National Park Service
U.S. Department of the Interior

Natural Resource Program Center

Effects of multiple intense disturbances at Manley Woods, Wilson's Creek National Battlefield

Natural Resource Technical Report NPS/HTLN/NRTR—2008/123

ON THE COVER
Tornado damage at Wilson's Creek National Battlefield, Manley Woods, 2003
Photo from The Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program files.

Effects of multiple intense disturbances at Manley Woods, Wilson's Creek National Battlefield

Natural Resource Technical Report NPS/HTLN/NRTR—2008/123

Sherry A. Leis
Missouri State University, The Heartland I&M Network and Prairie Cluster Prototype Monitoring Program, 901 S. National Ave., Springfield, MO 65897

Kevin James
National Park Service, The Heartland Inventory & Monitoring Network and Prairie Cluster Prototype Monitoring Program, Wilson's Creek National Battlefield, 6424 West Farm Road 182, Republic, MO 65735

November 2008

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

The Natural Resource Publication series addresses natural resource topics that are of interest and applicability to a broad readership in the National Park Service and to others in the management of natural resources, including the scientific community, the public, and the NPS conservation and environmental constituencies. Manuscripts are peer-reviewed to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and is designed and published in a professional manner.

The Natural Resource Technical Report series is used to disseminate the peer-reviewed results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service's mission. The reports provide contributors with a forum for displaying comprehensive data that are often deleted from journals because of page limitations. Current examples of such reports include the results of research that addresses natural resource management issues; natural resource inventory and monitoring activities; resource assessment reports; scientific literature reviews; and peer reviewed proceedings of technical workshops, conferences, or symposia.

Views and conclusions in this report are those of the authors and do not necessarily reflect policies of the National Park Service. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the National Park Service.

Printed copies of reports in these series may be produced in a limited quantity and they are only available as long as the supply lasts. This report is also available from the Heartland I&M Network website (http://www.nature.nps.gov/im/units/HTLN) on the internet, or by sending a request to the address on the back cover.

Please cite this publication as:

Leis, S. A., and K. James. 2008. Effects of multiple intense disturbances at Manley Woods, Wilson's Creek National Battlefield. Natural Resource Technical Report NPS/HTLN/NRTR—2008/123. National Park Service, Fort Collins, Colorado.

NPS D-85, November 2008

Executive Summary

Natural communities in southwest Missouri are often challenged by ecological disturbances of a catastrophic nature. Windthrow, wildfire, flooding, drought, and ice storm events all occur periodically and range in spatial extent from local to regional. Although in this region, local disturbances are common in singularity, it is unusual for several disturbances to affect the same locality within a short time period. Since 2003, however, the Ozark Highlands region has seen widespread events including tornados, fires, floods, and ice storms many occurring in succession on the same piece of land. Understanding the change in vegetation composition and recovery rates resulting from multiple severe disturbances is crucial to natural resource management planning.

In 2003, a tornado struck the Manley Woods area of Wilson's Creek National Battlefield (WICR) affecting 60 ha. The affected area included long-term monitoring sites sampled in three years both prior to and post-tornado. In the post tornado years, three additional notable disturbances occurred, but each disturbance differentially affected each of the sites. Increased fuel loads resulting from the tornado damage caused concern for elevated wildfire risk, so park staff made plans to reduce fuel loads. In 2005, a contractor removed salvageable timber from Manley Woods and the following year a prescribed fire was completed. In 2007, however, a January ice storm further affected communities in Manley Woods. The aim of this study was to determine the effectiveness of the fuels reduction activities and to describe the composition of overstory and understory plant communities currently inhabiting Manley Woods.

Fuel loads at Manley Woods were quite high post-tornado, especially at site 4. The fuels reduction process, log removal and fire, reduced mean fuel loads nearly by half leaving an average of 18.5 tons/ha. Mean fuel loads were significantly reduced at the site (4) that received the most damage and notable reductions were seen at site 5.

Changes occurred in several aspects of the plant community. Overstory tree density was reduced by 4.31 m^2/ha mainly by the tornado. In 2006, trees in the larger size classes (35+ cm dbh) could only be found at the less disturbed sites in the Woods and canopy closure trended towards a savannah structure. Regeneration, seedlings and saplings, was reduced overall including a significant decline in oak and hickory species. Diversity of the herbaceous understory plants dropped significantly during the period of heaviest disturbance (2003-2006). Understory plant community response lagged one year behind disturbance events. Plant community composition shifted towards more early seral woodland species after 2004 at all sites, but the greatest change occurred at the most heavily disturbed areas in the Woods. Furthermore, 2007 composition appeared to be on a path back toward previous community composition. Plant guilds, particularly woody plants, pulsed after the tornado, but returned to similar pre-disturbance conditions. Exotic species remained low and did not change significantly over time.

The analysis described herein may aid park natural resource managers to plan to achieve the desired conditions in Manley Woods. Prior to the 2003 tornado, park managers used fire to work towards a savannah community type. The disturbances had a heterogeneous effect on the whole management unit hastening the restoration process in parts of Manley Woods, but not greatly affecting others.

Contents

Page

List of Figures v

List of Tables vi

List of Appendixes vi

Introduction 1

Methods 3

Results 7

Discussion 19

Literature Cited 20

Appendixes 24

Figures

Page

Figure 1. Inset of Wilson's Creek National Battlefield on the left and magnification of Manley Woods with sample sites labeled on the right (2007 image). Sites 4-6 have W/SW aspects while site 7 has a more northerly aspect.. 2

Figure 2. HTLN vegetation community sample site (0.1 ha) design showing orientation of transects and plots including nested plots. 3

Figure 3. Total rainfall through the sampling period. Disturbance events of interest were inserted in the timeline.. 7

Figure 4. (A) Mean fuel loading by time lag class for Manley Woods. Error bars represent 1 standard deviation for mean total fuel load (not time lag class), (B) mean fuel loading by sampling site for Manley Woods. * indicates loadings at site 4 were significantly different through time ($P = 0.04$, $r^2 = 0.92$). 8

Figure 5. Total basal area (m^2/ha) of trees in each size class throughout monitoring history at Manley Woods, (diameter at breast height = dbh)..……..……..……. 9

Figure 6. Density of select tree species as measured by basal area A) oak species and B) early seral species from long-term monitoring sites at Manley Woods pre- (1997) and post-disturbance (2003, 2006)..... 10

Figure 7. Density of oak stems in each size class through time. Percent of all tree stems that were oak is given at the top of each stacked bar.. 11

Figure 8. Tree regeneration, including seedlings and all saplings, (total stems/ha) for each sampling site by species at Manley Woods.. 12

Figure 9. Comparision of *Carya* and *Quercus* regenerative stems through time…… 13

Figure 10. Distribution of ground cover, including bare ground, dead wood, leaf litter, and total unvegetated area, (means and standard deviations) before and after a series of disturbance events at Manley Woods in Wilson's Creek National Battlefield... 14

Figure 11. Mean diversity measures with standard error bars for the understory community in Manley Woods long-term monitoring plots. Measures are converted to effective number of species for comparison. 15

Figure 12. Principle components analysis biplot of sites through time and species where a portion of species are labeled. Site scores are labeled as site#/year and species scores are labeled with ITIS codes (for explanation of species codes, see Appendix C). Axis 1 represents a disturbance gradient, such that more heavily disturbed sites in a given year are located to the right of the biplot. Axis 2 represents a difference in aspect from South to North…… 16

Figures (cont'd)

Page

Figure 13. Mean percent cover of selected guilds within each sampling site at Manley Woods……17

Figure 14. Trend in exotic species richness across sample sites at Manley Woods..... 18

Tables

Page

Table 1. Diameter at breast height (cm) size classes and ranges for overstory trees…… 5

Table 2. Overstory canopy closure (±standard deviation) for Manley Woods long-term monitoring sites, post-disturbance……..... 9

Table 3. Most recent (2007) estimates of exotic species cover at sample sites for Manley Woods. Species occurrences of >1% are bolded. Missing standard deviations (stdev) indicate insufficient numbers of occurrences…….…….……. 18

Appendixes

Page

Appendix A. Long-term monitoring and disturbance history for Manley Woods...…...…… 24

Appendix B. Surface fuels summary……..……. 26

Appendix C. Master species list for Manley Woods……...… 27

Introduction

Natural communities in southwest Missouri are often affected by ecological disturbances of a catastrophic nature. Windthrow, wildfire, flooding, drought, and ice storm events all occur periodically and range in spatial extent from local to regional. Although in this region, local disturbances are common in singularity, it is unusual for several disturbances to affect the same locality within a short time period. Since 2003, the Ozark Highlands region has seen widespread events including tornados, fires, floods, and ice storms many occurring in succession on the same piece of land. Understanding the change in vegetation composition and recovery rates resulting from multiple severe disturbances is crucial to natural resource management planning.

Historically, fire was an important component of woodland and savannah ecosystems in the eastern U.S. Fire regime estimates for the Ozarks, based on studies by Guyette et al. (2002, 2006) and Dey et al. (2004) provide insight into local fire ecology from Ozarks regional data. Although fire scar data suggest a 3-5 year return interval from 1700 to 1800, fires may have been more frequent (Cutter and Guyette 1994). Fire frequencies declined in the 1800s as settler populations and infrastructure grew and Native Americans were displaced (Guyette et al. 2002). Then, in the early part of the 20th century, the landscape began to change as a result of new national fire suppression policies. Savannahs, glades, and open woodlands began to fill in with trees resulting in simultaneous shifts in the herbaceous understory (Gremaud 1986; National Park Service 2004). Prescribed fire was eventually reintroduced to WICR in 1988 (Gale et al. 2004).

Other disturbances are also common in this region. The return interval of catastrophic windthrow events on a given area of land may range from 100-1210 years (Canham and Loucks 1984; Foster et al. 1998). Tornados in woodlands typically have an intense impact within a small area increasing landscape heterogeneity (Whitmore 1989), while the extent of flooding or ice storm damage tends to be regional and the effect more uniform (Foster et al. 1998). The longevity of fire, as well as flooding and ice storm events can exceed that of tornados (Foster et al. 1998), but each of these disturbances can create gaps in the forest canopy. Responses to the open gaps vary by species and gap size with larger gaps having a more pronounced effect (Runkle 1982; Whitmore 1989). In 2003, the Manley Woods area of WICR was struck by a northeasterly traveling tornado affecting 60 ha (Figure 1). Areas around two of the four long-term monitoring sites (4, 5) were affected the most.

In the post tornado years, three notable disturbances occurred (Appendix A). 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 the following year 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. The salvage and prescribed fire operations had little effect on site 7. In 2007, however, a January ice storm event further stressed natural communities in Manley Woods.

This report describes vegetation community dynamics before and after the disturbance events in an effort to document the effects of multiple, sequential, severe disturbances and to aide natural resource management staff in planning restoration efforts.

Study Site

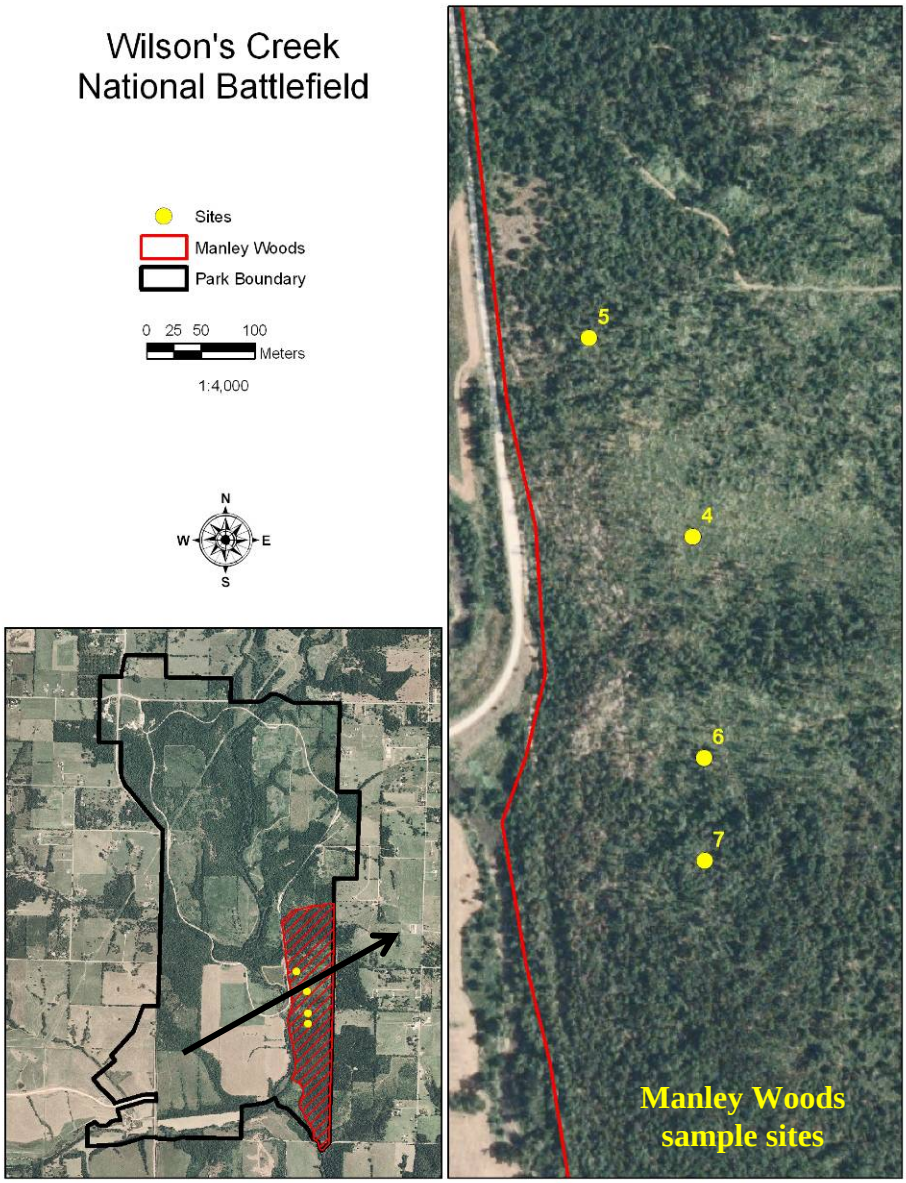


Figure 1. Inset of Wilson's Creek National Battlefield on the left and magnification of Manley Woods with sample sites labeled on the right (2007 image). The arrow indicates the path of the tornado. Sites 4-6 have W/SW aspects while site 7 has a more northerly aspect.

