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Twenty-five Year Trends of Change in Prairie and Wetland Natural Areas in the Chicago Region of Northeastern Illinois

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Summary

We re-investigated 109 high quality (grade A & B) prairies and wetlands that were identified and sampled by the Illinois Natural Areas Inventory in 1976. Our objectives were to re-sample vegetation transects in these sites to 1) determine their present condition, 2) assess floristic changes over time, 3) correlate changes with fire management histories, and 4) project vegetation trends and make recommendations on management needed to maintain these important natural areas.

We found that 77 % of the original natural areas remained intact, with greater losses of grade B areas, especially wetlands. The majority of sites were also stable over time with respect to measures of native species richness. This corresponds to a 60 % proportion of prairie sites that were burned > 20 % of the time, and a similar proportion of wetlands burned > 10 % of the time. However, negative trends of change in vegetation structure and floristic composition occurred across most vegetation types. These changes indicate a long-term trend of decreasing abundance of characteristic graminoid and herbaceous prairie and wetland species, and increasing abundance of woody vegetation, early-successional or weedy native species and invasive alien species. We attribute these changes to the smaller proportion of prairies (41 %) and wetlands (32 %) receiving fire frequencies that appear necessary to maintain their composition and structure, as well as to wide-scale invasion of wetlands by narrow-leaved cattail. Our data suggest that no more that two consecutive years without fire may be necessary to maintain mesic and wet-mesic prairies, and that at least one fire every five years is needed for graminoid fens and sedge meadows. Although we lack supportive data, increased browsing from eastern white-tailed deer and altered wetland hydrology, water chemistry and sedimentation rates are probably also significant factors that are affecting change in prairies and in wetlands. Applied research is needed to determine how combinations of fire management, supplemental woody vegetation removal, and control of other environmental factors, can maintain high quality vegetation.

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INTRODUCTION

MONITORING VEGETATION CHANGE

Vegetation maintained by natural processes such as fire or hydrology is vulnerable to loss of plant species, change in structure, or invasion of alien plants when such processes are altered (Pickett & White 1985). As a result, monitoring the condition of vegetation over time is critical for conservation resource managers. Sampling among a large number of sites under variable management regimes, such as different fire frequencies, can also help strengthen our understanding of how to maintain vegetation. For example, in their study of Wisconsin prairies originally examined by Curtis (1959), Leach and Givnish (1996) attributed a decrease in species richness to absence of fire, but they did not compare burned and unburned sites. However, by re-sampling burned and unburned sand prairies originally sampled by the Illinois Natural Areas Inventory (INAI) in 1976, Bowles et al. (2003) found that burned prairies had increased richness of native species and decreased alien richness, while unburned prairies had decreased native richness and increased alien richness.

The INAI provides a large prairie and wetland data set and an important opportunity to assess conditions and temporal change in Chicago region natural areas (Bowles & Jones 1999). Few studies have re-examined the condition of INAI sites, especially in light of their management histories. Little information is available on specific fire intervals needed to maintain this vegetation. However, two-year recovery periods following fire are recommended for fire-sensitive insects (Panzer 2002), and birds (Herkert 1994). In contrast, more frequent burning (e.g., biennial or annual) may be most effective in reducing alien species and in restoring or stabilizing prairie composition and structure, or in maximizing prairie species richness (Tester 1989, Bowles et al. 2002). Although prairie fens and sedge meadows are dependent upon hydrology, they are also assumed to be fire-dependent, and little experimental data are available to project fire frequencies needed to maintain this vegetation. In graminoid fen, Bowles et al. (1996) found that annual fire increased graminoid importance and reduced forb cover. In sedge meadows, Kost & De Steven (2000) found no difference between burned and unburned sites after seven years, and recommended several years between fires to maximize richness.

OBJECTIVES

To assess the condition of high quality Chicago region prairies and wetlands, during the 2001-02 growing seasons we re-investigated 84 prairies, savannas and wetlands that were identified and sampled by the INAI in the Chicago region of northeastern Illinois in 1976 (Table 1). These sites were classified by the INAI into natural communities based on substrate and soil moisture gradient classes (White & Madany 1978, 1981). The natural quality of each site was also graded by the INAI in 1976 based on degree of human-caused disturbance and stage of plant succession following disturbance. In this grading system, Grade A represented comparatively undisturbed late-successional vegetation, grade B represented moderately disturbed mid-successional, grade C heavily disturbed early-successional, and grade D very heavily disturbed early successional vegetation (White 1978). Usually, only grade A or B sites were sampled, although several grade C savannas were sampled to represent the best know examples of savanna vegetation (Table 1).

Our objectives were to resampling the INAI transects in order to 1) determine the present condition of vegetation in the transect areas, 2) quantify floristic changes in these sites by comparing their 1976 and 2001-2 data sets, 3) correlate these changes with fire management histories, and 4) project vegetation trends and make recommendations on management needed to maintain these important natural areas.

METHODS

DATA COLLECTION

Prairies and savannas were re-sampled in 2001. These included 23 dry and dry-mesic sites and 33 mesic and wet-mesic sites, which occurred on silt-loam, sand, gravel, and dolomite substrates (Table 1). Wetlands were re-sampled in 2002, and included 4 calcareous floating mats, 10 graminoid fens, 10 sedge meadows, two marshes, one calcareous seep and one graminoid bog (Table 1). Following original INAI methods, all sites were sampled for species presence in 20-30 circular 1/4m^2 plots placed randomly along transect lines mapped by the INAI on 1:7920 scale overlays of ASCS aerial photos. We also used GPS and ARC/INFO to provide coordinates and digital maps of transects, which are available as separate shapefiles. The general condition of each sites was assessed during sampling, and fire-management histories were obtained from land managers for 39 prairie sites and for most fens and sedge meadows. These records were assumed to be complete for the 1980-present time period, which covers > 20 years. We did not use records for the 1976-79 time period because they appeared incomplete, and represent a 4-year period that would have had little effect on the condition of vegetation that we sampled during 2001-02. Inspection of sampling data revealed some problematic identifications for temporal comparisons, primarily because of greater taxonomic precision with difficult species in 2001. This required collapsing some species into generic groups in order to avoid unwanted effects on change in species richness. For prairies, we collapsed species into *Melilotus* spp., a *Poa compressa/pratensis* group, *Rosa* spp., a *Rubus flagellaris/hispidus* group, a *Viola* spp. group exclusive of *V. sagittata*, and a *Carex* spp. group. For wetlands, we also used *Poa compressa/pratensis* and *Viola* spp. groups.

DATA ANALYSIS

Site-level changes

For statistical purposes, we assumed that data could be compared over time as independent random samples of homogeneous vegetation. We base this assumption on the availability of detailed vegetation maps that distinguished among natural community types by quality grade and also provided transect locations, as well as on our observations. We focused on species richness as a primary metric in our analysis, as this measure is useful and critical for evaluating effects of management and restoration (e.g., Bowles et al. 2002, Korb et al. 2003). We used the Species Richness Indices Program (Bowles et al. 2000) to provide basic statistics on each site, including species richness (S = total species sampled, Sn = total native), the average number of species sampled per plot ($\bar{x}$R = total species, $\bar{x}$Rn = native species), the Species Richness Index (SRI = Ln(S)*$\bar{x}$Rn), Native Richness Index (NRI = Ln(Sn)*$\bar{x}$Rn), and the Alien Component, or proportion, of alien species present (AC = SRI-NRI). Significance of temporal change in plot richness of native species ($\bar{x}$Rn) within each site was tested using t-tests. We also used this program to compare changes in relative abundance of graminoid, woody and forb vegetation, as well as changes in percent frequency of individual species.

Community-level changes in species richness

To test temporal changes within prairie and wetland groups, we used Repeated Analysis of Variance (RANOVA) in a General Linear Model with the Native Richness Index (NRI) and the proportion of alien species (AC) as performance variables, and drainage, quality grade and fire frequency as factors. Because we lacked fire frequency for all sites, it was added as an additional factor in separate RANOVAs for prairies and wetlands, in which testing for a significant interaction between fire and vegetation change over time was of primary interest (see Bowles et al. 2003). We also used linear regression to examine the relationship between fire frequency and change in NRI and AC in prairies and in fen and sedge meadow wetlands. As a comparison, we also evaluated the ability of the Floristic Quality Index (Swink & Wilhelm 1994) to differentiate between quality (A vs B), the effects of drainage and effects of time. This program uses a mean Coefficient of Conservatism (ranging from 1-10) that is subjectively assigned to species as a measure of their habitat fidelity. Here, $FQI = \bar{x}C * \sqrt{N}$, where $\bar{x}C$ is the average C value for all native species sampled, and N = total native species sampled.

In the prairie RANOVA, sites were nested within two factors: drainage (sites were collapsed into dry/dry-mesic and mesic/wet-mesic categories) and quality (INAI grade A or grade B). For prairie sites with fire management histories we added an additional factor to the analysis, using 1980-2001 two fire frequency categories of < 33% or ≥33%. In a 3-year rotation, < 33 % fire frequency results in ≥ 2 consecutive years without fire, thereby helping test how the recommended two-year recovery period following fire for fire-sensitive insects (Panzer 2002), and birds (Herkert 1994) will affect vegetation. Because fire frequencies represent continuous data, we also used linear regression to analyze the relationship between fire frequency and temporal change in NRI, and also the relationship between fire frequency and temporal change in $\bar{x}C$ values. Railroad prairies were excluded from most analyses because of their unknown management histories and often incomplete data sets (M. Bowles & M. Jones, pers. obs.). Because of their small sample size, the sand shrub prairie and savannas were also analyzed individually.

In the wetland RANOVA, sites were nested within calcareous floating mat, graminoid fen and sedge meadow community types. Because of their small sample sizes, marsh, bog and calcareous seep vegetation sites were analyzed individually. Because grade B sites were sampled only for graminoid fens and sedge meadows, we used INAI grade as a factor in a separate RANOVA for these vegetation types. We also added fire frequency as an additional factor for fens and sedge meadows with fire management histories. For this comparison, we used < 20 % and > 20 % fire frequencies as categories, assuming that wetlands may persist with greater fire intervals than prairies. Linear regression was used to examine the relationship between change in NRI in wetlands and fire frequency, as well as the relationship between native species richness and abundance of invasive native and alien species such as *Typha angustifolia* or *Lythrum salicaria*. Nomenclature follows Swink & Wilhelm (1994).

Community-level changes in composition

We used Multi-response Permutation Procedures (MRPP) on PC-ORD (McCune & Mefford 1999) to test whether INAI natural community types (Table 1) differed over time, using species frequencies as metrics within transect data sets. Euclidean distance was used as a distance measure with a rank transformed distance matrix. For sites that differed by $P < 0.10$ over time (mesic prairies, graminoid fens and sedge meadows), we also used MRPP to compare groups within years in burn frequency categories, using < 33 % vs ≥33% for prairies and < 20% vs > 20% for wetlands. For this comparison, we omitted wetlands that appeared to have deteriorated due to hydrological factors (M. Bowles & M. Jones, pers. obs.) We also used PC-ORD to ordinate these community types using Detrended Correspondence Analysis (DECORANA). To further evaluate compositional changes in structure of mesic prairies and graminoid fens (which had MRPP P values of <0.05), we compared relative abundance of native and alien graminoid and woody vegetation within each site over time.

We examined species-level changes over time within community types in prairies and in wetlands using Chi-square analysis to test whether the number of plots with or without a species present had changed over time. For prairies and savannas, these comparisons were made within dry-gravel prairies, mesic silt loam and gravel prairies, mesic sand prairies, wet mesic sand, silt and dolomite prairies and sand savannas. For wetlands, we made similar tests within calcareous floating mats, graminoid fens and sedge meadows. For these comparisons, multiple testing increases chances of significance in proportion to levels of α (e.g., 1 in 20 tests may be due to chance at $P < 0.05$). In such situations, acceptance levels may be adjusted by α/number of tests, although all differences at $\alpha < 0.05$ may be biologically important (Moran 2003). As a result, we report all changes significant at $P < 0.05$ in Appendix II, but discuss species changes at $P < 0.001$. To further understand compositional changes, we used a GLM two-factor ANOVA to test whether mean frequencies of increasing or decreasing (at $P < 0.05$) species differed in 1976 within community types. In this test, all species with zero frequencies in 1976 were excluded, and all values were log-transformed.

RESULTS

PRAIRIES AND SAVANNAS

We located and resampled 81 % of the original INAI prairie sites (Table 1), and found a greater proportion of surviving grade A sites (97 %) than grade B sites (69 %). One additional site, a dolomite prairie on private land, was inaccessible. Significant positive or negative changes in native species richness occurred between 1976 and 2001 in 57 % of all prairie sites, with about 36 % of the sites increasing in species richness and about 21 % decreasing in richness. Temporal change also varied with site quality grade. Half of the grade A sites remained stable while 25 % decreased in richness and 25 % increased in richness. In contrast, among grade B sites, 46 % increased in richness and 21 % decreased. Alien richness increased in almost all sites, regardless of quality, increasing in 89 % of all grade A sites and in 75 % of all grade B sites. We obtained fire frequency data on 76 % of the resampled sites, among which about 42 % were grade A and 58 % grade B. Over 60 % of the sites were burned > 20 % of the time and about 41 % were burned ≥33 % of the time. These sites were equally divided among grade A and grade B quality grades.

Changes in species richness

The Native Species Richness Index was sensitive to moisture gradient class, as well as to INAI grade. The NRI was higher in mesic/wet-mesic prairies than in dry/dry-mesic prairies and increased over time in grade B sites (Figure 1, upper panels). Species richness was also higher in grade A than in grade B prairies (Figure 1, center panels). Alien species richness increased significantly over time in both grade A and grade B sites, and did not differ between dry/dry-mesic and mesic/wet-mesic sites (Figure 1, lower panels). Abundance of alien species was not associated with a measurable decline in native species richness, nor with fire frequency. Temporal change in NRI was positively correlated with fire frequency in mesic/wet-mesic prairies, and only marginally associated with fire frequency in dry/dry-mesic sites (Figure 2). In 1976, species richness was similar in all grade A mesic and wet mesic sites, but had diverged by 2001, with greater richness in sites with ≥33 % fire frequency and less richness in less frequently burned sites (Figure 2). A similar change occurred in grade B mesic/wet-mesic sites, in which richness increased in sites with ≥33 % fire frequency (Figure 2). At the species group level, only woody plants showed a significant temporal change, by increasing in richness (P <0.0001), with a greater increase in woody plant richness in mesic/wet-mesic prairie than in dry/dry-mesic prairie (P = 0.048). Among the five savannas that were resampled, two declined in species richness, and one increased. The single sand shrub prairie remained stable.

Mean Coefficient of Conservatism values did not differentiate between A and B grade prairie vegetation, but responded to drainage and time, with higher $\bar{x}$C values assigned to dry/dry-mesic vegetation and to 1976 data. In contrast, FQI differentiated between A and B prairies but did not differ by drainage or time. Temporal change in $\bar{x}$C values was not significantly correlated with fire frequency in dry/dry-mesic prairies ($r^2 = 0.002$, P = 0.884) nor in mesic/ wet-mesic prairies ($r^2 = 0.152$, P = 0.081).

Changes in composition

Among prairie vegetation types, a significant compositional change occurred over time in relation to burn frequency for mesic prairies (Figure 3). Prairies with burn frequencies of < 33 % had greater change, with a temporal shift primarily along the first ordination axis, as well as significant or marginally significant declines in native species richness (Table 2). Sites with ≥33 % fire frequencies shifted primarily on the second axis, and none had significant declines in species richness. These compositional changes also corresponded to change in structure, with a decline in graminoid species and greater increase in woody vegetation in sites with < 33 % burn frequencies and a gain in graminoid abundance and only a slight increase in woody vegetation in sites with ≥33 % fire frequency (Figure 3). Differences in fire frequency also had effects at the species richness level. In the sites with low fire frequencies, decreases occurred for nine species, including the characteristic prairie grasses *Sorghastrum nutans* and *Sporobolus heterolepis* and forbs *Aster azureus, Lithospermum canescens* and *Solidago riddellii.* Increases occurred for the shrub *Cornus racemosa* and forbs *Solidago altissima, Solidago graminifolia nuttallii* and *Helianthus grossesseratus*. All species level changes are provided in Appendix II.

