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Vegetation Community Monitoring at Agate Fossil Beds National Monument, Nebraska

1999-2009

Natural Resource Technical Report NPS/HTLN/NRTR—2010/351

ON THE COVER
Prairie at Agate Fossil Beds National Monument, Nebraska. Photograph by: Karola Mlekush

Vegetation Community Monitoring at Agate Fossil Beds National Monument, Nebraska

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Natural Resource Technical Report NPS/HTLN/NRTR—2010/351

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Abstract

Vegetation community monitoring was conducted by the Heartland Inventory and Monitoring Network beginning in 1998 and concluded in 2009. During this period, eleven monitoring sites were established and sampled seven times. This report presents summary findings of that monitoring effort and concludes network vegetation monitoring efforts at Agate Fossil Beds National Monument. The Northern Great Plains Inventory and Monitoring Network will continue long-term vegetation monitoring at the park. The eleven monitoring sites were categorized into three community types: prairie sandreed – sand bluestem native prairie; needle-and-thread grass – blue grama – threadleaf sedge native prairie; and riparian community. A summary of the two native mixed-grass prairies is presented. Active management in areas with monitoring sites was nearly absent throughout the monitoring period. Therefore this report represents natural variability relative to weather and climate in the absence of active management.

Acknowledgments

This work is the culmination of over a decade of vegetation monitoring and was made possible by the field sampling efforts of the following individuals: Leo Acosta , John Boetsch, Pam Brown, Cindy Buck, Tyler Cribbs, Mike DeBacker, Jonathon Dingler, Ashley Dunkle, Jennifer Haack, Katy Holmer, Karola Mlekush, David Peitz, Alicia Sasseen, Amy Symstad, Lisa Thomas and Melanie Weber.

Introduction

North American prairie once extended across the mid-continent region from Canada to Texas and from the Rocky Mountains to the Appalachian forest. The vast landscape was nearly continuous grassland, transitioning gradually from shortgrass steppe in the west to tallgrass prairie and savanna in the east. These grasslands have figured prominently in our North American heritage.

During the last century, large portions of grassland landscapes were plowed for cropland or converted to livestock pasture. Today, Great Plains grasslands are fundamentally altered by the conversion of prairie to cropland and pasture, the removal or disappearance of native ungulates, drainage of wetlands, and an increase in woody vegetation through plantings and fire suppression. Scientists estimate the loss of native prairie ranges from 80 to 99.9%, with the greatest losses occurring in the tallgrass prairie and oak savanna communities. Further, only 71% of shortgrass prairie and 59% of mixed-grass prairie remain (Knopf and Samson 1997). Fragmentation and isolation continues today at an alarming rate. Additionally, ecological driving forces such as fire and the presence of native faunal species including bison (*Bos bison*), elk (*Cervus elaphus*), grizzly bear (*Ursus arctos horribilis*) and wolves (*Canis lupus*), remain largely absent from prairie systems, having been eliminated or placed under human control; only the plants remain as a reasonable legacy of this past system.

Grassland ecosystems are maintained by a complex disturbance regime including frequent large- and small-scale disturbances. The interactive effect of periodic fire and ungulate grazing is widely recognized as a critical component of the natural disturbance regime in tallgrass prairie ecosystems (Bragg 1995, Davison and Kindscher 1999, Howe 1999, Collins 2000). These in turn, interact with interannual climate variation to affect spatial and temporal dynamics (Collins 1987, Knapp and Seastedt 1998, Knapp *et al.* 1999, Collins 2000). Due to the complex disturbance regimes, grassland systems consist of dynamic mosaics of vegetation patches scattered across the landscape, highly variable in both space and time (Collins and Glenn 1991, Collins and Glenn 1997, Collins 2000, Fuhlendorf and Engle 2001).

Prairies are dominated by a few matrix-forming grass species that effectively control community structure. 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).

Understanding the interactive effects of landscape scale, prairie size, and community stability on prairie health is integral to the preservation and protection of public lands, and in determining the appropriate management strategies to employ. Prairie communities exhibit high year-to-year fluctuations in species composition and abundance; however, in stable systems, the community structure remains constant over long time frames or large spatial scales (Collins 2000, Earnest and Brown 2001). Long-term ecological monitoring, while contributing to our empirical understanding of prairie communities, is integral to the proper management and protection of the lands entrusted to the National Park Service (NPS).

Agate Fossil Beds National Monument (AGFO) was established in 1965 to protect the animal fossils found in the sedimentary rock beds. The 3055 acres includes 2270 acres that are fee-owned, which include the Niobrara River and its associated floodplain with upland areas of native mixed-grass prairie. Human use of the area has been estimated to date back 11,000 years, with more recent activity involving grazing, fire suppression and land conversion. For an overview of the cultural and natural history of the park see National Park Service (2005a).

Vegetation monitoring at AGFO was initiated in 1998 by the Heartland Network Inventory and Monitoring Program with three primary objectives:

1. Describe the species composition, structure, and diversity of prairie communities;
2. Determine temporal changes in the species composition, structure, and diversity of prairie communities;
3. Determine the relationship between temporal and spatial changes and environmental variables including specific management practices.

The entire park falls within the Northern Great Plains mixed-grass prairie. Within the park there are three general prairie community types: 1) native mixed-grass prairie; 2) degraded prairie; and 3) Niobrara River floodplain. See National Park Service (2005b) for a detailed description of each community type. The focus of this report is on the native mixed-grass prairie community.

Methods

Field methods

The Heartland Inventory and Monitoring Network implemented monitoring at AGFO in 1998 to provide analyses of baseline conditions and to assess future change in floral communities (see DeBacker *et al.* 2004 for detailed information on monitoring protocol). Initially nine prairie sites (consisting of ten $10m^2$ plots at each site) were sampled during the summer of 1998. In 1999, two additional sites were established and sampling continued of these sites through 2009 (Table 1).

Table 1. Sample size and the sites sampled during each monitoring year by Heartland Inventory and Monitoring Network at Agate Fossil Beds National Monument, Nebraska.

Year	N	Sites sampled
1998	9	2 - 10
1999	11	1 - 11
2000	11	1 - 11
2003	11	1 - 11
2004	11	1 - 11
2008	10	1 - 7, 9 - 11
2009	9	1 - 4, 6 - 7, 9 - 11

Monitoring sites were located in mixed-grass prairie along the Niobrara River floodplain and adjacent slopes (Fig. 1). Management at AGFO has been minimal throughout the sample years. Five HTLN sites (2-5 and 7) were impacted by the May 2009 prescribed fire (Carnegie Prescribed Fire Report).

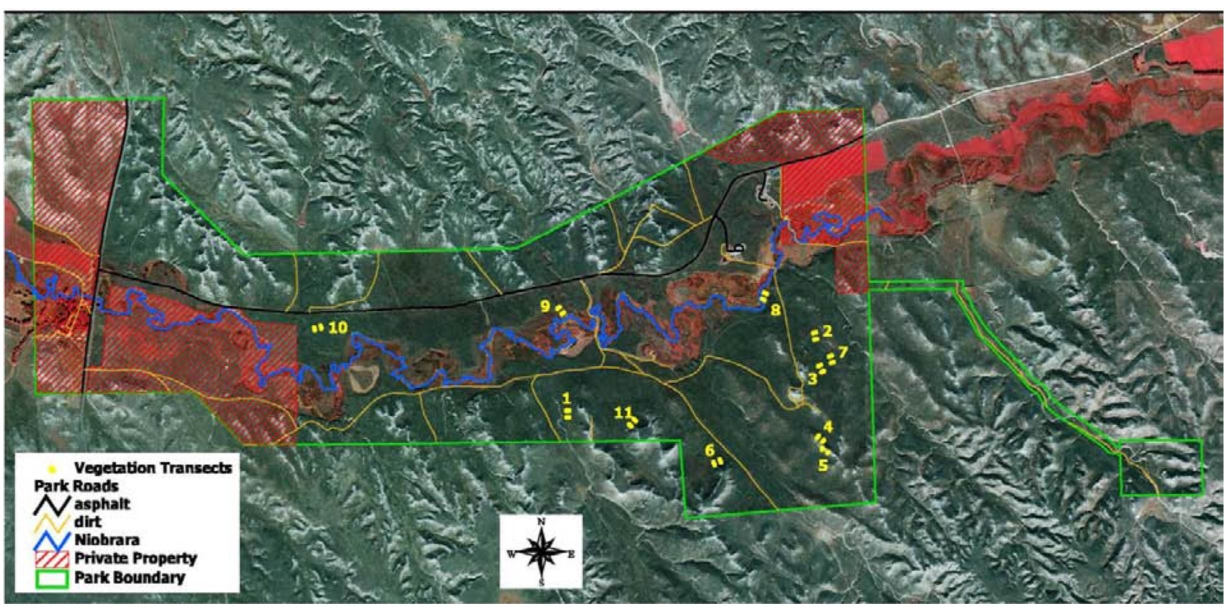

Figure 1. Map of Agate Fossil Beds National Monument, Nebraska, displaying Heartland Inventory and Monitoring Network plant community monitoring sites.

