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Effect of Hydrologic Restoration On The Habitat of The Cape Sable Seaside Sparrow

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Summary

After developing field sampling protocols and making a series of consultations with investigators involved in research in CSSS habitat, we determined that vegetation-hydrology interactions within this landscape are best sampled at a combination of scales. At the finer scale, we decided to sample at 100 m intervals along transects that cross the range of habitats present, and at the coarser scale, to conduct an extensive survey of vegetation at sites of known sparrow density dispersed throughout the range of the CSSS. We initiated sampling in the first week of January 2003 and continued it through the last week of May. During this period, we established 6 transects, one in each CSSS sub-population, completed topographic survey along the Transects A, C, D, and F, and sampled herb and shrub stratum vegetation, soil depth and periphyton along Transects A, and at 179 census points. We also conducted topographic surveys and completed vegetation and soil depth sampling along two of five transects used by ENP researchers for monitoring long-term vegetation change in Taylor Slough. We analyzed the data by summarizing the compositional and structural measures and by using cluster analysis, ordination, weighted averaging regression, and weighted averaging calibration. The mean elevation of transects decreased from north to south, and Transect F had greater variation than other transects. We identified eight vegetation assemblages that can be grouped into two broad categories, 'wet prairie' and 'marsh'. In the 2003 survey, wet prairies were most dominant in the northeastern sub-populations, and had shorter inferred-hydroperiod, higher species richness and shallower soils than marshes, which were common in Sub-populations A, D, and the southernmost regions of Sub-population B. Most of the sites at which birds were observed during 2001 or 2002 had an inferred-hydroperiod of 120-150 days, while no birds were observed at sites with an inferred-hydroperiod less than 120 days or more than 300 days. Management-induced water level changes in Taylor Slought during the 1980's and 1990's appeared to elicit parallel changes in vegetation. The results described in detail in the following pages serve as a basis for evaluating and modifying, if necessary, the sampling design and analytical techniques to be used in the next three years of the project.

1. Introduction

The research project "Effect of hydrologic restoration on the habitat of the Cape Sable Seaside Sparrow" is 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). FIU and USGS bear primary responsibility for the field work and data analysis. This document summarizes the progress that was made during the first year of the study.

2. Methods

2.1 Preparation and Study Design

The ENP-FIU cooperative agreement for this research was finalized in mid-June 2002. The first few months of the project were spent in hiring personnel, purchasing necessary equipment, arranging and training for helicopter transportation to the field sites, and developing the field sampling protocols. The primary FIU personnel involved were Michael Ross, Project Leader; Jay Sah, Post-doctoral Research Associate; Pablo Ruiz, GIS Specialist; David Jones, Lead Botanist; and Hillary Cooley and David Reed, Graduate Research Assistants. We were also assisted by the staff of Evelyn Gaiser's Periphyton Research Group, including also Serge Thomas, Rafael Travieso, Franco Tobias, and Alejandro Leon. The USGS participants included Jim Snyder, Project Leader, and his assistant, Curt Schaeffer.

The study design is intended to tie our work together with several other research and monitoring efforts in the broad landscape occupied by the Cape Sable seaside sparrow (CSSS). These include an ongoing FIU periphyton research project ("Characterization of periphyton response to hydroperiod in marl prairie wetlands of the Everglades", Evelyn Gaiser, Project Leader); the annual monitoring of Cape Sable seaside sparrow (CSSS) populations, lead for more than a decade by Sonny Bass, ENP and Stuart Pimm, Duke University; a study of CSSS recolonization of burned prairie, directed by Julie Lockwood, U of California, Santa Cruz; and research and monitoring conducted by Everglades National Park's vegetation and hydrology groups. The plan we settled on is to divide each year's work into two parts, with each addressing a different scale of variation in wet prairie vegetation. At the finer scale, we plan to describe detailed vegetation-hydrology interactions within this landscape by sampling at relatively short intervals along transects that cross the range of habitats present. At a coarser scale, our intent is to conduct an extensive survey of vegetation at sites of known sparrow density dispersed throughout the range of habitats available to the bird in the southern Everglades. By this strategy, the relationships learned at the smaller scale will aid in interpreting the large-scale patterns that might drive sparrow population dynamics.

The locations of transects were made in consultation with Sherry Mitchell, Tom Armentano, and Sonny Bass of ENP. We decided to establish one relatively long transect in each CSSS sub-population. As much as possible, we attempted to locate the transects such that they included (1) a wide range of hydrologic conditions, (2) one or two nearby water level recorders, and (3) at least a few sites known to have supported Seaside Sparrows during recent years. We settled on the following transects:

Table 1: Locations of CSSS habitat monitoring transects, relative to ENP stage recorders.

Sub-population	Location	Length (km)
A	Begin 2 km east of NP205, end 3 km west of NP205	5
B	D02 to CY3 to NP46	11.5
C	NTS1 to R3110	4.1
D	EVER4 to G1251	2.5
E	CR3 to A13	5
F	S-332B west to RG2	3

The plan for large-scale vegetation sampling includes co-location of our sampling stations at the same sites as the annual CSSS census points. The CSSS researchers census more than 600 points each year, which is far more than we could sample in a single season, given the available resources and the detailed nature of our sampling protocols (see next section). We therefore decided to visit each point on a three-year cycle, by sampling a well-dispersed one-third of the entire network each year

Sampling vegetation in the wet prairies loses precision once water rises more than 15 cm or so above the ground surface, limiting the sampling season to mid-December to early June in a normal year. We decided to do the transect work in the winter and early spring, and then initiate the census point sampling in mid-April, which is roughly the time that the CSSS census is conducted.

2.2 Sampling Methods

CSSS Transect and census plot methods. The transect surveys include observations of vegetation, periphyton, soils, and topography, while in the census surveys only the first three of these components are examined. In our operation, topographic surveying is a two-step process. In the first step, elevations are established along the transects listed in **Table 1**, by surveying by autolevel from a nearby USGS vertical-control benchmark. Temporary and semi-permanent (rebar) benchmarks are established along the way, and elevation differences between adjacent benchmarks are determined from at least two positions, such that the two estimates do not differ by more than 1 mm. The rebar benchmarks established at 100-meter intervals mark the north ends of the vegetation plots. In the second step, the elevations of specific microsites (subplots) within the plots are determined, again by autolevel, with reference to the previously determined rebar elevations. Mean plot or subplot elevations can then be used to estimate hydroperiod or other hydrologic variables from stage records at nearby water level recorders, and relate these to vegetation at either scale.

Biotic sampling is usually conducted by three-person teams composed of an accomplished botanist, a structural specialist, and a periphyton expert The vegetation sampling techniques are identical in transect and census surveys. The herb layer (<1 m height) is sampled in a N-S oriented, 1 x 60 m rectangular plot beginning 3 m south of the rebar established during the topographic survey. A second rebar marked the southern end of the plot, and both rebars were encased in aluminum conduit to facilitate relocation of transects after fire. Nested within the plots are thirty 0.25 m^2 (0.5 x 0.5 m) subplots, arrayed at 2-meter intervals along the baseline (east side) beginning at Meter 1. Vegetation structure is measured in all thirty subplots, while vegetation composition is estimated in ten subplots spaced at 6-meter intervals, beginning at Meter 5.

Structural sampling includes the following attributes: 1) *Canopy height,* i.e., the tallest vegetation present within a cylinder of ~5 cm width, measured at 4 points per subplot, in the center of each quadrant; 2) The height and species of the *tallest plant* in the plot; 3) *Understory closure heigh*t, i.e., the height above which vegetation obscures <50%, when viewed at 0.5 m distance, from a height of 1 meter. Closure height is sampled at 3 locations in each plot; 4) *Total vegetative cover*, in %; and 5) *live vegetation*, expressed as a % of total cover. Compositional sampling includes estimates of *species cover* (live + dead), and *density* of woody seedlings rooted in the subplot. After completing the compositional surveys in the ten subplots, we carefully search for and record any additional species present in the 1 x 60 m plot. Any such species are assigned a mean cover of 0.01% for the plot as a whole.

Vegetation sampling also includes a separate accounting of shrubs. Woody plants more than 1 meter tall are counted by species in a 5 x 60 meter rectangle that shares its eastern baseline with the herb plot. If the stems are rooted within the easternmost 1 meter of the plot, their total height, crown dimensions, and DBH are also estimated.

Shrub abundance is also assessed in the context of landscape observations along transects and at census plots. The methods for landscape observation differ for transect and census samples. In establishing the transects, one observer (Ruiz) recorded the GPS position, species and size class of all shrubs, as well as the characteristics of any tree islands that intercepted a band of 50 meters surrounding the long axis of the transect. At the census points, landscape measurements were made separately for four quadrants centered on the north rebar. From this position, an observer would estimate the density and size class of broad leaved shrubs, palms, and tree islands within 60 meters.

In each of the compositional subplots, we also measure soil depth at 4 locations by probing to bedrock with a thin rod. In the census plots only, surface soils (top 10 cm) were collected at 5-10 random locations and stored for future analysis. Observations of periphyton structure are also conducted in these subplots. Sampling methodology for these surveys has previously been reported by Dr. Gaiser.

Other plot types. In this document, we also report briefly on sampling done in the ENP Taylor Slough transects (Armentano et al. unpublished manuscript) during 2003. There are five E-W transects, each 2 km long, with sampling stations every 100 meters. These are longterm monitoring plots in which sampling was initiated in 1979 (southern three transects) or 1997 (northern two transects). As such, these data constitute an important record of vegetation changes in response to hydrologic manipulations along the eastern edge of Everglades National Park.

Vegetation and topographic surveys were conducted by an FIU team on the northern two transects (ENP-4 & ENP-5) in 2003, while an ENP team sampled vegetation on the other three transects. Topographic surveying was as described above for the CSSS transects. In contrast, vegetation sampling methods were identical to those used by the ENP survey teams since 1979; in fact, some of the observers (David Jones, Hillary Cooley) had participated in several of the earlier surveys. In brief, plots are 5 m^2 (1 m x 5 m), with all twenty 0.25 m^2 subplots sampled separately. Cover of individual species, as well as total vegetation cover, is estimated in each subplot.

2.3 Analytical Methods

Our study design emphasizes data collection over exhaustive data analysis in the first few years of the project, primarily because making conclusions on the basis of incomplete data sets can easily lead to misinterpretation and backtracking. If used cautiously, however, preliminary data analyses can be useful in making all sorts of mid-course corrections in longterm projects, e.g. in reformulating or expanding initial hypotheses, modifying sampling designs, or refining analytical approaches. We decided to use several techniques to examine the vegetation and environmental data collected during the first year's sampling. These include simple summaries of compositional and structural measures, in conjunction with: (1) Ordination and classification, (2) Weighted averaging regression, and (3) Weighted averaging calibration. Methods are described in turn below.

Ordination and classification. To examine the relationships among plant communities at the census sites sampled in 2003 in a visual and quantitative manner, we ordinated their relativized species abundances using non-metric multidimensional scaling (NMS) (Kruskal 1964). The NMS procedure involves an iterative search to position sites along a limited number of axes such that the among-site dissimilarities in vegetation composition are replicated, as much as possible, (McCune and Grace 2002). The discrepancy between the site x site dissimilarity matrix (when the individual elements are *ranked* from most dissimilar to least dissimilar), and its representation in reduced-dimensional space is measured as "stress". The measure of dissimilarity can be chosen by the investigator; we chose the Bray-Curtis index. The NMS analysis was done using PC-ORD software (McCune and Mefford 1999).

In order to define natural groupings within the subset of Year 2003 census plots, we used agglomerative cluster analysis (Goodall 1973) as an initial tool, with limited regrouping of smaller units upon review of site locations in the NMS ordination diagram. In this case, we used Euclidean distance as our distance measure, and Ward's linkage method to calculate relatedness among groups and/or individual sites. Once a classification of sites was available, these groups provided a template on which we could describe variation in community structure, or in the abundance of individual species, within the range of wet prairie environments.

Weighted averaging regression and calibration. Weighted averaging (WA) regression and calibration is a two-step sequence in which (1) species optima and tolerances (an expression of dispersion around the optimum) for individual, ecologically significant environmental variables are calculated from species abundances across a range of sites for which the environmental variable is known (*training data set*), and (2) these optima are utilized in order to infer the level of the environmental variable in data sets in which environmental variable is unknown, but species composition is known (*calibration data set*). These steps are weighted averaging regression and calibration, respectively (Birks et al. 1990). In our case, the training data set is the 91 plots in Transects A, ENP-4, and ENP-5, where vegetation observations were made in the winter and spring of 2003, and hydroperiod could be calculated on the basis of the FIU topographic surveys and water level records from 1996-2000 water years (June through May of subsequent year) at NP-205, CR-2, and NTS-1. Data were analyzed at the plot level, although in the future we intend to examine subplot-level compositional variation as well. We used the C2 program of Juggins (2003) to calculate species optima and tolerances.

We evaluated four alternative WA inference models in conjunction with the species relationships enumerated above. These models used different weighting parameters (tolerance-weighting or not) and methods of "deshrinking" the estimates (classical or inverse). In WA regression, deshrinking is needed to correct for contraction in the range of inferred hydroperiods associated with the double-averaging sequence outlined in the last paragraph. We used the root mean square error of prediction (RMSE) of 100 bootstrapped estimates from the training data set to compare among the models, selecting the model, which minimized RMSE.

Finally, we applied the best WA model to two calibration data sets. The first included the census plots surveyed in 2003, for which no site-specific hydrologic data were available. In this situation, the vegetation-inferred estimates can provide some information about spatial variation in hydrology in the wet prairies throughout the Everglades. The second data set included the historical and current vegetation data from the five Taylor Slough transects. Here the hydrologic record of the sites is already well-known, but dynamics in the vegetation-inferred estimates may shed some light on the responsiveness of the plant communities to annual or longer-term hydrologic variation.

3. Results

We began transect sampling in January 2003, completing those activities for the season by the first week in April. We completed the following activities: (1) Established the location of the plots by fixing a rebar into the limestone bedrock at pre-determined GPS coordinates 100 meter apart along all 6 transects outlined in **Table 1**. (2) Recorded landscape observations within a 50-meter band surrounding each transect, as described in Methods. (3) Surveyed to the top of each rebar, and to the ground surface at 33-66 meter intervals along the transect lines, in Sub-populations A, C, D, and F. (4) Sampled the vegetation, soil depth, periphyton, and topography within the 51 plots along Transect A. (5) Sampled vegetation, soil depth, and topography on ENP-4 and ENP-5.

