National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

# George Washington Carver National Monument Plant Community and Fire Ecology Report

*2004–2016*

Natural Resource Report NPS/HTLN/NRR—2017/1458

ON THIS PAGE
2015 photo of the north prairie at George Washington Carver National Monument after a prescribed burn aimed at reducing woody plants.
Photography by: Heartland Network, NPS

ON THE COVER
Top Photo: 2016 photo of Site 1 in the south prairie at George Washington Carver National Monument. Jordan Bell pictured. Bottom Photo: 2004 photo of Site 1 at George Washington Carver National Monument. Mike DeBacker and Alicia Sasseen pictured.
Photography by: Heartland Network, NPS

# George Washington Carver National Monument Plant Community and Fire Ecology Report

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Natural Resource Report NPS/HTLN/NRR—2017/1458

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Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.



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# Contents

# Figures

# Tables



# Appendices

# Executive Summary

The Heartland Inventory and Monitoring Network completed five monitoring events in the restored prairie at George Washington Carver National Monument (NM) from 2004–2016. The prairie plant community at the park remained relatively stable through the monitoring period. The mean proportion of trees decreased and grass cover dominated the community with an abundance of forbs and other species. There was concern over the increasing abundance of sumac (*Rhus* spp), but increased fire return intervals and targeted herbicide application were effective at reducing sumac to very low levels. Park staff expressed concern over the increasing blackberry populations; however sites with blackberry have legacy populations. Non-native species continue to be present in low numbers – less than 7% mean cover. Site level factors (e.g., soil moisture) contributed to a distinctly different community at one site in an area referred to as wet prairie. Prairie plant species recognized by Dr. Carver continue to be present. Future monitoring events will strengthen our ability to look at long-term trends for those particular species. Maintenance of the prairie includes a variety of processes and tools (e.g. fire, herbicide, cutting, mowing). Together these actions appear to be meeting fire management objectives for fuel reduction, completeness, and species richness as well as supporting a diverse prairie community.

# Acknowledgments

Many people were involved in data collection and processing over time. We are grateful for contributions from Kevin James and Karola Mlekush. George Washington Carver NM has graciously provided access, technicians, and other support to our monitoring efforts. Missouri State University also provided support for fire ecology monitoring efforts 2008-2016. Chad Gross and Jennifer Haack-Gaynor provided Geographic Information System technical support.

# 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 grassland and dissected along wooded streams.

The park commemorates the birthplace of George Washington Carver. Natural resource management seeks to complement and enhance interpretation of Dr. Carver's life in a variety of ways, notably, to provide 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). Tallgrass prairie would have been available for grazing in the surrounding area and some remnant prairie still remains at nearby Diamond Grove Prairie. During Dr. Carver's career, he was inspired by the beauty, medicinal and agricultural uses of plants. This curiosity began during his childhood on the Carver farm (Burchard 2005). Carver's work at the Tuskegee Institute also included mention of agricultural and medicinal uses of plants found in the George Washington Carver NM prairie (Appendix A).

Because of the importance of plants and the prairie in Dr. Carver's life, vegetation monitoring in the prairie has been central to the Heartland Inventory and Monitoring Network's (hereafter, Heartland Network) long-term monitoring program at George Washington Carver NM. Here we define prairie as a plant community dominated by herbaceous plants. Although tallgrass prairie has fewer grass than forb species, grass as a group is more abundant (Weaver 1954). Tree species should be relatively few in tallgrass prairie. Ecologists use benchmarks like <1 tree/acre (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 historically maintained prairies (Weaver 1959). 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. Although wildlife prairie species are important to consider, our focus for this report is the plant community and the role of fire.

Fire management goals and objectives for the park are largely vegetation management related. Draft objectives include (1) maintain gamma diversity (park-wide plant species richness) in the prairie of ≥ 71 species, (2) reduce native invasive and exotic woody plants to < 10% cover within three burns, (3) reduce 1- and 10-hour fuels by 70% of pre-burn amounts for each burn, (4), burns should be 75-95% complete, and lastly (5) make firefighter and public safety the highest priority of every fire management activity (Leis 2013 draft objectives).

Plant community monitoring of the George Washington Carver NM prairie aims to provide status and trends of the reconstructed prairie. We also endeavor to report on the role of fire in maintaining the park's prairie plant community. This information will aid in the interpretation of Carver's life, spirituality, passion for art, work, and achievements as well as provide foundational data for natural resource management decisions.

We aim to frame the analysis of the prairie community around some interpretive themes to facilitate integration of the information into park operations. These themes include the following:

1. How has the prairie changed through the monitoring record?

2. How does the interface of prescribed fire, precipitation trends, and plant community groups (guilds) like legumes, forbs, grasses, and exotic species contribute to the prairie?

3. What are the trends for species of interest to Carver as well as natural resource managers?

4. Can we identify unique communities within the park's prairie?

# Methods

## 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, and 2016 (Figure 1). Fire ecology monitoring was implemented annually from 2010-present with the exception of 2013 when there were no fires. Fire ecology monitoring utilized the same seven permanently marked sites with the addition of one GPS-monumented site (plot 19; n= 8; Figure 1).

The eight 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) and fire ecology monitoring protocol (Leis et.al. 2011). 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 1). Grassland monitoring at George Washington Carver NM consists of understory species observations and ground cover. Trees have been treated in two different ways over time. In the first two years of monitoring, they were tallied as regeneration phase trees, in 2008 they were not recorded at all, and in 2016 they were recorded as herbaceous species with cover values. As a result of the inconsistency, we looked at the proportion of plots in which trees were recorded each year as a surrogate for abundance.

## Data summary and analysis

### *Precipitation*

Precipitation data were obtained from National Centers for Environmental Information, https://www.ncdc.noaa.gov/; (Menne et al. 2012a, 2012b). Precipitation was summed by the date of the monitoring event including the 12 months prior to sampling. Analyses looking at relationships with precipitation (e.g., diversity elements and plant guilds) used linear regression for native and invasive species groups.

### *Basic vegetation metrics*

For all univariate vegetation metrics analyzed in this study except alpha, beta, and gamma diversity, we summarized species data to the site level as the plot mean ± 1 standard error of the mean. These metrics included species diversity measurements, tree abundance (i.e., proportion of plots with trees present per site), *Rhus* and *Rubus* abundance, and guild abundance. For metrics based on foliar cover, percent cover classes were converted to class midpoint values prior to analysis. One plot was excluded from the analysis because >75% of species were recorded without an accompanying abundance value.

The arcsine square root transformation was employed to normalize percentage or proportional data prior to parametric tests. Repeated measures Analysis of Variance (ANOVA) tests were performed to test for change over time. Sphericity, an important assumption of repeated measures ANOVA, was evaluated with Mauchly's test, which evaluates the hypothesis that the variances of the differences between years are equal. If data violated the sphericity assumption, the Huynh-Feldt correction was used when the Greenhouse-Geisser Epsilon > 0.75, and the Greenhouse-Geisser correction was used when the Greenhouse-Geisser Epsilon < 0.75.

If data could not be transformed to normality (e.g., too many zeros), the nonparametric Friedman test was employed. The Friedman test is the non-parametric analog to a one-way ANOVA with repeated measures. Statistical tests were conducted using SPSS software (IBM 2011) unless otherwise noted and significance was evaluated at the alpha = 0.05 level.

<u>Trees</u>

The proportion of plots in each site where trees were recorded, regardless of species, was arcsine square root transformed prior to performing a repeated measures ANOVA. (If more than one species occurred in a plot, the plot was tallied once. *Fraxinus* spp. was also tested independently. In 2008, tree species were not recorded.

<u>Species diversity</u>

Species were separated by their nativity status (native or introduced) prior to diversity calculations. For each site within the community, species richness (S) along with the effective number of species derived from both the Shannon diversity index (Shannon number or $H_e$) and Simpson's diversity index (Simpson's number or $D_e$) were calculated. Richness represents the number of native species observed,