HTLN plant community monitoring sample sites consist 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).

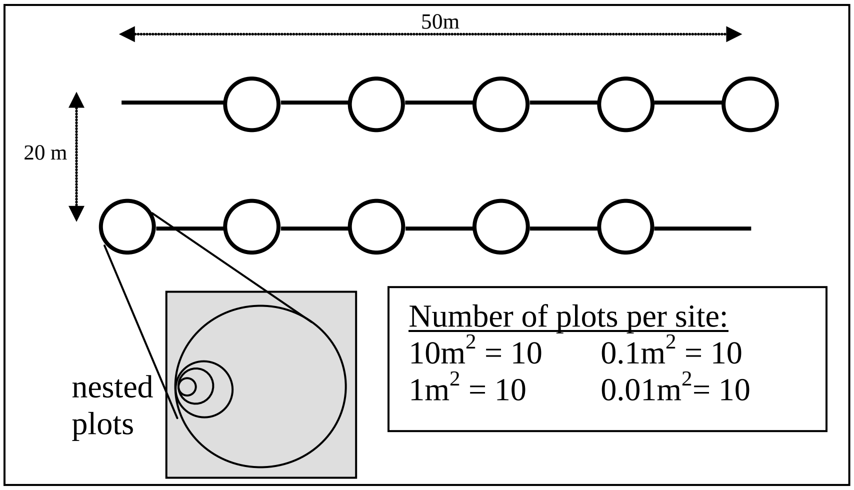

Figure 2. HTLN plant community monitoring sample site showing transects and plots including nested plots.

The primary sample unit is the site which is composed of the$10m^2$ circular plots along each transect. Each $10m^2$ plot 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. Foliar cover is estimated in the $10m^2$ plot using a modified Daubenmire scale (1959, Table 2). Prairie vegetation is sampled in this manner.

Table 2. Modified Daubenmire cover value scale.

Cover Class Codes	Range of Cover (%)
7	95-100
6	75-95
5	50-75
4	25-50
3	5-25
2	1-5
1	0-0.99

Precipitation data

Precipitation data were collected at the Agate 3E weather station (station ID: 250030). Monthly data were obtained from the NPS Climate/Streamflow Data Archive (National Park Service 2006). Annual data were summarized for the 30 year period between 1978 and 2009. Total annual precipitation for each year during the monitoring period 1998 – 2009 is presented as a measure of departure from the 30 year average.

Analytical methods

For analyses, the site was the unit of replication, and plots were pooled or averaged to produce a single parameter estimate for each site. Once estimates for all parameters were obtained for each site, averages and a measure of variability (standard error of the mean) were calculated among sample sites, to provide an estimate at the group level.

Species and guild abundance

Individual species percent foliar cover was calculated for each site. Foliar cover served as an estimate of abundance for herbaceous species. Cover class intervals were converted to median values to estimate percent cover for each herbaceous and shrub species. Mean percent cover was then calculated as the species percent cover for a site, averaged for all ten plots within the site.

Foliar cover was calculated at the guild level. Species were consolidated into one of five guild types (native forb, grass, grass-like/sedges, woody and non-native). These guild types correspond to the fire monitoring plan for AGFO (National Park Service 2005b). Foliar cover for all species within a guild was summed and an average for the guild was calculated for each site.

Cluster analysis

Agglomerative cluster analysis was performed to group all sites across all years based on species abundance (foliar cover). Ward's linkage method was used along with Euclidean distance measure to assemble groups. Cluster analysis and resulting dendrogram were run in PC-ORD version 5.0 (McCune and Mefford 1999). Groups of sites were formed by "pruning" the dendrogram at high information levels such that natural groups (as indicated by longer "legs" of the dendrogram) were delineated and represent differences in community type (riparian floodplain or prairie). Groups identified from cluster analysis were used in all subsequent analysis of monitoring sites and sample years.

Plant species richness, diversity and evenness

Plant diversity for each site was calculated using the **Shannon index**:

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

where pi was the relative cover of species i (Shannon 1948). **Species richness** was determined as the total number of plant taxa recorded per site. Species richness was calculated with all species (native and exotic) included in the estimate. **Simpson's index** of diversity for an infinite population (D) was calculated by site (McCune and Grace 2002). It was the likelihood that two randomly chosen individuals from a site would be different species and emphasized common species (McCune and Grace 2002). It was calculated by site using the complement of Simpson's original index of dominance:

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

Shannon and Simpson's 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 counts of distinct species in the community (Jost 2006). Shannon index was converted into effective number of species (H_e) using the following formula:

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

where H was the Shannon index value. The effective number of species based on Simpson's index (D_e) was the inverse of the index value or:

$$D_e = 1/(1\text{-}D)$$

where D was the Simpson's index value.

When measuring diversity in a single community, it is best to use species richness, Shannon index and Simpson's index to most accurately reflect diversity (Jost 2006). At the most basic 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. The Shannon index weights species by the natural log of their abundance. It is intermediate between species richness and Simpson's index in its sensitivity to rare species. Therefore this diversity measure provides information on both the count of unique species and their abundance in the community. Simpson's 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 species abundance and evenness of distribution in the community. The degree of species abundance and 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 the presence of uncommon species and how species diversity is partitioned within the community. If all species occur in equal abundance in the community within and among sample years, then $S = H_e = D_e$. Effective number of species for each diversity measure reflects the number of species found in a similar community when all species occur in equal abundance. That is to say if $S = 100$ and $D_e = 20$, then 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.

Alpha, beta and gamma diversity

Analyzing patterns in species richness at both the site and prairie scale allowed three kinds of diversity to be calculated (Whittaker 1972). Alpha diversity (i.e., local level diversity) was calculated as the average species richness per site; gamma diversity (i.e., landscape level diversity) was estimated as the total number of species across all sites (McCune and Grace 2002). Each measure of diversity was summarized for each prairie community. Beta diversity, as a measure of the diversity between sites, was calculated as (Whittaker 1972):

$$\beta_w = (S_c / S) - 1$$

where:

β_w = beta diversity,

S_c = the number of species in the prairie,
S = the average species richness in the sample sites.

As a rule of thumb, values of $\beta_w < 1$ are rather low and $\beta_w > 5$ are considered high beta diversity (McCune and Grace 2002). If $\beta_w = 0$, then all sample units have all of the species. The one is subtracted to make zero beta diversity correspond to zero variation in species presence. Beta diversity could be interpreted as an indicator of heterogeneity for the area of interest. While this measure does not have any formal units, it can be used to approximate the "number of distinct communities" among sites (McCune and Grace 2002).

Results

All sites sampled during the monitoring period were included in the initial analysis to determine community membership. However only those sites sampled in all years were subjected to further community level analyses. This report focuses on native prairie sites and does not present findings from the single riparian site (site 8). Site 5 is not included in the analysis of the native prairie sites. The site was oversampled in 2008 (three times in six weeks), which resulted in visible damage, and therefore was not sampled in 2009. Sites 1 and 11 were not established and sampled until 1999. Results are presented for sites 1-4, 6-7, and 9-11 (n=9). Sampling of these nine sites occurred in 1999, 2000, 2003, 2004, 2008 and 2009.

Cluster Analysis

Across all sample years (n=7) and monitoring sites (n=11), three groups of sites were identified through cluster analysis (Fig. 3). Clusters were formed by sites rather than by sample year. As delineated on the dendrogram, Group A (prairie, p) is the largest group with eight sites (sites 1-5, 7, 9 and 10). Group B (rocky prairie, rp) is composed of sites 6 and 11, while Group C identifies the single riparian site (site 8, r). Subsequent data summary follows this group designation with results presented separately for the prairie and rocky prairie sites. Species names, origin, guild and cluster group designation can be found in Appendix A.