Congress passed enacting legislation creating Wilson's Creek National Battlefield in 1960, and in 1968, the park was directed to restore the historic battlefield scene as well as to interpret the events of the battle (Gale et al. 2004). WICR is in the ecotone of the Ozarks Highlands and Osage Plains regions where the prairies meet the woodlands (Nelson 2005). Schoolcraft described highly variable ecosystems within this area including prairies, glades, savannahs, and woodlands (Schoolcraft 1821). Later, Civil War soldiers at WICR described an open savannah

scene interspersed with agricultural fields, but at the time of the Park's creation many of the upland savannahs and glades had become closed canopy woodlands (Gremaud 1986; National Park Service 2004).

Fire history records are available for the park, but spatial historical records of periodic disturbances like windthrows are not readily available. Many prairies and savannahs filled in with trees including eastern redcedar trees that advanced onto glades in the 44-year absence of fire. Fire was reintroduced at WICR in an effort to begin restoration of the ecosystems and historical views of the battle. Fire return intervals at WICR currently average five years and ecosystem and cultural restoration has progressed (Gale et al. 2004).

Manley Woods is located along the southeastern boarder of WICR (Fig. 1). Prior to the series of disturbance events, Manley Woods was a mature closed canopy oak woodland (Gremaud 1986) and management plans included restoring the area to a savannah type community using fire (National Parks Service 2004). The sampling and recent disturbance history for each sampling site were documented in Appendix A. The series of disturbances described above most affected two of the four long-term monitoring sites in Manley Woods (sites 4 and 5). Sites 6 and 7 received less intense disturbance (NPS, G. Sullivan, Supervisory Resource Management Specialist, interview, 2008).

Methods

The HTLN sampling design, based on the design of the Konza Prairie Long-Term Ecological Research Program, consists of randomly located, permanent, paired transects 50-m long and 20-m apart with five circular 10-m^2 plots systematically spaced along each transect (Figure 2; DeBacker et al. 2004).

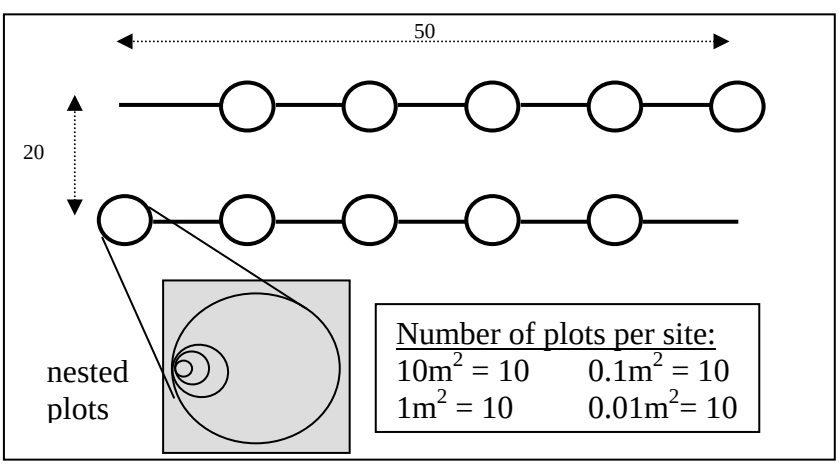


Figure 2. HTLN vegetation community sample site (0.1 ha) design showing orientation of transects and plots including nested plots.

The primary sample unit was the site (0.1 ha), circular plots along each transect were secondary sample units. Each 10-m^2 plot also included nested subplots of 1 m^2, 0.1 m^2, and 0.01 m^2 for frequency estimates at multiple scales. For this report, both understory frequency and cover estimates are reported from the 10-m^2 plots and summarized by site. Working systematically from the smallest subplot (0.01 m^2) to the largest (10 m^2), all understory species were identified and foliar cover estimated. Overstory canopy cover and regeneration species composition and structure data were collected at secondary sample units (plot level) in 1997, 2003 and 2006. Overstory tree (stems ≥ 5.0 cm diameter at breast height, dbh) size (dbh), composition, and condition data were collected for each species within the site in the 20 x 50-m area formed between the two transect lines every five years. Canopy closure was estimated by taking four densitometer readings at each of the 10 plots in each site (one in each cardinal direction). The four readings were then averaged and the means were used to calculate a grand mean for the site. Overstory tree density and basal area were calculated at the site scale. Understory species abundance was sampled at least every two years. Summaries were calculated at both the site and park scale.

Fuel loads were measured using four standard Brown's transects (Brown 1974; USDI National Park Service 2003) beginning in 2003. One 50-ft Brown's line was anchored at both ends of each transect (n = 4). Litter and duff depths, as well as occurrences of 1, 10, 100, and 1000-hr fuels were recorded. Litter, and duff depths and downed logs were measured at intervals along the transect.

Analytical methods

For analyses, the site was the unit of replication and secondary sample units were pooled or averaged. Once estimates for all parameters were calculated for each sample unit, averages with a measure of variability among sample sites were calculated. Statistical significance was determined at alpha = 0.10 for all tests.

Fuel loads

Fuel loads were calculated for each site-year combination using fuels constants for red oak (*Quercus rubra*) because, out of the available constants, *red oak* most closely approximates the species composition of Manley Woods. Fuel load formulas programmed in the FFI database were based on Brown (1974) and can also be found in USDI (2003). Total fuel load was calculated for each Brown's line and averaged to represent the site. Manley Woods scale measurements were calculated by averaging all four sites together. A regression analysis using SPSS was conducted to determine whether fuel loads, at the site scale, differed through time (2008).

Overstory and understory data summary

In the forest community, summary statistics such as density and basal area were calculated for overstory (stems ≥ 5.0 cm dbh) and understory tree species. Total basal area as measured by diameter at breast height (dbh) and density were scaled to the hectare. Density, or the total number of stems per sample unit, and basal area are measures of stand age distribution and abundance for tree species. Tree density was calculated for five size classes (Table 1). Regeneration of oak and hickory genera were assessed with a Friedman's test and within-site trends were analyzed using regression (SPSS 2008).

Table 1. Diameter at breast height size classes and ranges for overstory trees.

Size Class	dbh (cm)
1	5 - 14.9
2	15 - 24.9
3	25 - 34.9
4	35 - 44.9
5	45+

Individual species abundances

Individual species percent foliar cover were calculated for herbaceous species at each site. Foliar cover served as an estimate of abundance. The cover classes were converted to median values to estimate percent cover for each herbaceous and shrub species. Mean percent cover was then calculated as the species percent cover for a sampling unit and a grand mean was calculated to represent each site.

Community level analysis was conducted using principal components analysis (PCA) with PCOrd software (McCune and Mefford 1999). PCA is an indirect gradient analysis that correlates species and samples simultaneously allowing for analysis of community change. Mean percent cover data for each site and year combination were square root transformed before calculating the PCA. Site scores are a composite of the species abundances for that site in a particular year. Sites and species that are further apart (distance within the plot) are less strongly correlated (McCune and Grace 2002).

Plant species richness, diversity, and evenness

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

$$H' = -\sum_{i=1}^{n} p_i \ln(p_i)$$

where p*i* is the relative cover of species *i* (Shannon 1948).

Species distribution, **evenness,** was calculated by site using Pielou (J):

$$J' = H' / H_{max},$$

where H' is the Shannon diversity index and H_{max} is the maximum possible diversity for a given number of species if all species are present in equal numbers (ln(species richness)). J' is a measure of distribution of species within a community as compared to equal distribution and maximum diversity (Pielou 1974).

Species **richness** (S) is the total number of plant taxa recorded per site. Species richness was calculated with all species (native and exotic) included in the estimate.

Simpson's index of diversity for an infinite population (D) was calculated by site. D is the likelihood that two randomly chosen individuals from a site will be different species and

emphasizes common species (McCune and Grace 2002). It was calculated by site using the complement of Simpson's original index of dominance:

$$\text{Simpson's diversity index} = 1 - \sum_{i}^{n} p_i^{\,2}$$

Shannon and Simpson's diversity index values were converted into effective number of species for the understory vegetation, H_e and D_e, respectively. This allowed for both diversity measures to be compared directly to species richness of the sites (S) (Joust 2006). Shannon diversity index was converted into effective number of species (H_e) using the following formula:

$$H_e = \exp^{(H)}$$

where H is the Shannon diversity index value.
Effective number of species based on Simpson's diversity index (D_e) is the inverse of the index value or:

$$D_e = 1/(1\text{-}D)$$

where D is the Simpson's diversity index value.

Fully understanding diversity estimates requires comparison of all three diversity measures (Joust 2006). At the most basic level of species diversity, species richness provides a total number of distinct species sampled per unit area. Richness (S) only reflects species presence not species abundance in relation to other members of the community. Shannon diversity index (H) weights species by their abundance and is an intermediate between species richness and Simpson's diversity index (D) in its sensitivity to rare species. Therefore, Shannon's diversity index provides information on both the count of unique species and their abundance or density in the community. Simpson's diversity index goes one step further by disproportionately favoring dominant species based on species abundance and is little affected by gain or loss of rare species.

Dominance takes into account the species abundance and evenness of species distribution in the community. The degree of species dominance in the community is reflected by the degree to which $S > H_e > D_e$ when evenness (E) remains constant in a single community. The difference in number of species between the diversity measures reflects both how each metric considers uncommon species and how species diversity is partitioned within the community. If all species occurred in equal abundance in the community, then $S = H_e = D_e$. Effective number of species for each diversity measure reflects the number of species found in a similar community when all species occur in equal density. For example, if S = 100 and D_e is equal to 20, than the community is dominated by 20 species and 80 species occur in low abundance. Such a community would be equivalent to a community with just 20 species all occurring in equal abundance. Because diversity can be affected by disturbance we compared the above measures of diversity from 2003-2006 to the remaining sampling years using a Mann-Whitney U test (SPSS 2008).

Guild summary

Plants within a guild often respond similarly to disturbance so the herbaceous ground level communities were described in terms of species guilds (Kindscher 1992). Trends in mean relative cover over time were calculated for sample years and combination of years and sample sites. Presentation of data by sample site allows for better understanding of underlying trends as a response to disturbance. Exotic species were analyzed using PRO REG (SAS 2001) to understand whether abundances changed through time.

Results

Precipitation during the period of monitoring was variable, but most years were below normal (Figure 3; NOAA 2008). Temperature, relative humidity, and precipitation in addition to fuel loads are important factors in determining fire intensity and fire effects. During the 2006 prescribed fire, temperatures ranged from 72 to 89° F and relative humidity was 69-39% indicating moderate burning conditions. Precipitation was below normal for both 2005 and 2006, however.

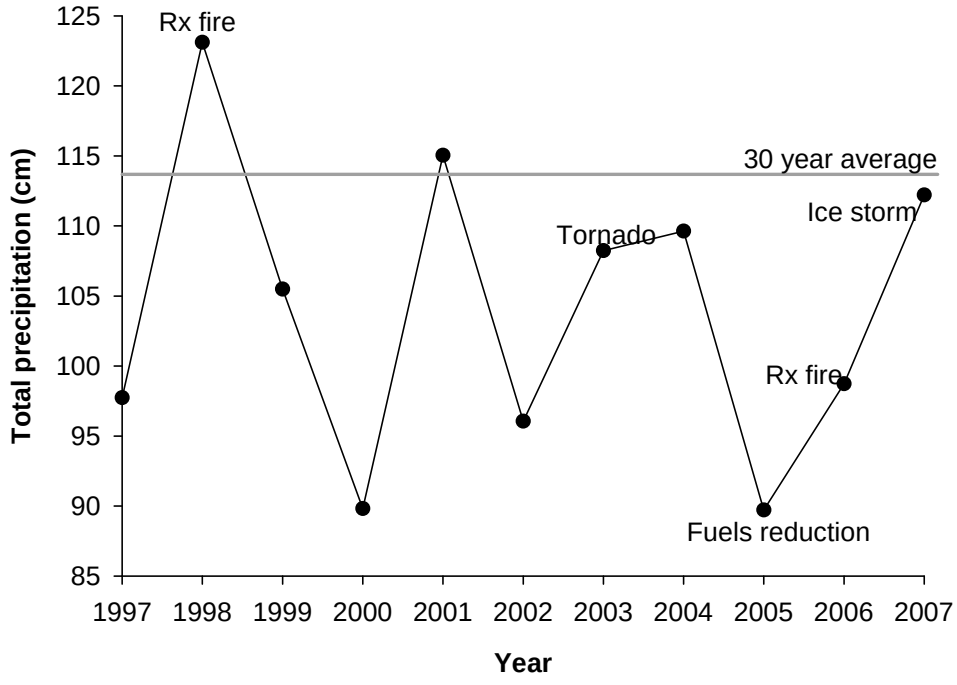


Figure 3. Total rainfall through the sampling period. Disturbance events of interest were inserted in the timeline.

Fuel load

Fuel loads contribute to fire intensity in that increased loads can lead to hotter fires. Fuel loads for Manley Woods were greatest in 2003 and loadings varied by site (Figure 4, Appendix B).

Mean fuel loading for 2003 may be inflated because of possible inclusion of blow down trees at site 4, which do not qualify as fuel. Overall, the fuels reduction program reduced mean fuels loads in the target area. Loadings at Site 4 changed significantly ($P = 0.04$, $r^2 = 0.92$), and loadings for site 5 were nearly significant ($P = 0.13$, $r^2 = 0.76$). Fuel loads at site 6 and 7, outside of the most heavily damaged area, remained fairly constant (Site 6: $P = 0.51$, Site 7: $P = 0.95$). Course fuels (1000-hr) currently remain high within the woodland.

