



Vegetation Community Monitoring at Scotts Bluff National Monument, Nebraska

1997-2009

Natural Resource Technical Report NPS/HTLN/NRTR—2010/364



ON THE COVER

Shiprock at Scotts Bluff National Monument, Nebraska. Photograph by: HTLN staff

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August 2010

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

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Please cite this publication as:

James, K. M. 2010. Vegetation community monitoring at Scotts Bluff National Monument, Nebraska: 1997-2009. Natural Resource Technical Report NPS/HTLN/NRTR—2010/364. National Park Service, Fort Collins, Colorado.

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Abstract

Vegetation community monitoring was conducted by the Heartland Inventory and Monitoring Network beginning in 1997 and concluded in 2009. During this period, fourteen monitoring sites were established in four vegetation communities. This report presents summary findings of that monitoring effort and concludes network vegetation monitoring efforts at Scotts Bluff National Monument. The Northern Great Plains Inventory and Monitoring Network will continue long-term vegetation monitoring at the park. The fourteen monitoring sites were categorized into four community types: needle-and-thread grass – blue grama – threadleaf sedge native prairie, Rocky Mountain juniper woodland, restored prairie and reseeded mixed grass prairie. A summary of the native mixed-grass prairie, woodland and restoration areas is presented. Active management was restricted to two prescribed fires during the monitoring period. These fires only minimally impacted the monitoring sites. Below average annual precipitation characterized the monitoring period. Therefore this report represents natural variability relative to weather and climate in the absence of continued 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 Symsted, 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*), 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).

Scotts Bluff National Monument (SCBL) is located in the western panhandle of Nebraska and is dominated by mixed-grass prairies. The park was established in 1919 to protect and preserve its namesake bluff and the associated heritage of western expansion that occurred in the area. The park consists of 3003 acres that encompass two prominent bluffs, mixed-grass prairies, woodlands, badlands, riparian areas, and prairie restoration.

Vegetation monitoring at SCBL was initiated in 1997 by the Heartland Network Inventory and Monitoring Program with three primary objectives:

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

Within the park there are 20 community types identified by the NPS vegetation mapping project (USGS 1998). Of those 20 types, HTLN vegetation community monitoring sites are located in the native mixed-grass prairie, non-native grassland (prairie restoration and reseeded) and native conifer stand (pine woodlands).

Methods

Field methods

The Heartland Inventory and Monitoring Network implemented monitoring at SCBL in 1997 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 twelve sites (consisting of ten 10m² plots at each site) were sampled during the summer of 1997. In 1998, two additional sites were established (Table 1, Fig. 1).

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

Year	N	Sites sampled
1997	12	1 – 12
1998	12	1 – 8, 11 – 14
1999	11	1 – 7, 11 – 14
2000	4	9 – 10, 13 – 14
2001	2	13 – 14
2003	14	1 – 14
2004	11	1 – 7, 11 – 14
2008	10	1 – 7, 11, 13 – 14
2009	11	1 – 7, 11 - 14

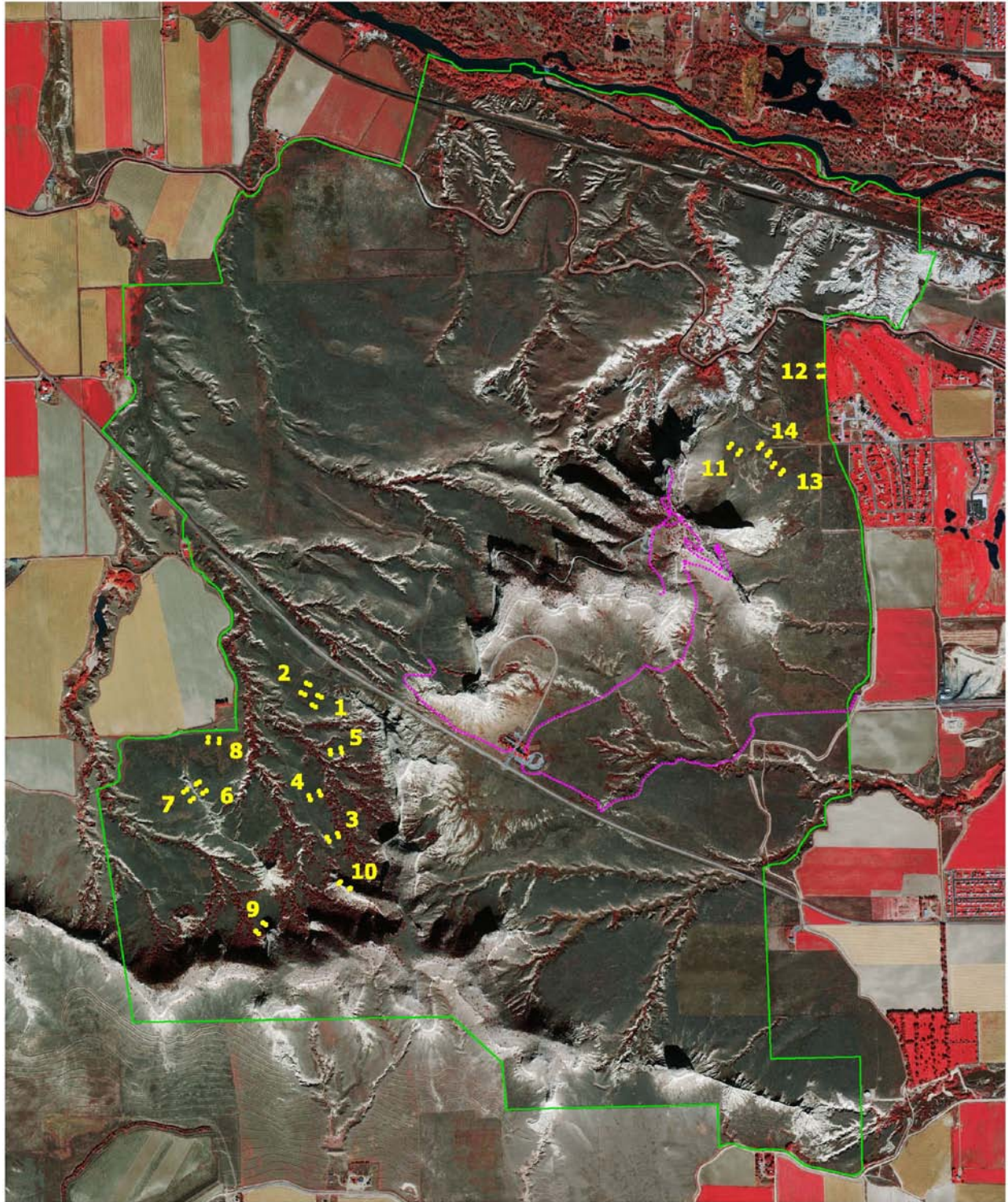


Figure 1. Map of Scotts Bluff National Monument, Nebraska displaying Heartland Inventory and Monitoring Network plant community monitoring sites.

HTLN plant community monitoring 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).

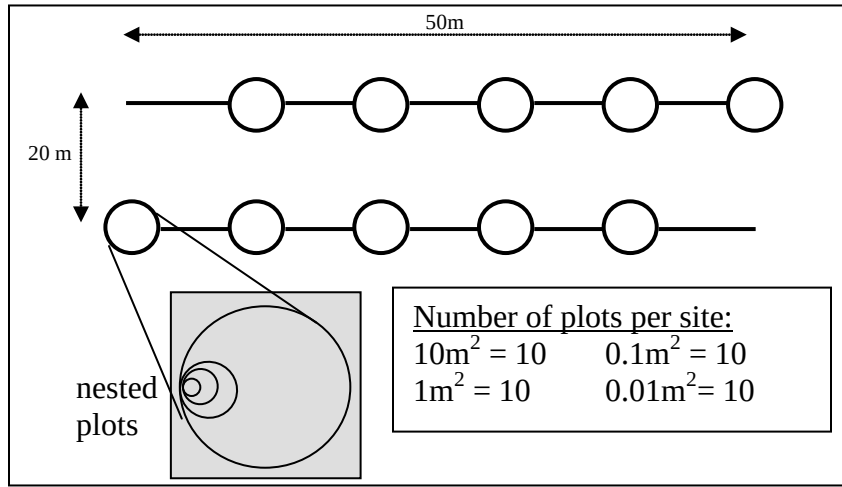


Figure 2. HTLN plant community monitoring site showing transects and plots including nested plots.

