Temporal Changes in Vegetation Composition and Structure in a Fire-Managed Prairie Fen

Marlin Bowles
Jeanette McBride
The Morton Arboretum Lisle, Illinois 60532 USA

Nick Stoynoff
Glenbard East High School
Lombard, Illinois 60148 USA

Ken Johnson
The Morton Arboretum Lisle, Illinois 60532 USA

Natural Areas Journal 16:275—288

ABSTRACT: Prairie fens, rare peatland features of the landscape of the midwestern United States, are often fire-managed to restore or maintain species diversity and prevent shrub and tree invasion. We quantified the effects of such management at Bluff Spring Fen Nature Preserve (Cook County, Illinois, USA), where eight dormant-season prescription burns supplemented by shrub cutting took place from 1982 to 1992. Baseline transects established across the fen in 1986—87 were resampled in 1992 in relatively undisturbed spring run/marl flat, calcareous seep, graminoid fen, and sedge meadow communities, and in disturbed graminoid fen vegetation where woody plant invasion and species change had occurred after previous grazing and fire suppression. Analyses of plot richness or diversity found no significant temporal changes. Correlation coefficients and indices of floristic similarity and coefficients of conservatism were sensitive to significant vegetation changes in sedge meadow and in disturbed fen habitats, but not in less-disturbed vegetation. More rigorous analyses found significant temporal changes throughout the fen, which paralleled known fire effects on grassland. In most relatively undisturbed communities, combined frequencies of graminoid species increased, forb frequencies decreased, and woody vegetation remained unchanged. At the species level, this pattern was supported by significant increases in cover of most dominant grasses and sedges. The decline in overall forb frequency was cumulative, as few individual forb species declined in cover or frequency. One exception was the common fen goldenrod *Solidago ohioensis*, which decreased in cover but not frequency in two communities. Disturbed fen underwent structural and successional changes that varied with habitat. Gray dogwood *(C'ornus racemosa)*, the most aggressive invader of disturbed fen, was more resistant to fire and cutting in unshaded fen and less resilient and more controllable in partial shade of bur oak *(Quercus macrocarpa)*. The prairie grass *Andropogon gerardii* increased only in unshaded areas of disturbed fen. Successional changes in herbaceous species included loss of alien species and gain of prevalent fen species, although some species that appear to represent late-successional graminoid fen have not yet appeared in disturbed graminoid fen. More precise and frequent monitoring and experimental management treatments are needed to determine the relevance of these findings. Because *Cornus racemosa* is also present in higher quality graminoid fen and in calcareous seep, continued control of woody vegetation may be required; it is doubtful that dormant-season prescribed burning or cutting without application of appropriate herbicides can eliminate this resilient species.

Index terms: disturbed fen, graminoid fen, prairie fen, vegetation succession

INTRODUCTION

There have been few quantitative studies of fire effects on graminoid fens in the tallgrass prairie region of North America. These "prairie fens" (Moran 1981) have strong floristic relations to wet prairie and sedge meadow, and fire is hypothesized to play an integral role in maintaining their structure and diversity (Curtis 1959, Moran 1981, Kohring 1982, Zimmerman 1983). In general, fire is said to structure prairie vegetation by increasing cover and annual biomass of graminoid plants, reducing total species diversity and cover of woody plants, and causing variable responses among different forb groups; but lack of fire reduces prairie species richness over time by allowing litter accumulation and woody plant invasion (e.g., Collins and Glenn 1988, Collins and Gib-son 1990, Johnson and Knapp 1995). How well this model applies to prairie fens, however, is unknown. These peatland plant communities present challenges for restoration management and monitoring when they are degraded by past land use practices such as grazing and fire protection. This paper analyzes vegetation change between 1986—87 and 1992, after an 11-year period of fire management to restore graminoid vegetation structure at the Bluff Spring Fen Nature Preserve (BSF), a 40-ha prairie fen in Cook County, Illinois.

Fire, Woody Plant Succession, and Grazing in Graminoid Fens

With fire suppression, shrub growth or invasion alters fen structure (White 1965, Collins et al. 1981), and herbaceous species richness declines as succession proceeds (Wheeler 1988). Thus, fire protection and woody plant invasion are thought to erode the structure and diversity of graminoid fens (Moran 1981, Carroll et al. 1984, Reuter 1986, Rooney 1990, Pearson and Leoschke 1992). For example, Moran (1981) observed that the richest and most floristically diverse of 12 Illinois prairie fens had highest fire frequencies. In a 2-year study, Kohring (1982) found that graminoid cover increased after fire in a Michigan fen. Although fire may reduce shrub cover in fens, shrub frequency may not decline (Zimmerman 1983) or the effects may be temporary (Reuter 1986). The impact on fens of domestic cattle grazing apparently is similar to its impact on prairie: late-successional grazing-intolerant species are replaced by grazing-tolerant species (Moran 1981), and this is often followed by invasion of gray dogwood *(Cornus racemosa).* (Nomenclature follows Swink and Wilhelm 1994). Such impacts are most severe along accessible fen borders (van der Valk 1976). Patterns of fen succession or recovery after disturbance are not well known. Zimmerman (1983) found that 66.7% of "climax" fen species had revegetated an exposed fen substrate after 8 years.

Research Objectives

Our objectives were to determine what changes in vegetation diversity, structure, or composition occurred over a decade of nearly annual fire management and supplemental cutting of invasive woody plants at BSF. We hypothesized that high fire frequency would select for increased graminoid dominance, alter cover or frequency of herbaceous vegetation, and re-duce cover or frequency of woody vegetation in areas of the fen that were not fire protected. To assist in development of strategies and methods for monitoring fens, we compared effectiveness of different quantitative methods in detecting temporal vegetation change.

STUDY AREA

Bluff Spring Fen Nature Preserve is located in Hanover Township, Cook County, Illinois, USA. The fen is one of 12 high quality prairie fens in the Chicago region of Illinois (Moran 1981, Stoynoff and Hess 1986, Stoynoff 1993). The fen occupies a sand and gravel outwash basin filled with alkaline, nutrient-rich peat; plant communities align along gradients of elevation, spring-water flow, fire protection, organic matter, cation exchange capacity, and chemical and nutrient concentrations (Table 1). Management needs at BSF were first assessed in 1976 by the statewide Illinois Natural Areas Inventory (INAI), which classified, mapped, and graded natural plant communities by the prevalence of species indicative of different successional stages following anthropogenic disturbance (White and Madany 1978). At BSF, the INAI identified (unpubl. data) a 4.45-ha (11-acre) core of grade A (undisturbed) calcareous seep (including spring runs and marl flats), bordered by 17 ha (42 acres) of grades B (lightly disturbed) and C (moderately to heavily disturbed) graminoid fen and sedge meadow, and by 6.1 ha (15 acres) of grades C and D (severely disturbed) savanna and dry gravel prairie. Although most of the fen is in full sun, a bur oak *(Quercus macrocarpa)* savanna canopy partially shades disturbed graminoid fen along the western edge of the fen basin.

Bluff Spring Fen is located in the forest-prairie ecotone of northern Illinois, which, at the time of European settlement, comprised a vegetation mosaic maintained by fire (Kilburn 1959, Moran 1978, Bowles et al. 1994). On the 1840 Public Land Survey vegetation map of Hanover Town-ship, the prairie-timber boundary crosses the eastern border of the fen, and a 40-ha pasture encompasses the eastern half of the fen. This indicates that presettlement fires occurred in the fen area and that grazing was apparently impacting the fen 150 years B.P. With settlement, fire frequency probably declined in the fen, but direct evidence of this is lacking. As in many Illinois fens (Moran 1981), livestock grazing apparently selected for grazing-tolerant plants and reduced species diversity in the graminoid fen and sedge mead-ow portions of the fen basin and in adjacent uplands. Evidence from historic descriptions (S. Byers, Field Representative, Illinois Nature Preserves Commission, McHenry, Ill., pers. com.) and a grazing pattern on a 1938 aerial photograph (Stoynoff and Hess 1986) suggest that grazing continued for some time. Once grazing was eliminated, reduced competition and fire protection apparently allowed gray dogwood *(Cornus racemosa),* black rasp-berry *(Rubus occidentalis),* and smooth sumac *(Rhus glabra)* to increase along the fen borders (Stoynoff and Hess 1986). Ongoing management to reverse effects of fire protection and past grazing at BSF was initiated by the Friends of the Fen volunteers in 1981. Their efforts—prescribed burning and supplemental cutting of woody vegetation— have reduced shrub cover, especially in more heavily disturbed vegetation (Stoynoff and Hess 1986). Cut stumps were treated with ammonium sulfate herbicide, which was ineffective against sprouting of dogwood (S. Byers, pers. com.). In 1991, as part of a prairie restoration effort, an artificial gravel kame was constructed by filling a quarry pond along the south fen border. This may have further affected subsurface hydrology that was already altered by past mining and grading.