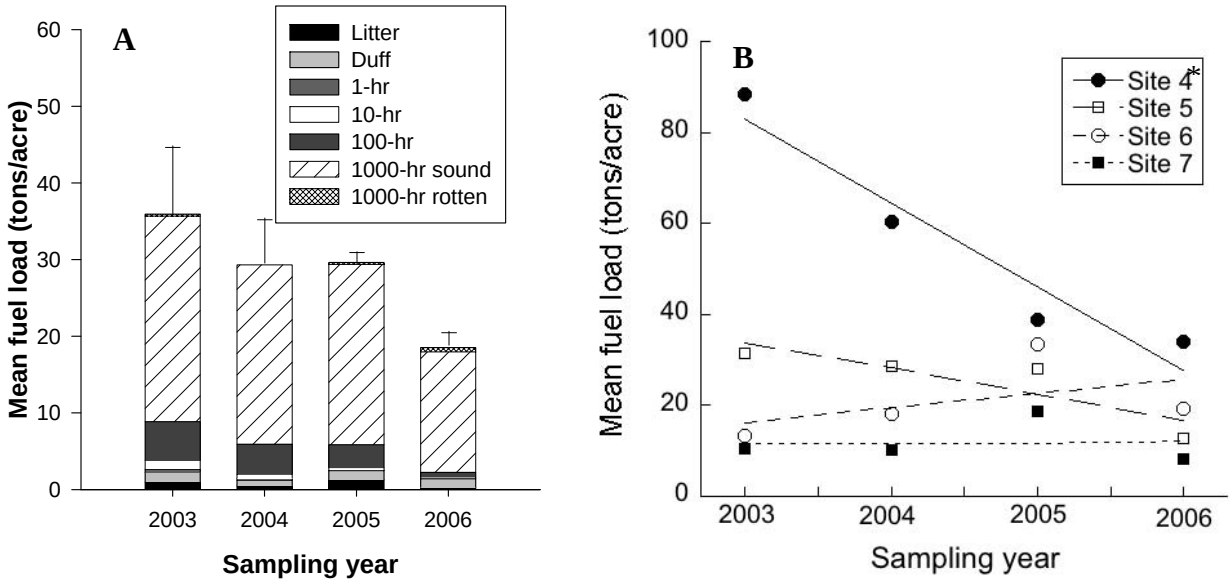


Figure 4. (A) Mean fuel loading by time lag class for Manley Woods. Error bars represent 1 standard deviation for mean total fuel load (not time lag class), (B) mean fuel loading by sampling site for Manley Woods. * indicates loadings at site 4 were significantly different through time ($P = 0.04$, $r^2 = 0.92$).

Overstory

The disturbance events that occurred at Manley Woods dramatically changed the overstory of sites 4 and 5 in particular. Basal area, another measure of woodland structure, revealed effects of the disturbances. Basal area was reduced by 4.31 m^2/ha from 1997 to 2006. Each sample site was affected to differing degrees, for example site 4 lost 2.15 m^2/ha, but basal area at site 7 increased, slightly, 0.19 m^2/ha, (Figure 5). Trees in size class 4 and 5 ($\geq$ 35cm dbh) were eliminated at these two sites following the tornado (Figure 5). At site 4, the subsequent fuels reduction and fire resulted in a loss of all size classes except class 1. At site 5, trees in size class 2 appeared to be released making up a greater portion of the total basal area in 2003 than prior to the tornado. Relative basal area at sites 6 and 7 was not affected by the series of disturbances. At site 6, some trees in size class 4 appeared to have been recruited into class 5 by 2003.

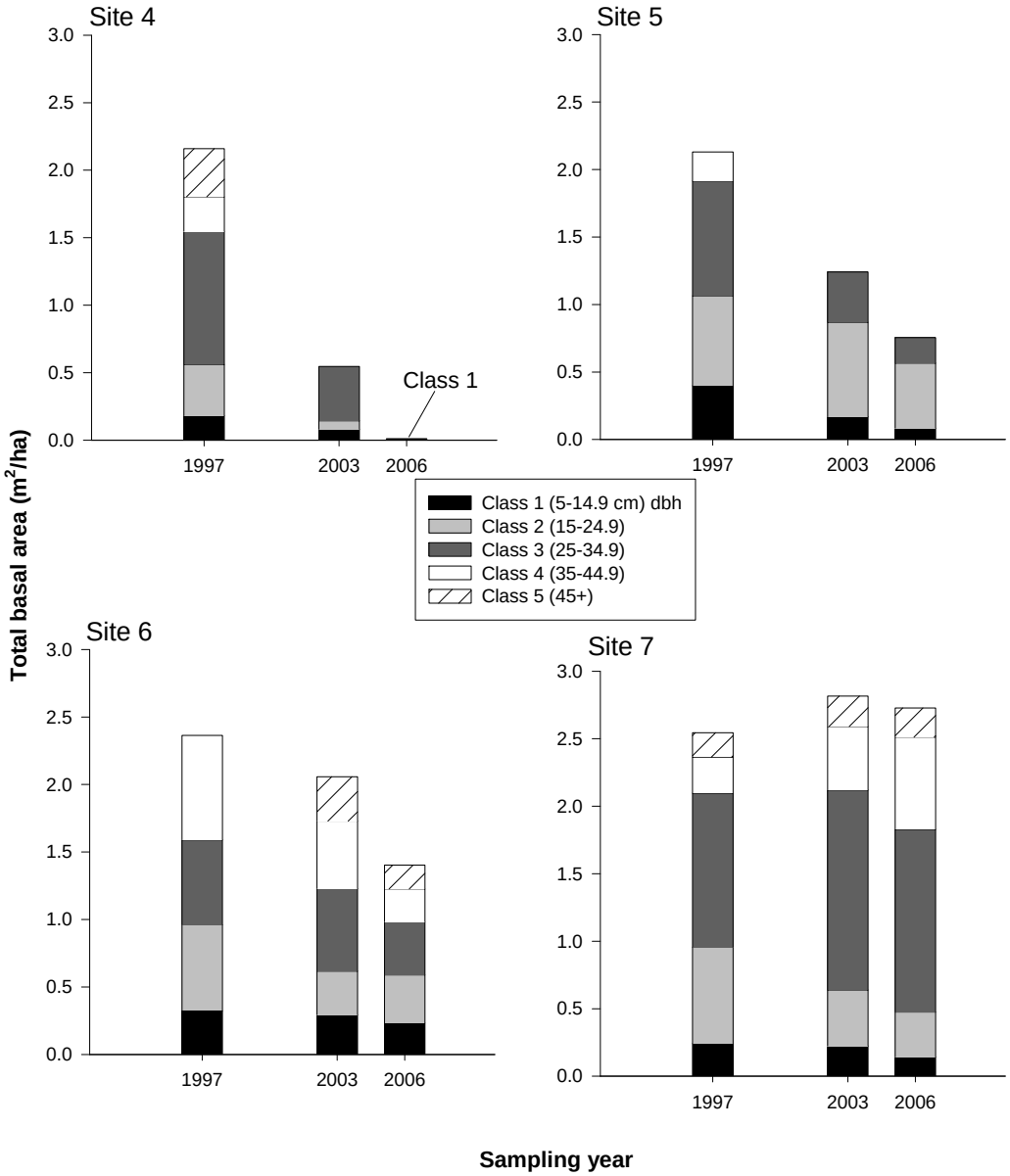


Figure 5. Total basal area (m^2/ha) of trees in each size class throughout monitoring history at Manley Woods, (diameter at breast height = dbh).

Table 2. Overstory canopy closure (± standard deviation) for Manley Woods long-term monitoring sites, post-disturbance.

Site	2003 mean canopy (%)	2006 mean canopy (%)
4	8.25 ± 6.4	8.55 ± 8.6
5	34.23 ± 15.2	34.38 ± 19.5
6	54.25 ± 19.9	33.85 ± 11.6
7	81.53 ± 4.2	77.80 ± 6.4
Manley Woods	44.6 ± 31.0	38.6 ± 28.8

Canopy closure, in part, characterizes woodland structure. Pre-disturbance overstory canopy cover was not available, but pre-disturbance management efforts were designed around opening the canopy to target a savannah structure (< 30% canopy closure; Nelson 2005).The initial structure of Manley Woods was closed canopy woodland (Table 2). Sites 4 and 5 did not experience notable change in canopy closure (+0.3, +0.2%, respectively), but 6 and 7 became more open by 2006 (-20.4, -3.73%, respectively). The large standard deviation for canopy cover indicates a heterogeneous canopy structure across Manley Woods.

Species composition of the overstory changed in that all species of oak except white oak (*Quercus alba*) and chinquapin oak (*Q. muhlenbergia*) decreased in total basal area (Figure 6A). White oak was most abundant in site 7, which was also the least affected by the disturbances. Likewise, the majority of the basal area of chinquapin oak was found in the more undisturbed areas. With the exception of site 6, oaks were not recruited from regeneration to the smaller tree size classes (Figure 7). Despite the overall loss of overstory basal area, the change in proportion of oaks in Manley Woods varied by site. We had expected to see an increase in earlier seral tree species but that was not apparent (Figure 6B).

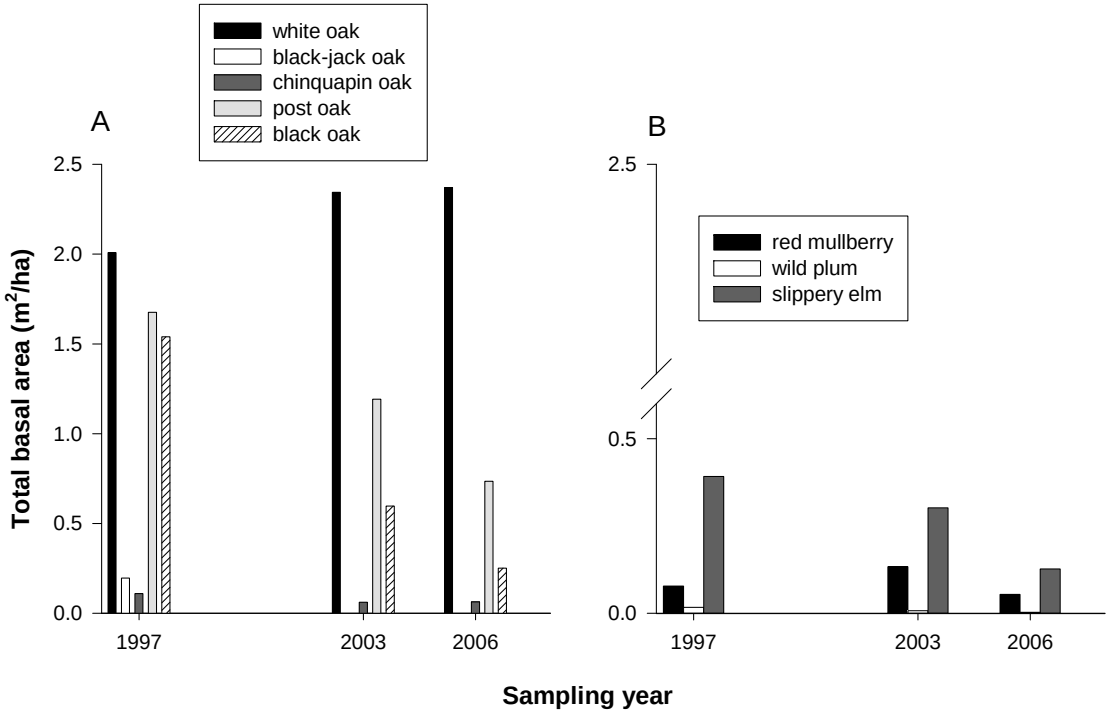


Figure 6. Density of select tree species as measured by total basal area A) oak species and B) early seral tree species from long-term monitoring sites at Manley Woods pre- (1997) and post-disturbance (2003, 2006). Scientific names for species are in Appendix C.

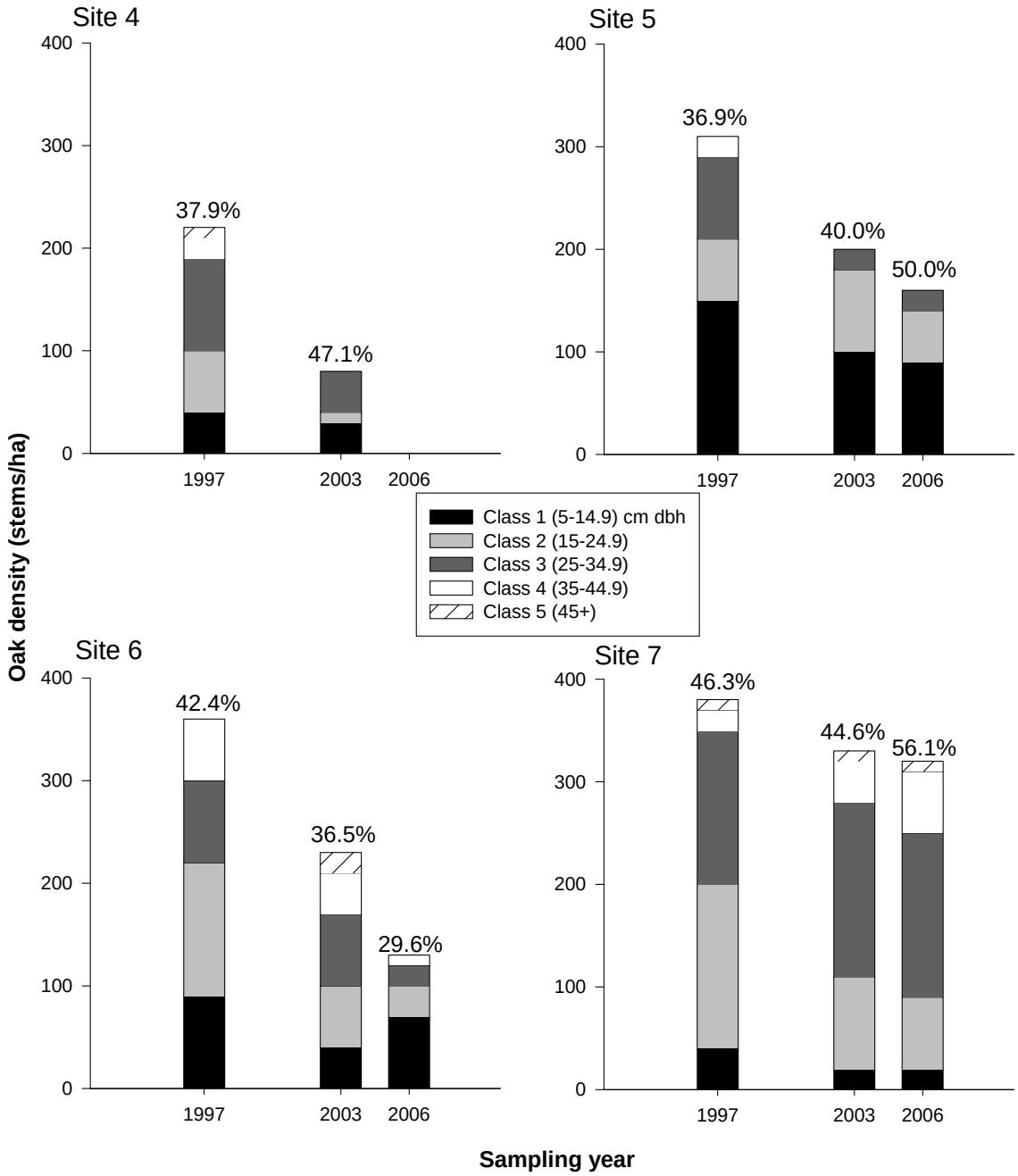


Figure 7. Density of oak stems (total stems/ha) in each size class through time. Percent of all tree stems that were oak is given at the top of each stacked bar.

