



Long-term Trends in Prairie Vegetation at Three National Parks

1998–2022

Natural Resource Report NPS/HTLN/NRR—2024/2623





ON THIS PAGE

Mary Short at a monitoring transect in Homestead National Historical Park in 2022.
NPS / SHERRY LEIS

ON THE COVER

From top left clockwise: reconstructed prairie at Homestead National Historical Park, reconstructed prairie at Herbert Hoover National Historic Site, Sioux Quartzite prairie at Pipestone National Monument, and reconstructed prairie at Pipestone National Monument. All photos taken in 2022.
NPS

Long-term Trends in Prairie Vegetation at Three National Parks

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Natural Resource Report NPS/HTLN/NRR—2024/2623

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National Park Service

Heartland Inventory and Monitoring Network

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Executive Summary

The Heartland Inventory and Monitoring Network has monitored plant communities in National Parks since 1998. Three of those parks in the northern tier of the network—Herbert Hoover National Historic Site (NHS), Homestead National Historical Park (NHP), and Pipestone National Monument (NM)—have reconstructed tallgrass prairie communities and were sampled concurrently in 2022. In this combined report, we describe similarities and differences among the three parks related to current vegetation and trends.

Climatically, Herbert Hoover NHS and Homestead NHP have similar temperature profiles, but Homestead NHP is drier. Pipestone NM differs from the other two parks in temperature and precipitation. Long-term climatic signals for major drought events varied by park, and moisture at Herbert Hoover NHS is likely to increase with climate change. Precipitation shifts could influence vegetation trends in the future requiring action such as flood mitigations, wildfire protections during prolonged drought, and consideration for species additions to adapt to new climate profiles.

Plant composition was similar for Herbert Hoover NHS and Homestead NHP while the combination of plant species and abundances at Pipestone NM was different from the other two parks, especially within the Sioux Quartzite community type. There appeared to be some compositional shifts over time for Homestead NHP. That trend was supported by greater species turnover at Homestead NHP than the other two parks. The reconstruction at Homestead NHP is older than that of Herbert Hoover NHS and possibly Pipestone NM, but we are unable to determine the underlying causes of species changes.

Quality assessment procedures provided a moderate level of confidence in our data with respect to botanist agreement on identifications. We met our goal of about 80% agreement in species composition. Cover class agreement was greater than 70%, with less than 4% of observations differing by more than one class.

Native species richness trends varied by park. Herbert Hoover NHS continues to gain native species while Pipestone NM is losing species. Species richness at Homestead NHP did not exhibit a directional trend. Pipestone NM tended to have less cover of forbs and grasses than the other two parks, reflecting the more complex geological landscape with surface rock. Grass abundance appears to be declining from baseline years for all three parks. Grass-like and fern guilds are much less abundant in all the parks than other plant guilds. Woody plants in 2022 were similar at Herbert Hoover NHS and Homestead NHP in terms of mean cover and heterogeneity across the prairies, but tree encroachment into the grasslands is a potential concern. Pipestone NM generally had fewer woody plants (including tree seedlings) in 2022, but the amount varied through time. Canopy closure, measured for the first time in 2022, was present in all three parks, but was greatest at Homestead NHP.

Nonnative plant cover was the greatest at Pipestone NM, but current abundance at Herbert Hoover NHS was greater in 2022 than baseline years. Homestead NHP consistently had little nonnative plant cover since 2005. Abundance (% cover) of two nonnative grasses of concern—Kentucky bluegrass

(*Poa pratensis*) and smooth brome (*Bromus inermis*)—differed by park and year. Recent increases in Kentucky bluegrass abundance at Herbert Hoover NHS might reflect changes in management.

Although these parks have individual differences in climate as well as in timing and use of management actions, they share similar histories of cultivation and reconstruction. Efforts to restore or reconstruct portions of the prairie at Pipestone NM were unique among the three parks. Future analyses might continue to combine Herbert Hoover NHS and Homestead NHP but examine Pipestone NM separately; the unique geologic history and differences in vegetation communities at Pipestone NM may make individual assessment a better option. However, comparing trends in guilds of concern, such as woody and nonnative plants, across all three parks can be helpful for gauging success with management tools in light of regional changes in climate.

Acknowledgments

We appreciate collaboration with the parks in learning about your management objectives and priorities. The work of many technicians and botanists over 24 years of monitoring provides the basis for the work we are doing today. M. Short was instrumental in collecting the 2022 data. We also appreciate GIS support from J. Haack-Gaynor and database support from G. Rowell.

Introduction

The Heartland Inventory and Monitoring Network (Heartland Network) conducts long-term vital signs monitoring of plant communities to (1) describe the current species composition, structure, and diversity of prairie, woodland, and forested communities, (2) determine temporal changes in the species composition, structure, and diversity of prairie, woodland, and forested communities, and (3) determine the relationship between temporal and spatial changes and environmental variables, including management practices where possible.

Prairie plant communities in three parks—Herbert Hoover National Historic Site (NHS), Homestead National Historical Park (NHP), and Pipestone National Monument (NM)—were most recently sampled in 2022 as part of long-term monitoring efforts. Traditionally, data for each park have been summarized and reported individually. However, as we designed the long-term analysis, we considered that analyzing and presenting data for these three parks as a regional cohort could elucidate patterns or facilitate inter-park understanding of similar resources.

Each of these parks has tallgrass prairie resources, either reconstructed or remnant prairie. Pipestone NM has both remnant and reconstructed prairie as well as a unique community, Sioux Quartzite prairie, located among the areas with Sioux Quartzite outcrops and surface rock. The three parks represent an east-west gradient, although Pipestone NM is the most northerly. All three parks were under cultivation and/or grazing at some point prior to their reconstruction and restoration efforts (Landers 1975, 1979; Becker et al. 1986). Homestead NHP has one of the oldest prairie reconstructions in the nation; planting began in 1939 (Stubbendieck and Willson 1987). The date of restoration at Pipestone NM is less clear. The western 80 acres previously under cultivation was left fallow in 1956 (Landers 1979), and some limited reseeding occurred in 1986 (Becker et al. 1986). The removal of grazing and other treatments also served to protect the remnant and Sioux Quartzite communities. Herbert Hoover NHS prairie reconstruction began in 1971, later than the other two parks (HEHO 2004; Henry 1977). All three parks have implemented prescribed fire but at different times: Pipestone NM in 1973, Homestead NHP in 1983, and Herbert Hoover NHS consistently after 1984 (Landers 1979; Stubbendieck and Willson 1987; Williams et al. 2007).

Long-term vegetation monitoring for both Homestead NHP and Pipestone NM began in 1997 while Herbert Hoover NHS monitoring began later in 2004. Monitoring design was consistent across the three parks as prescribed by the published protocol (Leis et al. 2022). Three different project leaders deployed the protocol over the 25 years of monitoring.

Our objectives for this report are to (1) describe the status and trend of the plant communities in the prairies at three National Parks, (2) learn whether species composition differs between the three parks, (3) learn whether parks with similar management resources experience similar or unique vegetation trends across their monitoring histories, and (4) provide insights into the ecology of these three parks by using a combined analysis approach.

Methods

Study Sites

Herbert Hoover NHS, Homestead NHP, and Pipestone NM are geographically in the northern tier of Heartland Network parks (Figure 1). All three parks include tallgrass prairie reconstructions as a dominant community type (Figures 2 and 3). Homestead NHP, one of the oldest prairie restorations in the U.S., also includes forest communities, which were reported on elsewhere (Leis 2023).

Pipestone NM also includes native remnant tallgrass prairie and remnant Sioux Quartzite prairie (Figure 4; Landers 1979). For this report, we summarized the three prairie communities at Pipestone NM as a single unit unless otherwise noted. Disparate summaries for Pipestone NM communities from prior monitoring events can be found in Leis and Morrison (2020).

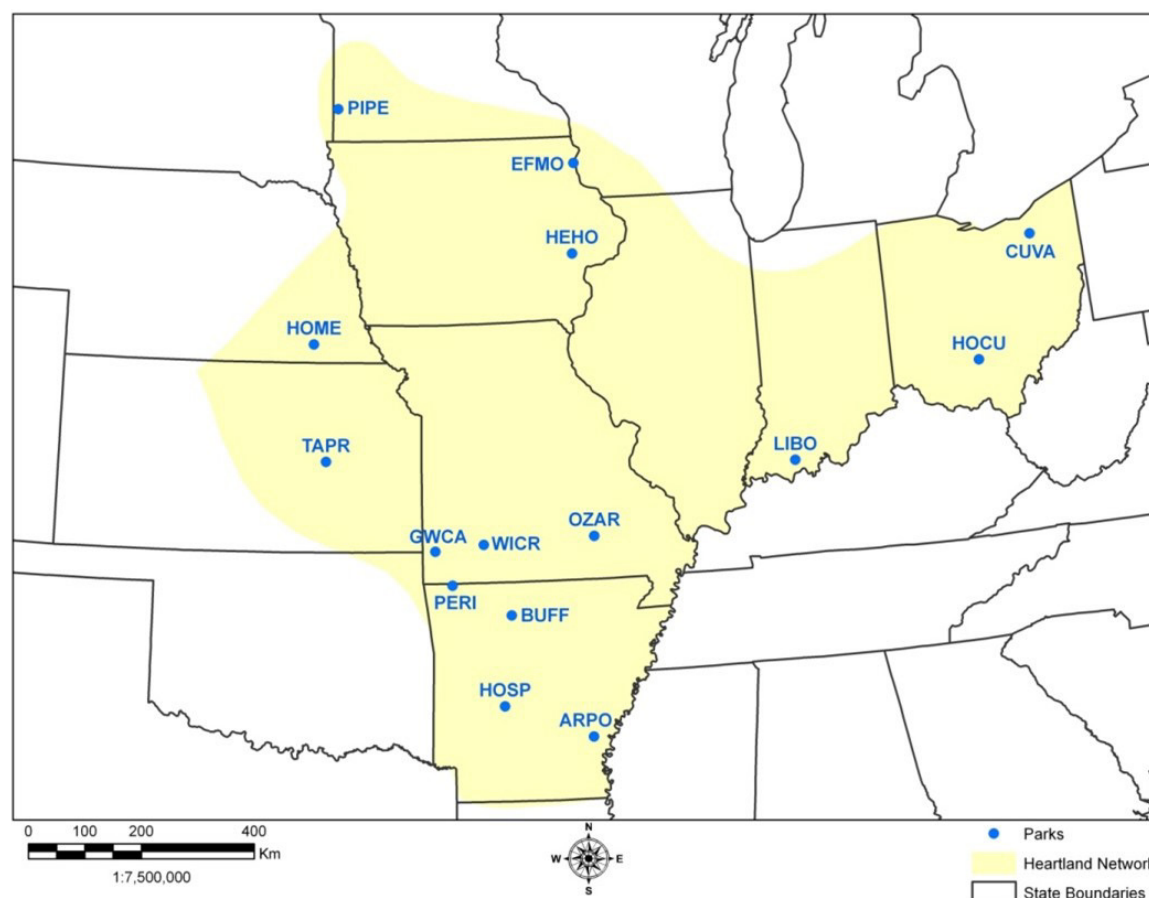


Figure 1. National parks monitored as part of the plant community vital sign project within the Heartland Inventory and Monitoring Network. ARPO = Arkansas Post National Memorial, BUFF = Buffalo National River, CUVA = Cuyahoga Valley National Park, EFMO = Effigy Mounds National Monument, GWCA = George Washington Carver National Monument, HEHO = Herbert Hoover National Historic Site, HOCU = Hopewell Culture National Historical Park, HOME = Homestead National Historical Park, HOSP = Hot Springs National Park, LIBO = Lincoln Boyhood National Memorial, OZAR = Ozark National Scenic Riverways, PERI = Pea Ridge National Military Park, PIPE = Pipestone National Monument, TAPR = Tallgrass Prairie National Preserve, WICR = Wilson's Creek National Battlefield.

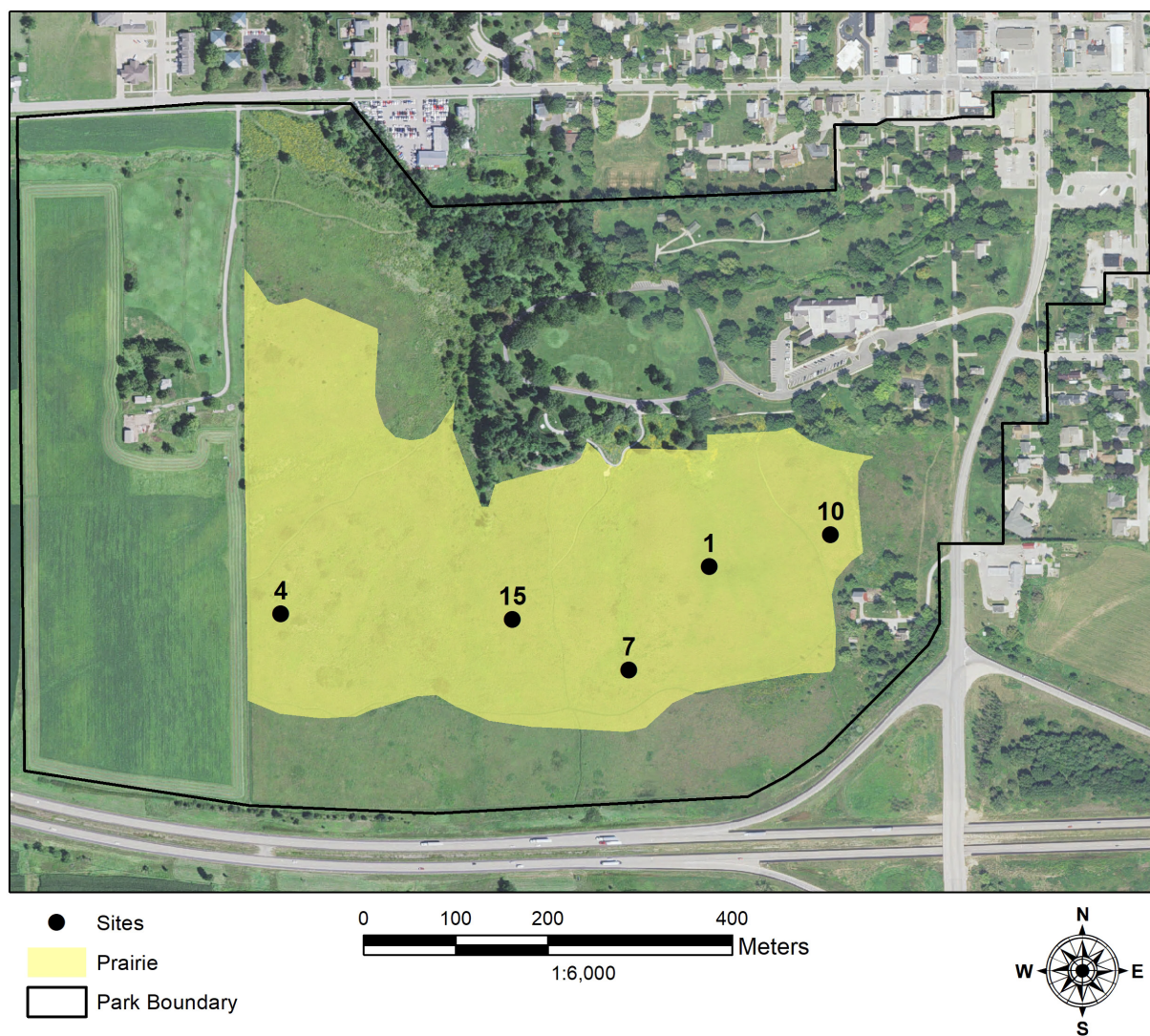


Figure 2. Heartland Inventory and Monitoring Network reference frame and vegetation monitoring sites at Herbert Hoover National Historic Site, Iowa.

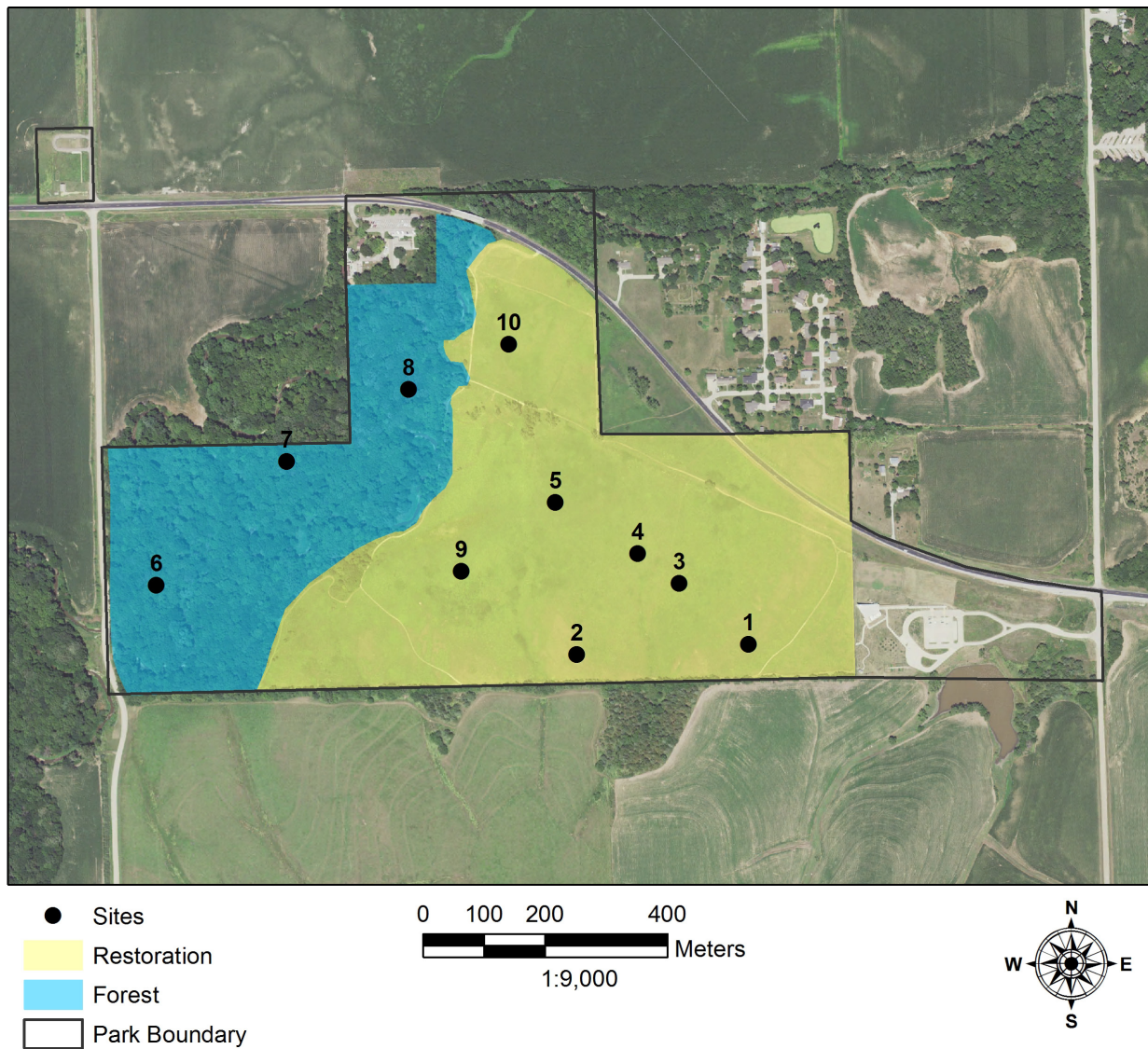


Figure 3. Heartland Inventory and Monitoring Network reference frame and vegetation monitoring sites at Homestead National Historical Park, Nebraska.

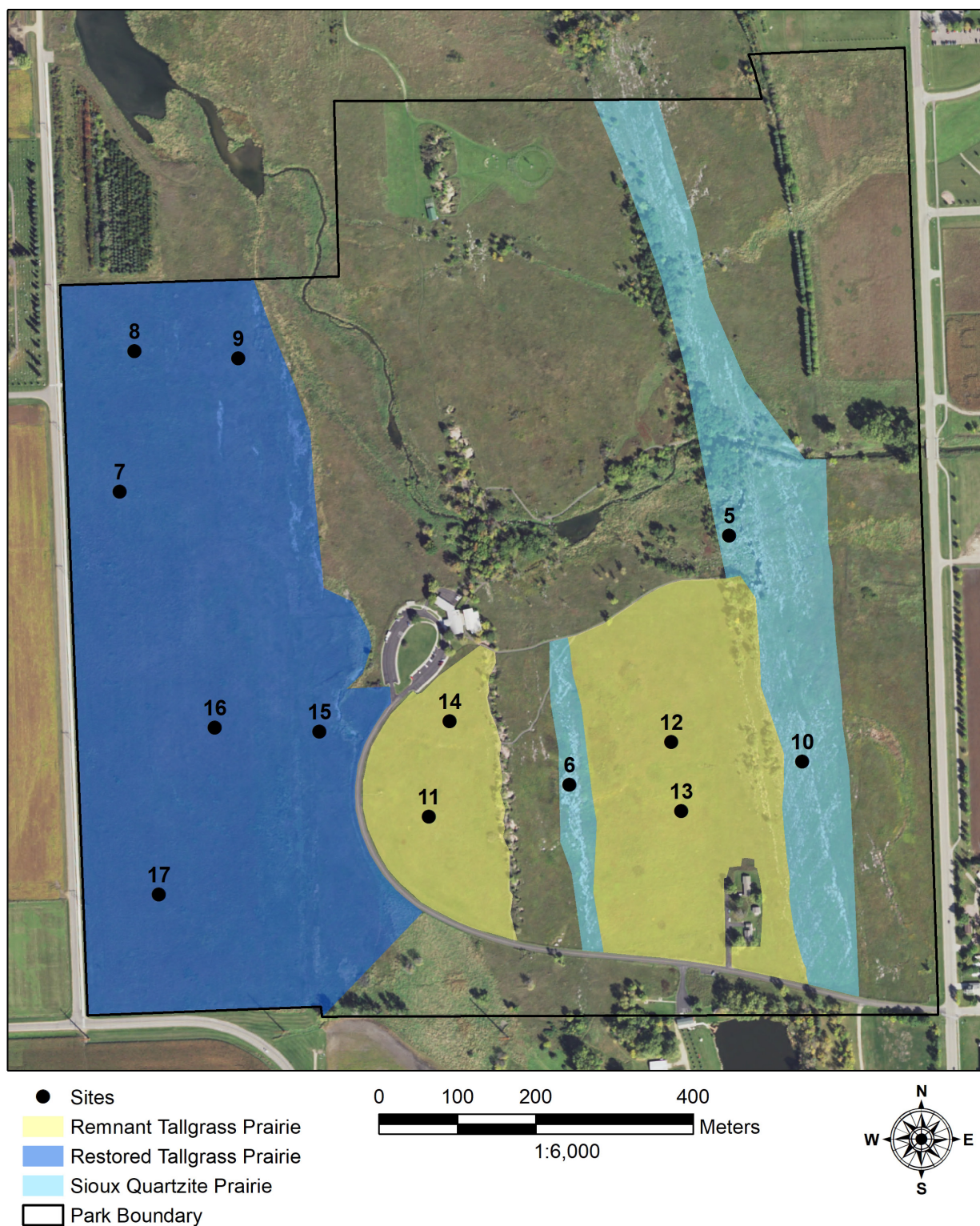


Figure 4. Heartland Inventory and Monitoring Network reference frame and vegetation monitoring sites at Pipestone National Monument, Minnesota.

