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Natural Resource Stewardship and Science

Tree survey of Historical Viewshed Area at Wilson's Creek National Battlefield, Missouri

2020 Report

Natural Resource Report NPS/HTLN/ December 2020

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ON THE COVER:

Cannon at Wilson's Creek National Battlefield

Executive Summary

Wilson's Creek National Battlefield preserves and commemorates the first major battle of the Civil War west of the Mississippi River which occurred on August 10, 1861. It is also the first battle where a union general was killed, Gen. Nathaniel Lyon. The open savanna landscape and Wilson's Creek and its associated branches were critical factors in determining the events that unfolded during the battle. However, the integrity of the park's historical viewsheds' is poor and restoration efforts are needed to return the landscape back to its 1861 conditions.

A tree survey on Wilson's Creek National Battlefield was conducted in summer 2020 to assess the state of the wooded portion of historical viewsheds to be restored to savanna and woodlands. Savanna restoration will enhance visitor interpretation of the battlefield because the local landscape influenced the 1861 Battle of Wilson's Creek. Furthermore, restoration will support habitat of an endangered ecosystem, limestone glades. We implemented a tree survey to assess the composition and structure of forested portions of the historical viewshed. We surveyed 151 plots across 149.52 acres. The area was split into eight stands based on habitat and soil types (four upland deciduous woodland and forest stands, three bottomland deciduous woodland and forest stands, and one remnant glade stand). Survey methods included deploying a variable radius plot sampling design. For all trees in the plot based on a Cruz-all basal area factor (BAF) of 10, species and diameter at breast height (DBH) were recorded.

The survey revealed that all stands were overcrowded with pole-size (5-10.9 in), evenly aged trees and do not resemble the historical savanna landscape present at the time of the battle. Stand 1 represented an open woodland habitat and Stands 2-8 were forest habitats. The most abundant tree species in the survey area were black walnut (*Juglans nigra*), followed by hackberry (*Celtis occidentalis*), Osage orange (*Maclura pomifera*), chinquapin oak (*Quercus muehlenbergii*), and black oak (*Quercus velutina*). If restoration recommendations outlined in the Cultural Landscape Report (John Milner Associates 2004), Vegetation Management Implementation Plan (NPS 2014), and Implementation of Cultural Landscape Report Treatment Recommendations (Common Heritage Group 2018) are implemented, the survey area may begin to resemble the historical landscape, but composition and structure will still be notably different from historical estimates. In particular, stands 1, 4, and 8 may be similar to historical habitat. The remaining stands will be closed woodland habitats with tree densities and canopy closures exceeding savanna estimates of the historical landscape and tree compositions differing from historical records. Additional stand thinning would be required beyond what was previously recommended.

Introduction

Historically, oak savannas and woodlands were common in Missouri as a result of fire and grazing regimes that created a broad transition zone between the grasslands to the West and forests to the East (Nelson 1985). Missouri's oak savannas and woodlands have densified over time. Present day

forests are 2.3 times denser than they were 200 or more years ago. Moreover, they are dominated by pole-size (5-10.9 in) trees in evenly aged stands (Hanberry et al. 2014). Oak savannas are now critically endangered ecosystems, with <1% of original oak savannas remaining (Nelson 1985).

Oak savannas and woodlands are highly heterogenous because trees are irregularly distributed across the landscape. Heterogeneity of canopy cover and light reaching ground flora results in diverse vegetation composition and structure, often more diverse than prairies or forests. Wildlife diversity, for example small mammals, herptofauna, and birds — most notably birds of high conservation concern — often also respond to this heterogeneity (Dey and Kabrick 2015). The high biodiversity of savannas and woodlands makes these ecosystems more resilient to climate change and better equipped to recover from disturbances that are predicted to increase such as drought, biotic threats, and wildfires (USFS 2014).

Today, like much of Missouri, the savannas and woodlands of Wilson's Creek National Battlefield are severely overcrowded with pole-size, evenly aged trees. It scarcely resembles the pre-settlement or 1861 Battle of Wilson's Creek landscape. The pre-settlement vegetation of Wilson's Creek National Battlefield was characterized as savanna with scatterings of prairies, glades, and woodlands (John Milner Associates 2004). The battlefield's landscape was estimated to have 10 - 20 % canopy cover, 10 - 11 trees/acre, and an average tree diameter of ≤14 inches (Gremaud 1986). This landscape was maintained by yearly autumnal fires set by Native Americans (Gremaud 1986). Bottomland habitats were more wooded than savannas, but not as wooded as present-day notions of woodlands (John Milner Associates 2004). However, middle and upper reaches of intermittent streams likely compositionally and structurally resembled the savanna that surrounded them (John Milner Associates 2004). At the time of the Battle of Wilson's Creek in 1861, the savanna landscape was largely still intact (John Milner Associates 2004). The varied distribution of tallgrasses and clumps of trees across the battlefield played a defining role in the events of the battle (John Milner Associates 2004).

Restoration of the historic landscape is critical for interpretation of the battle as well as conservation of rare and sensitive species. Information on the tree species composition and structure will be needed to plan restoration efforts. The purpose of this study was to survey the wooded portion of historical viewsheds in Wilson's Creek National Battlefield (Figure 1). The area surveyed encompasses land where critical events of the 1861 battle occurred.

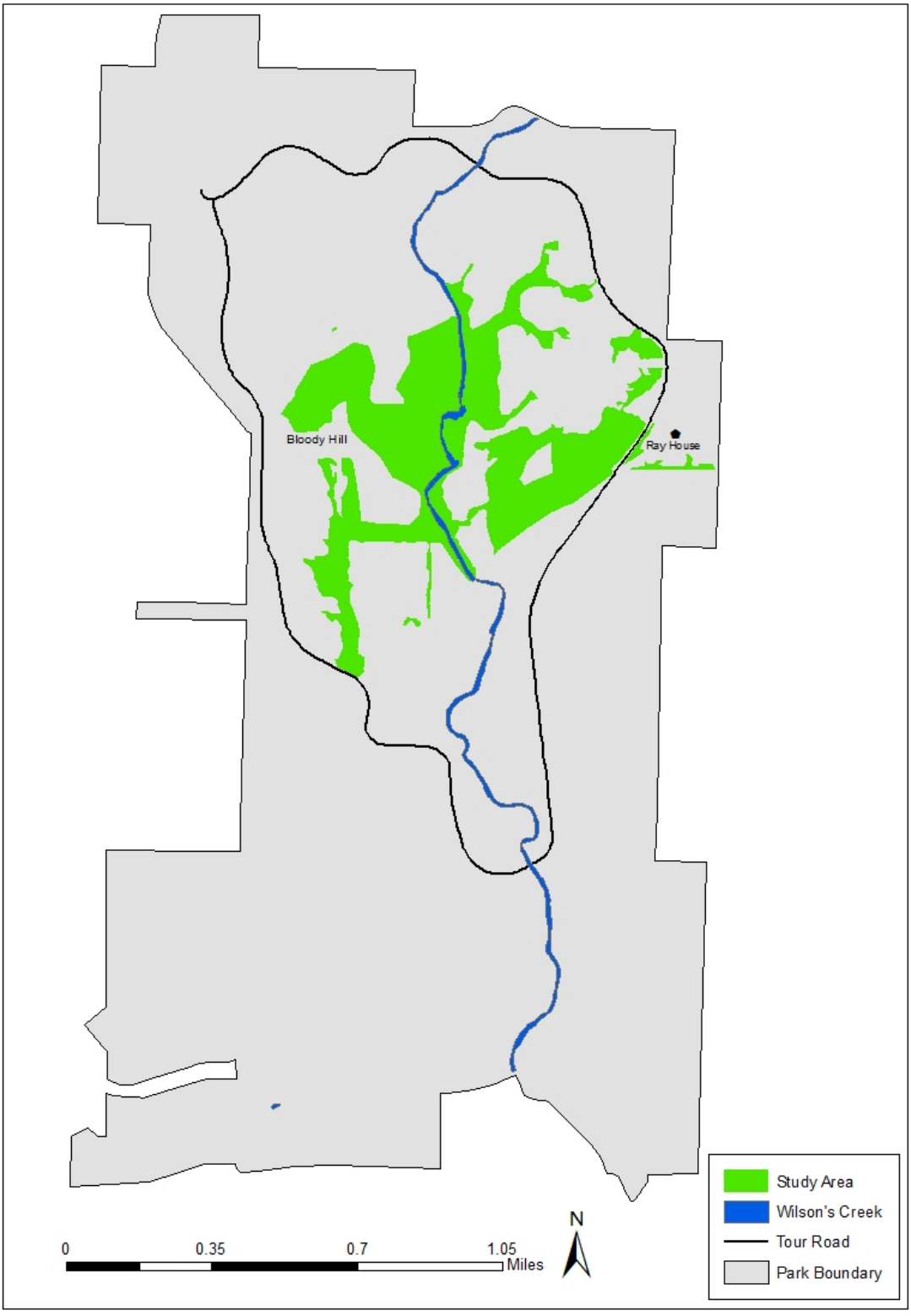

Figure 1. Wooded portion of historical viewshed area surveyed on Wilson's Creek National Battlefield during summer 2020.

Methods

Stand Delineation

We delineated woodlands within the historic viewshed area totaling 169.13 acres. The focal area was located at the center of the park between Bloody Hill and the Ray House, with Wilson's Creek separating it into two nearly equal units (86.12 acres on the Bloody Hill side and 83.01 acres on the Ray House side, Figure 1). The focal area is composed of upland deciduous woodland and forest, bottomland deciduous woodland and forest, and limestone glade (Diamond et al. 2013).

The focal area was divided into eight stands based on vegetation (Diamond et al. 2013), soils (NRCS 2020), and topography (Figure 2). Each stand has a unique combination of habitat and soil types. Stands were created in ArcMap 10.7.1. by overlaying the viewshed polygon with vegetation and soil polygons. Where there was a natural division between habitat types, soil types or both, a stand was drawn creating a separate polygon, eventually separating the viewshed polygon into eight stands. A section of the original viewshed area, the riparian protection zone (Figure 2), was not surveyed due to recommendations from the Cultural Landscape Report (John Milner Associates 2004). Therefore, the total area surveyed was reduced to 149.52 acres.

Survey plots were also created in ArcMap 10.7.1. Using Wilson's Creek as a boundary resulted in two zones for which to delineate stands and survey plots. Plots were established by overlaying two separate grids, originating from random starting points, composed of 200 x 200 ft cells. We established 151 plots, about 10% of the 149.52 acres sampled (Table 1). A 10% sample is a recommended sample size for an accurate tree survey (USFS 2000).

Table 1. Number of plots sampled and size in acres for each stand of the tree survey on Wilson's Creek National Battlefield, Missouri during 2020.

Stand	Acres	Number of Plots
1	8.82	10
2	33.6	37
3	26.4	22
4	9.14	11
5	6.52	6
6	29.43	36
7	20.91	21
8	12.27	8
All Stands	149.52	151

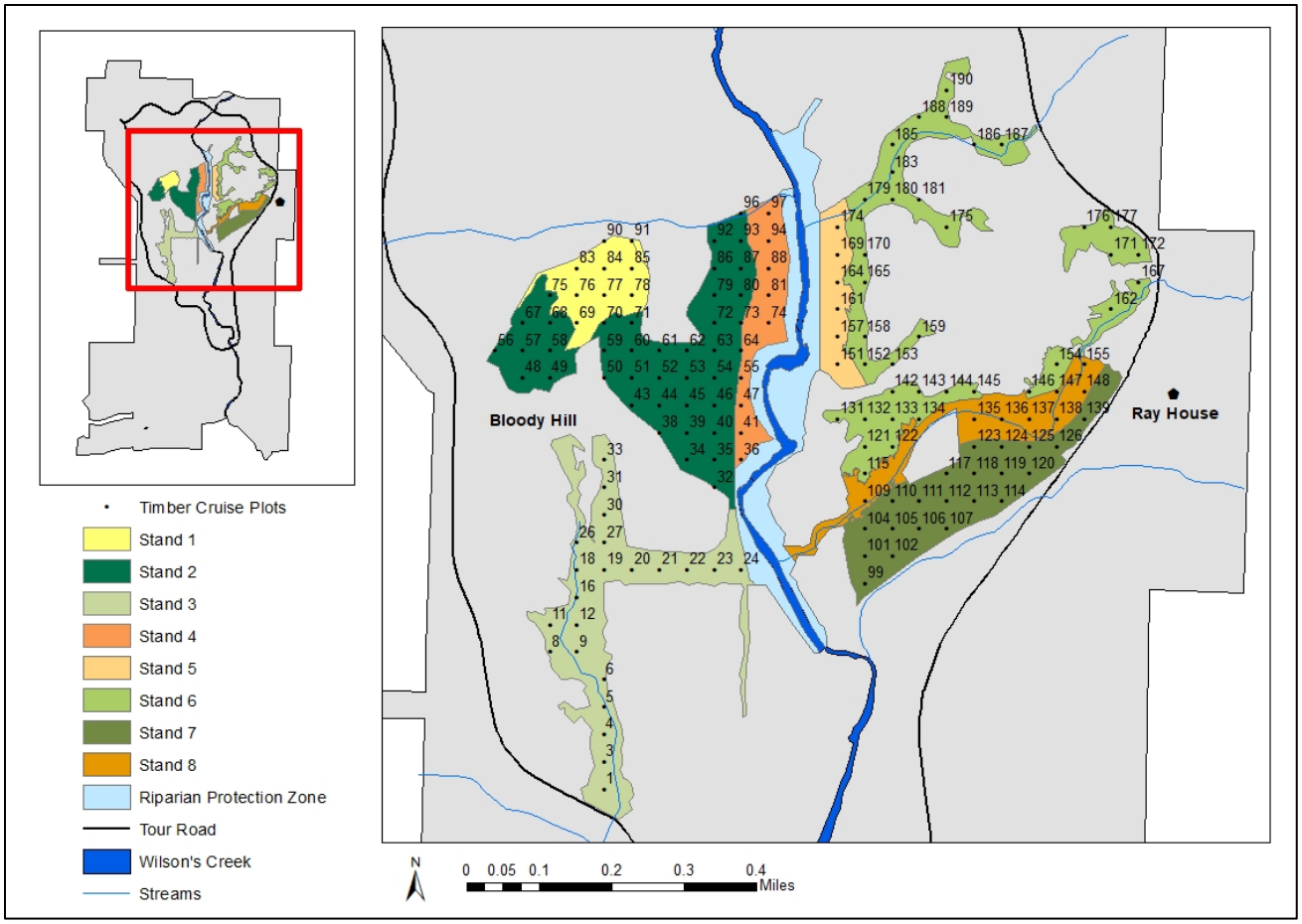

Figure 2. Tree survey plot locations on Wilson's Creek National Battlefield separated by stands. Yellow indicates limestone glade habitat. Shades of green indicate upland deciduous woodland and forest habitat. Shades of orange and the light blue indicate bottomland deciduous woodland and forest habitat. Habitat classification was provided by Diamond et al. (2013).

