



Vegetation Community Monitoring at Pea Ridge National Military Park, Arkansas

2007–2021

Natural Resource Report NPS/HTLN/NRR—2023/2526



ON THE COVER

Sherry Leis and Craig Young reading a vegetation monitoring plot at Pea Ridge National Military Park in July 2021.
Photography by NPS/HTLN/MARY SHORT.

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Executive Summary

Resource managers at Pea Ridge National Military Park manage the natural communities of the park as a backdrop for interpreting the civil war battle that occurred on March 7–8, 1862. Restoration of the landscape to the vegetation communities that were present at the time of the battle is ongoing. Priorities for restoration include density, form, and vegetation structure, but native representative species are also desired. Heartland Inventory and Monitoring Network ecologists observed plant community sites in park woodlands in 2007, 2012, 2016, and 2021.

Climate may influence vegetation and other park natural resources. Temperatures have been increasing at the park, but precipitation and drought indices did not demonstrate significant trends. There was a great degree of interannual variability in precipitation and drought metrics. Phenological data indicated earlier first bloom and leaf-out dates.

Overstory canopy, basal area, density, and tree stocking were similar through time, but class 1, midstory trees increased in basal area and density after 2007. The overstory structure remained that of a closed woodland despite prescribed fires and cedar thinning that occurred at the park. Our monitoring data show that fire management goals for overstory reduction have not yet been met.

Ground cover was similar through time except for bare soil and deciduous leaf litter. Bare soil and leaf litter experienced a pulse in variability in 2012 and 2021, presumably in response to heterogeneous prescribed fires. Maintaining heterogeneous ground cover may best support biodiversity across the landscape.

Ground flora cover (excluding tree regeneration) increased by 88% from 2007 to 2021, meeting a fire management goal. However, ground flora cover was heterogeneous across the sites. Concomitant with the increase in ground flora cover, we observed notable increases in alpha diversity (mean site species richness) and gamma diversity (parkwide species richness) across the monitoring period. Although increases may have been related to treatments and environmental factors, we also improved our botanical sampling preparation and included an expert botanist on the crew in 2021.

Species composition of the ground flora was assessed via guilds and indicator species. Although tree regeneration was not included in estimates of total ground flora cover, it was highly variable through time. The seedling class comprised the majority of the regeneration stems observed. Although mean small sapling density values increased by 535% over 2007 levels, there was a great deal of variability among the sites, indicating small sapling estimates were contained within the confidence intervals and not truly different through time. Forbs comprised the greatest abundance of the ground flora guilds through time, except in 2012. Forbs also exhibited the greatest variability in all years except for 2012. Woody species increased over our monitoring record but remained low in cover. We analyzed a set of 50 indicator species for Ozark highlands woodlands to understand changes in the ground flora. The number of woodland indicator species observed in each monitoring event was low (ranged from 7–14 species) with the highest number of species observed in 2021. We also calculated invasive species metrics and found the number of invasive species increased from 2 to 11 over the monitoring record. Nepalese browntop (*Microstegium vimineum*) was the most abundant of these species. Our confidence in the 2021 ground flora observations was high. We found our observer error to be within standard levels, including agreement on species cover estimates.

Not all sites have received the number of burns described in the park's ecological fire management goals. Our monitoring data show that one of the fire management goals, increased ground flora cover, has been met, but the other two goals for overstory density reduction and seedling density have not yet been met. Further analysis of species composition of the overstory and tree regeneration will be needed after the fire treatments have been completed to determine if all fire management goals are being met.

Acknowledgments

Amber Runyon provided climate data and analysis. We are grateful for the time and expertise of the Institute of Botanical Training during our 2021 sampling event. We appreciate the access to field sites and support from staff at Pea Ridge National Military Park.

Introduction

Natural resource managers at Pea Ridge National Military Park aim to restore the landscape to represent vegetation communities present at the time of the Battle of Pea Ridge that occurred on March 7–8, 1862. Studies of battlefield and settler accounts coupled with Government Land Office survey notes and 1940 imagery provide a sense of what the vegetation was like at the time of the battle in 1862 (NPS 2014). Present day woodland communities in conjunction with landscapes that reflect historical settlements may help visitors better understand the events of the battle.

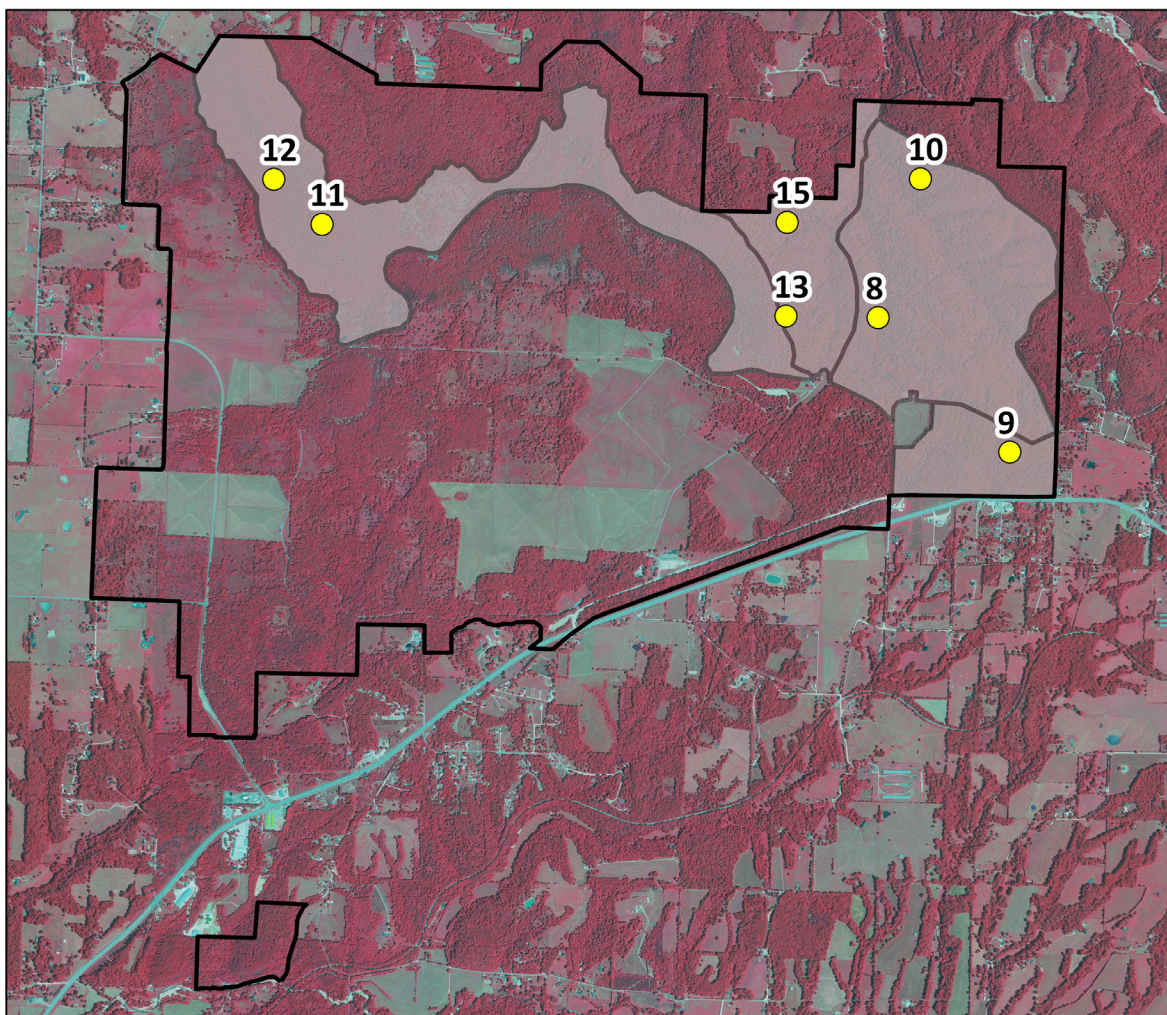
Vegetation communities at the time of the battle varied from the oak-hickory woodlands (explored in detail here) to farms and other settlements. Historical studies in conjunction with current monitoring data serve as a guide for plant community maintenance and restoration. Managers use prescribed fire, mechanical thinning, and other tools and techniques to restore plant communities. The park's vegetation management plan (NPS 2014) recommends the following approach to woodland management:

“Reestablish the historic open woodlands to reflect the historic character, including the density, form, and structure (but not necessarily the specific species) of the woodlands. Thin open woodlands to allow for reestablishment of species such as post oak, black oak, and blackjack oak, depending on current species composition for a given area. Open woodlands would receive the same treatments regardless of the management zones in which they are located.”

Although the vegetation management plan for the park generally prescribes the preference for an open woodland character with oak and hickory species, it does not provide quantitative objectives for evaluating the woodland communities. In 2003, Rob Klein, fire ecologist, articulated a suite of quantified objectives that can be used to put our monitoring into context (Klein 2003; NPS 2005). Pea Ridge National Military Park managers consider fire an important ecological process and a plant community restoration tool (NPS 2005). The fire management objectives and goals (NPS 2005) and the park

vegetation management plan (NPS 2014) describe the desired forest communities needed to approximate the vegetation within the battlefield at the time of the battle. All the permanent monitoring sites, except site 16, were burned at least twice over the monitoring period (2007–2021), and most were burned three or more times (D. Drees, NPS personal communication, June 1, 2022). However, it was predicted that four burns would be necessary to meet objectives. Monitoring the woodland vegetation communities is a critical component of the restoration process, providing insights into the progress of management efforts.

In this report, we endeavored to provide feedback on vegetation trends as they relate to park management goals. In addition to overstory structure and ground flora composition, we provided climate trends to put vegetation data into context. The Heartland Inventory and Monitoring Network (Heartland Network) maintains seven plant community sites while the NPS Ozark fire ecology program monitors 12 sites (Figure 1). The Heartland Network plant community monitoring project was designed to detect change in vegetation metrics over time, which limits our ability to evaluate management actions. Goals include describing species composition and structure, detecting temporal changes, and determining the relationship of environmental variables to plant community trends when possible (James et al. 2009). However, we also referenced vegetation goals discussed in fire ecology monitoring reports to put long-term monitoring data in context. Monitoring objectives for the fire effects program include (1) reduction of mean density of pole-sized trees (2.5–15 cm DBH) by 50–70% after four burns, (2) an increase in mean density of oak seedlings and/or resprouts by 300–500% after four burns in oak-hickory forest/woodlands, and (3) an increase in mean percent cover of native herbaceous (ground flora) species by 60–100% after four burns in post oak-blackjack oak savannah/woodlands (Drees 2017). The Heartland Network monitoring sites were installed in 2007—after the initiation of fire management—in a manner that complemented monitoring done by the fire ecology program.



The image background is the 2021 NAIP imagery from the USDA



- Site
- Park Boundary
- Burn Units

Figure 1. Map of Pea Ridge National Military Park with vegetation monitoring sites (numbered) and burn units.

Methods

Study Site

Natural communities of Pea Ridge National Military Park are in the Ozark Plateau physiographic region (Nelson 1997). Rolling hills paired with narrow hollows and broad uplands characterize this area of northwest Arkansas. The primary woodland community is oak-hickory and Heartland Network sites fall within three main historical vegetation communities: Dry-mesic Forest, Dry-mesic Woodland, and Dry Open Woodland (Table 1; NPS 2014). Oak species (*Quercus* spp.) dominate these communities. Geology, soil, and slope position help to define and restrict these forest types. Major characteristics of oak-hickory forests include a defined dominant overstory canopy composed of oak species and a defined sub-canopy of oaks or hickory species (*Carya* spp.) with a sparse understory shrub and herbaceous layer. Within this forested community, Ozark chinquapin (*Castanea pumila* v. *ozarkensis*) is of particular interest due to the detrimental impact of chestnut blight on its populations throughout the region (Paillet 1993; Tucker 1975).

Sampling Design

The Heartland Network established seven vegetation monitoring sites at Pea Ridge National Military Park in 2007 (Figure 1). Although monitoring sites at the park were characterized as two distinct oak-hickory forest types based on a vegetation map (Diamond et al. 2013; Table 1), we combined them here for analysis. See James et al. (2009) for details on sampling design. Monitoring methods followed the woodland standard operating procedures outlined in the Heartland Network vegetation community monitoring protocol (James et al. 2009). Monitoring sites were 50 x 20 m (0.1 ha) in size with two focal transects bounding the site on the 50-m sides (Figure 2). For this protocol, overstory tree data were collected within the entire 0.1-ha area, while all other metrics were collected within 10 subplots located along the site boundaries. Each subplot consisted of a series of nested subplots (0.01 m², 0.1 m², 1 m², and 10 m²), but only observations at the 10-m² scale were used for this study. In addition to the ground flora measurements, we monitor the overstory using a suite of sampling methods for characterizing overstory tree composition, canopy cover, and tree regeneration.

Table 1. Heartland Inventory and Monitoring Network vegetation sites; vegetation map community types, including the National Vegetation Classification System common name (Diamond et al. 2013); historical landscape classification (NPS 2014, Appendix B); and burn units (historical name and current unit number; D. Drees personal communication June 1, 2022) at Pea Ridge National Military Park.