Although significant compositional changes over time were detected by MRPP only in mesic prairie, highly significant (P <0.001) changes in individual species frequencies occurred within most vegetation types. Species that decreased over time had significantly higher mean frequencies in 1976 than did species that increased over time, indicating that declining species were more likely to be community dominants (Figure 4).

In dry-gravel prairies, declines occurred for the dominant grass *Stipa spartea* and forb *Solidago nemoralis*, and increases occurred for the grass *Panicum liebergii* and forb *Helianthus rigidus*. In mesic silt loam and gravel prairies, decreases occurred for the dominant grasses *Sorghastrum nutans* and *Sporobolus heterolepis* and for the forbs *Antennaria* sp, *Baptisia leucophaea*, *Krigia biflora, Physalis virginiana* and *Senecio pauperculus*. Increasing woody and graminoid species in these mesic prairies included the shrubs *Cornus racemosa* and *Rosa* spp, the alien grasses Poa *compressa/pratensis*, as well as the native grass *Spartina pectinata* and a sedge (presumably *Carex tetanica*). Increasing forbs included the alien *Hieraceium caespitosum,* as well as the native forbs *Cirsium discolor, Helianthus grossesseratus, Solidago altissima, Solidago gigantea* and *Solidago gymnospermoides*. In mesic sand prairies; the dominant grass *Sporobolus heterolepis* and forb *Liatris spicata* both declined (at P < 0.05) while nine species increased. These included the alien shrub *Rhamnus frangula* and native shrub *Rosa* sp., the alien grasses *Poa compressa/pratensis* and *Panicum implicatum* and a sedge (probably *C. tetanica*). Increasing forbs in mesic sand prairies included *Allium cernuum, Arenaria lateriflora,* *Physostegia virginiana, Solidago altissima* and *Solidago gigantea*. In wet-mesic prairies, the forbs *Liatris spicata* and *Senecio pauperculus* were the only decreasing species, while five species increased. These included the shrub *Cornus racemosa,* the grass *Panicum implicatum,* the alien forbs *Lythrum salicaria* and the native forbs *Monarda fistulosa* and *Solidago altissima.*

In sand savannas, decreases occurred for the grasses *Andropogon scoparius* and *Panicum villosissimum* and for the forbs *Erigeron strigosus, Lupinus perennis, Rudbeckia hirta* and *Viola sagittata.* Increasing species in sand savanna included the sedge *Carex pensylvanica* and the forbs *Aster ericoides, Eupatorium rugosum* and *Solidago altissima.*

WETLANDS

We located and resampled 70 % of the original INAI wetland sites (Table 3), and found a greater proportion of surviving grade A sites (95.5 %) than grade B sites (39 %). Positive or negative changes in native species richness between 1976 and 2001 occurred in 54 % of all wetland sites, with about 36 % increasing in species richness and about 18 % decreasing in richness. Most increases occurred in sedge meadows, where half of all sites increased in richness, four remained stable and one decreased. Two graminoid fens increased in richness and two decreased in richness, with six remaining stable. Among calcareous floating mats, one increased in richness while one declined. Both marshes and the graminoid bog declined in richness, while the calcareous seep remained stable. Alien richness increased in all but one of the wetland sites (Table 3). We obtained fire frequency data on about 78 % of the sites, among which 68 % were grade A and 32 % were grade B. Among these sites, 60 % were burned > 10 % of the time, and 32 % burned > 20 % of the time.

Changes in species richness

Species richness was higher in fens and in calcareous floating mats than in sedge meadows, but did not change over time (Figure 5, upper left panel). Species richness also did not differ between grade A and B graminoid fens and sedge meadows in 1976 or in 2002. In 1976, alien species were sampled from only single fen, floating mat and sedge meadow transects. However, by 2002, alien species were absent from only one each of these vegetation types. As a result, alien species richness increased significantly over time across these sites (Figure 5, upper right panel). *Typha latifolia* and *Typha angustifolia* also increased over time in these wetlands (Figure 5, center panels). Native richness was not correlated with abundance of alien species nor with abundance of *Typha latifolia*; however, it was significantly negatively correlated with the abundance of *T. angustifolia* (Figure 5, lower panels). When fire was added as a factor to RANOVA of graminoid fens and sedge meadow, it added a significant interaction with time for native species richness, but not alien richness (Figure 6). Species richness increased with ≥20 % fire frequency, and the effect was more apparent in sedge meadows than in fens. Temporal change in NRI was also positively correlated with fire frequency in fens and sedge meadows (Figure 6).

Changes in composition

Significant or marginally significant changes over time occurred for graminoid fens (Figure 7) and for sedge meadows (Figure 8). Although graminoid fens did not differ between burn treatments, all sites shifted temporally along the first ordination axis, while site differences corresponded to the second axis. In addition, compositional structure of graminiod fens changed over time, with a decrease in graminoid species and an increase in woody species (Figure 7).

Sedge meadows differed, with most sites shifting temporally along the first axis, but individual site differences corresponded to both the first and second axis, indicating greater differentiation among sedge meadows than among fens.

In addition to significant compositional changes over time in fens and sedge meadows, highly significant ($P < 0.001$) changes occurred in individual species frequencies across all wetland vegetation types. See Appendix II. for individual species changes. As with prairies, species that decreased over time had significantly higher frequencies in 1976 than did species that increased over time, indicating that declining species were more likely to be community dominants (Figure 4).

In calcareous floating mats, 7 species decreased while 6 species increased over time. Decreasing species included the dominant grasses *Calmagrostis canadensis* and *Muhlenbergia glomerata,* and the forbs *Hypericum virginicum, Lycopus uniflorus, Lysimachia quadriflora, Menyanthes trifoliata,* and *Scutellaria epilobiifolia*. Increasing species included the sedges *Carex lacustris* and *Eleocharis elliptica, Typha latifolia,* the alien forb *Lythrum salicaria,* and the native forbs *Galium obtusum* and *Sparganium* sp.

In graminoid fens, decreases occurred for 17 species, and increases for 10 species. Decreasing graminoid species included the prairie grasses *Andropogon gerardii, Andropogon scoparius* and *Sorghastrum nutans*, the grasses *Muhlenbergia frondosa* and *Muhlenbergia glomerata*, and the sedges *Carex buxbaumii,* and *Carex sterilis*. Declining forbs included *Aster puniceus firmus, Gentiana procera, Lythrum alatum, Senecio pauperculus, Solidago graminifolia, Solidago ohiensis, Solidago riddellii, Solidago uliginosa* and *Thalictrum dasycarpum*. Increasing alien species included the shrub *Rhamnus frangula* and forb *Lythrum salicaria*. Increasing native graminoid species included the sedge *Carex stricta* and the bulrush *Scirpus acutis* and the forbs *Aster puniceus*, *Dryopteris thelypteris*, *Impatiens capensis*, *Lycopus americanus* and *Oenothera biennis*. In sedge meadows, 4 species declined while 7 species increased. Declining graminoid species were *Carex stricta* and the grass *Muhlenbergia frondosa*. Decreasing forbs were *Aster puniceus firmus* and *Pycnanthemum virginianum*. Increasing graminoid species were the sedge *Carex haydennii*, the spike rush *Elleocharis elliptica* and the cattail *Typha angustiolia*. Increasing forbs included the alien *Lythrum salicaria*, as well as *Galium labradoricum*, *Lycopus americanus, Pilea pumila* and *Polygonum punctatum*.

In the two marshes that were sampled, severe declines occurred for the dominant graminoid species including the grass *Calamagrostis canadensis* and the sedges *Carex lacustris* and *Carex lasiocarpa*, which was countered by a large scale increase in *Typha angustifolia*. In the single graminoid bog, *Carex haydenii*, formerly the dominant graminoid species, was not resampled. Other decreasing dominant species included the shrub *Salix pedicellaris* and the forbs *Lycopus virginicus, Lysimachia thrysiflora*, and *Potentilla palustris.* Increasing species included the cottongrass *Eriophorum angustifolim*. the fern *Dryopteris thelypteris*, and the shrub *Betula pumila*, all of which increased to 100 % frequency.

DISCUSSION

Our investigation of original INAI prairies, savannas and wetlands indicates that most high quality grade A sites in the Chicago Wilderness region have been protected since the original inventory in 1976. In comparison, the loss of about 40% of the grade B sites represents a missed opportunity for ecological restoration. This difference probably reflects agency interests in preserving the best quality sites first, and the fact that many high quality sites were in public ownership at the time of the INAI. Many lower quality grade B sites that were originally in private ownership may have been lost to private enterprise because of lower preservation priorities. However, many high quality railroad prairies remain unprotected and apparently un-managed. These sites are often 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.

In addition to the high survivorship of grade A natural areas, the large proportion of sites that either remained stable or increased in species richness suggests that most sites have been managed. This appears to correspond to the 60 % proportion of prairie sites that received > 20 % burn frequencies and the 60 % proportion of wetland sites with > 10 % burn frequencies. However, only 41 % of the prairies and 32 % of the wetland sites received the higher fire frequencies (i.e. ≥33 % for mesic/wet mesic prairies and > 20 % for wetlands) that appear necessary to maintain their composition and structure. In comparison with grade B sites, the greater stability of grade A sites also fits an expected model, as grade A sites can only deteriorate, whereas grade B can improve or decline. Indeed, more grade B sites increased in richness than did grade A.

The effectiveness of the Native Richness Index in measuring differences between INAI quality grades, as well as indicating temporal change in relation to fire frequency indicates that species richness is useful for monitoring the condition of natural areas, as well as responses to vegetation management (Bowles et al. 2002, Korb et al. 2003). The failure of $\bar{x}$C values to differentiate between A and B grade prairie vegetation, and their insensitivity to fire effects, indicates that these subjective values may not have the precision to assess management effects on high quality prairie vegetation. The contrasting ability of FQI to differentiate between A and B prairies, but not between different vegetation types, occurred because of the use of total species richness in its calculation, as species richness was sensitive to these factors. This indicates that the formula is confounded by disparate metrics (Bowles & Jones 1999, Bowles et al. 2000).

TRENDS OF CHANGE

Prairies and savannas

Despite the preservation and apparent stability of most high quality natural areas with respect to species richness, examination of compositional changes indicates that negative trends are occurring across most prairie vegetation types. These changes involve shifts in compositional structure that include: 1) a decline of formerly dominant species, 2) an increase in abundance of alien species, 3) an increase of formerly infrequent herbaceous species, and 4) an increase in abundance of woody vegetation. This trend appears to increase along a moisture gradient, with less change in dry-mesic habitat. In mesic prairies (where this trend is most evident) there is also an increase in relative abundance of woody vegetation and a decline in abundance of graminoid species, as well as a decline in native species richness. As these trends continue, vegetation will have less resemblance to the baseline composition and structure originally sampled by the INAI.

The decline in formerly dominant species represents a critical shift in vegetation structure because it involves dominant prairie grasses, which provide the fuel matrix that allows fire to maintain prairie (Collins & Gibson 1990), and their continued loss threatens to reduce the effectiveness of fire. The decline of a large number of formerly common herbaceous species further threatens to alter the identities of prairie vegetation types because it includes characteristic indicator species (*sensu* White 1978), such as *Baptisia leucophaea* and *Senecio pauperculus* in mesic prairie, *Valeriana ciliata* in mesic gravel prairie, *Parthenium integtrifolium* in mesic sand prairie and *Lupinus perennis* in sand savanna. Many of these are often considered modal or mid- to late-successional in silt-loam prairie (Curtis 1959, Havercamp and Whitney 1983, Swink and Wilhelm 1994). Such species display low rates of invasion or colonization after disturbance and establish late in successive stages of prairie restoration (Sperry 1983, Betz 1986, Schramm 1992, Betz 2000) and may be vulnerable to fire protection.

The increase in alien richness involves primarily the grasses *Poa compressa/pratensis* and *Agrostis alba,* and the shrub *Rhamnus frangula*.. The graminoid species tend to occupy interstitial spaces between dominant grasses, where they probably compete with forbs. *Rhamnus frangula* was rare at the time of the INAI, but spread widely during the 1980's and threatens to convert unmanaged mesic and wet mesic prairies to shrublands.

Coupled with increasing alien abundance is the increase in species that were formerly uncommon in prairie, which further threatens to alter structure of the fuel matrix, as well as alter the makeup of species assemblages. For example, shade from increasing abundance of the shrub *Cornus racemosa* will reduce the prairie grass fuel matrix, while abundance of short-statured graminoid species such as *Carex tetanica* and *Panicum implicatum* further reduces the fuel base. The suite of increasing herbaceous species includes many disturbance-adapted early- to mid-successional species, as well as generalists that are not obligate prairie species. The most widespread increasing forb, *Solidago altissima*, is the weediest of all native goldenrods and typically colonizes mid-successional stages of old fields where it spreads by rhizomes (Swink & Wilhelm 1994). This species also increases with deer browsing (Anderson et. al., *in review*).

Wetlands

As with prairies and savannas, the compositional structure of wetlands appears to be changing through decline of community dominant or characteristic species, increasing abundance of alien species and increasing herbaceous and woody species that were formerly rare. These changes are more advanced in wetlands than in prairies.

The decline in formerly dominant wetland species indicates a significant shift in vegetation structure because it involves loss of graminoid and herbaceous species. This trend appears to be most severe in marshes and calcareous floating mats, where formerly dominant species have been replaced to a large degree by *Typha angustifolia*. However, a similar process is evident in graminoid fens, where graminoid species have declined, and to a lesser extent in sedge meadows. As in prairies, these declines indicate reduction of the fuel matrix, which will reduce the effectiveness of fire in structuring vegetation - a critical process in fire-dependent graminoid fens (Bowles et al. 1996). Many of the declining herbaceous species in wetlands also serve as indicators of these high quality communities, where their decline indicates a critical change in composition and loss of characteristic community assemblages. For example, *Muhlenbergia glomerata* and *Solidago ohiensis* are characteristic graminoid fen species (White 1978), while *Carex sterilis*, and *Gentiana procera* are highly prevalent fen plants (Moran 1981). *Menyanthes trifoliata* is a characteristic species of calcareous floating mats in the Chicago region.

The increase in alien richness in wetland sites has more potential negative impact than in prairies because the two primary increasers, *Lythrum salicaria* and *Rhamnus frangula*, can completely dominate vegetation and alter vegetation structure. In addition, increasing abundance of *Typha angustifolia* now correlates with loss of native species richness, a trend not yet identified in prairies. The increases in *Scirpus validus* in calcareous floating mats and *Scirpus acutis* in graminoid fens also may have potential for reducing species richness due to the large structure of these bullrushes. Additional shifts toward greater shrub dominance, for example by

Cornus racemosa in fens, and *Betula pumila* and *Cornus stolonifera* in calcareous floating mats, parallels changes in prairies that may further reduce graminoid fuel species. Little information is available to understand the meaning of shifts in many other species in these wetland habitats.

FACTORS AFFECTING LONG-TERM CHANGES

Fire

Our long-term data support conclusions of others that fire is a critical factor in maintaining composition and structure of midwestern prairies (Curtis 1959, Henderson 1992, Leach & Givnish 1996, Bowles et al. 2003) and graminoid wetlands (Curtis 1959, White 1965, Davis 1979, Moran 1981, Zimmerman 1983, Bowles et al. 1996, Kost & De Steven (2000).