All three parks reside within a 3.7° band of latitude. Pipestone NM is the farthest north, Homestead NHP is the farthest west, and Herbert Hoover NHS is the farthest east. Herbert Hoover NHS receives 236.5 mm more precipitation annually than Pipestone NM, the driest park. Across the three parks, average annual temperatures differ by only 0.5°C, while average maximum and minimum temperatures differ by 4.0°C and 3.7°C, respectively. Pipestone National Monument is the driest and coolest and Homestead NHP is the hottest of the three parks based on the 1981–2010 30-year climate normal (NOAA 2023).

All three parks have similar management tools available, such as prescribed fire, herbicide treatment, brush hogging, seeding, and cutting treatments. Each park also has an extensive fire history, primarily composed of prescribed fire operations, and wildfire is rare (Leis 2022b). Both Pipestone NM and Herbert Hoover NHS are adjacent to or embedded within an urban matrix. Homestead NHP, although about 4 miles from an urban center, does have a housing development adjacent to it. None of these parks include domestic grazing programs.

Monitoring Design

Monitoring methods followed the standard operating procedures outlined in the vegetation community monitoring protocol (Leis et al. 2022a). 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 5). All 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.

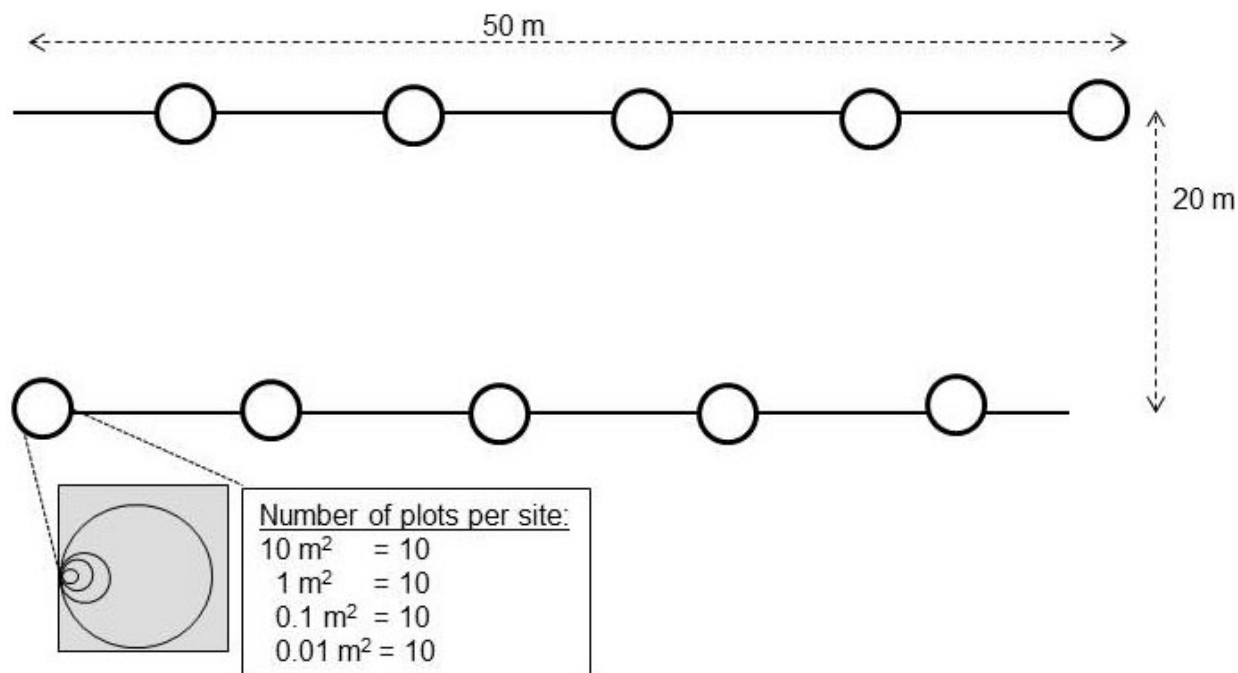


Figure 5. Heartland Inventory and Monitoring Network basic long-term vegetation monitoring sampling site design. Each site consists of 10 nested plots.

Tree regeneration, ground cover, 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 Inventory and Monitoring 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

Sampling histories, with the exclusion of 2022, were detailed in Leis (2019), Leis and Morrison (2020), and Leis and Young (2018; Table 2). Data were included for Homestead NHP and Pipestone NM for sample events beginning in 1998 and Herbert Hoover NHS in 2004. In 2009, the revisit design changed (DeBacker et al. 2004; James et al. 2009) from two visits per season (mid-May, early October) with two consecutive years of sampling and three years of no sampling to one visit per season (June–July) with sampling occurring every four years. Conversion of the two visits per season sampling to a single dataset was done by using the maximum cover of the two seasons for each species observed. See Leis et al. (2022a) for additional details on sampling design (Table 3).

Table 2. Number of sample sites for each monitoring event included in the analysis, by park (Herbert Hoover National Historic Site, Homestead National Historical Park, and Pipestone National Monument). NA indicates park was not sampled that year.

Sampling Year	Herbert Hoover National Historic Site (# of sites)	Homestead National Historic Park (# of sites)	Pipestone National Monument (# of sites)
1998	NA	5	10
1999	NA	5	10
2001	NA	5	10
2002	NA	3	3
2004	4	NA	NA
2005	6	5	10
2006	NA	5	10
2009	6	7	13
2013	6	7	13
2017	6	7	13
2022	5	7	13

Table 3. Plant community sampling dates for three national parks.

Park	Dates sampled in 2022
Herbert Hoover National Historic Site	10–12 July 2022
Homestead National Historical Park	21–25 June 2022
Pipestone National Monument	6–11 June 2022

Data Summary and Analysis

Climate

Climate data were obtained via [The Climate Analyzer](https://climateanalyzer.org/) in graph form (climateanalyzer.org). We used the filter for the Heartland Network parks and chose National Weather Service Cooperative Observer Network Stations (COOP) with adequate record lengths as close to the park as possible. Graphs were downloaded from the website.

Observer Error

Interobserver error was assessed for species composition, cover estimation, litter depth, regeneration, and ground cover using a double sampling method (Leis et al. 2022b). We aimed to double sample at least 10% of the plots in each prairie. At each site where observer error was measured, two plots, one from each transect, were randomly chosen for resampling. Sampling teams switched transects and

sampled the ground flora in the randomly chosen plots. Pseudoturnover was calculated by comparing the two species lists from each plot and identifying species that were overlooked (i.e., a species was recorded by one observer but not the other), misidentified (i.e., the same specimen was apparently recorded as different species by the two observers), or at different specificity levels (i.e., ‘cautious’ errors in which one observer identified a plant to species and the other identified it only to genus).

Pseudoturnover was calculated as in Nilsson and Nilsson (1985):

$$\frac{A + B}{S_A + S_B} * 100$$

Where A was the number of species recorded exclusively by observer 1, B was the number of species recorded exclusively by observer 2, SA was the total number of species recorded by observer 1, and SB was the total number of species recorded by observer 2. Pseudoturnover is expressed as a percentage. Pseudoturnover estimates are approximate because pseudoturnover was calculated at the plot level, but data are summarized at the site level. Additionally, because observer error was first measured at these parks in 2022, observer error estimates do not encompass potential greater interobserver error rates due to additional observers being previously involved in this long-term monitoring effort.

Community-level Analyses

Data summaries were created using Minitab Statistical Software (2020).

Species Richness and Composition

We calculated native species richness for sites within the prairies at the three parks. Species were filtered for origin prior to further summary. Native species richness was calculated by averaging the mean site richness of the sites sampled that year. Because monitoring sites and parks did not have the same sampling history, we could not analyze all three parks with a simultaneous, two-way test. We tested whether species richness changed directionally with time using a linear regression.

The Sørensen Index was calculated to compare changes in species composition between the initial year of sampling for each site and the most recent year. We calculated Sørensen’s index using the native species lists for each site by comparing the initial measurement to the most recent measurement. The initial observation year for all sites varied by installation date. For most sites, the most recent measurement was 2022. There were two sites at Herbert Hoover NHS where the most recent observations were in 2017 (monitoring history for each park can be found in Heartland Inventory and Monitoring Network 2021). The Sørensen Index was calculated for each site, and a park-wide mean was determined. The Sørensen Index was calculated as

$$SI = \frac{2a}{2a + b + c} * 100$$

Where *a* is number of species present in both years, *b* is the number of species present in the first year only, and *c* is the number of species present in the second year only. The Sørensen Index is expressed as a percentage, where 100% represents complete similarity and 0% complete

dissimilarity. We present changes in species composition as turnover (dissimilarity), which is simply the inverse of the Sørensen Index. We subtracted mean pseudoturnover for each park from observed turnover to provide an estimate of apparent turnover. The total apparent turnover was divided by the number of years in the record to give an annualized apparent turnover rate.

Species-abundance Relationships

Nonmetric multidimensional scaling (NMS; Kruskal 1964; Mather 1976) 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 interpoint distances reflect the redundant pattern of covariation in the original data (McCune and Grace 2002; McCune and Mefford 2016). PC-ORD (version 7.0.9) was employed to obtain the NMS solutions. Preliminary solutions were obtained using autopilot mode on the “slow and thorough” setting. This procedure was run at least three times for each data set to determine the appropriate dimensionality and evaluate the consistency of results, as recommended by Peck (2010). These runs always produced consistent results and the same dimensionality for each data set. The final NMS run for each data set employed the Sørensen 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).

Prior to analyses, rare species (i.e., species found at fewer than three sites) were removed. We calculated the ordinations with prairie sites for all three parks together as well as for each park individually. Centroids and convex hull diagrams were constructed by park, site, or year depending on the sites included in the analysis. Sites at Pipestone NM were stratified by community type to better understand the differences in plant composition.

Abundance by Guild

Species guilds were assigned as designated in the USDA Plants database (USDA NRCS 2017). Plants were filtered for origin, and native plants were summarized by guild (forb, grass, grass-like, fern, and woody). Woody plants included non-tree shrub and subshrub species. Nonnative species summaries were targeted to species of interest. Species level observations were averaged at the site and summed by guild.

Results

Climate

Climate plays an important role in determining plant community assemblages, and climatic shifts through time may be influential (Vankat 1992; Tercek et al. 2021). Herbert Hoover NHS and Homestead NHP have a similar temperature profile but differ in precipitation (Table 4). Pipestone NM is more arid and cooler than the other two parks (Table 4). Historical precipitation patterns for the three parks are presented in Figures 6, 7, and 8. Average rainfall since 1900 was greatest at Herbert Hoover NHS and least at Pipestone NM. Precipitation at Herbert Hoover NHS was below the local long-term average for most years prior to 1961 when moisture seemed to increase. At Pipestone NM, there were two distinct periods of low rainfall prior to about 1980 that coincided with known droughts of the 1930s (dust bowl) and 1950s eras. Long-term precipitation also revealed correlations with the dust bowl and 1950s drought signals for Homestead NHP, but dry periods were common until about 2009. The long-term climatic influences were relevant to Homestead NHP and to some extent Pipestone NM. The reconstruction for Homestead NHP began as the dust bowl subsided, and later climate fluctuations occurred as the planting was maturing. For Pipestone NM, the whole climate record provides context for the remnant communities in particular. Only more recent climate influences were relevant to the younger reconstruction at Herbert Hoover NHS. Although the monitoring record overlaps only a recent portion of the long-term climate record, long-term climate provides context for the historical vegetation the parks aspire to reconstruct.

Table 4. Climate normals for three national parks: Herbert Hoover National Historic Site (NHS), Homestead National Historical Park (NHP), and Pipestone National Monument (NM). Based on 30-year normals (1981–2010; NOAA 2023).

Climate Element	Herbert Hoover NHS	Homestead NHP	Pipestone NM
Annual Precipitation (mm)	954.79	791.46	718.31
Average Annual Temperature (°C)	10.7	10.7	7.2
Average Annual Maximum Temperature (°C)	16.7	17.2	13.2
Average Annual Minimum Temperature (°C)	4.8	4.2	1.1

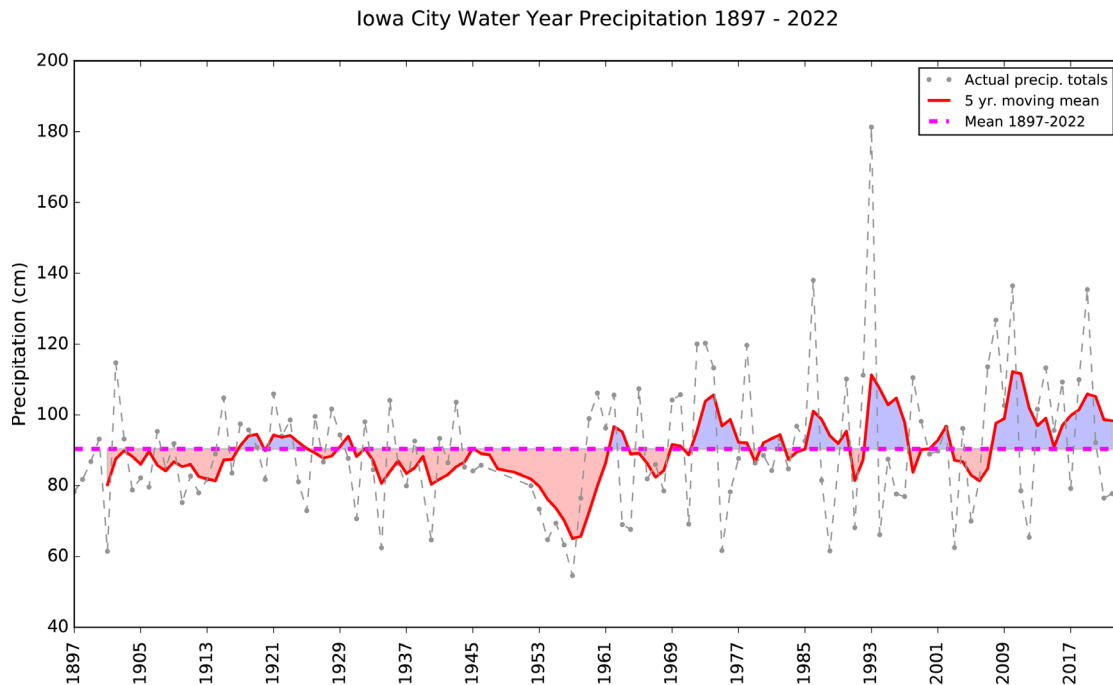


Figure 6. Annual precipitation departure from long-term mean (1897–2002 at Herbert Hoover National Historic Site (via Iowa City, IA, weather station). The running mean is based on a time series with 5.6% (7 out of 126) of values missing. Running average (solid, red line) includes current year and previous 4 years. Missing years are linearly interpolated (dashed, gray lines).

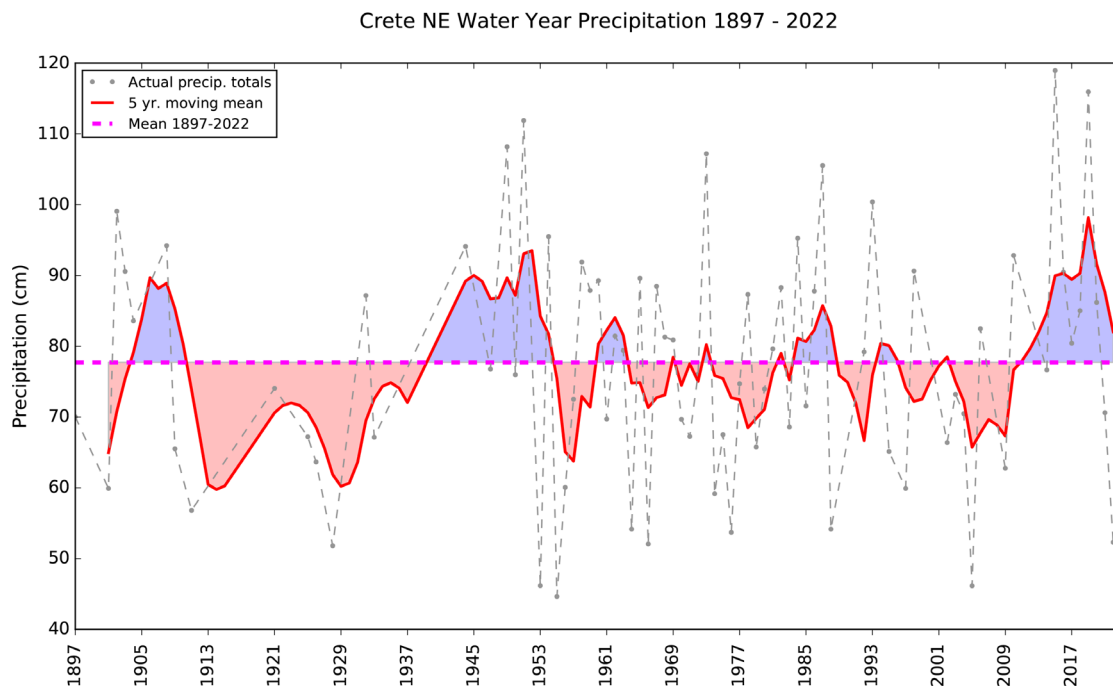


Figure 7. Annual precipitation departure from long-term mean (1897–2002) at Homestead National Historical Park (via Crete, NE, weather station). The running mean is based on a time series with 5.6% (7 out of 126) of values missing. Running average (solid, red line) includes current year and previous 4 years. Missing years are linearly interpolated (dashed, gray lines).

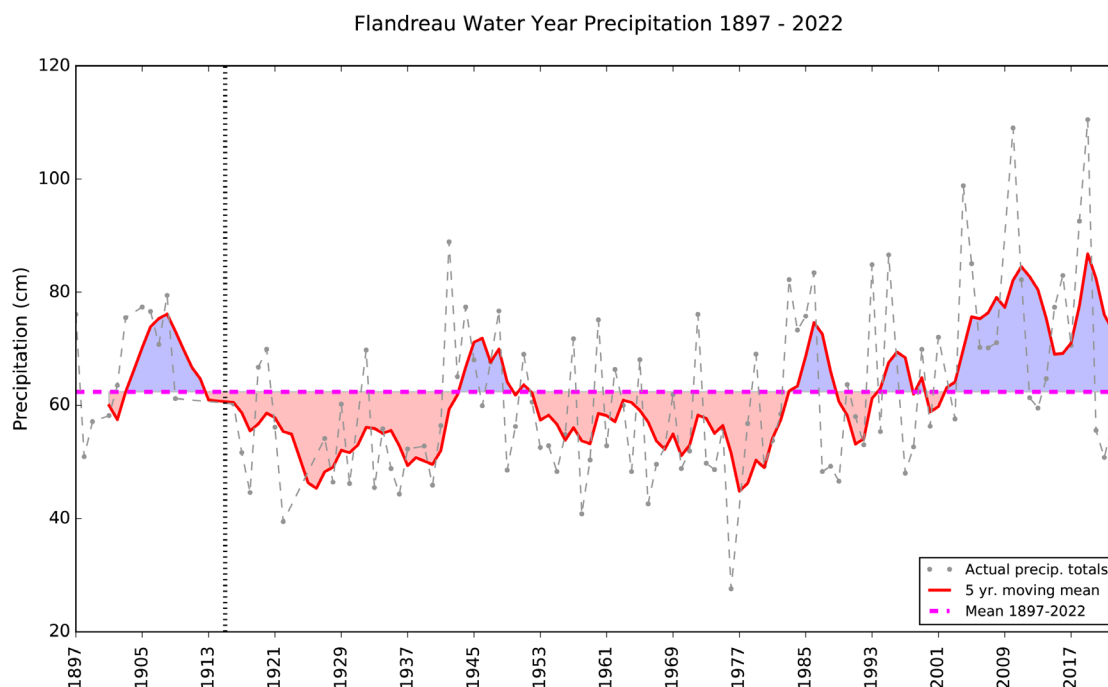


Figure 8. Annual precipitation departure from long-term mean (1897–2002) at Pipestone National Monument (via Pipestone airport weather station). The running mean is based on a time series with 5.6% (7 out of 126) of values missing. Running average (solid, red line) includes current year and previous 4 years. Missing years are linearly interpolated (dashed, gray lines).

Recent climate at Homestead NHP appeared to be within the natural range of variation in the historical record. (Monahan and Fisichelli 2014). Future climate scenarios may be more challenging to predict for southeast Nebraska. Additionally, all three parks have experienced earlier than average first leaf index dates while Pipestone NM also experienced earlier than normal first bloom index dates (Monahan et al. 2016). These climatic differences coupled with the unique geology of Pipestone NM indicate potentially unique conditions for vegetation among the three parks.

Observer Error

Species Composition and Abundance

Our goal to sample at least 10% of the plots for observer error was met at each of the parks sampled in 2022 (10.8% at Pipestone NM, 11.4% at Homestead NHP [prairie], and 10% at Herbert Hoover NHS). Although we implemented quality assurance protocols in 2018, this is the first time the procedure has been conducted in these three parks. Our goal was to minimize misidentification and achieve about 80% agreement in species composition. We came close to this goal for all three parks (Table 5). Cover class estimates agreed about 73% of the time with estimates differing by ≥ 2 classes occurring $< 4\%$ of the time for any of the parks (Table 5).