In early April we began sampling vegetation, soils, and periphyton at a pre-selected subset of the census plots. These plots were also marked with rebar, cased with conduit, and flagged at both ends. The GPS coordinate of the northern rebar was recorded. We scheduled to do as many as 210 plots, given that we could average 10 per day. For the most part, we were able to maintain that level of productivity, but two full and several partial days were lost as a result of weather. Nevertheless, we were able to sample 179 census plots before waters rose to make further vegetation work impractical for the season. The locations of the census plots visited in 2003, as well as the FIU-USGS transects, are illustrated in **Figure 1**.

3.1 Vegetation

During the course of the 2003 field season, we identified 140 plant species within or adjacent to our census or transect plots. The importance of monocots in general and graminoids in particular is evident in this flora; 48 monocots were identified in this wet prairie-marsh mosaic, including 35 graminoid species. All species encountered through June 2003 are listed with family and alternative nomenclature in **Appendix 1**.

We applied cluster analysis to compositional data from the 179 census plots, which represent a well-dispersed sample of non-forested wetlands within broad regions currently considered to be potential habitat for the CSSS. Eight groups were identified (**Figure 2**). At the coarsest scale, 92 *Cladium jamaicense*-dominated sites grouped together, distinguished from 87 sites dominated by five other species --- *Muhlenbergia filipes, Schizachyrium rhizomatum, Rhynchospora tracyi, Schoenus nigricans, and*

Spartina bakeri. Groups dominated by *Schoenus* and *Spartina* were represented by five sites or less, but all other types were encountered at more than fifteen locations each (range 18 - 41).

Affinities among **Figure 2**'s eight assemblages are demonstrated by virtue of their position within the NMS ordination (**Figure 3**). Stress in the two-axis ordination is relatively low (15.69), indicating that these site relationships are adequately described in two dimensions. The primary feature of this ordination is a V-shaped pattern, with separate wings directed toward the upper right and upper left corners of the diagram, and with sites representing the three *Cladium*-dominated groups at its fulcrum. *Cladium*-dominated sites formed a more compact grouping in the ordination diagram than *Muhlenbergia*-, *Schizachyrium*- or *Rhynchospora*-dominated sites, indicating a more heterogeneous species composition in the latter. The small *Schoenus*-dominated group is slightly isolated from other sites in the lower left, and the two *Spartina*-dominated sites are considerably separated from one another in the far right of the diagram.

Thus, vegetation within the landscape occupied by the CSSS is heterogeneous, with distinct community types distributed in a mosaic pattern. We distinguished two broad categories among the 8 groups identified in **Figures 2** and **3** --- "wet prairie" and "marsh". The application of these terms is based on hydrologic and edaphic as well as floristic considerations, and is discussed further in the "Soils" and "Vegetation-hydrologic relationships" sections. The wet prairie types may be most characteristic of the CSSS landscape, but marsh and tree island communities (the latter not sampled in this study) are also important elements in this habitat mosaic.

The mean composition of the eight vegetation types are detailed in **Table 2.** The data demonstrate that CSSS grasslands include several communities with rich herbaceous floras. At the same time, several of the less species-rich groups, particularly *Cladium* marsh and *Spartin*a prairie, exhibited very strong dominance by their namesake species. On a plot basis, mean species richness was 24 or more in three wet prairie vegetation types (*Muhlenbergia, Schizachyrium,* and *Cladium*), while the other prairie and marsh types averaged fewer than 20 species per 60 m^2 plot (**Table 3**). Considered as a group, the CSSS census plots ranged in species richness from 2 to 42. Concentrations of very rich plots were found in the northeast corner of the study area and immediately south of Long Pine Key (**Figure 4**). Areas notable for low species diversity were in the southeast, the far west, and areas closest to the coast.

Table 3: Mean species richness, evenness, and diversity in herb stratum of eight vegetation types. Means are based on 179 census plots sampled in 2003. Number of plots per type are 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 (S)	Shannon`s diversity index (H')	Evenness (E)
Spartina wet prairie	16.5	1.484	0.553
Muhlenbergia wet prairie	26.9	1.716	0.526
Schizachyrium wet prairie	24.6	1.501	0.471
Cladium wet prairie	23.9	1.288	0.411
Schoenus wet prairie	18.6	1.081	0.371
Cladium marsh	15.8	0.629	0.228
Cladium-Rhynchospora marsh	16.1	1.508	0.565
Rhynchospora-Cladium marsh	14.6	1.674	0.636

Mean values for five structural measures are presented in **Figure 5**. These data describe grasslands within the CSSS landscape that are relatively low in stature, with open canopies. Maximum and mean heights varied together, with maximum heights ranging around 90 cm above ground surface, and mean canopy heights ranging around 60 cm. Like maximum and mean canopy heights, total cover and understory closure height tended to co-vary among vegetation types. Both were lowest in *Spartina* wet prairie and in *Rhynchospora-Cladium* marsh types, and highest in *Cladium* marsh. The low percentage of live cover observed in the *Cladium* marsh supports the frequent observation that dead material tends to accumulate in this type.

Table 2: Mean species cover (%) in herb stratum of eight vegetation types, as defined in Figure 2. Means are based on 179 census plots sampled in 2003. Species listed are the 25 most abundant across all sites.

S. No.	Species	Vegetation Types							
		***Spartina* WP**	***Muhlenbergia* WP**	***Schizachyrium* WP**	***Cladium* WP**	***Schoenus* WP**	***Cladium* Marsh**	***Cladium-Rhynchospora* Marsh**	***Rhynchospora-Cladium* Marsh**
1	*Cladium jamaicense*	1.10	11.92	17.73	27.24	13.90	38.65	13.27	5.59
2	*Schizachyrium rhizomatum*	0.33	6.63	20.04	5.11	1.71	0.31		0.04
3	*Muhlenbergia filipes*	1.35	15.99	3.64	6.59	2.36	0.68	0.01	0.01
4	*Rhynchospora tracyi*	3.13	0.28	0.36	0.44	0.09	0.86	2.61	7.27
5	*Schoenus nigricans*		1.66	0.34	0.83	30.79	0.78		
6	*Panicum tenerum*		0.24	0.81	0.40	0.04	0.40	2.30	0.66
7	*Bacopa caroliniana*		0.08	0.02	0.02		0.20	1.34	2.39
8	*Eleocharis cellulosa*	0.25	0.01		0.05	0.01	0.41	1.98	1.47
9	*Centella asiatica*	0.15	0.91	1.20	0.47	0.10	0.12	0.14	0.00
10	*Panicum virgatum*	0.65	0.16	0.87	0.51	0.01	0.27	0.38	0.26
11	*Paspalum monostachyum*	0.70	0.78	0.52	0.81		0.08		0.11
12	*Cassytha filiformis*		0.43	0.98	0.30	0.76	0.13	0.20	0.01
13	*Pluchea rosea*	0.01	0.18	0.62	0.33	0.00	0.32	0.55	0.13
14	*Rhynchospora microcarpa*	0.10	0.35	0.45	0.17	0.23	0.24	0.27	0.37
15	*Crinum americanum*	0.06	0.12	0.20	0.08	0.02	0.19	0.68	0.55
16	*Spartina bakeri*	13.35	0.05						0.08
17	*Hymenocallis palmeri*	0.01	0.13	0.19	0.08	0.29	0.05	0.10	0.33
18	*Panicum hemitomon*			0.00			0.03	0.32	0.59
19	*Utricularia purpurea*				0.01		0.00	0.08	0.71
20	*Agalinis purpurea*		0.44	0.21	0.11	0.03	0.01		
21	*Sagittaria lancifolia var. lancifolia*		0.10	0.00	0.04	0.00	0.04	0.22	0.35
22	*Rhynchospora divergens*		0.43	0.15	0.08	0.18	0.03	0.01	0.01
23	*Eragrostis elliottii*		0.19	0.16	0.10	0.15	0.09	0.06	0.02
24	*Phyla nodiflora*	1.25	0.14	0.01	0.14		0.03	0.02	0.01
25	*Erianthus giganteus*		0.01	0.08	0.01		0.08	0.04	0.11

The spatial distribution of vegetation types throughout the CSSS landscape, based on the 179 census sites visited in 2003, is illustrated in **Figure 6**. Interesting distributional patterns are displayed by several groups. *Muhlenbergia* and *Schoenus* prairie plots are concentrated in the eastern half of the study area, *Cladium-Rhynchospora* marsh in the west. The two examples of *Spartina* prairie are located relatively near the coast. Prairie vegetation is much more prominent in the eastern sub-populations, though a core area of prairie is present in the west.

3.2 Soils

Soils in the census plots ranged from 0 cm (exposed limestone bedrock) to more than one meter in depth (**Figure 7**). Soils > 30 cm in depth characterized marsh vegetation types, while shallower soils were characteristic of prairie types. The *Schoenus* vegetation type was found on slightly deeper soils than were other prairie types. In general, marsh soils were more variable in depth than prairie soils. Many of the deeper marsh soils were also dark in color, which is probably indicative of higher organic content. In describing Everglades marshes, Gunderson (1994) recognized two prairie vegetation types ["wet prairie (peat)" and "wet prairie (marl)"]. In our vegetation classification, we followed Gunderson in part in his use of soils to distinguish low, open-canopied, mixed-graminoid Everglades communities, but assigned the Gunderson "wet prairie (peat)" assemblages to a "marsh" group on hydrologic grounds (see "Vegetation-hydrologic relationships").

3.3 Topography

The topography of the transects established in CSSS sub-populations A, C, D, and F are presented in **Figure 8**. The mean elevations of these transects decrease from north to south, i.e., from Transects A and F at about 1.4 meters above sea level (amsl) to Transect D at *ca* 0.2 meters elevation. At the 100-meter scale addressed in **Figure 8**, surface roughness is clearly highest along Transect F. Both Transects F and A display distinct E-W slopes, but Transect F slopes *toward* Shark Slough, while Transect A slopes *away* from it (i.e., the eastern end of the transect apparently occupies an important topographic boundary between Shark Slough and western drainage systems). In comparison to these directionally sloping transects, Transects C and D display only local variation in elevation.

3.4 Vegetation-hydrologic relationships

Assuming a reasonably flat water table, differences in elevation across the relatively short transects described in the previous section should translate directly to differences in hydroperiod, defined here as the annual, discontinuous period of flooding, expressed in days per year. Furthermore, such hydrologic variation may influence the nature of the resident plant communities. **Figure 9** illustrates the relationships among elevation, hydroperiod, and vegetation type and total cover along Transect A. Because these vegetation data were not included in the initial cluster analysis, we determined vegetation type for each plot by inserting a row representing its species abundances one at a time into the original data set, and determining with which unit it grouped. With the dip in elevation from 1.6 meters amsl at the east end of the transect to 1.3 meters at the west end, estimated hydroperiod during 1996-2000 more than doubled, from *ca* 120 to 300 days. The hydrologic gradient is paralleled by a gradient in vegetation from wet prairie communities at the east end to marsh communities on the west. The shift to marsh on the west end of the transect brings a more spatially variable structural mosaic, as the marsh communities include both the densest (*Cladium* marsh) and most open (mixed *Cladium-Rhynchospora* and *Rhynchospora-Cladium* marsh) of the communities in the CSSS landscape.

The presence in Transect A of species assemblages classified as *Muhlenbergia* wet prairie is also notable in **Figure 9**, because the dominant species in this vegetation type, *Muhlenbergia filipes*, was present, in low abundance, at only one location along the transect. For that to have occurred, other species characteristic of the group must be present in proportions strongly indicative of the *Muhlenbergia* wet prairie type. Data from the longterm Taylor Slough study (see next section) suggest that the abundance of *M. filipes* is very sensitive to changes in hydrology, but quite possibly many of its associates are less responsive. If the hydrology in Transect A has been changing, and if species respond at different rates to hydrologic change, then unorthodox assemblages like these could represent situations where equilibrium conditions have not yet been reached.

Species optima and tolerances were calculated from the vegetation and hydrology information collected along Transects A, ENP-4, and ENP-5 as a group (**Table 4**). Of the species that occurred in 3 plots or more, *Crinum americanum*, a species usually associated with central Everglades marshes, exhibited the highest hydroperiod optimum, and *Vernonia blodgettii*, which is common in the pine forest understory, was associated with the driest sites. Among the most abundant graminoid species, *Muhlenbergia filipes, Aristida purpurascens, Schizachyrium rhizomatum,* and *Spartina bakeri* were associated with relatively dry sites, and *Rhynchospora tracyi, Schoenus nigricans, Panicum virgatum, Rhynchospora microcarpa*, and *Cladium jamaicense* with more persistently flooded ones.

WA regression models were developed and evaluated by comparing the mean of the bootstrapped estimates of hydroperiod for sampling locations along Transect A with the observed hydroperiod. The best model was one 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 10**). The model was highly significant (R^2=0.73), but the root mean square error of prediction of the bootstrapped estimates (39.4) was relatively high, i.e., there was a fairly wide spread among the estimates for any given hydroperiod. We think this preliminary model is usable in its current state, but should improve considerably as the scope of the training data set is expanded (more transects, with more representatives of uncommon species), and as other analytical variations are explored.

Using the WA model described above, we estimated hydroperiod at the 179 census points; this is WA calibration, because hydroperiods are unknown at these remote locations. By superimposing and contouring these estimates on the ordination diagram introduced in **Figure 3**, the relationships among vegetation types becomes more amenable to interpretation (**Figure 11**). Communities classified as *Muhlenbergia* prairie typically occupy sites with hydroperiods of 120-180 days. At the other end of the hydrologic scale, *Rhynchospora-Cladium* and *Cladium-Rhynchospora* marsh usually experience hydroperiods of > 240 days. Other communities with inferred hydroperiods typically exceeding 210 days are *Cladium* marsh and, surprisingly, *Schoenus* wet prairie. The distinction of marsh communities at the wetter end of the hydrologic gradient and prairie communities at the drier end is nevertheless quite clear.

In **Figure 12**, the hydroperiods inferred on the basis of plant species composition observed at the census points are plotted on a map of the southern Everglades. Hydroperiods less than 180 days are concentrated east of Shark Slough, while only a few locations west of the Slough support vegetation indicative of these relatively dry conditions. Nearly half of the sampling locations west of Shark Slough yielded inferred hydroperiods of nine months or more. During the remaining years of the project, we plan to explore further how well these vegetation-inferred estimates describe true hydrologic conditions in remote locations in the Everglades.

Ultimately, the objective of our research is to address vegetation dynamics at the landscape level for its potential influence on CSSS populations. To this end, **Figure 13** displays the percentage of plots in which sparrows were observed at least once during the 2000-2001 censuses, when the plots are divided into 30-day increments of inferred hydroperiod. Birds were observed at nearly 80% of sites with an inferred hydroperiod of 120-150 days, and this percentage remained at 40% or so up to a hydroperiod of 210 days. At more hydric sites the chance of observing a sparrow dropped to 20% or less, and no birds were observed at sites with an inferred hydroperiod less than 120 days. It should be recognized, however, that while sparrow and vegetation observations were conducted in the same general locations, they may have been as much as a few hundred meters apart in a few cases. In the future the two surveys will be coordinated so that both teams work from the same center points.

