



# Vegetation Community Monitoring at Pea Ridge National Military Park, Arkansas

*2007–2016*

Natural Resource Report NPS/HTLN/NRR—2018/1614



**ON THE COVER**

Pea Ridge National Military Park monitoring plot in 2007.

Photography by NPS (Heartland Inventory and Monitoring Network)

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# Vegetation Community Monitoring at Pea Ridge National Military Park, Arkansas

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# Abstract

Resource managers at Pea Ridge National Military Park manage the park natural communities to interpret 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. Main priorities for restoration were density, form, and vegetation structure, but native representative species were also desired. Heartland Inventory and Monitoring Network ecologists observed plant community sites in park woodlands in 2007, 2012, and 2016. Overstory density was similar through time except density of small trees (class 1) was greater in 2012 and 2016. The woodland overstory retained a relatively closed canopy and oak dominance though mesic species increased. Tree seedlings and large saplings were dominated by oaks, but small saplings had a more diverse composition, indicating the potential for future changes in the overstory composition. The herbaceous community is sparsely vegetated. Diversity values have varied each year with an observed drop in 2012 followed by recovery in 2016. Woody species cover increased the most among understory guilds. Fire monitoring objectives have not yet been met based on our monitoring site data, but not all burns have been completed.

# Acknowledgments

I would like to acknowledge the contributions of previous team members, K. James and K. Mlekush, who collected and processed much of these data. Some basic language from the previous report by K. James was utilized in this manuscript. The Introduction and Methods in particular are based on James et al. 2009 and James 2008.

# Introduction

Natural resource managers at Pea Ridge National Military Park aim to provide a backdrop for the interpretation of the Battle of Pea Ridge that occurred on March 7-8, 1862 by restoring the landscape to represent vegetation communities present at that time. 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 historic 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. Historic studies in conjunction with current monitoring data serve as a guide for community maintenance and restoration. Managers use prescribed fire as well as other tools and techniques for plant community restoration. 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.”*

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 forested community is oak-hickory and Heartland Inventory and Monitoring 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

**Table 1.** Crosswalk of Heartland Inventory and Monitoring Network vegetation sites, vegetation map community types including the National Vegetation Classification System common name (Diamond et al. 2013), historic landscape classification (NPS 2014 Appendix B), and burn units (historical name and current unit number; A. Collins *personal communication* October 23, 2017) at Pea Ridge National Military Park.

| HTLN Site | Vegetation Map Community Type (NVC Common Name)                                                              | Historic 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 11        | 2008, 2013                    |
| 9         | Typic Upland deciduous woodland and forest (Black Oak-White Oak-Hickory Forest)                              | Dry-mesic Woodland | Huntsville East 7         | 2008, 2013                    |
| 10        | Typic Upland deciduous woodland and forest (Black Oak-White Oak-Hickory Forest)                              | Dry-mesic Forest   | Williams Hollow 11        | 2008, 2013                    |
| 11        | Dry deciduous woodland and forest (Ozark/Ouachita Post Oak-Blackjack Oak-Black Oak/Little Bluestem Woodland) | Dry Open Woodland  | Horsetrail South 8        | 2014                          |
| 12        | Dry deciduous woodland and forest (Ozark/Ouachita Post Oak-Blackjack Oak-Black Oak/Little Bluestem Woodland) | Dry Open Woodland  | Horsetrail South 8        | 2014                          |
| 13        | Typic Upland deciduous woodland and forest (Black Oak-White Oak-Hickory Forest)                              | Dry-mesic Forest   | North Central Boundary 11 | 2008, 2012                    |
| 15        | Typic Upland deciduous woodland and forest (Black Oak-White Oak-Hickory Forest)                              | Dry-mesic Forest   | North Central Boundary 11 | 2008, 2012                    |

forest types. The 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).

Although the vegetation management plan for the park generally prescribes an open 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 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 Pea Ridge National Military 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 (see Figure 1 for burn unit locations and Figure 2 for current vegetation communities). All of the permanent monitoring plots were burned at least once over the monitoring record 2007-2016, and most were burned twice (A. Collins, NPS *Personal Communication* October 23, 2017). However, it was predicted that four burns would be necessary to meet objectives. Monitoring the woodland vegetation communities (Table 1) is a critical component

of the restoration process providing insights into the progress of management efforts.

The NPS Ozark fire ecology program monitors an additional 12 sites. Monitoring objectives for the fire effects program include (1) reduction of mean density of pole-size trees (2.5-15 cm DBH) by 50-70% after 4 burns, (2) increased mean density of oak seedlings and/or resprouts by 300-500% after four burns in oak-hickory forest/woodlands and (3) increased mean percent cover of native herbaceous species by 60-100% after four burns in post oak-blackjack oak savannah/woodlands (Drees 2017). The reference condition was measured prior to initiation of burns (pre-burn), circa 2003, but we referenced the objectives for the period of our monitoring results.

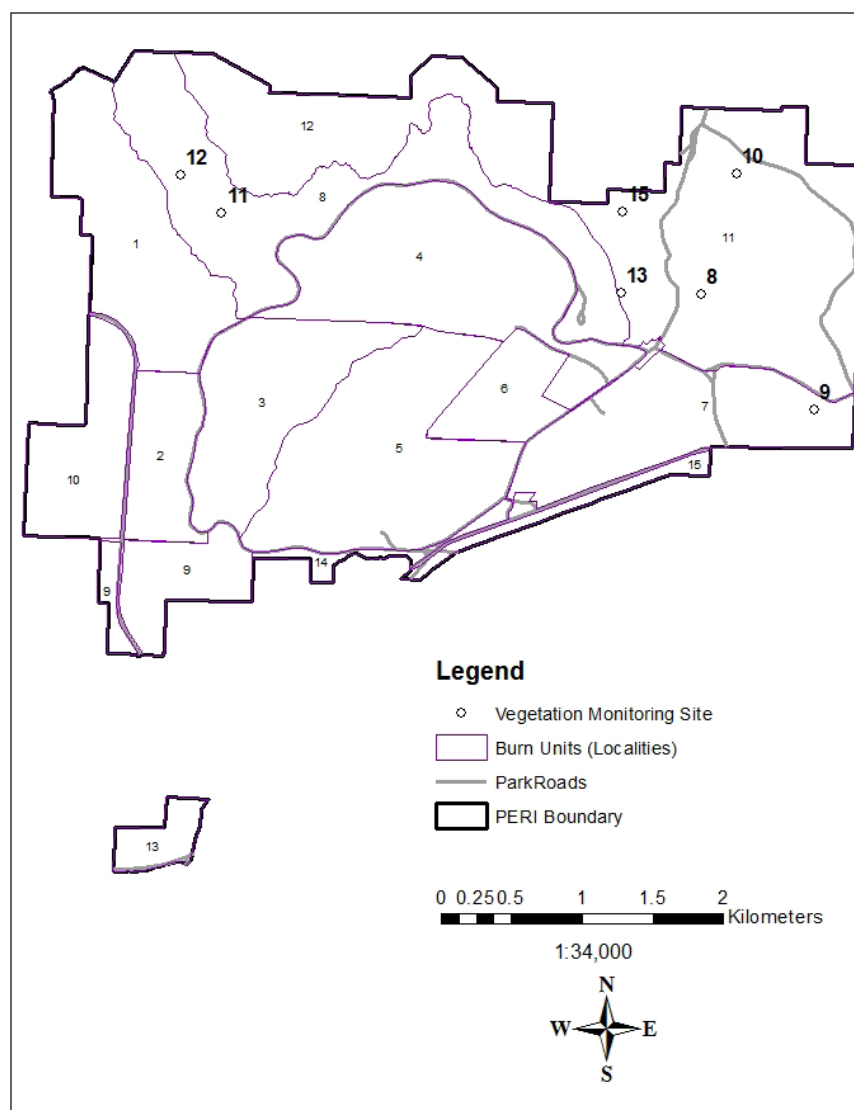


**Figure 1.** Map of burn units with respect to Heartland vegetation monitoring sites at Pea Ridge National Military Park.

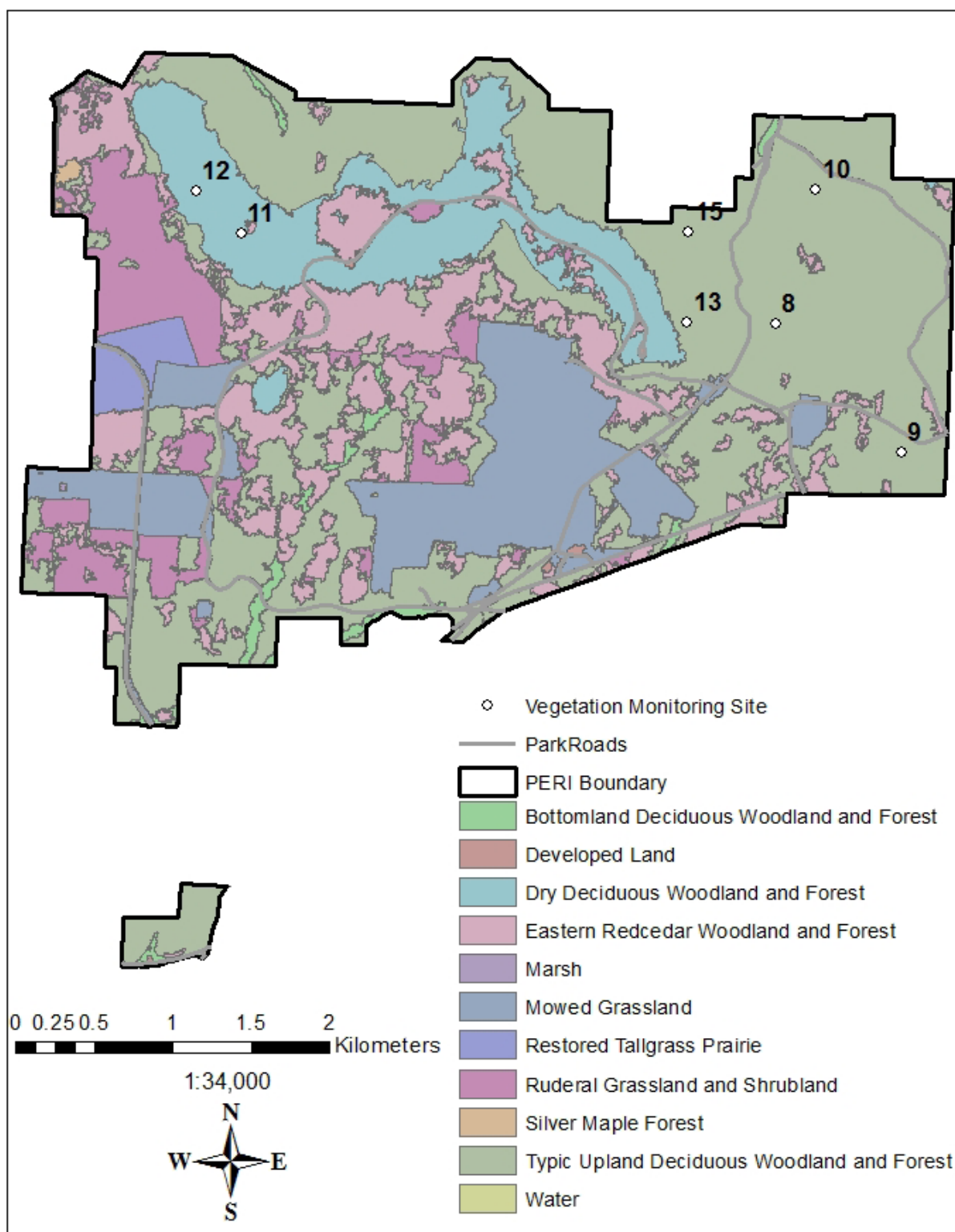


**Figure 2.** Map of extant vegetation communities at Pea Ridge National Military Park (Diamond et al. 2013) including locations of Heartland Inventory and Monitoring sites.

