



Prairie Vegetation Monitoring at Pipestone National Monument

1998–2017

Natural Resource Report NPS/HTLN/NRR—2020/2056





ON THIS PAGE

Culver's root (*Veronicastrum virginicum*) is a native perennial forb that can be found at Pipestone National Monument. Photography by NPS

ON THE COVER

Mike DeBacker measured prairie vegetation at Pipestone National Monument in 2017. Photography by NPS

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Executive Summary

The Heartland Inventory and Monitoring Network has sampled permanent monitoring sites in three vegetation community types (remnant prairie, restored prairie and Sioux quartzite prairie) at Pipestone National Monument 10 times over a 21-year period (1997–2017). Network scientists recorded species identities and estimates of ground cover, ground flora and tree regeneration within these permanent sites.

The monument has experienced two brief periods of drought through the monitoring record (2000 and 2012–2014). Fire return intervals varied through time with the longest mean fire-free interval of six years for a prairie community type occurring in 2014. Prescribed fire patterns were associated with ground cover patterns such as increased bare ground after burns or increased litter cover with longer fire return intervals.

Mean native species richness peaked in 2001 and 2002 across the prairie types with the Sioux quartzite prairie supporting the most species during that period. The restored prairie supported the fewest number of species. Native species diversity (i.e., Shannon Diversity Index, evenness) followed the same pattern with relatively low levels of within-year variability in the remnant prairie.

The woody guild includes trees and shrubs. Trees in particular remained at low levels throughout the study, especially in the Sioux quartzite prairie. The only notable trees observed were a large group of American plum seedlings in one plot in a single year. Species richness and cover of nonnative species—including two invasive grasses, smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) — remained within the range of variation. Fire was associated with a partial and temporary reduction in the abundance of these two grasses in particular. The abundance of prairie sagewort (*Artemisia frigida*), a plant of ethnographic importance, was similar from 1999 to 2017, but found infrequently.

Lastly, we sought to learn whether environmental factors influenced species composition. We observed only weak relationships between fire and drought levels and species composition. The relationship was weakest for the restored prairie. We concluded that while fire and climate have an influence on species composition, other unevaluated factors are also important.

Despite variation in fire regime, drought, and ground cover, prairie plant communities at the monument have been relatively stable through time. Fire appears to have had a beneficial role in reducing woody plant and nonnative plant abundance, at least in some prairie communities within the park. Continued practice of relatively frequent prescribed fire in Pipestone National Monument appears to correspond with high levels of native plant diversity and community stability, even during brief drought events.

Acknowledgments

We are grateful for the contributions of previous staff who helped to monitor vegetation at Pipestone National Monument. Rhett Johnson provided botanical support in 2017. We also appreciate field support from park staff. Craig Young provided guidance on analysis design. Some of the language of this report was taken from James (2011), particularly the methods. J. Haack-Gaynor provided maps. We thank two peer reviewers and the layout editor whose efforts improved the quality of this report.

Introduction

Pipestone National Monument has a rich cultural history. The landscape, including the prairie, is intertwined with this history. The mosaic of prairie, geologic, and hydrologic features are foundational to the human history of the site (NPS 2008). Conservation of the prairie has included regular vegetation monitoring by the Heartland Inventory and Monitoring Network since 1997.

Three prairie types are monitored by the Heartland Network: remnant tallgrass prairie, restored tallgrass prairie, and Sioux quartzite prairie (Figure 1). Remnant prairie is increasingly rare in the region (NPS 2008). Both a federally listed plant species and plants rare within the state have been recorded in the remnant prairie. The Sioux quartzite prairie is a globally rare community type in which state-listed plant species have been observed. Management work includes a variety of tools and processes to maintain the plant communities. Invasive species control is a

particular concern. Invasive species that present a threat to the prairies are both nonnative (e.g. smooth brome, *Bromus inermis*) and native (e.g., common pricklyash, *Zanthoxylum americanum*).

Monument vegetation management objectives include the reduction of invasive species (reduce buckthorn by 10–90%, reduce shrub cover by 10–90%, reduce smooth brome by more than 25% within 5 years post burn; NPS 2012) and conservation of native species (Maintain native dominance in the remnant prairie at or above 2009 levels; Bressler 2009).

In this report, we aim to describe trends in the three prairie plant communities based on monitoring by the Heartland Network from 1998 to 2017. Additionally, we asked if trends in fire return intervals were reflected in the plant composition of remnant, restored, and Sioux quartzite prairies over time.



Prairie monitoring at Pipestone National Monument, 2017. NPS

Methods

Study Site

Long-term vegetation sampling sites are located in three distinct plant community types: remnant tallgrass prairie, restored tallgrass prairie, and Sioux

quartzite prairie (Diamond et. al. 2014) at Pipestone National Monument (Figure 1). Sample sites were added in 1997, 1998, and 2009 to make a total of 13 sites.

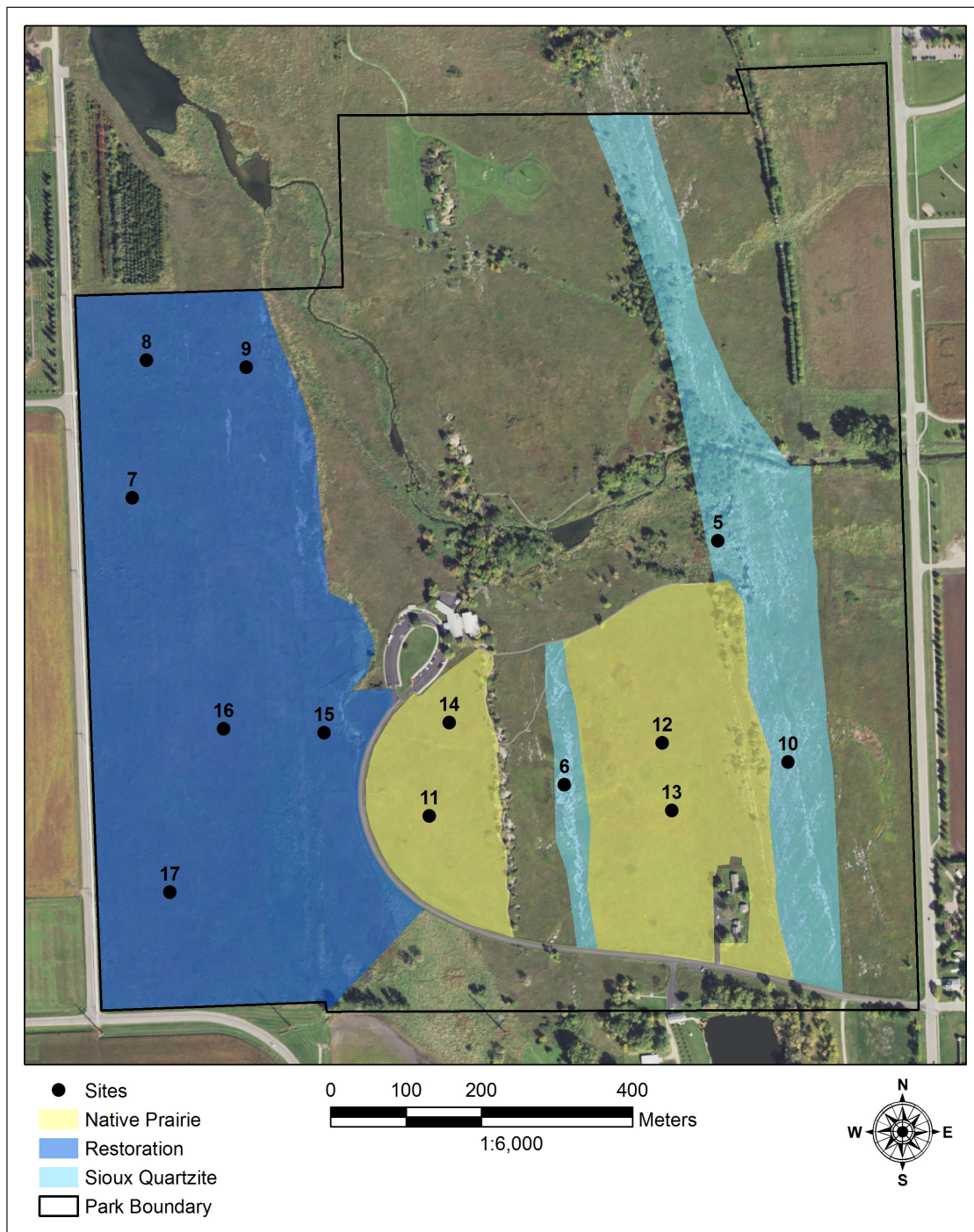


Figure 1. Heartland Network reference frame and vegetation monitoring sites at Pipestone National Monument, Minnesota. Pipestone includes three types of prairie: remnant tallgrass prairie, restored tallgrass prairie, and remnant Sioux quartzite prairie.

Sampling Design

Monitoring methods followed the standard operating procedures outlined in the vegetation community monitoring protocol (James et al. 2009). Monitoring sites were 50 m x 20 m (0.1 ha) in size with two focal transects bounding the site on the 50-m sides (Figure 2). For this protocol, overstory tree data were collected within the entire 0.1-ha area, while all other metrics were collected within 10 subplots located along the site boundaries. Each subplot consisted of a series of nested frames (0.01 m², 0.1 m², 1 m², and 10 m²), but only observations at the 10-m² scale were summarized to the site scale (0.1 ha) for this study. See James et al. (2009) for additional details on sampling design.

Tree regeneration and ground flora were measured within the ten 10-m² plots in each site. Foliar cover serves as an estimate of abundance for ground flora species. The cover class intervals are converted to median values to estimate percent cover for each herbaceous and shrub species (Table 1). Mean percent cover is then calculated as the species percent cover for a sampling unit, averaged for all plots (n = 10). Sampling unit (site) means were then used to calculate community level means.

Table 1. Modified Daubenmire cover value scale used to determine ground flora species cover for the Heartland Network Parks.

Cover Class Codes	Range of Cover (%)	Class Midpoints (%)
7	95-100	97.5
6	75-95	85.0
5	50-75	62.5
4	25-50	37.5
3	5-25	15.0
2	1-5	2.5
1	0-0.99	0.5

Data Analysis

Monitoring sites were added in 1998 and 2009 (Table 2). We did not include 1997 as part of this analysis to reduce uncertainty.

SPSS (Version 24; IBM 2016) was used for summary statistics. All site means were calculated based on 10 subplots for each year (for number of sites see Table 2). Confidence intervals (95%) were calculated and displayed.

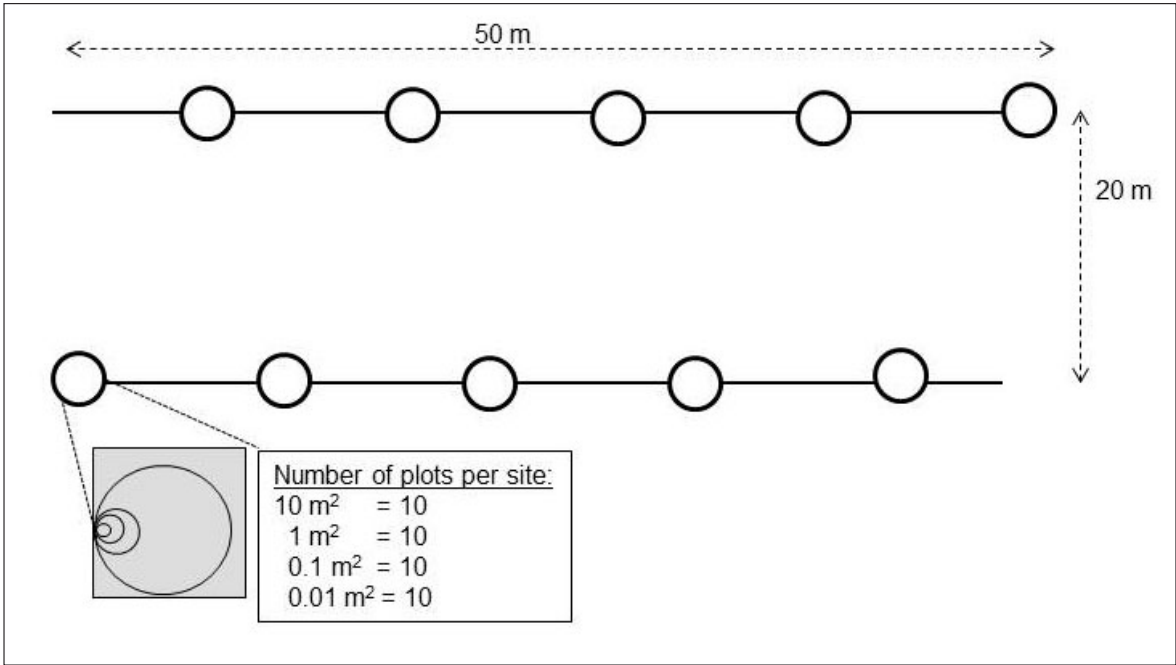


Figure 2. Plant community site monitoring design for Heartland Inventory and Monitoring Network parks.

Table 2. Heartland Inventory and Monitoring Network vegetation sampling history at Pipestone National Monument, Pipestone, MN (11 sample years, over 21 years).

Year	# Sites Sampled	Remnant Prairie Sites (N)	Restored Prairie Sites (N)	Sioux Quartzite Sites (N)	Included in Analysis?	Note
1997	5	0	7, 8, 9 (3)	5, 6 (2)	No,	sample size disparity with other years.
1998	10	11, 12, 13, 14 (4)	7, 8, 9 (3)	5, 6 10 (3)	YES	–
1999	10	11, 12, 13, 14 (4)	7, 8, 9 (3)	5, 6 10 (3)	YES	–
2001	10	11, 12, 13, 14 (4)	7, 8, 9 (3)	5, 6 10 (3)	YES	–
2002	3	11, 12, 14 (3)	(0)	(0)	YES	–
2005	10	11, 12, 13, 14 (4)	7, 8, 9 (3)	5, 6 10 (3)	YES	–
2006	10	11, 12, 13, 14 (4)	7, 8, 9 (3)	5, 6 10 (3)	YES	–
2009	13	11, 12, 13, 14 (4)	7, 8, 9, 15, 16, 17 (6)	5, 6, 10 (3)	YES	Burned 4 wks prior
2013	13	11, 12, 13, 14 (4)	7, 8, 9, 15, 16, 17 (6)	5, 6, 10 (3)	YES	–
2017	13	11, 12, 13, 14 (4)	7, 8, 9, 15, 16, 17 (6)	5, 6, 10 (3)	YES	–

Ordination (described later) of the native species data showed a large degree of overlap in species composition between the original three restored sites and the final six restored sites. This indicates that the dominant matrix species were very similar between the two sets of sites and we included all sites in the analyses.