The site 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 and woodland understory 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

Overstory and understory data summary

In the pine woodland community, summary statistics for overstory and understory (stems ≥ 5.0 cm dbh) tree species are calculated. Diameter at breast height (dbh) as measured in centimeters is collected for each overstory tree. Trees are categorized by species and dbh size class (Table 3). 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. Basal area is calculated using the standard formula: $\text{dbh}^2 \times 0.005454$ (Davis and Johnson 1987). Data are standardized to hectare, and summarized for the community using site data.

Table 3. Diameter at breast height (dbh, cm) size class ranges for overstory trees.

Size Class	dbh (cm)
1	5 - 14.9
2	15 - 24.9
3	25 - 34.9
4	35 - 44.9
5	45+

Seedling and sapling data summary

In the pine woodland community, summary statistics for seedlings and sapling (stems < 5.0 cm dbh) tree species are calculated. Tree seedling/sapling data are collected for 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)

Precipitation data

Precipitation data were collected at the Scottsbluff WSO AP weather station (station ID: 257665) located at Heilig Field in Scottsbluff, Nebraska. 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 1997 – 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 sites, to provide an estimate at the community 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 six guild types (native forb, native grass, native grass-like/sedges, native woody, nonnative grass and nonnative forb). These guild types correspond to the fire monitoring plan for SCBL (National Park Service 2005). Foliar cover for all species within a guild was summed within plot and an average for the guild was calculated for each site.

Plant species richness, diversity and evenness

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

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

6

where p_i 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:

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

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

Monitoring sites were located in native mixed-grass prairie (sites 1 – 7, 11-12), reseeded mixed-grass prairie (site 8), pine woodlands (sites 9 -10), and prairie restoration area (sites 13 -14)(Fig. 3). Management at SCBL has consisted of prescribed burns in the South Bluff and Scotts Spring fire burn units (Fig. 4). HTLN sites 1 – 10 were included in the March 1998 prescribed fire (South Bluff burn unit). The April, 2002 prescribed fire in the Scott's Spring burn unit did not include any HTLN sites.

Results are presented for the native mixed-grass prairie sites in the South Bluff unit, pine woodland sites in the South Bluff unit, and the two communities within the Saddle Rock unit (Fig. 4). Species names, origin, and guild designation can be found in Appendix A.

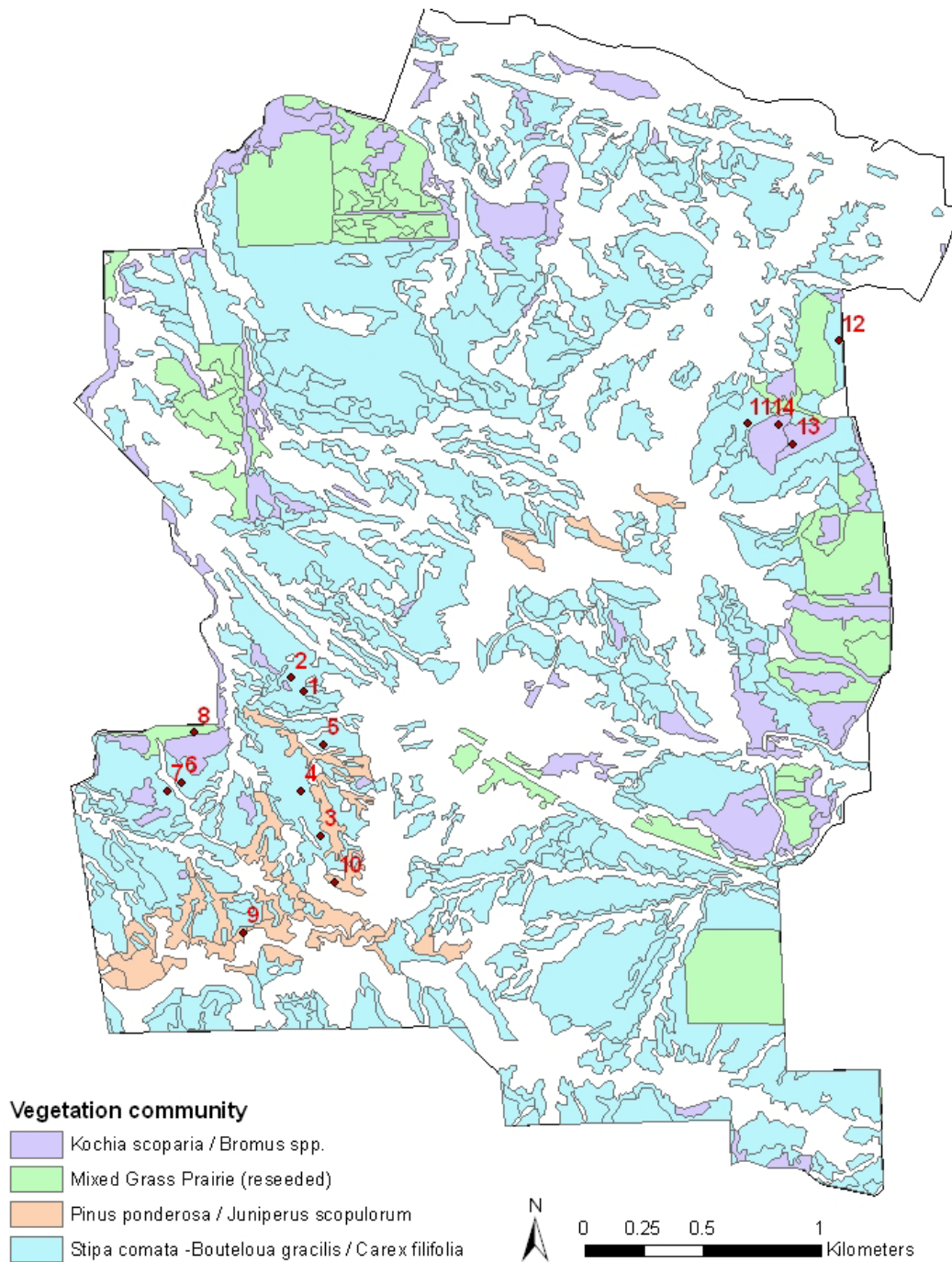


Figure 3. Vegetation community types associated with HTLN monitoring sites at Scotts Bluff National Monument, Nebraska.

