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Fort Collins, Colorado

Plant Community Monitoring Trend Report, Homestead National Monument of America

Natural Resource Technical Report NPS/HTLN/NRTR—2007/028
NPS D-48

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

Plant Community Monitoring Trend Report, Homestead National Monument of America

Natural Resource Technical Report NPS/HTLN/NRTR—2007/028
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Executive Summary

Plant community monitoring at Homestead National Monument of America (HOME) is designed to detect and describe changes in prairie and forested communities. This is accomplished by quantifying species composition, structure, and diversity of prairie and forest communities. Restoration of the prairie and the bur oak lowland forest is a focus of natural resource management at HOME.

The importance of prairie as the historic landscape to early settlers led the Park Service to restore 100 acres of former agricultural fields to native prairie at HOME. The first seed and sod transfer efforts date back to 1939 making the Homestead prairie the second oldest prairie restoration in the United States. In subsequent years, park managers have been diligent towards their goal of prairie restoration, and have utilized increasingly sophisticated techniques to restore and maintain the tallgrass prairie. Monitoring is a continuation of this effort and aims to quantify the effects of management and guard against degradation.

The hardwood forest occupies sixty acres along Cub Creek and comprises two distinct zones based on past land use. The species composition of the forest in the northern part of the park is consistent with the description of a mesic bur oak forest, a critically imperiled community in Nebraska. The southern portion is characterized as an eastern lowland forest and was heavily logged in the 1930's. Fire suppression, grazing cessation and changes in the hydrology of Cub Creek have produced significant changes in the woodlands since the establishment of the first homestead.

In the restored prairie five Heartland Inventory and Monitoring (HTLN) sites were sampled between 1998 and 2006. Baseline sampling of three sites in the lowland forest occurred from 2000 to 2006. The HTLN 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. In addition to frequency and foliar cover data collected for the prairie and understory vegetation, overstory stand data were collected in the lowland forest sites.

Management actions have been implemented to reduce the relative frequency of both woody and exotic species in the prairie (< 5% relative frequency for both is the goal). Current levels of both threats to the prairie have been well managed and are just above the desired condition. Although it is difficult to compare quantitatively the current prairie with a mid-1860's prairie of the region, the core-satellite distribution of species in the restored prairie reflects a functioning native prairie. Restoration of the bur oak lowland forest along Cub creek requires effort to reduce the north-south gradient in decreasing stand quality that currently exists. Promoting regeneration of native species other than hackberry and defining canopy layers so that recruitment of trees into the overstory can occur will enhance the lowland forest.

The restored prairie community composition and structure does provide an accurate backdrop for the interpretation of the homesteading experience in America. Through concerted efforts and succession the lowland forests will expand the limited area of the bur oak community along Cub creek.

Introduction

Plant community monitoring at Homestead National Monument of America (HOME) is designed to detect and describe changes in prairie and forested communities. This is accomplished by quantifying species composition, structure, and diversity of prairie and forest communities. Moreover, monitoring data are used to determine temporal changes in the species composition, structure, and diversity of those communities. A goal of long term monitoring is to estimate the rate of temporal change for measures of diversity, specifically as related to management efforts in restoration of prairie and woodland habitats. Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program (HTLN) vegetation monitoring objectives compliment HOME desired future conditions as outlined in the Vegetation Management Action Plan (Bolli 2006):

> "The Monument's natural resources are managed in such a way as to maintain a heterogeneous landscape composed of a mosaic of high quality remnant and restored tallgrass prairie, lowland bur oak forest and associated ecotones, as well as prairie streams and their hydrologic processes; that reflect the value of the site as a homestead, represents as accurately as possible the environment encountered by early settlers, and preserves native biodiversity."

Homestead National Monument goals associated with desired future conditions of vegetation include protecting species diversity, managing and monitoring exotic species, maintaining a "healthy ratio of shrubs" (< 5% relative cover) in the prairie, and restoring the lowland bur oak forest. Long term vegetation monitoring at HOME focuses on species diversity, composition and structure of the restored prairie and lowland forest with the intent to provide results that allow for an evaluation of the degree to which desired future conditions are being met at the park. The vegetation management plan outlines four specific goals that benefit from long term monitoring. This report provides findings that address the following goals as presented in the plan:

- Manage and monitor exotic species
- Manage thickets so they remain a small part of prairie
- Protect species diversity
- Restore lowland bur oak forest

By quantifying the affect of management actions on natural resources in the park, long term monitoring provides information at multiple temporal and spatial scales. Monitoring data address issues ranging from single species of concern and exotic species guilds to community function and integrity change through time.

Plant communities monitored

Restored tallgrass prairie

The importance of prairie as the historic landscape to early settlers lead the Park Service to restore 100 acres of former agricultural fields to native prairie at Homestead NM. The first seed and sod transfer efforts date back to 1939 making the Homestead prairie the second oldest prairie restoration in the United States. In subsequent years, park managers have been diligent towards

their goal of prairie restoration, and have utilized increasingly sophisticated techniques to restore and maintain the tallgrass prairie. Monitoring is a continuation of this effort and aims to quantify the effects of management and guard against degradation.

Lowland forest

The hardwood forest occupies sixty acres along Cub Creek (NPS 1999) and comprises two distinct zones based on past land use. The species composition of the forest in the northern part of the park is consistent with the description of a mesic bur oak forest, a critically imperiled (S1) community in Nebraska (Steinauer & Rolfsmeier 2000). The southern portion is characterized as an eastern lowland forest and was heavily logged in the 1930's. Fire suppression, grazing cessation and changes in the hydrology of Cub Creek have produced significant changes in the woodlands since the establishment of the first homestead. For a complete description, inventory and evaluation of the lowland forest along Cub Creek, see Mlekush and DeBacker (2003) and Rolfsmeier (2007).

Methods

Field methods

The Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program (HTLN) implemented monitoring at HOME in 1998 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). Five prairie sites (consisting of ten $10m^2$ plots at each site) were sampled in late spring and early fall during 1998, 1999, 2000, 2005 and 2006, to obtain accurate cover estimates and identification of warm season grasses and summer/fall flowering forbs (Fig. 1).