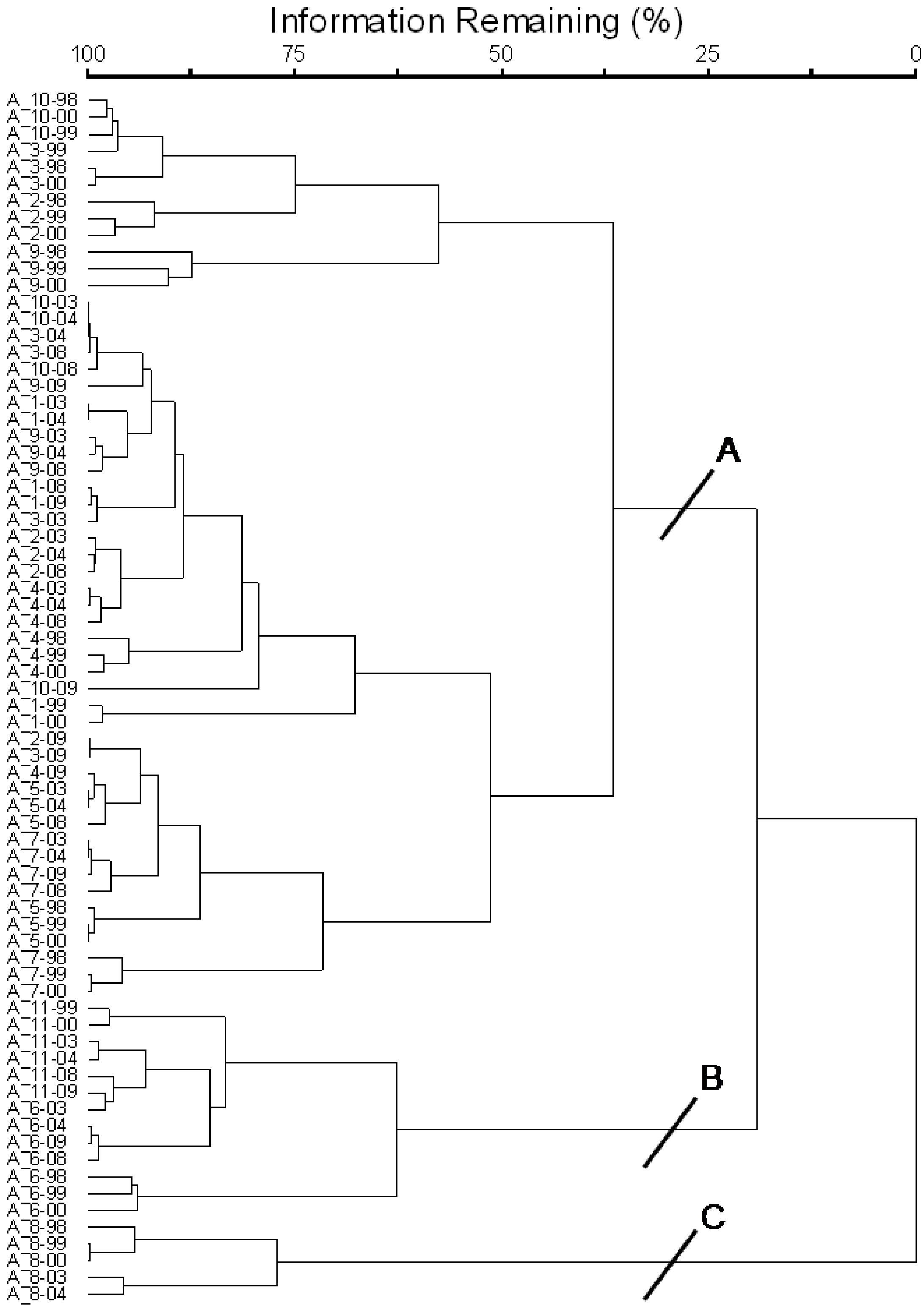

Figure 3. Dendrogram of monitoring site and year by species abundance matrix. Letters indicate groups of sites formed by pruning the dendrogram (see “/” marks). Groups correspond to mixed-grass prairie (A), rocky mixed-grass prairie (B) and riparian (C) community at Agate Fossil Beds National Monument, Nebraska. Site code is ‘A’ _ site number _ sample year.

Native mixed-grass prairie

The seven native mixed-grass prairie sites are representative of the prairie sandreed – sand bluestem (*Calamovilfa longifolia–Andropogon hallii*) plant community. In 2009, sites 2-4 and 7 were involved in a prescribed fire prior to sampling; otherwise active management of the area did not occur during the monitoring period.

These sites are dominated by native grass and forbs with low cover of invasive exotic plants. These sites are also characterized by having little exposed rock, with most of the ground cover being either bare soil or grass litter. Among the seven sites across the monitoring period, 124 species were observed of which only 13 were non-native species. Among all six sampling years, 54 species (44% of total richness) were common to all years with only three non-native species being observed each year. Of the 124 species observed during the monitoring period (1999 - 2009), 18 were detected in only a single year.

Species richness at the site level (alpha diversity) and for the prairie area (gamma diversity) decreased during the monitoring period (Table 3). The decrease was evident when considering all species and only native species. However, the number of invasive exotic plants (IEP) at the site and prairie scale remained nearly stable across each sample year (the annual difference in number of 'all' and 'native' species for both alpha and gamma diversity measures, Table 3).

Table 3. Alpha, beta and gamma diversity measures for the prairie group sites (n=7) by sample year. Each diversity measure is calculated by year for all species (All) and only native species (Native) in the sites.

	alpha		Beta		gamma	
Year	All	Native	All	Native	All	Native
1999	47.1	43	1.1	1.1	100	92
2000	43.9	40.4	1.2	1.2	96	89
2003	42.7	38	1.1	1.2	91	83
2004	30.3	27.9	1.6	1.7	80	75
2008	36.6	31.7	1.3	1.4	84	75
2009	32.1	28.4	1.4	1.4	78	68

Beta diversity remained low during the monitoring period for both all species and only native species (Table 3). Low beta diversity values are indicative of all sites within the group representing a single community. The beta diversity results support the cluster analysis.

As noted with alpha diversity, richness (all species) declined during the monitoring period, with a pronounced decrease being measured in 2004 (Fig. 4). However, site level species diversity (mean ± standard error of the mean) as measured by the Shannon diversity number and Simpson's diversity number indicate relative stability through time (Fig. 4).

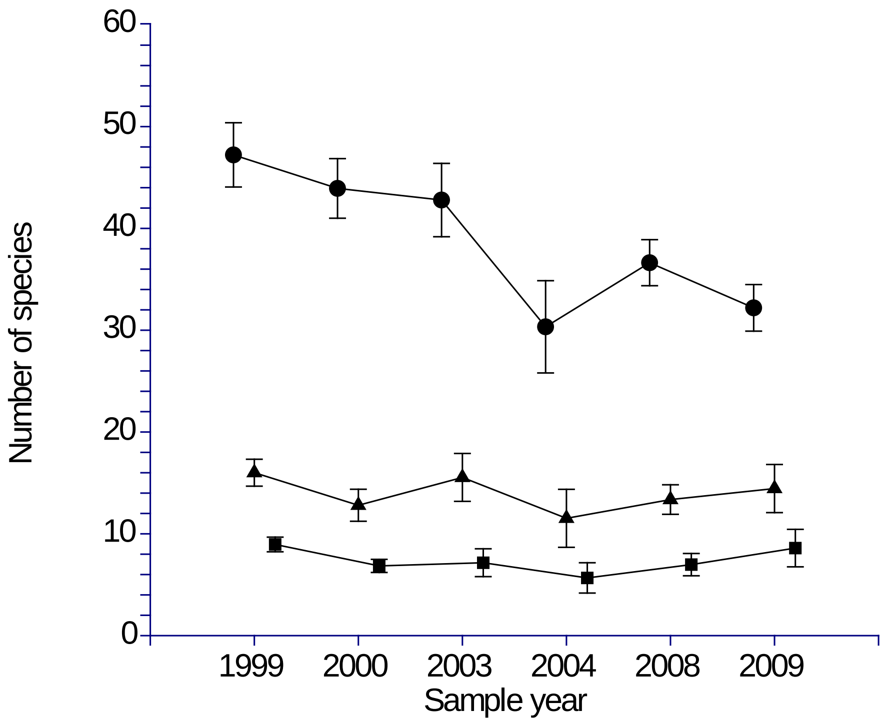

Figure 4. Species diversity calculated for prairie group sites (n=7) with all species included (native and invasive exotic plant species). Species richness (closed circle), Shannon diversity number (closed triangle) and Simpson's diversity number (closed square). Symbols and error bars are the site value mean ± standard error of the mean.

The difference in number of species between each diversity measure indicates that the community is composed of a few dominant species and many species which occur less frequently or in lower abundance (Fig. 4).

Considering only native species, species richness declines during the monitoring period while both Shannon and Simpson diversity numbers remain stable (Fig. 5). The large difference in the number of species between species richness and the other two diversity measures along with the smaller difference in number in species between Shannon and Simpson's diversity measures is indicative of native prairie composition. These seven prairie sites are composed of a few dominant native species and many native species which occur less frequently or in lower abundance (Fig. 5).

