



Vegetation Community Monitoring Trends in Restored Tallgrass Prairie at Wilson's Creek National Battlefield

2008–2020

Natural Resource Report NPS/HTLN/NRR—2022/2368



ON THE COVER

Restored tallgrass prairie at Wilson's Creek National Battlefield, 2020.
Photography by NPS/Heartland Inventory and Monitoring Network

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Executive Summary

Plant community monitoring at Wilson's Creek National Battlefield (NB) focused on the restored tallgrass prairie community. Six monitoring sites were visited four times and observations of plant species and ground cover were made. In addition to those observations, we included two environmental factors in this report—precipitation and recent fire history—to help understand the vegetation data status and trends.

Precipitation data (standardized vegetation index) indicated drought conditions in 2012 and some dry periods in 2016. Although prairies are adapted to drought, we found that species richness at the site and community scales (alpha and gamma diversity) were reduced in dry years. Fire management also plays an important role in shaping the plant communities. Prescribed fire occurrence became less frequent through the monitoring period. Also, additional treatments, including herbicide and mowing, likely shaped the prairie community. Tree regeneration and nonnative plants in particular may have been affected by these techniques.

The prairie plant community continues to be moderately diverse despite recent increases in tree seedlings and small saplings. Species richness varied over time and was correlated with precipitation. Diversity indices (H' and J') were similar across monitored years.

Species guilds (also known as functional groups) demonstrated differing patterns. Woody plants, long a concern at the park, were abundant and statistically similar across years. Many guilds were quite variable across the sites, but nonnative forbs declined, and nonnative grasses increased. Overstory trees and canopy cover, measured for the first time in 2020, have likely influenced the composition of one site. The composition of this site points to a shrubland-savanna community. Four of the sites tended towards shrubland rather than tallgrass prairie.

The vegetation monitoring protocol experienced some changes between 2008 and 2020. A key difference was a shift from sampling twice during the field season to sampling only once in a monitoring year. An anticipated decline in species richness was observed in 2012 and 2016, but we were unable to isolate sample design as the cause. Additionally, we remedied inconsistencies in how tree regeneration was recorded by tallying seedlings and saplings in the field. Our quality assurance procedures indicated that our observer error from pseudoturnover was 20.2%, meeting our expectations. Cover class estimates agreed 73% of the time, with all disagreements within one cover class.

Coordinating management actions to achieve plant community goals like structure and composition of tallgrass prairie will be critical to the survival of the prairie species at the park. Fire and nonnative plant treatments along with the reduction of woody cover including trees are needed to arrest the transition to savanna and woodland community types. Frequent prescribed fire is an integral process for this community and there is no equivalent substitute. Continued focus on management for the desired tallgrass prairie community will also provide needed habitat for imperiled pollinators such as the monarch butterfly. Best management practices for pollinators on federal lands specify that treatments (prescribed fire, mowing or haying) should not occur during the blooming season or when pollinator breeding, egg, larval or pupal stages are present.

Acknowledgments

We appreciate the support of park staff to access the park during the pandemic. Pandemic safety protocols were approved at the regional level for the 2020 survey. Seasonal staff were instrumental for completing field work throughout the monitoring history. In particular, we appreciate Missouri State University for supporting students in our work. J. Haack-Gaynor provided spatial support and M. Short was instrumental in supporting this work. We also appreciate L. Morrison for statistical support and thoughtful manuscript review.

Introduction

Wilson's Creek National Battlefield (NB) commemorates the 1861 Civil War battle for the control of Missouri. The vegetation at the time of the battle was an important aspect of the battle strategy and outcomes. As a result, restoring the battlefield conditions has been an important focus for staff since the park was established (John Milner Associates et al. 2004).

The park is in the Springfield Plain subsection of the Ozarks (Nigh and Schroeder 2002). The underlying substrate is dominated by limestone and sedimentary rock. Hills and bluff edges are complemented by the valleys and plains below. The area is a transition zone between the prairies of the Osage Plains and the woodlands of the Ozarks. The result is a heterogeneous mix of woodlands, prairies, and glades (Gremaud 1986; Diamond et al. 2012). At the time of the battle, several resident farms included cropland and grazing. At that time, the area was primarily savannas and grasslands with some open woodlands as well (Gremaud 1986). Fire, critical for maintaining open prairie landscapes, was long suppressed at Wilson's Creek NB but came into use again in 1988 (Gremaud 1986; Gale et al. 2004).

While natural community management at Wilson's Creek NB is focused on returning the woodlands and prairies to their more open structure at the time of the Civil War, promoting native species diversity is also a park management goal (Gale et al. 2004; John Milner Associates 2004). Additional goals for grassland management include preventing tree encroachment, limiting woody plant growth, and controlling invasive species (Gale et al. 2004). Treatment of invasive species, both native and nonnative, has occurred as part of the restoration process and ongoing management of the prairies (John Milner Associates 2004). This report is focused on long-term monitoring results from sites in the restored tallgrass prairie of Wilson's Creek NB.

The Heartland Inventory and Monitoring Network has conducted long-term vegetation monitoring in the prairies at Wilson's Creek NB since 1988. Although monitoring began in 1988, this report focuses on sites installed in 2008 and monitored through 2020. Monitoring was conducted in permanently located sites to determine status and trends of vegetation in the restored prairie.



Vegetation monitoring crew at Wilson's Creek NB, 2020. From the bottom of photo: Sherry Leis, Naomi Reibold, Mike DeBacker, and Mary Short.

Methods

Study Site

The prairie at Wilson’s Creek NB was replanted to native tallgrass prairie species beginning in the late 1970s and continuing to about 1993 (John Milner Associates et al. 2004). A recent vegetation map of the park shows the monitoring sites in a *mixed cool and warm season shrubland* vegetation type (Diamond et al. 2012), although the target is tallgrass prairie. Various processes have been used to manage the prairie through time, including burning and brush hogging. Park monitoring sites provide an understanding for the plant communities within the tallgrass prairie restoration reference frame (Figure 1). Cutting and herbicide treatments have also been implemented for problematic plants (John Milner Associates et al. 2004; HTLN unpublished project plan).

Sampling Design

Although we included the six active plant community monitoring sites in this analysis, two additional prairie sites have been established and monitored (HTLN 2019; Figure 1). Sites 8 and 9 were sampled from 1998–2008, but monitoring was suspended because they became overgrown and problematic to sample for safety and logistical reasons.

In 2008, sampling occurred in two seasons and data were merged into a single dataset using the maximum cover value from the two observations (Table 1). The protocol was revised in 2009 to include only one visit per monitored year.

Table 1. Sampling history for Wilson’s Creek NB prairie sites.

Sampling Year	Prairie Sampling Dates
2008	May 27–June 2, September 8–9
2012	June 8–20
2016	June 28–30
2020	June 22–25

Monitoring methods for the prairie sites followed the grassland standard operating procedures outlined in the Heartland Network vegetation monitoring protocol (DeBacker et al. 2004; James et al. 2009). Monitoring sites were 50 m x 20 m

(0.1 ha) in size with two transects bounding the site on the 50-m sides (Figure 2). Vegetation monitoring at Wilson’s Creek NB consists of ground flora species observations, ground cover, and overstory and canopy observations. The overstory, canopy, and litter depth observations were first included in the 2020 monitoring event.

Trees in the regeneration phase (seedlings, small saplings, and large saplings) were tallied by species within the plots. We maintained *Prunus* spp. within the herbaceous observations even though some species in that genus are shrubs because species can be challenging to identify at young stages.

Data Summary

Foliar cover serves as an estimate of abundance for ground flora species and ground cover. The cover class intervals were converted to midpoint values to estimate percent cover for each herbaceous and shrub species (Table 2). Mean percent cover was then calculated as the species percent cover for a sampling unit (N = 6), averaged for all subplots (n = 10, except for site 18 in 2016 where n = 9). Sampling unit (site) means were then used to calculate community-level means.

SPSS (Version 24, IBM 2016) and PC-ORD (McCune and Mefford 2016) were used for summary statistics. All site means were calculated from the included subplots (n = 10 per site). Confidence intervals (95%) were calculated and displayed.

Table 2. 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

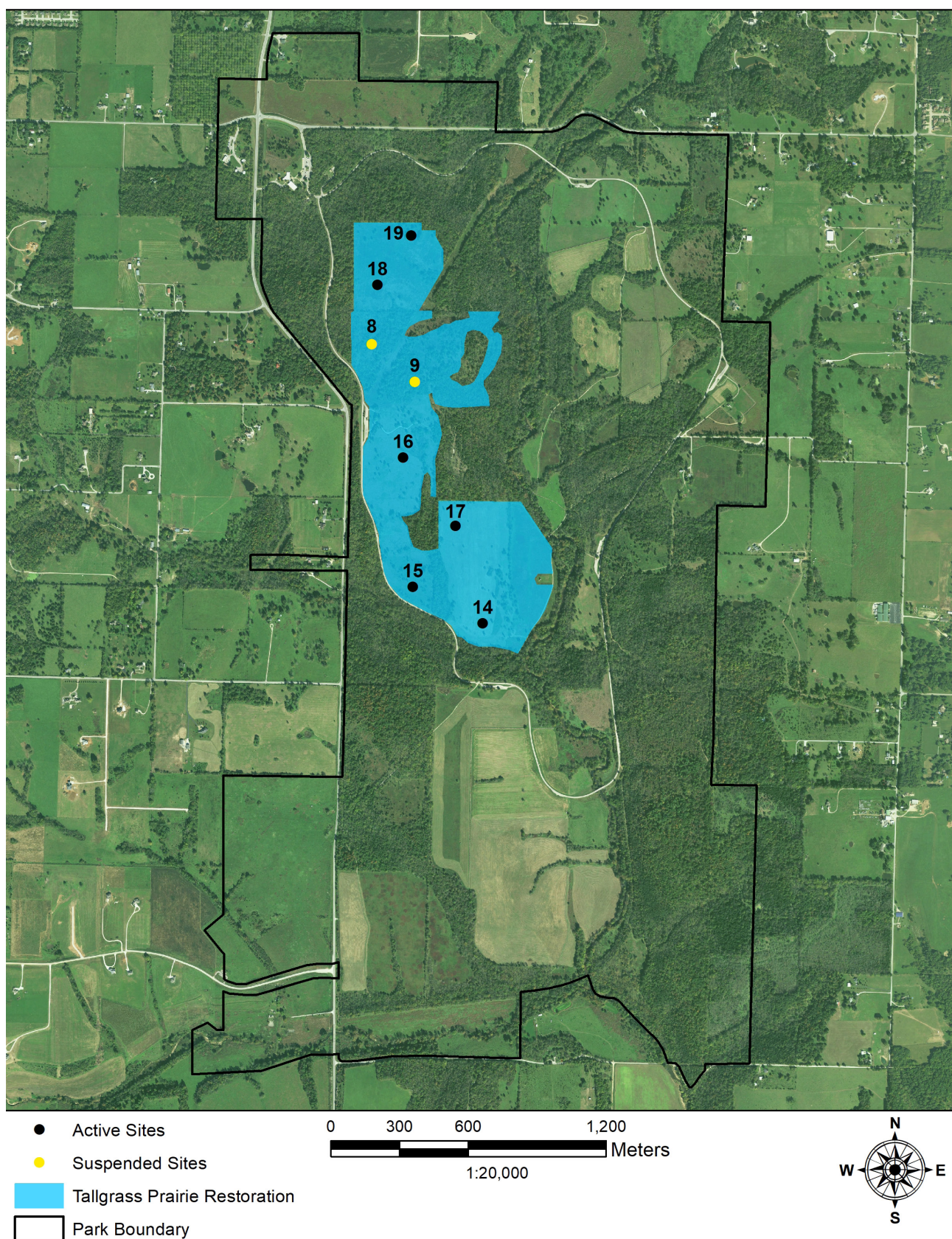


Figure 1. Vegetation monitoring sites at Wilson's Creek NB, Republic, Missouri. These Monitoring sites reflect the plant community within the tallgrass prairie restoration reference frame. Suspended sites were active 1998–2008; active sites were monitored 2008–2021.

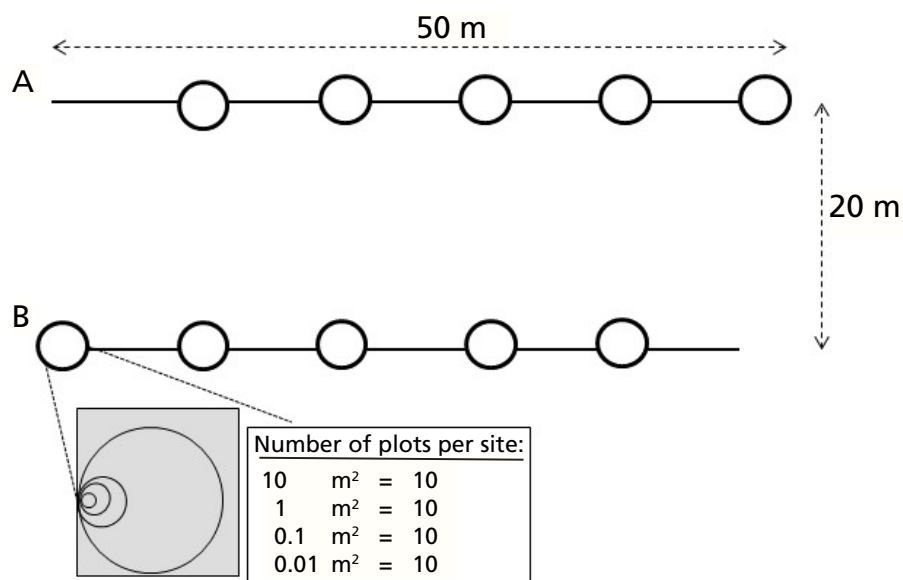


Figure 2. Sample site design for vegetation monitoring sites deployed by the Heartland Inventory and Monitoring Network at Wilson’s Creek NB, Republic, Missouri.

Climate

The Standardized Precipitation Index (SPI) calculated by 12-month intervals was obtained for station USW00013995 (Springfield airport). The SPI indicates drought or wetness in comparison to a normalized average. Values represent units of standard deviation from that average (Keyantash 2018; McKee et al. 1995). The Palmer Drought Severity Index (PDSI) was included as a complement to the SPI (Heggen 1993; Vose et al. 2014). Data were obtained from the [NOAA/National Climatic Data Center \(https://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp#\)](https://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp#). Monthly data were acquired for the southwestern division of Missouri.

Recent Fire History

Fire history records for 1995 to 2020 are included. Recent fire history for the prairie at Wilson’s Creek NB was determined using a fire history geodatabase. Although the park began using fire prior to 1995, earlier years had to be evaluated qualitatively. 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. We did

not account for seasonality in the time since fire calculations, rather we assigned burned status on an annual basis. We used a histogram approach to understand trends.

Overstory and Midstory

Overstory and midstory trees were first measured in 2020 although they were certainly present in earlier sample periods. Snags were calculated separately from live trees. Basal area and stem density were calculated within size class categories (Table 3) as described in James et al. (2009). We distinguished Class 1 (midstory trees) from classes 2 to 5 (overstory trees) for interpretation. Diameter at breast height (DBH) and stem density were scaled to the hectare for analysis.

Table 3. Diameter at breast height (DBH) measurement range (cm) and size class used to group midstory and overstory trees.

DBH (cm)	Size Class	Type
5.0–14.9	1	Midstory
15.0–24.9	2	Overstory
25.0–34.9	3	Overstory
35.0–44.9	4	Overstory
≥ 45.0	5	Overstory

Canopy Cover

Canopy cover data were collected using a densitometer. Densitometer readings were collected in the four cardinal directions in each of the ten 10-m² subplots and converted to canopy closure (multiplied by 1.04). Plot level mean canopy closure (n = 4 per subplot) was used to calculate site-level mean canopy closure. A grand mean was then calculated for all sites (N = 6).

Tree Regeneration

Tree regeneration stems were tallied by species in the 10-m² subplots and reported in three size classes: (1) seedlings = stems < 0.5 m tall; (2) small saplings = stems ≥ 0.5 m tall and < 2.5 cm DBH; and (3) large saplings = stems ≥ 0.5 m tall and between 2.5 cm and < 5.0 cm DBH. Density (stems/ha) was calculated for all stems by species. Site level densities were averaged across sites.

Ground Flora

Species Diversity Indices

Based on foliar cover measurements, diversity indices describe the number of species and their abundances. Mean site cover for all ground flora species was calculated using all subplots within each site. For each site within the community, species richness (S; for native and nonnative species, separately), Shannon diversity index (H'), and evenness (J') were calculated. Species richness, synonymous with alpha diversity, represents the number of species observed. PC-ORD (version 7.02) was used to calculate these diversity indices (McCune and Mefford 2016). A grand mean was then calculated for all sites in a community (IBM 2016).

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 and Weaver 1949).

Species distribution evenness (J') was calculated by site according to Pielou (1969):

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

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.

Additional analyses were done to understand patterns for two plant taxa: big bluestem (*Andropogon gerardii*) and milkweeds (*Asclepias* spp.). Big bluestem is an important indicator of tallgrass prairie and may be sensitive to climate change (Yurkonis and Harris 2019). Milkweeds are critical pollinator species that may be sensitive to management (Baum and Mueller 2015; Fischer 2015; Olava-Arenas et al. 2020).

Community Diversity Metrics

Native plant community richness metrics evaluate how species richness differs across monitoring sites and the park. We limited these calculations to native ground flora (not including tree regeneration) 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):

$$\text{Beta Diversity} = \frac{\text{Gamma Diversity}}{\text{Alpha Diversity}} - 1$$

Guild Abundance

Understory plant species were also summarized by guilds, also known as functional groups (James et al. 2009; designations per the USDA Plants database, USDA, NRCS 2017). Guild assignments were grasses, forbs, grass-like (species including sedges and rushes), and woody species for both native and nonnative species. A complete species

list with guild assignments 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. We also looked at the ratio of native species cover to nonnative species cover to understand trends in undesirable species. Additional species were assessed to take a deeper look into composition of the grasslands: milkweeds, big bluestem, nodding plumeless thistle (*Cadiuus nutans*), sericea lespedeza (*Lespedeza cuneata*) and annual brome grasses (*Bromus* spp.).

Ground Cover

Ground cover was assessed using cover classes (Table 2). A site mean was calculated by averaging the cover class midpoints for subplots in each site. We observed foliar cover of grass litter, leaf litter (deciduous plant leaves), exposed rock, and bare ground, and the cover of woody debris (e.g. branches and stems). Total unvegetated area reflects space unoccupied by stem basal area in the subplots (James et al. 2009). We also measured litter depth in each plot. One measurement was taken in each plot and the plots were averaged for a site mean.

Observer Error

We assessed our error in observing the ground flora with a double sampling method. At four of the seven monitoring sites, one plot from each of the two transects was randomly chosen for resampling after the transects were initially read. Sampling

teams switched transects and sampled the ground flora in the randomly chosen plot. Pseudoturnover was calculated by comparing the two reads on each plot and identifying species that were overlooked (a species was recorded by one observer but not the other), misidentified (the same specimen was apparently recorded as different species by the two observers), or at different specificity levels (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.

Statistical Analysis

Key metrics were selected for statistical testing. Repeated measures ANOVA was used for these tests. In the case of species richness, the post hoc Bonferroni test was applied to further understand the test results. SPSS v.20 was used for these analyses (IBM 2011).

Results

Climate

Standardized precipitation index (SPI) calculations indicate that conditions at Wilson’s Creek NB were primarily in the normal or wet ranges for the overall monitoring period (Figure 3). However, the 2012 monitoring event took place in dry conditions. The Palmer Drought Severity Index (PDSI) indicated extreme-exceptional drought ratings for conditions across two months in 2012. For 2016, SPI values were within normal range, but the Palmer Drought Severity Index indicated mild drought for four months (PDSI values < -1.5). Drought was not indicated for either index in 2008 or 2020.

Comparing historical data to present or predicted climate conditions can help us understand how vegetation may be changing. Climate change predictions for southwestern Missouri can be difficult to discern since climate patterns tend to be variable. However, climate tools indicate that Greene

County, where the park resides, has already entered a period of increased warming, particularly regarding the number of days with maximum temperatures over 100°F (37.8°C; US Federal Government 2016). Current or predicted precipitation patterns may be difficult to distinguish from historical ones, however, because of natural variability. Predictions indicate the number of days with large precipitation events (i.e., > 3 in [7.62 cm]) have begun to increase (US Federal Government 2016). Indications are that climate shifts have already manifested in changes to phenological events at Wilson’s Creek NB. The first leaf date is earlier than historical dates and first bloom dates are in the extremely early category (exceeds 95% of historical data; Monahan et al. 2016). Although grassland vegetation is well adapted to periodic drought, the earlier phenology and shifts in seasonality of precipitation could affect species composition by favoring C3 plants (Knapp et al. 2020).

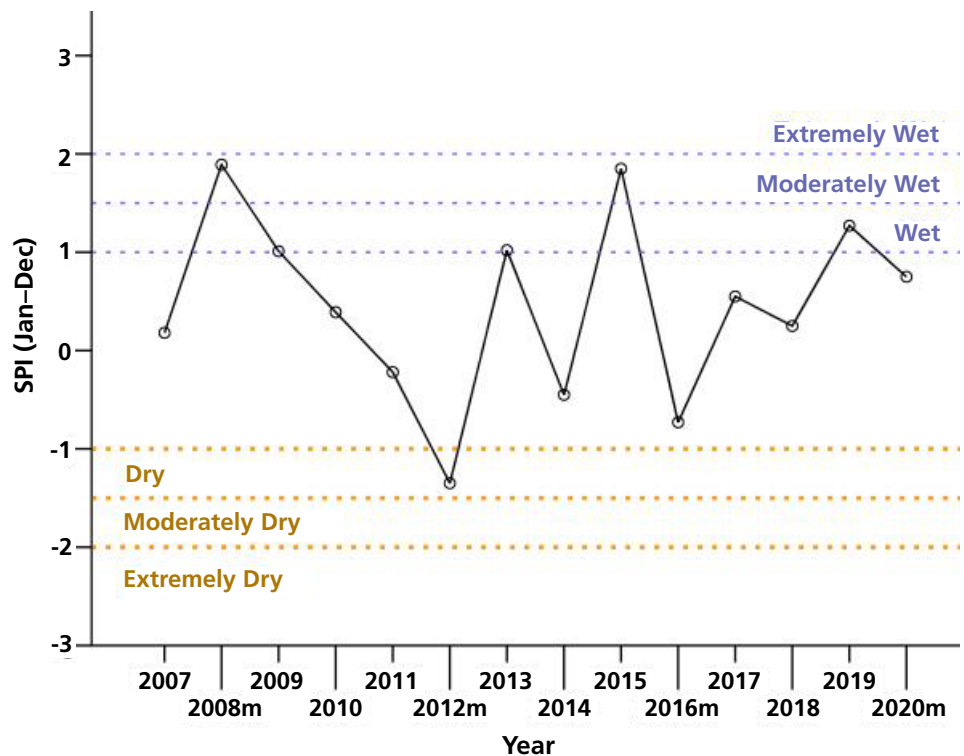


Figure 3. Standardized precipitation index (SPI) from 2007–2020 for Springfield, Missouri. SPI was calculated based on 12-month intervals. Monitored years are indicated with an “m” after the year.

Recent Fire History

Fire is an important ecological disturbance that maintains tallgrass prairie (Axelrod 1985; Anderson 1990; Howe 1994). The park fire management plan indicates that fire should be used frequently to maintain the tallgrass prairie restorations (Gale et al. 2004). The desired fire return interval for the park was 1–3 years. Our assessment of prescribed fire from prairie vegetation monitoring sites (N = 6) was that fire was being used as planned from 1994 through 2004 (Figure 4). The fire return interval increased from 2005 to present. In 2020, monitoring sites were found to be as many as seven years beyond the desired fire return interval. The loss of prescribed fire in these sites has many contributing factors. To offset the loss of fire, mowing operations increased in these prairie sites in recent years, but we do not have data on frequency or extent of mowing treatments. Mowing tends to occur in the late growing season while fires occur primarily in the spring or late growing season through November.

Overstory and Midstory Trees

Trees in the midstory and overstory classes (> 5.0 cm and > 15 cm DBH, respectively) were first measured in 2020. Live trees were present in only one of the six sites: site 19. Two species of live trees—sassafras (*Sassafras albidum*) and American elm (*Ulmus americana*)—occurred. This site approximated a savanna structure with live tree basal area of 6.77 m²/ha. Savanna communities typically have a basal area of 7 m²/ha (Nuzzo 1986; Hanberry et al. 2014; Dey and Kabraick 2015). American elm comprised the majority of the observed basal area (6.50 m²/ha). Most live trees were class 1, midstory trees (seven stems). Four stems were in larger size classes, including three in class 5. Site 15 had two snags, but no live trees. Continued measurement of overstory trees in these sites will allow us to identify a transition to a woodland state should it occur.

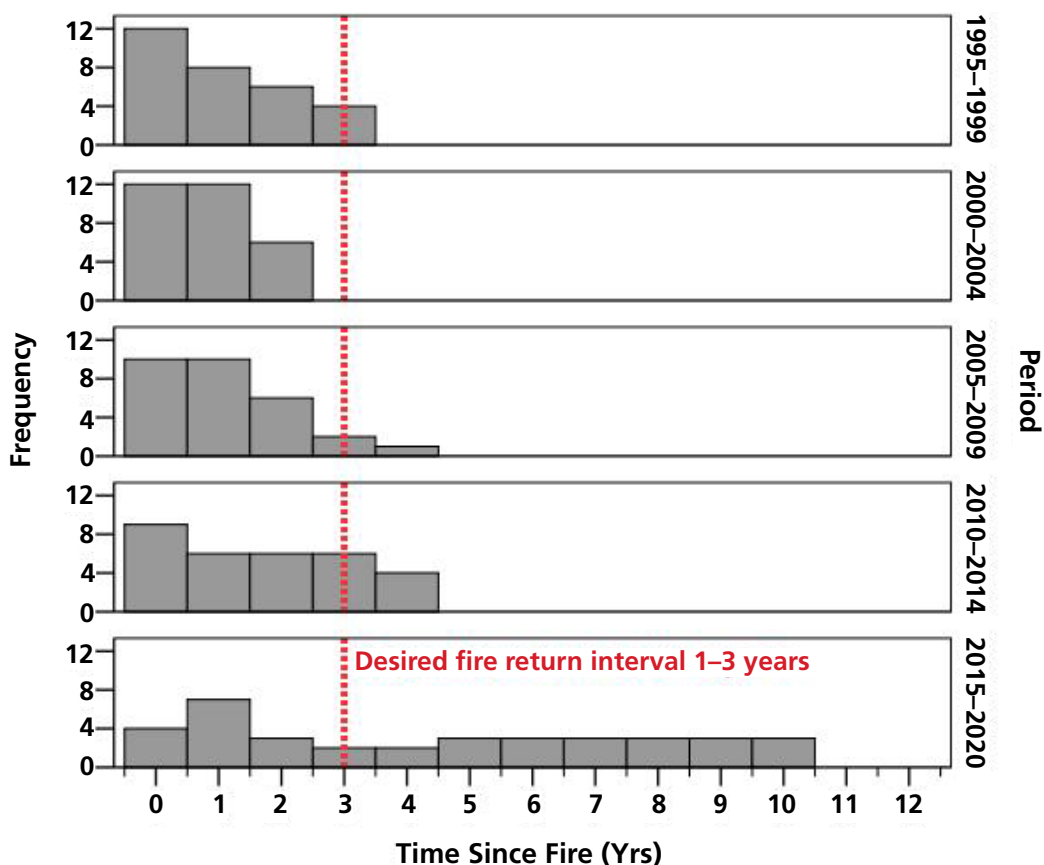


Figure 4. Time since fire frequency for six restored tallgrass prairie monitoring sites at Wilson’s Creek NB, Republic, Missouri. Each site was assigned a time since fire value for each year from 1995–2020 and results are displayed in fire-year intervals. The red dotted line indicates the maximum desired fire return interval for these sites.

Canopy Closure

Canopy closure was first measured for the prairie sites in 2020. We observed canopy closure >0% in two of the six sites. Sites 15 and 19 had mean canopy closure of 0.8% (± 1.4 SD) and 32.3% (± 31.90 SD), respectively. Both these sites either contained a cohort of trees or are in proximity to trees, which are the result of the heterogenous matrix of savanna and woodlands in the park (Diamond et al. 2012). Savanna ecosystems are characterized by up to 30% canopy closure (Nelson 2005), but the transition threshold from grassland to savanna is poorly defined. As a result, the monitoring site communities were on the continuum of savanna (mean canopy closure 4.7%). Although site 19 was near the threshold of transition from savanna to woodland for canopy closure, the combination of basal area and canopy closure together established site 19 as a savanna community type. Woodland transition could occur if basal area continues to increase (14 m²/ha is typical for open woodlands) and canopy closure remains above 30% (Hanberry et al. 2014). Many tallgrass prairie species are intolerant of tree

canopy, especially grassland birds (Briggs et al. 2002a; Chapman et al. 2004) and sun-loving herbaceous forbs and grasses (Nelson 2005).

Tree Regeneration

Prairie management at the park aims to minimize the establishment of trees using fire, mechanical, and chemical techniques. The density of tree stems in the regeneration phase was greatest in the 2020 sampling event (Figure 5). The number of seedlings was 165% greater than the next greatest sampled year, 2008. Like the overstory species, elm and sassafras were the densest species (Table 4). Coincidentally, site 19 had overstory trees and the greatest number of regeneration stems, twice the number of any other site. Observed for the first time in 2020, seedlings that progressed to the small sapling stage were found in half of the sites. Large saplings have not been observed during any of the monitoring events to date. Continued efforts to limit the establishment of trees in these sites will be needed to avoid further community level transition towards woodland.

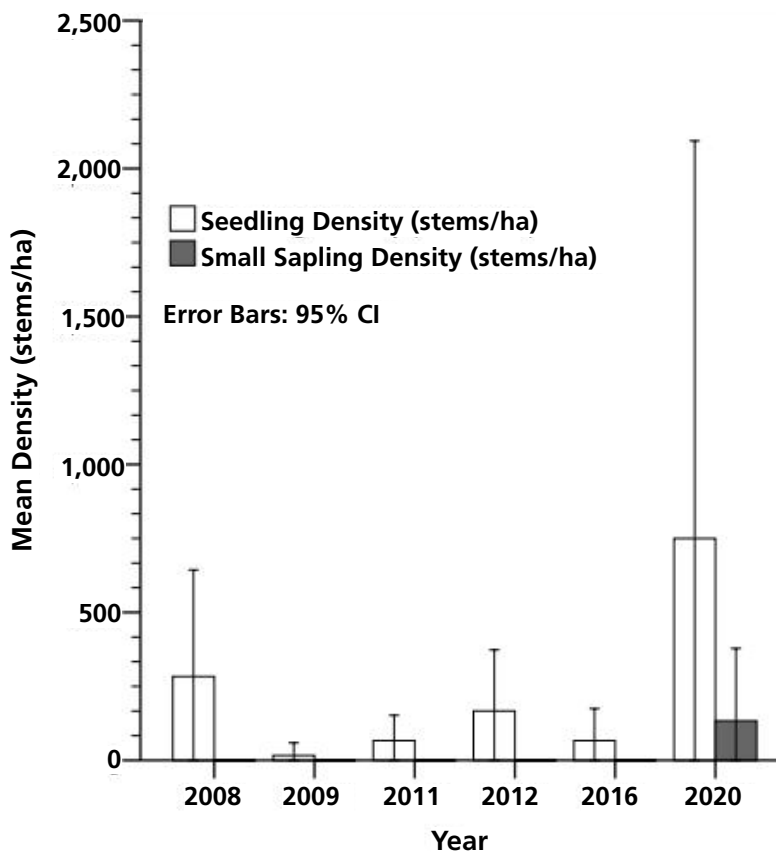


Figure 5. Tree regeneration stem density (stems/ha) by size class in the prairie monitoring sites at Wilson's Creek NB, Republic, Missouri. Size classes: seedlings = stems <0.5 m tall; small saplings = stems ≥ 0.5 m tall and <2.5 cm DBH; and large saplings = stems ≥ 0.5 m tall and between 2.5 cm and 5.0 cm DBH.

Table 4. Tree regeneration (seedlings and small saplings) mean stem density (mean stems/ha) in prairie monitoring sites at Wilson's Creek NB, Republic, Missouri. Size classes: seedlings = stems <0.5 m tall; small saplings = stems ≥0.5 m tall and <2.5 cm DBH.

Species	Seedlings 2008	Seedlings 2012	Seedlings 2016	Seedlings 2020	Small Saplings 2020
<i>Celtis occidentalis</i>	16.7	16.7	16.7	0.0	0.0
<i>Cornus florida</i>	0.0	0.0	0.0	216.7	16.7
<i>Gleditsia triacanthos</i>	33.3	16.7	33.3	0.0	0.0
<i>Juglans nigra</i>	0.0	16.7	0.0	0.0	0.0
<i>Pyrus calleryana</i>	0.0	0.0	0.0	16.7	0.0
<i>Quercus</i> spp.	0.0	0.0	16.7	0.0	0.0
<i>Sassafras albidum</i>	100.0	183.3	100	200.0	100.0
<i>Ulmus</i> spp.	150.0	116.7	16.7	300.0	16.67
<i>Ulmus pumila</i>	83.3	0	16.7	0	0

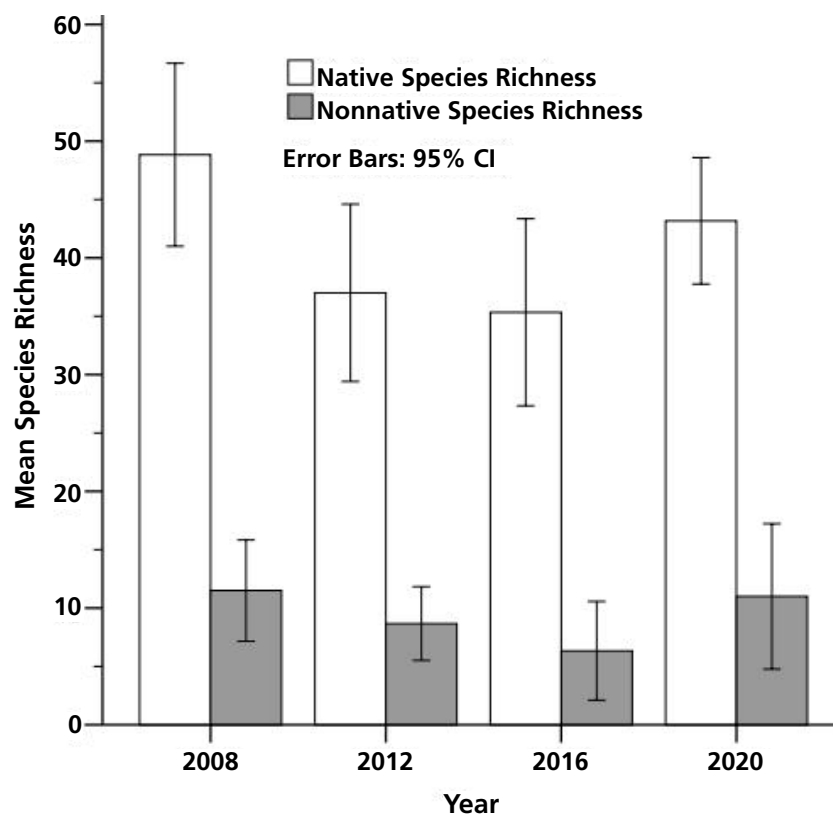


Figure 6. Mean species richness for prairie monitoring sites (N = 6) by origin at Wilson's Creek NB, Republic, Missouri.

Diversity

Species Diversity

Native species richness was significantly greater in 2008 and 2020 than in 2012 and 2016 (post hoc Bonferroni pairwise comparisons following a repeated measures ANOVA, $F = 18.43$, $df = 3,18$; $P < 0.001$). For both native and nonnative species, mean richness appeared to be greater in wetter years

(Figures 3 and 6), suggesting that the community is not resilient to changes in precipitation. In three of the four monitoring events, site 19 (site with overstory trees) had the most native species.

Species richness did not appear to respond directly to the change in prescribed fire, but other management actions such as mowing and herbicide treatments may have provided needed ecological disturbance to maintain species numbers. Changes to the

monitoring protocol in 2009 were expected to reduce species richness by a few species. Although species richness was less in the two subsequent years, we are unable to definitively attribute the trend to protocol changes.

Species diversity was measured using the Shannon diversity index (H') and an evenness index (J') (Figure 7). H' includes both species richness and cover in the calculation, with larger values indicating greater diversity. Mean diversity (H') appeared to decline after 2012, and the trend was marginally significant (repeated measures ANOVA $F = 3.33$, $df = 3,18$; $P = 0.048$). However, the more conservative post hoc Bonferroni comparisons revealed no significant difference among pairs of years. Considering that species richness was similar at the start and end of our study, the cause of decline in diversity is unclear. Evenness has been very steady and moderate, indicating that the species assemblages across sites have a variety of species including some species in common.

Although our design does not allow us to test for the causes of shifts in diversity indices, we can suggest some sources of variation. It is common for plant diversity in prairie restorations to decrease over time and our results may be documenting this

process of maturation (Wagle and Gowda 2018). As a restoration matures, early seral species may be outcompeted by dominant matrix species. Changes in management at the park, such as the reduction in burning, may have also contributed to the reduction in species diversity (Gibson and Hulbert 1987). Staffing changes resulting in differences in cover estimation may be a source of error as well and could influence the results.

Community Diversity

Community diversity allows us to understand the plant assemblages at different spatial scales. Values for 2020 were within the range of variation for previous measurements (Table 5) of all three indices. Gamma diversity (the number of native species recorded community wide) exhibited a similar pattern as alpha diversity (a site scale indication of the number of native species). Alpha diversity differed by 13.5 species across the monitored years. Gamma diversity has fluctuated by 28 species from the greatest species count in 2008 to the lowest in 2012 (also the driest year). Beta diversity (A measure of species heterogeneity among sample units) was relatively low, indicating that sites are somewhat similar with some unique species in their assemblages.

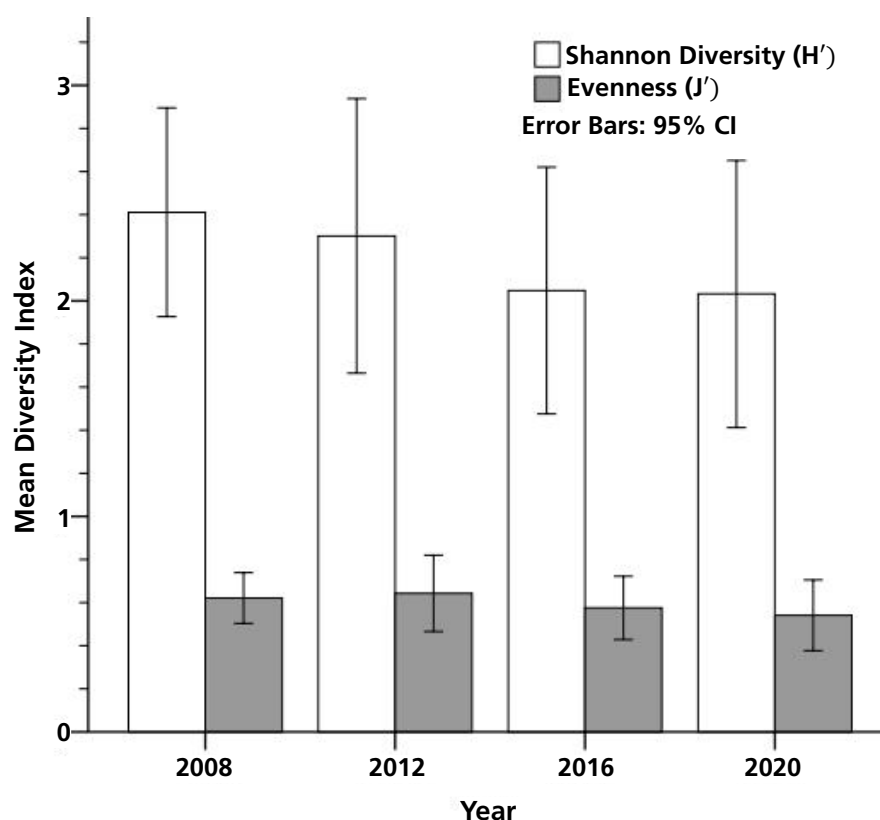


Figure 7. Mean native plant species diversity (H' , J') for prairie vegetation sites at Wilson's Creek NB, Republic, Missouri.

Table 5. Native plant community diversity metrics (alpha, gamma, and beta diversity) at Wilson’s Creek NB, Republic, Missouri, in monitored years.

Year	Alpha Diversity (mean site richness)	Gamma Diversity	Beta Diversity (gamma/alpha)-1
2008	48.5	109	1.2
2012	36.7	81	1.2
2016	35.0	85	1.4
2020	43.2	94	1.2

Guild Abundance

Grouping species by guild can be helpful for understanding how species are changing through time. There was a great deal of variability among the sites for many of the guilds (Figure 8). Of note was a substantial decline in nonnative forbs after 2008 and an increase in mean invasive grasses in 2020. We also found that the proportion of nonnative mean cover was substantial—greater than 50% of the vegetation cover in sites 14, 15, and 17 (Table 6). Similarly, in a study of long-term prairie restorations, McLachlan and Knispel found that restored prairie tends to have more nonnative species than remnant prairies and that proportion increases with restoration age (2005).

Table 6. Mean proportion of nonnative species cover and mean cover of two invasive plants in the ground flora at Wilson’s Creek NB, Republic, Missouri, 2008–2020 (± 1 SE [standard error]).

Year	Mean Proportion Nonnative (%)	<i>Bromus</i> sp. (%)	<i>Lespedeza cuneata</i> (%)
2008	47.9 (± 8.3)	9.5 (± 4.2)	47.7 (± 10.0)
2012	35.1 (± 10.2)	22.5 (± 8.3)	7.5 (± 2.4)
2016	29.9 (± 9.3)	8.4 (± 3.4)	13.1 (± 4.1)
2020	38.0 (± 10.3)	33.0 (± 10.4)	7.9 (± 3.1)

Of the nonnative forbs, sericea lespedeza (*Lespedeza cuneata*) was most dominant. This species decreased more than six-fold from 2008 to 2020, likely reducing the proportion of nonnative species (Table 6). Sericea lespedeza was most abundant in site 17 in 2008 at 87% cover compared to 13% in 2020. Although prescribed fire may have some ability to control sericea, a prior study at Wilson’s Creek NB did not detect a fire effect (Cummings et al. 2007; Mlekush and James 2012). Mowing and herbicide operations may have contributed to the decline in sericea over time. This species has been shown to disrupt grassland systems (Cummings et al. 2007; Allred et al. 2010; Hoch et al. 2002). Effective control efforts are

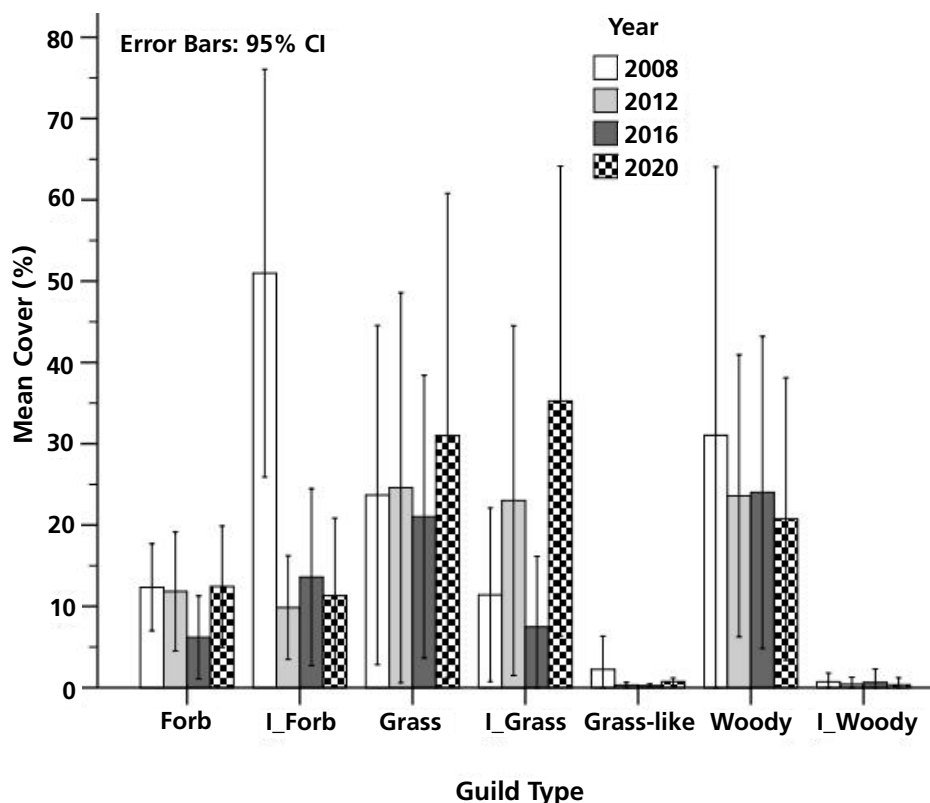


Figure 8. Species cover (%) by guild type at Wilson’s Creek NB, Republic, Missouri. “I_” preceding the guild name indicates nonnative species and other bars are native species.

likely to include a combination of approaches such as herbicide, fire, grazing, and mowing (Cummings et al. 2007; Wong et. al. 2012).

Of the nonnative grasses, we observed plots with substantial amounts of annual brome grasses (*Bromus arvensis*, *B. sterilis*, and *B. tectorum*; see Appendix A). Mean cover for these grasses more than doubled in 2020 (33%). We might surmise that the gaps left in the community by sericea were filled in part by annual brome grasses. For example, at site 17 mean annual brome cover increased from 4% to 60% between 2008 and 2020. Mowing treatments late in the season could have also favored these nonnative grasses (Whisenant 1990).

Mean cover of woody plants (nontree species) did not change over time (repeated measures ANOVA,

$F = 0.856$, $df = 3,18$; $P = 0.485$) despite the reduction of prescribed fire. Mean cover of woody plants was within 10% of the native grass guild in any given year, indicating a near codominance between native grasses and woody plants (Figure 8). For site 19, woody cover was 40.5% in 2020, a reduction of more than half over 2008 levels. Blackberry (*Rubus* spp.), coralberry (*Symphoricarpos orbiculatus*), and winged sumac (*Rhus copallinum*) were the most dominant woody plants in this site in 2008 and 2020. Mowing treatments have likely helped reduce the woody plant guild in site 19 (Figure 9). In remnant prairies that are in good condition, woody plants typically comprise up to about 5% of the native plant community (Bragg and Hulbert 1976). Only one site maintained woody cover below 5% for all four monitoring events (site 16).



Figure 9. Photos of site 19 at Wilson's Creek NB, Republic, Missouri. Left photo from 2010 prior to a prescribed fire. Note trees in the upper right and sericea lespedeza (*Lespedeza cuneata*) in the foreground and *Rhus* spp. (sumac) and trees in the background. Right photo taken in 2021, 10.5 years after the last fire. This area had recently been brush hogged after the most recent monitoring event.



Figure 10. Nodding plumeless thistle (*Carduus nutans*) infestation around stake at site 14. Brown grasses are nonnative annual brome species.

Community descriptions for central tallgrass prairie indicate shrubs are < 10% of the vegetation, while in the eastern North American ruderal grassland and shrublands type, shrubs and trees are < 25% (Nature Serve 2017, 2018). Our estimates of shrub cover in conjunction with community definitions confirm vegetation map assessments that the tallgrass prairie restorations in this reference frame are shrubland (Diamond et al. 2012; Ratajczak et al. 2014).

Although frequent fire can reduce the establishment of trees and shrubs in the prairie, proximity to seed sources from adjacent woodlands, atmospheric CO₂ enrichment, and other factors favor woody plant growth (Briggs et al. 2002b; Van Auken 2009; Fogarty et al. 2020; Knapp et al. 2020). Assertive management actions will be needed to limit or reverse woody encroachment in the restored prairie in the future.

Additional Species Studies

We highlight these additional species and species groups here to further understand how species composition changed over time: nodding plumeless thistle (*Carduus nutans*), milkweeds (*Asclepias* spp.), and big bluestem (*Andropogon gerardii*).

During the 2020 sampling, we observed a population of nodding plumeless thistle, a noxious, nonnative plant, adjacent to sites 14 and 17 (Figure 10). The park's maintenance crew promptly mowed the population to prevent seed production. Nodding plumeless thistle was observed in 2012 (0.07% mean cover) and then in 2020 with a slightly more prevalent mean cover (1.08%), but in the most abundant site, mean cover was nearly 5%. Continued treatment of this thistle is critical to limiting the infestation.

Milkweeds are known as critical plant species for pollinators, especially the monarch butterfly (*Danaus plexippu*; Baum and Mueller 2015; Zaya et al. 2017; Olaya-Arenas 2020). In the prairie monitoring sites, five species of milkweed have been observed since 2008. In the wetter years (2008, 2020) milkweeds were found in all six sites. In the intervening years they were only found in 2–3 sites. From 2008–2016, two species were recorded for each monitoring event, but four species were recorded in 2020. Mean cover was low (< 1% in all years), similar to other studies (McCain et al. 2010; Zaya et al. 2017).

Big bluestem is a matrix grass of the tallgrass prairie. Climate change is predicted to affect this grass by eventually shifting its range northeasterly away from the park. Although our time series is presently only 12 years long, this analysis can serve as a baseline for understanding future trends (Figure 11). Although mean big bluestem cover was 13% greater in 2020 than in 2008, it did not differ significantly (repeated measures ANOVA, $F = 0.29$, $df = 3,18$; $P = 0.82$). Sites were quite variable; for example in 2020, three of the sites had <1% cover while three sites had cover ranging from 16–76%. The site with the most big bluestem, site 16, also had the greatest amount of milkweed and fewest woody plants. Big bluestem often comes to dominate restorations at the expense of some forbs, but this grass was heterogeneously distributed at the park during the period of our study.

Ground Cover

Ground cover is affected by disturbance history and changes in species composition. The amount of rock visible at the Wilson's Creek NB is typically small

(Figure 12). Woody debris and deciduous leaf litter were related to the presence of trees in the sites and proximity to woodlands.

Grass litter cover was related to increasing time since fire (Figures 4 and 12). The least grass litter was observed in 2012 when all sites were two years since the last burn. The greatest litter cover occurred in 2020 when four sites ranged from 4–10 years since the last burn. Litter cover benefits some grassland plant and animal species while bare ground benefits others. The invasive annual brome species, for example, has been shown to increase germination rates with moisture provided by robust litter layers (Whisenant 1990). Litter can also limit germination of native species by shading the ground (Lamb 2008). Heterogeneity of litter cover can be achieved by staggering treatments yielding a diversity of habitats.

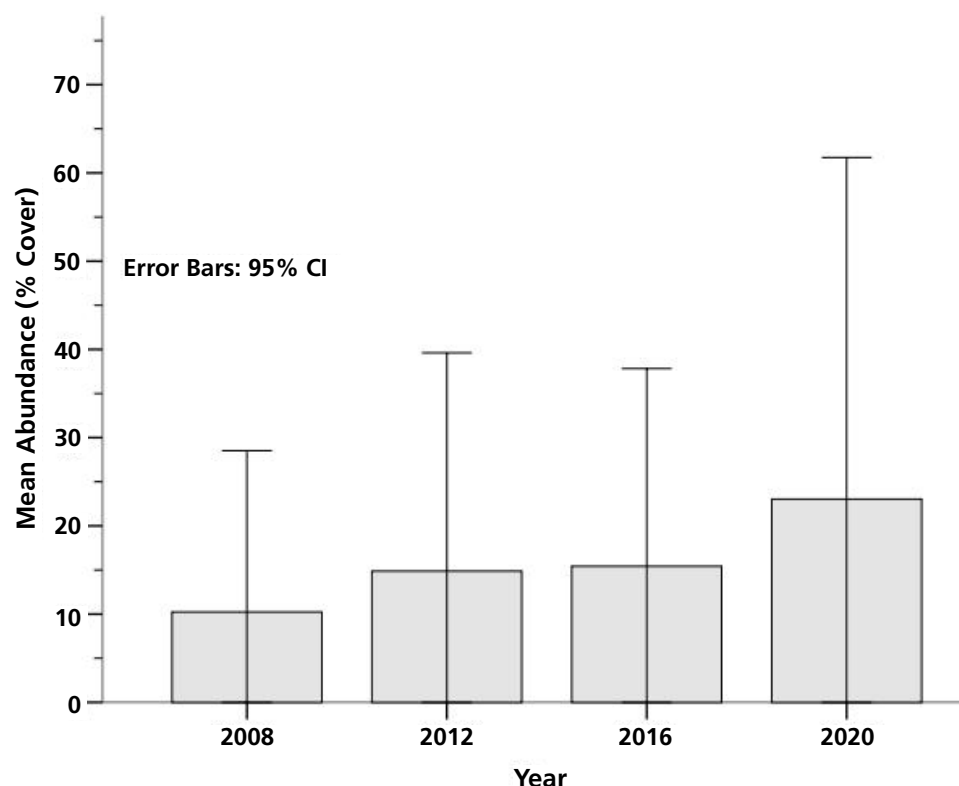


Figure 11. Mean cover of big bluestem (*Andropogon gerardii*) in prairie sites (N = 6) at Wilson's Creek NB, Republic, Missouri.

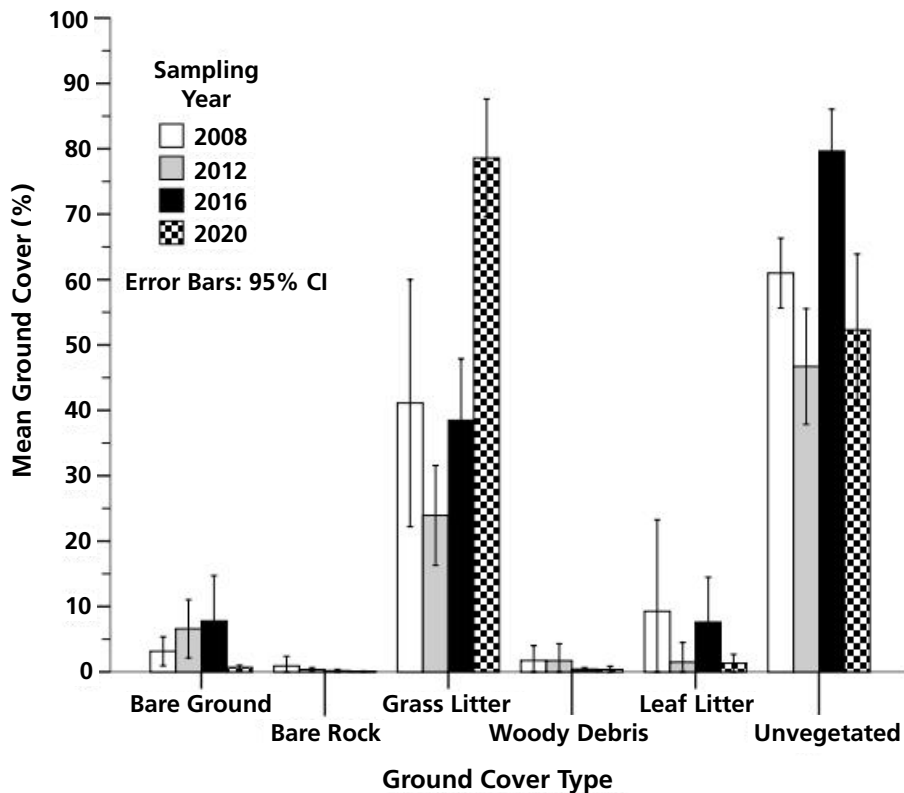


Figure 12. Mean ground cover (%) for six cover types for monitoring years 2008–2020 at Wilson’s Creek NB, Republic, Missouri.

Litter Depth

Litter depth (all types) was measured for the first time at Wilson’s Creek NB in 2020. Mean litter depth was 4.87 cm (± 1.08 SE). Site 17 had the greatest mean litter depth (10 cm) and the greatest litter cover.

Litter can be beneficial by facilitating water infiltration to the soil, thus maintaining soil moisture through reduction in soil respiration (Wagle and Gowda 2018). Conversely, accumulated litter can inhibit some plants from growing, potentially reducing productivity (Hulbert 1988; Lamb 2008). Furthermore, a study of small mammals found that litter depths near the maximums in the study (heavy [8,400 g, 20 cm, ca. 1,640 g/m²] or compact [4,200 g, 10 cm, 820 g/m²]) deterred small mammals from using the habitat (Clark and Kaufman 1991). Litter is an important component of grassland fuels and greater litter depth can indicate greater grassland biomass (Leis and Morrison 2011). When uncompacted and dry, litter facilitates the movement of fire (Wragg et al. 2018), but when compacted (from mowing or trampling, for example) oxygen is limited in this layer and fire spread is inhibited (Schwilk 2015).

Observer Error

Observer error was measured for the first time at Wilson’s Creek NB in 2020 (Table 7). Observer error has multiple components. Importantly, our misidentification error was low (0.9 %). We recorded few instances of cautious error (where one observer lumped an observation to the genus level and the other observer was more specific). Our greatest source of error came from overlooking of species by one of the observers (18.8%). Our total pseudoturnover is a function of all three types of error and averaged 20.2% for the sampling event resulting in 79.8% agreement (Table 7). We aimed to keep our species agreement $\geq 80\%$ based on a survey of the literature (Morrison 2016) and a previous sample event at Tallgrass Prairie National Preserve (Morrison et al. 2020). We suspect that sample frame relocation between observers may have been an important source of error that we could not control, although we made efforts to reduce it. We do not have a quantitative assessment of the contribution of this source of error, however.

Table 7. Species observer error rates for the 2020 sampling event at Wilson's Creek NB, Republic, Missouri (N = 6).

Error Component	Mean Error Rate (%)
Overlooking	18.8
Misidentification	0.9
Cautious	0.4
Total pseudoturnover	20.2

We also assessed the amount of agreement on the cover classes for species both observers recorded. Overall, on average there was 73% agreement on cover classes, 27% of observations were within one cover class, and no observations differed by > 1 cover class. This was within range the of values we measured at other parks where agreement ranged from 73–85% (Morrison et al. 2020; Leis 2021; Leis and Short 2021). The disagreement of cover class assignments could contribute to the variability observed in the analyses above. Sources of the disagreement could be training related or a function of the structure of the vegetation. Team training was hampered by teleworking requirements resulting from the pandemic. The structure of the vegetation was very complex with the intermixing of substantial senescing early season grasses and dense forbs and grasses intermixed with woody vegetation of varying heights.

Protocol Changes

We considered two key changes to the revisit design of the protocol. The revisit design changed in 2009 from sampling twice during the growing season to sampling once 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 as a result of changing to one visit per field season. Species richness did decline in the following two monitoring events. However, we cannot be certain which factors caused the decline. At other parks, we observed a decline in the cover of grasses that may have been the result of the change in the revisit design (Leis and Young 2018; Leis 2019; Leis and Short 2021), but we did not observe that pattern at Wilson's Creek NB. The native warm season grasses are normally at peak in the late summer rather than during the current June sampling period.

Revisions to the 2009 protocol are currently under peer review. These revisions affected tree regeneration observations in 2020. Previously, tree regeneration was recorded inconsistently, sometimes being assigned cover values with the herbaceous species and other times being tallied. We remedied this situation by converting all tree regeneration cover to stem tallies.

Conclusions

The restored tallgrass prairie monitoring sites at Wilson's Creek NB were heterogeneous in many ways, such as tree encroachment, grass cover, and woody plants. Although mean woody cover was similar through time, tree regeneration increased. Predictions for climate change would lead us to expect increases in both trees and native woody plants. Reductions in prescribed fire can also lead to increased woody plant growth, including tree growth (Bragg and Hulbert 1976; Ratajczak 2014). Species richness and gamma diversity (community-wide richness) were correlated with precipitation. Milkweeds are an important component of pollinator habitat. Although they were not abundant, they were observed in all the sites over time and observed in at least 33% of sites in a given year. *Sericea lespedeza* (a key nonnative, invasive plant) declined over the monitoring period, but other undesirable species expanded.

Changes to the sampling protocol did not clearly influence vegetation trends. However, inconsistencies in the recording of tree regeneration stem counts prior to 2020 may have contributed to the increase in stems in 2020. Nevertheless, the density of seedlings and small saplings coupled with the high level of woody plants signals the need for management intervention if tallgrass prairie remains the target community.

Pollinators and butterflies are currently a priority for natural resource management in regions 3, 4, and 5. This designation underscores the importance of managing for pollinators and the role of prairie as pollinator habitat. Moreover, monarch butterflies, which require milkweed plants found in the prairie at the park, are a candidate for listing under the endangered species act (see [Assessing the status of the monarch butterfly \[fws.gov\]](#)). Management of the park's prairies for pollinators and their host plants is of critical ecological importance as well as important for maintaining the historical scene. Management practices for the prairie have shifted from an emphasis on prescribed fire treatments to mowing, and tree growth and nonnative species have increased as a result. Timing treatments to target species' vulnerable periods while conserving pollinator host plants and avoiding sensitive periods of pollinator activity, such as migration and pupation, may aid in improving plant composition and resiliency and protect critically important pollinators. Whichever method of prairie management is used (prescribed fire, mowing, haying), best management practices for pollinators on federal lands specify that treatments should not occur during the blooming season or when pollinator breeding, egg, larval or pupal stages are present (USDA and USDOJ 2015).

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Appendix A. Plant Species

We provide a few notes here to elucidate our species designations provided in Table A1. The species recorded as *Bromus* spp. were annual species that can be difficult to distinguish. We noted that *B. arvensis*, *B. sterilis*, and *B. tectorum* were present. We noted that for *Vitis* spp., we observed both *V. aestivalis* and *V. vulpina* in the plots. *Desmodium* spp. is most likely *D. perplexum* or *D. glabellum*. We were unable to reliably distinguish these two species in vegetative form.

Table A1. All species observed in the prairie sites (N = 6) at Wilson's Creek NB, Republic, Missouri. Values for mean cover, standard error (SE) and occurrence are for 2020 only. Species with 0 values were observed in other years. N = native, I = nonnative. Tree species are not included in this table, see Table 3 for species and abundance values.

Species	Common Name	Guild	Origin	2020 Mean Cover (%)	SE	Occurrence (% Sites Observed, 2020)
<i>Acalypha virginica</i>	Virginia threeseed mercury	forb	N	33.33	0.01	0.03
<i>Achillea millefolium</i>	common yarrow	forb	N	66.67	0.09	0.43
<i>Agrostis hyemalis</i>	winter bentgrass	grass	N	33.33	0.13	0.53
<i>Allium vineale</i>	wild garlic	forb	I	50.00	0.02	0.08
<i>Ambrosia artemisiifolia</i>	annual ragweed	forb	N	33.33	0.01	0.06
<i>Amphicarpaea bracteata</i>	American hogpeanut	forb	N	0.00	0.00	0.00
<i>Andropogon gerardii</i>	big bluestem	grass	N	83.33	7.83	29.44
<i>Andropogon virginicus</i>	broomsedge bluestem	grass	N	16.67	0.10	0.61
<i>Apocynum cannabinum</i>	Indianhemp	forb	N	0.00	0.00	0.00
<i>Artemisia ludoviciana</i>	white sagebrush	forb	N	33.33	0.30	1.20
<i>Asclepias amplexicaulis</i>	clasping milkweed	forb	N	16.67	0.01	0.06
<i>Asclepias purpurascens</i>	purple milkweed	forb	N	0.00	0.00	0.00
<i>Asclepias syriaca</i>	common milkweed	forb	N	16.67	0.00	0.02
<i>Asclepias tuberosa</i>	butterfly milkweed	forb	N	16.67	0.00	0.02
<i>Asclepias viridiflora</i>	green comet milkweed	forb	N	50.00	0.02	0.06
<i>Aster</i> spp.	aster	forb	N	0.00	0.00	0.00
<i>Baptisia alba</i> var. <i>macrophylla</i>	largeleaf wild indigo	forb	N	33.33	0.04	0.14
<i>Baptisia bracteata</i> var. <i>leucophaea</i>	longbract wild indigo	forb	N	0.00	0.00	0.00
<i>Barbarea vulgaris</i>	garden yellowrocket	forb	I	66.67	0.05	0.17
<i>Botrychium virginianum</i>	rattlesnake fern	fern	N	16.67	0.00	0.02
<i>Bouteloua curtipendula</i>	sideoats grama	grass	N	33.33	0.01	0.03
<i>Brickellia eupatorioides</i>	false boneset	forb	N	16.67	0.01	0.04
<i>Bromus</i> spp.	brome	grass	I	83.33	13.46	25.58
<i>Bromus inermis</i>	smooth brome	grass	I	0.00	0.00	0.00
<i>Carduus nutans</i>	nodding plumeless thistle	forb	I	50.00	0.44	1.87
<i>Carex</i> spp.	sedge	grass-like	N	100.00	0.30	0.43
<i>Celastrus scandens</i>	American bittersweet	woody	N	0.00	0.00	0.00
<i>Cerastium pumilum</i>	European chickweed	forb	I	0.00	0.00	0.00
<i>Chaerophyllum tainturieri</i>	hairyfruit chervil	forb	N	0.00	0.00	0.00
<i>Chamaecrista fasciculata</i>	partridge pea	forb	N	16.67	0.00	0.02
<i>Chenopodium album</i>	lambsquarters	forb	N	0.00	0.00	0.00
<i>Chrysopsis pilosa</i>	soft goldenaster	forb	N	0.00	0.00	0.00

Table A1 (continued). All species observed in the prairie sites (N = 6) at Wilson's Creek NB, Republic, Missouri. Values for mean cover, standard error (SE) and occurrence are for 2020 only. Species with 0 values were observed in other years. N = native, I = nonnative. Tree species are not included in this table, see Table 3 for species and abundance values.

Species	Common Name	Guild	Origin	2020 Mean Cover (%)	SE	Occurrence (% Sites Observed, 2020)
<i>Cirsium altissimum</i>	tall thistle	forb	N	83.33	0.21	0.75
<i>Cirsium discolor</i>	field thistle	forb	N	50.00	0.05	0.16
<i>Conyza canadensis</i>	Canadian horseweed	forb	N	16.67	0.00	0.02
<i>Coreopsis palmata</i>	stiff tickseed	forb	N	0.00	0.00	0.00
<i>Cornus</i> spp.	dogwood	woody	N	0.00	0.00	0.00
<i>Croton monanthogynus</i>	prairie tea	forb	N	0.00	0.00	0.00
<i>Cruciata pedemontana</i>	piedmont bedstraw	forb	I	83.33	0.11	0.19
<i>Cyperus</i> spp.	flatsedge	grass-like	N	0.00	0.00	0.00
<i>Dactylis glomerata</i>	orchardgrass	grass	I	16.67	0.00	0.02
<i>Daucus carota</i>	Queen Anne's lace	forb	I	16.67	0.00	0.02
<i>Desmodium</i> spp.	ticktrefoil	forb	N	33.33	0.01	0.06
<i>Desmodium canadense</i>	showy ticktrefoil	forb	N	83.33	0.08	0.22
<i>Desmodium ciliare</i>	hairy small-leaf ticktrefoil	forb	N	0.00	0.00	0.00
<i>Desmodium glabellum</i>	Dillenius' ticktrefoil	forb	N	0.00	0.00	0.00
<i>Desmodium paniculatum</i>	panickedleaf ticktrefoil	forb	N	83.33	0.12	0.33
<i>Desmodium perplexum</i>	perplexed ticktrefoil	forb	N	0.00	0.00	0.00
<i>Desmodium sessilifolium</i>	sessileleaf ticktrefoil	forb	N	33.33	0.11	0.61
<i>Dianthus armeria</i>	Deptford pink	forb	I	50.00	0.02	0.06
<i>Dichanthelium</i> spp.	rosette grass	grass	N	100.00	0.35	0.56
<i>Dichanthelium clandestinum</i>	deertongue	grass	N	50.00	0.01	0.03
<i>Digitaria cognata</i>	fall witchgrass	grass	N	0.00	0.00	0.00
<i>Echinacea pallida</i>	pale purple coneflower	forb	N	33.33	0.11	0.63
<i>Elymus canadensis</i>	Canada wildrye	grass	N	33.33	0.01	0.03
<i>Elymus villosus</i>	hairy wildrye	grass	N	33.33	0.05	0.24
<i>Elymus virginicus</i>	Virginia wildrye	grass	N	66.67	0.10	0.23
<i>Eragrostis spectabilis</i>	purple lovegrass	grass	N	0.00	0.00	0.00
<i>Erigeron annuus</i>	eastern daisy fleabane	forb	N	0.00	0.00	0.00
<i>Erigeron strigosus</i>	prairie fleabane	forb	N	33.33	0.07	0.29
<i>Eryngium yuccifolium</i>	button eryngo	forb	N	0.00	0.00	0.00
<i>Euonymus atropurpureus</i>	Eastern burning bush	woody	N	0.00	0.00	0.00
<i>Euonymus fortunei</i>	winter creeper	woody	I	16.67	0.00	0.02
<i>Eupatorium altissimum</i>	tall thoroughwort	forb	N	0.00	0.00	0.00
<i>Euphorbia corollata</i>	flowering spurge	forb	N	66.67	0.07	0.20
<i>Euphorbia dentata</i>	toothed spurge	forb	N	0.00	0.00	0.00
<i>Fragaria virginiana</i>	Virginia strawberry	forb	N	16.67	0.10	0.61
<i>Galium aparine</i>	stickywilly	forb	N	0.00	0.00	0.00
<i>Gamochaeta purpurea</i>	spoonleaf purple everlasting	forb	N	33.33	0.02	0.12
<i>Gaura biennis</i>	biennial beeblossom	forb	N	0.00	0.00	0.00
<i>Geranium carolinianum</i>	Carolina geranium	forb	N	83.33	0.06	0.12

Table A1 (continued). All species observed in the prairie sites (N = 6) at Wilson's Creek NB, Republic, Missouri. Values for mean cover, standard error (SE) and occurrence are for 2020 only. Species with 0 values were observed in other years. N = native, I = nonnative. Tree species are not included in this table, see Table 3 for species and abundance values.

Species	Common Name	Guild	Origin	2020 Mean Cover (%)	SE	Occurrence (% Sites Observed, 2020)
<i>Geum canadense</i>	white avens	forb	N	50.00	0.02	0.06
<i>Glandularia canadensis</i>	rose mock vervain	forb	N	33.33	0.01	0.03
<i>Glycyrrhiza lepidota</i>	American licorice	forb	N	0.00	0.00	0.00
<i>Hackelia virginiana</i>	beggarslice	forb	N	0.00	0.00	0.00
<i>Helianthus</i> spp.	sunflower	forb	N	0.00	0.00	0.00
<i>Helianthus mollis</i>	ashy sunflower	forb	N	0.00	0.00	0.00
<i>Hieracium longipilum</i>	hairy hawkweed	forb	N	33.33	0.01	0.03
<i>Hordeum pusillum</i>	little barley	grass	N	0.00	0.00	0.00
<i>Hypericum</i> spp.	St. Johnswort	forb	N	0.00	0.00	0.00
<i>Hypericum perforatum</i>	common St. Johnswort	forb	I	16.67	0.00	0.02
<i>Hypericum punctatum</i>	spotted St. Johnswort	forb	N	33.33	0.01	0.04
<i>Juncus</i> spp.	rush	grass-like	N	16.67	0.00	0.02
<i>Koeleria macrantha</i>	prairie Junegrass	grass	N	16.67	0.00	0.02
<i>Kummerowia stipulacea</i>	Korean clover	forb	I	0.00	0.00	0.00
<i>Lactuca canadensis</i>	Canada lettuce	forb	N	33.33	0.01	0.04
<i>Lactuca serriola</i>	prickly lettuce	forb	I	0.00	0.00	0.00
<i>Lamium purpureum</i>	purple deadnettle	forb	I	0.00	0.00	0.00
<i>Lespedeza capitata</i>	roundhead lespedeza	forb	N	0.00	0.00	0.00
<i>Lespedeza cuneata</i>	sericea lespedeza	forb	I	100.00	3.21	7.50
<i>Lespedeza procumbens</i>	trailing lespedeza	forb	N	0.00	0.00	0.00
<i>Lespedeza repens</i>	creeping lespedeza	forb	N	0.00	0.00	0.00
<i>Lespedeza violacea</i>	violet lespedeza	forb	N	33.33	0.04	0.15
<i>Lespedeza virginica</i>	slender lespedeza	forb	N	16.67	0.00	0.02
<i>Leucanthemum vulgare</i>	oxeye daisy	forb	I	16.67	0.19	1.16
<i>Linum sulcatum</i>	grooved flax	forb	N	16.67	0.00	0.02
<i>Lonicera japonica</i>	Japanese honeysuckle	woody	I	16.67	0.11	0.65
<i>Melilotus officinalis</i>	yellow sweetclover	forb	I	0.00	0.00	0.00
<i>Mirabilis nyctaginea</i>	heartleaf four o'clock	forb	N	16.67	0.00	0.02
<i>Monarda fistulosa</i>	wild bergamot	forb	N	83.33	1.48	4.82
<i>Muhlenbergia schreberi</i>	nimblewill	grass	N	16.67	0.01	0.06
<i>Oenothera</i> spp.	evening primrose	forb	N	0.00	0.00	0.00
<i>Oenothera biennis</i>	common evening primrose	forb	N	50.00	0.01	0.03
<i>Oenothera laciniata</i>	cutleaf evening primrose	forb	N	16.67	0.00	0.02
<i>Oenothera speciosa</i>	pinkladies	forb	N	0.00	0.00	0.00
<i>Oligoneuron rigidum</i> var. <i>rigidum</i>	Stiff goldenrod	forb	N	0.00	0.00	0.00
<i>Oxalis</i> spp.	woodsorrel	forb	N	83.33	0.07	0.16
<i>Oxalis violacea</i>	violet woodsorrel	forb	N	0.00	0.00	0.00
<i>Panicum virgatum</i>	switchgrass	grass	N	50.00	0.06	0.22
<i>Parthenocissus quinquefolia</i>	Virginia creeper	woody	N	16.67	0.02	0.14

Table A1 (continued). All species observed in the prairie sites (N = 6) at Wilson's Creek NB, Republic, Missouri. Values for mean cover, standard error (SE) and occurrence are for 2020 only. Species with 0 values were observed in other years. N = native, I = nonnative. Tree species are not included in this table, see Table 3 for species and abundance values.

Species	Common Name	Guild	Origin	2020 Mean Cover (%)	SE	Occurrence (% Sites Observed, 2020)
<i>Paspalum setaceum</i>	thin paspalum	grass	N	0.00	0.00	0.00
<i>Passiflora incarnata</i>	purple passionflower	forb	N	66.67	0.29	0.98
<i>Penstemon digitalis</i>	talus slope penstemon	forb	N	0.00	0.00	0.00
<i>Physalis heterophylla</i>	clammy groundcherry	forb	N	33.33	0.01	0.03
<i>Physalis virginiana</i>	Virginia groundcherry	forb	N	0.00	0.00	0.00
<i>Phytolacca americana</i>	American pokeweed	forb	N	0.00	0.00	0.00
<i>Plantago</i> spp.	plantain	forb	N	33.33	0.01	0.04
<i>Plantago virginica</i>	Virginia plantain	forb	N	83.33	0.05	0.11
<i>Poa</i> spp.	bluegrass	grass	I	0.00	0.00	0.00
<i>Poa pratensis</i>	Kentucky bluegrass	grass	I	100.00	0.86	3.55
<i>Polygala verticillata</i>	whorled milkwort	forb	N	0.00	0.00	0.00
<i>Polygonum pensylvanicum</i>	Pennsylvania smartweed	forb	N	0.00	0.00	0.00
<i>Potentilla recta</i>	sulphur cinquefoil	forb	I	66.67	0.04	0.15
<i>Potentilla simplex</i>	common cinquefoil	forb	N	16.67	0.04	0.27
<i>Prunus</i> spp.	plum	woody	N	66.67	0.02	0.07
<i>Prunus americana</i>	American plum	woody	N	0.00	0.00	0.00
<i>Pseudognaphalium obtusifolium</i> ssp. <i>obtusifolium</i>	Fragrant cudweed	forb	N	0.00	0.00	0.00
<i>Ratibida pinnata</i>	pinnate prairie coneflower	forb	N	0.00	0.00	0.00
<i>Rhus aromatica</i>	fragrant sumac	woody	N	0.00	0.00	0.00
<i>Rhus copallinum</i>	winged sumac	woody	N	83.33	4.31	11.47
<i>Rhus glabra</i>	smooth sumac	woody	N	33.33	0.28	1.53
<i>Rosa</i> spp.	rose	woody	N	0.00	0.00	0.00
<i>Rosa carolina</i>	Carolina rose	woody	N	33.33	0.03	0.18
<i>Rosa multiflora</i>	multiflora rose	woody	I	16.67	0.03	0.16
<i>Rosa setigera</i>	climbing rose	woody	N	50.00	0.01	0.03
<i>Rubus</i> spp.	blackberry	woody	N	100.00	2.30	4.62
<i>Rubus occidentalis</i>	black raspberry	woody	N	0.00	0.00	0.00
<i>Rudbeckia hirta</i>	blackeyed Susan	forb	N	100.00	0.18	0.63
<i>Ruellia humilis</i>	fringeleaf wild petunia	forb	N	16.67	0.00	0.02
<i>Rumex crispus</i>	curly dock	forb	I	66.67	0.02	0.04
<i>Salvia azurea</i>	azure blue sage	forb	N	33.33	0.07	0.29
<i>Sanicula canadensis</i>	Canadian blacksnakeroot	forb	N	16.67	0.00	0.02
<i>Schedonorus phoenix</i>	Tall Fescue	grass	I	16.67	0.07	0.41
<i>Schizachyrium scoparium</i>	little bluestem	grass	N	83.33	1.28	2.48
<i>Setaria</i> spp.	bristlegrass	grass	I	0.00	0.00	0.00
<i>Setaria faberi</i>	Japanese bristlegrass	grass	I	0.00	0.00	0.00
<i>Silene antirrhina</i>	sleepy silene	forb	N	16.67	0.03	0.16
<i>Silene stellata</i>	widow'sfrill	forb	N	0.00	0.00	0.00

Table A1 (continued). All species observed in the prairie sites (N = 6) at Wilson's Creek NB, Republic, Missouri. Values for mean cover, standard error (SE) and occurrence are for 2020 only. Species with 0 values were observed in other years. N = native, I = nonnative. Tree species are not included in this table, see Table 3 for species and abundance values.

Species	Common Name	Guild	Origin	2020 Mean Cover (%)	SE	Occurrence (% Sites Observed, 2020)
<i>Silphium laciniatum</i>	compassplant	forb	N	33.33	0.03	0.12
<i>Silphium terebinthinaceum</i>	prairie rosinweed	forb	N	33.33	0.02	0.12
<i>Smilax</i> spp.	greenbrier	woody	N	16.67	0.00	0.02
<i>Smilax bona-nox</i>	saw greenbrier	woody	N	0.00	0.00	0.00
<i>Solanum carolinense</i>	Carolina horsenettle	forb	N	83.33	0.06	0.14
<i>Solidago</i> spp.	goldenrod	forb	N	0.00	0.00	0.00
<i>Solidago altissima</i>	Canada goldenrod	forb	N	83.33	0.05	0.13
<i>Sorghastrum nutans</i>	Indiangrass	grass	N	83.33	2.30	12.03
<i>Sorghum halepense</i>	Johnsongrass	grass	I	16.67	0.00	0.02
<i>Sporobolus compositus</i>	composite dropseed	grass	N	83.33	0.02	0.02
<i>Sporobolus heterolepis</i>	prairie dropseed	grass	N	33.33	0.02	0.12
<i>Stellaria media</i>	common chickweed	forb	I	33.33	0.01	0.06
<i>Stylosanthes biflora</i>	sidebeak pencilflower	forb	N	0.00	0.00	0.00
<i>Symphoricarpos orbiculatus</i>	coralberry	woody	N	83.33	1.43	4.58
<i>Symphyotrichum pilosum</i> var. <i>pilosum</i>	Awl wild aster	forb	N	50.00	0.04	0.16
<i>Taraxacum officinale</i>	common dandelion	forb	I	0.00	0.00	0.00
<i>Teucrium canadense</i>	Canada germander	forb	N	100.00	0.49	1.40
<i>Torilis arvensis</i>	spreading hedgeparsley	forb	I	83.33	0.30	1.17
<i>Torilis japonica</i>	erect hedgeparsley	forb	I	0.00	0.00	0.00
<i>Toxicodendron radicans</i>	eastern poison ivy	woody	N	16.67	0.00	0.02
<i>Tragia betonicifolia</i>	betonyleaf noseburn	forb	N	66.67	0.08	0.19
<i>Tragopogon dubius</i>	yellow salsify	forb	I	16.67	0.01	0.04
<i>Tridens flavus</i>	purpletop tridens	grass	N	66.67	0.35	1.18
<i>Trifolium</i> spp.	clover	forb	I	0.00	0.00	0.00
<i>Trifolium arvense</i>	rabbitfoot clover	forb	N	16.67	0.00	0.02
<i>Trifolium campestre</i>	field clover	forb	I	83.33	0.18	0.34
<i>Triodanis perfoliata</i>	clasping Venus' looking-glass	forb	N	100.00	0.11	0.14
<i>Valerianella radiata</i>	beaked cornsalad	forb	N	100.00	0.07	0.11
<i>Verbascum blattaria</i>	moth mullein	forb	N	0.00	0.00	0.00
<i>Verbascum thapsus</i>	common mullein	forb	I	16.67	0.00	0.02
<i>Verbena urticifolia</i>	white vervain	forb	N	16.67	0.00	0.02
<i>Verbesina alternifolia</i>	wingstem	forb	N	16.67	0.02	0.14
<i>Vernonia baldwinii</i>	Baldwin's ironweed	forb	N	66.67	0.20	0.75
<i>Veronica arvensis</i>	corn speedwell	forb	I	0.00	0.00	0.00
<i>Viburnum prunifolium</i>	blackhaw	woody	N	16.67	0.02	0.12
<i>Viola bicolor</i>	field pansy	forb	N	0.00	0.00	0.00
<i>Viola sororia</i>	common blue violet	forb	N	16.67	0.02	0.14
<i>Vitis</i> spp.	grape	woody	N	33.33	0.04	0.14
<i>Vulpia octoflora</i>	sixweeks fescue	grass	N	66.67	0.02	0.05

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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Natural Resource Stewardship and Science

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