Although our vegetation data represent only two measures 25 years apart, the application of continuous fire frequency data during this period has strengthened the results. These data indicate that comparatively high fire frequencies have been important in maintaining prairies while low fire frequencies have contributed to loss of species richness, and that these effects operate differently in relation to moisture gradient position and quality. For example, our findings that dry/dry-mesic sites had less significant responses to fire frequency agrees with findings of others that these sites need less frequent burning because they have lower rates of species loss with fire exclusions (Henderson 1992, Leach & Givnish 1996, Bowles et al. 2003). For mesic/wet-mesic prairies, our regression analysis suggests that fire frequencies of < 20 % (i.e. < 1 fire every 5 years) will result in loss of species richness. When sites are analyzed by quality grade, our data suggest that grade A prairies are vulnerable to loss of species richness with < 33 % fire frequency, while grade B prairies will increase in richness with ≥ 33 % fire frequency.

Our data also suggest that fire exclusion has been a driving force in the compositional changes that we detected across most prairie vegetation types. These data are most compelling for mesic prairies, where direct comparison of sites with < 33 % vs ≥ 33 % fire frequencies indicated loss of dominant grass and forb species, as well as increases in the invasive native shrub *Cornus racemosa* and the early successional goldenrod *Solidago altissima*. The failure of alien species to decline with higher fire frequencies appears problematic, as *Poa pratensis* is said to decline with annual or biennial burning (Towne & Owensby 1984, Henderson 1992, Svedarsky et al. 1986, Abrams & Hulbert 1987, Bowles et al. 2003). However, none of the mesic/wet-mesic sites had 100 % fire frequencies, preventing a direct comparison.

Our analysis of fire effects on graminoid fens and sedge meadows also produced meaningful results, despite the co-dependence of these wetlands upon hydrological processes and their sensitivity to water chemistry. Our data suggest that higher fire frequencies have been important in maintaining species richness in fens and sedge meadows, and that frequencies of < 10 % (i.e. < 1 fire every 10 years) will lead to loss of species richness. Species richness also increased over time with > 20 % fire frequency in these habitats, but the effect was most apparent in sedge meadows. This suggests that fire frequencies of ≥1 fire every 5 years are most likely to increase species richness in these wetlands. Kost & De Steven (2000) also indicated that non-burn intervals of ≥two consecutive years would maximize richness in sedge meadows by allowing regeneration of annuals after removal of litter. Alien richness appears to be less sensitive to fire in wetlands than in prairies, as it increased with either < 20 % or > 20 % frequency; however, it was slightly lower in more frequently burned fens in 2001. This effect probably reflects the biology of invasive wetland species. Perennial graminoids such as *Phragmites communis*, *Phalarus arundinacea* or *Typha angustifolia*, as well as *Lythrum* *salicaria*, survive dormant season fires as underground organs, from which they perennate during the growing season.

Environmental factors

Multiple environmental factors may be interacting with fire to affect changes in native and alien species richness in both prairies and wetlands. The presence of large deer herds throughout the Chicago region could be contributing to loss of forbs that are preferred as food, as well as causing increases in species that they tend to avoid as food. For example, increasing deer browsing results in selective reduction of many tallgrass forbs (Anderson et al. 2001), as well as causes an increase in *Solidago altissima* in high quality prairie (Anderson et al. *In review*). Altered hydrology and increasing sedimentation and pollution rates also may be linked with changes in wetlands, especially the increased abundance of alien and *Typha* species (Wilcox et al. 1985, Keddy 2000, Woo & Zedler 2002, Werner & Zedler 2002). For example, invasion by large rhizomatous species is often correlated with increased Nitrogen and Phosphorous from human impacts as these nutrients limit vegetation growth in wetlands (Verhoeven *et al.* 1996). Deposition of these nutrients also could be affecting increased abundance of alien species in tallgrass prairie, such as forage grasses, but few data are available. Once established, alien species also may have the capacity to further alter soil nutrient cycling processes, possibly in a feedback system (Ehrenfeld 2003).

MANAGEMENT AND RESEARCH APPLICATIONS

Vegetational changes are often interpreted as natural and expected (Pickett et al. 1992). However, the documented changes in composition and structure in this study represent shifts away from baseline conditions described in 1976. These original conditions provide a necessary context for management and restoration (Aronson et al. 1995). The greatest management needs shown by comparison with 1976 conditions are to 1) restore small-scale species richness to sites in which this measure has declined, 2) restore compositional structure by reversing the decline in dominant graminoid species and increase in woody vegetation 3) reverse the compositional shifts in vegetation that involve reduction of formerly dominant or characteristic species and increased abundance of formerly rare generalist species and 4) reverse the widespread increase in abundance of alien species.

Fire management is the crucial tool needed to restore compositional structure to prairies. Fire selects for greater abundance and cover of graminoid fuel species, which further structure prairie vegetation by competitive interactions with their fibrous root systems, and also reduces litter and promotes survival of forb species and greater species richness (Weaver & Rowland 1952, Hulbert 1969, Kucera & Koelling 1964, Collins 1987, Gibson & Hulbert 1987, Collins & Gibson 1990, Bowles et al. 2003). However, the timing and frequency of burning regulate grass cover and species richness, as well as effects on alien species (Collins & Glenn 1988, Collins & Gibson 1990, Bowles et al. 2003). Our data indicate that in mesic/wet-mesic prairie, fire frequencies of > 20 % (i.e. > 1 fire every 5 years) are needed to prevent loss of species richness and probably prevent deterioration of prairie structure. However fire frequencies of at least 33 % (i.e. no more than two consecutive years without fire) should enhance or maintain species richness and vegetation structure. Frequencies of 33 % also appear compatible with the 2-year non-burn intervals recommended for persistence of prairie invertebrates and birds (Panzer 2002, Herkert 1994). However, control of alien grasses may require more frequent burning (i.e. annual or biennial), as well as growing season applications (Towne & Owensby 1984, Henderson 1992, Svedarsky et al. 1986, Abrams & Hulbert 1987, Bowles et al. 2003). More direct experimentation is needed to test the strength of our temporal data, and to assess fire frequencies needed for dry and dry-mesic prairies. More monitoring and experimentation is also needed to assess fire frequencies needed to maintain and restore savanna vegetation while maintaining critical animal species. Tester (1989) found that 2-year burn/non-burn cycles maximized prairie species richness in sand savanna, and Bowles & McBride 1998) found that less than annual fires altered savanna canopy structure.

Fire management also appears important for restoring compositional structure to wetlands, especially graminoid fens (Bowles et al. 1996) and sedge meadows (Kost & De Steven 2000). Our data suggest that frequencies of > 10 % (i.e. > 1 fire every 10 years) may prevent loss of species richness and probably loss of vegetation structure. Fire frequencies of > 20 % (i.e. > 1 fire every 5 years) are probably more realistic for maintaining or restoring graminoid wetlands, but applied experimentation is also needed to test these suggestions. However, no data are available on fire frequencies needed to maintain wetland animal species. More work is needed to understand the degree to which altered hydrology and water chemistry are affecting compositional change in Chicago region wetlands. Unless other environmental factors causing the increase of alien and invasive plant species in wetlands can be controlled, fire management may be ineffective in maintaining graminoid wetland vegetation.

Removal of invasive alien and native shrubs is an essential supplementary management tool for reduction of woody vegetation, especially in both prairie and wetland habitats where loss of graminoid fuel structure will prevent successful fire management. Limited data also indicate that continued reduction of eastern white–tailed deer herds will also be needed to help maintain floristic composition in prairie habitats.

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Table 1. Number and grade of graminoid natural communities (White 1978) sampled by the Illinois Natural Areas Inventory in the Chicago Wilderness Region. Either Grade A or B communities were sampled at each natural area, while grade C sites were sampled when grade A or B communities were not found for a natural community. Zeros (0) indicate that sampling data were unavailable. Parentheses indicate number of sites re-sampled in 2001-02.

Natural community classification		No. of A	No. of B	No. of C
PRIMARY				
Lakeshore	Foredune	1 (1)	0	0
PRAIRIE				
Silt-loam prairie	Dry-mesic	4 (4)	3 (2)	0
	Mesic	7 (7)	8 (5)	0
	Wet-mesic	0	3 (2)	0
	Wet	0	1	0
Sand prairie	Dry	1 (1)	0	0
	Dry-mesic	3 (3)	0	0
	Mesic	2 (2)	7 (6)	0
	Wet-mesic	2 (1)	3 (3)	0
Gravel prairie	Dry	2 (2)	4	0
	Dry-mesic	1 (1)	3 (3)	0
	Mesic	2 (2)	1	0
Dolomite prairie	Dry-mesic	1 (1)	1 (1)	0
	Wet-mesic	0	3 (2)	0
Shrub prairie	Sand	0	1 (1)	0
SAVANNA				
Silt-loam savanna	Mesic	0	0	1 (1)
Sand savanna	Dry	1 (1)	0	0
	Dry-mesic	2 (2)	2 (1)	1 (1)
WETLAND				
Marsh		2 (2)	2	0
Graminoid bog		1 (1)	0	0
Fen	Graminoid fen	8 (7)	8 (3)	0
	Calcareous floating mat	4 (4)	1	0
Sedge meadow		6 (6)	7 (4)	0
Seep & spring	Calcareous seep	1 (1)	0	0
TOTAL		51 (49)	56 (33)	2 (2)

Table 2. Species richness index values for INAI prairies & savannas sampled in 2001. Ranked by substrate, grade, and NRI in 2001. T-test values indicate probabilities that xRn did not increase (+) or decrease (-) between 1976-2001. Significant differences are in **bold**; at $P < 0.05$, 1 of 20 could be due to chance. Sn = total native species sampled, xRn = native species per plot, NRI - Ln(Sn) * xRn, AC = alien component of species richness. Change in NRI & AC is the + or - change between 1976-2001. D = Dry, DM = dry-mesic, M = mesic, WM = wet mesic.

INAI Site #/Name	Grade	Substrate	Drainage-Vegetation	t-test prob.	xRn 2001	xRn sd	Sn 2001	NRI 2001	NIR Change	AC 2001	AC Change
254-2/Somme Prairie	A	Silt-loam	M-prairie	0.372-	17.67	3.71	72	75.55	-2.24	11.00	7.31
658-1/Shaw Prairie	A	Silt-loam	M-prairie	0.779+	13.97	4.12	87	62.37	4.77	1.22	-0.93
251-1/Wolf Road Prairie	A	Silt-loam	M-prairie	0.077-	14.20	3.16	60	58.14	-4.71	4.04	-1.72
1080-1/Vermont Cemetery Prairie	A	Silt-loam	DM-prairie	**<.001+**	14.35	2.23	51	56.42	19.97	6.29	3.27
901-1/Illinois C G RR Prairie	A	Silt-loam	DM-prairie	**<.001+**	12.25	3.09	53	48.64	26.60	8.92	8.92
900-1/Illinois C G RR Prairie	A	Silt-loam	DM-prairie	**<.001+**	10.80	3.41	41	40.11	14.66	5.57	3.73
393-1/Glen Brook N H S Prairie	A	Silt-loam	M-prairie	**<.001-**	9.00	2.68	46	34.46	-16.36	1.53	0.28
541-1/Penn Central RR Prairie	A	Silt-loam	M-prairie	**0.004-**	6.80	2.55	55	27.25	-5.67	6.87	2.82
396-1/Morton Grove Prairie	A	Silt-loam	M-prairie	0.067-	7.21	2.86	43	27.12	-5.38	4.18	1.48
540-1/Penn Central RR Prairie	A	Silt-loam	M-prairie	0.375-	6.50	3.55	46	24.89	-2.22	10.98	8.38
542-1/Penn Central RR Prairie	A	Silt-loam	DM-prairie	0.936-	6.60	2.06	41	24.51	-0.02	6.40	4.93
659-1/McLaughin Prairie	B	Silt-loam	M-prairie	**<.001+**	13.63	3.43	77	59.22	18.61	7.12	3.06
526-1/Belmont Prairie	B	Silt-loam	DM-prairie	**0.015+**	14.50	4.12	56	58.37	17.66	15.31	8.91
505-1/West Chicago Prairie	B	Silt-loam	WM-prairie	**0.024+**	13.05	3.22	63	54.07	13.58	6.48	4.91
1001-1/Lyons Prairie	B	Silt-loam	WM-prairie	0.051+	13.05	3.12	49	50.79	9.02	5.66	2.66
626-1/Burlington Prairie	B	Silt-loam	M-prairie	**<.001+**	12.95	2.95	45	49.30	25.05	6.25	1.48
888-1/Grant Creek Prairie	B	Silt-loam	M-prairie	0.946+	10.65	2.66	61	43.78	1.30	7.52	5.94
649-1/Wadsworth Prairie	B	Silt-loam	M-prairie	0.668+	9.44	2.06	39	34.58	3.46	1.57	-0.76
973-1/Chicago & N W RR Prairie	B	Silt-loam	DM-prairie	**<.001+**	7.35	2.28	30	25.00	8.55	3.85	3.14
718-1/Chicago & NW RR Prairie	B	Silt-loam	M-prairie	**0.037-**	5.36	2.19	23	16.82	-5.85	10.39	4.75
505-2/West Chicago Prairie	C	Silt-loam	M-savanna	**0.002-**	6.80	2.17	35	24.18	-10.86	14.36	2.94
1066-1/Illinois Dunes North	A	Sand	M-prairie	**<.001+**	17.05	3.14	62	70.37	30.43	4.98	-1.81
425-1/Dropseed Prairie	A	Sand	M-prairie	0.132+	14.40	3.03	53	57.17	9.55	12.92	9.67
461-1/Burnham Prairie	A	Sand	WM-prairie	**0.007+**	11.25	3.35	50	44.01	9.01	0.00	-2.52
1083-1/Illinois Beach S P	A	Sand	DM-prairie	0.262-	10.84	2.75	57	43.83	0.20	4.68	1.68
498-1/Wentworth Prairie	A	Sand	DM-prairie	**0.012-**	10.25	2.84	66	42.94	-9.09	1.67	-3.01
499-2/Sand Ridge Nat. Preserve	A	Sand	DM-prairie	0.159+	10.33	3.01	55	41.41	3.01	3.80	0.71
500-1/Thornton F H S Prairie	A	Sand	DM-savanna	**0.002-**	8.10	2.47	74	34.86	-7.92	3.30	-0.25
1083-2/Illinois Beach S P	A	Sand	D-prairie	**0.014+**	8.43	2.10	26	27.48	6.32	2.74	0.56
1083-4/Illinois Beach S P	A	Sand	D-savanna	0.148+	7.07	1.98	36	25.32	3.90	3.41	1.26
499-1/Sand Ridge Nat. Preserve	A	Sand	DM-savanna	**0.025-**	6.50	1.50	45	24.74	-6.98	0.54	-2.09
1083-3/Illinois Beach S P	A	Sand	D-dune	0.652-	5.93	1.66	28	19.77	1.85	0.77	0.77
1071-1/Powderhorn Lk & Prairie	B	Sand	M-prairie	**<.001+**	14.50	4.14	62	59.84	23.94	3.33	-1.27
504-1/Thorton-Lansing Rd Zander's Wds	B	Sand	WM-prairie	**0.013+**	12.27	3.33	65	51.21	8.46	2.99	1.70
400-1/Gensberg-Markham Prairie	B	Sand	M-prairie	**0.014+**	11.60	3.60	68	48.95	10.56	8.08	4.00
902-1/Munch Area	B	Sand	WM-prairie	**0.001-**	9.80	2.53	59	39.96	-15.87	4.08	-0.92
934-1/Vesley-Simpson	B	Sand	M-prairie	0.437+	10.75	1.74	36	38.52	-0.34	5.56	0.21
500-2/Thornton F H S Prairie	B	Sand	M-prairie	**0.002-**	5.59	2.40	30	19.02	-12.04	3.95	0.49
1047-1/Hitts Siding	B	Sand	M-prairie	0.224+	9.30	2.85	40	34.31	4.11	5.66	3.58
934-2/Vesley-Simpson	B	Sand	M-shrub prairie	0.821-	9.40	2.44	36	33.69	1.03	2.83	0.52
935-1/Braidwood Sand Prairie	B	Sand	DM-savanna	**0.015+**	7.70	2.35	51	30.28	6.41	0.54	-0.49
502-1/Tollgate Prairie	B	Sand	M-prairie	0.014-	5.59	2.40	30	19.02	-3.55	3.95	2.57
426-1/Dolton Avenue Prairie	B	Sand	WM-prairie	<.001-	3.85	2.58	25	12.39	-23.33	3.60	3.17
461-2/Burnham Prairie	C	Sand	DM-savanna	0.201+	8.45	2.65	41	31.38	7.40	11.24	5.25
630-1/Murray Prairie	A	Gravel	D-prairie	0.432-	14.20	2.86	39	52.02	-1.37	3.64	0.53
398-1/Chicago Ridge Prairie	A	Gravel	M-prairie	0.556-	12.61	4.02	50	49.33	-0.63	1.10	-1.10
394-1/Shoe Factory Rd Prairie	A	Gravel	D-prairie	0.166+	12.70	1.63	41	47.16	7.37	3.17	0.90
253-1/Santa Fe Prairie	A	Gravel	M-prairie	**<.001-**	9.42	2.30	50	36.84	-15.36	0.68	-0.97
253-2/Santa Fe Prairie	A	Gravel	D-prairie	**0.003-**	7.33	2.37	45	27.92	-7.68	2.66	-0.26
391-1/Spring Creek Prairie	B	Gravel	D-prairie	**<.001+**	9.30	2.20	36	33.33	11.67	8.05	1.09
713-1/Cary Prairie	B	Gravel	D-prairie	**<.001+**	6.00	1.52	25	19.31	7.13	1.79	-1.19
700-1/Ski Hill Prairie	B	Gravel	D-prairie	0.492+	5.00	1.45	17	14.17	0.47	2.62	1.09
932-1/Lockport Prairie	A	Dolomite	DM-prairie	**0.001-**	7.32	2.21	43	27.54	-5.68	5.09	0.43
936-1/Lockport Prairie	B	Dolomite	WM-prairie	0.338-	9.25	3.01	49	36.00	-1.44	1.16	0.53
882-1/Lockport Prairie North	B	Dolomite	WM-prairie	**<.001+**	9.35	2.76	47	36.00	13.96	2.53	-1.07
889-1/Des Plaines Cons Area	B	Dolomite	DM-prairie	**<.001+**	10.20	1.85	33	35.66	14.98	6.58	5.68