Heartland Network Site	Vegetation Map Community Type (NVC Common Name)	Historical Landscape	Burn Unit	Year(s) Unit Burned 2007–2016
8	Typic Upland deciduous woodland and forest (Black Oak-White Oak-Hickory Forest)	Dry-mesic Forest	Williams Hollow 14	2008, 2012, 2019
9	Typic Upland deciduous woodland and forest (Black Oak-White Oak-Hickory Forest)	Dry-mesic Woodland	Huntsville East 16	2004, 2018
10	Typic Upland deciduous woodland and forest (Black Oak-White Oak-Hickory Forest)	Dry-mesic Forest	Williams Hollow 14	2006, 2012, 2019
11	Dry deciduous woodland and forest (Ozark/Ouachita Post Oak-Blackjack Oak-Black Oak/Little Bluestem Woodland)	Dry Open Woodland	Horsetrail South 10	2012, 2017, 2021
12	Dry deciduous woodland and forest (Ozark/Ouachita Post Oak-Blackjack Oak-Black Oak/Little Bluestem Woodland)	Dry Open Woodland	Horsetrail South 12	2012, 2017, 2021
13	Typic Upland deciduous woodland and forest (Black Oak-White Oak-Hickory Forest)	Dry-mesic Forest	North Central Boundary 12	2006, 2012, 2019
15	Typic Upland deciduous woodland and forest (Black Oak-White Oak-Hickory Forest)	Dry-mesic Forest	North Central Boundary 11	2006, 2012, 2019

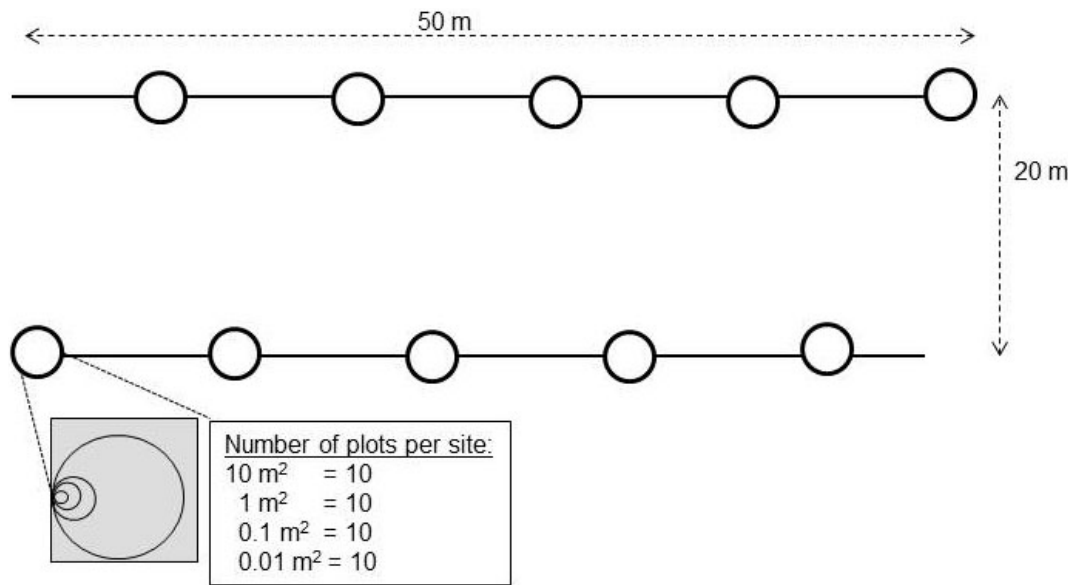


Figure 2. The Heartland Network vegetation community monitoring site comprising two 50-m-long transects with ten sets of nested plots ($n = 10$) systematically arranged.

Data Summary

Sites were pooled together rather than divided into community types. This was done to improve sample sizes and because management goals are similar across community types. For baseline descriptions by community type, see James (2008).

RStudio (RStudio Team 2020) and Minitab (2020) were used to calculate summary statistics. All site means ($N = 7$) were calculated based on 10 subplots for each year (2007, 2012, 2016, and 2021) with the exception of herbaceous species data at two sites with missing cover data in 2016 (site 9, $n = 5$ subplots, site 12, $n = 9$ subplots, all other sites, $n = 10$ subplots).

Climate

We evaluated historical (1895–2020) trends using the NOAA monthly U.S. Climate Gridded dataset (NClimGrid; Vose et al. 2014), which represents climate conditions for the continental U.S. as a 5-km gridded surface. The reference period (1895–1970) includes an initial period of data collection up to a point where significant changes in climate are more likely. The trend for the current period (1971–2020), can then be compared to the reference period. Climate data were derived from the 5-km grid cell that includes the Pea Ridge National Military Park centroid (Latitude = 36.45, Longitude = -94.03) and included precipitation and temperature, from which the Standardized Precipitation-Evapotranspiration Index (SPEI) was derived (See Runyon et al. [2021]

for detailed SPEI methods). The SPEI was used to characterize drought periods with values < 0 indicating drought and values > 0 indicating wet periods. SPEI represents climatic water deficit (precipitation minus potential evapotranspiration [PET]) and provides an assessment of water deficit or surplus that can influence vegetation (Li et al. 2019; Vicente-Serrano et al. 2010). The R package SPEI was used to calculate the metrics (Beguería and Vicente-Serrano 2017). Data from 2021 were not available when the graphs were made, but precipitation and temperature data are included in the results.

SPEI is calculated as the monthly difference (D) of precipitation (P) and PET (Thornthwaite 1948; Buytaert and De Bièvre 2012):

$$D_i = P_i - PET_i$$

Overstory and Midstory

Tree composition was based on individual tree counts for each species and diameter at breast height (DBH) for each tree > 5.0 cm in the 0.1-ha sites. Snags were calculated separately from live trees. Basal area and stem density were calculated within size class categories (Table 2) as described in James et al. (2009). We distinguished Class 1 (midstory trees) from classes 2–5 (overstory trees) for interpretation. Diameter at breast height (DBH) and stem density were scaled to the hectare for analysis.

Table 2. Diameter at breast height (DBH) measurement range (cm) and size class used to group midstory and overstory trees.

DBH (cm)	Size Class	Type
5.0–14.9	1	Midstory
15.0–24.9	2	Overstory
25.0–34.9	3	Overstory
35.0–44.9	4	Overstory
≥45	5	Overstory

Basal area and stem density were used to calculate the stocking percentage using the metric stocking equation developed by Rogers (1980). This metric equation was derived from Gingrich’s (1967) stocking equation for upland hardwood forests in the central US. We did not do an in-depth analysis of tree species composition for this report. (See Leis [2018] for overstory species composition). Taken together, all tree metrics were used to describe the forest structure for Pea Ridge National Military Park.

The occurrence of tree species in 2021 was calculated as the percentage of all sites (N = 7) occupied by each species in that year (See Appendix A, Table A4).

Canopy Closure

Canopy closure data were collected using a densiometer. Densiometer readings were collected in the four cardinal directions in each of the 10-m² subplots and converted to canopy closure (multiplied by 1.04). Subplot-level mean canopy closure (n = 4 per subplot) was used to calculate site-level mean canopy closure. A grand mean was then calculated for all sites (N = 7).

Ground Flora

Ground Cover

Ground cover was assessed using cover classes (Table 3). 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 subplot in 2021. One measurement in each subplot (n = 10) was averaged to create a site level mean for litter depth.

Table 3. Modified Daubenmire cover value scale used to determine ground 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

Tree Regeneration

Tree regeneration stems were tallied by species in the 10-m² subplots and reported in three size classes: (1) seedlings = stems < 0.5 m tall; (2) small saplings = stems ≥ 0.5 m tall, and < 2.5 cm DBH; and (3) large saplings = stems ≥ 0.5 m tall and DBH ≥ 2.5 cm and < 5.0 cm.

Species Diversity Indices

Based on foliar cover measurements, diversity indices describe the number of species and their abundances. Mean site cover for all ground flora species was calculated using all subplots within each site. For each site within the community, species richness (S; for native and nonnative species separately), Shannon diversity index (H'), and evenness (J') were calculated. Species richness, synonymous with alpha diversity, represents the number of species observed. PC-ORD (version 7.02) was used to calculate these diversity indices (McCune and Mefford 2016). A grand mean was then calculated for all sites in a community (Minitab 2020).

Plant diversity for each site was calculated using the Shannon diversity index:

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

where p_i is the relative cover of species i (Shannon and Weaver 1949).

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

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

where H' is the Shannon diversity index and $\ln(S)$ is the maximum possible Shannon diversity index value for a given number of species if all species were present in equal numbers. 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 and 0 indicates heterogeneous communities.

Community diversity metrics

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

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

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 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).

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 NRCA 2017). Guild assignments were grasses, forbs, grass-like (including sedges and rushes), vines, and woody species for both native and nonnative 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. We also summarized nonnative species trends using mean cover values for each monitoring event. Lastly, we compared our species lists to a list of indicator species for woodlands in the Ozark Highlands region (Kinkead et al. 2013, based

on indicator list developed by Missouri Department of Conservation) to better understand changes in composition and quality of native species.

Observer Error

We assessed our error in observing the ground flora with a double sampling method. At four of the seven monitoring sites, after the transects were read, one subplot from each of the two transects was randomly chosen for resampling. Sampling teams switched transects and sampled the ground flora in the randomly chosen subplot. Pseudoturnover was calculated by comparing the two species lists from each subplot 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 recorded at different specificity levels (cautious errors, in which one observer identified a plant to species and the other identified it only to genus).

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

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

where A was the number of species recorded exclusively by observer 1, B was the number of species recorded exclusively by observer 2, S_A was the total number of species recorded by observer 1, and S_B was the total number of species recorded by observer 2. Pseudoturnover is expressed as a percentage.

Statistical Analysis

Descriptive (graphical) analyses of ground cover and nonnative plants included all seven sites over four years (28 total observations) to obtain more precise parameter estimates. Vegetation summaries were calculated in Minitab version 20.1.3 (Minitab 2020) and RStudio (RStudio Team 2020). To evaluate the third fire management goal (increase in mean percent cover of native herbaceous species by 60–100% after four burns in post oak-blackjack oak savannah/woodlands), we summed vegetation cover of observed species for the initial year (2007, $N = 7$) and the current year (2021). We calculated the ratio

of the means to determine if the goal was achieved (Gerow et al. 2021). Next, the ratio of the means was bootstrapped (N = 10,000 samples) to calculate the attained confidence level using the management goals to define the interval. The lower limit used was 60% and the upper limit was undefined for our statistical analysis.

The forb and woody plant guilds as well as Shannon Diversity Index (H') were evaluated by comparing the initial year, 2007, to the most recent year, 2022. Data were not normally distributed, so the nonparametric Wilcoxon match-pairs test was used. Statistical significance was assessed at the $\alpha = 0.05$ level.

Results and Discussion

Climate

The long-term climate trend analysis (Figure 3) illustrates a characteristic mid-latitude continental climate with a high degree of interannual variability, particularly for precipitation. Temperatures in the recent period (1971–2020) increased over time ($P = 0.0004$, $r^2 = 0.23$), whereas temperatures in the historical period (1895–1970) did not exhibit a trend ($P = 0.86$, $r^2 = 0.0005$; Figure 3; Monahan and Fisichelli 2014). Mean temperature for 2021 was 59°F (not shown on Figure 3). Minimum winter temperatures were greater for the recent period (data not shown). Because of high interannual variability, there was no significant change in precipitation over time during the historical ($P = 0.88$, $r^2 = 0.0003$) or recent ($P = 0.44$, $r^2 = 0.012$) periods (Figure 3; Monahan and Fisichelli 2014). Total precipitation for 2021 was 46.9 in (not shown in Figure 3).

An analysis of SPEI, a composite index that describes drought conditions, demonstrated a high degree of interannual variability. There was no significant trend across the time series ($P = 0.26$, $r^2 = 0.01$), and the shorter, recent period also did not demonstrate any trend ($P = 0.70$, $r^2 = 0.003$). The SPEI shows that periodic drought has been common in this area. One monitoring year, 2012, was mildly dry, but the other monitoring events occurred during normal to wet conditions. (Figure 4; NOAA National Centers for Environmental information 2021). Increasing temperatures have also manifested earlier first leaf index dates and extremely early first bloom index dates at the battlefield (Monahan et al. 2016).

Models of tree species adaptability to predicted climate scenarios indicate that while many of the species recorded in monitoring sites will persist

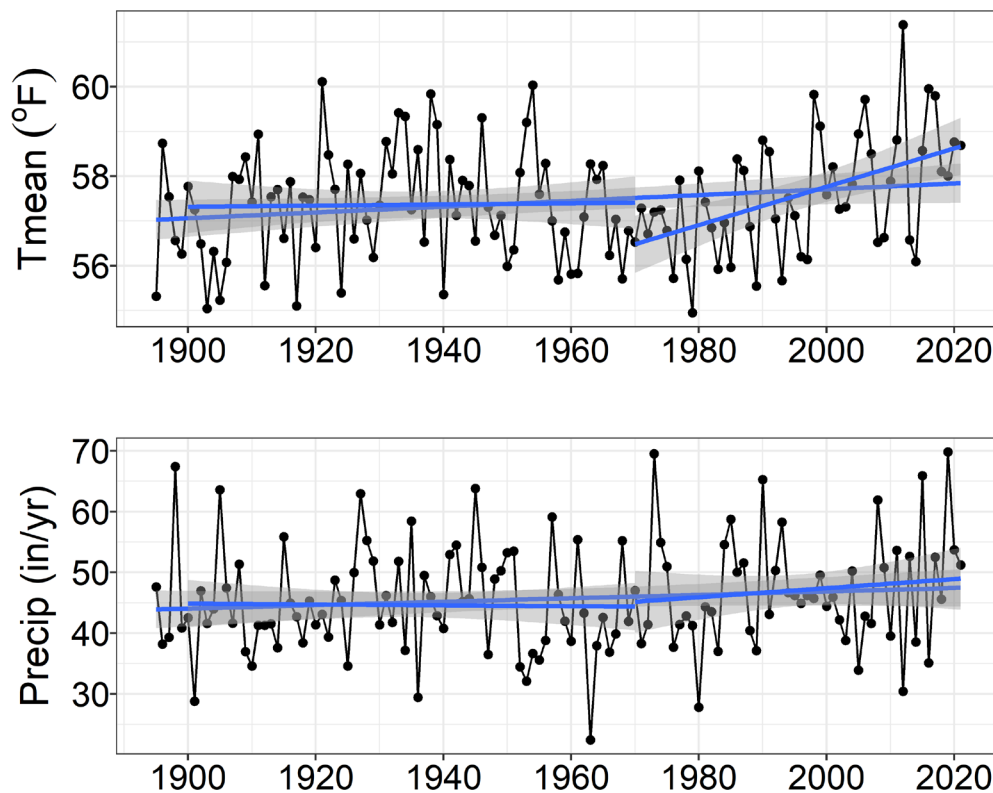


Figure 3. Temperature and precipitation trends for recent (1971–2020) and historical (1895–1970) periods at Pea Ridge National Military Park. The gray shaded areas around regression lines are the standard errors of temperature means and precipitation.