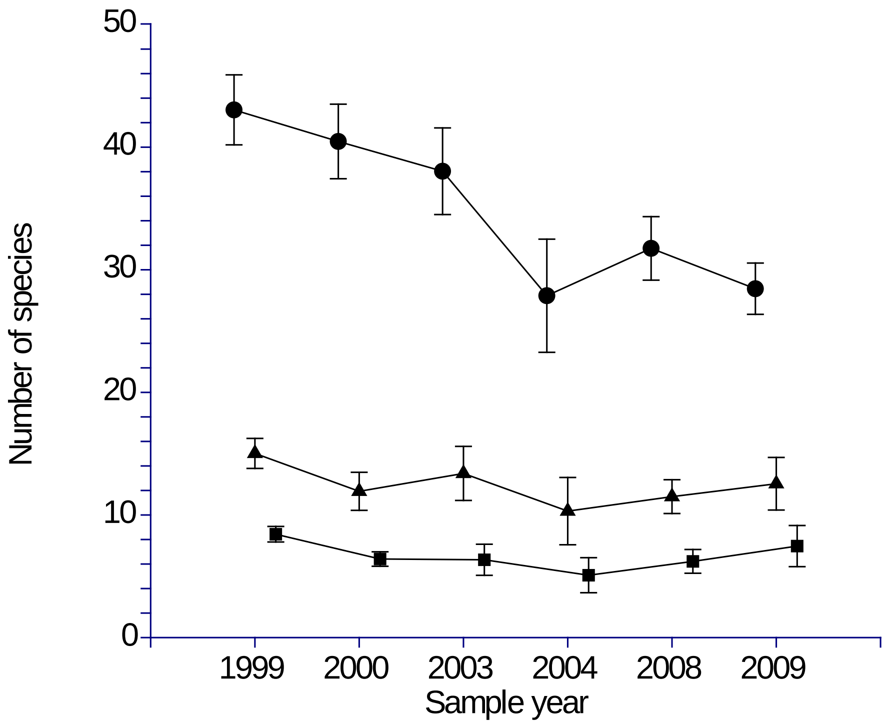

Figure 5. Species diversity calculated for prairie group sites (n=7) with only native species included. Species richness (closed circle), Shannon diversity number (closed triangle) and Simpson's diversity number (closed square). Symbols and error bars are the site value mean ± standard error of the mean.

Whether including all species or only native species, the three diversity measures have the same pattern throughout the monitoring period. A trend in species richness is difficult to discern, particularly because of the 2004 observations. Species richness could either be a linear declining trend from one sample year to the next or 2004 could mark the difference between a group of declining years (1999-2003) and a more stable group of years (2004-2009). In either case, 2004 marks a change in observed native mixed-grass prairie community composition.

Species abundance was measured at the guild level for all sites in the prairie group. Mean (± standard error of the mean) foliar cover for each guild shows that native grasses are dominant within the seven monitoring sites (Fig. 6).

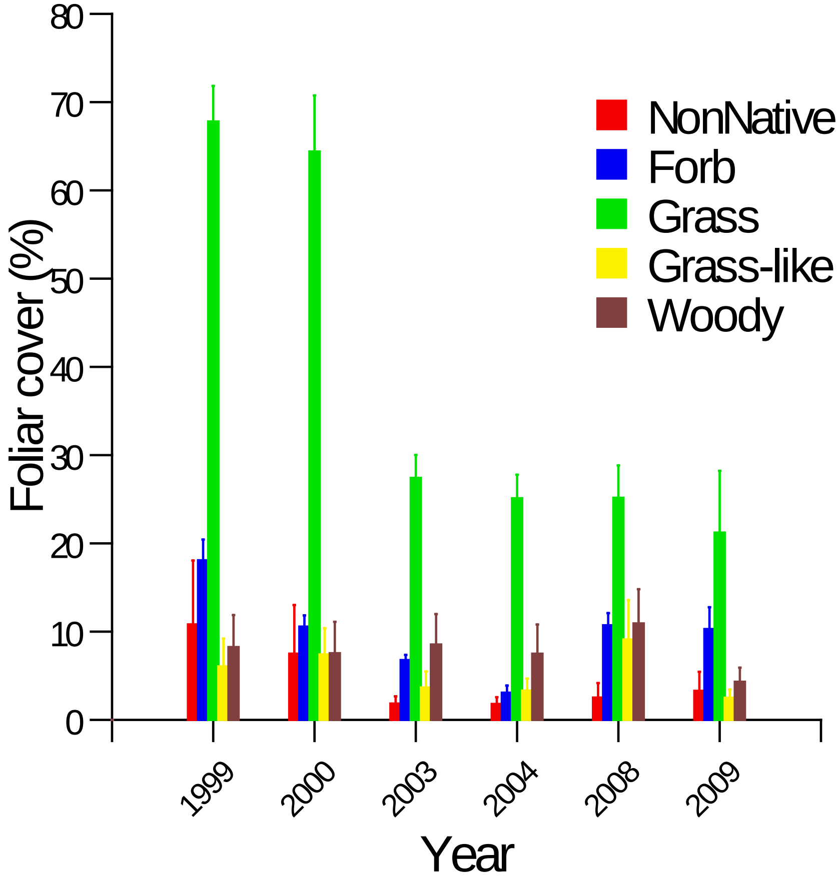

Figure 6. Foliar cover (%) of guilds in the native prairie (n=7). Colored bars are mean (± standard error of the mean) site value for each guild.

There is a marked difference in mean foliar cover of native grasses between the sample years before 2003 and the years from 2003 to 2009 (Fig. 6). This distinction is not observed in the other guilds. The woody guild is primarily composed of soap plant (*Yucca glauca*). Foliar cover of this guild peaked in 2008 and then decreased sharply following the 2009 prescribed fire which impacted four sites.

Bare soil and grass litter were the dominant ground cover types during the monitoring period (Fig. 7). Beginning in 2004, grass litter declined, with a marked decline in 2009 following the prescribed fire (Fig. 7).

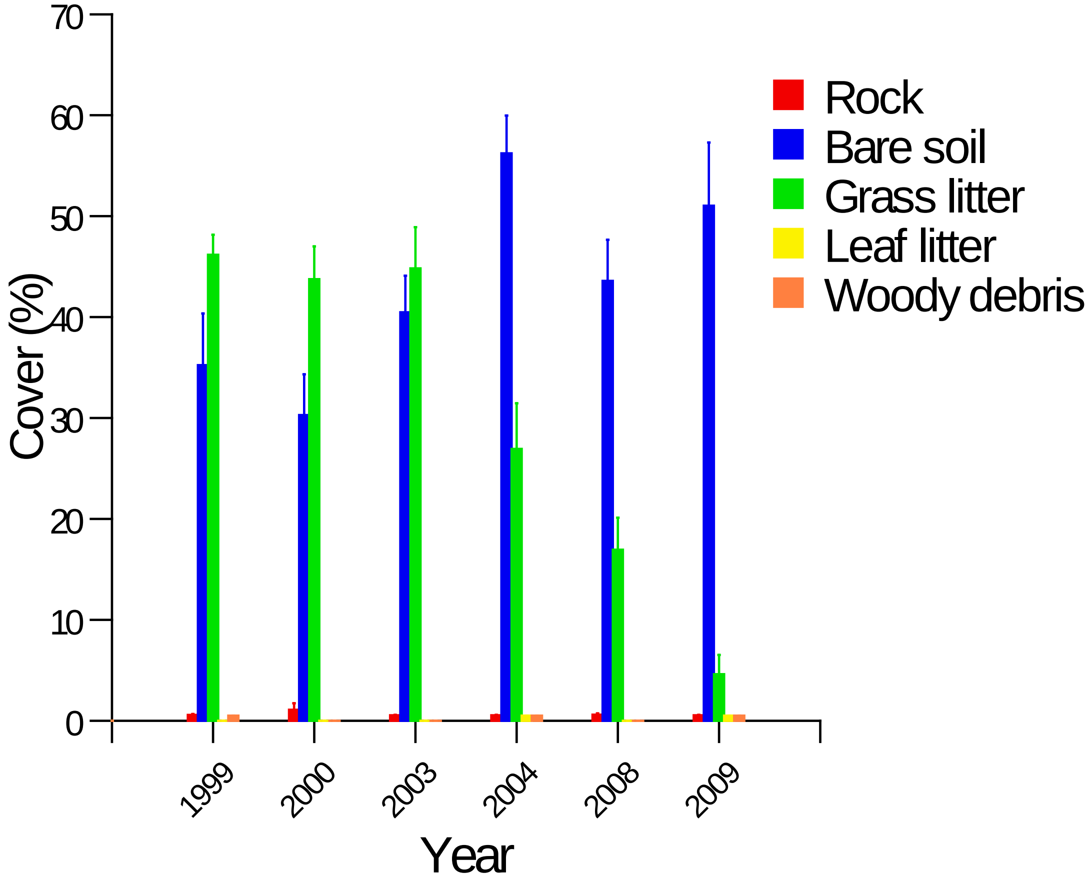

Figure 7. Ground cover (%) in the native prairie (n=7). Colored bars are mean (± standard error of the mean) site value for each ground cover type.

Rock, leaf litter and woody debris comprise a minimal amount of the non-vegetated ground cover in these sites (Fig. 7). As grass litter declined, bare soil was observed in greater amounts.