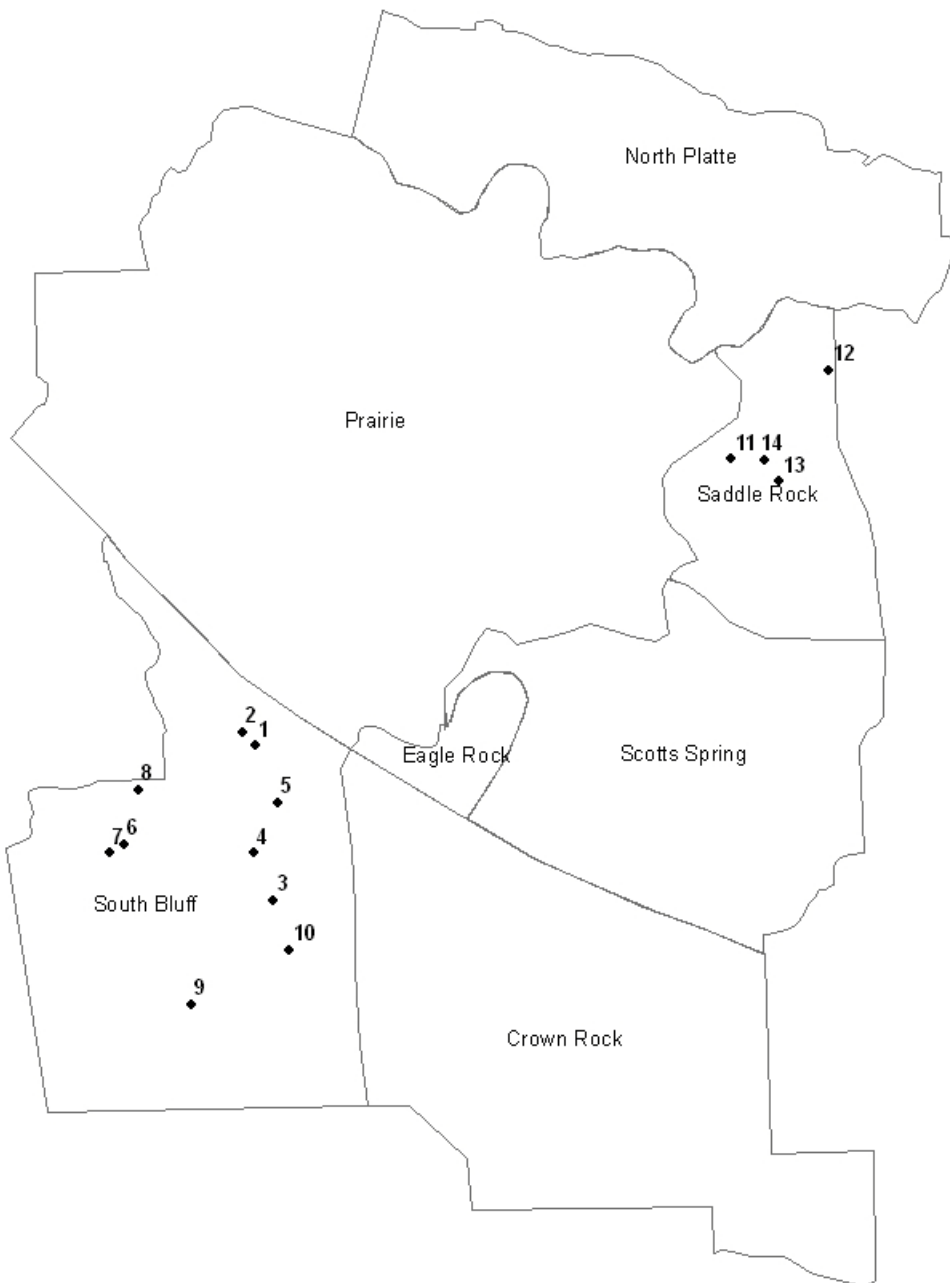


Figure 4. Fire burn units in place during the monitoring period and Heartland Inventory and Monitoring Network vegetation community sites at Scotts Bluff National Monument, Nebraska.

South Bluff native mixed-grass prairie

The seven native mixed-grass prairie sites in the South Bluff fire burn unit are representative of the needle-and-thread grass – blue grama – threadleaf sedge (*Stipa comata*–*Bouteloua gracilis*–*Carex filifolia*) plant community. In 1998, there was a prescribed fire in this unit; otherwise active management of the area did not occur during the monitoring period.

These sites are dominated by needle-and-thread grass and threadleaf sedge with moderate cover of annual bromes. 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, 85 species were observed of which only 11 are non-native species. Among all seven sampling years, 7 species (all native species) were observed in all years. Of the 85 species observed during the monitoring period, 12 were detected in only a single year.

Species richness at the site level (alpha diversity) and for the prairie area (gamma diversity) fluctuated during the monitoring period (Table 4). Alpha diversity was highest in 1999 and lowest in 2004. Gamma diversity was also lowest in 2004 while it peaked in 1998.

Table 4. Alpha, beta and gamma diversity measures for the South Bluff native prairie 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.

Year	Alpha		Beta		Gamma	
	All	Native	All	Native	All	Native
1997	24.6	22.7	1.32	1.33	57	53
1998	27.7	25	1.24	1.24	62	56
1999	30	27.1	1.03	1.03	61	55
2003	26.7	22.7	1.28	1.42	61	55
2004	17.6	15.9	1.39	1.45	42	39
2008	24.9	19.9	1.09	1.31	52	46
2009	22.6	18.1	1.30	1.49	52	45

Beta diversity remained low during the monitoring period for both all species and only native species (Table 4). Low beta diversity values are indicative of all sites within the unit representing a single community. Beta diversity was highest in 2004, when both site and prairie richness was lowest. This inverse relationship between diversity measures indicates that many of the species observed during that year were present in only a few sites.

Similar to alpha diversity, mean site richness fluctuated throughout the monitoring period with a large decline detected in 2004 (Fig. 5). Site level species diversity as measured by the Shannon and Simpson diversity numbers do not have the same pattern across the monitoring period as richness (Fig. 5).

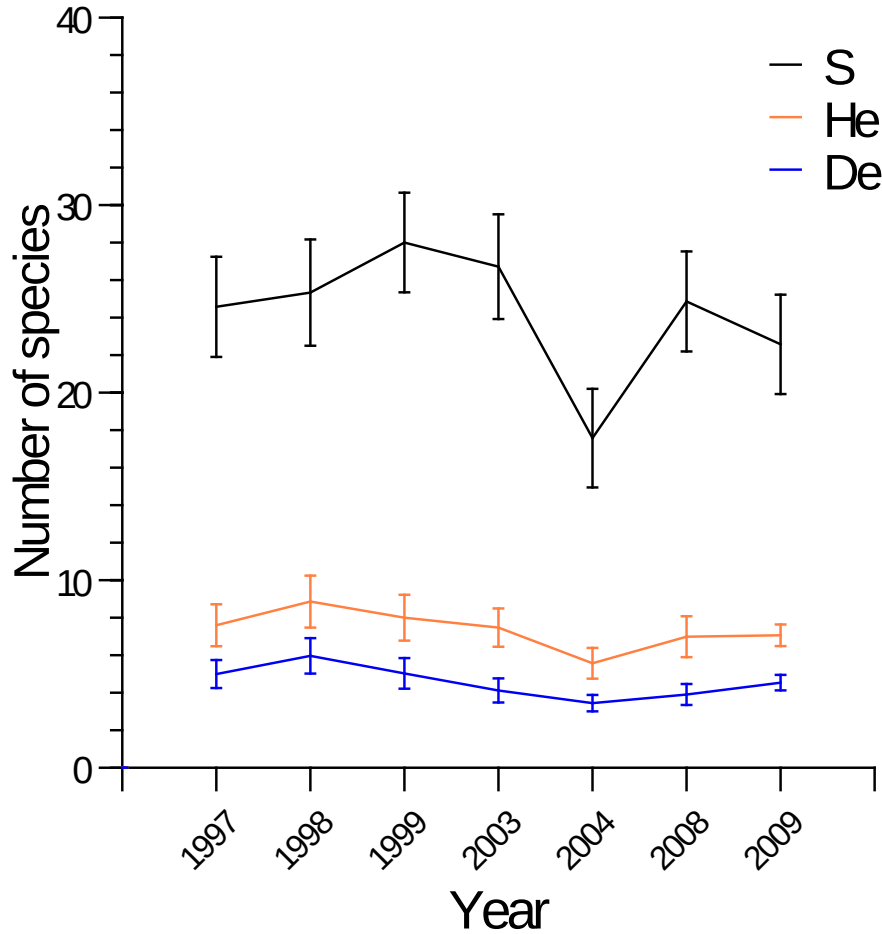


Figure 5. Species diversity calculated for South Bluff native prairie sites (n=7) with all species included (native and invasive exotic plant species). Species richness (S, black), Shannon diversity number (He, orange) and Simpson's diversity number (De, blue). Error bars are the site value mean $\pm$ 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. 5).

A similar pattern in site level species richness for the prairie area is observed when only native species are considered (Fig. 6). Mean site native species richness declines from its peak in 1999 until 2009, with a noticeable decrease in 2004 while Shannon and Simpson's diversity numbers remain fairly stable during the monitoring period (Fig. 6).

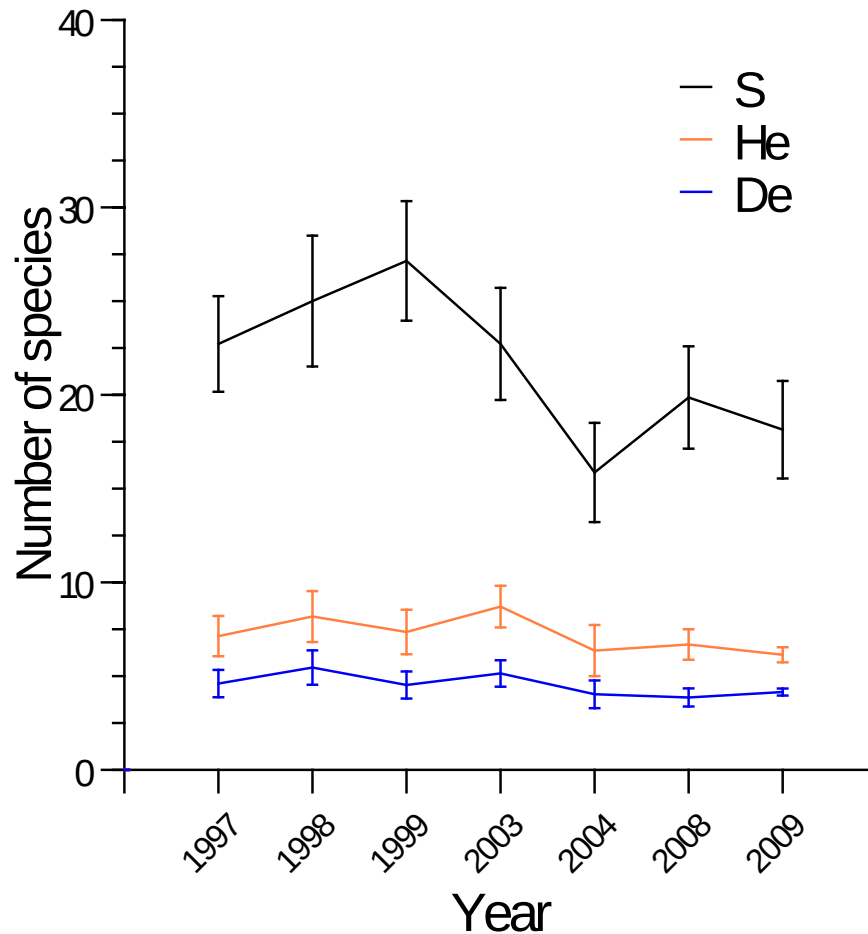


Figure 6. Species diversity calculated for South Bluff native prairie sites (n=7) with only native species included. Species richness (S, black), Shannon diversity number (He, orange) and Simpson's diversity number (De, blue). Error bars are the site value mean $\pm$ standard error of the mean.