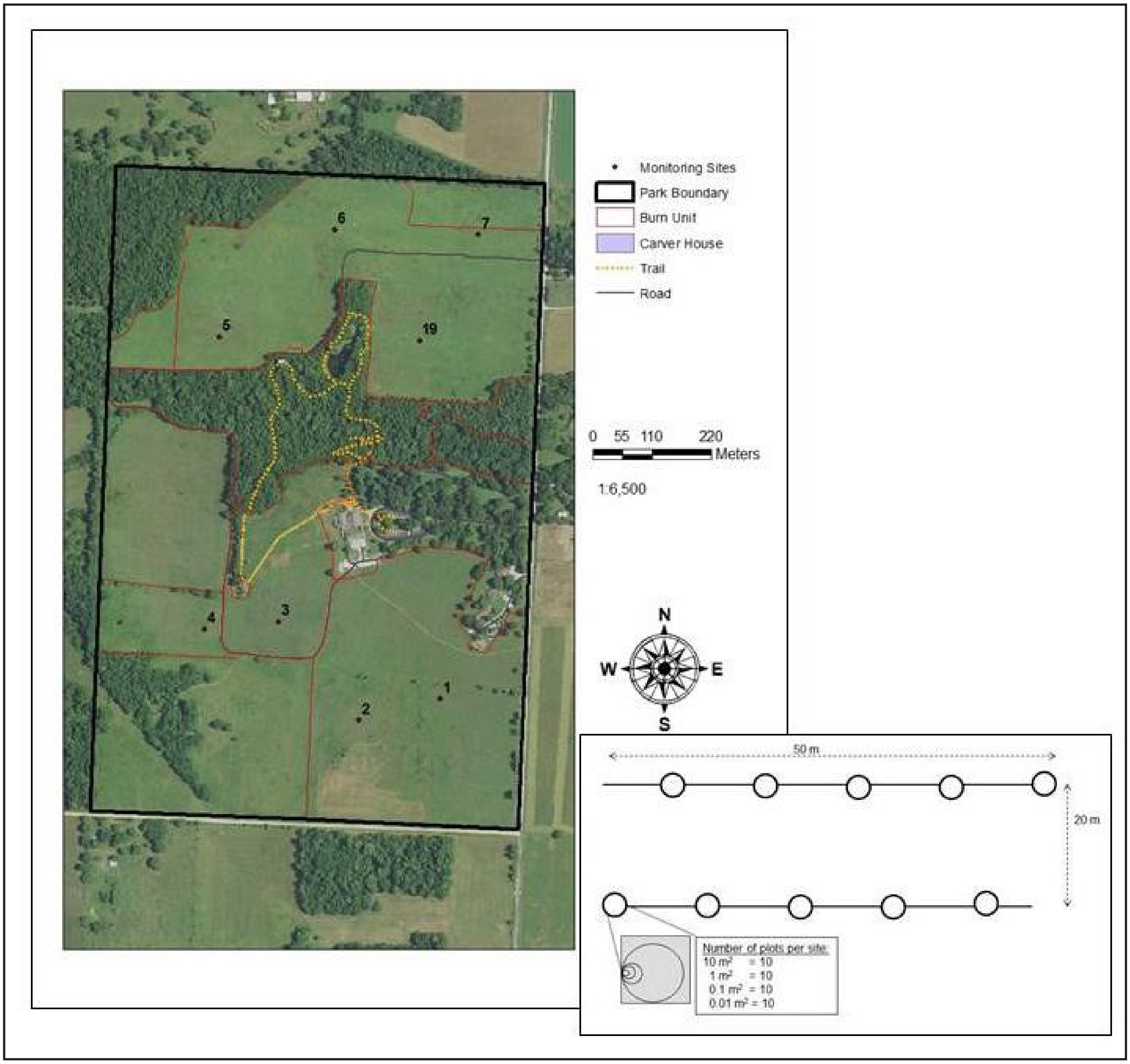



**Figure 1.** Map of Heartland Network vegetation (n=7) and fire ecology (n=8) monitoring sites at George Washington Carver NM, Missouri. Burn units are numbered within each unit. Inset illustrates sampling site design.

$H_e$ represents a measure of diversity, while $D_e$ refers to dominance within the community. Mean foliar cover estimates for each species in a site were used to determine these elements.

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

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

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

Simpson's index of diversity for an infinite population (D) was calculated by site (McCune and Grace 2002). D is the likelihood that two randomly chosen individuals from a site will be different species and emphasizes common species (McCune and Grace 2002). It was calculated by site using the complement of Simpson's original index of dominance:

$$\text{Simpson's Index:} \quad D = 1 - \sum_{i}^{n} p_i^2$$

Shannon and Simpson's index values were converted into effective number of species for each community ($H_e$ and $D_e$, respectively). This allowed for both diversity measures to be compared directly to species richness of the sites (S) within and among sample years based on counts of distinct species in the community (Jost 2006). Shannon index was converted into effective number of species ($H_e$) using the following formula:

$$H_e = exp^{H'}$$

where H was the Shannon index value. The effective number of species based on Simpson's index ($D_e$) was the inverse of the index value or:

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

where D was the Simpson's index value. PC-ORD (Version 6) was used for calculation of diversity indices (McCune and Mefford 2011) and output was converted to effective species using a spreadsheet.

*Interpretation:* As S, $H_e$ and $D_e$ approach the same number, species begin to be equally abundant in the understory while large differences in the number of species between each measure reflect an increasing number of rare species and decreasing number of abundant species. See Jost (2006) and McCune and Grace (2002) for a further explanation and implementation of species diversity measures, respectively. Generally in prairies, we expect species richness values to be greater than effective species for diversity and dominance. This is a result of prairie plant communities having a few species of grasses that are abundant, but more species of forbs that are less abundant. Additionally, most species (except a core of dominant matrix species) are rare in quality prairies.

**Herbaceous community metrics**

Community metrics are another way to think about how the plant community differs spatially. Alpha diversity is synonymous with species richness (mean number of species per monitoring site). This is equivalent to species richness in the diversity measures above. Gamma diversity is the park level diversity as measured by the number of species observed across our monitoring sites (park richness). Beta diversity is a measure of variation across monitoring sites such that small values, near 0, indicate a high degree of similarity across monitoring sites and greater values, >5, indicate a higher degree of variation between sites (McCune and Grace 2002).

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

***Rhus* and *Rubus* cover**

To understand specific species (e.g. *Rhus* and *Rubus*) changes over time, nonparametric Friedman tests were applied.

**Guild abundance**

Understory species were summarized by guilds, aka functional groups, (as per the USDA Plants database) to provide insight into the composition of the community. Guild assignments were grasses, forbs, grass-like (sedges/rushes), ferns, and woody species. Species were separated by nativity status prior to being summed by guild. To determine whether guild abundance changed through the monitoring period, we used Friedman tests on the midpoint values for observed cover classes for each guild. A complete species list along with guild assignment is provided in Appendix A.

### Ground cover

Ground cover includes estimates of aerial coverage of exposed soil, bare rocks, grass litter, deciduous leaf litter, woody debris, and the total unvegetated area based on stem basal area. To test whether ground cover components were related to precipitation, cover class midpoint values were arcsine square root transformed. Correlations using the Pearson correlation coefficient were calculated by ground cover element.

### Multivariate species composition analysis

Nonmetric multidimensional scaling in PC-ORD (McCune and Mefford 2011) was used to ordinate species abundance data, providing an understanding of the assemblage of species observed. The Sørensen distance measure and 250 runs with real data at the dimensionality determined by the autopilot setting with automatic rotation of the axes to orthogonal principal axes was used.

### *Fire effects monitoring*

Fire ecology standard operating procedures are outlined in Leis et al. (2011). This report includes analysis of fire history, fire severity, and fuel reduction. Fire severity is a categorical measurement that considers both standing fuels as well as substrate fuels (litter, duff, soil surface) in determining how severely a fire burned. Fuel estimates included all standing and litter plant matter comprising 1-hr fuels (fine fuels <0.25 inch in diameter). Fire severity classes were 5-unburned, 4-scorched, 3-lightly burned, 2-moderately burned, 1-severely burned.

Mean fire severity rankings for each site were used to infer fuel reduction. The proportion of severity observations in each class was used to assign a fuel reduction value. The reduction value assigned for each class differed by substrate and vegetation fuel types. Substrate fuels (litter, duff, soil surface) considered to be eliminated were in severity class 1, 2, and 50% of class 3. Vegetation fuels (standing plant matter) in severity class 1, 2, and 75% of class 3 were considered eliminated. The sum total reduction for each site was averaged by fuel type to infer fuels reduced.

# Results

## Precipitation

Annual precipitation during years of monitoring events were primarily below normal levels with the exception of 2008 (Figure 2).

## Trees

The mean proportion of plots per site that had trees, excluding 2008, did not differ among years (Repeated measures ANOVA, sphericity assumption validated; $F = 1.57$, $df = 3$, $p = 0.23$; Figure 3).

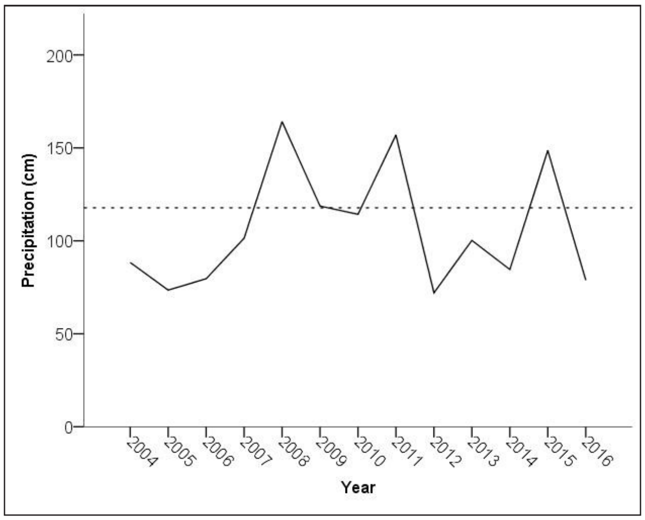



**Figure 2.** Annual total precipitation for Diamond, MO. Dotted line indicates the 30-year normal for the location. Stars indicate vegetation monitoring years.

*Fraxinus* spp. (ash) was the most frequently recorded tree through the monitoring period, so its abundance was analyzed separately (Figure 4). The assumption of sphericity was not met (unequal variances) so the Greenhouse-Geisser correction was used. *Fraxinus* spp. frequency did vary significantly over time ($F = 16.14$, $df = 1.3$, $p < 0.01$), with the last year being higher than all the rest.

## Diversity and community metrics

Diversity metrics fit our typical model for tallgrass prairie in that the number of species for diversity and dominance were less than the number of species for richness. Mean native species richness, the mean number of species per site, was similar for the first three monitoring events. It declined in 2012, but was recovering in 2016. Mean effective number of species for both the Shannon and Simpson's indices were fairly stable, but low through the monitoring period. Because Shannon and Simpson's indices included less than 10% of the mean richness, the prairie community was dominated by only a few species that sites have in common (Figure 5). Invasive species richness is within 10 species of Shannon and Simpson's effective numbers (Figure 6). This indicates that sites share a high degree of similar species and there are few rare species.

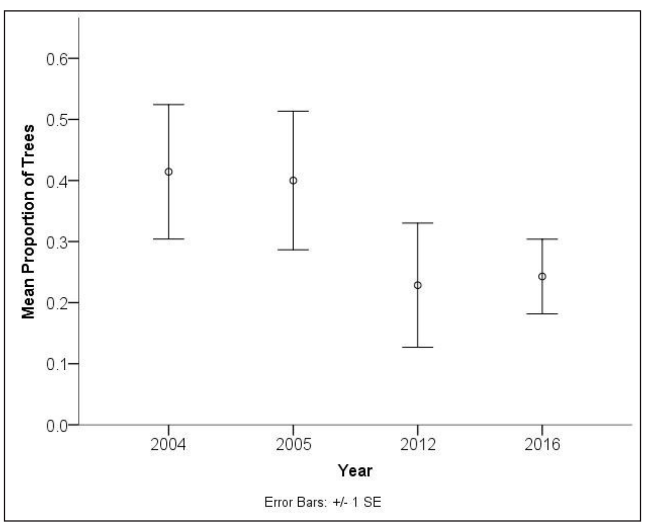



**Figure 3.** Mean proportion of plots per site (n=7) where trees were recorded during sample events at George Washington Carver NM, Diamond, Missouri.