Regeneration

Tree regeneration, seedlings and saplings, provide insight into a woodland's potential future composition. Oak regeneration was 22 ± 4% of the total regeneration throughout the sampling period, and seedlings comprised ≥ 82% of total regeneration each year, indicating a disparity of saplings (Figure 8). The spike in total regeneration in 1999 (1-year post-fire) was driven, in large part, by increased number of seedlings (47% increase) from recruits of elm (*Ulmus* spp.),

hackberry (*Celtis* spp.), and Eastern red cedar (*Juniperus virginiana*; Figure 8). Three of the four sites saw immediate declines in regeneration following the tornado. *Carya* and *Quercus* species are of particular interest to park managers and demonstrated significant declines over time (χ^2 = 13.81, P = 0.03 and χ^2 = 15.89, 0.01, respectively). When sites were looked at individually, all sites except 5 demonstrated a significant decline in these two genera (Figure 9).

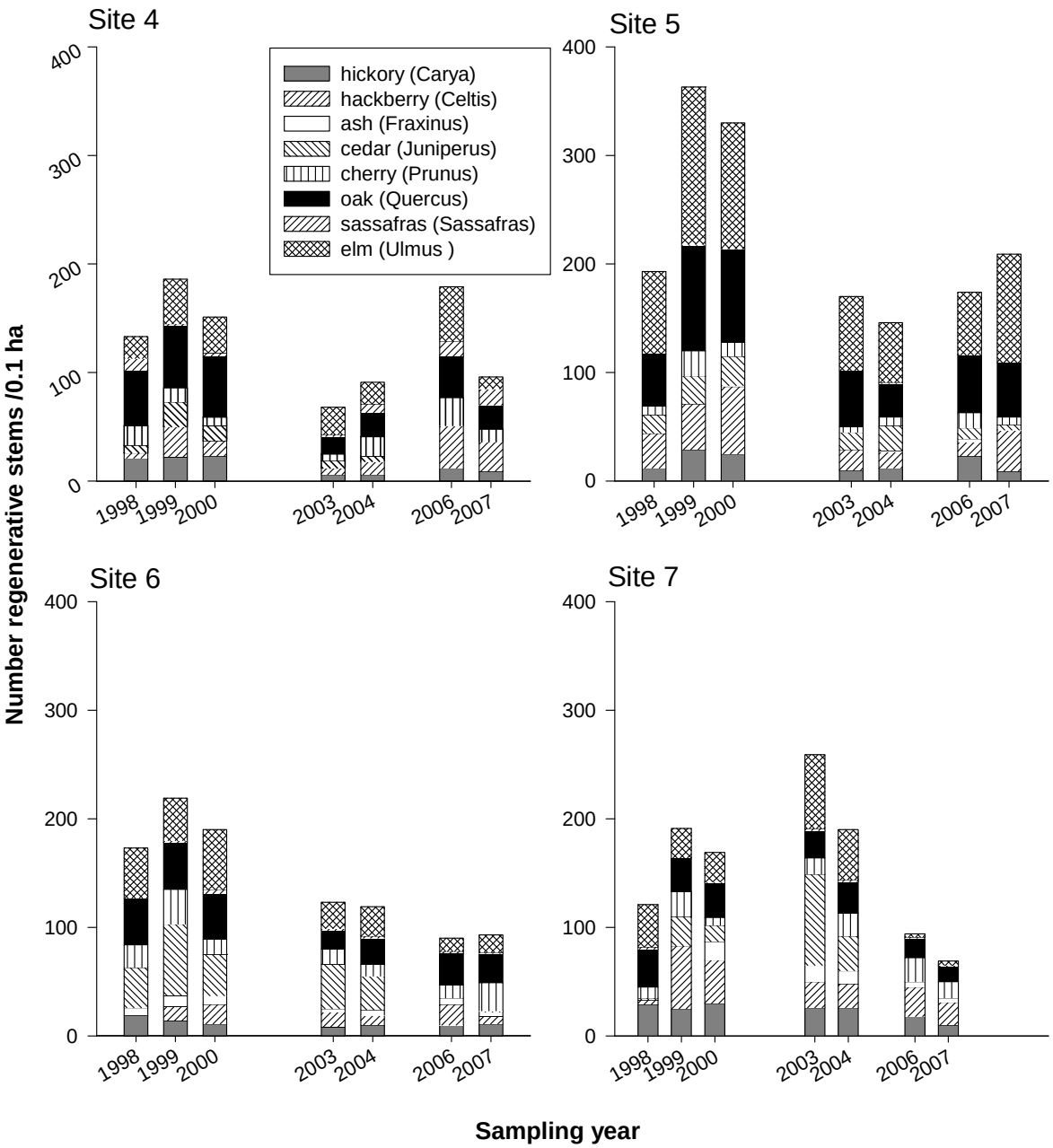


Figure 8. Tree regeneration, including seedlings and all saplings, (total stems/0.1 ha) for each sampling site by species at Manley Woods.

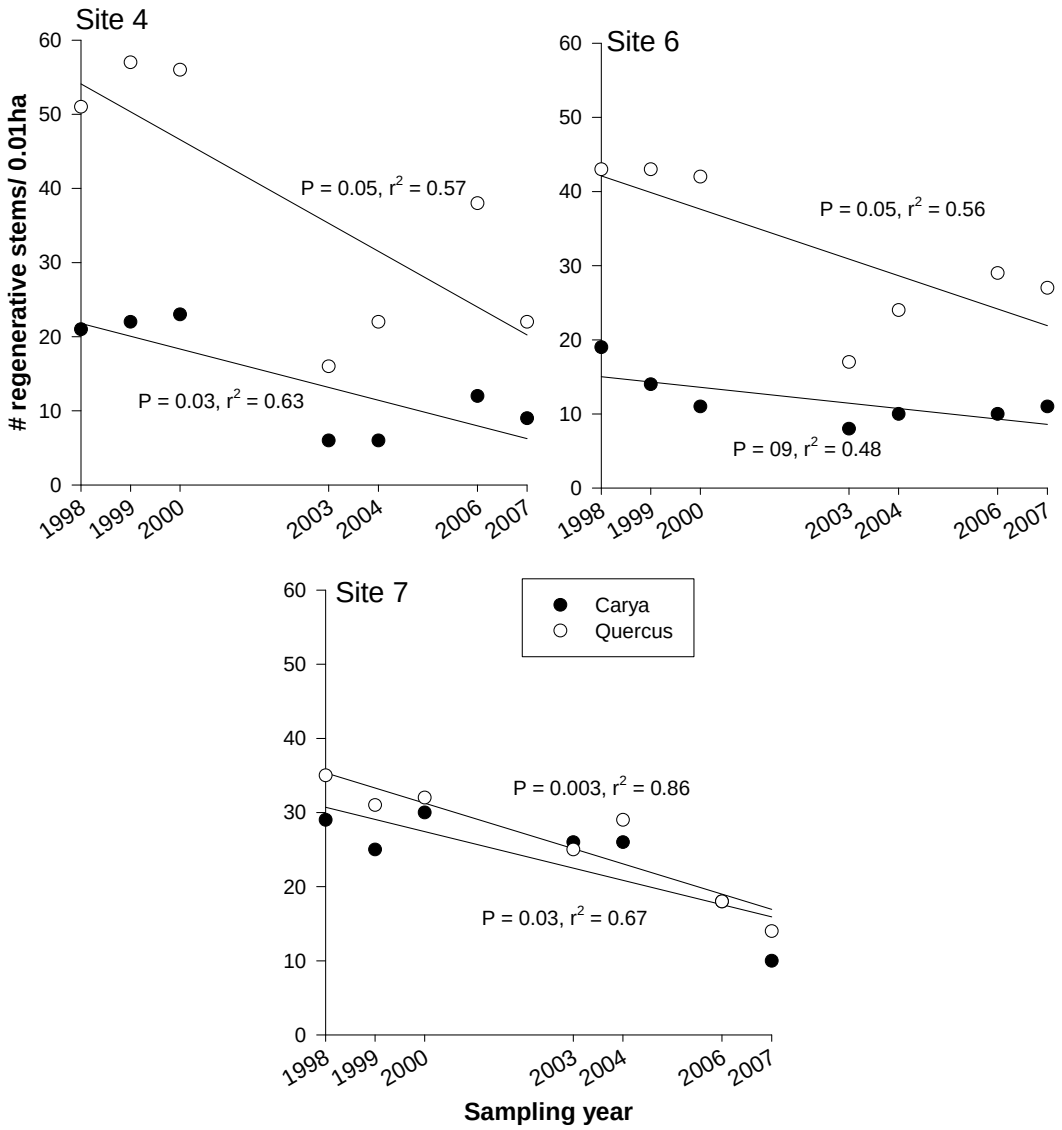


Figure 9. Comparision of *Carya* and *Quercus* regenerative stems through time.

Herbaceous Layer

The series of disturbances that occurred in Manley Woods altered a variety of aspects of the plant community through time. The understory vegetation structure (Figure 10) responded to disturbance but recovered to near pre-disturbance levels in 2007. Although fire increased bare ground after the fire in 1998, the total cover of bare ground was much greater and more variable after fuels reduction efforts (logging and subsequent fire). Dead wood, consistent with fuels observations, increased after the tornado. Leaf litter was steadily increasing until the prescribed fire, where after it fell by more than 50%. The series of disturbances including the ice storm appear to have contributed to a highly variable distribution of leaf litter in 2007. Total unvegetated area, the amount of space unoccupied by plant stems also varied from year to year.

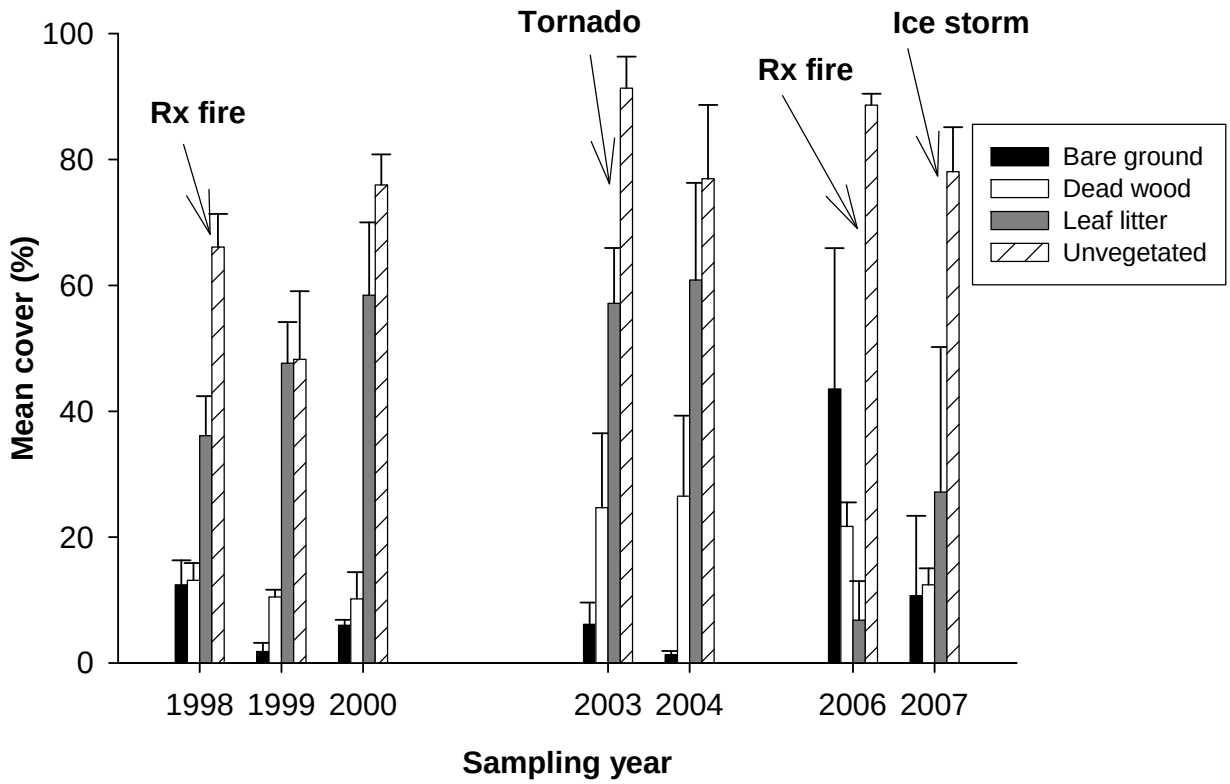


Figure 10. Distribution of ground cover, including bare ground, dead wood, leaf litter, and total unvegetated area, (means and standard deviations) before and after a series of disturbance events at Manley Woods in Wilson's Creek National Battlefield.

