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Plant Community Monitoring Trend Report, Pipestone National Monument

Natural Resource Technical Report NPS/HTLN/NRTR—2007/029
NPS D-42

ON THE COVER
Boutaloua gracilis (Willd. ex Kunth) Lag. ex Griffiths
Line drawing from Hitchcock (1950).

Plant Community Monitoring Trend Report, Pipestone National Monument

Natural Resource Technical Report NPS/HTLN/NRTR—2007/029
NPS D-42

Kevin James and Mike DeBacker
National Park Service, The Heartland I&M Network and Prairie Cluster Prototype Monitoring Program
Wilson's Creek National Battlefield, 6424 West Farm Road 182, Republic, MO 65738

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Executive Summary

The natural resources of Pipestone National Monument (PIPE) include 240 acres of tallgrass prairie. Management of the prairie has been ongoing since the parks inception in 1937. Natural and cultural resource management continues today through various activities with the goal of promoting native species diversity, composition and prairie function in addition to protecting the integrity of rare prairie community types and listed plant species.

The tallgrass prairie community is culturally significant as the historic background to the Pipestone quarries. Today, one hundred, sixty acres of virgin tallgrass prairie remain in the monument. Four sample sites are located in the native tallgrass prairie community. A goal at PIPE is maintenance and restoration of the historic tallgrass vista that surrounds the Pipestone quarries. A component of this goal is the restoration of tallgrass prairie communities. Restored areas are managed with fire, mowing and manual exotic removal. Three sample sites are located in the restored tallgrass prairie community. The Sioux quartzite prairie at PIPE represents one of the least disturbed examples of this rare community type globally. Three sample sites are located in the Sioux quartzite prairie type.

Heartland Inventory and Monitoring (HTLN) sites were sampled between 1998 and 2006. The sampling design consists of randomly located, permanent, paired transects 50 meters in length and 20 meters apart with five circular $10m^2$ plots systematically spaced along each transect. Species frequency and foliar cover and their derived metrics are used to address park management goals and evaluate changes in the communities.

The restored prairie is similar to the native prairie in terms of species richness and diversity. The core-satellite distribution of species in both prairies is indicative of functioning native prairies. Differences between the two communities reflect the seed source for the restoration, past condition of the restored prairie and different prescribed fire histories. The rare Sioux quartzite prairie community persists in a good quality state. It is being maintained through active management using prescribed fire and exotic species removal. Guild diversity of the Sioux quartzite prairie reflects the unique nature of this community type relative to the surrounding tallgrass prairie system.

Prescribed fire between 1997 and 2006 does not appear to be a driver in species richness, diversity or composition. However smooth brome did decrease in the wake of prescribed fires in the restored prairie.

The quality of the three prairie communities at PIPE along with continued exotic species management has contributed to the interpretation of the cultural resources of the park.

Introduction

The natural resources of Pipestone National Monument (PIPE) include 240 acres of tallgrass prairie. Management of the prairie has been ongoing since the parks inception in 1937. Natural and cultural resource management continues today through various activities with the goal of promoting native species diversity, composition and prairie function in addition to protecting the integrity of rare prairie community types and listed plant species. Maintaining and restoring the native communities not only protects rare natural communities and species it also allows for a more complete interpretation of the cultural resources in the park (NPS 2006).

Plant communities monitored

Tallgrass prairie

The tallgrass prairie community is culturally significant as the historic background to the Pipestone quarries. Today, one hundred, sixty acres of virgin tallgrass prairie remain in the monument. Previous botanical investigations have identified 250 vascular plants species occurring in the prairie including the federally endangered Western Prairie Fringed Orchid. Prescribed fire is employed as a management tool in this community. Four sample sites (40 plots) are located in the native tallgrass prairie community.

Restored tallgrass prairie

A goal at PIPE is maintenance and restoration of the historic tallgrass vista that surrounds the Pipestone quarries. A component of this goal is the restoration of tallgrass prairie communities. Restoration efforts in the 1990's focused on introducing native grasses and forb species into smooth brome dominated fields. The persistence of exotic species in these areas is a concern to resource managers. Restored areas are managed with fire, mowing and manual exotic removal. Three sample sites (30 plots) are located in the restored tallgrass prairie community.

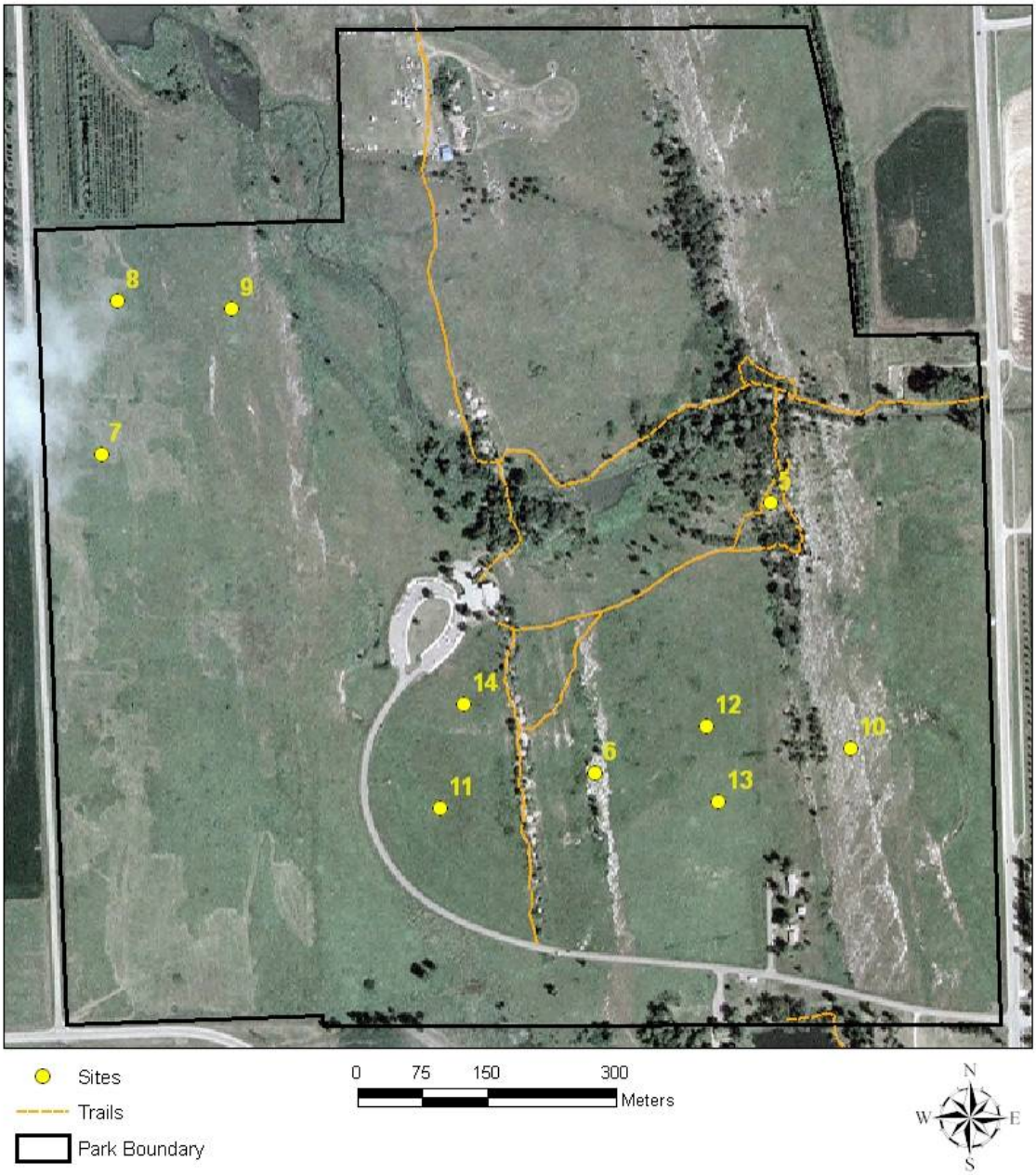
Sioux quartzite prairie

The Sioux quartzite prairie at PIPE represents one of the least disturbed examples of this rare community type globally. The combination of water retaining depressions and thin, arid soils support many unique species including several Minnesota state listed rare plants. Prescribed fire is employed as a management tool in this community. Three sample sites (20 plots) are located in the Sioux quartzite prairie type.

Methods

Field methods

The Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program (HTLN) implemented monitoring at PIPE in 1996 to provide analysis of baseline conditions and to assess future change in floral communities (see DeBacker *et al.* 2004 for detailed information on monitoring protocol). Ten sample sites (90 $10m^2$ plots) were sampled in late spring and early fall during 1998, 1999, 2001, 2005 and 2006 (Fig. 1, Table 1).



Figure

Figure 1. Map of Pipestone National Monument with HTLN vegetation monitoring sites.

Table 1. Prairie community types and HTLN vegetation monitoring sites at Pipestone National Monument (PIPE) sampled between 1998 and 2006.

Community type	HTLN site number	N	Number of $10m^2$ plots
Native tallgrass (native)	11, 12, 13, 14	4	40
Restored tallgrass (restored)	7, 8, 9	3	30
Sioux quartzite (SQP)	5, 6, 10	3	20

In this way, accurate cover estimates and identification of warm season grasses and summer/fall flowering forbs could occur. Data were summarized by community type for each of the five sample years. The years of 1996-1997 primarily focused on establishing permanent sample sites and the small amount of data from these years was not a focus for analysis.

The HTLN sampling design, based on the design of the Konza Prairie Long-Term Ecological Research Program, consists of randomly located, permanent, paired transects 50 meters in length and 20 meters apart with five circular $10m^2$ plots systematically spaced along each transect (Fig. 2).