Dormant-season spring or fall prescription burns occurred 8 out of 11 years in the fen basin from 1982 to 1992, with a 70.0% (14.97 SE) mean yearly burn cover of the study area (unpubl. data). The extent of fire cover was rarely 100% in burned areas, especially where spring run water courses provided firebreaks (S. Byers, pers. corn.).

METHODS

Previous Data

To provide a baseline for assessing effects of management at BSF, Stoynoff (1993) measured percent cover in 464 0.25-m^2 plots along stratified random permanent transects across the fen basin and adjacent uplands during August and September of 1986 and 1987. By 1987, the entire fen basin had been spring-burned four times;

thus, there were no control areas or pre-burn data. Nonetheless, the 1986–87 data set can be compared against ongoing vegetation change. Potentially different effects of burning and of cutting on shrubs were not separated by these methods.

Resampling Community Transects

In 1992, after four consecutive burns, we resampled Stoynoff's (1993) transects through the spring run/marl flat, calcareous seep, undisturbed and disturbed graminoid fen, and sedge meadow plant communities (Figure 1). The original transects were relocated from permanent markers or repositioned from transects identified on vegetation maps (Figure 1), and were resampled by estimating percent herbaceous and woody plant cover. To match temporal replicates as closely as possible, we used original plot data from Stoynoff (1993) only from sections of transects that we resampled in each community. However, new plots were essentially random with respect to the original plots, and sampling resulted in similar but unequal replicates of the original data sets (Table 2). Because of a very heterogeneous vegetation mosaic in spring run/marl flat, our transect locations may have introduced some sampling differences into the marl flat data. In addition, our sampling did not include plants that occurred only under edges of the sample plot frame, and which were more likely to have been included in the original study (N. Stoynoff, pers. obs.).

Analyses of Vegetation Change

Detrended correspondence analysis was used to ordinate the 1986–87 and 1992 transect plot data from each fen community using the DECORANA program on PCORD (McCune 1994); each plant species was weighted by its importance value (sum of relative frequency and relative total cover). DECORANA aligns community data along strong floristic gradients (Hill and Gauch 1980), and distances between temporally paired transects can indicate trajectories of vegetation change (e.g., Dunn and Sharitz 1987). To evaluate community changes over time, we also compared 1986–87 and 1992 community data using a variety of other measures and statistics. Sorensen's coefficient of species similarity (Sorensen 1948) was calculated by $S = 2c/S_{86\text{-}87}+S_{92}$, where c = number of species in common and S = number of species in each community for 1986–87 vs 1992. Because vegetation data are not normally distributed, we used Spearman's rank correlation coefficient (r_r) (Spearman 1904) to test correlation of species importance values between community data sets for 1986–87 vs 1992. Correlation coefficients also were used to compare species importance values in disturbed and undisturbed graminoid fen transects in 1986–87 and in 1992 to deter-mine if disturbed fen vegetation was succeeding toward less-disturbed graminoid fen. The Shannon diversity index (Shannon 1948) was calculated using $H' = -E_{pi} \log p_i$, where p_i = the frequency of species i. We used t-tests (Brower and Zar 1984) to test change in H' over time within each community. Average plot richness was calculated by dividing the total number of species occurrences sampled in each community by the number of sample plots. Overall mean plot richness was then calculated across all transects in each time period and compared by a t-test. We also made temporal comparisons using the mean coefficient of conservatism, which is said to measure "floristic quality" and can thus be used to identify, compare, and monitor natural areas (Swink and Wilhelm 1994). This coefficient is a subjective value (ranging from 0 to 10) assigned to reflect a native plant species' degree of restriction to undisturbed natural habitat (alien plants are omitted); 89% of native plants have values > 4, and "natural areas" are said to register a mean coefficient of > 4.5 (Swink and Wilhelm 1994). We calculated the mean of this coefficient based on total occurrences of all native plants with-in each community transect and used t-tests to test whether this index changed over time. To assess the coefficient's ability to compare floristic quality of the fen's plant communities, we also used one-way ANOVAs and multiple range tests of mean differences in the coefficient among community transects in 1986–87 and in 1992.

Two statistical procedures were used to test for significant temporal change in species life-form groups and in individual species. For each fen plant community (Table 1), plot frequencies were determined for woody, graminoid, and forb components of vegetation structure. Proportional

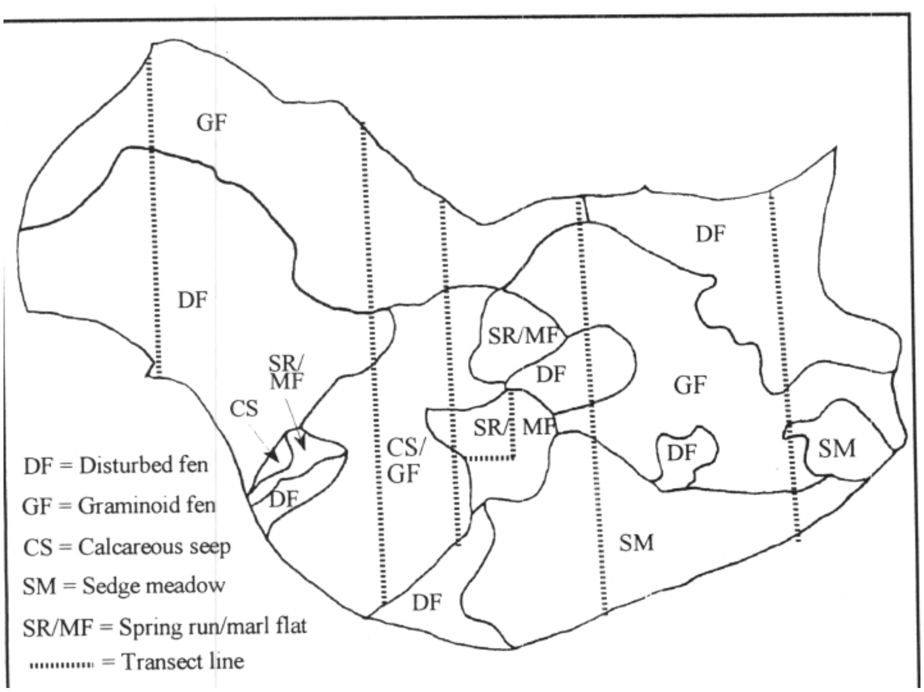

Figure 1. Vegetation map and sampling transect locations across the wetland basin of Bluff Spring Fen Nature Preserve. See Table 1 for community descriptions.

differences in the number of plots occupied by these groups in the 1986–87 vs 1992 data sets were tested by Chi-square (x^2) analysis. This test was also used to assess successional change in disturbed vegetation by comparing it with undisturbed graminoid fen transects in 1986–87 and in 1992. At the species level, mean percent cover per 0.25-m^2 plot (including zero values) was compared for species between the 1986–87 and 1992 data sets. Because such data are often skewed, we used the nonparametric Mann-Whitney test to compare rank differences between the cover values. When significant temporal changes in species cover were found, we tested 1986–87 vs 1992 plot frequencies by x^2 analysis to determine if these were related to changes in plant abundance. As an additional measure of successional change, we compared temporal change in summed importance values of prevalent fen species *(sensu* Moran 1981) in disturbed and undisturbed fen transects.

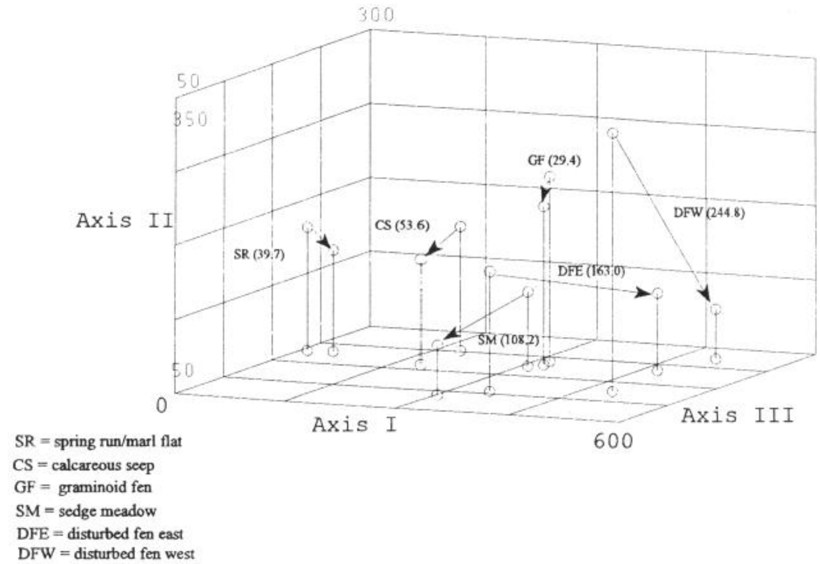

Figure 2. DECORANA ordination of paired community transects sampled in 1986-87 and in 1992 at Bluff Spring Fen. Arrows indicate direction of change from 1986-87 to 1992. Values in parentheses are Euclidean distances between paired transects. Each axis is labeled with DECORANA axes scores.