# Methods

The Heartland Inventory and Monitoring 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 m x 20 m (0.1 ha) in size with two focal transects bounding the site on the 50-m sides (Figure 3). For this protocol, overstory tree data were collected within the entire 0.1 ha area, while all other metrics were collected within 10 plots located along the site boundaries. Each plot consisted of a series of nested plots (0.01 m<sup>2</sup>, 0.1 m<sup>2</sup>, 1 m<sup>2</sup>, and 10 m<sup>2</sup>), but observations were only analyzed at the 10-m<sup>2</sup> scale for this study. Woodland monitoring consisted of a suite of sampling methods for characterizing overstory tree composition, canopy cover, regeneration, understory herbaceous species composition, and ground cover.

All site means were calculated based on 10 plots for each year (2007, 2012, 2016) with the exception of herbaceous species data at two sites in 2016 (2016: site 9, n = 5 plots and site 12, n = 9 plots, all other sites n = 10) with missing cover data.

## Data Summary

Sites were pooled 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).

## Precipitation

Precipitation was summarized by calendar year using station USW00053922 at the Fayetteville regional airport. A long-term normal was also obtained using the same station (<https://www.ncdc.noaa.gov> accessed October 16, 2017; Menne et.al. 2012a, 2012b).

## Forest overstory

Overstory tree composition in the forest was based on individual tree counts for each species and diameter at breast height (DBH) for each tree > 5.0 cm DBH in the 0.1 ha site. Snags were calculated separately from live trees for overstory analysis. Basal area and stem density were calculated within size class categories (Table 2) as described in James et al. (2009). Taken together, all tree metrics were used to describe the forest composition and structure for the park focus area.

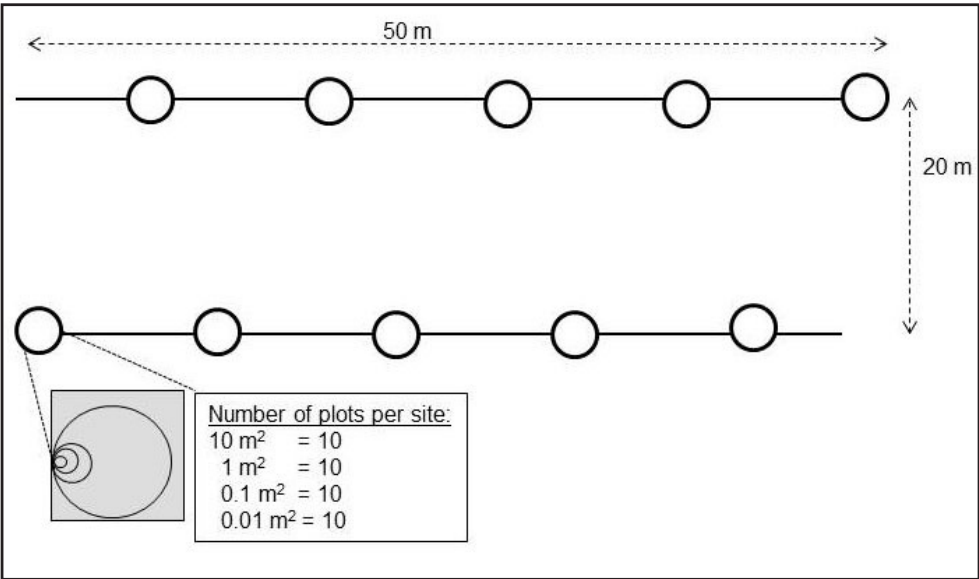


**Figure 3.** Plant community site monitoring design for Heartland Inventory and Monitoring Network parks.

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

| DBH (cm)    | Size Class |
|-------------|------------|
| 5.0 - 14.9  | 1          |
| 15.0 - 24.9 | 2          |
| 25.0 - 34.9 | 3          |
| 35.0 - 44.9 | 4          |
| ≥ 45        | 5          |

Canopy cover data were collected using a densitometer. Densitometer readings were collected in the four cardinal directions in each of the ten 10-m<sup>2</sup> plots and converted to canopy cover (multiplying by 1.04). Plot level mean canopy cover (n = 4 per plot) was used to calculate size level mean canopy cover. A grand mean was then calculated for all sites (n = 7). Change was calculated using the following formula:

$$\frac{2016 \text{ BA} - 2007 \text{ BA}}{2007 \text{ BA}} \times 100$$

### Forest understory

#### Regeneration

The regeneration layer was tallied by species in the ten 10-m<sup>2</sup> plots and reported in three size classes: (1) seedlings = stems < 0.5 m tall; (2) small saplings = stems ≥ 0.5 m tall and DBH < 2.5 cm; and (3) large saplings = stems ≥ 0.5 m tall and DBH > 2.5 cm and < 5.0 cm. Summary was done by pooling species to look at total stems/ha and by calculating stems/ha for each individual species. In both cases, mean stems/site (n = 10) was calculated, values were scaled to stems/ha and then a park level mean was calculated (n=7).

#### Understory species diversity indices

Diversity indices describe the number of species and their abundances (based on foliar cover measurements) and can be compared across monitoring sites in the park. Mean site cover for all non-tree species was calculated using all plots within each site (n = 10 with the exception of two sites in 2016 where n = 5, n = 9). For each site within the community, species richness (S) along with the effective number of species derived from Shannon diversity index (Shannon number,  $H_e$ ) and Simpson's diversity index (Simpson's number,  $D_e$ ) were calculated. S represents the number of species observed.  $H_e$  represents a

measure of diversity, while  $D_e$  describes dominance within the community. PC-ORD (version 7.02) was used to calculate these diversity indices (IBM 2016, McCune and Mefford 2016). Diversity indices were then converted to effective number of species and a grand mean was then calculated for all sites (n = 7).

Initial 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 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:

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

where  $p_i$  is the relative cover of species i (modified from Simpson 1949)

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.

These metrics express the degree of evenness or dominance in a community. All species are equally abundant when  $S = H_e = D_e$ . The degree to which effective number of species is less than S, represents the variability among species abundances within the

community. See Jost (2006) and McCune and Grace (2002) for a further explanation and implementation of species diversity measures, respectively. Generally, we expect species richness values to be greater than effective number of species for diversity and dominance as many plant communities have a matrix of common (dominant) species and a suite of rare species.

#### Understory community diversity metrics

Community richness metrics evaluate how species richness differs across study sites and the park. We limited these calculations to understory herbaceous species. Alpha diversity is synonymous with species richness at the site-scale (i.e., mean number of species per monitoring site). This is equivalent to species richness used to calculate the diversity measures described previously. Gamma diversity is the park richness (i.e., total number of species in the park) observed across all our monitoring sites. Beta diversity is a measure of variation in species richness across monitoring sites such that small values (near 0) indicate a high degree of similarity in richness across monitoring sites and greater values (>5) indicate a higher degree of variation in species between sites (more differentiated communities; McCune and Grace 2002).

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

#### Understory guild abundance

Understory species were also summarized by guilds, aka functional groups (designations per the USDA Plants database; James et al. 2009; USDA 2017). Guild assignments were grasses, forbs, sedges/rushes, ferns and woody species. A complete species list along with guild assignment is provided in Appendix A. Mean cover values were calculated for each guild-site-year combination. A grand mean was then calculated across all sites (n = 7).

#### Ground cover

Ground cover was assessed using cover classes (Table 2). A site mean was calculated by averaging the cover class midpoints for plots (n = 10) in each site. We observed areal cover of grass litter, leaf litter (woody plant leaves), rock (exposed rock), bare ground (soil), and the cover of woody debris (e.g. branches and sticks). Total unvegetated area reflects space unoccupied by stem basal areas in the plots (James et al. 2009).

# Results

## Precipitation

Precipitation for the monitoring period included an equal number of years above and below the 30-year normal. However, all the years in which monitoring occurred were below normal (Figure 4).

## Overstory

### Canopy Cover

The canopy at Pea Ridge National Military Park is relatively closed (Figure 5). Canopy cover was similar

in 2007 and 2012 monitoring visits, but increased slightly in 2016 to 96.6%. The vegetation community types of our 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 the expected range (Figure 5).

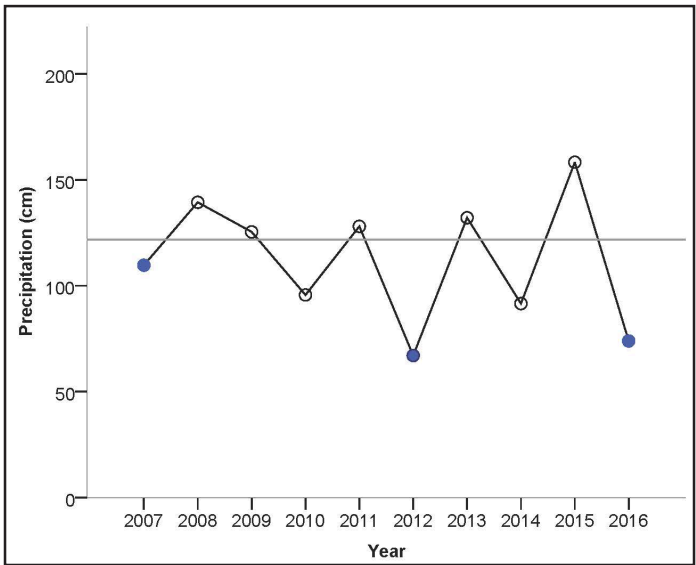


**Figure 4.** Annual precipitation (cm) for Fayetteville, Arkansas Northwest Arkansas Regional Airport, 26 miles southwest of Pea Ridge National Military Park. The gray bar indicates the 30-year normal and the annual data points that are solid blue are years in which monitoring took place (2007, 2012, and 2016).

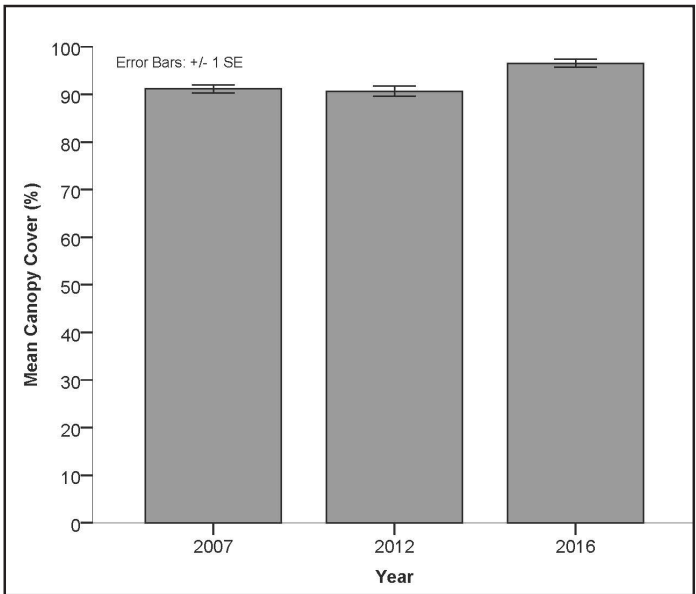


**Figure 5.** Mean percent canopy cover for seven monitoring sites across three sampling events at Pea Ridge National Military Park.