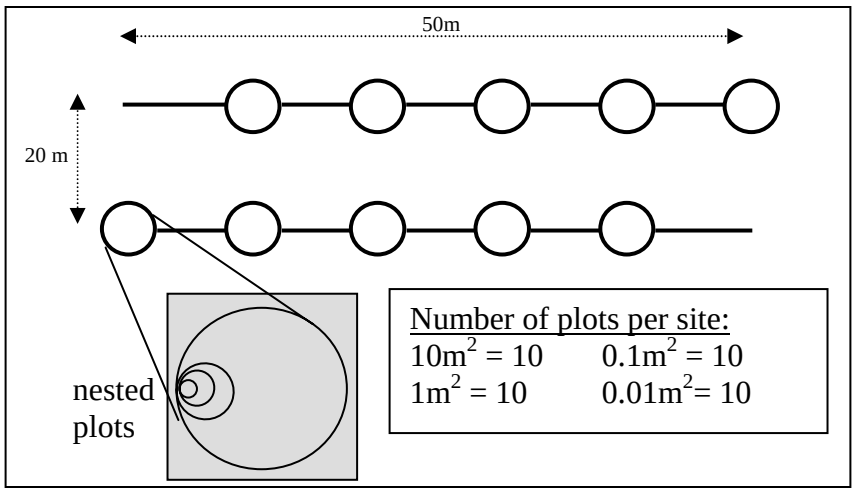


Figure 2. HTLN vegetation community sample design showing transects and plots including nested plots.

Each $10m^2$ plot also includes nested subplots of $1m^2$, $0.1m^2$ and $0.01m^2$ for frequency estimates at multiple scales. Working systematically from the smallest subplot ($0.01m^2$) to the largest ($10m^2$), all species are identified and foliar cover is estimated.

Analytical methods

For analysis, the site is used as the unit of replication and secondary sample units are pooled or averaged. Once estimates for all parameters have been obtained for each sample unit, averages and a measure of variability (standard deviation or standard error of the mean) among sample sites are obtained for individual study units (three prairie communities).

Individual species abundances

Individual species frequency and percent foliar cover are calculated for each site. Frequency is defined as the number of times a species is present in a given number of plots of a particular size (Raunkiaer 1934). With the sample unit (site), as the replicate, species frequency is reported as the proportion (or percentage) of plots in which the species occurs within each site.

Foliar cover serves as an estimate of abundance for herbaceous species. The cover class intervals are converted to median values to estimate percent cover for each herbaceous and shrub species. Mean percent cover is then calculated as the species percent cover for a sampling unit, averaged for all plots in which the species occurs (i.e., plots within a sampling unit with zero values for a species are excluded).

From these basic estimates of foliar cover and frequency are generated the following metrics for each sample unit: (1) species relative cover, (2) species relative frequency, and (3) species importance value. Relative frequency and relative cover are calculated using the following formulas:

$$\text{Relative cover, species X} = \frac{cover_{speciesX}}{\Sigma\ cover_{\ all\ species}}$$

$$\text{Relative frequency, species X} = \frac{occurrences_{speciesX}}{\Sigma\ occurrences_{\ all\ species}}$$

Where occurrence is the number of plots a species is present within a site. Species importance value (IV) is an index derived from relative cover and relative frequency, [*relative cover + relative frequency)/2*)*100]. The importance value gives an overall estimate of the influence or importance of a plant species in the community.

Plant species richness, diversity and evenness

Plant diversity for each sample unit in a study unit is calculated using **Shannon diversity index**:

$$H' = -\sum_{i=1}^{n} p_i \ln p_i$$

where p*i* is the relative cover of species *i* (Shannon 1948). Species distribution **evenness** is calculated by site using Pielou (J):

$$J' = H' / H_{max},$$

where H' is the Shannon diversity index and H_{max} is the maximum possible diversity for a given number of species if all species are present in equal numbers ((ln(species richness)). J' is a measure of distribution of species within a community as compared to equal distribution and maximum diversity (Pielou 1969). **Specie**s **richness** is determined as the total number of plant taxa recorded per site. Species richness is calculated with all species (native and exotic) included in the estimate. **Simpson's index of diversity** for an infinite population (D) is calculated by site. It is the likelihood that two randomly chosen individuals from a site will be different species and emphasizes common species (McCune and Grace 2002). It is calculated by site using the complement of Simpson's original index of dominance:

$$\text{Simpson's diversity index} = 1 - \sum_{i}^{n} p_i^2$$

Shannon and Simpson's diversity index values were converted into effective number of species for each community (H_e and D_e, respectively). This allowed for both diversity measures to be compared directly to species richness of the sites (S) within and among sample years based on

count of distinct species in the community (Joust 2006). Shannon diversity index was converted into effective number of species (H_e) using the following formula:

$$H_e = \exp^{(H)}$$

where H is the Shannon diversity index value. Effective number of species based on Simpson's diversity index (D_e) is the inverse of the index value or:

$$D_e = 1/(1-D)$$

where D is the Simpson's diversity index value.

When interested in measuring diversity in a single community it is best to use all three diversity measures to most accurately reflect diversity (Joust 2006). At the most base level of species diversity, species richness provides a total number of distinct species sampled per unit area. Richness is insensitive to species abundance. Therefore a single individual species occurring only once in a community is treated the same as a species with thousands of individuals in the community. This measure is an indicator of species diversity but does not provide any information about the composition of species within the community. Shannon diversity index weights species by their abundance. It is an intermediate between species richness and Simpson's diversity index in its sensitivity to rare species. Therefore this diversity measure provides information on both the count of unique species and their abundance or density in the community. Simpson's diversity index goes one step further by disproportionately favoring dominant species based on species abundance and is little affected by gain or loss of rare species.

Dominance takes into account the species abundance and evenness of species distribution in the community. The degree of species dominance in the community is reflected by the degree to which $S > H_e > D_e$ when evenness (E) remains constant in a single community. The difference in number of species between the diversity measures reflects both how each metric considers uncommon species and how species diversity is partitioned within the community among years. If all species occurred in equal abundance in the community within and among sample years than $S = H_e = D_e$. Effective number of species for each diversity measure reflects the number of species found in a similar community when all species occur in equal density. That is to say if S = 100 and D_e is equal to 20, than the community is dominated by 20 species and 80 species occur in low abundance. Such a community would be equivalent to a community with just 20 species all occurring in equal abundance.

Prairie plant guild and exotic species summary

Average relative frequency and cover and associated standard error of the mean are also calculated for 10 plant guilds: warm-season grasses, cool-season grasses, annuals and biennials, ephemeral spring forbs, spring forbs, summer/fall forbs, legumes, ferns, and woody species (shrubs) and grass-like species. Ecological prairie plant guilds are composed of species with significant overlap in niche requirements, and that occupy similar positions along a resource gradient in a community (Root 1967, Kindscher and Wells 1995). Guilds simplify the array of species into groups making ecosystem processes and functions more easily understood (Kindscher 1994).

Exotic species form a different type of species guild, specific to species intentionally or unintentionally introduced into an area outside of its natural range. Exotic species can influence ecological processes including trophic level relationships, interspecific competition, primary and secondary succession, nutrient cycling, and ecosystem productivity, diversity, and stability (Bratton 1982). Relative frequency of exotic species is calculated for each community. For park-wide review of exotic species at PIPE see Young et al. (2007).

For each calculated metric a mean value is presented along with a measure of variability (standard deviation or standard error of the mean). Standard deviation is presented with the mean when the variability of sites is of interest, thus displaying the range of variability in site level data. Standard error of the mean is a measure of how closely the sample mean estimates the entire population mean. This measure of variability is used to describe how accurately the sample mean represents the broader area of interest, such as the restored plant community.

Two-way Analysis of Variance (ANOVA) tests were performed on foliar cover data from sites for all sample years. This test was used to determine if site means within a community type were statistically different among sample years. The main effect of sample year was of interest. It is important to note that with a small sample size, as is the case at PIPE for each community type, statistically significant results must be interpreted with caution. This test was applied to species diversity measures (S, H_e and D_e). For each of these factors degrees of freedom (df), F-ratio and p-value were reported.

Results

Tallgrass prairie

Between 1998 and 2006 a total of 141 unique species were sampled in the four HTLN sites located in the native tallgrass prairie. The total number of species sampled per year (R) was 95 ± 6 (mean ± standard deviation) while the average number of species per site (S) was 55 ± 3. Species evenness (E) remained nearly constant across sample years (0.732 ± .03). On average during any year in the native prairie 63% of the total sampled species were detected among HTLN monitoring sites.

Converting diversity measure indices into effective number of species allowed for direct comparisons between Shannon diversity and Simpson's index with species richness. Effective number of species for Shannon diversity index (H_e) and Simpson's index (D_e) did not closely follow the same trend as species richness (S) across sample years (Fig. 3).

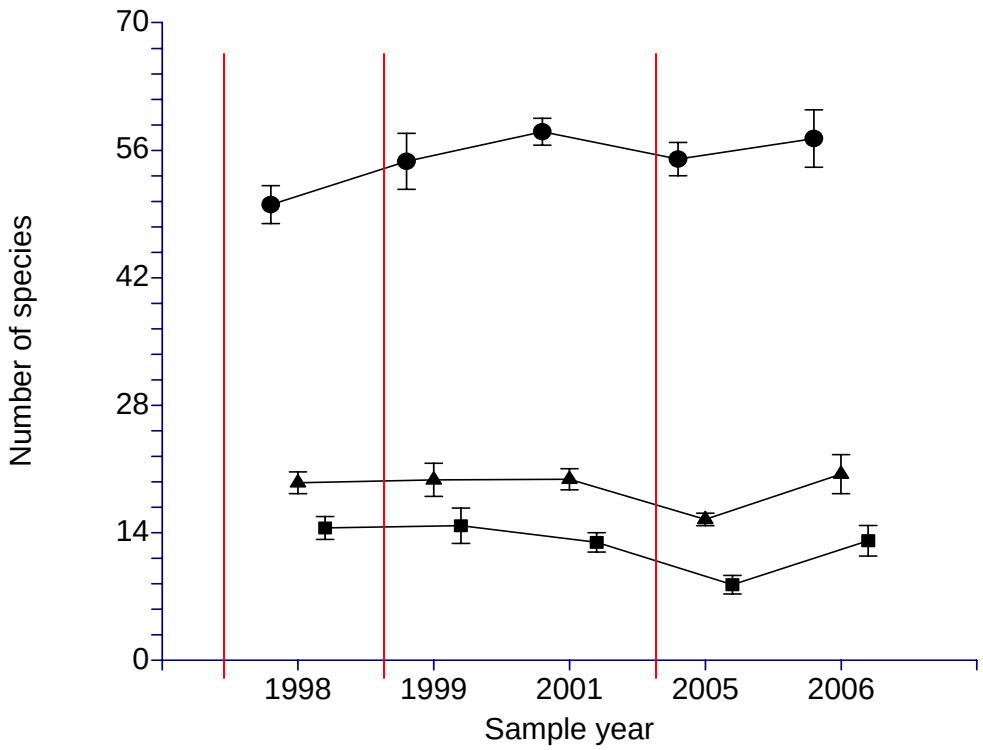


Figure 3. Species richness (circle) and effective number of species for two diversity measures (Shannon diversity, triangle; and Simpson's index, square) for native tallgrass prairie sites (n = 4). Red vertical lines indicate spring prescribed fires (1997, 1999 and 2005). Symbol is the mean and error bars are ± 1 standard error of the mean.