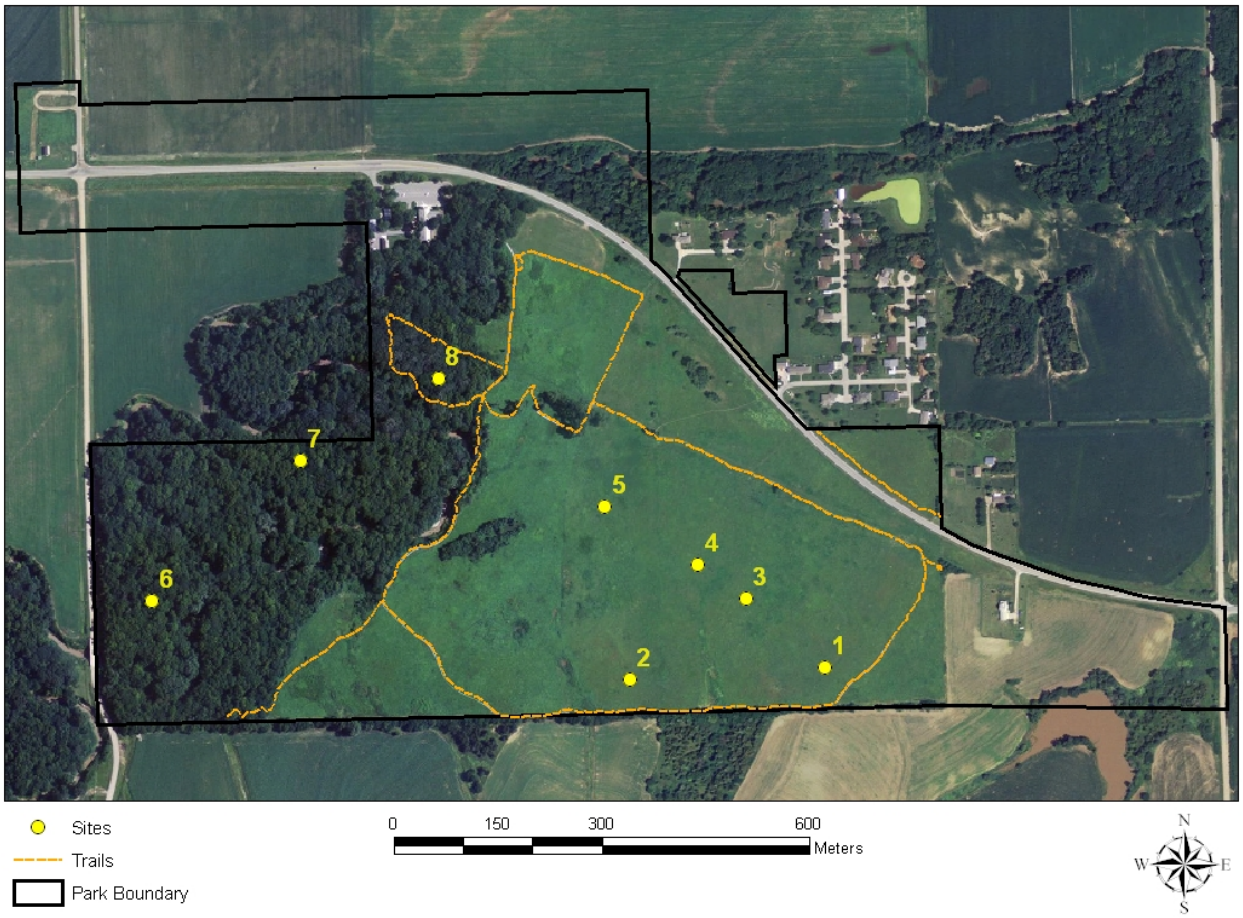

Figure 1. Map of Homestead National Monument of America displaying vegetation monitoring sites. Sites 1-5 occur in the restored prairie while sites 6 – 8 are located in the lowland forest along Cub Creek.

Additional monitoring data were collected from three sites in 2002. Prescribed fire heavily impacted two sites in 2002 just prior to late spring monitoring. Individual floodplain forests sites were established in 2000 and 2002, while a single mesic bur-oak forest site (site 8) was established in 2005 (Table 1). Forest sites were monitored in 2000, 2002 and 2005, while only forest understory was sampled in 2006.

Table 1. Vegetation monitoring sites and sample year for the restored prairie and lowland forest of Homestead National Monument of America.

Community	N	1998	1999	2000	2002	2005	2006
prairie	5	X	X	X	X	X	X
forest overstory	3			X	X	X	
forest understory	3			X	X	X	X

The 2006 Fire Management Plan for HOME defined only two fire management units, one in the 100 acre restored prairie (FMU#1) and the other in the lowland forest (FMU#2) (NPS 2006). Previous prescribed fires have been applied at a finer spatial scale in the prairie, thus not all HTLN monitoring sites burned during individual burn events between 1998 and 2006 (Table 2).

Table 2. Prescribed fire by HTLN prairie site and year at HOME. Prescribed fire applied prior to spring field sampling for indicated year, except 2005 which was burned in the fall after sampling.

HTLN site	1998	1999	2000	2001	2002	2003	2004	2005	2006
1	X				X				X
2				X				X	
3	X			X	X				
4				X				X	
5				X				X	

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).

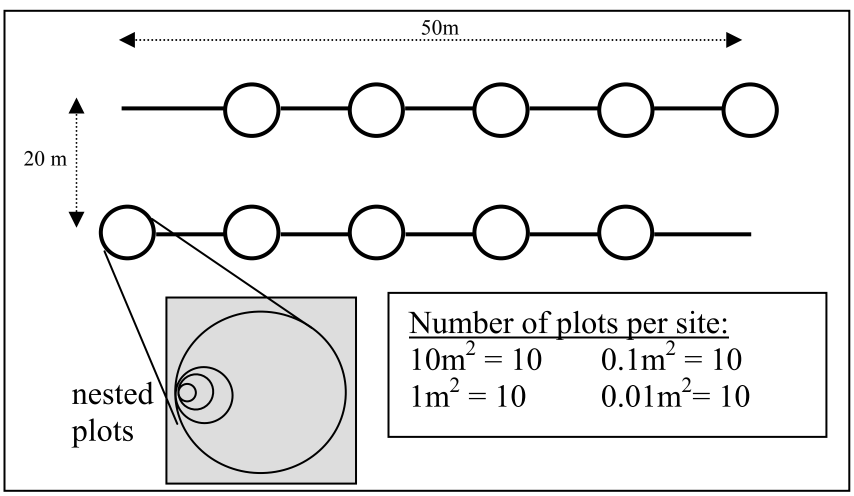

Figure 2. HTLN vegetation community sample design showing transects and plots including nested plots.

The primary sample unit is the site and circular plots along each transect are secondary sample units. 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. Prairie and forest

understory vegetation is sampled in this manner. For forested communities overstory canopy cover, basal area and regeneration species composition and structure data are collected at each site.

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 with a measure of variability (standard deviation or standard error of the mean) among sample sites are obtained for individual study units (restored prairie and lowland forest).

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:

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

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

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). **Species 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 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). Mean relative frequency, mean relative cover and importance values of exotic species are calculated for each community.

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 restored prairie sites for all sample years. This test was used to determine if site means within the restored prairie were statistically different among sample years. The main effect of sample year was of interest. This test was applied to species diversity measures (S, H_e and D_e), relative cover of woody species and relative frequency of exotic species. For each measure degrees of freedom (df), F-ratio and p-value were reported.

Overstory and understory data summary

In the lowland forest community, summary statistics for overstory and understory (stems ≥ 5.0 cm dbh) tree species are calculated. For each species, density and basal area are calculated. Density, or the number of stems per sample unit, is a measure of abundance for tree species. Overstory/understory density is calculated for five size classes (cm dbh):

- 5 to 14.9
- 15 to 24.9
- 25 to 34.9
- 35 to 44.9
- 45 +

Basal area is calculated using the standard formula: dbh^2 x 0.005454 (Davis and Johnson 1987). To convert basal area from ft^2/acre to m^2/ha, basal area as calculated above is divided by 4.356. Data are standardized to hectare, and summarized for the community using site data.

Seedling and sapling data summary

In the lowland forest community, summary statistics for seedlings and sapling (stems < 5.0 cm dbh) tree species are calculated. Tree seedling/sapling density is reported in three size classes (cm dbh):

- seedlings (stems < 0.5 m in height)
- small saplings (stems ≥ 0.5 m in height but < 2.5 cm dbh)
- large saplings (stems ≥ 2.5 cm dbh but < 5.0 cm dbh)

Results

Results are summarized according to community type (i.e., restored prairie or lowland forest). Findings from the restored tallgrass prairie are based on monitoring data collected between 1998 and 2006. Overstory data for the lowland forest sites are summarized by sample year for 2000, 2002 and 2005, while understory regeneration data are summarized by sample years 2000, 2005, 2005 and 2006. Lowland forest sample size in 2000 was one, in 2002 it was two and in 2005 it was three sites. Understory vegetation data for the lowland forest sites were summarized for 2005 and 2006 sample years (n = 3).

Restored tallgrass prairie

A total of 156 species have been sampled between 1998 and 2006 in HTLN prairie monitoring sites. The average number of unique species sampled per year (R) for six sample years was 97.5 ± 5.6 species (mean ± 1 standard deviation). The average number of species sampled per site (S) was 45.5 ± 5.9 species. Therefore a site contained on average 47% of the total species richness for that sample year.

The mean species richness for each year was not significantly different between 1998 and 2006 (Table 3). However evenness (E), Shannon's and Simpson's number of effective species (H_e and D_e, respectively) were statistically significant across sample years (Table 3). Although the number of abundant species (H_e) and dominant species (D_e) fluctuated annually a pattern was

difficult to discern (Fig 3). Driving the change in effective number of species was the significant annual changes in mean evenness during the sample period.

Table 3. Repeated measures ANOVA results for affect of sample year on diversity measure response variable. P-value in bold indicates significant difference among years at the $p < 0.05$ level.

Factor	df	F-ratio	p-value
Evenness (E)	5	5.843	**0.002**
Species richness (S)	5	2.386	0.079
Shannon's number (H_e)	5	5.537	**0.003**
Simpson's number (D_e)	5	8.067	**<0.001**

On average S and H_e differed in number of species by 75% (45.5 ± 5.9 vs. 11.2 ± 2.9 species, respectively) while the average difference increased to 85% when comparing S and D_e (45.5 ± 5.9 vs. 6.7 ± 2.3 species, respectively).