Native mixed-grass prairie: rocky sites

The two native mixed-grass rocky prairie sites are representative of the needle-and-thread grass – blue grama – threadleaf sedge (*Stipa comata–Bouteloua gracilis–Carex filifolia*) plant community. Sites 6 and 11 are on slopes with more exposed rock than the other sites. These two sites did not receive any active management during the monitoring period. The two groups of native mixed-grass prairie sites delineated by cluster analysis differ primarily in their abundance of exposed rock and the greater abundance of threadleaf sedge.

These sites are dominated by native sedges and grass with low cover of invasive exotic plants. These sites are also characterized by having more exposed rock, with most of the ground cover being bare soil, grass litter, and bare rock. Among the two sites across the monitoring period, 98 species were observed of which only nine were non-native species. Among all six sampling years, 35 species (36% of total richness) were common to all years. Of the 98 species observed during the monitoring period, 13 were detected in only a single year.

Species richness at the site level (alpha diversity) and among both rocky prairie sites (gamma diversity) decreased during the monitoring period (Table 4). The decrease was evident for both all species and only native species. However, the number of invasive exotic plants (IEP) within and among sites remained nearly stable across each sample year (the annual difference in number of ‘all’ and ‘native’ species for both alpha and gamma diversity measures, Table 4).

Table 4. Alpha, beta and gamma diversity measures for the rocky prairie group sites (n=2) by sample year. Each diversity measures is calculated by year for all species (All) and only native species (Native) in the sites.

	alpha		beta		gamma	
Year	All	Native	All	Native	All	Native
1999	55.1	53.5	0.45	0.38	80	74
2000	55	52	0.47	0.46	81	76
2003	51	46.5	0.39	0.40	71	65
2004	36	33.5	0.47	0.46	53	49
2008	43.5	41	0.40	0.39	61	57
2009	40.5	36.5	0.51	0.51	61	55

Beta diversity remained very low during the monitoring period for both all species and only native species (Table 4). Beta values close to zero indicate that both sites have nearly the same species composition. Again, the beta diversity results support the cluster analysis.

As noted with alpha diversity, richness (all species) declined during the monitoring period, with a pronounced decrease being measured in 2004 (Fig. 8). However, site level species diversity (mean ± standard error of the mean) as measured by the Shannon diversity number and Simpson’s diversity number indicate relative stability through time (Fig. 8).

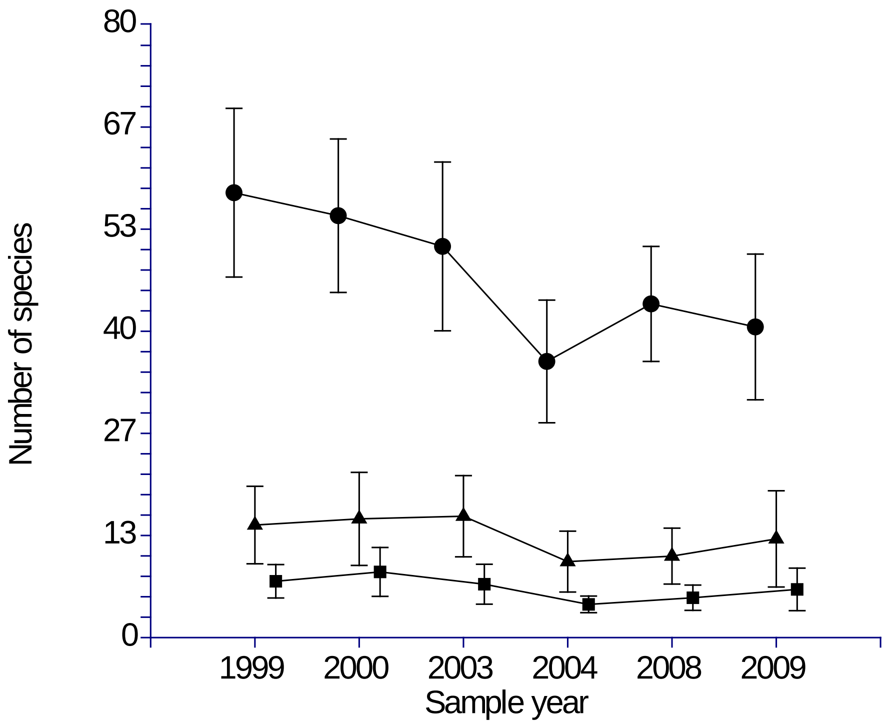

Figure 8. Species diversity calculated for rocky prairie group sites (n=2) with all species included (native and invasive exotic plant species). Species richness (closed circle), Shannon diversity number (closed triangle) and Simpson's diversity number (closed square). Symbols and error bars are the mean site value ± standard error of the mean.

The same pattern in species richness, Shannon diversity number and Simpson's diversity number observed in the native prairie sites is evident in the rocky prairie sites. This community is also composed of a few abundant species and many species which occur less frequently or in lower abundance (Fig. 8).

The similarity among the two community types is present when looking at species richness and the two diversity measures of only native species. In the rocky prairie sites, native species richness declines over time, with a noticeable decrease in 2004 while Shannon and Simpson's diversity numbers remain fairly stable during the monitoring period (Fig. 9).

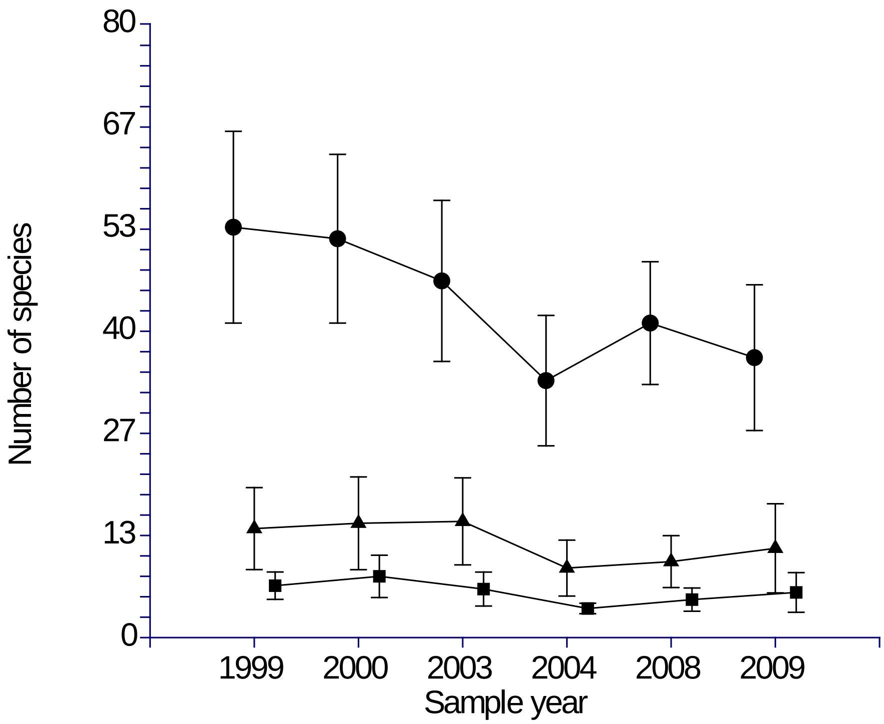

Figure 9. Species diversity calculated for rocky prairie group sites (n=2) with only native species included. Species richness (closed circle), Shannon diversity number (closed triangle) and Simpson's diversity number (closed square). Symbols and error bars are the site value mean ± standard error of the mean.

For these two sites, the pattern in diversity measures is the same among years whether looking at all species or only native species.

Species abundance was measured at the guild level for both rocky prairie sites. This is another distinction between the rocky prairie sites and the non-rocky native mixed-grass prairie sites. Mean foliar cover for each guild shows that native sedges dominate the two monitoring sites (Fig. 10). Mean foliar cover of native grass is a large component of the foliar cover for both sites. Like the non-rocky sites, IEP's either barely or do not exceed 10% mean foliar cover during the monitoring period (Fig. 10).