### Basal area and stem density

Basal area and density increased for small trees (class 1). Density of class 1 trees increased by 306% between 2007 and 2016. Basal area also increased for large trees (class 5), but density was similar over time. (Figure 6, 7). Hickories as a group increased in density but decreased in basal area over time. Oaks in 2016 were similar to 2007 for both basal area and density (Table 3, 4).

Oak and hickory species dominated the overstory basal area through the monitoring period (oak: 75%,

70%, and 71% for 2007, 2012, and 2017 respectively; hickory: 3% each year). The greatest absolute change in species basal area from 2007 baseline values was an increase in white ash (*Fraxinus americana*; Table 3). Red maple (*Acer rubrum*) and black oak (*Quercus velutina*) also had more basal area in 2016 than in 2007. White oak (*Q. alba*) blackjack oak (*Q. marilandica*) and red oak (*Q. rubra*) declined by 2016. Noteworthy declines were seen in elm (*Ulmus* spp.), Ozark chinquapin, and pignut hickory (*Carya glabra*). Elm may have declined because of a shift to more specific identification in subsequent years.

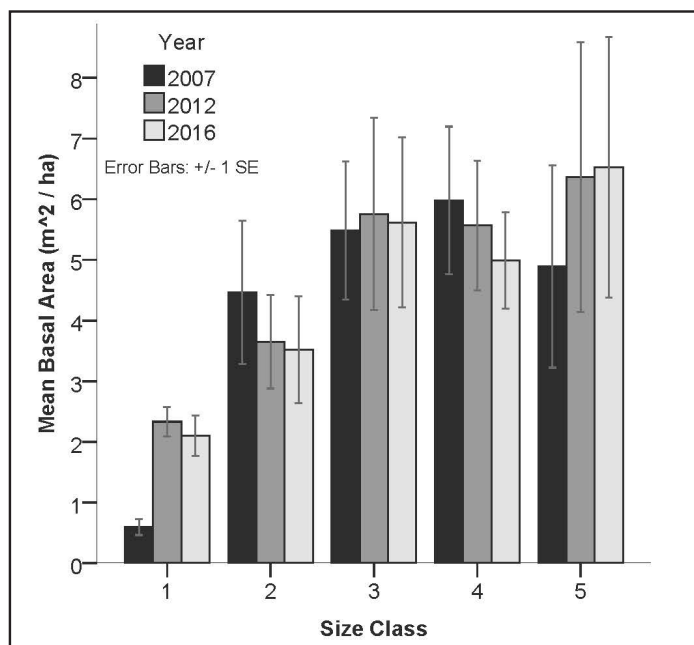


**Figure 6.** Mean basal area (m²/ha, n = 7) of live trees at Pea Ridge National Military Park by size class and year. Size classes are as follows: 1 = 5-14.9 cm; 2 = 15-24.9 cm; 3 = 25-34.9 cm; 4 = 35-44.9 cm, 5 = 45+ cm.

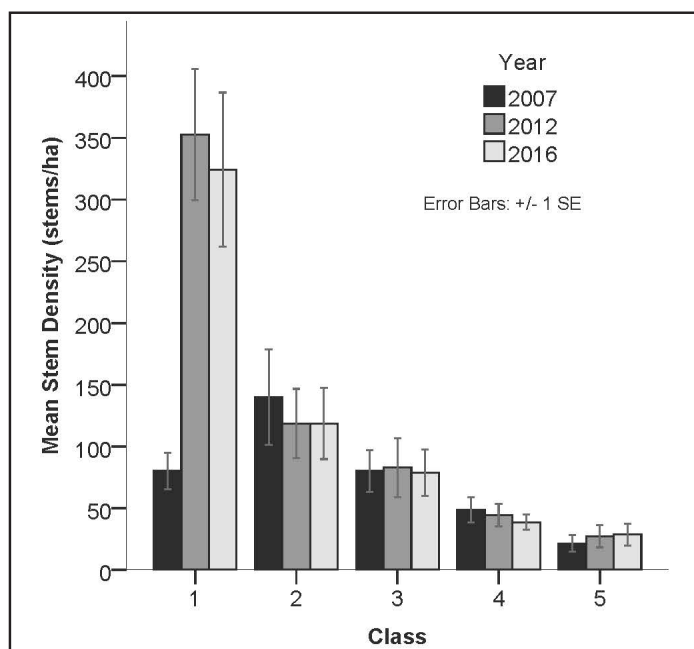


**Figure 7.** Mean stem density (stems/ha, n = 7) of live trees by size class at Pea Ridge National Military Park 2007-2016. Size classes are as follows: 1 = 5-14.9 cm; 2 = 15-24.9 cm; 3 = 25-34.9 cm; 4 = 35-44.9 cm, 5 = 45+ cm.

**Table 3.** Overstory species mean basal area (m<sup>2</sup>/ha, n = 7) and change between 2007 and 2016; observations are for all size classes combined. Negative values indicate less basal area in 2016. SE± 1 standard error.

| Species                                       | 2007                     |       | 2012                    |      | 2016                    |      | % Change<br>2016 - 2007   |
|-----------------------------------------------|--------------------------|-------|-------------------------|------|-------------------------|------|---------------------------|
|                                               | Mean                     | SE    | Mean                    | SE   | Mean                    | SE   |                           |
| <i>Acer rubrum</i>                            | 0.004                    | 0.004 | 0.10                    | 0.1  | 0.1                     | 0.1  | 1155.6                    |
| <i>Acer saccharum</i>                         | 0.0                      | –     | 0.0                     | –    | 0.02                    | 0.04 | –                         |
| <i>Aesculus glabra</i>                        | 0.0                      | 0.22  | 0.0                     | –    | 0.004                   | 0.01 | –                         |
| <i>Carya combined</i>                         | 3.04                     | 0.1   | 3.1                     | 0.1  | 2.5                     | 0.1  | -19.1                     |
| <i>Castanea pumila</i> var. <i>ozarkensis</i> | 0.01                     | 0.01  | 0.0                     | –    | 0.0                     | 0.0  | -100.0                    |
| <i>Celtis occidentalis</i>                    | 0.0                      | –     | 0.01                    | 0.02 | 0.0                     | 0.02 | –                         |
| <i>Cornus florida</i>                         | 0.4                      | 0.2   | 0.9                     | 0.9  | 0.8                     | 0.8  | 139.1                     |
| <i>Diospyros virginiana</i>                   | 0.5                      | 0.6   | 0.4                     | 1.0  | 0.03                    | 0.1  | -93.7                     |
| <i>Fraxinus americana</i>                     | 0.01                     | 0.01  | 0.4                     | 1.0  | 0.4                     | 1.4  | <b>5893.3<sup>b</sup></b> |
| <i>Juglans nigra</i>                          | 0.1                      | 0.1   | 0.2                     | 0.3  | 0.2                     | 0.3  | 30.1                      |
| <i>Juniperus virginiana</i>                   | 0.6                      | 0.4   | 0.7                     | 1.2  | 0.7                     | 1.4  | 33.1                      |
| <i>Morus rubra</i>                            | 0.0                      | –     | 0.04                    | 0.12 | 0.1                     | 0.1  | –                         |
| <i>Nyssa sylvatica</i>                        | 0.5                      | 0.5   | 0.9                     | 0.9  | 1.3                     | 2.1  | 182.0                     |
| <i>Quercus combined</i>                       | <b>16.10<sup>a</sup></b> | 0.3   | <b>16.6<sup>a</sup></b> | 0.3  | <b>16.1<sup>a</sup></b> | 0.3  | -0.2                      |
| <i>Sassafras albidum</i>                      | 0.0                      | –     | 0.04                    | 0.1  | 0.1                     | 0.1  | –                         |
| <i>Ulmus</i> spp.                             | 0.2                      | 0.2   | 0.0                     | 0.0  | 0.0                     | –    | -100.0                    |
| <i>Ulmus alata</i>                            | 0.0                      | –     | 0.1                     | 0.2  | 0.1                     | 0.2  | –                         |
| <i>Ulmus americana</i>                        | 0.0                      | –     | 0.03                    | 0.1  | 0.2                     | 0.6  | –                         |
| <i>Ulmus rubra</i>                            | 0.0                      | –     | 0.2                     | 0.5  | 0.1                     | 0.1  | –                         |

<sup>a</sup> Indicates most abundant species for a given year (also in bold).

<sup>b</sup> Indicates largest % change from 2007 to 2016 (also in bold).

**Table 4.** Overstory species mean density (stems/ha, n = 7) and change between 2007 and 2016; observations are for all size classes. Negative values indicate less basal area in 2016. SE± 1 standard error.

| Species                                       | 2007                     |      | 2012                     |      | 2016                     |      | % Change<br>2016 - 2007  |
|-----------------------------------------------|--------------------------|------|--------------------------|------|--------------------------|------|--------------------------|
|                                               | Mean                     | SE   | Mean                     | SE   | Mean                     | SE   |                          |
| <i>Acer rubrum</i>                            | 1.4                      | 1.4  | 4.3                      | 3.0  | 2.9                      | 2.9  | 99.9                     |
| <i>Acer saccharum</i>                         | 0                        | –    | 0                        | –    | 1.4                      | 1.4  | –                        |
| <i>Aesculus glabra</i>                        | 0                        | –    | 0                        | –    | 1.4                      | 1.4  | –                        |
| <i>Carya combined</i>                         | 60.0                     | 30.1 | 84.3                     | 44.6 | 80.0                     | 22.4 | 33.3                     |
| <i>Castanea pumila</i> var. <i>ozarkensis</i> | 38.6                     | 26.6 | 0                        | –    | 0                        | –    | -100.0                   |
| <i>Celtis occidentalis</i>                    | 0                        | –    | 1.4                      | 1.4  | 1.4                      | 1.4  | –                        |
| <i>Cornus florida</i>                         | 34.3                     | 16.5 | 160.0                    | 54.1 | 148.6                    | 54.1 | 333.3                    |
| <i>Diospyros virginiana</i>                   | 8.6                      | 8.6  | 7.1                      | 4.7  | 4.3                      | 3.0  | -50.0                    |
| <i>Fraxinus americana</i>                     | 1.4                      | 1.4  | 11.4                     | 11.4 | 11.4                     | 11.4 | <b>699.8<sup>b</sup></b> |
| <i>Juglans nigra</i>                          | 2.9                      | 1.8  | 2.9                      | 1.8  | 2.9                      | 1.8  | 0.0                      |
| <i>Juniperus virginiana</i>                   | 18.6                     | 14.2 | 30.0                     | 25.4 | 30.0                     | 25.4 | 61.5                     |
| <i>Morus rubra</i>                            | 0                        | –    | 2.9                      | 2.9  | 2.86                     | 2.86 | –                        |
| <i>Nyssa sylvatica</i>                        | 25.7                     | 24.1 | 55.7                     | 36.6 | 60.0                     | 36.3 | 133.3                    |
| <i>Quercus combined</i>                       | <b>208.6<sup>a</sup></b> | 50.2 | <b>231.4<sup>a</sup></b> | 50.3 | <b>207.1<sup>a</sup></b> | 25.9 | -0.7                     |
| <i>Sassafras albidum</i>                      | 0                        | –    | 8.6                      | 4.6  | 10.0                     | 5.4  | –                        |
| <i>Ulmus</i> spp.                             | 7.1                      | 5.7  | 0                        | –    | 0                        | –    | –                        |
| <i>Ulmus alata</i>                            | 0                        | –    | 14.3                     | 8.1  | 15.7                     | 8.1  | –                        |
| <i>Ulmus americana</i>                        | 0                        | –    | 1.4                      | 1.4  | 1.4                      | 1.4  | –                        |
| <i>Ulmus rubra</i>                            | 0                        | –    | 8.6                      | 5.5  | 7.1                      | 5.7  | –                        |

<sup>a</sup> Indicates most abundant species for a given year (also in bold).