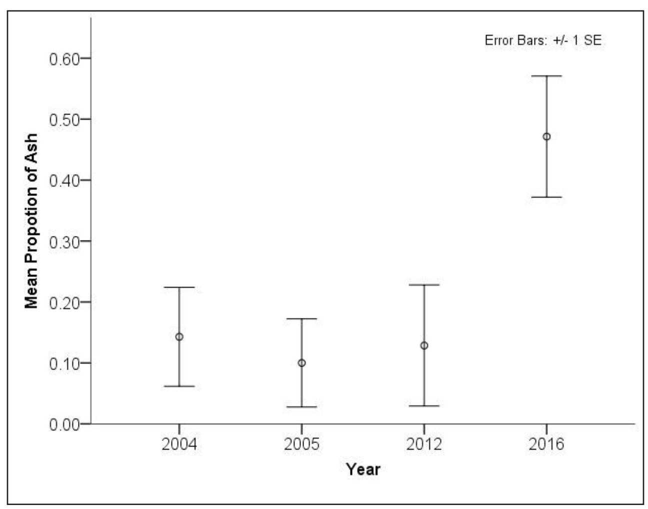



**Figure 4.** Mean proportion of plots per site (n=7) where *Fraxinus* spp. (ash) was recorded during monitoring events at George Washington Carver NM, Diamond, Missouri.

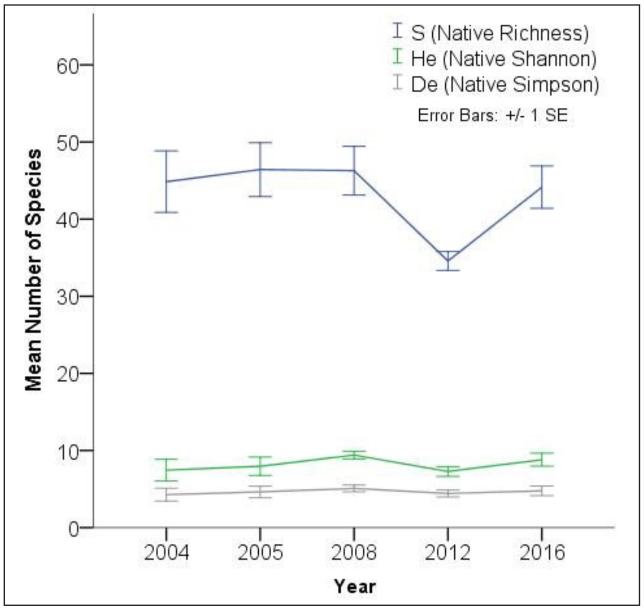



**Figure 5.** Diversity as a function of effective number of species for native species over the monitoring record at George Washington Carver NM, Diamond, Missouri. Mean species richness, Shannon index, and Simpson's index are indicated by blue, green, and gray lines. Error bars are ±1 SE (n=7 per year).

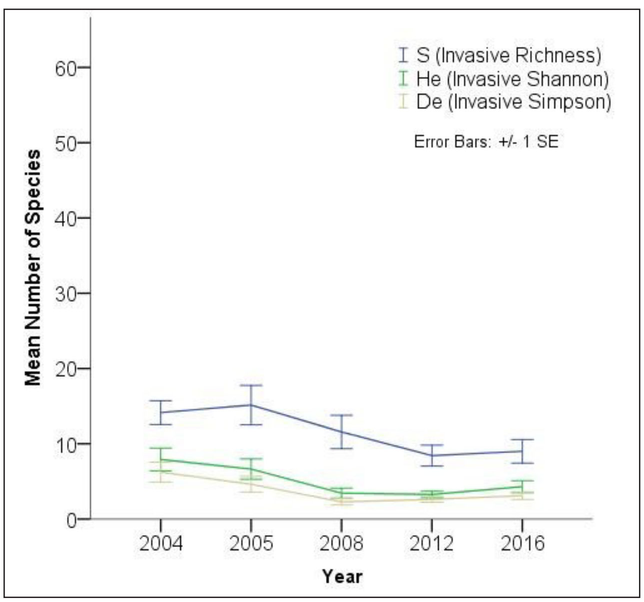



**Figure 6.** Diversity as a function of effective number of species for non-native species over the monitoring record at George Washington Carver NM, Diamond, Missouri. Mean species richness, Shannon index, and Simpson's index are indicated by blue, green, and gray lines. Error bars are ±1 SE (n=7 per year).

Species richness (native or invasive) was not related to precipitation over the monitoring period, however, sample sizes were small (native: F=0.04, P=0.86, n=5 invasive: F=1.08, P=0.38, n=5).

The native herbaceous plant community level metrics were similar in the first three monitoring years (Table 1). Although there was a decline of mean site richness and gamma diversity in 2012, the community is recovering. Beta diversity was greatest in 2016. Low beta diversity measures begin at 0 and high beta diversity is represented by values > 5. Park beta diversity is a low number indicating somewhat similar native herbaceous communities across the park monitoring sites. Fire management objectives drafted in 2013 state that the park wants to maintain gamma diversity in the prairie of ≥ 71 species. This goal has been met for all years.

**Table 1.** Native herbaceous plant community diversity by spatial scale for George Washington Carver NM, Diamond, Missouri. Alpha diversity refers to the mean number of species per monitoring site (n=7), gamma diversity is the total number of herbaceous species across all monitoring sites, beta diversity is a measure of species heterogeneity.

| Year | Alpha diversity (Mean site richness) | Gamma diversity (Park wide richness) | Beta diversity ((Gamma/ Alpha)-1) |
|---|---|---|---|
| 2004 | 45.3 (10.5) | 106 | 1.34 |
| 2005 | 46.7 (9.3) | 109 | 1.33 |
| 2008 | 46.1 (4.2) | 110 | 1.39 |
| 2012 | 32.9 (4.2) | 75 | 1.28 |
| 2016 | 41.7 (7.3) | 102 | 1.45 |

Two genera of particular note were sumac (*Rhus* spp) and blackberries (*Rubus* spp). Both genera demonstrated significant changes in mean cover through the period of monitoring (Friedman tests: *Rubus*, chi-square = 9.97, P = 0.04; *Rhus*, chi-square = 9.93, P = 0.04; Figure 7). Appendix C shows abundance of these species at each monitoring site through time (Figure 15).

To investigate whether monitoring sites at the park represented different plant communities, we performed an ordination analysis using nonmetric multidimensional scaling (NMS) (Figures 8 and 9). A three dimensional solution was the best fit, and the stress score (11.98) indicated a satisfactory result. The final instability was < 0.00001; 107 iterations

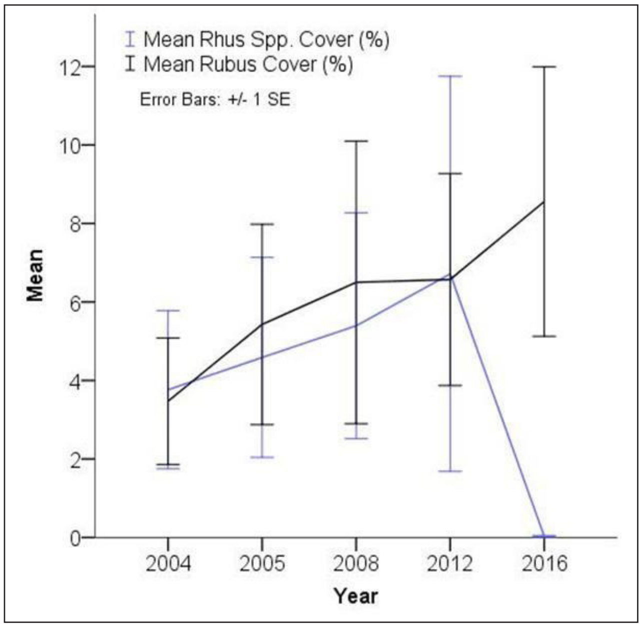



**Figure 7.** Mean cover of sumac (*Rhus* spp.) and blackberry (*Rubus* spp.) through the monitoring period, 2004-2016, at George Washington Carver NM, Diamond, Missouri. *Rhus* spp. is the light purple line and *Rubus* spp. is the black line.

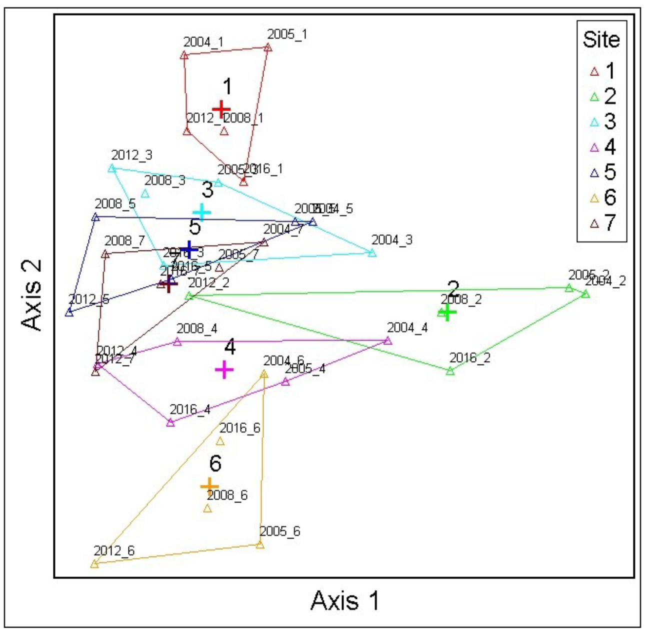



**Figure 8.** NMS ordination of species composition Axis 1, 2 by site through the monitoring period, 2004-2016, at George Washington Carver NM, Diamond, Missouri. Axis 1 appears to represent a soil moisture gradient; the variables influencing axis 2 are unclear.