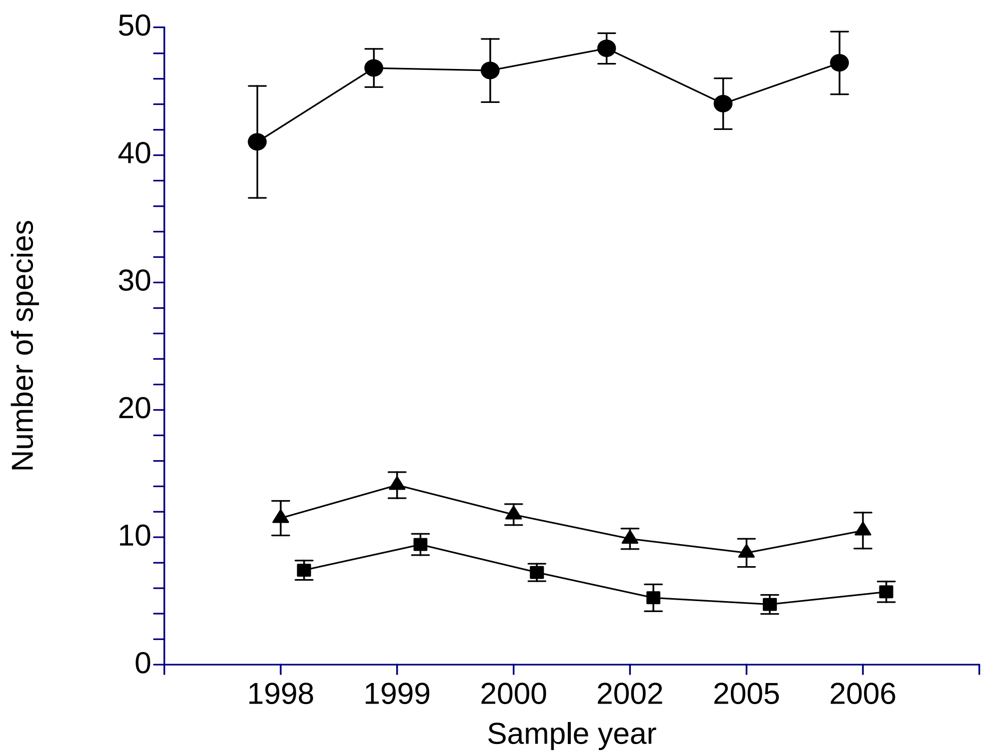

Figure 3. Species richness (circle) and effective number of species for two diversity measures (Shannon diversity, triangle; and Simpson's index, square) for prairie sites (n = 5; 2002, n = 3) across sample years. Symbol is the mean and error bars are ± 1 standard error of the mean.

The decrease in number of abundant and dominant species between 1999 and 2005 was not seen with species richness during that period (Fig 3).

Warm season grasses such as big bluestem (*Andropogon gerardii* Vitman) and little bluestem (*Schizachyrium scoparium* (Michx.) Nash) were the major components of the plant community (44.4 ± 3.0% standard error of the mean, Fig. 4). Summer and fall forbs relative foliar cover among years was 26.9 ± 3.2%, thus contributing greatly to the structure of the prairie community. Across sample years the general distribution of relative cover of species guilds remained similar; warm-season grasses and summer/fall forbs were the dominant functional groups.

Most species guilds showed little variation from year to year with one exception. In 2006 summer and fall forbs relative cover was noticeable greater than all other years. More so it was greater than warm season grasses (40 vs. 32% respectively) and the highest cover value of all guilds for that sample year (Fig. 4).

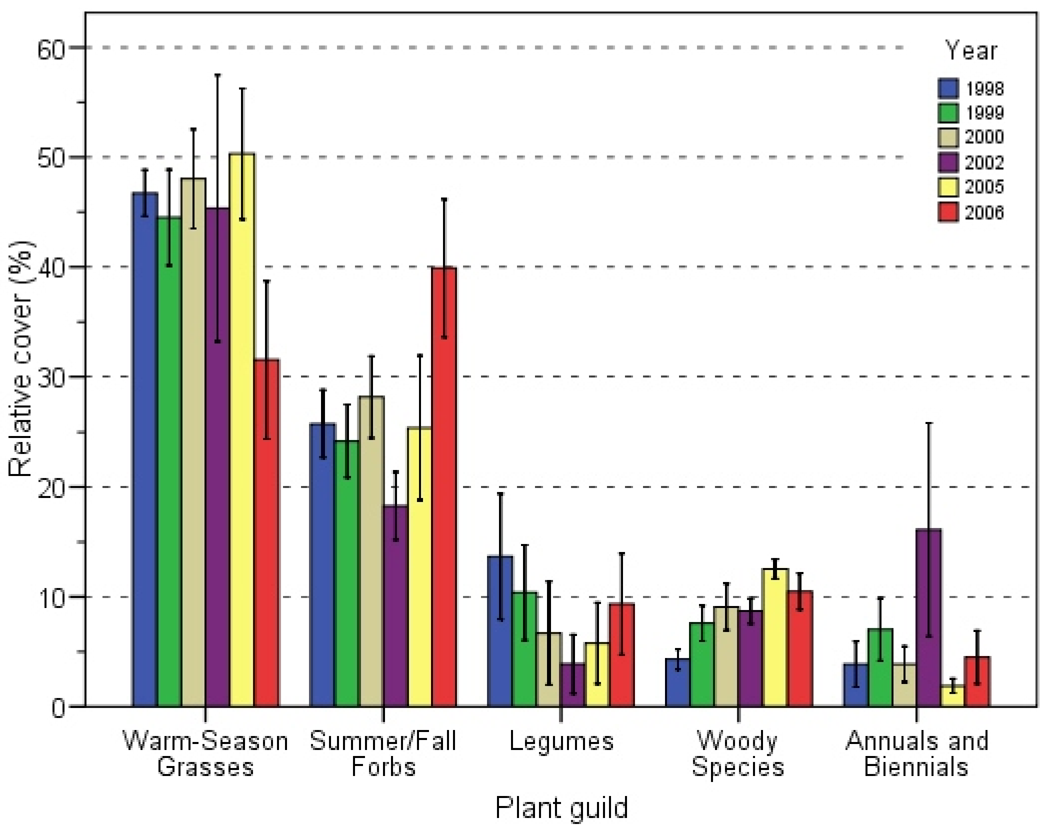

Figure 4. Mean relative cover (%) for plant guilds of prairie sites (n=5; 2002, n = 3) across sample years. Guilds with annual mean values less than 5% omitted from figure.
Mean annual value ± 1 standard error of the mean.

This pattern is characteristic of prairie guilds following a fall prescribed fire. For a complete list of dominant native species (IV ≥ 0.02) frequency and foliar cover in the restored prairie see Appendix A1 and A2, respectively.

The relative cover of the woody species guild increased over time (Fig. 4) although was detected in low amounts each year. Across all sample years, mean relative cover of woody species guild was 8.8 ± 2.8% (mean ± 1 standard deviation) across the restored prairie. There was a statistically significant difference among years of woody species relative cover ($p < 0.001$). Woody species relative cover was highest in 2005 and the declined the following year (Fig. 5).