Survey Design

Our survey was designed to capture tree density, basal area, species identities, and canopy closure. We used variable radius plot sampling to conduct the tree survey. In variable radius plot sampling, the plot radius varies according to the diameter at breast height (DBH) of each tree (Powell 2014). The probability of a tree being selected is proportional to its DBH. Using a basal area factor device, trees are determined "in" or "out" of the plot radius. We used a Cruz-all with a basal area factor of 10, meaning each tree that was counted as "in" represented a basal area of 10 ft^2/acre.

Survey plots were located using waypoints on a Trimble Geo 7x GNSS unit. When the GNSS unit first recorded being within 2 meters of the plot point, the navigator stopped and marked the point with a pin flag, indicating plot center. Then the surveyor stood at plot center and determined which trees were "in" or "out". Trees borderline between "in" or "out" were determined "in" on an alternating basis. For example, if in plot 1 there were three borderline trees, the first and third trees identified as borderline would be counted as "in" and the second borderline tree would be counted as "out." The species and DBH (cm) of all "in" trees were recorded. Four canopy cover measurements were also recorded in the four cardinal directions at plot center using a densiometer.

Data Analysis

Density and composition

Prior to calculations, all DBH measurements were converted to inches and observations were put into two-inch size classes. For example, trees in the 2-inch size class represented a DBH range from 1 to 2.9 inches. DBH was then separated into three size categories based on U.S. Forest Service definitions (USFS 2016): saplings (1 to 4.9 in), pole-size trees (5 to 10.9 in), and sawtimber trees ($\geq$11 in).

Basal area was calculated by multiplying the number of trees in each plot by 10, the basal area factor (BAF) we used in our survey, and a stand average was calculated:

$$\text{Average Basal Area } (\text{ft}^2/\text{acre}) = \frac{\Sigma(\#\text{ of trees in plot } \times \text{BAF})}{\#\text{ of plots in stand}}$$

Density (trees/acre) was calculated for each tree recorded using U.S. Forest Service formula (USFS 2014)

$$\text{Density } (\text{trees}/\text{acre}) = \frac{\text{BAF}}{\pi \times (\text{DBH}/24)^2}$$

Density was calculated for each plot and used to calculate stand average. The smaller the size class of the tree, the greater the tree density and vice versa. Density was calculated by either species or size class. For each stand, species abundance was also calculated and divided into two categories: trees

<11 inches in diameter (sapling and pole-size trees) and trees ≥11 inches in diameter (sawtimber trees).

Canopy closure

The four densiometer measurements collected for canopy cover (% closed) at each plot were averaged and converted to canopy closure and a stand average was calculated from these results:

$$\text{Average Canopy Closure} = \frac{\Sigma\left((CC1 + CC2 + CC3 + CC4)/4 \times 1.04\right)}{\#\text{ of plots in stand}}$$

Where CC1 is canopy cover measurement one, CC2 is canopy cover measurement two, and so forth.

Results

Stand Structure

All eight surveyed stands, excluding Stand 1, were dense with pole-size trees. The upland stands (2, 3, 6, 7) were up to two times denser than the bottomland stand (4, 5, 8). Stands 2 and 7 had the greatest tree densities (589 and 531 trees/acre, respectively) followed by Stand 3 (453 trees/acre) (Table 2). Stands 4 and 8, both bottomland stands, had the smallest tree densities (329 and 291 trees/acre, respectively) of the forest habitat stands. Stand 1 was the least dense overall (183 trees/acre). Stand 1 was a remnant glade habitat which characteristically have few trees.

Upland stands 2, 6, 7 and bottomland Stand 5 were dominated by pole-size trees with an average DBH of 9 - 10 in and average basal area of 88.06 - 93.33 ft^2/acre (Table 2). Upland Stand 3 and bottomland Stands 4 and 8 were dominated by sawtimber size trees with an average DBH of 12 - 14 inches and average basal area of 105.00 - 118.18 ft^2/acre. Stand 1 had an average DBH of 11 inches and average basal area of 31 ft^2/acre.

The most abundant tree species across stands were black walnut (*Juglans nigra*), followed by hackberry (*Celtis occidentalis*), Osage orange (*Maclura pomifera*), chinquapin oak (*Quercus muehlenbergii*), and black oak (*Quercus velutina*).

Table 2. Summary information for all stands in the wooded portion of the historical viewshed area on Wilson's Creek National Battlefield, Missouri. Stand number, acres, density (SD), estimated density following cutting recommendations, average basal area (SD), canopy closure (SD), average DBH (SD), and composition were recorded during summer 2020 field surveys. Vegetation type was provided by Diamond et al. (2013). The large standard deviations, especially in density, are likely due to using too small of a BAF which can lead to a higher coefficient of variation and heterogeneity in soil types within stands.

Stand	Acres	Density (trees/acre)	Estimated Density (trees/acre) following cutting recomendations	Average Basal Area (ft^2/acre)	Canopy Closure (%)	Average DBH (in)	Vegetation Type	Composition
1	8.82	183 (±316.45)	16	31.00 (±33.81)	53.87 (±37.87)	10.61 (±3.64)	Limestone Glade	Elm Species (19%), Black Walnut (16%), Red Oak Species (16%), Black Cherry (13%), Honey Locust (10%), Hackberry (6%), Autumn Olive (6%), White Oak Species (6%), Ash Species (3%), Eastern Redcedar (3%)
2	33.60	589 (±599.67)	152	89.46 (±37.86)	90.93 (±4.47)	8.91 (±2.37)	Upland Deciduous Woodland and Forest	Black Walnut (23%), Hackberry (14%), White Oak Species (13%), Red Oak Species (12%), Ash Species (9%), Honey Locust (7%), Elm Species (5%), Eastern Redcedar (5%), Osage Orange (5%), Black Cherry (3%), Hickory Species (6%), Red Mulberry (<1%), Black Locust (<1%), Viburnum Species (<1%)
3	26.40	453 (±371.01)	231	108.64 (±37.58)	92.03 (±4.21)	11.81 (±3.14)	Upland Deciduous Woodland and Forest	Black Walnut (21%), Red Oak Species (21%), White Oak Species (20%), Hackberry (17%), Eastern Redcedar (7%), Hickory Species (5%), Red Mulberry (3%), Elm Species (2%), Ash Species (1%), Osage Orange (1%), Black Cherry (1%), Viburnum Species (1%), Box Elder (<1%), Honey Locust (<1%), Gum Bumelia (<1%)
4	9.14	329 (±251.13)	47	118.18 (±52.12)	92.84 (±3.41)	14.47 (±4.53)	Bottomland Deciduous Woodland and Forest	Sycamore (26%), American Elm (25%), Black Walnut (22%), Hackberry (8%), Silver Maple (5%), Ash Species (3%), Eastern Redcedar (3%), White Oak Species (3%), Honey Locust (2%), Osage Orange (2%), Red Mulberry (1%)

Stand	Acres	Density (trees/acre)	Estimated Density (trees/acre) following cutting recomendations	Average Basal Area (ft^2/acre)	Canopy Closure (%)	Average DBH (in)	Vegetation Type	Composition
5	6.52	448 (±314.69)	144	93.33 (±27.33)	91.13 (±2.42)	10.08 (±1.61)	Bottomland Deciduous Woodland and Forest	Black Walnut (40%), Eastern Redcedar (27%), White Oak Species (16%), Hackberry (5%), Red Oak Species (5%), Osage Orange (3%), Red Mulberry (2%)
6	29.43	426 (±434.13)	114	88.06 (±40.91)	88.73 (±12.09)	10.03 (±3.01)	Upland Deciduous Woodland and Forest	Black Walnut (20%), Hackberry (16%), Osage Orange (16%), Red Oak Species (12%), Black Cherry (9%), Honey Locust (7%), White Oak Species (7%), Eastern Redcedar (5%), American Elm (5%), Ash Species (2%), Plum Species (1%), Sassafras (1%), Box Elder (<1%)
7	20.91	531 (±431.53)	219	91.90 (±28.74)	91.33 (±8.06)	9.79 (±2.98)	Upland Deciduous Woodland and Forest	Black Walnut (18%), Red Oak Species (14%), White Oak Species (13%), Osage Orange (10%), Hackberry (9%), Hickory Species (8%), Ash Species (8%), Eastern Redcedar (7%), American Elm (5%), Honey Locust (3%), Sassafras (2%), Red Mulberry (1%), Black Cherry (1%)
8	12.27	291 (±326.64)	41	105.00 (±26.73)	94.28 (±2.13)	13.06 (±4.18)	Bottomland Deciduous Woodland and Forest	Osage Orange (54%), Black Walnut (16%), Hackberry (10%), Honey Locust (6%), Box Elder (5%), Red Oak Species (2%), Ash Species (1%), Hawthorn Species (1%), Black Cherry (1%), Sycamore (1%), White Oak Species (1%), American Elm (1%)

Stand 1

This stand was a remnant glade with scattered clusters of pole-size trees (Table 3). The dominant tree species were elms (*Ulmus americana, Ulmus rubra*), black walnut, and red oak species (*Quercus Erythrobalanus spp.)* (Figure 3, Table 4). The understory was dense with woody shrubs, most notably blackberry (*Rubus spp.)* and sumac (*Rhus spp.*). Though Table 4 and Figure 4 estimate there were 92 stems/acre of autumn olive (*Elaeagnus umbellate*), the shrub was only found in one plot and was not observed to be present in the ground flora, thus this is likely an overestimation of the presence of this species.

Table 3. Summary information for Stand 1 on Wilson's Creek National Battlefield, Missouri. Acres, density (SD), average basal area (SD), canopy closure (SD), and average DBH (SD) were recorded during summer 2020 field surveys. Vegetation Type was provided by Diamond et al. (2013) and soil types were provided by NRCS SSURGO dataset (NRCS 2020).

Acres	Density (trees/acre)	Average Basal Area (ft^2/acre)	Canopy Closure (%)	Average DBH (in)	Vegetation Type	Soil Type
8.82	183 (±316.45)	31.00 (±33.81)	53.87 (±37.87)	10.61 (±3.64)	Limestone Glade	Wilderness Gravelly Silt Loam, Goss Gravelly Silt Loam

Table 4. Density (trees/acre) for each species recorded during summer 2020 field surveys in Stand 1 (8.82 acres) on Wilson's Creek National Battlefield, Missouri. Species are organized by removal recommendations outlined in the Wilson's Creek Vegetation Management Implementation Plan (NPS 2014). Numbers in () represent trees/acre for trees matching the selected removal guidelines of <14, <16 or <18 inches DBH.

Removal Conditions		Common Name	Scientific Name	Density (trees/acre)
100% Removal		Autumn Olive	*Elaeagnus umbellata*	92
		Eastern redcedar	*Juniperus virginiana*	2
Selected Removals	*<14 in DBH*	Black Walnut	*Juglans nigra*	23 (23)
		Hackberry	*Celtis occidentalis*	5 (5)
	<16 in DBH	Black Cherry	*Prunus serotina*	17 (17)
	<18 in DBH	Elm Species	*Ulmus spp.*	5 (4)
		Honey Locust	*Gleditsia triacanthos*	28 (28)
Do Not Remove		Red Oak Species	*Quercus Erythrobalanus spp.*	8
		White Oak Species	*Quercus Leucobalanus spp.*	3
		Ash Species	*Fraxinus spp.*	1

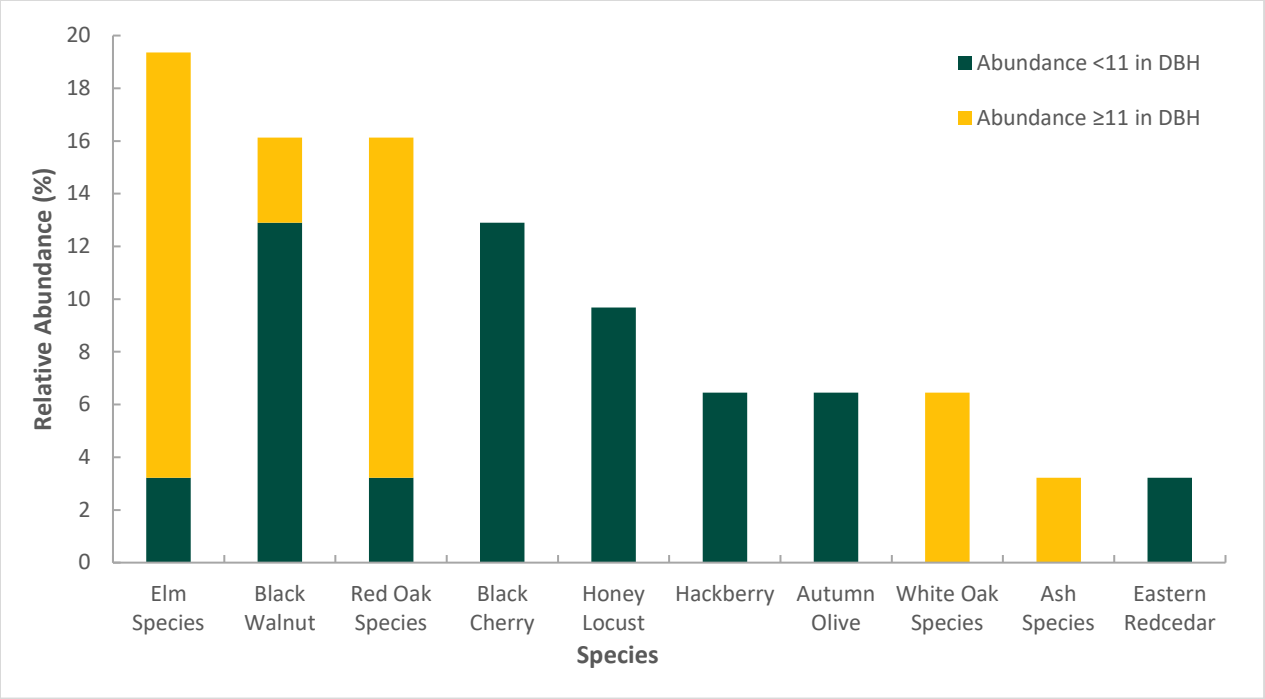

Figure 3. Relative abundance for each species recorded during summer 2020 field surveys in Stand 1 on Wilson's Creek National Battlefield, Missouri. Abundance was split by trees <11 inches DBH (sapling and pole-size trees) in green and ≥11 inches DBH (sawtimber trees) in yellow.