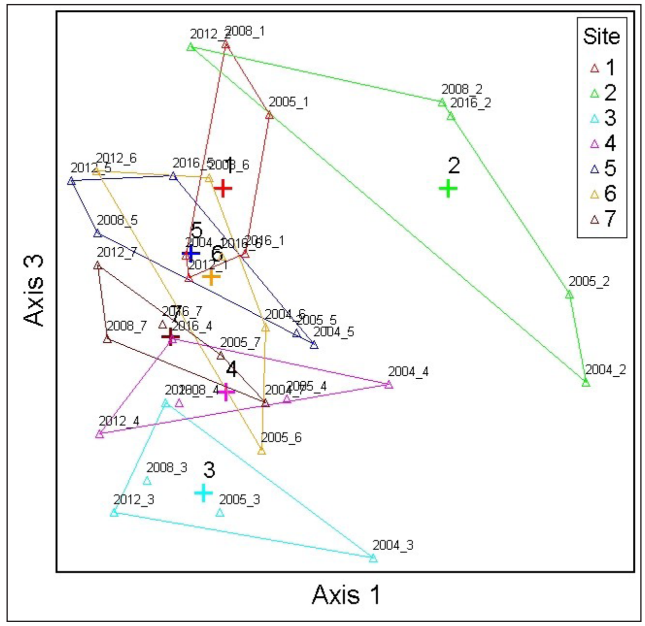



**Figure 9.** NMS ordination of species composition Axis 1,3 by site through the monitoring period, 2004-2016, at George Washington Carver NM, Diamond, Missouri. Axis 1 represents a soil moisture gradient. Axis 3 appears to be correlated with an environmental gradient that affects sumac (*Rhus* spp) abundance, with decreasing abundance along Axis 3.

were required. The cumulative coefficients of determination ($r^2$) were 0.433 (axis 1), 0.713 (axis 2), and 0.816 (axis 3). Because NMS is not based on partitioning of variance, the cumulative coefficients of determination do not represent variance explained by the ordination, but rather a comparison of how well the distances between points in ordination space represent distances in the original n-dimensional space, and the relative contribution of each axis. Site 2 appears to be distinct from the other sites that are more closely clustered. Based on the species represented at site 2 and our knowledge of the hydrology, we interpret this as the effect of greater soil moisture levels at site 2. This area is often referred to as wet prairie.

Because little quantitative data on environmental variables are available, we were unable to determine which variables are influencing Axis 2. Axis 3 appears to be correlated with an environmental gradient that affects sumac abundance (Figure 9, Appendix C). Sites with no or very little sumac are near the top of the figure, while site three with the greatest amount of sumac is aligned at the bottom of the graph (Figure 9).

We evaluated whether plant guild abundances changed over the monitoring period (Figure 10). Native forbs and native grasses declined, and native grass-like plants (e.g., sedges, rushes) increased (Table 2). Native woody plants, invasive forbs, and invasive grasses did not differ across the monitoring period, however (Figure 11, Table 2).

**Table 2.** Results of Friedman tests for changes in guild abundance over the monitoring period (2004-2016) at George Washington Carver NM, Diamond, Missouri.

| Guild | Chi-square value | Significance (P) |
|---|---|---|
| Native forbs | 1.46 | 0.01* |
| Native grass | 12.23 | 0.02* |
| Native grass-like | 11.02 | 0.03* |
| Native woody | 7.05 | 0.13 |
| Invasive forbs | 1.94 | 0.75 |
| Invasive grass | 5.15 | 0.27 |

* Indicates significant results.

## Ground cover

Measures of ground cover were tested for relationships with precipitation. Bare ground significantly increased during dry periods (linear regression; $r = -0.92$, $P = 0.03$). Precipitation was not related to trends in grass litter ($r = 0.09$, $P = 0.88$) or unvegetated cover, however ($r = -0.02$, $P = 0.98$).

## Fire ecology

Fire severity is a short-term measure of how fire may have affected vegetation. Mean fire severity as it related to the number of years since the previous burn for a monitoring site was similar through the monitoring record (Figure 12). Mean severity of standing vegetation was in the light to moderate range throughout the period of record (2010-2016).

We looked at fire severity as a measure of the prescribed fires. Although there appears to be a trend toward more severe fires (i.e. lower severity values = higher severity fire), the driving factor is unclear (Figure 13). Variables such as seasonality, fuel load, and fuel moisture were not informative so we did not present them here.

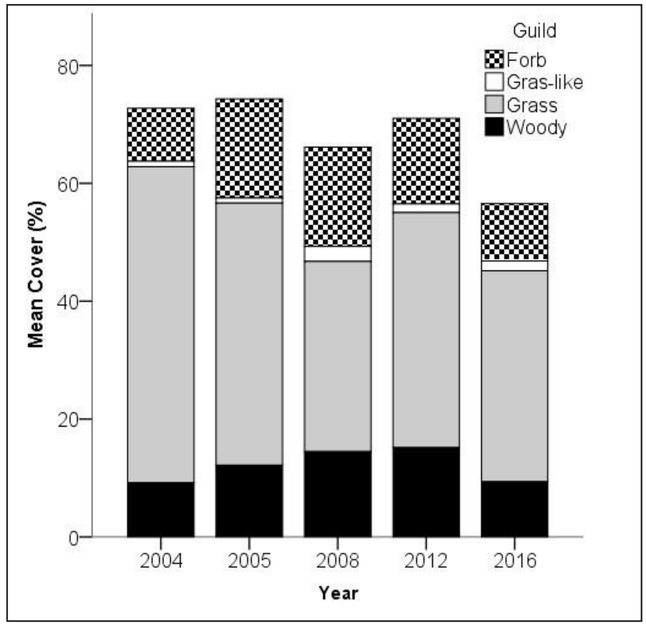



**Figure 10.** Native plant guild abundance (% cover) over the monitoring period 2004-2016 at George Washington Carver NM, Diamond, Missouri.

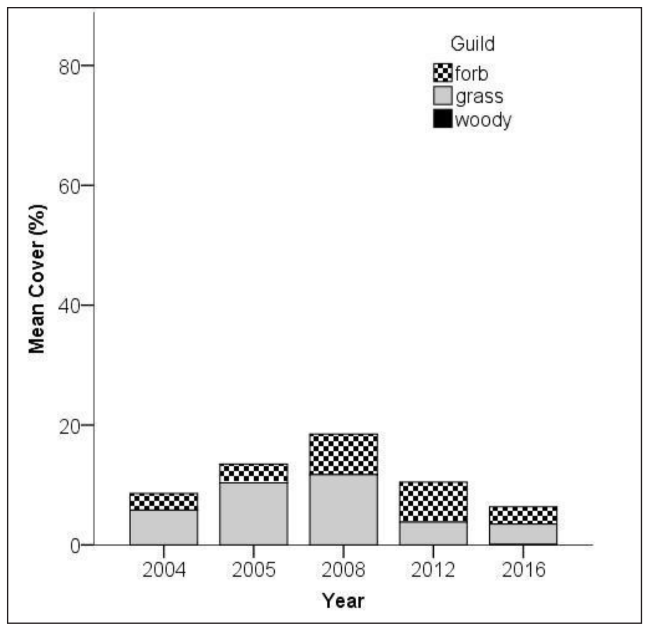



**Figure 11.** Invasive plant guild abundance (% cover) over the monitoring period 2004-2016 at George Washington Carver NM, Diamond, Missouri. A small amount of invasive woody plants, not visible, were observed for the first time in 2016.

## Fuel reduction and burn extent

Published prescribed fire objectives state that 1- and 10-hour fuels should be reduced by 20-50% (Mier and Morey 2010). Unpublished revised objectives state, in prairie burned areas, reduce 1- and 10-hour fuels (above ground standing plants and litter combined) by > 70% of the pre-burn amount (Leis 2013). Standing fuels for fires from 2012-2016 met the revised criteria while fuel reduction was exceeded for Mier and Morey's objective in all years (Table 3).

Both Mier and Morey's (2010) objectives and Leis's (2013) draft objectives have a goal of treating 75 to 95% of individual burn units. All monitored fires fell within the objective's range for burned area (Table 3).

A burned area map for 2016 is included in Appendix B. Previous burned area maps for the monitoring period can be accessed in fire monitoring reports. (Cole 2010, Leis 2012, 2014, 2016, Leis and Kopek 2011).

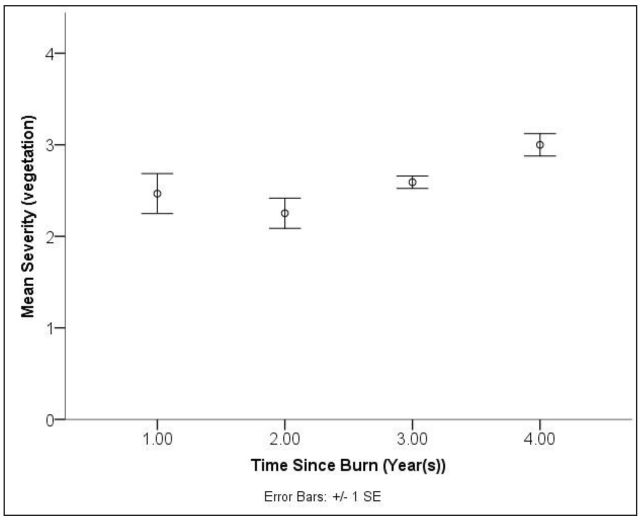



**Figure 12.** Mean fire severity as it relates to years since the last burn for George Washington Carver NM, Diamond, Missouri. Severity is ranked 5 (unburned) to 1 (severe).

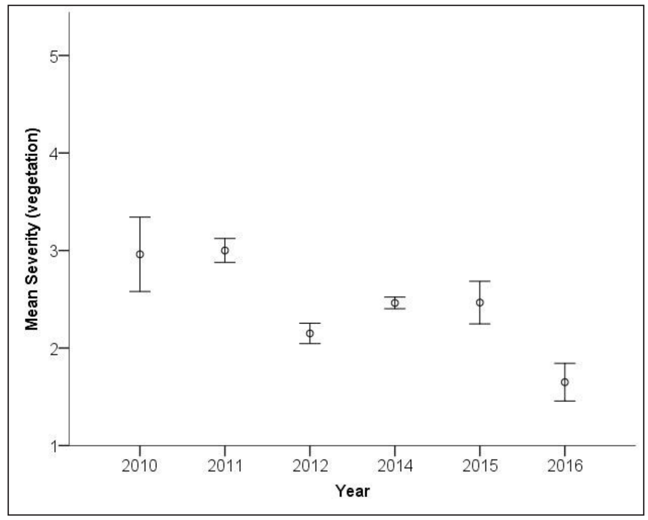



**Figure 13.** Mean fire severity of standing vegetation for monitored fires by year for George Washington Carver NM, Diamond, Missouri. Severity is ranked 5 (unburned) to 1 (severe).