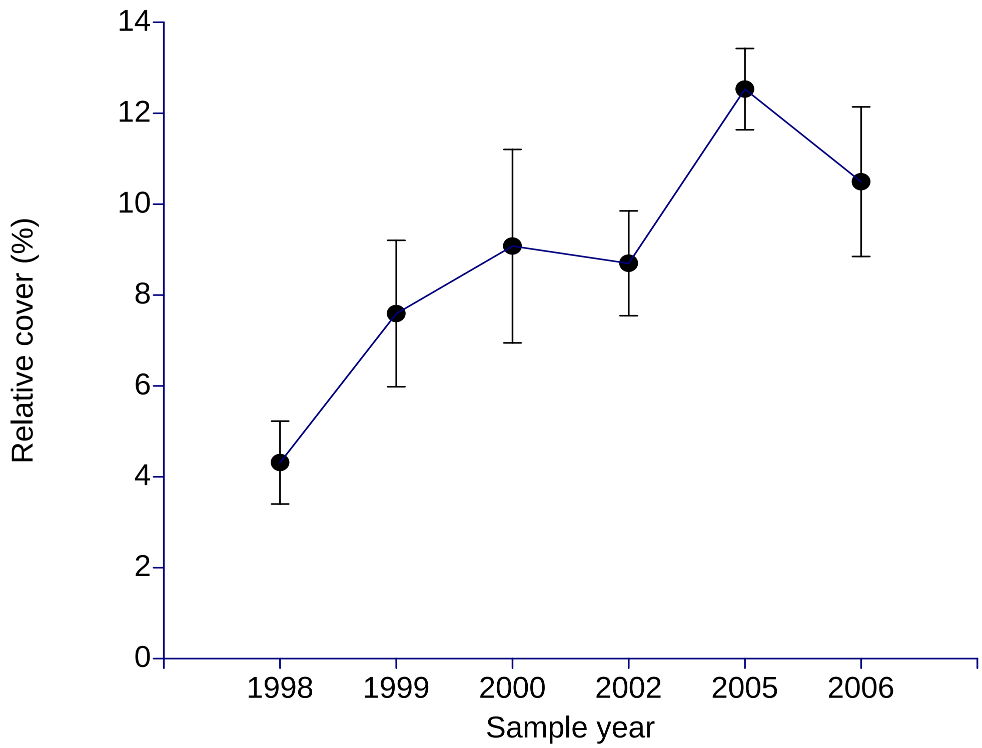

Figure 5. Woody species guild mean relative cover (± 1 standard deviation) in the restored prairie (n=5; 2002, n = 3).

The 3.8% increase in relative cover between 2002 and 2005 coincides with reduced prescribed burning during that period (Table 2). Three sites were subjected to a fall prescribed burn in 2005 after vegetation monitoring had taken place. The 2% decrease in woody species relative cover detected in 2006 may be a result of the prescribed fire the prior fall. Thus it appears that prescribed fire in the restored prairie has the desired affect of decreasing the relative cover of woody species.

Shrub structure group subset of the woody species guild represents the mean relative cover of only shrub species as apposed to all woody species (trees, vines, sub-shrubs and shrubs). The mean foliar cover of shrubs was 2.6 ± 1.0% (mean ± 1 standard deviation) among sample years (Fig. 6). Shrub relative cover follows the same pattern as the woody species guild.

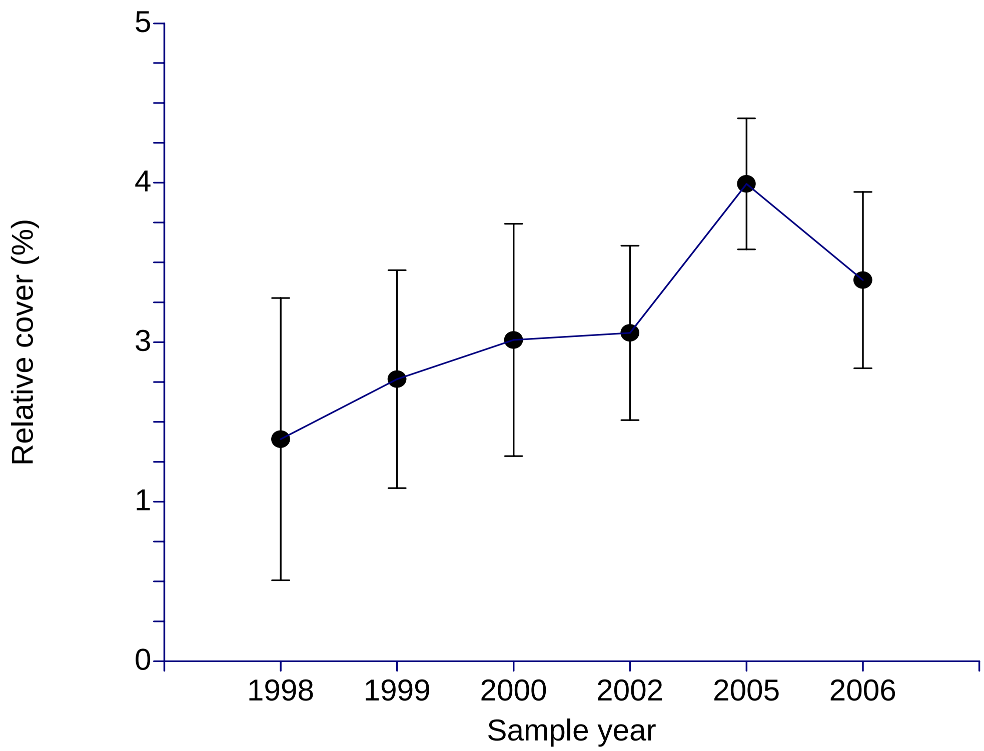

Figure 6. Shrub structural group mean relative cover (± 1 standard deviation) in the restored prairie (n=5; 2002, n = 3).

Bare soil cover in 2006 increased 11 times to 55% from the previous year. 2006 was also the highest year for unvegetated ground cover at 77% and the lowest year for grass litter at 35% (Fig. 7). Again a pattern that follows the application of prescribed fire in the prairie among sample years.

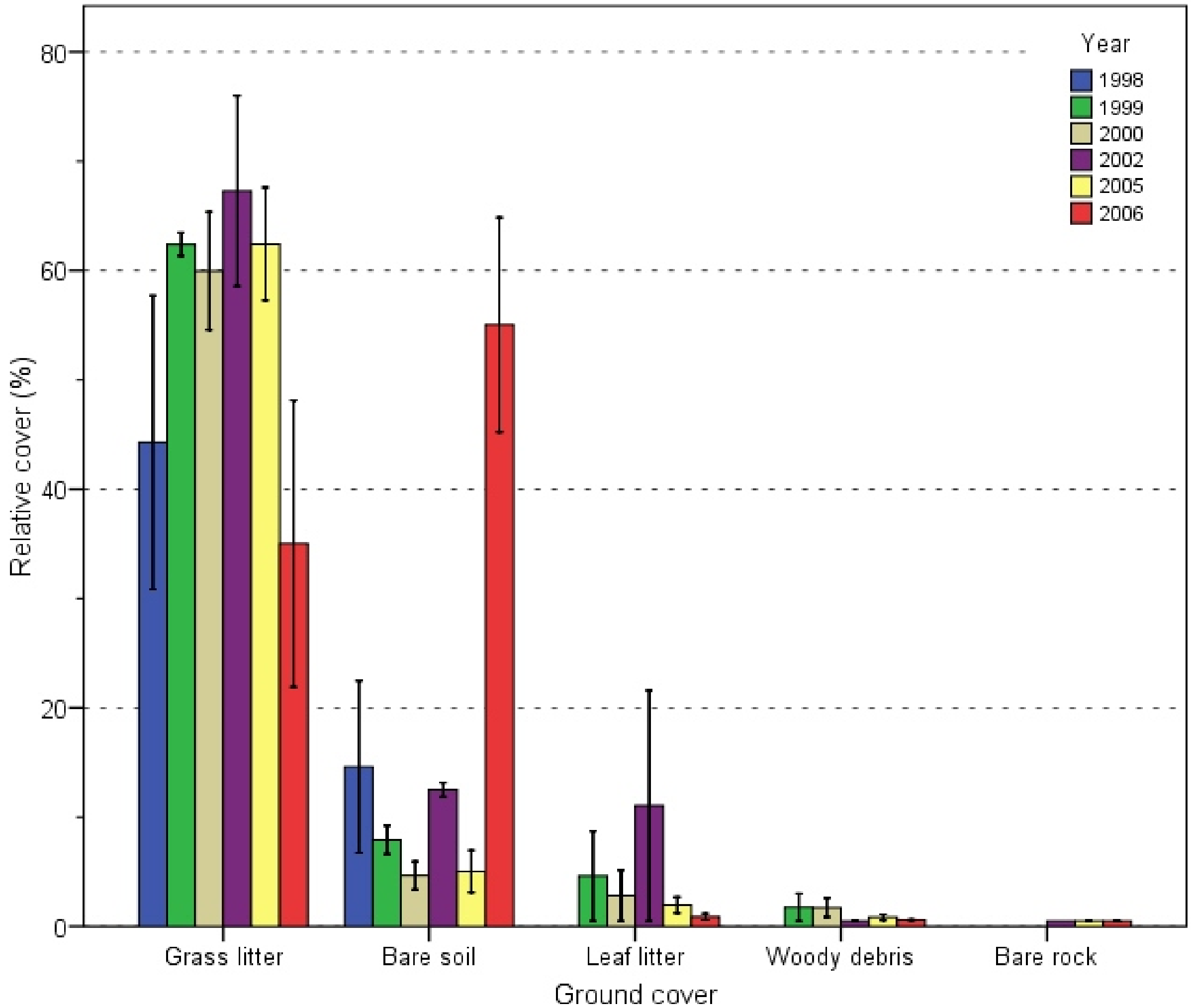

Figure 7. Mean relative cover (± 1 standard error) of ground cover types for prairie sites (n=5; 2002, n = 3) across sample years.

