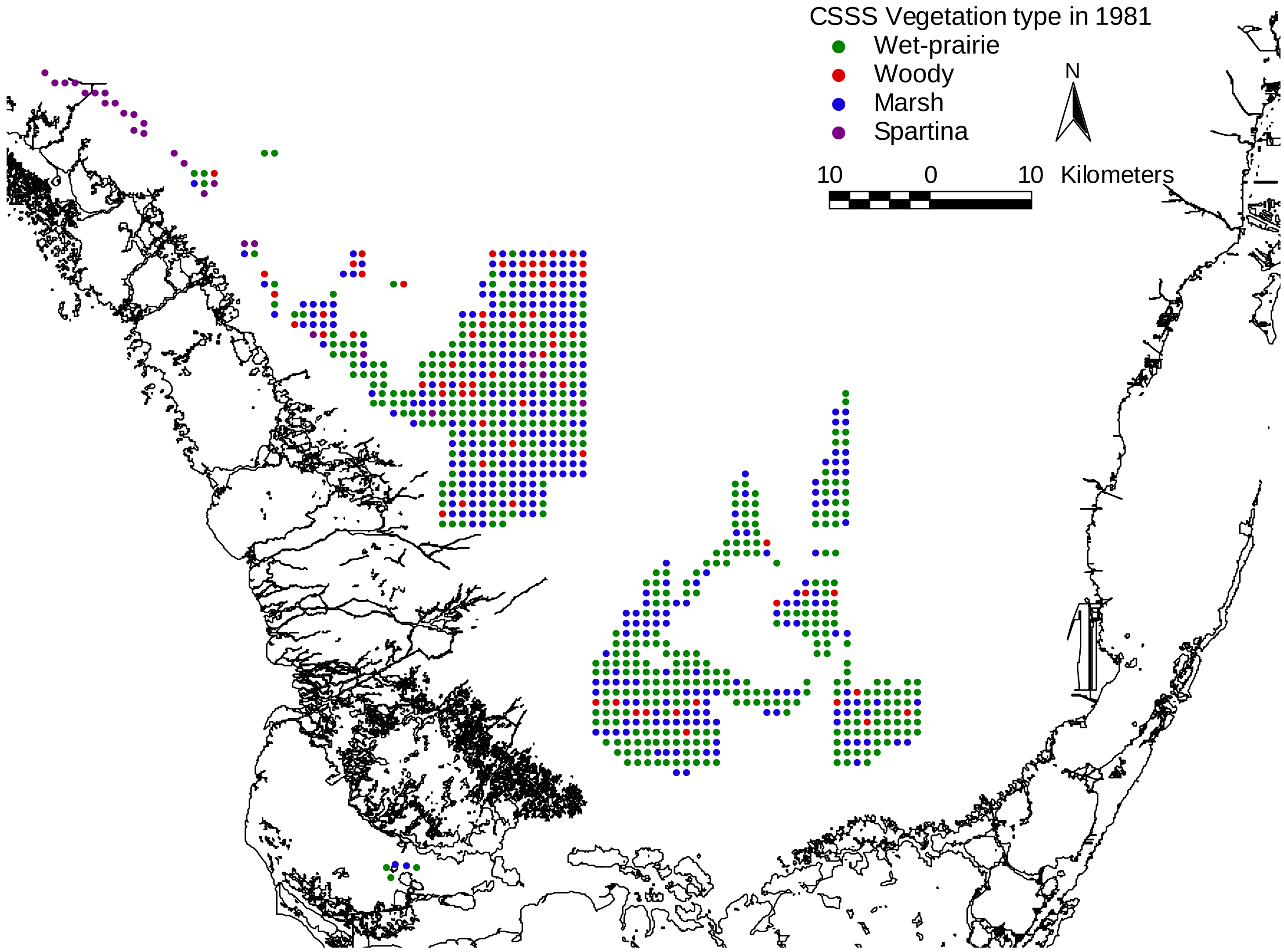

Figure 18: Distribution of four different vegetation types in 1981 within recent range of CSSS. Vegetation types are based on qualitative vegetation observations recorded during CSSS survey.

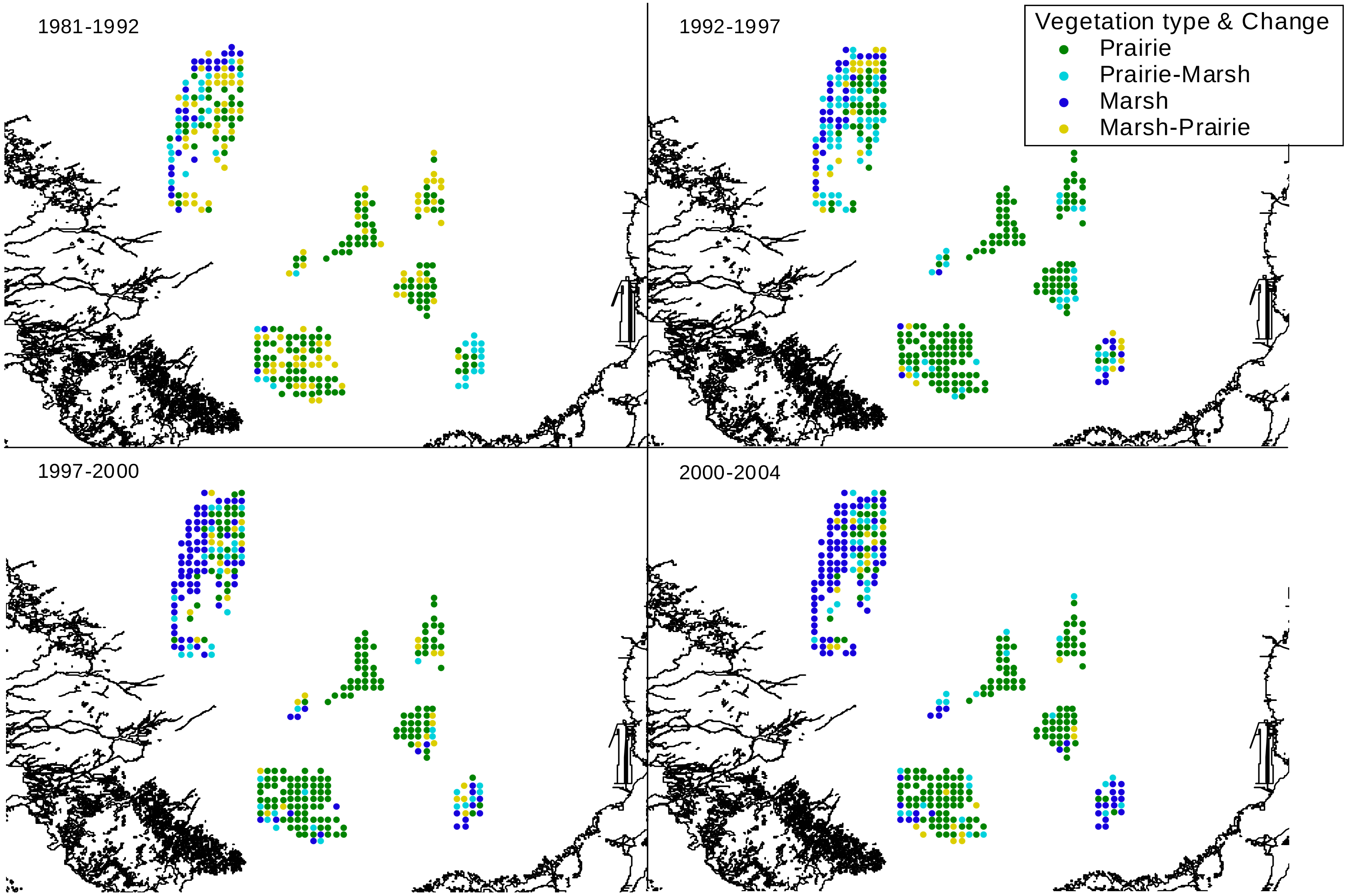

Figure 19: Distribution of two major vegetation types, wet-prairie and marsh that remained either unchanged or changed from one type to the other during four periods. (A) 1981-1992 (B) 1992-1997, (C) 1997-2000, and (D) 2000-2004.

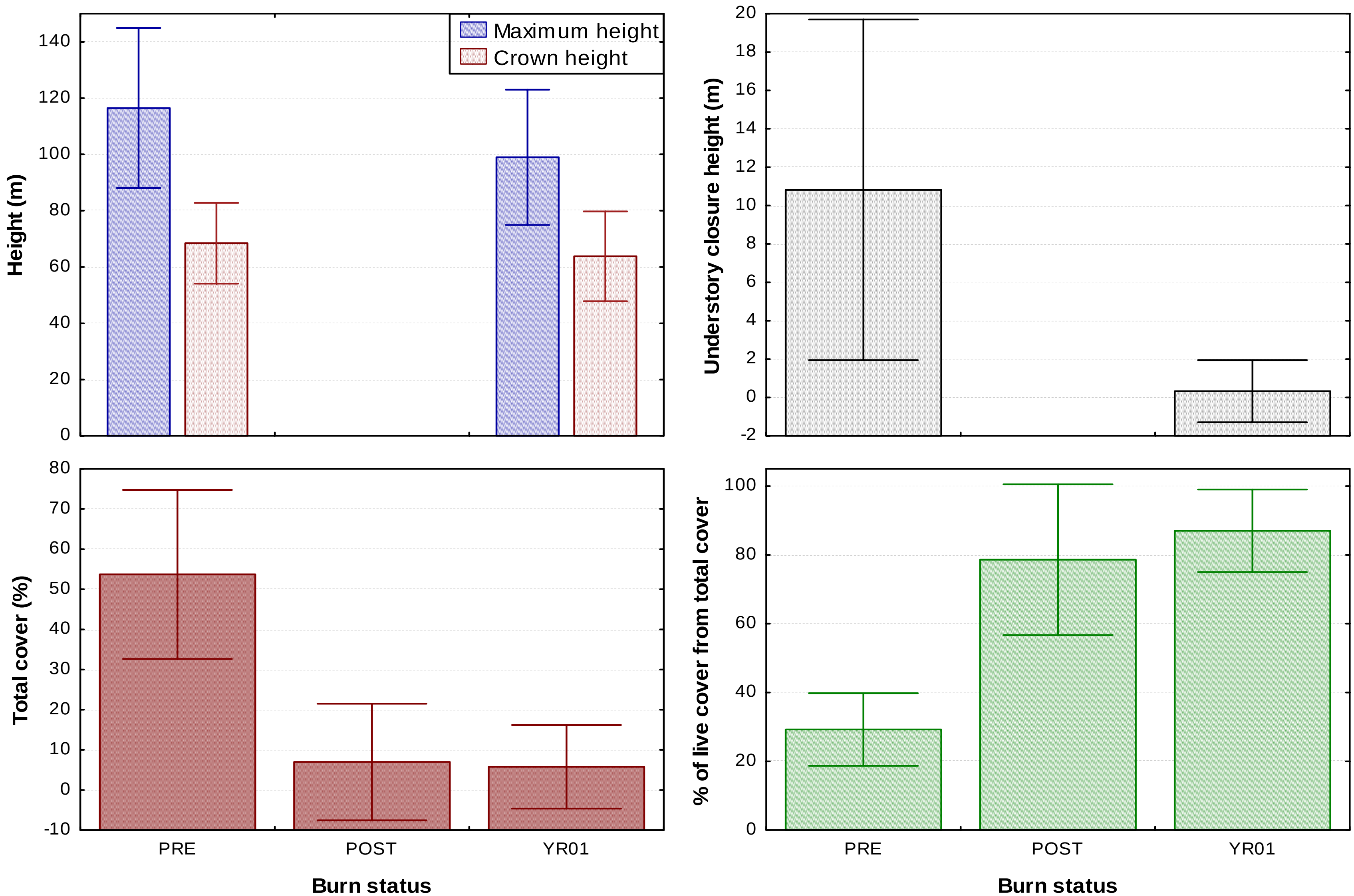

Figure 20: Mean (±1 S.D.) for five important structural variables in herb stratum of two burned plots sampled in 2003 & 2004.