**Table 3.** Prescribed fire fuel reduction and burned area for Heartland Network monitored fires at George Washington Carver NM, Diamond, Missouri. Percent area burned is based on the units attempted.

| Year | Location Burned | Standing fuels reduced[1] (%) | Substrate fuels reduced [2](%) | % area burned[3] |
|---|---|---|---|---|
| 2010 | South Prairie | 54 | 48 | 84 |
| 2011 | North Prairie | 68 | 21 | 10 0 |
| 2012 | South Prairie | 88 | 44 | 92.4 |
| 2014 | North and South Prairie | 86 | 48 | 94.2 |
| 2015 | North Prairie | 83 | 60 | 84.3 |
| 2016 | South Prairie | 93 | 71 | 89.7[4] |

[1] Goal Source: Mier and Morey (2010), 20-50%

[2] Goal Source: Leis (2013), >70%

[3] Goal Source: All, 75-90%

[4] Appendix B

# Discussion

Prairie community monitoring at the George Washington Carver NM contributes to management of the prairie and ultimately interpretation of Dr. Carver's life. We measured and analyzed a suite of metrics to evaluate the status of the prairie and provide information for interpreters as they share the story of the prairie with visitors. Over the monitoring period, a variety of management techniques—namely fire, haying, mowing, and herbicide application— have been implemented in the prairie that could influence the plant community (Appendix D).

Additionally, we set out to address four interpretive themes through the plant community and fire monitoring data with this report.

### *1. How has the prairie changed through the monitoring record?*

One basic concern in tallgrass prairie is the status of trees because prairies should have very few trees, if any. Trees and woody plants continually challenge the herbaceous community in the Carver prairie, and our monitoring indicated no significant change in the mean proportion of trees (Figure 3). Ash trees made up an increasing proportion of trees observed (Figure 4). Inconsistencies in monitoring methods over the data record prevent further analysis of trends for trees.

We consider two main aspects to the diversity indices we regularly report, relative trend through time and the relationship of the variables to each other. In prairie we expect native species richness to be much greater than Shannon diversity or Simpson's dominance. This is a function of healthy prairie communities. When we look at trends over time, we see that mean herbaceous plant richness, diversity, and community metrics were relatively stable with the exception of a decline in 2012. Mean exotic species abundance also trended lower (< 7% cover in 2016), but not significantly. The native invasive and exotic species control efforts by the Heartland Network exotic plant management team (EPMT) were complimented by fire treatments. With regard to potentially native invasive species, sumac dramatically declined after 2012, likely the result of targeted treatments (fire and herbicide), but blackberries increased (not targeted for control). Blackberries in general proliferate with frequent fire, although the particular stimulus at the park is not known. Overall, species composition in the George Washington Carver NM prairie is relatively stable. Although some unique plants inhabit monitoring sites, the prairie community composition is relatively similar across the park, with the exception of site 2.

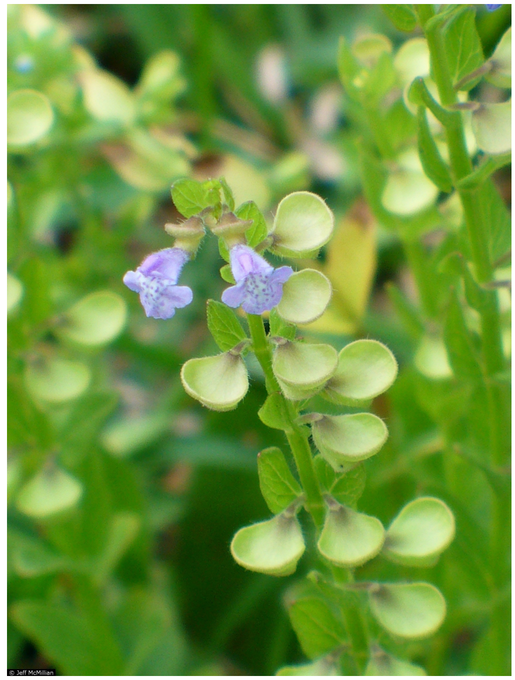
### *2. How does the interface of prescribed fire, precipitation trends, and plant community groups (guilds) like legumes, forbs, grasses, and exotic species contribute to the prairie?*

As expected, grass cover continues to dominate the prairie. Interestingly, grass-like plants (primarily sedges and rushes) have increased. Changing fire seasons to the late summer may better support grass-like plants because they tend to thrive in the cool season.

Prairie plant communities adjust to disturbances like drought, fire, and grazing. We observed both abundant precipitation and drought through the monitoring period. Precipitation was related to greater amounts of bare ground. We were unable to detect a significant relationship between precipitation and species richness, a pattern demonstrated in previous field studies (Tilman and Hadii 1992). Our sample sizes may not have been adequate to detect a relationship in this case. The mean cover of exotic species has also remained low and stable through the monitoring period (Figure 10).

We were unable to specifically link prescribed fire to trends in the plant community because of mismatches in the spatial and temporal data (e.g., fire monitoring targeted sites only within burned areas and not all fires fell within years with plant community monitoring). Furthermore, herbicide treatments and fire treatments were aimed at targeting some similar objectives and cannot be teased apart with the monitoring designs in use (Appendix D). However, the stability of the prairie has occurred simultaneously with the continued application of fire.

There is some concern that fire may be stimulating an increase in blackberries in the prairie because they do well with disturbance (Great Plains Flora Association 1986). Little specific information on the role of fire return intervals or fire seasonality is available for this species group. However, Tyrl et al. (2008) state that



**Left image:** *Lythrum alatum* (winged lythrum) found only on site 2, a wet prairie. NPS photo.

**Right image:** S*cultellaria parvula* (small skullcap), a wetland species also found on site 2. Photo: Jeff McMillan, hosted by the USDA-NRCS PLANTS Database.

*Rubus Oklahomus* [not a Missouri species] decreases with fire return intervals of 1-2 years and increases with 3-5 year return intervals. It is possible that the fire return interval being applied, 2 years, is contributing, but there may be other possible stimuli such as land use history (Moranz et al. 2012), the increase of nitrogen deposition or carbon dioxide in the atmosphere coupled with drought cycles, species replacement with sumac treatment, increases in neighborhood seed sources, or other unknown sources could all be considered (Archer et al. 2011). Our assessment (Figure 15) supports the notion that blackberries may be replacing sumac in some sites as a contributing factor.

Routine monitoring of post-burn fire severity demonstrated a potential trend toward increased fire severity. There are many factors that can influence severity and direct relationships with fuel moisture or fire history were not apparent. However, fire management objectives were aimed at reducing woody plants and as such, favor more severe fire. Recently, a change to late summer or fall may also facilitate changes in fire severity.

### *3. What are the trends for species of interest to Carver as well as natural resource managers?*

We identified species in Appendix A that were both observed in our monitoring and we found reference to in Carver's work. Future analyses could be targeted at trend analysis for a subset of these species of interest to the park. It is interesting to note that the majority of these species are early seral (e.g. weedy) species. Additional data from future monitoring events will help to provide a robust set of data for further work.

### *4. Can we identify unique communities within the George Washington Carver NM prairie?*

Although the prairie had a high degree of similarity in composition, we were able to observe that site 2 (Figure 1) is distinct from the other sites based on the species assemblage there (Figures 8 and 9). This site has been referred to as wet prairie and is known to have standing water during wet periods. It is the only site where we found *Lythrum alatum*, (winged lythrum or loosestrife), a wetland obligate (Yatskievych 2013) Likewise, grasses of the genus *Paspalum* (beadgrass) are associated with wet areas and were strongly associated with site 2 (Yatskievych 1999). *Scutellaria parvula* (small skullcap), a facultative wetland species (occurs in wetlands) was also associated with this site.

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# Appendix A: Species Recorded During Monitoring Events

**Table A-1.** Plant species observed in Heartland Network monitoring sites from 2004-2016 are listed here for reference. Taxonomy, guild assignment, and nativity data are consistent with USDA Plants database. (E-Exotic, N-native).

| Species | Common Name | Guild | Origin |
|---|---|---|---|
| *Acalypha virginica* | Virginia threeseed mercury | forb | N |
| **Achillea millefolium* | common yarrow | forb | N |
| *Ageratina altissima* | white snakeroot | forb | N |
| *Agrostis hyemalis* | winter bentgrass | grass | N |
| *Allium* | onion | forb | N |
| **Allium vineale* | wild garlic | forb | E |
| *Ambrosia artemisiifolia* | annual ragweed | forb | N |
| *Ambrosia bidentata* | lanceleaf ragweed | forb | N |
| **Ambrosia trifida* | great ragweed | forb | N |
| *Amphicarpaea bracteata* | American hogpeanut | forb | N |
| *Andropogon gerardii* | big bluestem | grass | N |
| *Andropogon virginicus* | broomsedge bluestem | grass | N |
| *Apocynum cannabinum* | Indianhemp | forb | N |
| *Arenaria serpyllifolia* | thymeleaf sandwort | forb | E |
| *Artemisia ludoviciana* | white sagebrush | forb | N |
| *Asclepias* | milkweed | forb | N |
| *Asclepias stenophylla* | slimleaf milkweed | forb | N |
| *Asclepias syriaca* | common milkweed | forb | N |
| *Asclepias verticillata* | whorled milkweed | forb | N |
| *Asclepias viridiflora* | green comet milkweed | forb | N |
| *Asclepias viridis* | green antelopehorn | forb | N |
| *Aster* | aster | forb | N |
| *Baptisia alba var. macrophylla* | largeleaf wild indigo | forb | N |
| *Barbarea vulgaris* | garden yellowrocket | forb | E |
| *Bidens* | beggarticks | forb | N |
| *Bidens aristosa* | bearded beggarticks | forb | N |
| *Bouteloua curtipendula* | sideoats grama | grass | N |
| *Brickellia eupatorioides* | false boneset | forb | N |
| *Bromus* | brome | grass | E |
| *Bromus inermis* | smooth brome | forb | E |
| *Calystegia sepium* | hedge false bindweed | forb | N |
| *Campsis radicans* | trumpet creeper | Woody | N |
| *Carduus nutans* | nodding plumeless thistle | forb | E |
| *Carex* | sedge | grass-like | N |
| *Carex bushii* | Bush's sedge | grass-like | N |
| *Carex molesta* | troublesome sedge | grass-like | N |
| *Carex shortiana* | Short's sedge | grass-like | N |
| *Chaerophyllum tainturieri* | hairyfruit chervil | forb | N |
| *Chamaecrista fasciculata* | partridge pea | forb | N |
| *Chamaecrista nictitans* | sensitive partridge pea | forb | N |

* Indicates species referred to in Burchard (2005).