Table 3. Species richness index values for INAI wetlands sampled in 2002. Ranked by grade and NRI in 2003. T-test values indicates probabilities that xRn did not increase (+) or decrease (-) between 1976-2003. Significant differences are **bold**; at P <0.05, 1 of 20 could be due to chance. Sn = total number of native species sampled, xRn = average number of native species per plot, NRI = Ln (Sn) * xRn, AC = alien component of species richness. Change in NRI . and AC is the + or - change between 1976-2002.

INAI Site #/Name	Grade	Natural Community Vegetation type	Ttest prob.	xRn 2002	xRn sd	Sn 2002	NRI 2002	Change in NRI	Change in AC
988-1/Mud Lake	A	Calcareous floating mat	0.089-	11.45	2.96	53	45.46	-5.45	2.01
1000-1/Lac Louette	A	Calcareous floating mat	0.079+	8.93	1.74	33	31.24	5.06	1.68
652-1/Fourth Lake	A	Calcareous floating mat	**<.001-**	8.30	3.05	30	28.23	-21.73	0.88
1012-2/Kettle Mor.	A	Calcareous floating mat	**0.014+**	5.90	1.21	19	17.37	3.21	0.00
		Mean		**8.65**		**34**	**30.57**		
537-1/Bluff Sp. Fen	A	Calcareous seep	0.289+	7.93	3.17	55	31.79	5.30	0.82
1014-1/Elizabeth Lk.	A	Graminoid Bog	**0.022-**	5.75	2.27	18	16.62	-7.98	0.46
987-1/Turner Lake	A	Graminoid Fen	**<.001+**	15.55	3.36	74	66.93	26.56	1.07
662-1/Tower Lk. Fen	A	Graminoid Fen	0.872+	13.15	2.54	52	51.96	1.24	6.70
1013-1/Stearn's Fen	A	Graminoid Fen	**0.021-**	11.60	2.48	55	46.49	-8.28	1.16
1012-1/Kettle Mor.	A	Graminoid Fen	**0.034+**	11.20	3.00	43	42.13	8.80	1.79
712-1/Spring Grove	A	Graminoid Fen	0.204-	9.30	3.36	49	36.19	-2.61	0.33
421-1/Palos Fen	A	Graminoid Fen	1.00+	9.55	2.01	42	35.69	2.02	0.79
1011-1/Spr. H.F. Fen	A	Graminoid Fen	**0.004-**	8.60	2.19	44	32.54	-6.63	0.38
1015-2/Boone Creek	B	Graminoid Fen	0.227-	12.50	2.98	53	49.63	-2.33	2.10
708-1/Bates Fen	B	Graminoid Fen	0.841+	10.95	3.20	51	43.05	3.95	4.02
701-1/Lk. In H. Fen	B	Graminoid Fen	0.400-	6.65	1.53	21	20.25	-3.90	5.50
		Mean		**10.44**		**46**	**40.13**		
988-2/Mud Lake	A	Sedge Meadow	**<.001+**	10.80	2.33	34	38.08	16.26	2.80
628-1/Fearsons Crk.	A	Sedge Meadow	**<.001+**	10.25	2.59	38	37.29	11.96	4.68
1011-2/Sp.H.Fm.Fen	A	Sedge Meadow	**0.019+**	7.75	1.77	33	27.10	7.48	0.81
712-2/Spring Grove	A	Sedge Meadow	0.117-	7.05	1.70	38	25.64	-0.56	0.73
969-1/South Elgin	A	Sedge Meadow	**<.001-**	4.85	1.46	21	14.77	-6.97	0.75
709-1/Weingart Rd	A	Sedge Meadow	0.788-	4.35	1.50	22	13.45	1.40	2.63
936-2/Lockport	B	Sedge Meadow	**<.001+**	9.32	2.48	37	33.65	14.70	0.39
1015-1/Boone Creek	B	Sedge Meadow	**0.015+**	8.10	2.29	40	29.88	8.98	0.00
886-1/Hickory Creek	B	Sedge Meadow	0.147-	6.15	2.54	33	21.50	-3.39	2.51
701-3Lk in the Hills	B	Sedge Meadow	0.105+	5.10	1.65	20	15.28	2.85	4.04
		Mean		**7.35**		**32**	**25.57**		
707-1/Cotton Creek	A	Marsh	**<.001-**	2.20	2.02	13	5.64	-16.92	0.82
1002-1/Wauc. Bog	A	Marsh	**<.001-**	4.30	1.17	13	11.03	-17.56	-0.30
		Mean		**3.25**		**13**	**8.335**		

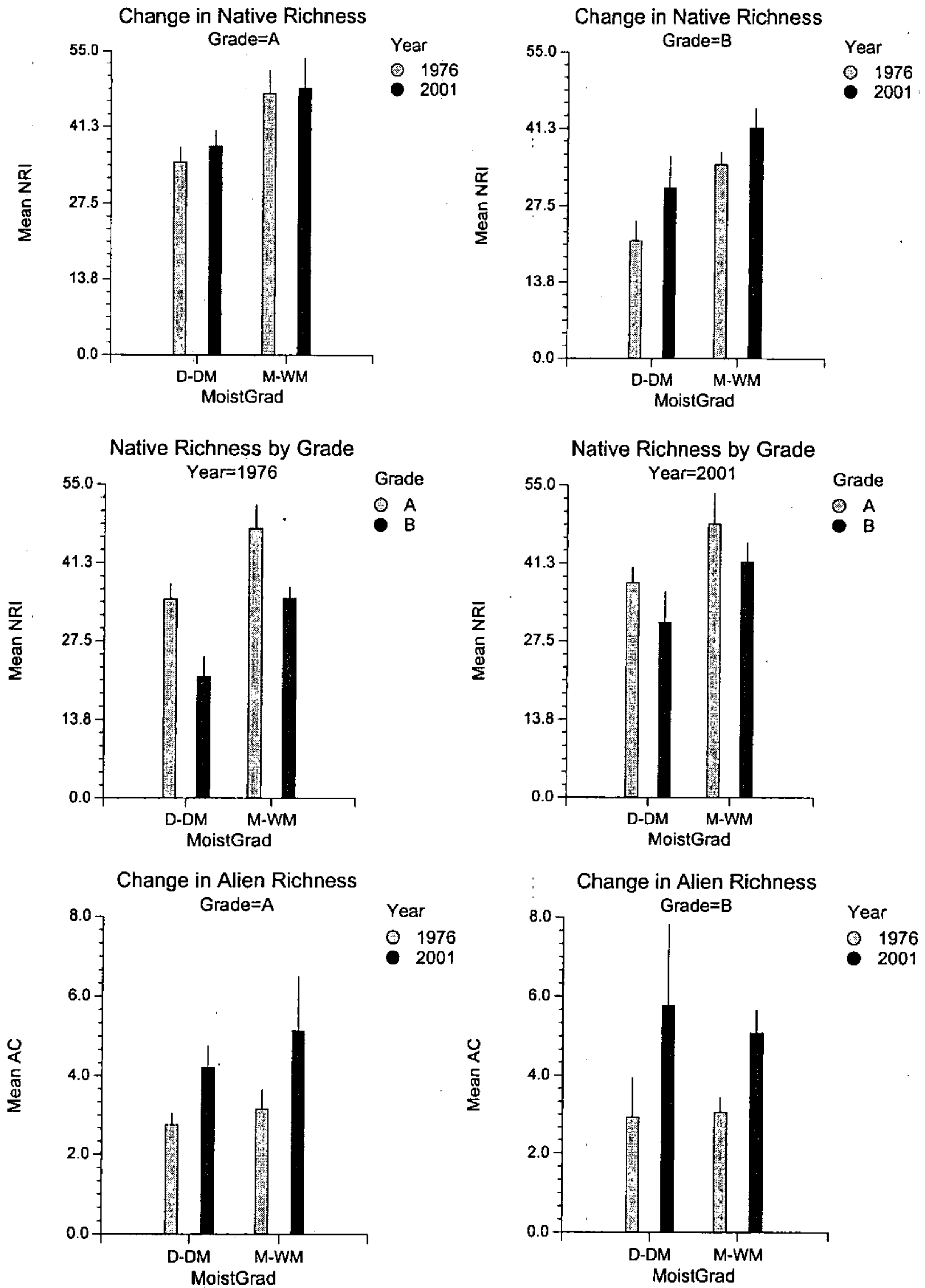


Figure 1. Temporal change in mean (+ std. err.) Native Species Richness Index (NRI) and Alien Component of species richness (AC) in dry/dry-mesic (D-DM) and mesic/wet-mesic (M-WM) prairies. RANOVA probabilities: NRI (moisture gradient < 0.001, grade = 0.002, year = 0.037, grade x year = 0.073), AC (moisture gradient = 0.700, grade = 0.345, year = 0.004, grade x year = 0.121).

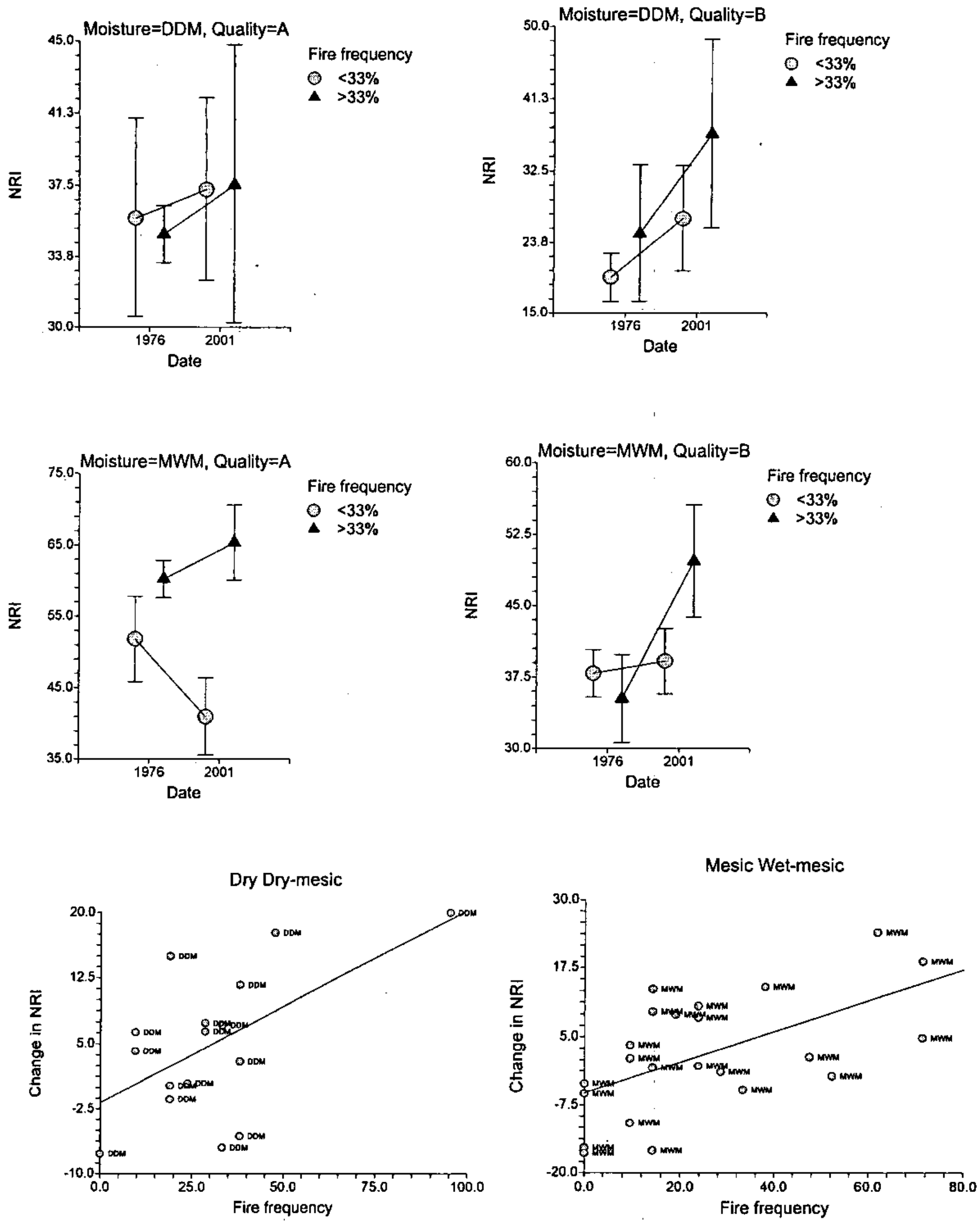
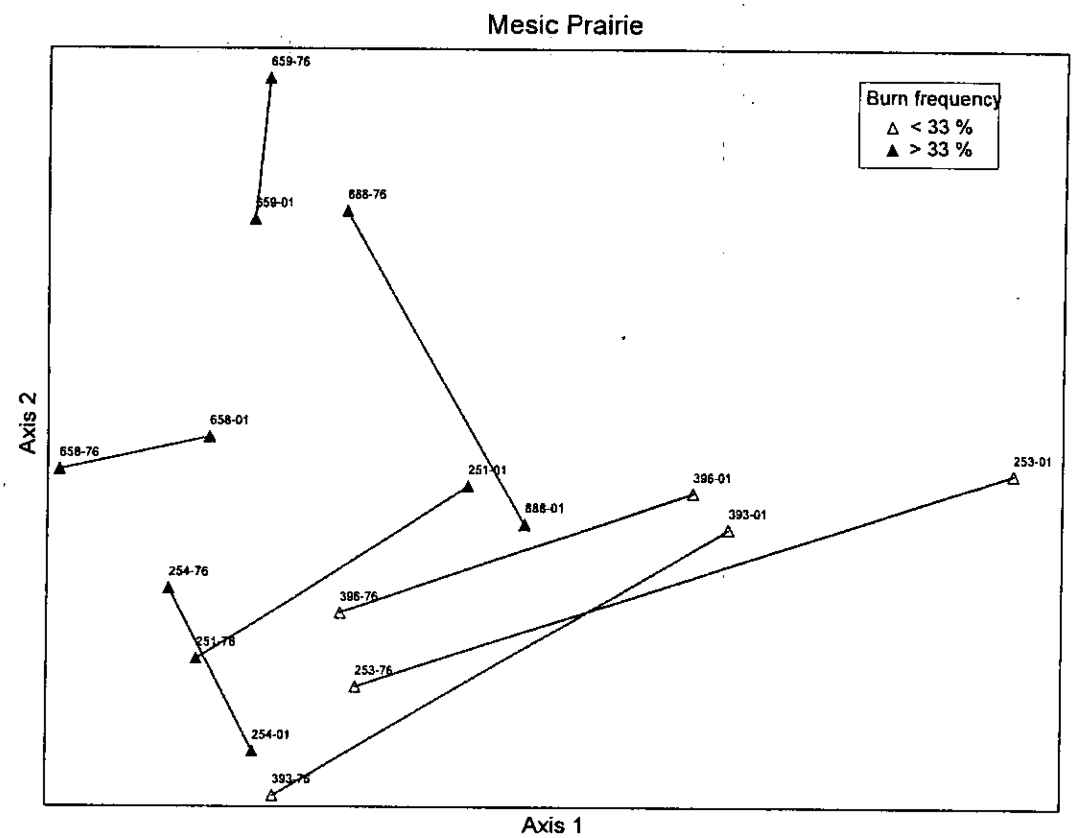