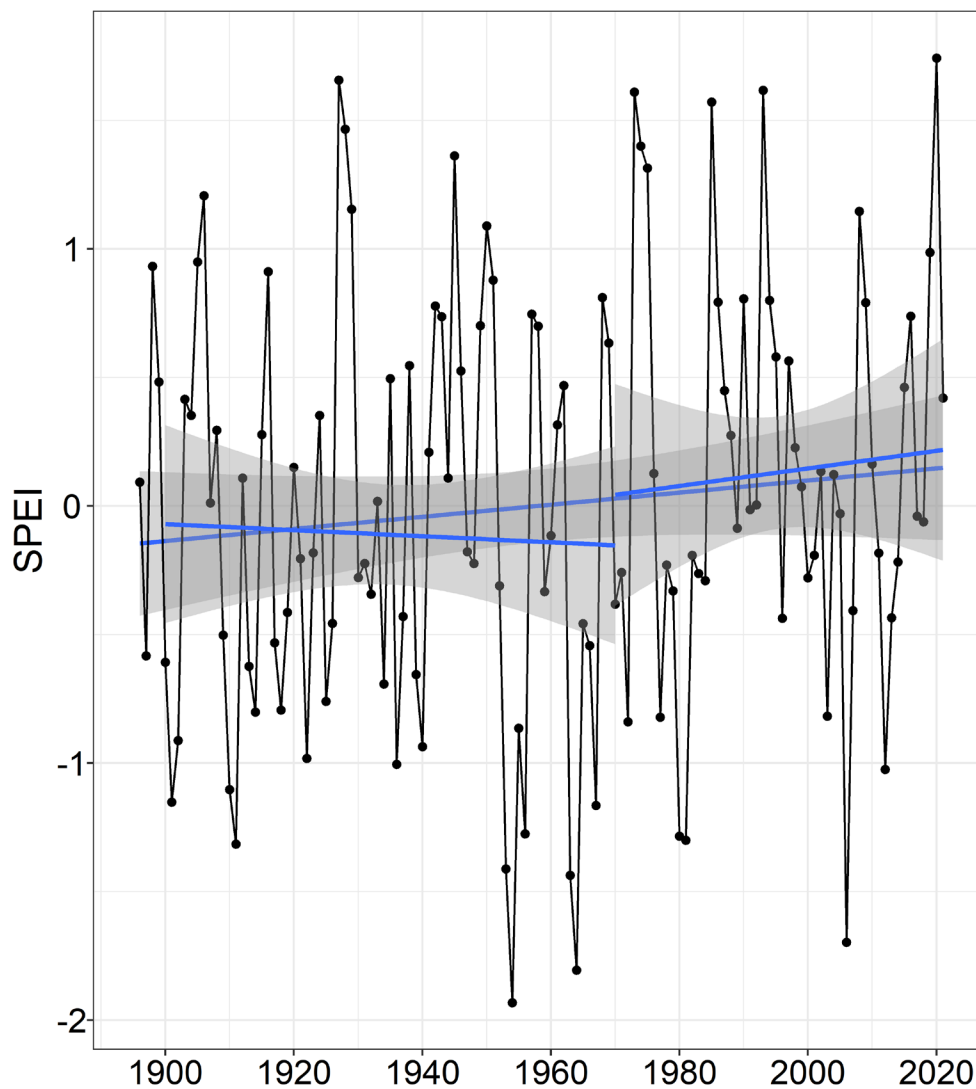


Figure 4. Standardized Precipitation-Evapotranspiration Index (SPEI) trends for recent (1971–2020) and historical (1895–1970) periods at the Pea Ridge National Military Park. The gray shaded areas around regression lines are standard errors of SPEI. Reference period is 1900–1970 and recent period is 1971–2020.

or increase, some will decline (Landscape Change Research Group 2021). They predict that white oak (*Quercus alba*), red oak (*Quercus rubra*), sassafras (*Sassafras albidum*), and flowering dogwood (*Cornus florida*) will experience small declines, while large declines will occur for silver maple (*Acer saccharinum*), sugar maple (*Acer saccharum*), serviceberry (*Amelanchier* spp.), and American basswood (*Tilia americana*). Yellow-poplar (*Liriodendron tulipifera*) and American hornbeam (*Carpinus caroliniana*) may be lost. Many other

species found in the monitoring sites will experience increases, such as post oak (*Quercus stellata*), mockernut hickory (*Carya tomentosa*), winged elm (*Ulmus alata*), and hackberry species (*Celtis* spp.).

While some oak species may thrive as the climate changes, the Ozark highlands oak-hickory forests may experience declines overall (Moser et al. 2020). Oak decline may result from a combination of factors that include climate change and land use history.

Overstory

Canopy Closure

The canopy at Pea Ridge National Military Park is relatively closed (Figure 5). Canopy cover was similar through time, but sites became more variable. Standard deviation of mean canopy closure more than doubled from 2016 ($SD \pm 2.14$) to 2021 ($SD \pm 5.01$). The vegetation community types that include these monitoring sites (Table 1) are described as highly variable. For example, the Typic Upland deciduous type (sites 8, 9, 10, 13, 15) definition includes wide ranging possibilities for canopy cover (50–100%; Diamond et al. 2013). Our measurements for canopy cover varied little and fall within this broad range (Figure 5).

Live Basal Area, Stem Density, and Stocking

Although total live basal area was similar across years (Table 4), we observed shifts in basal area between size classes. For example, class 1 midstory trees increased in basal area between 2007 and 2012 (Figure 6). Little change in other classes was observed through time. Class 5 trees were quite variable across years (Figure 6). Basal area for these woodland sites in 2021 fits within the Ozark closed

woodland community type (range 18–29 m^2/ha ; Hanberry et al. 2014), although the park aims for an open woodland type (NPS 2014).

Table 4. Total live basal area (m^2/ha) for midstory and overstory trees at Pea Ridge National Military Park, Arkansas, 2007–2021. CI95 represents the 95% confidence interval for each year.

Year	Mean Basal Area (m^2/ha)	CI95
2007	21.07	18.63–23.51
2012	23.19	20.02–26.36
2016	22.25	19.01–25.49
2021	22.60	18.83–26.37

Total live tree density increased by two-thirds between the first monitoring event in 2007 and the second in 2012 (Table 5; Figure 7). Class 1 midstory trees, were responsible for the increase (Leis 2018). Although prescribed fires early in the monitoring cycle (2006 and 2008) may have contributed to the flush of class 1 trees, we cannot be certain of the cause of increased recruitment to the midstory (Arthur et al. 2012).

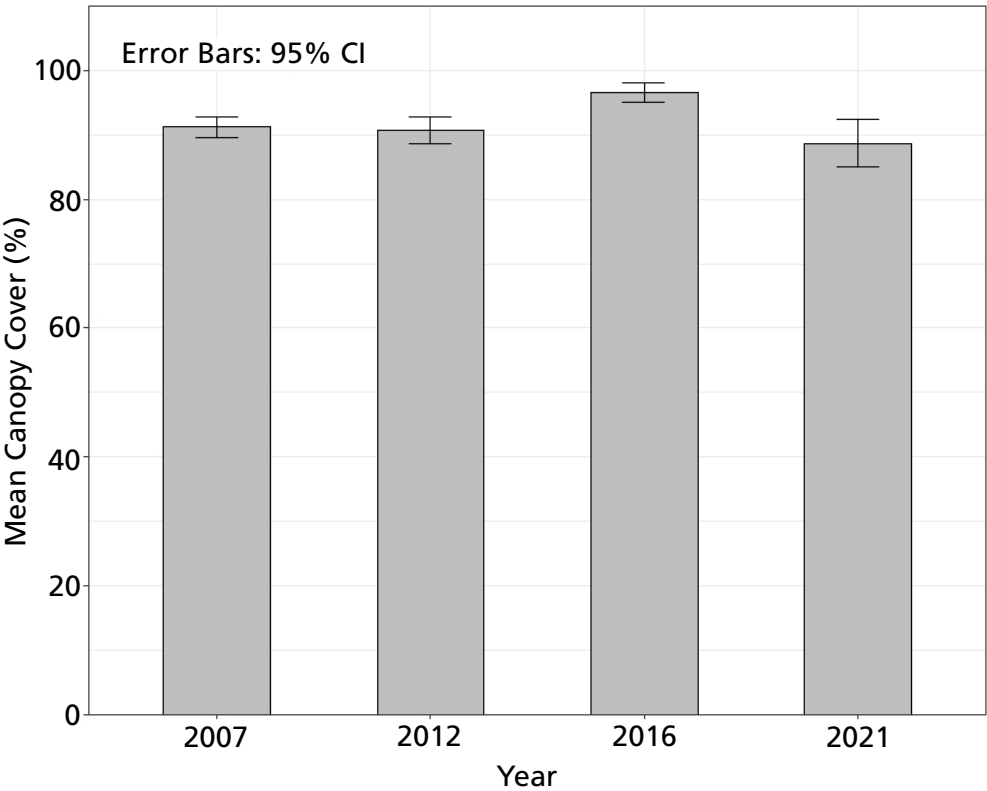


Figure 5. Mean percent canopy cover for seven monitoring sites across four sampling events at Pea Ridge National Military Park.

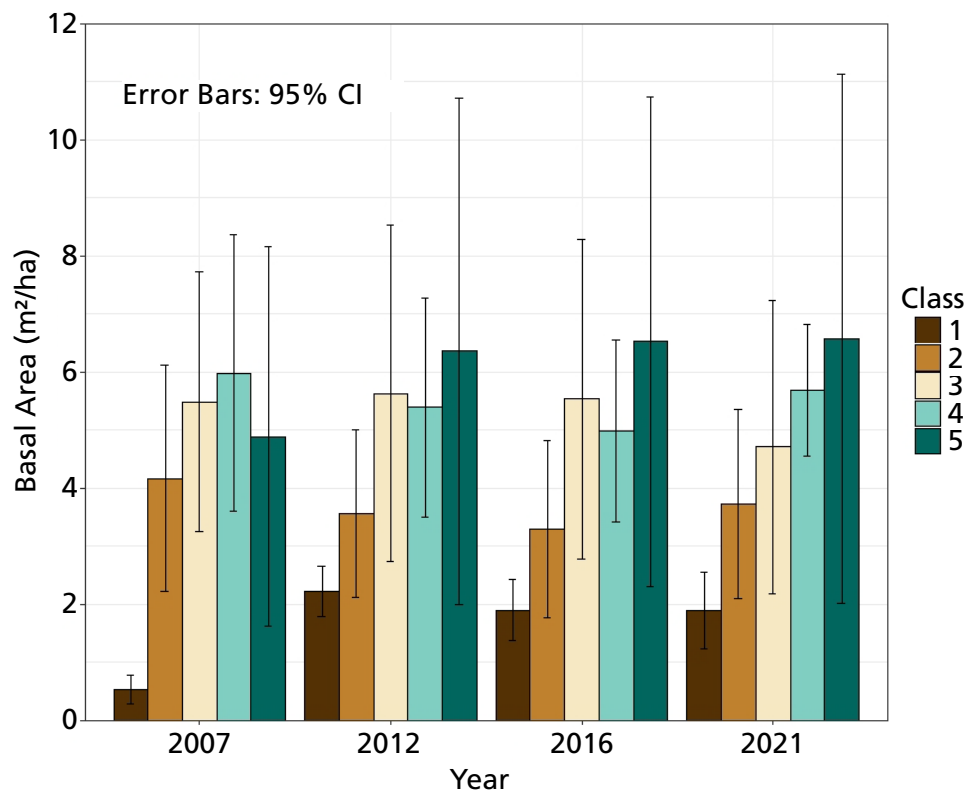


Figure 6. Basal area (m²/ha) for live midstory and overstory trees by size class at Pea Ridge National Military Park, Arkansas, 2007–2021.

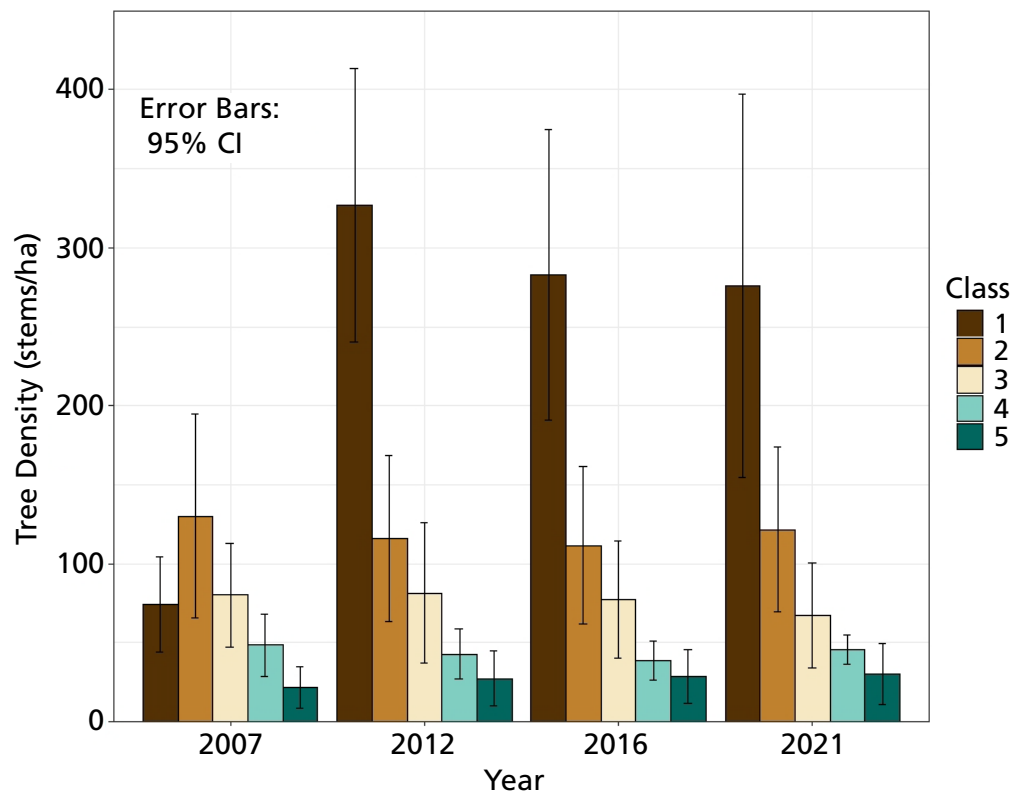


Figure 7. Tree density (stems/ha) for live midstory and overstory trees by size class at Pea Ridge National Military Park, Arkansas, 2007–2021.

Table 5. Total live tree density (stems/ha) for midstory and overstory trees at Pea Ridge National Military Park, Arkansas, 2007–2021. CI95 represents the 95% confidence interval for each year.

Year	Mean Density	CI95
2007	354.3	282.5–426.1
2012	594.3	492.6–695.9
2016	538.6	421.0–656.1
2021	540.0	406.8–673.2

Overall density and density within size classes was similar across all years except for 2007. As a result, the goal of reducing pole-sized trees after four burns has not yet been met for these sites. We anticipate that all sites will meet the four-burn threshold by the next monitoring event allowing for a final evaluation of the goal. Results from fire effects monitoring plots with three completed burns indicated a 65% reduction (with 90% CI, $N = 5$) in pole-sized trees (2.5–15.0 cm DBH) from 1999 to 2021 (Drees and Ladner 2022). Despite the differences in classifying trees between the Heartland Network protocol and the fire effects protocol, we did not observe the level of decrease in midstory tree density reported in the fire effects monitoring sites (Drees and Ladner 2022). However, the fire effects sites were installed eight years sooner, potentially accounting for differences in the trends.