**Table A-1 (continued).** Plant species observed in Heartland Network monitoring sites from 2004-2016 are listed here for reference. Taxonomy, guild assignment, and nativity data are consistent with USDA Plants database. (E-Exotic, N-native).

| Species | Common Name | Guild | Origin |
|---|---|---|---|
| *Chamaesyce* | sandmat | forb | N |
| *Chenopodium* | goosefoot | forb | N |
| *Chenopodium album* | lambsquarters | forb | N |
| *Cirsium* | thistle | forb | E |
| *Cirsium altissimum* | tall thistle | forb | N |
| *Cirsium discolor* | field thistle | forb | N |
| *Cirsium vulgare* | bull thistle | forb | E |
| *Convolvulus arvensis* | field bindweed | forb | E |
| *Conyza canadensis* | Canadian horseweed | forb | N |
| *Croton capitatus* | hogwort | forb | N |
| *Croton glandulosus* | vente conmigo | forb | N |
| *Croton monanthogynus* | prairie tea | forb | N |
| *Cruciata pedemontana* | piedmont bedstraw | forb | E |
| *Cyperus* | flatsedge | grass-like | N |
| *Cyperus echinatus* | globe flatsedge | grass-like | N |
| *Cyperus lupulinus* | Great Plains flatsedge | grass | N |
| *Daucus carota* | Queen Anne's lace | forb | E |
| *Desmodium* | ticktrefoil | forb | N |
| *Desmodium canadense* | showy ticktrefoil | forb | N |
| *Desmodium canescens* | hoary ticktrefoil | forb | N |
| *Desmodium illinoense* | Illinois ticktrefoil | forb | N |
| *Desmodium nuttallii* | Nuttall's ticktrefoil | forb | N |
| *Desmodium paniculatum* | panicledleaf ticktrefoil | forb | N |
| *Desmodium perplexum* | perplexed ticktrefoil | forb | N |
| *Dianthus armeria* | Deptford pink | forb | E |
| *Dichanthelium* | rosette grass | grass | N |
| *Digitaria cognata* | fall witchgrass | grass | N |
| *Digitaria sanguinalis* | hairy crabgrass | grass | E |
| *Diodia teres* | poorjoe | forb | N |
| *Diospyros virginiana* | common persimmon | woody | N |
| *Echinacea pallida* | pale purple coneflower | forb | N |
| *Elymus virginicus* | Virginia wildrye | grass | N |
| *Eragrostis spectabilis* | purple lovegrass | grass | N |
| *Erechtites hieraciifolia* | American burnweed | forb | N |
| *Erigeron* | fleabane | forb | N |
| *Erigeron annuus* | eastern daisy fleabane | forb | N |
| *Erigeron strigosus* | prairie fleabane | forb | N |
| *Euonymus fortunei* | winter creeper | woody | E |
| *Euphorbia corollata* | flowering spurge | forb | N |
| *Euphorbia cyathophora* | fire on the mountain | forb | N |
| *Euphorbia dentata* | toothed spurge | forb | N |
| *Fraxinus* | ash | woody | N |
| *Fraxinus americana* | white ash | woody | N |

* Indicates species referred to in Burchard (2005).

**Table A-1 (continued).** Plant species observed in Heartland Network monitoring sites from 2004-2016 are listed here for reference. Taxonomy, guild assignment, and nativity data are consistent with USDA Plants database. (E-Exotic, N-native).

| Species | Common Name | Guild | Origin |
|---|---|---|---|
| *Fraxinus pennsylvanica* | green ash | woody | N |
| *Galium aparine* | stickywilly | forb | N |
| *Gamochaeta purpurea* | spoonleaf purple everlasting | forb | N |
| *Gaura biennis* | biennial beeblossom | forb | N |
| *Geranium carolinianum* | Carolina geranium | forb | N |
| *Glandularia canadensis* | rose mock vervain | forb | N |
| *Gleditsia triacanthos* | honeylocust | woody | N |
| *Hieracium longipilum* | hairy hawkweed | forb | N |
| *Hordeum pusillum* | little barley | grass | N |
| *Hypericum* | St. Johnswort | forb | N |
| *Hypericum punctatum* | spotted St. Johnswort | forb | N |
| *Ipomoea pandurata* | man of the earth | forb | N |
| *Juncus* | rush | grass-like | N |
| *Juncus interior* | inland rush | grass-like | N |
| *Krigia caespitosa* | Sunflower | forb | N |
| *Kummerowia stipulacea* | Korean clover | forb | E |
| *Kummerowia striata* | Japanese clover | forb | E |
| *Lactuca* | lettuce | forb | N |
| **Lactuca canadensis* | Canada lettuce | forb | N |
| *Lactuca serriola* | prickly lettuce | forb | E |
| **Lepidium densiflorum* | common pepperweed | forb | N |
| *Lespedeza capitata* | roundhead lespedeza | forb | N |
| *Lespedeza cuneata* | sericea lespedeza | forb | E |
| *Lespedeza procumbens* | trailing lespedeza | forb | N |
| *Lespedeza violacea* | violet lespedeza | forb | N |
| *Lespedeza virginica* | slender lespedeza | forb | N |
| *Leucanthemum vulgare* | oxeye daisy | forb | E |
| *Linum sulcatum* | grooved flax | forb | N |
| *Lythrum alatum* | winged lythrum | forb | N |
| *Melilotus officinalis* | yellow sweetclover | forb | E |
| *Mimosa nuttallii* | Sensitive brier | forb | N |
| *Morus alba* | white mulberry | woody | E |
| *Muhlenbergia* | muhly | grass | N |
| *Myosotis verna* | spring forget-me-not | forb | N |
| *Nuttallanthus texanus* | Texas toadflax | forb | N |
| **Oenothera biennis* | common evening primrose | forb | N |
| **Oenothera laciniata* | cutleaf evening primrose | forb | N |
| **Oenothera speciosa* | pinkladies | forb | N |
| *Oxalis* | woodsorrel | forb | N |
| *Oxalis violacea* | violet woodsorrel | forb | N |
| Panicum | panicgrass | grass | N |
| Panicum anceps | beaked panicgrass | grass | N |
| Panicum capillare | witchgrass | grass | N |

* Indicates species referred to in Burchard (2005).

**Table A-1 (continued).** Plant species observed in Heartland Network monitoring sites from 2004-2016 are listed here for reference. Taxonomy, guild assignment, and nativity data are consistent with USDA Plants database. (E-Exotic, N-native).

| Species | Common Name | Guild | Origin |
|---|---|---|---|
| *Panicum virgatum* | switchgrass | grass | N |
| *Parthenocissus quinquefolia* | Virginia creeper | woody | N |
| *Pascopyrum smithii* | western wheatgrass | grass | N |
| *Paspalum laeve* | field paspalum | grass | N |
| *Passiflora incarnata* | purple passionflower | forb | N |
| *Penstemon digitalis* | talus slope penstemon | forb | N |
| *Phalaris canariensis* | annual canarygrass | grass | E |
| *Phleum pratense* | timothy | grass | E |
| *Physalis heterophylla* | clammy groundcherry | forb | N |
| *Physalis longifolia* | longleaf groundcherry | forb | N |
| *Physalis virginiana* | Virginia groundcherry | forb | N |
| *Phytolacca americana* | American pokeweed | forb | N |
| **Plantago* | plantain | forb | N |
| *Plantago aristata* | largebracted plantain | forb | N |
| *Plantago lanceolata* | narrowleaf plantain | forb | E |
| *Plantago rugelii* | blackseed plantain | forb | N |
| *Plantago virginica* | Virginia plantain | forb | N |
| *Platanus occidentalis* | American sycamore | woody | N |
| *Poa arida* | plains bluegrass | grass | N |
| *Poa compressa* | Canada bluegrass | grass | E |
| *Poa pratensis* | Kentucky bluegrass | grass | E |
| *Polygala sanguinea* | purple milkwort | forb | N |
| *Polygonum* | knotweed | forb | N |
| *Polygonum pensylvanicum* | Pennsylvania smartweed | forb | N |
| *Potentilla recta* | sulphur cinquefoil | forb | E |
| *Prunus* | plum | woody | N |
| *Prunus americana* | American plum | woody | N |
| *Prunus hortulana* | hortulan plum | woody | N |
| *Prunus serotina* | black cherry | woody | N |
| *Pseudognaphalium obtusifolium ssp. obtusifolium* | Fragrant cudweed | forb | N |
| *Ptilimnium nuttallii* | laceflower | forb | N |
| **Rhus copallinum* | winged sumac | woody | N |
| **Rhus glabra* | smooth sumac | woody | N |
| *Rosa carolina* | Carolina rose | woody | N |
| *Rubus* | blackberry | woody | N |
| *Rudbeckia* | coneflower | forb | N |
| *Rudbeckia hirta* | blackeyed Susan | forb | N |
| *Ruellia humilis* | fringeleaf wild petunia | forb | N |
| *Rumex* | dock | forb | E |
| *Rumex acetosella* | common sheep sorrel | forb | E |
| **Rumex crispus* | curly dock | forb | E |
| *Sabatia angularis* | rosepink | forb | N |

* Indicates species referred to in Burchard (2005).