The number of exotic species in the restored prairie ranged from six in 2005 to ten in 2000 (see Appendix B1 and B2 for exotic species frequency and foliar cover sample year, respectively). Exotic species comprised upwards of 10% of the species composition yet did not occur in great abundance at the sites (relative cover of 2.18 ± 2.65% among sample years). Kentucky bluegrass (*Poa pratensis* L.) was the single dominant exotic based on species importance values (IV >0.02, Appendix B1 and B2). Although exotic species did not occur in high abundance based on foliar cover, they did occur in high frequency within sites and among sample years. Mean relative frequency across all sample years was 6.25 ± 2.6% (Fig. 8).

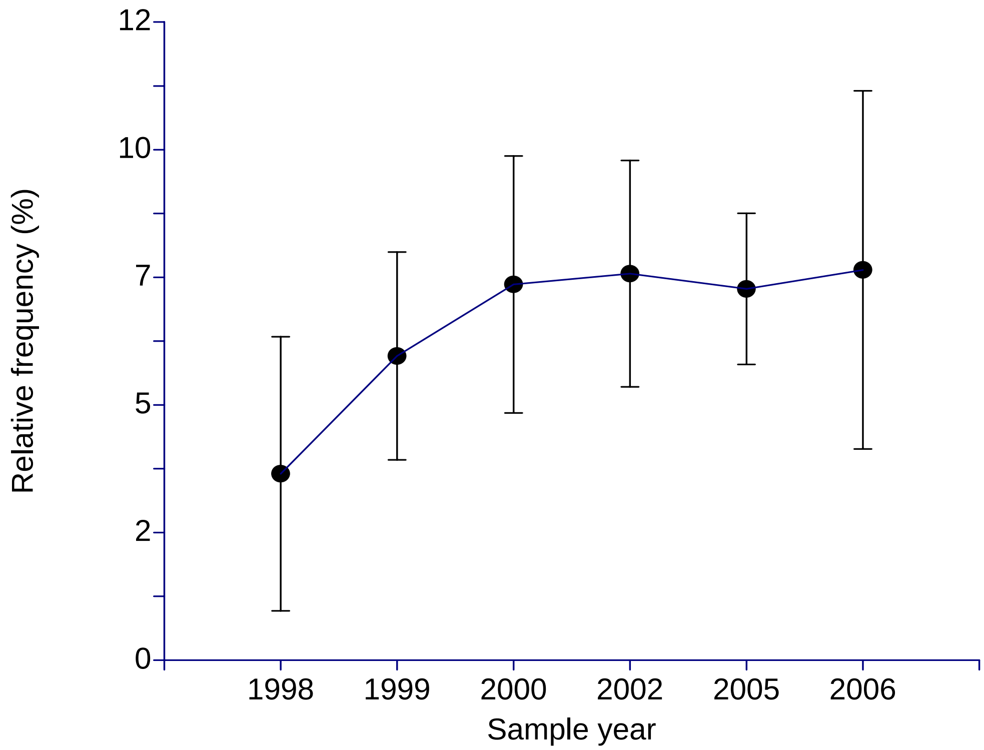

Figure 8. Relative mean frequency (± 1 standard deviation) of exotic species in the restored praire (n=5; 2002, n = 3).

There was a statistically significant difference among years of exotic species relative frequency ($p = 0.002$). While relative frequency of total exotics was low, frequency of individual exotic species was high, indicative of a wide distribution among all sample sites. Like foliar cover, P. *pratensis* (74 ± 14%) was the dominant exotic based on frequency, while smooth brome (*Bromus inermis* Lyess.) and sweet clover (Melilotus spp) were the only exotic species to occur at a frequency greater than 10% (frequency of 21 ± 12% and 8 ± 6%, respectively) in any sample year. For park-wide information regarding exotic species refer to Young et al. (2007).

Lowland forest

Baseline understory vegetation results for three HTLN sites in the lowland forest were summarized for the sample years 2005 – 2006. Overstory and regeneration data collected between 2000 and 2006 were summarized to the forest community.

The lowland forest along Cub Creek was dominated by *Celtis occidentalis* L. (hackberry). Hackberry was the dominant species based on density (424 ± 118 stems/ha for all sample years, Table 4).

Table 4. Summary of overstory trees by sample year(n = 1, 2000; n = 2, 2002; n = 3, 2005).

Year	Species	Stem count	Density (trees/ha)	DBH (SD) (cm)	Basal area (m2/ha)
2000	Celtis occidentalis	29	290	25.3 (22.2)	0.80
2000	Juglans nigra	1	10	12.9	0.21
2000	Quercus macrocarpa	2	20	54.6 (22.9)	3.73
2000	Ulmus americana	1	10	25.8	0.83
2000	Ulmus rubra	1	10	8.0	0.08
2002	Celtis occidentalis	103	515	16.9 (15.5)	0.36
2002	Fraxinus pennsylvanica	1	5	59.4	4.42
2002	Juglans nigra	1	5	12.8	0.21
2002	Morus alba	2	10	25.6 (6.9)	0.82
2002	Quercus macrocarpa	5	25	58.8 (17.7)	4.33
2002	Ulmus americana	1	5	26.6	0.89
2002	Ulmus rubra	1	5	9.9	0.12
2005	Acer saccharum	4	13	36.3 (1.7)	1.65
2005	Celtis occidentalis	140	467	14.9 (14.4)	0.28
2005	Fraxinus pennsylvanica	1	3	61.0	4.66
2005	Juglans nigra	2	7	16.0 (4.2)	0.32
2005	Morus alba	3	10	19.0 (10.7)	0.45
2005	Quercus macrocarpa	13	43	65.2 (15.8)	5.32
2005	Ulmus americana	10	33	21.3 (5.8)	0.57

Bur oak (*Quercus macrocarpa* Michx.) was the second most abundant tree species (29 ±12 stems/ha for all sample years). Bur oak and green ash (*Fraxinus pennsylvanica* Marsh.) both had the largest average basal area (4.5 ± 0.8 and 4.5 ± 0.17 m^2/ha, respectively) over the entire six year sample period. Of the eight overstory species sampled in the three sites hackberry was the dominant species (Table 4).

Percent canopy cover of each site was collected in June 2005. Canopy cover varied only a little (92 – 98%) among sites (Table 5).

Table 5. Mean percent canopy cover of the overstory for each forest site and the lowland forest recorded during June 2005

Site	canopy cover (%) ± 1 SD
6	95.1 ± 2.62
7	97.9 ± 0.54
8	92.3 ± 2.99
Forest	95.1 ± 2.05

Throughout the lowland forest canopy closure was nearly total by early summer. The structure of the live overstory contained more defined canopy layers in site 8, while sites 6 and 7 had less

distinguishable canopy layers. To that, across all three sites there were five standing dead trees sampled (four bur oak and one unidentified snag).

Hackberrry dominated all canopy layers of the lowland forest based on density. Small size class trees (5 – 14.9 cm dbh) in the understory accounted for the majority of hackberry density across the forest and sample years (Table 6).

Table 6. Summary of overstory tree density by species size class and sample year (n = 1, 2000; n = 2, 2002; n = 3, 2005).