<sup>b</sup> Indicates largest % change from 2007 to 2016 (also in bold).

### Snag density and basal area

Snags are important components of woodlands and forests. They are habitat for wildlife and indicators of ecosystem health. At Pea Ridge National Military

Park, we observed an increase in small snag stem basal area and density that corresponded to the increase of basal area and density of class 1 live trees (Figures 8 and 9).

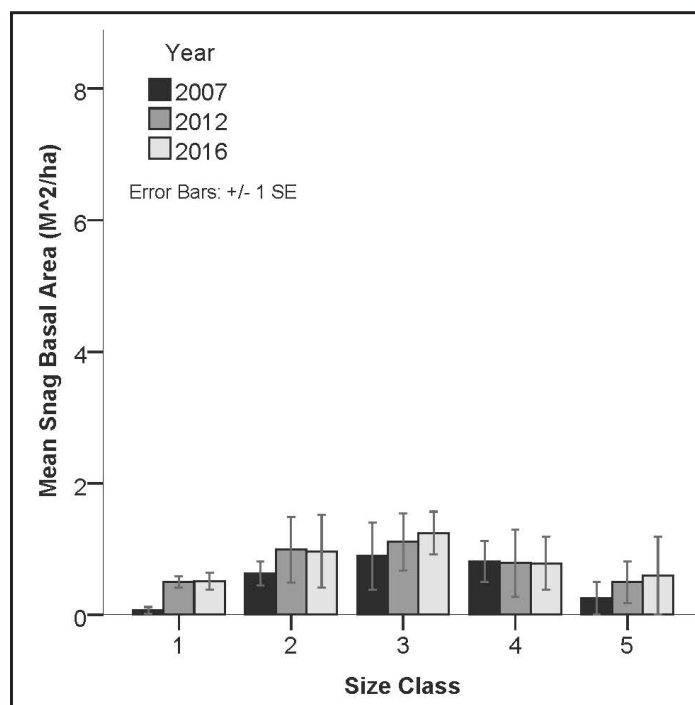


**Figure 8.** Mean basal area (m²/ha, n = 7) of snags by size class at Pea Ridge National Military Park 2007-2016. Size classes are as follows: 1 = 5-14.9 cm; 2 = 15-24.9 cm; 3 = 25-34.9 cm; 4 = 35-44.9 cm, 5 = 45+ cm.

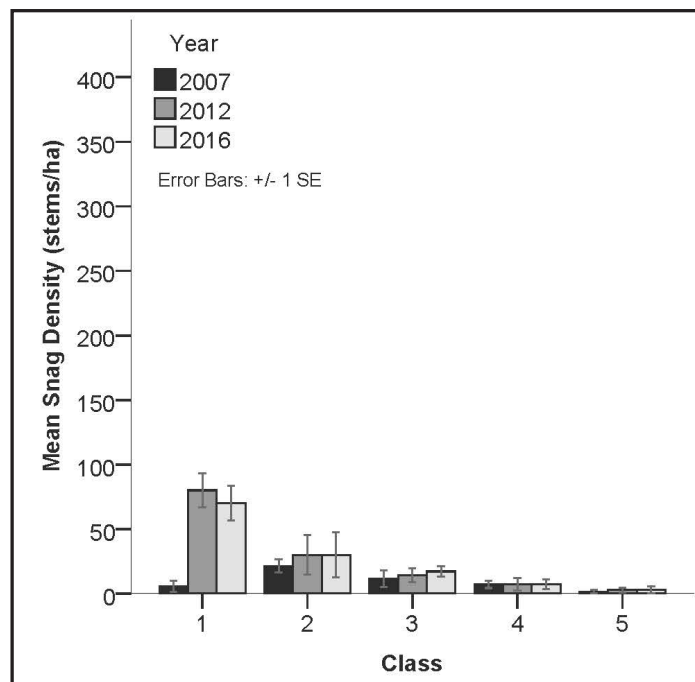


**Figure 9.** Mean density (stems/ha, n = 7) of snags by size class at Pea Ridge National Military Park 2007-2016. Size classes are as follows: 1 = 5-14.9 cm; 2 = 15-24.9 cm; 3 = 25-34.9 cm; 4 = 35-44.9 cm, 5 = 45+ cm.

# Understory

## Regeneration

Saplings and seedlings are the future of a woodland. Our observations indicated seedlings increased by 51% between 2007 and 2016. Small saplings increased by 400%, but large saplings declined by 75% during the same time period (Figure 10).

Oaks dominated the seedling class, but the greatest percentage increase in seedlings was from white ash (Table 5). Oak seedlings and saplings increased by 65% and 133% respectively over the monitoring period. This was below expected values for fire effects monitoring (Drees 2017). However, hickories and blackgum (*Nyssa sylvatica*) also recruited

a substantial percentage of seedlings as of 2016, 218% and 315% respectively. Small saplings were dominated by post oak (*Quercus stellata*) in 2007 but shifted to persimmon (*Diospyros virginiana*) and sassafras (*Sassafras albidum*) which recruited the greatest percentage of stems by 2016. The only large saplings observed in 2016 were post oaks whereas, in previous years, 2-3 species were recorded as large saplings. We did not record occurrence of northern spice bush (*Lindera benzoin*) in 2007, but it was present in the remaining years. It is possible that species that can take shrub or tree form, like northern spice bush and rusty blackhaw (*Viburnum rufidulum*), were treated differently in different years causing inconsistencies in the data.

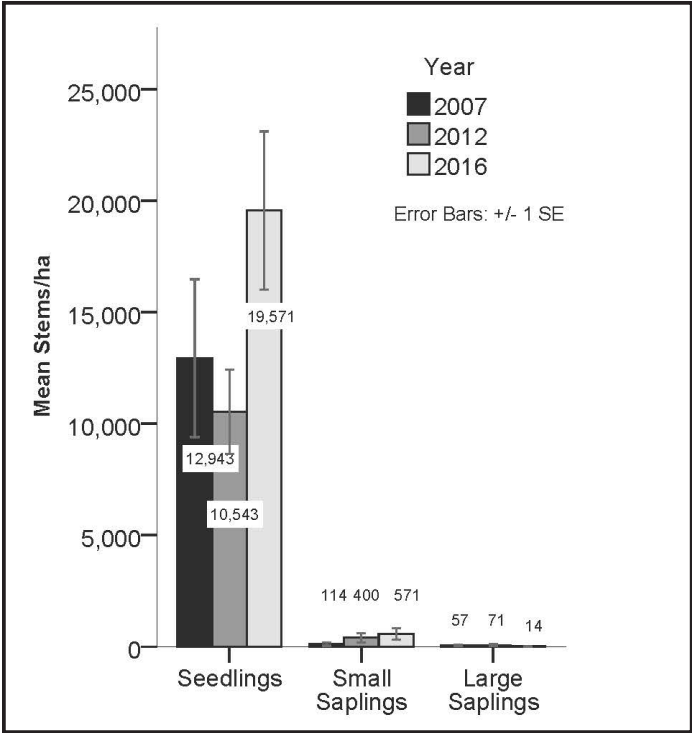


**Figure 10.** Mean number of stems ( $n = 7$ ) for tree regeneration components (mean stems/ha) of the forest monitoring sites at Pea Ridge National Military Park 2007-2016. Regeneration classes are as follows: seedlings = stems <0.5 m tall; small saplings = >0.5 m tall and <2.5 cm DBH, and large saplings = stems >0.5 m tall and 2.6-5.0 cm DBH.

**Table 5.** Regeneration density by species (mean stems/ha) in Pea Ridge National Military Park. Percent change indicates the difference in stems between 2007 and 2016, negative values indicate fewer stems in 2016.