**Table A-1 (continued).** Plant species observed in Heartland Network monitoring sites from 2004-2016 are listed here for reference. Taxonomy, guild assignment, and nativity data are consistent with USDA Plants database. (E-Exotic, N-native).

| Species | Common Name | Guild | Origin |
|---|---|---|---|
| *Salvia azurea* | azure blue sage | forb | N |
| *Saponaria officinalis* | bouncingbet | forb | E |
| **Sassafras albidum* | sassafras | woody | N |
| *Schedonorus phoenix* | Tall Fescue | grass | E |
| *Schizachyrium scoparium* | little bluestem | grass | N |
| *Schoenoplectus tabernaemontani* | softstem bulrush | grass-like | N |
| *Scutellaria parvula* | small skullcap | forb | N |
| *Setaria* | bristlegrass | grass | E |
| *Setaria faberi* | Japanese bristlegrass | grass | E |
| *Setaria pumila* | yellow foxtail | grass | E |
| *Setaria viridis* | green bristlegrass | grass | E |
| *Sida spinosa* | prickly fanpetals | forb | N |
| *Silene* | catchfly | forb | N |
| *Silene antirrhina* | sleepy silene | forb | N |
| *Smilax bona-nox* | saw greenbrier | Woody | N |
| *Solanum americanum* | American black nightshade | forb | N |
| *Solanum carolinense* | Carolina horsenettle | forb | N |
| *Solidago* | goldenrod | forb | N |
| *Solidago altissima* | Canada goldenrod | forb | N |
| *Solidago missouriensis* | Missouri goldenrod | forb | N |
| *Sorghastrum nutans* | Indiangrass | grass | N |
| *Sorghum halepense* | Johnsongrass | grass | E |
| *Sphenopholis obtusata* | prairie wedgescale | grass | N |
| *Spiranthes cernua* | nodding lady's tresses | forb | N |
| *Sporobolus compositus* | composite dropseed | grass | N |
| *Sporobolus heterolepis* | prairie dropseed | grass | N |
| **Stellaria media* | common chickweed | forb | E |
| *Strophostyles leiosperma* | slickseed fuzzybean | forb | N |
| *Strophostyles umbellata* | pink fuzzybean | forb | N |
| *Stylosanthes biflora* | sidebeak pencilflower | forb | N |
| *Symphoricarpos orbiculatus* | coralberry | woody | N |
| *Symphyotrichum ericoides var. ericoides* | Squarrose white wild aster | forb | N |
| *Symphyotrichum patens var. patens* | Clasping wild aster | forb | N |
| *Symphyotrichum pilosum var. pilosum* | Awl wild aster | forb | N |
| *Symphyotrichum praealtum var praealtum* | willowleaf aster | forb | N |
| **Taraxacum officinale* | common dandelion | forb | E |
| *Tephrosia virginiana* | Virginia tephrosia | forb | N |
| *Teucrium canadense* | Canada germander | forb | N |
| *Torilis japonica* | erect hedgeparsley | forb | E |
| *Tragia betonicifolia* | betonyleaf noseburn | forb | N |
| *Tragopogon dubius* | yellow salsify | forb | E |
| *Tridens flavus* | purpletop tridens | grass | N |

* Indicates species referred to in Burchard (2005).

**Table A-1 (continued).** Plant species observed in Heartland Network monitoring sites from 2004-2016 are listed here for reference. Taxonomy, guild assignment, and nativity data are consistent with USDA Plants database. (E-Exotic, N-native).

| Species | Common Name | Guild | Origin |
|---|---|---|---|
| *Trifolium* | clover | forb | E |
| *Trifolium arvense* | rabbitfoot clover | forb | N |
| *Trifolium campestre* | field clover | forb | E |
| *Trifolium pratense* | red clover | forb | E |
| *Trifolium repens* | white clover | forb | E |
| *Triodanis perfoliata* | clasping Venus' looking-glass | forb | N |
| *Ulmus* | elm | woody | N |
| *Valerianella radiata* | beaked cornsalad | forb | N |
| *Verbascum blattaria* | moth mullein | forb | N |
| *Verbena simplex* | narrowleaf vervain | forb | N |
| *Verbena stricta* | hoary verbena | forb | N |
| *Vernonia arkansana* | Arkansas ironweed | forb | N |
| *Vernonia baldwinii* | Baldwin's ironweed | forb | N |
| *Veronica arvensis* | corn speedwell | forb | E |
| *Vicia sativa* | garden vetch | forb | E |
| *Viola bicolor* | field pansy | forb | N |
| *Viola sororia* | common blue violet | forb | N |
| **Vitis* | grape | woody | N |
| *Vulpia octoflora* | sixweeks fescue | grass | N |

* Indicates species referred to in Burchard (2005).

# Appendix B: 2016 Burned Area Map

The fire was not observed by Heartland Network staff and no additional fire effects monitoring information (on-site weather, fire behavior, or smoke behavior) from the burn was shared with the network. The burned area was collected by Heartland Network, 1-day post-burn (Figure 14).

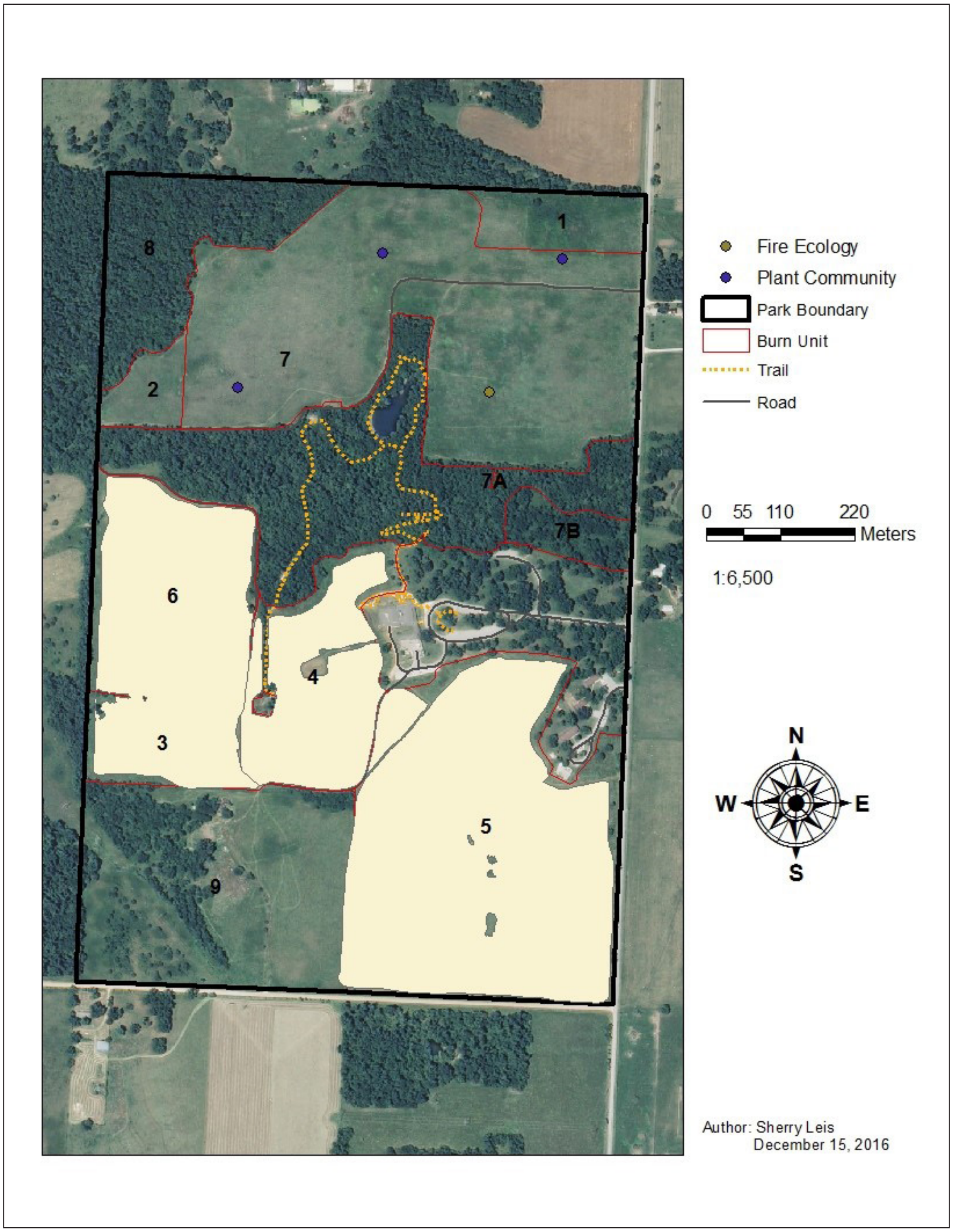
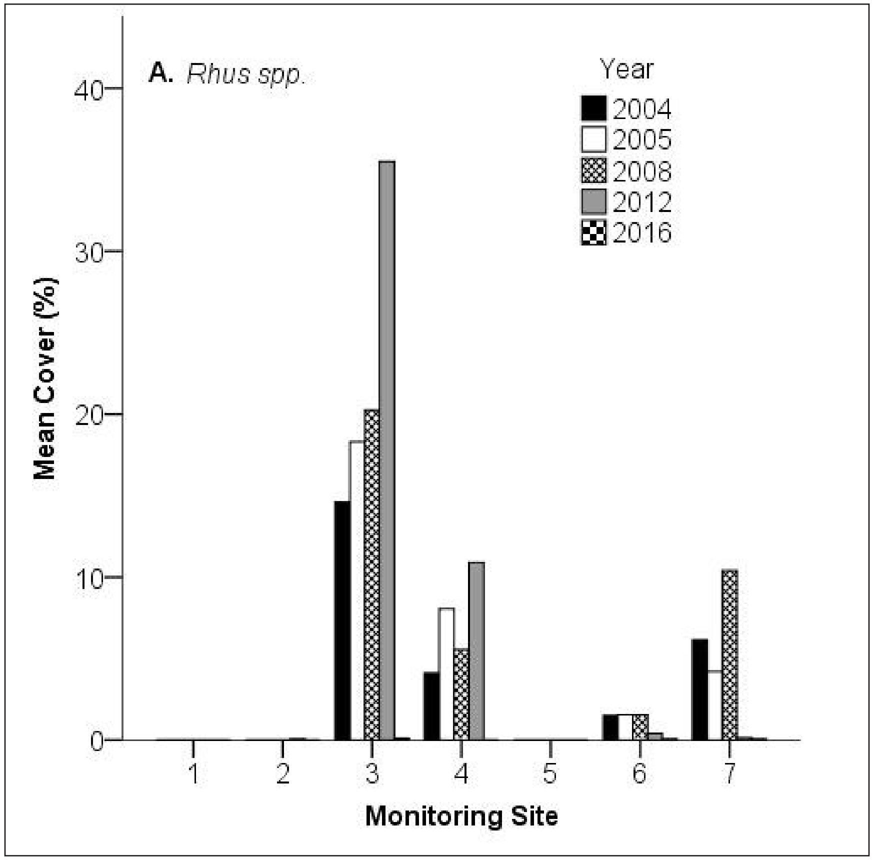



**Figure 14.** Area burned (yellow shaded polygons) during a prescribed fire on October 24, 2016 at George Washington Carver NM. 89.7% of the attempted area was burned.