Whether including all species or only native species, the three diversity measures have generally the same pattern across the monitoring period. A trend in species richness is difficult to discern, primarily due to the 2004 data.

Species abundance was measured at the guild level for all sites in the prairie group. Mean ($\pm$ standard error of the mean) foliar cover for each guild shows that the native grass-like guild and non-native grasses dominate the seven monitoring sites (Fig. 7).

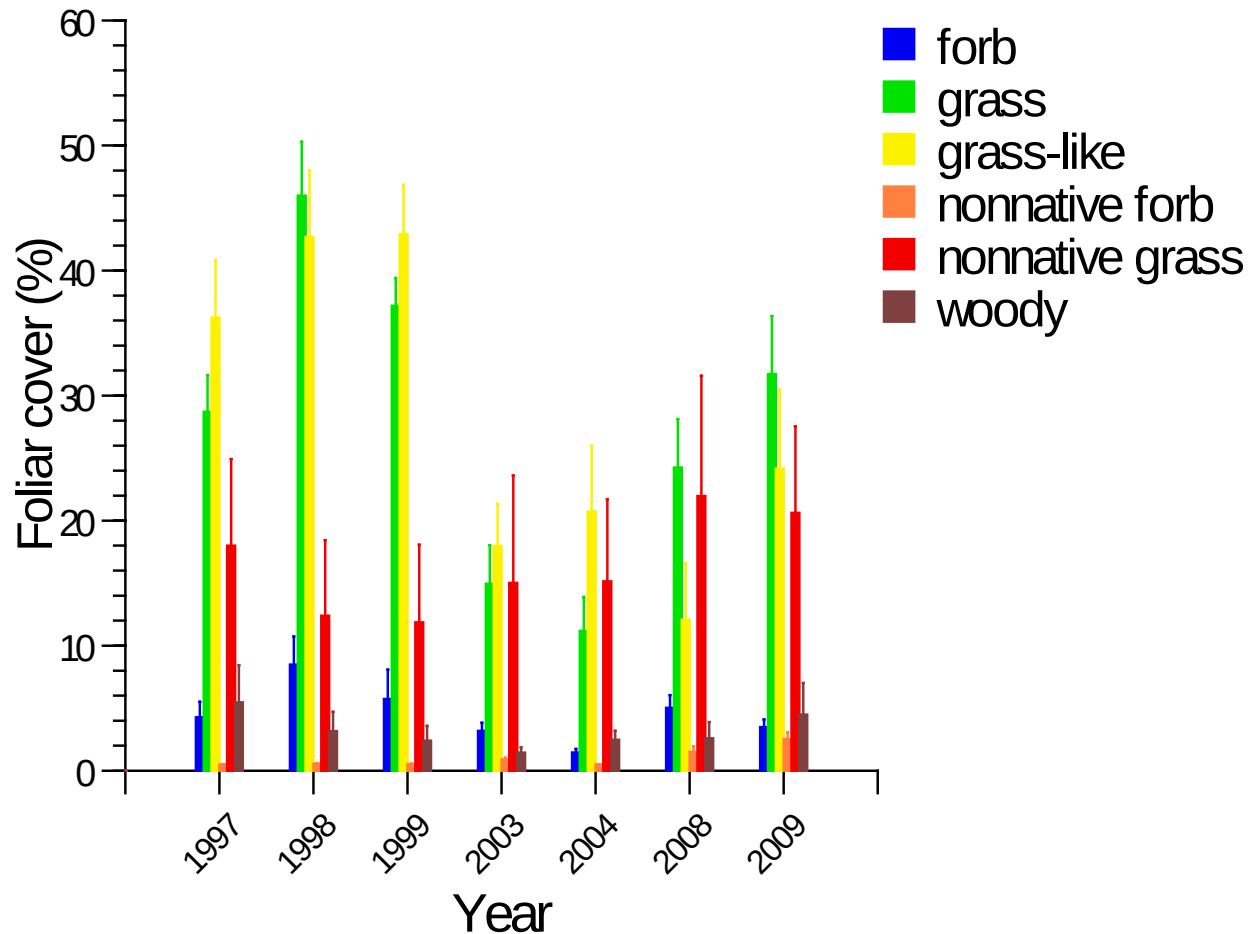


Figure 7. Foliar cover (%) of guilds in the South Bluff native prairie sites (n=7). Colored bars are mean ($\pm$ standard error of the mean) site value for each guild.

There is marked difference in mean foliar cover of native grasses and sedges between the sample years before 2003 and the years from 2003 to 2009 (Fig. 7). Between 1999 and 2003, a large decrease in the foliar cover of these two guilds was observed. The decline was followed by a six year period of fluctuation in foliar cover. This distinction is not observed in the other guilds. The woody guild is primarily composed of soap plant (*Yucca glauca*). Nonnative grass (primarily annual bromes) foliar cover varied throughout the monitoring period, exceeding 20% mean foliar cover in 2008 and 2009.

Bare soil and grass litter were the dominant ground cover types during the monitoring period (Fig. 8). Both bare soil and grass litter cover declined during each monitoring year between 2003 and 2009 (Fig. 8). A large amount of leaf litter was observed only once in 1998.

