How have the high quality prairies fared over the last 25 years? Marlin Bowles and Michael Jones re-sampled 62 sites to find out and to investigate the effects of fire.

Long-Term Changes in Chicago Region Prairie Vegetation in Relation to Fire Management

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Abstract
To understand long-term change in Chicago region prairies, in 2001 we re-investigated 62 prairie stands that were originally sampled in 1976 by the Illinois Natural Areas Inventory. For those sites with fire-management records, we correlated changes in species richness, composition and structure with the frequency at which the sites were burned over time. About 77% of all prairies remained intact, and, with the exception of many railroad prairies, most of the surviving sites are now protected. The majority of stands with fire records had been burned less than 40% of the time. With respect to change in species richness, higher quality prairies tended to be stable, while lower quality prairies increased in richness, presumably in response to fire management. We also found that alien species and woody vegetation increased across all sites, and that native species richness tended to decline as woody vegetation increased. Fire frequencies of about 50 %, i.e. biennial burning, appear necessary to maintain composition and structure of mesic and wet-mesic prairies, and few sites were burned at this rate. This appears to be causing long-term deterioration of many sites, and we propose that increased fire management will be needed to maintain these important natural areas.

Introduction

Vegetation monitoring

Monitoring prairies in a management context is an important objective for Chicago Wilderness scientists and land managers because this vegetation is vulnerable to changes in species richness, composition and structure when natural fire processes are altered (Leach & Givnish 1996, Bowles et al. 2002). It is common knowledge that burning is required to maintain tallgrass prairie (e.g. Collins & Glenn 1988, Collins & Wallace 1990). However, few studies have monitored the condition of Chicago region prairies in light of their management histories, and little specific information is available on fire frequencies needed to maintain species richness, composition and structure of this vegetation.

In this paper we report on our investigations of long-term vegetation change in high quality Chicago region prairies in relation to fire management. Baseline data collected by the Illinois Natural Areas Inventory (INAI) in 1976, as well as available management records, provided an opportunity for us to assess these changes. During the 2001 growing season we re-investigated 62 prairie stands that were originally sampled and ranked as grade A or B by the INAI in the Chicago region of northeastern Illinois (Bowles et al. 2003). White (1978) defined grade A as stable or undisturbed and grade B as late-successional following human disturbance. Some ecologists would define grade A as late-successional. The study sites occurred across dry habitats to wet-mesic habitats on silt–loam, sand, gravel, and dolomite substrates, with 25 grade A sites and 37 grade B sites, 33 of which had fire-management records. Our objectives were to 1) determine the present condition of these stands, 2) assess their vegetation changes since 1976, 3) correlate these changes with the frequencies at which they were burned over time, and 4) project vegetation trends and management needed to maintain these important natural areas. In particular, we were interested in learning how vegetation change corresponds to differences between grades (A vs B) and habitats (dry/dry-mesic vs mesic/wet-mesic).

Methods

All stands were sampled for species presence in 20 to 30 ¼-m^2 plots along transect lines that we surveyed to approximate original transect locations mapped by the INAI. We analyzed change over time in these sites using Species Richness Indices (Bowles et al. 2000), which include the total number of native species sampled (Sn), the average number of native species per plot ($\bar{x}$Rn), the Native Richness Index (NRI = Ln(Sn)*($\bar{x}$Rn), and an alien index (AI) representing the alien proportion of total species richness. For the 33 stands with fire-management records, we correlated change in species richness with how frequently the stands had been burned. We used two additional measures to assess temporal change in relation to fire. First, to determine how stand composition had changed, we calculated the percentage of species shared between the 1976 and 2001 data sets for each stand. We expected that grade A stands would stabilize with greater fire frequencies, which would be reflected by greater percent similarity within more frequently burned stands. We expected that grade B stands would not stabilize because greater fire frequencies should promote species replacement as they shift toward grade A conditions. For an additional measure of vegetation change, we calculated an index of compositional structure represented by the ratio of the relative abundance of woody to graminoid vegetation (W/G ratio). This ratio is usually less than 1.0, as grasses are structurally dominant in prairie. It increases as either woody presence increases or as grass and sedge presence decreases, which

Grade	Dry/ Dry-Mesic A	Dry/ Dry-Mesic B	Mesic/ Wet-Mesic A	Mesic/ Wet-Mesic B	Total A	Total B	Total A + B
1976	19	19	6	18	25	37	62
2001	19	11	5	13	24	24	48
% loss	0	42.1	16.7	27.8	4.0	35.1	22.6

Table 1. Abundance and percent loss of grade A and B prairies sampled by the INAI in 1976 and re-sampled in 2001.

represents a reduction in the fuel matrix needed to maintain prairie vegetation structure. We expected that greater fire frequencies would be associated with a decrease in this ratio.