Based on density for oak woodland types, the current total live tree density is in the oak forest community type, whereas basal area was in the closed woodland type (192–318 stems/ha for stems > 12.7 cm DBH; Hanberry et al. 2014). To better understand the relationship between basal area, density, and the stand structure we also calculated the stocking percentage. Tree stocking measures the extent to which the growth potential of a site is utilized by trees (Table 6). At approximately 60% stocking in upland hardwood communities, canopy closure occurs but growing space for trees is still available. A stocking value of $\geq 100\%$ represents an overstocked stand, where trees are utilizing all potential growing space (Gingrich 1967; Johnson et al. 2019). Stocking in woodlands ranges from 30–75%, with closed woodlands maintained at about 55–75% and open woodlands maintained between 30–55% (Hanberry et al. 2014; Dey et al. 2017). Over the monitoring

record, mean stocking was similar, however, the 95% confidence interval width was greatest in 2021 and least in 2007, indicating an increase in variability between sites. We determined the current mean stocking level of the monitoring sites to be 58%, which is consistent with a closed woodland community type.

Table 6. Total live tree stocking (%) for midstory and overstory trees at Pea Ridge National Military Park, Arkansas, 2007–2021. CI95 represents the 95% confidence interval for each year.

Year	Mean Stocking (%)	CI95
2007	54.01	47.72–60.30
2012	58.95	50.85–67.05
2016	56.66	48.45–64.87
2021	57.55	48.03–67.07

Snag Density

Snag trees were greatest in 2012 and 2016 and the greatest number of snags were in the class 1 midstory and class 2 overstory trees (Table 7, Figure 8). These size classes are vulnerable to mortality from a variety of sources including drought, self-thinning, and fire (Arthur et al. 2012). Interestingly, at the time when class 1 live trees had increased recruitment, mortality also increased in class 1 trees (Figure 8). A possible explanation is that class 1 trees can be large enough to survive fire, but as their numbers increase they are subject to the pressures of competition. Mortality can occur in this stem exclusion phase as trees compete for growing space, light, and a more dominant crown position than their cohorts (Dey 2014; Johnson et al. 2019).

Table 7. Total Snag Density (stems/ha) for midstory and overstory trees at Pea Ridge National Military Park, Arkansas, 2007–2021. CI95 represents the 95% confidence interval for each year.

Year	Mean Density (stems/ha)	CI95
2007	47.14	23.05–71.23
2012	131.43	84.69–178.17
2016	124.29	74.99–173.59
2021	58.57	38.31–78.83

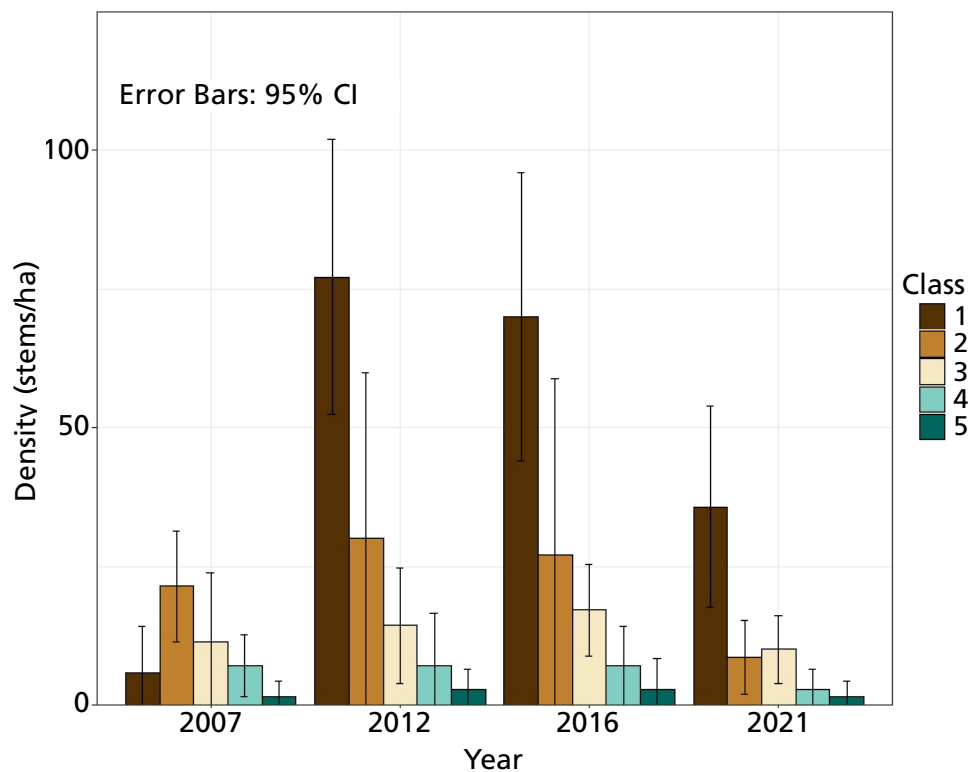


Figure 8. Tree density (stems/ha) for dead midstory and overstory trees by size class at Pea Ridge National Military Park, Arkansas, 2007–2021.

We did not do an in-depth analysis of overstory species composition for this report; however, we did analyze patterns of eastern redcedar (*Juniperus virginiana*) because the park actively manages this species. Eastern redcedar, although native, can be invasive in woodlands. We noted that eastern redcedar was a small portion of the tree composition across years and was observed in only two of the seven monitoring sites. There was no change in eastern redcedar over time (mean basal area was 0.7 m²/ha [± 0.10 SD] and mean density was 23.9 stems/ha [± 6.2 SD]).

Ground Flora

Ground Cover

Mean bare soil was the most variable in 2021. The magnitude of the confidence intervals for deciduous leaf litter similarly varied depending on the year. The increase in confidence intervals for bare soil and decrease in leaf litter confidence intervals may have been related to prescribed fires in the spring prior to monitoring, although we were not able to confirm that with our monitoring design (Figure 9). We also

observed overland water flow during a high rain event in the spring of 2021 that may have contributed to the movement of litter across the soil surface. Litter depth in 2021 averaged 2.0 cm (SE ± 0.40) and ranged from 0.0–6.0 cm. The most recently burned sites (11, 12) had the shallowest litter depth.

Since plant and wildlife needs vary in their use of ground cover, heterogeneity of ground types across the landscape may best support biodiversity. Deep litter shades the ground, which in turn affects soil moisture and germination for some species of ground flora and trees (Donath and Eckstein 2008; Nation et al. 2021). Nation et al. (2021) suggested that more frequent fires of lower severity supported more robust acorn germination and seedling establishment than less frequent fires with deep litter fuels. The amount of litter is also a key habitat component for some wildlife such as birds and herpetofauna (Fox et al. 2010; Harper et al. 2016). Furthermore, litter is important for some wildlife for finding insects, seeds, and hiding, while others utilize bare soil for basking, foraging for worms, or other activities.

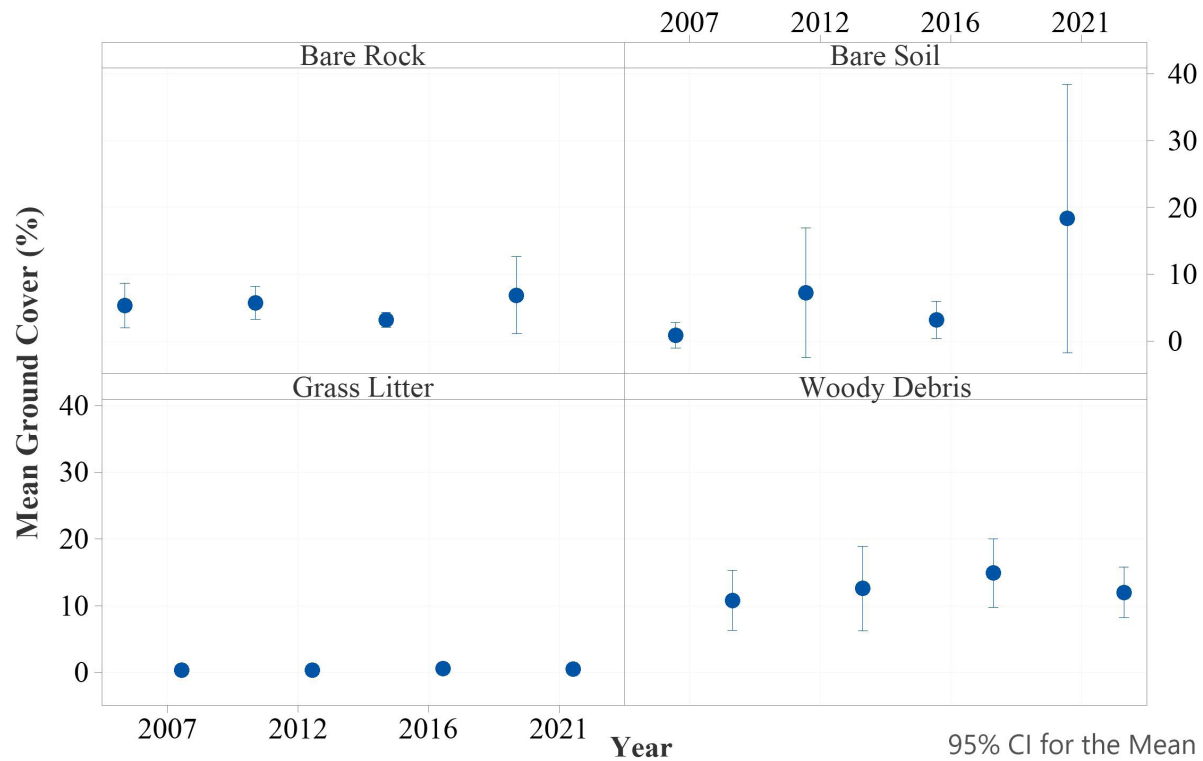
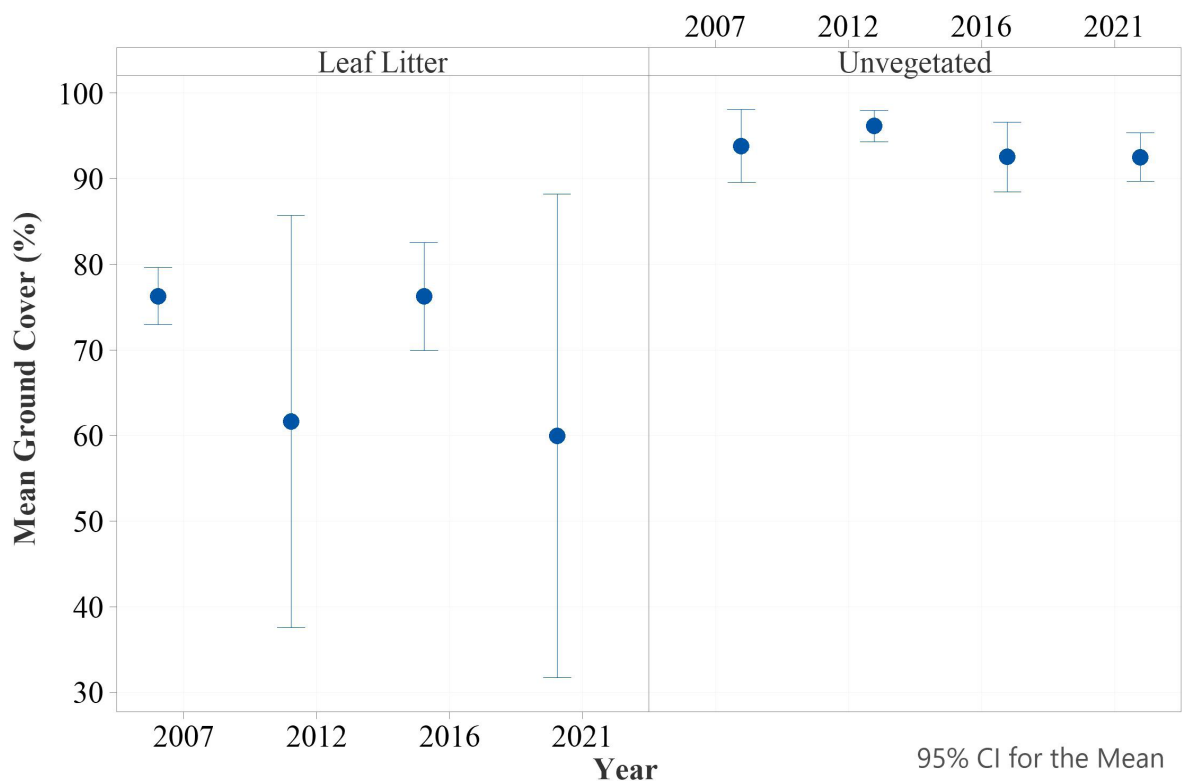
A**B**

Figure 9. Measures of mean ground cover (N = 7) in monitoring sites at Pea Ridge National Military Park, Arkansas, 2007–2021. (A) shows bare rock, bare soil, grass litter, woody debris and (B) shows leaf litter and unvegetated types.