We found plant identification difficult, especially at Pipestone NM, because the spring phenology was reported to have later onset than average when we arrived, contrary to the climate analysis described above. This made grass identification challenging. We lumped wildrye (*Elymus* spp.) species and milkweed (*Asclepias* spp.) species by genus because they were not easily distinguishable

at that stage. We noted at Herbert Hoover NHS that one double-sampled plot had a great deal of disagreement compared to the others and had been read after the observer had a break to attend a meeting. We don't recommend stepping away prior to re-sampling a plot in the future. Misidentification error at Herbert Hoover NHS and Pipestone NM was greater than in other surveys we conducted (i.e., 1.4% [Leis and Morrison 2022], 0.9% [Leis 2022a], 1.6% [Leis and Short 2021]), but it was still low (Table 5). Cautious error was 0 or nearly so at all three parks.

Table 5. Observer error ground flora species composition components for three national parks sampled in 2022: Herbert Hoover National Historic Site (NHS), Homestead National Historical Park (NHP), and Pipestone National Monument (NM).

Component	Herbert Hoover NHS	Homestead NHP-Prairie	Pipestone NM
Plots Double Sampled (%)	10.0	11.4	10.8
Mean Total Pseudoturnover	21.9	20.6	21.5
Mean Overlooking Error (%)	18.8	20.0	18.1
Mean Misidentification Error (%)	3.1	0	3.2
Mean Cautious Error (%)	0.0	0.6	0.0
Equal Cover (%)	72.7	73.2	73.5
Cover ± 1 Class (%)	24.2	24.1	26.0

Tree regeneration

Our quality assurance protocol included tree regeneration observations for the first time in 2022. Plots without stem counts resulted in invalid calculations recorded as NA in Table 6. For example, at Herbert Hoover NHS only two of the plots evaluated included regeneration, whereas four check plots at Homestead NHP and no check plots at Pipestone NM included regeneration.

Table 6. Observer error in tree regeneration observations (cover class assignment) for three parks sampled in 2022: Herbert Hoover National Historic Site (NHS), Homestead National Historical Park (NHP), and Pipestone National Monument (NM).

Component	Herbert Hoover NHS	Homestead NHP-Prairie	Pipestone NM
Plots Double Sampled (%)	10.0	11.4	10.8
Mean Total Pseudoturnover	NA	NA	0
Mean Overlooking Error (%)	NA	0	0
Mean Misidentification Error (%)	0	NA	0
Mean Cautious Error (%)	0	0	0
Equal Cover (%)	60	100	100
Cover ± 1 Class (%)	40	0	0

Community-level Analyses

Species Richness

In 2022, gamma richness (park-wide richness) was 83 (87% native), 106 (94% native), and 153 (89% native) species for Herbert Hoover NHS, Homestead NHP, and Pipestone NM, respectively. A list of all species found in each park, along with their mean cover and occurrence in 2022, are presented in Appendix A. Early in the monitoring record (2004–2009), Herbert Hoover NHS had the lowest mean site richness of the three parks, but in 2017 and 2022 richness was similar to the other two parks. Values for native plant evenness (J') and Shannon diversity index (H') are provided in Appendix C for each park and year monitored.

Mean site native species richness values over time are presented in Figure 9. Note that due to the magnitude of the overlooking component of pseudoturnover, true species richness for each park may be underestimated by up to about 20%.

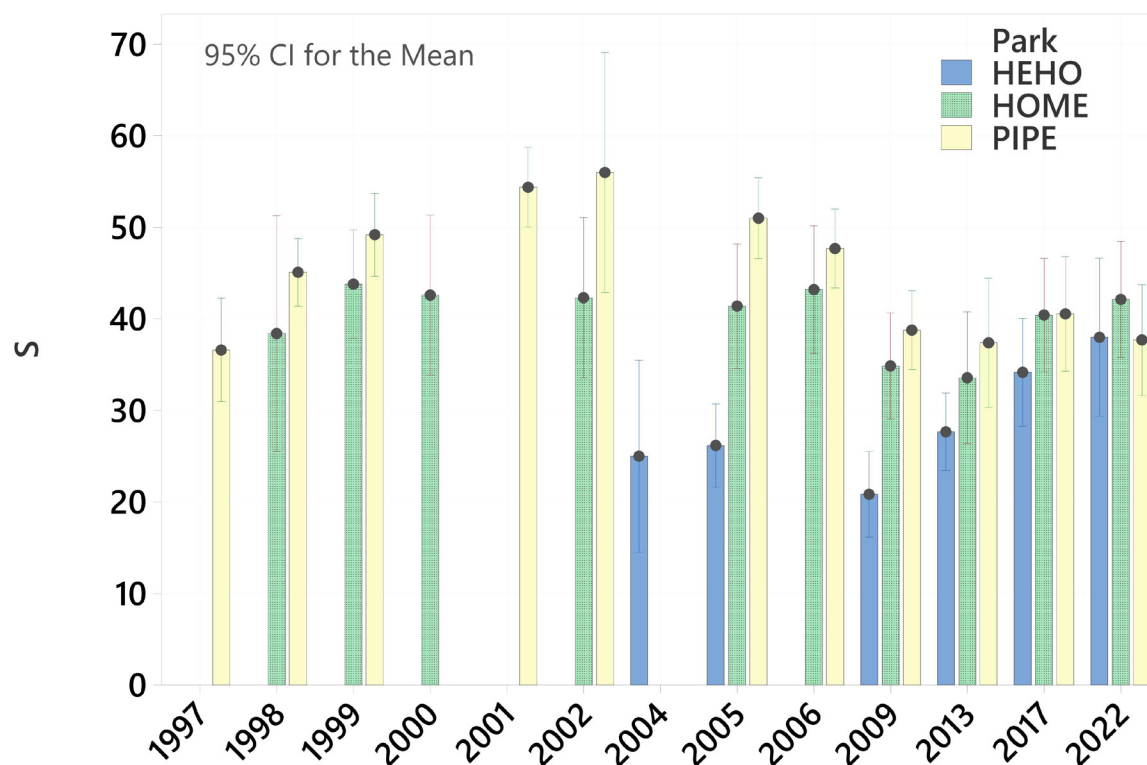


Figure 9. Average native species richness (S) among monitoring sites for three Heartland Network parks with prairie communities. Herbert Hoover National Historic Site (HEHO), Homestead National Historical Park (HOME), and Pipestone National Monument (PIPE). Individual standard deviations are used to calculate the intervals.

Plant diversity in prairie reconstructions often declines in prairie restorations over time (Wagle and Gowda 2018). But this pattern was only supported by one of the three parks. For Pipestone NM, native species richness in 2022 was about 19% less than during baseline years (Figure 10). Conversely, Herbert Hoover NHS native species richness increased by about 49% between baseline

years and 2022 (Figure 11). Species richness at Homestead NHP did not exhibit a directional trend over time (Figure 12).

Reconstruction age may have contributed to the species richness patterns we observed. When reconstruction was initiated at Herbert Hoover NHS, 51 years before the 2022 monitoring event, only five native grasses were used. Species additions over time have resulted in more native species across the prairie (Williams et al. 2007). Homestead NHP began with a similarly depauperate seed mix (7 grasses) that included nonnative plants, but planting began 83 years prior to the 2022 sample event. Homestead NHP also received native sod transplants as part of the reconstruction (Stubbendieck and Willson 1987). It is not known how the sod transplants are spatially related to the monitoring sites. The Homestead NHP reconstruction occurred 51 years prior to initiation of long-term monitoring, so we do not know the pattern of plant community richness at that restoration age. In addition to differences in management and climate, we may be observing a different stage of the maturation of each of these prairies.

The prairie restoration age at Pipestone NM is somewhat ambiguous and although some seed additions occurred, the prairie was left fallow for some years. Adjacent remnant prairie may also be considered a source of propagules.

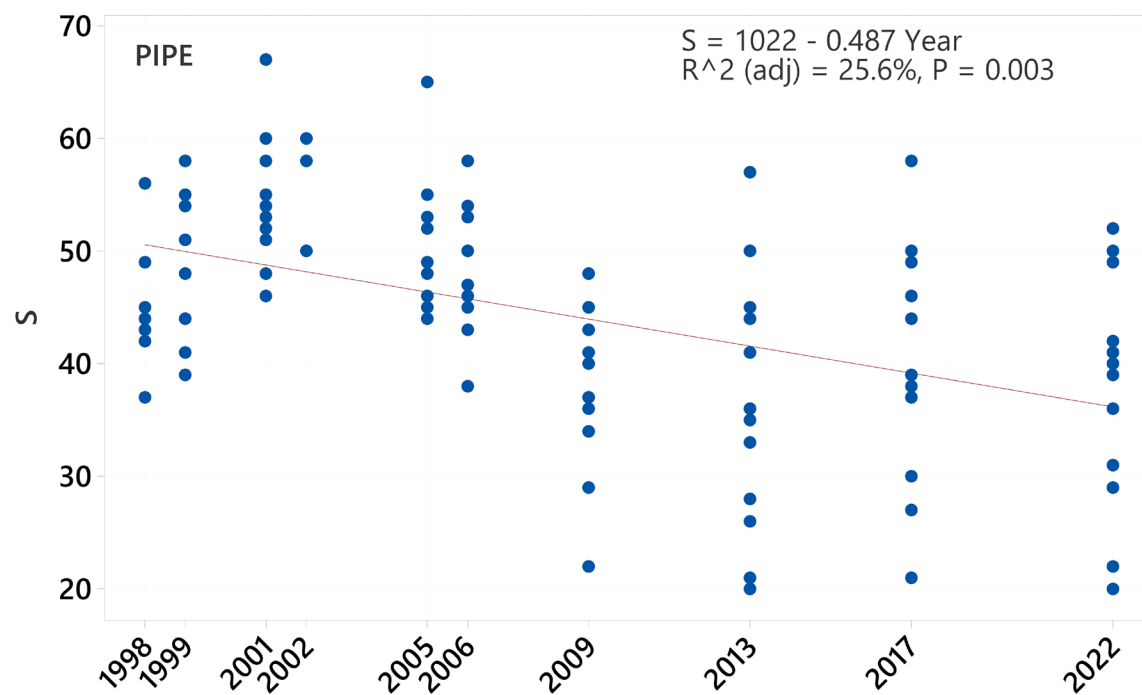


Figure 10. Native species richness (S) plotted for each site by monitoring year for Pipestone National Monument.

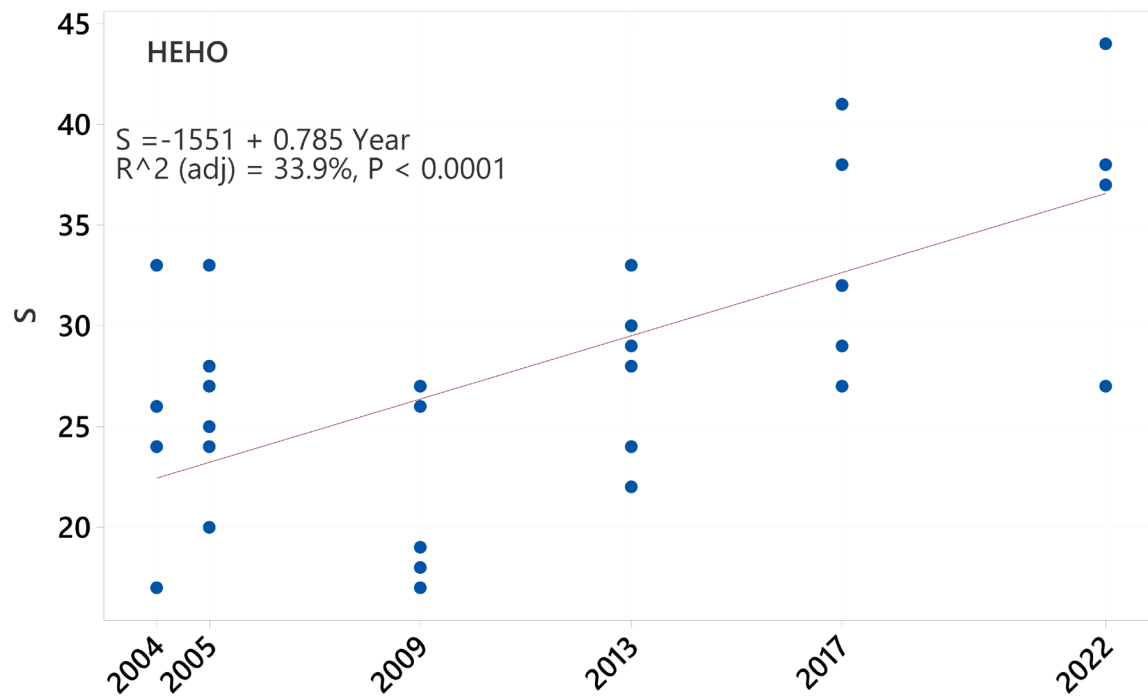


Figure 11. Native species richness (S) plotted for each site by monitoring year for Herbert Hoover National Historic Site (HEHO).

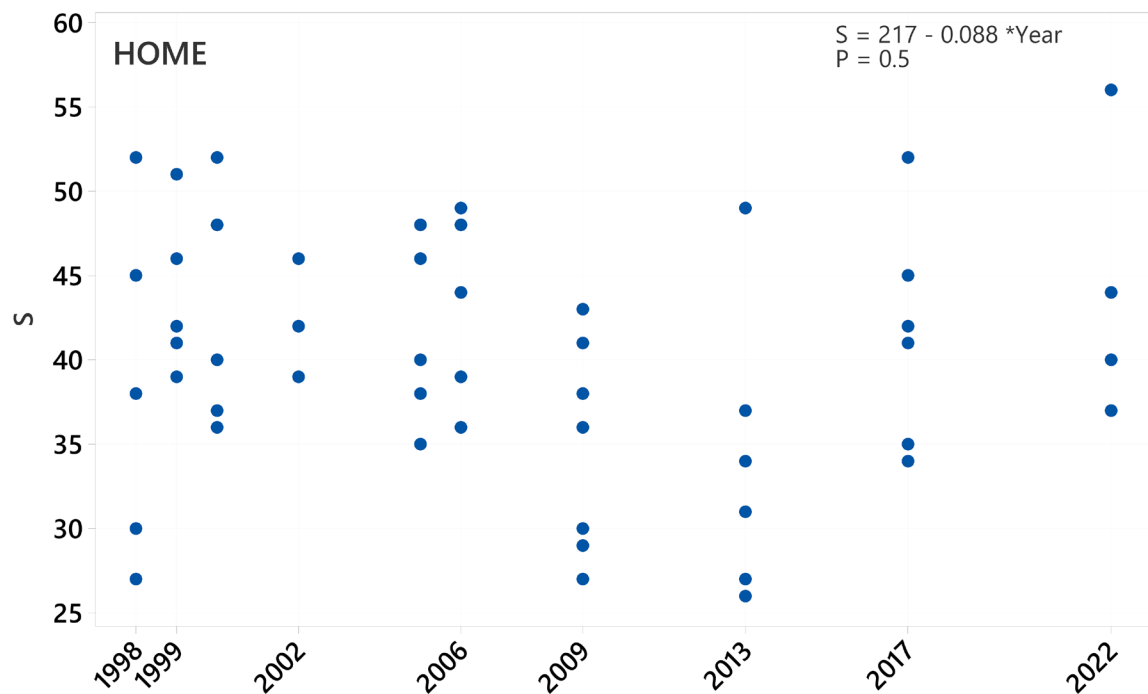


Figure 12. Native species richness (S) plotted for each site by monitoring year for Homestead National Historical Park (HOME).

Species Composition and Turnover

The Sørensen Index revealed relatively large changes in the communities. When stated as turnover (the inverse of the Sørensen Index; Table 7, column 2), there was an approximately 30–40% change in species compositions over entire monitoring intervals (which varied by park). However, if pseudoturnover (Table 7, column 3) is taken into account, the change in species composition based on the Sørensen Index (i.e., mean turnover) was considerably less compared to the uncorrected values (Table 7, column 4). Homestead NHP experienced the greatest level of species turnover among the three parks. Using the corrected values for turnover, we found that annual turnover was less than 1 species/year at Herbert Hoover NHS and Pipestone NM, but slightly more (1.1 species/year) at Homestead NHP. However, our correction for pseudoturnover is only an approximated estimate since observer error was measured at the plot scale rather than at the site scale.

Table 7. Species turnover (Sørensen Index) in ground flora for three parks sampled in 2022.

Park	Mean Total Dissimilarity— Turnover (% species/year)	Approximate Mean Pseudoturnover (% species/year)	Mean Turnover from Initial Year to Most Recent (% species/year)	Mean Annualized Turnover (% species/year)
Herbert Hoover NHS	32.6	18.6	14.0	0.86
Homestead NHP-prairie	41.3	20.0	21.3	1.1
Pipestone NM	34.4	21.2	13.3	0.67

Species-Abundance Relationships

Stress scores, the most important diagnostic indicator of ordination usefulness, ranged from 10 to 15 (Table 8), which are in the good to fair range (Kruskal 1964; Clarke 1993). Most ecological data sets have stress between 10 and 20, and values below 15 are usually considered quite satisfactory (McCune and Grace 2002). The final solutions for all data sets had a dimensionality of three, with the sole exception of the Pipestone NM Sioux Quartzite prairies data set, which was two-dimensional. All ordination graphs presented are two dimensional, and in the interest of saving space we do not present all the possible combinations of ordination graphs (i.e., axes 1 x 2, axes 1 x 3, axes 2 x 3), but instead selected axes that best illustrate the patterns of interest.

Table 8. Nonmetric multidimensional scaling results for Herbert Hoover National Historic Site (NHS), Homestead National Historical Park (NHP), and Pipestone National Monument (NM), 1998–2022.

Data Set	Community	Dimensions	Nonmetric Fit (R²)	Instability	Iterations	Final Stress
All Three Parks	Prairie	3	0.98	0	111	12.83
Homestead NHP	Reconstructed	3	0.99	0	42	10.24
Pipestone NM	Remnant	3	0.99	0	98	11.14
Pipestone NM	Reconstructed	3	0.98	0	72	13.09
Pipestone NM	Sioux Quartzite	2	0.98	0	63	15.69
Pipestone NM	All prairie types	3	0.98	0	78	13.34
Herbert Hoover NHS	Reconstructed	3	0.98	0	78	13.69

The analysis with all three parks together produced a three-dimensional solution. Convex hulls (which contained all sites for each park/prairie category) for Pipestone NM had little overlap with Homestead NHP and Herbert Hoover NHS along axes 1 and 2 (Figure 13). However, sites at Herbert Hoover NHS were mostly contained within the Homestead NHP convex hull, indicating site compositions and abundances were similar (Figure 13). The ordination results verify the uniqueness of the Sioux Quartzite community as compared to the other community types at Pipestone NM and compared to the communities at the other two parks (Figure 13). Within both the three-park and Pipestone NM-only ordinations, the Sioux Quartzite remnant prairie sites were plotted distinctly without overlapping any of the other community types (Figure 14). The reconstructed tallgrass prairie at Pipestone NM also had a smaller convex hull than the remnant prairie, which may be reflective of a smaller pool of species (Leis and Morrison 2020). Furthermore, the 2009 sample event at Pipestone NM stood out from other years (Figure 14). Trip notes indicate that sampling took place about four weeks post-prescribed fire. The vegetation recovery had not progressed enough to resemble the typical species and cover observed in other years.

Within park ordinations for Pipestone NM native remnant community and Homestead NHP indicated that the first two years of sampling (1998–1999) resulted in different species-abundance relationships than in other years (Figures 15 and 16). Previous reports for Homestead NHP and Pipestone NM noted that cover estimation may not have been well calibrated in those early years and overestimation compared to other years was possible (Leis 2019; Leis and Morrison 2020). Despite the potential sampling error for 1998–1999, there appears to be a shift in species composition through time for these two parks.

In the Homestead NHP-only ordination, sites 3, 4, and 9 appeared to have similar communities, but 1, 2, 5, and 10 were differentiated from the other three (Figure 17). Sites 1 and 2 are higher on the slope and may represent a dryer, sandier soil type than the other sites. Site 10 may also have a different management history than the other sites.

Herbert Hoover NHS sites demonstrated some compositional separation depending on which axes were included in the Herbert Hoover NHS-only ordination. For example, along axes 1 and 2, site 4 composition was distinct from the other sites (Figure 18).

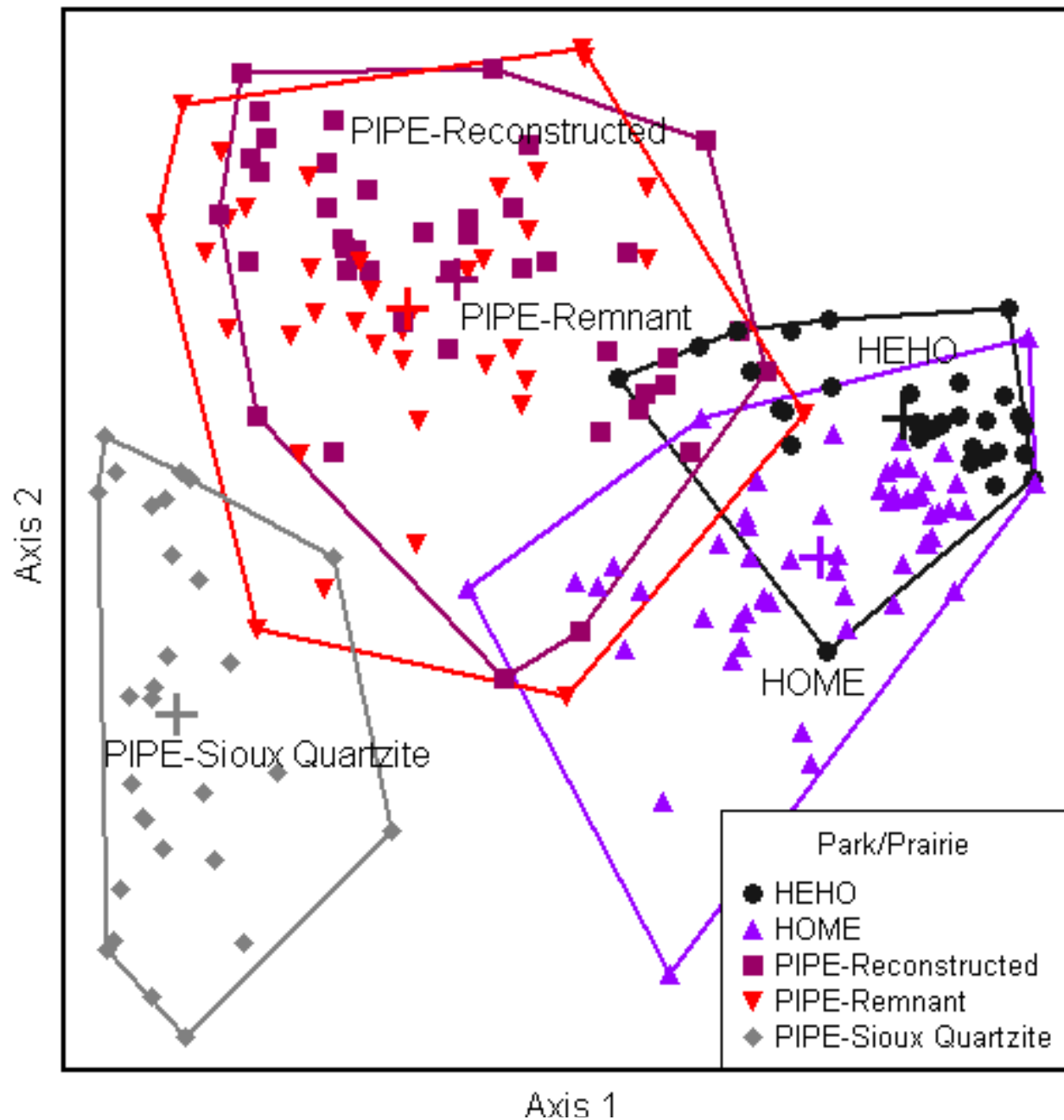


Figure 13. Prairie plant community ordination results (axes 1 and 2) for three parks (Herbert Hoover National Historic Site [HEHO], Homestead National Historical Park [HOME] and Pipestone National Monument [PIPE]), with convex hulls by park-community combinations.

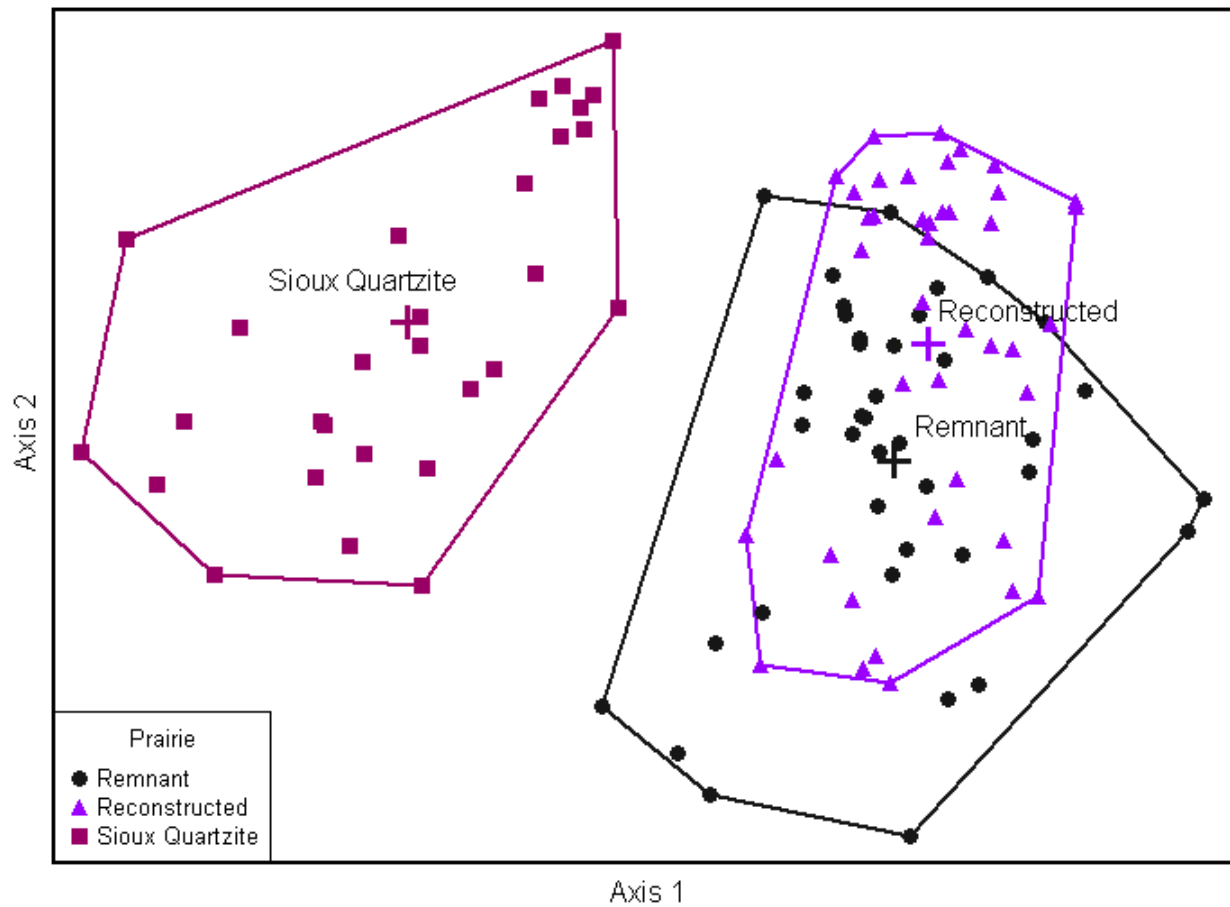


Figure 14. Prairie plant community ordination results for three community types at Pipestone National Monument (axes 1 and 2).

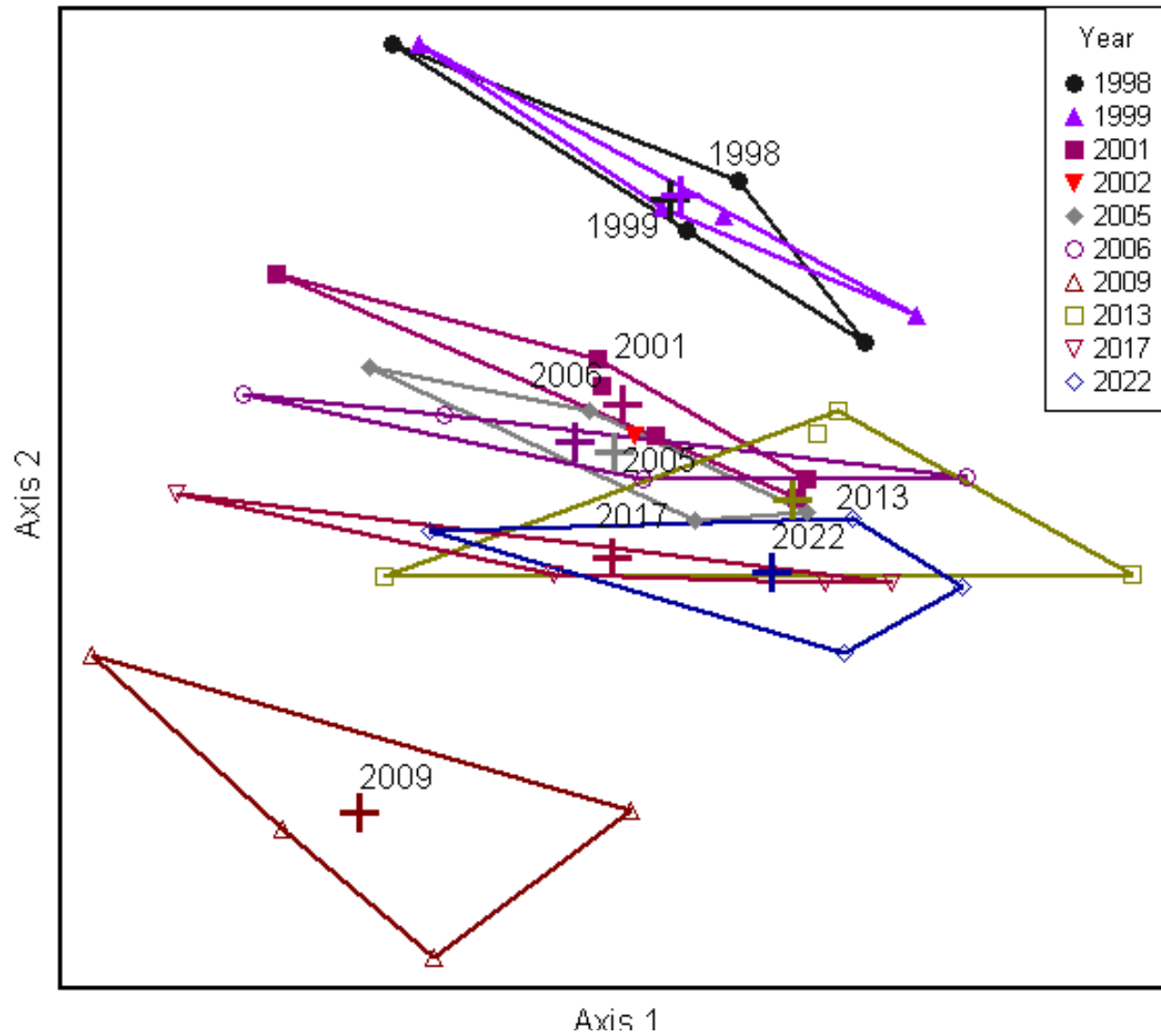


Figure 15. Ordination results for prairie plant community species by year at Pipestone National Monument remnant community.

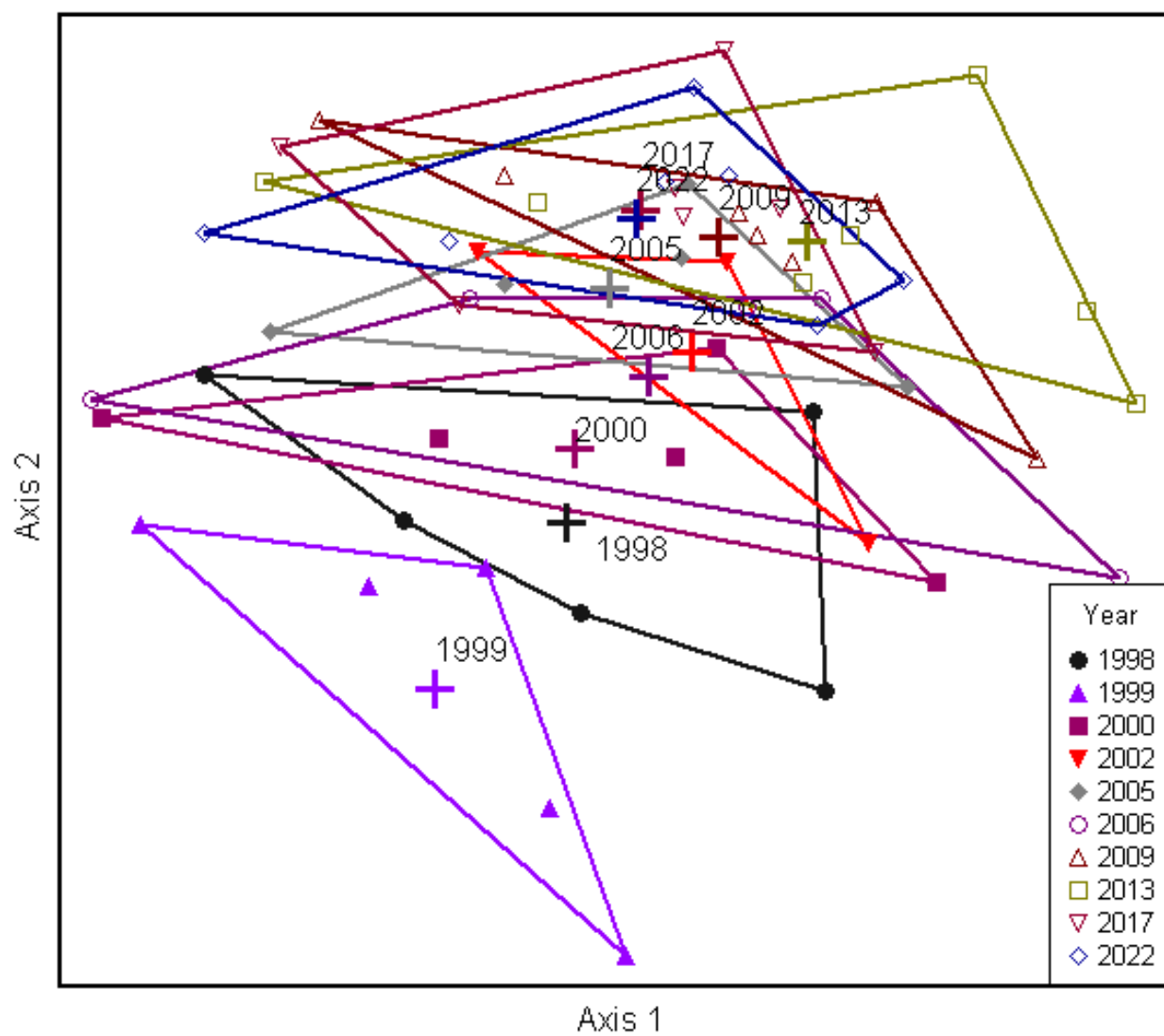


Figure 16. Ordination results for prairie plant community species by year at Homestead National Historical Park.

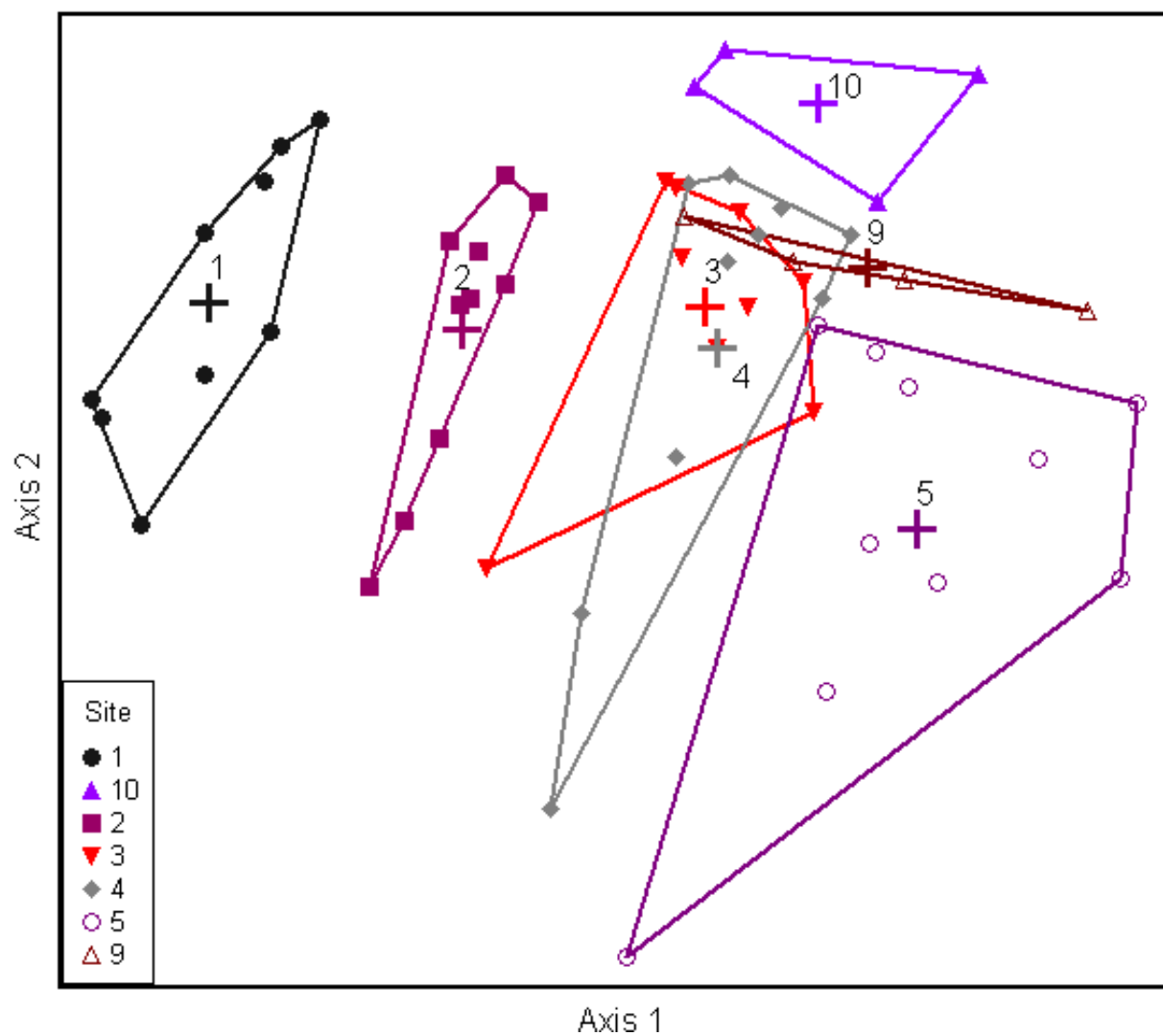


Figure 17. Ordination results for Homestead National Historical Park. Axes 1 and 2 shown with convex hulls grouped by monitoring site.

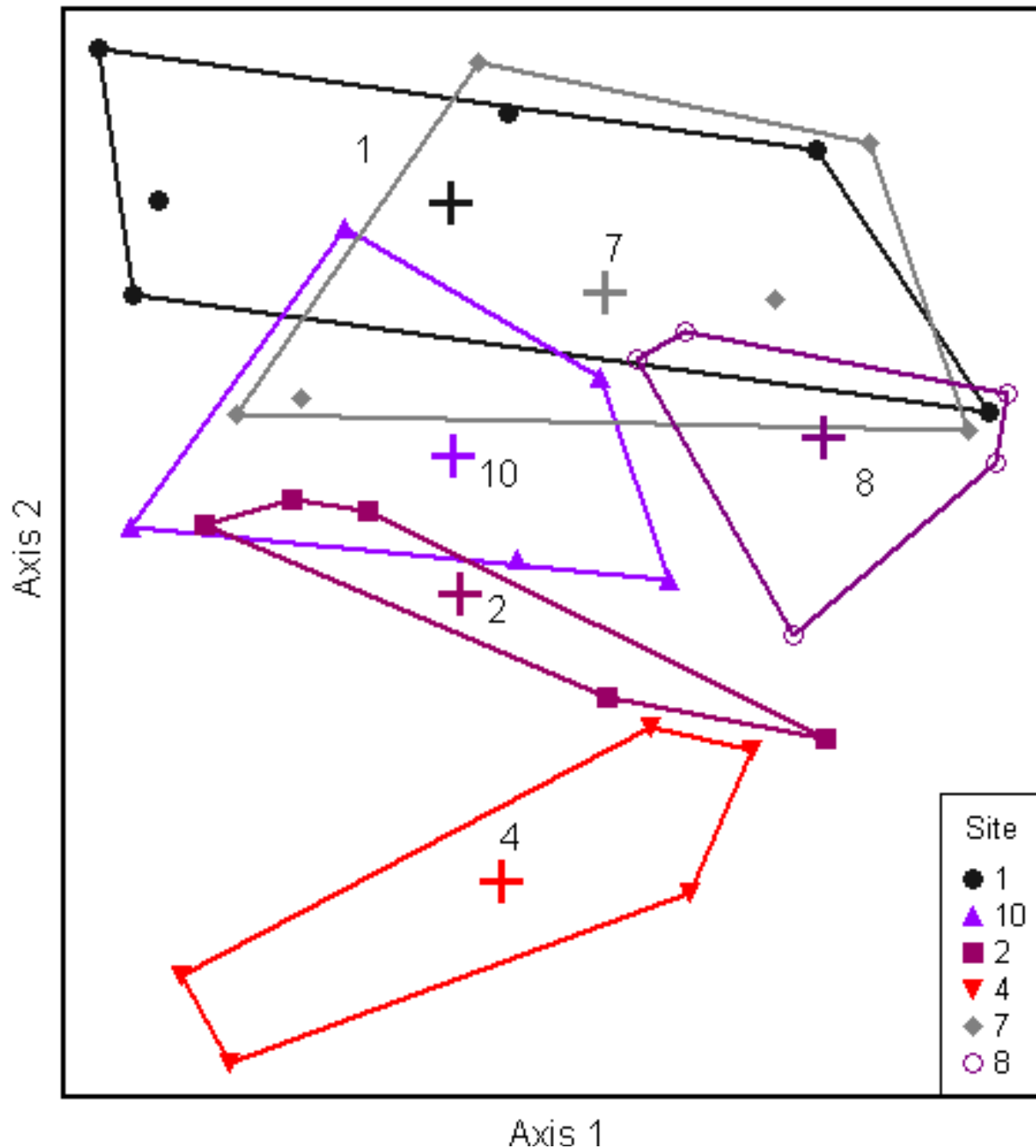


Figure 18. Ordination results for Herbert Hoover National Historical Site. Axes 1 and 2 shown with convex hulls grouped by monitoring site.

Guild Trends

Across the last four monitoring events (2009 and forward), we observed less native forb cover at Pipestone NM than at Herbert Hoover NHS and Homestead NHP (Figure 19). Pipestone NM and Homestead NHP experienced a decline in forb cover from baseline years and less so from 2009 forward. The reduction of native forb cover may be related to a change in either estimation calibration (around 2000) or the change in sampling design from two to one sample event per

monitoring year (2009). Cover estimates for species whose biomass peaks late in the season may have been most affected by the design change.

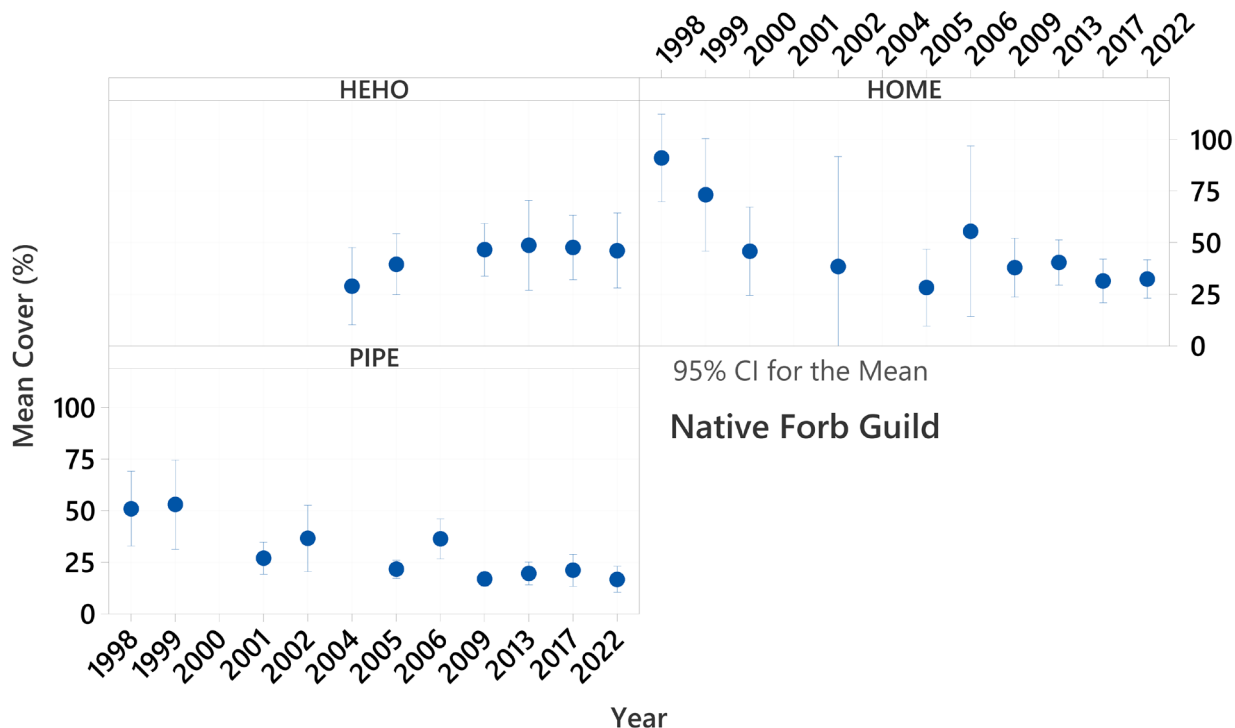


Figure 19. Native forb plant guild cover (%) for three Heartland Network parks with prairie communities: Herbert Hoover National Historic Site (HEHO), Homestead National Historical Park (HOME), and Pipestone National Monument (PIPE). Individual standard deviations are used to calculate the intervals.

All park estimates seem to be more consistent since 2009 when the design change was implemented. Cover estimates in 1998 and 1999 were much greater than in other years, potentially the result of poor calibration of staff observations, although Homestead NHP also showed a great deal of variability in 2002 and 2006. Canada goldenrod (*Solidago canadensis*) was the most abundant forb at Homestead NHP (2022 mean = 13.1% $\pm$ 4.2 SE) and Herbert Hoover NHS (2022 mean = 25.4% $\pm$ 5.93 SE). While the most abundant forbs at Pipestone NM in 2022 were northern bedstraw (*Galium boreale*) and Canada goldenrod, they were less abundant (2.4% $\pm$ 2.11 SE and 2.1% $\pm$ 1.1 SE, respectively) than in Homestead NHP and Pipestone NM. We recorded 92 (79 native, 13 nonnative) forb species at Herbert Hoover NHS through time, 173 (162 native, 11 nonnative) at Homestead NHP, and 198 (160 native, 38 nonnative) at Pipestone NM.

Since 2006, grasses were less abundant in Pipestone NM than in the other two parks (Figure 20). The Sioux Quartzite prairie sites are very rocky and have less grass cover than restored prairie sites, possibly reducing the overall mean. Patterns vary by park, however. Grass cover at Herbert Hoover NHS was 38% less in 2017 than in 2013 but estimates for 2017 and 2022 were within the range of the initial two years of sampling. It is unclear whether this pattern is influenced by the lack of prescribed fire (last burn in 2011) or some other factor. Homestead NHP native grass cover varied by year, but native grass was 59% less in 2022 than in 1998. Variability in 2002 at Homestead NHP

maybe related to only three sites being sampled that year. All three parks had less mean native grass cover in 2022 than in baseline years. We suspected that change in sampling phenology has contributed to reduction of grass cover estimates over time in addition to sampling calibration (Leis 2019). It is not clear whether individual park phenology contributed to differing levels of grass cover from 2009 to the present.

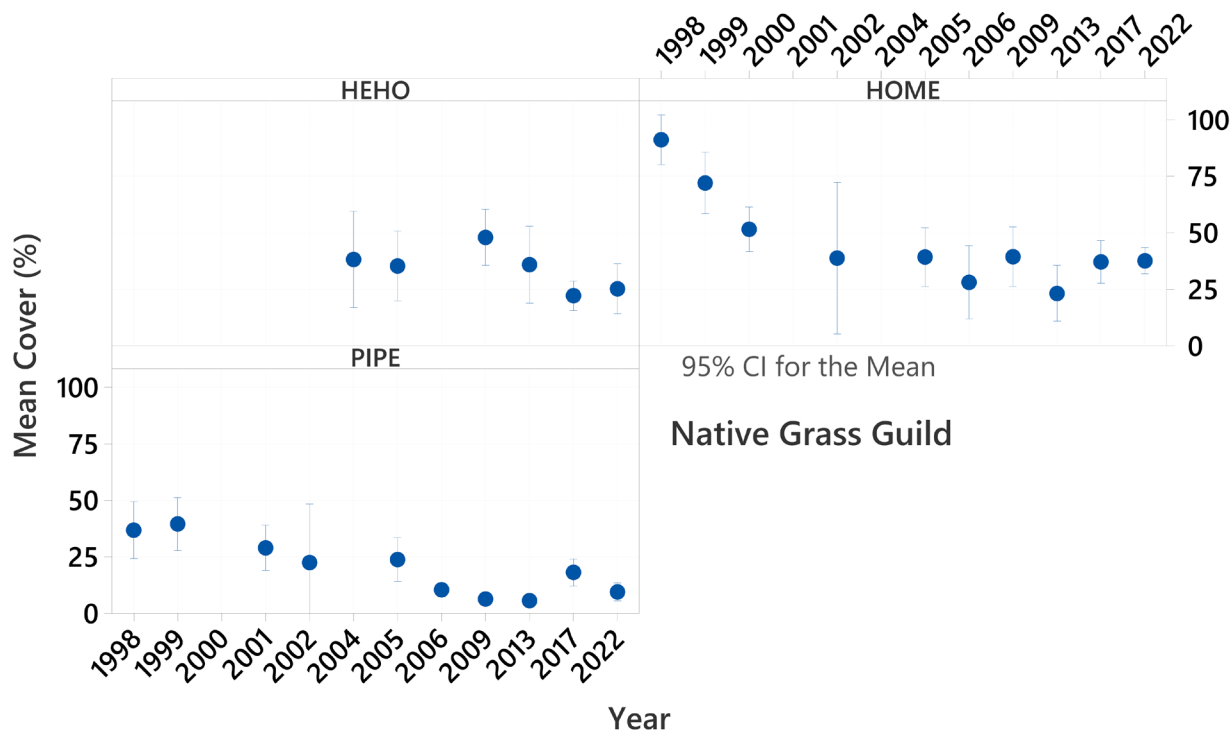


Figure 20. Native grass plant guild cover (%) for three Heartland Network parks with prairie communities: Herbert Hoover National Historic Site (HEHO), Homestead National Historical Park (HOME), and Pipestone National Monument (PIPE).

Grass-like plants included the sedges and rushes. These plants had very low abundance levels, typically < 3% cover, at all three parks (Figure 21). Grass-like plant cover was heterogeneous in the 1998–1999 baseline years with broad confidence intervals at Pipestone NM and Homestead NHP. Interestingly, at Pipestone NM grass-like plants were at their lowest mean cover during 2005–2009 but seemed to recover somewhat in 2013–2022. Sedges and rushes are often lumped by genus, so species richness counts were not meaningful for this group.

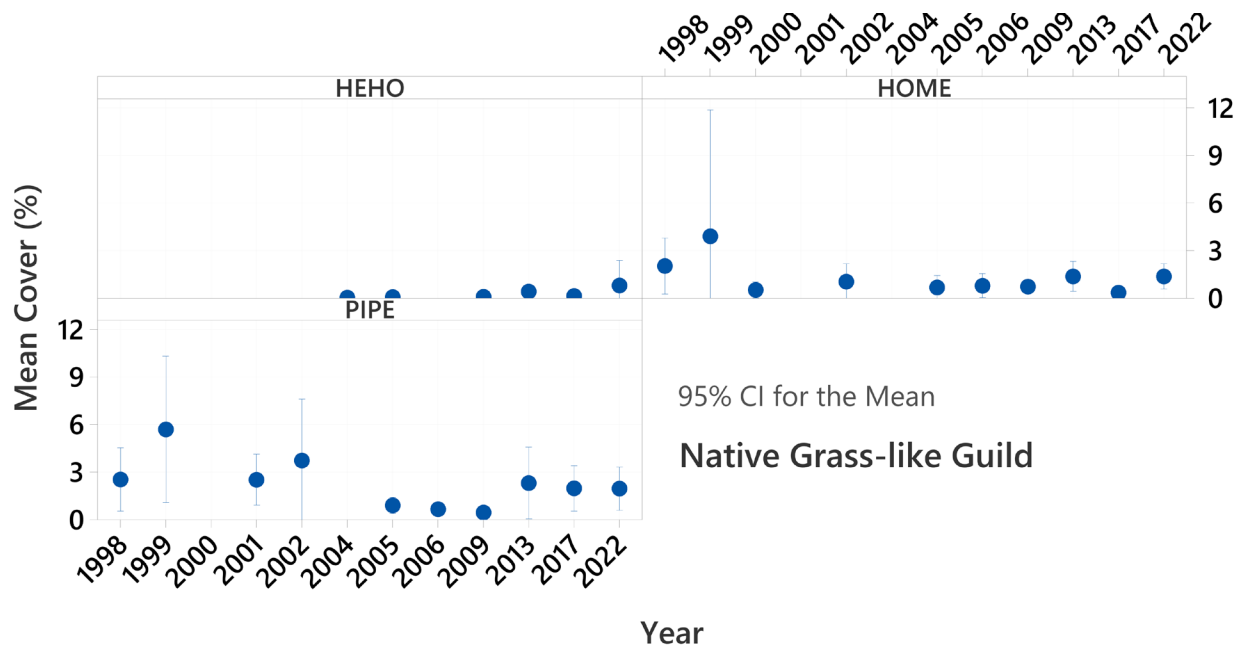


Figure 21. Native grass-like plant guild cover (%) for three Heartland Network parks with prairie communities: Herbert Hoover National Historic Site (HEHO), Homestead National Historical Park (HOME), and Pipestone National Monument (PIPE).

Ferns were uncommon in the three prairies, with no observations at Homestead NHP (Figure 22). Herbert Hoover NHS had the greatest mean observations of ferns during the period of 2005–2013, but fern abundance varied greatly by site. Herbert Hoover NHS site 4 had mean fern abundance of 8.5% in 2005 and a peak of 14.6% in 2013. Field horsetail (*Equisetum arvense*) was the only fern species observed at Herbert Hoover NHS. At Pipestone NM, six fern species were recorded with smooth horsetail (*Equisetum laevigatum*) and northern selaginella (*Selaginella rupestris*) being most common.

Native non-tree woody plants play an important role in tallgrass prairie communities but can increase beyond desirable levels without appropriate management. Community descriptions for central tallgrass prairie indicate shrubs are less than 10% of the vegetation, while in the eastern North American ruderal grassland and shrublands type, shrubs and trees are less than 25% of the vegetation (NatureServe 2017, 2018). Levels of native woody plants in 2022 were lower at Pipestone NM (mean = 3%) than the other two parks (9% at Herbert Hoover NHS and 11% at Homestead NHP; Figure 23). Herbert Hoover NHS had very low levels of native woody plants, but mean cover began to increase in 2017. At Homestead NHP, mean native woody cover ranged from 5.9% to 15.9 % with a peak in 2013. In 2022, mean site native woody cover at Homestead NHP varied between 1.4% and 32.8%. Site 5 was dominated by woody cover (Appendix B). Although Pipestone NM qualified as a shrubland community type in 1988 based on woody cover (mean = 13.3%), current levels at Pipestone NM fit within the NatureServe definition of tallgrass prairie. Current Herbert Hoover NHS and Homestead NHP estimates are very close to qualifying as shrubland types.

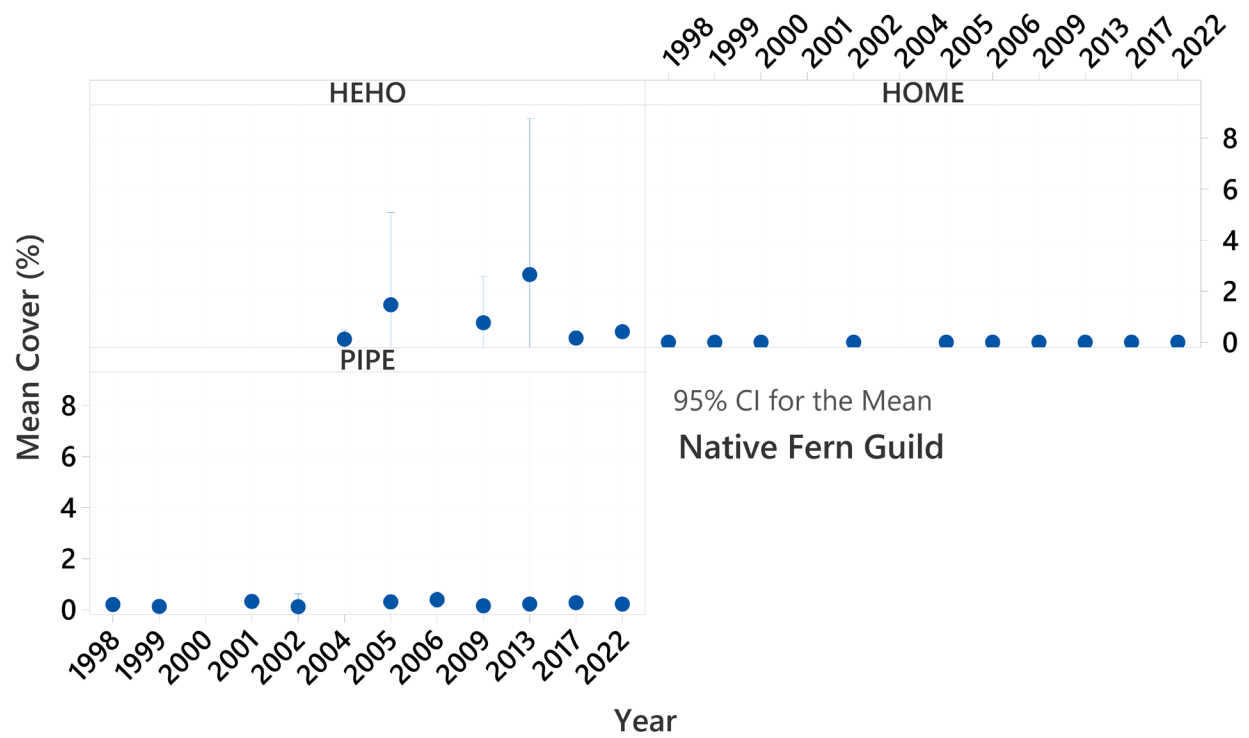


Figure 22. Fern plant guild cover (%) for three Heartland Network parks with prairie communities: Herbert Hoover National Historic Site (HEHO), Homestead National Historical Park (HOME), and Pipestone National Monument (PIPE).

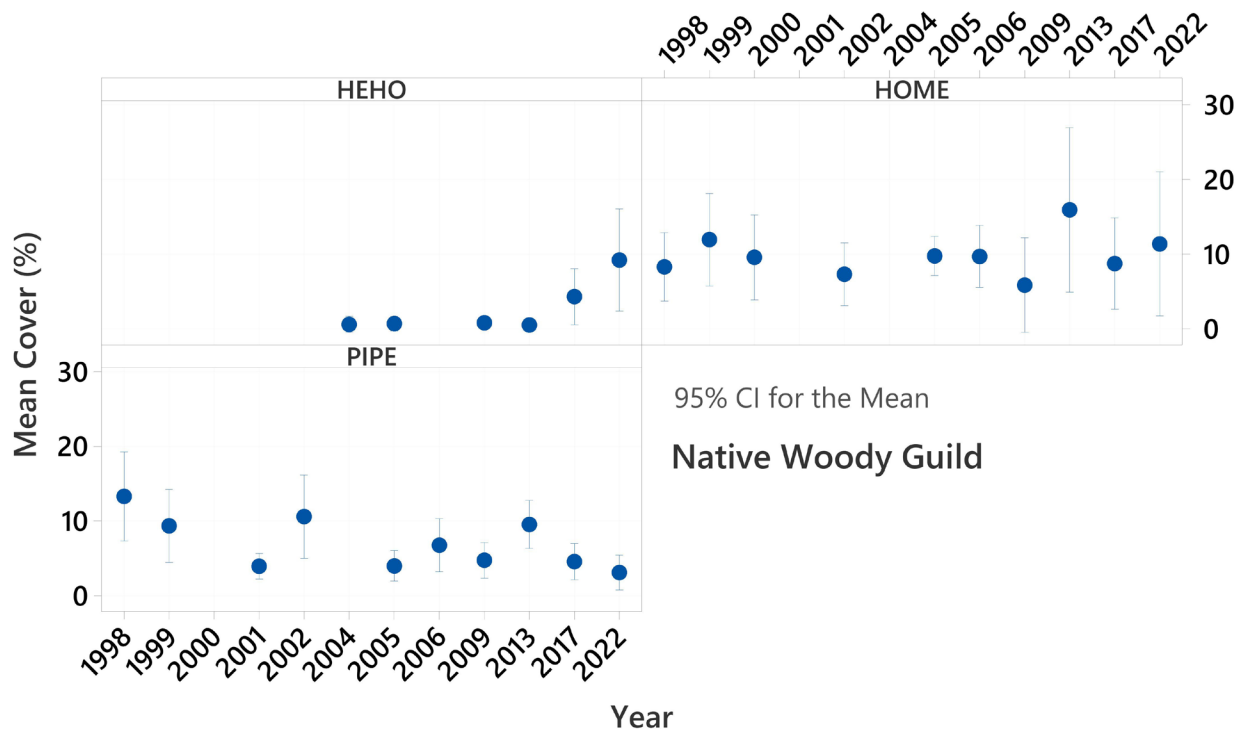


Figure 23. Native woody plant (non-tree species) guild cover (%) for three Heartland Network parks with prairie communities: Herbert Hoover National Historic Site (HEHO), Homestead National Historical Park (HOME), and Pipestone National Monument (PIPE).

Another component of the woody plant community, tree regeneration, is important to observe in prairies. Frequent prescribed fire often kills seedlings and small saplings maintaining the open character of tallgrass prairie. Archival photography (Appendix B) provides visual comparisons of select sample sites over time. Pipestone NM had the least tree regeneration overall (Figure 24). Mean stems/site at Herbert Hoover NHS began increasing in 2017, then rose sharply in 2022. This may be related to a lag in the effect from the stoppage of prescribed fire at the park and/or an indicator of disturbance from the recent construction projects. Homestead NHP tree regeneration observations were the least for that park during 2004–2013. Exploration of correlation with management actions such as prescribed fire or brush treatments may better elucidate these patterns. The peaks at Homestead NHP in 2002 and 2017 may coincide with longer time since fire intervals than in other years.

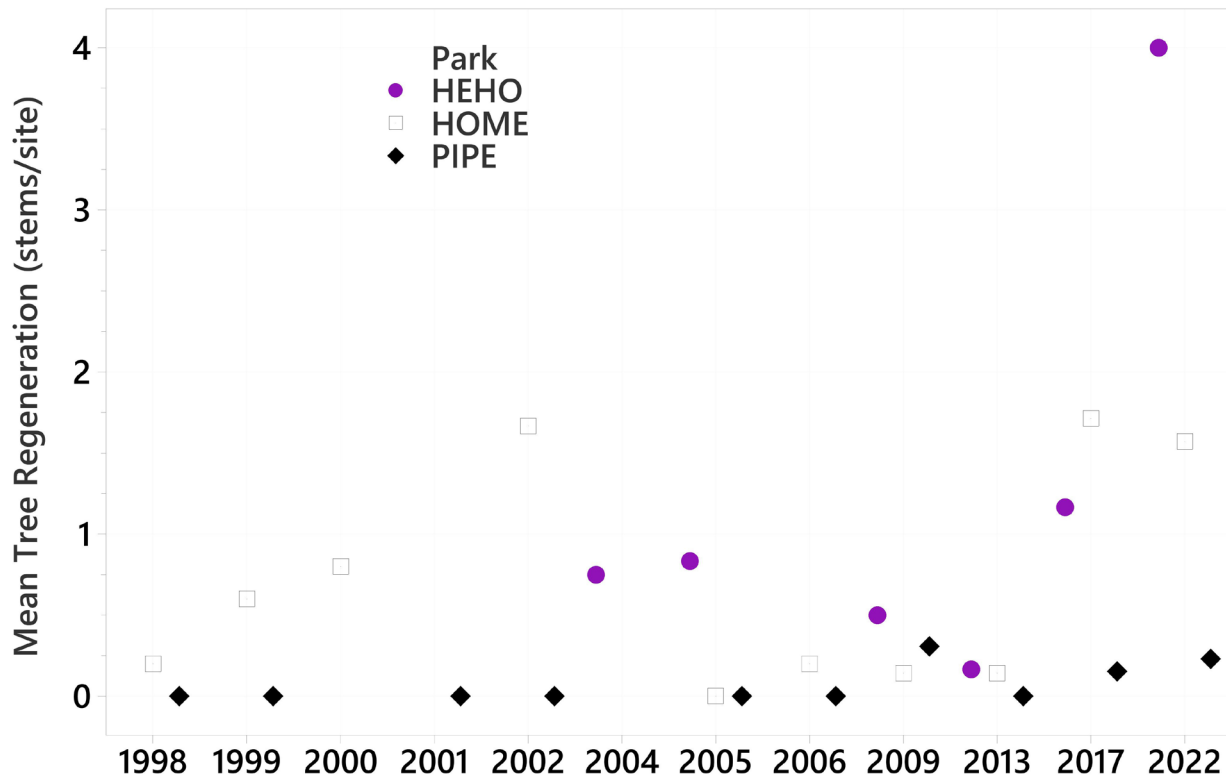


Figure 24. Mean tree regeneration (seedlings and small samplings) for three Heartland Network parks with prairie communities: Herbert Hoover National Historic Site (HEHO), Homestead National Historical Park (HOME), and Pipestone National Monument (PIPE).

Canopy closure, measured for the first time in 2022, provided further insight into the role of woody cover in the prairies. In cases where vegetation was tall and dense enough to be observed in a densiometer, the plants were exclusively woody plants, primarily large shrub species such as American plum (*Prunus americana*), roughleaf dogwood (*Cornus drummondii*), smooth sumac (*Rhus glabra*), or common buckthorn (*Rhamnus cathartica*; Figure 25). We detected canopy closure at all three parks. At Herbert Hoover NHS, canopy was measured in four of the five sites (mean closure = $1.2\% \pm 0.93$ SE). Homestead NHP had the most prairie canopy closure (mean closure = $3.2\% \pm 2.67$ SE). Four of the seven sites included canopy at Homestead NHP, but site 5 had 19.1% mean closure, the most of any sites in the three prairies. Pipestone NM only had canopy in one of the 13 sites (mean closure = $0.28\%, \pm 0.28$ SE). However, some woody species had not yet leafed out at the time of sampling at Pipestone NM in 2022.

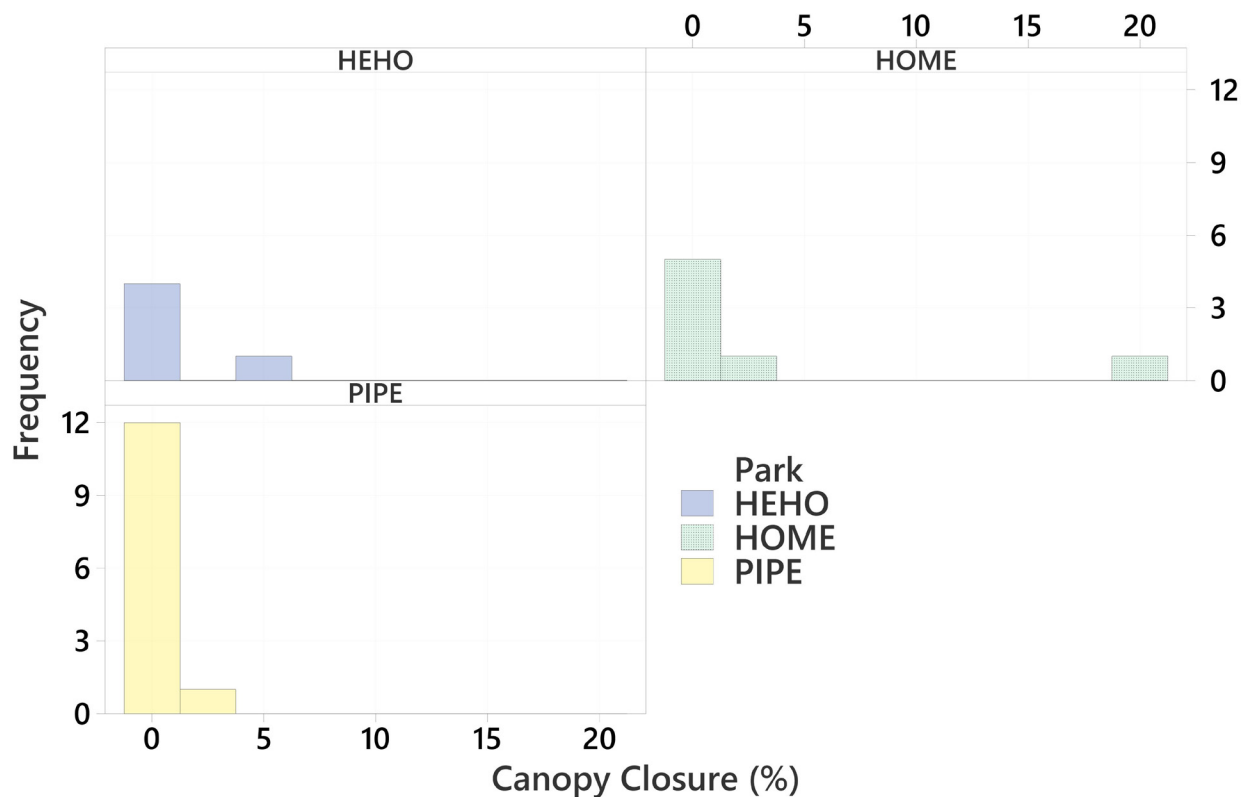


Figure 25. Histogram of canopy closure (%) observations in prairie sites in 2022 for three Heartland Network parks with prairie communities: Herbert Hoover National Historic Site (HEHO), Homestead National Historical Park (HOME), and Pipestone National Monument (PIPE).

Nonnative plants

Herbert Hoover NHS nonnative cover was the greatest in 2022 (20% cover) and may be trending upward, but confidence intervals remain overlapping for most years (Figure 26). Homestead NHP nonnative cover remains consistently minimal (3.4% in 2022). Pipestone NM nonnative cover was least in 2001 (11%) and was consistently greater than the other parks through time including in 2022 (33.4%).

Nonnative grasses comprised an important component of the nonnative cohort. These grasses are often targets with management treatments such as prescribed fire seasonality and herbicide treatments. Nonnative grasses may also be sensitive to climate change (Wilsey 2018). Two grasses, Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*), are common invaders to tallgrass prairie in the region (Figures 27, 28, and 29). We observed very little smooth brome at Herbert Hoover NHS although there was greater variability among the sites in 2022. Homestead NHP had consistently minimal smooth brome (mean cover <1%). Pipestone NM had smooth brome levels that were greater than or equal to 10% cover in half of the sample events and it was more prevalent in the remnant prairie than in the restored prairie and Sioux Quartzite sites.

Kentucky bluegrass is another pervasive nonnative cool season grass. Mean Kentucky bluegrass was greatest at Herbert Hoover NHS in 2022 but varied among sites. Mean Kentucky bluegrass was less

than or equal to 5% in all years except 2002. Kentucky bluegrass varied, almost alternating by year. Kentucky bluegrass was greater than 10% in 4 of 10 monitoring years at Pipestone NM. Together these two nonnative grasses comprised the majority of nonnative cover for Pipestone NM. Although Canada bluegrass (*Poa compressa*) has similar form and function to Kentucky bluegrass (*Poa pratensis*), we did not include it (or *Poa* sp.) in this analysis as they were uncommon at the other two parks. Canada bluegrass at Pipestone NM may be underestimated because of identification challenges over time.

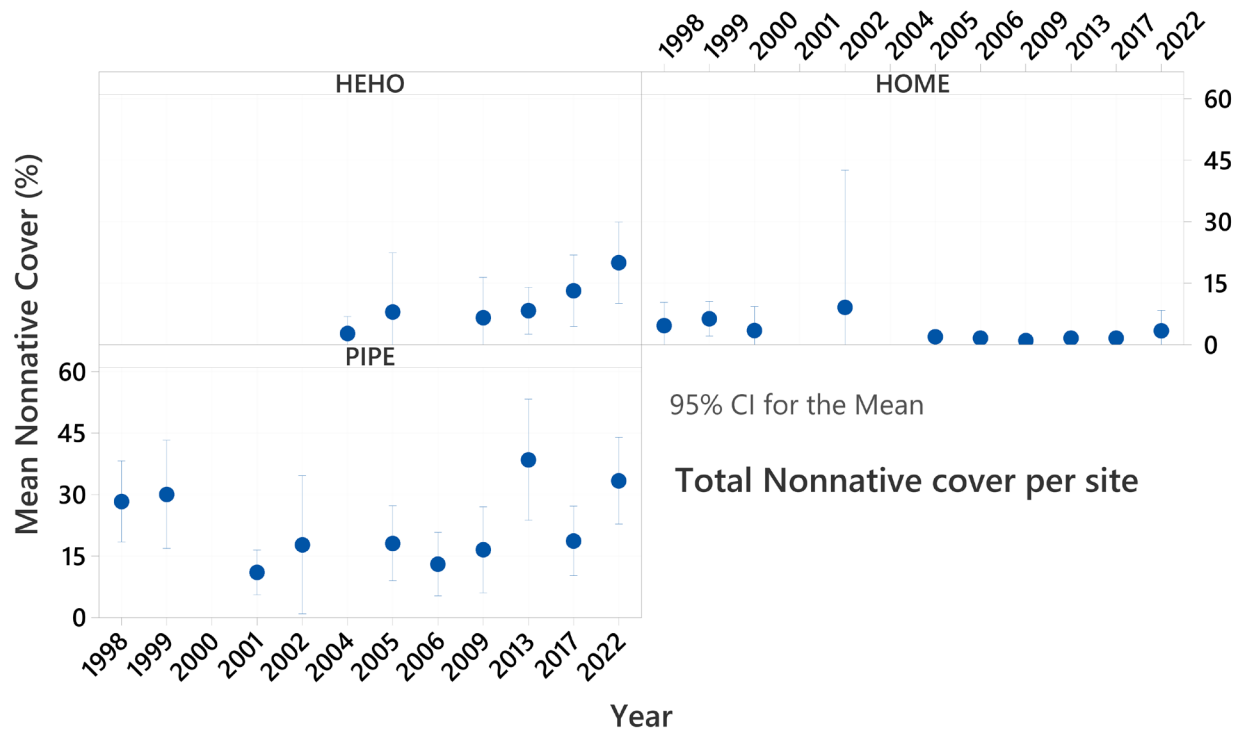


Figure 26. Mean nonnative species cover (%) for three Heartland Network parks with prairie communities: Herbert Hoover National Historic Site (HEHO), Homestead National Historical Park (HOME), and Pipestone National Monument (PIPE).

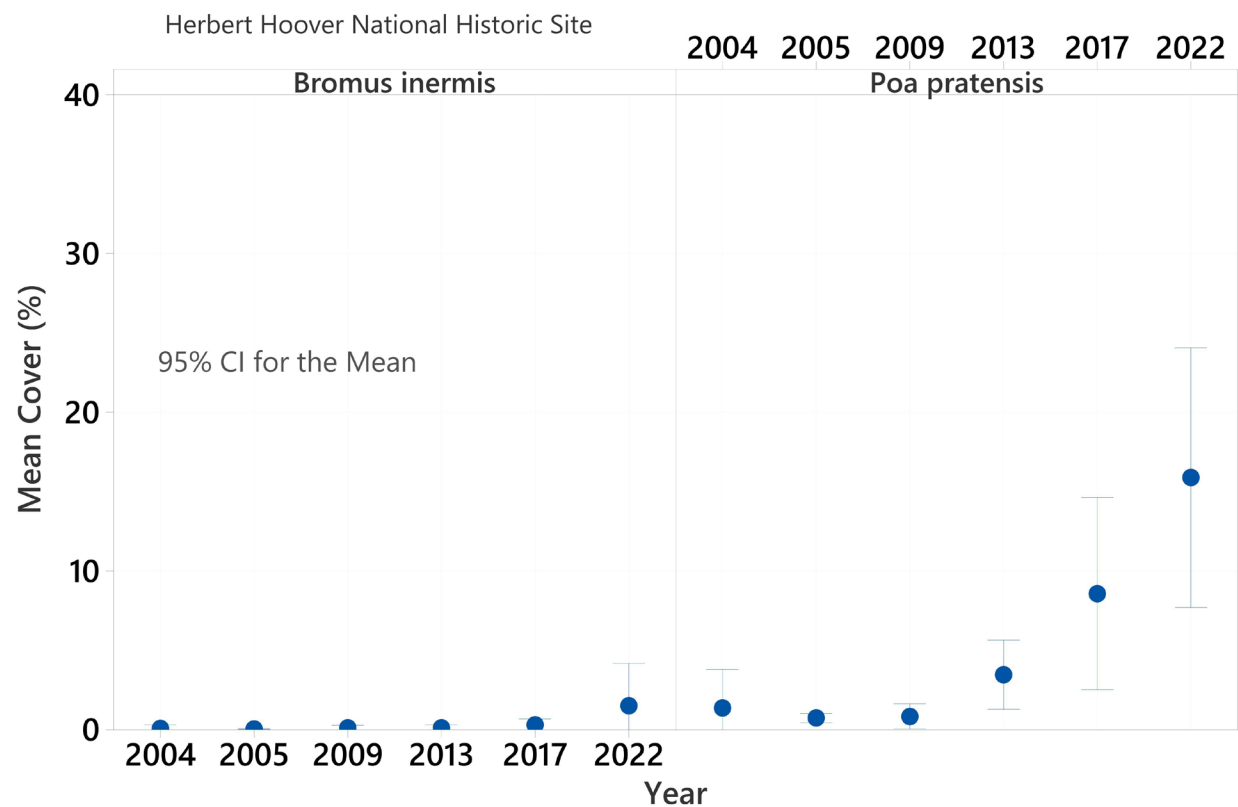


Figure 27. Mean cover (%) of smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) for the prairie communities in Herbert Hoover National Historic Site. Individual standard deviations are used to calculate the intervals.

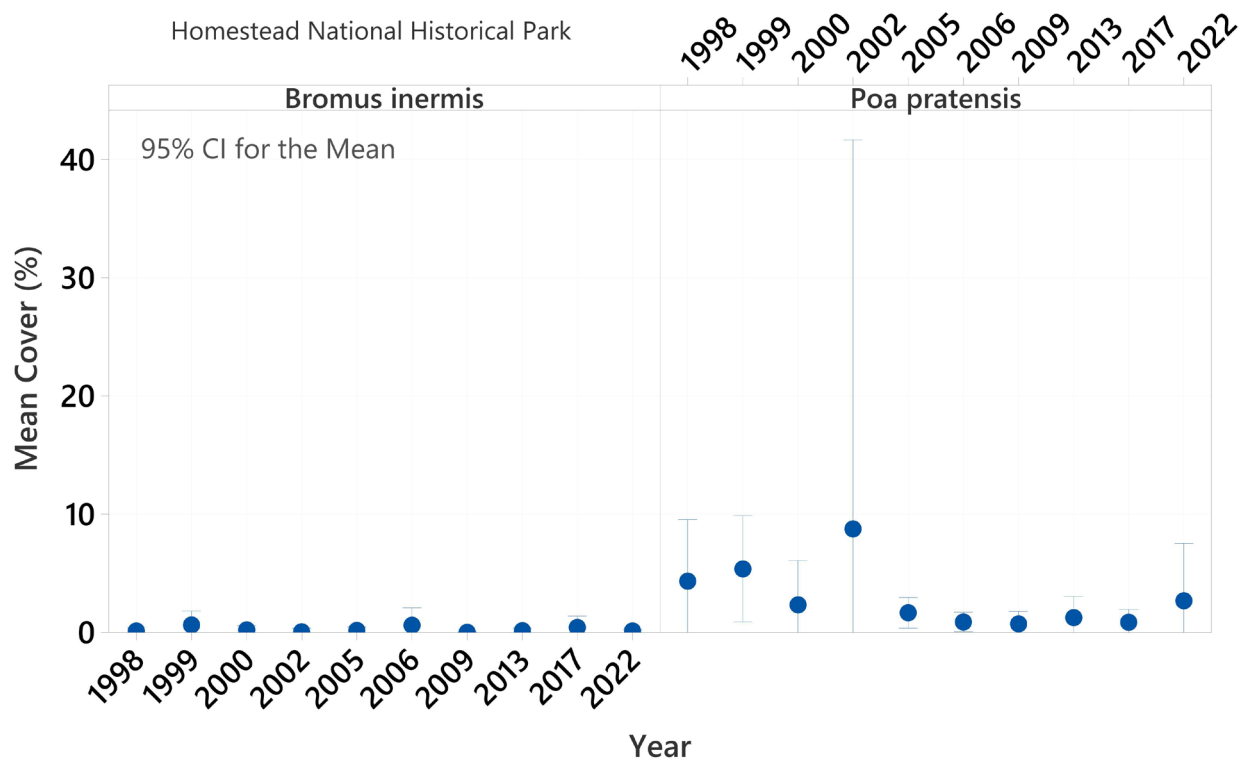


Figure 28. Mean cover (%) of smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) for the prairie communities in Homestead National Historical Park. Individual standard deviations are used to calculate the intervals.

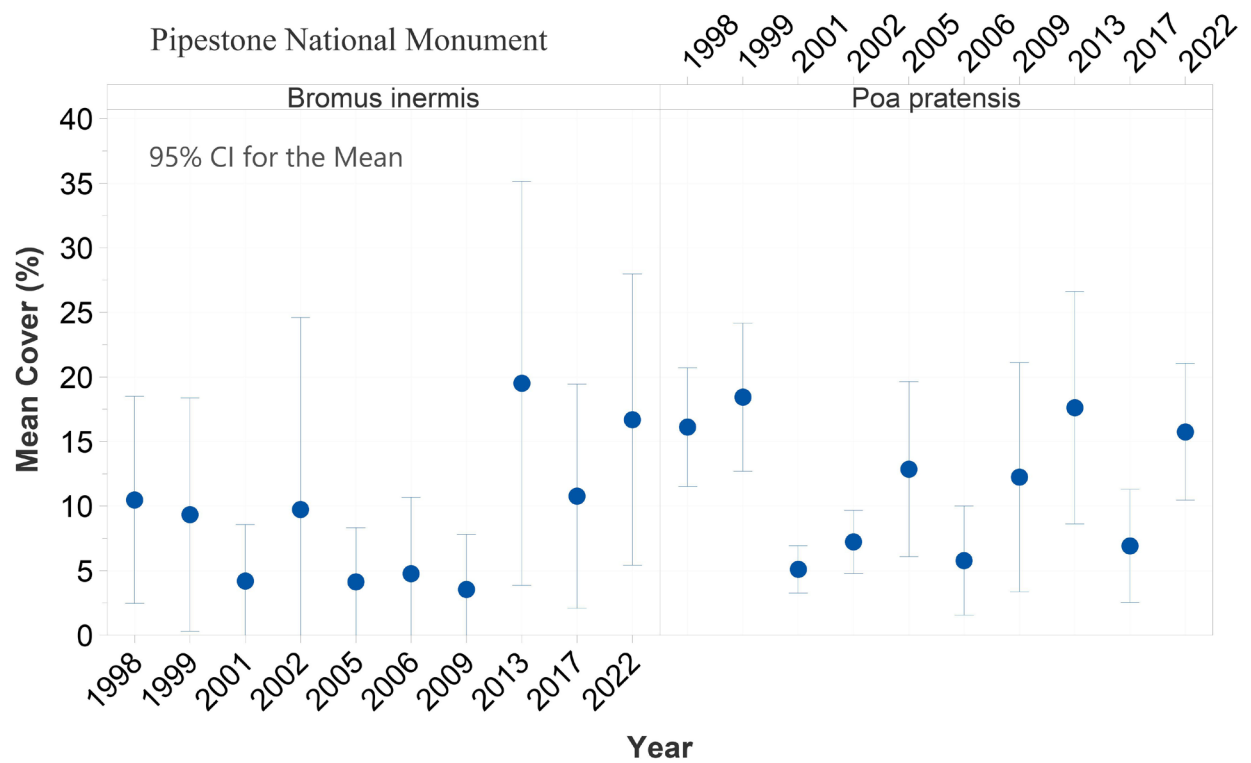


Figure 29. Mean cover (%) of smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) for the prairie communities in Pipestone National Monument. Individual standard deviations are used to calculate the intervals.

Conclusions

The three parks have unique climate signatures that can influence vegetation trends for individual years. Future analysis could explore the relationship of water balance to species observations, particularly of forbs and grasses with different photosynthetic pathways. Current trends for the eastern US (including Herbert Hoover NHS) indicate that precipitation is increasing. However, the baseline average, or set of climate normals, used in comparisons can affect the interpretation of trend data. For example, the long-term average indicates that the current period is wetter than the average period from 1900 to 2022, but comparison to the 30-year average indicates recent drought. Future analyses focused on looking for climate signals within the vegetation of these parks will support sensitivity or vulnerability analyses for better park planning.

Observer error was measured for the first time in the three parks. Observer error analysis provided a moderate level of confidence in the data, and quality of data collection was similar across parks. Species turnover at Homestead NHP did not result in species richness reductions. Although annualized species turnover was low (0.5–1.1 species/year), Homestead NHP experienced the most change in species (21.3 species) since monitoring began. Species richness has changed with time; Herbert Hoover NHS has greater site richness than initial years, but Pipestone NM has fewer species/site than earlier years. Additional management actions may be helpful to reverse species losses, but it is not clear if differences in climate play a role in the changes to species richness.

Prairie plant communities were the most similar at Homestead NHP and Herbert Hoover NHS, while Pipestone NM prairie communities were unique among the three parks. The Sioux Quartzite prairie plant community exhibited the greatest compositional divergence among the three parks—and among the three community types at Pipestone NM. The prairie at Homestead NHP exhibited chronological directionality, which may reflect the level of species turnover that we measured.

Species guild assessments allow us to think about important plant groups more easily. While there may be a reduction in native grass species cover, it is difficult to discern what role sampling error or protocol changes play in the observations. The shift in sampling timing and phenology may play a role in differences after 2008. Levels of total nonnative cover at Herbert Hoover NHS may require additional attention, while levels for Homestead NHP and Pipestone NM may be within the level of natural variation measured over the history of the project. For non-native grass cover, smooth brome may require additional management actions to reduce abundance at Herbert Hoover NHS and Pipestone NM, and Kentucky bluegrass may also be on the rise at Herbert Hoover NHS.

All three parks receive visits from the Invasive Plant Management Team, as well as treatments by the local park staff (although our knowledge of these treatments is incomplete). Each park also participates in the prescribed burn program, although Herbert Hoover NHS has not been burned since 2011 because of administrative challenges. Periodic brush hogging also occurs on the parks to treat problematic plants or as a replacement for prescribed fire, but the timing, location, and frequency of treatments vary. A focused study of the fire histories of these parks may demonstrate how the role of fire and access to treatments affects tallgrass prairie reconstructions. Leis and Young (2018) suggested that increases in woody plants at Herbert Hoover NHS were related to reductions in fire

treatments, but the role of fire in shaping the plant community was less influential at Pipestone NM (Leis and Morrison 2020). We have not conducted similar analyses for Homestead NHP.

By combining the three parks into a single analysis, we were able to highlight similarities in vegetation, such as composition at Herbert Hoover NHS and Homestead NHP, as well as divergent patterns, such as trends in species richness. Even though ecological processes, such as climate and land use history, may differ between these parks, they have some similar challenges with respect to maintaining the integrity of these communities.

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Appendix A. Species Observed

All species observed at prairie sites are listed for Herbert Hoover National Historic Site (Table A1), Homestead National Historical Park (Table A2), and Pipestone National Monument (Table A3).

Table A1. Species observed at Herbert Hoover National Historic Site in 2022, (N = 5 sites). Values for mean cover, standard error (SE), and occurrence are for 2022 (most recent monitoring event) only. N = native, I = nonnative.

Species	Common Name	Guild	Origin	2022 Mean Cover (%)	SE	Occurrence (% sites observed) 2022
<i>Abutilon theophrasti</i>	velvetleaf	forb	I	0.01	0.01	20
<i>Ambrosia artemisiifolia</i>	annual ragweed	forb	N	0.05	0.05	20
<i>Ambrosia trifida</i>	great ragweed	forb	N	0.08	0.08	20
<i>Andropogon gerardii</i>	big bluestem	grass	N	21.08	3.55	100
<i>Anemone canadensis</i>	Canadian anemone	forb	N	0.08	0.03	80
<i>Antennaria neglecta</i>	field pussytoes	forb	N	0.30	0.30	20
<i>Apocynum cannabinum</i>	Indianhemp	forb	N	0.53	0.36	100
<i>Asclepias syriaca</i>	common milkweed	forb	N	0.14	0.08	100
<i>Astragalus canadensis</i>	Canadian milkvetch	forb	N	0.36	0.36	20
<i>Baptisia alba</i> var. <i>macrophylla</i>	largeleaf wild indigo	forb	N	4.73	3.40	60
<i>Bouteloua curtipendula</i>	sideoats grama	grass	N	0.02	0.02	20
<i>Bromus inermis</i>	smooth brome	grass	I	1.50	0.97	40
<i>Calystegia sepium</i>	hedge false bindweed	forb	N	0.26	0.08	80
<i>Carex</i> spp.	sedge	grass-like	N	0.79	0.57	100
<i>Chamaecrista fasciculata</i>	partridge pea	forb	N	0.08	0.05	40
<i>Cirsium altissimum</i>	tall thistle	forb	N	0.07	0.03	80
<i>Cirsium discolor</i>	field thistle	forb	N	0.24	0.09	100
<i>Coreopsis tripteris</i>	tall tickseed	forb	N	0.51	0.17	100
<i>Cornus drummondii</i>	roughleaf dogwood	woody	N	1.91	1.62	100
<i>Dalea purpurea</i>	purple prairie clover	forb	N	0.06	0.06	20
<i>Daucus carota</i>	Queen Anne's lace	forb	I	0.16	0.08	60
<i>Desmodium canadense</i>	showy ticktrefoil	forb	N	0.96	0.89	40
<i>Desmodium sessilifolium</i>	sessileleaf ticktrefoil	forb	N	0.09	0.08	40

Table A1 (continued). Species observed at Herbert Hoover National Historic Site in 2022, (N = 5 sites). Values for mean cover, standard error (SE), and occurrence are for 2022 (most recent monitoring event) only. N = native, I = nonnative.

Species	Common Name	Guild	Origin	2022 Mean Cover (%)	SE	Occurrence (% sites observed) 2022
<i>Echinacea pallida</i>	pale purple coneflower	forb	N	0.20	0.09	60
<i>Echinacea purpurea</i>	eastern purple coneflower	forb	N	0.01	0.01	20
<i>Elaeagnus umbellata</i>	autumn olive	woody	I	0.75	0.75	20
<i>Elymus canadensis</i>	Canada wildrye	grass	N	0.21	0.10	100
<i>Equisetum arvense</i>	field horsetail	fern	N	0.41	0.08	100
<i>Erigeron strigosus</i>	prairie fleabane	forb	N	0.02	0.02	20
<i>Eryngium yuccifolium</i>	button eryngo	forb	N	0.81	0.64	60
<i>Gentiana puberulenta</i>	downy gentian	forb	N	0.01	0.01	20
<i>Geum canadense</i>	white avens	forb	N	0.07	0.06	40
<i>Hackelia virginiana</i>	beggarslice	forb	N	0.01	0.01	20
<i>Helianthus grosseserratus</i>	sawtooth sunflower	forb	N	0.12	0.12	20
<i>Heliopsis helianthoides</i>	smooth oxeye	forb	N	0.16	0.05	100
<i>Lactuca canadensis</i>	Canada lettuce	forb	N	0.17	0.03	100
<i>Lespedeza capitata</i>	roundhead lespedeza	forb	N	0.49	0.33	60
<i>Liatris pycnostachya</i>	prairie blazing star	forb	N	0.01	0.01	20
<i>Lonicera morrowii</i>	Morrow's honeysuckle	woody	I	1.41	0.83	100
<i>Melilotus officinalis</i>	yellow sweetclover	forb	I	0.05	0.02	60
<i>Monarda fistulosa</i>	wild bergamot	forb	N	1.52	0.47	100
<i>Oligoneuron rigidum</i> var. <i>rigidum</i>	Stiff goldenrod	forb	N	0.16	0.14	40
<i>Oxalis</i> sp.	woodsorrel	forb	N	0.06	0.06	20
<i>Packera plattensis</i>	Platte groundsel	forb	N	4.66	2.00	100
<i>Panicum virgatum</i>	switchgrass	grass	N	0.20	0.08	80
<i>Parthenocissus quinquefolia</i>	Virginia creeper	woody	N	0.01	0.01	20
<i>Pastinaca sativa</i>	wild parsnip	forb	I	0.05	0.04	40
<i>Phalaris arundinacea</i>	reed canarygrass	grass	I	0.06	0.06	20
<i>Phryma leptostachya</i>	American lopseed	forb	N	0.01	0.01	20
<i>Physalis heterophylla</i>	clammy groundcherry	forb	N	0.18	0.07	100

Table A1 (continued). Species observed at Herbert Hoover National Historic Site in 2022, (N = 5 sites). Values for mean cover, standard error (SE), and occurrence are for 2022 (most recent monitoring event) only. N = native, I = nonnative.

Species	Common Name	Guild	Origin	2022 Mean Cover (%)	SE	Occurrence (% sites observed) 2022
<i>Physalis virginiana</i>	Virginia groundcherry	forb	N	0.02	0.01	40
<i>Poa pratensis</i>	Kentucky bluegrass	grass	I	15.88	2.95	100
<i>Potentilla arguta</i>	tall cinquefoil	forb	N	0.39	0.37	40
<i>Prunus virginiana</i>	chokecherry	woody	N	0.06	0.02	80
<i>Ratibida pinnata</i>	pinnate prairie coneflower	forb	N	0.90	0.49	80
<i>Rhus glabra</i>	smooth sumac	woody	N	5.27	2.87	80
<i>Rosa carolina</i>	Carolina rose	woody	N	0.06	0.06	20
<i>Rosa multiflora</i>	multiflora rose	woody	I	0.01	0.01	20
<i>Rubus</i> sp.	blackberry	woody	N	1.03	0.96	40
<i>Rudbeckia hirta</i>	blackeyed Susan	forb	N	0.01	0.01	20
<i>Sanicula</i> sp.	sanicle	forb	N	0.15	0.13	60
<i>Sanicula canadensis</i>	Canadian blacksnakeroot	forb	N	0.03	0.02	40
<i>Schizachyrium scoparium</i>	little bluestem	grass	N	1.46	0.65	100
<i>Silphium integrifolium</i>	wholeleaf rosinweed	forb	N	0.01	—	20
<i>Silphium laciniatum</i>	compassplant	forb	N	0.30	0.30	20
<i>Silphium perfoliatum</i>	cup plant	forb	N	0.33	0.33	20
<i>Silphium terebinthinaceum</i>	prairie rosinweed	forb	N	0.06	0.06	20
<i>Solidago canadensis</i>	Canada goldenrod	forb	N	25.38	5.93	100
<i>Solidago gigantea</i>	giant goldenrod	forb	N	0.42	0.35	40
<i>Solidago speciosa</i>	showy goldenrod	forb	N	0.01	0.01	20
<i>Sorghastrum nutans</i>	Indiangrass	grass	N	2.23	0.45	100
<i>Symphyotrichum lanceolatum</i> ssp. <i>lanceolatum</i> var. <i>lanceolatum</i>	white panicle aster	forb	N	0.01	0.01	20
<i>Symphyotrichum novae-angliae</i>	New England wild aster	forb	N	0.05	0.04	40
<i>Symphyotrichum oolentangiense</i>	skyblue aster	forb	N	0.06	0.06	20
<i>Taraxacum officinale</i>	common dandelion	forb	I	0.08	0.03	80
<i>Tradescantia bracteata</i>	longbract spiderwort	forb	N	0.08	0.07	40
<i>Tradescantia ohiensis</i>	bluejacket	forb	N	0.51	0.37	40

Table A1 (continued). Species observed at Herbert Hoover National Historic Site in 2022, (N = 5 sites). Values for mean cover, standard error (SE), and occurrence are for 2022 (most recent monitoring event) only. N = native, I = nonnative.

Species	Common Name	Guild	Origin	2022 Mean Cover (%)	SE	Occurrence (% sites observed) 2022
<i>Tridens flavus</i>	purpletop tridens	grass	N	0.01	0.01	20
<i>Verbena urticifolia</i>	white vervain	forb	N	0.01	0.01	20
<i>Veronicastrum virginicum</i>	Culver's root	forb	N	0.02	0.01	40
<i>Viburnum lentago</i>	nannyberry	woody	N	0.31	0.30	40
<i>Viola</i> sp.	violet	forb	N	0.16	0.12	60
<i>Vitis riparia</i>	riverbank grape	woody	N	0.55	0.28	60

Table A2. Species observed at Homestead National Historical Park (N = 7 sites) in 2022. Values for mean cover, standard error (SE), and occurrence are for 2022 (most recent monitoring event) only. N = native, I = nonnative.

Species	Common Name	Guild	Origin	2022 Mean Cover (%)	SE	Occurrence (% sites observed) 2022
<i>Acalypha</i> sp.	copperleaf	forb	N	0.01	0.01	14.29
<i>Achillea millefolium</i>	common yarrow	forb	N	0.04	0.02	42.86
<i>Ageratina altissima</i>	white snakeroot	forb	N	0.04	0.02	57.14
<i>Agrostis hyemalis</i>	winter bentgrass	grass	N	0.05	0.04	28.57
<i>Ambrosia artemisiifolia</i>	annual ragweed	forb	N	0.06	0.04	42.86
<i>Ambrosia psilostachya</i>	Cuman ragweed	forb	N	0.02	0.01	42.86
<i>Amorpha canescens</i>	leadplant	forb	N	3.80	2.60	42.86
<i>Andropogon gerardii</i>	big bluestem	grass	N	27.74	3.40	100.00
<i>Anemone cylindrica</i>	candle anemone	forb	N	0.01	0.01	14.29
<i>Apocynum cannabinum</i>	Indianhemp	forb	N	0.19	0.06	85.71
<i>Artemisia ludoviciana</i>	white sagebrush	forb	N	0.19	0.18	28.57
<i>Asclepias sullivantii</i>	prairie milkweed	forb	N	0.06	0.04	28.57
<i>Asclepias syriaca</i>	common milkweed	forb	N	0.21	0.13	57.14
<i>Asclepias verticillata</i>	whorled milkweed	forb	N	0.05	0.03	42.86
<i>Asclepias viridiflora</i>	green comet milkweed	forb	N	0.01	0.01	14.29
<i>Baptisia bracteata</i> var. <i>leucophaea</i>	longbract wild indigo	forb	N	0.01	0.01	14.29
<i>Brickellia eupatorioides</i>	false boneset	forb	N	0.09	0.03	57.14
<i>Bromus inermis</i>	smooth brome	grass	I	0.12	0.05	71.43
<i>Carex</i> spp.	sedge	grass-like	N	1.21	0.29	100.00
<i>Chamaecrista fasciculata</i>	partridge pea	forb	N	0.11	0.07	42.86
<i>Cirsium altissimum</i>	tall thistle	forb	N	0.21	0.08	85.71
<i>Cornus drummondii</i>	roughleaf dogwood	woody	N	5.52	3.31	85.71
<i>Cuscuta</i> sp.	dodder	forb	N	0.05	0.05	14.29
<i>Dalea candida</i>	white prairie clover	forb	N	0.03	0.02	28.57
<i>Dalea purpurea</i>	purple prairie clover	forb	N	0.03	0.03	14.29
<i>Delphinium carolinianum</i>	Carolina larkspur	forb	N	0.03	0.03	14.29
<i>Desmodium canadense</i>	showy ticktrefoil	forb	N	0.01	0.01	14.29

Table A2 (continued). Species observed at Homestead National Historical Park (N = 7 sites) in 2022. Values for mean cover, standard error (SE), and occurrence are for 2022 (most recent monitoring event) only. N = native, I = nonnative.

Species	Common Name	Guild	Origin	2022 Mean Cover (%)	SE	Occurrence (% sites observed) 2022
<i>Desmodium illinoense</i>	Illinois ticktrefoil	forb	N	0.20	0.09	71.43
<i>Dichanthelium oligosanthes</i>	Heller's rosette grass	grass	N	0.29	0.06	100.00
<i>Dichanthelium wilcoxianum</i>	fall rosette grass	grass	N	0.07	0.04	42.86
<i>Elymus canadensis</i>	Canada wildrye	grass	N	0.74	0.34	85.71
<i>Eupatorium altissimum</i>	tall thoroughwort	forb	N	0.24	0.12	71.43
<i>Euphorbia corollata</i>	flowering spurge	forb	N	0.01	0.01	28.57
<i>Galium aparine</i>	stickywilly	forb	N	0.02	0.02	14.29
<i>Gentiana puberulenta</i>	downy gentian	forb	N	0.01	0.01	14.29
<i>Geum canadense</i>	white avens	forb	N	0.05	0.04	28.57
<i>Glycyrrhiza lepidota</i>	American licorice	forb	N	0.44	0.31	57.14
<i>Hackelia virginiana</i>	beggarslice	forb	N	0.01	0.01	14.29
<i>Helianthus</i> sp.	sunflower	forb	N	0.01	0.01	14.29
<i>Helianthus grosseserratus</i>	sawtooth sunflower	forb	N	0.56	0.56	14.29
<i>Helianthus maximiliani</i>	Maximilian sunflower	forb	N	0.01	0.01	14.29
<i>Helianthus mollis</i>	ashy sunflower	forb	N	0.54	0.54	14.29
<i>Helianthus pauciflorus</i> ssp. <i>pauciflorus</i>	stiff sunflower	forb	N	5.84	2.06	85.71
<i>Helianthus tuberosus</i>	Jerusalem artichoke	forb	N	0.27	0.27	14.29
<i>Heliopsis helianthoides</i>	smooth oxeye	forb	N	0.05	0.05	14.29
<i>Hesperostipa spartea</i>	Porcupine-grass	grass	N	0.03	0.02	28.57
<i>Hieracium longipilum</i>	hairy hawkweed	forb	N	0.04	0.04	28.57
<i>Juncus</i> sp.	rush	grass- like	N	0.15	0.11	28.57
<i>Koeleria macrantha</i>	prairie Junegrass	grass	N	0.01	0.01	14.29
<i>Lactuca canadensis</i>	Canada lettuce	forb	N	0.15	0.13	57.14
<i>Lactuca serriola</i>	prickly lettuce	forb	I	0.01	0.01	14.29
<i>Laportea canadensis</i>	Canadian woodnettle	forb	N	0.01	0.01	28.57
<i>Lespedeza capitata</i>	roundhead lespedeza	forb	N	0.07	0.03	57.14

Table A2 (continued). Species observed at Homestead National Historical Park (N = 7 sites) in 2022. Values for mean cover, standard error (SE), and occurrence are for 2022 (most recent monitoring event) only. N = native, I = nonnative.

Species	Common Name	Guild	Origin	2022 Mean Cover (%)	SE	Occurrence (% sites observed) 2022
<i>Liatris aspera</i>	tall blazing star	forb	N	0.01	0.01	28.57
<i>Liatris punctata</i>	dotted blazing star	forb	N	0.01	0.01	14.29
<i>Liatris pycnostachya</i>	prairie blazing star	forb	N	0.01	0.01	14.29
<i>Lotus unifoliolatus</i> var. <i>unifoliolatus</i>	American bird's-foot trefoil	forb	N	0.01	0.01	28.57
<i>Lycopus americanus</i>	American water horehound	forb	N	0.02	0.01	28.57
<i>Melilotus officinalis</i>	yellow sweetclover	forb	I	0.01	0.01	14.29
<i>Monarda fistulosa</i>	wild bergamot	forb	N	0.11	0.08	42.86
<i>Muhlenbergia</i>	muhly	grass	N	1.78	0.85	71.43
<i>Oenothera biennis</i>	common evening primrose	forb	N	0.01	0.01	28.57
<i>Oligoneuron rigidum</i> var. <i>rigidum</i>	Stiff goldenrod	forb	N	0.01	0.01	14.29
<i>Oxalis</i> sp.	woodsorrel	forb	N	0.11	0.04	71.43
<i>Oxalis violacea</i>	violet woodsorrel	forb	N	0.03	0.02	28.57
<i>Panicum virgatum</i>	switchgrass	grass	N	0.31	0.07	100.00
<i>Parthenocissus quinquefolia</i>	Virginia creeper	woody	N	0.01	0.01	14.29
<i>Phalaris arundinacea</i>	reed canarygrass	grass	I	0.54	0.54	14.29
<i>Physalis heterophylla</i>	clammy groundcherry	forb	N	0.06	0.05	28.57
<i>Physalis longifolia</i>	longleaf groundcherry	forb	N	0.01	0.01	14.29
<i>Physalis virginiana</i>	Virginia groundcherry	forb	N	0.24	0.07	85.71
<i>Poa pratensis</i>	Kentucky bluegrass	grass	I	2.67	1.99	100.00
<i>Polygonum pensylvanicum</i>	Pennsylvania smartweed	forb	N	0.14	0.07	57.14
<i>Prunus americana</i>	American plum	woody	N	0.08	0.07	28.57
<i>Psoraleidium tenuiflorum</i>	slimflower scurfpea	forb	N	0.22	0.22	14.29
<i>Rhus glabra</i>	smooth sumac	woody	N	0.49	0.24	57.14
<i>Rosa arkansana</i>	prairie rose	woody	N	0.79	0.42	100.00
<i>Rumex altissimus</i>	pale dock	forb	N	0.04	0.04	14.29
<i>Salvia azurea</i>	azure blue sage	forb	N	0.06	0.03	57.14
<i>Sanicula canadensis</i>	Canadian blacksnakeroot	forb	N	0.02	0.01	42.86

Table A2 (continued). Species observed at Homestead National Historical Park (N = 7 sites) in 2022. Values for mean cover, standard error (SE), and occurrence are for 2022 (most recent monitoring event) only. N = native, I = nonnative.

Species	Common Name	Guild	Origin	2022 Mean Cover (%)	SE	Occurrence (% sites observed) 2022
<i>Schizachyrium scoparium</i>	little bluestem	grass	N	4.39	2.17	100.00
<i>Silphium integrifolium</i>	wholeleaf rosinweed	forb	N	0.01	0.01	14.29
<i>Silphium perfoliatum</i>	cup plant	forb	N	0.02	0.02	14.29
<i>Smilax tamnoides</i>	bristly greenbrier	woody	N	0.01	0.01	14.29
<i>Solidago canadensis</i>	Canada goldenrod	forb	N	13.08	4.16	100.00
<i>Solidago gigantea</i>	giant goldenrod	forb	N	0.61	0.61	14.29
<i>Solidago missouriensis</i>	Missouri goldenrod	forb	N	0.72	0.56	42.86
<i>Sorghastrum nutans</i>	Indiangrass	grass	N	0.66	0.17	100.00
<i>Sphenopholis obtusata</i>	prairie wedgescale	grass	N	0.06	0.03	57.14
<i>Sporobolus compositus</i>	composite dropseed	grass	N	0.07	0.04	42.86
<i>Sporobolus heterolepis</i>	prairie dropseed	grass	N	1.21	1.12	42.86
<i>Symphoricarpos orbiculatus</i>	coralberry	woody	N	3.89	1.04	100.00
<i>Symphyotrichum ericoides</i> var. <i>ericoides</i>	Squarrose white wild aster	forb	N	0.29	0.18	57.14
<i>Symphyotrichum lanceolatum</i> ssp. <i>lanceolatum</i> var. <i>lanceolatum</i>	white panicle aster	forb	N	0.18	0.07	71.43
<i>Teucrium canadense</i>	Canada germander	forb	N	0.04	0.02	28.57
<i>Thlaspi arvense</i>	field pennycress	forb	I	0.02	0.01	28.57
<i>Toxicodendron radicans</i>	eastern poison ivy	woody	N	0.52	0.46	42.86
<i>Tridens flavus</i>	purpletop tridens	grass	N	0.01	0.01	14.29
<i>Triodanis perfoliata</i>	clasping Venus' looking- glass	forb	N	0.01	0.01	14.29
<i>Tripsacum dactyloides</i>	eastern gamagrass	grass	N	0.22	0.22	14.29
<i>Ulmus</i> sp.	elm	woody	N	0.06	0.04	28.57
<i>Verbena stricta</i>	hoary verbena	forb	N	0.10	0.06	42.86
<i>Verbena urticifolia</i>	white vervain	forb	N	0.01	0.01	28.57
<i>Vernonia baldwinii</i>	Baldwin's ironweed	forb	N	1.36	0.75	85.71
<i>Viola</i> sp.	violet	forb	N	1.00	0.58	85.71
<i>Viola pedatifida</i>	prairie violet	forb	N	0.01	0.01	14.29

Table A3. Species observed at Pipestone National Monument in 2022 (N = 13 sites). Values for mean cover, standard error (SE), and occurrence are for 2022 (most recent monitoring event) only. N = native, I = nonnative.

Species	Common Name	Guild	Origin	2022 Mean Cover (%)	SE	Occurrence (% sites observed) 2022
<i>Achillea millefolium</i>	common yarrow	forb	N	0.04	0.02	53.85
<i>Allium</i> sp.	onion	forb	N	0.00	0.00	7.69
<i>Allium canadense</i>	meadow garlic	forb	N	0.05	0.02	53.85
<i>Allium stellatum</i>	autumn onion	forb	N	0.07	0.03	46.15
<i>Ambrosia artemisiifolia</i>	annual ragweed	forb	N	0.02	0.01	23.08
<i>Ambrosia psilostachya</i>	Cuman ragweed	forb	N	1.53	0.84	53.85
<i>Amorpha canescens</i>	leadplant	forb	N	0.82	0.32	92.31
<i>Amorpha fruticosa</i>	desert false indigo	forb	N	0.03	0.03	7.69
<i>Amorpha nana</i>	dwarf false indigo	woody	N	0.02	0.02	7.69
<i>Andropogon gerardii</i>	big bluestem	grass	N	3.40	1.03	100.00
<i>Androsace occidentalis</i>	western rockjasmine	forb	N	0.02	0.01	15.38
<i>Anemone canadensis</i>	Canadian anemone	forb	N	0.38	0.17	38.46
<i>Anemone cylindrica</i>	candle anemone	forb	N	0.56	0.27	69.23
<i>Apocynum cannabinum</i>	Indianhemp	forb	N	0.12	0.05	53.85
<i>Artemisia frigida</i>	prairie sagewort	forb	N	0.03	0.03	7.69
<i>Artemisia ludoviciana</i>	white sagebrush	forb	N	1.18	0.82	23.08
<i>Asclepias</i> sp.	milkweed	forb	N	0.10	0.03	53.85
<i>Asclepias verticillata</i>	whorled milkweed	forb	N	0.00	0.00	7.69
<i>Astragalus canadensis</i>	Canadian milkvetch	forb	N	0.01	0.01	7.69
<i>Bouteloua curtipendula</i>	sideoats grama	grass	N	0.06	0.03	38.46
<i>Bouteloua dactyloides</i>	buffalograss	grass	N	0.13	0.07	23.08
<i>Bouteloua gracilis</i>	blue grama	grass	N	0.50	0.34	23.08
<i>Bromus arvensis</i>	Japanese chess	forb	I	0.02	0.01	23.08
<i>Bromus inermis</i>	smooth brome	grass	I	16.70	5.17	100.00
<i>Calystegia sepium</i>	hedge false bindweed	forb	N	0.03	0.02	23.08
<i>Carex</i> spp.	sedge	grass-like	N	1.87	0.60	100.00
<i>Cerastium arvense</i>	field chickweed	forb	N	0.06	0.03	30.77

Table A3 (continued). Species observed at Pipestone National Monument in 2022 (N = 13 sites). Values for mean cover, standard error (SE), and occurrence are for 2022 (most recent monitoring event) only. N = native, I = nonnative.

Species	Common Name	Guild	Origin	2022 Mean Cover (%)	SE	Occurrence (% sites observed) 2022
<i>Cirsium altissimum</i>	tall thistle	forb	N	0.01	0.01	7.69
<i>Cirsium flodmanii</i>	Flodman's thistle	forb	N	0.04	0.02	23.08
<i>Collomia linearis</i>	tiny trumpet	forb	N	0.01	0.01	7.69
<i>Coreopsis palmata</i>	stiff tickseed	forb	N	0.12	0.12	7.69
<i>Dalea candida</i>	white prairie clover	forb	N	0.01	0.01	23.08
<i>Dalea purpurea</i>	purple prairie clover	forb	N	0.02	0.02	23.08
<i>Delphinium carolinianum</i>	Carolina larkspur	forb	N	0.02	0.02	7.69
<i>Dichanthelium</i>	rosette grass	grass	N	0.63	0.21	92.31
<i>Draba reptans</i>	Carolina draba	forb	N	0.02	0.02	15.38
<i>Eleocharis compressa</i>	flatstem spikerush	grass- like	N	0.01	0.01	7.69
<i>Elymus</i> sp.	wildrye	grass	N	0.07	0.03	53.85
<i>Elymus repens</i>	quackgrass	grass	I	0.12	0.10	23.08
<i>Elymus trachycaulus</i>	slender wheatgrass	grass	N	0.00	0.00	7.69
<i>Equisetum arvense</i>	field horsetail	fern	N	0.00	0.00	7.69
<i>Equisetum laevigatum</i>	smooth horsetail	fern	N	0.07	0.04	23.08
<i>Erigeron strigosus</i>	prairie fleabane	forb	N	0.03	0.02	30.77
<i>Euphorbia spathulata</i>	warty spurge	forb	N	0.04	0.02	23.08
<i>Euthamia graminifolia</i>	flat-top goldentop	forb	N	0.02	0.02	7.69
<i>Fragaria virginiana</i>	Virginia strawberry	forb	N	0.06	0.04	30.77
<i>Galium boreale</i>	northern bedstraw	forb	N	2.43	2.11	30.77
<i>Galium obtusum</i>	bluntleaf bedstraw	forb	N	0.33	0.31	15.38
<i>Gentiana andrewsii</i>	closed bottle gentian	forb	N	0.02	0.02	7.69
<i>Gentiana puberulenta</i>	downy gentian	forb	N	0.02	0.01	15.38
<i>Geranium carolinianum</i>	Carolina geranium	forb	N	0.05	0.05	7.69
<i>Glycyrrhiza lepidota</i>	American licorice	forb	N	0.04	0.02	30.77
<i>Hackelia virginiana</i>	beggarslice	forb	N	0.00	0.00	7.69
<i>Hedeoma hispida</i>	rough false pennyroyal	forb	N	0.09	0.05	23.08

Table A3 (continued). Species observed at Pipestone National Monument in 2022 (N = 13 sites). Values for mean cover, standard error (SE), and occurrence are for 2022 (most recent monitoring event) only. N = native, I = nonnative.

Species	Common Name	Guild	Origin	2022 Mean Cover (%)	SE	Occurrence (% sites observed) 2022
<i>Helianthus grosseserratus</i>	sawtooth sunflower	forb	N	0.05	0.05	7.69
<i>Helianthus maximiliani</i>	Maximilian sunflower	forb	N	0.16	0.05	69.23
<i>Helianthus pauciflorus</i> ssp. <i>pauciflorus</i>	stiff sunflower	forb	N	0.87	0.36	69.23
<i>Heliopsis helianthoides</i>	smooth oxeye	forb	N	0.13	0.07	46.15
<i>Hesperostipa comata</i> ssp. <i>comata</i>	Needle-and-thread grass	grass	N	0.02	0.02	7.69
<i>Hesperostipa spartea</i>	Porcupine-grass	grass	N	0.67	0.46	30.77
<i>Heuchera richardsonii</i>	Richardson's alumroot	forb	N	0.03	0.02	23.08
<i>Hordeum pusillum</i>	little barley	grass	N	0.00	0.00	7.69
<i>Hypoxis hirsuta</i>	common goldstar	forb	N	0.03	0.02	15.38
<i>Juncus</i> sp.	rush	grass- like	N	0.00	0.00	7.69
<i>Juncus arcticus</i> ssp. <i>littoralis</i>	Wire-rush	grass- like	N	0.08	0.06	15.38
<i>Koeleria macrantha</i>	prairie Junegrass	grass	N	0.91	0.75	23.08
<i>Lactuca serriola</i>	prickly lettuce	forb	I	0.05	0.02	38.46
<i>Lathyrus venosus</i>	veiny pea	forb	N	0.11	0.04	53.85
<i>Lepidium densiflorum</i>	common pepperweed	forb	N	0.07	0.04	23.08
<i>Liatris aspera</i>	tall blazing star	forb	N	0.05	0.03	38.46
<i>Liatris punctata</i>	dotted blazing star	forb	N	0.03	0.02	23.08
<i>Liatris pycnostachya</i>	prairie blazing star	forb	N	0.04	0.04	15.38
<i>Linum sulcatum</i>	grooved flax	forb	N	0.04	0.02	23.08
<i>Lithospermum canescens</i>	hoary puccoon	forb	N	0.02	0.01	23.08
<i>Lotus unifoliolatus</i> var. <i>unifoliolatus</i>	American bird's-foot trefoil	forb	N	0.01	0.01	15.38
<i>Lycopus americanus</i>	American water horehound	forb	N	0.02	0.02	7.69
<i>Medicago lupulina</i>	black medick	forb	I	0.03	0.02	23.08
<i>Melilotus officinalis</i>	yellow sweetclover	forb	I	0.03	0.01	38.46
<i>Monarda fistulosa</i>	wild bergamot	forb	N	0.43	0.19	61.54

Table A3 (continued). Species observed at Pipestone National Monument in 2022 (N = 13 sites). Values for mean cover, standard error (SE), and occurrence are for 2022 (most recent monitoring event) only. N = native, I = nonnative.

Species	Common Name	Guild	Origin	2022 Mean Cover (%)	SE	Occurrence (% sites observed) 2022
<i>Myosotis verna</i>	spring forget-me-not	forb	N	0.05	0.03	15.38
<i>Oenothera biennis</i>	common evening primrose	forb	N	0.02	0.02	7.69
<i>Oligoneuron rigidum</i> var. <i>rigidum</i>	Stiff goldenrod	forb	N	0.13	0.07	53.85
<i>Opuntia fragilis</i>	brittle pricklypear	forb	N	0.08	0.04	23.08
<i>Opuntia macrorhiza</i>	twistspine pricklypear	forb	N	0.01	0.01	7.69
<i>Oxalis</i> sp.	woodsorrel	forb	N	0.04	0.02	30.77
<i>Oxalis violacea</i>	violet woodsorrel	forb	N	0.30	0.14	61.54
<i>Packera plattensis</i>	Platte groundsel	forb	N	0.02	0.01	15.38
<i>Panicum virgatum</i>	switchgrass	grass	N	0.01	0.01	7.69
<i>Parthenocissus quinquefolia</i>	Virginia creeper	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	0.10	0.05	38.46
<i>Phalaris arundinacea</i>	reed canarygrass	grass	I	0.00	0.00	7.69
<i>Phemeranthus parviflorus</i>	Prairie fame-flower	forb	N	0.04	0.03	23.08
<i>Phlox pilosa</i>	downy phlox	forb	N	0.02	0.01	15.38
<i>Physalis heterophylla</i>	clammy groundcherry	forb	N	0.01	0.01	7.69
<i>Physalis virginiana</i>	Virginia groundcherry	forb	N	0.12	0.05	46.15
<i>Plantago patagonica</i>	woolly plantain	forb	N	0.06	0.03	23.08
<i>Poa compressa</i>	Canada bluegrass	grass	I	0.23	0.21	23.08
<i>Poa pratensis</i>	Kentucky bluegrass	grass	I	15.75	2.43	100.00
<i>Polygonum ramosissimum</i>	bushy knotweed	forb	N	0.00	0.00	7.69
<i>Portulaca oleracea</i>	little hogweed	forb	N	0.02	0.01	15.38
<i>Potentilla arguta</i>	tall cinquefoil	forb	N	0.01	0.01	15.38
<i>Potentilla pensylvanica</i>	Pennsylvania cinquefoil	forb	N	0.01	0.01	7.69
<i>Prenanthes racemosa</i>	purple rattlesnakeroot	forb	N	0.00	0.00	7.69
<i>Prunus americana</i>	American plum	woody	N	0.12	0.11	15.38
<i>Prunus pumila</i>	sandcherry	woody	N	0.14	0.14	7.69

Table A3 (continued). Species observed at Pipestone National Monument in 2022 (N = 13 sites). Values for mean cover, standard error (SE), and occurrence are for 2022 (most recent monitoring event) only. N = native, I = nonnative.

Species	Common Name	Guild	Origin	2022 Mean Cover (%)	SE	Occurrence (% sites observed) 2022
<i>Psoraleidium tenuiflorum</i>	slimflower scurfpea	forb	N	0.00	0.00	7.69
<i>Ratibida pinnata</i>	pinnate prairie coneflower	forb	N	0.50	0.16	69.23
<i>Rhamnus cathartica</i>	common buckthorn	woody	I	0.23	0.23	15.38
<i>Rhus glabra</i>	smooth sumac	woody	N	0.82	0.81	15.38
<i>Rosa arkansana</i>	prairie rose	woody	N	1.43	0.63	69.23
<i>Rubus</i> sp.	blackberry	woody	N	0.00	0.00	7.69
<i>Rudbeckia hirta</i>	blackeyed Susan	forb	N	0.08	0.07	15.38
<i>Rumex crispus</i>	curly dock	forb	I	0.02	0.01	30.77
<i>Schizachyrium scoparium</i>	little bluestem	grass	N	1.86	0.61	100.00
<i>Scutellaria parvula</i>	small skullcap	forb	N	0.00	0.00	7.69
<i>Selaginella rupestris</i>	northern selaginella	fern	N	0.12	0.07	23.08
<i>Silene antirrhina</i>	sleepy silene	forb	N	0.04	0.03	15.38
<i>Silene latifolia</i> ssp. <i>alba</i>	bladder campion	forb	I	0.00	0.00	7.69
<i>Sisyrinchium campestre</i>	prairie blue-eyed grass	forb	N	0.04	0.02	46.15
<i>Solidago canadensis</i>	Canada goldenrod	forb	N	2.13	1.13	69.23
<i>Solidago gigantea</i>	giant goldenrod	forb	N	0.56	0.40	15.38
<i>Solidago missouriensis</i>	Missouri goldenrod	forb	N	0.55	0.17	92.31
<i>Sorghastrum nutans</i>	Indiangrass	grass	N	0.08	0.05	30.77
<i>Spartina pectinata</i>	prairie cordgrass	grass	N	0.18	0.15	15.38
<i>Sporobolus compositus</i>	composite dropseed	grass	N	0.03	0.03	7.69
<i>Sporobolus cryptandrus</i>	sand dropseed	grass	N	0.00	0.00	7.69
<i>Sporobolus heterolepis</i>	prairie dropseed	grass	N	0.97	0.26	69.23
<i>Sporobolus vaginiflorus</i>	poverty dropseed	grass	N	0.01	0.01	7.69
<i>Stachys palustris</i>	marsh hedgenettle	forb	I	0.02	0.02	7.69
<i>Stellaria longifolia</i>	longleaf starwort	forb	N	0.02	0.02	7.69
<i>Symphoricarpos occidentalis</i>	western snowberry	woody	N	0.32	0.29	15.38
<i>Symphyotrichum ericoides</i> var. <i>ericoides</i>	Squarrose white wild aster	forb	N	0.29	0.07	76.92

Table A3 (continued). Species observed at Pipestone National Monument in 2022 (N = 13 sites). Values for mean cover, standard error (SE), and occurrence are for 2022 (most recent monitoring event) only. N = native, I = nonnative.

Species	Common Name	Guild	Origin	2022 Mean Cover (%)	SE	Occurrence (% sites observed) 2022
<i>Symphyotrichum laeve</i> var. <i>laeve</i>	Smooth wild aster	forb	N	0.30	0.13	69.23
<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	0.04	15.38
<i>Symphyotrichum sericeum</i>	Western silvery wild aster	forb	N	0.00	0.00	7.69
<i>Taraxacum officinale</i>	common dandelion	forb	I	0.12	0.03	69.23
<i>Thalictrum dasycarpum</i>	purple meadow-rue	forb	N	0.03	0.02	30.77
<i>Tradescantia bracteata</i>	longbract spiderwort	forb	N	0.14	0.05	46.15
<i>Tragopogon dubius</i>	yellow salsify	forb	I	0.02	0.01	23.08
<i>Ulmus</i> sp.	elm	woody	N	0.02	0.02	23.08
<i>Verbascum thapsus</i>	common mullein	forb	I	0.00	0.00	7.69
<i>Veronica arvensis</i>	corn speedwell	forb	I	0.02	0.02	7.69
<i>Veronica peregrina</i>	neckweed	forb	N	0.00	0.00	7.69
<i>Veronicastrum virginicum</i>	Culver's root	forb	N	0.02	0.01	15.38
<i>Vicia americana</i>	American vetch	forb	N	0.17	0.08	46.15
<i>Viola</i> sp.	violet	forb	N	0.01	0.01	7.69
<i>Viola pedatifida</i>	prairie violet	forb	N	0.15	0.04	61.54
<i>Woodsia obtusa</i>	bluntlobe cliff fern	fern	N	0.02	0.02	7.69
<i>Zanthoxylum americanum</i>	common pricklyash	woody	N	0.23	0.23	7.69
<i>Zizia aptera</i>	meadow zizia	forb	N	0.01	0.01	15.38
<i>Zizia aurea</i>	golden zizia	forb	N	0.08	0.06	30.77

Appendix B. Archival Photography

Figures B1–B10 show a sampling of photographs from earlier monitoring events juxtaposed with photographs from the 2022 monitoring event at Herbert Hoover National Historic Site, Homestead National Historical Park, and Pipestone National Monument. These photos aide in visualizing changes in vegetation cover over time (especially transitions between herbaceous dominated sites to woody dominated sites. Plot code includes site number, transect (A, B) and location (S = start, 0 m; F = finish, 50 m).



Figure B1. Herbert Hoover NHS site 10 AS in 2013 (left) and in 2022 (right).



Figure B2. Herbert Hoover NHS site 10 AF in 2013 (left) and 2022 (right).



Figure B3. Pipestone NM site 11 AS in 2009 (left) and in 2022 (right).



Figure B4. Pipestone NM site 11 AF in 2009 (left) and in 2022 (right).



Figure B5. Pipestone NM site 14 AS in 2009 (left) and in 2022 (right).



Figure B6. Pipestone NM site 14 AF in 2009 (left) and in 2022 (right).



Figure B7. Pipestone NM site 14 BS in 2009 (left) and in 2022 (right).



Figure B8. Pipestone NM 14 BF in 2009 (left) and in 2022 (right).



Figure B9. Homestead NHP site 5 AS in May 2009 (left) and in 2022 (right).



Figure B10. Homestead NHP site 5 AS in May 2009 (left) and in 2022 (right).

Appendix C. Diversity Metrics (J', H', and Gamma Diversity) for Native Plants in Prairie Sites

Native species evenness (J'), Shannon's diversity index (H'), and gamma diversity for Herbert Hoover National Historic Site, Homestead National Historical Park, and Pipestone National Monument (Tables C1–C3).

Table C1. Native species evenness (J') for three prairie parks, 1998–2022: Herbert Hoover National Historic Site (NHS), Homestead National Historical Park (NHP), and Pipestone National Monument (NM). CI = 95% confidence interval.

Sampling Year	Herbert Hoover NHS		Homestead NHP		Pipestone NM	
	Mean J'	CI	Mean J'	CI	Mean J'	CI
1998	NA	NA	0.65	0.60, 0.70	0.74	0.71, 0.78
1999	NA	NA	0.68	0.63, 0.73	0.71	0.65, 0.76
2000	NA	NA	0.64	0.60, 0.67	NA	NA
2001	NA	NA	NA	NA	0.70	0.63, 0.76
2002	NA	NA	0.54	0.45, 0.64	0.74	0.70, 0.79
2004	0.40	0.35, 0.45	NA	NA	NA	NA
2005	0.38	0.26, 0.51	0.56	0.47, 0.64	0.72	0.65, 0.79
2006	NA	NA	0.60	0.51, 0.68	0.74	0.71, 0.77
2009	0.41	0.34, 0.48	0.52	0.47, 0.57	0.73	0.67, 0.78
2013	0.41	0.32, 0.50	0.55	0.49, 0.62	0.68	0.61, 0.75
2017	0.58	0.51, 0.64	0.53	0.47, 0.59	0.67	0.60, 0.74
2022	0.57	0.47, 0.66	0.56	0.54, 0.59	0.70	0.64, 0.76

Table C2. Native diversity, Shannon Index (H'), for three prairie parks, 1998–2022: Herbert Hoover National Historic Site (NHS), Homestead National Historical Park (NHP), and Pipestone National Monument (NM). CI = 95% confidence interval.

Sampling Year	Herbert Hoover NHS Mean H'	CI	Homestead NHP Mean H'	CI	Pipestone NM Mean H'	CI
1998	NA	NA	2.35	1.99, 2.7	2.83	2.65, 3.01
1999	NA	NA	2.56	2.37, 2.8	2.75	2.49, 3.00
2000	NA	NA	2.39	2.15, 2.62	NA	NA
2001	NA	NA	NA	NA	2.82	2.49, 3.14
2002	NA	NA	1.91	1.38, 2.44	2.99	2.98, 3.01
2004	1.28	1.03, 1.54	NA	NA	NA	NA
2005	1.25	0.83, 1.67	2.07	1.70, 2.43	2.83	2.52, 3.13
2006	NA	NA	2.24	1.84, 2.64	2.87	2.71, 3.04
2009	1.24	0.95, 1.53	1.83	1.69, 1.98	2.65	2.41, 2.90
2013	1.36	1.08, 1.65	1.94	1.68, 2.20	2.46	2.10, 2.82
2017	2.04	1.79, 2.28	1.96	1.69, 2.23	2.49	2.15, 2.83
2022	2.07	1.64, 2.50	2.22	1.97, 2.25	2.53	2.23, 2.84

Table C3. Native gamma diversity (parkwide native species richness), for three prairie parks, 1998–2022: Herbert Hoover National Historic Site (NHS), Homestead National Historical Park (NHP), and Pipestone National Monument (NM).

Sampling Year	Herbert Hoover NHS (# species)	Homestead NHP (# species)	Pipestone NM (# species)
1998	NA	87	136
1999	NA	90	147
2000	NA	90	NA
2001	NA	NA	157
2002	NA	78	83
2004	51	NA	NA
2005	59	90	145
2006	NA	96	146
2009	51	90	122
2013	66	86	136
2017	82	110	140
2022	72	100	136

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