| Species                       | Mean seedlings           |                          |                          | Mean small saplings    |                         |                         | Mean large saplings    |                        |                        | % Change<br>2016 - 2007  |                          |                   |
|-------------------------------|--------------------------|--------------------------|--------------------------|------------------------|-------------------------|-------------------------|------------------------|------------------------|------------------------|--------------------------|--------------------------|-------------------|
|                               | 2007                     | 2012                     | 2016                     | 2007                   | 2012                    | 2016                    | 2007                   | 2012                   | 2016                   | seedlings                | small<br>saplings        | large<br>saplings |
| <i>Acer rubrum</i>            | 71.4                     | 15.7                     | 38.6                     | 0                      | 0                       | 0                       | 0                      | 0                      | 0                      | -46.0                    | –                        | –                 |
| <i>Aesculus glabra</i>        | 0                        | 0                        | 0                        | 0                      | 0                       | 2.9                     | 0                      | 0                      | 0                      | –                        | –                        | –                 |
| <i>Amelanchier</i>            | 0                        | 0                        | 2.9                      | 0                      | 0                       | 0                       | 0                      | 0                      | 0                      | –                        | –                        | –                 |
| <i>Carya combined</i>         | 47.1                     | 62.9                     | 150.0                    | 0                      | 0                       | 0                       | 0                      | 0                      | 0                      | 218.2                    | –                        | –                 |
| <i>Celtis spp.</i>            | 0                        | 7.1                      | 0                        | 0                      | 0                       | 0                       | 0                      | 0                      | 0                      | –                        | –                        | –                 |
| <i>Celtis occidentalis</i>    | 47.1                     | 1.4                      | 78.6                     | 0                      | 0                       | 0                       | 0                      | 0                      | 0                      | 66.7                     | –                        | –                 |
| <i>Cercis canadensis</i>      | 5.7                      | 0                        | 7.1                      | 0                      | 0                       | 0                       | 0                      | 0                      | 0                      | 25.0                     | –                        | –                 |
| <i>Cornus florida</i>         | 210                      | 110.0                    | 282.9                    | 1.4                    | 2.9                     | 4.3                     | <b>2.9<sup>a</sup></b> | 0                      | 0                      | 34.7                     | 200.0                    | -100.0            |
| <i>Diospyros virginiana</i>   | 51.4                     | 22.9                     | 68.6                     | 1.4                    | 4.3                     | 8.6                     | 0                      | 1.4                    | 0                      | 33.3                     | 500.0                    | –                 |
| <i>Fraxinus americana</i>     | 12.9                     | 51.4                     | 85.7                     | 0                      | 0                       | 1.4                     | 0                      | 0                      | 0                      | <b>566.7<sup>b</sup></b> | –                        | –                 |
| <i>Fraxinus pennsylvanica</i> | 0                        | 0                        | 1.4                      | 0                      | 0                       | 0                       | 0                      | 0                      | 0                      | –                        | –                        | –                 |
| <i>Gleditsia triacanthos</i>  | 0                        | 0                        | 1.4                      | 0                      | 0                       | 0                       | 0                      | 0                      | 0                      | –                        | –                        | –                 |
| <i>Juniperus virginiana</i>   | 34.3                     | 20.0                     | 24.3                     | 2.9                    | 8.6                     | 4.3                     | 0                      | 0                      | 0                      | -29.7                    | 50.0                     | –                 |
| <i>Lindera benzoin</i>        | 0                        | 27.1                     | 22.9                     | 0                      | <b>14.3<sup>a</sup></b> | 7.1                     | 0                      | <b>5.7<sup>a</sup></b> | 0                      | –                        | –                        | –                 |
| <i>Morus rubra</i>            | 5.7                      | 4.3                      | 8.6                      | 0                      | 0                       | 0                       | 0                      | 0                      | 0                      | 50.0                     | –                        | –                 |
| <i>Nyssa sylvatica</i>        | 28.6                     | 10.0                     | 118.6                    | 0                      | 0                       | 1.4                     | 0                      | 0                      | 0                      | 315.0                    | –                        | –                 |
| <i>Prunus spp.</i>            | 14.3                     | 7.1                      | 4.3                      | 0                      | 0                       | 0                       | 0                      | 0                      | 0                      | -70.0                    | –                        | –                 |
| <i>Prunus serotina</i>        | 0                        | 0                        | 20.0                     | 0                      | 0                       | 0                       | 0                      | 0                      | 0                      | –                        | –                        | –                 |
| <i>Quercus combined</i>       | <b>402.9<sup>a</sup></b> | <b>437.1<sup>a</sup></b> | <b>665.7<sup>a</sup></b> | <b>4.3<sup>a</sup></b> | 2.9                     | 10.0                    | 1.4                    | 0                      | <b>1.4<sup>a</sup></b> | 65.2                     | 133.3                    | 0                 |
| <i>Sassafras albidum</i>      | 244.3                    | 72.9                     | 200.0                    | 1.4                    | 4.3                     | <b>11.4<sup>a</sup></b> | 0                      | 0                      | 0                      | -18.1                    | <b>700.0<sup>b</sup></b> | –                 |
| <i>Ulmus spp.</i>             | 118.6                    | 195.7                    | 151.4                    | 0                      | 2.9                     | 4.3                     | 0                      | 0                      | 0                      | 27.7                     | –                        | –                 |
| <i>Ulmus alata</i>            | 0                        | 0                        | 11.4                     | 0                      | 0                       | 1.4                     | 1.4                    | 0                      | 0                      | –                        | –                        | -100.0            |
| <i>Ulmus rubra</i>            | 0                        | 0                        | 11.4                     | 0                      | 0                       | 0                       | 0                      | 0                      | 0                      | –                        | –                        | –                 |
| <i>Viburnum rufidulum</i>     | 0                        | 8.6                      | 1.4                      | 0                      | 0                       | 0                       | 0                      | 0                      | 0                      | –                        | –                        | –                 |

<sup>a</sup> Indicates most abundant species for that year/category (also in bold).

<sup>b</sup> Indicates largest % change from 2007 to 2016 (also in bold).

# Herbaceous layer

## Diversity

While species richness varied over time, other measures of diversity were very similar through time at Pea Ridge National Military Park (Figure 11). We observed seven more species per site on average in 2016 than 2007 (species richness). The Shannon Index, which accounts for both richness and relative abundance, was similar through time. The effective number of species of the Shannon index indicates that this community has the equivalent diversity of a hypothetical community comprised of 10-12 equally abundant species depending on the year. Most species were rare in our observations (Simpson's Index). On average, 19-36% of species were dominant in a year. In 2012, Simpson's Index was similar to other years despite the drop in species richness resulting in a greater number of dominant species (26%, 36%, and 19% for 2007, 2012, and 2016, respectively). Only four invasive species were observed through the whole monitoring period (Table 6).

The native herbaceous community diversity metrics differed by metric (Table 7). Alpha diversity (site-scale species richness, Figure 11) and gamma diversity (park-scale species richness, Table 7) followed similar patterns. Beta diversity (variation between

sites) was low and stable through time, indicating that native herbaceous plant communities across monitoring sites were similar in terms of richness. The low beta diversity validates our decision to combine vegetation communities into a single analysis.

## Guilds

Patterns of guild abundance help describe plant communities. Similar to the 2012 decline in litter cover, we observed a temporary decline in forbs, grasses, and grass-like plants in 2012. Woody plants, however, appeared to increase in 2016 (Figure 12).

## Ground Cover

Ground cover measurements were largely similar through time. In 2012 there was a temporary decline in deciduous leaf litter accompanied by an increase in bare ground. High amounts of unvegetated cover through time indicated a sparse understory community (Figure 13). Plant communities found at the park have been described as having highly variable herbaceous cover but our data are relatively consistent across monitoring events (Diamond et.al. 2013).

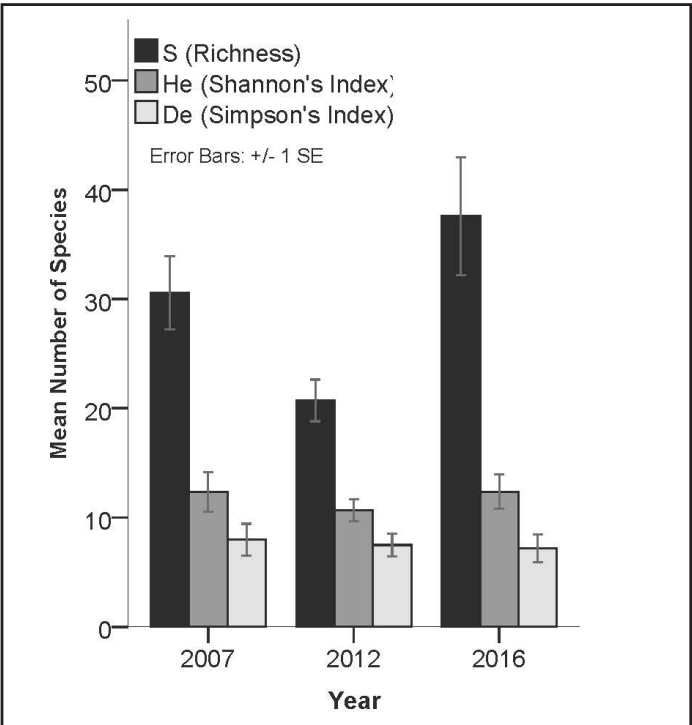


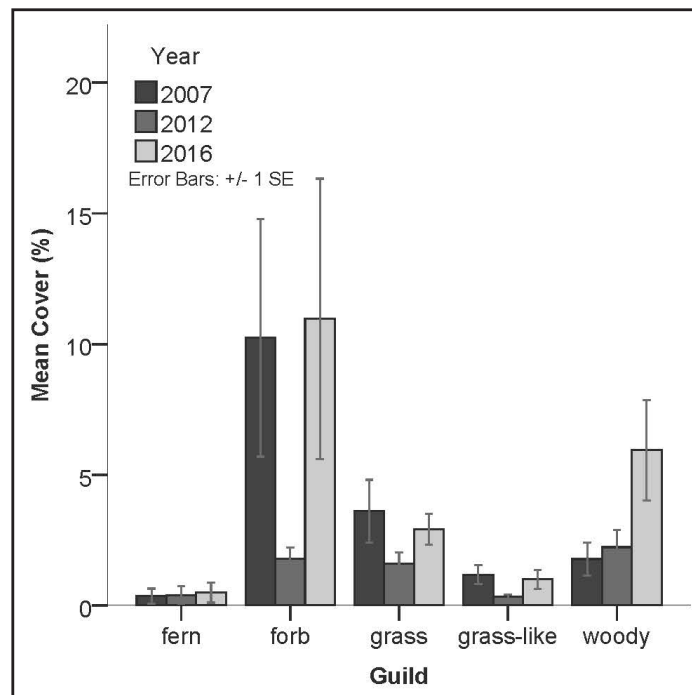
**Figure 11.** Mean species richness, Shannon Index, and Simpson's Index ( $n = 7$ ) over the monitoring record at Pea Ridge National Military Park 2007-2016. The Shannon Index and Simpson's Index are presented as the effective number of species (Jost 2006).

**Table 6.** Invasive species observed during vegetation monitoring at Pea Ridge National Military Park, 2007-2016.

| Year | Site | Species                      | Common Name          | Mean Cover (%) |
|------|------|------------------------------|----------------------|----------------|
| 2007 | 10   | <i>Lactuca serriola</i>      | prickly lettuce      | 0.05           |
| 2007 | 8    | <i>Taraxacum officinale</i>  | common dandelion     | 0.05           |
| 2016 | 9    | <i>Lonicera japonica</i>     | Japanese honeysuckle | 0.1            |
| 2016 | 10   | <i>Microstegium vimineum</i> | Nepalese browntop    | 0.1            |

**Table 7.** Native herbaceous plant community diversity metrics (n = 7) for Pea Ridge National Military Park, Arkansas. Alpha diversity refers to the mean number of species per monitoring site, gamma diversity is the total number of species across all monitoring sites, and beta diversity [(gamma/alpha)-1] is a measure of heterogeneity in species number among sites. Standard error is given in parentheses.

| Year | Alpha diversity (+ 1 SE) | Gamma diversity | Beta diversity |
|------|--------------------------|-----------------|----------------|
| 2007 | 30.6 (3.4)               | 82              | 1.7            |
| 2012 | 20.7 (1.9)               | 53              | 1.6            |
| 2016 | 37.6 (5.4)               | 106             | 1.8            |

**Figure 12.** Mean percent cover of plant guilds for three monitoring events at Pea Ridge National Military Park, Arkansas.