Table 4: Species hydroperiod optima and tolerances, as estimated by weighted averaging regression, based on species cover collected along Transects A, ENP-4, and ENP-5.

Species Order	Species	Species code	Occurrence (n)	Estimated hydroperiod	
				Optimum	Tolerance
1	*Cyperus haspan*	CYPHAS	1	293	48
2	*Pontederia cordata var. lanciifolia*	PONCOR	2	292	3
3	*Crinum americanum*	CRIAME	30	283	21
4	*Utricularia purpurea*	UTRPUR	1	283	48
5	*Eleocharis cellulosa*	ELECEL	16	282	25
6	*Panicum dichotomiflorum*	PANDIC	7	279	20
7	*Paspalidium geminatum var. geminatum*	PASGEM	5	276	25
8	*Schoenolirion albiflorum*	SCHALB	6	272	45
9	*Ludwigia repens*	LUDREP	6	272	25
10	*Panicum hemitomon*	PANHEM	15	267	33
11	*Rhynchospora inundata*	RHYINU	9	267	45
12	*Utricularia cornuta*	UTRCOR	2	266	32
13	*Erianthus giganteus*	ERIGIG	19	265	33
14	*Bacopa caroliniana*	BACCAR	52	264	40
15	*Agalinis* sp.	AGASPP	31	262	36
16	*Ludwigia* sp.	LUDSPP	1	260	48
17	*Rhynchospora tracyi*	RHYTRA	67	258	53
18	*Leersia hexandra*	LEEHEX	31	258	55
19	*Polygonum hydropiperoides*	POLHYD	3	258	18
20	*Schoenus nigricans*	SCHNIG	19	255	48
21	*Proserpinaca palustris*	PROPAL	14	247	35
22	*Peltandra virginica*	PELVIR	2	246	31
23	*Panicum rigidulum*	PANRIG	10	241	41
24	*Mitreola petiolata*	MITPET	22	240	46
25	*Caperonia castaneifolia*	CAPCAS	1	237	48
26	*Utricularia foliosa*	UTRFOL	2	237	9
27	*Cassytha filiformis*	CASFIL	42	237	63
28	*Aster dumosus*	ASTDUM	47	234	55
29	*Panicum virgatum*	PANVIR	51	233	61
30	*Panicum tenerum*	PANTEN	87	232	63
31	*Aeschynomene pratensis var. pratensis*	AESPRA	9	232	58
32	*Rhynchospora microcarpa*	RHYMIC	64	228	68
33	*Dichromena colorata*	DICCOL	8	228	59
34	*Eragrostis elliottii*	ERAELL	65	225	74
35	*Ipomoea sagittata*	IPOSAG	21	219	61
36	*Fuirena breviseta*	FUIBRE	5	217	56
37	*Pluchea rosea*	PLUROS	77	214	51
38	*Sagittaria lancifolia var. lancifolia*	SAGLAN	11	213	58
39	*Cladium jamaicense*	CLAJAM	91	213	64
40	*Asclepias longifolia*	ASCLON	7	212	59
41	*Phyla stoechadifolia*	PHYSTO	9	212	67
42	*Eupatorium mikanioides*	EUPMIK	15	212	42
43	*Nymphoides aquatica*	NYMAQU	5	208	57

Species Order	Species	Species code	Occurrence (n)	Estimated hydroperiod	
				Optimum	Tolerance
44	*Ludwigia microcarpa*	LUDMIC	11	207	30
45	*Oxypolis filiformis*	OXYFIL	18	206	62
46	*Helenium pinnatifidum*	HELPIN	28	206	55
47	*Setaria geniculata*	SETGEN	1	203	48
48	*Paspalum monostachyum*	PASMON	40	201	54
49	*Agalinis purpurea*	AGAPUR	2	196	70
50	*Mikania scandens*	MIKSCA	25	193	68
51	*Andropogon glomeratus var. glomeratus*	ANDGLO	1	192	48
52	*Eustachys petraea*	EUSGLA	1	192	48
53	*Dyschoriste angusta*	DYSANG	1	189	48
54	*Hyptis alata*	HYPALA	1	189	48
55	*Magnolia virginiana*	MAGVIR	1	189	48
56	*Parthenocissus quinquefolia*	PARQUI	1	189	48
57	*Asclepias lanceolata*	ASCLAN	7	189	66
58	*Linum medium var. texanum*	LINMED	2	187	45
59	*Aster tenuifolius*	ASTTEN	57	184	71
60	*Andropogon virginicus var. virginicus*	ANDVIR	21	183	70
61	*Phyla nodiflora*	PHYNOD	33	178	47
62	*Heliotropium polyphyllum*	HELPOL	4	176	31
63	*Annona glabra*	ANNGLA	15	175	66
64	*Justicia angusta*	JUSANG	14	174	48
65	*Centella asiatica*	CENASI	69	173	54
66	*Hymenocallis palmeri*	HYMPAL	42	172	57
67	*Schizachyrium rhizomatum*	SCHRHI	40	170	56
68	*Erigeron quercifolius*	ERIQUE	8	169	42
69	*Phyllanthus caroliniensis*	PIRCAR	6	169	49
70	*Dichanthelium dichotomum*	DICDIC	16	165	46
71	*Teucrium canadense*	TEUCAN	17	159	55
72	*Eupatorium leptophyllum*	EUPLEP	10	158	58
73	*Myrica cerifera*	MYRCER	12	152	88
74	*Aletris bracteata*	ALEBRA	1	144	48
75	*Coelorachis rugosa*	COERUG	1	140	48
76	*Solidago stricta*	SOLSTR	30	139	41
77	*Samolus ebracteatus*	SAMEBR	3	135	34
78	*Muhlenbergia fillipes*	MUHFIL	39	133	34
79	*Polygala grandiflora var. leiodes*	POLGRA	14	128	37
80	*Rhynchospora divergens*	RHYDIV	18	127	54
81	*Lobelia glandulosa*	LOBGLA	1	124	48
82	*Spartina bakeri*	SPABAK	3	117	34
83	*Sabal palmetto*	SABPAL	2	117	116
84	*Persea borbonia*	PERBOR	1	110	48
85	*Aristida purpurascens*	ARIPUR	26	110	41
86	*Cirsium horridulum*	CIRHOR	4	104	29
87	*Vernonia blodgettia*	VERBLO	6	98	19
88	*Bumelia reclinata*	BUMREC	2	96	12
89	*Conoclinium coelestinum*	CONCOE	1	84	48

3.5 Vegetation dynamics in Taylor Slough

To our knowledge, the historical vegetation database for upper Taylor Slough is the most complete one available for seasonal fresh water wetlands of the Everglades. As such, the record of vegetation dynamics in this area represent the best current opportunity to assess the temporal responsiveness of vegetation to hydrologic change in the CSSS landscape. Unfortunately, plot-specific data for the earliest (1979) survey are not available, so the preliminary analyses presented below are restricted to the period between 1992 and the present. A more extensive analysis that will incorporate the summarized 1979 data is currently being prepared (Armentano et al. in preparation).

Water level in Taylor Slough increased between 1961 and 2001 (**Figure 14**). Except in the dry year of 1979, water level never went below ground level after 1975. After water releases from the L31-W Canal to Taylor Slough via S332 were initiated in 1982, annual variation between dry and wet season decreased in comparison to earlier years, primarily as a function of higher water levels during the dry season. Except during the dry years between 1989 and 1992, the trend continued till 1999, when regular operations at S332 were eliminated.

Based on variation in vegetation-inferred hydroperiods presented in **Figure 15**, the changes in Taylor Slough water level during the 1980's and 1990's appeared to elicit parallel changes in vegetation; moreover, the lag between hydrologic change and vegetation response is relatively rapid. In this application, inferred hydroperiod is of interest primarily as a quantitative indication of the direction and degree of change in vegetation. Changes in vegetation-inferred hydroperiods were most distinct along Transect 2, especially between 1992 and 1995. During this period of continuous wet years (**Figure 14**), much more hydrophilic plant communities developed along the entire length of the transect, which is a short distance downstream of S332. Unfortunately, vegetation data that might have verified whether the changes observed along Transect 2 were due to increased pumping into the Slough during those years or to other ancillary causes were not available from transects north of S332 in 1992. A continued, though less dramatic, increase in inferred hydroperiod in many plots in Transects 1-3 between 1995 and 1999 indicates that plant species adapted to longer hydroperiod continued to increase in dominance during the period. Such changes were not observed along Transects 4 and 5, which are located north of the pumping station and beyond its effects. During the most recent period (1999-2003), inferred hydroperiods were generally lower along all transects except ENP-4, reflecting decreasing water levels in the slough, perhaps due to closure of the pumping station.

4. Future directions

Substantial progress was made in the first year of the CSSS project, most importantly in terms of establishing a solid sampling design that can effectively support other research efforts intended to benefit the sparrow and the health of the seasonal wetland landscapes it occupies. The utilization of WA models to relate vegetation and hydrologic dynamics on a broad spatial scale appears to be a robust analytical tool. Once an extensive baseline vegetation database has been established, these methods will become increasingly useful for monitoring ecological change associated with restoration activities. However, it is important to recognize that hydrology is not the only environmental variable to directly affect sparrow habitat. In particular, fire regime --- which of course is itself impacted by hydrology --- is a potent force for vegetation change in the wet prairie mosaic, and one that is critical if we are to fully understand population and landscape dynamics in this ecosystem (Lockwood et al. in review).

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

CLASS	FAMILY	SCIENTIFIC NAME	AUTHOR CITATION	REF	SPCODE	ALTERNATE NAME
DICOT	FABACEAE	*Acacia farnesiana*	(L.) Willd.	2	ACAFAR	
DICOT	FABACEAE	*Aeschynomene pratensis* var. *pratensis*	Small	2	AESPRA	
DICOT	SCROPHULARIACEAE	*Agalinis linifolia*	(Nutt.) Britton	1	AGAPUR	
DICOT	SCROPHULARIACEAE	*Agalinis purpurea*	(L.) Pennell	1	AGAPUR	
MONOCOT	LILIACEAE	*Aletris bracteata*	Northr.	3	ALEBRA	1,2 *A. farinosa* L.
MONOCOT	POACEAE	*Andropogon glomeratus* var. *glomeratus*	(Walt.) Britton et al.	2	ANDGLO	
MONOCOT	POACEAE	*Andropogon virginicus* var. *virginicus*	L.	1	ANDVIR	
PTERIDOPHYTE	SCHIZAEACEAE	*Anemia adiantifolia*	(L.) Sw.	5	ANEADI	
DICOT	APOCYNACEAE	*Angadenia berterii*	(A. DC.) Miers	2	ANGBER	3 *A. berteri* (A. DC.) Miers
DICOT	ANNONACEAE	*Annona glabra*	L.	1	ANNGLA	
MONOCOT	POACEAE	*Aristida purpurascens*	Poir.	2	ARIPUR	
DICOT	ASCLEPIADACEAE	*Asclepias lanceolata*	Walt.	1	ASCLAN	
DICOT	ASCLEPIADACEAE	*Asclepias longifolia*	Michx.	1	ASCLON	
DICOT	ASTERACEAE	*Aster adnatus*	Nutt.	2	ASTADN	
DICOT	ASTERACEAE	*Aster dumosus*	L.	1	ASTDUM	
DICOT	ASTERACEAE	*Aster subulatus*	Michx.	1	ASTSUB	
DICOT	ASTERACEAE	*Aster tenuifolius*	L.	1	ASTTEN	
DICOT	ASTERACEAE	*Baccharis halimifolia*	L.	1	BACHAL	
DICOT	SCROPHULARIACEAE	*Bacopa caroliniana*	(Walt.) Robins.	1	BACCAR	
DICOT	SCROPHULARIACEAE	*Buchnera floridana*	Gand.	1	BUCFLO	
DICOT	SAPOTACEAE	*Bumelia reclinata*	(Michx.) Vent.	1	BUMREC	3 *Sideroxylon reclinatum* Michx. subsp. *austrofloridense* (Whetstone) Kartesz & Gandhi
DICOT	SAPOTACEAE	*Bumelia salicifolia*	(L.) Sw.	4	BUMSAL	2 *Dipholis salicifolia* (L.) A. DC.; 3 *Sideroxylon salicifolium* (L.) Lam.

CLASS	FAMILY	SCIENTIFIC NAME	AUTHOR CITATION	REF	SPCODE	ALTERNATE NAME
MONOCOT	ORCHIDACEAE	*Calopogon tuberosus*	(L.) Britton et al.	1	CALTUB	
DICOT	EUPHORBIACEAE	*Caperonia castaneifolia*	(L.) A. St.-Hil.	1	CAPCAS	
DICOT	LAURACEAE	*Cassytha filiformis*	L.	2	CASFIL	
DICOT	APIACEAE	*Centella asiatica*	(L.) Urban	1	CENASI	
DICOT	EUPHORBIACEAE	*Chamaesyce adenoptera* subsp. *pergamena*	(Bertol.) Small/(Small) D.G. Burch	2	CHAADE	3 *C. pergamena* (Small) Small
DICOT	RUBIACEAE	*Chiococca parvifolia*	Wullschl. ex Griseb.	4	CHIPAR	2 *C. pinetorum* Britton; 3C. alba (L.) Hitchc.
DICOT	CHRYSOBALANACEAE	*Chrysobalanus icaco*	L.	1	CHRICA	
DICOT	ASTERACEAE	*Cirsium horridulum*	Michx.	1	CIRHOR	
MONOCOT	CYPERACEAE	*Cladium jamaicense*	Crantz	1	CLAJAM	
MONOCOT	POACEAE	*Coelorachis rugosa*	(Nutt.) Nash	3	COERUG	1,2 *Manisuris rugosa* (Nutt.) Kuntze
DICOT	COMBRETACEAE	*Conocarpus erectus*	L.	1	CONERE	
DICOT	ASTERACEAE	*Conoclinium coelestinum*	(L.) DC.	1	CONCOE	
MONOCOT	AMARYLLIDACEAE	*Crinum americanum*	L.	1	CRIAME	
MONOCOT	CYPERACEAE	*Cyperus haspan*	L.	1	CYPHAS	
MONOCOT	POACEAE	*Dichanthelium dichotomum*	(L.) Gould	3,4	DICDIC	1 *Panicum dichotomum* L.
MONOCOT	CYPERACEAE	*Dichromena colorata*	(L.) Hitchc.	1	DICCOL	
DICOT	RUBIACEAE	*Diodia virginiana*	L.	1	DIOVIR	
DICOT	ACANTHACEAE	*Dyschoriste angusta*	(A. Gray) Small	1	DYSANG	2 *D. oblongifolia* (Michx.) Kuntze var. *angusta* (A. Gray) R.W. Long
MONOCOT	CYPERACEAE	*Eleocharis cellulosa*	Torr.	1	ELECEL	
DICOT	ACANTHACEAE	*Elytraria caroliniensis* var. *angustifolia*	(J.F. Gmel.) Pers./(Fern.) Blake	1	ELYCAR	
MONOCOT	POACEAE	*Eragrostis elliottii*	S. Wats.	1	ERAELL	
MONOCOT	POACEAE	*Erianthus giganteus*	(Walt.) Muhl.	1	ERIGIG	3 *Saccharum giganteum* (Walt.) Pers.
DICOT	ASTERACEAE	*Erigeron quercifolius*	Lam.	2	ERIQUE	
DICOT	ASTERACEAE	*Eupatorium leptophyllum*	DC.	1	EUPLEP	
DICOT	ASTERACEAE	*Eupatorium mikanioides*	Chapm.	1	EUPMIK	
MONOCOT	POACEAE	*Eustachys petraea*	(Sw.) Desv.	3	EUSPET	1,2 *Chloris petraea* Sw.