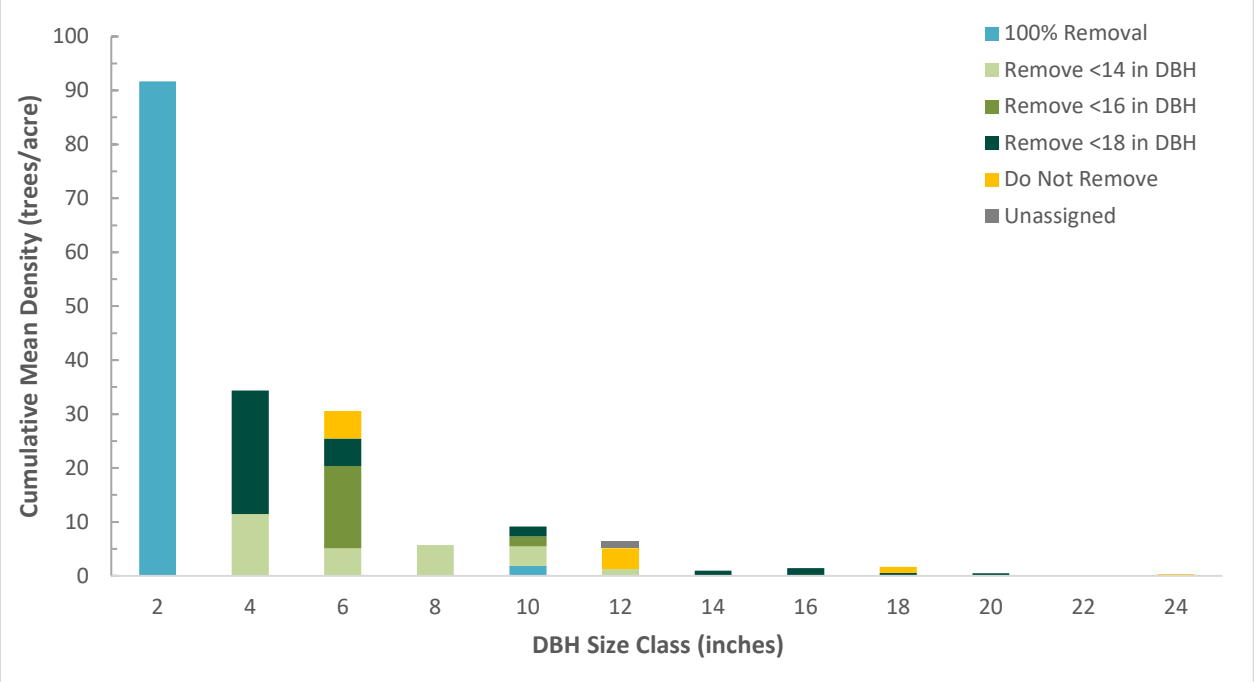

Figure 4. Cumulative mean density (trees/acre) by DBH size class (inches) in Stand 1 (8.82 acres) on Wilson's Creek National Battlefield, Missouri recorded during summer 2020. Trees were grouped by recommended removal guidelines (100% removal, remove <14 in DBH, remove <16 in DBH, remove <18 in DBH, do not remove, and unassigned) outlined in the Wilson's Creek Vegetation Management

Implementation Plan (NPS 2014). Removal groups do not indicate DBH of the tree, but at what DBH they should be removed.

Stand 2

This stand was a dense mix of sapling and pole-size hardwoods (Table 5, Figure 6). The dominant overstory trees were black walnut, red oak species and white oak species (*Quercus Leucobalanus spp*.) (Figure 5). Black walnut and hackberry comprised the majority of the saplings and pole-size trees. There were also scattered pockets of eastern redcedar (*Juniperus virginiana*) and Osage orange (Tables 6, A2).

Table 5. Summary information for Stand 2 on Wilson's Creek National Battlefield, Missouri. Acres, density (SD), average basal area (SD), canopy closure (SD), and average DBH (SD) were recorded during summer 2020 field surveys. Vegetation Type was provided by Diamond et al. (2013) and soil types were provided by NRCS SSURGO dataset (NRCS 2020).

Acres	Density (trees/acre)	Average Basal Area (ft^2/acre)	Canopy Closure (%)	Average DBH (in)	Vegetation Type	Soil Type
33.60	589 (±599.67)	89.46 (±37.86)	90.93 (±4.47)	8.91 (±2.37)	Upland Deciduous Woodland and Forest	Wilderness Gravelly Silt Loam, Goss Gravelly Silt Loam, Goss-Gasconade Complex, Gasconade-Rock Outcrop Complex, Pembroke Silt Loam

Table 6. Density (trees/acre) for each species recorded during summer 2020 field surveys in Stand 2 (33.60 acres) on Wilson's Creek National Battlefield, Missouri. Species are organized by removal recommendations outlined in the Wilson's Creek Vegetation Management Implementation Plan (NPS 2014). Numbers in () represent trees/acre of trees that are within the selected removal guidelines of <8, <14, <16, or <18 inches DBH.

Removal Conditions		Common Name	Scientific Name	Density (trees/acre)
100% Removal		Black Locust	*Robinia pseudoacacia*	12
		Eastern redcedar	*Juniperus virginiana*	42
		Osage-orange	*Maclura pomifera*	73
Selected Removals	*<8 in DBH*	Red Mulberry	*Morus rubra*	1 (1)
	<14 in DBH	Black Walnut	*Juglans nigra*	73 (70)
		Hackberry	*Celtis occidentalis*	106 (105)
	<16 in DBH	Black Cherry	*Prunus serotina*	50 (50)
	<18 in DBH	Elm Species	*Ulmus spp.*	40 (40)
		Honey Locust	*Gleditsia triacanthos*	43 (43)
Do Not Remove		Red Oak Species	*Quercus Erythrobalanus spp.*	43
		White Oak Species	*Quercus Leucobalanus spp.*	58
		Ash Species	*Fraxinus spp.*	22

Removal Conditions	Common Name	Scientific Name	Density (trees/acre)
Unassigned	Hickory Species	*Carya spp.*	13
	Viburnum Species	*Viburnum spp.*	12

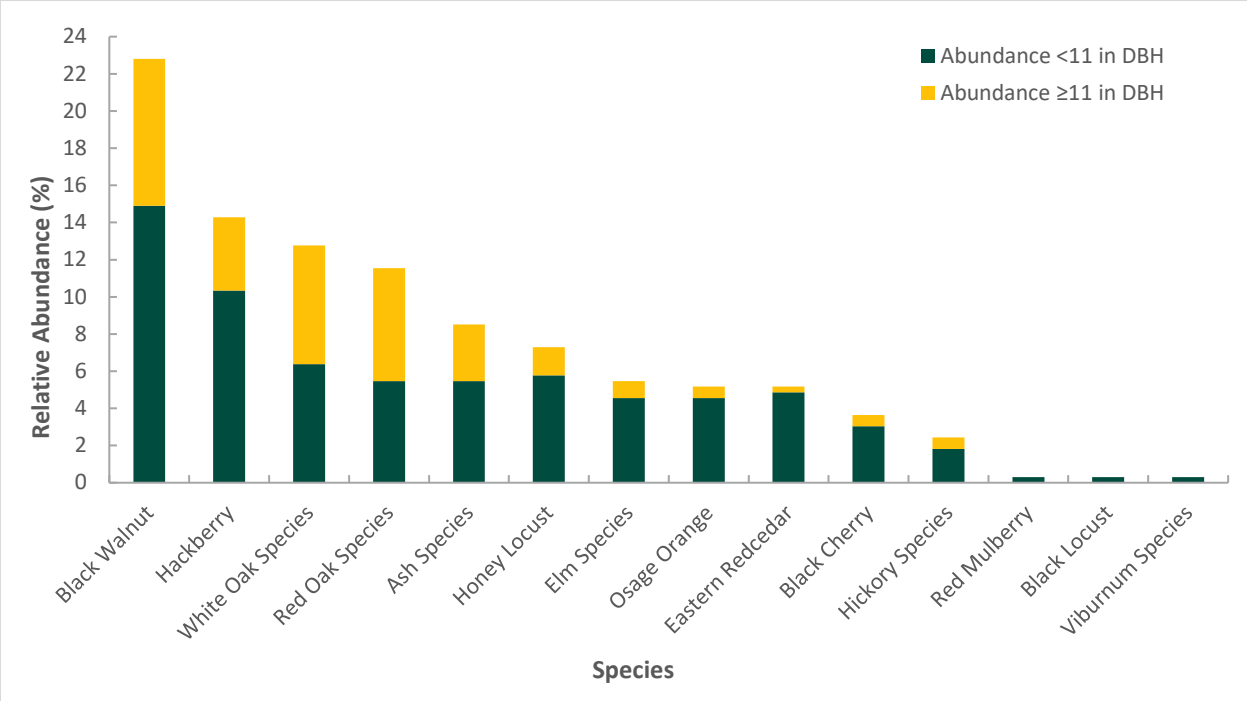

Figure 5. Relative abundance for each species recorded during summer 2020 field surveys in Stand 2 on Wilson's Creek National Battlefield, Missouri. Abundance was split by trees <11 inches DBH (sapling and pole-size trees) in green and ≥11 inches DBH (sawtimber trees) in yellow.

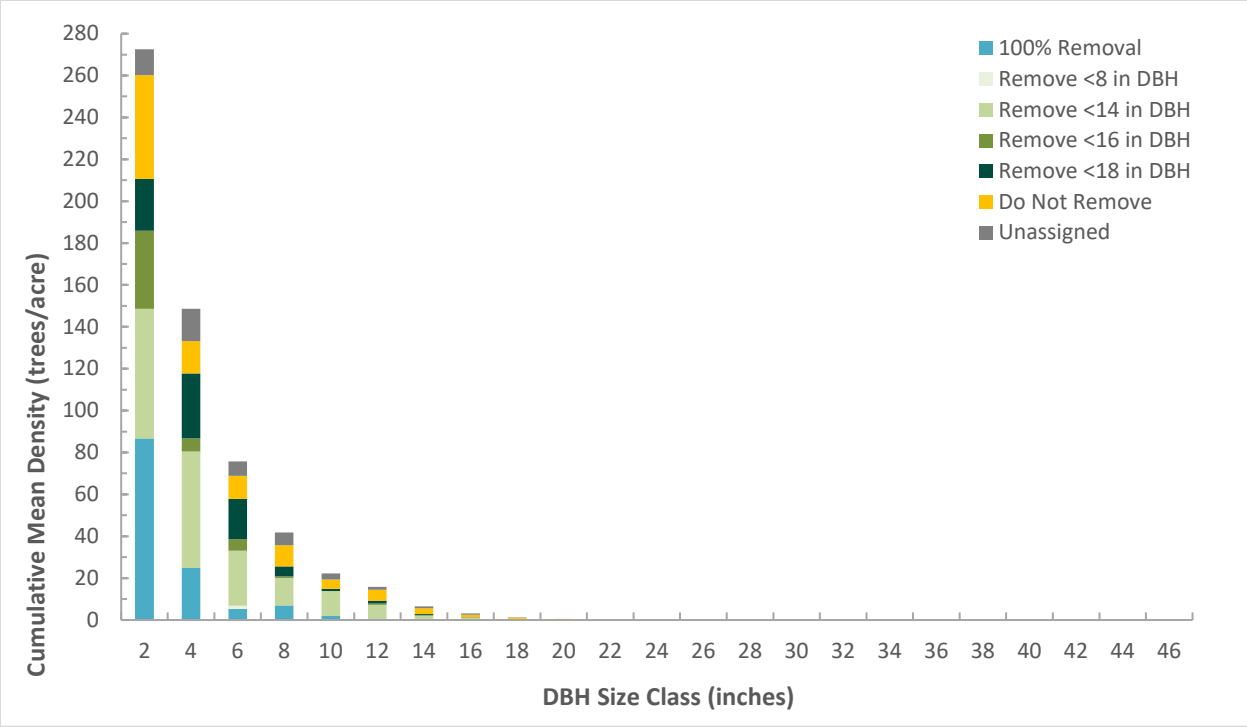

Figure 6. Cumulative mean density (trees/acre) by DBH size class (inches) in Stand 2 (33.60 acres) on Wilson's Creek National Battlefield, Missouri recorded during summer 2020. Trees are grouped by recommended removal guidelines (100% removal, remove <8 in DBH, remove <14 in DBH, remove <16 in DBH, remove <18 in DBH, do not remove, and unassigned) outlined in the Wilson's Creek Vegetation Management Implementation Plan (NPS 2014). Removal groups do not indicate DBH of the tree, but at what DBH they should be removed.

Stand 3

This stand was a dense mix of sapling and pole-size hardwoods (Tables 7, 8; Figure 8). The dominant overstory trees were black walnut, red oak species, and white oak species (Figure 7). The majority of sapling and pole-size trees were hackberry, red oak species, and white oak species.

Table 7. Summary information for Stand 3 on Wilson's Creek National Battlefield, Missouri recorded in 2020. Acres, density (SD), average basal area (SD), canopy closure (SD), and average DBH (SD) were recorded during summer 2020 field surveys. Vegetation Type was provided by Diamond et al. (2013) and soil types were provided by NRCS SSURGO dataset (NRCS 2020).

Acres	Density (trees/acre)	Average Basal Area (ft^2/acre)	Canopy Closure (%)	Average DBH (in)	Vegetation Type	Soil Type
26.40	453 (±371.01)	108.64 (±37.58)	92.03 (±4.21)	11.81 (±3.14)	Upland Deciduous Woodland and Forest	Wilderness Gravelly Silt Loam, Gasconade-Rock Outcrop Complex, Goss Gravelly Silt Loam

Table 8. Density (trees/acre)for each species recorded during summer 2020 field surveys in Stand 3 (26.40 acres) on Wilson's Creek National Battlefield, Missouri. Species are organized by removal recommendations outlined in the Wilson's Creek Vegetation Management Implementation Plan (NPS 2014). Numbers in () represent trees/acre of trees that are within the selected removal guidelines of <8, <14, <16, or <18 inches DBH.