Figure 2. Upper panels: fire effects on mean (+ std. err.) change in Native Richness Index (NRI) in grade A and grade B quality dry/dry-mesic (DDM) and wet/wet-mesic prairies (MWM). RANOVA probabilities: Quality x Year = 0.002, Fire x Year = 0.003), Moisture x Fire x Year = 0.044. Lower: temporal change in NRI was positively correlated ($r^2 = 0.414$, P = 0.0009, y = -5.2196 +0.2781 * Fire frequency) with fire frequency in mesic wet-mesic prairie, but was only marginally correlated ($r^2 = 0.208$, P = 0.0745 -1.764 +0.2201 * Fire frequency) in dry dry-mesic prairie.



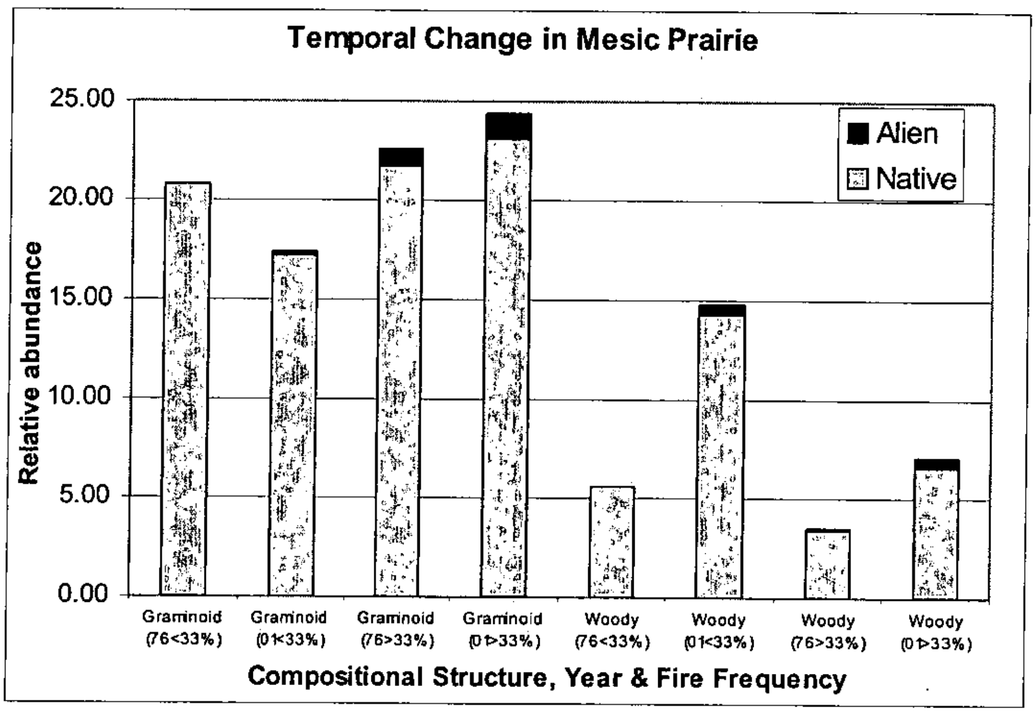


Figure 3. Upper: DECORANA ordination of temporal change in mesic silt-loam and gravel (No. 253) prairies with ≥33% and < 33% burn frequencies. Vectors indicate change between 1976 (site codes ending in 76) and 2001 (site codes ending in 01). MRPP: 1976-2001 ($P = 0.033$), 1976 fire ($P = 0.284$), 2001 fire ($P = 0.006$). Lower: temporal change in compositional structure of mesic silt-loam and gravel prairies with ≥33% and < 33% burn frequencies. Chi-square probability of no temporal difference in structure between different fire frequencies is <0.001.

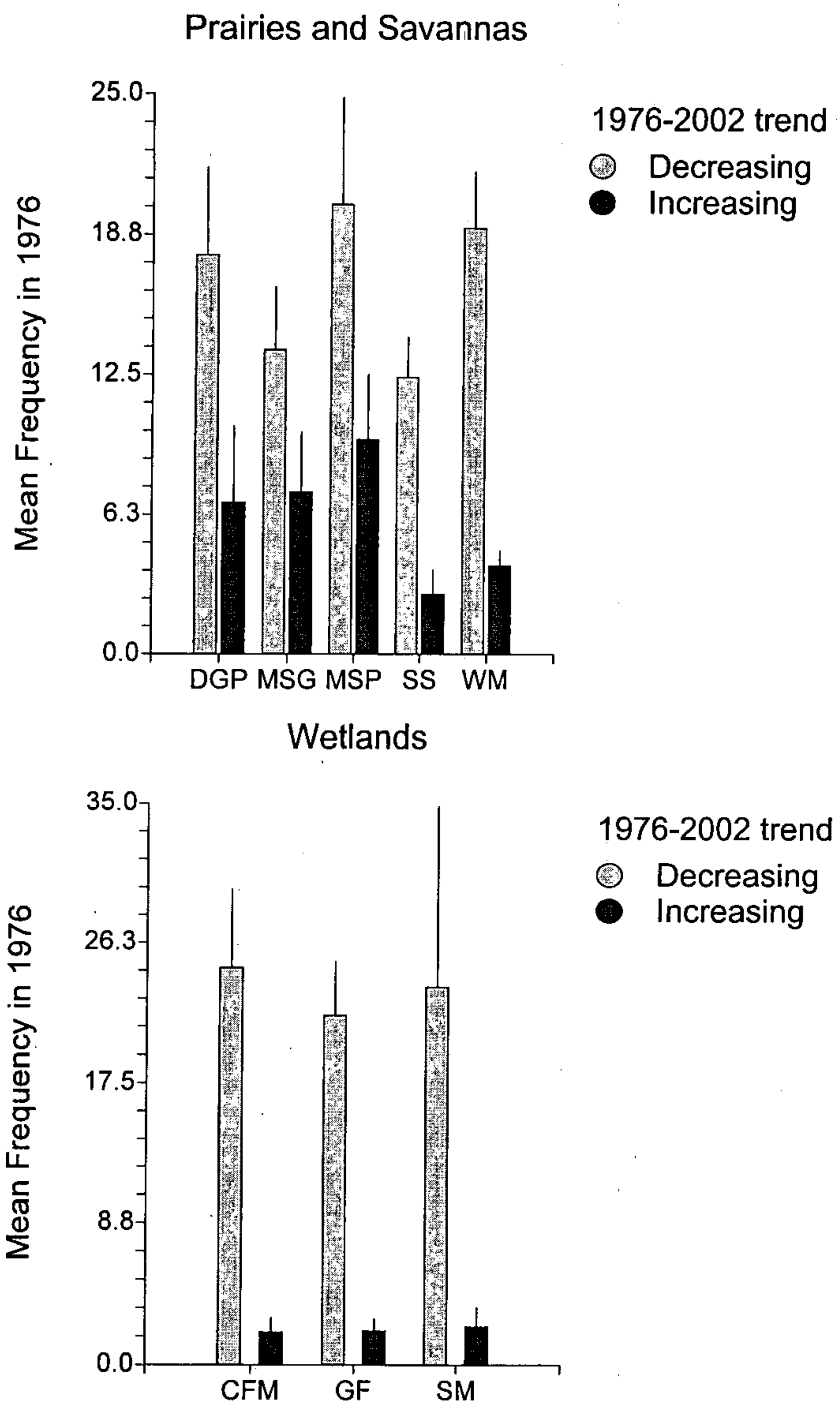


Figure 4. Mean frequencies (+ std. err.) in 1976 for decreasing and increasing species in prairies and savannas (upper: P <0.001) and wetlands (lower: P <0.001). Community codes: DGP = dry gravel prairie, MP = mesic silt and gravel prairie, MSP = mesic sand prairie, SS = sand savanna, WMP = wet mesic prairie, CFM = calcareous floating mat, GF = graminoid fen, SM = sedge meadow. Increasing species that were absent in 1976 are not included in analysis.

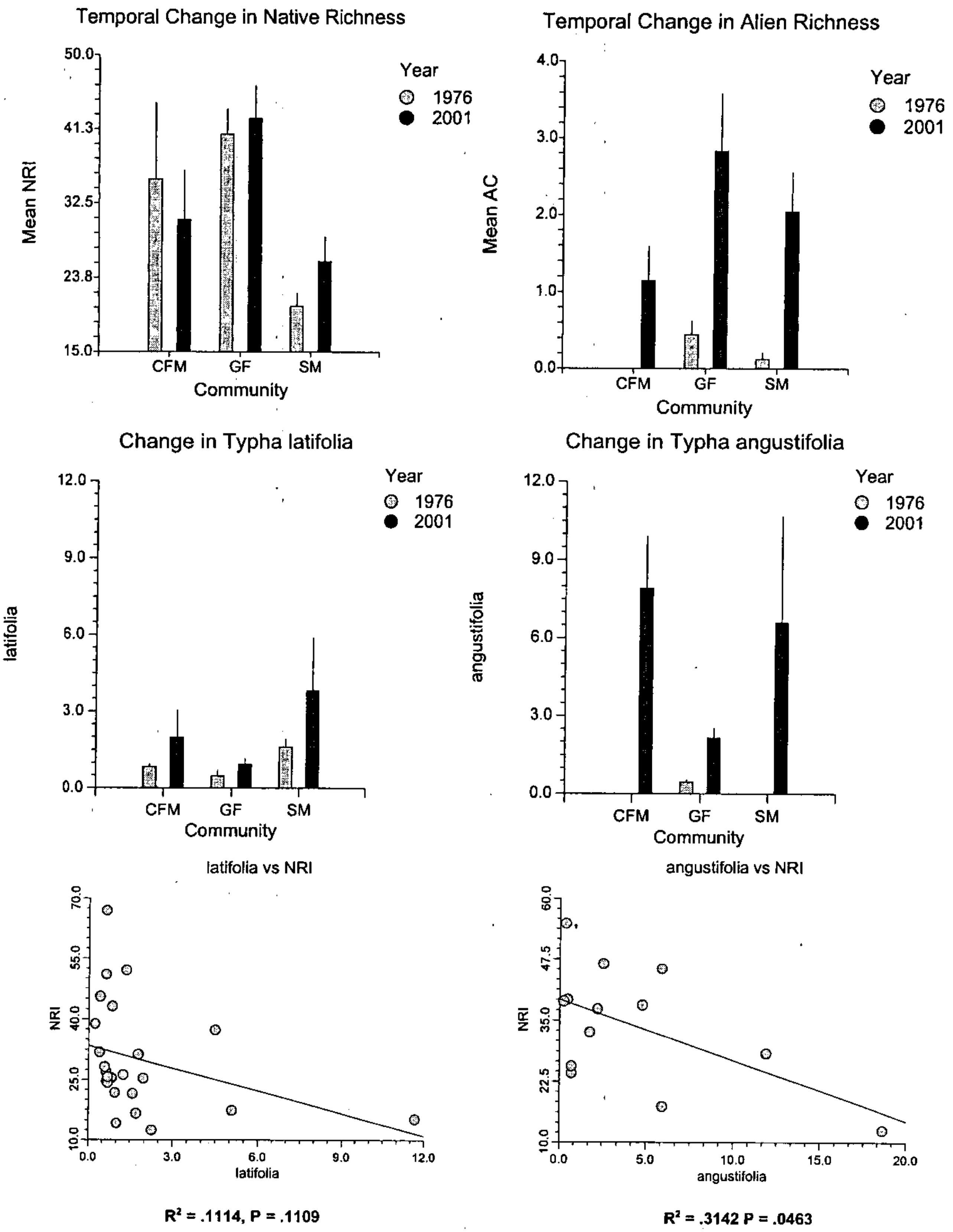


Figure 5. Temporal change in mean (+ std. err.) Native Species Richness Index (NRI), Alien Component of species richness (AC), relative abundance of *Typa latifolia* and *T. angustifolia,* and relationship between *Typha* species and NRI in wetland plant communities (CFM = calcareous floating mat, GF = graminoid fen, SM = sedge meadow). RANOVA probabilities: NRI (community <0.001, Year = 0.717), AC (community = .231, year <0.001), *Typha latifolia/angustifolia* (community = .030, year <.001).