Diversity

Diversity of herbaceous plant species was affected by disturbance in Manley Woods. Herbaceous species diversity temporarily declined following the 2003 tornado and 2006 fire (Figure 11) however, mean diversity measures recovered. The difference between diversity scores from 2003-2006, with the exception of evenness, differed significantly from the remaining years (De: U = 0.00, P= 0.06, He: U = 0.00, P = 0.06, S: U = 0.00, P = 0.06, and E: U = 3.00, P = 0.40). All species occurred in similar abundances because the number of species for all indices were tightly grouped.

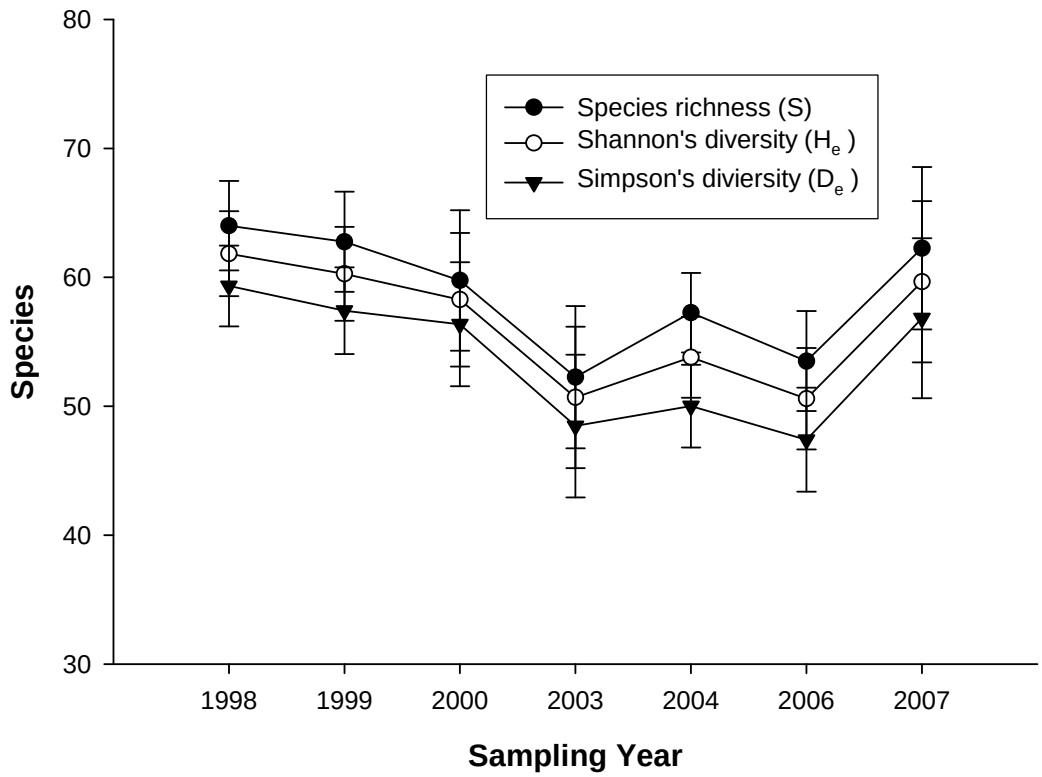


Figure 11. Mean diversity measures with standard error bars for the understory community in Manley Woods long-term monitoring plots. Measures were converted to effective number of species for comparison.

Species composition

Despite the relative stability of understory diversity, species composition expressed more long-term change. Proximity of site or species scores to each other relates to similarity in composition such that similar scores are nearer to each other. Species scores in relative proximity to site scores indicate the influence of that species on the overall site composition. The PCA Axis 1 represented a disturbance intensity gradient with more intense disturbance to the right of the axis, and Axis 2 represented a moisture gradient influenced by aspect. Site 7, the southernmost site also had a northerly aspect, whereas the other sites had more W, SW aspects (Figure 1).

Site scores (a composite measure of species composition at a given sample site) were arranged in the biplot so that communities prior to the 2004 sampling are on the left of the biplot and post disturbance communities, 2004 and later, are to the right of the biplot (Figure 12). Movement of the site scores from left to right through time demonstrates that species composition of the sites changed. The shift appeared to lag one year behind the tornado such that 2004 scores were ordinated to the right of center in the biplot, and the shift continued to the right as a result of cumulative disturbance events. Interestingly, scores for 2007 reversed direction and moved back towards the left of the plot. This movement may signal that community recovery has begun. The greatest amount of community change (distance between sites scores across years) coincided with the greatest impact of cumulative disturbance, e.g., site 4.

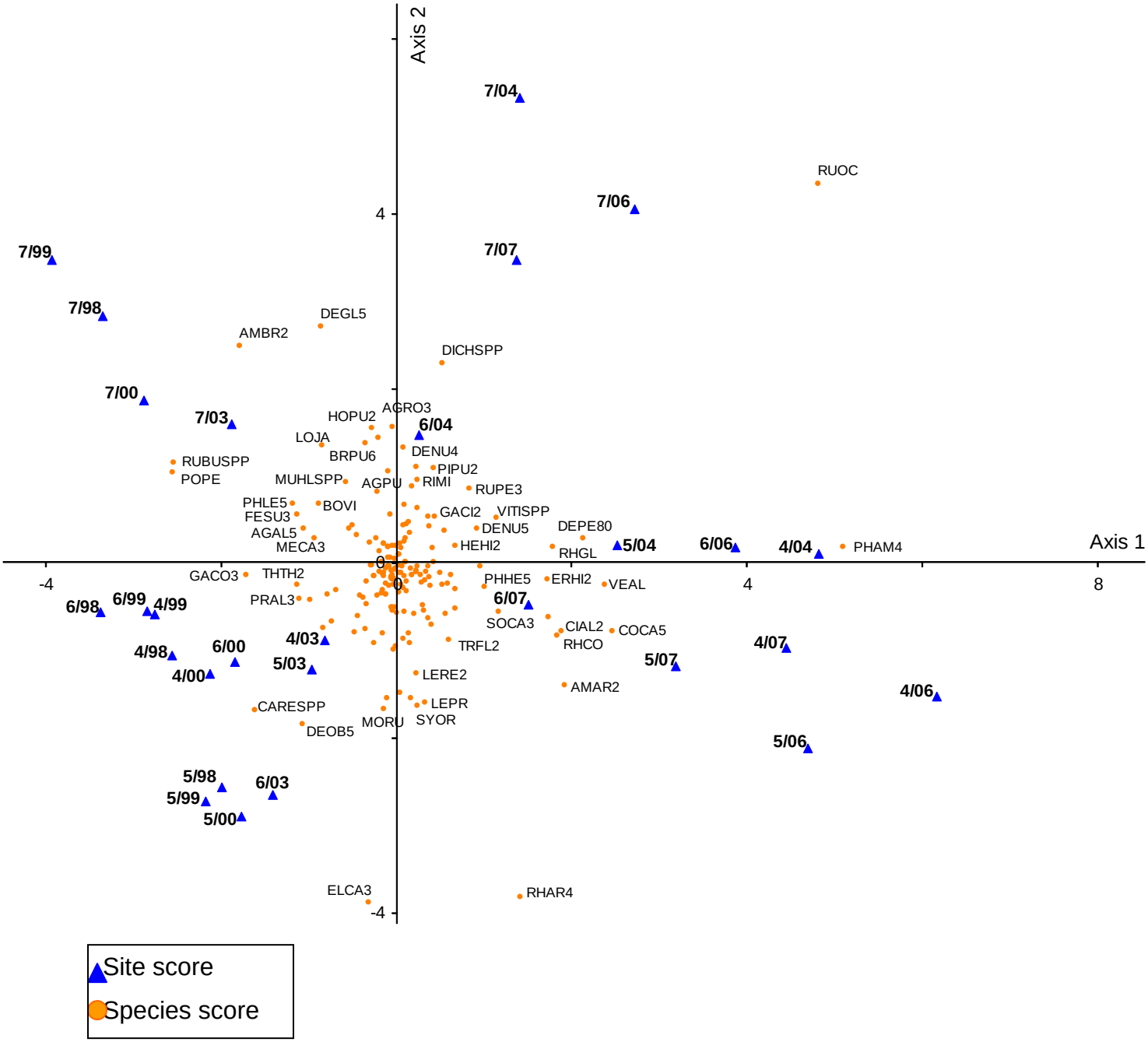


Figure 12. Principle components analysis biplot of sites through time and species where a portion of species are labeled. Site scores are labeled as site#/year and species scores are labeled with ITIS codes (for explanation of species codes, see Appendix C). Axis 1 represents a disturbance gradient, such that more heavily disturbed sites in a given year are located to the right of the biplot. Axis 2 represents a difference in aspect from South to North.

Annual ragweed (*Ambrosia artemisiifolia*), horseweed (*Coyza Canadensis*), perplexed ticktrefoil (*Desmodium perplexum*), polkweed (*Phytolacca Americana*), black raspberry (*Rubus*

occidentalis), squaw bush (*Rhus aromatica*), and wingstem (*Verbesina alternifolia*) had greater importance to sites after 2003. More ephemeral species and ferns were associated with sites prior to the tornado event, especially site 7. A list of species including species codes is in Appendix C. The ordination explained most of the variation in the community data (79.4 %) indicating the strength of the analysis. Correlations for axis 1 and 2 were r^2 = 0.60, 0.69, respectively.

Guilds

Guild abundance showed the most change at sites 4 and 5 (Figure 13). Although legumes declined after burns in 1998 and 2006, they spiked after the tornado. Interestingly, legumes followed a similar pulse pattern after the 1998 fire and 2003 tornado. Annual/biennial plants increased most at sites 4 and 5 over pre-tornado conditions. Woody understory plants and summer/fall forbs at sites 4 and 5 spiked after the tornado but soon recovered to pre-disturbance levels.

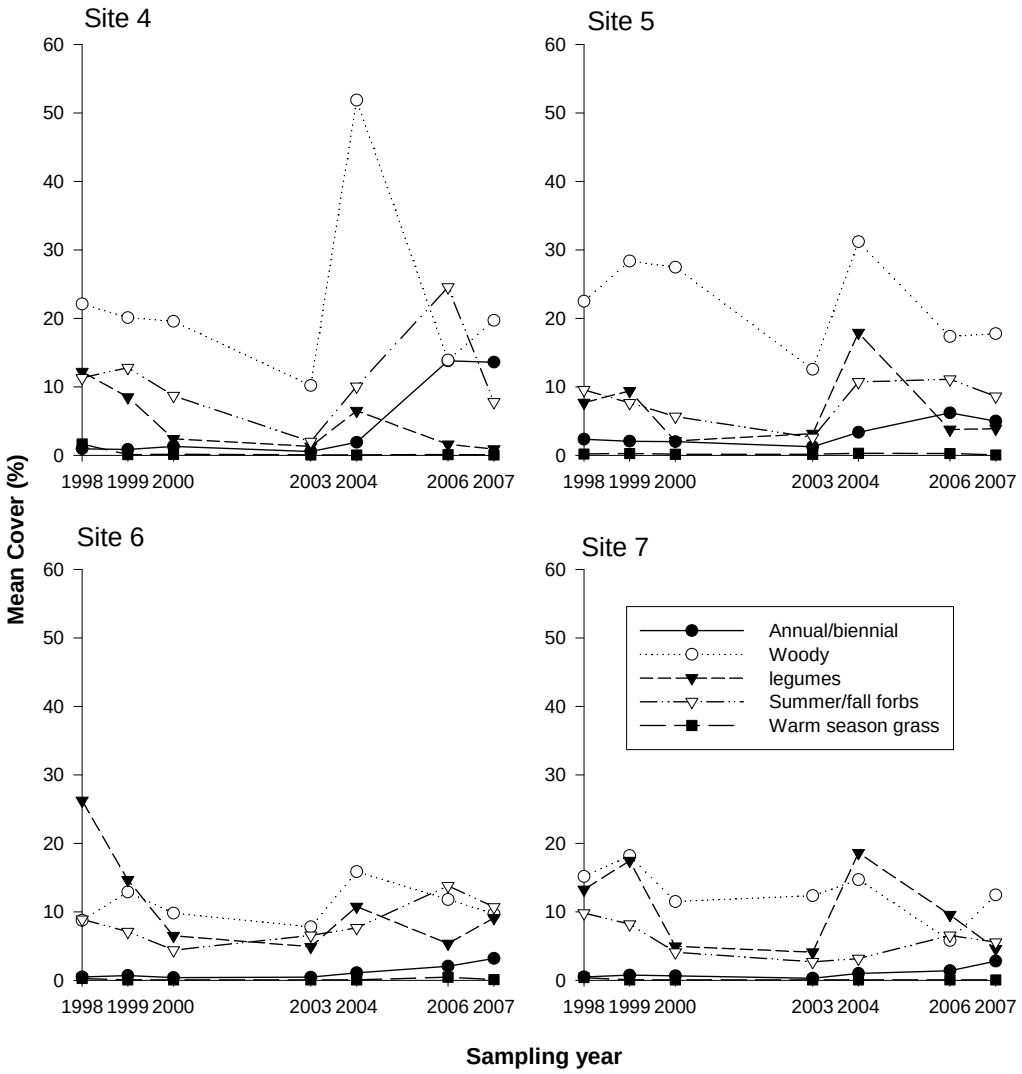


Figure 13. Mean percent cover of selected guilds within each sampling site at Manley Woods.