Results and Discussion

Status and management of sites

In 2001, 77.4% of the original INAI prairie stands were relocated; only one of 25 grade A stands was lost, but 35.1% of the grade B sites had been destroyed (Table 1). This difference probably reflects greater interests in preserving higher quality sites, as well as public ownership of many of these sites at the time of the INAI. However, several grade A prairies on private land, such as the Wheeling Prairie, were destroyed during the inventory before they could be sampled. The loss of many grade B sites also represents a missed opportunity for restoration management. Many high quality railroad prairies remain unprotected and most appeared to have been rarely burned. These sites are refuges for undisturbed prairie vegetation that was maintained by fire through the 1960's (Harrington & Leach 1989), and still represent important benchmarks with potential for landscape linkage across parts of the Chicago region.

Our analysis of fire management records found that 54% of the sites were burned more than 20% of the time, a rate of 4 or more burns in 20 years. However, more than 80% of the sites were burned less than 40% of the time, a rate of less than 8 burns in 20 years. Species richness usually exceeded 10 native species per ¼ m^2 plot for the highest ranking stands in 2001. But this measure varied with both soil moisture and texture and tended to be lower for dry and dry-mesic sand prairies and for dolomite prairies (Table 2). The highest ranking sites were a mesic silt–loam prairie and a wet-mesic sand prairie, which averaged over 17 native species per ¼ m^2 with Native Richness Index values exceeding 70.

Change in native and alien species richness

Significant positive or negative changes in native species richness per plot occurred between 1976 and 2001 in more than 60% of all prairies, with a greater proportion of these sites

Table 2. *Highest ranking sites by drainage and substrate for INAI prairies based on species richness indices calculated from 2001 data. Sn = total native species sampled, x̄Rn = average number of species/plot, NRI = Ln(Sn)* x̄Rn.*

Site	County	Drainage	Substrate	Sn	x̄Rn	NRI
Belmont Prairie	DuPage	Dry-mesic	Silt-loam	56	14.50	58.37
Somme Prairie	Cook	Mesic	Silt-loam	72	17.67	75.57
Lyons Prairie	Lake	Wet-mesic	Silt-loam	49	13.05	50.79
Illinois Beach State Park	Lake	Dry	Sand	26	8.43	27.47
Illinois Beach State Park	Lake	Dry-mesic	Sand	57	10.84	43.83
Powderhorn Lake	Cook	Mesic	Sand	62	14.50	59.84
Spring Bluff	Lake	Wet-mesic	Sand	62	17.05	70.37
Murray Prairie	Kane	Dry	Gravel	39	14.20	52.02
Chicago Ridge	Cook	Mesic	Gravel	50	12.61	49.33
DesPlaines Conservation Area	Will	Dry-mesic	Dolomite	33	10.20	35.66
Lockport Prairie	Will	Wet-mesic	Dolomite	47	9.35	36.00

