National Park Service
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Natural Resource Stewardship and Science

# George Washington Carver National Monument Plant Community Report

*2004–2020*

Natural Resource Report NPS/HTLN/NRR—2021/2334

ON THE COVER
Butterfly weed (*Asclepias tuberosa*) in bloom at George Washington Carver NM, June 2020
Photography by NPS/Mary Short

# George Washington Carver National Monument Plant Community Report

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Natural Resource Report NPS/HTLN/NRR—2021/2334

Sherry A. Leis and Mary F. Short

National Park Service
Heartland Inventory and Monitoring Network
6424 West Farm Road 182
Republic, MO 65738

*Editing and Design by*
Tani Hubbard

National Park Service &
Northern Rockies Conservation Cooperative
12661 E. Broadway Blvd.
Tucson, AZ 85748

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# Executive Summary

The Heartland Inventory and Monitoring Network completed its sixth year of plant community monitoring at George Washington Carver National Monument in 2020. Plant community monitoring focused on the restored prairie community. We visited seven monitoring sites in each of the six years and collected data on plant species and ground cover. In this report we also included two environmental factors—precipitation and recent fire history—to better understand the vegetation community status and trends.

Since 2000, precipitation has often been below the 30-year normal. Moreover, annual precipitation was below normal for all but one of the monitoring years. We found that the drought in 2012 stood out as possibly influencing plant guild cover. Although prairies are adapted to drought, further analyses might reveal more about the role of climate change in these vegetation communities. Fire management also plays an important role in shaping plant communities. Prescribed fire occurrence became more frequent and consistent through the period of plant monitoring. Additional treatments, including herbicide and mowing, also supported a healthy prairie.

The prairie plant community continues to be moderately diverse despite recent increases in tree seedlings and small saplings. Species richness in 2012 was different than in two of the six years monitored. However, diversity indices (H′ and J′) were very similar across monitored years.

Species guilds (also known as functional groups) exhibited differing patterns. Woody plants, long a concern at the monument, were statistically similar across years. In 2020, grass-like species increased, but grass species appeared to have declined below prior years. Grass cover in 2004 was statistically different (greater) than in 2008 and 2020. The reasons for this are not clear. Of particular interest to the park is the status of two sumac species (*Rhus glabra* and *R. copallinum*). These species were in decline as a result of focused management actions since 2012. However, the blackberry species (*Rubus* spp.) seemed to be replacing the sumac in some sites. In 2020, nonnative species richness and cover were below peak levels, demonstrating management actions have been successful in maintaining low levels.

The vegetation monitoring protocol experienced some changes between 2004 and 2020. A key difference was a shift from sampling twice during the field season to sampling only once in a monitoring year. Although a decline in species richness was anticipated, that pattern was not apparent. However, the abundance of grasses may have been affected by the shift in seasonality of sampling. Additionally, we remedied inconsistencies in how tree regeneration was recorded (stem tallies in some cases and cover estimates in other cases). We converted all cover data to stem tallies and density was calculated to be consistent with the protocol.

The monument has had success with coordinating fire management and invasive species management. A decrease in sumac across the prairie is evidence of this success. These actions will continue to be important for maintaining the prairie in good condition into the future.

# Acknowledgments

We appreciate park staff for supporting our access and work in the park during the pandemic. Pandemic safety protocols related to monitoring 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 the support of Missouri State University for facilitating student help for our work in 2020. We also appreciate the support of the HTLN quantitative ecologist for statistical analysis and prior network staff who collected and processed data from earlier monitoring events. We also appreciate the input of two network peer reviewers in improving this manuscript.

# Introduction

George Washington Carver National Monument (NM) is situated on the border of the Springfield Plain and Ozark Highlands major land resource areas (USDA-NRCS 2006). The Springfield Plain is a smooth plain dominated by grasslands dissected by wooded streams. Tallgrass prairie would have been available for grazing in the surrounding area at the time the Carvers lived there. Some remnant prairie persists at nearby Diamond Grove Prairie today.

Natural resource management at the park complements and enhances interpretation of Dr. Carver's life in a variety of ways. Most notably it provides landscape context for Carver's life and opportunities for contemplation (Bahr Vermeer & Haecker Architects, Ltd. et al. 2015). Reconstruction of the prairie at George Washington Carver NM began in 1985 to provide a sense for the dominant community type in the landscape at the time Carver lived there (Harrington et al. 1998).

Vegetation monitoring in the park's prairie has been central to the Heartland Inventory and Monitoring Network (hereafter, Heartland Network) long-term monitoring program at George Washington Carver NM because of the importance of plants and the prairie in Dr. Carver's life. Here we define prairie as a plant community dominated by herbaceous plants. In tallgrass prairie, grasses tend to be more abundant, although there may be more forb species (Weaver 1954). Tree species should be relatively few in tallgrass prairie. Ecologists use benchmarks like < 1 tree/acre (< 1 tree/0.4 ha; Curtis 1959) or < 10% tree canopy cover (Nelson 2005) to differentiate prairie from savanna or woodland.

The ecological processes of fire, grazing, and drought have historically maintained prairies (Weaver 1954). Today, we often substitute mowing and haying for some of those ecological processes. These processes support ecosystem functions like nutrient cycling, germination, and species competition needed to maintain a healthy ecosystem. We have included analysis of prescribed fire history at the park because it is an important process shaping the vegetation in the prairie. Furthermore, fire management goals and objectives for the park are largely vegetation management related. Draft objectives for the prairie include maintaining a gamma diversity (park-wide plant species richness) of ≥ 71 species and reducing native invasive and exotic woody plants to < 10% cover (Leis 2013).

Naomi Reibold and Sherry Leis record plant species at George Washington Carver NM, June 2020.

# Methods

## Study Site

The prairie at George Washington Carver NM was replanted to native species beginning in 1985 (Harrington et al. 1998). Burn units represent areas restored to tallgrass prairie (Figure 1). Various processes have been used to manage the prairie through time including haying, burning, brush hogging, herbicide application, and seed supplementation. Problematic plants have also been treated with cutting and herbicide treatments.

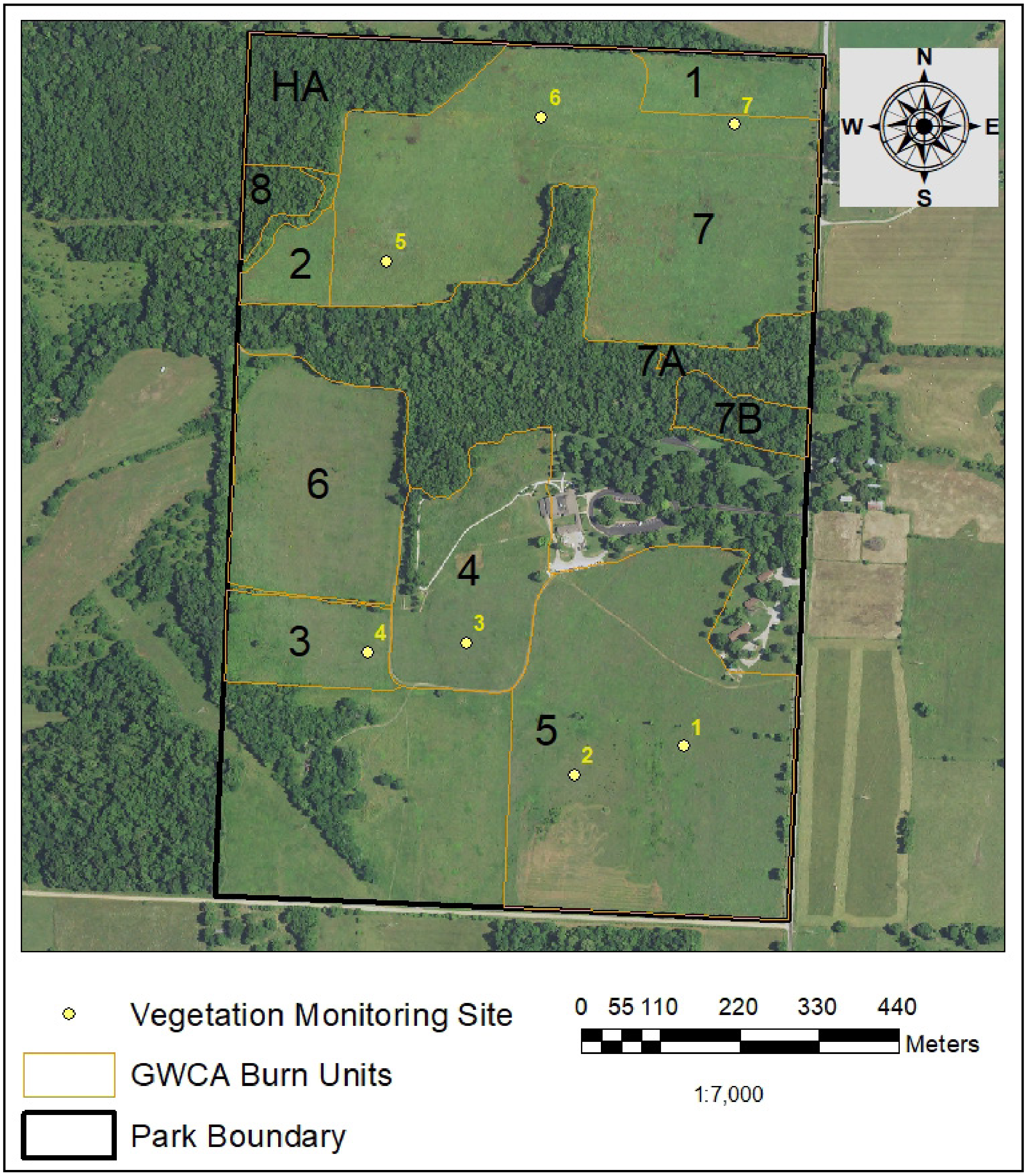


**Figure 1.** Burn unit boundaries and vegetation monitoring sites at George Washington Carver NM, Diamond, MO. Burn units represent areas restored to tallgrass prairie.

## Sampling Design

Seven vegetation community monitoring sites were established and sampled at George Washington Carver NM in 2004 and were revisited in 2005, 2008, 2012, 2016, and 2020 (Figure 1). The seven monitoring sites at the park were characterized as prairie. Monitoring methods follow the grassland standard operating procedures outlined in the Heartland Network vegetation monitoring protocol (James et al. 2009). Monitoring sites were 50 m x 20 m (0.1 ha) in size with the two transects bounding the site on the 50-m sides (Figure 2). Grassland monitoring at George Washington Carver NM consists of recording ground flora species and estimating ground cover within cover classes (Table 1).

Trees in the regeneration phase (seedlings, small saplings, and large saplings) were tallied by species within the plots. No overstory trees (stems >5 cm DBH) were observed within the monitoring sites. We maintained *Prunus* spp. within the herbaceous observations because some species in that genus are shrubs and species can be challenging to identify at young stages. Observations of ash (*Fraxinus* spp.) and elm (*Ulmus* spp.) trees were lumped to genus for tallying because immature stems can be difficult to classify.