Removal Conditions		Common Name	Scientific Name	Density (trees/acre)
100% Removal		Eastern redcedar	*Juniperus virginiana*	17
		Osage Orange	*Maclura pomifera*	3
Selected Removals	*<8 in DBH*	Red Mulberry	*Morus rubra*	11 (8)
	<14 in DBH	Black Walnut	*Juglans nigra*	34 (26)
		Hackberry	*Celtis occidentalis*	124 (123)
	<16 in DBH	Black Cherry	*Prunus serotina*	10 (10)
	<18 in DBH	Elm Species	*Ulmus spp.*	34 (34)
		Honey Locust	*Gleditsia triacanthos*	1 (1)
Do Not Remove		Red Oak Species	*Quercus Erythrobalanus spp.*	70
		White Oak Species	*Quercus Leucobalanus spp.*	59
Unassigned		Ash Species	*Fraxinus spp.*	3
		Box Elder	*Acer negundo*	2
		Gum Bumelia	*Sideroxylon lanuginosum*	21
		Hickory Species	*Carya spp.*	39
		Viburnum Species	*Viburnum spp.*	26

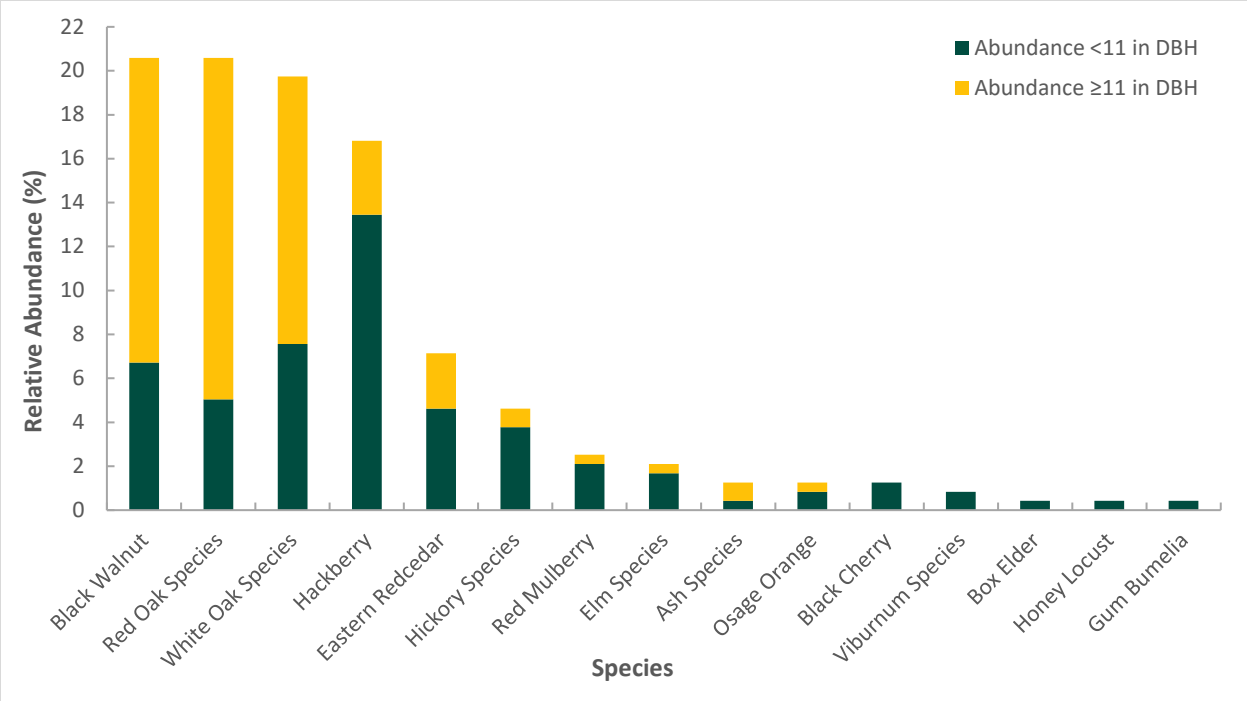

Figure 7. Relative abundance for each species recorded during summer 2020 field surveys in Stand 3 on Wilson's Creek National Battlefield, Missouri. Abundance was split by trees <11 inches DBH (sapling and pole-size trees) in green and ≥11 inches DBH (sawtimber trees) in yellow.

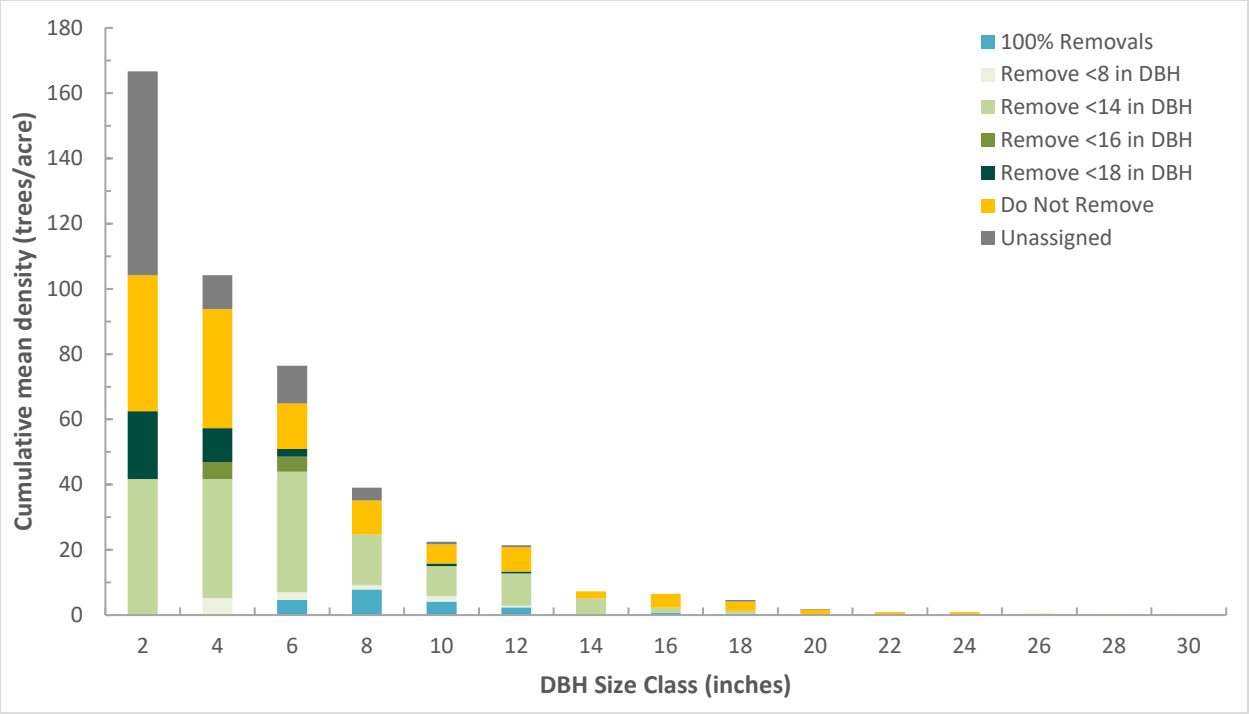

Figure 8. Cumulative mean density (trees/acre) by DBH size class (inches) in Stand 3 (26.40 acres) on Wilson's Creek National Battlefield, Missouri recorded during summer 2020. Trees are grouped by recommended removal guidelines (100% removal, remove <8 in DBH, remove <14 in DBH, remove <16 in DBH, remove <18 in DBH, do not remove, and unassigned) outlined in the Wilson's Creek Vegetation Management Implementation Plan (NPS 2014). Removal groups do not indicate DBH of the tree, but at what DBH they should be removed.

Stand 4

This stand was a less dense mix of pole-size and sawtimber trees (Tables 9, 10; Figure 10). The dominant sawtimber trees were sycamore (*Platanus occidentalis*) and black walnut (Figure 9). The majority of pole-size trees were American elm.

Table 9. Summary information for Stand 4 on Wilson's Creek National Battlefield, Missouri recorded in 2020. Acres, density (SD), average basal area (SD), canopy closure (SD), and average DBH (SD) were recorded during summer 2020 field surveys. Vegetation Type was provided by Diamond et al. (2013) and soil types were provided by NRCS SSURGO dataset (NRCS 2020).

Acres	Density (trees/acre)	Average Basal Area (ft^2/acre)	Canopy Closure (%)	Average DBH (in)	Vegetation Type	Soil Type
9.14	329 (±251.13)	118.18 (±52.12)	92.84 (±3.41)	14.47 (±4.53)	Bottomland Deciduous Woodland and Forest	Huntington Silt Loam, Wilderness and Goss Gravelly Silt Loams

Table 10. Density (trees/acre) for each species recorded during summer 2020 field surveys in Stand 4 (9.14 acres) on Wilson's Creek National Battlefield, Missouri. Species are organized by removal recommendations outlined in the Wilson's Creek Vegetation Management Implementation Plan (NPS 2014). Numbers in () represent trees/acre of trees that are within the selected removal guidelines of <8, <14, or <18 inches DBH.

Removal Conditions		Common Name	Scientific Name	Density (trees/acre)
100% Removal		Eastern redcedar	*Juniperus virginiana*	52
		Osage Orange	*Maclura pomifera*	52
Selected Removals	*<8 in DBH*	Red Mulberry	*Morus rubra*	1 (0)
	<14 in DBH	Black Walnut	*Juglans nigra*	30 (18)
		Hackberry	*Celtis occidentalis*	12 (9)
	<18 in DBH	American Elm	*Ulmus americana*	149 (149)
		Honey Locust	*Gleditsia triacanthos*	2 (2)
Do Not Remove		White Oak Species	*Quercus Leucobalanus spp.*	2
Unassigned		Ash Species	*Fraxinus spp.*	3
		Silver Maple	*Acer saccharinum*	5
		Sycamore	*Platanus occidentalis*	20

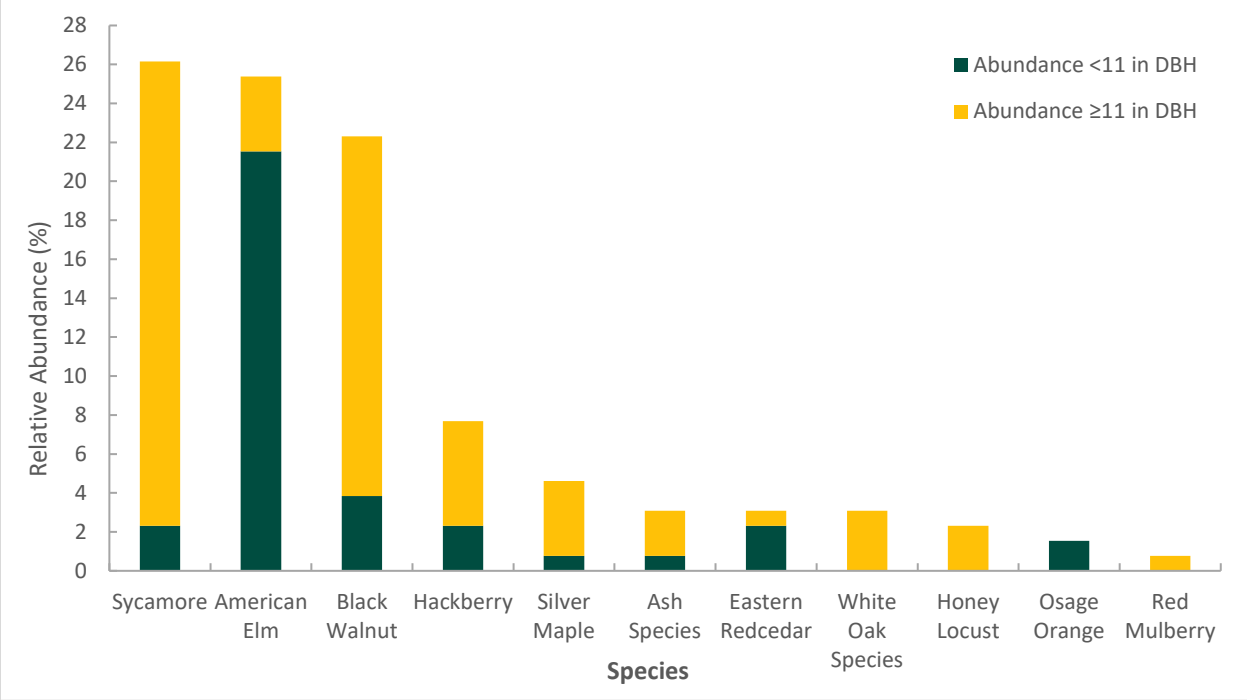

Figure 9. Relative abundance for each species recorded during summer 2020 field surveys in Stand 4 on Wilson's Creek National Battlefield, Missouri. Abundance was split by trees <11 inches DBH (sapling and pole-size trees) in green and ≥11 inches DBH (sawtimber trees) in yellow.

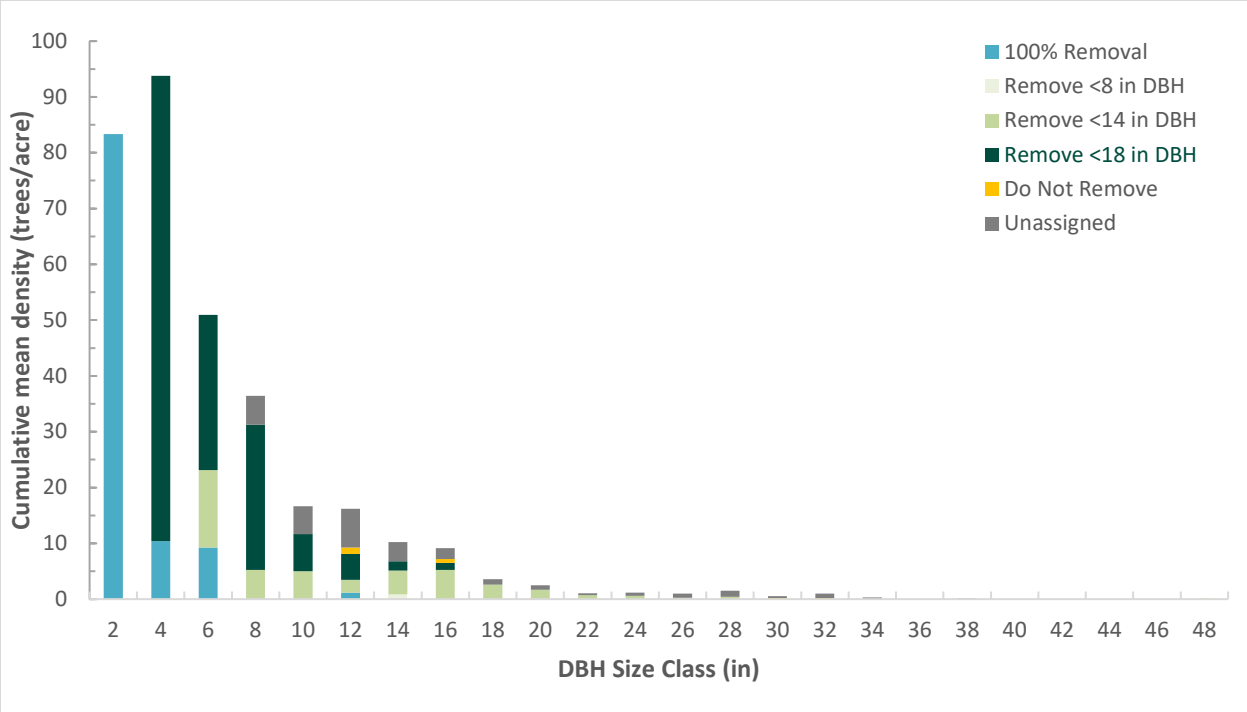

Figure 10. Cumulative mean density (trees/acre) by DBH size class (inches) in Stand 4 (9.14 acres) on Wilson's Creek National Battlefield, Missouri recorded during summer 2020. Trees are grouped by recommended removal guidelines (100% removal, remove <8 in DBH, remove <14 in DBH, remove <18 in DBH, do not remove, and unassigned) outlined in the Wilson's Creek Vegetation Management Implementation Plan (NPS 2014). Removal groups do not indicate DBH of the tree, but at what DBH they should be removed.