# Appendix C: *Rhus* and *Rubus* Abundance by Site and Year

Rhus copallinum and Rhus glabra (winged and smooth sumac, respectively), are common at George Washington Carver NM (Figure 15). Abundances became a concern and a concerted effort to treat and reduce sumac began in 2012. During this period, concerns also began to grow over the amount of Rubus (blackberry species) at the park. Graphs of the mean abundance at each site through the monitoring record are provided for reference.



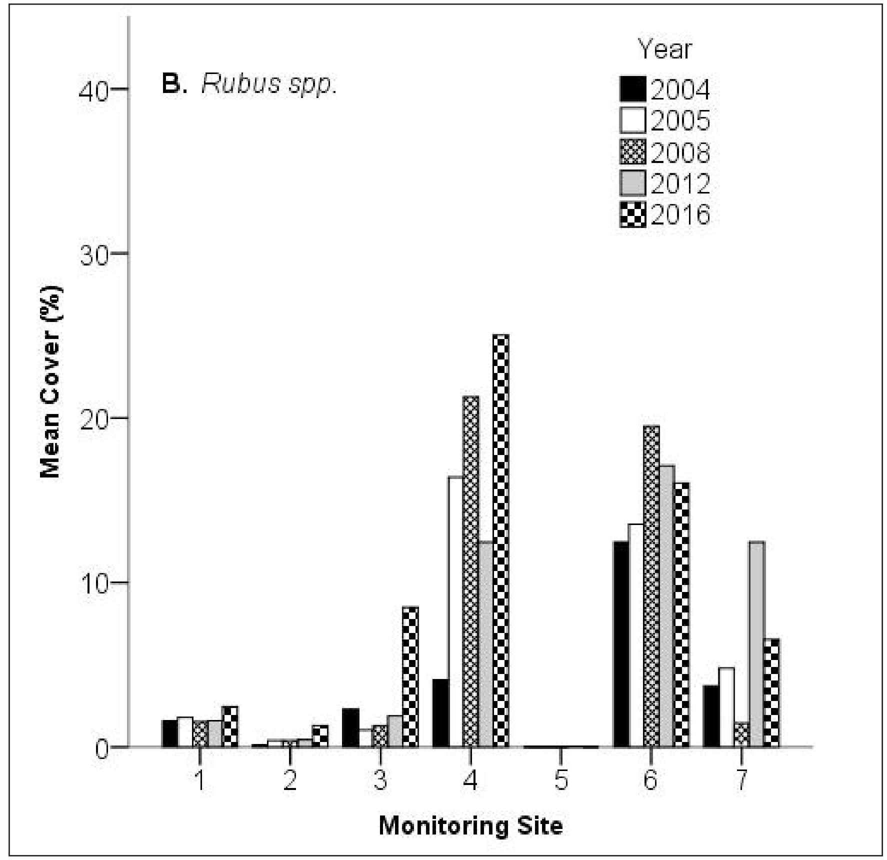
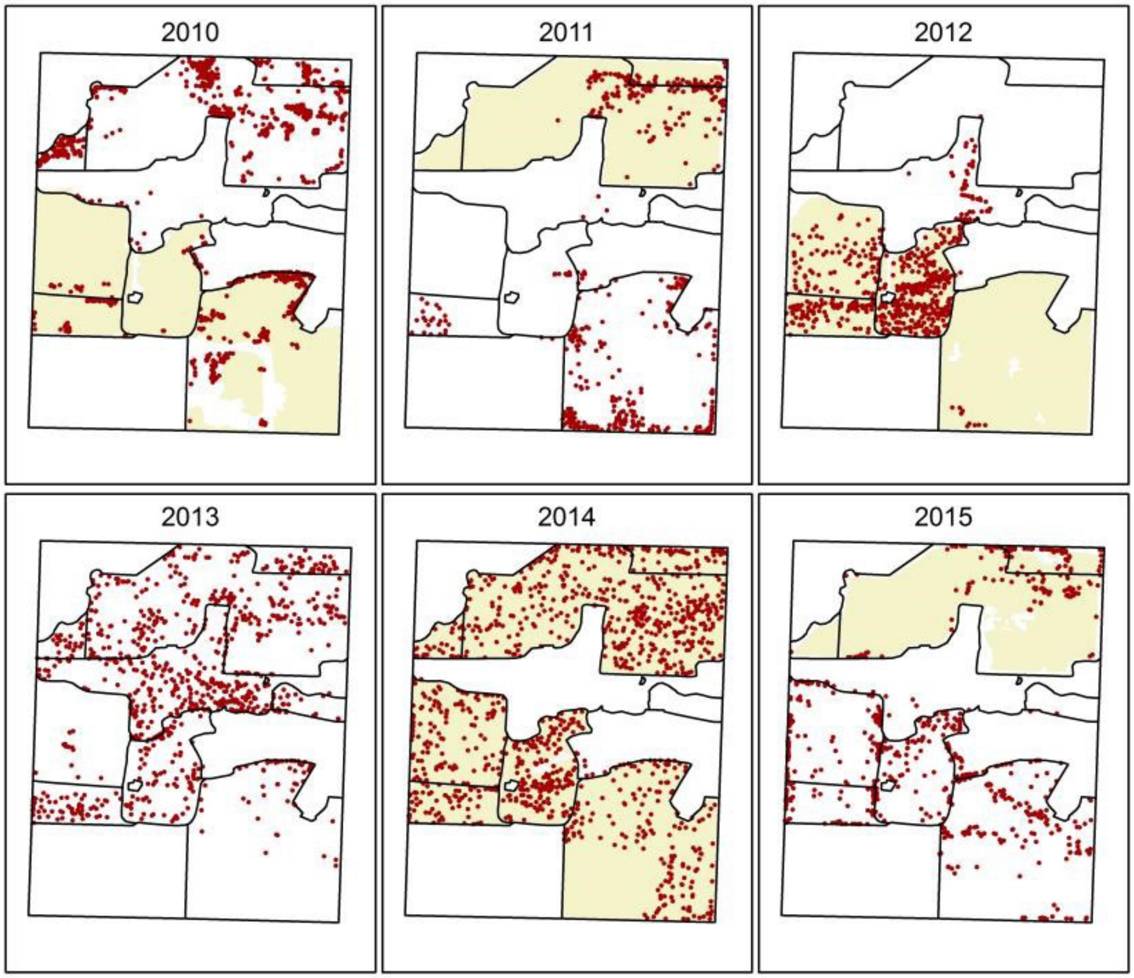
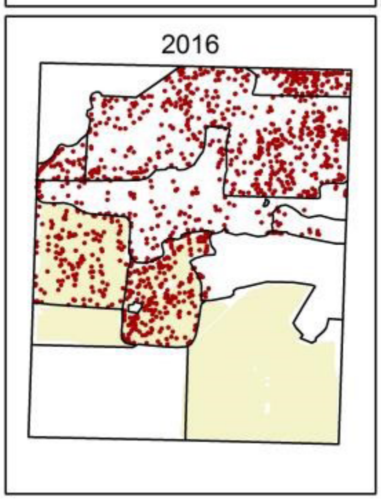
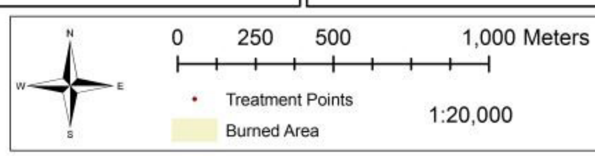




**Figure 15.** Mean percent cover of two species groups by monitoring site and year. A. *Rhus* spp. (sumac), B. *Rubus* spp. (blackberry).

# Appendix D: Exotic Plant Management Team Treatments




**Exotic Plant Management Team Treatments ($m^2$)**

| Unit | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| 1 | 914 | 469 | 0 | 669 | 1340 | 560 | 909 |
| 2 | 301 | 0 | 0 | 165 | 119 | 15 | 921 |
| 3 | 147 | 910 | 1185 | 527 | 237 | 373 | 0 |
| 4 | 75 | 70 | 6736 | 1153 | 419 | 564 | 989 |
| 5 | 1741 | 2269 | 160 | 766 | 882 | 589 | 0 |
| 6 | 26 | 0 | 849 | 156 | 410 | 947 | 1644 |
| 7 | 3044 | 1789 | 100 | 3563 | 2640 | 1044 | 5095 |
| Other | 114 | 366 | 3025 | 10937 | 142 | 1134 | 4154 |

**Figure 16.** Annual area ($m^2$) treated by the Heartland Network's exotic plant management team by burn unit at George Washington Carver NM, Diamond, Missouri. The area burned is shaded yellow for each year of EPMT treatments. The embedded table gives the area treated by burn unit and year. See Appendix B for unit labels.

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**National Park Service**
**U.S. Department of the Interior**

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