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

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

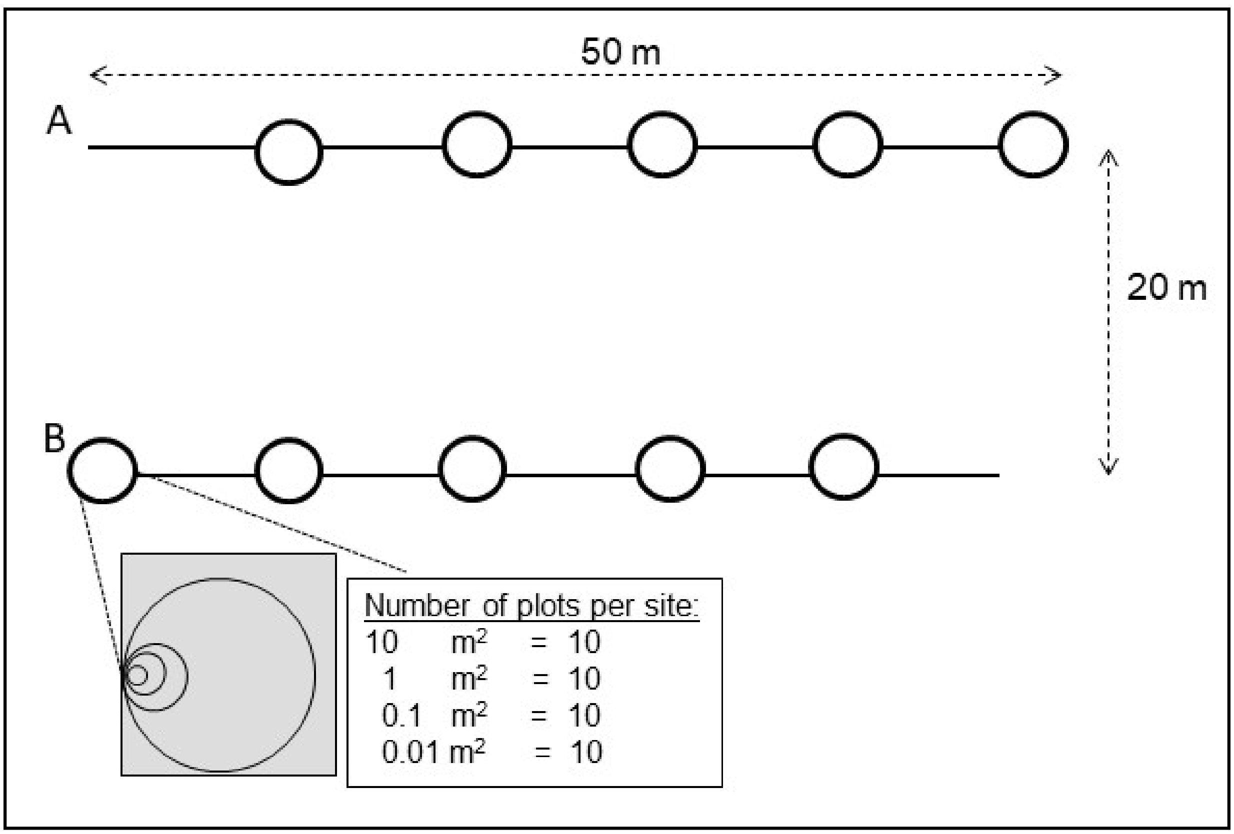


**Figure 2.** Sample site design for vegetation monitoring sites deployed by the Heartland Network at George Washington Carver NM, Diamond, MO.

## Data Summary

Foliar cover served as an estimate of abundance for ground flora species. The cover class intervals were converted to midpoint values to estimate percent cover for each herbaceous and shrub species (Table 1). Mean percent cover was then calculated as the species percent cover for a sampling unit, averaged for all 10 $m^2$ subplots. Sampling unit (site) means were then used to calculate community level means.

SPSS, V. 24 (IBM 2016) and PC-ORD V.7.02 (McCune and Mefford 2016) were used for summary statistics. All site means (N = 7) and 95% confidence intervals were calculated from the included subplots (n = 10/site).

### *Climate*

Daily precipitation and thirty-year normal precipitation data were obtained from [National Centers for Environmental Information, NOAA, (https://www.ncdc.noaa.gov/cdo-web/search)](https://www.ncdc.noaa.gov/cdo-web/search). These data were summarized by year. Precipitation data for 2020 included January–October only.

### *Recent Fire History*

Fire history records for 2000 to 2020 are included. Recent fire history for the prairie at George Washington Carver NM was determined using a fire history geodatabase. Although the monument began using fire prior to 2000, the available data for this analysis began in 2000. 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., ≥ 848 $m^2$), 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.

### *Ground Flora*

Field crews noted during 2020 sampling that one plot in site 5 and four plots in site 7 had previously been mowed. Time of mowing was likely prior to June 1 and the onset of warm season plant growth. We did not note any difficulty identifying plants in those plots and plot-wise summaries by guild did not reveal any clear effects of mowing for sites 5 and 7. Mowing was used to affect cover of slower growing woody plants or tree regeneration stem counts.

#### Tree Regeneration

Seedling and sapling stems were tallied by species in the 10-$m^2$ 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 2.5 to < 5.0 cm DBH. Density (stems/ha) was calculated for all tree regeneration stems by site and by species for each site. Site level densities were averaged across sites (N = 7). Regeneration data were not collected in 2008.

#### Species Diversity Indices

Based on foliar cover measurements, diversity indices describe the number of species and their abundances. Mean site cover for all non-tree species was calculated using all subplots within each site. For each site, species richness (S), 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 (IBM 2016; McCune and Mefford 2016). A grand mean was then calculated for all sites in a community.

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 1949).

Species distribution evenness (J′) is 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 analysis was done to understand patterns for three particular species groups: blackberries (*Rubus* spp.), sumac (*Rhus* spp.), and big bluestem (*Andropogon gerardii*).

### Community Diversity Metrics

Community richness metrics evaluate how species richness differs across monitoring sites and the park. We limited these calculations to native ground flora (non-tree) 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):

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

### Guild Abundance

Understory plant species were also summarized by guilds, also known as functional groups (designations per the USDA Plants database; James et al. 2009; USDA-NRCS 2017). Guild assignments were grasses, forbs, grass-like (species including sedges and rushes), and woody species. A complete species list along with guild assignment is provided in Appendix A. Mean cover values were calculated for each guild-site-year combination. A grand mean was then calculated across all sites.

The abundance of nonnative (e.g. exotic) species was assessed using mean cover values. Mean cover values and counts for species within a site were summed by origin (native or nonnative).

### *Ground Cover*

Ground cover was assessed using cover classes (Table 1). 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, bare ground, and the cover of woody debris (e.g. branches and sticks). 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. Three measurements in each plot were averaged and the plot means were used to create a site level mean for litter depth.

### *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 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 where 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 cases of species richness and grass guild, the post hoc Bonferroni test was applied to further understand the test results. SPSS v.20 was used for these analyses (IBM 2011).

# Results and Discussion

## Climate

In the Great Plains, annual precipitation is highly variable from year to year with cycles of drought (Anderson 1990). The site of George Washington NM in southwest Missouri experiences similar climate to the adjacent Great Plains biome. The park experienced below normal precipitation for all but six years since 2000 (Figure 3). All but one of the monitoring years had annual precipitation below the 30-year average. Moreover, the monitoring baseline in 2004/2005 occurred during a dry period.

Native tallgrass prairie species have evolved with periodic drought (Axelrod 1985). Warm season (C4) grasses draw moisture from upper layers of the soil profile, while cool season (C3) grasses and woody plants tend to access water from deeper layers of the soil profile (Nippert et al. 2012). This distinction may be important to understand future vegetation patterns under climate change scenarios, which are projected to include an increase in periodic droughts punctuated by high precipitation events (Polley et al. 2013). It may be helpful for future analyses to explore how climate change may affect the natural communities at the park.

## Recent Fire History

The monument applied fire more consistently in the period from 2010 to the present than in prior years (Figures 4 and 5). Management shifted in 2010 to request prescribed fire be applied with a two-year return interval where half of the prairie was burned each year. The park has applied fire in both the spring and fall seasons. Four of the seven monitoring sites are situated in the southern prairie burn units and three are in the northern units (Figure 1). This pattern of burning the north units one year and south units the following year can be seen in Figure 4 by noting the number of monitoring sites burned each year. Confidence intervals around mean time since fire for each year indicate the level of fire heterogeneity. Small intervals indicate that all sites were treated with fire similarly and larger error bars indicate larger differences in the occurrence of fire across the monitoring sites (Figure 5).

Prescribed fire is critical for establishing new prairie restorations and maintaining them (Packard and Mutel 1997). Fire also plays a critical role in reducing many undesirable plants and stimulating native grassland plants through nutrient cycling, germination, and flowering (Hulbert 1988; Jefferson et al. 2008; Wagle and Gowda 2018).

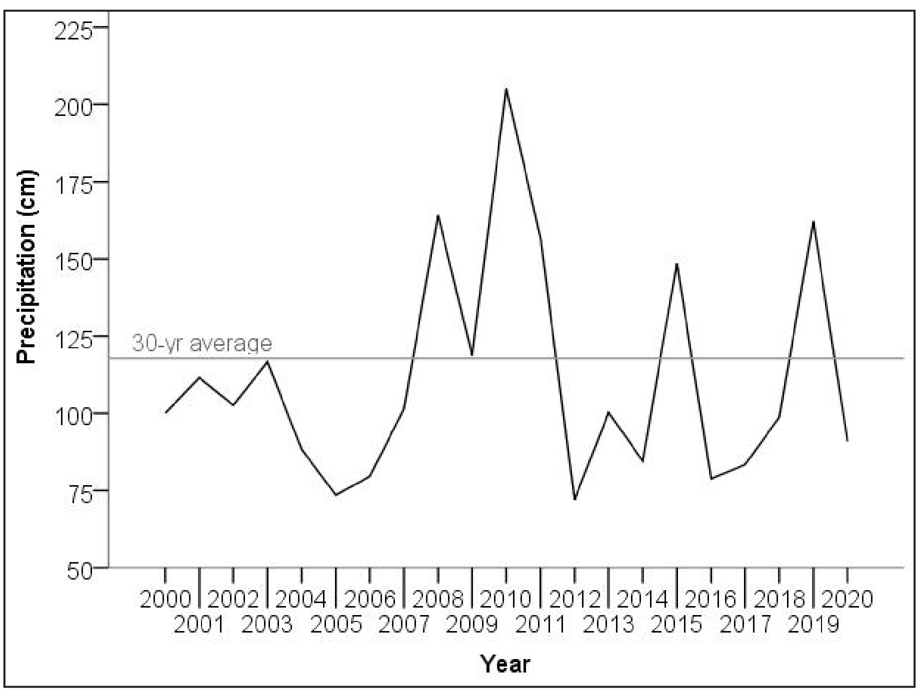


**Figure 3.** Annual precipitation for Diamond, MO. Horizontal line represents the 30-year normal. Data for 2020 include January–October only.

Fire effects may vary with precipitation and season (Wagle and Gowda 2018). Burning in dry years may reduce soil moisture further. This can be advantageous to C4 grasses (warm season grasses) as compared to C3 grasses (cool season grasses). Fire timing may also affect species guilds differently (Towne and Craine 2014; Weir and Scasta 2017).