Year	Species	Size class	Stem count	Density (trees/ha)
2000	Celtis occidentalis	1	14	140
2000	Juglans nigra	1	1	10
2000	Ulmus rubra	1	1	10
2000	Celtis occidentalis	2	4	40
2000	Celtis occidentalis	3	2	20
2000	Ulmus americana	3	1	10
2000	Celtis occidentalis	4	3	30
2000	Quercus macrocarpa	4	1	10
2000	Celtis occidentalis	5	6	60
2000	Quercus macrocarpa	5	1	10
2002	Celtis occidentalis	1	68	340
2002	Juglans nigra	1	1	5
2002	Ulmus rubra	1	1	5
2002	Celtis occidentalis	2	17	85
2002	Morus alba	2	1	5
2002	Celtis occidentalis	3	6	30
2002	Morus alba	3	1	5
2002	Ulmus americana	3	1	5
2002	Celtis occidentalis	4	3	15
2002	Quercus macrocarpa	4	1	5
2002	Celtis occidentalis	5	9	45
2002	Fraxinus pennsylvanica	5	1	5
2002	Quercus macrocarpa	5	4	20
2005	Celtis occidentalis	1	103	343
2005	Juglans nigra	1	1	3
2005	Morus alba	1	1	3
2005	Ulmus americana	1	1	3
2005	Celtis occidentalis	2	19	63
2005	Juglans nigra	2	1	3
2005	Morus alba	2	1	3
2005	Ulmus americana	2	7	23
2005	Acer saccharum	3	1	3
2005	Celtis occidentalis	3	6	20
2005	Morus alba	3	1	3
2005	Ulmus americana	3	2	7
2005	Acer saccharum	4	3	10
2005	Celtis occidentalis	4	2	7
2005	Quercus macrocarpa	4	1	3
2005	Celtis occidentalis	5	10	33
2005	Fraxinus pennsylvanica	5	1	3
2005	Quercus macrocarpa	5	12	40

In fact it was the most dominant species by density each year in each size class individuals occurred. For the seven other species that made up the forest overstory, nearly all were represented by a single or few individuals in the larger size classes (Table 6).

The pattern of hackberry density was also found in the regeneration layer among sample years (Table 7).

Table7. Seedling density of three forest sites for sample year (n = 1, 2000; n = 2, 2002; n = 3, 2005).

Year	Species	Seedling count	Density (seedlings/ha)
2000	Celtis spp	3	30
2000	Fraxinus spp	1	10
2000	Ulmus spp	6	60
2002	Celtis occidentalis	102	510
2002	Gleditsia triacanthos	1	5
2002	Juniperus virginiana	1	5
2002	Quercus macrocarpa	6	30
2002	Ulmus spp	19	95
2005	Celtis occidentalis	44	147
2005	Gleditsia triacanthos	1	3
2005	Quercus macrocarpa	4	13
2005	Ulmus americana	4	13
2005	Ulmus spp	1	3
2006	Celtis occidentalis	49	163
2006	Gleditsia triacanthos	3	10
2006	Juniperus virginiana	2	7
2006	Prunus spp	1	3
2006	Quercus macrocarpa	12	40
2006	Ulmus rubra	1	3
2006	Ulmus spp	17	57

Seedlings of nine species were sampled. However, only hackberry was represented in the small and large sapling sizes (one and three individuals respectively in 2000; three and one individuals, respectively in 2006). Regeneration of forest species in the lowland forest was restricted primarily to hackberry seedlings with barely any individuals of any species surviving to larger sapling size classes.

A total of 45 unique species were sampled in the understory vegetation during 2005 and 2006 in HTLN forest monitoring sites. The average number of unique species sampled among sites (R) across the two sample years was 33.5. The average number of species sampled per site (S) was 23 in 2005 and 22 in 2006. Species evenness between sites within a year (E) remained almost constant for the two sample years. Site 6 had fewer species than the other two sites in 2005 and 2006 (3 and 8 fewer species, respectively). Effective number of understory species for Shannon

diversity index (7± 0.6), Simpson's index (3 ± 0.2) and species richness (23 ± 0.5) showed little difference between the two sample years.

The understory was dominated by broadleaf summer and fall forbs (Fig. 9). Nettle (*Laportea canadensis* (L.) Wedd.), wingstem (*Verbesina alternifolia* (L.) Britt.), sedges (Carex spp), false nettle (*Boehmeria cylindrical* (L.) Sw) and Virginia creeper (*Parthenocissus quinquefolia* (L.) Planch.) dominated the herbaceous understory in all forest sites each year. Mean percent cover for these species across sample years ranged from only 1% to 30%, while percent frequency was from 10 – 100% (see Appendix C for frequency, foliar cover and importance value of all understory species by sample year). All other species guild groups were less than 10% mean relative cover during the sample periods (Fig. 10).

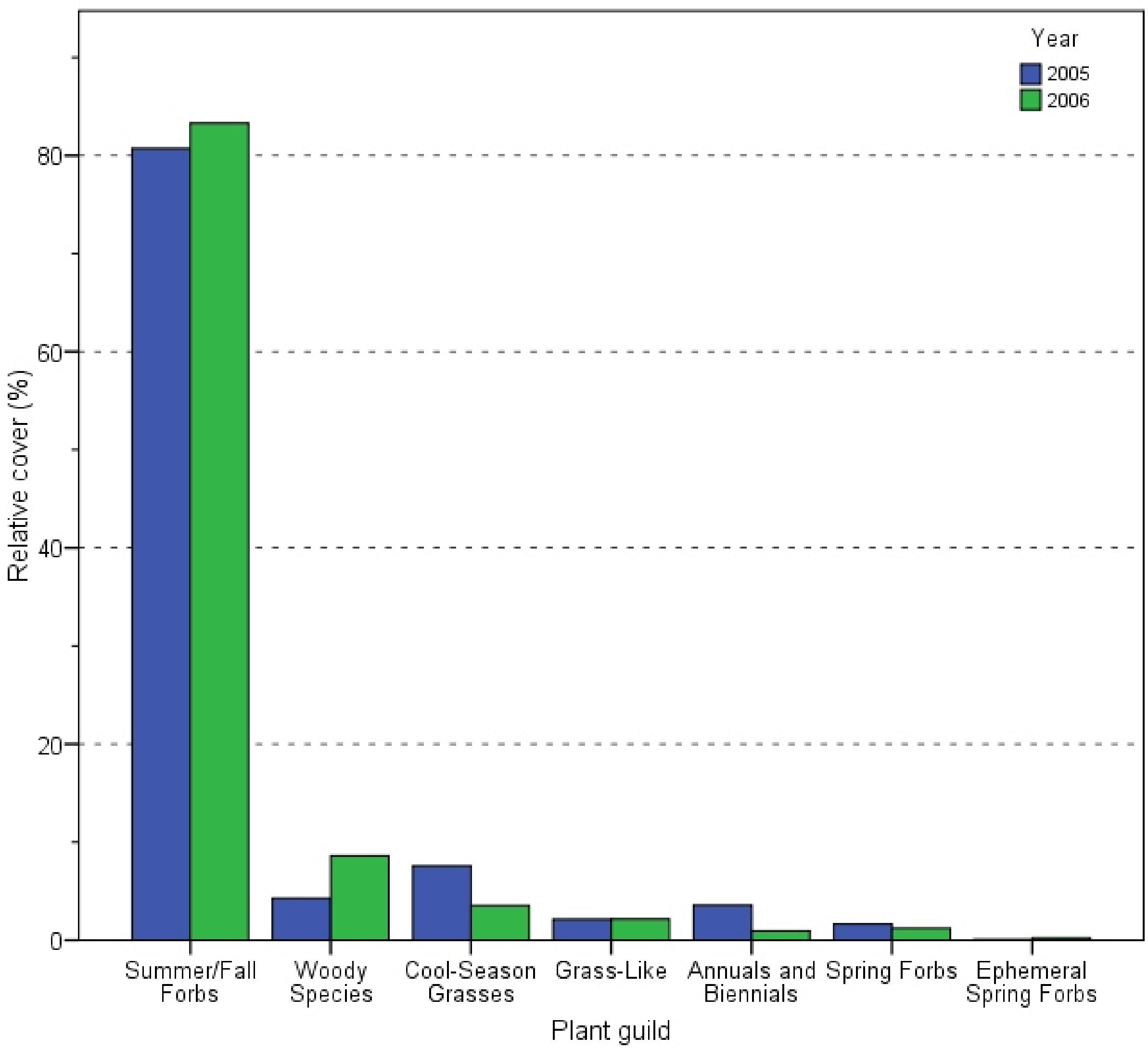

Figure 9. Mean relative cover for plant guilds of forest sites (n=3) across sample years.

The forest floor was primarily unvegetated surface (86%) with large amounts of leaf litter (74%) over the two sample years. Woody debris was present in much lower amounts each year, composed mainly of twigs and limbs fallen from the overstory. Exotic herbaceous species were not detected in the baseline sampling.