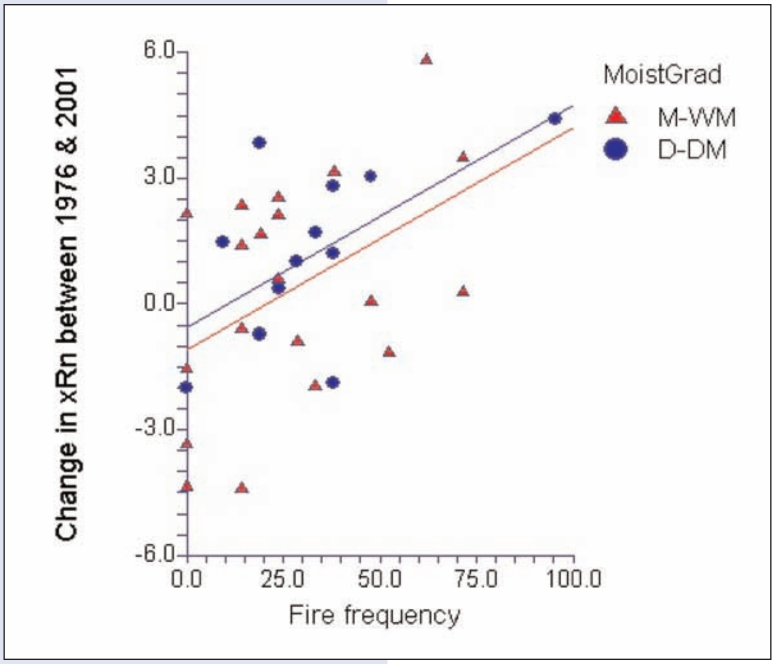

Figure 1. Change in plot richness of native species is positively correlated with fire frequency in mesic/wet mesic ($r^2 = 0.2071$, $P = 0.0438$) and in dry/dry mesic ($r^2 = 0.3518$, $P = 0.0326$) prairies.

increasing in this measure. These changes also varied with site grade, as only a small proportion of grade A sites increased in richness, while more grade B sites increased in richness. These differences seem intuitive, as grade B sites would have a greater potential to increase in native species richness with management, whereas grade A sites should be near maximum levels of native taxa. When burned sites were examined for change over time in relation to fire frequency, native species richness increased with increasing fire frequency (Figure 1). Our regression models predict that burning about 10% of the time would prevent a loss of species richness in dry/dry-mesic prairies, but burning at 20% is needed to maintain species richness in mesic/wet-mesic prairies. More frequent burning is probably needed in mesic and wet-mesic prairies because they accumulate litter at faster rates than drier sites. This appears to be good news, as most sites were burned more than 20% of the time.

We also found a significant increase over time in abundance of alien species in grade A and B prairies (Figure 2), and this change was not affected by fire frequencies. This was surprising, as burning is thought to reduce abundance of the alien blue grasses *Poa pratensis* and *P. compressa* (Bowles & Jones 2002), which are frequent in our study sites. However, other alien species such as the grass *Agrostis alba* and the buckthorn *Rhamnus frangula* also increased, and factors we did not measure may be affecting the abundance of alien species.

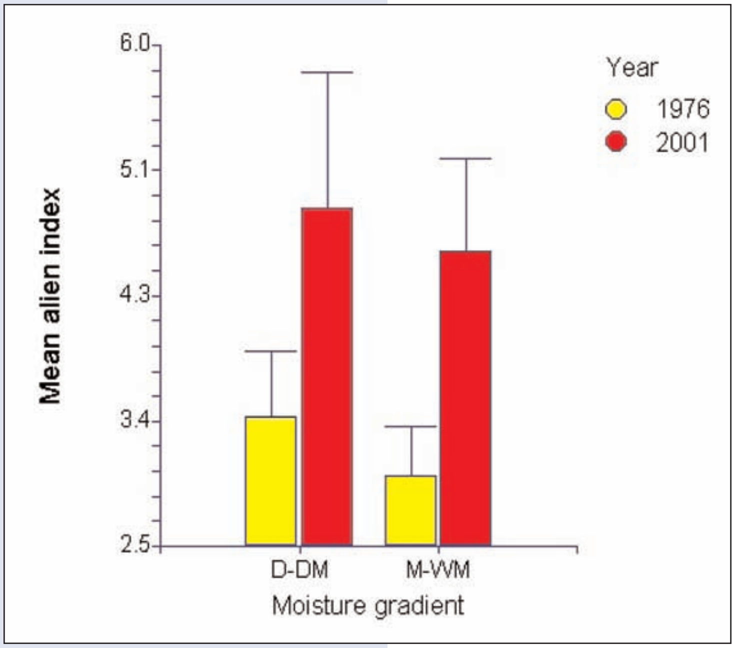

Figure 2. Abundance of alien plant species increased over time in dry/dry-mesic and in mesic/wet mesic prairies (P < 0.0001).