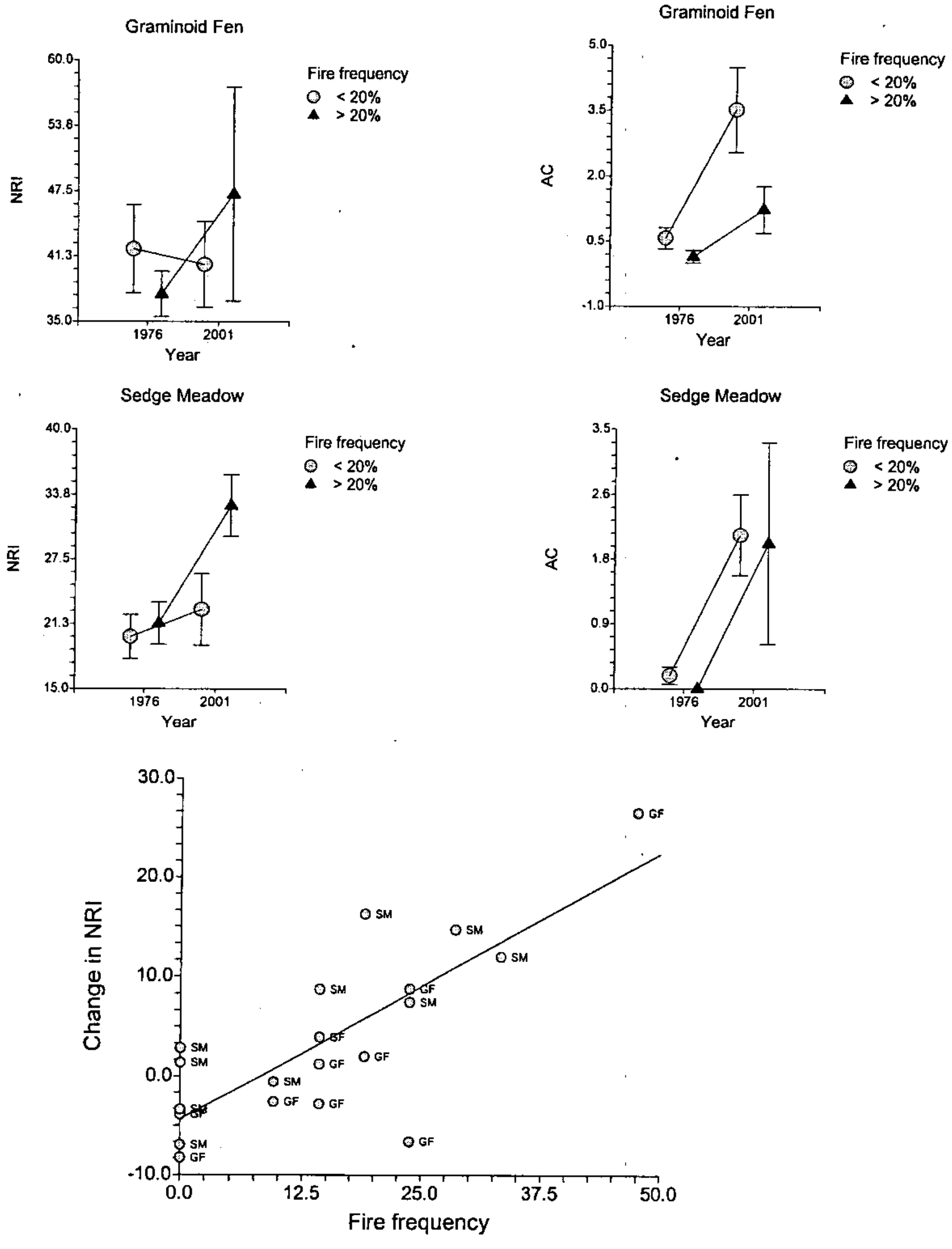
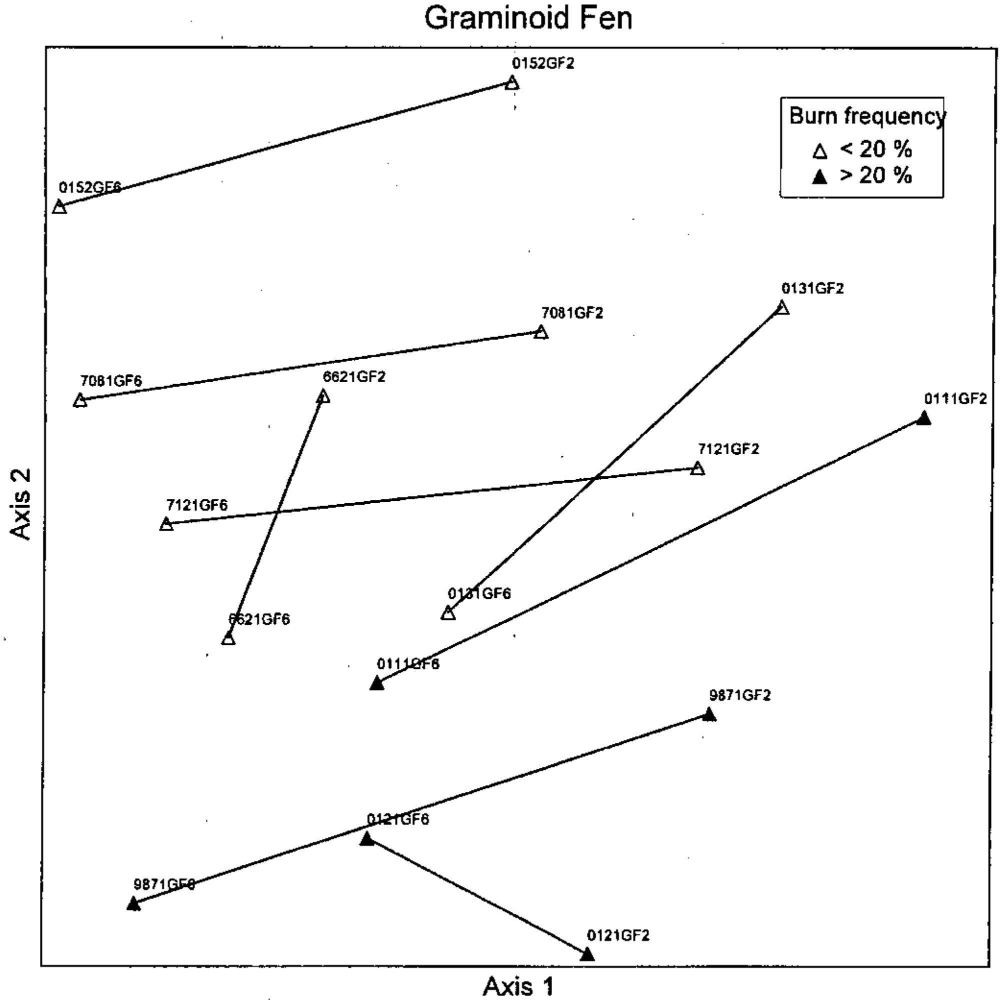


Figure 6. Upper panels: fire effects on mean (+ std. err.) change in Native Species Richness Index (NRI) and Alien Component of species richness (AC) in graminoid fens and sedge meadows. RANOVA probabilities: NRI (Fire x Year = 0.023, Fire x Vegetation x Year = 0.774), AC (Fire x Year = 0.349, Fire x Vegetation x Year = 0.319). Lower: temporal change in NRI is positively correlated ($r^2 = 0.613$, $P < 0.0001$, $y = -4.3618 + 0.5352 * \text{Fire frequency}$) with fire frequency in graminoid fens and sedge meadows.



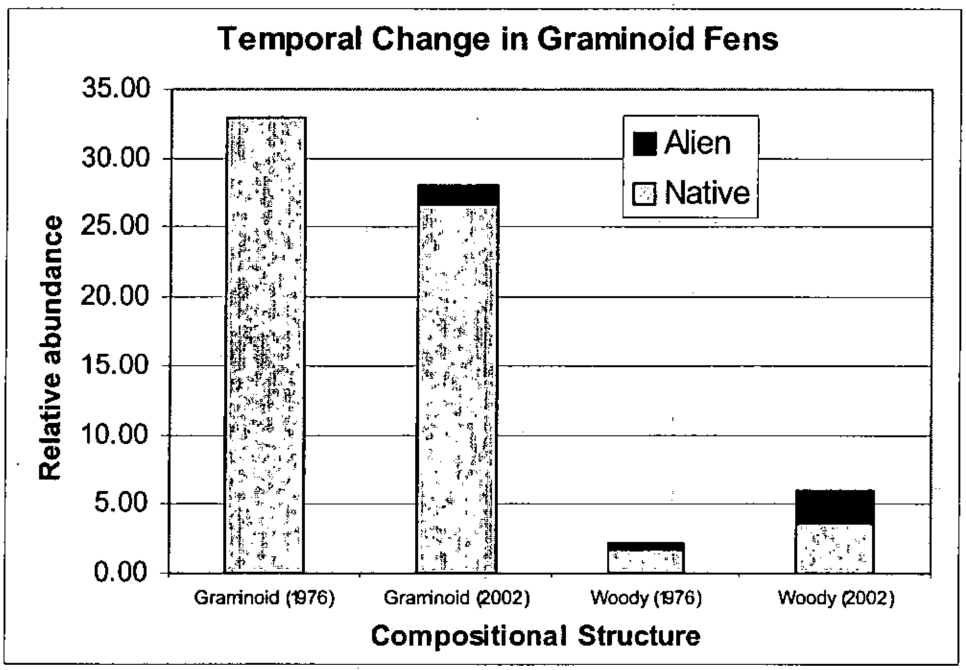


Figure 7. Upper: DECORANA ordination of graminoid fens with >20% and <20% burn frequencies. Vectors indicate change between 1976 (site codes ending in 6) and 2002 (site codes ending in 2). MRPP: 1976-2001 ($P < 0.001$), 1976 fire ($P = 0.110$), 2001 fire ($P = 0.456$). Lower, temporal change in compositional structure of graminoid fens. Chi-square probability of no temporal difference between structure is $P < 0.001$.

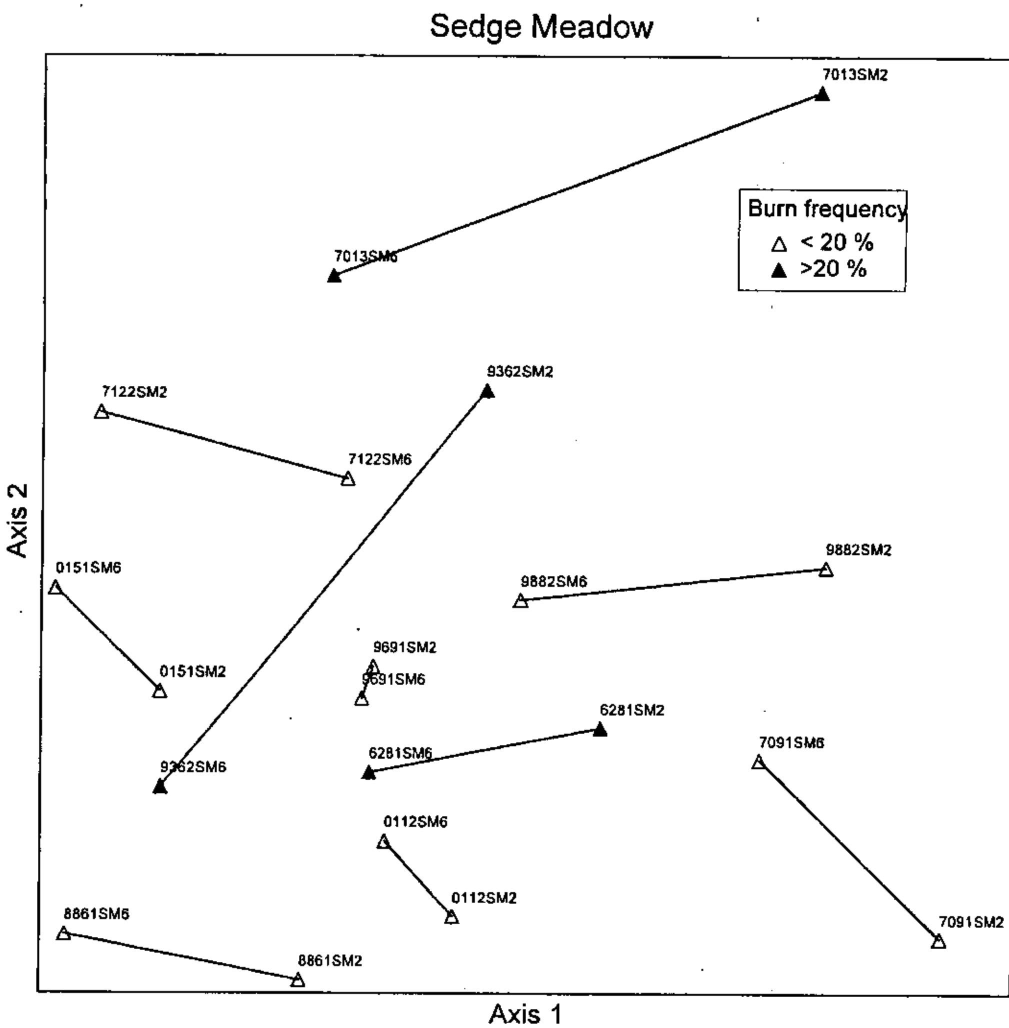


Figure 8. DECORANA ordination of sedge-meadows with >20% and < 20%) burn frequencies. Vectors indicate change between 1976 (site codes ending in 6) and 2002 (site codes ending in 2). MRPP: 1976-2001 (P = 0.064), 1976 fire (P = 0.7365), 2001 fire (P = 0.109).

Appendix I. Statistical Reports

I.1. Repeated Measures ANOVA: Prairies Without Fire as a Factor

I.2. Repeated Measures ANOVA: Prairies With Fire as a Factor

I.3. Repeated Measures ANOVA: Wetlands Without Fire as a Factor

I.4. Repeated Measures ANOVA: Wetlands With Fire as a Factor

Appendix I.1

Repeated Measures ANOVA Report: Prairies Without Fire as a Factor

Response Cn

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: MoistGrad	1	4.209628	4.209628	6.87	0.012353*	0.724799
B: Grade	1	3.778619E-05	3.778619E-05	0.00	0.993775	0.050007
AB	1	1.714082E-02	1.714082E-02	0.03	0.868044	0.053058
C(AB): INAI#	40	24.52157	0.6130391			
D: Year	1	2.000187	2.000187	14.84	0.000414*	0.963926
AD	1	3.589415E-02	3.589415E-02	0.27	0.608668	0.079543
BD	1	4.671928E-03	4.671928E-03	0.03	0.853249	0.053793
ABD	1	2.563152E-02	2.563152E-02	0.19	0.665129	0.071006
CD(AB)	40	5.391596	0.1347899			
S	0					
Total (Adjusted)	87	36.63251				
Total	88					

* Term significant at alpha = 0.05

Response FQISn

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: MoistGrad	1	179.7545	179.7545	2.38	0.130844	0.324997
B: Grade	1	414.5488	414.5488	5.49	0.024226*	0.627758
AB	1	116.0391	116.0391	1.54	0.222466	0.227293
C(AB): INAI#	40	3022.24	75.55599			
D: Year	1	17.09875	17.09875	1.17	0.285601	0.184404
AD	1	0.4318525	0.4318525	0.03	0.864303	0.053236
BD	1	7.548339	7.548339	0.52	0.476258	0.108081
ABD	1	1.307458	1.307458	0.09	0.766275	0.059835
CD(AB)	40	583.8887	14.59722			
S	0					
Total (Adjusted)	87	4147.715				
Total	88					

* Term significant at alpha = 0.05

Response xRn

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: MoistGrad	1	132.4448	132.4448	11.30	0.001716*	0.906546
B: Grade	1	122.4821	122.4821	10.45	0.002459*	0.883779
AB	1	1.870527	1.870527	0.16	0.691664	0.067597
C(AB): INAI#	40	468.8495	11.72124			
D: Year	1	7.751002	7.751002	2.35	0.133528	0.321164
AD	1	2.695547	2.695547	0.82	0.371865	0.142676
BD	1	14.30556	14.30556	4.33	0.043924*	0.528136
ABD	1	2.235076	2.235076	0.68	0.415737	0.126462
CD(AB)	40	132.1933	3.304832			
S	0					
Total (Adjusted)	87	836.4074				
Total	88					

* Term significant at alpha = 0.05

Response Sn

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: MoistGrad	1	2819.458	2819.458	8.70	0.005294*	0.820734
B: Grade	1	1668.75	1668.75	5.15	0.028719*	0.600485
AB	1	402.7909	402.7909	1.24	0.271561	0.192828
C(AB): INAI_	40	12962.64	324.0659			
D: Year	1	673.4354	673.4354	15.89	0.000277*	0.973112
AD	1	1.113215E-02	1.113215E-02	0.00	0.987151	0.050029
BD	1	1.142445	1.142445	0.03	0.870420	0.052948
ABD	1	54.34447	54.34447	1.28	0.264245	0.197444
CD(AB)	40	1695.435	42.38589			
S	0					
Total (Adjusted)	87	18970.44				
Total	88					