Discussion

Restored tallgrass prairie

The 100 acres of restored prairie at HOME reflects the species richness and diversity of its historic source and native species augmentation. It is a species rich plant community with a distribution pattern composed of core and satellite species (Hanski 1982). There are a few dominant species with numerous species occurring either in low abundance or patchily distributed (Grubb 1986). The degree of difference between S, H_e and D_e is indicative of a community dominated by a few species when species diversity is partitioned among sites as is the case at HOME. This difference is due to annual variability in presence of locally rare or patchily distributed species. An important aspect of the model underlying this type of community structure is that stochastic variation in species composition may be due to either demographic or environmental random variability (Hanski 1982). That is to say that a high turnover in native species composition among years is to be expected and does not affect the overall structure or function of the community. After all it is the core species, in this case warm season grasses and summer/fall forbs that gives the prairie its unique and enduring characteristics. Therefore the community benefits from increased and sustained species richness without concern for the specific composition of satellite species. The diversity of the restored prairie at HOME is being protected as reflected in the described community structure and measured species richness and diversity for the sample period 1998 – 2006.

This claim is further supported by the functional group or guild results. The functional plant guilds that the core species belong occur in high relative cover among sample years. This functional dominance coupled with high species richness acts as a buffer against species loss and promotes functional diversity (Zavaleta and Hulvey 2004). As long as native species occupy space in the restored prairie and management actions do not stray from past efforts then the prairie will persist at current levels of diversity and function while maintaining a buffer against both exotic and woody species encroachment.

After 2006 monitoring, woody species guild relative cover (10.5 ± 3.7%) was above the desired goal of less than five percent as outlined in the vegetation management plan. However woody species declined in 2006 following prescribed fire. More work is required to achieve this objective. If only concerned with relative cover of shrubs than the objective has been met (in 2006 shrub relative cover was 3.0 ± 0.7%). However, it is more appropriate to consider all woody species encroachment rather than only shrubs in order to preserve the integrity of the grassland prairie. It is important to note that the current amount of woody species has not affected the dominant functional guilds or overall species richness and diversity in the sample sites. This is a result of the restricted distribution of woody species in the restored prairie.

Mean relative frequency of exotic species was above the desired limit of 5% both for the entire sample period (6.25 ± 2.6%) and at the end of 2006 (7.34 ± 3.4%). Kentucky bluegrass accounts for the majority of exotic species presence and is distributed nearly throughout the prairie. For a survey of exotic species across the entire park refer to Young et al. (2007). Current management has controlled exotic species in the prairie, especially between 2000 and 2006 (Fig. 8). Even though relative frequency of exotics is higher than desired it has remained consistent for the last six years.

Trends or patterns in species diversity and changes in relative cover of guilds are still hard to discern due to the small number of sample sites and number of sample years. As the span of sample years increases so does the ability to account for variability in the community and recognize trends that can be linked to management activity rather than innate variability of the larger grassland ecosystem.

Lowland forest

The lowland riparian forest along Cub Creek reflects past disturbance history in terms of both tree species composition and stand structure. Site 8 in the northern portion of the forest reflects a more natural state with defined canopy layers and a bur oak component in the overstory and regeneration layer along with standing dead individuals. Tree density increased as basal area decreased while canopy layers became less defined in sample sites moving south through the forest. This trend in forest stand dynamics reflects past disturbance typical of logging and fire suppression. These findings were in line with Rolfsmeier (2007) and Mlekush and DeBacker (2003); for a complete review and analysis of the lowland forest refer to their work. Bur oak restoration in the lowland forest requires maintaining the forest characteristics around site 8 as well as developing a restoration plan that promotes the growth and regeneration of bur oak in and around sites 6 and 7. Hackberry dominance throughout each canopy layer will continue to hinder restoration efforts and prevent establishment of bur oak. In the southern portion of the forest, reducing tree density and creating defined canopy layers is a possible first step toward lowland forest restoration. Further, restoration will require re-establishing natural disturbance regimes that promote forest stand structure and successional pathways once seen around prairie waterways.

Understory vegetation was sparse and dominated by forbs, probably a response to the closed canopy of the overstory. Small and large sapling regeneration was almost completely absent from the forest. Seedlings were nearly all hackberry, which was a function of the overstory acting as the dominant seed source throughout the forest.

The two plant communities at HOME provide an accurate representation and historical backdrop to the story and legacy of homesteading in America during the 19^{th} century. More work is required to further restore the lowland forest bur oak woodland and continued effort is required to maintain the restored prairie in a condition that best approximates a mid-1860’s prairie once typical of the surrounding area.

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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 restored tallgrass prairie (n = 5; n = 3, 2002).

Scientific name	1998	1999	2000	2002	2005	2006
Ambrosia artemisiifolia	0.58	0.62	0.64	0.77	0.32	0.44
Amorpha canescens	0.36	0.36	0.36	0.27	0.36	0.36
Andropogon gerardii	1	0.96	0.98	0.97	1	1
Aster ericoides	0.34	0.36	0.34	0.27	0.32	0.36
Brickellia eupatorioides	0.56	0.64	0.68	0.6	0.56	0.64
Carex spp	0.7	0.58	0.68	0.7	0.74	0.6
Chamaecrista fasciculata	0.2	0.28	0.22	0.07	0.18	0.3
Cirsium altissimum	0.5	0.58	0.46	0.63	0.36	0.5
Cornus foemina	0.06	0.16	0.22	0.23	0.24	0.26
Dichanthelium spp	0.72	0.76	0.82	0.73	0.72	0.76
Helianthus laetiflorus	0.2	0.24	0.26	0.17	0.24	0.26
Muhlenbergia frondosa	0	0	0.3	0	0.2	0.22
Muhlenbergia racemosa	0.48	0.5	0.48	0.53	0.18	0.28
Oxalis spp	0.52	0.78	0.5	0.6	0.14	0.42
Panicum virgatum	0.52	0.64	0.54	0.6	0.66	0.44
Polygonum pensylvanicum	0.32	0.32	0.36	0.5	0.3	0.3
Rosa arkansana	0.76	0.88	0.86	0.83	0.8	0.84
Schizachyrium scoparium	0.88	0.88	0.96	0.67	0.56	0.66
Solidago canadensis	0.7	0.1	0.8	0.8	0.72	0.74
Solidago spp	0.44	0.8	0.38	0.03	0	0
Sorghastrum nutans	0.78	0.78	0.76	0.47	0.32	0.48
Vernonia baldwinii	0.42	0.3	0.32	0.5	0.44	0.46
Viola pratincola	0.3	0.44	0.54	0.67	0.38	0.44

Appendix A2. Foliar cover (%) for dominant native species (IV ≥ 0.02 in at least one sample year) by sample year in the restored tallgrass prairie (n = 5; n = 3, 2002).

Scientific name	1998	1999	2000	2002	2005	2006
Ambrosia artemisiifolia	6	4	1.8	12	0.7	5.7
Amorpha canescens	26.9	18.5	15.1	7.8	9.3	14.2
Andropogon gerardii	43.8	21.9	25.2	31.1	29.9	21.6
Aster ericoides	16.1	11.4	8.4	1.1	1.8	4.8
Brickellia eupatorioides	2.3	2.6	1.2	1.2	0.8	2.2
Carex spp	2.9	6.5	0.7	1.2	0.8	1.2
Chamaecrista fasciculata	59.8	27.3	2.3	0.5	0.5	2.8
Cirsium altissimum	1	5.8	0.5	4.6	0.5	0.7
Cornus foemina	18.5	21.3	11.3	9.9	15.1	13
Dichanthelium spp	1.8	1	0.6	0.5	0.6	0.8
Helianthus laetiflorus	17.4	13.1	7.6	6.8	9.7	19.7
Muhlenbergia frondosa	0	0	12.1	0	2.2	1.2
Muhlenbergia racemosa	18.6	14.8	9.7	0.8	2.7	3.3
Oxalis spp	1.3	0.76	0.5	0.5	0.5	0.5
Panicum virgatum	5.6	7.4	1.7	3.6	3.3	0.8
Polygonum pensylvanicum	10	12.1	6.9	3.3	3.4	4.7
Rosa arkansana	6.2	5.1	3.2	1.8	3.7	3.7
Schizachyrium scoparium	27.3	27.9	6.7	3.9	6.5	4.8
Solidago canadensis	29.8	11.8	20.4	14.9	19	33
Solidago spp	25.1	26.9	15	0.5	0	0
Sorghastrum nutans	5.3	8.6	8.8	1.5	0.74	1.6
Vernonia baldwinii	8.7	4.6	1.8	2.3	2.4	9.8
Viola pratincola	3.7	3	1.9	2.5	1	1

Appendix B1. Frequency for exotic species by sample year in the restored tallgrass prairie (n = 5; n = 3, 2002).