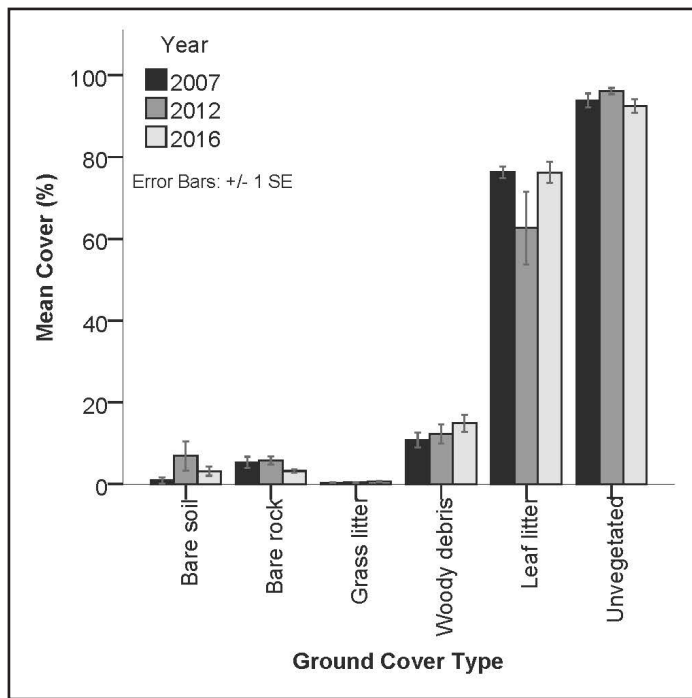


**Figure 13.** Measures of mean ground cover (n = 7) across seven monitoring sites 2007-2016 at Pea Ridge National Military Park, Arkansas.

# Conclusions

The Battle of Pea Ridge was set in the oak-hickory woodlands of northwestern Arkansas. An open woodland character is a critical goal for park managers. Managers prioritized the basic structure of the woodlands over species abundances, but desire native species characteristic of the physiographic area (NPS 2014). Heartland Network monitoring observations help to describe the current state of the woodlands. Although monitoring sites cross two vegetation communities (Table 1), we combined all the monitoring sites in our analysis because the communities are similar in composition, structure and management. *See James (2008) for baseline conditions by community type.*

Basic descriptions of these community types explain that a wide range of canopy cover is possible. Overstory canopy conditions at Pea Ridge National Military Park appear to be similar among sites and relatively closed across our monitoring record. Management techniques that may affect the canopy cover include mechanical removal and prescribed fire, but fire monitoring objectives did not specifically address canopy cover.

The overstory composition continues to represent the target oak-hickory community, although we observed increases in more mesic species like white ash and red maple. These increases were reflected in the regeneration layer (Tables 3-5). Ozark chinquapin a rare tree species of interest was only found as a live tree in 2007 and later as a snag in 2016.

In the latter two monitoring events, there was notable recruitment of trees into size class 1 over the baseline year. Although fire management generally aims to decrease density of such stems, it is unclear as to whether the use of fire stimulated the growth in that size class because snags in that class also increased (Figure 9). Two species characteristic of Typic Upland deciduous woodland and forest, mockernut hickory (*Carya alba*) and flowering dogwood (*Cornus florida*), showed increases in live trees of class 1 (Diamond et.al. 2013). Mockernut hickory basal area increased most over the monitoring period, but flowering dogwood, had the greatest basal area in 2016 for this size class (Table 4).

Trends in the regeneration phase of trees differed from the overstory patterns (Table 5, Figure 10). For

regeneration, oak saplings declined, despite increased mean number of oak seedlings. Our trends were consistent with fire management goals to increase oak seedlings, but we didn't see that trend continue into the sapling phase. Small saplings shifted from post oak to sassafras dominated over time. Large sapling richness decreased from 2-3 species in the first two monitoring years to only one species (post oak) in 2016. Hickory seedlings also increased from 2007-2016, but no saplings were observed. White ash seedlings had the greatest percentage increase over baseline seedling observations.

Although the shaded canopy likely contributed to a sparse herbaceous layer (Figure 5), community diversity metrics indicated an increase in diversity at all scales from the site level (Alpha) to the park level (Gamma; Table 7). However, species diversity metrics demonstrated different patterns (Figure 11). Species richness ended the monitoring period with an increase of 23% over 2007, but effective numbers of species for the Shannon and Simpson's indices in 2007 were similar to 2016. This suggests that the additional species are rare. Simultaneously, we observed an increase in cover of woody plants such as greenbriars (*Smilax* spp.), blueberries (*Vaccinium* spp.), and Virginia creeper (*Parthenocissus quinquefolia*; Figure 12). Understory species experienced a disturbance in 2012 as evidenced by temporary declines in richness, leaf litter, forbs, grasses, and grass-like plants, while unvegetated cover and bare ground increased. While we did not detect a direct cause, 2012 precipitation was lower than the other two years and prescribed fires took place that year (Table 1, Figure 4).

Vegetative cover in 2016 was similar to 2007 despite the increase in species richness (Figure 13). Fire monitoring goals predicted increases in native herbaceous mean percent cover, but this has not yet been met based on our observations (Drees 2017). Both overstory and herbaceous layers maintained a strong cohort of native plants with very few invasive plants observed (Table 6).

The patterns of increases in mesic tree species at Pea Ridge National Military Park hint at the possibility of mesophication, a process taking place in dry woodlands in the eastern US (Nowacki and Abrams 2008).

The process describes the transition of woodlands from shade intolerant species such as post oak and blackjack oak to species that thrive in shade such as maples (*Acer* spp.), blackgum, and black cherry (*Prunus serotina*). As this process occurs, the shade tolerant species cast heavy shade on the forest floor changing understory dynamics as well. The forest floor increases in moisture and litter, becomes less flammable, and decomposes more rapidly. Mesophytic forests may be difficult to restore back to xeric woodlands (Abrams 1992; Nowacki and Abrams 2008).

Fire frequency plays an important role in maintaining oak woodlands and preventing or slowing mesophication. Fire monitoring objectives were designed for

completion of 4 burns. Although those objectives haven't been fully met from our observations, only 1-2 burns have been completed on most monitoring sites so far.

Future monitoring will provide a better understanding of the trends that are difficult to understand from just three monitoring events. We plan to improve our monitoring by specifically defining transitional woody species as trees or shrubs going forward. This will improve data consistency and interpretation.

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# Appendix A: Species observed at Pea Ridge National Military Park 2007–2016

**Table A-1.** Plant species observed during monitoring at Pea Ridge National Military Park 2007–2016. N = native; I = nonnative.

| Scientific Name                               | Common Name                     | Origin | Guild      |
|-----------------------------------------------|---------------------------------|--------|------------|
| <i>Acalypha monococca</i>                     | Ozarkian short-stalk copperleaf | N      | forb       |
| <i>Acalypha virginica</i>                     | Virginia threeseed mercury      | N      | forb       |
| <i>Acer rubrum</i>                            | red maple                       | N      | woody      |
| <i>Acer saccharum</i>                         | sugar maple                     | N      | woody      |
| <i>Actaea racemosa</i> var. <i>racemosa</i>   | black bugbane                   | N      | forb       |
| <i>Aesculus glabra</i>                        | Ohio buckeye                    | N      | woody      |
| <i>Ageratina altissima</i>                    | white snakeroot                 | N      | forb       |
| <i>Agrimonia</i> sp.                          | agrimony                        | N      | forb       |
| <i>Agrimonia pubescens</i>                    | soft agrimony                   | N      | forb       |
| <i>Agrostis perennans</i>                     | upland bentgrass                | N      | grass      |
| <i>Ambrosia artemisiifolia</i>                | annual ragweed                  | N      | forb       |
| <i>Amelanchier</i> sp.                        | serviceberry                    | N      | woody      |
| <i>Amphiachyris dracunculoides</i>            | prairie broomweed               | N      | forb       |
| <i>Amphicarpaea bracteata</i>                 | American hogpeanut              | N      | forb       |
| <i>Andropogon gerardii</i>                    | big bluestem                    | N      | grass      |
| <i>Andropogon virginicus</i>                  | broomsedge bluestem             | N      | grass      |
| <i>Anemone</i> sp.                            | anemone                         | N      | forb       |
| <i>Antennaria plantaginifolia</i>             | woman's tobacco                 | N      | forb       |
| <i>Aristolochia serpentaria</i>               | Virginia snakeroot              | N      | forb       |
| <i>Asplenium platyneuron</i>                  | ebony spleenwort                | N      | fern       |
| <i>Aster</i> sp.                              | aster                           | N      | forb       |
| <i>Bidens</i> sp.                             | beggarticks                     | N      | forb       |
| <i>Bidens bipinnata</i>                       | Spanish needles                 | N      | forb       |
| <i>Botrychium virginianum</i>                 | rattlesnake fern                | N      | fern       |
| <i>Brachyelytrum erectum</i>                  | bearded shorthusk               | N      | grass      |
| <i>Bromus</i> sp.                             | brome                           | –      | grass      |
| <i>Bromus pubescens</i>                       | hairy woodland brome            | N      | grass      |
| <i>Campanulastrum americanum</i>              | American bellflower             | N      | forb       |
| <i>Cardamine concatenata</i>                  | cutleaf toothwort               | N      | forb       |
| <i>Carex</i> sp.                              | sedge                           | N      | grass-like |
| <i>Carya</i> sp.                              | hickory                         | N      | woody      |
| <i>Carya alba</i>                             | mockernut hickory               | N      | woody      |
| <i>Carya cordiformis</i>                      | bitternut hickory               | N      | woody      |
| <i>Carya glabra</i>                           | pignut hickory                  | N      | woody      |
| <i>Carya texana</i>                           | black hickory                   | N      | woody      |
| <i>Castanea pumila</i> var. <i>ozarkensis</i> | Ozark chinquapin                | N      | woody      |
| <i>Ceanothus</i>                              | ceanothus                       | N      | woody      |

**Table A-1 (continued).** Plant species observed during monitoring at Pea Ridge National Military Park 2007–2016. N = native; I = nonnative.

| Scientific Name                 | Common Name                   | Origin | Guild |
|---------------------------------|-------------------------------|--------|-------|
| <i>Celtis</i> sp.               | hackberry                     | N      | woody |
| <i>Celtis occidentalis</i>      | common hackberry              | N      | woody |
| <i>Cercis canadensis</i>        | eastern redbud                | N      | woody |
| <i>Chamaecrista nictitans</i>   | sensitive partridge pea       | N      | forb  |
| <i>Chasmanthium latifolium</i>  | Indian woodoats               | N      | grass |
| <i>Cirsium altissimum</i>       | tall thistle                  | N      | forb  |
| <i>Conyza canadensis</i>        | Canadian horseweed            | N      | forb  |
| <i>Cornus florida</i>           | flowering dogwood             | N      | woody |
| <i>Cunila origanoides</i>       | common dittany                | N      | forb  |
| <i>Danthonia spicata</i>        | poverty oatgrass              | N      | grass |
| <i>Desmodium</i> sp.            | ticktrefoil                   | N      | forb  |
| <i>Desmodium ciliare</i>        | hairy small-leaf ticktrefoil  | N      | forb  |
| <i>Desmodium glutinosum</i>     | pointedleaf ticktrefoil       | N      | forb  |
| <i>Desmodium laevigatum</i>     | smooth ticktrefoil            | N      | forb  |
| <i>Desmodium marilandicum</i>   | smooth small-leaf ticktrefoil | N      | forb  |
| <i>Desmodium nudiflorum</i>     | nakedflower ticktrefoil       | N      | forb  |
| <i>Desmodium nuttallii</i>      | Nuttall's ticktrefoil         | N      | forb  |
| <i>Desmodium obtusum</i>        | stiff ticktrefoil             | N      | forb  |
| <i>Desmodium paniculatum</i>    | panicledleaf ticktrefoil      | N      | forb  |
| <i>Desmodium perplexum</i>      | perplexed ticktrefoil         | N      | forb  |
| <i>Desmodium rotundifolium</i>  | prostrate ticktrefoil         | N      | forb  |
| <i>Dichanthelium</i> sp.        | rosette grass                 | N      | grass |
| <i>Dichanthelium boscii</i>     | Bosc's panicgrass             | N      | grass |
| <i>Dioscorea villosa</i>        | wild yam                      | N      | forb  |
| <i>Diospyros virginiana</i>     | common persimmon              | N      | woody |
| <i>Elymus virginicus</i>        | Virginia wildrye              | N      | grass |
| <i>Erechtites hieraciifolia</i> | American burnweed             | N      | forb  |
| <i>Erigeron</i> sp.             | fleabane                      | N      | forb  |
| <i>Erigeron annuus</i>          | eastern daisy fleabane        | N      | forb  |
| <i>Erigeron strigosus</i>       | prairie fleabane              | N      | forb  |
| <i>Eupatorium serotinum</i>     | lateflowering thoroughwort    | N      | forb  |
| <i>Euphorbia corollata</i>      | flowering spurge              | N      | forb  |
| <i>Festuca subverticillata</i>  | nodding fescue                | N      | grass |
| <i>Fraxinus</i> sp.             | ash                           | N      | woody |
| <i>Fraxinus americana</i>       | white ash                     | N      | woody |
| <i>Fraxinus pennsylvanica</i>   | green ash                     | N      | woody |
| <i>Galactia regularis</i>       | eastern milkpea               | N      | forb  |
| <i>Galium aparine</i>           | stickywilly                   | N      | forb  |
| <i>Galium arkansanum</i>        | Arkansas bedstraw             | N      | forb  |
| <i>Galium circaezans</i>        | licorice bedstraw             | N      | forb  |
| <i>Geum canadense</i>           | white avens                   | N      | forb  |