*Term significant at alpha = 0.05

Appendix I.1

Repeated Measures ANOVA Report: Prairies Without Fire as a Factor

Response NRI

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: MoistGrad	1	3132.268	3132.268	13.49	0.000702*	0.947761
B: Grade	1	2511.426	2511.426	10.82	0.002103*	0.894174
AB	1	12.68577	12.68577	0.05	0.816371	0.055986
C(AB): INAI_	40	9286.925	232.1731			
D: Year	1	280.4417	280.4417	4.64	0.037270*	0.556776
AD	1	25.90187	25.90187	0.43	0.516343	0.097963
BD	1	204.8275	204.8275	3.39	0.072993	0.435407
ABD	1	44.32756	44.32756	0.73	0.396765	0.133138
CD(AB)	40	2416.407	60.41017			
S	0					
Total (Adjusted)	87	16803.51				
Total	88					

* Term significant at alpha = 0.05

Response AC

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: MoistGrad	1	1.369552	1.369552	0.15	0.699891	0.066613
B: Grade	1	8.310167	8.310167	0.91	0.344631	0.154252
AB	1	7.404764	7.404764	0.81	0.372054	0.142600
C(AB): INAI_	40	363.4288	9.08572			
D: Year	1	39.20411	39.20411	9.30	0.004047*	0.845245
AD	1	8.918371E-04	8.918371E-04	0.00	0.988465	0.050023
BD	1	10.51841	10.51841	2.50	0.121999	0.338235
ABD	1	2.539851	2.539851	0.60	0.442099	0.117947
CD(AB)	40	168.5522	4.213805			
S	0					
Total (Adjusted)	87	596.1204				
Total	88					

* Term significant at alpha = 0.05

Appendix I.2

Repeated Measures ANOVA Report: Prairies with Fire as a Factor

Response **NRI**

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Moisture	1	3977.957	3977.957	17.08	0.000253*	0.979384
B: Quality	1	2178.275	2178.275	9.35	0.004565*	0.841801
AB	1	86.84926	86.84926	0.37	0.545932	0.090998
C: Fire freq	1	769.2725	769.2725	3.30	0.078870	0.421185
AC	1	161.0833	161.0833	0.69	0.412031	0.127096
BC	1	18.0593	18.0593	0.08	0.782536	0.058386
ABC	1	419.7447	419.7447	1.80	0.189249	0.255479
D(ABC): INAI#	31	7221.897	232.9644			
E: Date	1	278.0195	278.0195	9.25	0.004753*	0.838078
AE	1	44.98426	44.98426	1.50	0.230308	0.220285
BE	1	334.3921	334.3921	11.13	0.002215*	0.898177
ABE	1	9.104269	9.104269	0.30	0.585932	0.083207
CE	1	303.826	303.826	10.11	0.003333*	0.868679
ACE	1	132.7887	132.7887	4.42	0.043742*	0.530733
BCE	1	0.245612	0.245612	0.01	0.928538	0.050881
ABCE	1	10.68341	10.68341	0.36	0.555293	0.089072
DE(ABC)	31	931.356	30.04374			
S	0					
Total (Adjusted)	77	15030.35				
Total	78					

* Term significant at alpha = 0.05

Response **AC**

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Moisture	1	0.3585164	0.3585164	0.03	0.871952	0.052848
B: Quality	1	11.0495	11.0495	0.81	0.373888	0.141157
AB	1	2.584	2.584	0.19	0.665635	0.070733
C: Fire freq	1	42.1188	42.1188	3.10	0.088012	0.400253
AC	1	17.23019	17.23019	1.27	0.268531	0.193839
BC	1	7.925339	7.925339	0.58	0.450576	0.114826
ABC	1	27.87698	27.87698	2.05	0.161842	0.284363
D(ABC): INAI#	31	420.7875	13.57379			
E: Date	1	43.25956	43.25956	9.01	0.005257*	0.828498
AE	1	5.302281E-02	5.302281E-02	0.01	0.916963	0.051190
BE	1	3.030013	3.030013	0.63	0.432889	0.120236
ABE	1	3.654699	3.654699	0.76	0.389551	0.135128
CE	1	0.2049517	0.2049517	0.04	0.837629	0.054610
ACE	1	3.923347E-02	3.923347E-02	0.01	0.928537	0.050881
BCE	1	0.1460766	0.1460766	0.03	0.862632	0.053283
ABCE	1	0.4144427	0.4144427	0.09	0.770815	0.059348
DE(ABC)	31	148.7686	4.798987			
S	0					
Total (Adjusted)	77	719.3971				
Total	78					

* Term significant at alpha = 0.05

Appendix I.3

Repeated Measures ANOVA Report: Wetlands without Fire as a Factor

Response xRn
Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Community	2	167.5964	83.79819	9.79	0.000992*	0.965461
B(A): INAI#	21	179.7949	8.561661			
C: Year	1	0.3136835	0.3136835	0.12	0.736825	0.062205
AC	2	9.264617	4.632308	1.71	0.204637	0.318694
BC(A)	21	56.80002	2.704763			
S	0					
Total (Adjusted)	47	413.7499				
Total	48					

* Term significant at alpha = 0.05

Response Sn
Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Community	2	2786.663	1393.331	9.01	0.001497*	0.951098
B(A): INAI#	21	3248.15	154.6738			
C: Year	1	340.2778	340.2778	11.95	0.002358*	0.909120
AC	2	32.12917	16.06458	0.56	0.577156	0.130976
BC(A)	21	597.85	28.46905			
S	0					
Total (Adjusted)	47	7178.313				
Total	48					

* Term significant at alpha = 0.05

Response NRI
Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Community	2	3443.008	1721.504	9.84	0.000965*	0.966291
B(A): INAI#	21	3673.393	174.9235			
C: Year	1	6.141543	6.141543	0.13	0.717153	0.064205
AC	2	143.0372	71.51862	1.57	0.231491	0.295019
BC(A)	21	956.5761	45.55124			
S	0					
Total (Adjusted)	47	8272.066				
Total	48					

* Term significant at alpha = 0.05

Response AC
Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Community	2	7.175275	3.587638	1.57	0.231201	0.295259
B(A): INAI#	21	47.94133	2.282921			
C: Year	1	32.94156	32.94156	20.25	0.000197*	0.990000
AC	2	2.237475	1.118738	0.69	0.513656	0.150246
BC(A)	21	34.15794	1.626569			
S	0					
Total (Adjusted)	47	138.7087				
Total	48					

* Term significant at alpha = 0.05

Appendix I.4

Repeated Measures ANOVA Report: Wetlands with Fire as a Factor

Response **NRI**

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Vegetation	1	2618.258	2618.258	17.70	0.000668*	0.976365
B: Fire freq	1	99.05659	99.05659	0.67	0.425144	0.120234
AB	1	41.86668	41.86668	0.28	0.601992	0.079197
C(AB): INAI#	16	2366.247	147.8904			
D: Year	1	256.0703	256.0703	7.83	0.012879*	0.747820
AD	1	18.34643	18.34643	0.56	0.464676	0.108596
BD	1	206.3387	206.3387	6.31	0.023102*	0.655262
ABD	1	2.783815	2.783815	0.09	0.774193	0.058689
CD(AB)	16	523.1268	32.69542			
S	0					
Total (Adjusted)	39	6834.096				
Total	40					

* Term significant at alpha = 0.05

Response **AC**

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A: Vegetation	1	0.8058211	0.8058211	0.33	0.572986	0.084234
B: Fire freq	1	4.729878	4.729878	1.94	0.182322	0.258791
AB	1	3.07243	3.07243	1.26	0.277733	0.184583
C(AB): INAI#	16	38.93407	2.433379			
D: Year	1	32.64277	32.64277	17.82	0.000649*	0.977060
AD	1	0.0135646	0.0135646	0.01	0.932496	0.050752
BD	1	1.702865	1.702865	0.93	0.349335	0.148292
ABD	1	1.938279	1.938279	1.06	0.318967	0.162265
CD(AB)	16	29.31184	1.83199			
S	0					
Total (Adjusted)	39	129.5576				
Total	40					

* Term significant at alpha = 0.05

Appendix II. Species Level Changes: Decreasing and Increasing Species

II.1. Decreasing and Increasing Species in Dry-gravel Prairies

II.2. Decreasing and Increasing Species in Mesic Silt-loam and Gravel Prairies

II.3. Decreasing and Increasing Species in Mesic Sand Prairies

II.4. Decreasing and Increasing Species in Wet-mesic Sand, Silt and Dolomite Prairies

II.5. Decreasing and Increasing Species in Sand Savanna

II.6. Decreasing Species in Calcareous Floating Mats, Graminoid Fens and Sedge Meadows

II.7. Increasing Species in Calcareous Floating Mats, Graminoid Fens and Sedge Meadows

II.1. Frequencies of decreasing (upper table) and increasing (lower table) species in dry-gravel prairies. Changes are significant at P <0.05 (*), < 0.01(**), or <0.001(***); at P <0.05, one in 20 may be due to chance; G = graminoid, F = forb, W = woody, # = alien species

Habit	Decreasing species	1976	2001
G	Stipa spartea***	33.00	0.91
F	Solidago nemoralis***	24.00	5.45
F	Silphium integrifolium**	11.00	0.00
F	Liatris cylindracea*	16.00	4.55
F	Viola palmata*	6.00	0.00
F	Comandra umbellata*	17.00	7.27

Habit	Increasing species	1976	1991
G	Panicum leibergii***	1.00	18.18
G	Andropogon gerardii**	26.00	45.45
G	Bouteloua curtipendula*	27.00	40.91
F	Helianthus rigidus***	4.00	22.73
F	Lithospermum canescens**	0.00	11.82
F	Helianthus occidentalis**	0.00	10.00
F	Scutellaria parvula**	0.00	10.00
F	Anemone cylindrica*	9.00	21.82
F	Echinacea pallida*	0.00	6.36
F	Fragaria virginiana*	1.00	8.18

II.2. Frequencies of decreasing (upper table) and increasing (lower table) species in mesic silt-loam and gravel prairie. Changes are significant at P <0.05 (*), < 0.01(**) or <0.001(***); at P <0.05, one in 20 may be due to chance; G = graminoid, F = forb, W = woody, # = alien species. Columns labled < 33 % fire indicate frequencies for species with significant (P <0.001) temporal change only in sites with <33% fire frequency between 1980-2001.

Habit	Decreasing species	1976	2001	< 33% fire 1976.00	< 33% fire 2001.00
G	Bromus kalmii*	8.00	2.99		
G	Panicum villosissimum**	5.00	0.00		
G	Panicum virgatum*	8.00	2.49		
G	Sorghastrum nutans***	37.50	21.39	55.00	1.45
G	Sporobolus heterolepis***	50.00	26.87	58.33	10.14
F	#Cirsium vulgare**	4.00	0.00		
F	Allium cernuum*	46.00	36.32	58.33	5.80
F	Antennaria sp.***	7.50	0.00		
F	Aser azureus			48.33	4.35
F	Aster laevis**	15.50	7.46		
F	Baptisia leucophaea***	6.00	0.00		
F	Desmodium canadense*	7.00	1.99		
F	Equisetum arvense*	9.00	2.99		
F	Helianthus rigidus*	6.50	1.49		
F	Krigia biflora***	11.00	1.99		
F	Lithospermum canescens			21.67	2.90
F	Physalis virginiana***	8.00	0.00		
F	Physostegia virginiana			18.33	0.00
F	Ratibida pinnata			36.67	10.14
F	Senecio pauperculus***	13.50	2.49		
F	Solidago graminifolia**	9.50	1.99		
F	Solidago missouriensis var fasciculata**	7.00	1.00		
F	Solidago nemoralis*		5.97		
F	Solidago riddellii			21.67	0.00
F	Solidago rigida			31.67	2.90
F	Thalictrum dasycarpum*	4.00	0.50		
F	Valeriana ciliata**	5.50	0.50		
F	Zizia aptera*	4.50	1.00		
F	Zizia aurea**	28.50	15.92		

Habit	Increasing species	1976	2001	< 33% fire 1976.00	< 33% fire 2001.00
W	Cornus racemosa***	12.00	40.80	3.33	49.28
W	Rosa sp***	26.50	46.27		
G	#Agrostis alba*	3.00	9.95		
G	#Poa sp***	18.50	41.79		
G	Agropyron trachycaulum var unilateral*	0.00	2.99		
G	Carex sp***	53.50	87.56		
G	Panicum oligosanthes var scribnerianum*	5.50	12.44		
G	Spartina pectinata***	1.50	10.95		
F	Aster novae-angliae**	0.50	7.46		
F	Cirsium discolor***	0.00	6.97		
F	Gentiana quinquefolia var occident*	1.00	6.47		
F	Helianthus grosseserratus***	5.00	22.39	2.67	33.33
F	#Hieracium caespitosum****	0.00	7.46		
F	Lespedeza capitata*	0.50	4.98		
F	Lycopus americanus*	1.00	5.47		
F	Scutellaria parvula var leonardii**	0.00	5.47		
F	Solidago altissima***	5.00	20.90	1.67	46.38
F	Solidago gigantea***	1.00	9.45		
F	Solidago graminifolia**			0.00	20.29
F	Solidago gymnospermoides***	0.00	6.97		
F	Solidago juncea**	17.00	31.84		
F	Thalictrum dasycarpum var hypoglaucum*	0.00	3.98		
F	Veronicastrum virginicum*	8.00	16.42		

II.3. Frequencies of decreasing (upper table) and increasing (lower table) species in mesic sand prairie. Changes are significant at P <0.05 (*), < 0.01(**) or <0.001(***); at P <0.05, one in 20 may be due to chance, G = graminoid, F = forb, W = woody, # = alien species

Habit	Decreasing species	1976	2001
G	Andropogon gerardii*	45.56	32.74
G	Panicum virgatum*	6.67	1.79
G	Sporobolus heterolepis**	17.22	7.14
F	Lespedeza capitata**	16.67	6.55
F	Liatris spicata**	19.44	8.33
F	Parthenium integrifolium*	23.89	14.88
F	Solidago riddellii*	11.11	4.76

Habit	Increasing species	1976	2001
W	#Rhamnus frangula***	0.00	12.50
W	Rosa sp***	9.44	29.17
G	#Poa sp***	26.11	48.21
G	Calamagrostis canadensis**	6.67	18.45
G	Carex sp***	38.33	58.93
G	Panicum implicatum***	0.00	16.07
F	Allium cernuum***	6.67	19.05
F	Arenaria lateriflora***	0.56	16.67
F	Physostegia virginiana***	0.00	7.14
F	Silphium integrifolium**	6.67	17.26
F	Smilacina stellata**	3.89	13.10
F	Solidago altissima***	16.11	42.86
F	Solidago gigantea***	11.67	26.19
F	Viola sagittata**	8.33	20.24

II.4. Frequencies of decreasing (upper table) and increasing (lower table) in wet-mesic sand silt and dolomite prairies (MP). Changes are significant at P <0.05 (*), P <0.01 (**), or P <0.001(***); at P <0.05, one in 20 may be due to chance; G = graminoid, F = forb, W = woody, # = alien species.

Habit	Decreasing species	1976	2001
G	Andropogon scoparius*	26.67	15.29
G	Deschampsia cespitosa*	6.11	1.18
F	Allium canadense*	5.56	1.18
F	Fragaria virginiana**	30.56	15.88
F	Galium obtusum*	16.67	7.65
F	Liatris spicata***	18.89	6.47
F	Oenothera pilosella*	8.89	2.94
F	Senecio pauperculus***	27.78	4.12
F	Silphium terebinthinaceum	18.89	10.59
F	Solidago gigantea**	28.89	15.88
F	Solidago riddellii*	22.22	11.76
F	Viola sp*	17.22	8.24

Habit	Increasing species	1976	2001
W	Aronia prunifolia**	2.78	10.59
W	Cornus racemosa***	3.89	17.65
G	Panicum implicatum***	9.44	23.53
F	#Lythrum salicaria***	0.00	8.82
F	Aster azureus*	6.67	13.53
F	Cassia fasciculata*	4.44	11.18
F	Coreopsis tripteris**	5.00	15.29
F	Helianthus mollis*	2.78	8.82
F	Monarda fistulosa***	0.56	9.41
F	Parthenium integrifolium**	3.89	13.53
F	Solidago altissima***	7.22	21.76
F	Solidago juncea**	5.00	15.29
F	Solidago speciosa*	0.56	4.71
F	Tradescantia ohiensis*	5.00	11.76
F	Viola sagittata**	2.22	11.18

II.5. Frequencies of decreasing (upper table) and increasing (lower table) in sand savanna. Changes are significant at P <0.05 (*), P <0.01 (**), or P <0.001(***); at P <0.05, one in 20 may be due to chance; G = graminoid, F = forb, W = woody, # = alien species.