Climate

The Palmer Drought Severity Index (PDSI) was used to describe the climate over the period of monitoring at the monument (Heggen 1993; Vose et al. 2014). Data were obtained from the NOAA/National Climatic Data Center (accessed April 12, 2019). Monthly data were acquired for the southwestern region of Minnesota and averaged by year.

Recent Fire History

Fire history records for 1995 to 2017 are included. Recent fire history for the prairies of Pipestone National Monument was determined using a fire history geodatabase. Although our fire history data begin in 1971, we used fire history data starting in 1995 for these analyses to coincide with our vegetation monitoring history. A 30-m buffer was constructed from the center point of each monitoring site. If the buffered area was greater than 30% burned (i.e., $\geq 848 \text{ m}^2$), the whole site was considered burned. On the ground observations since 2009 validated the spatial data. Time since last fire (TSF) was

then calculated from this dataset for each monitoring site-year combination. TSF values were then averaged by prairie community type for further analysis.

Ground Cover

Ground cover was assessed using cover classes (Table 1). A site mean was calculated by averaging the cover class midpoints for plots ($n = 10$) in each site. We observed aerial cover of grass litter, leaf litter (deciduous plant leaves), rock (exposed rock), bare ground (soil), and woody debris (e.g. branches and sticks). Total unvegetated area reflects space unoccupied by stem basal area in the plots (James et al. 2009).

Vegetation

Community Diversity Metrics

Community richness metrics evaluate how species richness differs across study sites and the park. We limited these calculations to understory herbaceous species. Alpha diversity is synonymous with species richness at the site scale (i.e., mean number of species per monitoring site). Gamma diversity is the community level richness (i.e., total number of species in the community) observed across all our monitoring sites. Beta diversity is a measure of heterogeneity in species distributions across monitoring sites such that small values (near 0) indicate a high degree of similarity in species occurrence across monitoring sites and greater values (>5) indicate a higher degree

of variation in species between sites (more differentiated communities; McCune and Grace 2002).

$$\text{Beta Diversity} = (\text{gamma}/\text{alpha}) - 1$$

Species Diversity Indices

Diversity indices describe the number of species and their abundances (based on foliar cover measurements) and can be compared across prairie communities in the monument. Mean site cover for all non-tree species was calculated using all plots within each site ($n = 5$ or 10). For each site within the community, species richness (S), Shannon diversity index (H') and evenness (J') were calculated. Synonymous with alpha diversity, S represents the number of species observed. PC-ORD (version 7.02) was used to calculate these diversity indices (IBM 2016; McCune and Mefford 2016). A grand mean was then calculated for all sites in a community.

Initial plant diversity for each site was calculated using the Shannon diversity index:

$$\text{Shannon Index: } H' = - \sum_{i=1}^n p_i \ln p_i$$

where p_i is the relative cover of species i (Shannon 1948).

Species distribution evenness (J') is calculated by site according to Pielou (1977):

$$\text{Evenness: } J' = \frac{H'}{\ln(S)}$$

where H' is the Shannon index and $\ln(S)$ is the maximum possible Shannon diversity for a given number of species if all species were present in equal abundance. Evenness is a measure of distribution of species within a community as compared to equal distribution and maximum diversity (Pielou 1969). A value of 1 indicates even communities whereas 0 indicates a heterogeneous community.

Guild Abundance

Plant species were also summarized by guilds, a.k.a. functional groups (designations per the USDA Plants database; James et al. 2009; USDA 2017). Guild

assignments were grasses, forbs, grass-like (species including sedges and rushes), and woody species. A complete species list along with guild assignment is provided in Appendix A. Mean cover values were calculated for each guild-site-year combination. A grand mean was then calculated across all sites in each community type.

The abundance of native versus nonnative (i.e., exotic) species was assessed using mean cover values. Mean cover values for species within a site were summed by origin and analyzed by prairie community type.

Tree Regeneration

Tree regeneration phase stems were tallied by species in the ten 10-m² subplots of each site and reported in three size classes: (1) seedlings = stems < 0.5 m tall; (2) small saplings = stems $\geq$ 0.5 m tall, but < 2.5 cm DBH; and (3) large saplings = stems $\geq$ 0.5 m tall and DBH > 2.5 cm and < 5.0 cm. Summary was done by adding number of stems (Table 2).

Ordination

Nonmetric multidimensional scaling (NMS) was used to evaluate patterns in the species abundance data. NMS is an ordination technique that orders sample units in ordination space so that their inter-point distances reflect the redundant pattern of covariation in the original data (Peck 2010). PC-ORD (version 6.0; McCune and Grace 2002) was employed to obtain the NMS solutions. The final NMS run for each data set employed the Sorenson distance measure and 250 runs with real data at the dimensionality determined by the autopilot setting. The option to automatically rotate the axes to orthogonal principal axes was selected; this eigenanalysis procedure is a rigid rotation designed to make the axes independent of each other (Peck 2010).

Correlation coefficients of two habitat variables—fire return interval (FRI) and Palmer Drought Severity Index (PDSI)—were calculated for all ordination axes. The squared correlation coefficients (i.e., coefficients of determination) express the amount of variation in position along an axis that is explained by a given habitat variable.

Results

Climate

Analysis of the Palmer Drought Severity Index revealed two distinct drought periods: a single year drought in 2000, then later, a three-year dry period

from 2012 to 2014 (Figure 3). The central grasslands of the United States are adapted to cycles of drought and greater moisture (Bragg 1995). Overall, the park has had adequate moisture in most years.

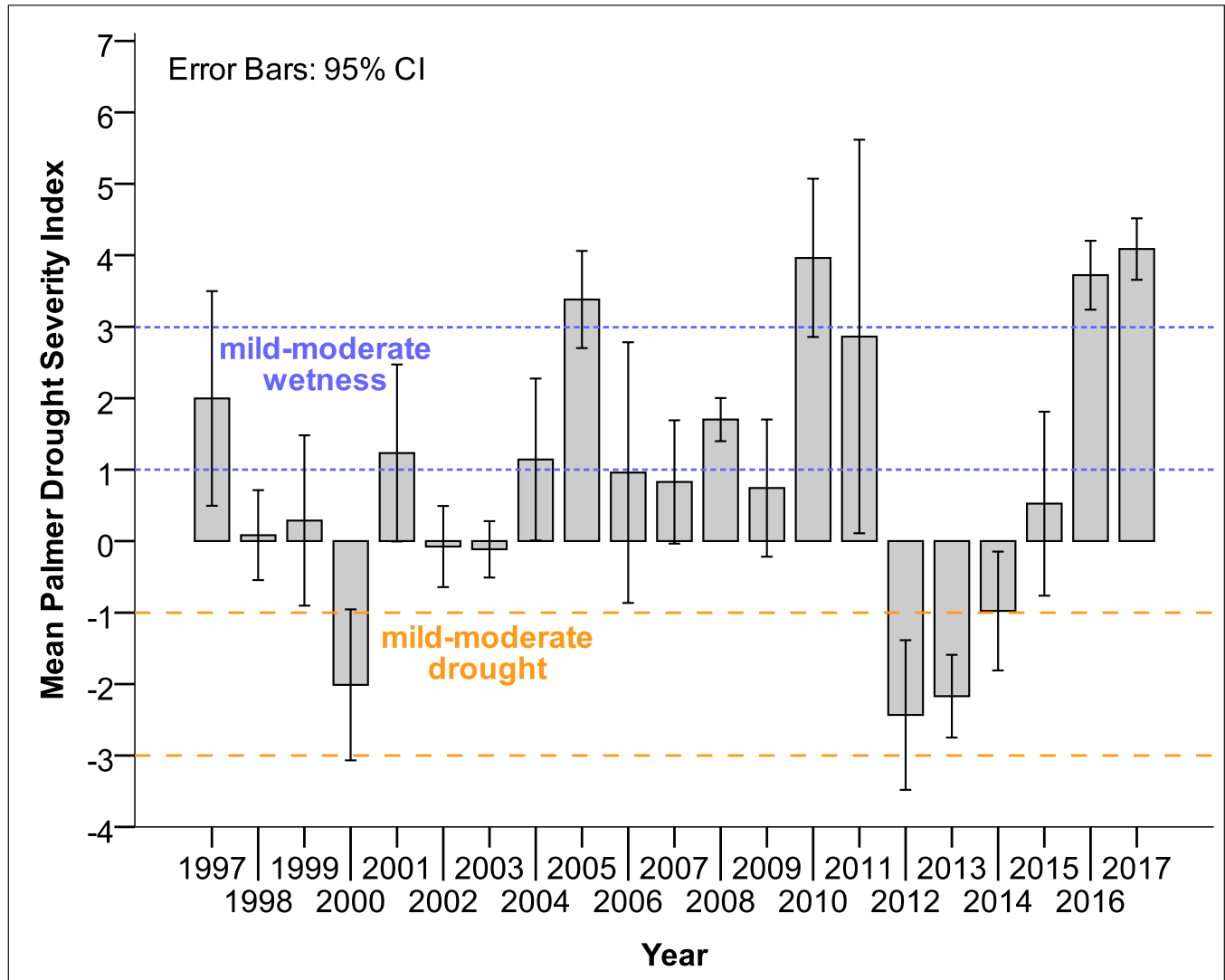


Figure 3. The Palmer Drought Severity Index (PDSI) for Southwestern Minnesota indicates the region as being relatively wet over the period of vegetation monitoring.

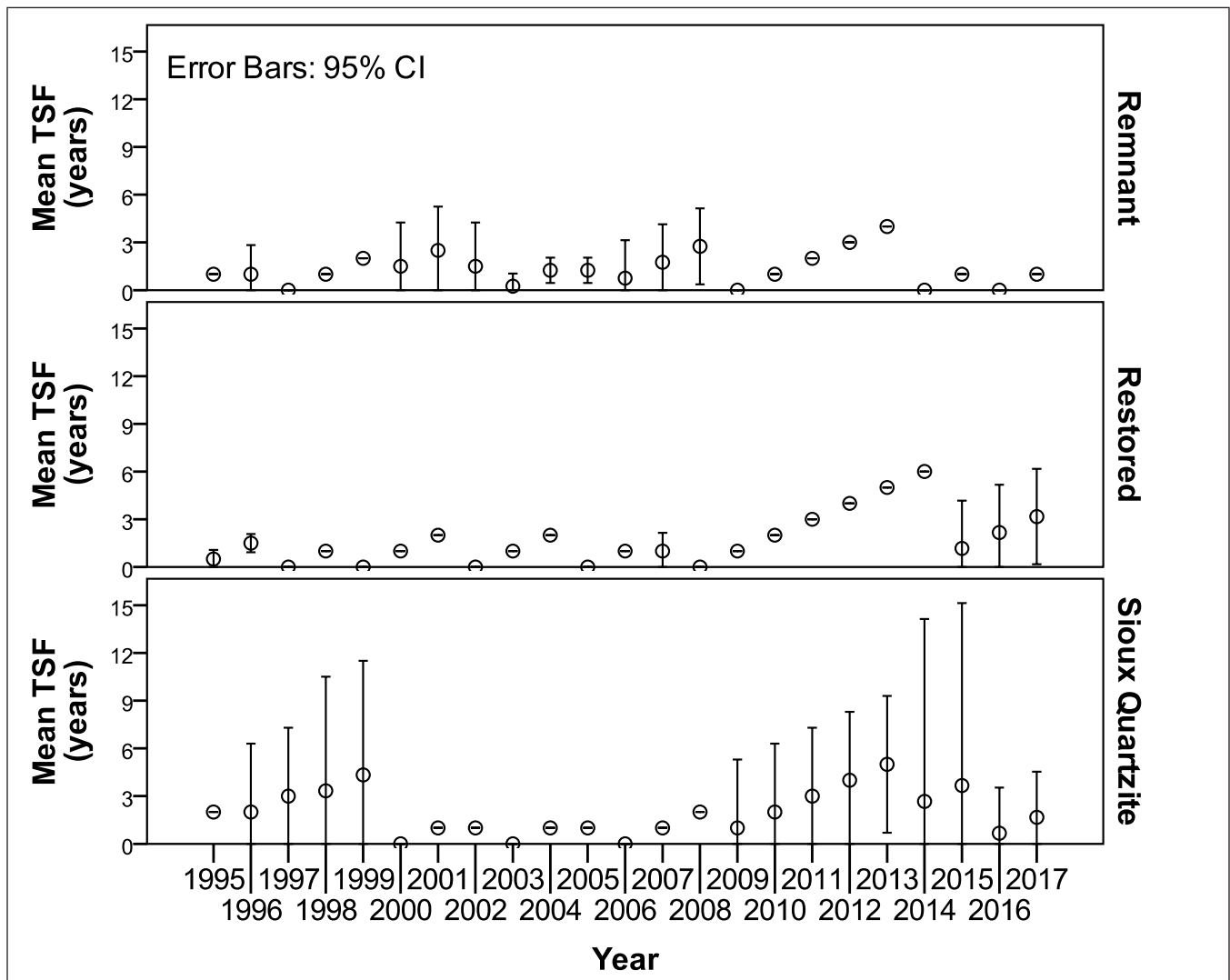


Figure 4. Mean time since fire (in years) for three prairie communities at Pipestone National Monument, Pipestone, MN, 1995–2017. Values of 0 indicate all sites were burned.

Fire History

Prescribed fire is the primary source of ignition in the prairie at Pipestone National Monument. Fire was prescribed in management units on a five-year rotation. This sequence consisted of burning in two consecutive years followed by three years of rest, but exceptions were suggested for specific treatment areas (Becker et al. 1986). Because fire was applied rotationally, not all sites are burned in a given year. A site may remain unburned because it did not have sufficient fuel, or fell outside of the burn unit boundary, or an area within the unit was purposefully excluded. Burn unit boundaries within the park changed periodically. These actions resulted in unequal treatment of monitoring sites within a community type, especially Sioux quartzite prairie sites.

The pattern of fire return intervals indicates that the restored prairie and Sioux quartzite prairie types have been burned less frequently and consistently in more recent years (i.e., 2012–2017; Figure 4). Coincidentally, 2011 to 2013 was a dry period for the region. The restored prairie had the longest mean fire return interval (six years), although one site was unburned for 10 years as of 2017. Remnant prairie sites appear to cycle in frequency, however the longest fire return interval (5 years) occurred in 2013. Variability in fire return intervals likely declined in the remnant prairie after a reorganization of burn units consolidated all four sites in the same burn unit. The Sioux quartzite prairie sites may be more challenging to burn consistently because of a disparity of fuel on the rock outcrops. These rocky areas also hold water in wet years limiting fire spread.