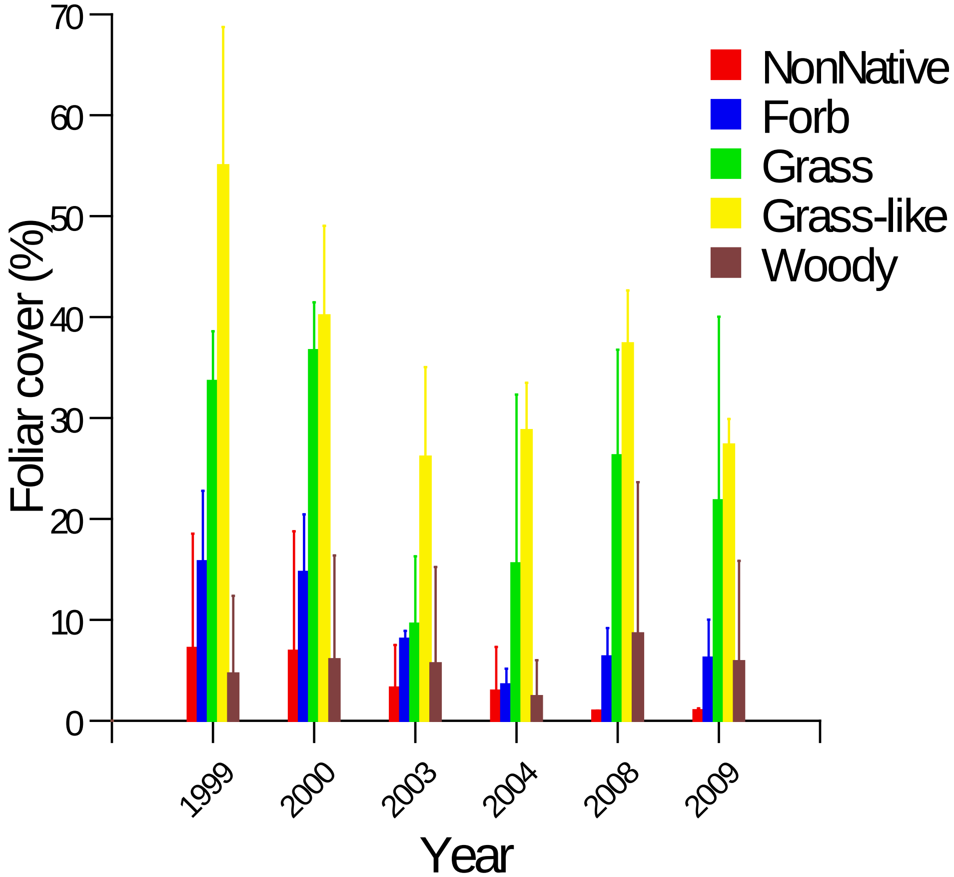

Figure 10. Foliar cover (%) of guilds in the native rocky prairie (n=2). Colored bars are mean (± standard error of the mean) site value for each guild.

Ground cover among the rocky sites is primarily composed of both grass litter and bare soil (Fig. 11). However exposed rock is a noticeable component of the ground cover within these two sites. Leaf litter and woody debris occur in similar abundances as the other native mixed-grass prairie sites. Again there is a declining trend in grass litter during the monitoring period.

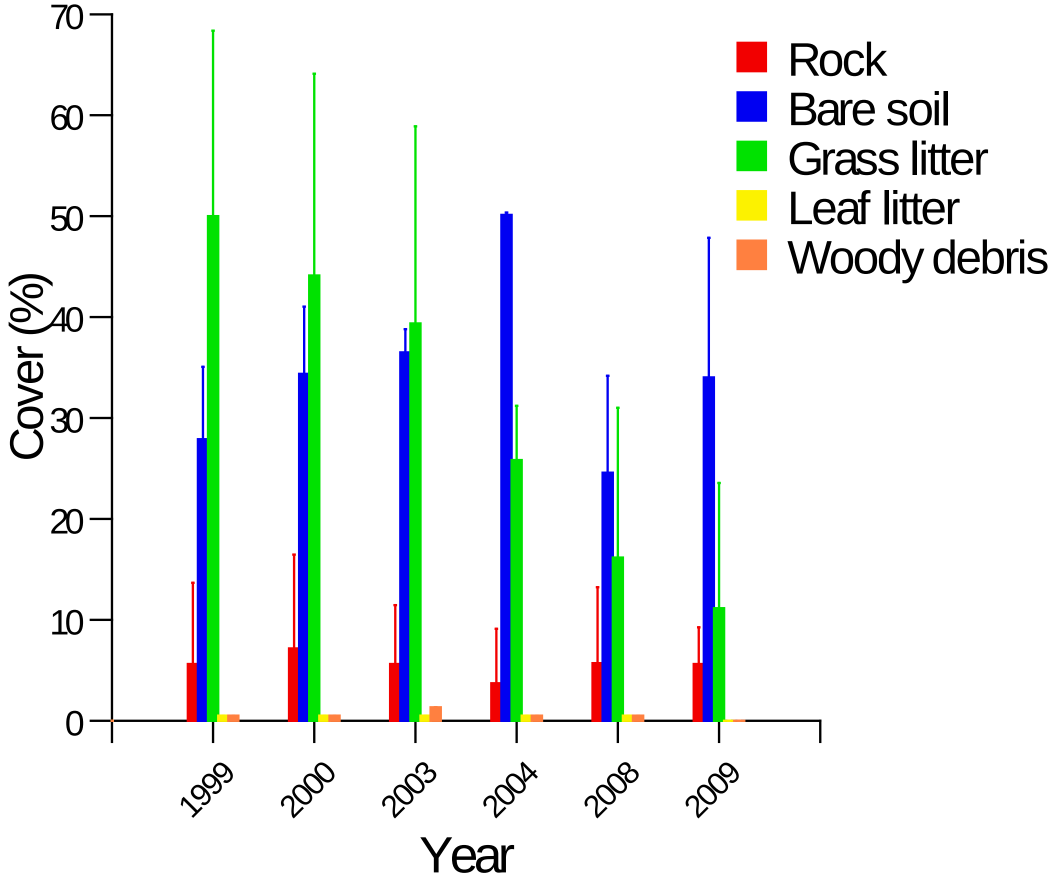

Figure 11. Ground cover (%) in the native rocky prairie (n=2). Colored bars are mean (± standard error of the mean) site value for each ground cover type.

During the monitoring period, departure from the 30 year average of precipitation illustrates annual variability in precipitation at AGFO (Fig. 12). The monitoring period experienced periods of both above and below average precipitation that lasted more than a single year.

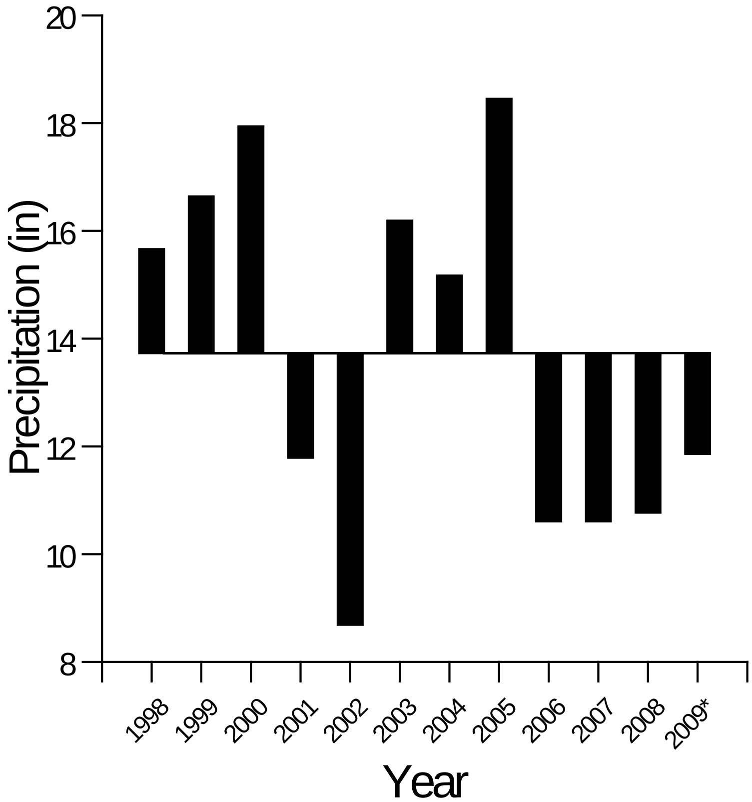

Figure 12. Precipitation during the monitoring period at Agate Fossil Beds National Monument, Nebraska. The 30 year average (13.73 inches) is indicated with the horizontal baseline. Total precipitation for 2009 is reported up through June (*).

The most pronounced dry year (negative departure from average) was observed during 2002 while the wettest year (positive departure from average) was 2005. Following this wet year were four years of below average precipitation.

Discussion

Historically, native prairie was characterized by heterogeneity, with the interaction of fire, grazing and climate influencing vegetation community dynamics. This interplay of ecosystem drivers determined the spatial patterns, variation, dynamics, and structure of plant populations across the prairie.

Based on species composition and abundance across all sample years, the prairie sites were able to be divided into two distinct groups. Each group corresponds to a community type originally identified as part of the reference frame: prairie sandreed – sand bluestem (n=7, prairie sites), needle-and-thread grass – blue grama – threadleaf sedge (n=2, rocky sites).