RESULTS

Temporal Changes in Plant Community Indices

DECORANA (Figure 2) aligned communities on the first ordination axis as their compositions changed in relation to physical factors of increasing elevation and decreasing water flow and soil saturation, which relate to more complex physical and chemical soil features (Table 1). The second and third axes appear to represent primarily successional changes in species composition. For example, the greatest temporal shifts occurred on the second and third ordination axes for the disturbed fen communities, which received the highest frequency of burning and mechanical shrub removal. Sedge meadow also had its most important shift on the second axis. Graminoid fen, calcareous seep, and spring run/marl flat had lower quantitative shifts and, as indicated, have received comparatively little historic human impact or disturbance.

Correlations between the temporally paired species importance values for each community were high ($r^2 > 0.60$), except for disturbed fen, which had r^2 values < 0.40; Spearman's rank correlation coefficients

Table 1. Plant community descriptions and nomenclature for Bluff Spring Fen Nature Preserve. Classification follows White and Madany 1978 except that spring run and marl flat are subdivided from calcareous seep.

Spring run/marl flat
Occupies substrates with relatively high $CaCO_3$, Mg, and Na, in areas of greatest spring water flow and fire protection in the central fen basin. Species richness is relatively low, and *Potentilla fruticosa is* the dominant species. Subdominant species are the graminoids *Eleocharis rostellata, Carex sterilis, Deschampsia caespitosa, and Rhynchospora capillacea,* and the alga *Chara.* Other important species include the forbs *Silphium terebinthinaceum, Solidago uliginosa,* and *Lobelia kalmii.*

Calcareous seep
Positioned above marl flats in the fen basin, in raised areas with strong seepage and greater organic matter and nutrients. Many species overlap with marl flats, but richness is higher, with *Eleocharis rostellata* as the dominant species. Subdominant species are *Carex sterilis, Potentilla fruticosa,* and ***Solidago** ohioensis. Carex stricta is* important but less abundant, while *Muhlenbergia glomerata, Lysimachia quadrifolia,* and *Cladium mariscoides* are infrequent but cahracteristic species.

Graminoid fen
Occurs in areas of raised peat situated above calcareous seeps in the upper portions of the fen basin. Strong seepage is lacking and substrates have high organic matter and nutrient concentrations. Species richness is highest in this part of the fen, with *Carex stricta, Solidago ohioensis, Calamagrostis canadensis, Aster umbellatus, Solidago altissima,* and *Cornus racemosa* as dominant species. Important prairie species include *Muhlenbergia mexicana, Rudbeckia hirta, Andropogon scoparius, Smilacina stellata, Solidago gigantea, Monarda fistulosa,* and *Silphium perfoliatum.* Wetland species include *Scirpus validus, S. acutus,* and *Lycopus americanus.*

Disturbed graminoid fen
Graminoid fen disturbed by former grazing and shrub invasion, which occurs on the west and east borders of the fen basin. This vegetation is spatially variable and successionally unstable, changing with management. Dominant species include the grasses *Andropogon gerardii* and *Calamagrostis canadensis,* the sedge *Carex stricta,* or the shrub *Cornus racemosa.* Important forbs include *Solidago altissima, Aster puniceus, Eupatorium maculatum,* and *E. serotinum.*

Sedge meadow
Occurs in low, periodically inundated areas of acid peat along the south border of the fen basin. Species richness is relatively low. Dominant species are *Carex stricta, Calamagrostis canadensis,* and *Typha latifolia;* important forbs include *Solidago altissima* and ***Pycnanthemum** virginianum.*

(r_s) were significant for spring run/marl flat, calcareous seep, and sedge meadow (Table 2). Lowest Sorensen's coefficients (<50% floristic similarity) between 1986-87 and 1992 occurred for the disturbed graminoid fen data (Table 2). Plot richness was identical over time only for the disturbed graminoid fen east transect. Although overall richness dropped from 6.66 (±1.42) species per plot in 1986-87 to 5.67 (± 1.23) species in 1992, this change was not statistically significant (Table 2). The Shannon diversity index (H') showed minor nonsignificant changes and increased only for the disturbed graminoid fen east transect (Table 2). T-tests of the mean coefficient of conservatism found a significant decrease for the sedge meadow transect and a significant increase for the disturbed graminoid fen east transect (Table 2). This coefficient also differed significantly among communities in 1986-87 and in 1992 (Table 2). Multiple-range tests of the coefficient suggest that in 1986-87 the spring run/marl flat vegetation was higher quality than calcareous seep, which was higher than graminoid fen and sedge meadow, which were, in turn, higher than the disturbed vegetation. There were similar differences in 1992, with the exception that the east disturbed graminoid fen transect no longer differed in quality from the graminoid fen.

Temporal Changes in Plant Community Structure and Species

Significant changes occurred in frequencies of woody, graminoid, or forb life-form groups in almost all fen transects (Figure 3); these changes were supported by comparison with life-form group importance values (Table 3). At the species level, most mean covers had high and unequal variances; but there were 16 significant ($P < 0.05$) Mann-Whitney tests for changes in ranks of mean species cover. Because multiple testing increases chances of finding significant differences (i.e., < 0.05) at a rate of 1 out of 20 tests, fewer than 1 of these tests is probably due to chance.

Table 2. Comparison of sample size, floristic similarity, plot species richness, Shannon diversity index (H'), mean coefficient of conservatism, and correlation coefficients of species importance values for plant community transects sampled in 1986-87 and in 1992 at Bluff Spring Fen, Cook County, Ilinois.

	Spring Run/ Marl Flat	Calcareous Seep	Graminoid Fen	Disturbed Gr. Fen-E	Disturbed Gr. Fen-W	Sedge Meadow
Number of Plots						
1986-87	16	30	20	30	26	19
1992	15	28	23	25	22	21
Plot Species Richness[a]						
1986-87	6.19	8.37	8.75	5.20	6.81	5.84
1992	5.20	6.79	7.48	5.24	5.18	4.14
Shannon Diversity (H')						
1986-87	1.278	1.526	1.512	1.441	1.619	1.342
1992	1.220	1.466	1.374	1.511	1.617	1.078
t-calc.	0.373	0.160	0.356	0.183	0.005	0.645
P	>0.50	>0.50	>0.50	>0.50	>0.50	>0.50
Sorensen's Coefficient 1986-87 vs 1992	64%	68%	54%	40%	44%	57%
Correlation **(r^2) between** 1986-87 & 1992	0.8132	0.7062	0.6304	0.3987	0.3290	0.8042
Spearman's Rank Correlation Coefficient 1986-87 vs 1992						
(r_s)	0.5746	0.5499	0.2359	0.2413	-.0176	0.5028
P	<0.002	<0.0001	<0.10	<0.10	>0.50	<.005
Mean Coefficient of Conservatism[b]						
1986-87	8.60a	6.39b	5.22c	2.73d	2.87d	5.32c
1992	9.04a	6.87b	4.91c	4.33c	3.02d	4.22c
t-calc.	-1.40	-1.817	1.10	-5.51	-0.485	3.19
P	0.1644	0.0692	0.271	<0.0001	0.627	0.002

[a] T-test of mean plot species richness for 1986-87 ($\bar{X}$ = 6.68 ± 1.42) vs 1992 ($\bar{X}$ = 5.67 ± 1.23): t_{55}= 1.55, P = 0.152.
[b] ANOVA: for mean coefficient 1986-87, $F_{5,135}$= 3.15, P <0.0001; for 1992, $F_{5,128}$ = 70.75, P <0.0001; mean C values sharing similar letters for each row are not different at 0.05, Duncan's multiple-range test.

Table 3. Temporal changes In Importance values (relative cover + relative frequency /2) for species life-form groups at Bluff Spring Fen (Cook County, Illinois).

	Spring Run/ Marl Flat		Calcareous Seep		Graminoid Fen		Disturbed Gr. Fen-E		Disturbed Gr. Fen-W		Sedge Meadow	
Life Form	**86-87**	**1992**	**86-87**	**1992**	**86-87**	**1992**	**86-87**	**1992**	**86-87**	**1992**	**86-87**	**1992**
Woody	26.05	25.79	5.87	4.76	12.25	8.76	35.67	13.85	37.85	17.72	1.04	0
Graminoid	36.43	52.83	33.43	57.03	19.86	35.21	8.06	37.84	5.11	11.94	43.54	65.81
Forbs	36.94	21.38	60.71	38.21	66.77	56.03	52.91	47.89	42.68	60.51	54.34	34.18
Aliens	0.58	0	0	0	1.13	0	3.36	0.40	14.35	9.92	1.07	0

Table 4. Changes in mean species cover in temporally paired community transects at Bluff Spring Fen (Cook County, Illinois). Probabilities levels of P < 0.05 are boldfaced; at this level, 1 of 20 significant differences could be significant by chance. All species with changes of P < 0.10 are Included; other species were selected based on their magnitude of change.