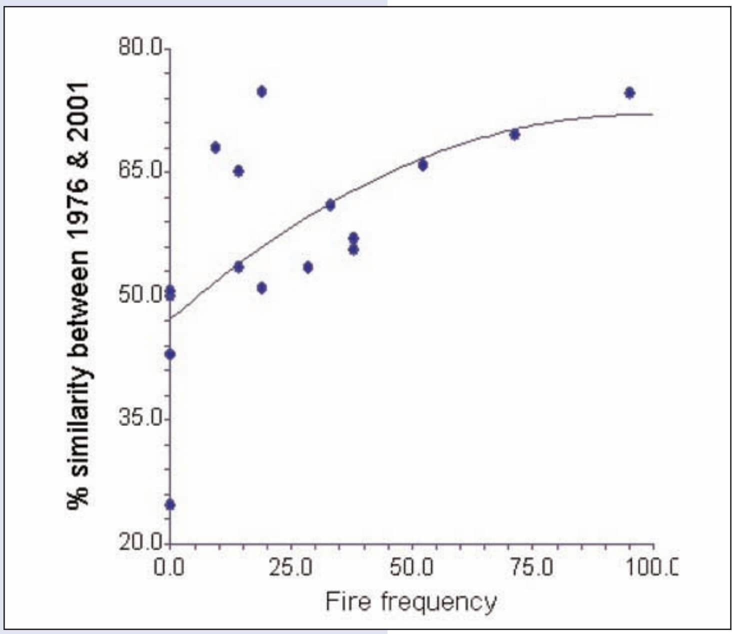

Figure 3. Percent similarity between 1976 and 2001 increased with increasing fire frequency in grade A prairies (r^2 = 0.5147).

Change in composition and structure

Composition of grade A and B prairies responded differently to fire over time. For grade A stands, greater fire frequencies since 1976 corresponded to greater similarity in species composition between each 1976-2001 data set, with 65% similarity achieved by 50% fire frequency (Figure 3). Thus, higher fire frequencies appear to stabilize native species composition in late-successional grade A prairies, while lower fire frequencies may de-stabilize them. Similarity within grade B stands did not have a significant response to fire (r^2 = 0.0137, P = 0.6956), indicating that they did not stablilize with greater fire frequency. This makes sense if fire-managed grade B stands are undergoing changes in composition, as well as increasing in native species richness.

The ratio of woody to graminoid vegetation increased significantly since 1976 in both grade A and grade B prairies, indicating a significant shift in vegetation structure (Figure 4). Change in the W/G ratio was negatively correlated with native species richness in mesic/wet-mesic stands (Figure 5), indicating that native species richness declines as vegetation structure deteriorates in these prairies. This relationship did not hold in dry/dry-mesic stands (r^2 = 0.019, P = 0.6531). Change in the W/G ratio was also negatively correlated with fire in mesic and wet-mesic stands (Figure 5), but not in dry and dry-mesic stands (r^2 = 0.0029, P = 0.8691). In this case, our regression model predicts that burning at 65% of the time (13 burns in 20 years) is needed to prevent an increase in woody vegetation or a decline in grasses in mesic and wet-mesic prairies. The lack of a significant relationship between fire frequency and change in this ratio in dry and dry-mesic prairie suggests that they do not require burning as frequently as do mesic and wet-mesic stands, or that more data are needed.

The effects of long-term fire-exclusion at the species level can be seen by examining changes in unburned mesic prairies, which underwent undesirable decreases and increases in

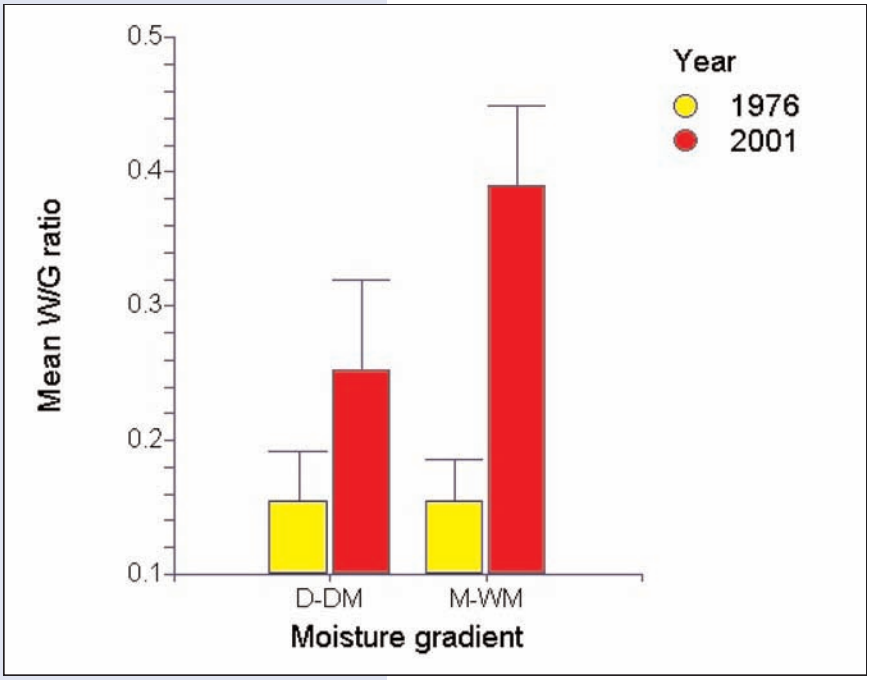

Figure 4. The ratio of woody to graminoid species increased over time in dry/dry-mesic and in mesic/wet mesic prairies (P = 0.0058).