For all native prairie sites, 2004 stands out for its low species richness values. Aside from the 2009 prescribed fire, management of the prairie communities has not occurred and therefore cannot explain the noticeable decline in species richness sites observed during 2004. Prior to 2004, HTLN sampled all sites twice per year (June and July). Beginning in 2004, all sites were sampled once per year (late June). This reduction in sampling effort may have contributed to the low 2004 observation; however richness values in subsequent years did not continue to decline from 2004 observations.

Total precipitation for the first half of 2004 (January through June) totaled 4.8 inches (11 additional inches of precipitation fell during 2004 following June data collection). During the 2004 field sampling it was noted that the conditions were very dry and it appeared that there were few forbs and an abundance of blue grama (*Bouteloua gracilis*) (internal 2004 HTLN trip report). This observation is consistent with the decrease in richness (reduction in total number of species) without a proportional decrease in other site level diversity measures (Shannon and Simpson's diversity, which consider overall abundance of each species).

There is pronounced difference in species abundance within the sandreed – sand bluestem community beginning in 2003. Earlier sampling detected native grass abundances over twice that of abundance values collected from 2003 onward. This temporal distinction was not observed with other guilds in this community or as prominent of a difference in the needle-and-thread grass – blue grama – threadleaf sedge community. Again it is difficult to explain this change in native grass abundance by patterns in precipitation or changes in sampling efforts as noted above. An extended period of monitoring may indicate that this shift is part of a longer temporal pattern in the variability of native grass foliar cover for this community type.

The 2009 prescribed fire that affected four native mixed-grass prairie sites did have a detectable and measurable impact as noted in reduced abundance of woody species and grass litter with an increase in bare ground cover within the community.

Overall, all HTLN vegetation monitoring sites can be categorized into three community types that are widespread throughout the park (Fig. 13). Data from these sites and results presented here can be considered representative of the mapped community to which they are associated. Site 8 is the single representative monitoring site for the western wheatgrass community type. This site was included in the cluster analysis and omitted from further community level analyses.

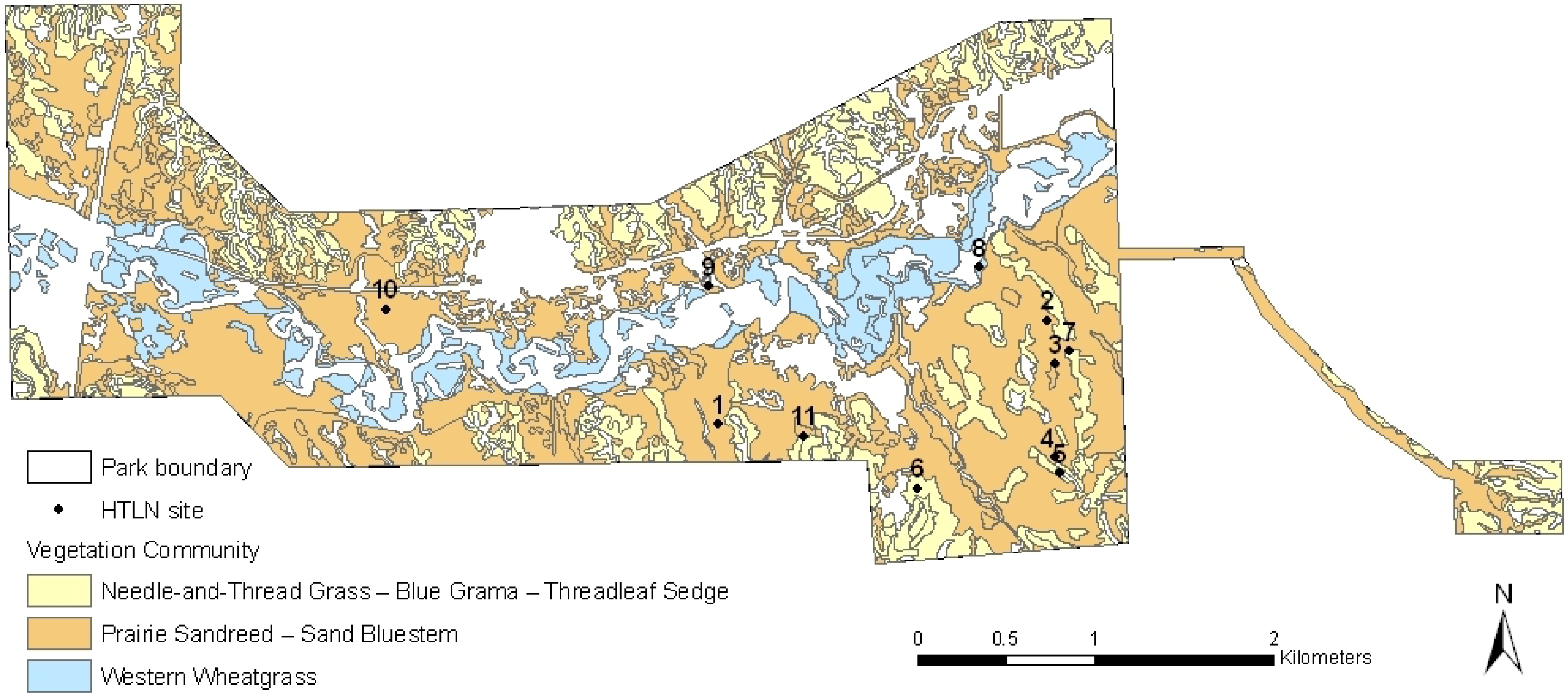

Figure 13. Vegetation community types associated with HTLN monitoring sites at Agate Fossil Beds National Monument, Nebraska.

Monitoring site 7 crosses the mapped boundary of the needle-and-thread grass - blue grama – threadleaf sedge community and the prairie sandreed – sand bluestem community. Based on species composition and ground cover abundance, this site is characteristic of the other prairie sandreed – sand bluestem sites. Even though data from site 5 were not included in the community analysis, this site is like site 7 in that it straddles two community types. As with site 7, species composition and ground cover abundance are similar to the sites in the needle-and-thread grass - blue grama – threadleaf sedge community. This classification is supported by the cluster analysis, which involved all sites and sample years for the entire monitoring period. See the USGS-NPS vegetation map for more detailed community descriptions (USGS 1998).

In the absence of active management during all but the last year of the monitoring period, this report presents natural variability of two native mixed-grass prairie communities for the period between 1999 and 2009. In addition this report classifies all HTLN monitoring sites into community types that correspond to the USGS-NPS vegetation map for the park. This work can be used to simply characterize the native prairie at AGFO, act as a baseline to which further monitoring can be compared, or integrated with the fire effects monitoring of the Northern Great Plains fire module. Mostly this report acts to summarize the major vegetation community monitoring efforts of the Heartland Inventory and Monitoring Network efforts at AGFO over the last eleven years. Further it represents the conclusion of HTLN monitoring and completes the monitoring transition to the Northern Great Plains Inventory and Monitoring Network.

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Appendix

Appendix A. Species list compiled from Heartland Inventory and Monitoring Network vegetation monitoring sites sampled from 1998 to 2009. For each species there is a scientific name, common name, origin (N = native, I = invasive exotic plant), guild (Northern Great Plains fire module guild types), and group (defined by cluster analysis where p = native prairie sites, rp = native rocky prairie sites, r = riparian site).

Scientific name	Common name	Origin	Guild	Group
Allium textile	Onion	N	forb	p, rp
Ambrosia psilostachya	Western ragweed	N	forb	p
Ambrosia trifida	Giant ragweed	N	forb	r
Amphiachyris dracunculoides	Broomweed	N	forb	p
Andropogon hallii	Sand bluestem	N	grass	p, rp
Antennaria parvifolia	Plains pussytoes	N	forb	p
Arabis holboellii	Rock-cress	N	forb	p, rp
Arenaria hookeri	Sandwort	N	forb	p, rp
Aristida purpurea	Purple three-awn	N	grass	p, rp
Artemisia campestris	Wormwood	N	forb	p
Artemisia dracunculus	Wormwood	N	forb	p
Artemisia frigida	Prairie-sagewort	N	forb	p, rp
Asclepias pumila	Milkweed	N	forb	p, r
Asclepias speciosa	Showy milkweed	N	forb	r
Asclepias viridiflora	Green milkweed	N	forb	p
Asclepias viridis	Ozark milkweed	N	forb	p
Aster ericoides	Squarrose white wild aster	N	forb	p, r
Astragalus ceramicus	painted milkvetch	N	forb	p, rp
Astragalus crassicarpus	Ground-plum	N	forb	p
Astragalus gracilis	Milk-vetch	N	forb	p, rp
Astragalus laxmannii	Prairie milkvetch	N	forb	p
Astragalus lotiflorus	Lotus milk-vetch	N	forb	p
Astragalus missouriensis	Nuttall milk-vetch	N	forb	p, rp
Astragalus sericoleucus	Milk-vetch	N	forb	p
Astragalus spatulatus	Milk-vetch	N	forb	p, rp
Bouteloua curtipendula	Side-oats grama-grass	N	grass	p
Bouteloua gracilis	Blue grama	N	grass	p, rp
Bromus inermis	Smooth brome	I	NonNative	p
Bromus japonicus	Japanese brome	I	NonNative	p, rp
Bromus tectorum	Cheatgrass	I	NonNative	p, rp
Calamovilfa longifolia	Sand-reed	N	grass	p, r, rp
Calylophus serrulatus	Evening-primrose	N	forb	p, rp
Camelina microcarpa	Small-seed false flax	I	NonNative	p, r
Carex filifolia	Sedge	N	grass-like	p, rp
Castilleja sessiliflora	Downy paintbrush	N	forb	p
Chamaesyce glyptosperma	Ridge-seed spurge	N	forb	rp
Chamaesyce serpens	Round-leaved spurge	N	forb	p
Chenopodium berlandieri	Pitseed goosefoot	N	forb	p, r
Chenopodium pratericola	Narrow-leaf goosefoot	N	forb	p, r, rp
Cirsium canescens	Thistle	N	forb	p, rp
Cirsium flodmanii	Prairie thistle	N	forb	p, r, rp