**Table A-1 (continued).** Plant species observed during monitoring at Pea Ridge National Military Park 2007–2016. N = native; I = nonnative.

| Scientific Name                    | Common Name               | Origin | Guild |
|------------------------------------|---------------------------|--------|-------|
| <i>Geum vernum</i>                 | spring avens              | N      | forb  |
| <i>Gleditsia triacanthos</i>       | honeylocust               | N      | woody |
| <i>Hackelia virginiana</i>         | beggarslice               | N      | forb  |
| <i>Hieracium gronovii</i>          | queendevil                | N      | forb  |
| <i>Hieracium longipilum</i>        | hairy hawkweed            | N      | forb  |
| <i>Houstonia purpurea</i>          | Venus' pride              | N      | forb  |
| <i>Hypericum</i> sp.               | St. Johnswort             | N      | forb  |
| <i>Hypericum hypericoides</i>      | St. Andrew's cross        | N      | forb  |
| <i>Juglans nigra</i>               | black walnut              | N      | woody |
| <i>Juniperus virginiana</i>        | eastern redcedar          | N      | woody |
| <i>Krigia biflora</i>              | twoflower dwarf dandelion | N      | forb  |
| <i>Lactuca canadensis</i>          | Canada lettuce            | N      | forb  |
| <i>Lactuca serriola</i>            | prickly lettuce           | I      | forb  |
| <i>Laportea canadensis</i>         | Canadian woodnettle       | N      | forb  |
| <i>Leersia virginica</i>           | whitegrass                | N      | grass |
| <i>Lespedeza</i> sp.               | lespedeza                 | –      | forb  |
| <i>Lespedeza procumbens</i>        | trailing lespedeza        | N      | forb  |
| <i>Lespedeza repens</i>            | creeping lespedeza        | N      | forb  |
| <i>Lespedeza stuevei</i>           | tall lespedeza            | N      | forb  |
| <i>Lespedeza violacea</i>          | violet lespedeza          | N      | forb  |
| <i>Lespedeza virginica</i>         | slender lespedeza         | N      | forb  |
| <i>Lindera benzoin</i>             | northern spicebush        | N      | woody |
| <i>Lobelia inflata</i>             | Indian-tobacco            | N      | forb  |
| <i>Lonicera japonica</i>           | Japanese honeysuckle      | I      | woody |
| <i>Matelea decipiens</i>           | oldfield milkvine         | N      | forb  |
| <i>Menispermum canadense</i>       | common moonseed           | N      | woody |
| <i>Microstegium vimineum</i>       | Nepalese browntop         | I      | grass |
| <i>Mimosa nuttallii</i>            | sensitive brier           | N      | forb  |
| <i>Monarda fistulosa</i>           | wild bergamot             | N      | forb  |
| <i>Morus rubra</i>                 | red mulberry              | N      | woody |
| <i>Muhlenbergia sobolifera</i>     | rock muhly                | N      | grass |
| <i>Nyssa sylvatica</i>             | blackgum                  | N      | woody |
| <i>Orbexilum pedunculatum</i>      | Sampson's snakeroot       | N      | forb  |
| <i>Oxalis</i> sp.                  | woodsorrel                | N      | forb  |
| <i>Oxalis dillenii</i>             | slender yellow woodsorrel | N      | forb  |
| <i>Parthenocissus quinquefolia</i> | Virginia creeper          | N      | woody |
| <i>Paspalum laeve</i>              | field paspalum            | N      | grass |
| <i>Passiflora lutea</i>            | yellow passionflower      | N      | forb  |
| <i>Penstemon digitalis</i>         | talus slope penstemon     | N      | forb  |
| PERlunk_772016 11_20A              | unknown collected         | –      | –     |
| <i>Phegopteris hexagonoptera</i>   | broad beechfern           | N      | fern  |

**Table A-1 (continued).** Plant species observed during monitoring at Pea Ridge National Military Park 2007–2016. N = native; I = nonnative.

| Scientific Name                                               | Common Name             | Origin | Guild |
|---------------------------------------------------------------|-------------------------|--------|-------|
| <i>Phryma leptostachya</i>                                    | American lopseed        | N      | forb  |
| <i>Physalis pumila</i>                                        | dwarf groundcherry      | N      | forb  |
| <i>Physalis virginiana</i>                                    | Virginia groundcherry   | N      | forb  |
| <i>Phytolacca americana</i>                                   | American pokeweed       | N      | forb  |
| <i>Polystichum acrostichoides</i>                             | Christmas fern          | N      | fern  |
| <i>Potentilla simplex</i>                                     | common cinquefoil       | N      | forb  |
| <i>Prunus</i> sp.                                             | plum                    | N      | woody |
| <i>Prunus serotina</i>                                        | black cherry            | N      | woody |
| <i>Pseudognaphalium obtusifolium</i> ssp. <i>obtusifolium</i> | fragrant cudweed        | N      | forb  |
| <i>Quercus alba</i>                                           | white oak               | N      | woody |
| <i>Quercus marilandica</i>                                    | blackjack oak           | N      | woody |
| <i>Quercus rubra</i>                                          | northern red oak        | N      | woody |
| <i>Quercus stellata</i>                                       | post oak                | N      | woody |
| <i>Quercus velutina</i>                                       | black oak               | N      | woody |
| <i>Ranunculus hispidus</i>                                    | bristly buttercup       | N      | forb  |
| Red oak group                                                 | red oak group           | N      | woody |
| <i>Rhus copallinum</i>                                        | winged sumac            | N      | woody |
| <i>Rosa</i> sp.                                               | rose                    | N      | woody |
| <i>Rubus</i> sp.                                              | blackberry              | N      | woody |
| <i>Rudbeckia hirta</i>                                        | blackeyed Susan         | N      | forb  |
| <i>Ruellia humilis</i>                                        | fringeleaf wild petunia | N      | forb  |
| <i>Ruellia pedunculata</i>                                    | stalked wild petunia    | N      | forb  |
| <i>Ruellia strepens</i>                                       | limestone wild petunia  | N      | forb  |
| <i>Sanicula canadensis</i>                                    | Canadian blacksnakeroot | N      | forb  |
| <i>Sassafras albidum</i>                                      | sassafras               | N      | woody |
| <i>Schizachyrium scoparium</i>                                | little bluestem         | N      | grass |
| <i>Scutellaria ovata</i>                                      | heartleaf skullcap      | N      | forb  |
| <i>Smilax</i> sp.                                             | greenbrier              | N      | woody |
| <i>Smilax bona-nox</i>                                        | saw greenbrier          | N      | Woody |
| <i>Smilax tamnoides</i>                                       | bristly greenbrier      | N      | woody |
| <i>Solanum carolinense</i>                                    | Carolina horsenettle    | N      | forb  |
| <i>Solidago</i>                                               | goldenrod               | N      | forb  |
| <i>Solidago ulmifolia</i>                                     | elmleaf goldenrod       | N      | forb  |
| <i>Stylosanthes biflora</i>                                   | sidebeak pencilflower   | N      | forb  |
| <i>Symphoricarpos orbiculatus</i>                             | coralberry              | N      | woody |
| <i>Symphyotrichum patens</i> var. <i>patens</i>               | clasping wild aster     | N      | forb  |
| <i>Taraxacum officinale</i>                                   | common dandelion        | I      | forb  |
| <i>Thalictrum thalictroides</i>                               | rue anemone             | N      | forb  |
| <i>Toxicodendron radicans</i>                                 | eastern poison ivy      | N      | woody |
| <i>Tridens flavus</i>                                         | purpletop tridens       | N      | grass |

**Table A-1 (continued).** Plant species observed during monitoring at Pea Ridge National Military Park 2007–2016. N = native; I = nonnative.

| Scientific Name               | Common Name          | Origin | Guild |
|-------------------------------|----------------------|--------|-------|
| <i>Ulmus</i> sp.              | elm                  | N      | woody |
| <i>Ulmus alata</i>            | winged elm           | N      | woody |
| <i>Ulmus americana</i>        | American elm         | N      | woody |
| <i>Ulmus rubra</i>            | slippery elm         | N      | woody |
| <i>Vaccinium</i> sp.          | blueberry            | N      | woody |
| <i>Vaccinium pallidum</i>     | Blue Ridge blueberry | N      | woody |
| <i>Vaccinium stamineum</i>    | deerberry            | N      | woody |
| <i>Verbena urticifolia</i>    | white vervain        | N      | forb  |
| <i>Verbesina alternifolia</i> | wingstem             | N      | forb  |
| <i>Vernonia baldwinii</i>     | Baldwin's ironweed   | N      | forb  |
| <i>Viburnum rufidulum</i>     | rusty blackhaw       | N      | woody |
| <i>Viola</i> sp.              | violet               | N      | forb  |
| <i>Viola triloba</i>          | three-lobed violet   | N      | forb  |
| <i>Vitis</i> sp.              | grape                | N      | woody |
| White oak group               | white oak group      | N      | woody |
| <i>Woodsia obtusa</i>         | bluntlobe cliff fern | N      | fern  |

## Appendix B: Herbaceous Community Metrics, Pea Ridge National Military Park 2007–2016

**Table B-1.** Herbaceous community metrics: percentage of sites (n = 7) each herbaceous species was observed in at Pea Ridge National Military Park 2007–2016.