Habit	Decreasing species	1976	2001
G	*Sorghastrum nutans*	55.00	1.45
G	*Sporobolus heterolepis*	58.33	10.14
F	*Allium cernuum*	58.33	5.80
F	*Lithospermum canescens*	21.67	2.90
F	*Physostegia virginiana*	18.33	0.00
F	*Ratibida pinnata*	36.67	10.14
F	*Solidago riddellii*	21.67	0.00
F	*Solidago rigida*	31.67	2.90
Habit	**Increasing species**	**1976**	**2001**
W	*Cornus racemosa*	3.33	49.28
F	*Helianthus grosseserratus*	2.67	33.33
F	*Solidago altissima*	1.67	46.38
F	*Solidago graminifolia*	0.00	20.29

Table 3. Plot frequencies of decreasing and increasing species in unburned mesic prairies between 1976 and 2001. All changes are significant with Chi-square analysis. Habitat: G = graminoid, F = forb, W = woody.

species composition (Table 3). Decreasing species included the characteristics prairie grasses *Sorghastrum nutans* and *Sporobolus heterolepis*, as well as a number of characteristic forbs. The increasing species were gray dogwood (*Cornus racemosa*), sawtooth sunflower (*Helianthus grossesserratus*), tall goldenrod (*Solidago canadensis*), and grass-leaved goldenrod (*S. graminifolia var. nuttallii*). This change in composition portends multiple threats to the quality of prairie vegetation. It represents a shift toward an increasing W/G ratio, which reduces the fuel base needed to maintain vegetation structure, a decline in indicator prairie grasses and forbs that signals a loss of biodiversity, and an increase in generalist species that are not fire-adapted and tend to dominate unburned prairies by spreading rhizomatously and overtopping smaller fire-adapted prairie species.

Conclusions

Our results indicate that a large proportion of high quality prairies has been protected and managed since completion of the INAI. When we use native species richness to evaluate the condition of these sites, most appear to have been either stable or to have increased in richness. In this case, burning at 10-20% of the time (depending upon landscape moisture gradient position), appears to appears to prevent loss of species richness. However, much greater burning frequencies (e.g. 50% or more) may be required to maintain composition and structure of high quality prairies, and less than 20% of the study sites were burned at this rate. Our subset of fire-managed sites represents about half