Stand 5

This stand was a dense mix of pole-size trees (Tables 11, 12; Figure 12). Black walnut dominated the sawtimber class. It was five times more abundant than other species in that class (Figure 11). Pole-size trees were primarily black walnut and chinquapin oak. We noted a concentration of sapling-sized eastern redcedar on the east side of the stand (Table A5).

Table 11. Summary information for Stand 5 on Wilson's Creek National Battlefield, Missouri recorded in 2020. Acres, density (SD), average basal area (SD), canopy closure (SD), and average DBH (SD) were recorded during summer 2020 field surveys. Vegetation Type was provided by Diamond et al. (2013) and soil types were provided by NRCS SSURGO dataset (NRCS 2020).

Acres	Density (trees/acre)	Average Basal Area (ft^2/acre)	Canopy Closure (%)	Average DBH (in)	Vegetation Type	Soil Type
6.52	448 (±314.69)	93.33 (±27.33)	91.13 (±2.42)	10.08 (±1.61)	Bottomland Deciduous Woodland and Forest	Huntington Silt Loam, Goss Gravelly Silt Loams

Table 12. Density (trees/acre) for each species recorded during summer 2020 field surveys in Stand 5 (6.52 acres) on Wilson's Creek National Battlefield, Missouri. Species are organized by removal recommendations outlined in the Wilson's Creek Vegetation Management Implementation Plan (NPS 2014). Numbers in () represent trees/acre of trees that are within the selected removal guidelines of <8 or <14 inches DBH.

Removal Conditions		Common Name	Scientific Name	Density (trees/acre)
100% Removal		Eastern redcedar	*Juniperus virginiana*	201
		Osage Orange	*Maclura pomifera*	20
Selected Removals	*<8 in DBH*	Red Mulberry	*Morus rubra*	19 (19)
	<14 in DBH	Black Walnut	*Juglans nigra*	75 (68)
		Hackberry	*Celtis occidentalis*	8 (7)
Do Not Remove		Red Oak Species	*Quercus Erythrobalanus spp.*	8
		White Oak Species	*Quercus Leucobalanus spp.*	116

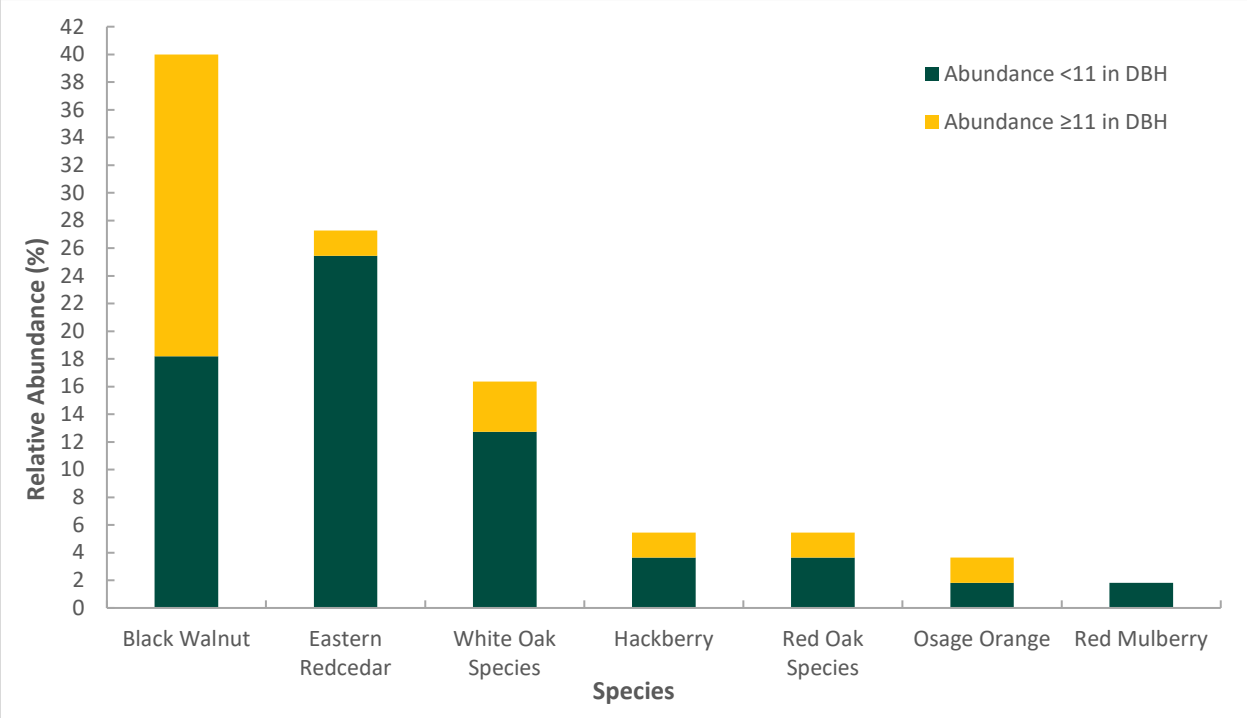

Figure 11. Relative abundance for each species recorded during summer 2020 field surveys in Stand 5 on Wilson's Creek National Battlefield, Missouri Abundance was split by trees <11 inches DBH (sapling and pole-size trees) in green and ≥11 inches DBH (sawtimber trees) in yellow.

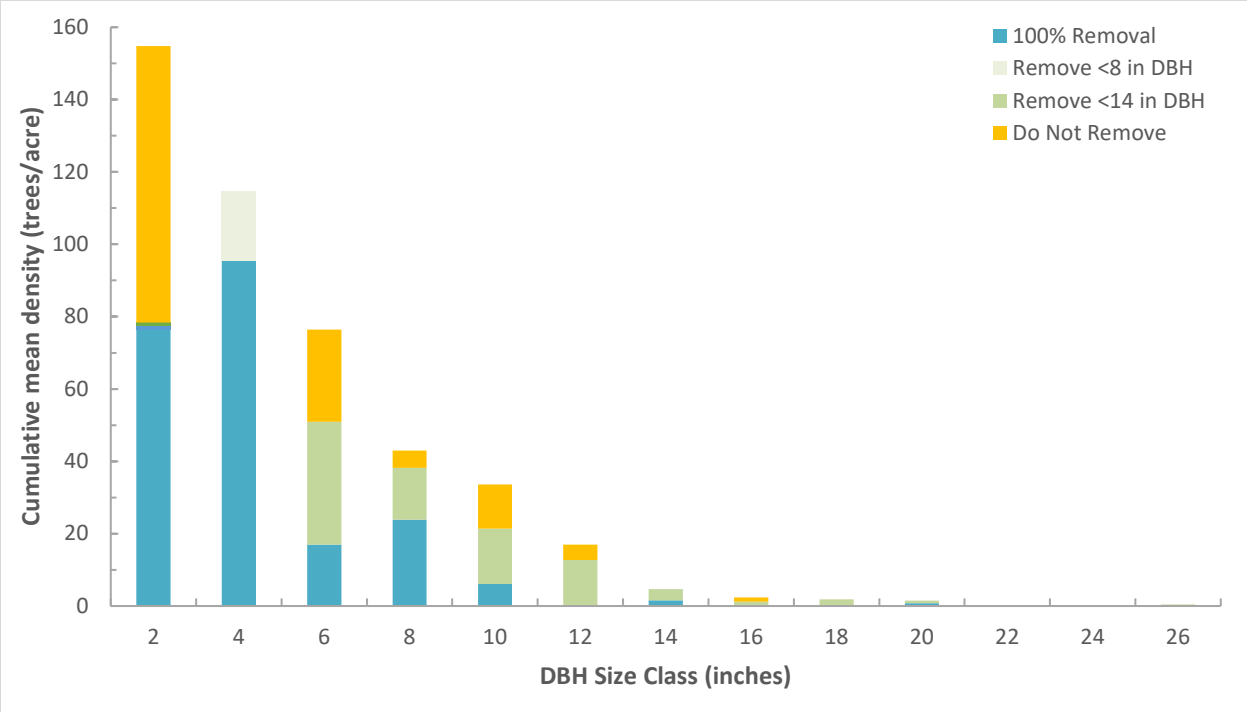

Figure 12. Cumulative mean density (trees/acre) by DBH size class (inches) in Stand 5 (6.52 acres) on Wilson's Creek National Battlefield, Missouri recorded during summer 2020. Trees are grouped by recommended removal guidelines (100% removal, remove <8 in DBH, remove <14 in DBH, and do not remove) outlined in the Wilson's Creek Vegetation Management Implementation Plan (NPS 2014). Removal groups do not indicate DBH of the tree, but at what DBH they should be removed.

Stand 6

This stand was a dense mix of mostly pole-size trees (Tables 13, 14; Figure 14). Black walnut composed most of the sawtimber trees (Figure 13). Pole-size trees were a mix of black walnut, black cherry (*Prunus serotina*), hackberry, Osage orange, and red oak species.

Table 13. Summary information for Stand 6 on Wilson's Creek National Battlefield, Missouri recorded in 2020. Acres, density (SD), average basal area (SD), canopy closure (SD), and average DBH (SD) were recorded during summer 2020 field surveys. Vegetation Type was provided by Diamond et al. (2013) and soil types were provided by NRCS SSURGO dataset (NRCS 2020).

Acres	Density (trees/acre)	Average Basal Area (ft^2/acre)	Canopy Closure (%)	Average DBH (in)	Vegetation Type	Soil Type
29.43	426 (±434.13)	88.06 (±40.91)	88.73 (±12.09)	10.03 (±3.01)	Upland Deciduous Woodland and Forest	Wilderness Gravelly Silt Loam, Goss Gravelly Silt Loam, Secesh-Cedargap Silt Loams, Pembroke Silt Loam, Newtonia Silt Loam

Table 14. Density (trees/acre) for each species recorded during summer 2020 field surveys in Stand 6 (29.43 acres) on Wilson's Creek National Battlefield, Missouri. Species are organized by removal recommendations outlined in the Wilson's Creek Vegetation Management Implementation Plan (NPS 2014). Numbers in () represent trees/acre of trees that are within the selected removal guidelines of <14, <16, or <18 inches DBH.

Removal Conditions		Common Name	Scientific Name	Density (trees/acre)
100% Removal		Eastern redcedar	*Juniperus virginiana*	32
		Osage Orange	*Maclura pomifera*	45
Selected Removals	*<14 in DBH*	Black Walnut	*Juglans nigra*	51 (46)
		Hackberry	*Celtis occidentalis*	66 (64)
	<16 in DBH	Black Cherry	*Prunus serotina*	66 (65)
	<18 in DBH	American Elm	*Ulmus americana*	43 (43)
		Honey Locust	*Gleditsia triacanthos*	20 (20)
Do Not Remove		Red Oak Species	*Quercus Erythrobalanus spp.*	32
		White Oak Species	*Quercus Leucobalanus spp.*	25
Unassigned		Ash Species	*Fraxinus spp.*	3
		Box Elder	*Acer negundo*	1
		Plum Species	*Prunus spp.*	29
		Sassafras	*Sassafras albidum*	14

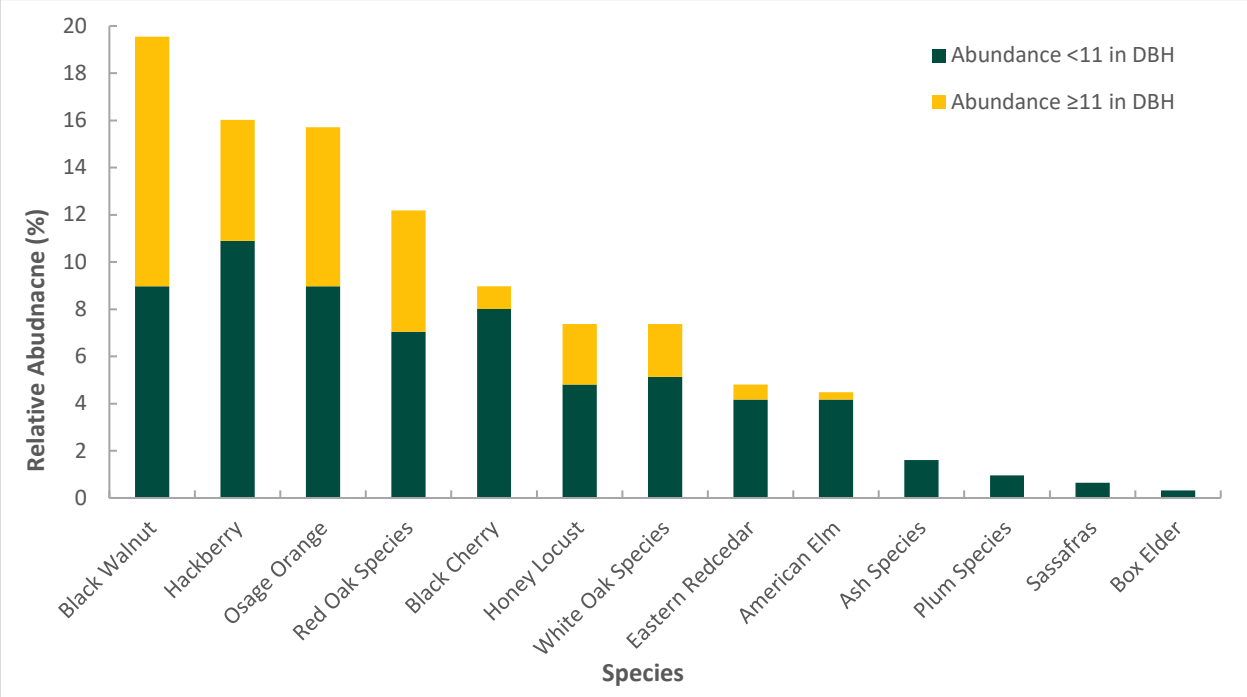

Figure 13. Relative abundance for each species recorded during summer 2020 field surveys in Stand 6 on Wilson's Creek National Battlefield, Missouri. Abundance was split by trees <11 inches DBH (sapling and pole-size trees) in green and ≥11 (sawtimber trees) inches DBH in yellow.