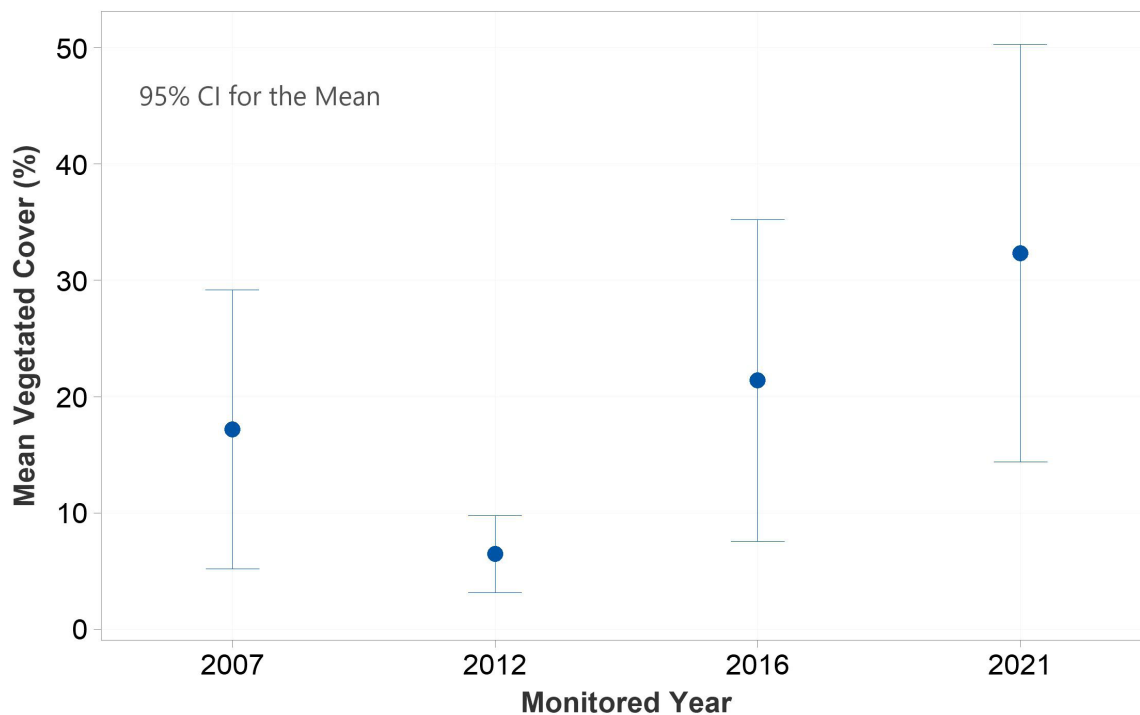


Figure 10. Total vegetated cover (%) of ground flora (N = 7) at Pea Ridge National Military Park, Arkansas, 2007–2021. Individual standard deviations are used to calculate the intervals.

Ground Flora Cover

We calculated total ground flora cover to address the fire management goal to increase total herbaceous vegetation cover by 60–100% after four burns (Drees 2017). Mean vegetated cover in 2021 was about 88% greater than vegetated cover in 2007 (Figure 10). Our attained confidence level of 99.1% indicated certainty that vegetation cover in sites increased by at least 60%. Some observations exceeded the 100% upper limit (attained confidence level of 69.7%). Although the goal was constructed with an upper boundary, we are not aware of an ecological basis for limiting expansion of ground flora cover. The fire effects monitoring program also reported an increase (32.5%) in herbaceous plant density after three fires from 1999 to 2021 (Drees and Ladner 2022). Fire treatments may not reduce the canopy, but other fire effects such reduction in litter and increased nutrient cycling that result from burning can stimulate ground flora production. Increased precipitation could also contribute to ground flora growth, but we did not see evidence for increasing precipitation in the climate record (Figure 3). Unfortunately, our monitoring design did not allow us to understand the cause of the increased vegetation cover. Comparison of

photos from the 2012 and 2021 sampling events provides a visual representation of the change and variation in vegetated cover across the monitoring sites (Appendix B).

Tree Regeneration

Seedlings and saplings represent the potential future composition of a stand. Although mean tree regeneration increased by 54% between 2007 and 2021, the 2021 mean was included in the 2007 confidence interval making change difficult to detect (Table 8). Seedlings composed the majority of the regeneration and small saplings demonstrated a similar pattern where variability among sites increased over time.

Table 8. Tree regeneration density (stems/ha) for monitoring sites (N = 7) at Pea Ridge National Military Park, Arkansas, 2007–2021. Density includes seedlings, small saplings and large saplings.

Year	Mean Density (stems/ha)	CI 95%
2007	13,114	6,093–20,134
2012	10,914	7,296–14,531
2016	20,057	13,235–26,878
2021	20,157	14,801–25,512

Mean seedlings in 2021 represent a 50% increase over 2007 seedling stem density (Figure 11), while mean small saplings increased by 535% over 2007 levels (Figure 12). There was a great deal of variability between the sites in 2021 with respect to small saplings (95% CI: ± 710.18 stems/ha). Large sapling density was the same in 2007 and 2021. Fire management goals included increasing oak seedlings by 300–500% after four burns. Some sites have not yet reached the four-burn threshold, but seedlings as a whole have not yet reached the goal of a 300–500% increase over our monitoring time frame. Leis (2018) found that the thresholds for oak seedlings in particular had not been met in 2016 and density was similar between the 2016 and 2021 monitoring events.

While regeneration variability increased, continuing to work towards increasing light to the woodland floor across all sites may further stimulate regeneration of desired species such as oak and hickory. Litter is helpful for maintaining adequate soil moisture and protecting acorns from freezing,

but thick layers of litter can impede germination (Johnson et al. 2019). Many oak species require 20% or greater of full sun light to grow and mature into advanced stages in the midstory and overstory woodland layers (Lorimer et al. 1994; Ostrom and Loewenstein 2006; Brose 2011). Furthermore, removal of the midstory can increase light 10–20%, but that may not be sufficient to achieve the needed light levels (Ostrom and Loewenstein 2006). Prescribed fire can increase light levels by thinning the midstory layer. Increasing light by above 20% of full sunlight and canopy gaps > 0.04 ha can provide an advantage to oak regeneration over more shade tolerant competitors (Ostrom and Loewenstein 2006; Sander et al. 1983). Monitoring of snags indicated some thinning of the midstory layer took place, especially from 2012–2016. Additional thinning of overstory trees may be needed to meet the fire management goal for oak seedlings, as the combination of thinning and fire has often been found most effective at maintaining structure and species composition goals (Thomas-Van Gundy et al. 2014; Dey et al. 2017; Johnson et al. 2019).

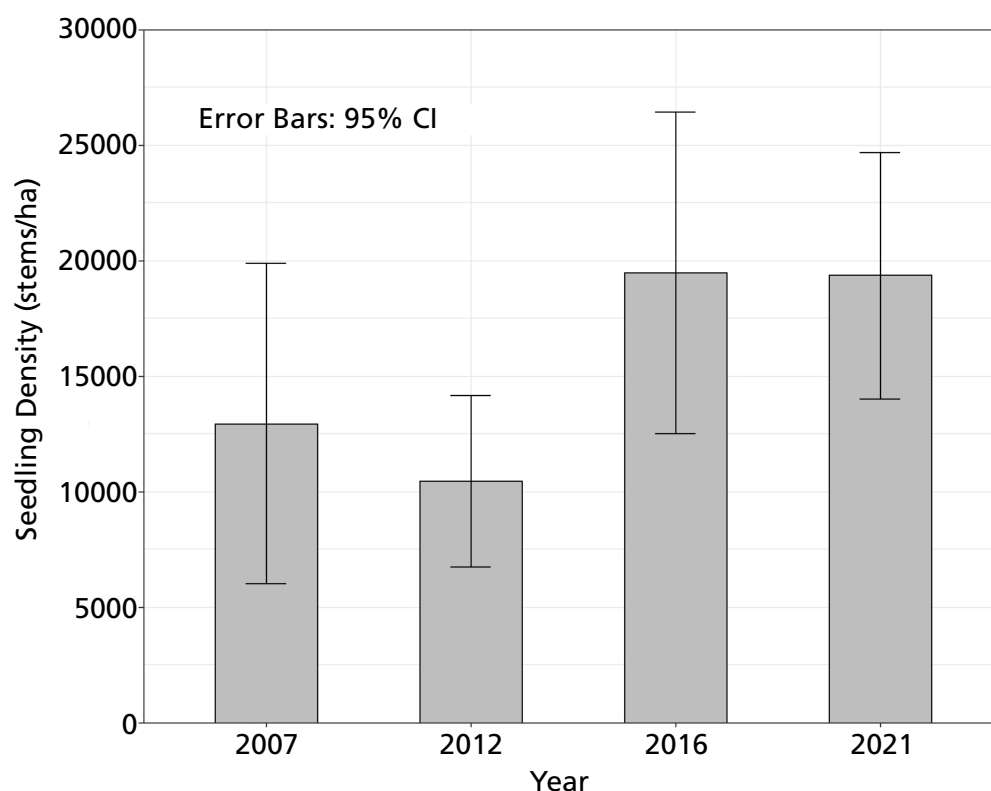


Figure 11. Mean seedling density in monitoring sites (N = 7) at Pea Ridge National Military Park, Arkansas, 2007–2021.

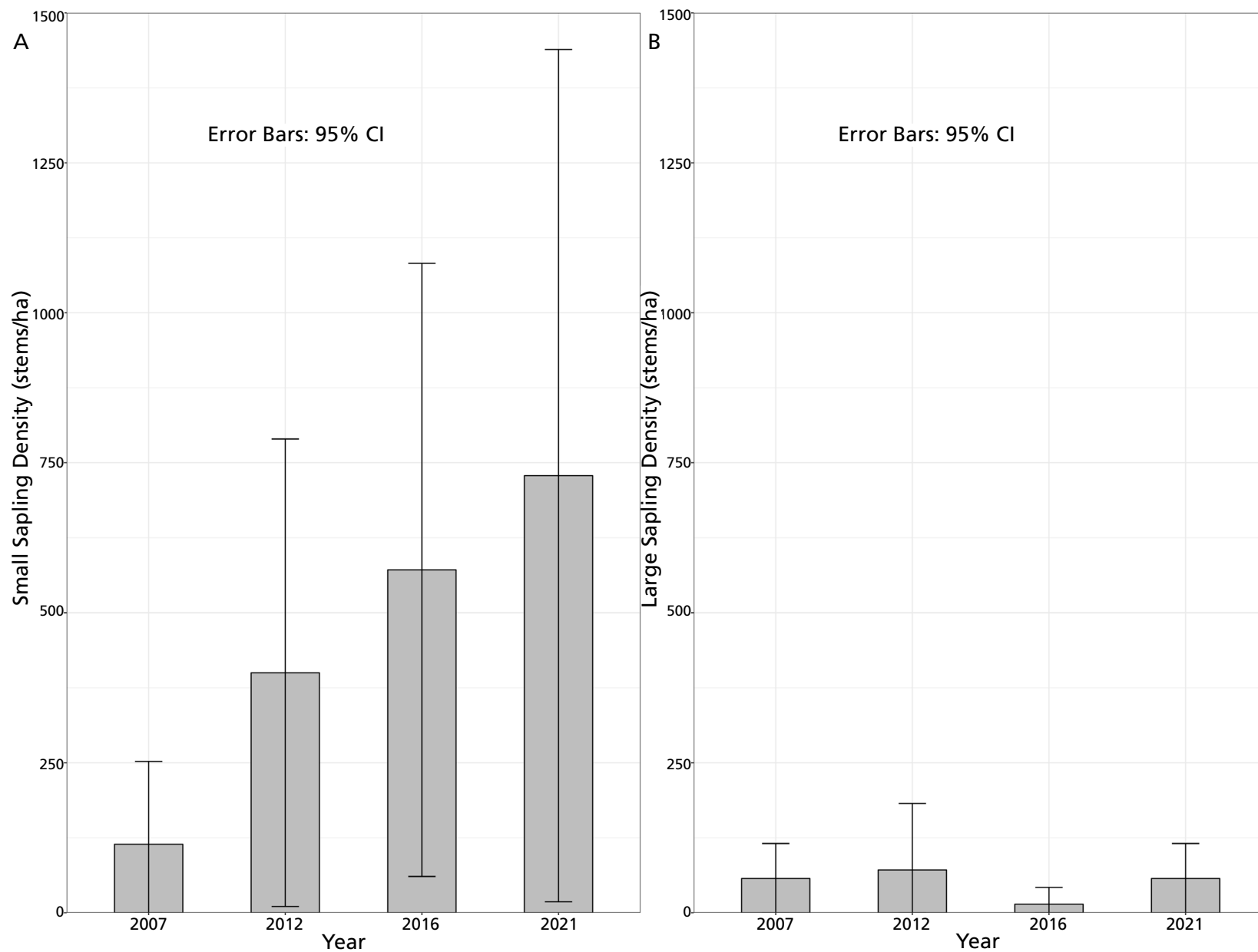


Figure 12. Mean sapling density (small saplings (A) = stems ≥ 0.5 m tall, and < 2.5 cm DBH and large saplings (B) = stems ≥ 0.5 m tall and DBH ≥ 2.5 cm and < 5.0 cm) in monitoring sites (N = 7) at Pea Ridge National Military Park, Arkansas, 2007–2021.

Species Diversity

Species richness increased with each monitoring event since 2012 when the species count was lowest (Figure 13). The mean number of species per site in 2021 was 15 to 32 species greater than in previous years. We also attribute some of the additional species to improvements in botanical sampling that included preparation as well as the inclusion of an expert botanist to the team in 2021. However, the fire effects monitoring program reported a mean increase in native herbaceous species of 103% for plots with two burns from 1999–2021 (90% CI, N =5).

Mean Shannon Diversity Index (H') estimates for 2021 were not significantly different from 2007 ($Z = -0.85$, $P = 0.40$; Figure 14). J' values (evenness) indicate that sites had similar numbers of species across the monitoring events but moderate heterogeneity among the sites (values of 1 indicate even communities, whereas 0 indicates a heterogeneous community).

Community Diversity

Species richness at the park scale (gamma diversity, Table 9) increased by 46% from 2007 to 2021. Similarly, site-scale mean alpha diversity increased by 74% in that time frame (Table 9). The increase in gamma diversity did not translate into meaningful change in beta diversity, however. The low beta

diversity values indicate that there is a great deal of similarity in the number of species among the sites.

Table 9. Mean ground flora community diversity metrics for monitoring sites (N = 7) at Pea Ridge National Military Park, Arkansas, 2007–2021.

Year	Alpha	Gamma	Beta
2007	30.7	81	1.6
2012	21.4	55	1.6
2016	37.7	103	1.7
2021	52.9	131	1.5

Guilds and Additional Species Spotlight

Native Guilds

Most of the six standard native species guilds showed little changed through time (Figure 15). Forbs dominated the other ground flora but were characterized by relatively large variabilities among sites in all years except for 2012. Although forb cover was greatest in 2021, it was not different from the baseline year of 2007 ($Z = -1.52$, $P = 0.13$). Woody species cover was more variable in the last two monitoring events. Woody species cover in 2021 was greater than in 2007 ($Z = -2.03$, $P = 0.043$; after correction for multiple comparisons, however, it would not be significantly different).