Scientific name	1998	1999	2000	2002	2005	2006
Bromus inermis	0.04	0.18	0.32	0.13	0.24	0.32
Convolvulus arvensis	0.02	0.04	0.04	0.10	0.02	0
Fagopyrum vulgare	0.02	0	0	0	0	0
Kochia scoparia	0	0	0.02	0	0	
Lactuca serriola	0	0.04	0	0.07	0	0.02
Melilotus spp	0.04	0.08	0.02	0.20	0	0.16
Morus alba	0.02	0.02	0.02	0.03	0	0.02
Poa pratensis	0.48	0.72	0.80	0.83	0.84	0.76
Rumex crispus	0.04	0.08	0.06	0.03	0.02	0.06
Setaria faberi	0	0	0.08	0	0.04	0.02
Setaria pumila	0	0	0	0		0.04
Taraxacum officinale	0	0.02	0.08	0.13	0.02	0.04
Ulmus pumila	0	0	0.02	0	0	0

Appendix B2. Foliar cover (%) for exotic species by sample year in the restored tallgrass prairie (n = 5; n = 3, 2002).

Scientific name	1998	1999	2000	2002	2005	2006
Bromus inermis	3.0	3.5	0.7	0.5	0.7	1.9
Convolvulus arvensis	3.0	1.8	0.5	1.3	0.5	0
Fagopyrum vulgare	3.0	0	0	0	0	0
Kochia scoparia	0	0	0.5	0	0	0
Lactuca serriola	0	0.5	0	0.5	0	0.5
Melilotus spp	7.8	1.1	0.5	0.9	0	8.9
Morus alba	0.5	3.0	3.0	3.0	0	0.5
Poa pratensis	9.0	7.5	2.9	10.5	2.0	1.2
Rumex crispus	1.8	2.4	0.5	0.5	0.5	0.5
Setaria faberi	0	0	9.8	0	0.5	0.5
Setaria pumila	0	0	0	0	0	0.5
Taraxacum officinale	0	0.5	0.5	0.5	0.5	0.5
Ulmus pumila	0	0	0.5	0	0	0

Appendix C. Native species understory percent frequency, percent foliar cover and importance value summarized for forest sites (n=3) by sample year.

Year: 2005

ScientificName	CommonName	Frequency	Cover	IV
Ageratina altissima	Tall ageratina	50.0%	1.80	0.032
Boehmeria cylindrica	False nettle	33.3%	1.75	0.022
Campanulastrum americanum	Tall bellflower	3.3%	0.50	0.001
Carex spp		86.7%	0.79	0.049
Chenopodium berlandieri	Pitseed goosefoot	23.3%	0.86	0.012
Cuscuta megalocarpa	bigfruit dodder	3.3%	0.50	0.002
Diarrhena obovata	obovate beakgrain	6.7%	1.75	0.006
Elymus hystrix var. hystrix	Bottlebrush-grass	6.7%	0.50	0.004
Ellisia nyctelea	Water-pod	50.0%	0.50	0.028
Elymus virginicus	Virginia wild rye	90.0%	2.76	0.070
Festuca subverticillata	Nodding fescue	36.7%	0.50	0.019
Galium aparine	Cleavers	86.7%	0.50	0.046
Geum canadense	White avens	33.3%	0.50	0.017
Hackelia virginiana	Stickseed, beggar's lice	43.3%	0.69	0.021
Laportea canadensis	Nettle	100.0%	21.15	0.347
Leersia virginica	whitegrass	16.7%	1.00	0.009
Maianthemum stellatum	starry false lily of the valley	3.3%	0.50	0.002
Parietaria pensylvanica	Pennsylvania pellitory	30.0%	1.33	0.016
Parthenocissus quinquefolia	Virginia-creeper, woodbine	83.3%	0.80	0.049
Phytolacca americana	Pokeweed, pokeberry	6.7%	0.50	0.004
Phryma leptostachya	Lopseed	3.3%	0.50	0.001
Polygonum virginianum	Jumpseed	36.7%	1.82	0.033
Ribes missouriense	Missouri gooseberry	13.3%	0.50	0.007
Sanicula odorata	clustered blacksnakeroot	16.7%	0.50	0.009
Smilax tamnoides	Catbrier	66.7%	0.50	0.035
Stachys tenuifolia	smooth hedgenettle	3.3%	0.50	0.002
Symphoricarpos orbiculatus	Coralberry	16.7%	0.50	0.007
Toxicodendron radicans	Common poison-ivy	33.3%	0.50	0.017
Urtica dioica ssp. gracilis	Nettle, stinging nettle	16.7%	0.50	0.010
Verbesina alternifolia	Wingstem	73.3%	6.61	0.092
Viola missouriensis	Missouri violet	50.0%	0.50	0.024
Viola spp		3.3%	0.50	0.002
Viola pubescens	downy yellow violet	3.3%	0.50	0.002
Viola sororia	Violet	3.3%	0.50	0.002

Appendix C. Native species understory percent frequency, percent mean cover and importance value summarized for forest sites (n=3) by sample year (continued).

Year: 2006

ScientificName	CommonName	Frequency	Cover	IV
Ageratina altissima	Tall ageratina	33.3%	0.75	0.017
Boehmeria cylindrica	False nettle	13.3%	1.75	0.009
Carex spp		70.0%	1.45	0.045
Chenopodium album	Lamb's quarters, pigweed	6.7%	0.50	0.003
Chenopodium berlandieri	Pitseed goosefoot	10.0%	0.50	0.005
Chenopodium simplex	mapleleaf goosefoot	3.3%	0.50	0.002
Cryptotaenia canadensis	Canadian Honewort	6.7%	1.75	0.005
Cuscuta megalocarpa	bigfruit dodder	3.3%	0.50	0.002
Diarrhena obovata	obovate beakgrain	6.7%	1.75	0.005
Elymus virginicus	Virginia wild rye	93.3%	1.21	0.057
Festuca subverticillata	Nodding fescue	36.7%	1.41	0.021
Galium aparine	Cleavers	30.0%	0.50	0.018
Geum canadense	White avens	23.3%	0.50	0.013
Hackelia virginiana	Stickseed, beggar's lice	26.7%	0.50	0.014
Laportea canadensis	Nettle	100.0%	30.18	0.344
Lactuca floridana	Woodland Lettuce	3.3%	0.50	0.002
Leersia virginica	whitegrass	3.3%	0.50	0.002
Maianthemum stellatum	starry false lily of the valley	6.7%	0.50	0.003
Parietaria pensylvanica	Pennsylvania pellitory	40.0%	1.13	0.022
Parthenocissus quinquefolia	Virginia-creeper, woodbine	76.7%	3.04	0.064
Phytolacca americana	Pokeweed, pokeberry	6.7%	0.50	0.004
Phryma leptostachya	Lopseed	16.7%	0.50	0.008
Pilea pumila	Clearweed	10.0%	0.50	0.005
Polygonum virginianum	Jumpseed	43.3%	2.19	0.034
Ribes missouriense	Missouri gooseberry	13.3%	0.50	0.008
Sanicula odorata	clustered blacksnakeroot	20.0%	0.50	0.010
Smilax tamnoides	Catbrier	80.0%	0.92	0.046
Symphoricarpos orbiculatus	Coralberry	13.3%	1.13	0.008
Toxicodendron radicans	Common poison-ivy	53.3%	1.13	0.032
Urtica dioica ssp. gracilis	Nettle, stinging nettle	36.7%	1.18	0.025
Verbesina alternifolia	Wingstem	76.7%	13.72	0.131
Viola missouriensis	Missouri violet	56.7%	0.65	0.031
Viola spp		16.7%	0.50	0.009

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.

NPS D-48, May 2007

National Park Service
U.S. Department of the Interior

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