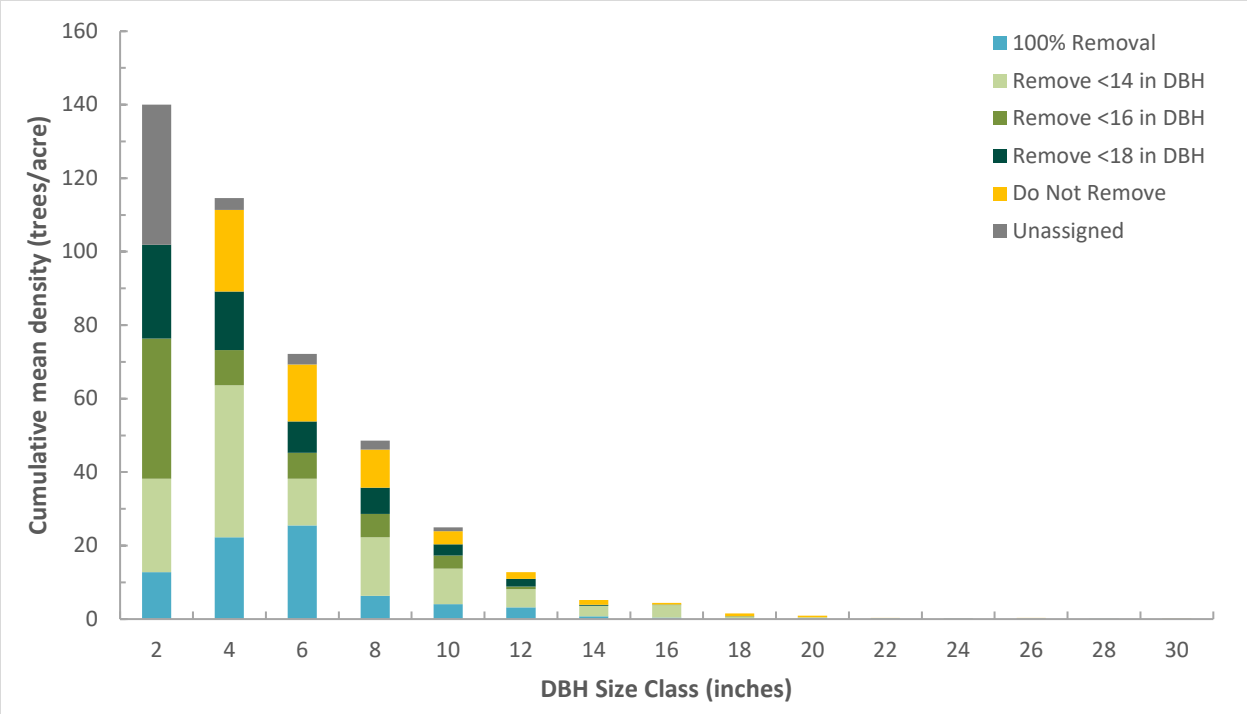

Figure 14. Cumulative mean density (trees/acre) by DBH size class (inches) in Stand 6 (29.43 acres) on Wilson's Creek National Battlefield, Missouri recorded during summer 2020. Trees are grouped by recommended removal guidelines (100% removal, remove <14 in DBH, remove <16 in DBH, remove <18 in DBH, do not remove, and unassigned) outlined in the Wilson's Creek Vegetation Management Implementation Plan (NPS 2014). Removal groups do not indicate DBH of the tree, but at what DBH they should be removed.

Stand 7

This stand was a dense mix of mostly pole-size trees (Tables 15, 16; Figure 16). Red oak species, hickory species (*Carya spp*.) and black walnut dominanted the few sawtimber trees (Figure 15). Pole-size trees were primarily composed of black walnut, red and white oak species, and Osage orange.

Table 15. Summary information for Stand 7 on Wilson's Creek National Battlefield, Missouri recorded in 2020. Acres, density (SD), average basal area (SD), canopy closure (SD), and average DBH (SD) were recorded during summer 2020 field surveys. Vegetation Type was provided by Diamond et al. (2013) and soil types were provided by NRCS SSURGO dataset (NRCS 2020).

Acres	Density (trees/acre)	Average Basal Area (ft^2/acre)	Canopy Closure (%)	Average DBH (in)	Vegetation Type	Soil Type
20.91	531 (±431.53)	91.90 (±28.74)	91.33 (±8.06)	9.79 (±2.98)	Upland Deciduous Woodland and Forest	Goss Gravelly Silt Loam, Newtonia Silt Loam

Table 16. Density (trees/acre) for each species recorded during summer 2020 field surveys in Stand 7 (20.91 acres) on Wilson's Creek National Battlefield, Missouri. Species are organized by removal recommendations outlined in the Wilson's Creek Vegetation Management Implementation Plan (NPS 2014). Numbers in () represent trees/acre of trees that are within the selected removal guidelines of <8, <14, <16, or <18 inches DBH.

Removal Conditions		Common Name	Scientific Name	Density (trees/acre)
100% Removal		Eastern redcedar	*Juniperus virginiana*	135
		Osage Orange	*Maclura pomifera*	47
Selected Removals	*<8 in DBH*	Red Mulberry	*Morus rubra*	6 (5)
	<14 in DBH	Black Walnut	*Juglans nigra*	62 (58)
		Hackberry	*Celtis occidentalis*	24 (22)
	<16 in DBH	Black Cherry	*Prunus serotina*	4 (4)
	<18 in DBH	American Elm	*Ulmus americana*	39 (39)
		Honey Locust	*Gleditsia triacanthos*	3 (3)
Do Not Remove		Red Oak Species	*Quercus Erythrobalanus spp.*	21
		White Oak Species	*Quercus Leucobalanus spp.*	64
Unassigned		Ash Species	*Fraxinus spp.*	78
		Hickory Species	*Carya spp.*	10
		Sassafras	*Sassafras albidum*	38

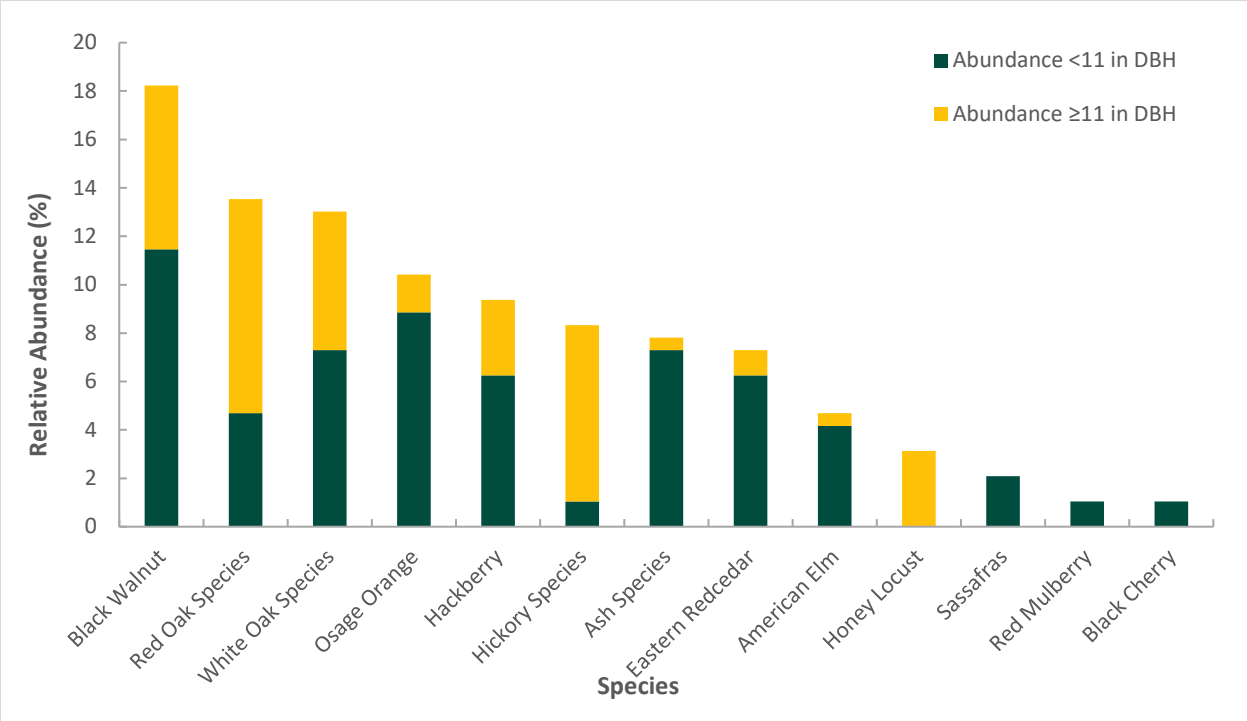

Figure 15. Relative abundance for each species recorded during summer 2020 field surveys in Stand 7

on Wilson's Creek National Battlefield, Missouri. Abundance was split by trees <11 inches DBH in green (sapling and pole-size trees) and ≥11 inches DBH (sawtimber trees) in yellow.

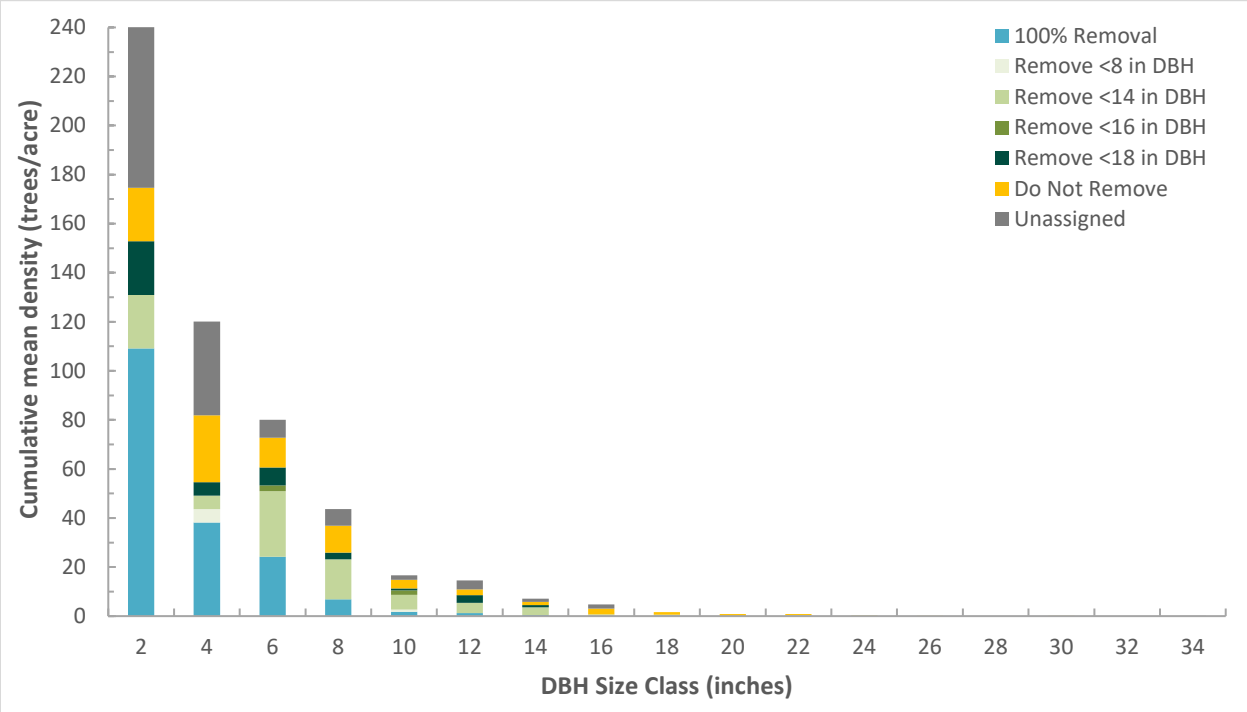

Figure 16. Cumulative mean density (trees/acre) by DBH size class (inches) in Stand 7 (20.91 acres) on Wilson's Creek National Battlefield, Missouri recorded during summer 2020. Trees are grouped by recommended removal guidelines (100% removal, remove <8 in DBH, remove <14 in DBH, remove <16 in DBH, remove <18 in DBH, do not remove, and unassigned) outlined in the Wilson's Creek Vegetation Management Implementation Plan (NPS 2014). Removal groups do not indicate DBH of the tree, but at what DBH they should be removed.

Stand 8

This stand was less dense and composed primarily of pole-size trees (Tables 17, 18; Figure 18). Osage Orange dominated the stand with a relative abundance of 54 % (Figure 17).

Table 17. Summary information for Stand 8 on Wilson's Creek National Battlefield, Missouri recorded in 2020. Acres, density (SD), average basal area (SD), canopy closure (SD), and average DBH (SD) were recorded during summer 2020 field surveys. Vegetation Type was provided by Diamond et al. (2013) and soil types were provided by NRCS SSURGO dataset (NRCS 2020).

Acres	Density (trees/acre)	Average Basal Area (ft^2/acre)	Canopy Closure (%)	Average DBH (in)	Vegetation Type	Soil Type
12.27	291 (±326.64)	105.00 (±26.73)	94.28 (±2.13)	13.06 (±4.18)	Bottomland Deciduous Woodland and Forest	Goss Gravelly Silt Loam, Secesh-Cedargap Silt Loams

Table 18. Density (trees/acre) for each species recorded during summer 2020 field surveys in Stand 8 (12.27 acres) on Wilson's Creek National Battlefield, Missouri. Species are organized by removal recommendations outlined in the Wilson's Creek Vegetation Management Implementation Plan (2014). Numbers in () represent trees/acre of trees that are within the selected removal guidelines of <14, <16, or <18 inches DBH.

Removal Conditions		Common Name	Scientific Name	Density (trees/acre)
100% Removal		Osage Orange	*Maclura pomifera*	158
Selected Removals	*<14 in DBH*	Black Walnut	*Juglans nigra*	13 (6)
		Hackberry	*Celtis occidentalis*	19 (17)
	<16 in DBH	Black Cherry	*Prunus serotina*	4 (4)
	<18 in DBH	American Elm	*Ulmus americana*	57 (57)
		Honey Locust	*Gleditsia triacanthos*	7 (7)
Do Not Remove		Red Oak Species	*Quercus Erythrobalanus spp.*	7
		White Oak Species	*Quercus Leucobalanus spp.*	1
Unassigned		Ash Species	*Fraxinus spp.*	1
		Box Elder	*Acer negundo*	8
		Hawthorn Species	*Crataegus spp.*	14
		Sycamore	*Platanus occidentalis*	1

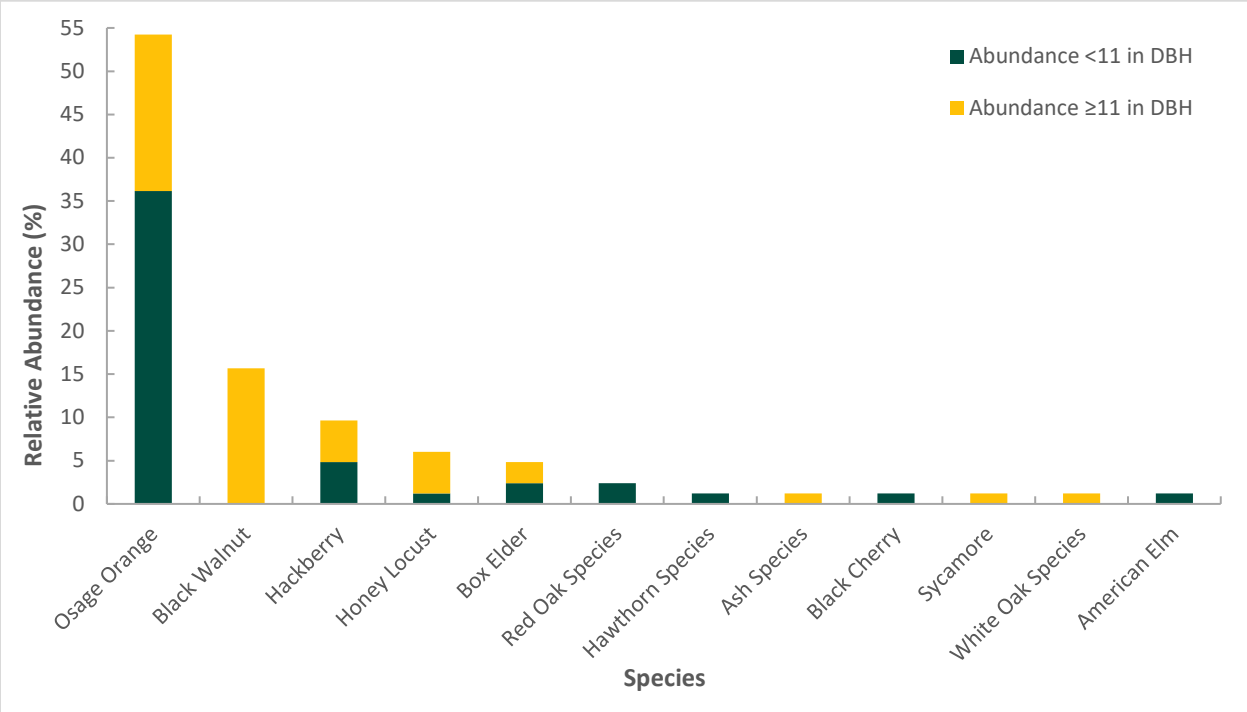

Figure 17. Relative abundance for each species recorded during summer 2020 field surveys in Stand 8

on Wilson's Creek National Battlefield, Missouri. Abundance was split by trees <11 inches DBH (sapling and pole-size trees) in green and ≥11 inches DBH (sawtimber trees) in yellow.

