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Vegetation Monitoring in the Manley Woods Unit at Wilson's Creek National Battlefield

1998–2020

Natural Resource Report NPS/HTLN/NRR—2022/2391



ON THE COVER
Vegetation sampling gear laid out on a site at Manley Woods in Wilson's Creek National Battlefield, 2020.
Photography by NPS/Heartland Inventory and Monitoring Network

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Natural Resource Report NPS/HTLN/NRR—2022/2391

Mary F. Short and Sherry A. Leis

National Park Service
Heartland Inventory and Monitoring Network
Republic, MO

Editing and Design by
Tani Hubbard

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

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Executive Summary

Natural resource management at Wilson's Creek National Battlefield (NB) is guided by our understanding of the woodlands and prairies at the time of the Civil War battle in 1861. This report is focused on the Manley Woods unit of the park. This unit is an oak-hickory woodland in the Springfield Plain subsection of the Ozarks. Canopy closure for Missouri oak woodlands can be highly variable and ranges from 30–100% across the spectrum of savanna, open woodland, and closed woodland types. In 1861, the woodland was likely a savanna community. Changes in land use (e.g., fire exclusion) caused an increase in tree density in woodlands at Wilson's Creek NB and across the Ozarks. Savannas and open woodlands transitioned to closed canopy woodlands over time. Park management plans include restoring the area to a savanna/open woodland structure. Prescribed fire was reintroduced to Wilson's Creek NB in 1988 and continues as the primary mechanism for reducing the tree canopy.

The Manley Woods unit of Wilson's Creek NB has been subject to intense natural and anthropogenic disturbance events such as a tornado in 2003, timber removal in 2005, prescribed fires in 2006, 2009, and 2019, an ice storm in 2007, and periodic drought. The Heartland Inventory and Monitoring Network (hereafter, Heartland Network) installed four permanent monitoring sites within the Manley Woods area of the park in 1997. Initially, we assessed ground flora and regeneration within the sites (1998–1999). We added fuel sampling after the 2003 tornado. Although overstory sampling occurred prior to the tornado, the protocol was not yet stabilized and pre-2003 overstory data were not included in these analyses. In this report, we focus on the overstory, tree regeneration, and ground cover metrics; ground flora data will be assessed in future analyses.

Heartland Network monitoring data reveal that Manley Woods has undergone substantial change in canopy cover and midstory trees since 1998. While basal area and density metrics classify Manley Woods as an open woodland, the closed canopy of the midstory and overstory reveal a plant community that is moving toward closed woodland or forest structure. The most recent fire in 2019 was patchy and mild, resulting in continued increases in fuels. Ground cover metrics indicate infrequent disturbance since leaf litter continued to increase.

Management objectives to restore savanna or woodland composition and structure to the Manley Woods overstory, regeneration layer, and ground cover will require implementation of prescribed fire in the future. Repeated fires can thin midstory trees and limit less fire tolerant early seral species. Additionally, mechanical or chemical treatments to reduce undesirable tree species should be considered for woodland restoration. Decreasing canopy closure is an important and essential step toward the restoration of a functioning savanna/open woodland plant community in Manley Woods. Treatments that thin the midstory and reduce fuel loading will also benefit these plant communities. With the anticipated changing climate, maintaining an open woodland community type may also provide resilience through management for native species tolerant of increasingly warmer temperatures.

Acknowledgments

We appreciate access to the park from the staff at Wilson's Creek National Battlefield. We are grateful for the contributions of previous staff who helped to monitor vegetation at the park. J. Thomas provided botanical support in 2017. J. Haack-Gaynor provided GIS support. We also appreciate helpful comments from peer reviewers.

Introduction

Wilson's Creek National Battlefield (NB) was created in 1960, and the park was later directed to restore the historic battlefield scene in addition to interpreting the events of the battle (Gale et al. 2004). Natural community management at Manley Woods in Wilson's Creek NB is focused on returning the woodlands and prairies to their structure at the time of the Civil War battle in 1861 (John Milner Associates 2004; Gremaud 1986). John Milner Associates (2004) provided qualitative targets for plant community maintenance and restoration in addition to describing the historic battle scene (also see Commonwealth Heritage Group and Sargent 2018). They recommended maintaining an open woodland character that represents the historical plant community. Canopy closure for Missouri oak woodlands can be highly variable, ranging from 30–100% across the savanna, open woodland, and closed woodland types (Nelson 2005). At the time of the battle, Manley Woods more closely aligned with the characteristic structure and composition of a savanna community (<30% canopy closure) than an open or closed woodland (>30% canopy closure) in the 1860s (Gremaud 1986). Civil War soldiers at Wilson's Creek NB described an open savanna scene interspersed with agricultural fields, but at the time of the park's creation, many of the upland savannas and glades had become closed canopy woodlands (Gremaud 1986; John Milner Associates 2004).

These types of changes across the woodlands of the Ozarks resulted from changes in land use history that decreased fire frequency (Gremaud 1986; Guyette et al. 2002; John Milner Associates 2004). Prescribed fire was reintroduced to Wilson's Creek NB in 1988 (Gale et al. 2004) and managers have been working towards savanna/open oak-hickory woodland targets using fire as the primary mechanism (Gale et al. 2004).

The Heartland Inventory and Monitoring Network (Heartland Network) provides long-term vegetation monitoring to Wilson's Creek NB. We have collected data at permanent monitoring sites to track the status and trends in Manley Woods since 1997. For this report, we analyzed woodland data from 2003–2020 to inform park management (Leis and Short 2019; HTLN 2021)

Ecological disturbances other than fire are also common in this region. In 2003, 60 ha of the Manley Woods area of Wilson's Creek NB was struck by a northeasterly traveling tornado (Figure 1). Areas around two of the four long-term monitoring sites (sites 4 and 5) were most affected (Leis and James 2008).

In the post-tornado years, several notable disturbances occurred. Increased fuel loads resulting from the tornado damage caused concern for increased wildfire risk, so park staff made plans to reduce fuel loads. In 2005, a contractor removed salvageable timber from Manley Woods, and in 2006 a prescribed fire was completed. The salvage and prescribed fire operations concentrated on the areas most affected by the tornado and thus received the greatest disturbance. In 2007, a severe ice storm further stressed natural communities in Manley Woods. Another prescribed fire was applied in 2009 to continue fuel reduction efforts. A fire-free period was then prescribed to allow regeneration of trees—specifically oaks (*Quercus* spp.) and hickories (*Carya* spp.)—to grow to a more fire-resistant stage (Dey and Hartman 2005; Leis and James 2008). Another prescribed fire was implemented in 2019.

In this report, we describe changes in fuel loads, ground cover characteristics, and tree structure, composition, and dynamics in Manley Woods since 2003. We relate these changes to the history of severe disturbances and park natural resource goals for fuel reduction and savanna restoration. While the tornado and subsequent treatments affected each plot differently (Leis and James 2008), we sought to describe changes to the Manley Woods plant community as a whole in these analyses. We provide this information to Wilson's Creek NB natural resource and fire managers to guide future treatments in Manley Woods.

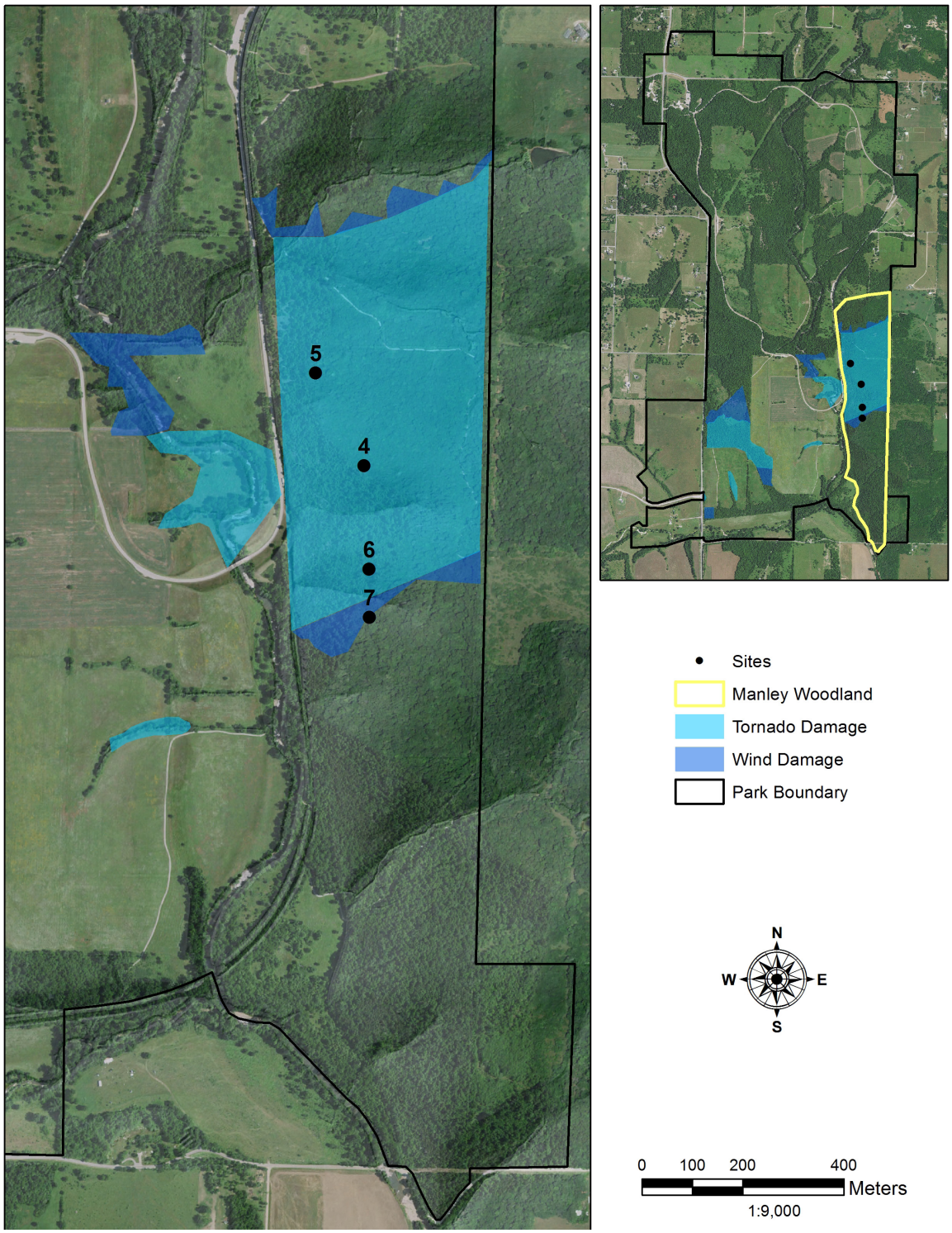


Figure 1. Inset of Wilson's Creek National Battlefield on the right and magnification of Manley Woods with vegetation monitoring sites labeled on the left (2016 image).

Methods

Wilson's Creek NB is located in the Springfield Plain subsection of the Ozarks (Nigh and Schroeder 2002), specifically in the ecotone of the Ozarks Highlands and Osage Plains regions where the prairies meet the woodlands (Nelson 2005). Schoolcraft (1821) described prairies, glades, savannas and woodlands in this area as well as the variability within these plant communities. Manley Woods is located along the southeastern border of the park (Figure 1).

Prior to the 2003 tornado, the four monitoring sites in Manley Woods could have been classified as open oak woodlands. A 2012 vegetation mapping project (Diamond et al. 2012) underscored the heterogeneity resulting from the tornado. The map classified three of the monitoring sites as "Manley shrubland and woodland" community types because they were in a highly disturbed state. The remaining site was characterized as "upland deciduous woodland and forest" type within the South-Central Interior Oak Forest Group (Figure 2).

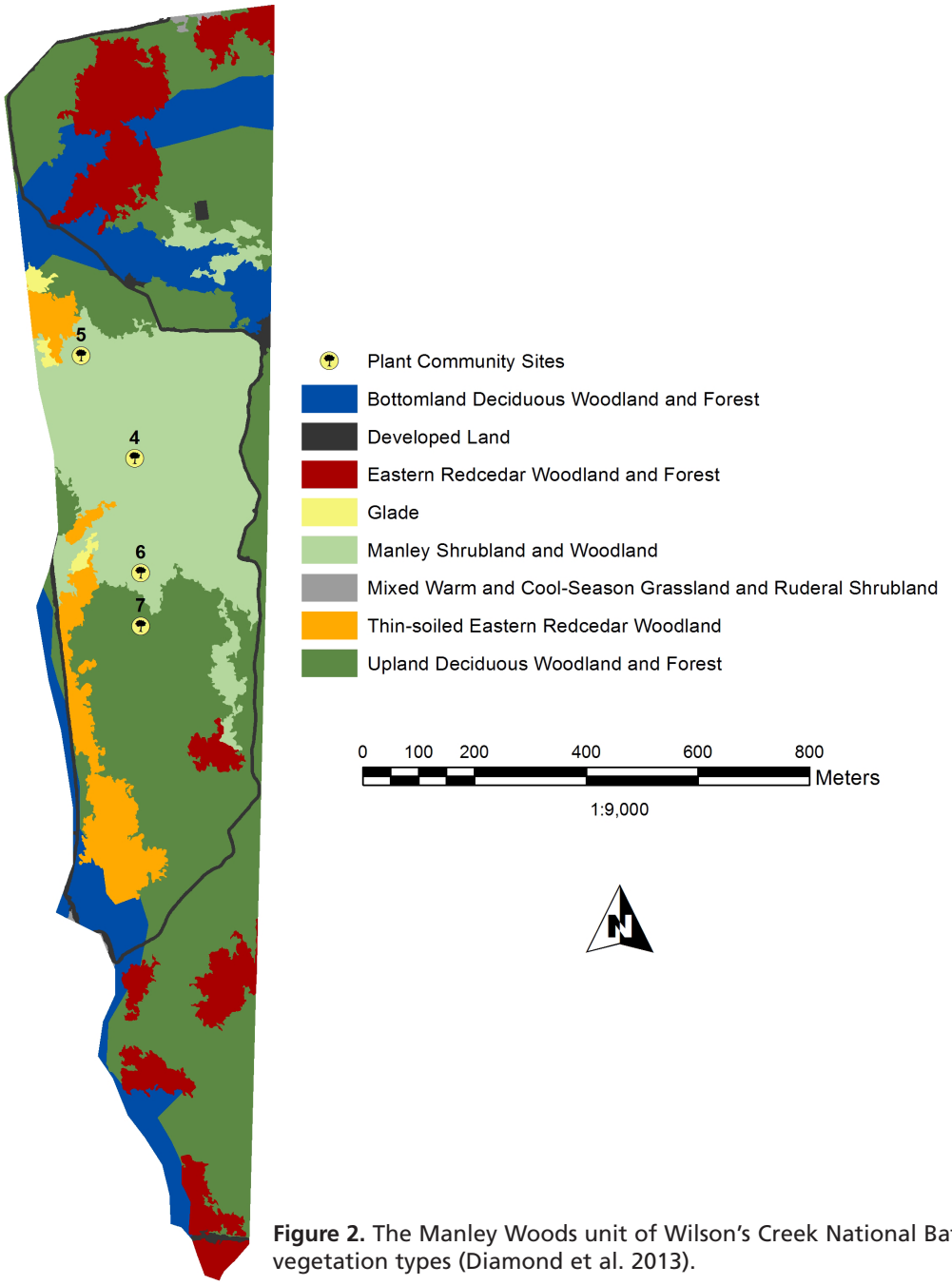


Figure 2. The Manley Woods unit of Wilson's Creek National Battlefield includes a variety of vegetation types (Diamond et al. 2013).

Appendix B documents the sampling and recent disturbance history for each sampling site. The series of disturbances described above most affected two of the four long-term monitoring sites (sites 4 and 5) in Manley Woods. Sites 6 and 7 received less intense disturbance (G. Sullivan, NPS Supervisory Resource Management Specialist, interview, 2008; Leis and James 2008). All four monitoring sites within the woodland were aggregated for these analyses despite this heterogeneity to provide an understanding of the Manley Woods unit as a whole.

Sampling Design

We established the four vegetation monitoring sites in the Manley Woods unit of Wilson's Creek NB in 1997 (Figure 1). Because the overstory methods were still in development at the time of the 1997 sampling, 1997 data were not included in these analyses (Appendix B). Although the 1997 data were previously reported, we found that inconsistencies in the data collection reduced confidence in these data (Leis and James 2008). Insights from the 1997 analysis continue to provide a picture of the pre-tornado conditions for qualitative comparison.

See James et al. (2009) for details on sampling design. Monitoring methods followed the woodland standard operating procedures outlined in the vegetation community monitoring protocol (James et al. 2009). Monitoring sites were 50 m x 20 m (0.1 ha) with two focal transects bounding the site on the 50-m sides (Figure 3). For this protocol, midstory and 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 frames (0.01 m^2, 0.1 m^2, 1 m^2, and 10 m^2), but only observations at the 10-m^2 scale were summarized to the site scale (0.1 ha) for this study. To refer to sample sizes in this report, we use small "n" for count of subplots and large "N" for count of sites. Woodland monitoring consisted of a suite of sampling methods for characterizing overstory tree composition, canopy cover, regeneration, understory herbaceous species composition, and ground cover. This report does not discuss data collected for understory herbaceous species composition and ground cover.

Monitoring components such as understory, overstory, and regeneration monitoring were added at different times (Appendix B). Understory monitoring included all non-tree species (not discussed in this report), while overstory and regeneration monitoring included only tree species. Understory and tree regeneration monitoring were implemented first (sampled twice annually from 1997 to 2000). In 2003, sampling resumed with both understory, overstory, and regeneration completed between May and June, post-tornado. The next sample event was in September 2006 and included all three elements. In the following year, only understory and regeneration were sampled. An attempt to conduct monitoring in 2012 yielded data only for site 7 because of safety concerns (those data were not included in this report). In 2017 and 2020, all three monitoring components were again sampled.

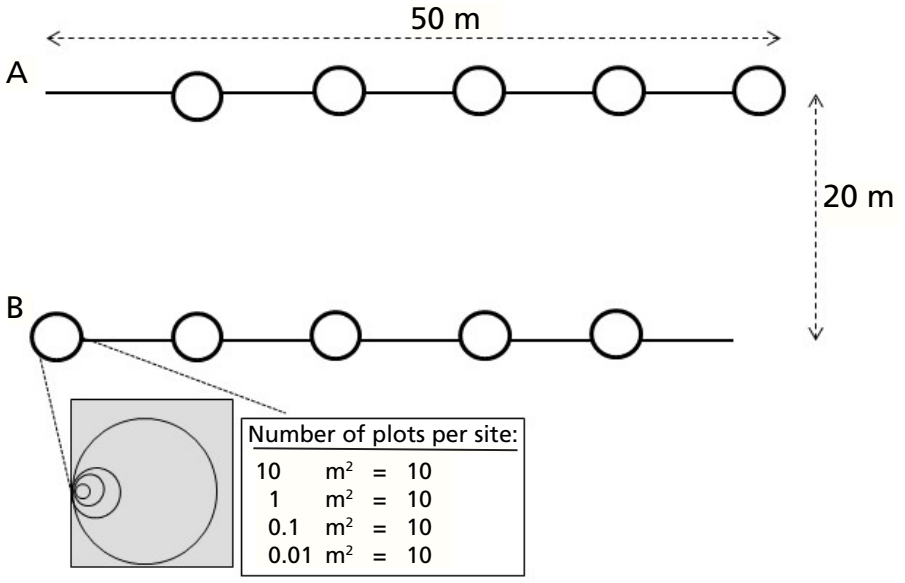


Figure 3. Plant community site monitoring design for Heartland Network parks.

Data Summary

Foliar cover serves as an estimate of abundance for ground flora species and ground cover. The cover class intervals are converted to midpoint values to estimate percent cover for each herbaceous and shrub species (Table 1). Mean percent cover was then calculated as the species percent cover for a sampling unit (N = 4), averaged across all subplots (n = 10). Sampling unit (site) means were then used to calculate community-level means. Confidence intervals (95%) were calculated and displayed.

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

Cover Class	Cover Range (%)	Class Midpoint (%)
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

RStudio (RStudio Team 2020) and SPSS version 28.0.0.0 (IBM 2021) were used to calculate summary statistics. All site means for canopy closure and regeneration were calculated based on 10 subplots for each year (N = 4 sites with n = 10 subplots each).

Climate

Standardized precipitation index (SPI) calculated by 12-month intervals was obtained for station USW00013995 (Springfield airport). The SPI indicates drought or wetness by comparison to a normalized average. Values represent units of standard deviation from that average (Keyantash and National Center for Atmospheric Research Staff 2018; McKee et al. 1995).

Recent Fire History

Fire history records for 1995 to 2020 are included. Recent fire history for Manley Woods at Wilson's Creek NB was determined using a fire history geodatabase. Although the battlefield began using fire prior to 1995, earlier years must be evaluated qualitatively. A 30-m buffer was constructed from the center point of each monitoring site. If the buffered area was greater than 30% burned (i.e., ≥ 848 m^2), the whole site was considered burned. On-the-ground observations since 2009 validated the spatial data. Time since last fire (TSF) was then calculated from this dataset for each monitoring site-year combination. We did not account for seasonality in the time since fire calculations, rather we assigned burned status on an annual basis. We used a histogram approach to visualize and understand trends.

Fire Severity

Fire severity was measured for vegetation and substrate using a categorical scale between 1 (heavily burned) and 5 (unburned; Leis et al. 2011). Severity was measured on the vegetation monitoring transects at 3-m intervals in a 0.10 m^2 area (circular hoop). Site-level means of fire severity were calculated (n = 32) for both vegetation and substrate and then used to calculate a grand mean for all sites (N = 2). In 2019, fire severity was only measured in sites 6 and 7.

Fuel Load

Fuel loads were first measured in 2003, post-tornado (see Appendix B). Downed woody fuel load, including 1-hour to 1000-hour, duff, and litter components, was estimated by using the planar intercept method (Brown et al. 1982; Leis et al. 2011). Four fuel load transects are associated with each long-term vegetation monitoring site. Fuel loading was calculated with FFI (FEAT/FIREMON Integrated Version 1.05.13.44; FFI Ecological Monitoring Utilities 2021; Lutes et al. 2009). Red oak fuel constants (Table 2) were the most comparable for the dominant species in our study area. In 2009, fuel loads were measured both pre- and post-burn. Following the prescribed burn in 2019, post-burn fuel loads were only measured in burned sites (6, 7).

Table 2. Fuels constants used in loading calculations by fuel lag class: QMD (quadratic mean diameter), NHC (nonhorizontal correction factor), SG (specific gravity), and BD (Bulk density).

Factor	1-hr	10-hr	100-hr
QMD	0.28	0.1	2.82
NHC	1.13	1.13	1.13
SG	0.65	0.58	0.5
BD litter	0.9	–	–
BD duff	6.0	–	–

Ground Cover

Ground cover was assessed using cover classes (Table 1). A site mean was calculated by averaging the cover class midpoints for subplots in each site. We observed foliar cover of grass litter, leaf litter (deciduous plant leaves), exposed rock, bare ground, and the cover of woody debris (e.g., branches and sticks). Total unvegetated area reflects space unoccupied by stem basal area in the subplots (James et al. 2009). We also measured litter depth in each plot. Three measurements in each plot were averaged and the plot means were used to create a site-level mean for litter depth.

Overstory and Midstory

Overstory and midstory trees were first measured in 2003 (see Appendix B). 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 3) 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. In 2017, we measured a subplot (200 m^2) in three of the four sites because of the high volume of trees.

Table 3. Diameter at breast height (DBH) measurement range (cm) and size class used to group 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 percent stocking 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 U.S. and allows parameter estimates to be made from data collected in the metric system. Species change was assessed by subtracting mean basal area or density in 2003 from that in 2020 (change = 2020 value - 2003 value). Negative values reflect cases where the metric was greater in 2003 than 2020. Taken together, all tree metrics were used to describe the forest composition and structure for Manley Woods.

The incidence of tree species was calculated as the percent of all sites (N = 4) occupied by the species. These data are provided in the appendix.

Canopy Closure

Canopy closure data were collected using a densiometer. Densiometer readings were collected in the four cardinal directions in each of the 10-m^2 subplots and converted to canopy closure (multiplied by 1.04). Plot level mean canopy closure (n = 4 per subplot) was used to calculate site-level mean canopy closure. A grand mean was then calculated for all sites (N = 4).

Tree Regeneration

Tree regeneration stems were tallied by species in the 10-m^2 subplots and reported in three size classes: (1) seedlings = stems < 0.5 m tall; (2) small saplings = stems ≥ 0.5 m tall, and < 2.5 cm DBH; and (3) large saplings = stems ≥ 0.5 m tall and DBH ≥ 2.5 cm and < 5.0 cm. Summary was done by combining all species to look at total stems/ha and by calculating stems/ha for each individual species. In both cases, stems were summed and averaged by the number of sites (N = 4).

Statistical Testing

We used a repeated measures ANOVA (SPSS version 20, IBM 2011) to determine if hickory (*Carya* spp.) densities differed among years. Statistical significance was evaluated at the alpha = 0.05 level. Sphericity could be assumed based on Mauchly's test (W = 0.015, P = 0.27, df = 5), so no correction was needed (Norusis 2008).

Results and Discussion

Climate

SPI calculations indicate that conditions at Wilson's Creek NB were primarily in the normal or wet ranges for the overall monitoring period and years where monitoring occurred in Manley Woods (Figure 4). Moderately to extremely dry conditions occurred prior to 1960 at the park.

Comparing historical climate data to present climate conditions to detect trends, such as the development of warming temperatures or more frequent drought, can help us understand why vegetation may be changing. In a 2014 analysis of national parks using gridded data from the Climatic Research Unit high-resolution time series (version 3.21), Monahan and Fisichelli (2014) found that temperatures for Wilson's Creek NB were warming above the historical (1901-2012) range of variability. Precipitation trends were not clear, however. Furthermore, the recent average onset of spring (first leaf and bloom dates) was earlier than 95% of historical measurements (Monahan et al. 2016).

Changes in climate have the potential to have profound effects on forests and woodlands of the Central Hardwoods Region, with effects dependent on variables such as local climate and species composition (Brandt et al. 2014). Potential stressors from climate change could include increasing temperatures, the lengthening of growing seasons, changes to the nature and timing of precipitation, increased occurrence of heavy precipitation events, and an increase in droughts (Brandt et al. 2014). Continuing to promote oak and hickory species in the woodlands at Wilson's Creek NB could increase resilience in the face of potential climate change scenarios as these species may be less vulnerable to a changing climate due to greater tolerance of hot and dry conditions (Swanston et al. 2018).

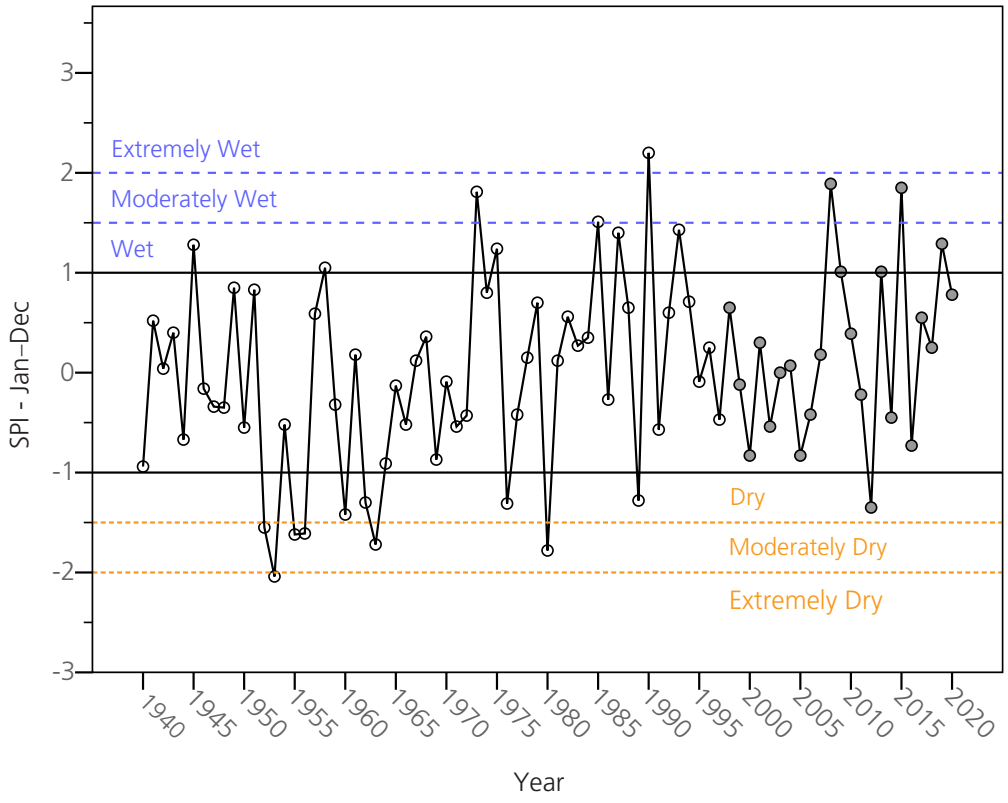


Figure 4. The Standardized Precipitation Index (SPI) from the nearby Springfield regional airport weather station, 1940 to 2020. Normal values fall within the 1 to -1 range. Filled circles represent the vegetation monitoring time period.

Recent Fire History

Earlier in the record, fire in Manley Woods occurred more consistently at the frequency (1-3 years) prescribed in the fire management plan (Figure 5; Gale et al. 2004). In recent years, fire occurred much less frequently in these sites. After 2009, Heartland Network staff in consultation with the U.S. Forest Service recommended that fire be excluded for up to seven years to allow some tree regeneration to reach a fire tolerant stage (Arthur et al. 2012). Conclusions from the 2017 monitoring event included a recommendation to restart the prescribed fire program for Manley Woods because overstory stem density was at a tipping point, moving away from the open woodland/savanna target community. Burning was attempted in 2019 (Leis and Short 2019) resulting in a heterogeneous burn; only two of the four monitoring sites burned (28% of the target area, see Appendix C).

Severity

Mean fire severity for standing vegetation and substrate components in the two burned sites following the 2019 prescribed fire in Manley Woods was mild, just scorching standing vegetation. The litter was partially blackened, duff was nearly unchanged, and wood/leaf structures were unchanged. Mean fire severity, measured on a scale from 1 (heavily burned) to 5 (unburned), was 4.4 for standing vegetation and 4.3 for substrate. Overall, the 2019 prescribed fire in Manley Woods was patchy and low severity. Severity data are not available for the 2006 and 2009 prescribed fires.

Fuel Load

We reported fuel loading as a function of disturbance events (post-tornado or time since fire). Fuel loads were the greatest (mean = 36 tons/acre) and most variable immediately post-tornado (Figure 6). Fuel loading was reduced by the 2006 and 2009 prescribed

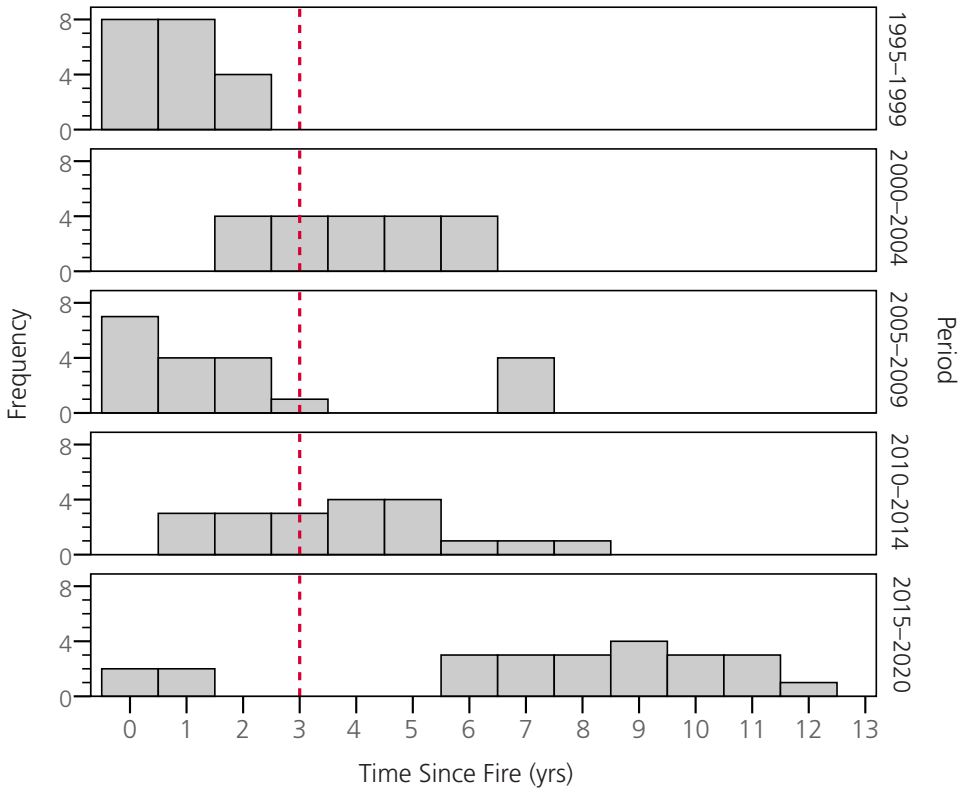


Figure 5. Number of years (Frequency) woodland monitoring sites (N = 4) were observed per Time Since Burn (years) category at Wilson's Creek NB, Republic, Missouri. Each site was assigned a time since fire value for each year from 1995–2020 and results are displayed in five-year intervals. The dotted line (red) indicates the maximum desired fire return interval for these sites (Gale et al. 2004).

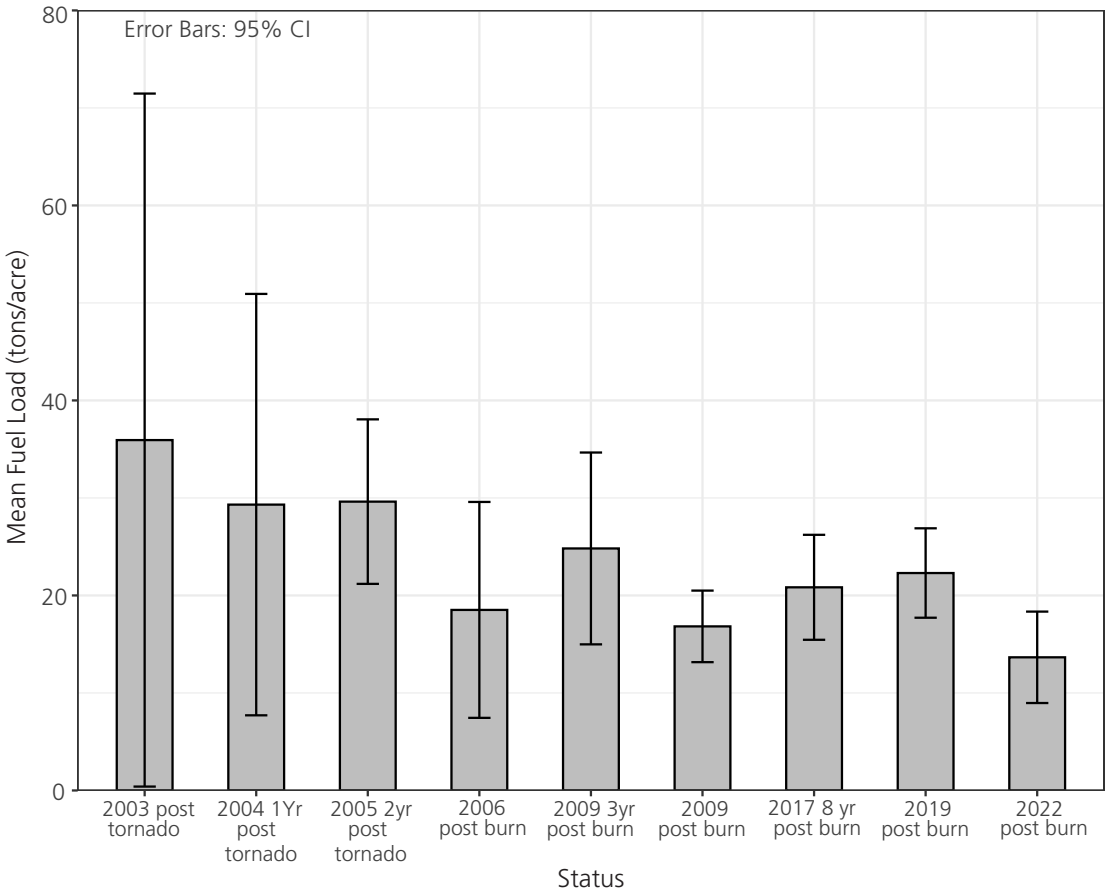


Figure 6. Fuel loading measured in monitoring sites in the Manley Woods unit of Wilson's Creek National Battlefield 2003–2017 (N = 4) and 2019 (N = 2).

fires, but fuel was increasing by 2017. Fuel load after the 2019 prescribed fire remained similar to 2017 levels. Because only sites 6 and 7 were measured post-burn in 2019, the values for 2019 in Figure 6 do not represent the true mean of all Manley Woods sites. For the two burned sites measured post-burn in 2019, the fuel load for site 6 was reduced by 2.5 tons/acre over the pre-burn amount but fuels for site 7 increased by 6.3 tons/acre over pre-burn levels. The patchy, incomplete burn in 2019 likely contributed to 2019 fuel load remaining similar to levels in 2017.

Ground Cover

Ground cover patterns in the Manley Woods unit of Wilson's Creek NB reflect the 2003 tornado and prescribed fires in 2006, 2009, and 2019 (Figure 7). Leaf litter was the dominant ground cover type, although bare ground, rock, and woody debris occupied a comparatively greater area immediately following the 2006 fire. Woody debris cover was greatest in 2003 and 2004 following the tornado, a pattern consistent with the high fuel load observations in those years. Since 2006, mean bare soil and rock declined with each monitoring event while deciduous leaf litter steadily increased despite two additional prescribed fires. The patchy, incomplete nature of recent prescribed fires likely contributed to the accumulation of leaf litter and woody debris. Mean unvegetated cover was variable through the monitoring record. Although sites were mostly unvegetated in 2020, there was still more vegetation than after the 2003 tornado and 2006 prescribed fire.

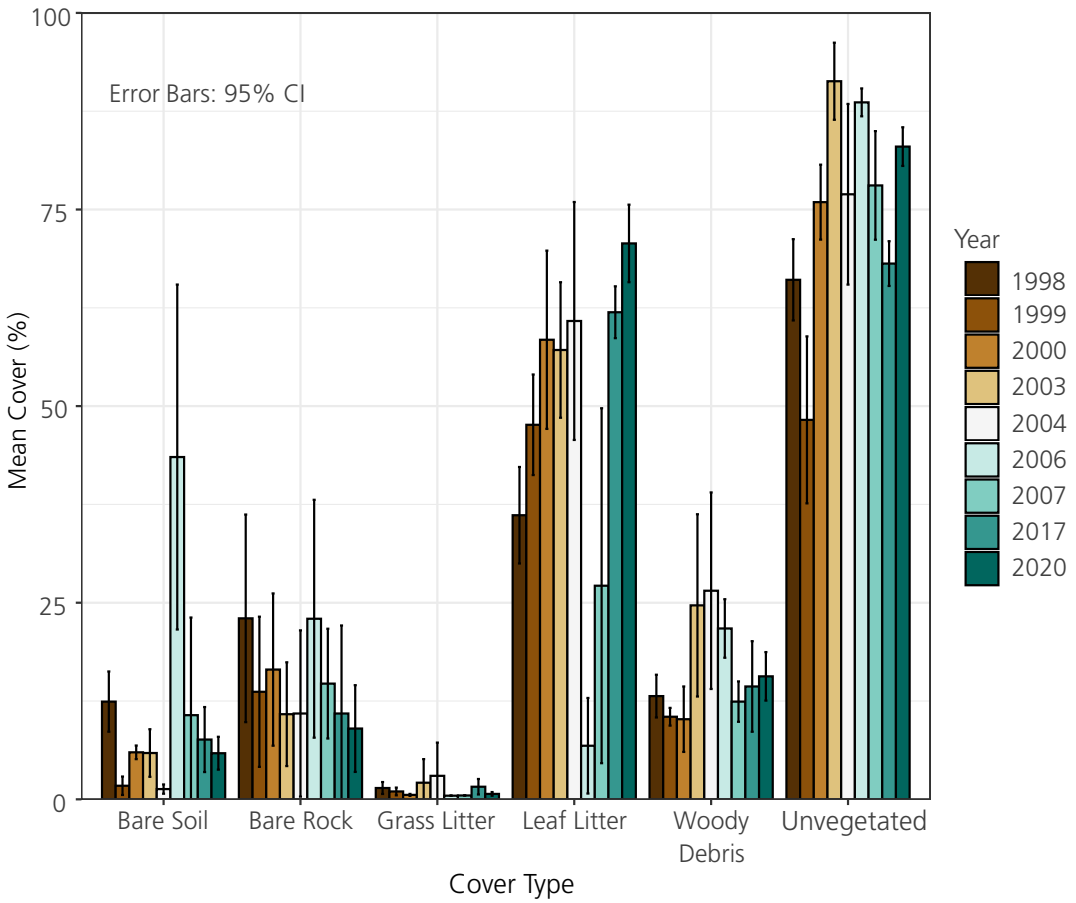


Figure 7. Mean ground cover in monitoring sites in the Manley Woods unit of Wilson's Creek National Battlefield 1998–2020.

Midstory and Overstory Trees

Stand structure was assessed by calculating mean basal area (Figure 8) and density (Figure 9). Through the sampling period, class 1 (midstory) and class 3 (see Table 3 for definitions of overstory classes 2–5) trees exhibited the most amount of change in mean basal area but there was substantial variability among the sites, especially from 2003–2006. The increase in class 1 trees in 2020 represents recruitment to the midstory following a break in disturbance (Figure 5). Mean basal area was greatest in class 3 trees through time.

Mean density was similar between 2003 and 2006, but class 1 trees increased more than four-fold between 2006 and 2020 (817.5 stems/ha in 2020). Midstory trees in 2020 far surpassed the densities of all other tree sizes, with the next greatest class (class 2) having a mean density of 92.5 stems/ha. Size class 5 trees were not observed in 2017, likely the result of sampling a subplot rather than the whole site.

The species-wise summary of overstory basal area and density shows the continued dominance of oaks (*Quercus* spp.) and hickories (*Carya* spp.) in Manley Woods (Tables 4 and 5). Oaks collectively showed little change in basal area, but oak mean density increased more than two-fold from 2003 to 2020 (Tables 4 and 5). White oak (*Quercus alba*) had the greatest species-level mean basal area in each year. The species with the greatest density changed from hickory to black oak (*Quercus velutina*) in 2020. Although mean density for black oak increased substantially, there was a great deal of variability across the sites. It is notable that blackjack oak (*Quercus marilandica*), an historically characteristic tree for this ecosystem, was not observed in the woods until 2020. Future monitoring of the Manley Woods sites will elucidate whether this is a persistent compositional shift.

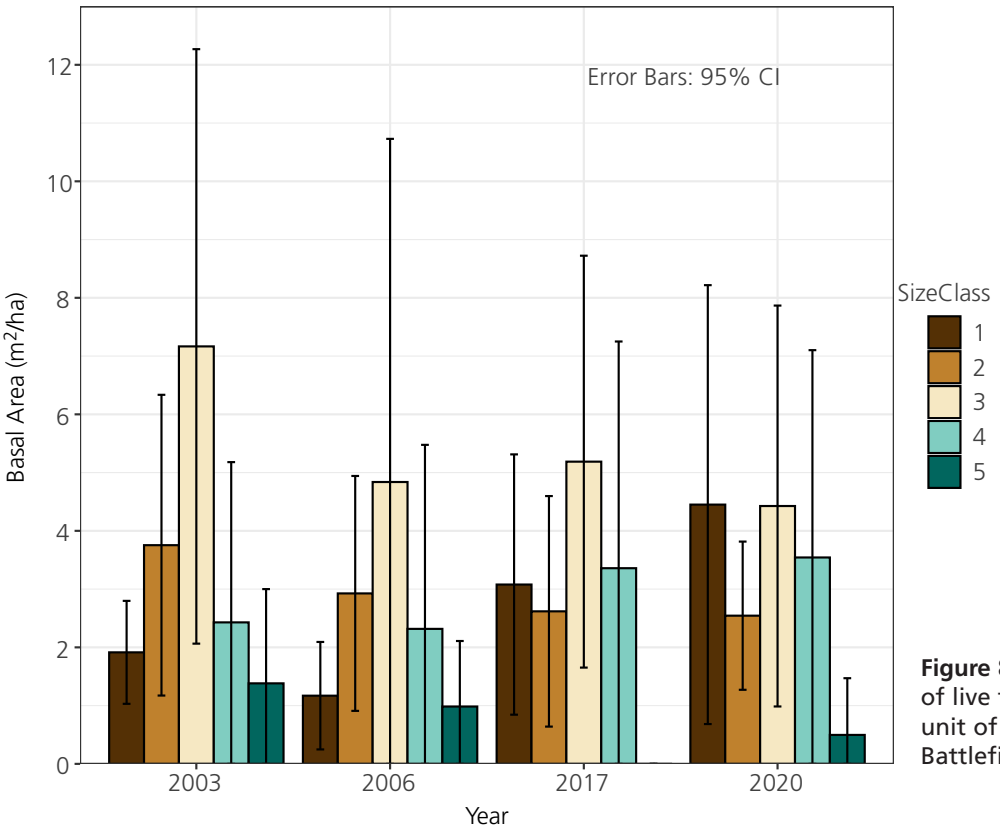


Figure 8. Mean basal area (m^2/ha) of live trees in the Manley Woods unit of Wilson's Creek National Battlefield, 2003–2020 (N = 4).

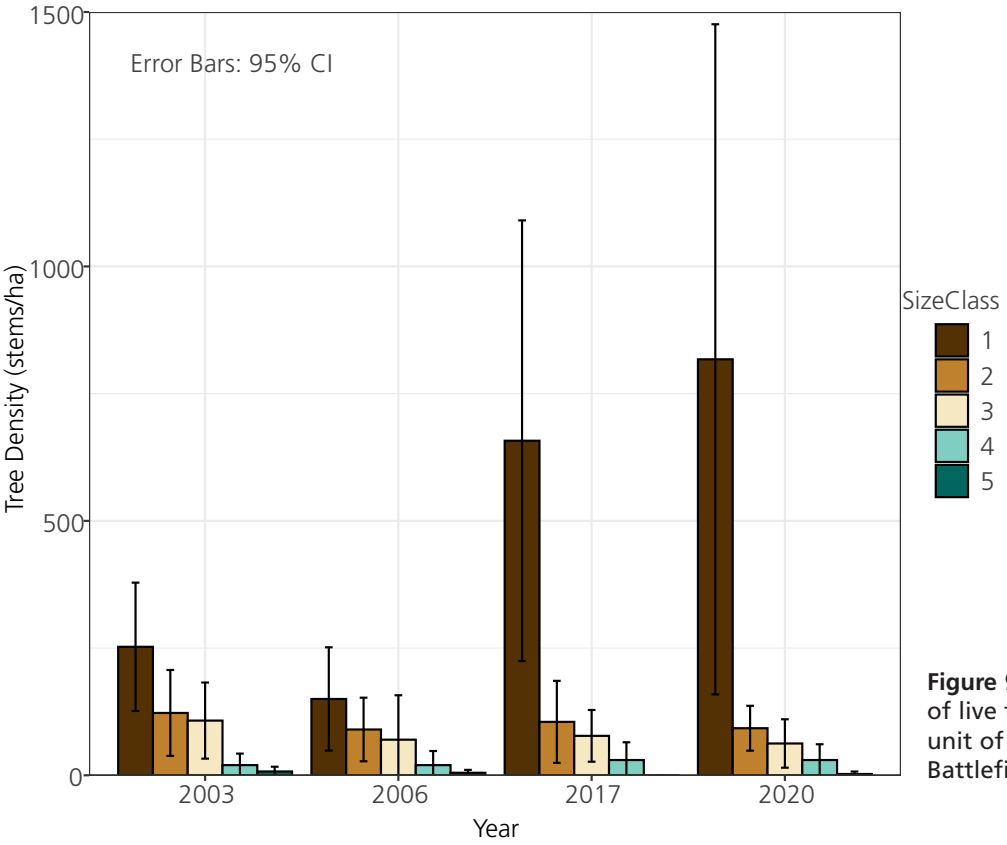


Figure 9. Mean density (stems/ha) of live trees in the Manley Woods unit of Wilson's Creek National Battlefield, 2003–2020 (N = 4).

Table 4. Midstory and overstory species mean basal area (m^2/ha, N = 4), 95% confidence intervals (CI), and change between 2003 and 2020 for the Manley Woods unit of Wilson's Creek National Battlefield; observations are for all size classes combined. Negative change values indicate greater basal area in 2003. All oak species are represented as *Quercus* spp. collectively and by individual species.

Species	Common name	2003 Mean (± CI)	2006 Mean (± CI)	2017 Mean (± CI)	2020 Mean (± CI)	Change from 2003 to 2020
Carya spp.	hickory	3.28 (±2.97)	2.32 (±2.09)	2.07 (±2.49)	2.23 (±2.00)	-1.05
Celtis occidentalis	common hackberry	0.26 (±0.33)	0.11 (±0.16)	0.32 (±0.63)	0.44 (±0.70)	0.18
Cercis canadensis	eastern redbud	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.06 (±0.11)	0.06
Diospyros virginiana	common persimmon	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.02 (±0.03)	0.02
Fraxinus spp.	ash	0.06 (±0.04)	0.08 (±0.05)	0.05 (±0.09)	0.15 (±0.19)	0.09
Juglans nigra	black walnut	0.86 (±0.48)	0.31 (±0.61)	0.36 (±0.70)	0.39 (±0.74)	-0.47
Juniperus virginiana	eastern redcedar	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.02 (±0.03)	0.02
Morus alba	white mulberry	0.03 (±0.07)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	-0.03
Morus rubra	red mulberry	0.04 (±0.08)	0.07 (±0.13)	0.12 (±0.23)	0.14 (±0.27)	0.1
Prunus serotina	black cherry	0.02 (±0.02)	0.01 (±0.01)	0.49 (±0.50)	0.73 (±0.64)	0.71
Quercus spp.	oak	11.34 (±9.00)	9.02 (±9.92)	10.37 (±5.46)	10.94 (±3.24)	-0.40
Quercus alba	white oak	**5.86[a] (±8.36)**	**5.93[a] ±9.00)**	**3.83[a] (±7.37)**	**4.25[a] (±5.55)**	**-1.61[b]**
Quercus macrocarpa	bur oak	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.26 (±0.51)	0.26
Quercus marilandica	blackjack oak	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.06 (±0.12)	0.06
Quercus muehlenbergii	chinquapin oak	0.15 (±0.20)	0.16 (±0.21)	0.22 (±0.30)	0.84 (±0.87)	0.69
Quercus rubra	northern red oak	0.86 (±0.96)	0.47 (±0.47)	1.57 (±2.91)	0.93 (±0.85)	0.07
Quercus stellata	post oak	2.98 (±4.17)	1.84 (±1.83)	3.26 (±6.03)	2.39 (±2.90)	-0.59
Quercus velutina	black oak	1.49 (±1.12)	0.63 (±1.23)	1.49 (±0.95)	2.21 (±2.40)	0.72
Sassafras albidum	sassafras	0.00 (±0.00)	0.00 (±0.00)	0.09 (±0.18)	0.22 (±0.39)	0.22
Ulmus spp.	elm	0.76 (±1.23)	0.32 (±0.59)	0.38 (±0.45)	0.13 (±0.09)	-0.63

[a] indicates species with the greatest mean basal area each year (also in bold).

[b] indicates species with greatest change in mean basal areas from 2003 baseline (also in bold).

Hickory species represent a large proportion of the overstory composition, but there was much variability, especially in density. For example, sites 5 and 6 had 1.5–5 times more hickory stems than sites 4 and 7. Means for hickory were not significantly different among sampling years (F = 0.64, P = 0.61; repeated measure ANOVA). The ecology of hickories is similar in some ways to the ecology of oaks. Both genera have low to intermediate shade tolerance, large taproots, and high probability of resprouting following topkill of stems (Smith 1990a, b) but oak species tend to have thicker, more fire-resistant bark than hickories (Coladonato 1992a, b; Johnson et al. 2009).

Early seral species have increased in recent years. Of note is the first occurrence of eastern redcedar (*Juniperus virginiana*) in 2020. The mean density of early seral species such as black cherry (*Prunus serotina*), hackberry (*Celtis occidentalis*), and sassafras (*Sassafras albidu*m) were greatest in 2020. The magnitude of basal area and density increases for black cherry is notable among the individual species change assessments (Tables 4 and 5). As the climate continues to change, an oak-hickory community type may provide resilience in addition to meeting the goal of restoring historical plant communities. Species characteristic of oak-hickory communities are adapted for the variable conditions of periodic drought punctuated by extreme weather events. Although the characteristic oak and hickory species have persisted after intense disturbances, increasing mesic species abundance may weaken the community's resilience to climate change. These early seral species tend to require consistently moister conditions to persist, and future climate moisture may be more variable with frequent dry periods.

Table 5. Midstory and overstory species mean density (stems/ha, N = 4), 95% confidence intervals (CI), and change between 2003 and 2020 for Manley Woods unit, Wilson's Creek National Battlefield; observations are for all size classes combined. Negative values indicate greater density in 2003. All oak species are represented as *Quercus* spp. collectively and by individual species.

Species	Common Name	2003 Mean (±CI)	2006 Mean (±CI)	2017 Mean (±CI)	2020 Mean (±CI)	Change from 2003 to 2020
Carya spp.	hickory	**175.0[a] (±153.0)**	**122.5[a] (±127.1)**	175.0 (±213.6)	152.5 (±123.0)	-22.5
Celtis occidentalis	common hackberry	15.0 (±17.0)	17.5 (±28.1)	17.5 (±34.3)	22.5 (±28.1)	7.5
Cercis canadensis	eastern redbud	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	7.5 (±14.7)	7.5
Diospyros virginiana	common persimmon	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	7.5 (±9.4)	7.5
Fraxinus spp.	ash	12.5 (±9.4)	10.0 (±8.0)	7.5 (±14.7)	20.0 (±22.6)	7.5
Juglans nigra	black walnut	20.0 (±8.0)	5.0 (±9.8)	5.0 (±9.8)	10.0 (±11.3)	-10
Juniperus virginiana	eastern redcedar	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	5.0 (±9.8)	5
Morus alba	white mulberry	2.5 (±4.9)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	-2.5
Morus rubra	red mulberry	2.5 (±4.9)	5.0 (±9.8)	2.5 (±4.9)	2.5 (±4.9)	0
Prunus serotina	black cherry	5.0 (±5.7)	2.5 (±4.9)	90.0 (±106.2)	132.5 (±106.0)	127.5
Quercus spp.	oak	210.0 (±100.9)	152.5 (±128.9)	495.0 (±215.7)	537.5 (±394.3)	327.5
Quercus alba	white oak	85.0 (±121.0)	80.0 (±125.2)	72.5 (±89.6)	85.0 (±61.2)	0
Quercus macrocarpa	bur oak	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	2.5 (±4.9)	2.5
Quercus marilandica	blackjack oak	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	2.5 (±4.9)	2.5
Quercus muehlenbergii	chinquapin oak	12.5 (±18.6)	12.5 (±18.6)	65.0 (±121.0)	80.0 (±82.0)	67.5
Quercus rubra	northern red oak	45.0 (±42.7)	22.5 (±31.4)	62.5 (±73.5)	50.0 (±34.9)	5
Quercus stellata	post oak	47.5 (±55.7)	32.5 (±35.2)	75.0 (±63.3)	45.0 (±47.0)	-2.5
Quercus velutina	black oak	20.0 (±17.9)	5.0 (±9.8)	**220.0[a] (±174.2)**	**272.5[a] (±313.8)**	**252.5[b]**
Sassafras albidum	sassafras	0.0 (±0.0)	0.0 (±0.0)	25.0 (±49.0)	72.5 (±129.1)	72.5
Ulmus spp.	elm	67.5 (±119.6)	20.0 (±33.0)	52.5 (±67.1)	35.0 (±25.9)	-32.5

[a] indicates species with the greatest mean density (also in bold).

[b] indicates species where mean density changed the most from 2003 baseline (also in bold).

Woodland structure can be described and defined using several metrics, including stocking level and canopy closure. Tree stocking is a measure of the extent to which the growth potential of a site is utilized by trees and is determined using both tree density and basal area (Table 6). Stocking level also provides insight into how woodland community structure (e.g., savanna, open woodland, closed woodland, forest) may change over time. Canopy closure occurs at approximately 60% stocking in upland hardwood communities, but growing space for trees is still available. A stocking value ≥ 100% represents an overstocked stand, where trees are utilizing all potential growing space (Gingrich 1967; Johnson et al. 2009). Stocking in woodlands ranges from 30–75%, with closed woodlands maintained at about 60–75% and open woodlands maintained between 30–60% (Hanberry et al. 2014; Dey et al. 2017). We determined the current stocking level of Manley Woods to be 38%, which by definition would classify it as the desired open woodland community type.

Table 6. Mean basal area (m^2/ha) and tree density (stems/ha) were used to determine stocking density in the Manley Woods unit of Wilson's Creek National Battlefield from 2003 to 2020 (N = 4). CI = 95% confidence intervals.

Year	Mean Basal Area (m^2/ha) (± CI)	Mean Density (stems/ha) (± CI)	Stocking Percent (± CI)
2003	16.6 (±9.7	510 (±242)	42.3 (±24.3)
2006	12.2 (±11.3)	335 (±234.7)	31.2 (±28.7)
2017	14.2 (±6.9)	870 (±313.9)	35.4 (±18.4)
2020	15.5 (±3.8)	1005 (±554.7)	38.3 (±10.9)

Mean canopy closure, however, indicated that the community changed from an open to closed type over time (Figure 10). The 2003 tornado impacted sites 4 and 5 to a greater extent than the other sites, and as a result those two sites had low canopy closure in the years immediately following that disturbance. In contrast, the canopy was more closed and homogenous across all sites in 2017 and 2020 (90.1% and 89.5%, respectively). The increased canopy closure coincided with the increase in stem density of midstory trees. While midstory trees have relatively little effect on stocking and basal area, they can greatly impact canopy closure by reducing sunlight to the forest floor. Thus, while stocking levels alone suggest Manley Woods is in an open woodland structure, the canopy closure and small tree density may be too high for it to function as an open woodland. The complementary nature of stand stocking and canopy closure demonstrates the importance of monitoring multiple metrics of stand structure and the overall plant community.

The proportion of snags (i.e., dead trees) to total stems (live trees plus dead trees) was found to have decreased between the 2003 and 2020 (Table 7). However, snag density increased between those years, a result of overall live and dead stem densities increasing (Tables 6 and 7). Maintaining snags in Manley Woods is important, as snags provide critical habitat for a wide variety of wildlife (Dey and Kabrick 2015).

Table 7. Mean density (stems/ha) of snags (dead trees) and the percent of total stems that were snags in the Manley Woods unit of Wilson's Creek National Battlefield from 2003 to 2020 (N = 4). CI = 95% confidence intervals.

Year	Mean Density (stems/ha) (± CI)	Percent Snags (# of snags/ # of total stems)
2003	63 (± 56.2)	10.9
2006	75 (± 33.5)	18.3
2017	105 (± 41.2)	10.8
2020	78 (± 44.1)	7.2

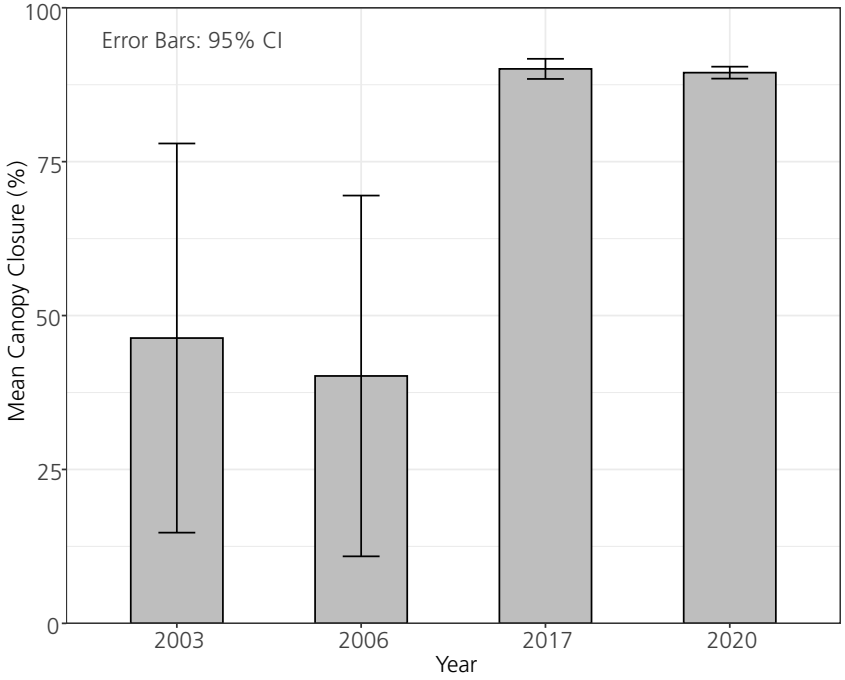


Figure 10. Canopy closure in the Manley Woods unit of Wilson's Creek National Battlefield 2003–2020 (N = 4).

Tree Regeneration

Total tree regeneration stem density (including seedlings, small saplings, and large saplings) was greatest in 1999 (Figure 11) and declined between 1999 and 2007. Recovery of regeneration stem density began in 2017 and continued in 2020 (Figure 11). We found seedlings to be less dense since 2000 (Figure 12). The mean density of small saplings was greatest in 2017 and remained high in 2020 (Figure 13). On the other hand, small and large saplings increased dramatically compared to pre-disturbance levels. Large saplings have the lowest density among regeneration size classes, but 2020 mean density was more than 13 times greater than at the start of monitoring in 1998. No large saplings were observed in 1999 or 2003. The reduction and reduced intensity of prescribed fire over the last decade may have allowed for regeneration to reach more mature developmental stages similar to the rise in midstory trees.

In 2020, oak and hickory species accounted for a large portion of the increase in density of large saplings. Elms (*Ulmus* spp.), eastern redcedar, and sassafras, however, had comparably high mean densities (Table 8). Early successional species like elm, hackberry (*Celtis* spp.), black cherry, mulberry (*Morus* spp.), and sassafras had increases in seedlings and/or small saplings. Eastern redcedar was at its lowest seedling density but we observed the greatest density of large saplings in 2020. The regeneration density of this species is important to monitor because of its potential to become invasive in the absence of fire in woodland and glade habitats.

Oak species are of particular interest in this upland woodland community. Blackjack and black oaks (red oak group in Table 8) were dominant overstory trees in presettlement times (Gremaud 1986). For oaks, development and recruitment are ideal when stocking is below 60% (1/3 full light; Johnson et al. 2009; Blizzard et al. 2013; Dey et al. 2017), and stocking was well within this range in 2020. However, the high canopy closure could be a limiting factor in the establishment of new oak regeneration. Furthermore, given the current woodland structure (Gingrich 1967), we can expect midstory and overstory density and/or basal area will continue to increase in the absence of disturbance as trees take advantage of the growing space still available.

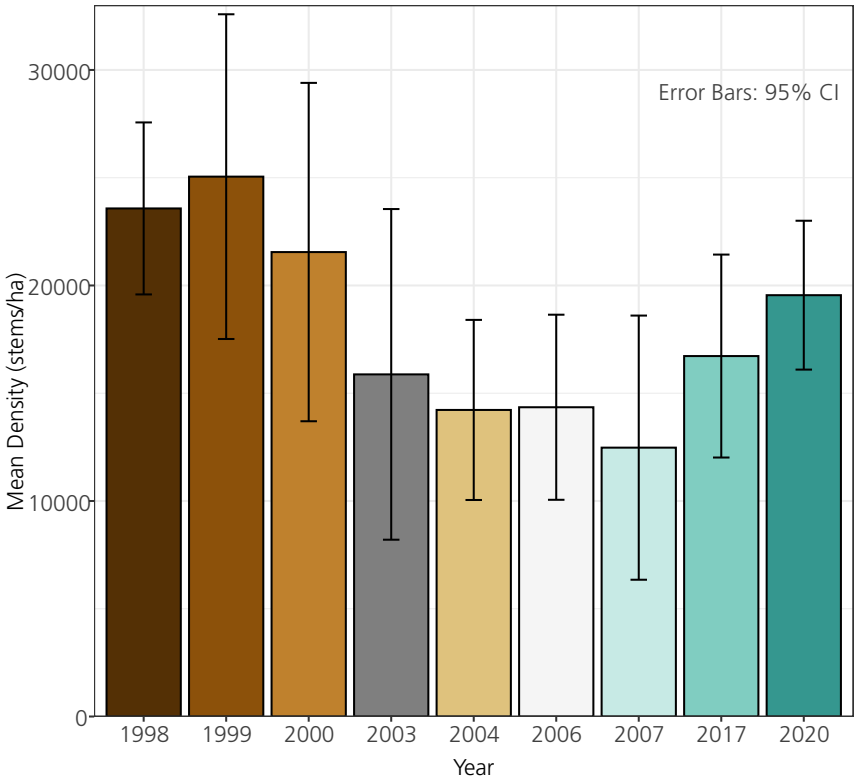


Figure 11. Mean density (stems/ha) of all tree regeneration classes (seedlings and saplings) in the Manley Woods unit of Wilson's Creek National Battlefield, 2003–2020 (N = **4).**

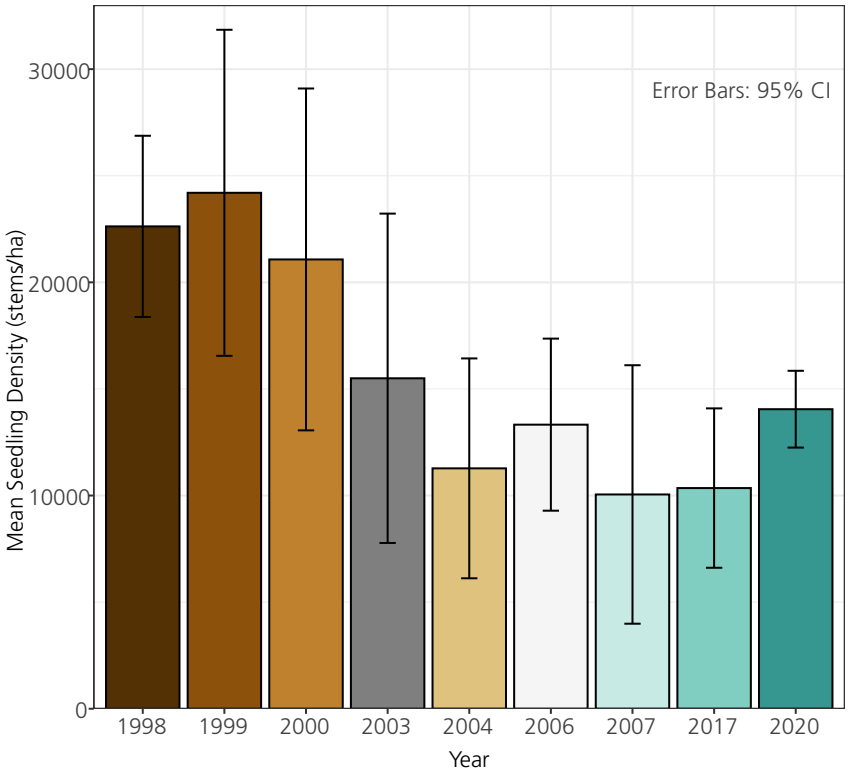


Figure 12. Mean density (stems/ha) of tree seedlings (<0.5 m tall) in the Manley Woods unit of Wilson's Creek National Battlefield, 2003–2020 (N = 4).

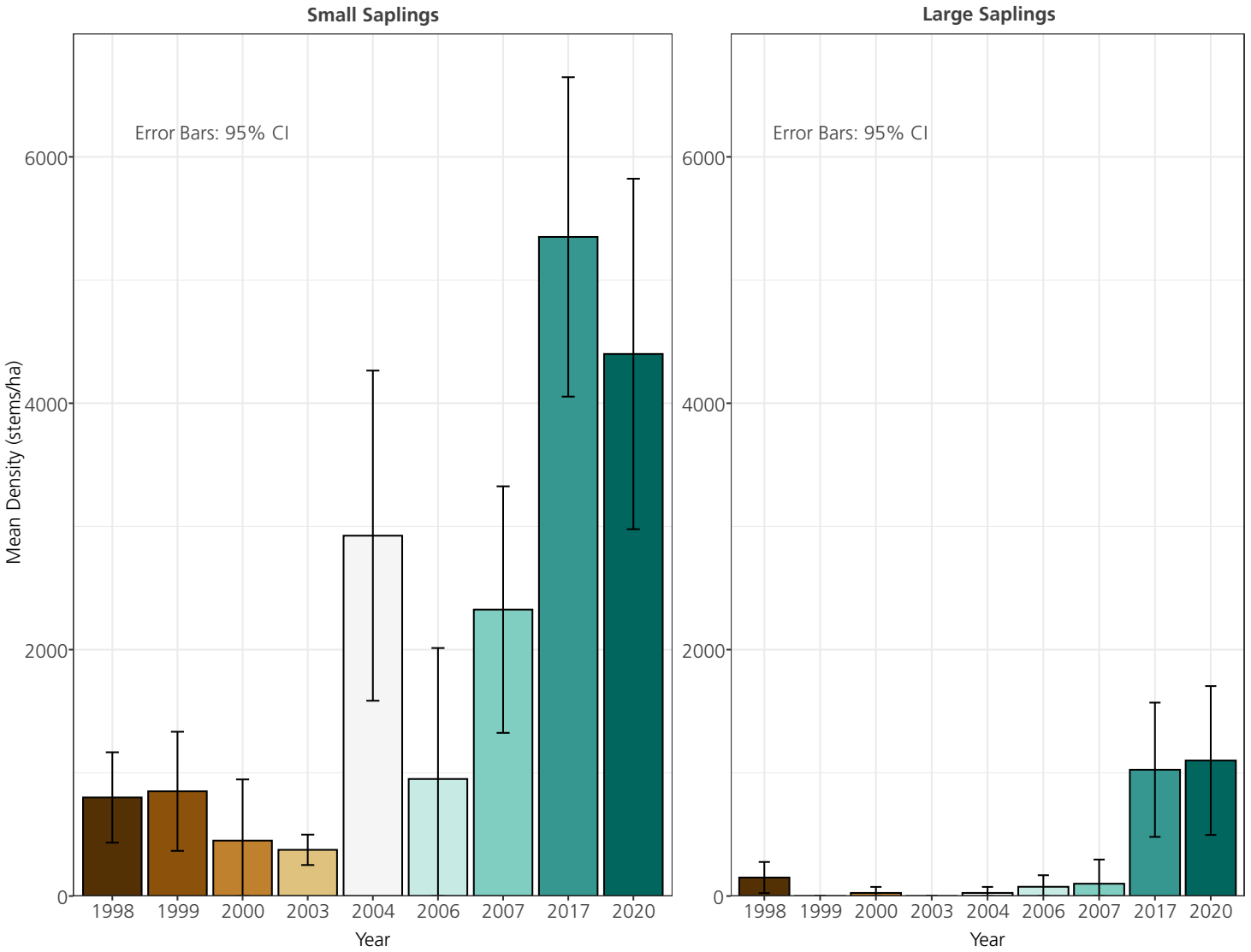


Figure 13. Mean density (stems/ha) of small tree saplings (≥0.5 tall and <2.5 cm DBH) and large tree saplings (≥0.5 m tall and DBH ≥2.5 cm and <5.0 cm) in the Manley Woods unit of Wilson's Creek National Battlefield, 2003–2020 (N = 4).

Table 8. Regeneration density by species (mean stems/ha) in Manley Woods unit, Wilson's Creek National Battlefield. Change indicates the difference in stems between 1998 and 2020. Negative values indicate more stems in 1998.

	Mean Seedling Density (stems/ha)				Mean Small Sapling Density (stems/ha)				Mean Large Sapling Density (stems/ha)				Change from 1998 to 2020 (stems/ha)		
Species	**1998**	**2004**	**2017**	**2020**	**1998**	**2004**	**2017**	**2020**	**1998**	**2004**	**2017**	**2020**	**seedling**	**small sapling**	**large sapling**
Acer negundo	0	0	100	25	0	0	0	0	0	0	0	0	25	0	0
Acer rubrum	0	0	0	425	0	0	0	0	0	0	0	0	425	0	0
Aesculus glabra	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0
Carya spp.	2500	1125	1150	1125	100	225	725	725	0	0	150	125	-1375	625	125
Celtis spp.	1150	1075	1600	2075	0	375	**1225**[a]	**925**[a]	25	0	0	25	925	**925**[b]	0
Cercis canadensis	625	25	50	775	25	175	50	75	0	0	125	75	150	50	75
Cornus florida	0	0	25	50	0	0	0	0	0	0	0	0	50	0	0
Corylus americana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diospyros virginiana	525	25	50	150	25	50	125	175	0	0	0	25	-375	150	25
Fraxinus spp.	675	275	275	400	100	175	350	200	25	0	0	25	-275	100	0
Gleditsia triacanthos	50	75	0	0	0	0	0	0	0	0	0	0	-50	0	0
Juglans nigra	75	0	25	100	0	0	0	0	0	0	0	0	25	0	0
Juniperus virginiana	1550	2150	450	275	0	125	175	125	25	0	25	100	-1275	125	75
Maclura pomifera	0	0	0	0	0	0	50	25	0	0	0	0	0	25	0
Morus alba	0	175	0	0	0	75	0	0	0	0	0	0	0	0	0
Morus rubra	200	0	450	200	25	0	50	100	0	0	25	75	0	-75	-75
Nyssa sylvatica	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0
Prunus hortulana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prunus serotina	2075	650	250	250	**250**[a]	**725**[a]	400	475	0	**25**[a]	125	75	-1825	225	75
Red oak group	3350	825	375	300	200	400	500	175	25	0	175	125	**-3050**[b]	-25	100
White oak group	3575	1350	950	925	75	75	575	600	25	0	100	125	-2650	525	100
Sassafras albidum	550	125	50	600	0	200	175	25	0	0	125	125	50	25	125
Ulmus spp.	**5725**[a]	**3375**[a]	**4525**[a]	**6300**[a]	0	325	950	775	25	0	175	**200**[a]	575	775	**175**[b]

[a] indicates species with the greatest density for each year-type combination (also in bold).

[b] indicates species that changed the most from 2003 for each type (also in bold).

Conclusions

During the fire-free interval, midstory and regeneration density increased, and treatment is now required. Furthermore, seedlings of the target tree eastern redcedar were successfully reduced, but large saplings and overstory stems increased. Canopy closure rates are above desired levels, and we observed large increases in density in less desirable early seral species such as black cherry and sassafras. We suggest resuming prescribed fire on an approximate 3-year interval (Nelson 2005; Dey and Kabrick 2015) to more closely align with historical fire regimes (Guyette et al. 2006; Guyette et al. 2012).

Multiple prescribed fires have been documented to be considerably more effective than one burn at killing sapling-sized stems, particularly of non-oaks (Dey and Hartman 2005). However, midstory trees may be large enough that prescribed fire alone may not consistently control even non-oak competitors (Dey and Hartman 2005; Short et al. 2019). For these larger stems, removal using mechanical and chemical treatments (Dey and Kabrick 2015; Dey et al. 2017) may be necessary to reduce density of undesirable species, promote oak and hickory dominance, and restore target open canopy woodland conditions.



Mary Short at Manley Woods site 4 in Wilson's Creek National Battlefield after a mild prescribed fire in 2019.

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Appendix A. Species Occurrence

Table A1. Overstory tree species (regeneration not included) for Manley Woods unit, Wilson's Creek National Battlefield. Mean basal area (m^2/ha) and incidence data (% of all sites occupied by the species) from the most recent monitoring event (2020). Origin codes: N = native, E = nonnative. CI = 95% confidence intervals.

Species	Common Name	Origin	Mean Basal Area (2020)	± CI (95%)	2020 Incidence (%)
Carya sp.	hickory	N	0.04	0.09	25
Carya cordiformis	bitternut hickory	N	0.70	0.38	100
Carya ovata	shagbark hickory	N	0.01	0.01	25
Carya texana	black hickory	N	0.89	1.46	75
Carya tomentosa	mockernut hickory	N	0.58	1.07	50
Celtis occidentalis	common hackberry	N	0.44	0.70	25
Cercis canadensis	estern redbud	N	0.06	0.11	50
Diospyros virginiana	common persimmon	N	0.02	0.03	50
Fraxinus americana	white ash	N	0.05	0.09	25
Fraxinus pennsylvanica	green ash	N	0.10	0.19	25
Juglans nigra	black walnut	N	0.39	0.74	50
Juniperus virginiana	eastern redcedar	N	0.02	0.03	25
Morus rubra	red mulberry	N	0.14	0.27	25
Prunus serotina	black cherry	N	0.73	0.64	100
Quercus alba	white oak	N	4.25	5.55	100
Quercus macrocarpa	bur oak	N	0.26	0.51	25
Quercus marilandica	blackjack oak	N	0.06	0.12	25
Quercus muehlenbergii	chinquapin oak	N	0.84	0.87	100
Quercus rubra	northern red oak	N	0.93	0.85	75
Quercus stellate	post oak	N	2.39	2.90	75
Quercus velutina	black oak	N	2.21	2.40	100
Sassafras albidum	sassafras	N	0.22	0.39	75
Ulmus americana	American elm	N	0.02	0.05	25
Ulmus rubra	slippery elm	N	0.10	0.08	75

Appendix B. Management and Sampling History

Here, we present the sampling and management history (Table B1) and the fire and disturbance history (Table B2) for the Manley Woods unit at Wilson's Creek National Battlefield.

Table B1. Sampling and management history for the Manley Woods unit, Wilson's Creek National Battlefield. Years not listed had no activity. X = sampling occurred.

Element	Site	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2020
Understory	4	–	X	X	X	–	–	X	X	–	X	X	–	–	–	–	–	–	–	–	–	X	X
Regeneration	4	–	X	X	X	–	–	X	X	–	X	X	–	–	–	–	–	–	–	–	–	X	X
Overstory	4	–	–	–	–	–	–	X	–	–	X	–	–	–	–	–	–	–	–	–	–	X	X
Fuels-pre	4	–	–	–	–	–	–	X	X	X	–	–	–	X	–	–	X	–	–	–	–	X	–
Fuels-post	4	–	–	–	–	–	–	–	–	–	X	–	–	X	–	–	–	–	–	–	–	–	–
Fire history	4	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Understory	5	–	X	X	X	–	–	X	X	–	X	X	–	–	–	–	–	–	–	–	–	X	X
Regeneration	5	–	X	X	X	–	–	X	X	–	X	X	–	–	–	–	–	–	–	–	–	X	X
Overstory	5	–	–	–	–	–	–	X	–	–	X	–	–	–	–	–	–	–	–	–	–	X	X
Fuels-pre	5	–	–	–	–	–	–	X	X	X	–	–	–	–	–	–	–	–	–	–	–	X	–
Fuels-post	5	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–
Fire history	5	X	X	X	X	X	X	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X
Understory	6	X	X	X	X	–	–	X	X	–	X	X	–	–	–	–	–	–	–	–	–	X	X
Regeneration	6	–	X	X	X	–	–	X	X	–	X	X	–	–	–	–	–	–	–	–	–	X	X
Overstory	6	–	–	–	–	–	–	X	–	–	X	–	–	–	–	–	–	–	–	–	–	X	X
Fuels-pre	6	–	–	–	–	–	–	X	X	X	–	–	–	X	–	–	X	–	–	–	–	X	–
Fuels-post	6	–	–	–	–	–	–	–	–	–	X	–	–	X	–	–	–	–	–	–	–	–	–
Fire history	6	–	–	–	–	–	–	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Understory	7	–	X	X	X	–	–	X	X	–	X	X	–	–	–	–	X	–	–	–	–	X	X
Regeneration	7	–	X	X	X	–	–	X	X	–	X	X	–	–	–	–	X	–	–	–	–	X	X
Overstory	7	–	–	–	–	–	–	X	–	–	X	–	–	–	–	–	X	–	–	–	–	X	X
Fuels-pre	7	–	–	–	–	–	–	X	X	X	–	–	–	X	–	–	X	–	–	–	–	X	–
Fuels-post	7	–	–	–	–	–	–	–	–	–	X	–	–	X	–	–	–	–	–	–	–	–	–
Fire history	7	X	X	X	X	X	X	X	X	X	X	X	X	–	X	X	X	X	X	X	X	X	X

Table B2. Manley Woods fire and disturbance history (1992–2017). X = fire occurred, T = tornado, L = logging, I = ice storm, D = drought. Years not listed had no activity.

Element	Site	1992	1993	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2019
Fire Occurrence	4	–	–	X	–	X	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–
Other Disturbance	4	–	–	–	–	–	–	–	–	–	T	–	L	–	I	–	–	–	–	D	D	D	–	–	D	–
Fire Occurrence	5	X	X	X	–	X	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–
Other Disturbance	5	–	–	–	–	–	–	–	–	–	T	–	L	–	I	–	–	–	–	D	D	D	–	–	D	–
Fire Occurrence	6	X	X	X	–	X	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	X
Other Disturbance	6	–	–	–	–	–	–	–	–	–	T	–	–	–	I	–	–	–	–	D	D	D	–	–	D	–
Fire Occurrence	7	X	X	X	–	X	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	X
Other Disturbance	7	–	–	–	–	–	–	–	–	–	–	–	–	–	I	–	–	–	–	D	D	D	–	–	D	–

Appendix C. Map of 2019 Prescribed Fire in Manley Woods Unit

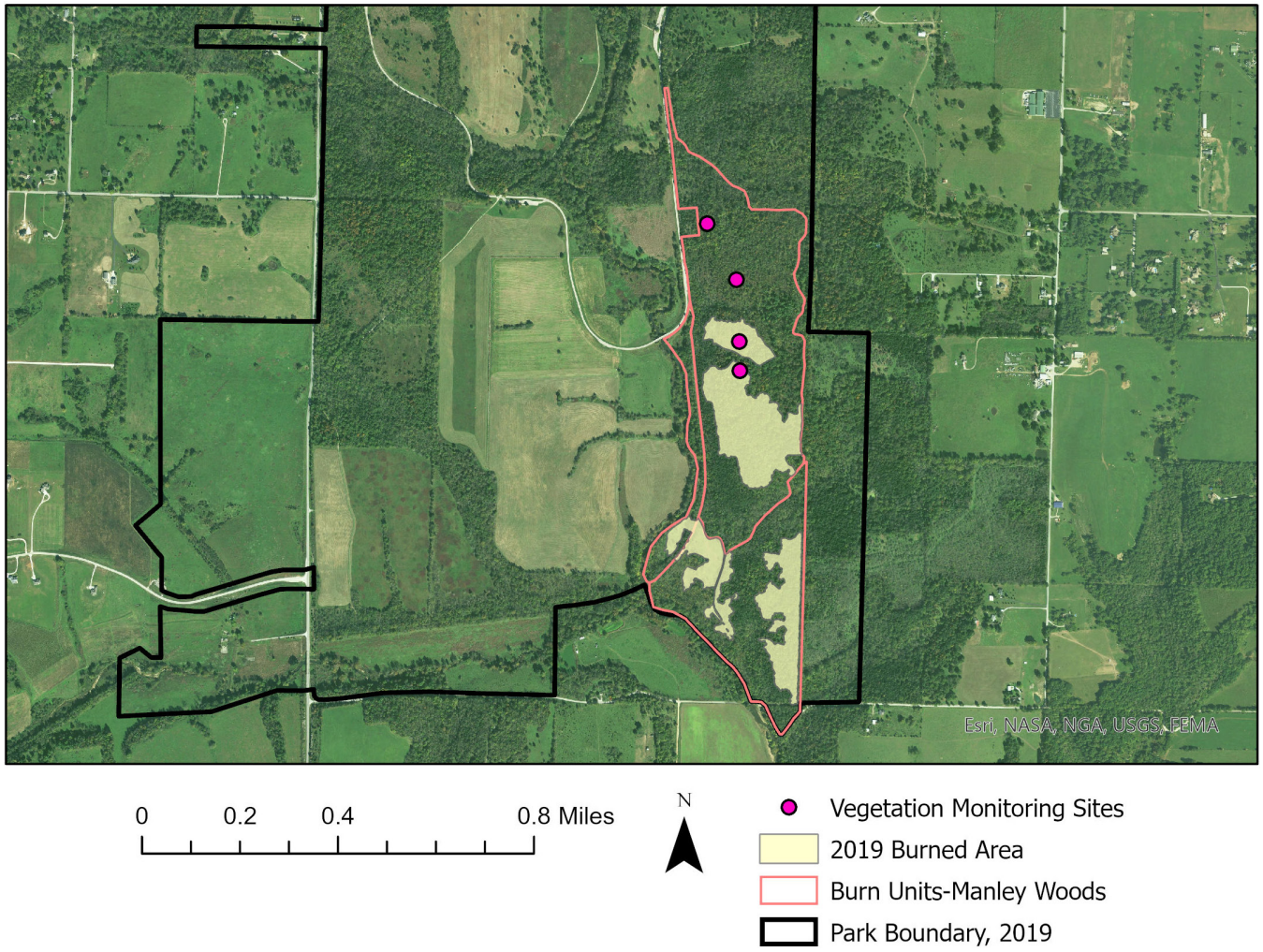


Figure C1. Map of the area burned in the 2019 prescribed fire in the Manley Woods burn unit of Wilson's Creek National Battlefield.

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National Park Service
U.S. Department of the Interior

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