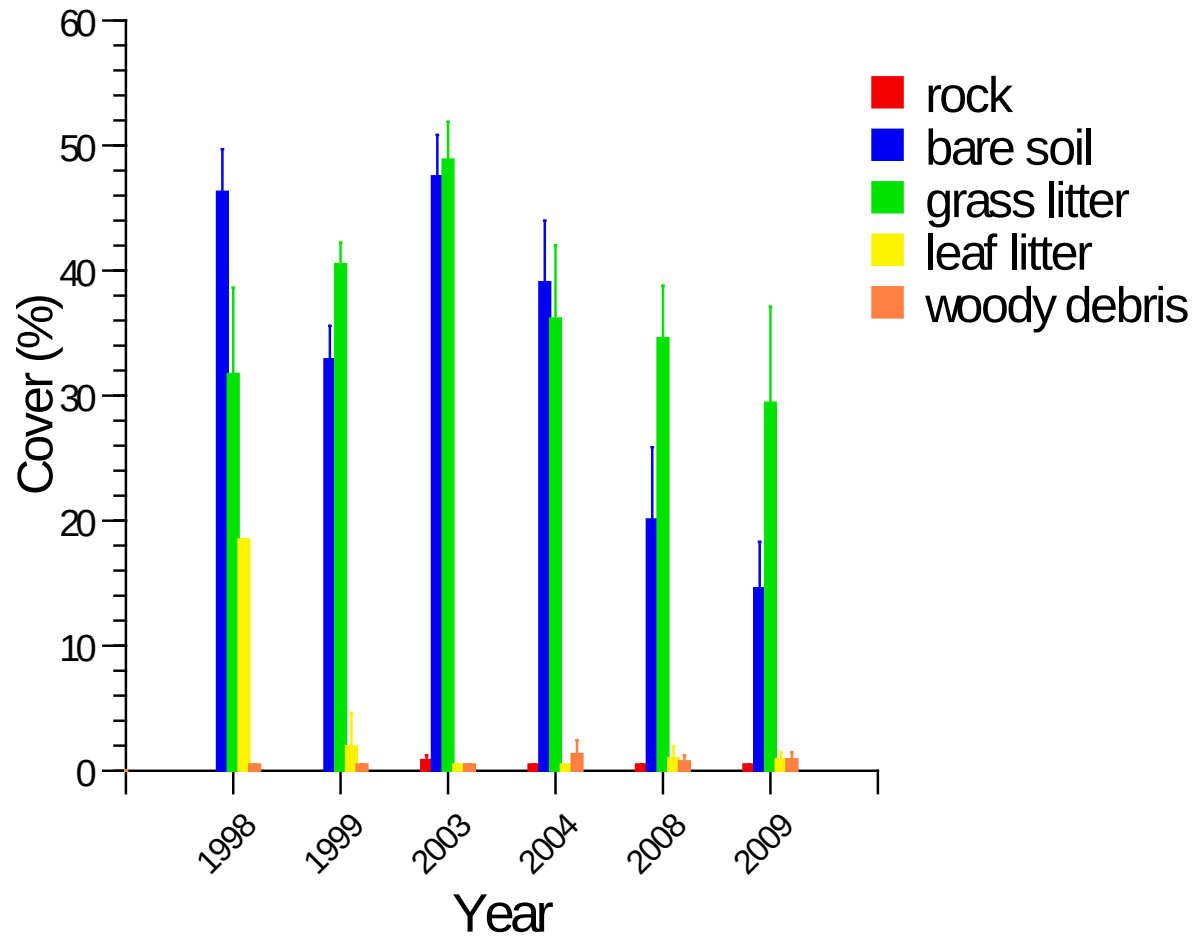


Figure 8. Ground cover (%) in the South Bluff native prairie sites (n=7). Colored bars are mean ($\pm$ standard error of the mean) site value for each ground cover type.

Saddle Rock unit communities

The Saddle Rock fire burn unit contains four HTLN vegetation monitoring sites (11 – 14). Two sites (11, 12) are located within the needle-and-thread grass – blue grama – threadleaf sedge (*Stipa comata*–*Bouteloua gracilis*–*Carex filifolia*) native community type while sites 13 and 14 are in the prairie restoration area (*Kochia scoparia* / *Bromus* spp. community). No fire activity occurred in this burn unit during the monitoring period.

Comparing native and invasive species richness among the two community types (native and restored) does not reveal any trends either within or among the communities (Fig. 9).

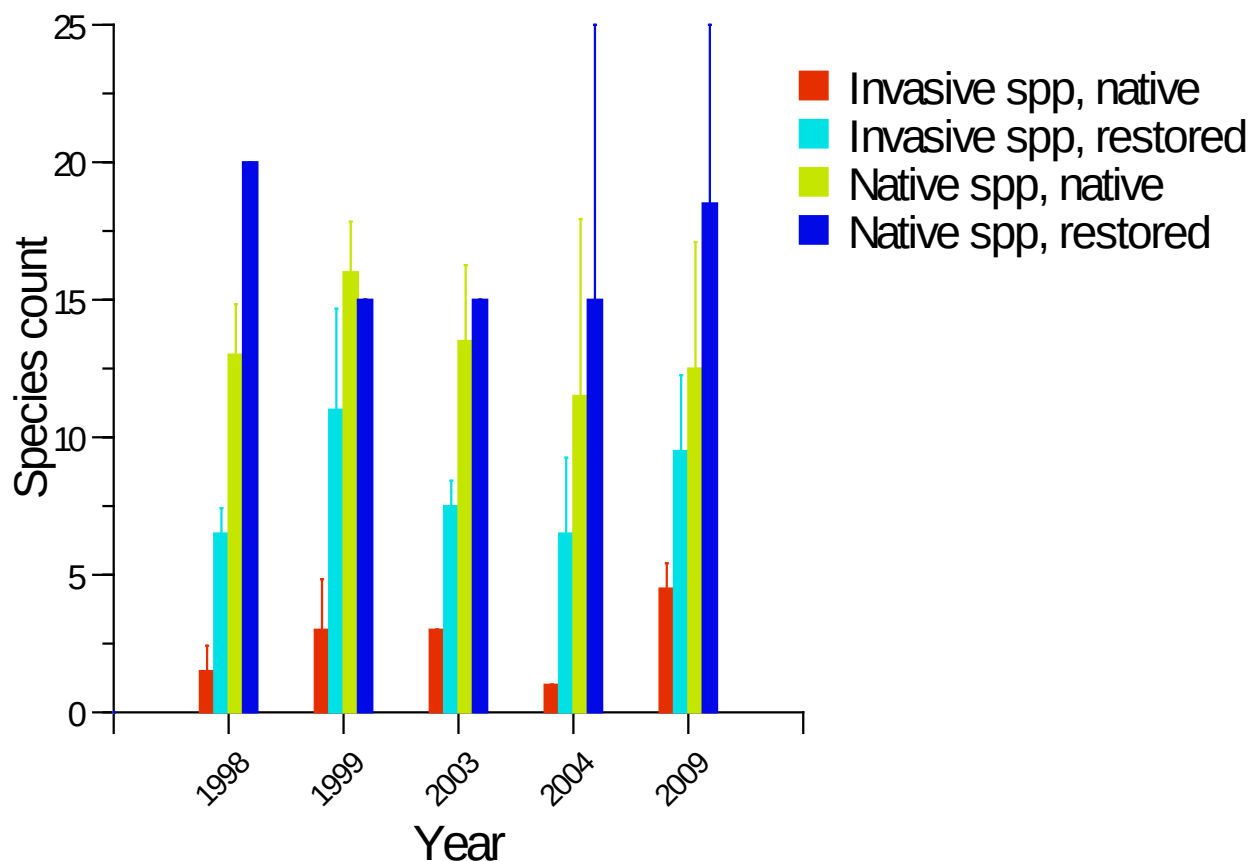


Figure 9. Native and invasive species richness within a community type (native and restored) in the Saddle Rock fire burn unit. Colored bars represent the mean site value $\pm$ standard error of the mean.

In each sample year except 1999, native species richness in the restored community was greater than the native community, mainly due native annuals (Fig. 9). However, during 2004 and 2009 the standard error of the mean was very large, indicating that the number of native species within each restored site varied greatly. The mean number of invasive species within a site was lowest in the native community.

In the native prairie sites (n=2), foliar cover of native grasses and sedges (grass-like guild) dominated the sites (Fig. 10). Even though there were a number of invasive species in these sites, they accounted for a small percentage of foliar cover (nonnative forb and nonnative grass guilds, Fig. 9). Similar to the native sites in the South Bluff fire management unit, foliar cover of native

grasses and sedges decreased between 1999 and 2003, without a corresponding decline in the other guilds.

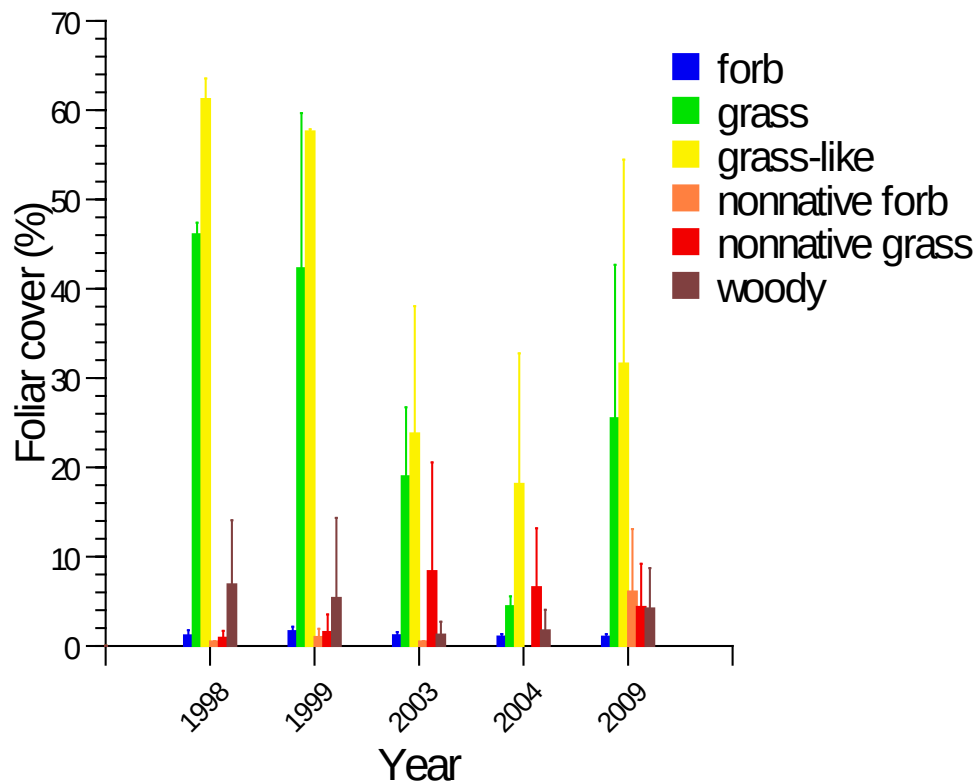


Figure 10. Foliar cover (%) of guilds in the native prairie (n=2) of the Saddle Rock fire burn unit. Colored bars are mean ($\pm$ standard error of the mean) site value for each guild.