Species	Community	1986-87 Mean % Cover (±SE)	1992 Mean % Cover (±SE)	Mann-Whitney Test Statistic	Mann-Whitney Test Probability
WOODY					
Cornus racemosa	Dist. fen-W	27.04 (±32.7)	3.64 (t7.8)	$z_{26\ 22}$ = *2.85*	***P=0.004***
Rhus glabra	Dist. fen-E	30.53 (±43.6)	3.20 (±9.9)	$z_{30,25}$ = 2.51	***P=0.01***
Rubus occidentalis	Dist. fen-E	10.77 (±23.0)	0.40 (±2.0)	$z_{30,25}$ = 2.47	**P=0.01**
Rubus occidentalis	Dist. fen-W	17.77 (±29.4)	3.86 (±7.7)	$z_{26\ 22}$ = *2.85*	**P=0.03**
GRAMINOID					
Andropogon gerardii	Dist. fen-E	0.00	15.12 (±28.55)		
Calamagrostis canadensis	Gram. fen	0.00	11.74 (±20.3)		
Calamagrostis canadensis	Dist. fen-W	0.19 (t1.0)	7.95 (±17.5)	z_{2622} = 2.02	***P=0.04***
Calamagrostis canadensis	S. meadow	0.86 (±2.4)	20.24 (±30.1)	219 21 = *1.65*	P=0.10
Carex sterilis	Spring r./m.fl.	0.38 (±1.5)	14.33 (±15.1)	$Z_{16,15}$ = *3.56*	**P=0.0001**
Carex stricta	Cal. seep	12.67 (±13.4)	27.86 (±23.2)	Z_{3028} = *2.57*	**P=0.01**
Cladium mariscoides	Cal. seep	2.00 (±10.95)	3.75 (±8.1)	Z_{3028} = 1.99	***P=0.05***
Eleocharis rostellata	Cal.seep	2.33 (±12.8)	11.25 (±27.25)	Z_{3028} = 1.80	*P=0.07*
Muhlenbergia mexicana	Gram. fen	0.60 (t1.6)	5.48 (±11.35)	z_{2023} = 1.65	P=0.10
Scirpus acutus	Cal. seep	0.98 (±2.65)	7.39 (±13.1)	Z_{3028} = 1.96	***P=0.05***
Sorghastrum nutans	Cal. seep	7.18 (±16.8)	0.36 (±1.3)	$z_{30\ 28}$ = 1.79	*P=0.07*
Typha latifolia	S. meadow	0.55 (±2.3)	8.81 (±11.6)	$z_{19,21}$ = 3.17	**P=0.002**
Fo^{g}s					
Aster puniceus	Dist. fen-E	1.33 (±5.7)	4.20 (±7.0)	$z_{30,25}$ = *2.32*	**P=0.02**
Aster puniceus var. *firm us*	Dist. fen-E	2.43 (±6.5)	0.00		
Aster puniceus var. *firmus*	Dist. fen-W	1.46 (±4.25)	0.00		
Aster umbellatus	Gram. fen	1.80 (±3.9)	13.83 (±13.7)	$z_{20\ 23}$ = *3.33*	**P=0.001**
Impatiens capensis	Dist. fen-E	21.33 (±30.9)	0.00		
Liatris pycnostachya	Cal. seep	1.53 (±3.6)	0.18 (±0.7)	Z_{3028} = *1.99*	***P=0.05***
Silphium perfoliatum	Dist. fen-E	2.00 (±10.95)	5.60 (±11.7)	Z_{3025} = ***2.16***	**P=0.03**
Solidago ohioensis	Cal. seep	19.40 (±17.1)	8.61 (±12.4)	z_{3028} = 2.48	**P=0.01**
Solidago ohioensis	Gram. fen	14.15 (±14.7)	3.09 (±10.1)	z_{2023} = 2.47	**P=0.01**
Valerians ciliata	Cal. seep	8.87 (±15.45)	1.36 (±3.5)	$z_{30\ 28}$ = 1.66	P=0.10

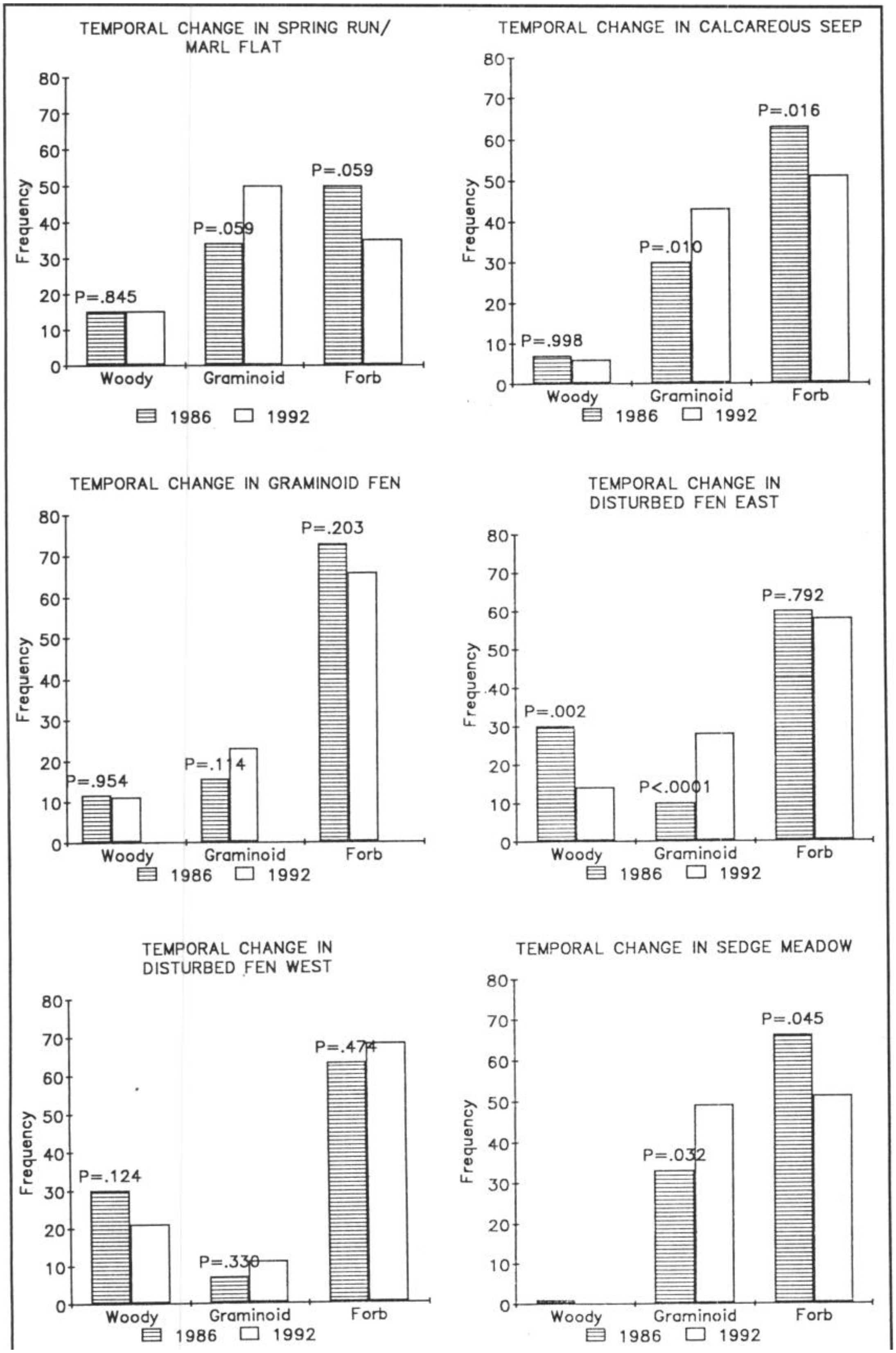

Figure 3. Temporal changes in vegetation structure (woody, graminoid, and forb frequencies) In Bluff Spring Fen plant communities. P = probability that proportional differences in total plot frequencies are due to chance with Chi-Square analysis.

Spring run/marl flat

Frequency of woody vegetation did not change, but graminoid vegetation in-creased ($P = 0.059$) from 35% to 50% frequency, while forbs dropped ($P = 0.059$) from 50% to 35% frequency (Figure 3). Among graminoid species (Table 4), the sedge *Carex sterilis* increased *(P* < 0.0001) from 0.38 (±1.5) to 14.33 (±15.1) mean percent cover and from 6% to 67% frequency (P= 0.002). The spikerush *Eleocharis rostellata* increased from 6.56 (±2.9) to 19.33 (t8.2) mean percent cover and from 31% to 33% frequency, but neither change was significant. There were no significant changes in cover among forbs, although the golden-rod *Solidago ohioensis* dropped from 8.40 (±11.4) to 1.93 (±7.5) mean percent cover and from 56% to 40% plot frequency.

Calcareous seep

Frequency of woody vegetation did not change appreciably. But graminoids increased ($P = 0.01$) from 30% to 43% frequency, while forbs dropped ($P = 0.016$) from 63% to 51% frequency (Figure 3). Significant increases occurred in mean percent cover but not frequency for three sedges (Table 4). *Carex stricta* cover increased ($P = 0.01$) from 12.67 (±13.4) to 27.86 (±23.2), *Cladium mariscoides* cover in-creased ($P = 0.05$) from 2.0 (±10.95) to 3.75 (±8.1), and *Scirpus acutus* cover in-creased ($P = 0.05$) from 0.98 (12.65) to 7.39 (±13.1). Significant declines in mean percent cover, but not frequency, occurred for two forbs (Table 4). Cover of the co-dominant *Solidago ohioensis* dropped *(P* = 0.01) from 19.4 (±17.1) to 8.61 (±12.4), and cover for the less abundant *Liatris pycnostachya* dropped *(P* = 0.05) from 1.53 (±3.6) to 0.18. (±0.7).

Graminoid fen

Although no changes were significant, graminoid species increased from 15.5% to 23% frequency, and forbs declined from 73% to 66% frequency; woody vegetation remained essentially unchanged (Figure 3). There were no significant changes in mean per-cent cover or frequency of graminoid species. But *Calamag ro stis canadensis* was absent from the original data and appeared in 1992 at 11.74 (±20.3) mean percent cover (Table 4), while importance values for *Carex stricta* and *Muhlenbergia mexicana* increased 23.3% and 77.2%, respectively (Table 5). Significant changes in mean percent cover, but not frequency, occurred for two forbs (Table 4). *Solidago ohioensis* cover decreased (P = 0.01) from 14.15 (±14.7) to 3.09 (±10.1), while *Aster umbellatus* cover increased *(P* = 0.001) from 1.80 (±3.9) to 13.83 (±13.7). Total importance values of prevalent fen species changed only from 44.4 in 1986–87 to 45.57 in 1992.

Disturbed fen vegetation (east transect)

In contrast to other communites, in the disturbed fen (east), frequency of woody vegetation dropped (P = 0.002) from 30% to 14%, while graminoid frequency increased (P < 0.0001) from 10% to 28% and forb frequency remained essentially unchanged (Figure 3). Among woody species (Table 4), significant declines occurred for *Rubus occidentalis,* which dropped *(P* = 0.01) from 10.77 (±23.0) to 0.4 (±2.0) mean percent cover and from 30% to 4% frequency (P = 0.033), and for *Rhus glabra,* which declined (P = 0.01) from 30.53 (±43.6) to 3.2 (±9.9) mean percent cover and from 40% to 12% frequency (P = 0.044). How-ever, *Cornus racemosa* did not change significantly in cover and increased only from 40% to 44% frequency. Among graminoid species (Table *4), Andropogon gerardii* was absent in 1986—87 and appeared at 15.12 (±28.55) mean percent cover in 1992. Significant changes in mean per-cent cover, but not frequency, occurred for two forbs (Table 4). *Silphium perfoliatum* cover increased (P = 0.03) from 2.0 (±10.95) to 5.6 (±11.7), and *Aster puniceus* cover increased (P = 0.02) from 1.33 (±5.7) to 4.2 (±7.0). *Aster punicus* var. *firmus* and the shade-tolerant *Impatiens capensis* disappeared from the data in 1992.

The east disturbed fen had higher (P = 0.0001) woody and lower (P = 0.018) forb frequencies than graminoid fen in 1986

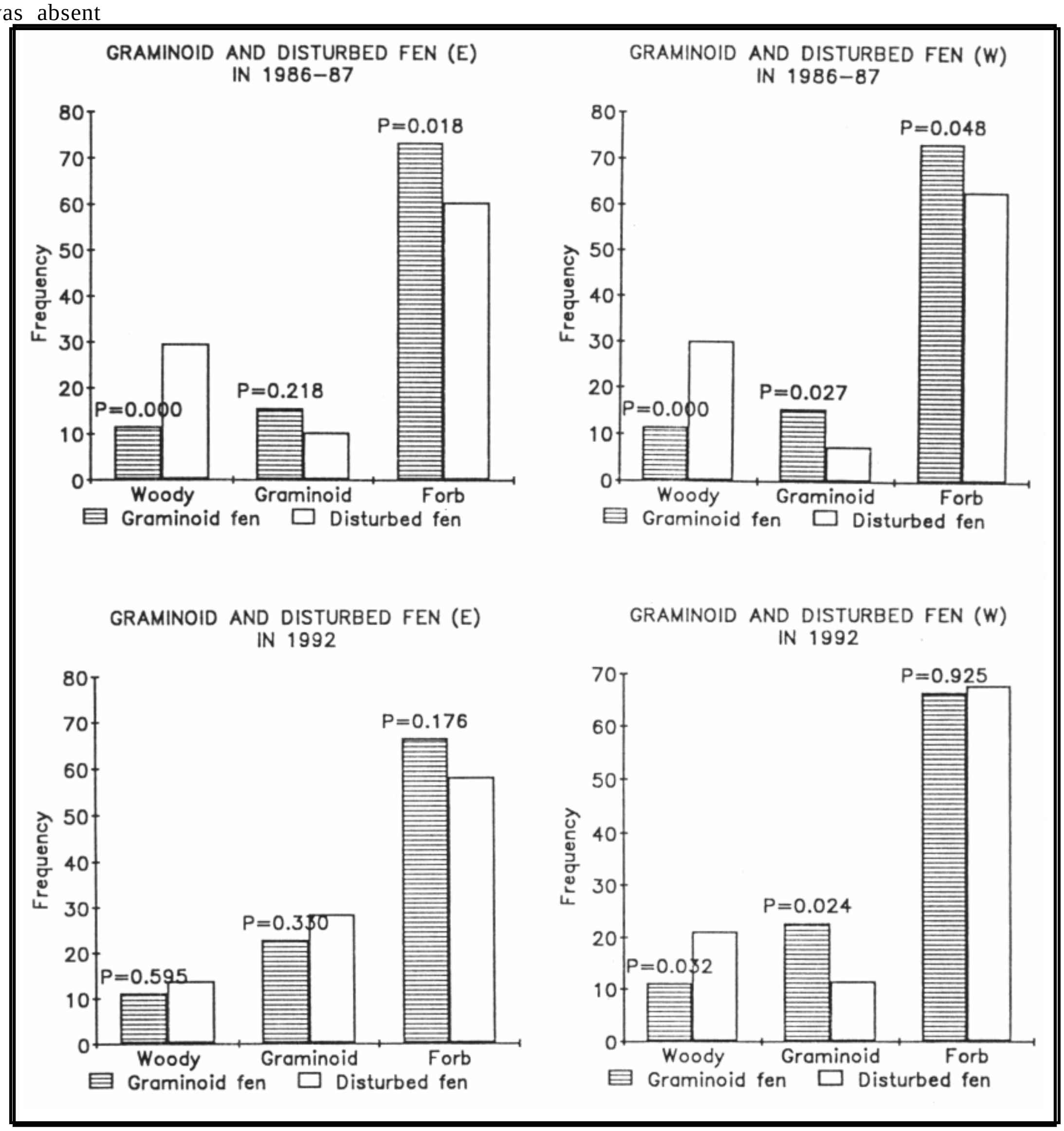

Figure 4. Comparisons of differences in vegetation structure (woody, graminoid, and forb frequencies) between disturbed and undisturbed graminoid fen in 1986—87 and In 1992. P = probability that proportional differences in total plot frequencies are due to chance with Chi-Square analysis.

Table 5. Importance values (IV) for plant species with IV? 2.5 and for prevalent (*) fen species (*sensu* Moran 1981) in graminoid and disturbed graminoid fen plant communities at Bluff Spring Fen (Cook County, Illinois). Species are ranked by IV is each successive community.

Species	Graminoid Fen		Dlst. Graminoid Fen-E		Dist. Graminoid Fen-W	
	1986-87	1992	1986-87	1992	1986-87	1992
* *Carex stricta*	13.11	17.10	5.78	13.15	2.30	-
* *Solidago ohioensis*	9.18	2.70	-	1.61	0.36	-
* *Solidago gigantea*	7.51	6.90	4.95	2.86	2.12	1.17
Solidago altissima	6.37	7.35	11.06	6.47	5.52	5.67
Viburnum lentago	5.54	1.34	1.93	0.47	-	-
Silphium perfoliatum	5.31	3.94	0.96	4.84	1.52	-
Helianthus grossesseratus	4.34	-	0.37	2.28	0.33	-
Smilacina stellata	4.32	4.76	-	-	0.67	-
* *Pycnanthemum virginianum*	3.82	0.62	-	1.33	0.67	-
Silphium integrifolium	3.62	1.90	-	-	-	-
Aster puniceus var. *firms*	3.54	0.83	3.03	-	1.65	-
* *Lycopus americanus*	3.24	2.79	-	-	-	-
Stachys palustris	3.23	2.31	1.41	-	0.72	-
Cornus racemosa	3.14	5.37	8.96	9.35	14.43	4.95
Rosa sp.	2.87	1.64	0.34	-	1.06	1.31
Fragaria virginiana	2.67	0.69	-	-	7.07	3.00
Aster umbellatus	2.59	11.83	-	0.45	-	1.02
Eriophorum angustifolium	2.52	-	-	-	-	-
* *Eupatorium maculatum*	2.18	-	3.12	6.52	-	4.65
**Muhlenbergia glomerata*	2.05	1.42	1.45	3.04	-	-
* *Oxypolis rigidior*	1.44	-	-	1.06	-	-
Monarda fistulosa	1.18	2.44	2.31	-	-	3.79
Muhlenbergia mexicana	1.15	5.05	-	-	0.47	-
* *Parnassia glauca*	0.96	-	-	-	-	-
* *Aster puniceus*	0.91	1.02	1.07	5.03	0.31	2.25
Aster novae-angliae	0.87	-	-	3.04	0.82	1.17
Solidago patula	0.77	-	-	3.79	0.62	1.34
* *Sorghastrum nutans*	0.77	-	-	-	0.57	-
Cirsium arvense	0.72	-	2.22	-	0.72	2.74
* *Rudbeckia hirta*	0.67	-	1.50	3.54	-	-
* *Valerian ciliata*	0.67	-	-	-	-	-
* *Solidago riddellii*	0.59	-	-	-	-	-
Apocynum cannabinum	0.29	-	2.00	-	5.57	-
Rosa blanda	-	3.28	-	-	2.12	-
* *Gentian procera*	-	1.45	-	-	-	-
* *Andropogon scoparius*	-	1.23	-	-	-	-
* *Cirsium muticum*	-	0.62	-	-	0.72	1.17
Rhus *glabra*	-	-	13.68	2.65	2.39	1.54
Impatiens capensis	-	-	12.28	-	-	5.00