On average S and H_e differed in number of species by 65% (55 ± 5 vs. 19 ± 3 species, respectively) while the average difference increased to 76% (55 ± 3 vs. 13 ± 4 species) when comparing S and D_e. Although species richness and diversity fluctuated through time, the variability does not appear to be connected with prescribed fire (Fig. 3).

Of the native plant community indices only D_e (Simpson number) was statistically significant among sample years ($p = 0.042$, Table 2). Evenness, species richness and H_e (Shannon number) did not vary significantly between 1998 and 2006. The mean number of dominant species as calculated by D_e was lower in 2005 than all other sample years. There was a similar pattern in 2005 with H_e, yet the mean differences were not statistically significant. Although there was a greater change in the mean number of dominant species between years, it did not affect mean H_e across sample years.

Table 2. Two-wau ANOVA results for affect of sample year on diversity measure response variable for each community type. P-values in bold are significant at $p \leq 0.05$ level.

Community	Response	df	F-ratio	p-value
Native	Evenness	4	2.782	0.076
Native	Richenss	4	3.004	0.062
Native	Shannon number	4	2.03	0.154
Native	Simpson number	4	3.464	**0.042**
Restored	Evenness	4	1.231	0.371
Restored	Richenss	4	11.136	**0.002**
Restored	Shannon number	4	0.701	0.613
Restored	Simpson number	4	1.691	0.244
Sioux quartzite	Evenness	4	2.273	0.15
Sioux quartzite	Richenss	4	26.018	**<0.001**
Sioux quartzite	Shannon number	4	4.002	**0.045**
Sioux quartzite	Simpson number	4	0.857	0.528

Summer and fall forbs along with warm-season grasses were the most abundant plant species guilds represented each sample year (Fig. 4). The native tallgrass prairie of PIPE was composed primarily of warm-season grasses, forbs and legumes. However there was a sizeable woody species (mostly *Rosa arkansana*) component in the prairie (Fig. 4).

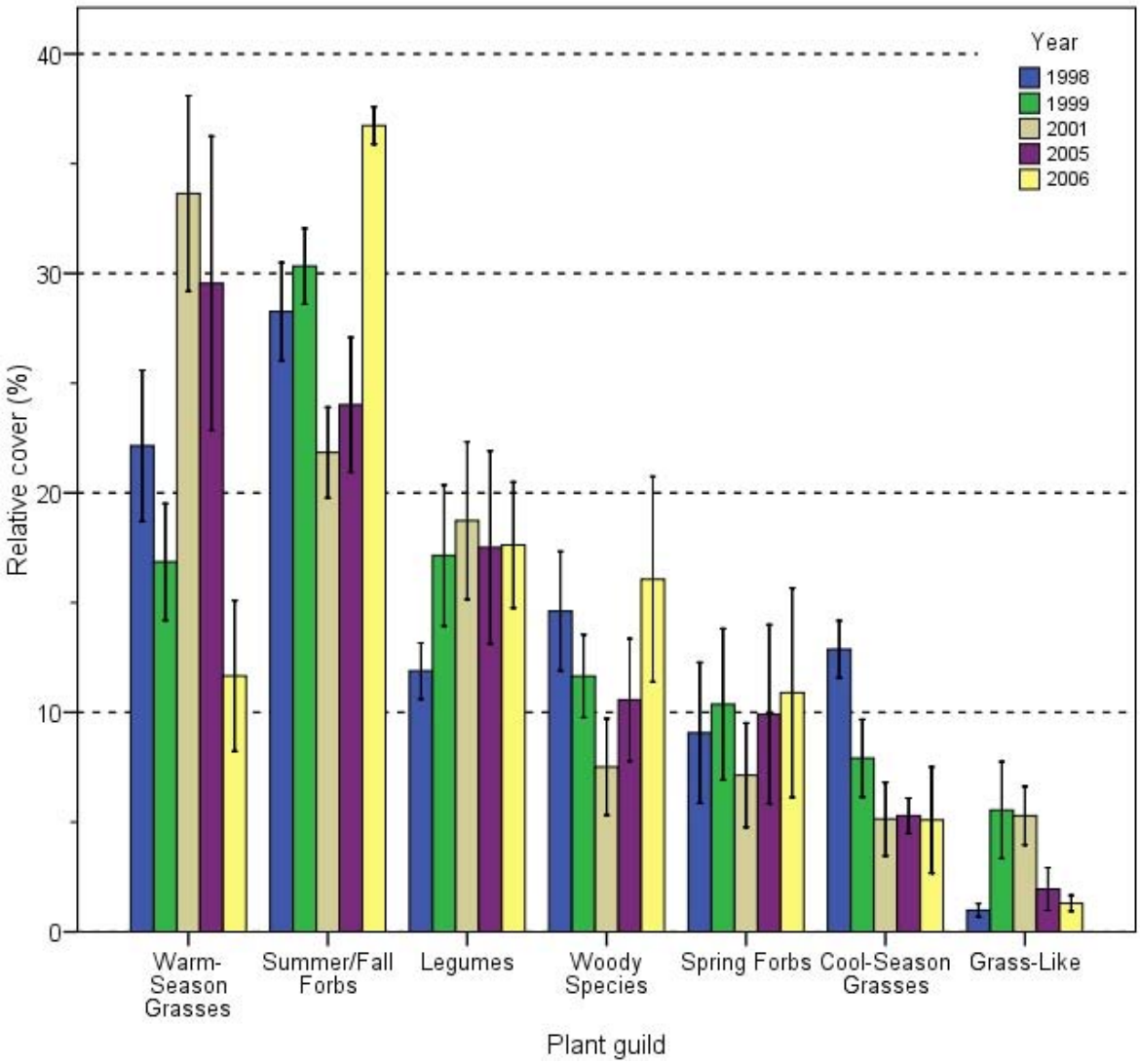


Figure 4. Relative cover (mean ± 1 standard error of the mean) for plant guilds in native tallgrass prairie (n=4).

For a complete list of dominant native species (IV ≥ 0.02) frequency and foliar cover in the native prairie see Appendix A1 and A2, respectively.

Non-native cool-season grasses along with sweet clover (*Melilotus* spp.) were the main exotic species in terms of relative frequency in the native tallgrass prairie (Fig. 5).

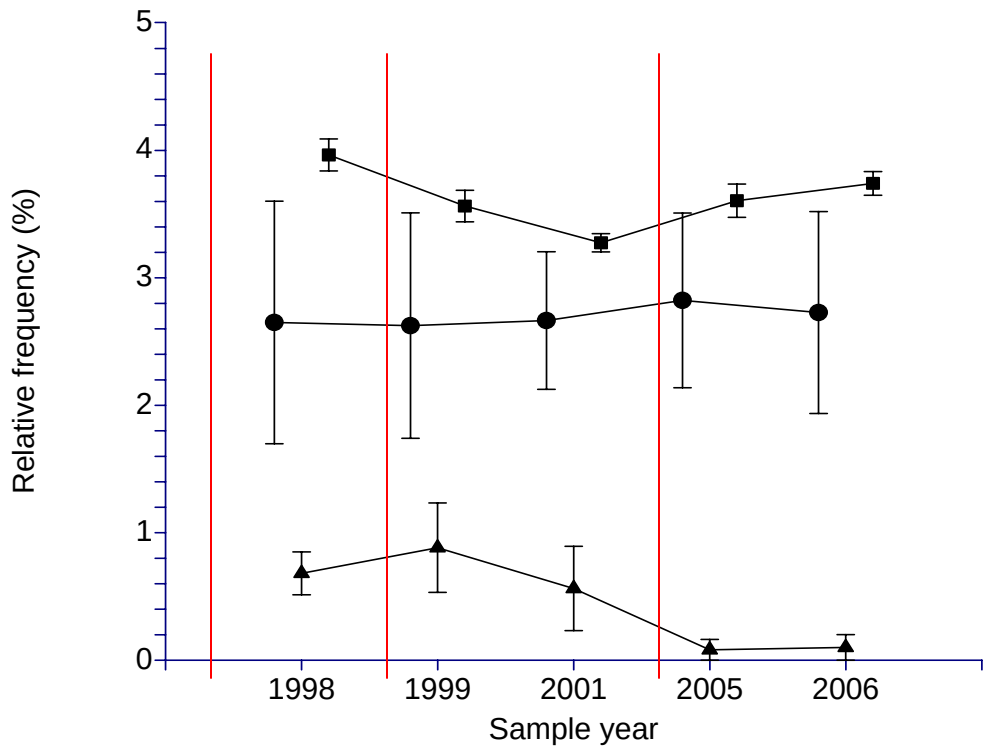


Figure 5. Relative frequency (mean ± 1 standard deviation) of three exotic species by sample year in the native tallgrass prairie sites (n = 4). Red vertical lines indicate spring prescribed fires (1997, 1999 and 2005). Square = *Poa pratensis*; circle = *Bromus inermis*; triangle = Melilotus spp.