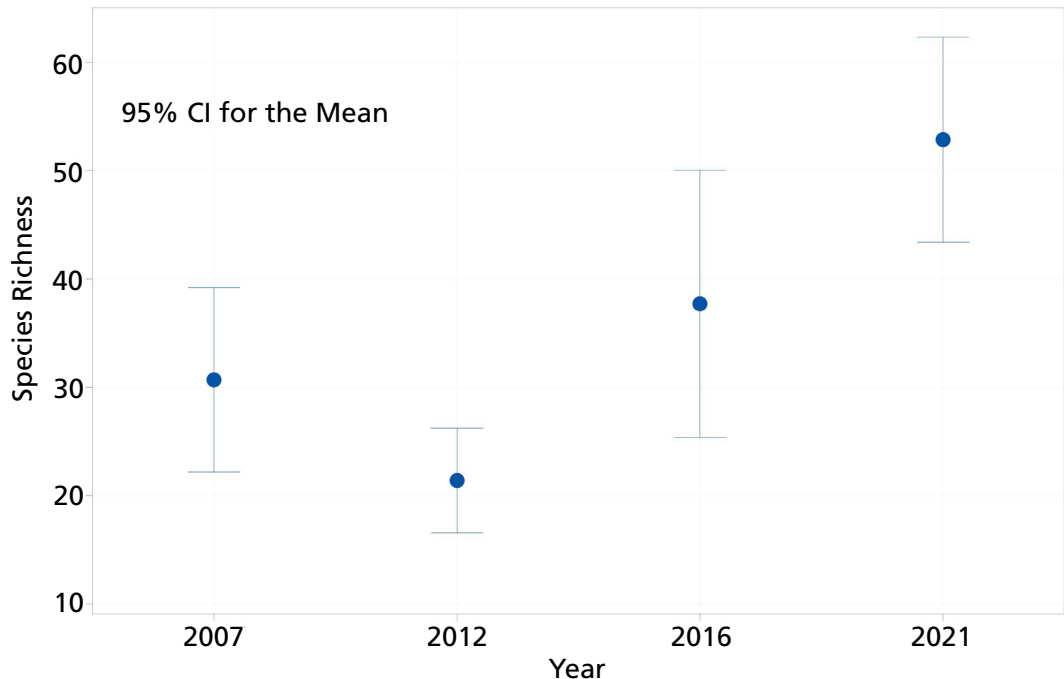


Figure 13. Mean ground flora species richness in monitoring sites (N = 7) at Pea Ridge National Military Park, Arkansas, 2007–2021.

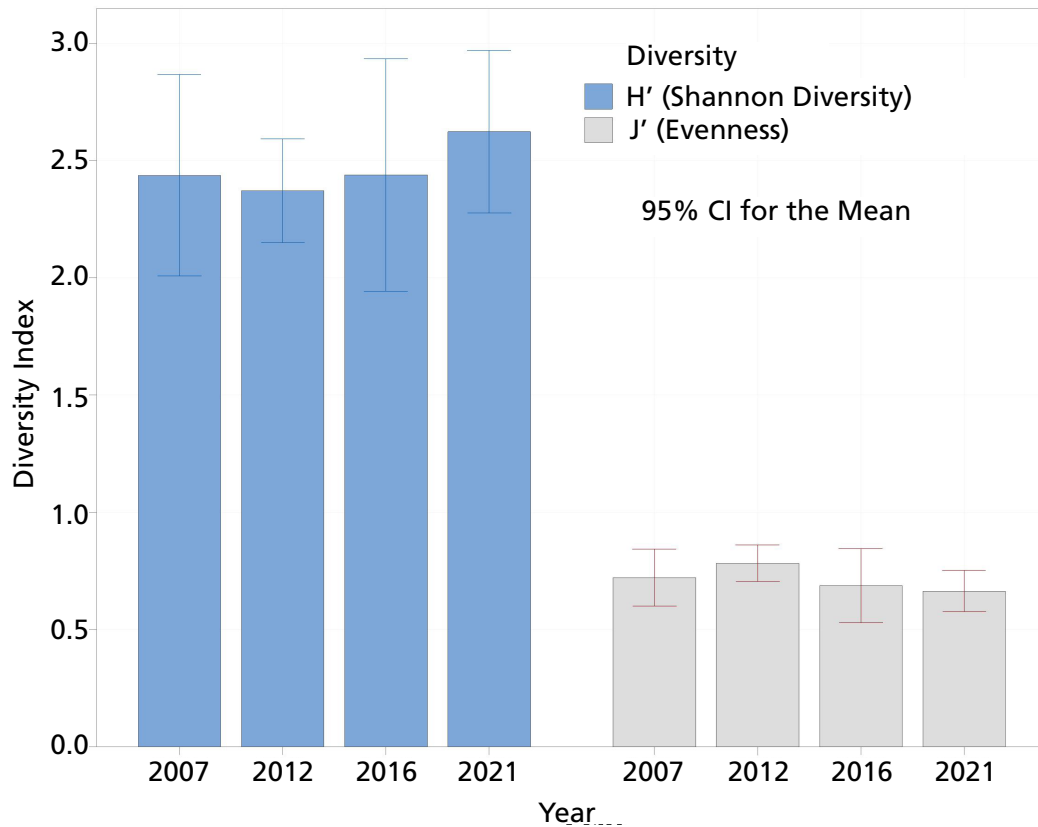


Figure 14. Mean ground flora diversity in monitoring sites (N = 7) at Pea Ridge National Military Park, Arkansas, 2007–2021.

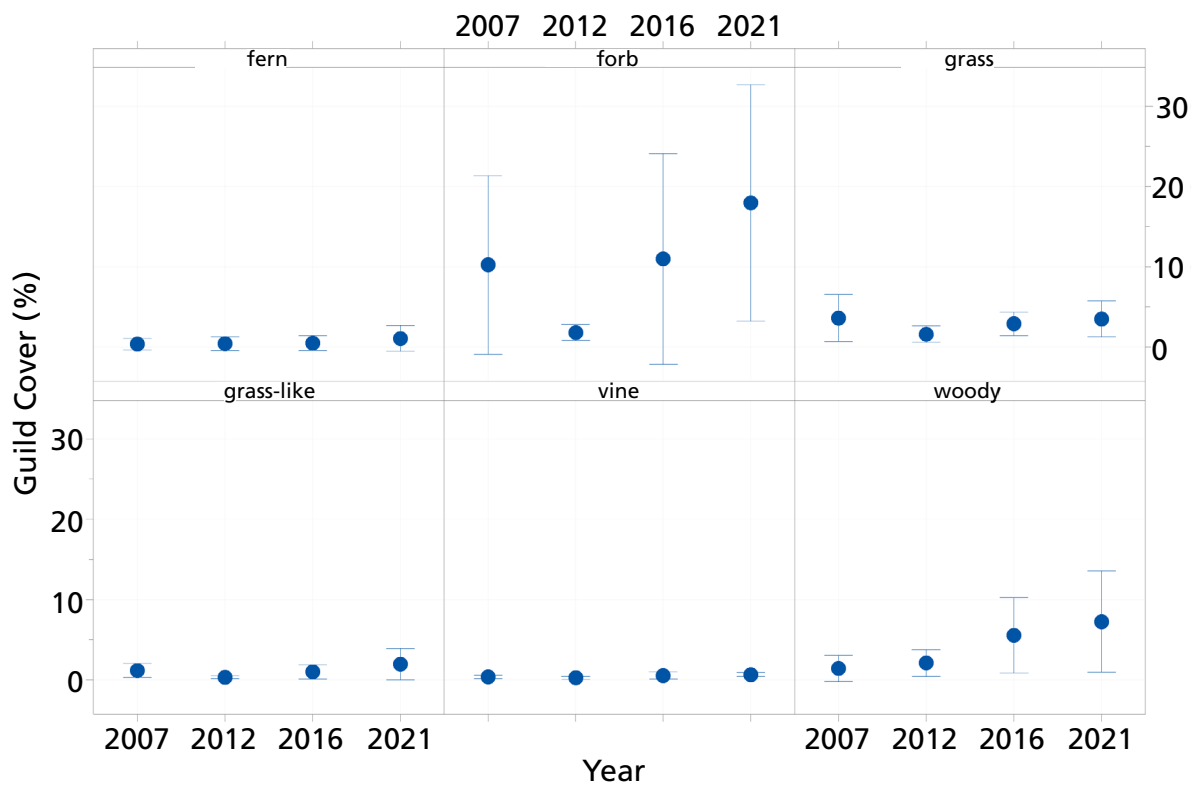


Figure 15. Mean cover of guilds for ground flora vegetation in monitoring sites (N = 7) at Pea Ridge National Military Park, Arkansas, 2007–2021.

In 2018, we clarified the designation of guild type for species whose form varies from shrub to tree, such as northern spicebush (*Lindera benzoin*) and rusty blackhaw (*Viburnum rufidulum*). It is possible that these species were overlooked in earlier monitoring events or inconsistently recorded. Interestingly, *Vaccinium* spp. (blueberries) were not observed in 2007 but were found in increasing numbers of sites for each subsequent monitoring event. Although mean blueberry cover more than tripled from 0.4% in 2012 and 2016 to 1.37% in 2021, the abundance of these species is still small. The grape species (*Vitis* spp.) were also classified as vines for this analysis. Previously, the grapes had variable guild designations depending on species and specificity. Future clarification to this guild designation will stabilize the woody and vine summaries.

We assessed changes in species composition by using native plant species known to be indicators of Ozark Highlands woodlands. The list of Ozark Highlands woodland plant indicator species shown below is adapted from Kinkead et al. (2013) based on S. Farrington's indicator list. Species marked with an asterisk (*) are species observed in long-term monitoring sites at Pea Ridge National Military Park, Arkansas (The observed species are also marked with an asterisk in Appendix A for reference).

- *Andropogon gerardii**
- *Asclepias tuberosa*
- *Aureolaria grandiflora*
- *Baptisia bracteata*
- *Blephilia ciliata*
- *Ceanothus americanus**
- *Comandra umbellata*
- *Coreopsis palmata*
- *Cunila origanoides**
- *Dalea purpurea*
- *Desmodium rotundifolium**
- *Echinacea pallida*
- *Eryngium yuccifolium*
- *Euphorbia corollata**
- *Gentiana alba*
- *Gillenia stipulata*
- *Helianthus hirsutus*
- *Ionactis linariifolius*
- *Lespedeza hirta*
- *Lespedeza procumbens**
- *Lespedeza violacea**
- *Lespedeza virginica**
- *Liatris aspera*

- *Liatris squarrosa*
- *Lithospermum canescens*
- *Monarda bradburiana**
- *Orbexilum pedunculatum**
- *Parthenium integrifolium*
- *Phlox pilosa*
- *Pycnanthemum tenuifolium**
- *Schizachyrium scoparium**
- *Silene regia*
- *Silene stellata*
- *Silphium integrifolium*
- *Silphium terebinthinaceum*
- *Solidago hispida*
- *Solidago petiolaris*
- *Solidago radula*
- *Solidago rigida*
- *Solidago speciosa*
- *Solidago ulmifolia**
- *Sorghastrum nutans*
- *Symphyotrichum anomalum**
- *Symphyotrichum oolentangiense*
- *Symphyotrichum patens**
- *Symphyotrichum turbinellum*
- *Taenidia integerrima*
- *Tephrosia virginiana*
- *Verbesina helianthoides**
- *Viola pedata*

Disturbance to woodlands in the region may result in changes in ground flora species composition. Activities that include soil disturbance and heavy grazing may favor more generalist species over species with high fidelity to undisturbed woodlands. The battlefield has undergone a variety of land use disturbances such as homesteading and agriculture, a civil war battle, and conservation actions like fire and forest thinning. We applied the set of Ozark highland woodland indicator species to our long-term monitoring data to better understand changes in the quality of the vegetation over time. This suite of native species are summer flowering and seed producing and are appropriate for woodland ecosystems where sufficient light penetrates to the forest floor (i.e., savanna, open woodland).

We observed 32% of the listed indicator species in our monitoring sites with increasing numbers of species with each monitoring event, except for 2012 (Table 10). The increase in the number of woodland indicator species observed along with increases in native species richness are positive indications that treatments may be improving the composition

and quality of the woodland ground flora. The occurrence and abundance of these species is still quite low, however (mean cover < 2% in 2021). Addressing the closed canopy and stand density through thinning and prescribed fire could improve the abundance of these indicator species.

Table 10. Summary of Ozark woodland indicator species observed in monitoring sites at Pea Ridge National Military Park, Arkansas, 2007–2021.

Year	Number of Indicator Species Observed	Percentage of Subplots Where Indicators Were Observed
2007	8	32.9%
2012	7	28.6%
2016	11	50.0%
2021	14	55.7%

In addition to the species observations detailed in the above analyses, in 2021 we listed graminoid species to greater specificity for species that are normally lumped to genera (e.g. *Carex* and *Dichanthelium*). These species are difficult to consistently identify in the field, but with the help of a contract botanist we were able to confirm the identity of those species (listed in Appendix A, Tables A2 and A3, for reference). These detailed lists can be used for future investigations and trainings and further indicates the diversity of the plant community in the monitoring sites.

Table 11. Nonnative plant species and abundance observed in long-term monitoring sites at Pea Ridge National Military Park, Arkansas, 2007–2021.

Species	Common Name	2007 Mean Cover (%)	2016 Mean Cover (%)	2021 Mean Cover (%)
<i>Euonymus fortunei</i>	winter creeper	0.00	0.00	0.01
<i>Lactuca serriola</i>	Prickly lettuce	0.01	0.00	0.01
<i>Lonicera japonica</i>	Japanese honeysuckle	0.00	0.01	0.01
<i>Melilotus officinalis</i>	Yellow sweetclover	0.00	0.00	0.01
<i>Microstegium vimineum</i>	Nepalese browntop	0.00	0.01	0.77
<i>Perilla frutescens</i>	Beefsteakplant	0.00	0.00	0.04
<i>Polygonum cespitosum</i>	Oriental lady's thumb	0.00	0.00	0.05
<i>Setaria pumila</i>	yellow foxtail	0.00	0.00	0.01
<i>Stellaria media</i>	common chickweed	0.00	0.00	0.01
<i>Taraxacum officinale</i>	common dandelion	0.01	0.00	0.01
<i>Viola tricolor</i>	johnny jumpup	0.00	0.00	0.01

Invasive Species

Only two nonnative species were observed in the 2007 and 2016 sample events, and none were found in 2012, but 11 species were observed in 2021 (Table 11). Mean abundance of nonnative species remained low, however. *Microstegium vimineum* (Nepalese browntop) averaged 0.77% mean cover in 2021 and was found in three of the seven sites when it was previously only 0.1% mean cover and found in one site. The invasive plant monitoring project also reported that estimates for minimum cover of Nepalese browntop increased from 1.2 acres in 2013 to 17.4 acres in 2018 (Young 2020). Opening the woodland canopy, which would cause increased light levels, may increase the effort required to control this plant (Horton and Neufeld 1998; Cheplick and Fox 2011).