CLASS	FAMILY	SCIENTIFIC NAME	AUTHOR CITATION	REF	SPCODE	ALTERNATE NAME
DICOT	CONVOLVULACEAE	*Evolvulus sericeus*	Sw.	1	EVOSER	
DICOT	ASTERACEAE	*Flaveria linearis*	Lag.	1	FLALIN	
MONOCOT	CYPERACEAE	*Fuirena breviseta*	(Coville) Coville	1	FUIBRE	
MONOCOT	CYPERACEAE	*Fuirena scirpoidea*	Michx.	1	FUISCI	
DICOT	NYCTAGINACEAE	*Guapira discolor*	(Spreng.) Little	4	GUADIS	2 *Pisonia discolor* Spreng.
DICOT	ASTERACEAE	*Helenium pinnatifidum*	(Nutt.) Rydb.	1	HELPIN	
DICOT	BORAGINACEAE	*Heliotropium polyphyllum*	Lehm.	1	HELPOL	
DICOT	HYDROPHYLLACEAE	*Hydrolea corymbosa*	J. Macbr. ex Elliott	1	HYDCOR	
MONOCOT	AMARYLLIDACEAE	*Hymenocallis palmeri*	S. Wats.	2	HYMPAL	
MONOCOT	HYPOXIDACEAE	*Hypoxis wrightii*	(Baker) Brackett	2	HYPWRI	
DICOT	LAMIACEAE	*Hyptis alata*	(Raf.) Shinners	1	HYPALA	
DICOT	AQUIFOLIACEAE	*Ilex cassine*	L.	1	ILECAS	
DICOT	CONVOLVULACEAE	*Ipomoea sagittata*	Poir.	1	IPOSAG	
DICOT	ASTERACEAE	*Iva microcephala*	Nutt.	1	IVAMIC	
MONOCOT	JUNCACEAE	*Juncus megacephalus*	M.A. Curtis	1	JUNMEG	
MONOCOT	CYPERACEAE	*Juncus roemerianus*	Scheele	1	JUNROE	
DICOT	ACANTHACEAE	*Justicia angusta*	(Chapm.) Small	3	JUSANG	1,2 *Justicia ovata* (Walt.) Lindau
MONOCOT	POACEAE	*Leersia hexandra*	Sw.	1	LEEHEX	
DICOT	LINACEAE	*Linum medium* var. *texanum*	(Planch.) Britt./(Planch.) Fern.	1	LINMED	
DICOT	CAMPANULACEAE	*Lobelia glandulosa*	Walt.	1	LOBGLA	
DICOT	ONAGRACEAE	*Ludwigia alata*	Elliott	1	LUDALA	
DICOT	ONAGRACEAE	*Ludwigia microcarpa*	Michx.	1	LUDMIC	
DICOT	ONAGRACEAE	*Ludwigia repens*	Forst.	1	LUDREP	
DICOT	LYTHRACEAE	*Lythrum alatum* var. *lanceolatum*	Pursh/(Elliott) T. & G. ex Rothr.	1	LYTALA	
DICOT	MAGNOLIACEAE	*Magnolia virginiana*	L.	1	MAGVIR	
DICOT	SCROPHULARIACEAE	*Mecardonia acuminata* var. *peninsularis*	(Walt.) Small/(Pennell) Rossow	1,2	MECACU	
DICOT	MYRTACEAE	*Melaleuca quinquenervia*	(Cav.) S.T. Blake	1	MELQUI	
DICOT	ASTERACEAE	*Melanthera angustifolia*	A. Rich.	2	MELANG	3 *M. nivea* (L.) Small

CLASS	FAMILY	SCIENTIFIC NAME	AUTHOR CITATION	REF	SPCODE	ALTERNATE NAME
DICOT	ASTERACEAE	*Melanthera parvifolia*	Small	2	MELPAR	3 *M. nivea* (L.) Small
DICOT	ANACARDIACEAE	*Metopium toxiferum*	(L.) Krug & Urb.	1	METTOX	
DICOT	ASTERACEAE	*Mikania scandens*	(L.) Willd.	1	MIKSCA	*Mikania batatifolia* DC.
DICOT	LOGANIACEAE	*Mitreola petiolata*	(J.F. Gmel.) T. & G.	1	MITPET	2 Cynoctonum mitreola (L.) Britt.
MONOCOT	POACEAE	*Muhlenbergia fillipes*	M.A. Curtis	2	MUHFIL	1 *M. capillaris* (Lam.) Trin.; 3 *M. capillaris* var. *filipes* (M.A. Curtis) Chapm. ex Beal
DICOT	MYRICACEAE	*Myrica cerifera*	L.	1	MYRCER	
DICOT	MENYANTHACEAE	*Nymphoides aquatica*	(S.G. Gmel.) Kuntze	1	NYMAQU	
DICOT	APIACEAE	*Oxypolis filiformis*	(Walt.) Britt.	1	OXYFIL	
MONOCOT	POACEAE	*Panicum dichotomiflorum*	Michx.	1	PANDIC	
MONOCOT	POACEAE	*Panicum hemitomon*	Schult.	1	PANHEM	
MONOCOT	POACEAE	*Panicum rigidulum*	Nees	1	PANRIG	
MONOCOT	POACEAE	*Panicum tenerum*	Beyr. ex Trin.	1	PANTEN	
MONOCOT	POACEAE	*Panicum virgatum*	L.	1	PANVIR	
DICOT	VITACEAE	*Parthenocissus quinquefolia*	(L.) Planch.	2	PARQUI	
MONOCOT	POACEAE	*Paspalidium geminatum* var. *geminatum*	(Forst.) Stapf	1	PASGEM	
MONOCOT	POACEAE	*Paspalum monostachyum*	Vasey ex Chapm.	1	PASMON	
MONOCOT	ARACEAE	*Peltandra virginica*	(L.) Schott & Endl.	1	PELVIR	
DICOT	LAURACEAE	*Persea borbonia*	(L.) Spreng.	1	PERBOR	
MONOCOT	POACEAE	*Phragmites australis*	(Cav.) Trin. Ex Steud.	1	PHRAUS	
DICOT	VERBENACEAE	*Phyla nodiflora*	(L.) Greene	1	PHYNOD	
DICOT	VERBENACEAE	*Phyla stoechadifolia*	(L.) Small	1	PHYSTO	
DICOT	EUPHORBIACEAE	*Phyllanthus caroliniensis*	Walt.	1	PHYCAR	2 *P. caroliniensis* subsp. *saxicola* (Small) G.L. Webster
DICOT	LENTIBULARIACEAE	*Pinguicula pumila*	Michx.	1	PINPUM	
DICOT	TURNERACEAE	*Piriqueta caroliniana*	(Walter) Urb.	2	PIRCAR	
DICOT	ASTERACEAE	*Pluchea rosea*	Godfrey	1	PLUROS	
DICOT	POLYGALACEAE	*Polygala balduinii*	Nutt.	1	POLBAL	

CLASS	FAMILY	SCIENTIFIC NAME	AUTHOR CITATION	REF	SPCODE	ALTERNATE NAME
DICOT	POLYGALACEAE	*Polygala boykinii*	Nutt.	1	POLBOY	
DICOT	POLYGALACEAE	*Polygala grandiflora* var. *leiodes*	Walt./Blake	2	POLGRA	
DICOT	POLYGONACEAE	*Polygonum hydropiperoides*	Michx.	1	POLHYD	
MONOCOT	PONTEDERIACEAE	*Pontederia cordata* var. *lanciifolia*	L./(Muhl.) Torr.	1	PONCOR	
MONOCOT	POTAMOGETONACEAE	*Potamogeton illinoensis*	Morong	1	POTILL	
DICOT	HALORAGACEAE	*Proserpinaca palustris*	L.	1	PROPAL	
DICOT	RUBIACEAE	*Randia aculeata*	L.	2	RANACU	
DICOT	RHIZOPHORACEAE	*Rhizophora mangle*	L.	1	RHIMAN	
MONOCOT	CYPERACEAE	*Rhynchospora divergens*	Chapm. ex M.A. Curtis	1	RHYDIV	
MONOCOT	CYPERACEAE	*Rhynchospora inundata*	(Oakes) Fern.	1	RHYINU	
MONOCOT	CYPERACEAE	*Rhynchospora microcarpa*	Baldw. ex Gray	1	RHYMIC	
MONOCOT	CYPERACEAE	*Rhynchospora tracyi*	Britt.	1	RHYTRA	
DICOT	ACANTHACEAE	*Ruellia caroliniensis*	(J.F. Gmel) Steud.	2	RUECAR	
MONOCOT	ARECACEAE	*Sabal palmetto*	(Walt.) Lodd. ex Schult. & Schult.	1	SABPAL	
DICOT	GENTIANACEAE	*Sabatia grandiflora*	(Gray) Small	1	SABGRA	
DICOT	GENTIANACEAE	*Sabatia stellaris*	Pursh.	1	SABSTE	
MONOCOT	ALISMATACEAE	*Sagittaria lancifolia* var. *lancifolia*	L.	1	SAGLAN	
DICOT	PRIMULACEAE	*Samolus ebracteatus*	Kunth.	1	SAMEBR	
DICOT	ANACARDIACEAE	*Schinus terebinthifolius*	Raddi	1	SCHTER	
MONOCOT	POACEAE	*Schizachyrium rhizomatum*	(Swallen) Gould	1	SCHRHI	
MONOCOT	LILIACEAE	*Schoenolirion albiflorum*	(Raf.) R.R. Gates	3	SCHALB	1,2 *S. elliottii* Feay ex A. Gray
MONOCOT	CYPERACEAE	*Schoenus nigricans*	L.	1	SCHNIG	
MONOCOT	CYPERACEAE	*Scleria verticillata*	Muhl. ex. Willd.	1	SCLVER	
MONOCOT	ARECACEAE	*Serenoa repens*	(W. Bartram) Small	1	SERREP	
MONOCOT	POACEAE	*Setaria geniculata*	(Poir.) Beauv.	1	SETGEN	3 *S. parviflora* (Poir.) Kerguelen
MONOCOT	IRIDACEAE	*Sisyrinchium angustifolium*	Mill.	3	SISANG	2 *S. atlanticum* Bickn.

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DICOT	SOLANACEAE	*Solanum blodgettii*	Chapm.	2	SOLBLO	3 *S. verbascifolium* L.; 4 *S. donianum* Walp.
DICOT	ASTERACEAE	*Solidago stricta*	Ait.	1	SOLSTR	
MONOCOT	POACEAE	*Spartina bakeri*	Merr.	1	SPABAK	
DICOT	RUBIACEAE	*Spermacoce terminalis*	(Small) Kartesz & Gandhi	3	SPETER	2 *Borreria terminalis* Small
DICOT	ACANTHACEAE	*Stenandrium dulce* var. *floridanum*	(Cav.) Nees/A. Gray	2	STEDUL	1 *S. floridanum* (Gray) Small
DICOT	EUPHORBIACEAE	*Stillingia aquatica*	Chapm.	1	STIAQU	
GYMNOSPERM	CUPRESSACEAE	*Taxodium distichum var. imbricarium*	(L.) L.C./(Nutt.) Croom		TAXDIS	
DICOT	LAMIACEAE	*Teucrium canadense*	L.	1	TEUCAN	
PTERIDOPHYTE	THELYPTERIDACEAE	*Thelypteris palustris* var. *pubescens*	Schott/(Laws.) Fern.	5	THEPAL	
DICOT	LENTIBULARIACEAE	*Utricularia cornuta*	Michx.	1	UTRCOR	
DICOT	LENTIBULARIACEAE	*Utricularia foliosa*	L.	1	UTRFOL	
DICOT	LENTIBULARIACEAE	*Utricularia purpurea*	Walt.	1	UTRPUR	