The restored community vegetation monitoring sites (n=2) is characterized by the dominance of nonnative species and the variability in guild foliar cover among sites (Fig. 11). As seen in the native communities, native grasses declined between the 1999 and 2003 monitoring, with an increase being observed in 2009.

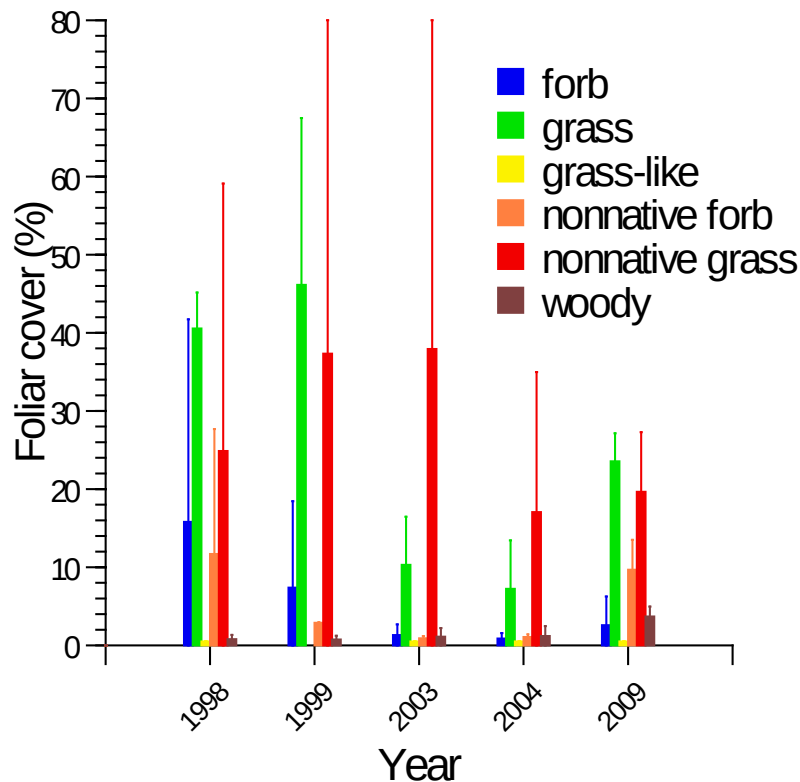


Figure 11. Foliar cover (%) of guilds in the restored prairie (n=2) of the Saddle Rock fire burn unit. Colored bars are mean ($\pm$ standard error of the mean) site value for each guild.

Network vegetation monitoring in the Saddle Rock unit is split between a native mixed-grass prairie (n=2) and restored prairie (n=2). Throughout the monitoring period, the native prairie sites remained similar to the native prairie sites in the South Bluff unit. The restored prairie sites showed a decrease in native grasses and forbs during the monitoring period with an increase in native grasses in 2009. This is the same pattern observed for the native grass guild in the South Bluff native prairie sites.

Pine woodland

Heartland Network vegetation monitoring in the pine woodlands community at Scotts Bluff consisted of two sites (sites 9 and 10) sampled three times between 1997 and 2003. These sites are located in the South Bluff fire burn unit. The Scotts Bluff fire management plan refers to this community as Rocky Mountain juniper stands (National Park Service 2005). These sites are dominated by Rocky Mountain juniper (*Juniperus scopulorum*) and ponderosa pine (*Pinus ponderosa*) in the overstory.

Only two tree species were detected during the monitoring period. Individual trees of both species occurred in dbh size class 1 (5 -14.9 cm) and 2 (15-24.9 cm), with single ponderosa pine belonging to size class 3 (25-34.9 cm). Ponderosa pine basal area increased for both size class 1 and 2 trees between 1997 and 2000 with the recruitment of a single tree into size class 3 during the same time (Table 5). Rocky Mountain juniper showed a similar pattern in basal area for size class 1 trees, while basal area for size class 2 trees increased between each monitoring event (Table 5).

Table 5. Basal area (m²/ha) for all size classes of ponderosa pine (PIPO) and Rocky Mountain juniper (JUSC2) observed during the monitoring period.

Year	Size class 1		Size class 2		Size class 3	
	PIPO	JUSC2	PIPO	JUSC2	PIPO	JUSC2
1997	3.67	3.54	3.58	1.04		
2000	3.91	5.10	4.90	2.03	0.49	
2003	3.35	4.35	4.29	2.78		

While basal area looks at the volume of trees in the community during the monitoring period, density measures the number of individual trees (stems per hectare). Density follows the same pattern as basal area for each species across size classes and monitoring years (Table 6). Individual trees were not only increasing in size (basal area) but trees were being recruited into larger size classes as well.

Table 6. Density (stems/hectare) for all size classes of ponderosa pine (PIPO) and Rocky Mountain juniper (JUSC2) observed during the monitoring period.

Year	Size class 1		Size class 2		Size class 3	
	PIPO	JUSC2	PIPO	JUSC2	PIPO	JUSC2
1997	265	310	70	20		
2000	250	430	90	40	5	
2003	220	360	80	50		

Size class representation of overstory trees was limited by tree growth (as measured by dbh) during the seven years of monitoring overstory trees in this community. Even though basal area and density increased within species among size classes through time, individual trees primarily grew within a size class category. One exception was the single ponderosa pine observed in size class 3 during 2000. However, this tree was not living in 2003.

Woodland and forested communities are maintained by overstory tree regeneration as measured by seedling and sapling density (stems per hectare). Total regeneration (seedlings + small and large sapling counts) was highest in 1997 (Table 7). Regeneration density declined more than 50% between 1997 and 2000 followed by a modest increase in 2003.

Table 7. Total regeneration (seedling and sapling) density (stems/hectare) for ponderosa pine (PIPO) and Rocky Mountain juniper (JUSC2) observed during the monitoring period.

Year	PIPO	JUSC2
1997	550	350
2000	200	200
2003	250	250

Understory foliar cover as measured by mean site percentages by guild, decreased for all native guilds during the monitoring period (Fig. 12). For any single guild, the mean site foliar cover did not exceed 20%, indicating the understory of the pine woodlands was moderately open and free of vegetation.

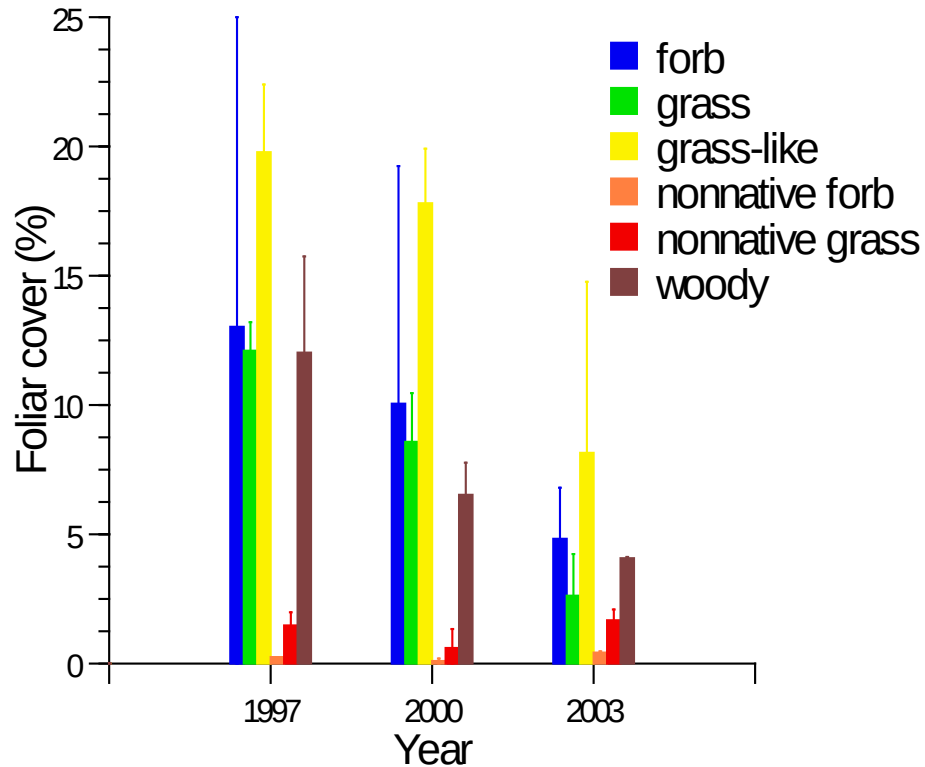


Figure 12. Foliar cover (%) of guilds in the pine woodland sites (n=2) in the South Bluff fire burn unit. Colored bars are mean ($\pm$ standard error of the mean) site value for each guild.

Nonnative forbs and grasses, even though present, were detected in low abundance throughout the monitoring period.

Precipitation

During the monitoring period, departure from the 30 year average of precipitation illustrates annual variability in precipitation at SCBL (Fig. 13). Beginning in 2000, annual precipitation was less than average with the exception of 2005.

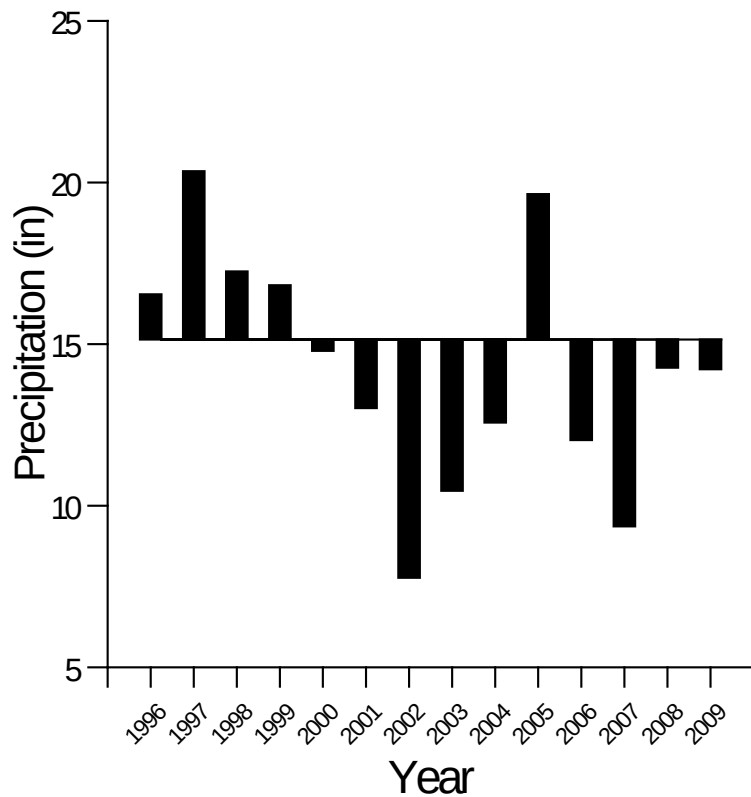


Figure 13. Precipitation during the monitoring period at Scotts Bluff National Monument, Nebraska. The 30 year average (15.14 inches) is indicated with the horizontal baseline. Total precipitation for 2009 is reported up through June.

Above average precipitation characterized the early years of the monitoring period (1996-1999). Between 2000 and 2009 below average annual precipitation characterized the period. However, during that time, the second largest positive departure from the 30-year average occurred in 2005, following four years of below average annual precipitation. This may have acted to reduce the effect of nine years of below average annual precipitation at the monument.

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.

Vegetation monitoring sites in the prairies occurred in four different vegetation types according to the USGS-NPS vegetation map: native needle-and-thread grass – blue grama – threadleaf sedge community (n=9), reseeded mixed-grass type (n=1), and the prairie restoration area that was formerly part of an adjacent golf course (n=2, *Kochia scoparia* / *Bromus* spp. community). Native prairie sites in the South Bluff burn unit are summarized together, while a comparison of the native prairie with the prairie restoration is presented for sites in the Saddle Rock burn unit. The single site (site 8) in the reseeded mixed-grass community type was removed from further HTLN sampling in 2003 and no summary information is presented in this report.

Active management in the park during the monitoring period consisted of two prescribed burns. Only one of the prescribed burns occurred in a burn unit containing HTLN sites. The March 1998 prescribed fire in the South Bluff burn unit included seven HTLN sites. The timing of this burn coupled with three years of above average annual precipitation may have been associated with the observed increase in native species richness, lower nonnative grass abundance, and greater overall native species foliar cover. In fact, for the monitoring period, 1999 represents the highest values for native species observed for this community in the Saddle Rock burn unit. Only a slight rise in native foliar cover was seen in the similar native community in the unburned Saddle Rock unit sites in 1999. Native foliar cover in the Saddle Rock burn unit was on average half of what was observed in the South Bluff burn unit.

Below annual average precipitation was recorded for all but 2005 for the period between 2000 and 2009. This persistent drought may be associated with the decrease in native species richness and foliar cover observed during that period. In addition to the dry conditions, 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 observations in 2004, 2008, and 2009. After the low 2004 observation, native richness and foliar cover increased in the South Bluff burn unit. In this unit, throughout the monitoring period, species diversity remained nearly constant. This flat trend in diversity indicates that even though individual species (richness) was changing between sampling events, the abundance of those individual species was not very high. For all native prairie sites among both units, it is difficult to explain the change in native grass abundance by patterns in precipitation or changes in sampling efforts. 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 pine woodlands community in the South Bluff burn unit was sampled three times between 1997 and 2003. Two sites were established to characterize the overstory and understory cover of the community. The woodland area of the South Bluff unit is characterized by a ponderosa pine and Rocky Mountain juniper cover type. In fact, these were the only two species observed in the overstory at both HTLN sites. These sites represent pine woodlands with a moderate canopy cover and smaller size class trees. In addition, the understory is a mix of native grass and sedges

occurring in low abundance, mean foliar cover of understory guilds did not exceed 20%. During the monitoring period, both overstory tree mortality and regeneration for both species was low. Initial seedling establishment may have benefited from above average precipitation between 1996 and 1999. Later drought between 2000 and 2003 then may have negated any further seedling establishment and recruitment.

In the absence of active management during all but a single year (1998) of the monitoring period, this report presents natural variability of two native mixed-grass prairie communities for the period between 1997 and 2009. This work can be used to simply characterize the native prairie at SCBL, provide a comparison for the restoration efforts at the park, act as a baseline to which further monitoring can be compared, or integrated with the Northern Great Plains fire effects monitoring program's results. Mostly this report acts to summarize the major vegetation community monitoring efforts of the Heartland Inventory and Monitoring Network efforts at SCBL over the last twelve 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 1997 to 2009. For each species there is a scientific name, common name, origin (N = native, I = invasive exotic plant), and guild (Northern Great Plains fire effects monitoring program guild types).

ScientificName	CommonName	Origin	Guild
<i>Agropyron cristatum</i>	Crested wheatgrass	I	nonnative grass
<i>Allium textile</i>	Onion	N	forb
<i>Alyssum desertorum</i>	Desert madwort	I	nonnative forb
<i>Amaranthus albus</i>	Tumbleweed	N	forb
<i>Amaranthus retroflexus</i>	Redroot, rough pigweed	I	nonnative forb
<i>Ambrosia psilostachya</i>	Western ragweed	N	forb
<i>Antennaria parvifolia</i>	Plains pussytoes	N	forb
<i>Arabis holboellii</i>	Rock-cress	N	forb
<i>Arenaria hookeri</i>	Sandwort	N	forb
<i>Aristida purpurea</i>	Purple three-awn	N	grass
<i>Artemisia cana</i>	Dwarf sagebrush	N	woody
<i>Artemisia frigida</i>	Prairie-sagewort	N	forb
<i>Asclepias pumila</i>	Milkweed	N	forb
<i>Aster ericoides</i>	Squarrose white wild aster	N	forb
<i>Aster falcatus</i>	White prairie wild aster	N	forb
<i>Astragalus gracilis</i>	Milk-vetch	N	forb
<i>Astragalus missouriensis</i>	Nuttall milk-vetch	N	forb
<i>Bouteloua curtipendula</i>	Side-oats grama-grass	N	grass
<i>Bouteloua gracilis</i>	Blue grama	N	grass
<i>Brickellia eupatorioides</i>	Aster	N	forb
<i>Brickellia grandiflora</i>	Aster	N	forb
<i>Bromus inermis</i>	Smooth brome	I	nonnative grass
<i>Bromus tectorum</i>	Junegrass, downy chess	I	nonnative grass
<i>Buchloe dactyloides</i>	Buffalograss	N	grass
<i>Calamovilfa longifolia</i>	Sand-reed	N	grass
<i>Calylophus serrulatus</i>	Evening-primrose	N	forb
<i>Carex duriuscula</i>	Sedge	N	grass-like
<i>Carex filifolia</i>	Sedge	N	grass-like
<i>Cercocarpus montanus</i>	Mountain mahogany	N	woody
<i>Chamaesyce glyptosperma</i>	Ridge-seed spurge	N	forb
<i>Chamaesyce maculata</i>	Spotted sandmat	N	forb
<i>Chenopodium album</i>	Lamb's quarters, pigweed	N	forb
<i>Chenopodium berlandieri</i>	Pitseed goosefoot	N	forb
<i>Chenopodium pratericola</i>	Narrow-leaf goosefoot	N	forb
<i>Cirsium canescens</i>	Thistle	N	forb
<i>Comandra umbellata</i>	Bastard toad-flax	N	forb
<i>Convolvulus arvensis</i>	Field-bindweed	I	nonnative forb
<i>Conyza canadensis</i>	Horseweed	N	forb

<i>Coryphantha vivipara</i>	Pincushion cactus	N	forb
<i>Cryptantha cana</i>	Borage	N	forb
<i>Cymopterus acaulis</i>	Wild parsley	N	forb
<i>Cymopterus montanus</i>	Cymopterus	N	forb
<i>Dactylis glomerata</i>	Orchard grass	I	nonnative grass
<i>Dalea candida</i>	White prairie clover	N	forb
<i>Descurainia pinnata</i>	Tansy-mustard	N	forb
<i>Descurainia sophia</i>	Tansy-mustard	I	nonnative forb
<i>Elymus canadensis</i>	Canada wild rye	N	grass
<i>Elymus trachycaulus</i>	Slender wheatgrass	N	grass
<i>Elytrigia elongata</i>	Tall wheatgrass	I	nonnative grass
<i>Elytrigia intermedia</i>	Intermediate wheatgrass	I	nonnative grass
<i>Elytrigia repens</i>	Quack-grass	I	nonnative grass
<i>Erigeron canus</i>	Fleabane	N	forb
<i>Eriogonum annuum</i>	Annual eriogonum	N	forb
<i>Erysimum asperum</i>	Western wallflower	N	forb
<i>Escobaria missouriensis</i>	Missouri coryphanthe	N	forb
<i>Gaura coccinea</i>	Scarlet gaura	N	forb
<i>Grindelia squarrosa</i>	Curly-top gum-weed	N	forb
<i>Gutierrezia sarothrae</i>	Matchbrush	N	forb
<i>Hedeoma drummondii</i>	False pennyroyal	N	forb
<i>Helianthus annuus</i>	Common sunflower	N	forb
<i>Helianthus petiolaris</i>	Plains sunflower	N	forb
<i>Heterotheca villosa</i>	Golden aster	N	forb
<i>Hordeum jubatum</i>	Foxtail-barley	N	grass
<i>Hordeum pusillum</i>	Little barley	N	grass
<i>Juniperus scopulorum</i>	Rocky Mountain juniper	N	tree
<i>Kochia scoparia</i>	Summer-cypress	I	nonnative forb
<i>Koeleria macrantha</i>	Junegrass	N	grass
<i>Krascheninnikovia lanata</i>	White sage, winter fat	N	woody
<i>Lactuca serriola</i>	Prickly lettuce	I	nonnative forb
<i>Lactuca tatarica</i>	Blue lettuce	N	forb
<i>Lappula occidentalis</i>	Western stickseed	N	forb
<i>Lathyrus polymorphus</i>	Vetchling, wild pea	N	forb
<i>Lepidium densiflorum</i>	Prairie-pepperweed	N	forb
<i>Lesquerella arenosa</i>	Great plains bladderpod	N	forb
<i>Lesquerella ludoviciana</i>	Mustard	N	forb
<i>Leucocrinum montanum</i>	Mountain lily	N	forb
<i>Liatris punctata</i>	Blazing star, gay feather	N	forb
<i>Lithospermum incisum</i>	Narrow-leaved puccoon	N	forb
<i>Lygodesmia juncea</i>	Skeleton-weed	N	forb
<i>Machaeranthera grindelioides</i>	Rayless aster	N	forb
<i>Machaeranthera pinnatifida</i>	Aster	N	forb
<i>Melilotus officinalis</i>	Yellow sweet clover	I	nonnative forb
<i>Mirabilis hirsute</i>	Hairy umbrella-wort	N	forb

<i>Mirabilis linearis</i>	Narrow-leaf umbrella-wort	N	forb
<i>Monarda pectinata</i>	Pony beebalm	N	forb
<i>Muhlenbergia cuspidata</i>	Muhly	N	grass
<i>Muhlenbergia pungens</i>	Muhly	N	grass
<i>Nothocalais cuspidata</i>	False dandelion	N	forb
<i>Oenothera cespitosa</i>	Evening-primrose	N	forb
<i>Opuntia fragilis</i>	Little prickly pear	N	forb
<i>Opuntia macrorhiza</i>	Plains prickly pear	N	forb
<i>Opuntia polyacantha</i>	Plains prickly pear	N	forb
<i>Oryzopsis hymenoides</i>	Indian ricegrass	N	grass
<i>Oxytropis sericea</i>	White locoweed	N	forb
<i>Parietaria pensylvanica</i>	Pennsylvania pellitory	N	forb
<i>Paronychia depressa</i>	Whitlow-wort	N	forb
<i>Pascopyrum smithii</i>	Western wheatgrass	N	grass
<i>Penstemon albidus</i>	White beardtounge	N	forb
<i>Penstemon angustifolius</i>	Beard-tongue	N	forb
<i>Penstemon glaber</i>	Sawsepal penstemon	N	forb
<i>Phlox andicola</i>	Phlox	N	forb
<i>Phlox hoodii</i>	Phlox	N	forb
<i>Physalis hederifolia</i>	Ground cherry	N	forb
<i>Physalis longifolia</i>	Longflower ground cherry	N	forb
<i>Poa compressa</i>	Canada bluegrass	I	nonnative grass
<i>Poa pratensis</i>	Kentucky bluegrass	I	nonnative grass
<i>Pinus ponderosa</i>	Ponderosa pine	N	tree
<i>Psathyrostachys juncea</i>	Russian wildrye	I	nonnative grass
<i>Psoralea argophylla</i>	Silvery scurf-pea	N	forb
<i>Psoralea esculenta</i>	Breadroot scurf-pea	N	forb
<i>Psoralidium tenuiflorum</i>	Gray scurf-pea	N	forb
<i>Ratibida columnifera</i>	Columnar coneflower	N	forb
<i>Rhus aromatic</i>	Squaw-bush	N	woody
<i>Rhus trilobata</i>	Squaw-bush	N	woody
<i>Ribes cereum</i>	Gooseberry	N	woody
<i>Rosa arkansana</i>	Dwarf prairie rose	N	woody
<i>Rosa woodsii</i>	Western rose	N	woody
<i>Salsola spp</i>	Russian thistle	I	nonnative forb
<i>Schedonnardus paniculatus</i>	Tumblegrass	N	grass
<i>Schizachyrium scoparium</i>	Little bluestem	N	grass
<i>Senecio canus</i>	Gray groundsel	N	forb
<i>Senecio integerrimus</i>	Single-stemmed groundsel	N	forb
<i>Setaria viridis</i>	Green foxtail-grass	I	nonnative grass
<i>Sisymbrium altissimum</i>	Tumbling-mustard	I	nonnative forb
<i>Solanum triflorum</i>	Cut-leaved nightshade	N	forb
<i>Solidago missouriensis</i>	Missouri goldenrod	N	forb
<i>Sphaeralcea coccinea</i>	Scarlet mallow	N	forb
<i>Sporobolus cryptandrus</i>	Sand dropseed	N	grass

<i>Stipa comata</i>	Needle-and-thread grass	N	grass
<i>Stipa viridula</i>	Green needle-grass	N	grass
<i>Symphoricarpos occidentalis</i>	Wolfberry	N	woody
<i>Taraxacum officinale</i>	Common dandelion	I	nonnative forb
<i>Tetrameuris acaulis</i>	Bitterweed	N	forb
<i>Thermopsis rhombifolia</i>	Buckbean	N	forb
<i>Toxicodendron rydbergii</i>	Western poison-ivy	N	woody
<i>Tragopogon dubius</i>	Fistulous goat's beard	I	nonnative forb
<i>Verbena bracteata</i>	Prostrate vervain	N	forb
<i>Vicia americana</i>	American vetch	N	forb
<i>Viola nuttallii</i>	Yellow prairie violet	N	forb
<i>Vulpia octoflora</i>	Six-weeks fescue	N	grass
<i>Yucca glauca</i>	Soap plant	N	woody
<i>Zigadenus venenosus</i>	Death camas	N	forb

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NPS 317/105360, August 2010

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