Observer Error

Observer error was measured for the first time at Pea Ridge National Military Park in 2021 (Table 12). Observer error has multiple components. In this study, we quantified overlooking error (i.e., when a species was present but not noticed by an observer), misidentification error (i.e., when a species was noticed but incorrectly identified), and cautious error (i.e., when one observer lumped an observation to genus level and the other observer was more specific). The greatest source of error came from overlooking a species by one of the

observers (16.0%). Misidentification error was low (1.4%), and no cautious error was documented. Total pseudoturnover is a function of all three types of error and averaged 17.4% for the sampling event, resulting in 82.6% agreement (Table 12). We aimed to keep our species agreement around 80% based on a survey of the literature (Morrison 2016) and a previous sample event at the 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. In cases where tree trunks or woody debris interfered with plot placement, it was more challenging to match the plot placement between observers. We do not have a quantitative assessment of the contribution of this source of error, however.

Table 12. Components of observer error for plant community monitoring observed in 2021 at Pea Ridge National Military Park, Arkansas.

Error Component	Mean Error Rate (%)
Overlooking	16.0
Misidentification	1.4
Cautious	0.0
Total pseudoturnover	17.4

We also assessed the amount of agreement on the cover classes for species both observers recorded. Overall, on average there was 78.9% agreement on cover classes: 17.4% of observations were within one cover class and 3.7% of observations differed by > 1 cover class. At other parks, agreement has ranged from 73–85% (Morrison et al. 2020; Leis 2021; Leis and Short 2021).

Conclusions

The oak-hickory woodlands at Pea Ridge National Military Park experienced changes to both the overstory and ground flora between 2007 and 2021. Managers aimed to implement fire to reduce midstory trees, increase oak regeneration, and increase ground flora cover. In contrast to the Ozarks fire effects monitoring program data, we found that midstory trees were not reduced as desired and the desired increase for regeneration density has not yet been met, although ground flora cover did increase above the 60% lower threshold. Not all sites have reached the four-burn criteria for evaluation, so future assessments should continue to review these

goals. As ground flora cover increased, the number of Ozark woodland indicator species also increased, as well as the number and abundance of nonnative species. Although the role of climate change is not clear, temperatures have been increasing and first bloom and first leaf dates are earlier in the spring. Precipitation was variable, but no trend was apparent. Tree species have variable responses to climate change, but generally, species adapted to the dry Ozark highlands woodland communities are expected to thrive while more mesic species may decline (Landscape Change Research Group 2021).

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Appendix A. Plant Species

Table A1 shows all species observed from 2007 to 2021 and mean cover in 2021.

Table A1. All species observed in the woodland sites (N = 7) at Pea Ridge National Military Park, Arkansas. Values for mean cover, standard error (SE) and occurrence are for 2021 only; species with 0 values were observed in other years. N = native, I = nonnative. Tree species are not included in this table, see Table A4.

Species	Common Name	Guild	Origin	Mean Cover (%) 2021	SE	Occurrence (% Sites Observed) 2021
<i>Acalypha moncocca</i>	Ozarkian short-stalk copperleaf	forb	N	0.07	0.05	42.86
<i>Acalypha virginica</i>	Virginia threeseed mercury	forb	N	0.34	0.20	71.43
<i>Actaea racemosa</i> var. <i>racemosa</i>	black bugbane	forb	N	0.07	0.05	28.57
<i>Ageratina altissima</i>	white snakeroot	forb	N	1.91	1.67	85.71
<i>Agrimonia</i> spp.	agrimony	forb	N	0.00	0.00	0.00
<i>Agrimonia pubescens</i>	soft agrimony	forb	N	0.00	0.00	0.00
<i>Agrimonia rostellata</i>	beaked agrimony	forb	N	0.03	0.02	28.57
<i>Agrostis perennans</i>	upland bentgrass	grass	N	0.05	0.04	28.57
<i>Ambrosia artemisiifolia</i>	annual ragweed	forb	N	0.04	0.03	28.57
<i>Amphiachyris dracunculoides</i>	prairie broomweed	forb	N	0.00	0.00	0.00
<i>Amphicarpaea bracteata</i>	American hogpeanut	forb	N	7.84	4.41	85.71
<i>Andropogon gerardii</i> *	big bluestem	grass	N	0.04	0.04	14.29
<i>Andropogon virginicus</i>	broomsedge bluestem	grass	N	0.10	0.08	42.86
<i>Anemone</i> spp.	anemone	forb	N	0.00	0.00	0.00
<i>Antennaria plantaginifolia</i>	woman's tobacco	forb	N	0.04	0.02	42.86
<i>Aristolochia serpentaria</i>	Virginia snakeroot	forb	N	0.09	0.03	57.14
<i>Asplenium platyneuron</i>	ebony spleenwort	fern	N	0.05	0.02	57.14
<i>Aster</i> spp.	aster	forb	N	0.00	0.00	0.00
<i>Bidens</i> spp.	beggarticks	forb	N	0.00	0.00	0.00
<i>Bidens bipinnata</i>	Spanish needles	forb	N	0.02	0.02	28.57
<i>Boehmeria cylindrica</i>	smallspike false nettle	forb	N	0.23	0.21	42.86
<i>Botrychium dissectum</i>	cutleaf grapefern	fern	N	0.01	0.01	14.29
<i>Botrychium virginianum</i>	rattlesnake fern	fern	N	0.07	0.03	57.14
<i>Brachyelytrum erectum</i>	bearded shorthusk	grass	N	0.58	0.29	57.14
<i>Bromus pubescens</i>	hairy woodland brome	grass	N	0.05	0.05	14.29
<i>Campanulastrum americanum</i>	American bellflower	forb	N	0.00	0.00	0.00
<i>Cardamine concatenata</i>	cutleaf toothwort	forb	N	0.00	0.00	0.00
<i>Cardamine parviflora</i>	sand bittercress	forb	N	0.01	0.01	14.29
<i>Carex</i> spp.	sedge	grass-like	N	1.93	0.80	100.00
<i>Ceanothus</i> *	ceanothus	woody	N	0.00	0.00	0.00
<i>Ceanothus americanus</i> *	New Jersey tea	woody	N	0.01	0.02	14.29
<i>Chamaecrista nictitans</i>	sensitive partridge pea	forb	N	0.02	0.02	28.57
<i>Chasmanthium latifolium</i>	Indian woodoats	grass	N	0.02	0.02	14.29
<i>Cirsium altissimum</i>	tall thistle	forb	N	0.00	0.00	0.00
<i>Clematis virginiana</i>	devil's darning needles	woody	N	0.01	0.01	14.29

* Species identified as indicators for Ozark Highlands woodlands (Kinkead et al. 2013).

Table A1 (continued). All species observed in the woodland sites (N = 7) at Pea Ridge National Military Park, Arkansas. Values for mean cover, standard error (SE) and occurrence are for 2021 only; species with 0 values were observed in other years. N = native, I = nonnative. Tree species are not included in this table, see Table A4.

Species	Common Name	Guild	Origin	Mean Cover (%) 2021	SE	Occurrence (% Sites Observed) 2021
<i>Conyza canadensis</i>	Canadian horseweed	forb	N	0.01	0.01	28.57
<i>Cunila origanoides</i> *	common dittany	forb	N	0.59	0.32	71.43
<i>Danthonia spicata</i>	poverty oatgrass	grass	N	0.18	0.10	85.71
<i>Desmodium</i> spp.	ticktrefoil	forb	N	0.01	0.01	14.29
<i>Desmodium ciliare</i>	hairy small-leaf ticktrefoil	forb	N	0.00	0.00	0.00
<i>Desmodium dillenii</i>	Dillenius' ticktrefoil	forb	N	0.44	0.19	85.71
<i>Desmodium glutinosum</i>	pointedleaf ticktrefoil	forb	N	0.00	0.00	0.00
<i>Desmodium marilandicum</i>	smooth small-leaf ticktrefoil	forb	N	0.26	0.26	14.29
<i>Desmodium nudiflorum</i>	nakedflower ticktrefoil	forb	N	1.99	1.21	71.43
<i>Desmodium nuttallii</i>	Nuttall's ticktrefoil	forb	N	0.13	0.09	71.43
<i>Desmodium obtusum</i>	stiff ticktrefoil	forb	N	0.00	0.00	0.00
<i>Desmodium paniculatum</i>	panickedleaf ticktrefoil	forb	N	0.06	0.03	71.43
<i>Desmodium perplexum</i>	perplexed ticktrefoil	forb	N	0.00	0.00	0.00
<i>Desmodium rotundifolium</i> *	prostrate ticktrefoil	forb	N	0.13	0.06	71.43
<i>Dichanthelium</i> spp.	rosette grass	grass	N	0.41	0.18	100.00
<i>Dichanthelium boscii</i>	Bosc's panicgrass	grass	N	0.94	0.36	85.71
<i>Dioscorea villosa</i>	wild yam	forb	N	0.00	0.00	0.00
<i>Elephantopus carolinianus</i>	Carolina elephantsfoot	forb	N	0.04	0.04	14.29
<i>Elymus glabriflorus</i>	southeastern wildrye	grass	N	0.16	0.13	57.14
<i>Elymus virginicus</i>	Virginia wildrye	grass	N	0.01	0.01	14.29
<i>Eragrostis hirsuta</i>	bigtop lovegrass	grass	N	0.01	0.01	14.29
<i>Erechtites hieraciifolia</i>	American burnweed	forb	N	0.71	0.42	85.71
<i>Erigeron</i> spp.	fleabane	forb	N	0.00	0.00	0.00
<i>Erigeron annuus</i>	eastern daisy fleabane	forb	N	0.00	0.00	0.00
<i>Erigeron strigosus</i>	prairie fleabane	forb	N	0.02	0.02	14.29
<i>Euonymus fortune</i>	winter creeper	woody	I	0.01	0.01	14.29
<i>Eupatorium serotinum</i>	lateflowering thoroughwort	forb	N	0.01	0.01	14.29
<i>Euphorbia corollata</i> *	flowering spurge	forb	N	0.02	0.02	28.57
<i>Euphorbia dentata</i>	toothed spurge	forb	N	0.03	0.02	28.57
<i>Festuca subverticillata</i>	nodding fescue	grass	N	0.06	0.06	28.57
<i>Fleischmannia incarnata</i>	pink thoroughwort	forb	N	0.06	0.04	28.57
<i>Fraxinus</i> spp.	ash	woody	N	0.00	0.00	0.00
<i>Galactia regularis</i>	eastern milkpea	forb	N	0.08	0.06	42.86
<i>Galium aparine</i>	stickywilly	forb	N	0.00	0.00	0.00
<i>Galium arkansanum</i>	Arkansas bedstraw	forb	N	0.01	0.01	14.29
<i>Galium circaeazans</i>	licorice bedstraw	forb	N	0.16	0.06	85.71
<i>Galium pilosum</i>	hairy bedstraw	forb	N	0.01	0.01	14.29
<i>Geum canadense</i>	white avens	forb	N	0.06	0.03	57.14
<i>Geum vernum</i>	spring avens	forb	N	0.00	0.00	0.00

* Species identified as indicators for Ozark Highlands woodlands (Kinkead et al. 2013).

Table A1 (continued). All species observed in the woodland sites (N = 7) at Pea Ridge National Military Park, Arkansas. Values for mean cover, standard error (SE) and occurrence are for 2021 only; species with 0 values were observed in other years. N = native, I = nonnative. Tree species are not included in this table, see Table A4.

Species	Common Name	Guild	Origin	Mean Cover (%) 2021	SE	Occurrence (% Sites Observed) 2021
<i>Hackelia virginiana</i>	beggarslice	forb	N	0.08	0.06	42.86
<i>Hieracium gronovii</i>	queendevil	forb	N	0.04	0.02	42.86
<i>Houstonia longifolia</i>	longleaf summer bluet	forb	N	0.01	0.01	14.29
<i>Houstonia purpurea</i>	Venus' pride	forb	N	0.01	0.01	14.29
<i>Hypericum</i> spp.	St. Johnswort	forb	N	0.00	0.00	0.00
<i>Hypericum hypericoides</i>	St. Andrew's cross	forb	N	0.06	0.03	42.86
<i>Ipomoea pandurata</i>	man of the earth	forb	N	0.01	0.01	14.29
<i>Juncus tenuis</i>	poverty rush	grass-like	N	0.01	0.01	14.29
<i>Krigia biflora</i>	twoflower dwarf dandelion	forb	N	0.02	0.02	28.57
<i>Lactuca canadensis</i>	Canada lettuce	forb	N	0.01	0.01	28.57
<i>Lactuca floridana</i>	woodland lettuce	forb	N	0.01	0.01	14.29
<i>Lactuca serriola</i>	Prickly lettuce	forb	I	0.01	0.01	28.57
<i>Laportea canadensis</i>	Canadian woodnettle	forb	N	0.00	0.00	0.00
<i>Leersia virginica</i>	whitegrass	grass	N	0.44	0.44	14.29
<i>Lespedeza</i> spp. *	lespedeza	forb	N	0.00	0.00	0.00
<i>Lespedeza procumbens</i> *	trailing lespedeza	forb	N	0.26	0.06	100.00
<i>Lespedeza repens</i>	creeping lespedeza	forb	N	0.02	0.02	28.57
<i>Lespedeza violacea</i> *	violet lespedeza	forb	N	0.05	0.02	57.14
<i>Lespedeza virginica</i> *	slender lespedeza	forb	N	0.08	0.04	71.43
<i>Lindera benzoin</i>	northern spicebush	woody	N	0.70	0.69	28.57
<i>Lobelia inflata</i>	Indian-tobacco	forb	N	0.01	0.01	14.29
<i>Lobelia siphilitica</i>	great blue lobelia	forb	N	0.01	0.01	14.29
<i>Lonicera japonica</i>	Japanese honeysuckle	woody	I	0.01	0.01	14.29
<i>Lysimachia lanceolata</i>	lanceleaf loosestrife	forb	N	0.02	0.02	28.57
<i>Maianthemum racemosum</i> ssp. <i>racemosum</i>	feathery false lily of the valley	forb	N	0.01	0.01	14.29
<i>Matelea decipiens</i>	oldfield milkvine	forb	N	0.00	0.00	0.00
<i>Melilotus officinalis</i>	Yellow sweetclover	forb	I	0.01	0.01	14.29
<i>Menispermum canadense</i>	common moonseed	woody	N	0.00	0.00	0.00
<i>Microstegium vimineum</i>	Nepalese browntop	grass	I	0.77	0.67	42.86
<i>Mimosa nuttallii</i>	Sensitive brier	forb	N	0.00	0.00	0.00
<i>Monarda bradburiana</i> *	eastern beebalm	forb	N	0.21	0.22	14.29
<i>Monarda fistulosa</i>	wild bergamot	forb	N	0.00	0.00	0.00
<i>Muhlenbergia sobolifera</i>	rock muhly	grass	N	0.36	0.19	57.14
<i>Orbexilum pedunculatum</i> *	Sampson's snakeroot	forb	N	0.01	0.01	14.29
<i>Oxalis</i> spp.	woodsorrel	forb	N	0.04	0.02	42.86
<i>Panicum anceps</i>	beaked panicgrass	grass	N	0.05	0.04	28.57
<i>Parietaria pensylvanica</i>	Pennsylvania pellitory	forb	N	0.03	0.02	28.57
<i>Parthenocissus quinquefolia</i>	Virginia creeper	woody	N	0.57	0.11	100.00

* Species identified as indicators for Ozark Highlands woodlands (Kinkead et al. 2013).