In fact for nearly every plot sampled between 1998 and 2006 bluegrass (P. *pratensis*) was recorded. Smooth brome (B. *inermis*) was consistently found in at least two-thirds of the sample area each year. Sweet clover did not occur in such high relative frequency as the other two exotics and decreased the most in frequency following the 2003 prescribed fire (Fig. 5). Bluegrass does not appear to be impacted by fire while sweet clover was reduced in relative frequency following prescribed fire (Fig. 5). However, the amount of variation following fire is small (< 1%). Sweet clover, while a concern in other areas of the park is not very abundant in the native tallgrass prairie. For a complete list of exotic species sampled in the native prairie along with relative frequency see Appendix D1. It is important to note that of the three most abundant exotic species in the native prairie, their relative frequency is below five percent for each sample year. The variability in relative frequency (indicated by standard error bars in Fig. 5) of brome indicates that it is unevenly distributed between sites in the native prairie.

Restored tallgrass prairie

Between 1998 and 2006 a total of 115 species were sampled in the three HTLN sites located in the restored tallgrass prairie. The total number of species sampled per year (R) was 86 ± 5 (mean ± standard deviation) while the average number of species per site (S) was 53 ± 4. Species

evenness (E) remained nearly constant across sample years (0.648 ± .04). Species richness was the only diversity measure that was statistically significant among sample years (Table 2). On average during any year in the restored prairie about 71% of the total sampled species were detected among HTLN monitoring sites.

Species richness varied independently from the effective number of species of both diversity measures through time (Fig. 6).

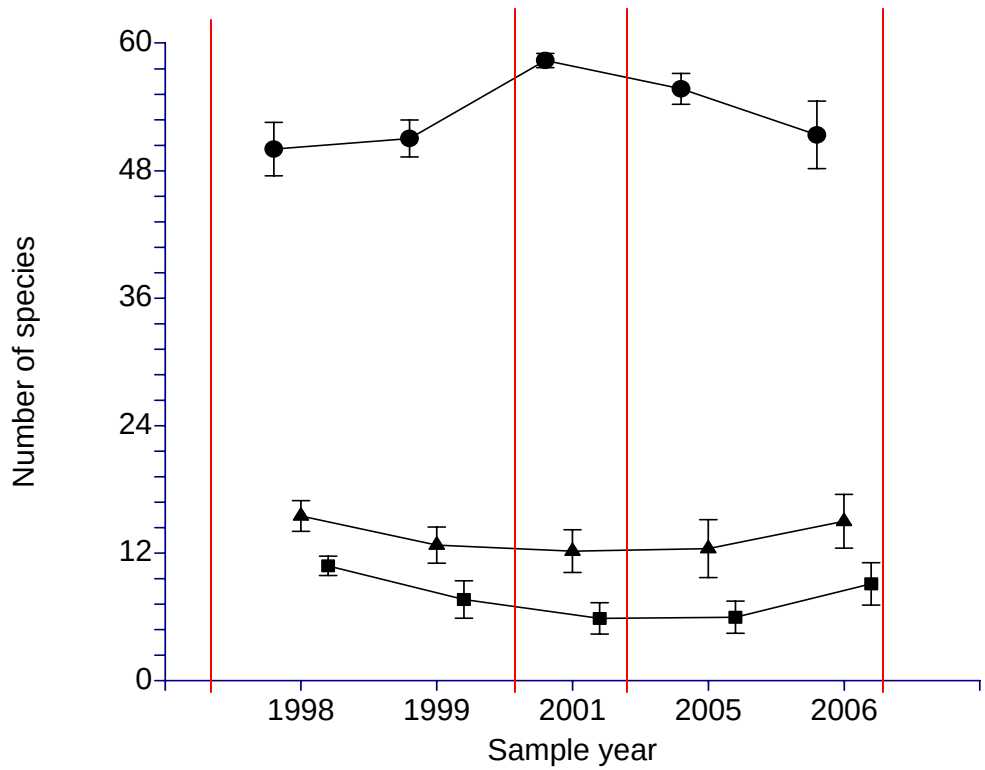


Figure 6. Species richness (circle) and effective number of species for two diversity measures (Shannon diversity, triangle; and Simpson's index, square) for restored tallgrass prairie sites (n = 4). Red vertical lines indicate prescribed fires (1997, 2000, 2003 and fall of 2006). Symbol is the mean and error bars are ± 1 standard error of the mean.

As with the native prairie, evenness remained similar across years. The degree to which $S > H_e > D_e$ was indicative of a community dominated by a few species. On average S and H_e differed in number of species by 74% (53 ± 5 vs. 14 ± 3 species, respectively) while the average difference increased to 85% (53 ± 5 vs. 8 ± 3 species) when comparing S and D_e.

Of the restored plant community indices only species richness was statistically significant among sample years ($p = 0.002$, Table 2). Evenness, H_e (Shannon number) and D_e (Simpson number) did not vary significantly between 1998 and 2006. The mean number of total species varied by year yet it did not affect mean number of abundant or dominant species among sample years (as indicated by non-significant p-values for both Shannon and Simpson number's, Table 2).

While the changes in diversity measures were different between the native and restored prairie sites, the overall number of species and magnitude of change in number of species across years was similar (Fig. 7).

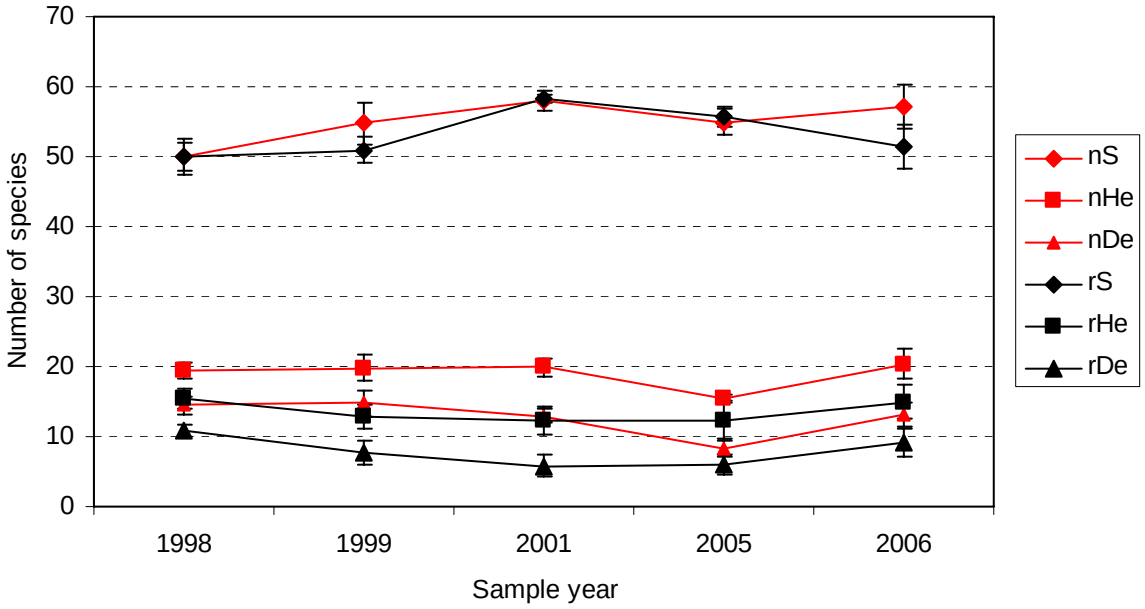


Figure 7. Comparison of restored (black) and native (red) tallgrass prairie sites for species richness (S) and effective number of species for two diversity measures (Shannon diversity, H_e and Simpson's index, D_e). Symbol is the mean and error bars are ± 1 standard error of the mean.

For the sample period of 1998 – 2006 the native prairie averaged higher effective number of species for species richness, Shannon diversity and Simpson's index than the restored prairie (a difference of 2, 5 and 5 species, respectively). Each community received a different prescribed fire regime during the sample period which may account for some of these differences.

Again summer/fall forbs along with warm-season grasses dominated species guilds in terms of mean relative cover (Fig. 8).

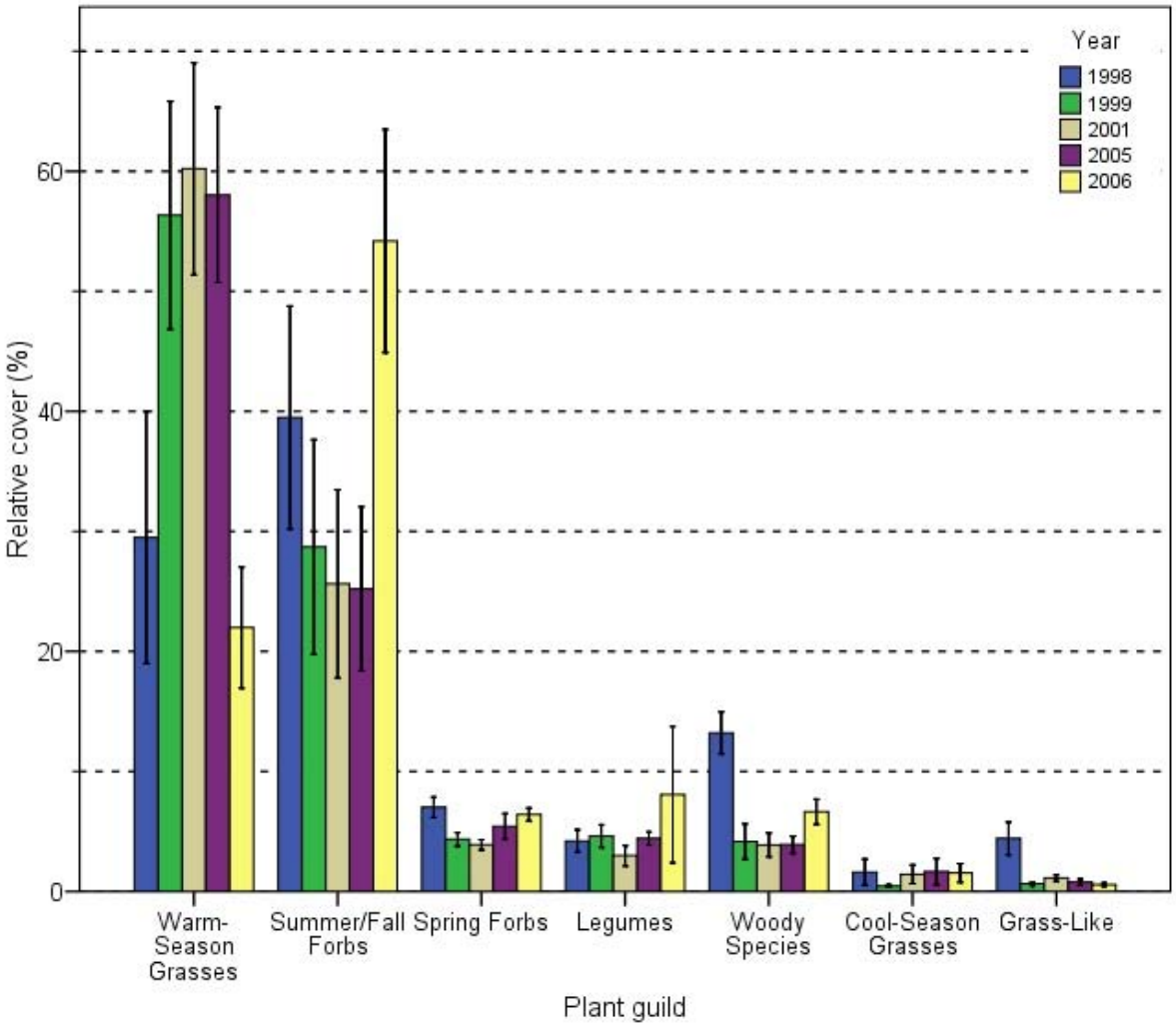


Figure 8. Relative cover (mean ± 1 standard error of the mean) for plant guilds in restored tallgrass prairie (n=3).