| Species                                     | % Sites Observed (n = 7) |      |      |
|---------------------------------------------|--------------------------|------|------|
|                                             | 2007                     | 2012 | 2016 |
| <i>Acalypha monococca</i>                   | –                        | –    | 29   |
| <i>Acalypha virginica</i>                   | 57                       | 43   | 86   |
| <i>Actaea racemosa</i> var. <i>racemosa</i> | 29                       | 14   | 29   |
| <i>Ageratina altissima</i>                  | 57                       | 14   | 71   |
| <i>Agrimonia</i> spp.                       | –                        | –    | 14   |
| <i>Agrimonia pubescens</i>                  | –                        | 14   | 14   |
| <i>Agrostis perennans</i>                   | –                        | –    | 14   |
| <i>Ambrosia artemisiifolia</i>              | 14                       | 14   | –    |
| <i>Amphiachyris dracunculoides</i>          | 14                       | –    | –    |
| <i>Amphicarpaea bracteata</i>               | 86                       | 71   | 86   |
| <i>Andropogon gerardii</i>                  | –                        | –    | 29   |
| <i>Andropogon virginicus</i>                | 43                       | 29   | 57   |
| <i>Anemone</i> spp.                         | 29                       | –    | –    |
| <i>Antennaria plantaginifolia</i>           | 29                       | 43   | 43   |
| <i>Aristolochia serpentaria</i>             | 43                       | 43   | 43   |
| <i>Asplenium platyneuron</i>                | 43                       | 43   | 43   |
| <i>Aster</i> spp.                           | 43                       | –    | 14   |
| <i>Bidens</i> spp.                          | –                        | 14   | –    |
| <i>Bidens bipinnata</i>                     | –                        | –    | 29   |
| <i>Botrychium virginianum</i>               | 29                       | –    | 14   |
| <i>Brachyelytrum erectum</i>                | 29                       | 43   | 57   |
| <i>Campanulastrum americanum</i>            | 14                       | –    | –    |
| <i>Cardamine concatenata</i>                | 14                       | –    | –    |
| <i>Carex</i> spp.                           | 100                      | 100  | 100  |
| <i>Ceanothus</i>                            | 14                       | –    | –    |
| <i>Chamaecrista nictitans</i>               | 14                       | –    | 14   |
| <i>Chasmanthium latifolium</i>              | –                        | –    | 14   |
| <i>Cirsium altissimum</i>                   | 14                       | –    | –    |
| <i>Conyza canadensis</i>                    | 14                       | –    | 14   |
| <i>Cunila origanoides</i>                   | 71                       | 71   | 57   |
| <i>Danthonia spicata</i>                    | 86                       | 100  | 71   |
| <i>Desmodium</i> spp.                       | –                        | 14   | –    |
| <i>Desmodium ciliare</i>                    | –                        | –    | 14   |
| <i>Desmodium glutinosum</i>                 | –                        | –    | 14   |
| <i>Desmodium laevigatum</i>                 | –                        | –    | 29   |

**Table B-1 (continued).** Herbaceous community metrics: percentage of sites (n = 7) each herbaceous species was observed in at Pea Ridge National Military Park 2007–2016.

| Species                         | % Sites Observed (n = 7) |      |      |
|---------------------------------|--------------------------|------|------|
|                                 | 2007                     | 2012 | 2016 |
| <i>Desmodium marilandicum</i>   | –                        | –    | 14   |
| <i>Desmodium nudiflorum</i>     | 71                       | 71   | 71   |
| <i>Desmodium nuttallii</i>      | –                        | –    | 71   |
| <i>Desmodium obtusum</i>        | 57                       | 57   | –    |
| <i>Desmodium paniculatum</i>    | –                        | –    | 43   |
| <i>Desmodium perplexum</i>      | –                        | –    | 43   |
| <i>Desmodium rotundifolium</i>  | 29                       | 14   | 57   |
| <i>Dichanthelium</i> spp.       | 100                      | 100  | 100  |
| <i>Dichanthelium boscii</i>     | 43                       | 86   | 86   |
| <i>Dioscorea villosa</i>        | –                        | –    | 14   |
| <i>Elymus virginicus</i>        | 43                       | 43   | 43   |
| <i>Erechtites hieraciifolia</i> | 86                       | 14   | 71   |
| <i>Erigeron</i> spp.            | 14                       | –    | –    |
| <i>Erigeron annuus</i>          | –                        | –    | 14   |
| <i>Erigeron strigosus</i>       | 57                       | –    | 14   |
| <i>Eupatorium serotinum</i>     | 14                       | 14   | –    |
| <i>Euphorbia corollata</i>      | 29                       | 29   | 14   |
| <i>Festuca subverticillata</i>  | –                        | 14   | 29   |
| <i>Fraxinus</i> spp.            | –                        | –    | 14   |
| <i>Galactia regularis</i>       | –                        | –    | 29   |
| <i>Galium aparine</i>           | –                        | –    | 14   |
| <i>Galium arkansanum</i>        | 14                       | 14   | 29   |
| <i>Galium circaeans</i>         | 86                       | 43   | 71   |
| <i>Geum canadense</i>           | –                        | –    | 43   |
| <i>Geum vernum</i>              | –                        | –    | 14   |
| <i>Hackelia virginiana</i>      | 43                       | –    | 43   |
| <i>Hieracium gronovii</i>       | 29                       | –    | 29   |
| <i>Hieracium longipilum</i>     | –                        | –    | 14   |
| <i>Houstonia purpurea</i>       | 14                       | –    | –    |
| <i>Hypericum</i> spp.           | 14                       | –    | –    |
| <i>Hypericum hypericoides</i>   | 57                       | 29   | 57   |
| <i>Krigia biflora</i>           | –                        | –    | 14   |
| <i>Lactuca canadensis</i>       | 14                       | –    | 14   |
| <i>Laportea canadensis</i>      | –                        | 14   | 14   |
| <i>Leersia virginica</i>        | –                        | –    | 29   |
| <i>Lespedeza procumbens</i>     | 100                      | 100  | 100  |
| <i>Lespedeza repens</i>         | 43                       | 29   | –    |
| <i>Lespedeza stuevei</i>        | –                        | –    | 29   |
| <i>Lespedeza violacea</i>       | 29                       | 14   | 43   |
| <i>Lespedeza virginica</i>      | 57                       | 43   | 71   |

**Table B-1 (continued).** Herbaceous community metrics: percentage of sites (n = 7) each herbaceous species was observed in at Pea Ridge National Military Park 2007–2016.

| Species                                                       | % Sites Observed (n = 7) |      |      |
|---------------------------------------------------------------|--------------------------|------|------|
|                                                               | 2007                     | 2012 | 2016 |
| <i>Lobelia inflata</i>                                        | –                        | –    | 14   |
| <i>Matelea decipiens</i>                                      | 0                        | –    | 14   |
| <i>Menispermum canadense</i>                                  | 29                       | –    | –    |
| <i>Mimosa nuttallii</i>                                       | 29                       | 14   | 14   |
| <i>Monarda fistulosa</i>                                      | 14                       | 14   | 14   |
| <i>Muhlenbergia sobolifera</i>                                | 43                       | 43   | 29   |
| <i>Orbexilum pedunculatum</i>                                 | –                        | –    | 14   |
| <i>Oxalis</i> spp.                                            | 29                       | –    | 43   |
| <i>Oxalis dillenii</i>                                        | –                        | –    | 14   |
| <i>Parthenocissus quinquefolia</i>                            | 100                      | 100  | 100  |
| <i>Paspalum laeve</i>                                         | 14                       | –    | –    |
| <i>Passiflora lutea</i>                                       | –                        | –    | 14   |
| <i>Penstemon digitalis</i>                                    | –                        | –    | 14   |
| <i>Phegopteris hexagonoptera</i>                              | –                        | –    | 14   |
| <i>Phryma leptostachya</i>                                    | 14                       | –    | 29   |
| <i>Physalis pumila</i>                                        | –                        | –    | 14   |
| <i>Physalis virginiana</i>                                    | –                        | –    | 29   |
| <i>Phytolacca americana</i>                                   | 29                       | –    | –    |
| <i>Polystichum acrostichoides</i>                             | 29                       | 43   | 43   |
| <i>Potentilla simplex</i>                                     | –                        | –    | 14   |
| <i>Pseudognaphalium obtusifolium</i> ssp. <i>obtusifolium</i> | 43                       | –    | 14   |
| <i>Ranunculus hispidus</i>                                    | –                        | –    | 14   |
| <i>Rhus copallinum</i>                                        | 57                       | –    | 14   |
| <i>Rosa</i> spp.                                              | 29                       | –    | –    |
| <i>Rubus</i> spp.                                             | 86                       | 100  | 100  |
| <i>Rudbeckia hirta</i>                                        | 14                       | –    | 14   |
| <i>Ruellia humilis</i>                                        | –                        | 14   | –    |
| <i>Ruellia pedunculata</i>                                    | –                        | –    | 29   |
| <i>Ruellia strepens</i>                                       | 14                       | –    | –    |
| <i>Sanicula canadensis</i>                                    | 14                       | –    | 43   |
| <i>Schizachyrium scoparium</i>                                | –                        | –    | 14   |
| <i>Scutellaria ovata</i>                                      | 29                       | 14   | 14   |
| <i>Smilax</i> spp.                                            | 14                       | 14   | 43   |
| <i>Smilax bona-nox</i>                                        | 29                       | 14   | 29   |
| <i>Smilax tamnoides</i>                                       | 14                       | –    | –    |
| <i>Solanum carolinense</i>                                    | 14                       | –    | 43   |
| <i>Solidago</i> spp.                                          | 14                       | 14   | 14   |
| <i>Solidago ulmifolia</i>                                     | –                        | –    | 57   |
| <i>Stylosanthes biflora</i>                                   | 14                       | –    | –    |
| <i>Symphoricarpos orbiculatus</i>                             | 86                       | 71   | 100  |

**Table B-1 (continued).** Herbaceous community metrics: percentage of sites (n = 7) each herbaceous species was observed in at Pea Ridge National Military Park 2007–2016.

| Species                                         | % Sites Observed (n = 7) |      |      |
|-------------------------------------------------|--------------------------|------|------|
|                                                 | 2007                     | 2012 | 2016 |
| <i>Symphyotrichum patens</i> var. <i>patens</i> | 14                       | 14   | 29   |
| <i>Thalictrum thalictroides</i>                 | 14                       | –    | 14   |
| <i>Toxicodendron radicans</i>                   | 29                       | 14   | 29   |
| <i>Tridens flavus</i>                           | 57                       | –    | 14   |
| <i>Vaccinium</i> spp.                           | –                        | 57   | –    |
| <i>Vaccinium pallidum</i>                       | –                        | –    | 29   |
| <i>Vaccinium stamineum</i>                      | –                        | –    | 71   |
| <i>Verbena urticifolia</i>                      | 14                       | –    | –    |
| <i>Verbesina alternifolia</i>                   | 14                       | 14   | 14   |
| <i>Vernonia baldwinii</i>                       | –                        | –    | 14   |
| <i>Viola</i> spp.                               | 43                       | 14   | –    |
| <i>Viola triloba</i>                            | –                        | –    | 57   |
| <i>Vitis</i> spp.                               | 100                      | 86   | 86   |
| <i>Woodsia obtusa</i>                           | 14                       | 14   | 14   |

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

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**Natural Resource Stewardship and Science**

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