Cleome serrulata	Stinking clover	N	forb	p
Comandra umbellata	Bastard toad-flax	N	forb	p, rp
Conyza canadensis	Horseweed	N	forb	p, r, rp
Corispermum hyssopifolium	Bugseed	I	NonNative	p
Coryphantha vivipara	Pincushion cactus	N	forb	p, rp
Croton texensis	Texas croton	N	forb	rp
Cryptantha cana	Borage	N	forb	rp
Cryptantha celosioides	Borage	N	forb	p
Cymopterus acaulis	Wild parsley	N	forb	p, rp
Dalea candida	White prairie clover	N	forb	p, rp
Dalea purpurea	Purple prairie clover	N	forb	p, rp
Descurainia pinnata	Tansy-mustard	N	forb	p, r, rp
Descurainia sophia	Tansy-mustard	I	NonNative	p, r
Ellisia nyctelea	Water-pod	N	forb	p, r
Elymus elymoides	Wild rye	N	grass	p
Elymus trachycaulus	Slender wheatgrass	N	grass	p, r, rp
Equisetum laevigatum	Smooth scouring rushes	N	grass-like	r
Erigeron bellidiastrum	Fleabane	N	forb	p
Erigeron pumilus	Fleabane	N	forb	rp
Eriogonum annuum	Annual eriogonum	N	forb	p, rp
Eriogonum cernuum	Nodding wild buckwheat	N	forb	rp
Eriogonum flavum	Yellow wild buckwheat	N	forb	p, rp
Erysimum asperum	Western wallflower	N	forb	p, rp
Escobaria missouriensis	Missouri coryphanthe	N	forb	p, rp
Euphorbia glyptosperma	Ridge-seeded spurge	N	forb	p
Euphorbia missurica	Prairie spurge	N	forb	p
Euphorbia robusta	Spurge	N	forb	p, rp
Gaura coccinea	Scarlet gaura	N	forb	p, r, rp
Gaura parviflora	Gaura	N	forb	p, r
Gutierrezia sarothrae	Matchbrush	N	forb	p, rp
Hedeoma drummondii	Drummond false pennyroyal	N	forb	p
Hedeoma hispidum	Mint	N	forb	p
Helianthus annuus	Common sunflower	N	forb	p, r
Helianthus petiolaris	Plains sunflower	N	forb	p, r, rp
Heterotheca villosa	Golden aster	N	forb	p, rp
Hymenopappus filifolius	Aster	N	forb	p
Iva xanthifolia	Big marsh-elder	N	forb	r
Kochia scoparia	Summer-cypress	I	NonNative	p, r, rp
Koeleria macrantha	Junegrass	N	grass	p, rp
Lactuca serriola	Prickly lettuce	I	NonNative	p, r, rp
Lactuca tatarica	Blue lettuce	N	forb	p, r, rp
Lappula occidentalis	Western stickseed	N	forb	p, r, rp
Lathyrus polymorphus	Vetchling, wild pea	N	forb	p, rp
Lepidium densiflorum	Prairie-pepperweed	N	forb	p, rp
Lesquerella arenosa	Great Plains bladderpod	N	forb	p, rp
Lesquerella ludoviciana	Mustard	N	forb	p, rp
Liatris punctata	Blazing star, gay feather	N	forb	p, rp
Linum puberulum	Plains flax	N	forb	p
Linum rigidum	Stiffstem yellow flax	N	forb	p, rp
Lithospermum incisum	Narrow-leaved puccoon	N	forb	p, r, rp

Lupinus plattensis	Lupine	N	forb	p, rp
Lupinus pusillus	Lupine	N	forb	p
Lygodesmia juncea	Skeleton-weed	N	forb	p, rp
Machaeranthera grindelioides	Rayless aster	N	forb	p
Machaeranthera pinnatifida	Aster	N	forb	p, r, rp
Melilotus officinalis	Yellow sweet clover	I	NonNative	p, r, rp
Mirabilis hirsuta	Hairy umbrella-wort	N	forb	p, r, rp
Mirabilis linearis	Narrow-leaved umbrella-wort	N	forb	p, rp
Muhlenbergia pungens	Muhly	N	grass	p, rp
Musineon tenuifolium	Parsley	N	forb	p, rp
Oenothera albicaulis	Evening-primrose	N	forb	p, rp
Oenothera cespitosa	Evening-primrose	N	forb	p
Oenothera nuttallii	White-stemmed evening-primrose	N	forb	p, rp
Oenothera villosa	Evening-primrose	N	forb	r
Opuntia fragilis	Little prickly pear	N	forb	p, rp
Opuntia macrorhiza	Plains prickly pear	N	forb	p, rp
Opuntia polyacantha	Plains prickly pear	N	forb	p, rp
Orobanche fasciculata	Clustered broom-rape	N	forb	p
Oryzopsis hymenoides	Indian ricegrass	N	grass	p, rp
Oxytropis sericea	White locoweed	N	forb	p, rp
Paronychia depressa	Whitlow-wort	N	forb	p, rp
Paronychia sessiliflora	Creeping nailwort	N	forb	p
Pascopyrum smithii	Western wheatgrass	N	grass	p, r, rp
Penstemon angustifolius	Beard-tongue	N	forb	p, rp
Penstemon eriantherus	Beard-tongue	N	forb	p
Phacelia hastata	Silverleaf phacelia	N	forb	p
Phlox andicola	Phlox, Sweet William	N	forb	p, rp
Phlox hoodii	Phlox, Sweet William	N	forb	p, rp
Physalis hispida	Plains-sandhill ground cherry	N	forb	p
Plantago patagonica	Wooly plantain	N	forb	p, rp
Poa compressa	Canada bluegrass	I	NonNative	rp
Poa pratensis	Kentucky bluegrass	I	NonNative	p, r, rp
Poa secunda	Bluegrass	N	grass	p
Polygonum ramosissimum	Smartweed	N	forb	p, rp
Psoralea esculenta	Breadroot scurf-pea	N	forb	p
Psoralidium lanceolatum	Pea, Bean	N	forb	p, rp
Psoralidium tenuiflorum	Gray scurf-pea	N	forb	p, rp
Rhus trilobata	Squaw-bush	N	woody	p, rp
Rumex venosus	Veiny dock	N	forb	p, rp
Salsola spp	Russian thistle	I	NonNative	p, rp
Schizachyrium scoparium	Little bluestem	N	grass	p, rp
Senecio canus	Gray groundsel	N	forb	p, rp
Senecio plattensis	Platte groundsel	N	forb	p
Senecio riddellii	Groundsel, ragwort	N	forb	p, rp
Silene drummondii	Drummond's campion	N	forb	p, rp
Sisymbrium altissimum	Tumbling-mustard	I	NonNative	p, r, rp
Sphaeralcea coccinea	Scarlet mallow	N	forb	p, rp
Sporobolus cryptandrus	Sand dropseed	N	grass	p, rp
Stipa comata	Needle-and-thread grass	N	grass	p, r, rp
Stipa viridula	Green needle-grass	N	grass	p

Taraxacum officinale	Common dandelion	I	NonNative	p
Tetraneuris acaulis	Bitterweed	N	forb	p, rp
Thermopsis rhombifolia	Buckbean	N	forb	p
Townsendia grandiflora	Easter daisy	N	forb	p, rp
Tradescantia occidentalis	Prairie spiderwort	N	forb	p, rp
Tragopogon dubius	Fistulous goat's beard	I	NonNative	p, r, rp
Viola nuttallii	Yellow prairie violet	N	forb	p, r, rp
Vulpia octoflora	Six-weeks fescue	N	grass	p, rp
Yucca glauca	Soap plant	N	woody	p, rp

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