In contrast to the native prairie, no other species guild had relative mean cover values greater than 10% for more than a single sample year (woody species in 1998 was the only exception, Fig. 8). The restored prairie was burned in 1997, 2000, 2003 prior to sampling and fall of 2006 after sampling had occurred. Species guilds did not show any marked response to prescribed fires. For a complete list of dominant native species (IV ≥ 0.02) frequency and foliar cover in the restored prairie see Appendix B1 and B2, respectively.

Relative cover for three exotic species in the restored prairie is below five percent. The variability in relative cover for each species is large within and among sample years (Fig. 9).

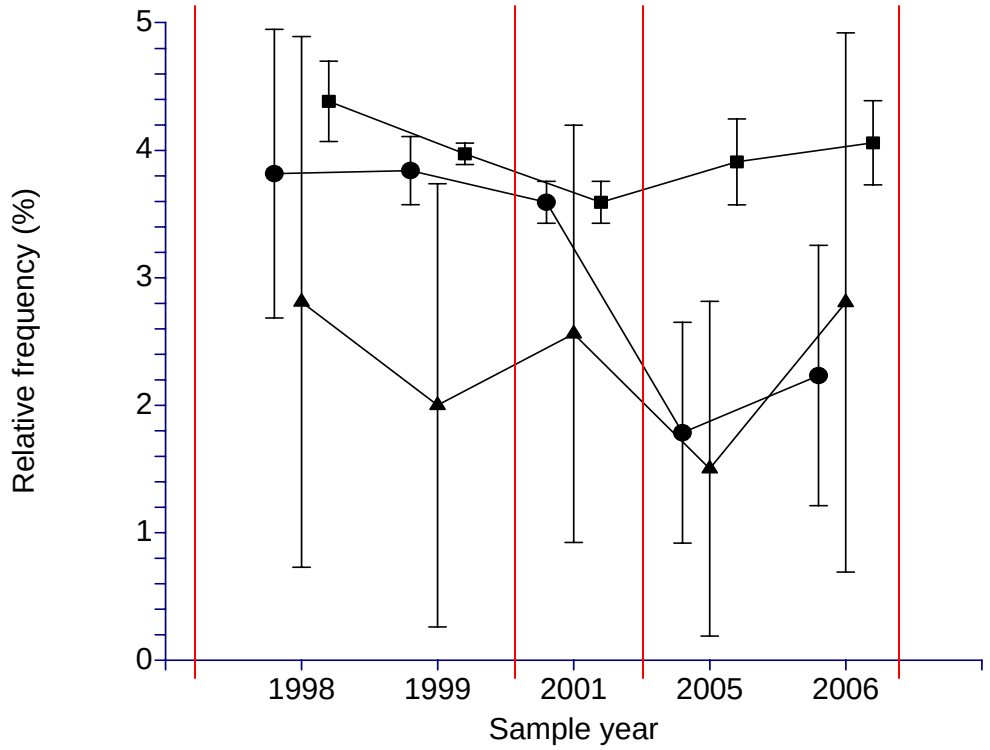


Figure 9. Relative frequency (mean ± 1 standard deviation) of three exotic species by sample year in the restored tallgrass prairie (n = 3). Red vertical lines indicate prescribed fires (1997, 2000, 2003 and fall of 2006). Square = *Poa pratensis*; circle = *Bromus inermis*; triangle = Melilotus sp.

The range of relative frequency for each exotic species is indicative of its distribution within and among the three monitoring sites as illustrated by sweet clover (triangle symbol, Fig. 9). For a complete list of exotic species in the restored prairie along with relative frequency see Appendix D2. The local distribution of the three main exotic species makes it difficult to address the connection between prescribed fire and change in their relative frequency in the restored prairie. Of note, smooth brome did decrease by nearly 50% after both the 2000 and 2003 spring burns.

Sioux quartzite prairie

Between 1998 and 2006 a total of 147 species were sampled in the three HTLN sites located in the Sioux quartzite prairie. The total number of species sampled per year (R) was 94 ± 9 (mean ± standard deviation) while the average number of species per site (S) was 62 ± 6. Species evenness (E) remained nearly constant across sample years (0.739 ± .023). Little variation in species evenness coupled with the narrow range of S among years kept both Shannon diversity index and Simpson's index nearly unchanged during the sample period. On average during any year in the Sioux quartzite prairie about 61% of the total sampled species were detected among HTLN monitoring sites.

Species richness (S), effective number of species for Shannon diversity index (H_e) and Simpson's index (D_e) did not follow a similar trend across sample years (Fig. 10).

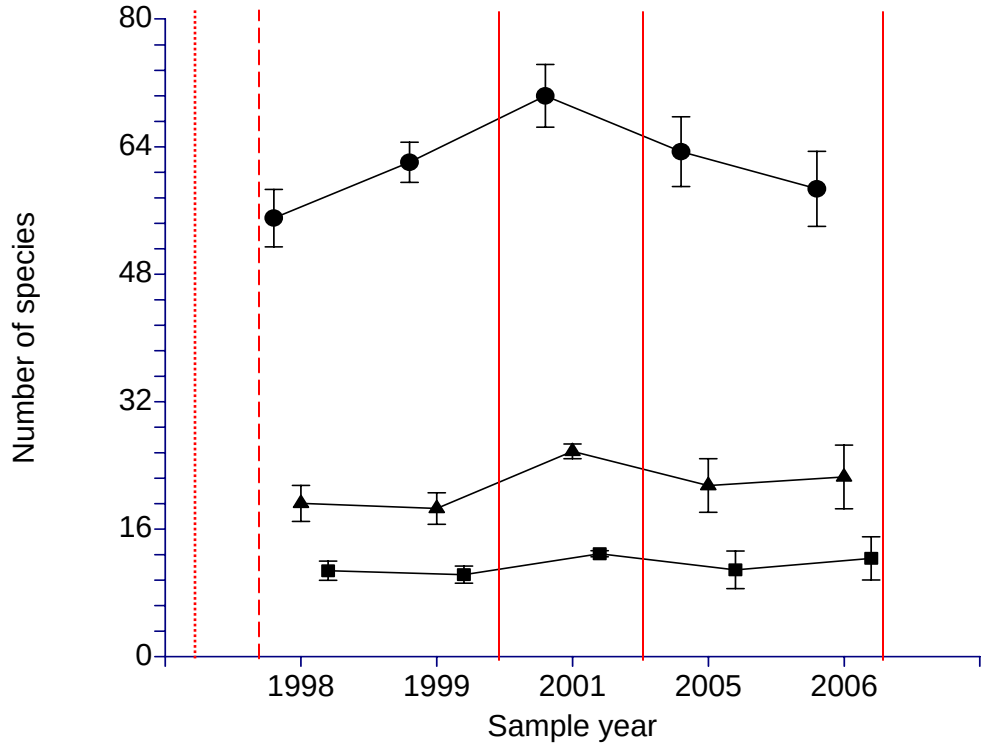


Figure 10. Species richness (circle) and effective number of species for two diversity measures (Shannon diversity, triangle; and Simpson's index, square) for Sioux quartzite prairie sites (n = 3) across sample years. Solid red vertical lines indicate prescribed fires (2000, 2003 and fall of 2006). Dotted red line indicates prescribe fire in site 6 and 10 (1997). Dashed red line indicates prescribed fire in site 5 only (1998). Symbol is the mean and error bars are ± 1 standard error of the mean.

On average S and H_e differed in number of species by 65% (62 ± 8 vs. 22 ± 5 species, respectively) while the average difference increased to 82% (62 ± 8 vs. 11 ± 3 species) when comparing S and D_e. An increase in species richness that is not reflected in an increase in H_e or D_e indicates the addition of unique species represented by either a single or few individuals patchily distributed across the community. In addition to prescribe fire, the community type had extensive manual removal and treatment of buckthorn (*Rhamnus cathartica*).

Of the Sioux quartzite plant community indices both species richness and Shannon number (H_e) was statistically significant among sample years (Table 2). Evenness and Simpson number (D_e) did not vary significantly between 1998 and 2006. Both mean number of total species and mean number of abundant species varied by year. However the change in species composition did not affect dominant species among sample years in the Sioux quartzite prairie (as indicated by non-significant p-value for Simpson number, Table 2).

Relative cover of species guilds reflects the unique community composition of the Sioux quartzite prairie (Fig. 11).

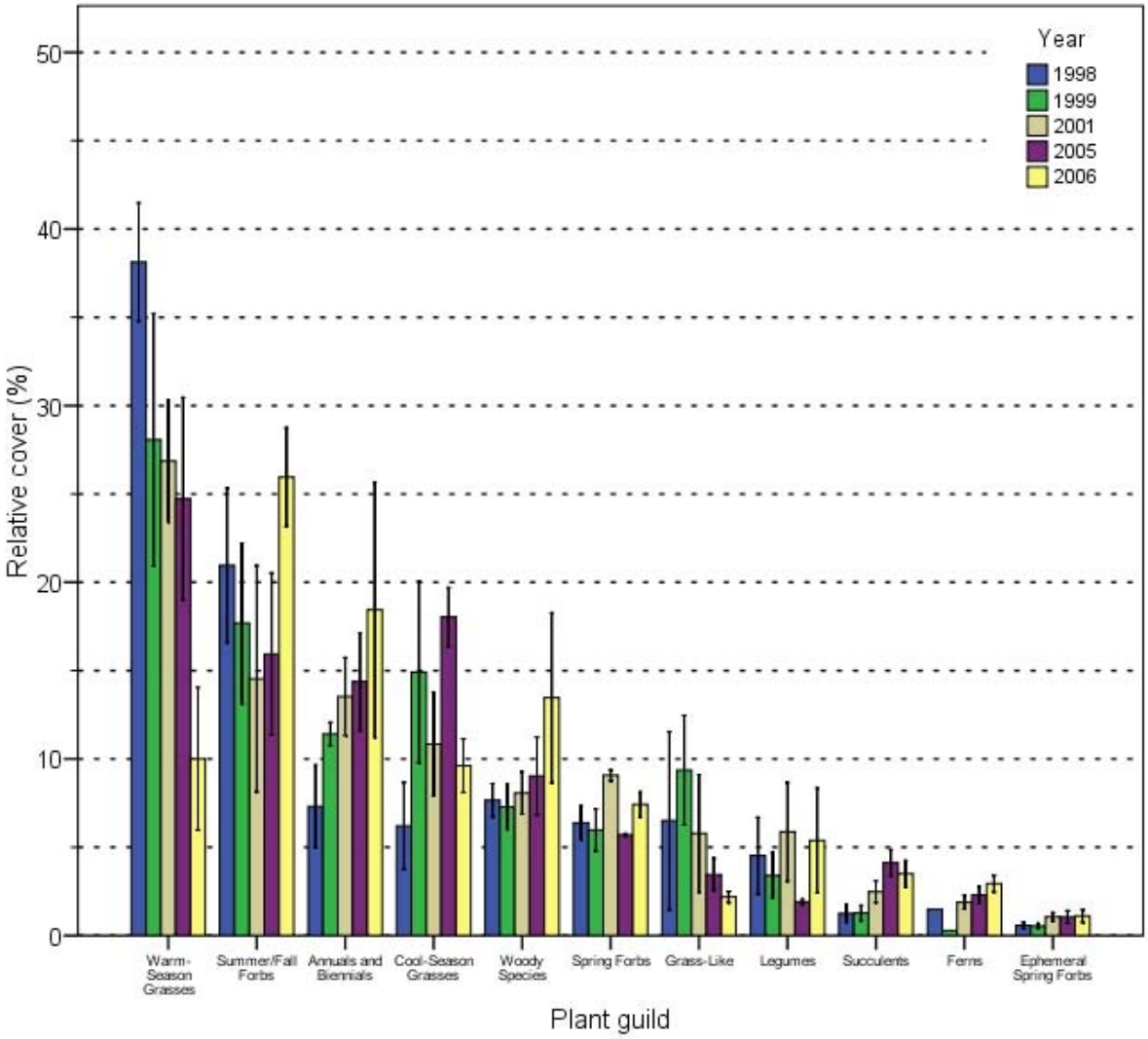


Figure 11. Relative cover (mean ± 1 standard error of the mean) for plant guilds in Sioux quartzite prairie (n=3).

Even though warm-season grasses and summer/fall forbs were the most abundant (as with all prairie communities at PIPE) the remaining guild classes were represented across the sample period. Relative cover of warm-season grasses declined each sample year while annuals and biennials increased (Fig. 11). The detectable presence of succulents, ephemeral spring forbs and ferns points to the unique nature of this community. Even though these guilds did not have high foliar cover values, they were represented among all three Sioux quartzite prairie sites and contribute to the overall guild diversity and community function. For a complete list of dominant

native species (IV ≥ 0.02) frequency and foliar cover in the Sioux quartzite prairie see Appendix C1 and C2, respectively.

Sweet clover was absent from the Sioux quartzite prairie sites in relative frequency above one percent. The frequency of bluegrass and smooth brome remained fairly constant through all sample years with the exception of 2001 (Fig. 12).

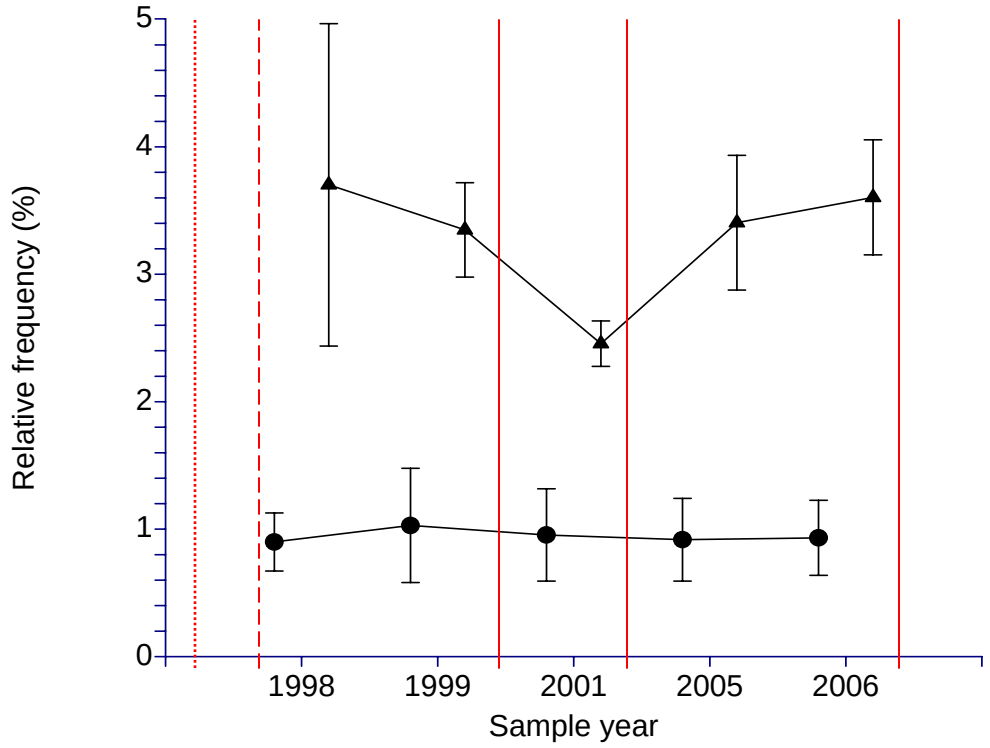


Figure 12. Relative frequency (mean ± 1 standard deviation) of two exotic species by sample year in the Sioux quartzite prairie sites (n = 3). Solid red vertical lines indicate prescribed fires (2000, 2003 and fall of 2006). Dotted red line indicates prescribe fire in site 6 and 10 (1997). Dashed red line indicates prescribed fire in site 5 only (1998).Circle = *Bromus inermis*; triangle = *Poa pratensis*;

During 2001, bluegrass dropped in relative frequency while smooth brome remained unchanged. As with the two previous communities, relative frequency of these exotic species was below five percent. It is important to note the conspicuous absence of buckthorn (*Rhamnus cathartica*) which is a result of focused and diligent removal by park staff. For a complete list of exotic species in the Sioux quartzite prairie along with relative frequency see Appendix D3.

Discussion

Long term plant community monitoring at PIPE is conducted with the goal of detecting and quantifying any change in species diversity, composition and structure in the communities of interest. Prairie communities at PIPE are dominated by a few matrix-forming grass species that effectively control community structure (Hanski 1982). A large number of less abundant species, referred to as satellite species, contribute to the diversity of prairie systems (Collins 1987, Collins and Glenn 1988, Collins and Glenn 1990). Distribution patterns of satellite species are inherently bimodal, varying within and between growing seasons (Collins and Glenn 1988, Collins and Gibson 1990). The nature of the above-ground plant community (e.g., the diversity of species and functional guilds) plays an important role in determining the stability or resistance to disturbance of a prairie system (Wardle et al. 2000). Differences between species richness and diversity measures reflect number of core and satellite species along with different prescribed fire regimes. Therefore H_e and D_e are measures that present diversity of both core and satellite species and primarily core species, respectively. The difference in number of species between species richness and diversity measures is attributable to annually variable and/or locally rare species that may be patchily distributed and thus not always detectable within monitoring sites (Grubb 1986). Increased species diversity and functional guilds act as a buffer against climatic variability, disturbance regimes, woody species encroachment and invasive species in prairie systems (Zavaleta and Hulvey 2004). Overall between 1997 and 2006 prescribed fire did not affect the prairies at a community scale relative to species richness and diversity.

Tallgrass prairie

There were minimal changes in dominant species diversity within the native prairie between 1998 and 2006 (dominant species were defined by having an importance value > 0.02, Appendix A1 and A2). The native prairie community was primarily composed of warm-season grasses and forbs that varied annually in their abundance but not presence at the community scale. Other native species that occurred infrequently or at lower densities varied more so among sample years but did not define the tallgrass community. The differences in effective number of species between diversity measures highlights the composition and structure of the community; a few dominant core species (D_e) and a larger number of less frequent (H_e) and less abundant (S) satellite species. While core species contribute greatly to the function of the community, satellite species occupy space and prevent the establishment or spread of exotic species throughout the native prairie. These functions are not species specific beyond the requirement of being native species. That is to say as long as other native species are present in conjunction with the dominant native species the community has the ability to function within its natural range of variability.

Nearly 60% of annual species diversity is represented within each monitoring site. In addition the high evenness of species distribution points to the bulk of species being partitioned among monitoring sites. That is to say that the native tallgrass prairie is more similar as a whole and less spatially structured at the community level. Therefore species composition in any monitoring site within the community reflects the majority of species diversity and richness of the entire community. This type of community structure is carried through up to the guild level. Dominant

guild types occurred in greater abundance than their annual variability, as was seen with dominant species that make up those guilds.