Exotic species

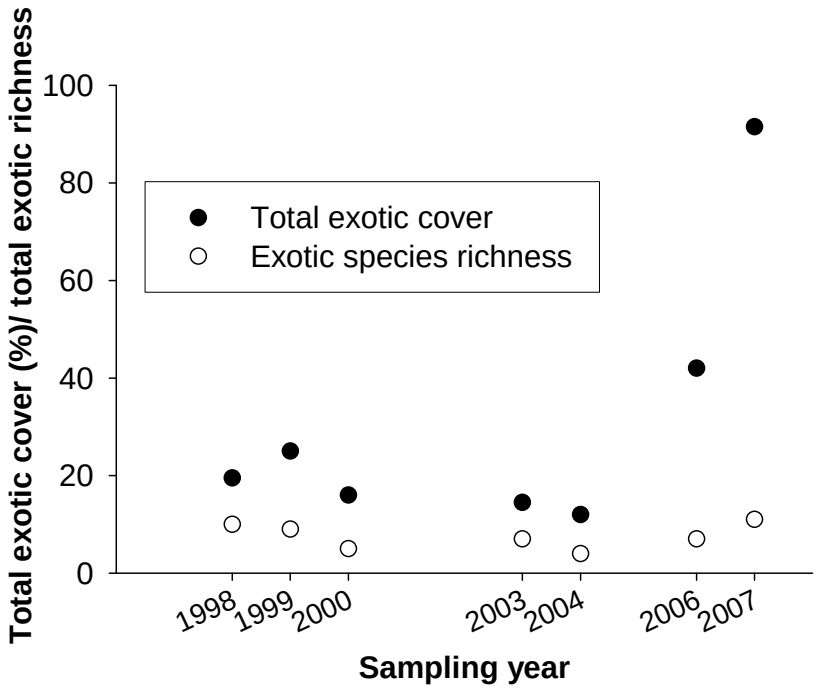


Figure 14. Trends in exotic species across sample sites at Manley Woods. Exotic species did not appear to change significantly through time, (P > 0.1).

Exotic species in the understory are an important concern for managers especially in the wake of multiple severe disturbance events. Mean relative cover of exotics increased following the multiple disturbance events (most notably at site 4) but remained relatively small, overall (Figure 14). Although exotic species increased in 2007, total cover and richness did not change significantly over the sampling period (cover: P = 0.12, r^2 = 0.30, F = 3.58; richness: P = 0.95, F = 0.01, r^2 = 0.20). Most occurrences of exotic species were < 1% in a given year at a single plot (Table 3). *Cirsium vulgare* (Bull thistle) and *Verbascum thapsus* (common mullein) showed a marked increase in 2007, especially at site 4.

Table 3. Most recent (2007) estimates of exotic species cover at sample sites for Manley Woods. Species occurrences of >1% are bolded. Missing standard deviations (stdev) indicate insufficient numbers of occurrences.

Scientific Name	Common Name	Site	Mean cover (%)	Stdev
Carduus nutans	Musk-thistle	4	0.50	0.00
Carduus nutans	Musk-thistle	5	0.50	
Cirsium vulgare	**Bull thistle**	**4**	**6.17**	**7.75**
Cirsium vulgare	**Bull thistle**	**6**	**3.00**	
Dianthus armeria	Deptford pink	5	0.50	0.00
Lactuca serriola	Prickly lettuce	4	0.50	0.00

Table 3 cont'd.

Scientific Name	Common Name	Site	Mean cover (%)	Stdev
Lactuca serriola	Prickly lettuce	6	0.50	0.00
Poa pratensis	Kentucky bluegrass	5	0.50	
Stellaria media	Common chickweed	5	0.50	0.00
Taraxacum officinale	Common dandelion	5	0.50	0.00
Torilis japonica	Japanese hedge-parsley	4	0.50	0.00
Torilis japonica	Japanese hedge-parsley	5	0.75	0.79
Torilis japonica	Japanese hedge-parsley	6	0.50	0.00
Trifolium campestre	Pinnate hop-clover	5	0.50	0.00
Verbascum thapsus	**Common mullein**	**4**	**4.06**	**4.19**
Verbascum thapsus	Common mullein	5	0.92	1.02
Veronica arvensis	Corn speedwell	5	0.50	0.00

Discussion

Management plans for the Manley Woods unit of Wilson's Creek National Battlefield prior to 2003 included regular prescribed fires with an objective of restoring an oak dominated savannah. The area had become a closed canopy woodland as a result of fire suppression, but historical records suggest that the area was more open at the time of the battle (Gremaud 1986; National Park Service 2004).

Fuels reduction efforts were successful at site 4 which received the greatest impact from the tornado and to a lesser extent fuel loads at site 5 were notably affected. A fuels study found 1000-hr and total fuel loads in the Springfield Plain to average 2.9 (±6.2 stdev, range 0-36.9) tons/acre and 4.4 (±6.4 stdev, range 0.1-36.8) tons/acre, respectively (Stambaugh et al. 2007). Comparatively, fuel loads in Manley Woods remain elevated primarily because of the 1000-hr component. Little of the 1000-hr fuels were consumed across Manley woods similar to the Kolacks et al. (2004) study that demonstrated little consumption of 1000-hr fuels. Furthermore, thinning operations have been found to increase fuel loads beyond the capacity of fire to control it as a burn only treatment would (Kolacks et al. 2004). Two years of below normal precipitation prior to the 2006 prescribed fire in Manley Woods could have further increased plant mortality, especially for the sites with S/SW aspects (Stambaugh et al. 2007).

Plant community successional pathways can be altered as a result of environmental stress (Pickett et al. 1987). Studies of windstorms in Missouri and elsewhere have described changes in the species composition of trees and/or the understory herbaceous community (Peterson and Pickett 1995; Liu et al. 1997; Peterson and Rebertus 1997; Held et. al. 1998; Harrington et al. 1995). The responses of the plant community at Manley Woods differ from these studies in that a series of disturbance events delayed successional recovery. The tornado itself had an affect on the overstory structure but the understory community dynamics were more clearly affected by the combination of disturbance events. For example, the canopy was opened in parts of the woods providing more light to the ground and the subsequent fire increased bare ground allowing opportunistic plants to establish (Collins et al. 1985). Although the fire was most likely a cool fire, two years of below normal precipitation could have made plants more susceptible at lower fire intensities. Diversity measures demonstrated a decline during 2003-2006, but began to recover thereafter. Furthermore, understory composition shifted toward early seral species

especially at sites 4 and 5, but in 2007 communities seemed to be recovering towards pre-disturbance compositions. Similarly, McMurry et al. (2007) found that species composition of Ozark woodlands was more affected by a combination of disturbances (thinning and burning) than a single disturbance (thinning). Peterson and Pickett (1995) also observed a short-lived response in shade intolerant herbs and shrubs in that they declined by year-five after a windstorm.

Tree regeneration density was generally reduced by the disturbance events in Manley Woods similar to the burning and thinning study done by McMurry et al. (2007). However, Peterson and Pickett (1995) saw increases in seedling density one year after a windthrow, but decreasing densities thereafter. This pattern was seen at site 7, the site least impacted by disturbance. Perhaps, if only a single disturbance had been recorded at Manley Woods during this time, the overall response would have more closely resembled that found by Peterson and Pickett (1995). Likewise, another study of oak regeneration recorded either positive or neutral effects of fire on regeneration rather than the negative effects seen in Manley Woods (Brose et al. 2006). A large 1000-hr fuel component in the fuel bed of Manley Woods coupled with a cool fire may not have adequately prepared the seedbed for a spike of oak germination to take place. Additionally, nutrient dynamics resulting from a series of disturbances may differ from those recorded after a single fire or windthrow event (Harrington et al. 2001, 1995; Boerner 2006).

The series of disturbance events created a more heterogeneous community in Manley Woods, especially with respect to the overstory, fuel loads, and ground cover structure. Previous management goals emphasized creating a savannah physiognomy (Gale et al. 2004; National Park Service 2004) and based on mean canopy closure Manley Woods is very close to achieving that goal (savannah <30% tree cover; Nelson 2005). However, woodland plants rather than grassland plants dominated the herbaceous community. Although the herbaceous community experienced change, few notable invasive species were observed.

Literature Cited

Boerner, R. E. J. 2006. Soil, fire, water, and wind: how the elements conspire in the forest context. Pages 104-122 *in* M.B. Dickinson editor. Fire in eastern oak forests: delivering science to land managers, proceedings of a conference, 2005 November 15-17. Columbus, OH. Gen. Tech. Rep. NRS-P-1. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.

Brose, P. H., T. M. Schuler, and J. S. Ward. 2006. Responses of oak and other hardwood regeneration to prescribed fire: what we know as of 2005. Pages 123-135 *in*: M.B. Dickinson editor. Fire in eastern oak forests: delivering science to land managers, proceedings of a conference, 2005 November 15-17. Columbus, OH. Gen. Tech. Rep. NRS-P-1. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.

Brown, J. K. 1974. Handbook for inventorying downed woody material. USDA Forest Service General Technical Report INT-16.

Canham, C. D., and O. L. Loucks. 1984. Catastrophic Windthrow in the Presettlement Forests of Wisconsin. Ecology **65**:803-809.

Collins, B. S, K. P. Dunne, and S. T. A. Pickett. 1985. Responses of forest herbs to canopy gaps. Pages 218-234 *in* S. T. A. Pickett and P. S. White editors. The ecology of natural disturbances and patch dynamics. Academic Press, Inc, Orlando.

Cutter, B. E. and Guyette, R. P. 1994. Fire history of an oak-hickory ridge top in the Missouri Ozarks. American Midlands Naturalist **132**:393-398.

DeBacker, M.D., A.N. Sasseen, C. Becker, G.A. Rowell, L.P. Thomas, J.R. Boetsch, and G.D. Willson. 2004. Vegetation Community Monitoring Protocol for the Heartland I&M Network and Prairie Cluster Prototype Monitoring Program. National Park Service, Republic, MO.

Dey, D. C., Guyette, R. P. and M. C. Stambaugh. 2004. Fire history of a forest, savanna, and fen mosaic at White Ranch State Forest. Pages 132-137 *in* M. Spetich editor. Proceedings of the Upland Oak Ecology Symposium. Gen. Tech. Rep. SRS-73. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.

Foster, D. R., D. H. Knight, and J. F. Franklin. 1998. Landscape patterns and legacies resulting from large, infrequent forest disturbances. Ecosystems **1**:497-510.

Gale, C. Shaw, R., and Sullivan, G. P. 2004. Fire management plan for Wilson's Creek National Battlefield. United States Department of the Interior, National Park Service. Wilson's Creek National Battlefield, Republic, Missouri.

Gremaud, G. G. 1986. Wilson's Creek National Battlefield: a plan for the restoration of the historic vegetation. Missouri Department of Conservation report, December 1986.

Guyette, R. P., D. C. Dey, M. C. Stambaugh, and R. M. Muzika. 2006. Fire scars reveal variability and dynamics of Eastern fire regimes. Pages 20-39 *in* Dickinson, M. B. editor. Fire in Eastern Oak Forests: Delivering science to land managers. Department of Agriculture, Forest Service, Northern Research Station, Newtown Square, PA: U.S.

Guyette, R. P., R. M. Muzika, and D. C. Dey. 2002. Dynamics of an anthropogenic fire regime. Ecosystems **5**:472-486.

Harrington, T. B., and A. A. Bluhm. 2001. Tree regeneration responses to microsite characteristics following a severe tornado in the Georgia Piedmont, USA. Forest ecology and management **140**:265-275.

Harrington, T. B. Bluhm, A. A. and K. D. Howell. 1995. Tree regeneration in the Georgia piedmont following a tornado disturbance. Pages 144-146 *in* M. B. Edwards (compiled). Proceedings of the Eighth biennial southern silvicultural research conference, Auburn, AL, November 1-3, 1994. Gen. Tech. Rep. SRS-1. USDA forest Service Southern Research Station.

Held, M. E., S. Jones-Held, and J. E. Winstead. 1998. Forest community structure and tornado damage in an old-growth system in Northern Kentucky. Castanea **63**:474-481.

Joust. L. 2006. Entropy and diversity. Oikos **113**:2.

Kindscher, K. 1992. Rockefeller prairie: a case study on the use of plant guild classification of a tallgrass prairie. Pages 123-140 *in* R. G. Wickett, P. Dolan Lewis, A. Woodiffe, and P. Pratt editors. North American Prairie Conference. Department of Parks and Recreation, Windsor, Ontario, Canada.

Kolacks, J. J., B. E. Cutter, E. F. Loewenstein, K. W. Grabner, G. W. Harman, and J. M. Kabrick. 2004. The effect of thinning and prescribed fire on fuel loading in the central hardwood region of Missouri. Pages 168-178 *in* D. A. Yaussy, D. M. Hix, R. P. Long, and P. C. Goebel editors. Proceedings. 14th Central Hardwood Forest Conference 2004 March 16-19; Wooster, OH. Gen. Tech. Rep. NE-316. Newtown Square, PA: U.S. Department of Agriculture. Forest Service. Northeastern Research Station.

Liu, C., J. S. Glitzenstein, P. A. Harcombe, and R. G. Knox. 1997. Tornado and fire effects on tree species composition in a savanna in the Big Thicket National Preserve, southeast Texas, USA. Forest ecology and management **91**:279-289.

McCune, B. and M. J. Mefford. 1999. PC-ORD. Multivariate Analysis of Ecological Data. Version 5.0 MjM Software, Gleneden Beach, Oregon, U.S.A.

McCune, B. and J. B. Grace. 2002. Analysis of ecological communities. MjM Software design, Gleneden Beach, Oregon.

McMurry, E. R., R. M. Muzika, E. F. Loewenstein, K. W. Grabner, G. W. Hartman. 2007. Initial effects of prescribed burning and thinning on plant communities in the southeast Missouri Ozarks. Pages 241-249 *in* D. S. Buckley, W. K. Clatterbuck Editors. Proceedings, 15th central hardwood forest conference. e-Gen. Tech. Rep. SRS–101. U.S. Department of Agriculture, Forest Service, Southern Research Station.