Continued

Table 5, *continued*

Species	Graminoid Fen 1986-87	Graminoid Fen 1992	Dist. Graminoid Fen-E 1986-87	Dist. Graminoid Fen-E 1992	Dist. Graminoid Fen-W 1986-87	Dist. Graminoid Fen-W 1992
Rubus occidentalis	-	0.40	6.35	0.70	**9.96**	**4.66**
Circaea lutetiana	-	-	**5.08**	-	-	-
* *Andropogon gerardii*	-	1.26	-	**9.80**	-	-
Typha sp.	-	-	0.34	3.45	-	-
Carex hystricina	-	-	-	3.21	-	1.75
Helianthus giganteus	-	-	-	2.53	-	-
Rubus pennsilvanicus	-	-	-	-	3.52	1.16
Eupatorium rugosum	-	-	0.43	-	3.48	-
Vitis riparia	-	-	0.75	-	3.01	3.50
Arctium minus	-	-	0.34	-	2.93	-
Eupatorium serotinum	-	-	-	-	-	10.01
* *Calamagrostis canadensis*	-	8.46	1.20	1.80	0.34	7.27
Salix interior	-	-	3.75	-	-	-
Rhus typhina	-	-	3.64	-	-	-
Polygonum scandens	-	-	3.12	1.14	-	2.33
Typha angustifolia	-	-	-	6.91	-	-
Pedicularis lanceolata	-	-	-	3.99	-	-
Polygonum amphibum	-	-	-	3.45	-	
Scirpus validus	-	-	-	2.17	-	3.78
* *Carex sterilis*	-	-	-	**1.89**	-	-
* *Galium boreale*	-	-	-	1.75	-	-
Parthenocissus quinquefolia	-	-	-	0.80	**1.96**	3.77
Salix glaucophylloides	-	-	-	-	3.16	-
Anemone virginiana	-	-	-	-	2.78	-
Phalaris arundinacea	-	-	-	-	2.64	-
Festuca elatior	-	-	-	-	2.56	-
* *Thalictrum dasycarpum*	-	-	-	-	1.34	-
Hackelia virginiana	-	-	-	-	-	4.84
Carex pensylvanica	-	-	-	-	-	4.35
Poa pratensis	-	-	-	-	-	4.07
Sambucus canadensis	-	-	-	-	-	3.20
Symplocarpus foetidus	-	-	-	-	-	2.80
Rosa carolina	-	-	-	-	-	2.62
Clematis virginiana	-	-	-	-	-	2.61
* *Convolvulus sepium*	-	-	-	-	-	2.16

87, but not in 1992 (Figure 4). Related to this, correlations of species importance values between the east disturbed fen and graminoid fen were low in 1986-87 (r^2 = 0.195) **but** had increased (r^2 = **0.508) by** 1992. By 1992, these communities shared high importance of *Carex stricta, Solidago altissima,* and *Cornus racemosa* (Table 5). Compositional changes in the east disturbed graminoid fen transect included loss of 25 species, 5 of which were aliens, and gain of 28 species, including 6 plants *(Solidago ohioensis, Pycnanthemum virginianum, Oxypolis rigidior, Andropogon gerardii, Carex sterilis* and *Galium bore-ale)* considered prevalent fen species by Moran (1981). Importance values of all prevalent fen species increased from 19.07

to 53.38 in 1992. However, this disturbed fen transect differed from graminoid fen by having greater importance of *Eupatorium maculatum*, *Andropogon gerardii*, and *Aster puniceus* and absence or low importance of *Muhlenbergia glomerata*, *M. mexicana*, *Smilacina stellata*, *Silphium integrifolium*, *Lycopus americanus*, and *Aster umbellatus* (Table 5).

Disturbed fen vegetation (west transect)

In contrast to the east disturbed fen transect, woody plants in the west transect under-went only a moderate (P = 0.124) decline from 30% to 21% frequency, while overall frequencies of graminoid and forb species remained essentially unchanged (Figure 3). However, *Cornus racemosa* declined (*P* = 0.004) from 27.04 (±32.7) to 3.64 (±7.8) mean percent cover and from 62% to 27% frequency (*P* = 0.038), and *Rubus occidentalis* dropped (P = 0.03) from 17.77 (±29.4) to 3.86 (±7.7) mean percent cover and from 54% to 23% (P = 0.058) frequency (Table *4)*. *Calamagrostis canadensis* was the only graminoid species to change significantly, increasing (P = 0.04) from 0.19 (±1.0) to 7.95 (±17.5) mean percent cover, but it did not change in frequency. In contrast to observations in the east disturbed fen transect, *Aster puniceus* did not change significantly in cover, but the variety *firmus* also was not resampled.

Changes in the west disturbed fen appeared only weakly related to succession toward graminoid fen. Overall woody and graminoid structures of these communities remained different over time (Figure 4), with frequencies of woody species significantly higher in disturbed fen in 1986–87 (P < 0.0001) and in 1992 (P = 0.032), and graminoid frequencies lower (P = 0.027) in disturbed fen in 1986–87 and in 1992 (P = 0.024). Although west disturbed fen forb frequencies differed from those of graminoid fen (P = 0.048) in 1986–87, they were similar in 1992 (Figure 4). How-ever, total species importance values were poorly correlated with graminoid fen in 1986–87 (r^2= 0.137) and in 1992 (r^2= 0.074). In 1992, these communities shared only *Calamagrostis canadensis*, *Cornus racemosa*, and *Solidago altissima* as dominant species, while *Eupatorium maculatum*, *E. serotinum*, and *Impatiens capensis* were important in disturbed fen but absent from graminoid fen (Table 5). Compositional changes in the west disturbed fen transect included loss of 35 species, including 10 aliens and 6 prevalent fen species, and gain of 25 species including 3 aliens and 2 prevalent fen species. Related to this, importance values of prevalent fen species increased from 8.73 to 18.67 in 1992. As with the east disturbed fen transect, the grasses *Muhlenbergia mexicana* and *M. glomerata*, and the fortis *Smilacina stellata*, *Silphium integrifolium*, *Lycopus americanus*, and *Aster umbellatus* were absent or unimportant in the west transect.

Sedge meadow

As in other less-disturbed fen communities, woody vegetation did not change, but graminoid species frequencies increased (P = 0.032) from 33% to 49%, while forb species frequencies dropped (P = 0.045) from 66% to 51% (Figure 3). Among graminoid vegetation (Table 4), *Typha latifolia* increased (P = 0.002) from 0.55 (±2.3) to 8.81 (±11.6) mean percent cover and from 11% to 57% (P = 0.006) frequency. *Calamagrostis canadensis* in-creased from 0.86 (±2.4) to 20.24 (±30.1) mean percent cover and from 21% to 38% frequency, but neither change was signif icant. Among forbs, *Solidago ohioensis* mean percent cover was 4.74 (±2.6) in 1986–87 and 0.71 (±0.5) in 1992, and *Eupatorium maculatum* cover was 10.37 (±5.4) in 1986–87 and 3.19 (±1.45) in 1992; none of the differences were significant. However, 19 species that occurred at low importance values in 1986–87 were not sampled in 1992, dropping total richness from 33 to 16 species.