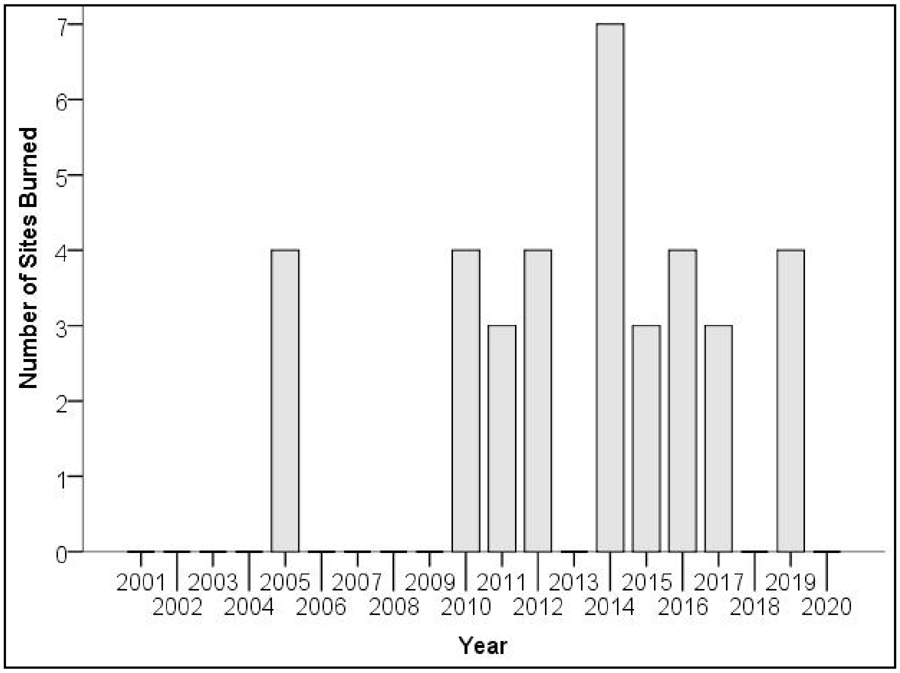


**Figure 4.** The number of sites burned out of seven during the period 2001–2020 at George Washington Carver NM, Diamond, MO.

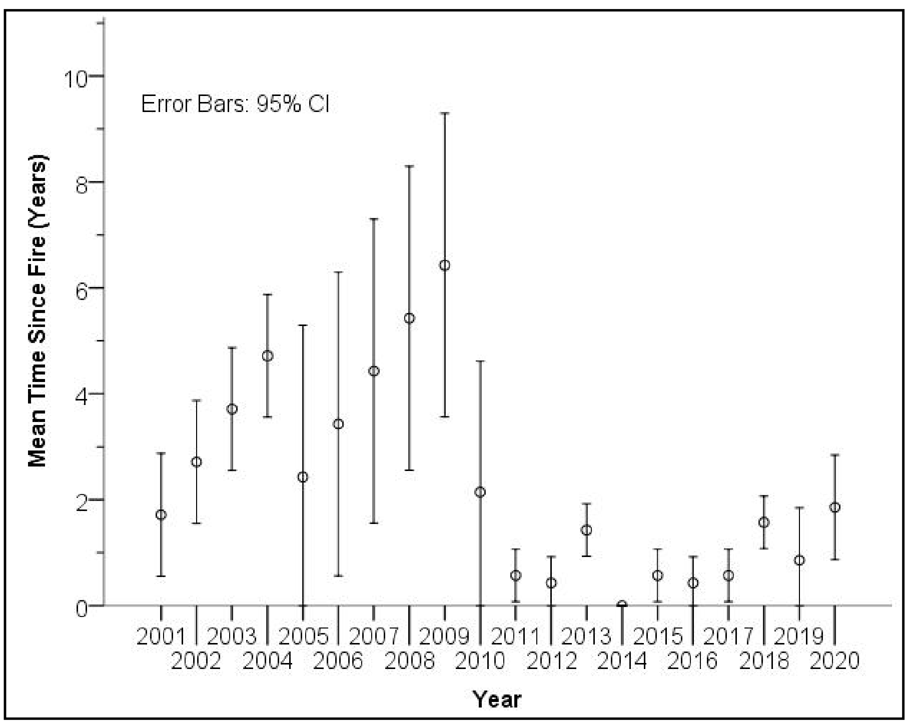


**Figure 5.** Mean time since fire during the period 2001–2020 at George Washington Carver NM, Diamond, MO. Means were calculated from the time since fire value for each monitoring site each year. Larger confidence intervals represent greater heterogeneity of fire timing among monitoring sites.

## Tree Regeneration

The park uses fire, mechanical, and chemical techniques to minimize the establishment of trees in the prairie. Tree stem density was greatest in the 2020 sample event (Figure 6). Large saplings were only recorded during the 2005 sampling (at site 1). The distribution of tree regeneration is variable across the sites with sites 4 and 5 harboring the greatest number of stems. While white mulberry (*Morus alba*) and American sycamore (*Platanus occidentalis*) were reduced in 2020, honeylocust (*Gleditsia triacanthos*) and elm (*Ulmus* spp.) became more abundant (Table 2).

Although frequent fire can reduce the establishment of trees in the prairie, proximity to seed sources from adjacent woodlands, atmospheric $CO_2$ enrichment, and other factors favor woody plant growth (Briggs et al. 2002; Van Auken 2009; Fogarty et al. 2020; Knapp et al. 2020). Managers will need to be vigilant in preventing woody encroachment in the future. We noted that management actions have been sufficient to prevent tree stems from being recruited into the large sapling or midstory tree size classes.

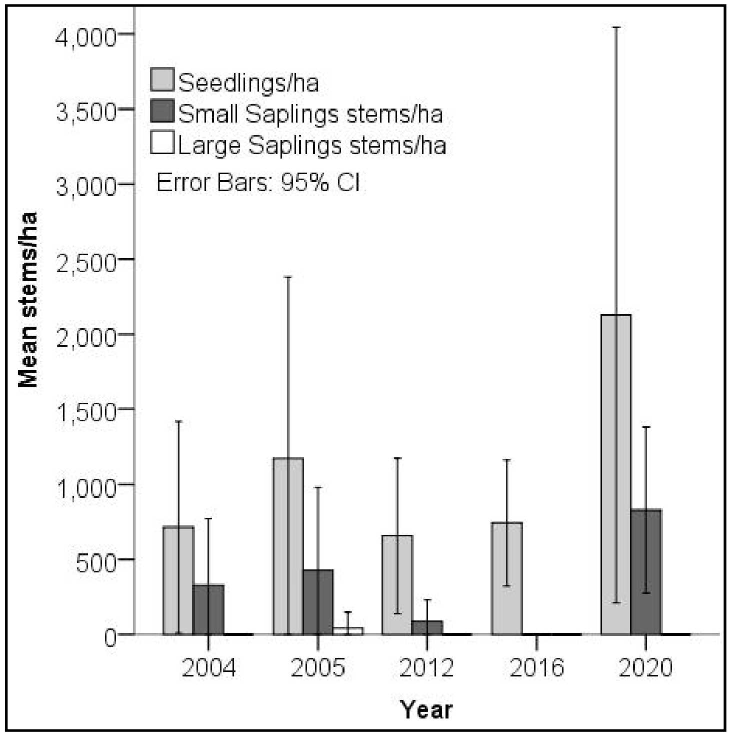


**Figure 6.** Tree regeneration stem density (stems/ha) by size class in the prairie monitoring sites at George Washington Carver, NM, Diamond, MO. Regeneration data were not collected in 2008.

**Table 2.** Tree regeneration stem density by species (mean stems/ha) in monitoring sites at George Washington NM, Diamond, MO. Percent change indicates the difference in stems between 2004 and 2020; negative values indicate fewer stems in 2020. Regeneration was not collected in 2008.

| | Mean Stem Density (stems/ha) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Species** | **2004** | **2005** | **2012** | **2016** | **2020** | **±CI (2020)** | **% Change 2020–2004** |
| *Acer rubrum* | 0.00 | 0.00 | 0.00 | 0.00 | 14.29 | 5.60 | – |
| *Celtis occidentalis* | 0.00 | 0.00 | 0.00 | 0.00 | 14.29 | 5.60 | – |
| *Diospyros virginiana* | 0.00 | 14.29 | 0.00 | 28.57 | 314.29 | 119.45 | – |
| *Fraxinus* spp. | 271.43 | 371.43 | 357.14 | 171.43 | 271.43 | 70.50 | 0 |
| *Gleditsia triacanthos* | 57.14 | 228.57 | 85.71 | 100.00 | 142.86 | 58.46 | 150 |
| *Morus alba* | 28.57 | 14.29 | 14.29 | 42.86 | 0.00 | 14.28 | -100 |
| *Morus rubra* | 0.00 | 0.00 | 0.00 | 0.00 | 42.86 | 16.80 | – |
| *Platanus occidentalis* | 42.86 | 57.14 | 28.57 | 0.00 | 0.00 | 22.40 | -100 |
| *Prunus hortulana* | 0.00 | 0.00 | 0.00 | 42.86 | 0.00 | 16.80 | – |
| *Prunus serotina* | 0.00 | 0.00 | 0.00 | 42.86 | 14.29 | 16.33 | – |
| *Sassafras albidum* | 28.57 | 85.71 | 28.57 | 0.00 | 14.29 | 28.55 | -50 |
| *Ulmus* spp. | 614.29 | 871.43 | 228.57 | 314.29 | 2128.57 | 673.58 | 247 |

## Species Diversity

Species richness at George Washington Carver NM has been very stable through the monitoring period, with the exception of 2012 (Figure 7; repeated measures ANOVA, F = 3.60; df = 5, 30; P = 0.011). In post hoc comparisons, species richness in 2012 proved statistically different from both 2005 and 2008 (Bonferroni pairwise comparisons). In Figure 3, we can see 2012 was an exceptionally dry year, and it coincided with increasing woody plant cover within the park (see Guild Abundance results section). It was also the first year of monitoring after major changes to the monitoring protocol. Heartland Network scientists expected a decline in the number of species recorded because of changing the revisit design from two visits to one visit per monitoring year. Since the decline did not persist, we suggest other factors are more likely to have influenced species richness observations.

Species diversity is measured here using the Shannon diversity index (H′) and an evenness index (J′) (Figure 8). H′ includes both species richness and cover, with larger values indicating greater diversity. In 2020, mean H′ recovered from a low point in 2012. However, the difference in H′ between years was not statistically significant (repeated measures ANOVA, F = 2.06, df = 5, 30, P = 0.10). J′ values near 0 indicate dominance by a single species whereas a value of 1 indicates similar composition across the sites. Evenness has been very steady and moderate across the monitored years, indicating that sites have a variety of species and are not dominated by a single species. Although studies have found that plant diversity tends to decrease in restorations over time, measures of species diversity at the park have remained relatively stable over the last 16 years (Wagle and Gowda 2018).