Table A1 (continued). All species observed in the woodland sites (N = 7) at Pea Ridge National Military Park, Arkansas. Values for mean cover, standard error (SE) and occurrence are for 2021 only; species with 0 values were observed in other years. N = native, I = nonnative. Tree species are not included in this table, see Table A4.

Species	Common Name	Guild	Origin	Mean Cover (%) 2021	SE	Occurrence (% Sites Observed) 2021
<i>Paspalum laeve</i>	field paspalum	grass	N	0.00	0.00	0.00
<i>Passiflora lutea</i>	yellow passionflower	forb	N	0.01	0.01	14.29
<i>Penstemon digitalis</i>	talus slope penstemon	forb	N	0.06	0.06	14.29
<i>Perilla frutescens</i>	beefsteakplant	forb	I	0.04	0.04	14.29
<i>Phegopteris hexagonoptera</i>	broad beechfern	fern	N	0.00	0.00	0.00
<i>Phryma leptostachya</i>	American lopseed	forb	N	0.16	0.06	85.71
<i>Physalis heterophylla</i>	clammy groundcherry	forb	N	0.01	0.01	14.29
<i>Physalis pumila</i>	dwarf groundcherry	forb	N	0.00	0.00	0.00
<i>Physalis virginiana</i>	Virginia groundcherry	forb	N	0.01	0.01	28.57
<i>Phytolacca americana</i>	American pokeweed	forb	N	0.00	0.00	0.00
<i>Poa sylvestris</i>	woodland bluegrass	grass	N	0.01	0.01	14.29
<i>Polygonum cespitosum</i>	Oriental lady's thumb	forb	I	0.05	0.04	28.57
<i>Polystichum acrostichoides</i>	Christmas fern	fern	N	0.89	0.68	42.86
<i>Potentilla simplex</i>	common cinquefoil	forb	N	0.01	0.02	14.29
<i>Prunus americana</i>	American plum	woody	N	0.01	0.01	28.57
<i>Pseudognaphalium obtusifolium</i> ssp. <i>obtusifolium</i>	Fragrant cudweed	forb	N	0.02	0.02	14.29
<i>Pycnanthemum tenuifolium</i> *	narrowleaf mountainmint	forb	N	0.01	0.01	14.29
<i>Ranunculus hispidus</i>	bristly buttercup	forb	N	0.03	0.02	28.57
<i>Ranunculus recurvatus</i>	blisterwort	forb	N	0.02	0.02	28.57
<i>Rhus copallinum</i>	winged sumac	woody	N	0.29	0.21	85.71
<i>Rhus glabra</i>	smooth sumac	woody	N	0.04	0.02	42.86
<i>Rosa</i> spp.	rose	woody	N	0.00	0.00	0.00
<i>Rubus</i> spp.	blackberry	woody	N	3.54	2.06	100.00
<i>Rudbeckia hirta</i>	blackeyed Susan	forb	N	0.01	0.01	28.57
<i>Ruellia humilis</i>	fringeleaf wild petunia	forb	N	0.00	0.00	0.00
<i>Ruellia pedunculata</i>	stalked wild petunia	forb	N	0.04	0.03	28.57
<i>Ruellia strepens</i>	limestone wild petunia	forb	N	0.01	0.01	14.29
<i>Sanicula</i> spp.	sanicle	forb	N	0.04	0.02	42.86
<i>Sanicula canadensis</i>	Canadian blacksnakeroot	forb	N	0.20	0.06	100.00
<i>Schizachyrium scoparium</i> *	little bluestem	grass	N	0.00	0.00	0.00
<i>Scutellaria ovata</i>	heartleaf skullcap	forb	N	0.07	0.05	28.57
<i>Setaria pumila</i>	yellow foxtail	grass	I	0.01	0.01	14.29
<i>Sisyrinchium angustifolium</i>	narrowleaf blue-eyed grass	forb	N	0.01	0.01	14.29
<i>Smilax</i> spp.	greenbrier	woody	N	0.00	0.00	0.00
<i>Smilax bona-nox</i>	saw greenbrier	woody	N	0.05	0.02	57.14
<i>Smilax tamnoides</i>	bristly greenbrier	woody	N	0.01	0.01	28.57
<i>Solanum carolinense</i>	Carolina horsenettle	forb	N	0.07	0.04	42.86
<i>Solidago</i> spp. *	goldenrod	forb	N	0.00	0.00	0.00

* Species identified as indicators for Ozark Highlands woodlands (Kinkead et al. 2013).

Table A1 (continued). All species observed in the woodland sites (N = 7) at Pea Ridge National Military Park, Arkansas. Values for mean cover, standard error (SE) and occurrence are for 2021 only; species with 0 values were observed in other years. N = native, I = nonnative. Tree species are not included in this table, see Table A4.

Species	Common Name	Guild	Origin	Mean Cover (%) 2021	SE	Occurrence (% Sites Observed) 2021
<i>Solidago ulmifolia</i> *	elmleaf goldenrod	forb	N	0.14	0.06	71.43
<i>Sphenopholis nitida</i>	shiny wedgescale	grass	N	0.01	0.01	14.29
<i>Stellaria media</i>	common chickweed	forb	I	0.01	0.01	14.29
<i>Stylosanthes biflora</i>	sidebeak pencilflower	forb	N	0.00	0.00	0.00
<i>Symphoricarpos orbiculatus</i>	coralberry	woody	N	0.66	0.39	100.00
<i>Symphyotrichum anomalum</i> *	Limestone heart-leaved wild aster	forb	N	0.01	0.01	28.57
<i>Symphyotrichum lateriflorum</i> var. <i>lateriflorum</i>	Goblet wild aster	forb	N	0.01	0.02	14.29
<i>Symphyotrichum patens</i> var. <i>patens</i> *	Clasping wild aster	forb	N	0.01	0.02	14.29
<i>Symphyotrichum pilosum</i> var. <i>pilosum</i>	Awl wild aster	forb	N	0.02	0.01	42.86
<i>Taraxacum officinale</i>	common dandelion	forb	I	0.01	0.01	14.29
<i>Thalictrum thalictroides</i>	rue anemone	forb	N	0.01	0.01	14.29
<i>Toxicodendron radicans</i>	eastern poison ivy	woody	N	0.03	0.02	28.57
<i>Tradescantia ohiensis</i>	bluejacket	forb	N	0.01	0.01	14.29
<i>Tridens flavus</i>	purpletop tridens	grass	N	0.03	0.02	42.86
<i>Vaccinium</i> spp.	blueberry	woody	N	0.00	0.00	0.00
<i>Vaccinium pallidum</i>	Blue Ridge blueberry	woody	N	1.04	0.97	42.86
<i>Vaccinium stamineum</i>	deerberry	woody	N	0.14	0.08	57.14
<i>Verbena urticifolia</i>	white vervain	forb	N	0.01	0.01	28.57
<i>Verbesina alternifolia</i>	wingstem	forb	N	0.00	0.00	0.00
<i>Verbesina helianthoides</i> *	gravelweed	forb	N	0.01	0.01	28.57
<i>Verbesina virginica</i>	white crownbeard	forb	N	0.06	0.06	28.57
<i>Vernonia baldwinii</i>	Baldwin's ironweed	forb	N	0.01	0.01	14.29
<i>Viburnum rufidulum</i>	rusty blackhaw	woody	N	0.14	0.04	100.00
<i>Viola</i> spp.	violet	forb	N	0.04	0.02	42.86
<i>Viola tricolor</i>	johnny jumpup	forb	I	0.01	0.01	14.29
<i>Viola triloba</i>	three-lobed violet	forb	N	0.21	0.07	100.00
<i>Vitis</i> spp.	grape	vine	N	0.00	0.00	0.00
<i>Vitis aestivalis</i>	summer grape	vine	N	0.20	0.05	100.00
<i>Vitis vulpina</i>	frost grape	vine	N	0.27	0.12	57.14
<i>Woodsia obtusa</i>	bluntlobe cliff fern	fern	N	0.05	0.04	28.57

* Species identified as indicators for Ozark Highlands woodlands (Kinkead et al. 2013).

Most species of sedges (*Carex*) and rosette grasses (*Dichanthelium*) have been lumped to genus because the species are challenging to distinguish in the field. The expert botanist that assisted with monitoring in 2021 was able to identify these species. We made note of them and created a rough tally of these observations. This list can be used to update or validate park species lists or for future project needs. Table A2 lists species found specifically in the monitoring subplots, while A3 lists additional species in the sites but outside of the subplots. Table A4 shows tree species observed and occurrence rates within monitoring sites in 2021.

Table A2. Species observed in monitoring subplots in 2021 that were typically lumped to genus level for consistent identification.

Species	Proportion of 7 Sites Observed (%)	Number of Plots Observed (of 700)
<i>Carex albicans</i>	14.3	6
<i>Carex blanda</i>	28.6	2
<i>Carex cephalophora</i>	14.3	2
<i>Carex digitalis</i>	14.3	3
<i>Carex festucacea</i> *	14.3	2
<i>Carex hirsutella</i>	85.7	22
<i>Carex muehlenbergii</i>	57.1	18
<i>Carex nigromarginata</i> *	28.6	2
<i>Carex retroflexa</i>	42.9	6
<i>Carex umbellata</i>	71.4	24
<i>Dichanthelium dichotomum</i>	28.6	10
<i>Dichanthelium acuminatum</i> (var. <i>lanuginosum</i>)	14.3	1
<i>Dichanthelium laxiflorum</i>	28.6	2
<i>Dichanthelium linearifolium</i>	42.9	3
<i>Dichanthelium linearifolium</i> var. <i>wernerii</i>	14.3	4
<i>Dichanthelium sphaerocarpon</i>	28.6	2
<i>Dichanthelium villosissimum</i> *	14.3	1
<i>Dichanthelium acuminatum</i> (var. <i>implicatum</i>)	14.3	1
<i>Oxalis dillenii</i>	28.6	4

* Species not previously indicated for Benton County or Pea Ridge National Military Park on available maps.

Table A3. Species observed within monitoring sites in 2021, but outside of subplots.

Species	Sites Observed
<i>Carex albicans</i>	1
<i>Carex blanda</i>	2
<i>Carex digitalis</i>	3
<i>Carex muehlenbergii</i> var. <i>enervis</i>	5
<i>Carex umbellata</i>	4
<i>Dichanthelium commutatum</i> (var. <i>ashei</i>) *	1
<i>Dichanthelium acuminatum</i> (var. <i>lanuginosum</i>)	2
<i>Dichanthelium linearifolium</i> x <i>boscii</i>	1
<i>Dichanthelium sphaerocarpon</i>	3
<i>Poa sylvestris</i>	1
<i>Rubus meracrus</i>	3
<i>Rubus serissimus</i> (invasive)	1

* Species not previously recorded in NPSpecies or Heartland Network lists.

Table A4. Tree species observed and occurrence rates within monitoring sites in 2021. Species with 0 values were observed in years other than 2021.

Species	Common Name	Occurrence (% Sites Observed) 2021
<i>Acer rubrum</i>	red maple	28.57
<i>Acer saccharum</i>	sugar maple	0.00
<i>Aesculus glabra</i>	Ohio buckeye	14.29
<i>Amelanchier arborea</i>	common serviceberry	14.29
<i>Carya cordiformis</i>	bitternut hickory	0.00
<i>Carya glabra</i>	pignut hickory	0.00
<i>Carya texana</i>	black hickory	28.57
<i>Carya tomentosa</i>	mockernut hickory	57.14
<i>Castanea pumila</i> var. <i>ozarkensis</i>	Ozark chinquapin	0.00
<i>Celtis occidentalis</i>	common hackberry	14.29
<i>Cornus florida</i>	flowering dogwood	71.43
<i>Diospyros virginiana</i>	common persimmon	28.57
<i>Fraxinus americana</i>	white ash	14.29
<i>Juglans nigra</i>	black walnut	28.57
<i>Juniperus virginiana</i>	eastern redcedar	28.57
<i>Morus rubra</i>	red mulberry	14.29
<i>Nyssa sylvatica</i>	blackgum	71.43
<i>Quercus alba</i>	white oak	85.71
<i>Quercus marilandica</i>	blackjack oak	14.29
<i>Quercus rubra</i>	northern red oak	14.29
<i>Quercus stellata</i>	post oak	85.71
<i>Quercus velutina</i>	black oak	100.00
<i>Sassafras albidum</i>	sassafras	28.57
<i>Ulmus alata</i>	winged elm	42.86
<i>Ulmus americana</i>	American elm	28.57
<i>Ulmus rubra</i>	slippery elm	28.57

Appendix B. Site Photos

We compared site transect photos from monitoring events at Pea Ridge National Military Park in 2012 to those from 2021 to provide context for monitoring results (Figures B1–B6). Photos for 2007 and 2016 were not available. Photos in 2012 were taken on July 16–18 and Photos in 2021 were taken on July 12–16. Yellow dots indicate a reference point in each pair of photographs.



Figure B1. Site 11 transect ASAF in 2012 (left) and in 2021 (right).



Figure B2. Site 09 transect ASAF in 2012 (left) and in 2021 (right).



Figure B3. Site 12 Transect ASAF in 2012 (left) and in 2021 (right).



Figure B4. Site 15 Transect ASAF in 2012 (left) and in 2021 (right).



Figure B5. Site 15 Transect BSBF in 2012 (left) and in 2021 (right).



Figure B6. Site 13 Transect BSBF in 2012 (left) and in 2021 (right).

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

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National Park Service
U.S. Department of the Interior



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