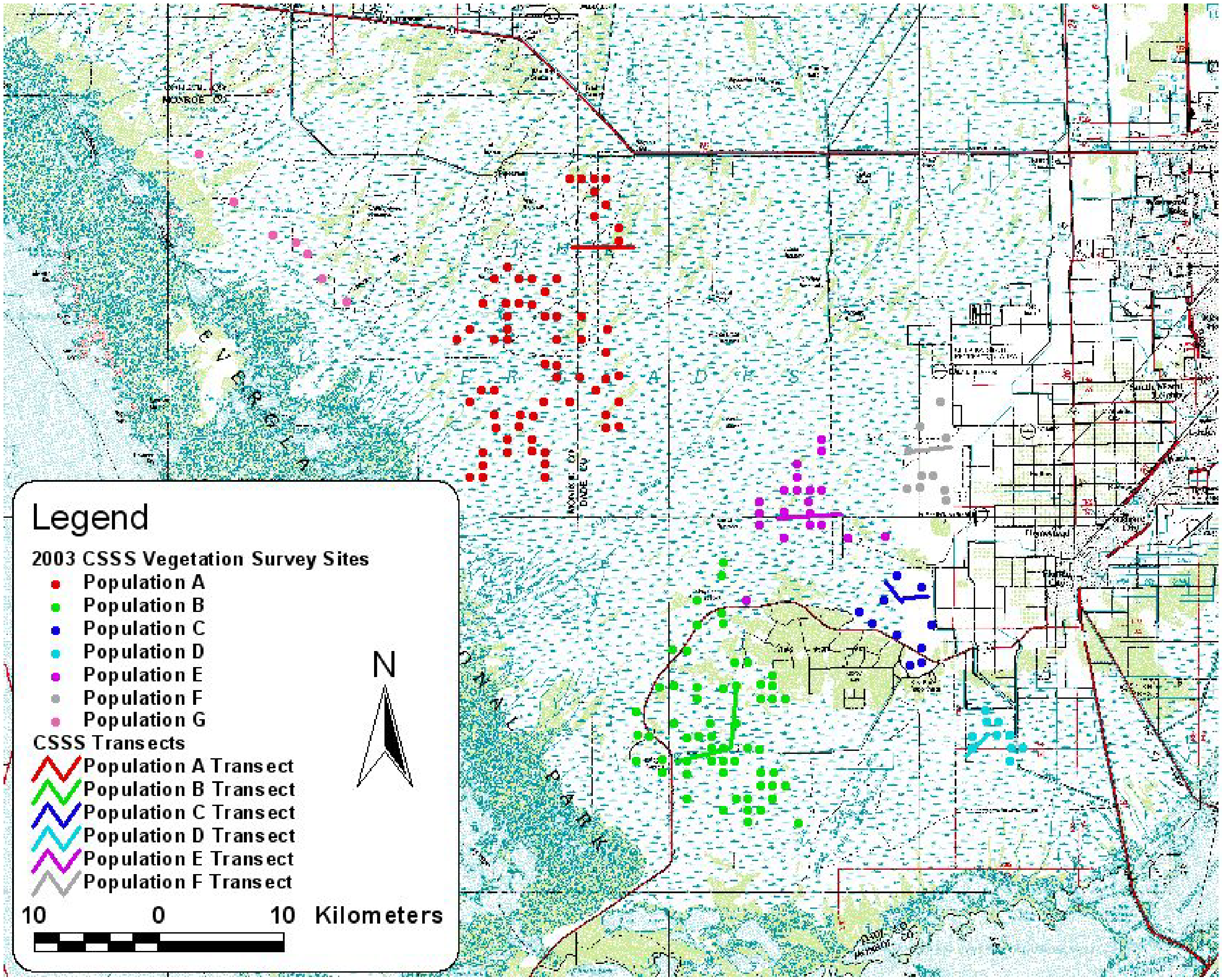

Figure 1: Location of CSSS vegetation survey sites and transects.

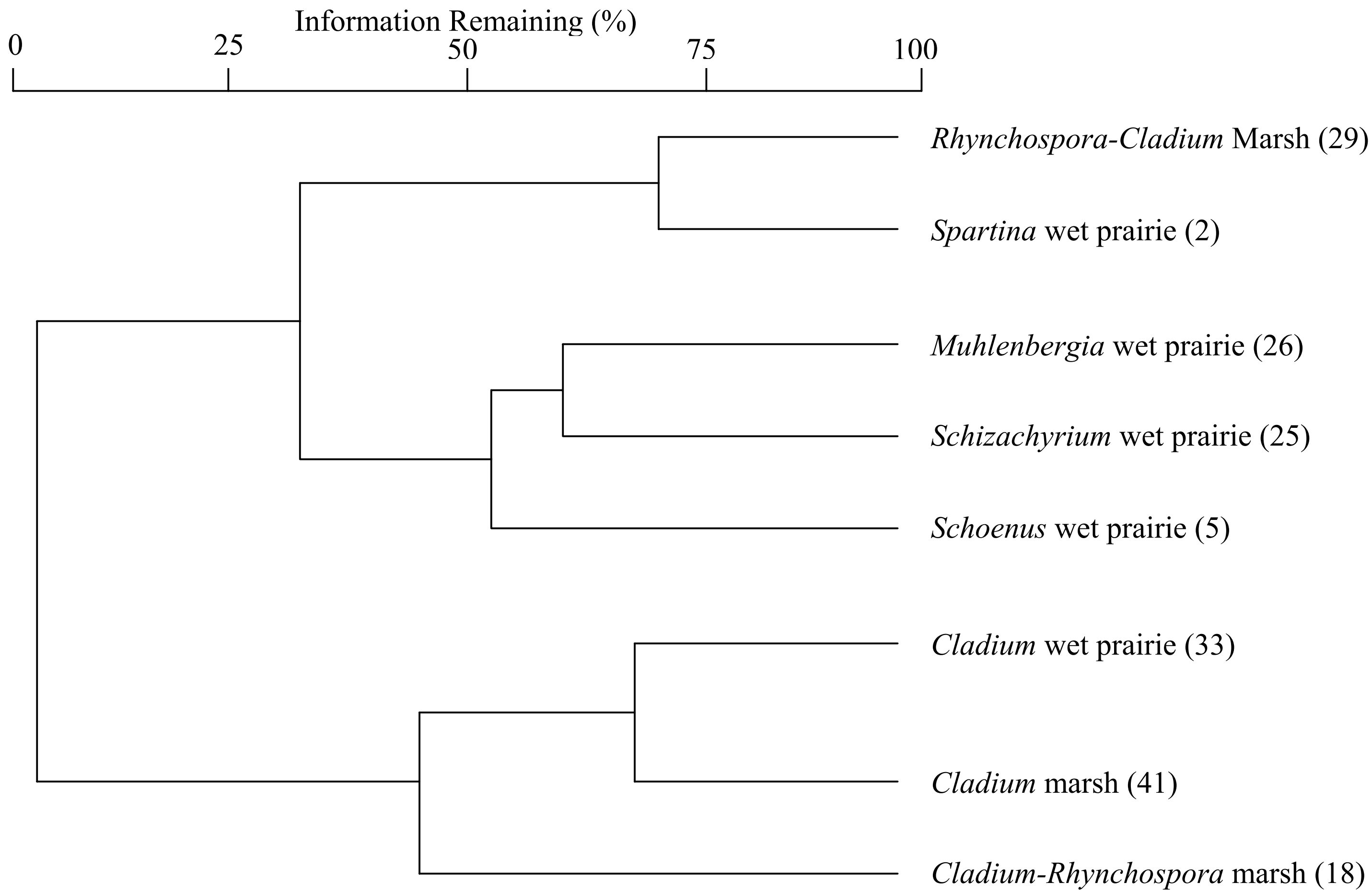

Figure 2: Vegetation types identified through cluster analysis of species cover values at 179 census plots sampled in 2003. Numbers in parentheses are number of sites sampled in each type. Information remaining (%) is based on Wishart's objective function, following McCune and Grace (2002).

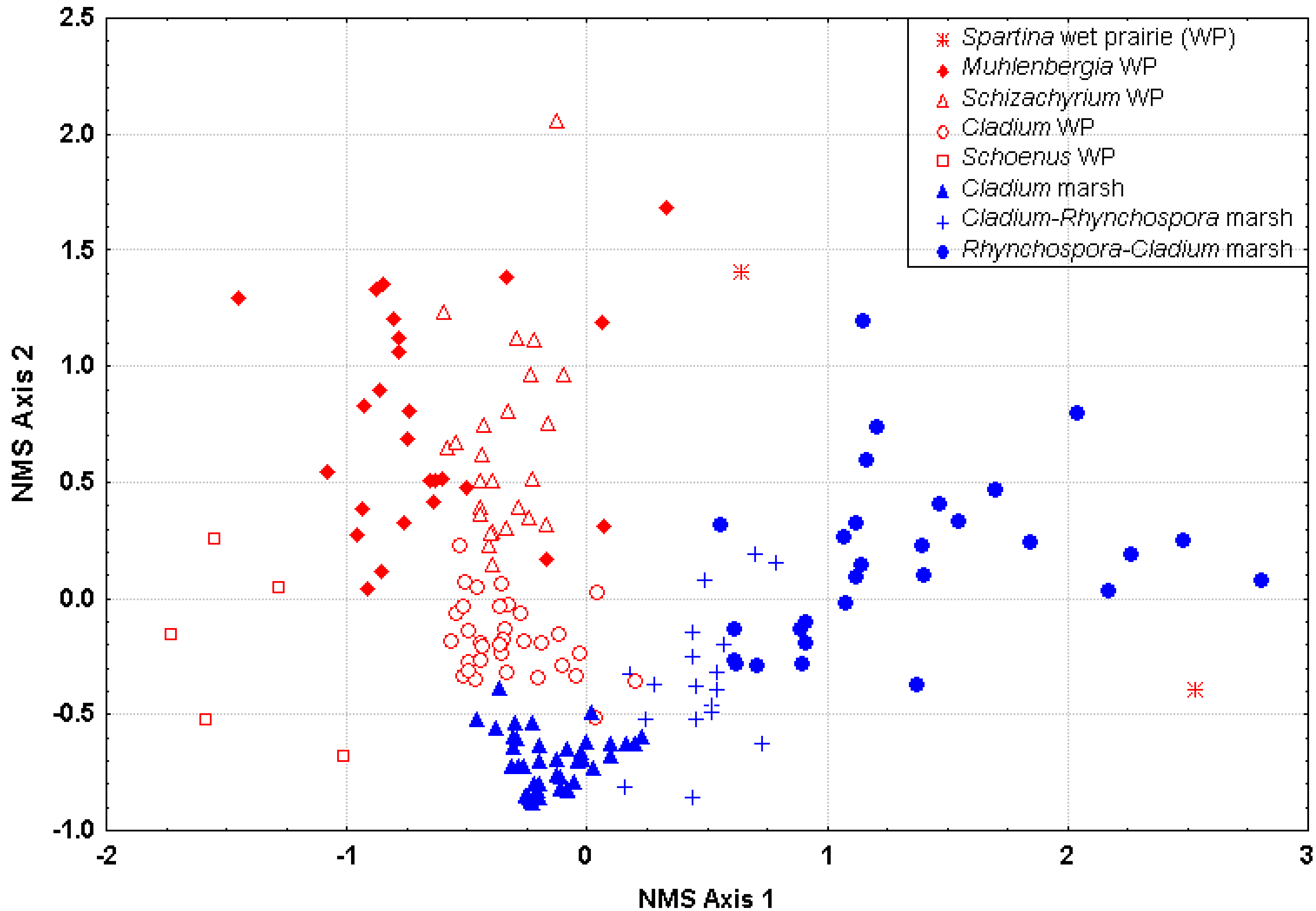

Figure 3: Site scores from 2-axis non-metric multidimensional scaling (NMS) ordination, based on relative cover at 179 census plots samples in 2003 (Stress = 15.69). Vegetation types are those identified from cluster analysis (Figure 2).

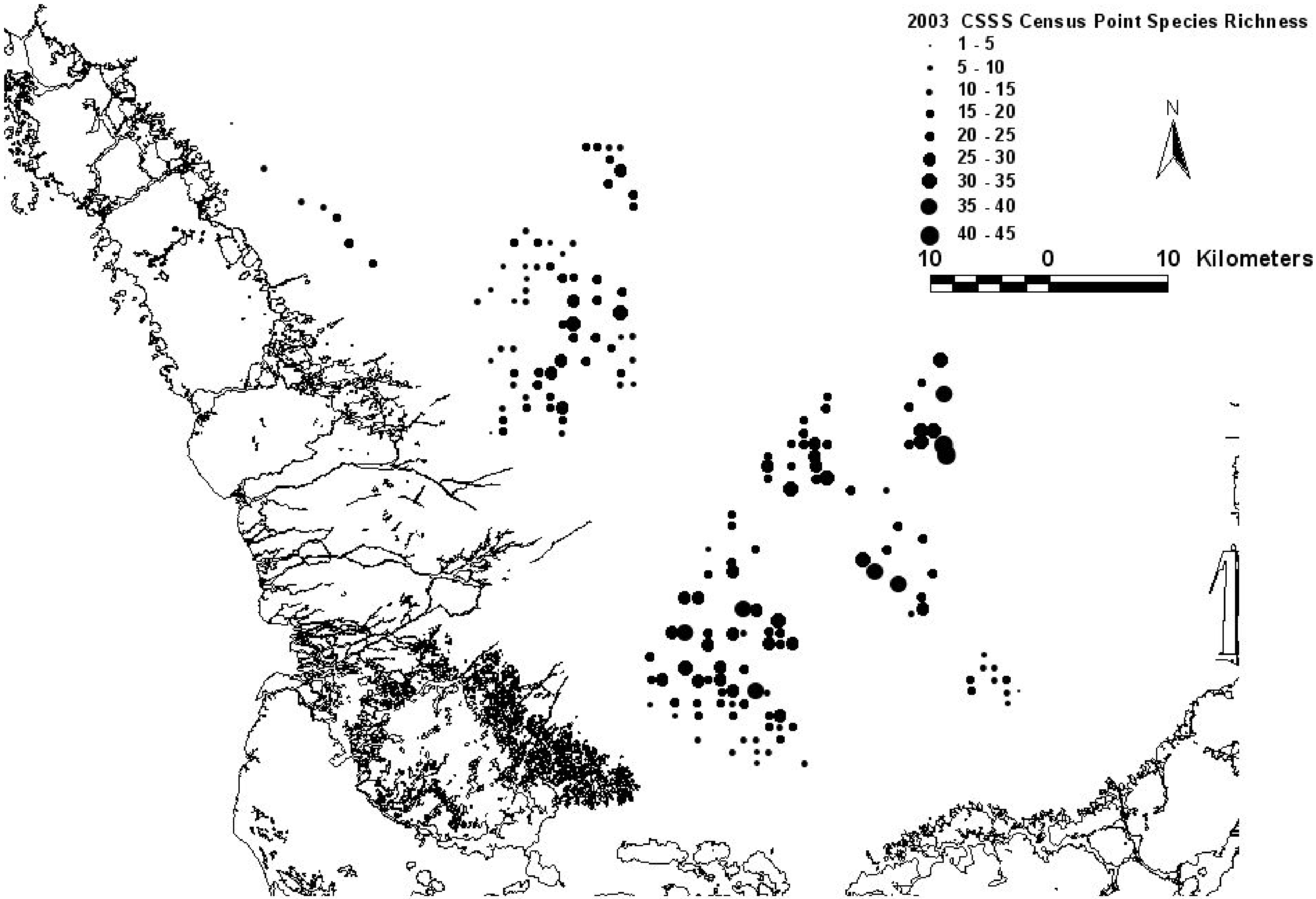

Figure 4: Distribution of herb stratum species richness (total number of macrophytes taxa present per 60 squared meter) at sites sampled in 2003 within recent range of CSSS.

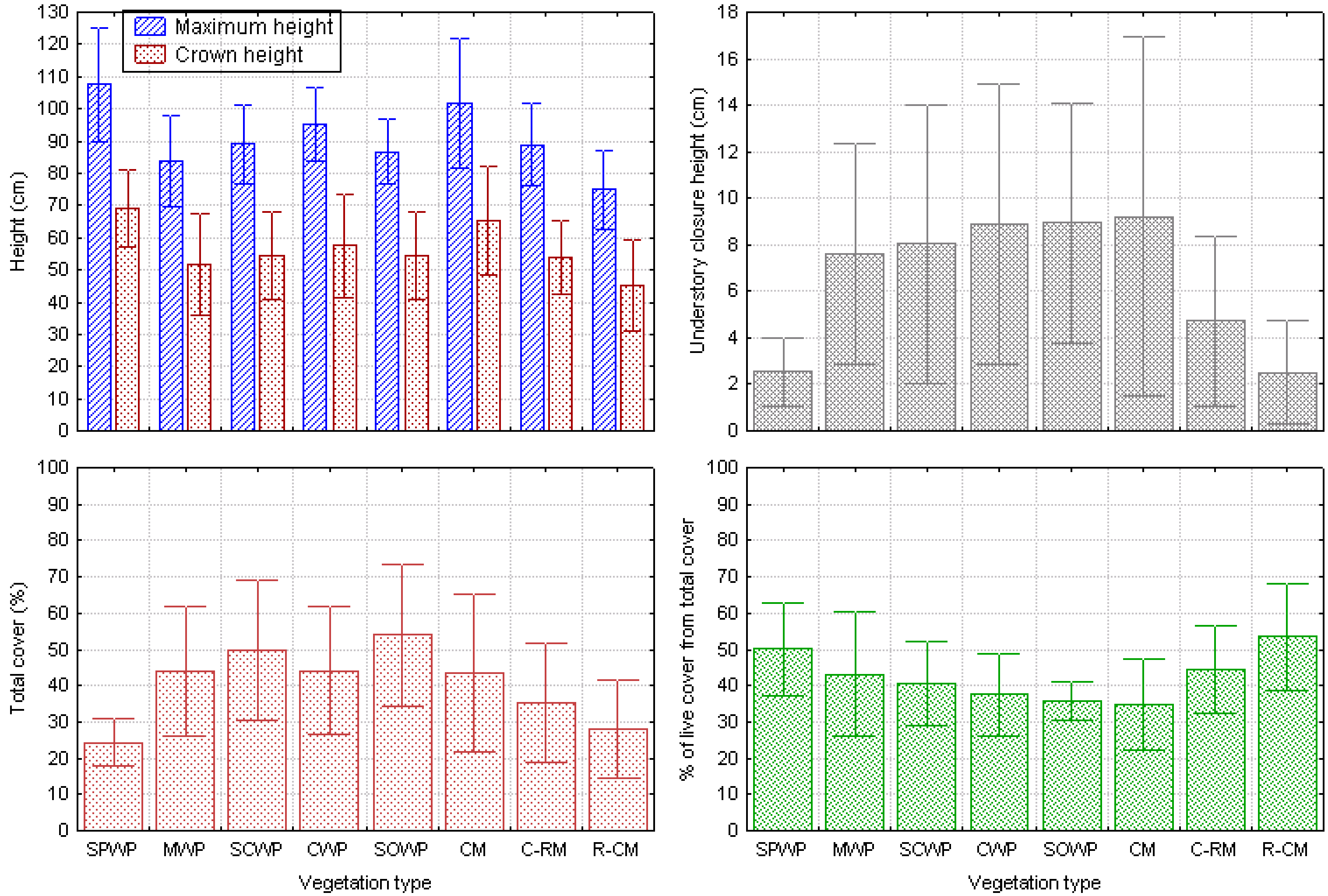

Figure 5: Mean (±1 S.E.) for five important structural variables in herb stratum of eight vegetation types, based on census plots sampled in 2003. SPWP = *Spartina* wet prairie; MWP = *Muhlenbergia* wet prairie; SCWP = *Schizachyrium* wet prairie; CWP = *Cladium* wet prairie; SOWP = *Schoenus* wet prairie; CM = *Cladium* marsh; C-RM = *Cladium-Rhynchospora* marsh; R-CM = *Rhynchospora-Cladium* marsh

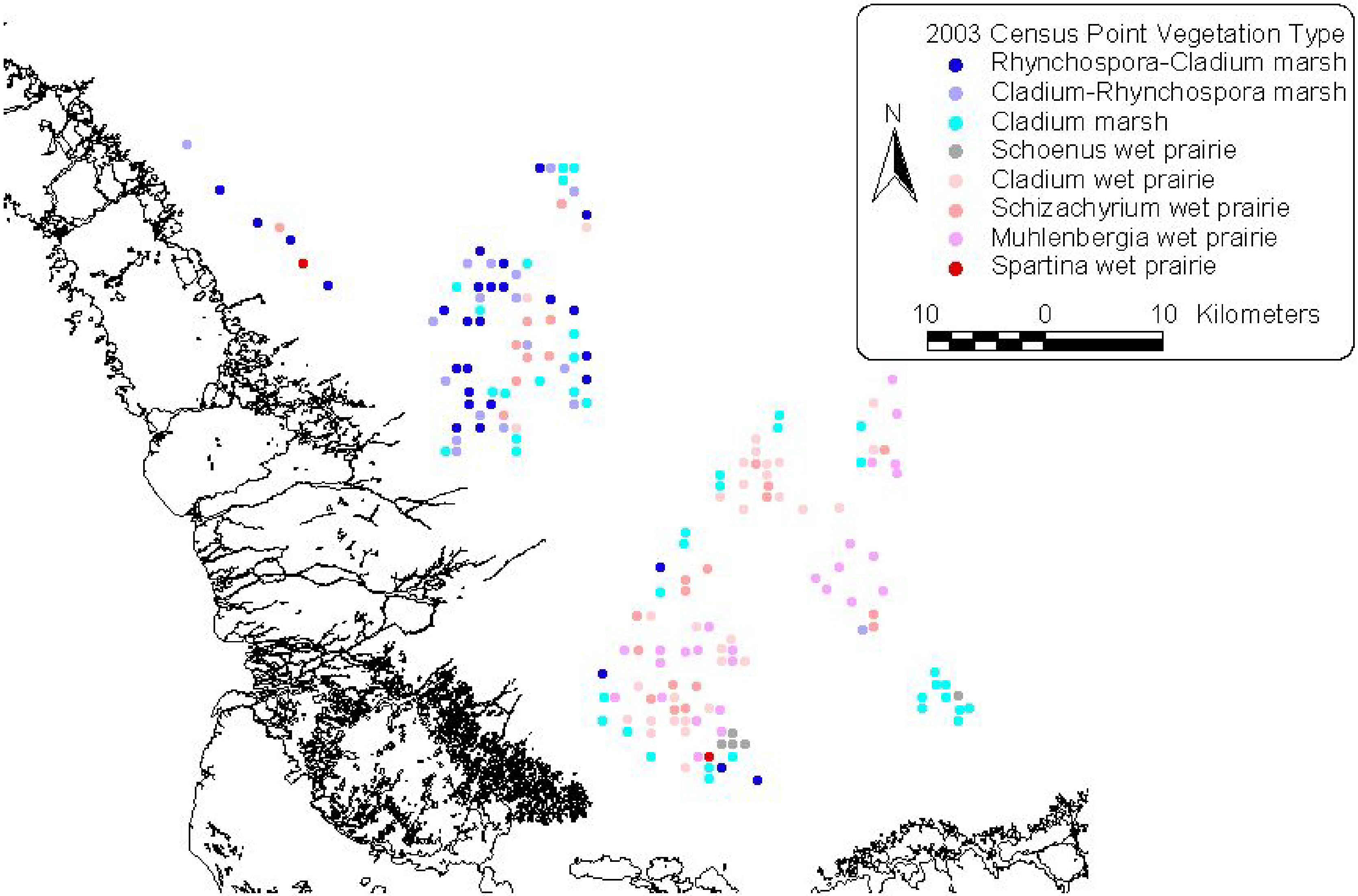

Figure 6: Distribution of vegetation types within recent range of CSSS, based on census plots sampled in 2003

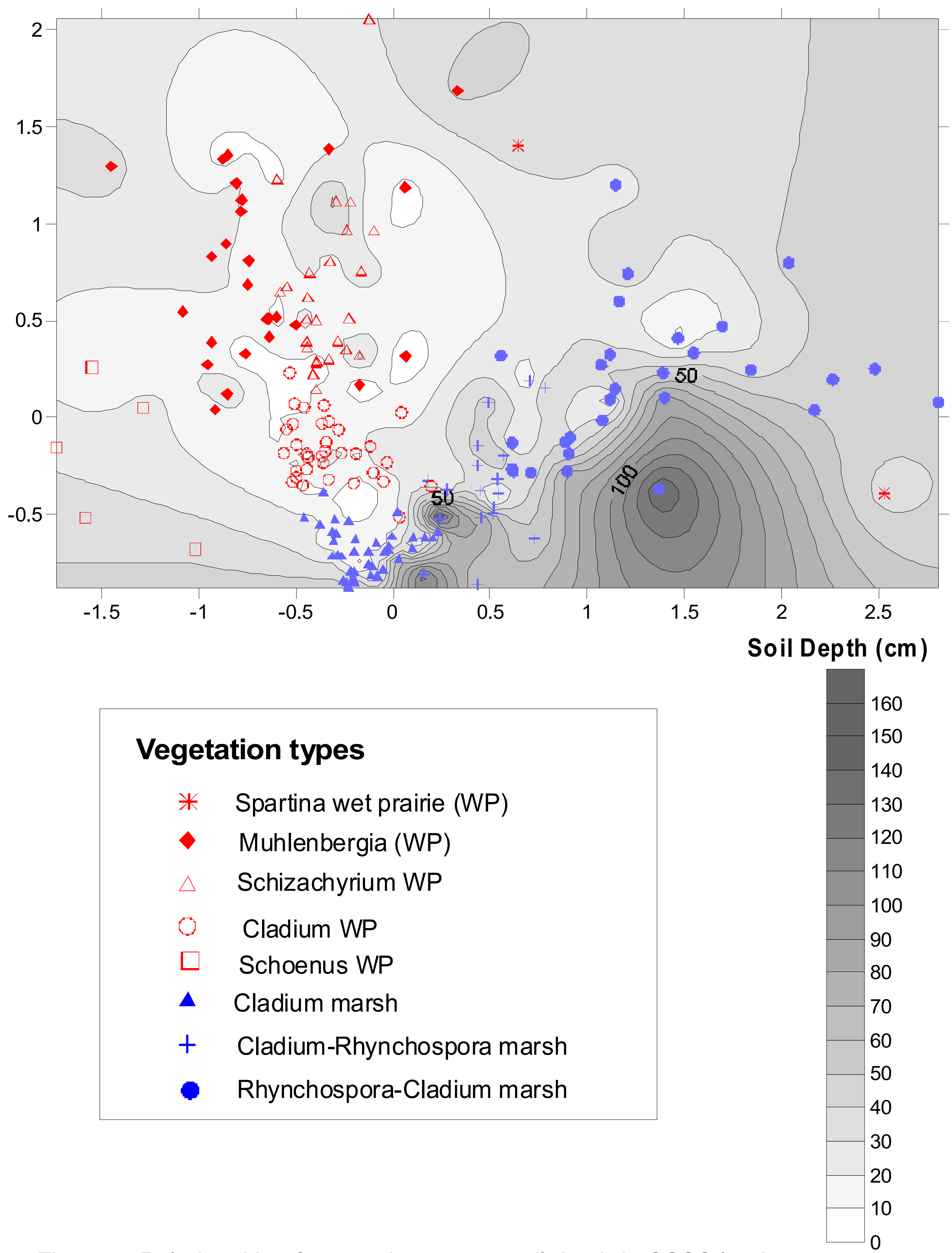

Figure 7: Relationship of vegetation type to soil depth in CSSS landscape, as indicated by their covariation in NMS ordination space.

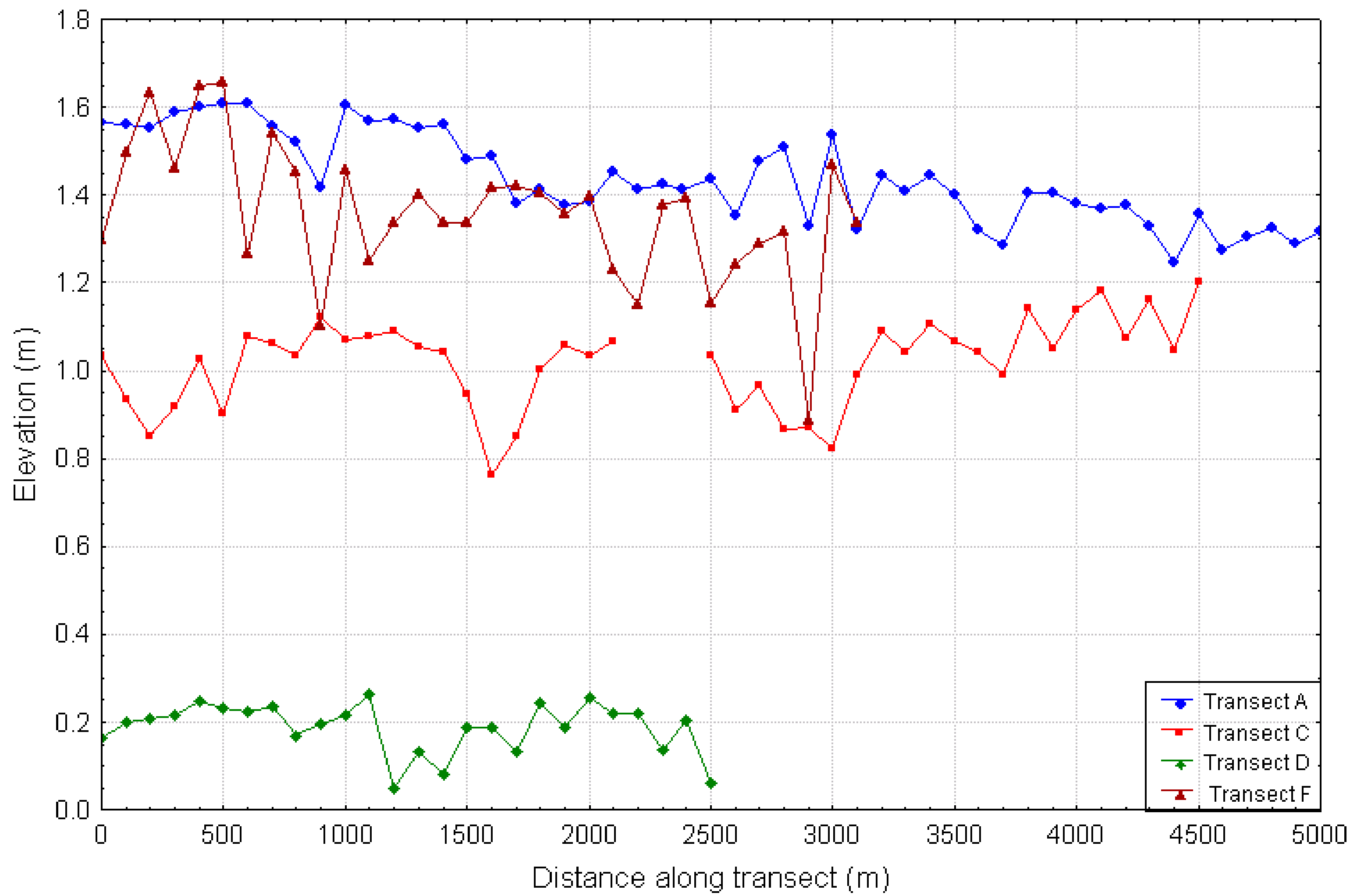

Figure 8: Ground elevation (based on NGVD 88) at the 100 m sample points along the transects in subpopulations A, C, D and F. Transects in subpopulation A and C run east to west, and in sub-population D, northeast to southwest. In subpopulation C, the transect has two parts, the first section runs east to west, and the second section runs southeast to northwest.

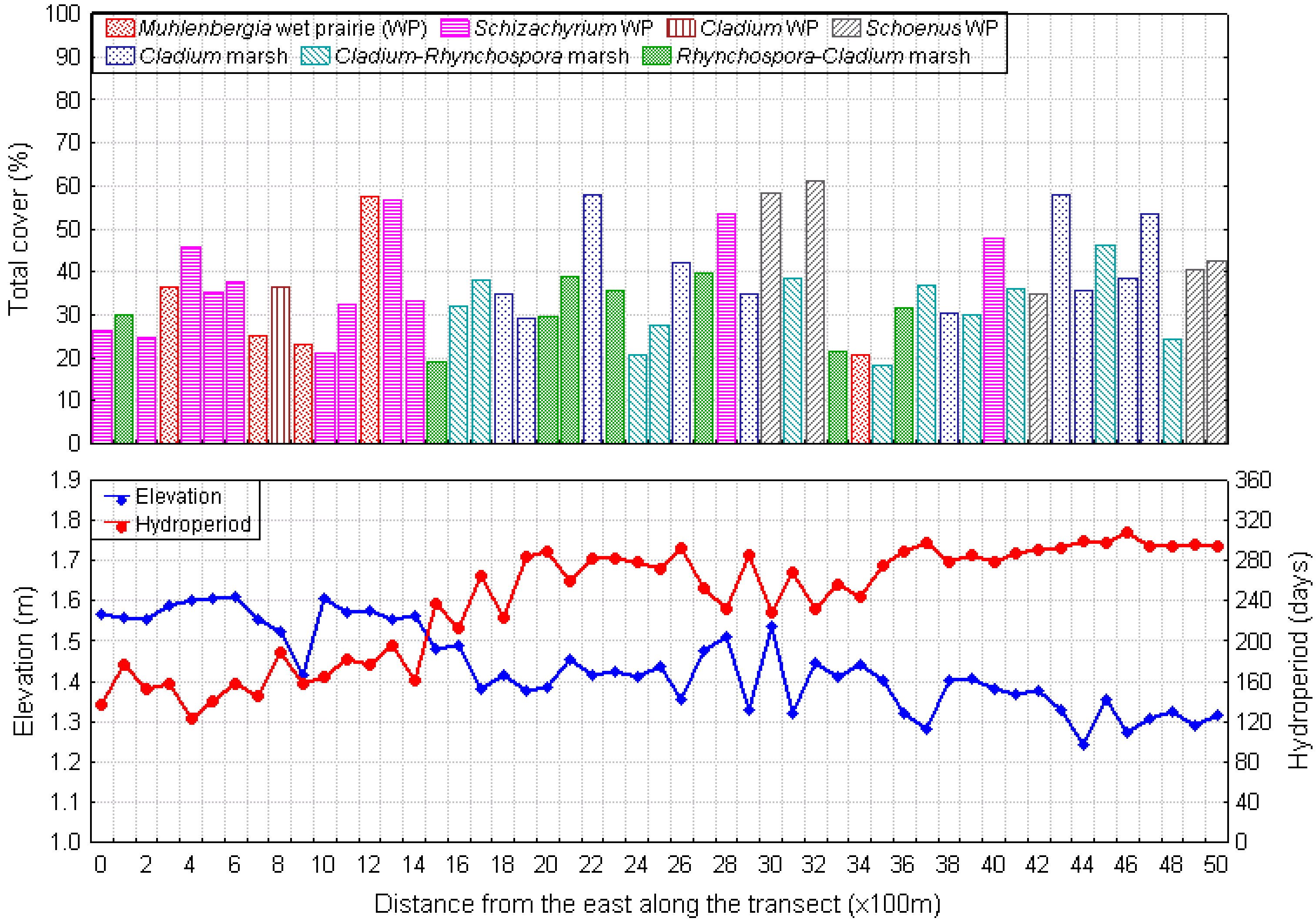

Figure 9: Vegetation type and total herb stratum vegetation cover, in relation to ground elevation and hydroperiod along Transect A. Hydroperiods are calculated from elevation at north ends of plots, and stage records from NP205 station, near meter 2300 along transect.

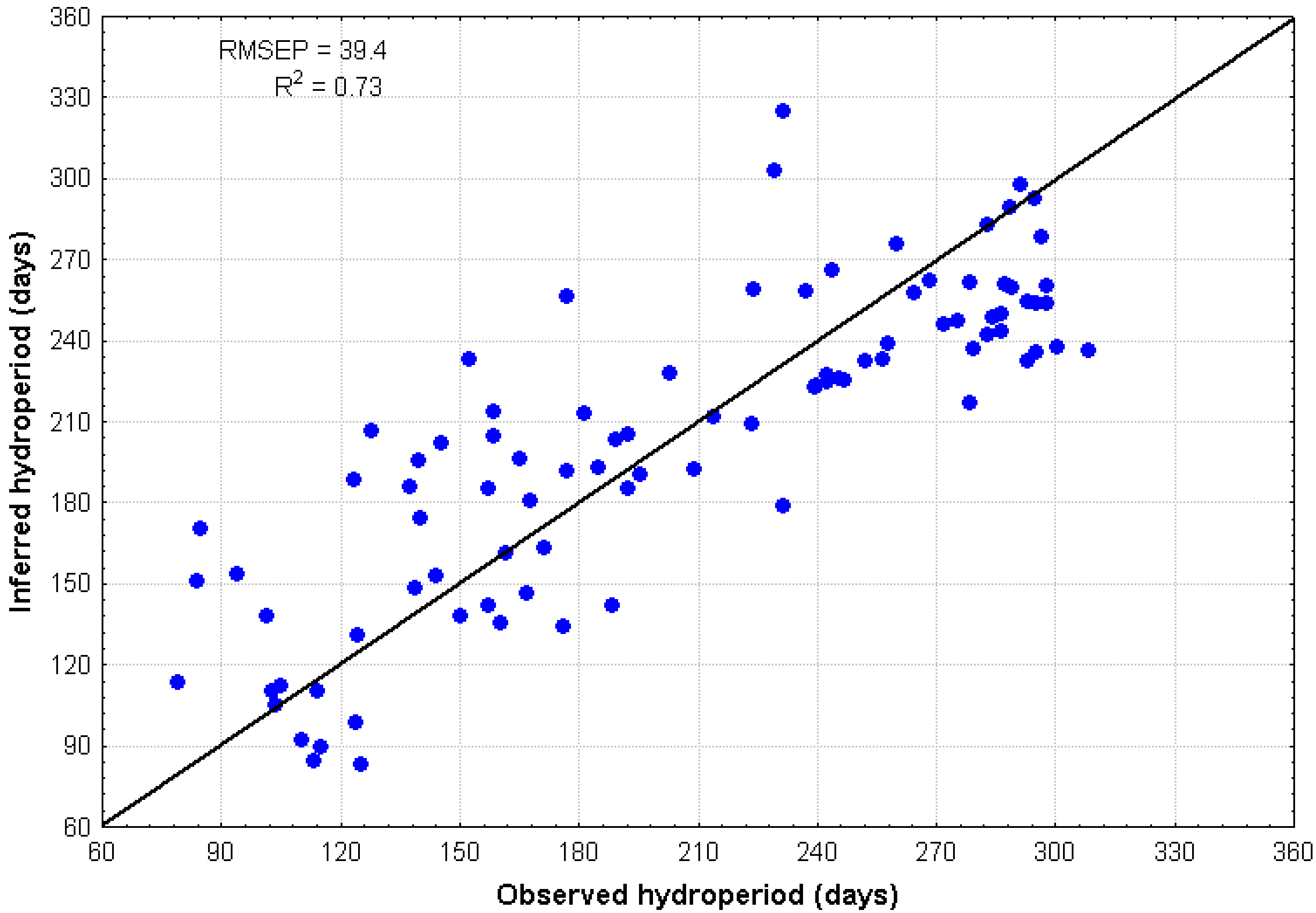

Figure 10: Observed vs inferred hydroperiods at 91 locations along Transects A, ENP-4, and ENP-5. Inferred values are derived from bootstrapping procedure (100 runs) in WA regression, C^2 program (Juggins 2003).

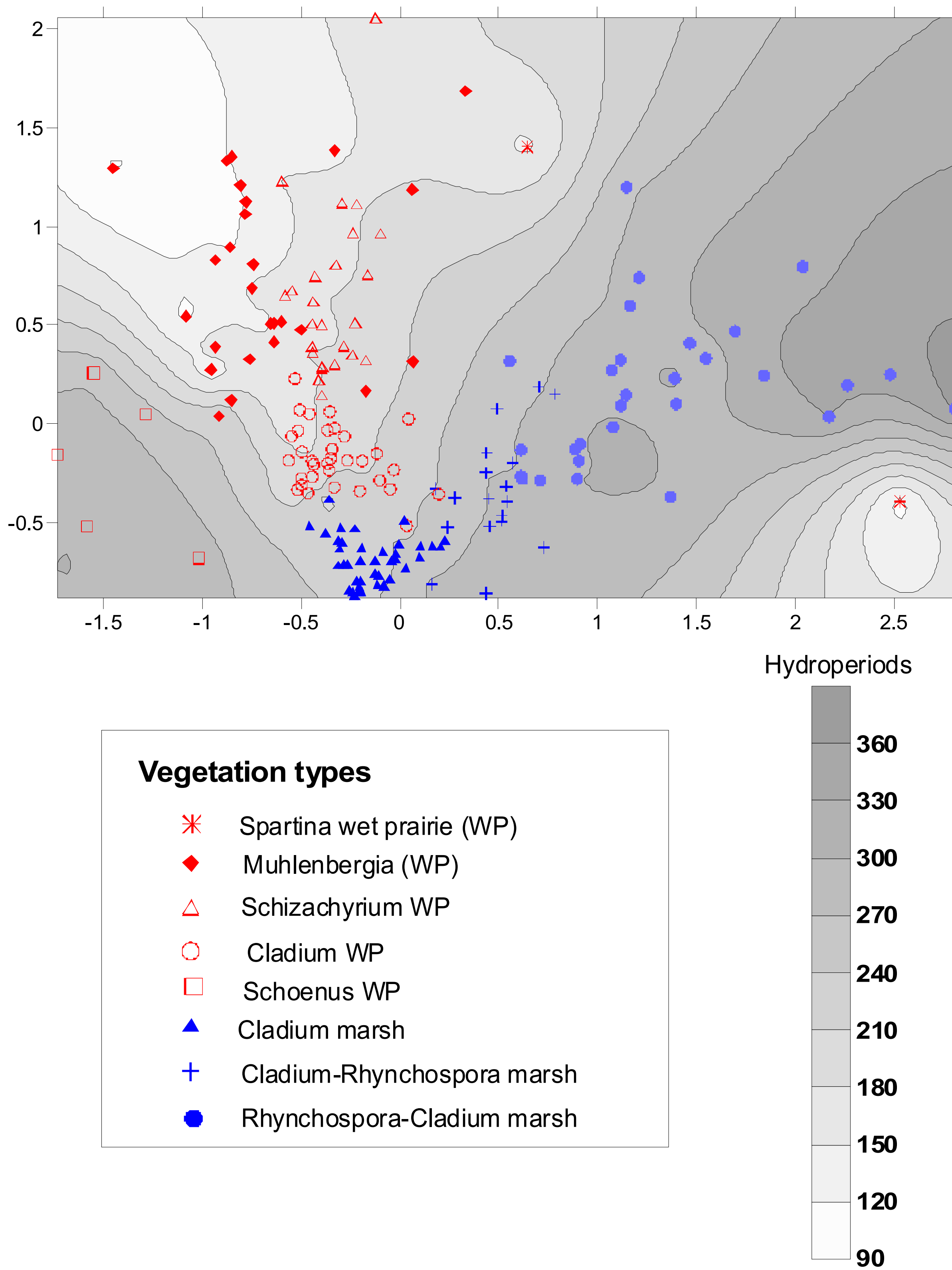

Figure 11: Relationships of vegetation type to inferred hydroperiod in the CSSS landscape, as indicated by their co-variation in NMS ordination space