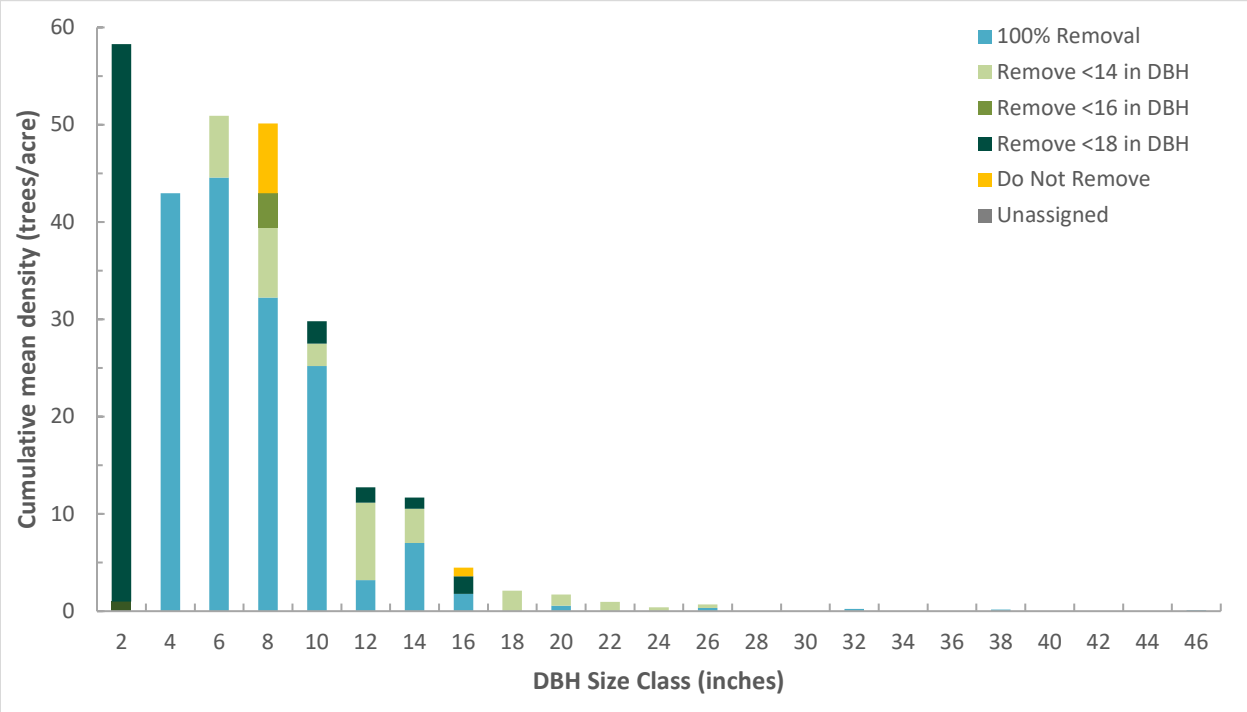

Figure 18. Cumulative mean density (trees/acre) by DBH size class (inches) in Stand 8 (12.27 acres) on Wilson's Creek National Battlefield, Missouri recorded during summer 2020. Trees are grouped by recommended removal guidelines (100% removal, remove <14 in DBH, remove <16 in DBH, remove <18 in DBH, do not remove, and unassigned) outlined in the Wilson's Creek Vegetation Management Implementation Plan (NPS 2014). Removal groups do not indicate DBH of the tree, but at what DBH they should be removed.

Discussion

We surveyed the woodland portion of historical viewsheds on Wilson's Creek National Battlefield (149.52 acres). Eight stands were delineated in the survey area: remanent glade stand, N=1, upland deciduous woodland and forest stands, N=4, and bottomland deciduous woodland and forest stands, N = 3. All stands, excepted for Stand 1, were overcrowded with pole-size, evenly aged trees composed primarily of black walnut, hackberry, Osage orange, chinquapin oak, and black oak.

Historical Vegetation Comparison

The tree structure and composition of the area surveyed scarcely resembled its pre-settlement or 1861 condition. In the pre-settlement era, this area was primarily savanna with blackjack oak (*Q. marilandica*), black oak and post oak (*Q. stellata*) dominating the upland sites (John Milner Associates 2004). Today, the upland areas are comprised of black walnut, hackberry, black oak, chinquapin oak, and Osage orange. Blackjack oak appears to be nearly absent from the area. If restoration guidelines are implemented, trees remaining in the upland areas will predominantly be red and white oak species (mostly black oak and chinquapin oak), with ash species (*Fraxinus spp.*),

hickory species and black walnut present but less abundant. The bottomlands in the pre-settlement era were dominated by black oak, black walnut, sugar maple (*Acer saccharum*), and sycamore (John Milner Associates 2004). Today, they are comprised of black walnut, sycamore, American elm and Osage orange. If restoration guidelines are implemented, the species composition of the bottomlands will closely match pre-settlement conditions, except for a greater presence of chinkapin oak as opposed to sugar maple.

The average DBH was ≤14 inches in the 1800s (Gremaud 1986). Presently, the average DBH is ≤11 inches. Tree density in the 1800s was 10 to 11 trees/acre with some places averaging only 1 to 2 trees/acre (Gremaud 1986). Present day tree density is 26 to 58 times greater (291 - 589 trees/acre) than historical tree density. If restoration recommendations are implemented, tree density will range from 41 - 231 trees/acre. Canopy closure averaged 10 - 20 % in the 1800s (Gremaud 1986), but present, average canopy closure is more than five times greater (89 - 94 %).

We found the glade area (Stand 1) was also degraded. In pre-settlement conditions, the glades had a canopy closure of 0 - 10 % and an occasional tree of blue ash (*Fraxinus quadrangulata*), chinquapin oak, or post oak (John Milner Associates 2004). Today, the glade canopy closure is five times greater (54 %) with a notably different composition (clumps of American elm, slippery elm, black walnut, honey locust (*Gleditsia triacanthos*), and black oak). If restoration guidelines are implemented, the glade tree density will decrease from 183 trees/acre to 16 trees/acre and have scatterings of black oak, American and slippery elm, and chinquapin oak. Although the Cultural Landscape Report (John Milner Associates 2004) provides no historical canopy closure for glades, Nelson (2012) defines Missouri glades with basal area of <10 ft^2/acre. If restoration guidelines for tree removal are implemented, Stand 1 will still have greater basal area (14ft^2/acre) than recommended for glades.

Restoration Guidelines Evaluation

If restoration guidelines outlined in the Wilson's Creek National Battlefield Cultural Landscape Report (2004) and Vegetation Management Implementation Plan (NPS 2014) are implemented, the area surveyed will begin to resemble historical conditions. However, tree density, canopy closure, and tree composition will likely exceed savanna definitions or fail to meet historical conditions of the battlefield. The largest discrepancy will be in tree densities, which even after thinning will be 4 - 20 times greater than the park's historical tree densities (John Milner Associates 2004, Table 2). Thinning guidelines for stands 4 and 8 may be sufficient to meet recommended densities, (47 and 41 trees/acre, respectively, Table 2).

Low tree density and canopy closure are essential for restoring savannas. The dominant species are not trees, but understory grasses and forbs that require specific light levels in order to grow. While tree densities will decrease with restoration thinning recommendations, it may not open the overstory or midstory canopy enough for desired grasses and forbs to return (Nelson 1985). In upland stands (2, 3, 6, and 7) and bottomland stand 5, remaining sapling and pole-size trees after thinning may keep the midstory canopy closed (Appendix A).

Additional restoration techniques may be required to further increase light levels to the ground. Restoring a fire regime which complements mechanical thinning is an essential practice for savanna

restoration. Fire specifically reduces woody sprouts, decreases litter, and increases understory diversity (McCarty 1998, Dey and Kabrick 2015, Hanberry et al. 2017). Studies have found that yearly prescribed fires may kill trees < 3 - 4 in DBH depending on species but are an insufficient and imprecise tool for opening the canopy (Dey and Hartman 2005, Dey et al. 2017, McCarty 1998). While frequent fire is encouraged in the beginning of restoration to prevent a flush of woody sprouts and maintain understory light availability, it should not be relied upon to further increase light availability significantly. Thus, additional mechanical thinning of sapling and pole-size trees can complement fire to fully restore the viewshed area to savanna conditions.

Species composition will become like historical compositions if recommended restoration guidelines are implemented. Bottomland stands will have species compositions fairly similar to historical levels, but upland stands will be different. While oaks will once again become the most dominant tree in the upland stands, the composition will not match historical ratios. In the 1800s, the most dominant oaks were blackjack oak, black oak and post oak. After restoration, dominant oaks will be black oak and chinquapin oak, with red oak (*Q. rubra*), and Shumard's oak (*Q. shumardii*) making up a smaller but still significant portion. Post oak will be present but at much lower numbers than other oaks. Blackjack oak was only identified once across all stands during the tree survey and appears to be nearly absent from the survey area. The re-establishment of blackjack and post oak may improve fire and drought resilience needed for woodlands to persist in the face of future changes in climate (USFS 2014). Red oak and Shumard's oak were not present in pre-settlement communities but may be increasing in abundance in Missouri due to climate change (John Milner Associates 2004, USFS 2014).

Stand 1, the remnant glade area, will also have too large a tree density compared to historical averages after recommended thinning. Tree composition will be different compared to historical composition. Chinkapin oak is the only species in the stand today that was present in the 1800s (John Milner Associates 2004, Appendix A). Like the other stands, additional thinning may be needed to properly restore glade conditions.

Thinning Recommendations

The survey area was split into 8 stands that differed in acreage, species composition, density, and basal area. As such, the cost, duration, difficulty, and method of thinning will depend on the stand. For example, Stand 8 has a large population of Osage orange, a difficult tree to cut, which may cause thinning to take longer and cost more (Table 18). Additionally, larger trees cut could be sold as firewood or timber to help offset the cost of restoration and prevent a buildup of fuel. Sawlogs of black walnut, a valuable timber product, are common in all stands and could be of interest to vendors. However, if larger trees prove difficult to remove following best practices, trees >10 in DBH may be girdled as mentioned in the Vegetation Management Implementation Plan (NPS 2014). Girdling would create snags that provide critical habitat for wildlife.

Conclusions

The surveyed woodlands of the historical viewshed area in Wilson's Creek National Battlefield do not resemble their historical savanna conditions. Greater tree densities and canopy closures in all stands, excluding stand 1, indicate a closed forest system dominated by pole-size trees. Thinning recommendations outlined in the Implementation of Cultural Landscape Report Treatment Recommendations (Common Heritage Group 2018) and Vegetation Management Implementation Plan (NPS 2014) will reduce tree density, but the majority of the landscape (excluding stands 1, 4, and 8) will still be closed woodland or forest even after thinning. More thinning will be needed to further open the landscape. Restoring the landscape back to oak savanna and woodland is essential for returning the battlefield back to its 1861 conditions for accurate visitor interpretation and for increasing flora and fauna diversity and ecosystem resilience to climate change.

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Appendix A. Density (trees/acre) by Diameter at Breast Height Size Classes

Table A1. Density (trees/acre) by DBH size class (inches) for species recorded during summer 2020 field surveys in Stand 1 on Wilson's Creek National Battlefield, Missouri. Species are organized by removal recommendations outlined in the Wilson's Creek Vegetation Management Implementation Plan (2014); 100% removal of all stems, selected removals of stems <14, <16, or <18 in DBH, do not remove, and unassigned.

Removal Conditions		Species	Density (trees/acre) by DBH size class (in)												
			2	4	6	8	10	12	14	16	18	20	22	24	Total
100% Removal		Autumn Olive	92	0	0	0	0	0	0	0	0	0	0	0	92
		Eastern redcedar	0	0	0	0	2	0	0	0	0	0	0	0	2
Selected Removals	**<14 in DBH**	Black Walnut	0	11	5	3	2	1	0	0	0	0	0	0	23
		Hackberry	0	0	0	3	2	0	0	0	0	0	0	0	5
	<16 in DBH	Black Cherry	0	0	15	0	2	0	0	0	0	0	0	0	17
	< 18 in DBH	American Elm	0	0	0	0	0	0	0	1	1	<1	0	0	2
		Slippery Elm	0	0	0	0	2	0	1	0	0	0	0	0	3
		Honey Locust	0	23	5	0	0	0	0	0	0	0	0	0	28
Do Not Remove		Black Oak	0	0	0	0	0	1	0	0	1	0	0	<1	3
		Chinquapin Oak	0	0	0	0	0	3	0	0	0	0	0	0	3
		Shingle Oak	0	0	5	0	0	0	0	0	0	0	0	0	5
Unassigned		Ash Species	0	0	0	0	0	1	0	0	0	0	0	0	1
		Total	92	34	31	6	9	6	1	1	2	<1	0	<1	183

Table A2. Density (trees/acre) by DBH size class (inches) for species recorded during summer 2020 field surveys in Stand 2 on Wilson's Creek National Battlefield, Missouri. Species are organized by removal recommendations outlined in the Wilson's Creek Vegetation Management Implementation Plan (2014); 100% removal of all stems, selected removals of stems <8, <14, <16, or <18 inches DBH, do not remove, and unassigned.

Removal Conditions		Species	Density (trees/ha) by DBH size class (in)														
			2	4	6	8	10	12	14	16	18	20	22	24	26	46	Total
100% Removal		Black Locust	12	0	0	0	0	0	0	0	0	0	0	0	0	0	12
		Eastern redcedar	25	6	4	5	1	<1	0	0	0	0	0	0	0	0	42
		Osage Orange	50	19	1	2	<1	<1	0	<1	0	0	0	0	0	0	73
Selected Removals	**<8 in DBH**	Red Mulberry	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
	<14 in DBH	Black Walnut	0	34	17	8	8	4	2	1	1	<1	0	0	0	0	73
		Hackberry	62	22	10	5	4	2	1	<1	0	0	0	0	<1	0	106
	<16 in DBH	Black Cherry	37	6	6	1	0	1	0	0	0	0	0	0	0	0	50
	<18 in DBH	American Elm	0	15	3	2	<1	<1	1	0	0	0	0	0	0	0	21
		Slippery Elm	12	3	3	1	0	0	0	0	0	0	0	0	0	0	19
		Honey Locust	12	12	14	2	<1	1	0	<1	0	<1	0	0	0	0	43
Do Not Remove		Black Oak	12	0	4	2	1	1	1	0	0	<1	<1	0	0	<1	21
		Chinquapin Oak	25	15	7	5	1	1	2	1	<1	<1	0	0	0	0	57
		Post Oak	0	0	0	0	0	<1	0	<1	<1	0	0	0	0	0	1
		Red Oak	0	0	0	3	2	1	<1	<1	0	<1	0	0	0	0	7
		Shingle Oak	12	0	0	0	0	0	0	0	0	0	0	0	0	0	12
		Shumard's Oak	0	0	0	1	0	1	<1	0	0	0	0	0	0	0	2
Unassigned		Ash Species	0	6	6	5	3	1	1	1	<1	0	0	0	0	0	22
		Black Hickory	0	3	0	0	0	0	0	0	0	0	0	0	0	0	3
		Shagbark Hickory	0	6	1	2	0	1	0	0	0	0	0	0	0	0	10
		Viburnum Species	12	0	0	0	0	0	0	0	0	0	0	0	0	0	12
		Total	273	149	76	42	22	16	7	3	1	1	<1	0	<1	<1	589

Table A3. Density (trees/acre) by DBH size class (inches) for species recorded during summer 2020 field surveys in Stand 3 on Wilson's Creek National Battlefield, Missouri. Species are organized by removal recommendations outlined in the Wilson's Creek Vegetation Management Implementation Plan (2014); 100% removal of all stems, selected removals of stems <8, <14, <16, or <18 inches DBH, do not remove, and unassigned.

			Density (trees/acre) by DBH size class (in)															
Removal Conditions		**Species**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**Total**
100% Removal		Eastern redcedar	0	0	5	5	4	2	0	<1	<1	0	0	0	0	0	0	17
		Osage Orange	0	0	0	3	0	0	0	<1	0	0	0	0	0	0	0	3
Selected Removals	**<8 in DBH**	Red Mulberry	0	5	2	1	2	1	0	0	0	0	0	0	0	0	0	11
	<14 in DBH	Black Walnut	0	0	5	10	5	6	5	1	1	<1	0	<1	0	0	0	34
		Hackberry	42	36	32	5	4	3	<1	<1	0	0	0	0	0	0	0	124
	<16 in DBH	Black Cherry	0	5	5	0	0	0	0	0	0	0	0	0	0	0	0	10
	<18 in DBH	American Elm	21	5	2	0	0	1	0	0	0	0	0	0	0	0	0	29
		Slippery Elm	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	5
		Honey Locust	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Do Not Remove		Black Oak	21	0	2	4	2	3	<1	2	1	1	<1	0	0	0	<1	37
		Blackjack Oak	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	0	<1
		Chinquapin Oak	0	31	9	7	3	3	1	<1	<1	0	0	<1	<1	0	<1	55
		Post Oak	0	0	0	0	0	1	0	1	1	1	0	<1	0	<1	0	4
		Red Oak	21	5	2	0	0	0	<1	<1	1	<1	0	<1	0	0	0	30
		Shingle Oak	0	0	0	0	1	0	0	0	0	0	<1	0	0	0	0	1
		Shumard's Oak	0	0	0	0	1	0	<1	<1	0	0	<1	0	<1	0	0	2
Unassigned		Ash Species	0	0	2	0	0	0	0	0	<1	<1	0	0	0	0	0	3
		Box Elder	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2
		Gum Bumelia	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21
		Bitternut Hickory	0	0	0	0	0	0	0	0	<1	0	0	0	0	0	0	<1

Removal Conditions	Species	Density (trees/acre) by DBH size class (in)															
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	Total
Unassigned	Black Hickory	0	5	2	1	0	0	0	0	0	0	0	0	0	0	0	9
	Mockernut Hickory	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2
	Shagbark Hickory	21	0	2	3	1	1	0	0	0	0	0	0	0	0	0	27
	Viburnum Species	21	5	0	0	0	0	0	0	0	0	0	0	0	0	0	26
	Total	168	104	76	39	23	21	7	7	5	2	1	1	<1	<1	<1	453

Table A4. Density (trees/acre) by DBH size class (inches) for species recorded during summer 2020 field surveys in Stand 4 on Wilson's Creek National Battlefield, Missouri. Species are organized by removal recommendations outlined in the Wilson's Creek Vegetation Management Implementation Plan (2014); 100% removal of all stems, selected removals of stems <8, <14, or <18 inches DBH, do not remove, and unassigned.

			Density (trees/acre) by DBH size class (in)																		
Removal Conditions		**Species**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**38**	**48**	**Total**
100% Removal		Eastern redcedar	42	0	9	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	52
		Osage Orange	42	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	52
Selected Removals	**<8 in DBH**	Red Mulberry	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
	<14 in DBH	Black Walnut	0	0	9	3	3	2	4	4	2	2	<1	<1	0	<1	0	0	0	0	0	30
		Hackberry	0	0	5	3	2	0	0	1	1	0	<1	<1	<1	<1	0	0	0	0	0	12
	<18 in DBH	American Elm	0	83	28	26	7	3	2	0	0	0	0	0	0	0	0	0	0	0	0	149
		Honey Locust	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2
Do Not Remove		Bur Oak	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2
		Chinquapin Oak	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1	<1	0	0	0	<1
Unassigned		Ash Species	0	0	0	3	0	0	0	0	0	0	<1	0	0	<1	0	0	0	0	0	3
		Silver Maple	0	0	0	3	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	5
		Sycamore	0	0	0	0	5	7	3	1	1	1	0	0	1	1	<1	1	<1	<1	<1	20
		Total	83	94	51	36	17	16	10	9	4	3	1	1	1	1	1	1	<1	<1	<1	329

Table A5. Density (trees/acre) by DBH size class (inches) for species recorded during summer 2020 field surveys in Stand 5 on Wilson's Creek National Battlefield, Missouri. Species are organized by removal recommendations outlined in the Wilson's Creek Vegetation Management Implementation Plan (2014); 100% removal of all stems, selected removals of stems <8 or <14 inches DBH, and do not remove.

Removal Conditions		Species	Density (trees/acre) by DBH size class (in)													
			2	4	6	8	10	12	14	16	18	20	22	24	26	Total
100% Removal		Eastern redcedar	76	76	17	24	6	0	2	0	0	0	0	0	0	201
		Osage Orange	0	19	0	0	0	0	0	0	0	1	0	0	0	20
Selected Removals	**<8 in DBH**	Red Mulberry	0	19	0	0	0	0	0	0	0	0	0	0	0	19
	<14 in DBH	Black Walnut	0	0	34	10	12	13	3	1	1	1	0	0	<1	75
		Hackberry	0	0	0	5	3	0	0	0	1	0	0	0	0	9
Do Not Remove		Bur Oak	0	0	0	0	3	0	0	0	0	0	0	0	0	3
		Chinquapin Oak	76	0	25	5	3	2	0	0	0	0	0	0	0	112
		Post Oak	0	0	0	0	0	0	0	1	0	0	0	0	0	1
		Shumard's Oak	0	0	0	0	6	2	0	0	0	0	0	0	0	8
		Total	153	115	76	43	34	17	5	2	2	2	0	0	<1	448

Table A6. Density (trees/acre) by DBH size class (inches) for species recorded during summer 2020 field surveys in Stand 6 on Wilson's Creek National Battlefield, Missouri. Species are organized by removal recommendations outlined in the Wilson's Creek Vegetation Management Implementation Plan (2014); 100% removal of all stems, selected removals of stems <14, <16, or <18 inches DBH, do not remove, and unassigned.

			Density (trees/acre) by DBH size class (in)															
Removal Conditions		**Species**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**Total**
100% Removal		Eastern redcedar	13	6	10	2	1	0	1	0	0	0	0	0	0	0	0	32
		Osage Orange	0	16	16	5	4	3	<1	<1	<1	<1	<1	0	<1	<1	<1	45
Selected Removals	**<14 in DBH**	Black Walnut	13	13	7	5	6	2	2	3	<1	<1	0	<1	0	<1	0	51
		Hackberry	13	29	6	11	4	2	1	1	0	<1	0	0	<1	0	0	66
	<16 in DBH	Black Cherry	38	10	7	6	4	1	0	<1	0	0	0	0	0	0	0	66
	<18 in DBH	American Elm	25	10	4	2	2	<1	0	0	0	0	0	0	0	0	0	43
		Honey Locust	0	6	4	6	2	2	<1	0	<1	0	0	<1	0	0	0	20
Do Not Remove		Black Oak	0	10	7	2	2	1	1	<1	<1	<1	<1	0	0	0	<1	24
		Chinquapin Oak	0	10	4	6	1	<1	0	0	<1	0	0	0	<1	0	0	20
		Post Oak	0	3	0	0	1	0	<1	0	<1	<1	0	0	0	0	0	4
		Red Oak	0	0	0	0	0	0	0	0	0	<1	0	0	0	0	0	<1
		Shingle Oak	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
		Shumard's Oak	0	0	4	2	1	1	0	0	<1	0	0	0	0	0	0	7
Unassigned		Ash Species	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	3

Removal Conditions	Species	Density (trees/acre) by DBH size class (in)															
		2	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**Total**
Unassigned	Box Elder	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
	Plum Species	25	3	0	0	0	0	0	0	0	0	0	0	0	0	0	29
	Sassafras	13	0	1	0	0	0	0	0	0	0	0	0	0	0	0	14
	Total	140	115	72	49	25	13	5	4	2	1	<1	<1	<1	<1	<1	426

Table A7. Density (trees/acre) by DBH size class (inches) for species recorded during summer 2020 field surveys in Stand 7 on Wilson's Creek National Battlefield, Missouri. Species are organized by removal recommendations outlined in the Wilson's Creek Vegetation Management Implementation Plan (2014); 100% removal of all stems, selected removals of stems <8, <14, <16, or <18 inches DBH, do not remove, and unassigned.

			Density (trees/acre) by DBH size class (in)															
Removal Conditions		**Species**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**30**	**34**	**Total**
100% Removal		Eastern redcedar	109	16	7	1	0	1	<1	0	0	0	0	0	0	0	0	135
		Osage Orange	0	22	17	5	2	1	0	0	<1	0	<1	0	0	0	0	47
Selected Removals	**<8 in DBH**	Red Mulberry	0	5	0	0	1	0	0	0	0	0	0	0	0	0	0	6
	<14 in DBH	Black Walnut	22	0	17	12	4	3	2	1	0	0	0	<1	0	0	0	62
		Hackberry	0	5	10	4	2	1	1	0	<1	0	<1	0	0	0	0	24
	<16 in DBH	Black Cherry	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	4
	<18 in DBH	American Elm	22	5	7	3	1	0	<1	0	0	0	0	0	0	0	0	39
		Honey Locust	0	0	0	0	0	3	<1	0	0	0	0	0	0	0	0	3
Do Not Remove		Black Oak	0	0	0	3	1	0	<1	1	1	<1	<1	0	<1	0	0	7
		Chinquapin Oak	22	22	7	4	2	1	<1	1	0	0	0	0	0	0	0	59
		Post Oak	0	0	2	0	0	1	0	0	0	0	<1	<1	0	<1	0	4
		Red Oak	0	5	2	4	0	0	0	0	0	<1	0	0	0	0	0	12
		Shumard's Oak	0	0	0	0	1	0	<1	1	0	<1	<1	0	0	0	0	2
Unassigned		Ash Species	44	22	5	5	2	0	0	0	0	0	0	0	0	0	<1	78

Removal Conditions	Species	Density (trees/acre) by DBH size class (in)															
		2	4	6	8	10	12	14	16	18	20	22	24	26	30	34	Total
Unassigned	Bitternut Hickory	0	0	0	0	0	0	0	<1	0	0	0	0	0	0	0	<1
	Black Hickory	0	0	2	1	0	4	1	1	0	0	0	0	0	0	0	9
	Pignut Hickory	0	0	0	0	0	0	<1	0	0	0	0	0	0	0	0	<1
	Mockernut Hickory	0	0	0	0	0	0	0	<1	0	0	0	0	0	0	0	<1
	Sassafras	22	16	0	0	0	0	0	0	0	0	0	0	0	0	0	38
	Total	240	120	80	44	17	15	7	5	2	1	1	<1	<1	<1	<1	531

Table A8. Density (trees/acre) by DBH size class (inches) for species recorded during summer 2020 field surveys in Stand 8 on Wilson's Creek National Battlefield, Missouri. Species are organized by removal recommendations outlined in the Wilson's Creek Vegetation Management Implementation Plan (2014); 100% removal of all stems, selected removals of stems <14, <16, or <18 inches DBH, do not remove, and unassigned.

			Density (trees/acre) by DBH size class (in)																
Removal Conditions		**Species**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**32**	**38**	**46**	**Total**
100% Removal		Osage Orange	0	43	45	32	25	3	7	2	0	1	0	0	<1	<1	<1	<1	158
Selected Removals	**<14 in DBH**	Black Walnut	0	0	0	0	0	6	4	0	1	1	1	0	<1	0	0	0	13
		Hackberry	0	0	6	7	2	2	0	0	1	0	0	<1	0	0	0	0	19
	<16 in DBH	Black Cherry	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	4
	<18 in DBH	American Elm	57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57
		Honey Locust	0	0	0	0	2	2	1	2	0	0	0	0	0	0	0	0	7
Do Not Remove		Black Oak	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	4
		Chinquapin Oak	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
		Shumard's Oak	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	4
Unassigned		Ash Species	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
		Box Elder	0	0	0	4	0	5	0	0	0	0	0	0	0	0	0	0	8
		Hawthorn Species	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
		Sycamore	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
		Total	57	57	51	54	30	18	13	4	2	2	1	<1	1	<1	<1	<1	291