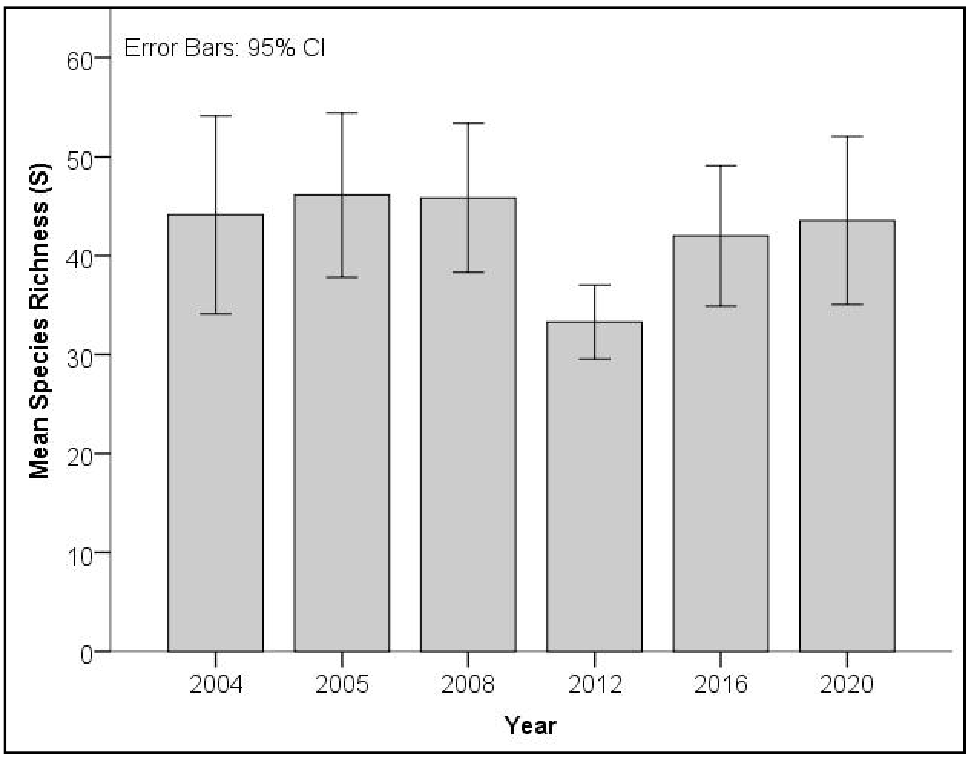


**Figure 7.** Mean native plant species richness for prairie monitoring sites at George Washington Carver NM, Diamond, MO.

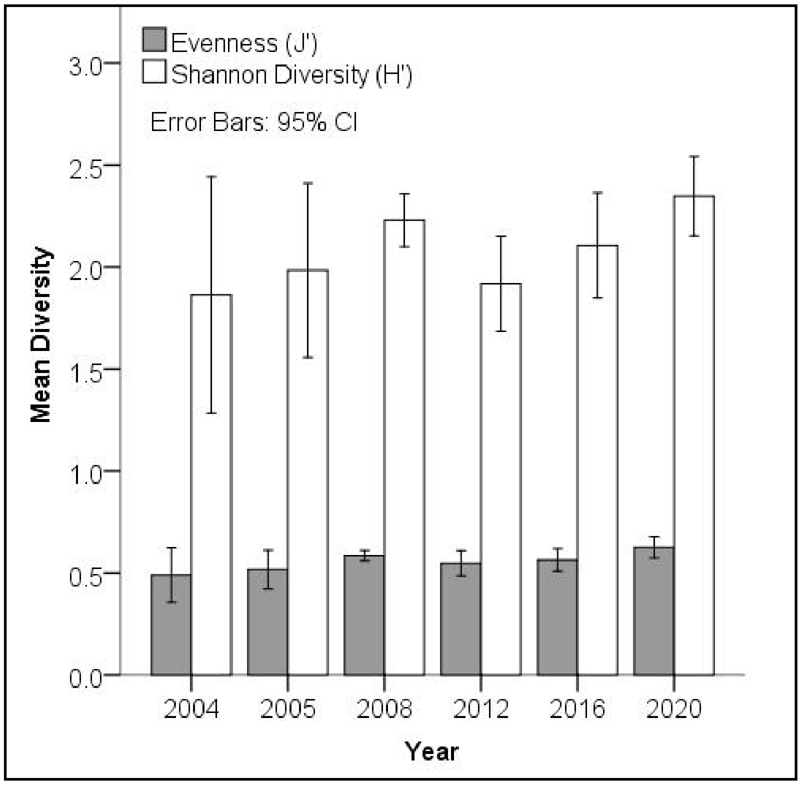


**Figure 8.** Mean native plant species diversity (J′, H′) for prairie vegetation monitoring sites at George Washington Carver NM, Diamond, MO.

## Community Diversity

Community diversity allows us to understand the plant assemblages at different spatial scales. Values for all three indices were within the range of variation that we have previously measured (Table 3). Alpha diversity, a site scale indication of the number of species, has a range of 12.8 species from the maximum to minimum values across the monitored years.

**Table 3.** Community diversity metrics (alpha, gamma, and beta diversity) in monitored years at George Washington Carver NM, Diamond, MO.

| Year | Alpha Diversity (mean site richness ±CI) | Gamma Diversity | Beta Diversity ((gamma diversity/ alpha diversity)-1) |
|---|---|---|---|
| 2004 | 44.1 ±8.0 | 106 | 1.40 |
| 2005 | 46.1 ±6.7 | 109 | 1.36 |
| 2008 | 45.9 ±6.0 | 110 | 1.40 |
| 2012 | 33.3 ±3.0 | 75 | 1.25 |
| 2016 | 42.0 ±5.7 | 102 | 1.43 |
| 2020 | 43.6 ±6.8 | 99 | 1.27 |

Gamma diversity, the number of species recorded park-wide, has fluctuated by 34 species from the greatest species count in 2005 to the lowest in 2012. Beta diversity was relatively low, indicating that sites are somewhat similar with a small number of unique species in their assemblages.

## Guild Abundance

Grouping species by guild can be helpful for understanding how species are changing through time. Native grasses have been in decline since 2005 (Figure 9). Interestingly, grass-like plants (primarily sedges and rushes) more than doubled in 2020. The explanation for the statistically significant decline in native grasses is unclear (repeated measures ANOVA, $F = 5.50$; $df = 5, 30$; $P = 0.001$). A post hoc Bonferroni test indicated that grass cover in 2004 was statistically different than in both 2008 and 2020. Based on analyses from other Heartland Network parks, we suspected that the shift in monitoring revisit design in 2009 may have led to a decrease in observed grass cover. However, if that were the only source of decline, the grass cover values should have leveled off after the 2009 change. Since they have continued to decline, we infer that other factors are influencing the native grass cover at the park.

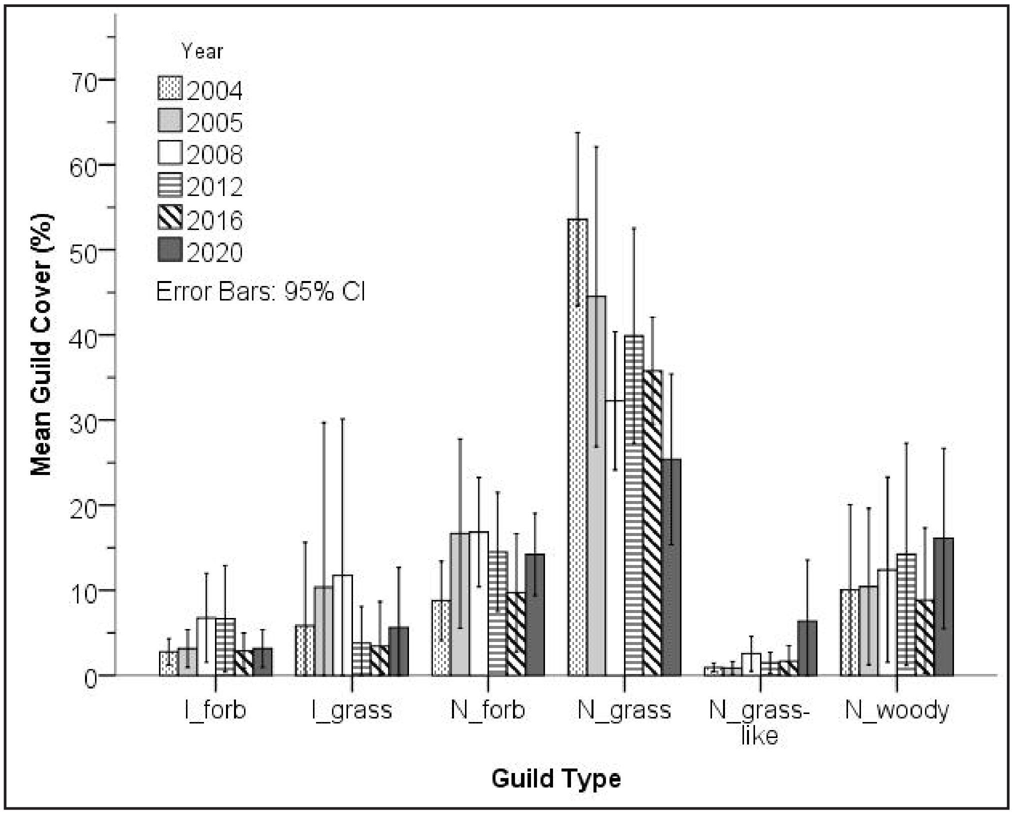


**Figure 9.** Species cover (%) by guild type and year at George Washington Carver NM, Diamond, MO. N indicates native species and I indicates nonnative species.

We hypothesized that woody species may have been competing with native grasses, but the woody plant guild did not exhibit a statistically significant trend in cover over time (repeated measures ANOVA, $F = 1.72$, $df = 5, 30$; $P = 0.16$). Woody cover was heterogeneous in the prairie making park level trends difficult to discern.

2020 abundances of nonnative forbs and grasses were below their peak levels (2008-2012; Figures 9 and 10). Continued investment in chemical and mechanical treatments appear to be beneficial to the prairie. Two woody-invasive plants (winter creeper [*Euonymus fortunei*] and Japanese honeysuckle [*Lonicera japonica*]) were only observed in 2016 and 2020 (mean cover of 0.05 and 0.15%, respectively). The top three nonnative herbaceous species with the greatest abundance (mean cover) in 2020 were tall fescue (*Schedonorus phoenix*; 3.9%), sericea lespedeza (*Lespedeza cuneata*; 1.44%), and Kentucky bluegrass (*Poa pratensis*; 1.31%).

Species of interest to the park include sumac species (*Rhus copallinum* and *Rhus glabra*) and blackberry species (*Rubus* spp.). The park has implemented treatments to reduce sumac species. Sumac peaked in 2012 when chemical treatments were applied coupled with frequent fire return intervals. Sumac was effectively reduced across the park (Figure 11). Blackberry species, however, have increased over time. Interestingly, blackberry appears to have taken over the niche previously occupied by sumac (Leis and Morrison 2017). Native blackberry species are known to be more productive with frequent fire (Great Plains Flora Association 1986). The monument has implemented spot mowing to treat areas with greater levels of blackberry. Although four plots in site 7 and one in site 5 were mowed ahead of the 2020 sample season, it was not clear if this affected abundance estimates.