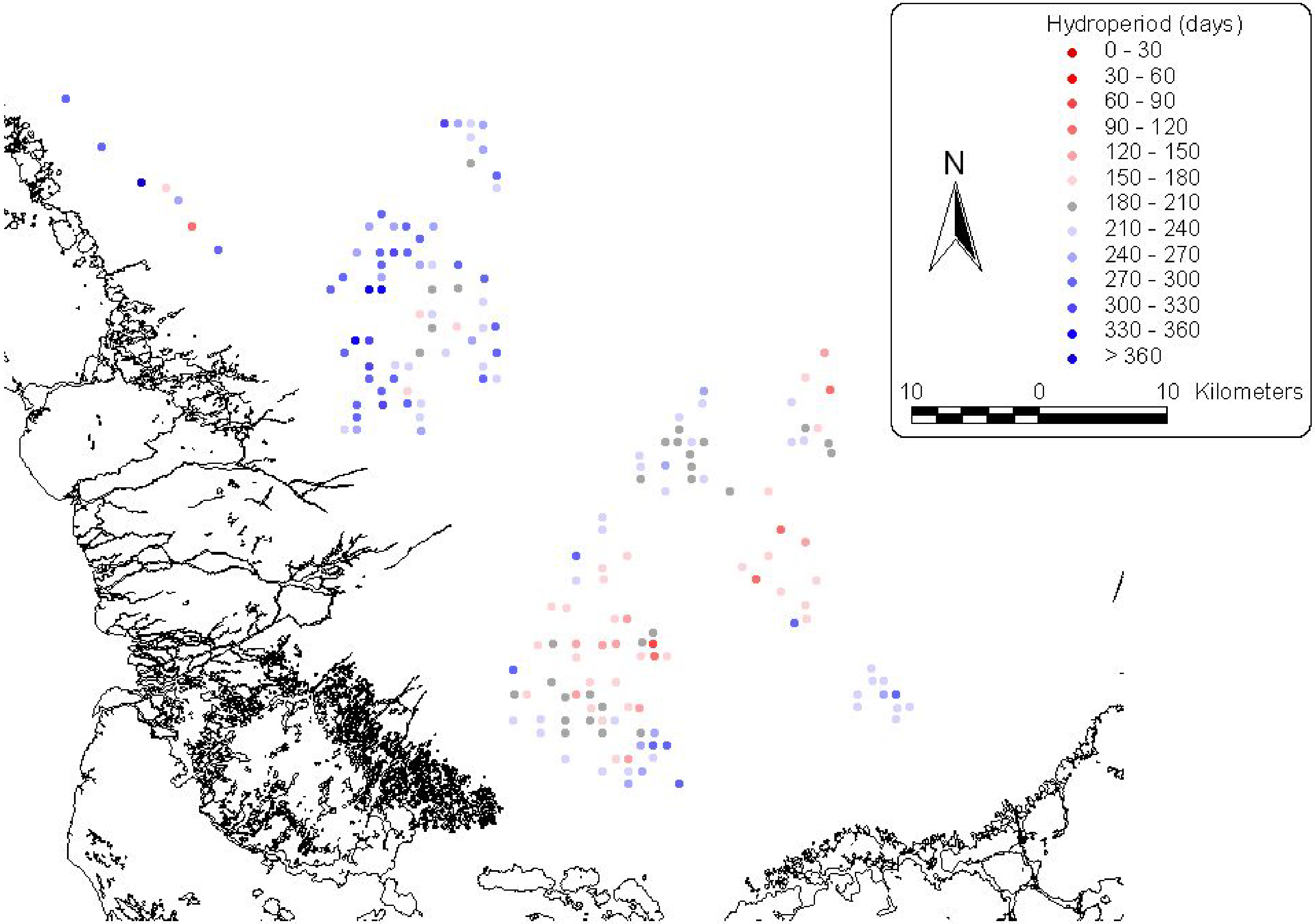

Figure 12: Distribution of inferred hydroperiods within recent range of CSSS, based on census plots sampled in 2003.

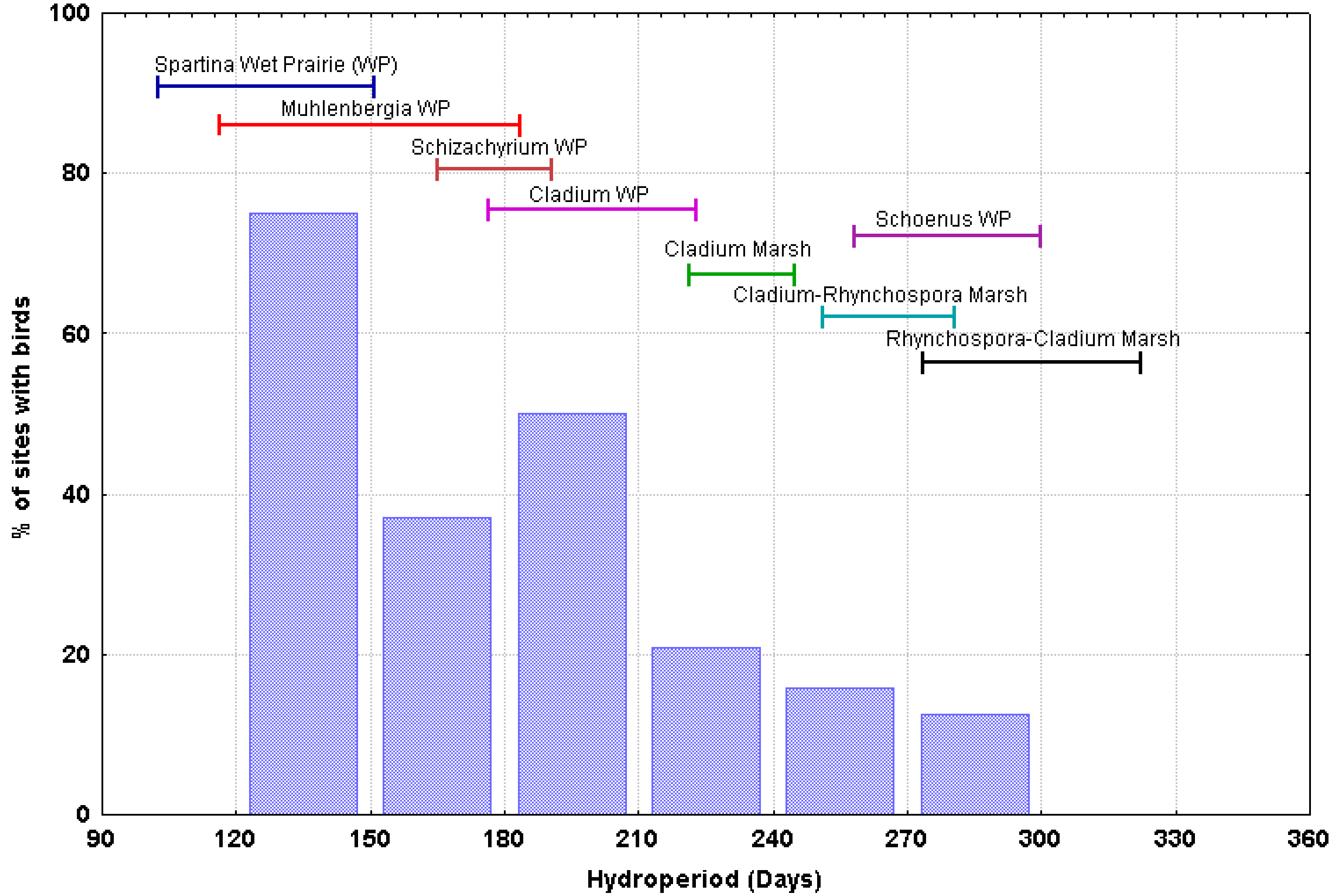

Figure 13: Percentage of census locations, subdivided into 30-day increments of inferred hydroperiod, in which CSSS were observed at least once during 2001-2002. Data are based on 179 sites in which vegetation was sampled in 2003. Mean (±1 S.E.) inferred hydroperiod for eight vegetation types among 2003 vegetation census plots are superimposed.

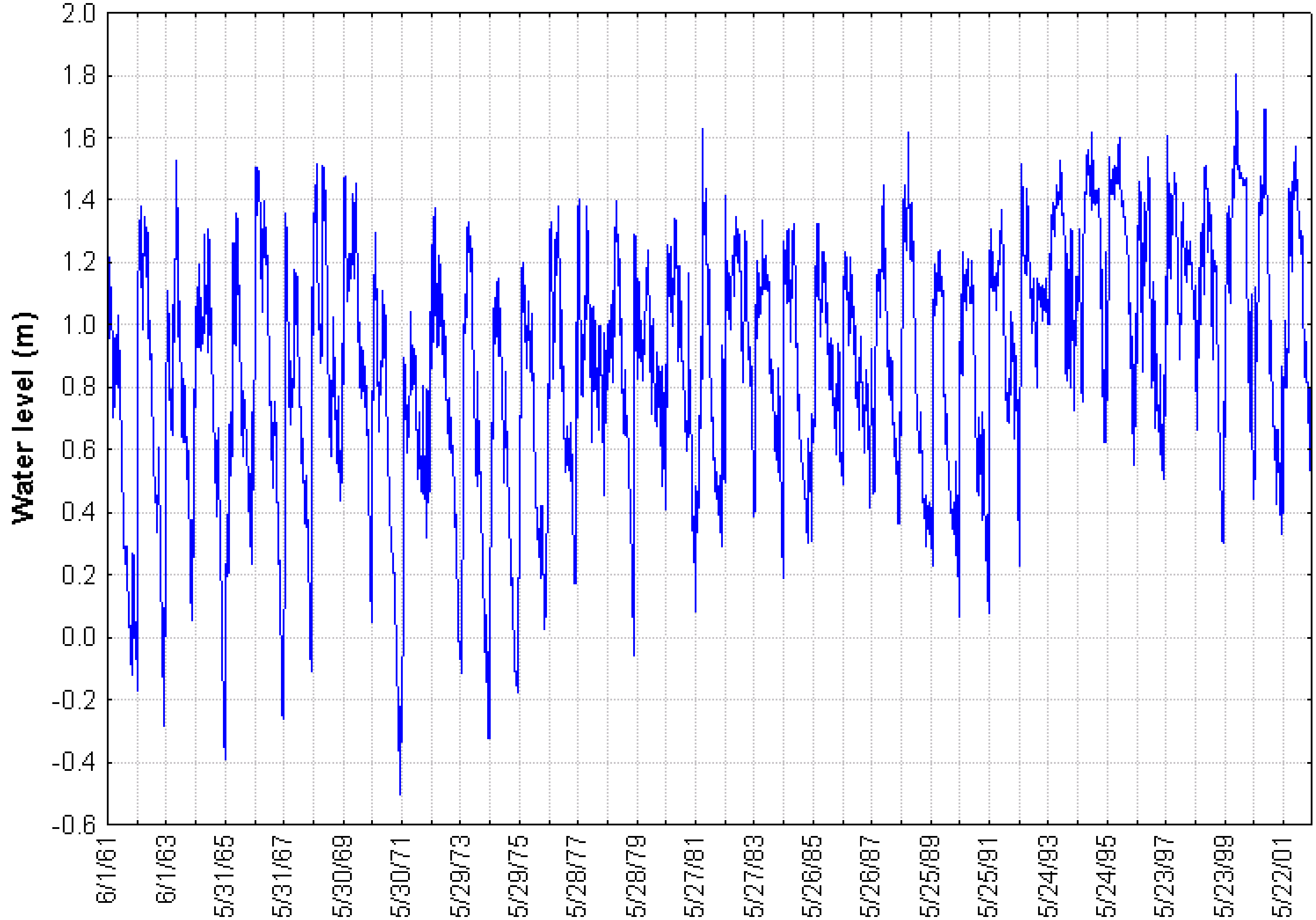

Figure 14: Water level (amsl) recorded daily at the Everglades National Park water level recorders, TSB and TS2. Data from June 1, 1961 to Aug 25, 1999 are from TSB, and data from Aug 26, 1999 to April 24, 2002 are from TS2.

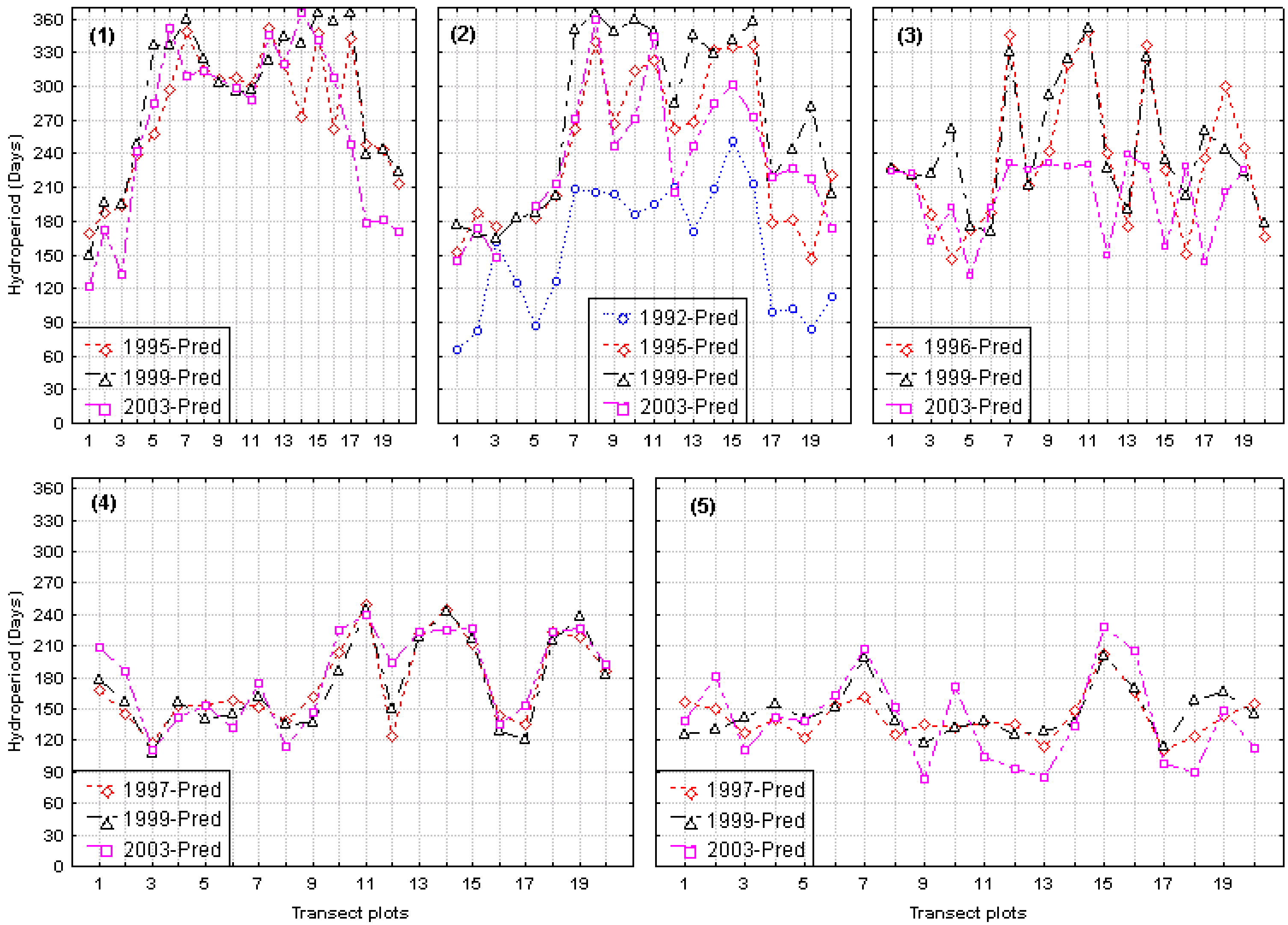

Figure 15: Changes in vegetation-inferred hydroperiod in plots along ENP Taylor Slough Transects 1-5, 1992-2003.