National Park Service. 2004. Wilson's Creek National Battlefield, Cultural Landscape Report. Vol. 1. Republic, Missouri.

Nelson P. W. 2005. The terrestrial natural communities of Missouri. Missouri Natural Areas Committee.

NOAA. 2008. Online at http://lwf.ncdc.noaa.gov/oa/climate/online/ccd/nrmlprcp.html Accessed Thursday, 03-Apr-2008 14:57:26 EDT.

Peterson, C. J., and S. T. A. Pickett. 1995. Forest reorganization: a case study in an old-growth forest catastrophic blowdown. Ecology **76**:763-774.

Peterson, C. J., and A. J. Rebertus. 1997. Tornado damage and initial recovery in three adjacent, lowland temperate forests in Missouri. Journal of Vegetation Science **8**:559-564.

Pickett, S. T. A., S. L. Collins, and J. J. Armesto. 1987. Models, mechanisms, and pathways of succession. The Botanical Review **53**:335-371.

Pielou, E.C. 1974. Population and community ecology. Gordon and Breach, New York.

Runkle, J. R. 1982. Patterns of disturbance in some old-growth mesic forests of Eastern North America. Ecology **63**:1533-1546.

SAS Institute. 2001. The SAS System for Windows. Version 8.02. Cary, NC, USA.

Schoolcraft, H. R. 1821. Journal of a tour into the interior of Missouri and Arkansaw from Potosi, or Mine a Burton, in Missouri Territory, in a South-West Direction, toward the Rocky Mountains, performed in the years 1818 and 1819. Richard Phillips and Co., London.

SPSS Inc. 2008. SPSS 16.0.2 for Windows. 233 S. Wacker Drive, 11th floor, Chicago, Illinois 60606

Stambaugh, M. C., R. P. Guyette, and D. C. Dey. 2007. Forest fuels and landscape-level fire risk assessment of the Ozark Highlands, Missouri. Pages 258-266 *in* D. S. Buckley and W. K. Clatterbuck editors. 15th central hardwood forest conference. e-Gen. Tech. Rep. SRS–101. U.S. Department of Agriculture, Forest Service, Southern Research Station.

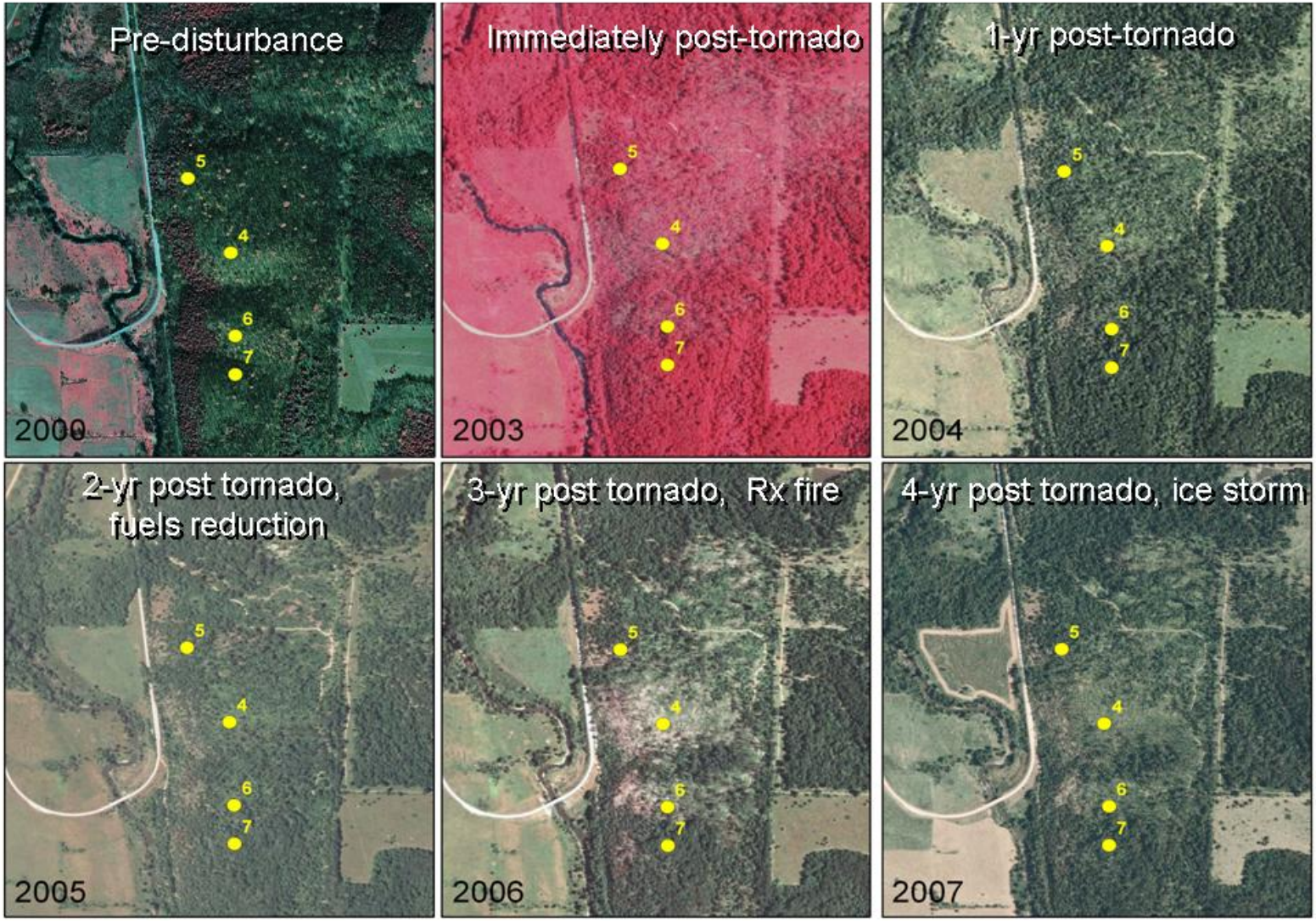
USDI National Park Service. 2003. Fire monitoring handbook. Boise (ID): Fire management program center, National interagency fire center.

Whitmore, T. C. 1989. Canopy gaps and the two major groups of forest trees. Ecology **70**: 536-538.

Appendix A. Long-term monitoring and disturbance history for Manley Woods. The fourth table column indicates type of plants surveyed (overstory, regeneration, or understory) during each site visit.

Year	Site	Sampling history	Overstory (O) regeneration (R) understory (U)	Fire history (spring)	Other disturbances
1992	4				
	5			burn	
	6			burn	
	7			burn	
1993	4				
	5			burn	
	6			burn	
	7			burn	
1994 no activity					
1995	4			burn	
	5			burn	
	6			burn	
	7			burn	
1996 no activity					
1997	4	X	U R		
	5				
	6	X	U R		
	7	X	U R		
1998	4	X	U R O	burn	
	5	X	U R O	burn	
	6	X	U R O	burn	
	7	X	U R O	burn	
1999	4	X	U R		
	5	X	U R		
	6	X	U R		
	7	X	U R		
2000	4	X	U RO		
	5	X	U RO		
	6	X	U RO		
	7	X	U RO		
2001 no activity					
2002 no activity					
2003	4	X	U O		tornado (May)
	5	X	U O		tornado (May)
	6	X	U RO		
	7	X	U RO		
2004	4	X	U R		
	5	X	U R		
	6	X	U R		
	7	X	U R		
2005	4				fuels reduction (March-October)
	5				fuels reduction (March-October)
	6				
	7				
2006	4	X	U R O	burn	
	5	X	U R O	burn	
	6	X	U R O	burn	
	7	X	U R O		
2007	4	X	U R		ice storm (Jan.)
	5	X	U R		ice storm (Jan.)
	6	X	U R		ice storm (Jan.)
	7	X	U R		ice storm (Jan.)

Appendix A. Long-term monitoring and disturbance history for Manley Woods. The fourth table column indicates type of plants surveyed (overstory, regeneration, or understory) during each site visit (continued).



Appendix B. Fuel loadings.

Surface Fuels Summary

Macroplot	Year	1-hr	10-hr	100-hr	Fine fuel total	1000-hr sound	1000-hr rotten	Course fuel total	Duff	Litter	Total fuel load	Duff	Litter	Total
		Average Tons per Acre										Avg. Depth (in.)		
WICR4	2003	0.481	2.430	14.776	17.687	67.013	0.982	85.682	1.634	1.164	88.480	0.15	0.71	0.86
WICR4	2004	0.462	1.279	11.284	13.025	45.777	0.000	58.802	1.035	0.588	60.425	0.10	0.36	0.46
WICR4	2005	0.080	0.213	4.145	4.438	32.215	0.000	36.653	1.525	0.555	38.733	0.14	0.34	0.48
WICR4	2006	0.030	0.032	0.000	0.062	33.172	0.000	33.233	0.708	0.100	34.041	0.07	0.06	0.13
WICR5	2003	0.302	0.706	1.960	2.968	27.123	0.000	30.091	0.898	0.572	31.562	0.08	0.35	0.43
WICR5	2004	0.221	0.354	1.566	2.141	24.605	0.000	26.746	1.307	0.474	28.526	0.12	0.29	0.41
WICR5	2005	0.060	0.320	1.955	2.335	22.632	0.000	24.966	2.232	0.711	27.909	0.21	0.44	0.64
WICR5	2006	0.221	0.257	1.566	2.044	6.812	2.223	11.079	1.307	0.384	12.770	0.12	0.24	0.36
WICR6	2003	0.433	1.026	2.333	3.791	7.104	0.000	10.895	1.388	1.107	13.390	0.13	0.68	0.81
WICR6	2004	0.141	0.418	1.562	2.121	15.392	0.000	17.513	0.163	0.412	18.089	0.02	0.25	0.27
WICR6	2005	0.071	0.610	4.702	5.383	23.886	0.954	30.223	0.408	2.675	33.306	0.04	1.64	1.68
WICR6	2006	0.030	0.032	0.391	0.453	17.442	0.000	17.896	0.980	0.286	19.162	0.09	0.18	0.27
WICR7	2003	0.361	0.447	1.168	1.976	6.007	0.000	7.983	1.280	1.050	10.312	0.12	0.64	0.76
WICR7	2004	0.160	0.096	1.180	1.436	7.834	0.000	9.270	0.381	0.572	10.222	0.04	0.35	0.39
WICR7	2005	0.040	0.127	1.167	1.335	15.366	0.000	16.700	0.653	1.184	18.538	0.06	0.73	0.79
WICR7	2006	0.160	0.159	0.387	0.706	5.451	0.000	6.157	1.497	0.445	8.100	0.14	0.27	0.41

Appendix C. Master species list for Manley Woods.

Species Code	Scientific Name	Common Name
ACGRM	*Acalypha gracilens var. monococca*	Ozarkian short-stalk copperleaf
ACVI	*Acalypha virginica*	Virginia copperleaf
AEGL	*Aesculus glabra*	Ohio buckeye
AGAL5	*Ageratina altissima*	Tall ageratina
AGPU	*Agrimonia pubescens*	Downy agrimony, harvest lice
AGRO3	*Agrimonia rostellata*	Woodland agrimony, harvest lice
AGRIMONI	*Agrimonia* spp	
ALCA3	*Allium canadense*	Onion
AMAR2	*Ambrosia artemisiifolia*	Common ragweed
AMTR	*Ambrosia trifida*	Giant ragweed
AMCA6	*Amorpha canescens*	Lead-plant
AMDR	*Amphiachyris dracunculoides*	Broomweed
AMBR2	*Amphicarpa bracteata*	Hog-peanut
ANGE	*Andropogon gerardii*	Big bluestem
ANVI2	*Andropogon virginicus*	Broom-sedge
ANVI3	*Anemone virginiana*	Tall anemone, thimbleweed
ANNBROME	*Annual bromus* spp	B. tectorum, B. japonicus
ANPL	*Antennaria plantaginifolia*	Plantain pussytoes
ARCA	*Arabis canadensis*	Sickle-pod
ARSE2	*Arenaria serpyllifolia*	Thyme leaf sandwort
ARSE3	*Aristolochia serpentaria*	Snakeroot
ASSY	*Asclepias syriaca*	Common milkweed
ASPL	*Asplenium platyneuron*	Ebony spleenwort
ASAN	*Aster anomalus*	Limestone heart-leaved wild aster
ASPA5	*Aster patens*	Clasping wild aster
ASTERSPP	*Aster* spp	Aster
ASTU2	*Aster turbinellus*	Prairie wild aster
BIBI7	*Bidens bipinnata*	Spanish Needles
BOCY	*Boehmeria cylindrica*	False nettle
BOVI	*Botrychium virginianum*	Rattlesnake-fern
BRPU6	*Bromus pubescens*	Brome, Brome-grass, Chess, Cheat
BRRA2	*Bromus racemosus*	Brome, Brome-grass, Chess, Cheat
CAAM18	*Campanulastrum americanum*	Tall bellflower
CACO26	*Cardamine concatenata*	Five-parted toothwort
CANU4	*Carduus nutans*	Musk-thistle
CARESPP	*Carex* spp	Sedge
CAAL27	*Carya alba*	Mockernut hickory
CACO15	*Carya cordiformis*	Bitternut hickory
CAOV2	*Carya ovata*	Shagbark hickory
CARYASPP	*Carya* spp	Hickory
CATE9	*Carya texana*	Ozark hickory
CEAM	*Ceanothus americanus*	New Jersey tea, redroot
CESC	*Celastrus scandens*	American bittersweet

Appendix C. Master species list for Manley Woods (continued).