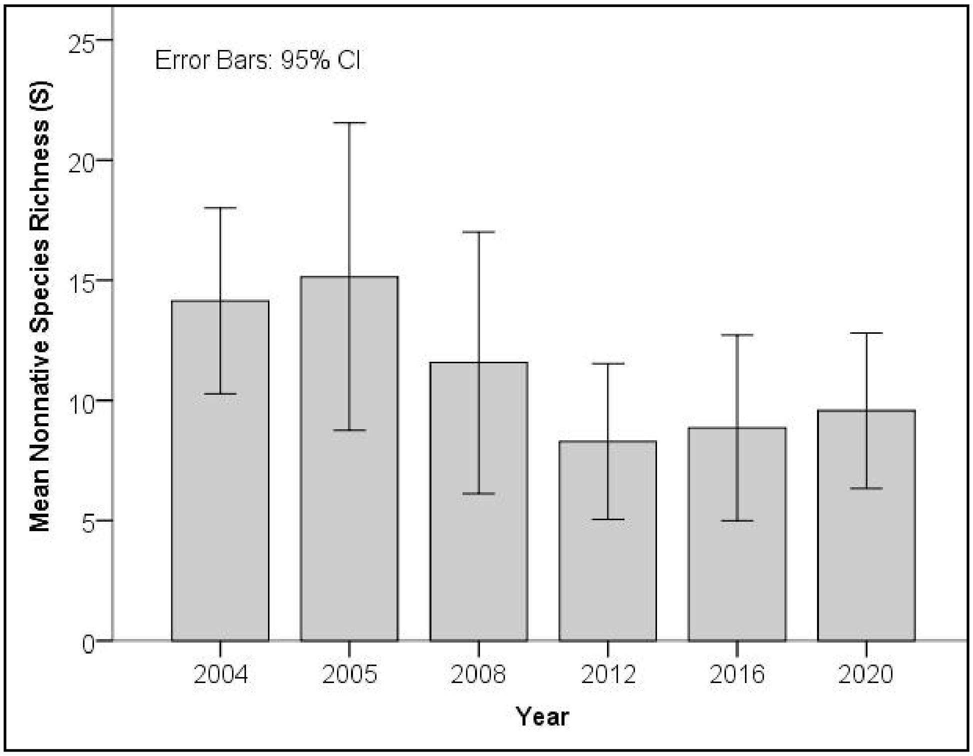


**Figure 10.** Species richness of nonnative species at George Washington NM, Diamond, MO.

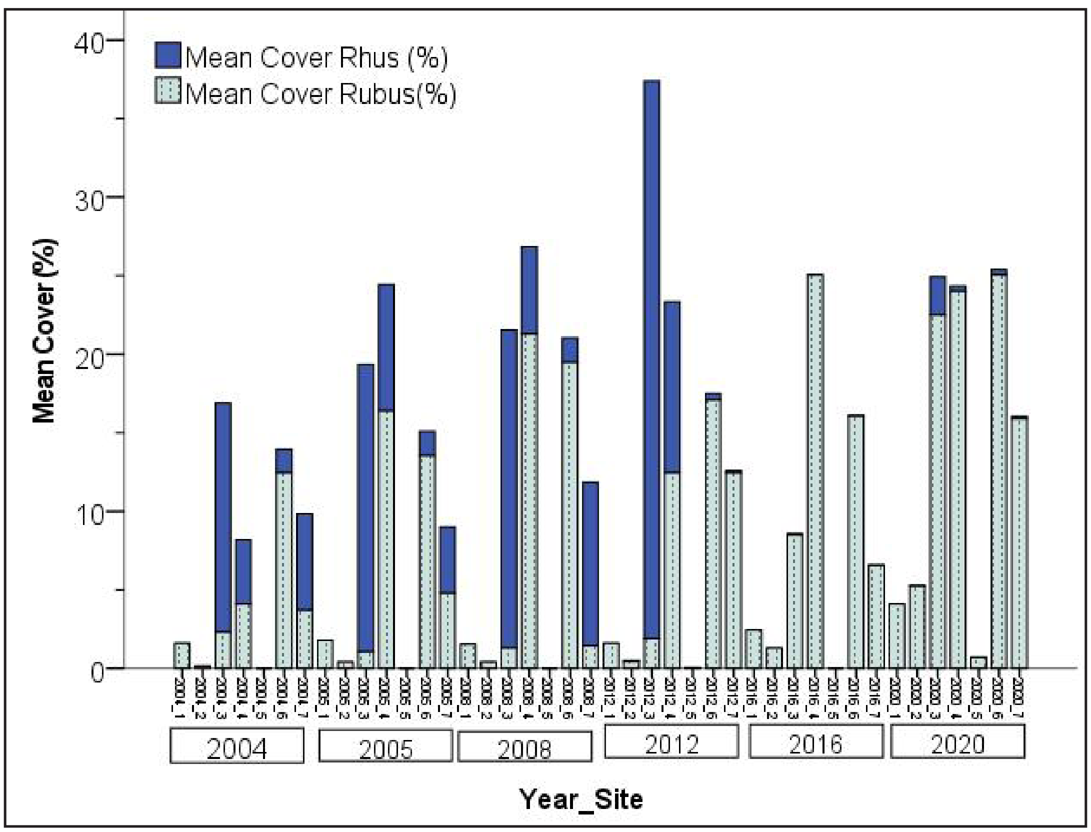


**Figure 11.** Cumulative mean cover (%) of sumac (*Rhus* spp.) and blackberry (*Rubus* spp.) in monitoring sites (N = 7) at George Washington Carver NM, Diamond, MO. The horizontal axis lists each site year combination as Year_Site number. Years are identified as blocks for easier viewing.

Another species of interest to the park is big bluestem (*Andropogon gerardii*). This species is a matrix grass within the tallgrass prairie. Mean cover of big bluestem ranged from 15–25% through the monitoring record (Figure 12). Trends in big bluestem cover were not statistically significant (repeated measures ANOVA: $F = 0.84$, $df = 5, 30$; $P = 0.5$). Big bluestem's abundance can be affected by drought, temperature, or competition from other species, particularly nonnative grasses. One model shows the range of big bluestem may become greatly reduced and shift northeasterly away from Missouri under climate change scenarios (Smith et al. 2017). We present the data for this species to establish the natural variation within the park for later comparison.

## Ground Cover

Ground cover is affected by disturbance history and changes in species composition. The amount of visible rock cover at the park is typically very low (Figure 13). Rock cover may increase as the number of sites recently burned increases. Woody debris and deciduous leaf litter are also characteristically low in the park's prairie because of the low number of trees (Figure 13). Bare ground and the amount of grass litter are much more dependent on disturbances (Figure 14). Fire is the primary disturbance that can remove litter nearly completely, leaving bare ground. The large confidence intervals reflect the burn histories between the north and south units (Figure 5). We also previously found that bare ground is greater in dry years (Leis and Morrison 2017).

Litter cover benefits some plant and animal species, while bare ground benefits others. The heterogeneity introduced by burning a suite of burn units each year may provide the greatest benefits for supporting a diversity of habitats.

### *Litter Depth*

Litter depth was measured for the first time at George Washington Carver NM in 2020. Mean litter depth was 3.3 cm (± 1.35 SE). Mean litter depth for the sites on the south side of the prairie (N = 4) were all below 1 cm because of a recent prescribed fire. The sites on the north side (N = 3) had mean litter depths ranging from 5.4–10.0 cm. The north side sites had not been burned since 2016 allowing litter to accumulate.

Litter facilitates water infiltration to the soil and maintains soil moisture through reduction in soil respiration (Wagle and Gowda 2018). Deep litter can inhibit growth in some plants, potentially reducing productivity (Hulbert 1988). Deep litter also signals substantial buildup of grassland fuels.

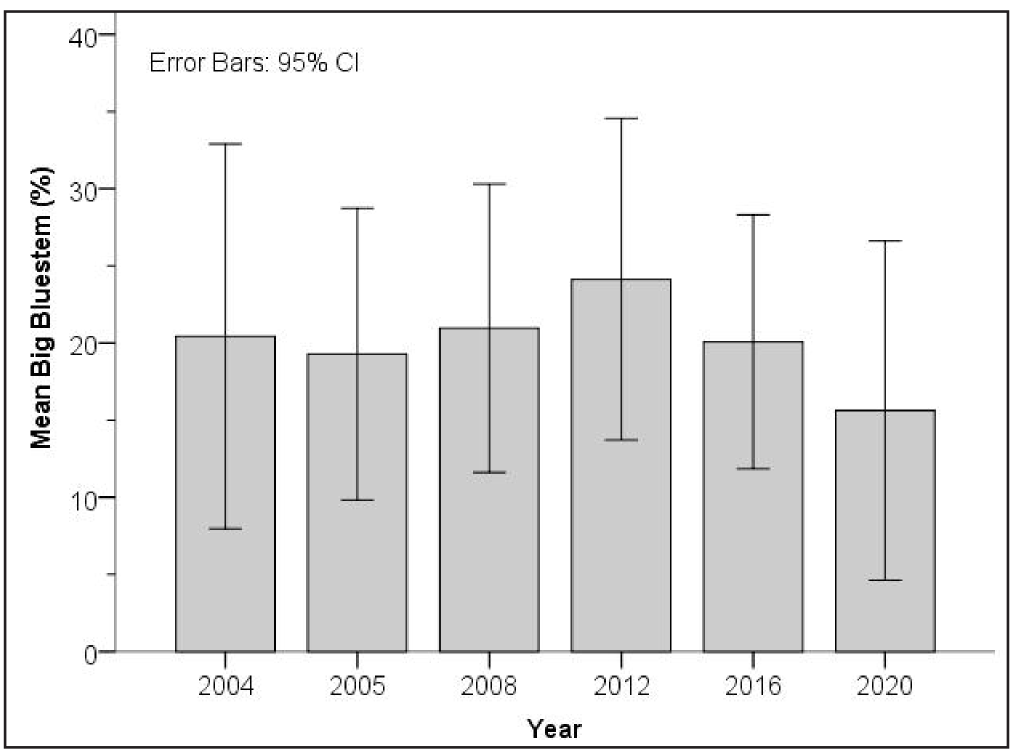


**Figure 12.** Mean cover of big bluestem (*Andropogon gerardii*) in monitoring sites at George Washington Carver NM, Diamond, MO.

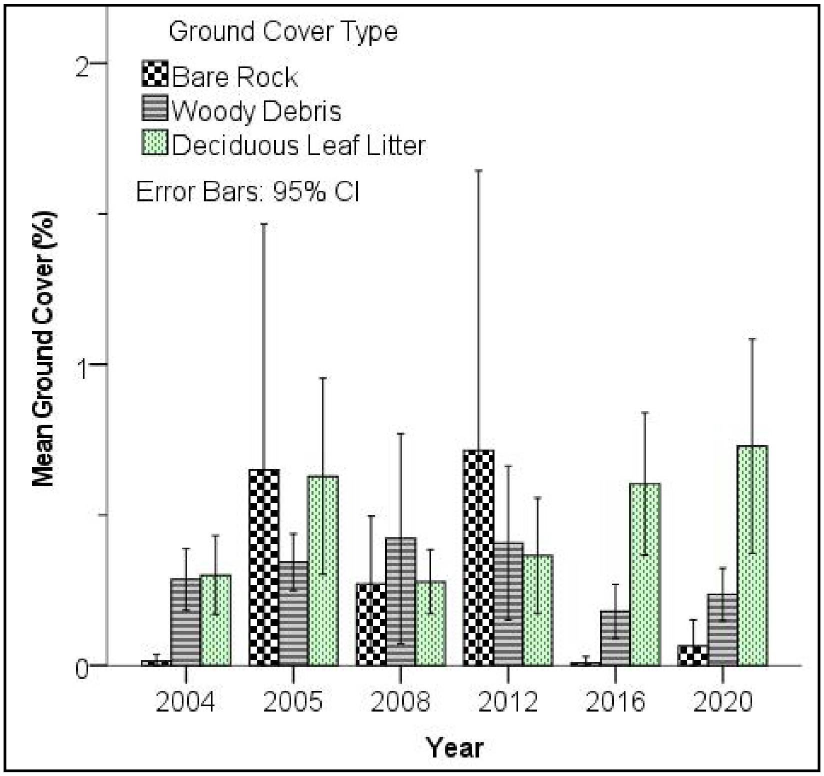


**Figure 13.** Mean Ground Cover (%) of bare rock, woody debris, and deciduous leaf litter at George Washington Carver NM, Diamond, MO.