Even in the native tallgrass community there was a measurable exotic species component. The presence of exotic species accounted for 12% of the total species composition within sample year and 10% of the relative frequency (Appendix C1). Prescribed fires in the community appeared to initially reduce frequency of exotics however more data and prescribed burns are required to determine any trend or correlation between exotic species control and prescribed fire in the native tallgrass community. With an overall relative frequency of the most abundant exotic species being less than five percent exotic species control at PIPE has been effective between 1998 and 2006.

Restored tallgrass prairie

Restoration of 80 acres of the prairie began in the 1990's and was conducted using locally gathered seeds. This seed source is now reflected in the species diversity of the restored tallgrass prairie monitoring sites. Core-satellite distribution of species as seen in the native prairie is observed in the restored prairie as well. Dominant species for each sample year were nearly the same as seen in the native prairie (Appendix B1 and B2). Further the effective number of species for all diversity measures was similar to the native prairie (Fig. 8). Species diversity and composition in the restored prairie reflects that of the native prairie. Differences between the two community types were attributed to total species richness which was a product of the relatively short time since restoration began verses the longer evolutionary history afforded to the native tallgrass prairie.

Relative mean cover of species guilds showed little community structure among guild types. The dominant guilds were a result of restoration efforts to establish native warm-season grasses and forbs. It is this disparity in guild structure that highlights the differences between the restored and native tallgrass prairie community at PIPE. It is important to note that the restored prairie appears to be functioning within the same range of variability as native tallgrass prairie.

Both prairie communities have benefited from manual treatment and removal of exotic species and increased prescribed fire. In the restored prairie, exotic species accounted for 16% of total species composition and relative frequency (Appendix D2). Through time exotic species frequency decreased in the restored sites, mostly as a result of spring burns targeting smooth brome. Prescribed fire affects woody species encroachment and exotic species more so than species richness, diversity and composition within all three prairie types.

Over time the restored prairie has the potential to become more like the native prairie in terms of total species richness, composition and function under the current management. The determining factor in this transformation will be continued exotic species control and application of prescribed fires that mimic the temporal variability of fire under a natural disturbance regime of mesic grassland systems.

Sioux quartzite prairie

The rare Sioux quartzite prairie community has benefited from buckthorn removal. Through management efforts mean cover of buckthorn decreased from 37.5% in 2001 down to 0.5% in 2005 and 2006. However there was not a corresponding affect in terms of species diversity or composition. The community had not been dramatically impacted by buckthorn prior to its removal as indicated by species diversity and relative cover of guilds across the sample period. Thus it appears shrub removal was more of a preventive measure than a prescriptive application in the Sioux quartzite prairie. Not seeing a dramatic change in the plant community associated with buckthorn removal points to the overall good condition of the community. Guild diversity is probably the main indicator of the community's condition. Non-native cool-season grasses persist as a threat to this community and maybe targeted by prescribed fire with similar success much like smooth brome in the restored prairie communities.

In terms of species diversity the Sioux quartzite prairie closely resembles the native prairie. Differing species assemblages separate the two communities and reflect their different underlying geology and hydrology. Although both communities evolved under the same climate and disturbance regime they developed different strategies to adapt that are now reflected in each plant community.

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Appendixes

Appendix A1. Frequency for dominant native species (IV ≥ 0.02 in at least one sample year) by sample year in the native tallgrass prairie (n = 4).

ScientificName	1998	1999	2001	2005	2006
Amorpha canescens	0.88	0.90	0.90	0.90	0.93
Andropogon gerardii	0.93	0.98	1.00	0.98	0.98
Anemone canadensis	0.5	0.45	0.45	0.60	0.58
Apocynum cannabinum	0.45	0.35	0.38	0.28	0.35
Artemisia ludoviciana	0.45	0.48	0.53	0.48	0.45
Aster ericoides	0.90	0.93	0.85	0.90	0.85
Bouteloua curtipendula	0.35	0.0	0.43	0.48	0.18
Carex spp	0.60	0.90	0.98	0.80	0.78
Dichanthelium spp	0.98	0.95	1.00	0.98	0.93
Glycyrrhiza lepidota	0.43	0.40	0.43	0.40	0.40
Helianthus pauciflorus	0.78	0.73	0.75	0.73	0.83
Lathyrus venosus	0.43	0.50	0.43	0.78	0.58
Phlox pilosa	0.90	0.83	0.75	0.85	0.78
Prunus americana	0.15	0.13	0.18	0.28	0.30
Ratibida pinnata	0.70	0.75	0.83	0.85	0.78
Rosa arkansana	0.98	1.00	1.00	1.00	1.00
Schizachyrium scoparium	0.58	0.53	0.70	0.68	0.60
Solidago canadensis	0.58	0.60	0.65	0.60	0.60
Solidago missouriensis	0.73	0.68	0.70	0.73	0.68
Solidago rigida	0.33	0.38	0.35	0.73	0.53
Sorghastrum nutans	0.73	0.80	0.83	0.80	0.60
Sporobolus heterolepis	0.60	0.55	0.68	0.15	0.48
Stipa spartea	0.50	0.58	0.68	0.68	0.53
Zizia aurea	0.35	0.35	0.23	0.25	0.38

Appendix A2. Foliar cover (%) for dominant native species (IV ≥ 0.02 in at least one sample year) by sample year in the native tallgrass prairie (n = 4).

ScientificName	1998	1999	2001	2005	2006
Amorpha canescens	10.9	14.8	8.1	6.3	8.8
Andropogon gerardii	11.1	9.5	12.0	7.9	2.4
Anemone canadensis	2.1	4.2	2.0	1.4	3.0
Apocynum cannabinum	6.0	7.6	3.9	1.4	5.9
Artemisia ludoviciana	10.5	9.6	2.9	1.9	2.4
Aster ericoides	5.5	6.7	3.7	1.0	2.1
Bouteloua curtipendula	9.9	0.0	3.1	6.2	0.5
Carex spp	2.0	7.6	3.8	1.1	0.8
Dichanthelium spp	15.5	10.8	2.2	1.7	1.8
Glycyrrhiza lepidota	9.6	7.9	3.1	2.3	3.4
Helianthus pauciflorus	6.8	11.4	1.8	1.0	4.2
Lathyrus venosus	3.9	8.9	11.5	1.1	1.4
Phlox pilosa	2.7	4.6	0.5	0.5	0.5
Prunus americana	10.6	4.9	9.1	8.2	13.7
Ratibida pinnata	3.1	1.5	0.7	0.6	2.0
Rosa arkansana	19.5	14.0	3.8	2.7	5.8
Schizachyrium scoparium	4.7	3.2	1.5	3.1	1.5
Solidago canadensis	10.7	12.7	5.8	4.1	11.0
Solidago missouriensis	9.8	13.4	5.1	1.9	2.8
Solidago rigida	3.3	1.8	0.7	2.0	4.2
Sorghastrum nutans	10.4	9.0	8.1	2.7	0.9
Sporobolus heterolepis	6.8	7.0	6.9	1.8	7.8
Stipa spartea	7.6	3.9	2.6	1.4	3.0
Zizia aurea	12.4	14.7	2.4	1.3	3.6

Appendix B1. Frequency for dominant native species (IV ≥ 0.02 in at least one sample year) by sample year in the restored tallgrass prairie (n = 3).

ScientificName	1998	1999	2001	2005	2006
Amorpha canescens	0.40	0.43	0.47	0.43	0.50
Andropogon gerardii	0.83	1.00	1.00	1.00	1.00
Artemisia ludoviciana	0.37	0.33	0.40	0.37	0.37
Aster laevis	0.83	0.83	0.90	0.87	0.93
Carex spp	0.53	0.50	0.97	0.77	0.70
Dichanthelium spp	0.67	0.5	0.77	0.80	0.77
Phlox pilosa	0.87	0.80	0.73	0.67	0.80
Ratibida pinnata	0.63	0.73	0.77	0.83	0.83
Rosa arkansana	0.97	1.00	1.00	1.00	1.00
Schizachyrium scoparium	0.47	0.63	0.77	0.77	0.77
Solidago canadensis	0.80	0.90	0.80	0.73	0.80
Solidago rigida	0.87	0.93	1.00	1.00	1.00
Sorghastrum nutans	0.50	0.70	0.93	0.87	0.93
Sporobolus asper	0.33	0.37	0.47	0.33	0.40

Appendix B2. Foliar cover (%) for dominant native species (IV ≥ 0.02 in at least one sample year) by sample year in the restored tallgrass prairie (n = 3).

ScientificName	1998	1999	2001	2005	2006
Amorpha canescens	1.5	1.1	1.6	1.1	3.8
Andropogon gerardii	13.1	26.1	19.8	24.5	6.1
Artemisia ludoviciana	21.7	7.1	7.0	4.7	13.1
Aster laevis	10.4	9.9	1.8	1.4	4.1
Carex spp	6.1	1.2	0.8	0.7	0.5
Dichanthelium spp	2.5	0.7	0.7	1.2	0.9
Phlox pilosa	0.5	0.5	0.5	0.5	0.8
Ratibida pinnata	1.0	0.7	1.2	3.6	4.8
Rosa arkansana	12.7	3.6	2.3	2.4	4.0
Schizachyrium scoparium	8.6	7.5	4.0	1.2	1.1
Solidago canadensis	11.0	7.7	5.4	1.6	6.2
Solidago rigida	5.5	3.6	3.4	4.7	10.4
Sorghastrum nutans	13.9	17.3	15.9	13.4	6.7
Sporobolus asper	8.5	13.0	4.6	4.2	1.1

Appendix C1. Frequency for dominant native species (IV ≥ 0.02 in at least one sample year) by sample year in the Sioux quartzite prairie (n = 3).