DISCUSSION

Interpreting Temporal Vegetation Change

Four factors constrain our interpretation of management effects on vegetation at BSF. First, neither unburned controls nor preburn data exist. Second, an unquantified reduction of woody species and change in herbaceous vegetation occurred prior to initial data collection (Stoynoff and Hess 1986); these could not be detected in our analysis. Third, the presence and cover of fen vegetation may vary annually in response to seasonal rainfall and fire (Zimmerman 1983). For example, in 1988, northeastern Illinois experienced its most serious drought in the last 50 years. Al-though this could have affected fen vegetation structure, there were no burns at BSF prior to the 1988 growing season, a factor that might have ameliorated soil moisture loss. Fourth, transects and plots may have been aligned differently between 1986–87 and 1992, and sampling bias may have differed among data collectors. As a result, the vegetation changes detected in this study must be interpreted with caution. A bias toward lower estimates of plant cover within plots in 1992 could have contributed to the apparent loss of cover of some forbs, but this bias would have underestimated the significant in-creases in graminoid species' cover. On the other hand, higher cover estimates would have masked a more significant decrease in forb cover and contributed to an apparent increase in graminoid cover. Including plants occurring on sample plot borders in 1986–87 would contribute to overall higher species richness and frequency than in 1992.

Changes in Undisturbed Fen Vegetation

Since 1986-87, the combined plot frequencies of graminoid species have increased while those of other herbaceous species have declined in spring run/marl flat, calcareous seep, graminoid fen, and sedge meadow communities at BSF. These changes represent a cumulative effect, as most individual species' changes were in cover and not frequency. Among graminoid species, for example, *Carex sterilis* and *Eleocharis rostellata* cover increased in spring run/marl flat; *C. stricta*, *Scirpus acutus*, and *Cladium mariscoides* cover increased in calcareous seep; *Calamagrostis canadensis* cover increased in graminoid fen; and *Typha latifolia* cover increased in sedge meadow. But only two of these species, *Carex sterilis* and *Typha latifolia*, increased in frequency. Unlike graminoid species, only one forb, *Aster umbellatus,* increased significantly in cover, and this species also increased in frequency. Although few forbs decreased in cover, the fen goldenrod *Solidago ohioensis* decreased in cover in a large part of the fen.

Based on the pervasive use of prescribed burning over an 11-year period at BSF, and the apparent absence of other environmental perturbations, fire appears to have been the causal agent for the vegetation changes detected by this study. Such effects are well known in prairie (Collins and Glenn 1988, Collins and Gibson 1990, Johnson and Knapp 1995) and might be expected in prairie fen vegetation. The different responses of graminoid and forb species to fire might be explained in part by different growth patterns. Although some forb recovery may have occurred prior to initial data collection, graminoid species may be expanding more quickly than forbs into adjacent interstitial spaces formerly covered by unburned litter. We hypothesize that fire has stimulated spread of the fibrous root systems of graminoid species, allowing competitive exclusion of many forbs. Although evidence for such exclusion is lacking in fen vegetation, graminoid species are known for root dominance or competitive exclusion of plants in grassland habitats (e.g., Gurevitch 1986, Louda et al. 1990, Hook et al. 1994).

Changes in Disturbed Fen Vegetation

The combined effects of fire, cutting of woody plants, and time appear to have caused significant structural and compositional changes in disturbed fen vegetation at BSF, primarily by reversing trajectories toward woody dominance and increasing graminoid importance. These changes have been most rapid in the east tract, where overall frequencies of woody, graminoid, and forb species do not differ from relatively undisturbed graminoid fen. Correlations among species importance values, loss of alien species, and increase of native species, especially prevalent fen species, also indicate that successional changes are occurring in disturbed fen vegetation, especially in the east tract. However, species such as *Muhlenbergia mexicana, M. glomerata, Smilacina stellata, Silphium integrifolium, Lycopus americanus,* and *Aster umbellatus* remain rare or absent from the disturbed fen tracts and are more abundant in undisturbed graminoid fen. These species may represent a late-successional graminoid fen component that has yet to become important in disturbed fen.

Differences in vegetation structure between the two disturbed fen tracts appear related to partial shade over the west tract. For example, in the east tract, the shade-intolerant prairie grass *Andropogon gerardii* increased, whereas the shade-adapted *Impatiens capensis* declined. Although the west tract underwent a significant increase in cover of *Calamagrostis canadensis,* overall grass frequency was lower (11%) than in the east tract (28%). The shade-adapted *Impatiens capensis* occurred at relatively high frequencies in the west tract. Although cover of *Rhus glabra* and *Rubus occidentalis* was reduced in the east tract, *Cornus racemosa* was resistant to fire, cutting, and herbicide in this habitat. As with other invasive woody species (e.g., Luken and Mattimiro 1991), *Cornus racemosa* was less resistant to management in the shaded west tract, where it decreased in cover and frequency.

CONCLUSIONS

Management Implications

Data from BSF suggest that, as in tallgrass prairie, continuous fire management and cutting of woody vegetation increase graminoid dominance in prairie fen habitat and select for lower frequencies of forb species. However, at BSF, no individual fen species declined in abundance and there was no evidence of a significant decline in species richness or diversity. Some rare species, such as *Cypripedium candidum,* may be increasing locally within the fen (Swink and Wilhelm 1994). In disturbed fen, fire management also increases graminoid dominance and can promote recovery of some aspects of vegetation structure. However, some prevalent and late-successional species have not reached high importance after at least 7 years, and their recovery may take much longer. For example, appearance of late-successional prairie species from seed may take up to 20 years in prairie restorations (Schramm 1992). If graminoid dominance is enhanced by dormant-season fires that promote grass competition, other treatments could pro-vide different results. For example, infrequent growing-season burns, especially under drought conditions, might provide the disturbance necessary to reduce importance of vigorous graminoid species, promote colonization by forbs, and enhance community diversity and richness, but they may also promote invasion by alien species (Howe 1994a, 1994b).

Control of woody species is complex and related to habitat ecological differences. In addition to being present in disturbed habitats, *Cornus racemosa* occurs in graminoid fen and calcareous seep and may increase if burning is eliminated. Thus, continued control of woody vegetation will be required at BSF, and it is doubtful that dormant-season prescribed burning or cutting can eliminate resilient woody species (Luken and Mattimiro 1991). As a result, application of the more effective herbicide glyphosate is being used to further reduce C. *racemosa* at BSF (S. Byers, pers. corn.). Growing-season burns, especially under drought conditions, also may be more effective against aggressive woody vegetation than dormant-season burns (e.g., Anderson 1990).

The cause for the significant increase of *Typha latifolia* in sedge meadow at BSF is not known. Altered surface hydrology enhances cattail invasion (Apfelbaum 1985) and might have been exacerbated by an interaction between historic gravel mining and subsequent construction of an artificial kame along the south fen border. If this change represents an actual cattail invasion that extends into the fen, it may require corrective management. More precise monitoring is needed to assess the apparent loss of species from sedge meadow, and to determine if it is related to a cattail invasion or an effect of sampling bias.

Monitoring Implications

Even after 5 years of burning and woody species cutting before initial data collection (Stoynoff and Hess 1986), vegetation continues to change at BSF and cannot be monitored adequately by a single statistic. For example, DECORANA ordinated large-scale compositional changes in disturbed fen and sedge meadow, changes which were detected differently by various one-dimensional statistics and indices. The Shannon diversity index (H') was least sensitive, finding no significant changes in any communities. Correlation coefficients and Sorensen's coefficient of similarity indicated greater change (less similarity) only in the disturbed fen transects. The coefficient of conservatism found significant temporal changes in sedge meadow and in the east, but not the west, disturbed fen. It also found no significant difference between the east disturbed fen tract and the graminoid fen in 1992, although some prevalent and late-successional species were absent or infrequent in the disturbed fen. Because these coefficients are applied universally, they would be confounded by plants that occupy different successional stages in different habitats, or by natural disturbance regimes or processes such as gap-phase dynamics.

Metrics that are more sensitive to floristic changes than to quantitative shifts in species or changes in vegetation structure can be problematic to use in monitoring natural areas. To be most useful, these analyses should supplement analyses of change in species populations and vegetation structure. Vegetation structure affects, and can reflect, both plant and animal community processes, resource use, trophic levels, and species population levels (August 1983, Erdelen 1984, Pickett and White 1985, During et al. 1988). These factors should be important components of natural area monitoring and management. Tracking community change or management treatments with single statistics and without other measuring criteria could overlook significant structural changes that have important consequences for natural areas.

We expect vegetation change to continue at BSF, especially successional change in disturbed vegetation. Owing to unknown changes that took place prior to sampling, effects of time, and more specific factors such as climatic cycles, the effects of initial management at BSF may never be clarified. The resolution and frequency of vegetation monitoring would have to be increased to determine if trends identified in this study continue. Important objectives should be to determine (1) if graminoid dominance is increasing at the expense of forb species abundance or cover, (2) if plot richness is changing over time, (3) how disturbed fen vegetation continues to undergo succession-al change, (4) how woody vegetation such as *Cornus racemosa* changes with continued fire and herbicide application, and (5) how alternative management, such as growing-season fire, can affect woody and herbaceous vegetation. Furthermore, monitoring should be more specifically integrated with management treatments, weather, and hydrologic changes. These objectives should help resolve ongoing fen management questions and eventually help with restoration of more degraded fen habitats by identifying appropriate species for restoring or re-covering different successional stages.