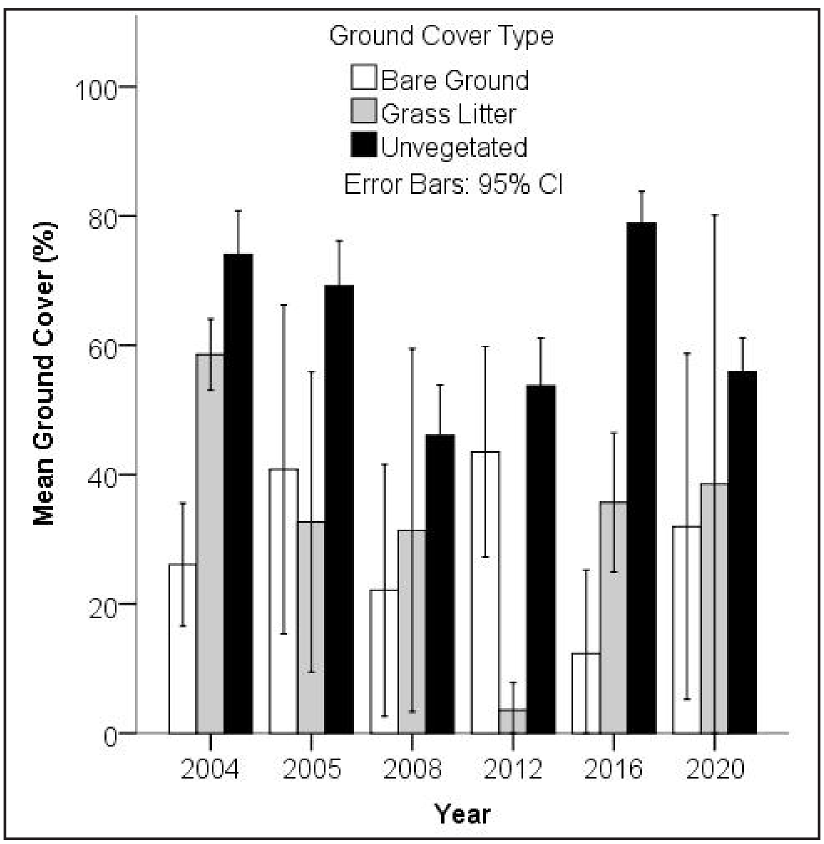


**Figure 14.** Mean Ground Cover (%) of bare ground, grass litter, and unvegetated types at George Washington Carver NM, Diamond, MO.

## Observer Error

Observer error was measured for the first time in 2020 at George Washington Carver NM. Observer error has multiple components. Importantly, our misidentification error appeared to be low (1.6%). We did not record any instances of cautious error (where one observer lumped to a genus level and the other was more specific). Our greatest source of error came from overlooking of species by one of the observers (20.6%). Our total pseudoturnover is a function of all three types of error and averaged 22.1% for the sampling event resulting in 77.9% agreement (Table 4). We aimed to keep our species agreement around 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. However, we do not have a quantitative assessment of the contribution of this source of error.

**Table 4.** Species observer error rates for 2020 monitoring (N = 7).

| Error Component | Mean Error Rate (%) |
|---|---|
| Overlooking | 20.6 |
| Misidentification | 1.6 |
| Cautious | 0.0 |
| Total Pseudoturnover | 22.1 |

We also assessed the amount of agreement between observers on species cover classes. Overall, there was 78.5% agreement on cover classes. Nineteen percent of observations were within one cover class and two observations differed by more than one class.

## 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. The frequency of sampling also changed to once every four years from a more frequent revisit schedule (see appendices in James et al. 2009). We anticipated the possibility of a small decline in species richness as a result of changing to one visit per field season. Since mean species richness only differed in one year (2012), we concluded that species richness was not affected by the change. During analysis we observed that the change to one visit per season may have affected the cover estimates instead. Grasses in particular seemed to be affected. The native warm season grasses are normally at peak in the late summer rather than during the current June sampling period (Figure 9).

We also recognized that plant cover estimation may have been more conservative from 2012 to the present than in the first two sampling years (2004 and 2005). Crew calibration exercises were implemented to reduce this source of error.

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

Precipitation at George Washington Carver NM appears to have been below normal for many of the last twenty years, including during the baseline monitoring years. The role of climate change in prairies is not clear for the park based on our analysis, in part because prairies are adapted to drought. It may be beneficial to learn more about climate change projections for the area in the future.

The park prairie has been actively managed with prescribed fire since 2010 and chemical and mechanical treatments of problematic plants. Species and community diversity remained within the range of variation measured in long-term monitoring sites since 2004. The prairie continues to be free of overstory trees, but tree regeneration has increased. Assessments of species guilds indicated a reduction of grasses. Since the decline in grasses does not seem to be offset by an increase in other guilds, it is unclear what is responsible for the difference. It is possible that drought conditions, increased tree regeneration, or the change in the revisit design are contributing factors.

We assessed the trends for specific species: sumac (*Rhus* spp.), blackberry (*Rubus* spp.), and big bluestem (*Andropogon gerardii*). While sumac cover was very low, blackberry cover has been increasing. Mean big bluestem cover was similar through time, and there was a great deal of variation between sites. Nonnative species were below their previous peak but appear to be slowly increasing. Continued vigilance and active management of the prairie including prescribed fire will be important for maintaining species diversity and the open prairie structure.

Our total pseudoturnover was greater than our goal by 2.1%. This is still a reasonable level of agreement between observers (Morrison 2016). However, we will continue to work towards agreement on species identification and reducing sampling frame placement error.

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# Appendix A. Plant Species Observed in 2020

**Table A1.** All species observed in 2020 at George Washington Carver, NM, Diamond, MO. Values for mean cover, standard error (SE) and occurrence are for 2020 only. N = native, I = nonnative, SE = standard error. Tree species are not included in this table, see Table 2 for species and abundance values.

| Species | Common name | Guild | Origin | 2020 Mean Cover (%) | 2020 SE | 2020 Occurrence (% Sites Observed) |
|---|---|---|---|---|---|---|
| *Acalypha virginica* | Virginia threeseed mercury | forb | N | 0.24 | 0.08 | 85.71 |
| *Achillea millefolium* | common yarrow | forb | N | 0.26 | 0.13 | 57.14 |
| *Ageratina altissima* | white snakeroot | forb | N | 0.01 | 0.01 | 14.29 |
| *Agrostis hyemalis* | winter bentgrass | grass | N | 0.51 | 0.14 | 100.00 |
| *Allium* spp. | onion | forb | N | 0.00 | 0.00 | 0.00 |
| *Allium vineale* | wild garlic | forb | I | 0.02 | 0.01 | 28.57 |
| *Ambrosia artemisiifolia* | annual ragweed | forb | N | 0.14 | 0.11 | 28.57 |
| *Ambrosia bidentata* | lanceleaf ragweed | forb | N | 0.00 | 0.00 | 0.00 |
| *Ambrosia trifida* | great ragweed | forb | N | 0.00 | 0.00 | 0.00 |
| *Amphicarpaea bracteata* | American hogpeanut | forb | N | 0.00 | 0.00 | 0.00 |
| *Andropogon gerardii* | big bluestem | grass | N | 15.62 | 4.50 | 100.00 |
| *Andropogon virginicus* | broomsedge bluestem | grass | N | 0.11 | 0.08 | 42.86 |
| *Antennaria neglecta* | field pussytoes | forb | N | 0.01 | 0.01 | 14.29 |
| *Apocynum cannabinum* | Indianhemp | forb | N | 0.51 | 0.47 | 57.14 |
| *Arenaria serpyllifolia* | thymeleaf sandwort | forb | I | 0.00 | 0.00 | 0.00 |
| *Artemisia ludoviciana* | white sagebrush | forb | N | 0.00 | 0.00 | 0.00 |
| *Asclepias* spp. | milkweed | forb | N | 0.00 | 0.00 | 0.00 |
| *Asclepias amplexicaulis* | clasping milkweed | forb | N | 0.01 | 0.01 | 14.29 |
| *Asclepias stenophylla* | slimleaf milkweed | forb | N | 0.00 | 0.00 | 0.00 |
| *Asclepias syriaca* | common milkweed | forb | N | 0.04 | 0.04 | 14.29 |
| *Asclepias verticillata* | whorled milkweed | forb | N | 0.00 | 0.00 | 0.00 |
| *Asclepias viridiflora* | green comet milkweed | forb | N | 0.03 | 0.01 | 42.86 |
| *Asclepias viridis* | green antelopehorn | forb | N | 0.00 | 0.00 | 0.00 |
| *Aster* spp. | aster | forb | N | 0.00 | 0.00 | 0.00 |
| *Baptisia alba* var. *macrophylla* | largeleaf wild indigo | forb | N | 0.04 | 0.04 | 14.29 |
| *Barbarea vulgaris* | garden yellowrocket | forb | I | 0.04 | 0.02 | 57.14 |
| *Bidens* spp. | beggarticks | forb | N | 0.00 | 0.00 | 0.00 |
| *Bidens aristosa* | bearded beggarticks | forb | N | 0.00 | 0.00 | 0.00 |
| *Bouteloua curtipendula* | sideoats grama | grass | N | 0.01 | 0.01 | 14.29 |
| *Brickellia eupatorioides* | false boneset | forb | N | 0.04 | 0.03 | 28.57 |
| *Bromus* spp. | brome | grass | I | 0.10 | 0.05 | 57.14 |
| *Bromus inermis* | smooth brome | grass | I | 0.00 | 0.00 | 0.00 |
| *Callirhoe involucrata* | purple poppymallow | forb | N | 0.01 | 0.01 | 14.29 |
| *Calystegia sepium* | hedge false bindweed | forb | N | 0.00 | 0.00 | 0.00 |
| *Campsis radicans* | trumpet creeper | Woody | N | 0.21 | 0.17 | 28.57 |
| *Carduus nutans* | nodding plumeless thistle | forb | I | 0.00 | 0.00 | 0.00 |

**Table A1 (continued).** All species observed in 2020 at George Washington Carver, NM, Diamond, MO. Values for mean cover, standard error (SE) and occurrence are for 2020 only. N = native, I = nonnative, SE = standard error. Tree species are not included in this table, see Table 2 for species and abundance values.