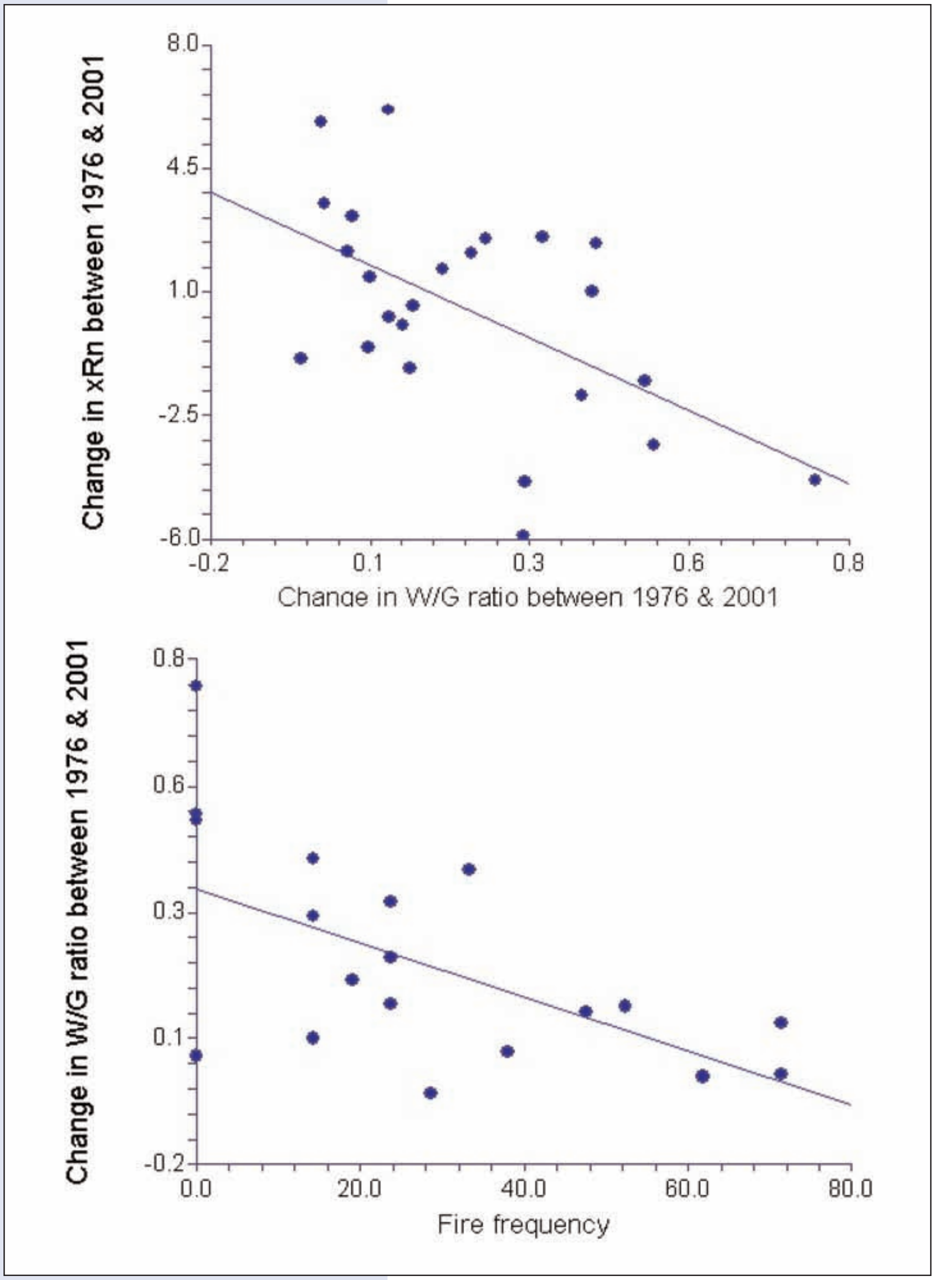

Figure 5. Upper: the plot richness of native species decreased over time as the ratio of woody to graminoid species increased in mesic/wet-mesic prairies (r^2 = 0.3711, P = 0.0044). Lower: the ratio of woody to graminoid species decreased over time with increasing fire frequency in mesic/wet-mesic prairies (r^2 = 0.3246, P = 0.0009).

of the total number of study sites; many of the remainder may have had even less frequent burning. As a result, our data suggest a long-term trend of deteriorating structure and composition, especially in mesic/wet-mesic prairies. The increased fire frequencies needed to reverse this deterioration will require careful application to prevent loss of fire-sensitive invertebrates that appear to require two consecutive years without fire to recover to pre-burn population levels (Panzer 2002, Pascoe 2003). Resolving this apparent conflict should be an important future objective of Chicago Wilderness managers and scientists. One solution may lie with rotating burned and unburned patches to enhance re-colonization after fire. However, this becomes more difficult on isolated small prairie remnants. Restoration of buffer areas to enlarge prairie preserves can enhance this approach. Similar strategies may apply for prairie-nesting birds, many of which also require unburned nesting habitat, as well as large habitat area (Herkert 1994).

Our data represent samples taken twice in a 25-year period and linked by fire frequencies. Clearly, more repeated sampling in relation to fire treatments is needed to better understand how burning maintains prairie species composition and structure. However, these data provide testable management prescriptions that predict that 1) native species richness can be maintained with fire frequencies of about 10-20%, depending upon habitat, 2) burn frequencies of 65% are needed to maintain vegetation structure in mesic/wet-mesic habitat, and 3) burn frequencies of about 50% are needed to stabilize grade A vegetation, and may enhance successional recovery of grade B vegetation. There are also other environmental factors that may be interacting with fire to affect changes in native and alien species composition. Increased browsing levels from increasingly larger deer numbers in Illinois are probably contributing to loss of forbs (Anderson et al. 2001), as well as increasing native generalist species such as the goldenrod *Solidago canadensis* (Anderson et al. *in press*), and possibly aliens. Altered hydrology and increasing sedimentation and pollution rates are linked with negative changes in wetlands, especially increased abundance of invasive species (e.g. Keddy 2000). These factors, as well as elevated nitrogen levels could be affecting the abundance of alien and native species in Chicago region prairies.

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