ScientificName	1998	1999	2001	2005	2006
Allium stellatum	1	0.95	1	0.6	0.75
Ambrosia psilostachya	1	1	0.95	0.95	1
Amorpha canescens	0.45	0.45	0.45	0.4	0.5
Andropogon gerardii	0.7	0.75	0.75	0.85	0.8
Artemisia frigida	0.2	0.2	0.15	0.15	0.2
Bouteloua gracilis	0.85	0.85	0.9	0.85	0.75
Carex spp	0.4	0.85	0.85	0.8	0.7
Dichanthelium spp	0.75	0.7	0.9	0.95	1
Erigeron strigosus	0.15	0.75	0.5	0.95	0.7
Hedeoma hispidum	0.9	0.95	1	0.95	0.9
Koeleria macrantha	0.8	0.8	0.8	0.85	0.85
Lepidium densiflorum	0.8	0.9	0.8	0.75	0.6
Opuntia fragilis	0.8	0.85	0.85	0.9	0.9
Oxalis spp	0.9	1	1	0.45	0.75
Oxalis violacea	0.5	0.4	0.8	0.75	0.2
Panicum capillare	0.7	0.5	0.65	0.3	0.1
Prunus americana	0.1	0.1	0.5	0.2	0.15
Rhus glabra	0.1	0.1	0.1	0.1	0.1
Schizachyrium scoparium	0.9	0.9	0.9	0.9	0.9
Selaginella rupestris	0.0	0.0	0.0	0.85	0.75
Silene antirrhina	0.75	1	0.8	0.15	0.0
Solidago missouriensis	0.2	0.15	0.1	0.2	0.4
Sporobolus heterolepis	0.4	0.3	0.45	0.2	0.3
Stipa spartea	0.5	0.5	0.3	0.5	0.3

Appendix C2. Foliar cover (%) for dominant native species (IV ≥ 0.02 in at least one sample year) by sample year in the Sioux quartzite prairie (n = 3).

ScientificName	1998	1999	2001	2005	2006
Allium stellatum	0.5	0.5	0.5	0.5	0.5
Ambrosia psilostachya	3.9	9.6	5.0	5.1	6.4
Amorpha canescens	6.7	4.8	5.9	1.1	3.0
Andropogon gerardii	8.6	3.3	0.8	0.9	1.1
Artemisia frigida	8.4	1.1	1.3	2.2	1.8
Bouteloua gracilis	1.2	1.2	1.5	0.9	0.7
Carex spp	5.8	7.0	1.5	1.6	0.7
Dichanthelium spp	2.1	4.0	1.1	1.7	1.6
Erigeron strigosus	0.5	3.0	0.5	2.0	5.6
Hedeoma hispidum	1.1	2.7	0.5	0.5	0.5
Koeleria macrantha	1.9	6.2	1.8	2.8	0.9
Lepidium densiflorum	1.3	0.5	0.5	0.5	0.5
Opuntia fragilis	1.1	1.1	1.1	1.7	1.2
Oxalis spp	1.2	1.1	0.5	0.5	0.5
Oxalis violacea	0.8	0.5	0.7	0.7	0.5
Panicum capillare	1.7	0.5	0.5	0.5	0.5
Prunus americana	7.8	7.8	3.0	0.5	6.2
Rhus glabra	1.8	3.0	7.8	15.0	15.0
Schizachyrium scoparium	9.6	11.8	7.0	5.8	1.3
Selaginella rupestris	0.0	0.0	0.0	0.9	1.0
Silene antirrhina	0.7	0.5	0.5	0.5	0.0
Solidago missouriensis	11.0	5.3	0.5	0.5	0.8
Sporobolus heterolepis	3.6	1.3	0.5	1.1	1.0
Stipa spartea	0.5	0.5	0.9	3.7	0.5

Appendix D1. Relative frequency (%) of exotic species in the native tallgrass prairie (n = 4).

ScientificName	1998	1999	2001	2002	2005	2006
Asparagus officinalis	0.83	0.37	0.32	0.33	0.72	0.73
Bromus inermis	3.53	3.5	2.66	3.17	2.82	2.73
Carduus nutans	0	0.39	0	0	0	0
Cirsium arvense	0	0	0	0	0	0.36
Cirsium vulgare	0.39	0	0	0	0	0
Convolvulus arvensis	2.07	0.9	0.95	1.31	1.81	0.36
Elymus repens	0	0	0	0	0.36	1.2
Lactuca serriola	0.36	0	0	0	0	0.36
Linaria vulgaris	0.39	0	0	0	0	0
Medicago lupulina	0	0	0	0	0	0.36
Melilotus spp	0.68	1.18	1.12	0.83	0.33	0.4
Phalaris arundinacea	0	0	0	0	0	1.09
Phleum pratense	0	0.38	0	0	0	0
Poa pratensis	3.96	3.56	3.27	3.17	3.6	3.74
Poa spp	0	0	0	0	0	1.13
Rhamnus cathartica	0.41	0.37	0.32	0.33	0.36	0.36
Rumex crispus	0	0	0	0	0.39	0.36
Silene latifolia ssp. alba	0	0	0	0	0.33	0
Stachys palustris	0	0.38	0	0	0	0
Taraxacum laevigatum	0	0	0.35	0	0	0
Taraxacum officinale	1.5	1.45	1.93	2.65	1.7	0.93
Tragopogon dubius	0	0	0	0.32	0	0
Trifolium pratense	0.36	1	0.96	0.9	0.72	0
Verbascum thapsus	0	0.33	0	0	0	0.4

Appendix D2. Relative frequency (%) of exotic species in the restored tallgrass prairie (n = 3).

ScientificName	1998	1999	2001	2005	2006
Asparagus officinalis	0.47	0.41	0.37	0.41	0
Bromus inermis	3.81	3.84	3.59	1.78	2.23
Carduus nutans	0.69	0.99	0.37	0	0
Cirsium arvense	0.43	0	0.37	0.4	0.43
Convolvulus arvensis	0.47	0.41	0	0.41	0
Elymus repens	0	0	0	0	0.74
Lactuca serriola	2.37	1.99	1.47	1.22	0.87
Linaria vulgaris	1.07	0.4	1.83	0	0
Medicago lupulina	0	0	1.1	0.81	2.16
Melilotus spp	2.81	3	2.56	2.25	2.8
Poa pratensis	4.38	3.97	3.59	3.91	4.06
Poa spp	0	0	0	0	0.41
Rhamnus cathartica	0	0	0.37	0.41	0.41
Setaria viridis	1.82	2.01	2.01	1.87	0.6
Sonchus arvensis	0	0	1.11	0.41	0.41
Taraxacum laevigatum	0	0	0	0.41	0.37
Taraxacum officinale	2.19	2.78	3.12	3.4	2.42
Tragopogon dubius	0.43	0.39	0.37	0.35	0
Trifolium repens	0.83	0.79	0.73	0.81	0.43
Trifolium spp	0	0.39	0.37	0	0

Appendix D3. Relative frequency (%) of exotic species in the Sioux quartzite prairie (n = 3).

ScientificName	1998	1999	2001	2005	2006
Asparagus officinalis	0.35	0.33	0.28	0.8	0.81
Bromus inermis	0.9	1.03	0.95	0.92	0.93
Bromus japonicus	1.01	1.8	0.74	1.46	1.14
Cerastium glomeratum	0	0	1.45	2	0
Cirsium arvense	0	0	0	0	0.36
Convolvulus arvensis	0	0.75	0	0	0
Draba nemorosa	0	0	1.06	0.8	0
Elymus repens	0	0	0	0	0.81
Eriochloa villosa	0	0	0	0.8	0
Erysimum cheiranthoides	0	0.33	0	0	0
Medicago lupulina	0	0.33	0	0.8	0
Melilotus spp	0	0.33	0.93	0.33	0.71
Nepeta cataria	0	0	0.64	0	0
Poa compressa	0	0	1.72	1.75	2.58
Poa pratensis	3.7	3.35	2.45	3.4	3.6
Poa spp	0	0	0	0	3.16
Rhamnus cathartica	1.01	0.75	0.64	0.8	0.81
Rumex crispus	0.99	0.75	0.46	0	0
Setaria pumila	1.01	0	0	0	0
Setaria viridis	2.23	1.26	0.46	1	2.1
Taraxacum officinale	2.02	0.54	0	0	1.08
Tragopogon dubius	1.4	0.33	0.28	0	0.85
Veronica arvensis	0	0	0	0.8	0

The NPS has organized its parks with significant natural resources into 32 networks linked by geography and shared natural resource characteristics. HTLN is composed of 15 National Park Service (NPS) units in eight Midwestern states. These parks contain a wide variety of natural and cultural resources including sites focused on commemorating civil war battlefields, Native American heritage, westward expansion, and our U.S. Presidents. The Network is charged with creating inventories of its species and natural features as well as monitoring trends and issues in order to make sound management decisions. Critical inventories help park managers understand the natural resources in their care while monitoring programs help them understand meaningful change in natural systems and to respond accordingly. The Heartland Network helps to link natural and cultural resources by protecting the habitat of our history.

The I&M program bridges the gap between science and management with a third of its efforts aimed at making information accessible. Each network of parks, such as Heartland, has its own multi-disciplinary team of scientists, support personnel, and seasonal field technicians whose system of online databases and reports make information and research results available to all. Greater efficiency is achieved through shared staff and funding as these core groups of professionals augment work done by individual park staff. Through this type of integration and partnership, network parks are able to accomplish more than a single park could on its own.

The mission of the Heartland Network is to collaboratively develop and conduct scientifically credible inventories and long-term monitoring of park "vital signs" and to distribute this information for use by park staff, partners, and the public, thus enhancing understanding which leads to sound decision making in the preservation of natural resources and cultural history held in trust by the National Park Service.

www.nature.nps.gov/im/units/htln/

Heartland Network

Natural Resource Monitoring

The U.S. Department of the Interior (DOI) is the nation's principal conservation agency, charged with the mission "*to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian tribes and our commitments to island communities."* More specifically, Interior protects America's treasures for future generations, provides access to our nation's natural and cultural heritage, offers recreation opportunities, honors its trust responsibilities to American Indians and Alaska Natives and its responsibilities to island communities, conducts scientific research, provides wise stewardship of energy and mineral resources, fosters sound use of land and water resources, and conserves and protects fish and wildlife. The work that we do affects the lives of millions of people; from the family taking a vacation in one of our national parks to the children studying in one of our Indian schools.

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National Park Service
U.S. Department of the Interior

Natural Resource Program Center
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nps.gov

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