ACKNOWLEDGMENTS

This study was partially funded by the Illinois Department of Conservation non-game fund (project #93023) and the Illinois Chapter of The Nature Conservancy. We especially thank Steve Byers, Illinois Nature Preserves Commission, Maggie Cole, Illinois Department of Conservation, and the Friends of the Fen for field assistance and information on past management history of BSF, and Rita Hassert of the Morton Arboretum Library for library research. Helpful reviews and statistical assistance were provided by Christopher Dunn, Pat Kelsey, Noel Pavlovic, Jennifer Windus, Christopher Whelan, and Gerould Wilhelm.

Marlin Bowles is a Plant Conservation Biologist at the Morton Arboretum, where he works with restoration and monitoring of endangered species. He also conducts community-level vegetation studies and is interested in fire management and restoration of plant communities of the mid-western states.

Jeanette McBride is a Plant Conservation Research Assistant at the Morton Aboretum, where she works on endangered plant recovery programs and vegetation monitoring.

Nick Stoynoff teaches chemistry and biology at Glenbard East High School in Lombard, Illinois. His recent research includes wetland floristics; taxonomy of the Quercus shumardii *complex; and taxonomy, ecology, and distribution of the genus* Quercus *in Illinois.*

Ken Johnson is a field Botanist and Restoration Ecologist at Conservation Design Forum in Naperville, Illinois. His work has also included field assistance with the fourth edition of Plants of the Chicago Region *(Swink and Wilhelm 1994).*

LITERATURE CITED

Anderson, R.C. 1990. The historic role of fire in the North American grassland. Pp. 8-18 *in* S.L. Collins and L.L. Wallace, eds., Fire in North American Tallgrass Prairies. University of Oklahoma Press, Norman.

Apfelbaum, S.I. 1985. Cattail *(Typha* spp.) management. Natural Areas Journal 5(3): 3-17.

August, P.V. 1983. The role of habitat complexity and heterogeneity in structuring tropical mammal communities. Ecology 64: 1495-1507.

Bowles, M.L., M.D. Hutchison, and J.L. McBride. 1994. Landscape pattern and structure of oak savanna, woodland, and barrens in northeastern Illinois at the time of European settlement. Pp. 65-73 *in* J.S. Fralish, R.C. Anderson, J.E. Ebinger, and R. Szafoni, eds., Proceedings of the North American Conference on Savannas and Barrens, Illinois Conference on Savannas and Barrens, Illinois State University, Normal.

Brower, J.E. and J.H. Zar. 1984. Field and Laboratory Methods for General Ecology. Wm. C. Brown Publishers, Dubuque, Iowa.

Carroll, S., R.L. Miller, and P.D. Whitson. 1984. Status of four orchid species at Silver Lake Fen Complex. Proceedings of the Iowa Academy of Science 91:132-139

Collins, S.L., J. Perino, and J.L. Vankat. 1981. Woody vegetation and microtopography in the bog meadow association of Cedar Bog, a West-central Ohio fen. American Mid-land Naturalist 108:245-249.

Collins, S.L. and D.J. Gibson. 1990. Effects of fire on community structure in tallgrass and mixed-grass prairie. Pp. 81-98 *in* S.L. Collins and L.L. Wallace, eds., Fire in North American Taligrass Prairie. University of Oklahoma Press, Norman.

Collins, S.L. and S.M. Glenn. 1988. Disturbance and community structure in North American prairies. Pp. 131-143 *in* H. During, M. Werger, and J. Willems, eds., Diversity and Pattern in Plant Communities. SPB Academic Publishing, The Hague, The Netherlands.

Curtis, J.T. 1959. Vegetation of Wisconsin. University of Wisconsin Press, Madison.

Dunn, C.P. and R.R. Shantz. 1987. Revegetation of a *Taxodium-Nyssa* forested wetland following complete vegetation destruction. Vegetatio 72:151-157.

During, H.J., M.J.A. Werger, and H.J. Willems. 1988. Diversity and Pattern in Plant Communities. SPB Academic Publishing, The Hague, The Netherlands.

Erdelen, M. 1984. Bird communities and vegetation structure: I. Correlations and comparisons of simple and diversity indices. Oecologia 61:277-284.

Gurevitch, J. 1986. Competition and the local distribution of the grass *Stipa neomexicana.* Ecology 67:46-57.

Hill, M.O. and H.G. Gauch. 1980. Detrended correspondence analysis, an improved ordination technique. Vegetatio 56:31-43.

Hook, P.B., W.K. Lauenroth, and I. C. Burke. 1994. Spatial patterns of roots in a semiarid grassland: abundance of canopy openings and regeneration gaps. Journal of Ecology 82:485-494.

Howe, H.F. 1994a. Response of early- and late-flowering plants to fire season in experimental prairies. Ecological Applications 4:121-133.

Howe, H.F. 1994b. Managing species diversity in tallgrass prairie: assumptions and implications. Conservation Biology 8:691-704.

Johnson, S.R. and A.K. Knapp. 1995. The influence of fire on *Spartina pectinata* wet-land communities in a northeastern Kansas tallgrass prairie. Canadian Journal of Botany 73:84-90.

Kilburn, P.D. 1959. The forest-prairie ecotone in northeastern Illinois. American Midland Naturalist 62:206-217.

Kohring, M.A. 1982. Ecological and flowering analysis of Bakertown Fen. Masters thesis, Michigan State University, Lansing.

Louda, S.M., M.A. Potvin, and S.K. Collinge. 1990. Predispersal seed predation, postdispersal seed predation and competition in the recruitment of seedlings of a native thistle in sandhills prairie. American Midland Naturalist 124:105-113.

Luken, J.O. and D.T. Mattimiro. 1991. Habitat-specific resilience of the invasive shrub Amur honeysuckle *(Lonicera maackii)* during repeated clipping. Ecological Applications 1:104-109.

McCune, B. 1994. Multivariate analysis on the PC-ORD system. Oregon State University, Corvallis.

Moran, R.C. 1978. Presettlement vegetation of Lake County, Illinois. Pp. 12-18 *in* D.C. Glenn-Lewin and R.Q. Landers, Jr., eds., Fifth Midwest Prairie Conference Proceedings, Iowa State University, Ames.

Moran, R.C. 1981. Prairie fens in northeastern Illinois: floristic composition and disturbance. Pp. 164-168 *in* R.L. Stuckey and K.J. Reese, eds., The Prairie Peninsula—In the "Shadow" of Transeau: Proceedings of the Sixth North American Prairie Conference. Ohio Biological Survey Notes No. 15.

Pearson, J.A. and M.J. Leoschke. 1992. Floristic composition and conservation status of fens in Iowa. Proceedings Iowa Academy of Science 99(2-3):41-52.

Pickett, S.T.A. and P.S. White. 1985. The Ecology of Natural Disturbance and Patch Dynamics. Academic Press, Orlando, Ha.

Reuter, D.D. 1986. Wetland shrub management study. Restoration and Management Notes 4:29.

Rooney, S.C. 1990. Fire suppresses woody vegetation in fens. Restoration and Management Notes 8:40.

Schramm, P. 1992. Prairie restoration: a twenty-five year perspective on establishment and management. Pp. 169-177 *in* D.D. Smith and C.A. Jacobs, eds., Proceedings of the Twelfth North American Prairie Conference. University of Northern Iowa, Cedar Falls.

Shannon, C.E. 1948. A mathematical theory of communication. Bell System Technical Journal 27:379-423, 623-656.

Sorensen, T. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content. Det Kongelige Danske videnskabemes, Biologiske shifter (Copenhagen) 5:1-34.

Spearman, C. 1904. The proof and measurement of association between two things. American Journal of Psychology 15:72-101.

Stoynoff, N.A. 1993. A quantitative analysis of the vegetation of Bluff Spring Fen Nature Preserve. Transactions Illinois Academy of Science 86:93-110.

Stoynoff, N.A. and W.J. Hess. 1986. Bluff City Fen: communities, vegetation history, and management. Transactions Illinois Academy of Science 79:53-58.

Swink, F. and G. Wilhelm. 1994. Plants of the Chicago Region. 4th Ed. Indiana Academy of Science, Indianapolis.

van der Valk, A.G. 1976. Zonation, competitive displacement, and standing crop of northwest Iowa fen communities. Proceedings Iowa Academy of Science 83:51-54.

Wheeler, B.D. 1988. Species richness, species rarity and conservation evaluation of rich-fen vegetation in lowland England and Wales. Journal of Applied Ecology 25:331-353.

White, J. and M. Madany. 1978. Classification of natural communities in Illinois. Appendix 30 *in* Illinois Natural Areas Inventory Technical Report. Department of Landscape Architecture, University of Illinois, Urbana-Champaign, and Natural Land Institute, Rockford, Ill.

White, K.L. 1965. Shrub-carrs of southeastern Wisconsin. Ecology 46:286-304.

Zimmerman, J.H. 1983. The revegetation of a small Yahara Valley prairie fen. Wisconsin Academy of Science, Arts and Letters 71(2):87-102.