| Species | Common name | Guild | Origin | 2020 Mean Cover (%) | 2020 SE | 2020 Occurrence (% Sites Observed) |
|---|---|---|---|---|---|---|
| *Carex* spp. | sedge | grass-like | N | 4.51 | 1.92 | 100.00 |
| *Carex bushii* | Bush's sedge | grass-like | N | 0.00 | 0.00 | 0.00 |
| *Carex molesta* | troublesome sedge | grass-like | N | 0.00 | 0.00 | 0.00 |
| *Carex shortiana* | Short's sedge | grass-like | N | 0.00 | 0.00 | 0.00 |
| *Chaerophyllum tainturieri* | hairyfruit chervil | forb | N | 0.00 | 0.00 | 0.00 |
| *Chamaecrista fasciculata* | partridge pea | forb | N | 0.06 | 0.04 | 28.57 |
| *Chamaecrista nictitans* | sensitive partridge pea | forb | N | 0.00 | 0.00 | 0.00 |
| *Chamaesyce* spp. | sandmat | forb | N | 0.00 | 0.00 | 0.00 |
| *Chenopodium* spp. | goosefoot | forb | N | 0.00 | 0.00 | 0.00 |
| *Chenopodium album* | lambsquarters | forb | N | 0.00 | 0.00 | 0.00 |
| *Cirsium* spp. | thistle | forb | I | 0.00 | 0.00 | 0.00 |
| *Cirsium altissimum* | tall thistle | forb | N | 0.53 | 0.24 | 71.43 |
| *Cirsium discolor* | field thistle | forb | N | 0.14 | 0.09 | 42.86 |
| *Cirsium vulgare* | bull thistle | forb | I | 0.00 | 0.00 | 0.00 |
| *Convolvulus arvensis* | field bindweed | forb | I | 0.00 | 0.00 | 0.00 |
| *Conyza canadensis* | Canadian horseweed | forb | N | 0.00 | 0.00 | 0.00 |
| *Croton capitatus* | hogwort | forb | N | 0.01 | 0.01 | 14.29 |
| *Croton glandulosus* | vente conmigo | forb | N | 0.00 | 0.00 | 0.00 |
| *Croton monanthogynus* | prairie tea | forb | N | 0.00 | 0.00 | 0.00 |
| *Cruciata pedemontana* | piedmont bedstraw | forb | I | 0.08 | 0.06 | 28.57 |
| *Cyperus* spp. | flatsedge | grass-like | N | 0.00 | 0.00 | 0.00 |
| *Cyperus echinatus* | globe flatsedge | grass-like | N | 0.12 | 0.05 | 71.43 |
| *Cyperus lupulinus* | Great Plains flatsedge | grass | N | 0.00 | 0.00 | 0.00 |
| *Daucus carota* | Queen Anne's lace | forb | I | 0.00 | 0.00 | 0.00 |
| *Desmanthus illinoensis* | Illinois bundleflower | forb | N | 0.01 | 0.01 | 14.29 |
| *Desmodium* spp. | ticktrefoil | forb | N | 0.00 | 0.00 | 0.00 |
| *Desmodium canadense* | showy ticktrefoil | forb | N | 0.44 | 0.20 | 71.43 |
| *Desmodium canescens* | hoary ticktrefoil | forb | N | 0.00 | 0.00 | 0.00 |
| *Desmodium illinoense* | Illinois ticktrefoil | forb | N | 0.04 | 0.04 | 14.29 |
| *Desmodium nuttallii* | Nuttall's ticktrefoil | forb | N | 0.00 | 0.00 | 0.00 |
| *Desmodium paniculatum* | panicledleaf ticktrefoil | forb | N | 0.01 | 0.01 | 14.29 |
| *Desmodium perplexum* | perplexed ticktrefoil | forb | N | 0.00 | 0.00 | 0.00 |
| *Dianthus armeria* | Deptford pink | forb | I | 0.02 | 0.01 | 28.57 |
| *Dichanthelium* spp. | rosette grass | grass | N | 0.29 | 0.07 | 85.71 |
| *Digitaria cognata* | fall witchgrass | grass | N | 0.00 | 0.00 | 0.00 |
| *Digitaria sanguinalis* | hairy crabgrass | grass | I | 0.00 | 0.00 | 0.00 |
| *Diodia teres* | poorjoe | forb | N | 0.00 | 0.00 | 0.00 |
| *Echinacea pallida* | pale purple coneflower | forb | N | 0.05 | 0.05 | 14.29 |
| *Elymus virginicus* | Virginia wildrye | grass | N | 0.19 | 0.08 | 71.43 |

**Table A1 (continued).** All species observed in 2020 at George Washington Carver, NM, Diamond, MO. Values for mean cover, standard error (SE) and occurrence are for 2020 only. N = native, I = nonnative, SE = standard error. Tree species are not included in this table, see Table 2 for species and abundance values.

| Species | Common name | Guild | Origin | 2020 Mean Cover (%) | 2020 SE | 2020 Occurrence (% Sites Observed) |
|---|---|---|---|---|---|---|
| *Eragrostis spectabilis* | purple lovegrass | grass | N | 0.01 | 0.01 | 28.57 |
| *Erechtites hieraciifolia* | American burnweed | forb | N | 0.00 | 0.00 | 0.00 |
| *Erigeron* spp. | fleabane | forb | N | 0.00 | 0.00 | 0.00 |
| *Erigeron annuus* | eastern daisy fleabane | forb | N | 0.00 | 0.00 | 0.00 |
| *Erigeron strigosus* | prairie fleabane | forb | N | 0.61 | 0.31 | 57.14 |
| *Euonymus fortunei* | winter creeper | woody | I | 0.01 | 0.01 | 28.57 |
| *Eupatorium altissimum* | tall thoroughwort | forb | N | 0.01 | 0.01 | 14.29 |
| *Euphorbia corollata* | flowering spurge | forb | N | 0.01 | 0.01 | 14.29 |
| *Euphorbia cyathophora* | fire on the mountain | forb | N | 0.00 | 0.00 | 0.00 |
| *Euphorbia dentata* | toothed spurge | forb | N | 0.00 | 0.00 | 0.00 |
| *Galium aparine* | stickywilly | forb | N | 0.00 | 0.00 | 0.00 |
| *Gamochaeta purpurea* | spoonleaf purple everlasting | forb | N | 0.00 | 0.00 | 0.00 |
| *Gaura biennis* | biennial beeblossom | forb | N | 0.00 | 0.00 | 0.00 |
| *Geranium carolinianum* | Carolina geranium | forb | N | 0.19 | 0.04 | 100.00 |
| *Geum canadense* | white avens | forb | N | 0.01 | 0.01 | 14.29 |
| *Glandularia canadensis* | rose mock vervain | forb | N | 0.06 | 0.04 | 28.57 |
| *Hieracium longipilum* | hairy hawkweed | forb | N | 0.03 | 0.02 | 28.57 |
| *Hordeum pusillum* | little barley | grass | N | 0.00 | 0.00 | 0.00 |
| *Hypericum* spp. | St. Johnswort | forb | N | 0.00 | 0.00 | 0.00 |
| *Hypericum perforatum* | common St. Johnswort | forb | I | 0.02 | 0.01 | 42.86 |
| *Hypericum punctatum* | spotted St. Johnswort | forb | N | 0.04 | 0.01 | 57.14 |
| *Ipomoea pandurata* | man of the earth | forb | N | 0.09 | 0.09 | 14.29 |
| *Juncus* spp. | rush | grass-like | N | 1.28 | 0.87 | 100.00 |
| *Juncus interior* | inland rush | grass-like | N | 0.00 | 0.00 | 0.00 |
| *Krigia caespitosa* | Sunflower | forb | N | 0.00 | 0.00 | 0.00 |
| *Kummerowia stipulacea* | Korean clover | forb | I | 0.00 | 0.00 | 0.00 |
| *Kummerowia striata* | Japanese clover | forb | I | 0.00 | 0.00 | 0.00 |
| *Lactuca* spp. | lettuce | forb | N | 0.00 | 0.00 | 0.00 |
| *Lactuca canadensis* | Canada lettuce | forb | N | 0.03 | 0.01 | 42.86 |
| *Lactuca serriola* | prickly lettuce | forb | I | 0.00 | 0.00 | 0.00 |
| *Lepidium densiflorum* | common pepperweed | forb | N | 0.00 | 0.00 | 0.00 |
| *Lespedeza capitata* | roundhead lespedeza | forb | N | 0.29 | 0.12 | 85.71 |
| *Lespedeza cuneata* | sericea lespedeza | forb | I | 1.44 | 0.73 | 85.71 |
| *Lespedeza procumbens* | trailing lespedeza | forb | N | 0.00 | 0.00 | 0.00 |
| *Lespedeza violacea* | violet lespedeza | forb | N | 0.32 | 0.31 | 28.57 |
| *Lespedeza virginica* | slender lespedeza | forb | N | 0.19 | 0.18 | 28.57 |
| *Leucanthemum vulgare* | oxeye daisy | forb | I | 0.00 | 0.00 | 0.00 |
| *Liatris pycnostachya* | prairie blazing star | forb | N | 0.01 | 0.01 | 14.29 |
| *Linum sulcatum* | grooved flax | forb | N | 0.00 | 0.00 | 0.00 |

**Table A1 (continued).** All species observed in 2020 at George Washington Carver, NM, Diamond, MO. Values for mean cover, standard error (SE) and occurrence are for 2020 only. N = native, I = nonnative, SE = standard error. Tree species are not included in this table, see Table 2 for species and abundance values.

| Species | Common name | Guild | Origin | 2020 Mean Cover (%) | 2020 SE | 2020 Occurrence (% Sites Observed) |
|---|---|---|---|---|---|---|
| *Lonicera japonica* | Japanese honeysuckle | woody | I | 0.01 | 0.01 | 14.29 |
| *Lythrum alatum* | winged lythrum | forb | N | 0.00 | 0.00 | 0.00 |
| *Melilotus officinalis* | yellow sweetclover | forb | I | 0.00 | 0.00 | 0.00 |
| *Mimosa nuttallii* | Sensitive brier | forb | N | 0.31 | 0.26 | 28.57 |
| *Mirabilis albida* | white four o'clock | forb | N | 0.01 | 0.01 | 14.29 |
| *Monarda fistulosa* | wild bergamot | forb | N | 0.01 | 0.01 | 14.29 |
| *Muhlenbergia* spp. | muhly | grass | N | 0.00 | 0.00 | 0.00 |
| *Nuttallanthus texanus* | Texas toadflax | forb | N | 0.00 | 0.00 | 0.00 |
| *Oenothera biennis* | common evening primrose | forb | N | 0.00 | 0.00 | 0.00 |
| *Oenothera laciniata* | cutleaf evening primrose | forb | N | 0.00 | 0.00 | 0.00 |
| *Oenothera speciosa* | pinkladies | forb | N | 0.00 | 0.00 | 0.00 |
| *Oxalis* spp. | woodsorrel | forb | N | 0.24 | 0.05 | 100.00 |
| *Oxalis violacea* | violet woodsorrel | forb | N | 0.00 | 0.00 | 0.00 |
| *Panicum* spp. | panicgrass | grass | N | 0.00 | 0.00 | 0.00 |
| *Panicum anceps* | beaked panicgrass | grass | N | 0.18 | 0.17 | 28.57 |
| *Panicum capillare* | witchgrass | grass | N | 0.00 | 0.00 | 0.00 |
| *Panicum virgatum* | switchgrass | grass | N | 0.59 | 0.29 | 100.00 |
| *Parthenocissus quinquefolia* | Virginia creeper | woody | N | 0.04 | 0.04 | 14.29 |
| *Pascopyrum smithii* | western wheatgrass | grass | N | 0.00 | 0.00 | 0.00 |
| *Paspalum laeve* | field paspalum | grass | N | 0.00 | 0.00 | 0.00 |
| *Passiflora incarnata* | purple passionflower | forb | N | 0.07 | 0.07 | 14.29 |
| *Penstemon digitalis* | talus slope penstemon | forb | N | 0.11 | 0.06 | 42.86 |
| *Phalaris canariensis* | annual canarygrass | grass | I | 0.00 | 0.00 | 0.00 |
| *Phleum pratense* | timothy | grass | I | 0.00 | 0.00 | 0.00 |
| *Physalis heterophylla* | clammy groundcherry | forb | N | 0.09 | 0.05 | 71.43 |
| *Physalis longifolia* | longleaf groundcherry | forb | N | 0.00 | 0.00 | 0.00 |
| *Physalis virginiana* | Virginia groundcherry | forb | N | 0.01 | 0.01 | 28.57 |
| *Phytolacca americana* | American pokeweed | forb | N | 0.00 | 0.00 | 0.00 |
| *Plantago* spp. | plantain | forb | N | 0.00 | 0.00 | 0.00 |
| *Plantago aristata* | largebracted plantain | forb | N | 0.00 | 0.00 | 0.00 |
| *Plantago lanceolata* | narrowleaf plantain | forb | I | 0.00 | 0.00 | 0.00 |
| *Plantago rugelii* | blackseed plantain | forb | N | 0.00 | 0.00 | 0.00 |
| *Plantago virginica* | Virginia plantain | forb | N | 0.67 | 0.33 | 71.43 |
| *Poa arida* | plains bluegrass | grass | N | 0.00 | 0.00 | 0.00 |
| *Poa compressa* | Canada bluegrass | grass | I | 0.00 | 0.00 | 0.00 |
| *Poa pratensis* | Kentucky bluegrass | grass | I | 1.31 | 0.55 | 100.00 |
| *Polygala sanguinea* | purple milkwort | forb | N | 0.04 | 0.03 | 28.57 |
| *Polygala verticillata* | whorled milkwort | forb | N | 0.01 | 0.01 | 14.29 |
| *Polygonum* spp. | knotweed | forb | N | 0.00 | 0.00 | 0.00 |

**Table A1 (continued).** All species observed in 2020 at George Washington Carver, NM, Diamond, MO. Values for mean cover, standard error (SE) and occurrence are for 2020 only. N = native, I = nonnative, SE = standard error. Tree species are not included in this table, see Table 2 for species and abundance values.

| Species | Common name | Guild | Origin | 2020 Mean Cover (%) | 2020 SE | 2020 Occurrence (% Sites Observed) |
|---|---|---|---|---|---|---|
| *Polygonum pensylvanicum* | Pennsylvania smartweed | forb | N | 0.00 | 0.00 | 0.00 |
| *Potentilla recta* | sulphur cinquefoil | forb | I | 0.11 | 0.04 | 85.71 |
| *Prunus* spp. | plum | woody | N | 0.84 | 0.37 | 71.43 |
| *Prunus americana* | American plum | woody | N | 0.00 | 0.00 | 0.00 |
| *Pseudognaphalium obtusifolium* ssp. *obtusifolium* | fragrant cudweed | forb | N | 0.00 | 0.00 | 0.00 |
| *Ptilimnium nuttallii* | laceflower | forb | N | 0.01 | 0.01 | 14.29 |
| *Rhus copallinum* | winged sumac | woody | N | 0.48 | 0.33 | 71.43 |
| *Rhus glabra* | smooth sumac | woody | N | 0.00 | 0.00 | 0.00 |
| *Rosa carolina* | Carolina rose | woody | N | 0.21 | 0.21 | 14.29 |
| *Rubus* spp. | blackberry | woody | N | 13.93 | 3.93 | 100.00 |
| *Rudbeckia* spp. | coneflower | forb | N | 0.00 | 0.00 | 0.00 |
| *Rudbeckia hirta* | blackeyed Susan | forb | N | 0.21 | 0.07 | 85.71 |
| *Ruellia humilis* | fringeleaf wild petunia | forb | N | 0.14 | 0.09 | 42.86 |
| *Rumex* spp. | dock | forb | I | 0.00 | 0.00 | 0.00 |
| *Rumex acetosella* | common sheep sorrel | forb | I | 0.01 | 0.01 | 14.29 |
| *Rumex crispus* | curly dock | forb | I | 0.22 | 0.10 | 71.43 |
| *Sabatia angularis* | rosepink | forb | N | 0.00 | 0.00 | 0.00 |
| *Salvia azurea* | azure blue sage | forb | N | 0.04 | 0.03 | 42.86 |
| *Sanicula* spp. | sanicle | forb | N | 0.01 | 0.01 | 14.29 |
| *Saponaria officinalis* | bouncingbet | forb | I | 0.00 | 0.00 | 0.00 |
| *Schedonorus phoenix* | tall fescue | grass | I | 3.91 | 2.28 | 42.86 |
| *Schizachyrium scoparium* | little bluestem | grass | N | 3.56 | 0.63 | 100.00 |
| *Schoenoplectus tabernaemontani* | softstem bulrush | grass-like | N | 0.00 | 0.00 | 0.00 |
| *Scirpus* spp. | bulrush | grass-like | N | 0.47 | 0.47 | 14.29 |
| *Scutellaria parvula* | small skullcap | forb | N | 0.00 | 0.00 | 0.00 |
| *Setaria* spp. | bristlegrass | grass | I | 0.00 | 0.00 | 0.00 |
| *Setaria faberi* | Japanese bristlegrass | grass | I | 0.00 | 0.00 | 0.00 |
| *Setaria pumila* | yellow foxtail | grass | I | 0.00 | 0.00 | 0.00 |
| *Setaria viridis* | green bristlegrass | grass | I | 0.00 | 0.00 | 0.00 |
| *Sida spinosa* | prickly fanpetals | forb | N | 0.00 | 0.00 | 0.00 |
| *Silene* spp. | catchfly | forb | N | 0.00 | 0.00 | 0.00 |
| *Silene antirrhina* | sleepy silene | forb | N | 0.00 | 0.00 | 0.00 |
| *Smilax bona-nox* | saw greenbrier | woody | N | 0.09 | 0.06 | 28.57 |
| *Solanum americanum* | American black nightshade | forb | N | 0.00 | 0.00 | 0.00 |
| *Solanum carolinense* | Carolina horsenettle | forb | N | 0.24 | 0.06 | 85.71 |
| *Solidago* spp. | goldenrod | forb | N | 0.00 | 0.00 | 0.00 |
| *Solidago altissima* | Canada goldenrod | forb | N | 3.86 | 2.00 | 85.71 |
| *Solidago missouriensis* | Missouri goldenrod | forb | N | 0.00 | 0.00 | 0.00 |

**Table A1 (continued).** All species observed in 2020 at George Washington Carver, NM, Diamond, MO. Values for mean cover, standard error (SE) and occurrence are for 2020 only. N = native, I = nonnative, SE = standard error. Tree species are not included in this table, see Table 2 for species and abundance values.

| Species | Common name | Guild | Origin | 2020 Mean Cover (%) | 2020 SE | 2020 Occurrence (% Sites Observed) |
|---|---|---|---|---|---|---|
| *Sorghastrum nutans* | Indiangrass | grass | N | 2.87 | 0.73 | 100.00 |
| *Sorghum halepense* | Johnsongrass | grass | I | 0.31 | 0.31 | 14.29 |
| *Sphenopholis intermedia* | slender wedgescale | grass | N | 0.01 | 0.01 | 14.29 |
| *Sphenopholis obtusata* | prairie wedgescale | grass | N | 0.28 | 0.15 | 71.43 |
| *Spiranthes cernua* | nodding lady's tresses | forb | N | 0.00 | 0.00 | 0.00 |
| *Sporobolus compositus* | composite dropseed | grass | N | 0.09 | 0.06 | 42.86 |
| *Sporobolus compositus* var. *compositus* | tall dropseed | grass | N | 0.00 | 0.00 | 0.00 |
| *Sporobolus heterolepis* | prairie dropseed | grass | N | 0.00 | 0.00 | 0.00 |
| *Stellaria media* | common chickweed | forb | I | 0.10 | 0.06 | 57.14 |
| *Strophostyles leiosperma* | slickseed fuzzybean | forb | N | 0.22 | 0.13 | 71.43 |
| *Strophostyles umbellata* | pink fuzzybean | forb | N | 0.00 | 0.00 | 0.00 |
| *Stylosanthes biflora* | sidebeak pencilflower | forb | N | 0.03 | 0.03 | 14.29 |
| *Symphoricarpos orbiculatus* | coralberry | woody | N | 0.26 | 0.21 | 42.86 |
| *Symphyotrichum ericoides* var. *ericoides* | squarrose white wild aster | forb | N | 0.01 | 0.01 | 14.29 |
| *Symphyotrichum oolentangiense* | skyblue aster | forb | N | 0.01 | 0.01 | 14.29 |
| *Symphyotrichum patens* var. *patens* | clasping wild aster | forb | N | 0.00 | 0.00 | 0.00 |
| *Symphyotrichum pilosum* var. *pilosum* | awl wild aster | forb | N | 0.22 | 0.20 | 28.57 |
| *Symphyotrichum praealtum* var. *praealtum* | willowleaf aster | forb | N | 1.39 | 0.68 | 85.71 |
| *Taraxacum officinale* | common dandelion | forb | I | 0.00 | 0.00 | 0.00 |
| *Tephrosia virginiana* | Virginia tephrosia | forb | N | 0.00 | 0.00 | 0.00 |
| *Teucrium canadense* | Canada germander | forb | N | 0.92 | 0.41 | 71.43 |
| *Torilis arvensis* | spreading hedgeparsley | forb | I | 0.01 | 0.01 | 14.29 |
| *Torilis japonica* | erect hedgeparsley | forb | I | 0.00 | 0.00 | 0.00 |
| *Tragia betonicifolia* | betonyleaf noseburn | forb | N | 0.08 | 0.04 | 42.86 |
| *Tragopogon dubius* | yellow salsify | forb | I | 0.00 | 0.00 | 0.00 |
| *Tridens flavus* | purpletop tridens | grass | N | 0.26 | 0.22 | 42.86 |
| *Trifolium* spp. | clover | forb | I | 0.00 | 0.00 | 0.00 |
| *Trifolium arvense* | rabbitfoot clover | forb | N | 0.01 | 0.01 | 14.29 |
| *Trifolium campestre* | field clover | forb | I | 0.91 | 0.58 | 100.00 |
| *Trifolium pratense* | red clover | forb | I | 0.11 | 0.09 | 28.57 |
| *Trifolium repens* | white clover | forb | I | 0.00 | 0.00 | 0.00 |
| *Triodanis perfoliata* | clasping Venus' looking-glass | forb | N | 0.26 | 0.11 | 71.43 |
| *Valerianella radiata* | beaked cornsalad | forb | N | 0.37 | 0.08 | 100.00 |
| *Verbascum blattaria* | moth mullein | forb | N | 0.00 | 0.00 | 0.00 |
| *Verbena simplex* | narrowleaf vervain | forb | N | 0.01 | 0.01 | 14.29 |
| *Verbena stricta* | hoary verbena | forb | N | 0.06 | 0.06 | 14.29 |
| *Verbena urticifolia* | white vervain | forb | N | 0.01 | 0.01 | 14.29 |
| *Vernonia arkansana* | Arkansas ironweed | forb | N | 0.00 | 0.00 | 0.00 |

**Table A1 (continued).** All species observed in 2020 at George Washington Carver, NM, Diamond, MO. Values for mean cover, standard error (SE) and occurrence are for 2020 only. N = native, I = nonnative, SE = standard error. Tree species are not included in this table, see Table 2 for species and abundance values.

| Species | Common name | Guild | Origin | 2020 Mean Cover (%) | 2020 SE | 2020 Occurrence (% Sites Observed) |
|---|---|---|---|---|---|---|
| *Vernonia baldwinii* | Baldwin's ironweed | forb | N | 0.03 | 0.02 | 28.57 |
| *Veronica arvensis* | corn speedwell | forb | I | 0.00 | 0.00 | 0.00 |
| *Vicia sativa* | garden vetch | forb | I | 0.05 | 0.02 | 57.14 |
| *Viola* spp. | violet | forb | N | 0.01 | 0.01 | 14.29 |
| *Viola bicolor* | field pansy | forb | N | 0.00 | 0.00 | 0.00 |
| *Viola sororia* | common blue violet | forb | N | 0.00 | 0.00 | 0.00 |
| *Vitis* spp. | grape | woody | N | 0.01 | 0.01 | 28.57 |
| *Vulpia octoflora* | sixweeks fescue | grass | N | 0.80 | 0.56 | 100.00 |

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U.S. Department of the Interior

**Natural Resource Stewardship and Science**
1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525