Ground Cover

Woody debris (annual mean values <1%) and leaf litter (annual means <1.5%) were a small component of the ground cover observations. Bare ground and grass litter observations largely follow prescribed fire occurrence in the remnant and restored prairies (Figure 5). Bare ground was greater in remnant

prairie for 2009 because sampling took place only a few weeks after burning. The 2016 prescribed fire occurred in October. The effect was reduced litter and increased bare ground during the 2017 monitoring event. Unvegetated cover may have been underestimated in the remnant and restored prairies in 1998 and 1999.

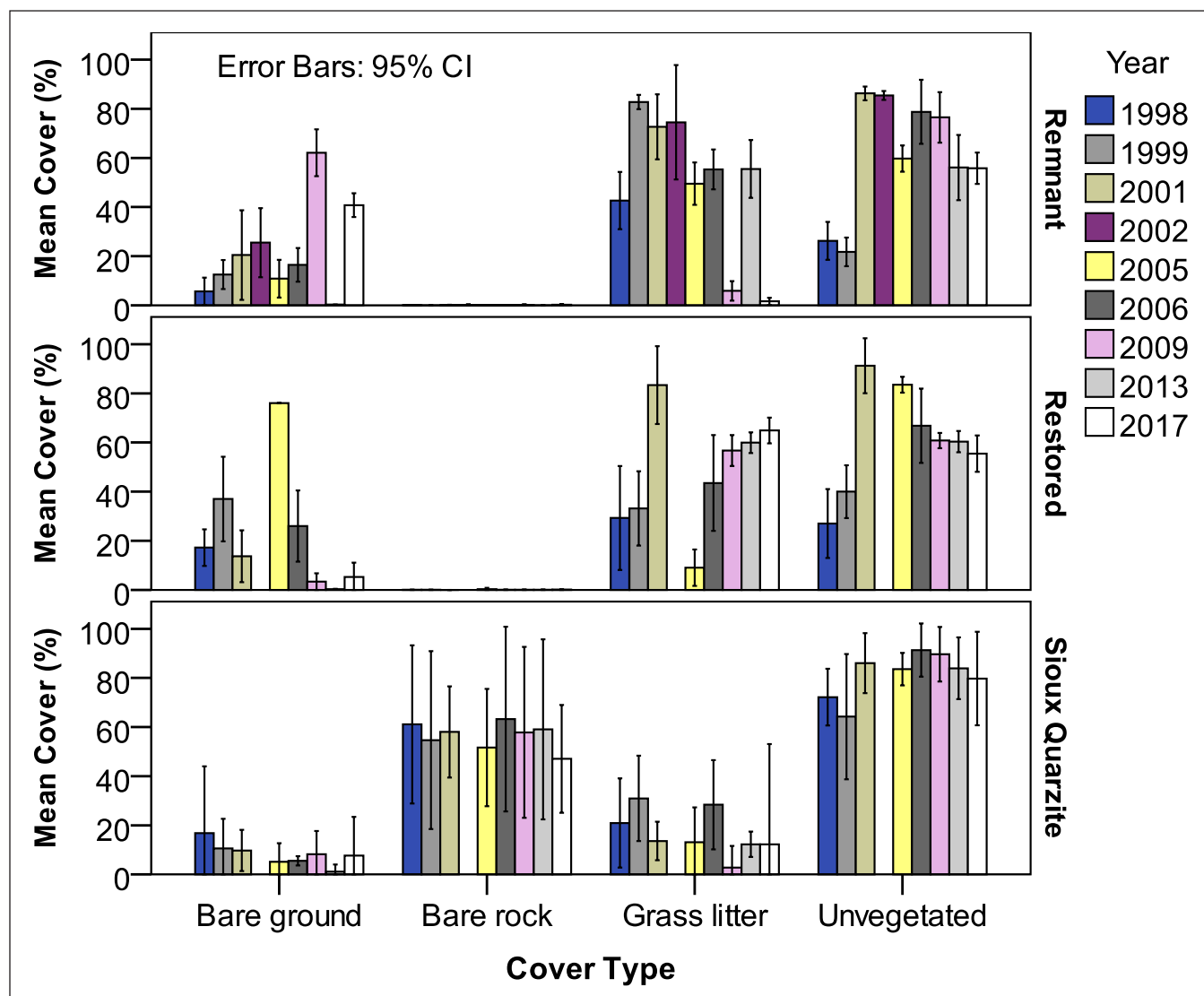


Figure 5. Mean cover (%) of selected ground cover types for three prairie communities at Pipestone National Monument, Pipestone, MN, 1998–2017.

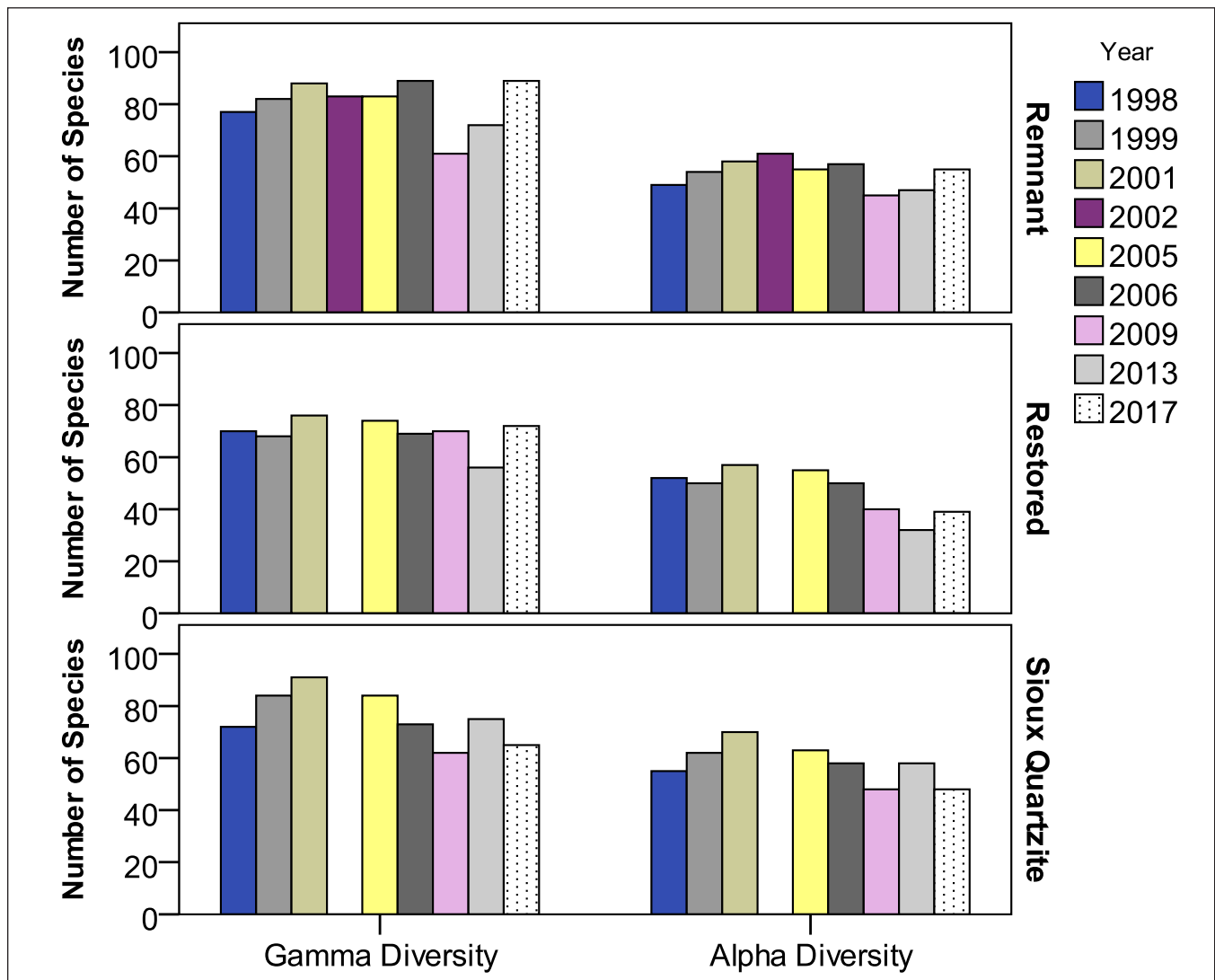


Figure 6. Community diversity for native species at Pipestone National Monument, Pipestone, MN, 1998–2017.

Diversity

Community Diversity

Gamma and alpha diversity for native species were greatest in the Sioux quartzite prairie (2001; Figures 6 and 7). Alpha diversity patterns varied across communities from 2005 forward. Field notes indicate that prescribed fire occurred in the remnant and Sioux quartzite prairies just four weeks before the 2009 sampling. This could have contributed to the drop in species for those prairie types that year. We also noted that in 2013, mean fire return intervals were high and the Palmer Drought Severity Index (PDSI) indicated drought conditions. Remnant and restored prairies demonstrated resiliency in 2017 as gamma diversity nearly equaled or exceeded the maximum levels observed during the monitoring period.

Beta diversity values were generally low indicating similar suites of species within the prairie communities (Figure 7). The increase in beta diversity in the restored prairie beginning in 2009 could be a reflection of the addition of three sampling sites (Table 2). The original three restored sites were clustered in the northern sector of the restored prairie while the newer three sites were distributed in the middle and southern sectors of that prairie unit (Unit 3). Although Nonmetric multidimensional scaling (NMS) analysis showed similarity in composition among all six sites, NMS more strongly weights abundant species, and less abundant species unique to the newer sites likely contributed to an increase in beta diversity values.

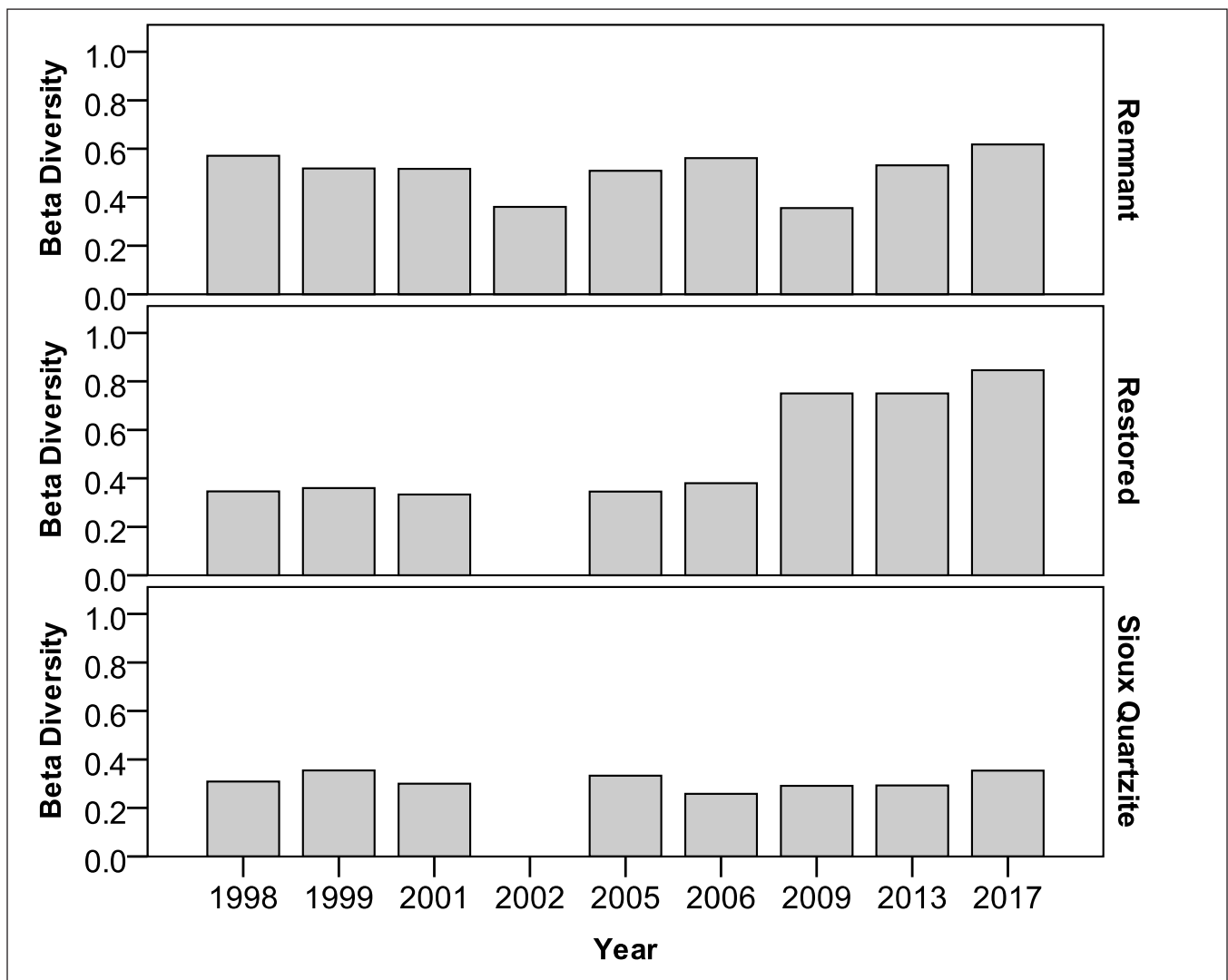


Figure 7. Community beta diversity for native plant species at Pipestone National Monument, Pipestone, MN, 1998–2017.

Species Diversity

Mean species richness declined in all communities in 2009, but patterns varied in subsequent years. (Figure 8). Sioux quartzite and restored prairie sites were richest in 2001, but remnant prairie sites were richest in 2002. Of the three community types, only the restored prairie species richness indicated a decline with longer time since fire intervals (Remnant prairie: $r^2 = 0.02$, $df = 7$, $p = 0.73$; Restored prairie: $r^2 = 0.69$, $df = 7$, $p = 0.01$; Sioux quartzite prairie: $r^2 = 0.02$, $df = 8$, $p = 0.8$).

Evenness (J') values closer to 1 indicate more even (simplified) plant communities (Figure 9). The

remnant prairie has the most consistent evenness through time while restored prairie evenness varies. In general, restored prairie was less even than the other two types. Sources of the difference are unclear.

Diversity (H'), like evenness, has been the most consistent in the remnant prairie (Figure 10). The other two prairie types have larger confidence intervals and varied more through time in comparison. The restored prairie was the least diverse of the prairie types.

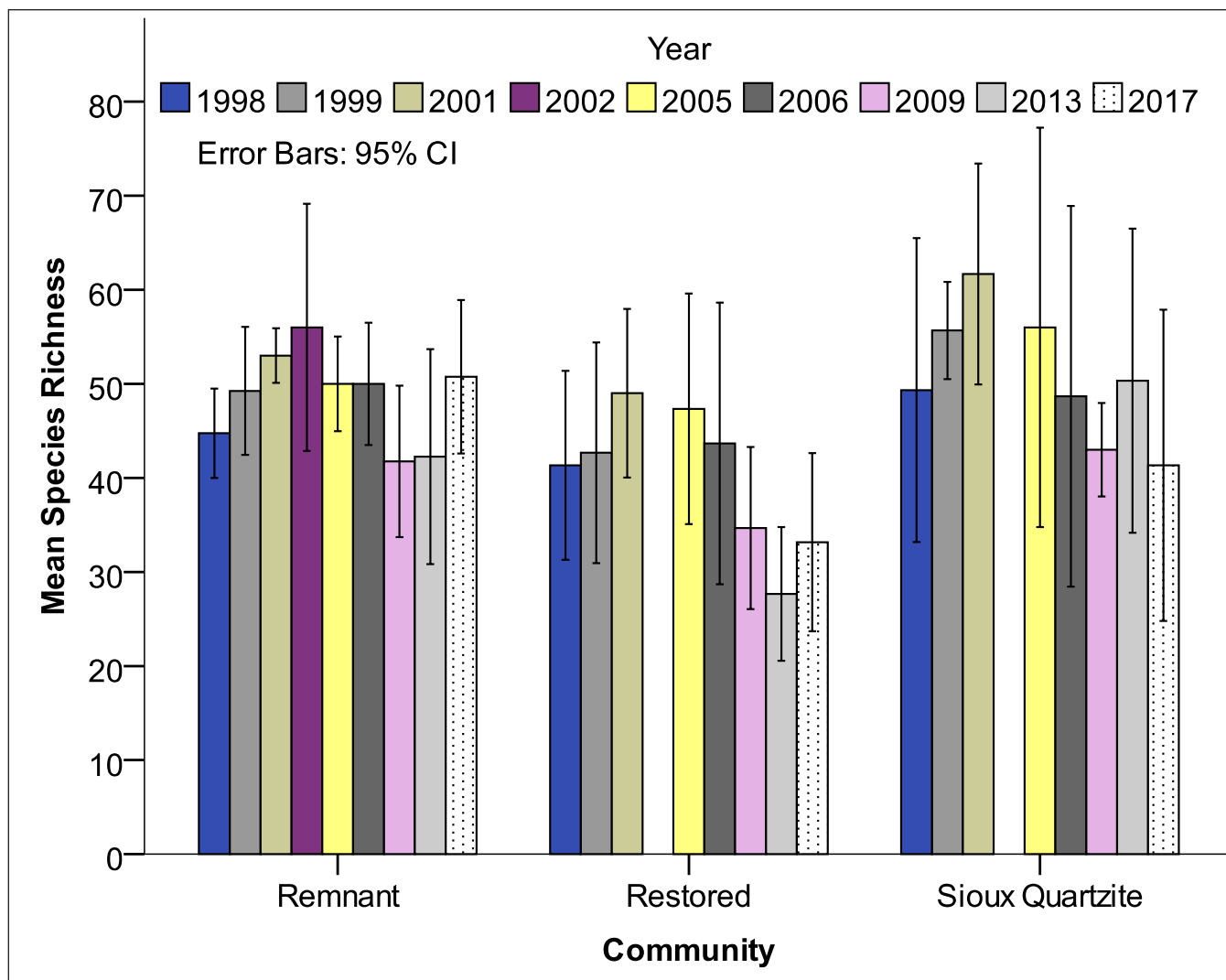


Figure 8. Mean species richness for native plants in three prairie communities at Pipestone National Monument, Pipestone, MN, 1998–2017.

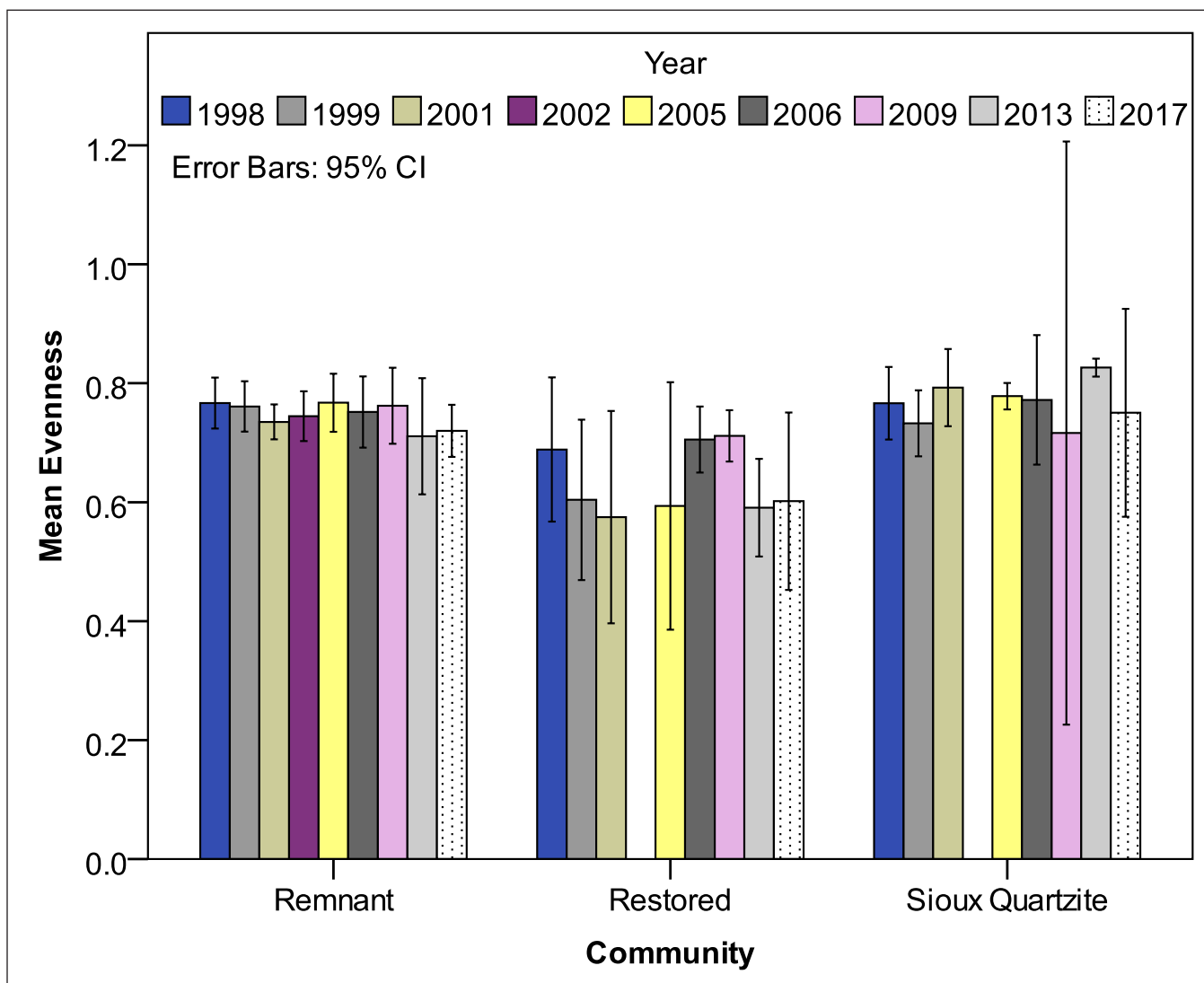


Figure 9. Evenness (J') for native plants in three prairie communities at Pipestone National Monument, Pipestone, MN, 1998–2017.

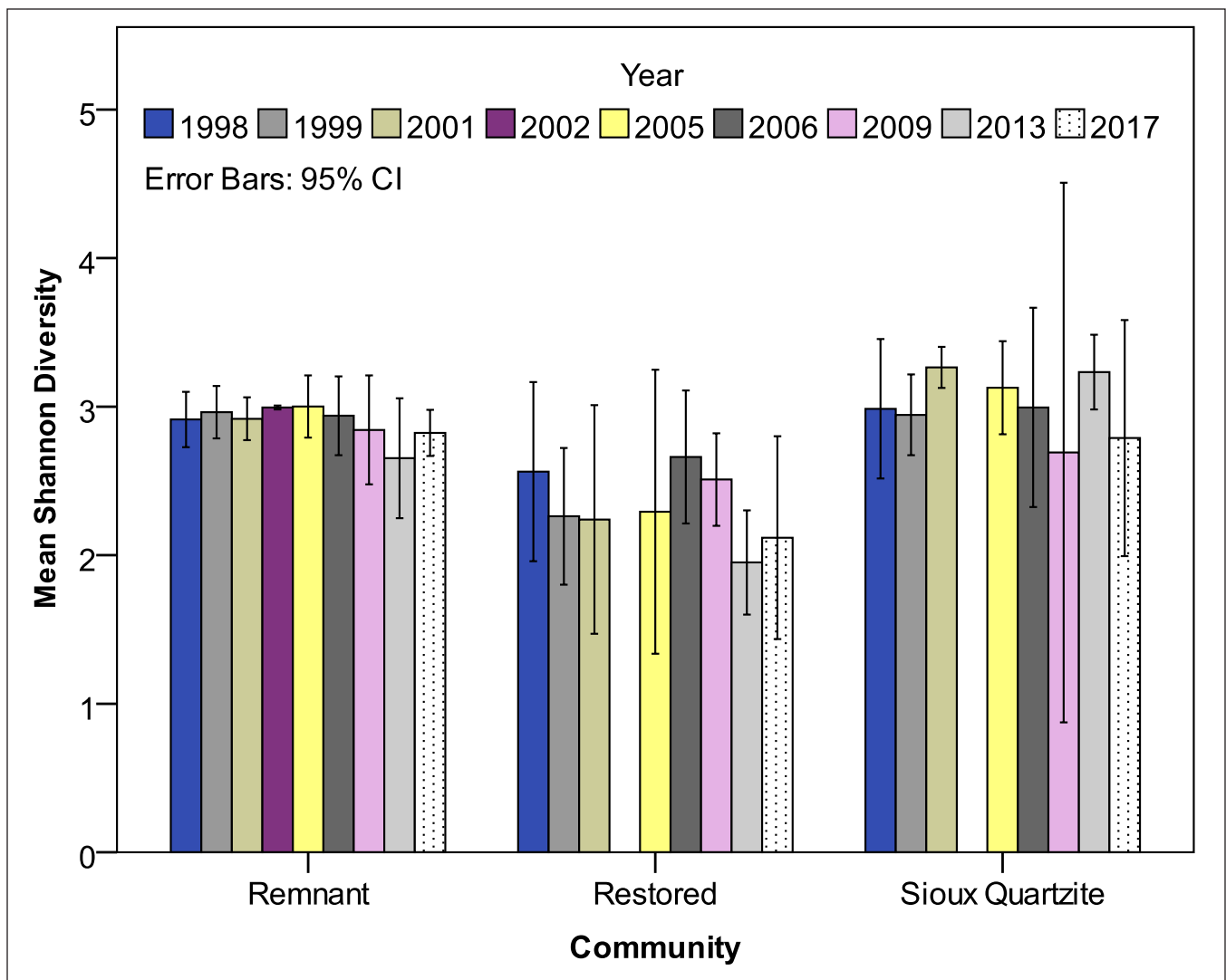


Figure 10. Shannon diversity (H') for native plants in three prairie communities at Pipestone National Monument, Pipestone, MN, 1998–2017.

Guild

Species composition can be understood by summarizing data by plant guilds (Figure 11 and 12). Ferns were only found in the Sioux quartzite prairie and had only 1% cover in most years. Grass-like (sedges and rushes) species were a small component of the prairies and more abundant in the remnant prairie sites (Figure 11). We observed a reduction of these species in the Sioux quartzite prairie sites overtime. Native woody plants include beneficial shrubs like lead plant (*Amorpha canescens*) and prairie rose (*Rosa arkansana*), but also shrubs or trees that become invasive like elm (*Ulmus* spp.; see Appendix A). Abundance of woody plants was most consistent in the Sioux quartzite prairie. In 2017, native woody plants had 2%, 5%, and 4% cover in the remnant, restored, and Sioux quartzite prairies, respectively.

In typical grasslands, grasses dominate the suite of plant guilds in terms of percent cover (Weaver 1954; Sims and Risser 2000). However, at Pipestone National Monument, mean grass cover and forb cover varied by year and community type (Figure 12). Forb cover appeared to be more abundant in several year-community comparisons. Although it is possible that the switch to one-season sampling may have emphasized forbs in the sward because the dominant warm season grasses have not matured at the time of sampling, there may be other factors supporting the forb component in the park. For example, the 2009 prescribed fire in the remnant prairie or the drought from 2012 to 2014 may have contributed to the patterns of mean cover for forbs and grasses we observed. Additionally, the nonnative species component of the prairie is not accounted for in Figure 13.

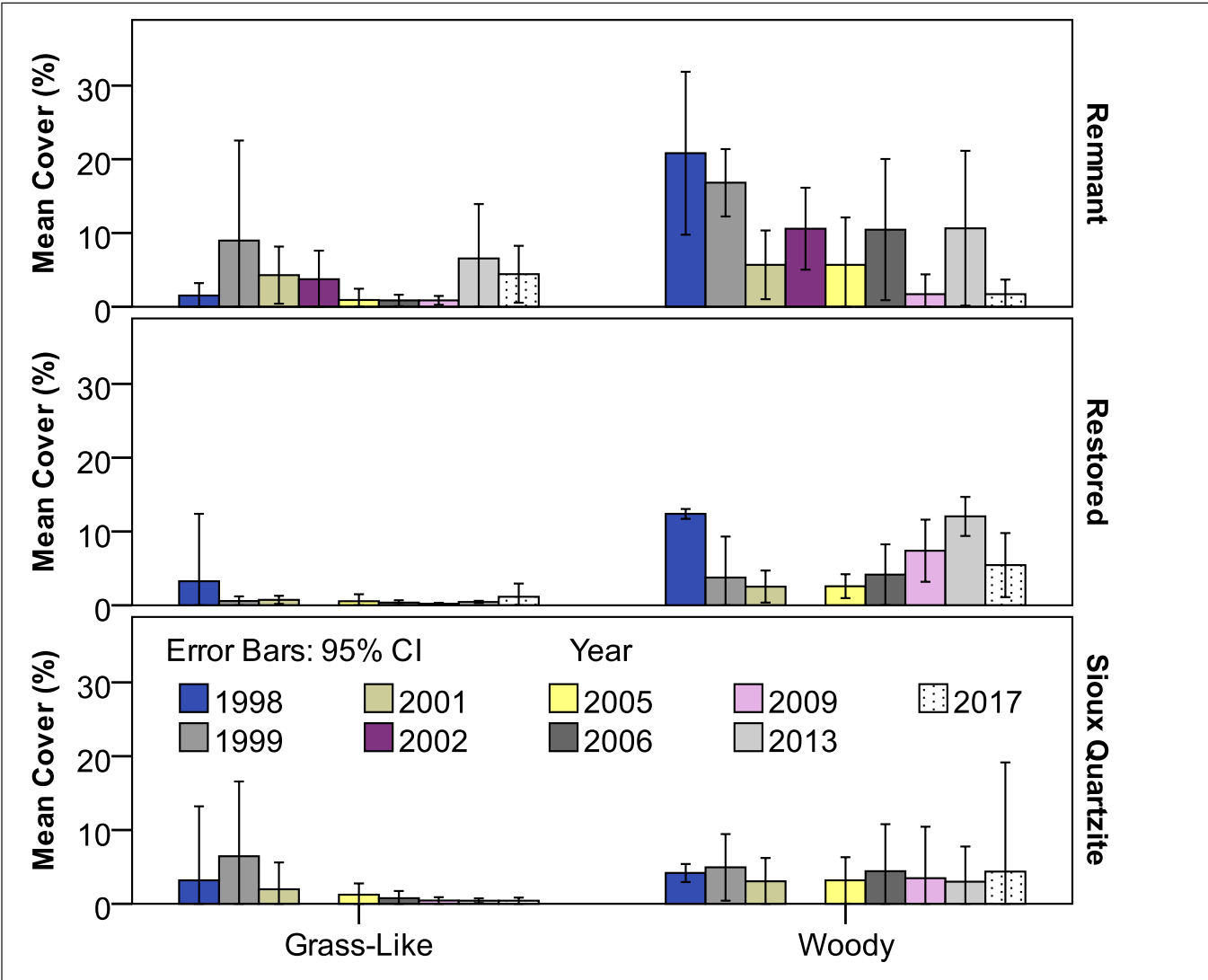


Figure 11. Mean cover (%) of grass-like and woody plant guilds in the prairie communities at Pipestone National Monument, Pipestone, MN, 1998–2017.

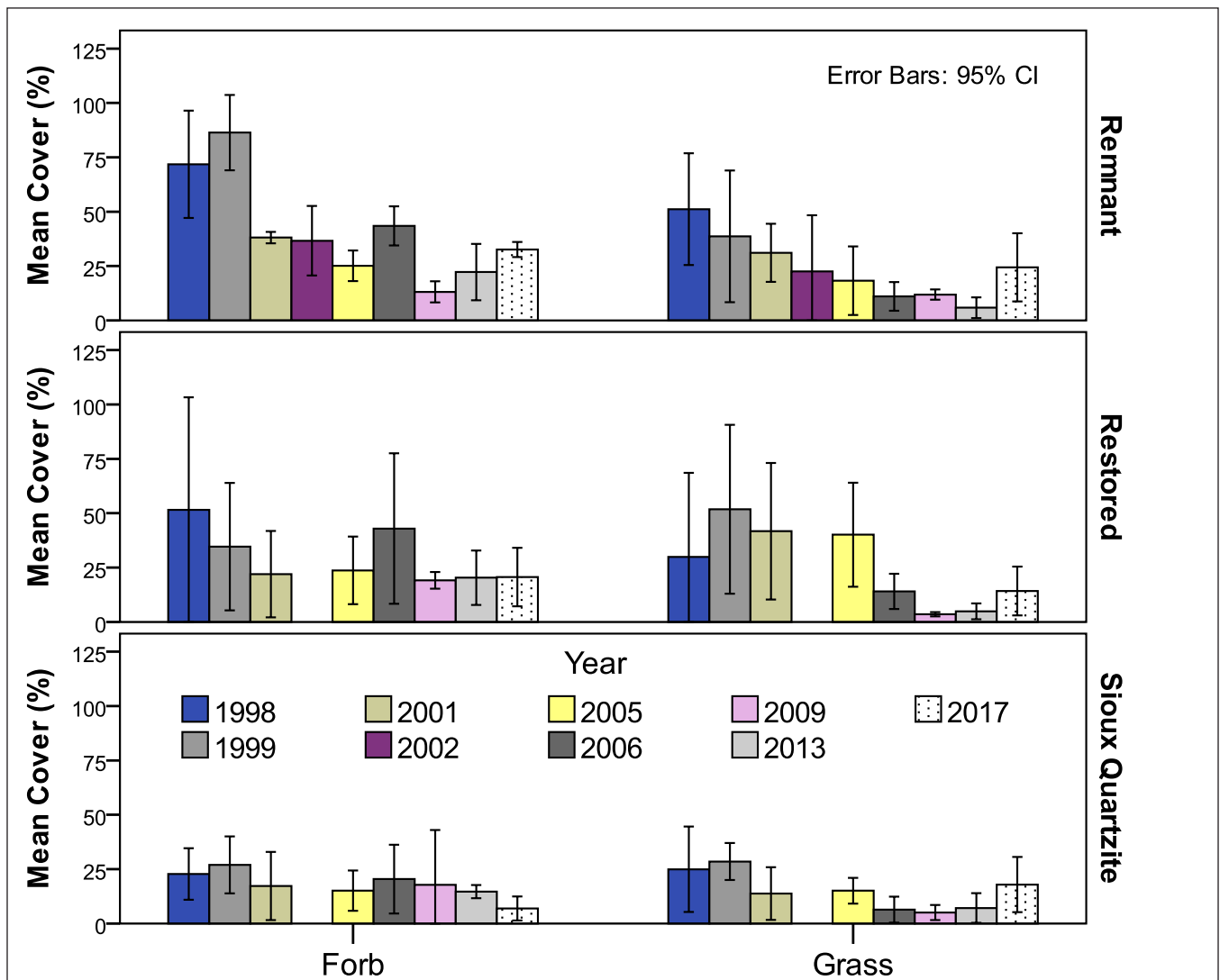


Figure 12. Mean cover of native plants in two plant guilds in three prairie communities at Pipestone National Monument, Pipestone, MN, 1998–2017.

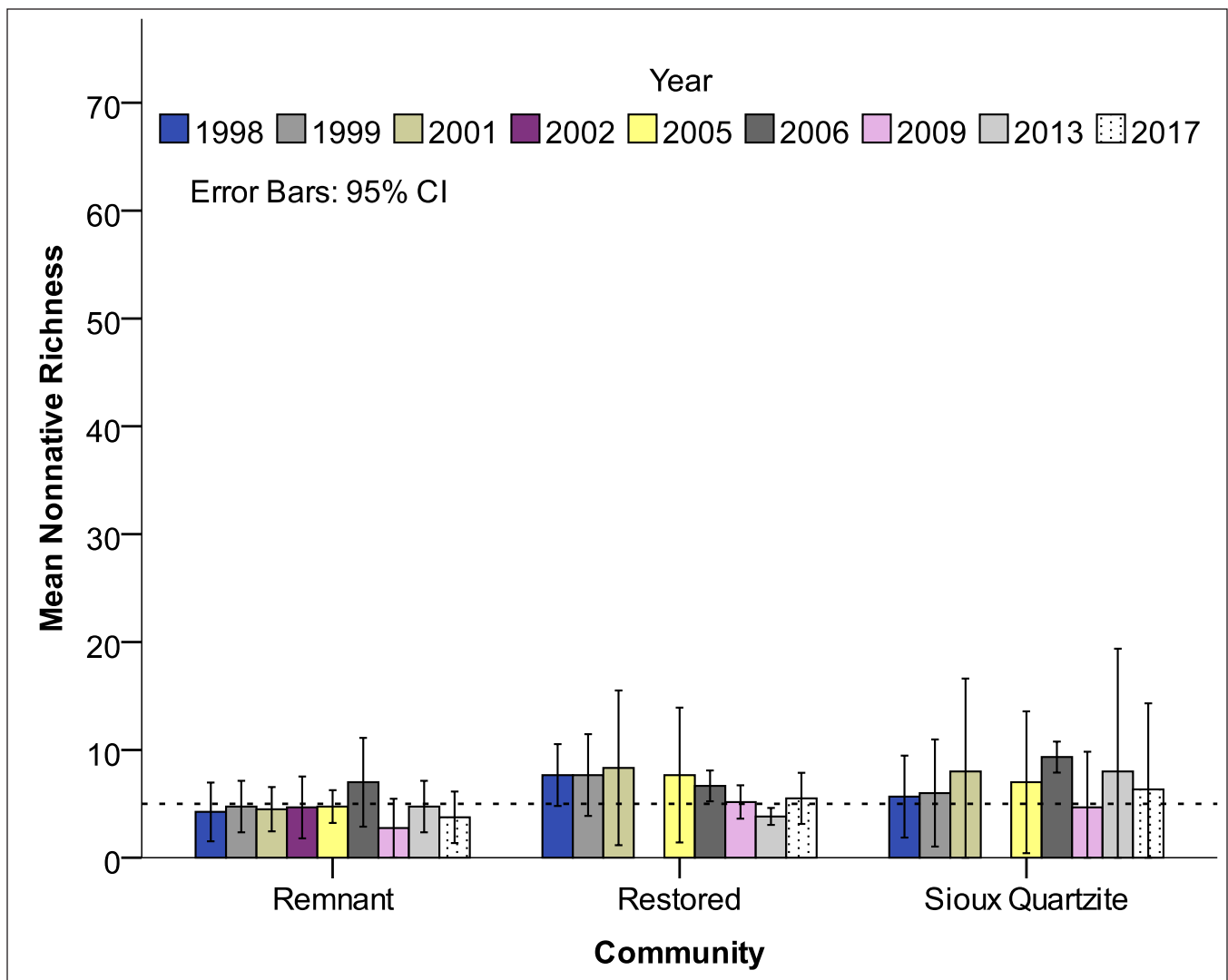


Figure 13. Mean nonnative plant species richness in three prairie communities at Pipestone National Monument, Pipestone, MN, 1998–2017. A dashed reference line was placed at 5 species as a suggested threshold for management attention.

Nonnative species have been part of the matrix of the three prairie communities through the monitoring record (Figure 13). Current levels were low and within the range of variation observed through time. Management goals indicate that fire is expected to reduce smooth brome by more than 25% with each burn (Bressler 2009). The dashed line in Figure 13 indicates the greatest number of nonnative species in a community for 2009 as a reference point for management objectives. Mean nonnative species richness stayed below this level after 2009 in the remnant prairie but was not below this level in the other two communities.

We observed elevated estimates for species cover in 1998 and 1999 as compared to other years (Figure

14). We suspect sampling error (over estimation) as the source for the difference. Sampling crews worked to calibrate estimation in subsequent years. Cover was lower for the remnant and Sioux quartzite prairies in 2009 as a result of a prescribed fire four weeks prior to sampling. Also in 2009, nonnative plant cover was nearly absent (<2%) from those same community types. In other years (except 1998–1999 and 2009), total plant cover was similar, but nonnative plant cover expanded in remnant and restored prairies in 2013. Coincidentally, fire return intervals peaked and a drought occurred that same year. Nonnative richness (Figure 13) did not follow this same trend, so values reflect an expansion of a limited suite of species rather than an influx of new species.

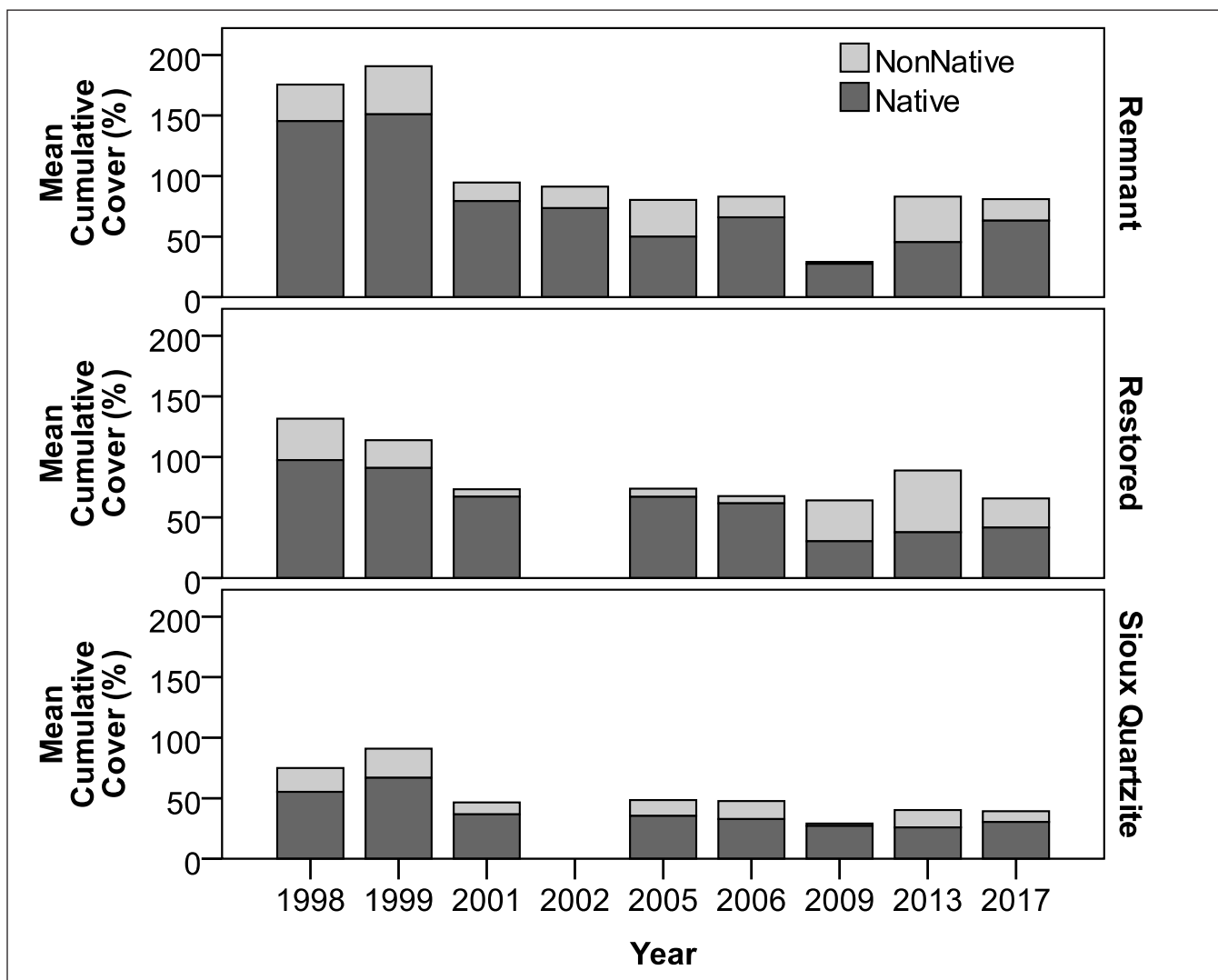


Figure 14. Mean cumulative cover (%) of native and nonnative plants in three prairie communities at Pipestone National Monument, Pipestone, MN, 1998–2017.

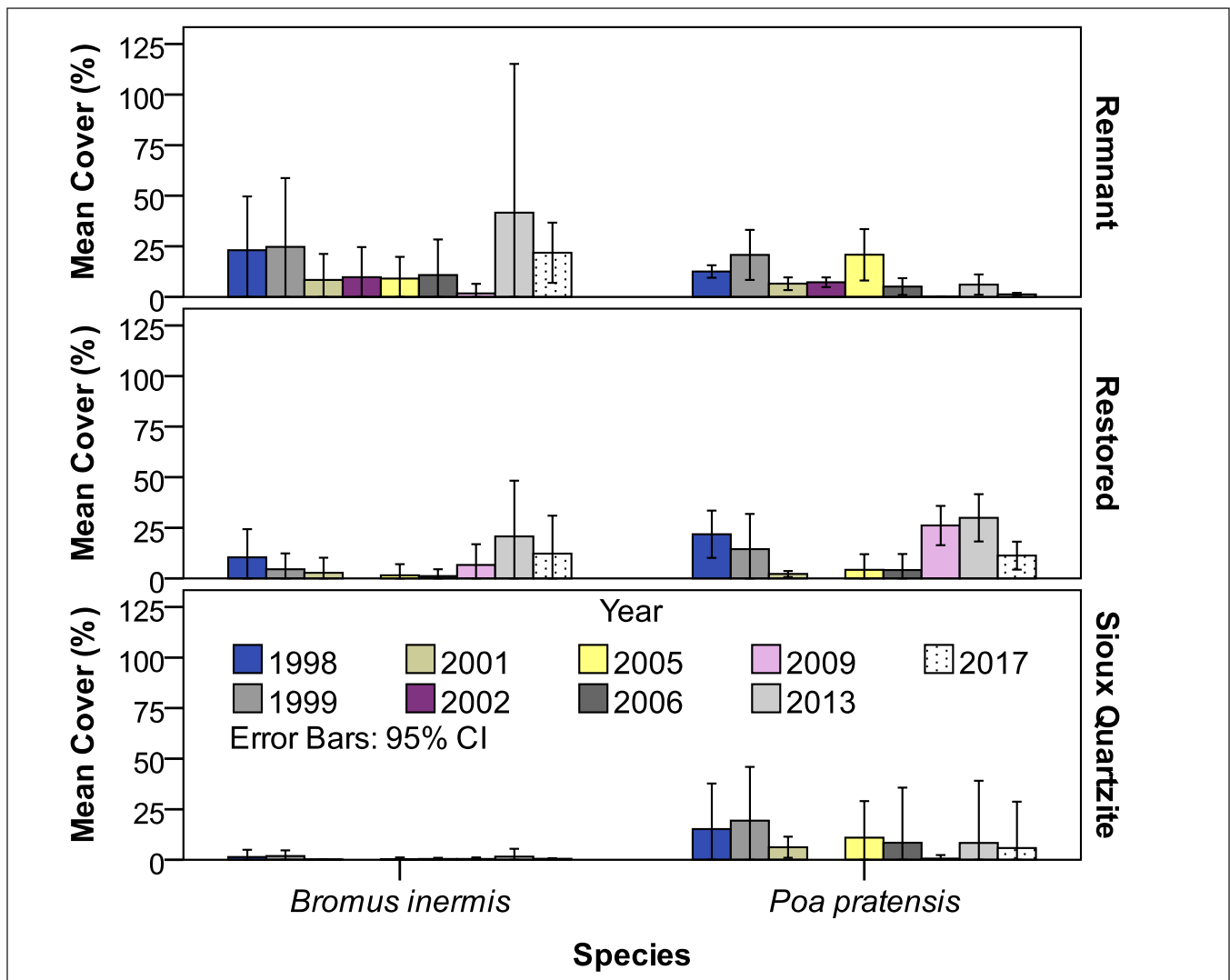


Figure 15. Mean cover of two nonnative, invasive grasses at Pipestone National Monument, Pipestone, MN, for 1998–2017.

Changes in nonnative plant cover in remnant and Sioux quartzite prairies may be largely attributed to the dominant nonnative grasses, smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*; Figure 15). Fire in 2009 corresponded with a decrease in smooth brome and Kentucky bluegrass in the burned prairies (remnant and Sioux quartzite prairies). Smooth brome is rare in the Sioux quartzite

prairie, but common in the remnant and restored prairies where it is increasing. Prescribed fire treatments have targeted the most physiologically sensitive part of smooth brome’s lifecycle (Willson and Stubbendieck 2000). However, Kentucky bluegrass may be more sensitive to fire in the late growing and dormant seasons (Kral et. al. 2018).

Table 3. Tree regeneration in monitoring sites at Pipestone National Monument, Pipestone, MN, 1998–2017. Tree seedlings only recorded in 2009 and 2017.

Community	Year	Species	Common Name	Number of Seedlings
Sioux quartzite prairie	2009	<i>Quercus macrocarpa</i>	bur oak	1
Sioux quartzite prairie	2009	<i>Fraxinus pennsylvanica</i>	green ash	3
Sioux quartzite prairie	2017	<i>Fraxinus pennsylvanica</i>	green ash	1
Sioux quartzite prairie	2017	<i>Celtis occidentalis</i>	common hackberry	1
Remnant prairie	2017	<i>Prunus americana</i>	American plum	298

Tree Regeneration

Trees have remained sparse in the three focal prairie communities throughout the monitoring period with seedlings of only four species observed (Table 3). No saplings or nonnative trees have been recorded in the plots. The most abundant species was *Prunus americana*, but 93% of observations were recorded in a single site in 2017. Note that elm species (*Ulmus* sp.) were assigned a cover value and evaluated as a woody plant rather than tallied as a tree (See Appendix A, Table A-1 for 2017 abundance).

Species of Interest

The western prairie fringed orchid (*Platanthera praeclara*) is a federally listed species present in the park. Orchids are rarely observed in the monitoring plots; only two monitoring sites had mean abundances less than 0.11 % for all years observed. Targeted monitoring of this species better describes trends in the populations (Morrison et. al. 2015).

Prairie sagewort (*Artemisia frigida*) is a plant of interest to American Indians visiting Pipestone National Monument (NPS 1996). It is sought for its spiritual and medicinal properties (Kindscher 1992; Stevens 2000). Only two of the monitoring sites include observations of this plant. In these sites, we found prairie sagewort to have inconsistent, but relatively low abundance through time (Figure 16).

Plant Composition and Environmental Factors

To test for relationships between environmental factors (i.e., fire and drought) and plant composition (cover and abundance), we first looked for general patterns in the plant species data using an ordination technique (Nonmetric multidimensional scaling, NMS). Analyses by community type revealed stress scores that were in the good to fair range (Table 4).

Table 4. Nonmetric multidimensional scaling results by three prairie community types at Pipestone National Monument, Pipestone, MN, 1998–2017.

Community	Stress	Axis 1 R ²	Axis 2 R ²	Axis 3 R ²
Remnant prairie	10.5	0.39	0.34	0.15
Restored prairie	12.5	0.37	0.26	0.20
Sioux quartzite prairie	12.2	0.40	0.26	0.17

Most ecological data sets have stress scores between 10 and 20, and values below 15 are usually considered quite satisfactory (McCune and Grace 2002). A three-dimensional solution was recommended for all community types. The coefficients of determination (R²) in Table 4 do not represent variance explained by the ordination, but rather a comparison of how well the distances between points in ordination space represent distances in the original n-dimensional space, and the relative contribution of each axis (McCune and Grace 2002).

Next, we evaluated correlations between the two habitat variables—time since fire (fire return interval, FRI) and Palmer Drought Severity Index (PDSI)—and the ordination axes. In this case, the coefficients of determination (r²) express the amount of variation in position along an axis that is explained by a given habitat variable. The relationship of the habitat variables to the ordination axes was stronger for the remnant and Sioux quartzite prairies, but only explained a relatively small portion of the variation (Table 5). The relationship between PDSI and FRI to the ordination axes was strongest on axis 3 for the remnant and Sioux quartzite prairies, but relationships for the restored prairie were much weaker for all axes. The relationship is such that fire return intervals tended to be greater during drought periods.

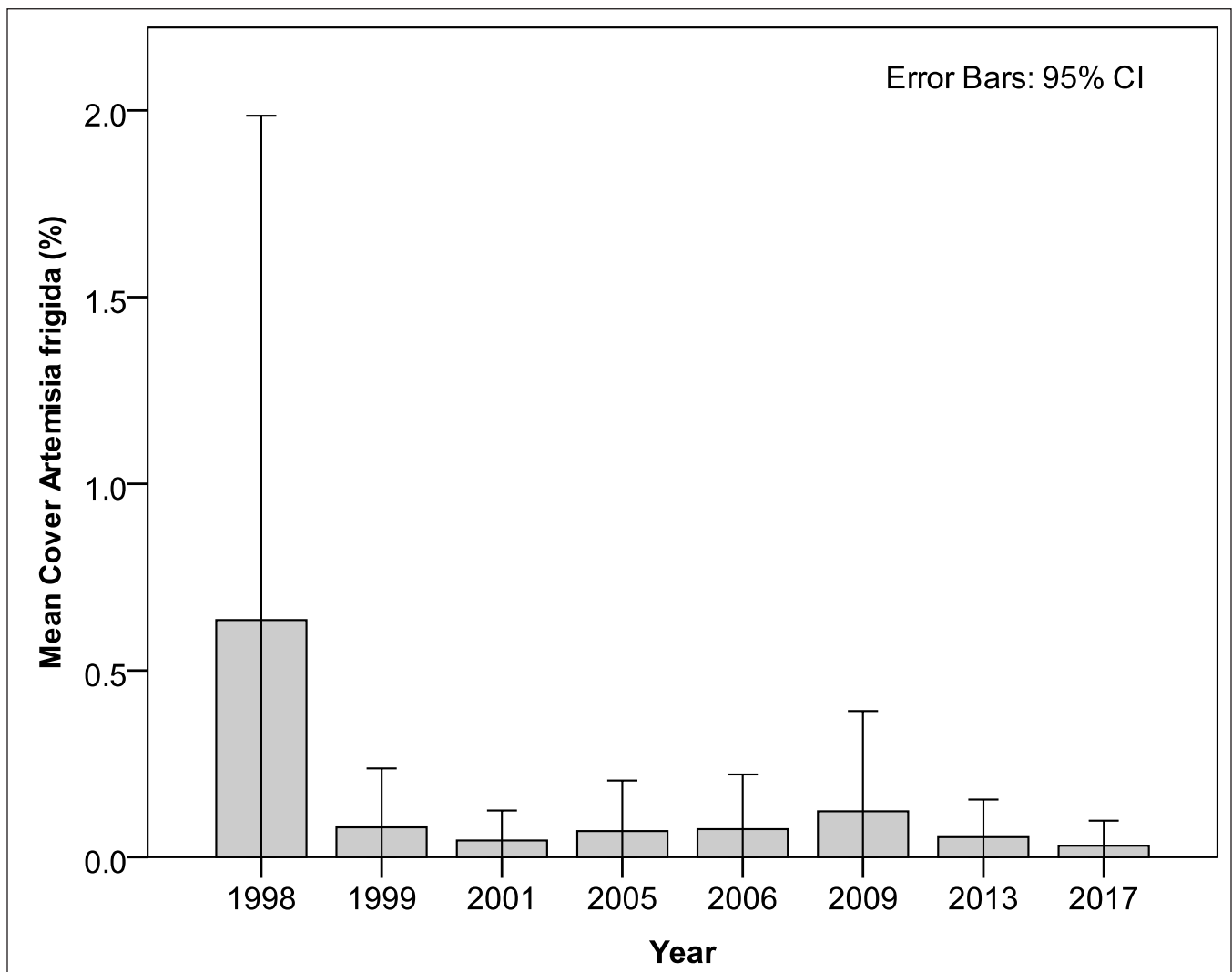


Figure 16. Mean cover (%) of prairie sagewort (*Artemisia frigida*) at Pipestone National Monument, Pipestone, MN, 1998–2017.

We then examined the potential relationships between environmental factors and species composition. We observed that the Sioux quartzite prairie composition was distinctly different from the remnant and restored prairie compositions, and the latter two had many species in common. Considering that the restored prairie may have been sourced in part from the remnant prairie, it follows that the dominant species would be similar. We conclude that fire history and climate play a role in affecting species composition at Pipestone National Monument, but the trajectory and intensity is unclear.

Table 5. Nonmetric multidimensional scaling results for plant species composition and two environmental variables (FRI-fire return interval, PDSI-Palmer drought severity index) for Pipestone National Monument, 1998–2017.

Community	Variable	Axis 1 r^2	Axis 2 r^2	Axis 3 r^2
Remnant prairie	TSF	0.03	0.01	0.14
Remnant prairie	PDSI	0.00	0.05	0.24
Restored prairie	TSF	<0.00	0.04	0.00
Restored prairie	PDSI	0.11	0.01	0.05
Sioux quartzite prairie	TSF	0.13	0.09	0.18
Sioux quartzite prairie	PDSI	0.00	0.04	0.21

Protocol Changes

We considered two changes in the monitoring protocol that may have affected the results. The revisit design changed in 2009 from two-season sampling to one-season sampling in monitored years. The frequency of sampling also changed to once every four years from a more frequent revisit schedule (James et. al. 2009, see appendices). We anticipated the possibility of a small decline in species richness of about nine species as a result. Mean species richness decreased across the monument by 12 species, which was more than predicted. During analysis we observed that this change may have also affected the cover estimates. Grasses that are normally at peak in the fall period may not be at the same level of biomass production during the June sampling period (Figure 12).

Also in 2009, we added three restored prairie sites, increasing the sample size from three to six. Despite the addition of the new sites, mean species richness

declined for the restored prairie, but gamma diversity only increased by one species (Figure 6). The ordination of the native species conducted during this study showed a large degree of overlap in species composition between the original three restored sites and the final six restored sites. This indicates that the dominant matrix species were very similar between the two sets of sites. As a result of the minimal impact of the additional sites, we included all sites in the analyses provided in this report.

We also recognized that plant cover estimation may have been more conservative from 2001 to the present than in the first two sampling years. Crew calibration exercises were implemented in 2001 to keep estimation consistent through time. Lastly, we included a list of species in the Appendix that were observed but lumped to genus in the analysis for consistency (Appendix A, Table A-3).



Prairie Monitoring in 2017, Pipestone National Monument. NPS

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Appendix A. Species Lists

The following tables show all native species (Table A-1), nonnative species (Table A-2), and species recorded at a higher level of taxonomy (Table A-3) in monitoring sites at Pipestone National Monument from 1998 to 2017.

Table A-1. Cumulative species list of native plants observed in monitoring sites at Pipestone National Monument, 1998–2017. Values for mean cover, standard error (SE) and occurrence are for 2017 only. N = native.

Species	Common Name	Guild	Origin	Mean Cover (%)	SE	Occurrence (% of Sites Observed)
<i>Acalypha virginica</i>	Virginia threeseed mercury	forb	N	0.00	0.00	0.00
<i>Achillea millefolium</i>	common yarrow	forb	N	0.03	0.01	38.46
<i>Agrostis scabra</i>	rough bentgrass	grass	N	0.02	0.01	15.38
<i>Allium</i> sp.	onion	forb	N	0.01	0.01	7.69
<i>Allium canadense</i>	meadow garlic	forb	N	0.15	0.04	69.23
<i>Allium stellatum</i>	autumn onion	forb	N	0.02	0.02	15.38
<i>Alopecurus carolinianus</i>	Carolina foxtail	grass	N	0.00	0.00	0.00
<i>Ambrosia artemisiifolia</i>	annual ragweed	forb	N	0.00	0.00	0.00
<i>Ambrosia psilostachya</i>	Cuman ragweed	forb	N	0.76	0.33	69.23
<i>Amorpha canescens</i>	leadplant	forb	N	4.27	1.47	92.31
<i>Amorpha fruticosa</i>	desert false indigo	forb	N	0.02	0.02	7.69
<i>Amorpha nana</i>	dwarf false indigo	woody	N	0.004	0.004	7.69
<i>Andropogon gerardii</i>	big bluestem	grass	N	8.30	2.95	92.31
<i>Androsace occidentalis</i>	western rockjasmine	forb	N	0.01	0.01	7.69
<i>Anemone</i> sp.	anemone	forb	N	0.00	0.00	0.00
<i>Anemone canadensis</i>	Canadian anemone	forb	N	0.56	0.26	46.15
<i>Anemone caroliniana</i>	Carolina anemone	forb	N	0.00	0.00	0.00
<i>Anemone cylindrica</i>	candle anemone	forb	N	0.23	0.10	38.46
<i>Antennaria neglecta</i>	field pussytoes	forb	N	0.00	0.00	0.00
<i>Apocynum cannabinum</i>	Indianhemp	forb	N	0.27	0.11	61.54
<i>Arabis hirsuta</i>	hairy rockcress	forb	N	0.01	0.01	7.69
<i>Aristida</i> sp.	threeawn	grass	N	0.03	0.02	23.08

Table A-1 (continued). Cumulative species list of native plants observed in monitoring sites at Pipestone National Monument, 1998–2017. Values for mean cover, standard error (SE) and occurrence are for 2017 only. N = native.

Species	Common Name	Guild	Origin	Mean Cover (%)	SE	Occurrence (% of Sites Observed)
<i>Aristida dichotoma</i>	churchmouse threawn	forb	N	0.00	0.00	0.00
<i>Artemisia campestris</i>	field sagewort	forb	N	0.01	0.01	7.69
<i>Artemisia frigida</i>	prairie sagewort	forb	N	0.03	0.03	7.69
<i>Artemisia ludoviciana</i>	white sagebrush	forb	N	0.91	0.57	53.85
<i>Asclepias</i> sp.	milkweed	forb	N	0.38	0.22	38.46
<i>Asclepias ovalifolia</i>	oval-leaf milkweed	forb	N	0.00	0.00	0.00
<i>Asclepias syriaca</i>	common milkweed	forb	N	0.07	0.04	30.77
<i>Asclepias verticillata</i>	whorled milkweed	forb	N	0.02	0.01	38.46
<i>Astragalus canadensis</i>	Canadian milkvetch	forb	N	0.02	0.01	15.38
<i>Bouteloua curtipendula</i>	sideoats grama	grass	N	0.04	0.03	15.38
<i>Bouteloua dactyloides</i>	Buffalograss	grass	N	0.004	0.004	7.69
<i>Bouteloua gracilis</i>	blue grama	grass	N	0.74	0.41	23.08
<i>Bouteloua hirsuta</i>	hairy grama	grass	N	0.01	0.01	7.69
<i>Brickellia eupatorioides</i>	false boneset	forb	N	0.00	0.00	0.00
<i>Calamagrostis stricta</i>	slimstem reedgrass	grass	N	0.02	0.02	7.69
<i>Calystegia sepium</i>	hedge false bindweed	forb	N	0.10	0.05	46.15
<i>Carex</i> sp.	sedge	grass-like	N	1.83	0.66	100.00
<i>Cerastium arvense</i>	field chickweed	forb	N	0.13	0.07	30.77
<i>Chamaesyce nutans</i>	Spotted sandmat	forb	N	0.00	0.00	0.00
<i>Chamaesyce prostrata</i>	prostrate sandmat	forb	N	0.00	0.00	0.00
<i>Chenopodium</i>	goosefoot	forb	N	0.00	0.00	0.00
<i>Chenopodium album</i>	lambsquarters	forb	N	0.00	0.00	0.00
<i>Cicuta maculata</i>	spotted water hemlock	forb	N	0.00	0.00	0.00
<i>Cirsium altissimum</i>	tall thistle	forb	N	0.03	0.02	15.38
<i>Cirsium flodmanii</i>	Flodman's thistle	forb	N	0.04	0.03	15.38
<i>Collomia linearis</i>	tiny trumpet	forb	N	0.04	0.03	15.38
<i>Comandra umbellata</i>	bastard toadflax	forb	N	0.00	0.00	0.00

Table A-1 (continued). Cumulative species list of native plants observed in monitoring sites at Pipestone National Monument, 1998–2017. Values for mean cover, standard error (SE) and occurrence are for 2017 only. N = native.

Species	Common Name	Guild	Origin	Mean Cover (%)	SE	Occurrence (% of Sites Observed)
<i>Conyza canadensis</i>	Canadian horseweed	forb	N	0.00	0.00	0.00
<i>Coreopsis palmata</i>	stiff tickseed	forb	N	0.02	0.02	7.69
<i>Cuscuta</i> sp.	dodder	forb	N	0.00	0.00	0.00
<i>Cyperus</i> sp.	flatsedge	grass-like	N	0.00	0.00	0.00
<i>Cyperus squarrosus</i>	bearded flatsedge	grass-like	N	0.00	0.00	0.00
<i>Cystopteris fragilis</i>	brittle bladderfern	fern	N	0.00	0.00	0.00
<i>Dalea candida</i>	white prairie clover	forb	N	0.07	0.03	46.15
<i>Dalea purpurea</i>	purple prairie clover	forb	N	0.06	0.03	38.46
<i>Delphinium carolinianum</i>	Carolina larkspur	forb	N	0.02	0.01	15.38
<i>Dichanthelium</i>	rosette grass	grass	N	2.50	0.74	100.00
<i>Dichanthelium villosissimum</i> var. <i>praecocius</i>	whitehair rosette grass	grass	N	0.00	0.00	0.00
<i>Draba reptans</i>	Carolina draba	forb	N	0.00	0.00	0.00
<i>Echinacea angustifolia</i>	blacksamson echinacea	forb	N	0.00	0.00	0.00
<i>Eleocharis</i> sp.	spikerush	grass-like	N	0.00	0.00	0.00
<i>Eleocharis compressa</i>	flatstem spikerush	grass-like	N	0.11	0.08	15.38
<i>Eleocharis obtusa</i>	blunt spikerush	grass-like	N	0.00	0.00	0.00
<i>Ellisia nyctelea</i>	Aunt Lucy	forb	N	0.00	0.00	0.00
<i>Elymus</i> sp.	wildrye	grass	N	0.00	0.00	0.00
<i>Elymus canadensis</i>	Canada wildrye	grass	N	0.004	0.004	7.69
<i>Elymus hystrix</i> var. <i>hystrix</i>	eastern bottlebrush grass	grass	N	0.00	0.00	0.00
<i>Elymus trachycaulus</i>	slender wheatgrass	grass	N	0.01	0.01	15.38
<i>Elymus virginicus</i>	Virginia wildrye	grass	N	0.01	0.01	15.38
<i>Equisetum arvense</i>	field horsetail	fern	N	0.00	0.00	0.00
<i>Equisetum laevigatum</i>	smooth horsetail	fern	N	0.06	0.04	15.38
<i>Erigeron philadelphicus</i>	Philadelphia fleabane	forb	N	0.00	0.00	0.00
<i>Erigeron strigosus</i>	prairie fleabane	forb	N	0.07	0.03	38.46
<i>Euphorbia corollata</i>	flowering spurge	forb	N	0.00	0.00	0.00

Table A-1 (continued). Cumulative species list of native plants observed in monitoring sites at Pipestone National Monument, 1998–2017. Values for mean cover, standard error (SE) and occurrence are for 2017 only. N = native.

Species	Common Name	Guild	Origin	Mean Cover (%)	SE	Occurrence (% of Sites Observed)
<i>Euphorbia spathulata</i>	warty spurge	forb	N	0.01	0.01	7.69
<i>Euthamia graminifolia</i>	flat-top goldentop	forb	N	0.02	0.02	15.38
<i>Euthamia gymnospermoides</i>	Texas goldentop	forb	N	0.00	0.00	0.00
<i>Fragaria virginiana</i>	Virginia strawberry	forb	N	0.15	0.14	30.77
<i>Galium</i> sp.	bedstraw	forb	N	0.00	0.00	0.00
<i>Galium aparine</i>	stickywilly	forb	N	0.00	0.00	0.00
<i>Galium boreale</i>	northern bedstraw	forb	N	1.39	1.39	7.69
<i>Galium obtusum</i>	bluntleaf bedstraw	forb	N	0.44	0.43	15.38
<i>Gaura coccinea</i>	scarlet beeblossom	forb	N	0.00	0.00	0.00
<i>Gentiana andrewsii</i>	closed bottle gentian	forb	N	0.02	0.02	7.69
<i>Gentiana puberulenta</i>	downy gentian	forb	N	0.01	0.01	7.69
<i>Geranium carolinianum</i>	Carolina geranium	forb	N	0.00	0.00	0.00
<i>Geum triflorum</i>	old man's whiskers	forb	N	0.00	0.00	0.00
<i>Glycyrrhiza lepidota</i>	American licorice	forb	N	0.45	0.31	30.77
<i>Hedeoma hispida</i>	rough false pennyroyal	forb	N	0.03	0.02	15.38
<i>Helianthus</i> sp.	sunflower	forb	N	0.12	0.12	7.69
<i>Helianthus grosseserratus</i>	sawtooth sunflower	forb	N	0.17	0.16	15.38
<i>Helianthus maximiliani</i>	Maximilian sunflower	forb	N	0.65	0.33	61.54
<i>Helianthus nuttallii</i>	Nuttall's sunflower	forb	N	0.00	0.00	0.00
<i>Helianthus pauciflorus</i> ssp. <i>pauciflorus</i>	stiff sunflower	forb	N	0.60	0.23	69.23
<i>Helianthus petiolaris</i>	prairie sunflower	forb	N	0.00	0.00	0.00
<i>Heliopsis helianthoides</i>	smooth oxeye	forb	N	0.12	0.04	46.15
<i>Hesperostipa comata</i> ssp. <i>comata</i>	Needle-and-thread grass	grass	N	0.00	0.00	0.00
<i>Hesperostipa spartea</i>	Porcupine-grass	grass	N	1.30	0.69	61.54
<i>Heuchera richardsonii</i>	Richardson's alumroot	forb	N	0.04	0.02	30.77
<i>Hordeum jubatum</i>	foxtail barley	grass	N	0.00	0.00	0.00
<i>Hordeum pusillum</i>	little barley	grass	N	0.01	0.01	7.69

Table A-1 (continued). Cumulative species list of native plants observed in monitoring sites at Pipestone National Monument, 1998–2017. Values for mean cover, standard error (SE) and occurrence are for 2017 only. N = native.

Species	Common Name	Guild	Origin	Mean Cover (%)	SE	Occurrence (% of Sites Observed)
<i>Hypoxis hirsuta</i>	common goldstar	forb	N	0.02	0.01	15.38
<i>Juncus</i> sp.	rush	grass-like	N	0.00	0.00	0.00
<i>Juncus arcticus</i> ssp. <i>littoralis</i>	Wire-rush	grass-like	N	0.03	0.02	15.38
<i>Juncus dudleyi</i>	Dudley's rush	grass-like	N	0.01	0.01	15.38
<i>Juncus interior</i>	inland rush	grass-like	N	0.01	0.01	15.38
<i>Koeleria macrantha</i>	prairie Junegrass	grass	N	0.50	0.34	23.08
<i>Lactuca</i> sp.	lettuce	forb	N	0.00	0.00	0.00
<i>Lactuca canadensis</i>	Canada lettuce	forb	N	0.00	0.00	0.00
<i>Lactuca tatarica</i> var. <i>pulchella</i>	blue lettuce	forb	N	0.004	0.004	7.69
<i>Lappula</i> sp.	stickseed	forb	N	0.01	0.01	7.69
<i>Lappula occidentalis</i> var. <i>occidentalis</i>	flatspine stickseed	forb	N	0.00	0.00	0.00
<i>Lathyrus palustris</i>	marsh pea	forb	N	0.02	0.01	23.08
<i>Lathyrus venosus</i>	veiny pea	forb	N	0.15	0.07	46.15
<i>Leersia virginica</i>	whitegrass	grass	N	0.00	0.00	0.00
<i>Lepidium densiflorum</i>	common pepperweed	forb	N	0.06	0.04	23.08
<i>Lespedeza capitata</i>	roundhead lespedeza	forb	N	0.00	0.00	7.69
<i>Liatris</i> sp.	blazing star	forb	N	0.00	0.00	0.00
<i>Liatris aspera</i>	tall blazing star	forb	N	0.00	0.00	7.69
<i>Liatris punctata</i>	dotted blazing star	forb	N	0.06	0.02	53.85
<i>Liatris pycnostachya</i>	prairie blazing star	forb	N	0.06	0.03	38.46
<i>Linum sulcatum</i>	grooved flax	forb	N	0.00	0.00	0.00
<i>Lithospermum canescens</i>	hoary puccoon	forb	N	0.01	0.01	15.38
<i>Lithospermum incisum</i>	narrowleaf stoneseed	forb	N	0.00	0.00	0.00
<i>Lobelia spicata</i>	palespike lobelia	forb	N	0.00	0.00	0.00
<i>Lotus unifoliolatus</i> var. <i>unifoliolatus</i>	American bird's-foot trefoil	forb	N	0.01	0.01	7.69
<i>Mirabilis hirsuta</i>	hairy four o'clock	forb	N	0.00	0.00	0.00
<i>Mirabilis nyctaginea</i>	heartleaf four o'clock	forb	N	0.00	0.00	0.00

Table A-1 (continued). Cumulative species list of native plants observed in monitoring sites at Pipestone National Monument, 1998–2017. Values for mean cover, standard error (SE) and occurrence are for 2017 only. N = native.

Species	Common Name	Guild	Origin	Mean Cover (%)	SE	Occurrence (% of Sites Observed)
<i>Monarda fistulosa</i>	wild bergamot	forb	N	0.08	0.03	53.85
<i>Muhlenbergia cuspidata</i>	plains muhly	grass	N	0.004	0.004	7.69
<i>Muhlenbergia frondosa</i>	wirestem muhly	grass	N	0.00	0.00	0.00
<i>Muhlenbergia glomerata</i>	spiked muhly	grass	N	0.004	0.004	7.69
<i>Muhlenbergia racemosa</i>	marsh muhly	grass	N	0.00	0.00	0.00
<i>Myosotis verna</i>	spring forget-me-not	forb	N	0.00	0.00	0.00
<i>Oenothera biennis</i>	common evening primrose	forb	N	0.02	0.02	15.38
<i>Oenothera villosa</i>	hairy evening primrose	forb	N	0.00	0.00	0.00
<i>Oligoneuron rigidum</i> var. <i>rigidum</i>	Stiff goldenrod	forb	N	0.22	0.10	69.23
<i>Onosmodium bejariense</i> var. <i>bejariense</i>	Western false gromwell	forb	N	0.00	0.00	0.00
<i>Opuntia fragilis</i>	brittle pricklypear	forb	N	0.08	0.04	23.08
<i>Opuntia macrorhiza</i>	twistspine pricklypear	forb	N	0.02	0.01	15.38
<i>Oxalis</i> sp.	woodsorrel	forb	N	0.06	0.03	30.77
<i>Oxalis violacea</i>	violet woodsorrel	forb	N	0.16	0.06	46.15
<i>Packera plattensis</i>	Platte groundsel	forb	N	0.02	0.01	15.38
<i>Panicum capillare</i>	witchgrass	grass	N	0.00	0.00	0.00
<i>Panicum virgatum</i>	switchgrass	grass	N	0.13	0.06	53.85
<i>Parietaria pensylvanica</i>	Pennsylvania pellitory	forb	N	0.00	0.00	0.00
<i>Parthenocissus vitacea</i>	woodbine	woody	N	0.01	0.01	7.69
<i>Pascopyrum smithii</i>	western wheatgrass	grass	N	0.02	0.02	7.69
<i>Pediomelum argophyllum</i>	Silvery scurf-pea	forb	N	0.60	0.36	38.46
<i>Phemeranthus parviflorus</i>	Prairie fame-flower	forb	N	0.05	0.03	23.08
<i>Phlox pilosa</i>	downy phlox	forb	N	0.20	0.04	76.92
<i>Physalis</i> sp.	groundcherry	forb	N	0.00	0.00	0.00
<i>Physalis heterophylla</i>	clammy groundcherry	forb	N	0.02	0.01	15.38
<i>Physalis longifolia</i>	longleaf groundcherry	forb	N	0.00	0.00	0.00
<i>Physalis pumila</i>	dwarf groundcherry	forb	N	0.00	0.00	0.00

Table A-1 (continued). Cumulative species list of native plants observed in monitoring sites at Pipestone National Monument, 1998–2017. Values for mean cover, standard error (SE) and occurrence are for 2017 only. N = native.

Species	Common Name	Guild	Origin	Mean Cover (%)	SE	Occurrence (% of Sites Observed)
<i>Physalis virginiana</i>	Virginia groundcherry	forb	N	0.14	0.04	53.85
<i>Plantago patagonica</i>	woolly plantain	forb	N	0.05	0.04	23.08
<i>Platanthera praeclara</i>	Great Plains white fringed orchid	forb	N	0.01	0.01	15.38
<i>Polygonum</i> sp.	knotweed	forb	N	0.00	0.00	0.00
<i>Polygonum ramosissimum</i>	bushy knotweed	forb	N	0.00	0.00	0.00
<i>Portulaca oleracea</i>	little hogweed	forb	N	0.00	0.00	0.00
<i>Potentilla arguta</i>	tall cinquefoil	forb	N	0.05	0.03	23.08
<i>Potentilla pensylvanica</i>	Pennsylvania cinquefoil	forb	N	0.01	0.01	7.69
<i>Prenanthes racemosa</i>	purple rattlesnakeroot	forb	N	0.01	0.01	7.69
<i>Prunus americana</i>	American plum	woody	N	0.01	0.01	15.38
<i>Prunus pumila</i>	sandcherry	woody	N	0.14	0.12	23.08
<i>Psoralegium tenuiflorum</i>	slimflower scurfpea	forb	N	0.00	0.00	0.00
<i>Ratibida pinnata</i>	pinnate prairie coneflower	forb	N	0.55	0.26	69.23
<i>Rhus glabra</i>	smooth sumac	woody	N	0.82	0.81	15.38
<i>Rosa arkansana</i>	prairie rose	woody	N	2.78	1.00	76.92
<i>Rubus</i> sp.	blackberry	woody	N	0.00	0.00	0.00
<i>Rudbeckia hirta</i>	blackeyed Susan	forb	N	0.08	0.05	15.38
<i>Schedonnardus paniculatus</i>	tumblegrass	grass	N	0.00	0.00	0.00
<i>Schizachyrium scoparium</i>	little bluestem	grass	N	1.76	0.43	84.62
<i>Scirpus</i> sp.	bulrush	grass-like	N	0.00	0.00	0.00
<i>Scutellaria parvula</i>	small skullcap	forb	N	0.004	0.004	7.69
<i>Selaginella rupestris</i>	northern selaginella	fern	N	0.14	0.09	23.08
<i>Silene antirrhina</i>	sleepy silene	forb	N	0.02	0.02	7.69
<i>Silene stellata</i>	widowsfrill	forb	N	0.00	0.00	0.00
<i>Sisyrinchium</i>	blue-eyed grass	forb	N	0.00	0.00	0.00
<i>Sisyrinchium campestre</i>	prairie blue-eyed grass	forb	N	0.02	0.01	23.08
<i>Solanum</i> sp.	nightshade	forb	N	0.00	0.00	0.00

Table A-1 (continued). Cumulative species list of native plants observed in monitoring sites at Pipestone National Monument, 1998–2017. Values for mean cover, standard error (SE) and occurrence are for 2017 only. N = native.

Species	Common Name	Guild	Origin	Mean Cover (%)	SE	Occurrence (% of Sites Observed)
<i>Solidago canadensis</i>	Canada goldenrod	forb	N	2.68	0.86	69.23
<i>Solidago gigantea</i>	giant goldenrod	forb	N	0.23	0.16	15.38
<i>Solidago missouriensis</i>	Missouri goldenrod	forb	N	1.15	0.60	92.31
<i>Solidago nemoralis</i>	gray goldenrod	forb	N	0.004	0.004	7.69
<i>Sorghastrum nutans</i>	Indiangrass	grass	N	0.21	0.09	61.54
<i>Spartina pectinata</i>	prairie cordgrass	grass	N	0.17	0.15	23.08
<i>Spiraea alba</i>	white meadowsweet	woody	N	0.07	0.07	7.69
<i>Sporobolus compositus</i>	composite dropseed	grass	N	0.12	0.12	15.38
<i>Sporobolus heterolepis</i>	prairie dropseed	grass	N	2.28	0.90	76.92
<i>Sporobolus vaginiflorus</i>	poverty dropseed	grass	N	0.00	0.00	0.00
<i>Symphoricarpos occidentalis</i>	western snowberry	woody	N	0.12	0.12	15.38
<i>Symphyotrichum ericoides</i> var. <i>ericoides</i>	Squarrose white wild aster	forb	N	0.30	0.06	92.31
<i>Symphyotrichum laeve</i> var. <i>laeve</i>	Smooth wild aster	forb	N	0.40	0.10	76.92
<i>Symphyotrichum lanceolatum</i> ssp. <i>lanceolatum</i> var. <i>lanceolatum</i>	white panicle aster	forb	N	0.05	0.02	30.77
<i>Symphyotrichum novae-angliae</i>	New England wild aster	forb	N	0.02	0.02	7.69
<i>Symphyotrichum oblongifolium</i>	Aromatic wild aster	forb	N	0.06	0.05	15.38
<i>Symphyotrichum sericeum</i>	Western silvery wild aster	forb	N	0.004	0.004	7.69
<i>Teucrium canadense</i>	Canada germander	forb	N	0.004	0.004	7.69
<i>Thalictrum dasycarpum</i>	purple meadow-rue	forb	N	0.04	0.02	38.46
<i>Tradescantia bracteata</i>	longbract spiderwort	forb	N	0.14	0.06	53.85
<i>Trichostema brachiatum</i>	fluxweed	forb	N	0.00	0.00	0.00
<i>Ulmus</i> sp.	elm	woody	N	0.05	0.03	15.38
<i>Verbena stricta</i>	hoary verbena	forb	N	0.00	0.00	0.00
<i>Vernonia fasciculata</i>	prairie ironweed	forb	N	0.00	0.00	0.00
<i>Veronica peregrina</i>	neckweed	forb	N	0.00	0.00	0.00
<i>Veronicastrum virginicum</i>	Culver's root	forb	N	0.01	0.01	7.69
<i>Vicia americana</i>	American vetch	forb	N	0.08	0.04	38.46

Table A-1 (continued). Cumulative species list of native plants observed in monitoring sites at Pipestone National Monument, 1998–2017. Values for mean cover, standard error (SE) and occurrence are for 2017 only. N = native.

Species	Common Name	Guild	Origin	Mean Cover (%)	SE	Occurrence (% of Sites Observed)
<i>Viola</i> sp.	violet	forb	N	0.004	0.004	7.69
<i>Viola pedatifida</i>	prairie violet	forb	N	0.12	0.03	53.85
<i>Vulpia octoflora</i>	sixweeks fescue	grass	N	0.00	0.00	0.00
<i>Woodsia ilvensis</i>	rusty woodsia	fern	N	0.06	0.06	7.69
<i>Zanthoxylum americanum</i>	common pricklyash	woody	N	0.05	0.05	7.69
<i>Zizia aptera</i>	meadow zizia	forb	N	0.01	0.01	15.38
<i>Zizia aurea</i>	golden zizia	forb	N	0.51	0.49	23.08

Table A-2. Cumulative species list of non-native plants observed in monitoring sites at Pipestone National Monument, 1998–2071. Values for mean cover, standard error (SE) and occurrence are for 2017 only. I = introduced species (nonnative).

Species	Common Name	Guild	Origin	Mean Cover (%)	SE	Occurrence (% of Sites Observed)
<i>Asparagus officinalis</i>	garden asparagus	forb	I	0.02	0.01	23.08
<i>Bromus arvensis</i>	Japanese chess	forb	I	0.08	0.04	23.08
<i>Bromus inermis</i>	smooth brome	grass	I	10.78	3.98	92.31
<i>Cirsium arvense</i>	Canada thistle	forb	I	0.004	0.004	7.69
<i>Cirsium vulgare</i>	bull thistle	forb	I	0.01	0.01	15.38
<i>Convolvulus arvensis</i>	field bindweed	forb	I	0.01	0.01	7.69
<i>Dianthus armeria</i>	Deptford pink	forb	I	0.01	0.01	7.69
<i>Elymus repens</i>	quackgrass	grass	I	0.24	0.15	38.46
<i>Lactuca serriola</i>	prickly lettuce	forb	I	0.01	0.01	15.38
<i>Medicago lupulina</i>	black medick	forb	I	0.02	0.01	23.08
<i>Melilotus officinalis</i>	yellow sweetclover	forb	I	0.02	0.02	7.69
<i>Phalaris arundinacea</i>	reed canarygrass	grass	I	0.004	0.004	7.69
<i>Poa compressa</i>	Canada bluegrass	grass	I	0.40	0.34	15.38
<i>Poa pratensis</i>	Kentucky bluegrass	grass	I	6.93	2.01	100.00
<i>Rhamnus cathartica</i>	common buckthorn	woody	I	0.02	0.01	23.08
<i>Taraxacum officinale</i>	common dandelion	forb	I	0.08	0.02	61.54
<i>Tragopogon dubius</i>	yellow salsify	forb	I	0.02	0.01	30.77
<i>Trifolium pratense</i>	red clover	forb	I	0.004	0.004	7.69
<i>Veronica arvensis</i>	corn speedwell	forb	I	0.02	0.02	7.69

Table A-3. Species observed in 2017, but recorded to a higher level of taxonomy.

Species	Recorded to	Number of plots where observed
<i>Carex bicknellii</i>	<i>Carex</i> sp.	11
<i>Carex gravida</i>	<i>Carex</i> sp.	1
<i>Carex laeviconica</i>	<i>Carex</i> sp.	5
<i>Carex meadii</i>	<i>Carex</i> sp.	9
<i>Carex pensylvanica</i>	<i>Carex</i> sp.	1
<i>Carex pellita</i>	<i>Carex</i> sp.	5
<i>Carex praegracilis</i>	<i>Carex</i> sp.	1
<i>Dichanthelium oligosanthes</i>	<i>Dichanthelium</i> sp.	16
<i>Dichanthelium ovale</i>	<i>Dichanthelium</i> sp.	4
<i>Dichanthelium leibergii</i>	<i>Dichanthelium</i> sp.	48

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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