Habit	Decreasing species	1976	2001
W	Arctostaphylos uva-ursi**	7.69	0.71
W	Vaccinium pallidum**	6.92	0.00
G	Andropogon scoparius***	29.23	9.29
G	Koeleria cristata*	4.62	0.00
G	Panicum villosissimum***	19.23	2.14
G	Stipa spartea*	35.38	21.43
F	#Achilea millefolium*	12.31	4.29
F	Aster azureus*	13.08	5.00
F	Aster linariifolius*	4.62	0.00
F	Coreopsios lanceolata*	8.46	2.14
F	Coreopsis tripteris**	10.77	2.14
F	Erigeron strigosus***	9.23	0.00
F	Helianthemum bicknellii**	6.92	0.00
F	Krigia biflora**	7.69	0.71
F	Lupinus perrenis***	11.54	0.71
F	Polygonatum canaliculatum*	8.46	2.14
F	Rudbeckia hirta***	15.38	2.14
F	Sisyrinchium albidum*	6.15	0.71
F	Solidago nemoralis	10.77	3.57
F	Viola sagittata***	19.23	4.29

Habit	Increasing species	1976	2001
W	Corus racemosa*	1.54	7.14
W	Rubus pennsylvanicus**	0.00	7.14
W	Vaccinium angustifolium**	10.00	25.00
G	#Agrostis alba*	0.00	5.00
G	Carex pensylvanica***	0.00	27.14
G	Panicum oligosanthes scrib**	0.00	8.57
F	Allium canadense*	0.00	4.29
F	Allium cercuum*	0.00	5.00
F	Arenaria lateriflora*	3.08	9.29
F	Aster ericoides***	0.00	10.00
F	Aster umbellatus*	0.00	4.29
F	Eupatorium rugosum***	0.00	10.00
F	Maianthemum canadensis*	6.15	13.57
F	Pterdium aquilinum*	14.62	27.14
F	Smilacina stellata*	9.23	17.86
F	Solidago altissima***	0.77	23.57
F	Solidago gigantea**	0.00	'6.43

II.6. Frequencies of decreasing species frequencies in Calcareous Floating Mats (CFM) Graminoid Fens (GF), and Sedge Meadows (SM). W = woody, G = graminoid, F = forb, # = alien. Changes are significant at P <0.05 (*), < 0.01(**) or <0.001(***); at P <0.05, one in 20 may be due to chance.

	Vegetation type	**CFM**	**CFM**	**GF**	**GF**	**SM**	**SM**
Habit	**Year**	**1976**	**2001**	**1976**	**2001**	**1976**	**2001**
W	Salix pedicularis*	28.89	14.44				
G	Andropogon gerardii***			57.27	22.50		
G	Andropogon scoparius***			36.36	11.50		
G	Calamagrostis canadensis***	73.33	36.67				
G	Carex buxbaumii***			22.27	5.50		
G	Carex hystricina**			5.91	0.50		
G	Carex sp***			20.91	7.50		
G	Carex sterelis***			53.18	27.00		
G	Carex stricta***					95.71	62.93
G	Muhlenbergia frondosa***			7.73	0.00	9.05	0.00
G	Muhlenbergia glomerata***	37.78	12.22	44.09	21.50		
G	Scirpus validus creber**			5.91	0.00		
G	Sorghastrum nutans***			18.18	2.50		
G	Spartina pectinata*					5.24	0.98
G	Sporobolus heterolepis**			5.45	0.00		
F	Aster puniceus firmus***			25.91	10.00	14.29	2.44
F	Aster sp***					7.14	0.00
F	Bidens coronata*	8.89	0.00				
F	Epilopium leptophyllum*	11.11	2.22			4.29	0.49
F	Eupatorium perfoliatum**	10.00	0.00				
F	Galium trifidum*, GF = **	12.22	2.22	8.64	1.50		
F	Gentiana procera***			12.27	2.00		
F	Hypericum virginicum**	30.00	11.11				
F	Lathrys palustris*	8.89	1.11				
F	Lycopus sp***					7.14	0.00
F	Lycopus uniflorus***	53.33	23.33				
F	Lysimachia quadriflora***	16.67	0.00				
F	Lysimachia terrestris**	10.00	0.00				
F	Lythrum alatum***			12.73	1.50		
F	Menyanthes trifoliata**	17.78	2.22				
F	Panicum sp*			4.09	0.00		
F	Parnassia glauca**	12.22	0.00				
F	Phlox glaberrima**			4.55	0.00		
F	Pycnanthemum virginianum***					44.76	25.85
F	Rudbeckia hirta*			34.55	23.50		
F	Scutellaria epilobiifolia***	38.89	10.00				
F	Senecio paupercuus***			18.64	6.00		
F	Solidago graminifolia***			9.09	0.00		
F	Solidago missouiriensis*			4.09	0.00		
F	Solidago ohiensis***			63.64	37.00		
F	Solidago riddellii***			29.55	7.50		
F	Solidago uliginosa***			15.45	2.50		
F	Thalictrum dasycarpum***			16.36	3.00		
F	Valeriana ciliata*			26.82	18.00		

II.7. Frequencies of increasing species frequencies in Calcareous Floating Mats (CFM) Graminoid Fens (GF), and Sedge Meadows (SM). W = woody, G = graminoid, F = forb, # = alien. Changes are significant at P <0.05 (*), < 0.01(**) or <0.001(***); at P <0.05, one in 20 may be due to chance.

	Vegetation type	CFM	CFM	GF	GF	SM	SM
Habit	Year	1976	2001	1976	2001	1976	2001
W	#Rhamnus frangula***			5.45	20.00		
W	Betula pumila*	7.78	21.11	0.91	4.50		
W	Cornus racemosa*			2.27	8.00	0.00	3.41
W	Cornus stolonifera*	1.11	10.00				
G	#Phalarus arundinacea**					0.00	4.39
G	#Agrostis alba*			0.00	3.50		
G	Carex aquatilis*			0.00	3.50		
G	Carex buxbaumii**					0.00	4.88
G	Carex haydenii***					1.90	15.61
G	Carex lacustris***	2.22	24.44				
G	Carex lep**			0.00	4.50		
G	Carex sp**			0.00	4.00		
G	Carex stricta***			9.09	30.50		
G	Carex trichocarpa**	0.00	10.00				
G	Eleocharis elliptica***	0.00	16.67			0.00	7.32
G	Glyceria striata***			0.45	17.50	0.00	12.68
G	Muhlenbergia glomerata*					0.95	4.88
G	Muhlenbergia mexicana**					3.33	10.24
G	Panicum implicatum*			5.45	12.50		
G	Scirpus acutis***			2.27	16.00		
G	Scirpus validus**	3.33	18.89				
G	Scleria verticillata**			0.00	5.00		
G	Typha angustifolia**, SM = ***	0.00	45.56	0.45	6.00	0.00	17.07
G	Typha latifolia*					5.71	13.66
F	#Lythrum salicaria***	0.00	24.44	0.00	7.00	1.43	28.78
F	#Potentila norvegica*			0.00	3.50		
F	Aster puniceus***			3.18	12.50		
F	Bidens cernua**			0.91	7.00		
F	Campanula aparanoides**					6.19	16.59
F	Cirsium arvense*			0.00	9.50	0.00	3.90
F	Dryopteris thelypteris***			5.45	26.00		
F	Epilobium coloratum**			0.00	4.50		
F	Erigeron philadephicus**					0.00	4.39
F	Gallium labradoricum***					0.48	9.27
F	Gallium obtusum***	0.00	15.56				
F	Gallium triflorum*					0.00	3.90
F	Impatiens capensis***			0.00	15.50		
F	Lycopus americanus***			16.82	35.50	8.10	20.98
F	Lycopus uniflorus**					26.67	42.44
F	Lythrum alatum*					1.43	5.85
F	Oenothera biennis***			0.00	9.00		
F	Onoclea sensibilis*					0.00	3.41
F	Pilea pumila*, SM = ***			0.00	3.50	0.00	18.54
F	Polygonum punctatum***					0.00	8.29
F	Sagittaria latifora*					0.00	3.41
F	Selaginella apoda**					0.00	4.88
F	Solidago altissima*			1.36	5.50		
F	Sparganium sp***	5.56	32.22				
F	Thalictrum dasycarpum hyp***			0.00	8.00		

Appendix III. Species Richness Index Program Statistical Summary of Site Data
Prairies and Savannas

INAI Site No.	Transect No.	Community type	Quality Grade	Site Name	County
251	1	Mesic prairie	A	Wolf Road Prairie	Cook
253	1	Mesic gravel prairie	A	Santa Fe Prairie	Cook
253	2	Dry-mesic gravel prairie	A	Santa Fe Prairie	Cook
254	1	Mesic prairie	A	Somme Prairie	Cook
391	1	Dry gravel prairie	B	Spring Creek Prairie	Cook
393	1	Mesic prairie	A	Glen Brook North High School Prairie	Cook
394	1	Dry gravel prairie	A	Shoe Factory Road Prairie	Cook
396	1	Mesic prairie	A	Morton Grove Prairie	Cook
398	1	Mesic gravel prairie	A	Chicago Ridge Prairie	Cook
400	1	Mesic sand prairie	B	Gensberg-Markham Prairie	Cook
425	1	Mesic sand prairie	A	Dropseed Prairie	Cook
426	1	Wet-mesic sand prairie	B	Dolton Avenue Prairie	Cook
461	1	Wet-mesic sand prairie	A	Burnham Prairie	Cook
461	2	Dry-mesic sand savanna	C	Burnham Prairie	Cook
498	1	Dry-mesic sand prairie	A	Wentworth Prairie	Cook
499	1	Dry-mesic sand savanna	A	Sand Ridge Prairie Nature Preserve	Cook
499	2	Dry-mesic sand prairie	B	Sand Ridge Prairie Nature Preserve	Cook
500	1	Dry-mesic sand savanna	A	Thornton Fractional H.S Prairie	Cook
500	2	Mesic sand prairie	B	Thornton Fractional H.S Prairie	Cook
502	1	Mesic sand prairie	B	Tollgate Prairie	Cook
504	1	Wet-mesic sand prairie	B	Thorton-Lansing Road-Zanders Woods Nature Preserve	Cook
505	1	Wet-mesic prairie	B	West Chicago Prairie	DuPage
505	2	Mesic savanna	C	West Chicago Prairie	DuPage
526	1	Dry-mesic prairie	B	Belmont Prairie	DuPage
540	1	Mesic prairie	A	Pen Central RR Prairie	Cook
541	1	Mesic prairie	A	Penn Central RR Prairie	Cook
542	1	Dry-mesic prairie	A	Pen Central RR Prairie	Cook
626	1	Mesic prairie	B	Burlington Prairie	Kane
630	1	Dry gravel prairie	A	Murray Prairie	Kane
649	1	Mesic prairie	B	Wadsworth Prairie	Lake
658	1	Mesic prairie	A	Shaw Prairie	Lake
659	1	Mesic prairie	B	McLaughin Prairie	Lake
700	1	Dry gravel prairie	B	Ski Hill Prairie	McHenry
713	1	Dry gravel prairie	B	Cary Prairie	McHenry
718	1	Mesic prairie	B	Chicago&Northwestern RR Prairie	McHenry
882	1	Wet-mesic dolomite prairie	B	Lockport Prairie North	Will
888	1	Mesic prairie	B	Grant Creek Prairie	Will
889	1	Dry-mesic dolomite prairie	B	Des Plaines Conservation Area	Will
900	1	Dry-mesic prairie	A	Illinois Central Gulf RR Prairie	Will
901	1	Dry-mesic prairie	A	Illinois Central Gulf RR Prairie	Will
902	1	Wet-mesic sand prairie	B	Munch Area	Will
932	1	Dry-mesic dolomite prairie	A	Lockport Prairie	Will
934	1	Mesic sand prairie	B	Vesley-Simpson Prairie	Will
934	2	Sand shrub prairie	B	Vesley-Simpson Prairie	Will
936	1	Wet-mesic dolomite prairie	B	Romeoville Prairie	Will
935	1	Dry-mesic sand savanna	B	Braidwood	Will
973	1	Dry-mesic prairie	B	Chicago & Northwestern RR Prairie	Kane
1001	1	Wet-mesic prairie	B	Lyons Prairie	Lake
1047	1	Mesic sand prairie	B	Hitts Siding Prairie	Will
1066	1	Mesic sand prairie	A	Illinois Dunes North	Lake
1071	1	Mesic sand prairie	B	Powderhorn Lake and Prairie	Cook
1080	1	Dry-mesic prairie	A	Vermont Cemetery Prairie	Will
1083	1	Dry-mesic sand prairie	A	Illinois Beach State Park	Lake
1083	2	Dry sand prairie	A	Illinois Beach State Park	Lake
1083	3	Dune	A	Illinois Beach State Park	Lake
1083	4	Dry sand savanna	A	Illinois Beach State Park	Lake

Appendix III. Species Richness Index Program Statistical Summary of Site Data
Wetlands

INAI Site No.	Transect No.	Community type	Quality Grade	Site Name	County
421	1	Graminoid fen	A	Palos Fen	Cook
537	1	Calcareous seep	A	Bluff City Fen	Cook
628	1	Sedge meadow	A	Feresons Creek Sedge Meadow	Kane
652	1	Calcareous floating mat	A	Fourth Lake	Lake
662	1	Graminoid fen	A	Tower Lake Prairie	Lake
701	1	Graminoid fen	B	Lake in the Hills Fen	McHenry
701	3	Sedge meadow	B	Lake in the Hills Fen	McHenry
707	1	Marsh	A	Cotton Creek Marsh	McHenry
708	1	Graminoid fen	B	Bates Fen	McHenry
709	1	Sedge meadow	A	Weingart Road Sedge Meadow	McHenry
712	1	Graminoid fen	A	Spring Grove Fen	McHenry
712	2	Sedge meadow	A	Spring Grove Fen	McHenry
886	1	Sedge meadow	B	Hickory Creek Sedge Meadow	Will
936	2	Sedge meadow	B	Romeoville Prairie	Will
969	1	Sedge meadow	A	South Elgin Sedge Meadow	Kane
987	1	Graminoid fen	A	Turner Lake	Lake
988	1	Calcareous floating mat	A	Mud Lake	Lake
988	2	Calcareous floating mat	A	Mud Lake	Lake
1000	1	Calcareous floating mat	A	Lac Lovette	McHenry
1002	1	Marsh	B	Wauconda Bog	Lake
1011	1	Graminoid fen	A	Spring Hill Farm	McHenry
1011	2	Sedge meadow	A	Spring Hill Farm	McHenry
1012	1	Graminoid fen	A	Kettle Moraine Nature Preserve	McHenry
1012	2	Calcareous floating mat	A	Kettle Moraine Nature Preserve	McHenry
1013	1	Graminoid fen	A	Stern's Fen	McHenry
1014	1	Graminoid bog	A	Elizabeth Lake	McHenry
1015	1	Sedge meadow	B	Boone Creek Fen	McHenry
1015	2	Graminoid fen	B	Boone Creek Fen	McHenry