Species Code	Scientific Name	Common Name
CEOC	*Celtis occidentalis*	Northern hackberry
CELTSPP	*Celtis* spp	
CEPU4	*Cerastium pumilum*	Mouse-ear chickweed
CECA4	*Cercis canadensis*	Redbud
CIAL2	*Cirsium altissimum*	Tall thistle
CIRSIUM	*Cirsium* spp	Thistle
CIVU	*Cirsium vulgare*	Bull thistle
CLVI3	*Claytonia virginica*	Spring-beauty
COAR4	*Convolvulus arvensis*	Field-bindweed
COCA5	*Conyza canadensis*	Horseweed
COAM3	*Corylus americana*	American hazelnut
CRATSPP	*Crateagus* spp	Hawthorn
CRGL2	*Croton glandulosus*	Tooth-leaved croton
CYPER	*Cyperus* spp	
DASP2	*Danthonia spicata*	Poverty oatgrass
DACA6	*Daucus carota*	Wild carrot, Queen Anne's lace
DECU	*Desmodium cuspidatum*	Big tick-trefoil
DEGL5	*Desmodium glutinosum*	Cluster-leaf tick-trefoil
DENU4	*Desmodium nudiflorum*	Naked tick-trefoil
DENU5	*Desmodium nuttallii*	Nuttall's Ticktrefoil
DEOB5	*Desmodium obtusum*	Tick-trefoil
DEPA6	*Desmodium paniculatum*	Tick-trefoil
DEPA7	*Desmodium pauciflorum*	Few-flowered tick-trefoil
DEPE80	*Desmodium perplexum*	Perplexed ticktrefoil
DERO3	*Desmodium rotundifolium*	Round-leaved tick-trefoil
DESMSPP	*Desmodium* spp	
DIAR	*Dianthus armeria*	Deptford pink
DICHSPP	*Dichanthelium* spp	
DIGIT2	*Digitaria spp*	Crabgrass
DIVI4	*Dioscorea villosa*	Colic-root
DIVI5	*Diospyros virginiana*	Persimmon
DIVI5	*Diospyros virginiana*	Persimmon
ELCA3	*Elephantopus carolinianus*	Leafy elephant's foot
ELVI	*Elymus villosus*	Downy wild rye
ELVI3	*Elymus virginicus*	Virginia wild rye
ERHI2	*Erechtites hieraciifolia*	Fireweed
ERIGE2	*Erigeron* spp	Fleabane
ERST3	*Erigeron strigosus*	Rough fleabane
ERAL9	*Erythronium albidum*	Trout-lily, fawn-lily
EUAT3	*Euonymus atropurpurea*	Eastern burning bush
EUCO10	*Euphorbia corollata*	Flowering spurge
FESU3	*Festuca subverticillata*	Nodding fescue
FRVI	*Fragaria virginiana*	Thick-leaved wild strawberry
FRAM2	*Fraxinus americana*	White ash

Appendix C. Master species list for Manley Woods (continued).

Species Code	Scientific Name	Common Name
GAVO	*Galactia volubilis*	Downy milkpea
GAAP2	*Galium aparine*	Cleavers
GAAR4	*Galium arkansanum*	Bedstraw, cleavers
GACI2	*Galium circaezans*	Forest bedstraw, wild licorice
GACO3	*Galium concinnum*	Bedstraw, cleavers
GAOB	*Galium obtusum*	Bluntleaf bedstraw
GAPI2	*Galium pilosum*	Beadstraw, Cleavers
GATR2	*Galium trifidum*	Northern three-lobed bedstraw
GATR3	*Galium triflorum*	Sweet-scented bedstraw
GAPU3	*Gamochaeta purpurea*	Purple cudweed
GECA5	*Geranium carolinianum*	Carolina crane's-bill
GEMA	*Geranium maculatum*	Wild geranium
GECA7	*Geum canadense*	White avens
GLTR	*Gleditsia triacanthos*	Honey-locust
GNOB	*Gnaphalium obtusifolium*	Fragrant cudweed
HAVI2	*Hackelia virginiana*	Stickseed, beggar's lice
HENIN	*Hedyotis nigricans var. nigricans*	Madder
HEHI2	*Helianthus hirsutus*	Hairy sunflower
HEAM6	*Heuchera americana*	American alumroot
HERI	*Heuchera richardsonii*	Prairie alum-root
HIGR3	*Hieracium gronovii*	Beaked hawkweed
HOPU2	*Houstonia purpurea*	Mountain houstonia
HYPERICU	*Hypericum spp*	St. Johnswort
ISBI2	*Isopyrum biternatum*	False rue anemone
JUNI	*Juglans nigra*	Black walnut
JUNCUS	*Juncus* spp	Rush
JUVI	*Juniperus virginiana*	Eastern red cedar
KRBI	*Krigia biflora*	Orange dwarf dandelion
KUST	*Kummerowia stipulacea*	Korean clover
LACA	*Lactuca canadensis*	Tall lettuce
LAFL	*Lactuca floridana*	Woodland Lettuce
LASE	*Lactuca serriola*	Prickly lettuce
LACTSPP	*Lactuca* spp	
LAPU2	*Lamium purpureum*	Red dead nettle
LEPR	*Lespedeza procumbens*	Downy trailing lespedeza
LERE2	*Lespedeza repens*	Creeping lespedeza
LEVI6	*Lespedeza violacea*	Violet lespedeza
LEVI7	*Lespedeza virginica*	Virginia lespedeza
LEVU	*Leucanthemum vulgare*	Ox-eye daisy
LOJA	*Lonicera japonica*	Japanese honeysuckle
MAPO	*Maclura pomifera*	Osage-orange
MECA3	*Menispermum canadense*	Moonseed
MORU	*Monarda russeliana*	Bee-balm
MORU2	*Morus rubra*	Red mulberry

Appendix C. Master species list for Manley Woods (continued).

Species Code	Scientific Name	Common Name
MUHLSPP	*Muhlenbergia* spp	Muhly
OXALSPP	*Oxalis* spp	wood-sorrel
OXVI	*Oxalis violacea*	Violet wood-sorrel
PAPE5	*Parietaria pensylvanica*	Pennsylvania pellitory
PAQU2	*Parthenocissus quinquefolia*	Virginia-creeper, woodbine
PEFR4	*Perilla frutescens*	beefsteakplant
PHLE5	*Phryma leptostachya*	Lopseed
PHHE5	*Physalis heterophylla*	Clammy ground cherry
PHVI5	*Physalis virginiana*	Virginia ground cherry
PHAM4	*Phytolacca americana*	Pokeweed, pokeberry
PIPU2	*Pilea pumila*	Clearweed
POPR	*Poa pratensis*	Kentucky bluegrass
POWO	*Poa wolfii*	Bluegrass
POPE	*Podophyllum peltatum*	May-apple, mandrake
POBI2	*Polygonatum biflorum*	Solomon's seal
POSC3	*Polygonum scandens*	False buckwheat
POLYGSPP	*Polygonum* spp	
POVI2	*Polygonum virginianum*	Jumpseed
POSI2	*Potentilla simplex*	Old-field five-fingers
PRAL3	*Prenanthes altissima*	Tall white lettuce
PRAS	*Prenanthes aspera*	Rough white lettuce
PRAM	*Prunus americana*	Wild plum
PRHO	*Prunus hortulana*	Hortulan plum
prse2	*Prunus serotina*	Wild black cherry
PRSE2	*Prunus serotina*	Wild black cherry
PRSPP	*Prunus* spp	
PRVI	*Prunus virginiana*	Choke-cherry
QUAL	*Quercus alba*	White oak
QUIM	*Quercus imbricaria*	Shingle-oak, jack-oak
QUMA3	*Quercus marilandica*	Black-jack oak
QUMU	*Quercus muhlenbergii*	Yellow oak, chinquapin oak
QUPA2	*Quercus palustris*	pin oak
QURU	*Quercus rubra*	Northern red oak
QUSH	*Quercus shumardii*	Shumard's oak
QUERSPP	*Quercus* spp	Oak
QUST	*Quercus stellata*	Post oak
QUVE	*Quercus velutina*	Black oak
RAAB	*Ranunculus abortivus*	Small-flowered crowfoot
RAHI	*Ranunculus hispidus*	Hispid buttercup
RAMI2	*Ranunculus micranthus*	Small-flowered crowfoot
RHLA	*Rhamnus lanceolata*	Lance-leaved buckthorn
RHAR4	*Rhus aromatica*	Squaw-bush
RHCO	*Rhus copallinum*	Shining sumac
RHGL	*Rhus glabra*	Smooth sumac

Appendix C. Master species list for Manley Woods (continued).

Species Code	Scientific Name	Common Name
RIMI	*Ribes missouriense*	Missouri gooseberry
ROCA4	*Rosa carolina*	Pasture rose
ROMU	*Rosa multiflora*	Multiflora rose
ROSE2	*Rosa setigera*	Climbing prairie rose
RUOC	*Rubus occidentalis*	black raspberry
RUPE3	*Rubus pensilvanicus*	Pennsylvanica blackberry
RUBUSPP	*Rubus* spp	
RUTR2	*Rudbeckia triloba*	Three-lobed coneflower
RUHU	*Ruellia humilis*	Fringeleaf ruellia
RUST2	*Ruellia strepens*	Limestone wild petunia
SACA15	*Sanicula canadensis*	Canada sanicle
SAOD	*Sanicula odorata*	clustered blacksnakeroot
SANICULA SPP	*Sanicula spp - wicr*	Sanicule
SAAL5	*Sassafras albidum*	Sassafras
SCMA2	*Scrophularia marilandica*	carpenter's square
SCPA7	*Scutellaria parvula*	Little skullcap
SEFA	*Setaria faberi*	Nodding or giant foxtail-grass
SEVI4	*Setaria viridis*	Green foxtail-grass
SHAR2	*Sherardia arvensis*	Field-madder
SILAA4	*Sideroxylon lanuginosum ssp. albicans*	Southern or Carolina buckthorn
SILAL3	*Sideroxylon lanuginosum* ssp. *lanuginosum*	Southern or Carolina buckthorn
SMTA2	*Smilax tamnoides*	Catbrier
SOCA3	*Solanum carolinense*	Horse-nettle
SOBU	*Solidago buckleyi*	Buckley's goldenrod
SOCA4	*Solidago caesia*	wreath goldenrod
SOHIH	*Solidago hispida var. hispida*	Hairy Goldenrod
SOPE	*Solidago petiolaris*	Goldenrod
SOLISPP	*Solidago* spp	
SOUL2	*Solidago ulmifolia*	Elm-leaved goldenrod
SONU2	*Sorghastrum nutans*	Indian grass
STME2	*Stellaria media*	Common chickweed
SYOR	*Symphoricarpos orbiculatus*	Coralberry
TAIN	*Taenidia integerrima*	Yellow pimpernel
TAOF	*Taraxacum officinale*	Common dandelion
TECA3	*Teucrium canadense*	American germander
THDA	*Thalictrum dasycarpum*	Purple meadow-rue
THTH2	*Thalictrum thalictroides*	Meadow-rue
THBA	*Thaspium barbinode*	Bearded meadow-parsnip
TOJA	*Torilis japonica*	Japanese hedge-parsley
TORA2	*Toxicodendron radicans*	Common poison-ivy
TRBR	*Tradescantia bracteata*	Sticky spiderwort
TROH	*Tradescantia ohiensis*	Smooth spiderwort

Appendix C. Master species list for Manley Woods (continued).

Species Code	Scientific Name	Common Name
TRTH	*Tradescantia tharpii*	Spiderwort
TRBE4	*Tragia betonicifolia*	Tragia
TRFL2	*Tridens flavus*	Purpletop
TRCA5	*Trifolium campestre*	Pinnate hop-clover
TRSE2	*Trillium sessile*	Toadshade
TRPE4	*Triodanis perfoliata*	Round-leaved triodanis
TRPE5	*Triosteum perfoliatum*	Perfoliate horse-gentian
ULAM	*Ulmus americana*	White or American elm
ULRU	*Ulmus rubra*	Slippery or red elm
ULMUSPP	*Ulmus* spp	Elm
VARA	*Valerianella radiata*	Corn salad
VETH	*Verbascum thapsus*	Common mullein
VEUR	*Verbena urticifolia*	White vervain
VEAL	*Verbesina alternifolia*	Wingstem
VEBA	*Vernonia baldwinii*	Western ironweed
VEAR	*Veronica arvensis*	Corn speedwell
VIPR	*Viburnum prunifolium*	Black haw
VIRU	*Viburnum rufidulum*	Southern black haw
VIRU	*Viburnum rufidulum*	Southern black haw
VISO	*Viola sororia*	Violet
VIOLSPP	*Viola* spp	
VITR	*Viola tricolor*	Johnny-jump-up
VIAE	*Vitis aestivalis*	Summer grape
VITISPP	*Vitis* spp	Grape
WOOB2	*Woodsia obtusa*	Blunt cliff fern

The NPS has organized its parks with significant natural resources into 32 networks linked by geography and shared natural resource characteristics. HTLN is composed of 15 National Park Service (NPS) units in eight Midwestern states. These parks contain a wide variety of natural and cultural resources including sites focused on commemorating civil war battlefields, Native American heritage, westward expansion, and our U.S. Presidents. The Network is charged with creating inventories of its species and natural features as well as monitoring trends and issues in order to make sound management decisions. Critical inventories help park managers understand the natural resources in their care while monitoring programs help them understand meaningful change in natural systems and to respond accordingly. The Heartland Network helps to link natural and cultural resources by protecting the habitat of our history.

The I&M program bridges the gap between science and management with a third of its efforts aimed at making information accessible. Each network of parks, such as Heartland, has its own multi-disciplinary team of scientists, support personnel, and seasonal field technicians whose system of online databases and reports make information and research results available to all. Greater efficiency is achieved through shared staff and funding as these core groups of professionals augment work done by individual park staff. Through this type of integration and partnership, network parks are able to accomplish more than a single park could on its own.

The mission of the Heartland Network is to collaboratively develop and conduct scientifically credible inventories and long-term monitoring of park "vital signs" and to distribute this information for use by park staff, partners, and the public, thus enhancing understanding which leads to sound decision making in the preservation of natural resources and cultural history held in trust by the National Park Service.

www.nature.nps.gov/im/units/htln/

Heartland Network

Natural Resource Monitoring

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

NPS D-85, November 2008

National Park Service
U.S. Department of the Interior

Natural Resource Program Center
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA ™