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# The Effect of Prescribed Fires on Vernal Herbs

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THE EFFECTS OF PRESCRIBED FIRES ON VERNAL HERBS

A Capstone Experience/Thesis Project

Presented in Partial Fulfillment of the Requirements for

the Degree Bachelor of Science with

Honors College Graduate Distinction at Western Kentucky University

By

Janis K. LeMaster

\*\*\*\*\*

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2016

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## ABSTRACT

The effects of fire on vernal herbs are little known. David Kem attempted to assess the influences of spring and winter prescribed fires on vernal herbs by collecting abundance data on three sets of research plots located at the WKU Green River Preserve in Hart County, KY, on April 9-10, 2010. On April 10 he conducted spring burns, and on February 22, 2011, he conducted winter burns. He then collected post-fire data on the abundance of the herbs on the 12-19 of March, 2011. He found little influence of fire on overall species richness and the density of common species. In spring of 2015, these plots were re-sampled. Results indicated that there was a change between years in overall stem density and the density of several common vernal herbs, including *Dentaria laciniata* and *Claytonia virginica*. There was also a slight change in species richness between years. Fire treatment was found to have little or no effect on herb stem density and species richness. We suspect that changes between years could be caused by differing precipitation amounts for each respective year.

Keywords: Fire, Moisture, Herbs, Mesic Forest, Vernal

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## PRESENTATIONS

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Major Field: Biology

Minor Field: Sustainability

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## CHAPTER 1

### INTRODUCTION

The herbaceous layer of eastern deciduous forests often does not receive the same attention and notoriety as the woody overstory. However, the herb layer serves an important role within the forest. It contains the highest amount of plant biodiversity, and is a good indicator for the health of the forest, despite having less biomass than the overstory (Gilliam & Turrill, 1993; Whigham, 2004; Gilliam, 2007). The herb layer contains all plant species less than one meter in height, including both herb species and woody species. Herb species are a permanent part of the herbaceous layer, while most woody species eventually grow to higher layers (Gilliam, 2014). Herb species also generally have a much higher ratio of cover compared to young woody species within the herb layer, depending on competitive interactions and responses to environmental conditions (Gilliam, 2014). In light of climate change, many different strategies and techniques are being used to help conserve herbs within the forest. Common techniques include the use of prescribed fires (Iverson & Hutchinson, 2002; Hutchinson, Sutherland, & Yaussy, 2005; Elliott & Vose, 2010; Matlack, 2013). Knowing the influence of fire on vernal herb species could give a better idea of when this technique would be effective, if at all. Herb communities differ based on soil moisture regimes and geography (Rogers, 1982). Common vernal herbs within mesic forests are often perennial, and include *Dicentra cucullaria*, *Sanguinaria canadensis*, *Viola spp.*, *Dentaria laciniata*, *Asarum*

*canadense*, *Claytonia virginica*, *Hydrophyllum virginianum*, and the annual herb *Galium aparine* (Rogers, 1982). Mesic sites tend not to have a frequent or intense history of burning, so species commonly found in these sites are less fire adapted and may respond differently to the use of fire (Matlack, 2013). Moreover, understanding how changing environmental factors, including moisture levels, affect herb species can help lead to better decisions when managing their populations.

Herb species contain higher concentrations of nutrients than woody species, and so are important in nutrient retention of the forest (McEwan & Muller, 2011). They can also account for up to 10-15 percent of annual foliar litter, despite being only one percent or less of the living biomass of the forest (Muller, 2014). Nutrient uptake by herb species varies seasonally with higher concentrations of nutrients found in the foliage of vernal species compared to summer species (Muller, 2014). Within the herbaceous layer, vernal herbs are those seen on the forest floor before the canopy closes in late spring (Meier, et al., 1995). Vernal herb species have the advantage of being productive before canopy closure, where there is higher light availability and soil moisture (Muller & Bormann, 1976). This productivity can be important to the health of the forest. Studies have indicated that vernal herbs act to incorporate and retain important nutrients within the forest ecosystem that otherwise would have been lost (Muller & Bormann, 1976; Blank, et al., 1980).

There has been significant focus on loss of biodiversity and species extinction across the world. Herb species are particularly vulnerable to extinction compared to woody species due to higher sensitivity to environmental changes and disturbances (Duffy & Meier, 1992; Chandy & Gibson, 2009), and because they contain such high

plant biodiversity in comparison to the rest of the forest plant community, threats to herb species often signify threats to the plant biodiversity of the entire forest (Jolls & Whigham, 2014).

Herbs are vulnerable to both natural and anthropogenic disturbances, including logging, habitat fragmentation, overgrazing, and the growing presence of invasive species (Jolls & Whigham, 2014). A study conducted by Duffy and Meier (1992) found that damage from logging to herb richness had not recovered at all over a period of 85 years. Species of herbs that have low reproductive and dispersal rates are particularly vulnerable (McEwan & Muller, 2011). Vernal herb species specifically have also been shown to be more vulnerable to disturbance, and take longer to recover than other herb species (McLachlan & Bazely, 2001).

Environmental factors such as light availability, and soil, microtopographical, and temporal gradients are known to have significant influence over the occurrence and composition of herb species (Bratton, 1976; Rogers, 1982; Gilliam & Turrill, 1993; Small & McCarthy, 2002). Light availability is often referenced as the main factor in herb distribution and cover (Gilliam, 2007). Seasonal changes in overstory density cause alterations in light availability as well as soil fertility, and drive the presence and distribution of different herb species (Gilliam, 2007; Muller, 2014). Rogers (1982) noted that overstory composition has less influence on the growth of vernal herbs compared to soil type, drainage, and microtopography of the site. Knowledge of how environmental factors affect herbs is important to consider, especially in the advent of climate change.

*Fire*

With changing environmental conditions leading to potentially major effects on herb species, special attention has been paid to techniques on how to best manage them. This has included the application of prescribed fires. The environments of eastern North America have a long history of being disturbed by fire. Before being settled by Europeans, fires were sometimes ignited by lightning strikes (Matlack, 2013). However, most pre-settlement fires were started by Native Americans as a management tool (Brose, Schuler, Van Lear, & John, 2001; Nowacki & Abrams, 2008; Bratton & Meier, 1998; Delcourt & Delcourt, 1997; Abrams, 1992). These practices encouraged the dominance of oaks, a mildly fire-adapted species (Brose, et al., 2001). Overall, there was a wide variance in fire regimes in the east, with some environments experiencing fire more often than others. As a result, vegetation types and plant adaptations to fire also varied significantly (Wade, et al., 2000). After European settlement, early settlers continued with the practice of fire as a management tool, and fire regimes in eastern North America did not change much (Brose, et al., 2001). Once paired with timber harvesting in the late 1800s, fire became more widespread, frequent, and intense (Brose, et al., 2001). This included the burning of mesic forests, which previously had rarely burned due to their moister conditions (Nowacki & Abrams, 2008). In the 1920s a policy of fire suppression began in the U.S. The suppression of fire caused a shift in fire regimes and consequently dominant vegetation types across the east. Hardwoods and mesic species of plants became much more widespread across the eastern U.S. in response to lower incidences of fire (Abrams, 1992; Elliott, et al., 1999; Bratton & Meier, 1998; Brose, et al., 2001). It was not until the 1980s that the use of prescribed fires as a forest management tool began to increase (Matlack, 2013).

Prescribed fires are known to have varying effects on the soil. A study by Iverson and Hutchinson (2002) indicated that soils experience elevated temperatures for several months after lower-intensity prescribed burns, though xeric sites experienced increased temperatures longer on average than mesic sites. Burning also helps release nutrients from leaf litter into the soil, including phosphorous and nitrogen, possibly encouraging higher plant productivity (Hutchinson, 2006). A long-term study of the effects of low-intensity fires on an oak-hickory forest resulted in higher soil pH, conductivity, cation levels and nitrogen levels in the soils of burned areas compared to unburned areas (Scharenbroch, et al., 2012). Burning during the dormant season in a submesic mixed oak forest only increased soil ammonium concentrations immediately after, with concentrations returning to pre-burn levels by the following summer, and had no effect on inorganic nitrogen concentration of the soil (Knoepp, et al., 2009).

Fires can also alter the successional stage of an environment. Late-successional tree species are usually more vulnerable to fire (Abrams, 1992), so frequent or recurring fires can lead to dominance of early or mid-successional plant species such as graminoids and oaks (Abrams, 1992; Matlack, 2013). Fire suppression in the eastern United States has led to higher dominance of hardwood and mesic forests in areas that previous fire activity had maintained as grasslands or oak forests (Nowacki & Abrams, 2008).

Fire can have several significant effects on the understory of the forest. Direct effects of fire can include damage to leaf area of plants. A study by Primack et al. (1994) found that fire reduced the leaf area of a vernal orchid by up to 50 percent – however, the effect was short-term, and the herb returned to normal reproductive levels the next year. The abundance of perennial herbs also seems to be little affected by fire, probably due to

the rhizomes of the herbs not being damaged by low intensity fires (Hutchinson, 2006). This is most likely because heat does not transfer well into the soil after a low-intensity prescribe fire, so despite the rhizomes of herbs being shallow, they are still for the most part unaffected (Hutchinson , 2006). Soil temperatures, at their peak, generally only reached 18°C during multiple prescribed fires in a forest in Ohio (Iverson & Hutchinson, 2002). In contrast, it was found that rhizomes of herb species only started to die once temperatures were around 60°C (Pringle & Flinn, 1983). The effect of fire on species richness of the herb layer seems to vary significantly. A study by Elliot et al. (1999) found that species richness on a xeric, pine and hardwood site located on a ridge significantly increased within the herbaceous layer after a prescribed burn. Ridges are often drier and contain more fire-dependent plants that could have contributed to this result (Whittaker, 1956). Other studies reported little to no effect of prescribed fire on species richness. Hutchinson et al. (2005) demonstrated very little effect of prescribed burns on herb species richness in a mixed-oak forest. Prescribed burns in their study seemed to change species composition more on xeric sites, alternatively, mesic sites were relatively unaffected (Hutchinson, et al., 2005). A shorter-term study by Elliott and Vose (2010) , that included only one burn per site or either a low or moderate intensity, found no effect of prescribed fire on species richness of the herb layer of a mesic to submesic mixed-oak forest. De Grandpre et al. (2014) found that species richness of most herb species (save for invasives) had decreased in a mesic forest site as resulting from high fire recurrence. High fire recurrence causes much more disturbance than most prescribed fires, however, and could have been the cause of the decrease in species richness of most herb species, save for invasives, which thrive on disturbance (De Grandpre, et al., 2014).

The variance in results could be due to several other factors. The season when a prescribed burn was applied seems to have an influence on fire effectiveness (Elliott & Vose, 2010), as well as the type of environment. Studies have indicated that fire intensity and effects are often less pronounced on mesic sites compared to others (Hutchinson, et al., 2005).

Prescribed fires can indirectly influence herb species through their effects on the overstory. The use of fire is known to reduce the density and composition of the overstory, which allows more light to reach plants within the understory. This would benefit summer-flowering herb species much more than vernal species, since summer-flowering species are more reliant on light availability below the forest canopy (Hutchinson, et al., 2005). The increase in light resulting from a reduced overstory could also benefit rare herb species, since overstory shade is often a major threat to those species (Hutchinson, 2006). However, low-intensity fires have been shown to have little influence on the overstory, with high intensity fires having a much greater effect (Roberts, 2004; Hutchinson, Sutherland, & Yaussy, 2005). There is concern that the use of higher intensity prescribed fires could encourage establishment or increased densities of invasive plant species, since those species establish quickly into disturbed environments (Hutchinson, 2006).

### *Climate Change*

Climate change and global warming have widespread effects on many ecosystems. Forest herb species are no exception, though there is significantly less research on the impact of climate change on these species compared to others within the forest. One major concern with climate change is that rising temperatures cause earlier



flowering times, particularly for spring and winter herb species (Bradley, et al., 1999; McEwan, et al., 2011). While climate change is known to have an impact on temperature, increased soil temperature, CO<sub>2</sub>, nitrogen, and ozone levels are also expected to occur. Notably, evidence has shown that alterations in precipitation patterns is predicted to occur. In areas containing temperate deciduous forests, this includes a more intense hydrologic cycle, with some areas receiving less rainfall while others receive more (Lensing & Wise, 2007; Neufeld & Young, 2014). Several studies have shown evidence of an increase in the total number of wet days in North America over time, as well as an increase in annual rainfall. In addition, the increase in annual rainfall seems to result from an increase in the frequency of extreme precipitation events rather than spread out throughout the year. The increase in extreme precipitation events is also concentrated towards spring months across the eastern U.S. (Karl & Knight, 1998; Groisman, Knight, & Karl, 2001; Knapp, et al., 2008). This has major implications for environmental conditions in those areas. Changes could lead to indirect effects on herb species, including changing microclimates of the understory, phenological shifts, and changes in soil moisture (Neufeld & Young, 2014). Climate change is also expected to alter the geographic distribution of plant communities, which could have far-reaching effects for conservation and management practices (Fridley & Wright, 2012). Small-ranged endemic herb species are especially at risk for extinction due to climate change (Bellemare & Moeller, 2014). With climate change leading to notable changes in precipitation patterns across temperate forests, special attention should be paid to how moisture and water influence the herbaceous layer. This knowledge could lead to more effective management techniques when these changes occur.

## *Soils*

Soils of rich mesic forests are characterized by high levels of moisture, nutrients, and organic matter. Forests with mesic soils often have faster plant growth rates, and higher amounts of plant diversity and cover (Sperduto & Nichols, 2004). The decomposition of leaf litter and woody debris contributes nutrients to the soil, leading to high soil fertility (Kost, et al., 2007). A thick humus layer is often present at the soil surface and rich in many mineral nutrients including nitrogen (Sperduto & Nichols, 2004). Soils in mesic forests have a high water-holding capacity and generally do not experience drought. They are also well-drained, and rarely become water logged or oversaturated (Sperduto & Nichols, 2004).

## *Moisture*

On the temperate forest floor, moisture is considered one of the main resources affecting the growth of forest herbs (Muller, 2014). Herbs receive most of their moisture through the soil. Herbs have limited root volumes, so they mostly rely on the moisture content of surface soils, compared with woody species that can tap much deeper down into the soil profile for water (Muller, 2014). In combination with light energy, soil moisture has been correlated with species composition and diversity of the understory. Variations in soil moisture in different sites is also correlated with variations in site productivity in the forest (Hutchinson, et al., 1999). Several different factors can affect soil moisture content within forests, including variations in soil morphology and topography (Hutchinson et al., 1999; Burton, et al., 2011). Elevation is also known to affect the moisture gradient, with higher elevations being negatively associated with soil moisture levels (Whittaker, 1956; McEwan & Muller, 2011). Soil moisture and fertility

are often linked (Hutchinson et al., 1999). Burton et al. (2011) found that well-drained soils had a positive relationship between soil moisture and nitrogen and phosphorous mineralization. Hutchinson et al. (1999) also linked nitrogen mineralization rates with soil moisture. Graves, Peet, and White (2006) linked soils with high moisture and base cation content (including Ca and Mg) with greater herb abundance and richness. In contrast, their study indicated that woody species have much lower cover on moist, nutrient-rich sites, likely due to competition with herb species. Soil moisture levels are mostly determined by the inflow and outflow of water into the soil profile. Inflow consists of precipitation and snowmelt, while outflow is determined by evaporation rates, drainage, and the uptake of water by roots (Ma, et al., 2014). Higher amounts of snowmelt, precipitation, and stream flow occur during spring months, leading to much higher soil moisture content and higher nutrient loss (Muller, 2014).

In regards to the soil moisture gradient, herb species populations form a bell-shaped curve between each extreme of the gradient, with species distribution along the gradient overlapping, a pattern similar to the distribution of tree species (Whittaker, 1956). Moisture levels are strongly correlated with total herb coverage (Hutchinson et al., 1999; Graves, et al., 2006), with herb cover maximized in mesic deciduous forests where moisture conditions are higher (Whittaker, 1956). Seasonal variations of soil moisture content can have a strong effect on herb species. Summer and winter herb species are more likely to be stressed by low water levels, a problem less often encountered by vernal species (Neufeld & Young, 2014). In a study done by Gilliam, et al. (2006), vernal herb species diversity was speculated to be more affected by changes in meteorological conditions that led to fluctuations in soil moisture content, rather than by

other factors such as temperature. Overall, little research has been focused on examining the relationship between herbs and moisture (Neufeld & Young, 2014; Albrecht & McCarthy, 2009).

Soil moisture can also have a direct effect on the seedlings and morphology of the herbs present. Albrecht & McCarthy (2009) determined that soil moisture levels were a key factor limiting seed mortality risk in herb species, with seedlings emerging in drier years more likely to die than those emerging in wetter years. The presence of morphologically different herb species can also be influenced by soil moisture, with ferns and species with delicate foliage being indicative of mesic sites over xeric or submesic sites. Herbs that are moderately sized and have broader, thinner leaves, including genera such as *Impatiens*, *Trillium*, and *Thalictrum*, are also more common in mesic sites. In contrast, grasses and tougher-leaved herbs such as *Goodyera pubescens* and *Gaultheria* are more likely to be found in xeric sites (Whittaker, 1956).

Though water from soil moisture has the largest influence, herbs can be affected by water in other ways. Water balance, defined as the interaction between evaporation rates and total available water within the soil, is known to have a significant influence over the distribution of herbs in deciduous forests (Stephenson, 1998). Svenning and Skov (2006) found that changes in water balance caused by climate change was one of the major factors leading to suitability declines for up to 40 percent of herb species in areas of Northern Europe. Many herb species had low dispersal rates, and with suitability declines occurring quickly, it puts them at risk for extinction (Svenning & Skov, 2006). Besides contributing to soil moisture, rainfall has also been known to influence leaf litter on the forest floor. A study by Lensing and Wise (2007) indicated that increasing rainfall

amounts led to faster litter decay on the forest floor. The quality of leaf litter is important to when nutrients from the litter become available to plants, with higher quality leaf litter releasing more nutrients (Burton et al., 2011). Rainfall also contributes to throughfall in the forest. Throughfall has significant influence on chemical exchange between plants within the forest community, including plants within the herbaceous layer. The herbaceous layer is known to both capture nutrients from throughfall as well as contribute them. This could possibly influence the morphology of herb root systems, since more extensive root systems would be less important plants received more of their needed nutrients (Muller, 2014).

#### *Purpose and A priori Hypothesis*

The purpose of this study is to determine whether the richness, overall herb density, and density of specific common vernal herb species within eastern North American mesic forests has changed over the last six years. The research plots used are part of an ongoing study examining the effects of fire treatment on the herbaceous understory. As a result, further tests will be needed to examine possible long-term effects of fire. However, previous studies on these plots concerning both vernal (Kem, 2013), summer, and fall (Wilder, 2011) herb species observed no significant influences of fire, so I do not expect there to be any significant effects of fire on vernal herb density and richness. However, there was a change in climatic conditions across years in the study area, including precipitation. Higher soil moisture has been linked to higher herb coverage and growth, and so a larger amount of herbs competing, therefore I hypothesized that there would be an increase in vernal herb species richness across years. This hypothesis already has some support from a study done by Hutchinson et al. (1999)

which found a positive correlation between soil moisture and forb species richness. I also hypothesize that there will be an increase in the overall density of herb species within sites between years.

Moisture has a positive effect on herb species composition. However, little research has been done concerning the effect of moisture on specific species of herbs, including vernal herbs. Vernal herb species with shorter lifespans and higher rates of reproduction could respond to changes in moisture levels faster than longer-lived species with lower reproductive rates. Common herb species within mesic forests that have short lifespans and higher reproductive rates include *Dentaria laciniata* (Brassicaceae) and *Claytonia virginica* (Portulacaceae) (Bierzzychudek, 1982). I hypothesize that there would be an increase in the presence and density of these herb species between the years of study. In a report filed by the US Forest Service, *D. laciniata* (also known as *Cardamine concatenata*) was chosen as an indicator species for management effects in northern hardwood forests (US Forest Service, 2006). How *D. laciniata* is affected by changes in climate or fire could give insight into how vernal herbs could be affected as a group. Studies have shown that *C. virginica* and *Erythronium americanum* (Liliaceae) are common vernal herb species that have significant roles in nutrient retention and cycling in temperate forests during spring months (Muller & Bormann, 1976; Anderson & Eickmeier, 2000). Whether these species are affected by climate or fire could be important in understanding how nutrient cycling within the forest could be effected. Knowledge of this can help management planning for conservation of the herbaceous layer.

## CHAPTER 2

### METHODS & MATERIALS

#### *Site Description*

The Western Kentucky University (WKU) Green River Preserve is located in Hart County, Kentucky, and consists of 615 ha. of land stretching across both sides of the Green River. WKU owns and manages the property for research as well as to provide education enrichment. The preserve contains a wide variety of habitats, including upland forests, bottomland forests, and barrens, as well as a large number of plant and animal species.

Three separate study sites are located within the mesic forests of the preserve. Sites were originally set up in 2010 by David Kem, a graduate student at WKU at the time. For this study, only sites 1 and 3 were examined. David Kem set up each site with four replicates and three plots within each replicate. Plots are 2 x 4 m, with 1 m between each quadrat and 2 m between each replicate. Plots were also divided into subplots that were 1 m<sup>2</sup> (Figure 2). Each plot had a total of 8 subplots. All sites are located at least 5 meters from the forest edge so potential edge effects could be avoided. Both sites differ significantly in several ways, including soil composition, slope, and distance from the forest edge. Site 1 is located at N37° 14'33.0" and W085°59'00.7" with a 10% grade. The site is located on a north facing slope at 127 m above sea level and 19.5 m from the

edge of an alluvial floodplain. The site is found on Mississippian St. Genevieve limestone. According to soil maps of the region, the dominant soil type is a Caneyville silt loam, rocky, with a 6-20% slope. As stated by the previous owner of the property, the area has had a history of heavy grazing. (Wilma Jean Kilmey, pers. comm.). Site 3 is located at N37° 14'28.7" and W085° 58'58.5" with a 25% grade, making it steeper than site 1. The site is on a north-facing slope at 141 m above sea level, and is 32.8 m from the edge of the alluvial floodplain, placing it farther from the forest edge than site 1. The site is found on Mississippian St. Genevieve limestone. The dominant soil types are described as a rocky outcrop of Caneyville complex and Caneyville rocky silt loam. The site shows no evidence of being heavily grazed in the past. Samples of soils from all sites were taken on 22 February, 2011 by David Kem. Using these samples, soil composition for all sites was analyzed for nutrient content (Table 2.1).

Table 1. Mehlich III analysis of soil. Data shown are the average in plots in lbs/acre. (\*) indicates that the variable was significant within the respective site. (Kem, 2013)

Site	P*	K*	Ca*	Mg	Zn*	Soil pH*	Buffer pH*
1	16.875	177.5	3717.25	269.75	7.3875	6.175	6.8375
3	23.375	202.25	5054.125	293.75	5.675	6.375	6.875

One of three treatments was randomly selected and applied to each plot. David Kem was responsible for originally applying treatments to all plots and sites. Treatments included a winter burn, a spring burn, and a control (no burn). Winter burns were conducted on 22 February, 2011, and consisted of low intensity fires. Spring burns took place on 10 April, 2010 and also consisted of low intensity fires. The fires were ignited



using a drip torch and a fuel mixture consisting of 70% diesel and 30% gasoline. The scorch height was recorded on a dowel rod to indicate fire intensity. Each plot was completely burned within one hour of being ignited. Burn severity data is described in Appendix 1. Layout of plot treatments in each site can be seen in Figure 1. Subplot layout can be seen in Figure 2.

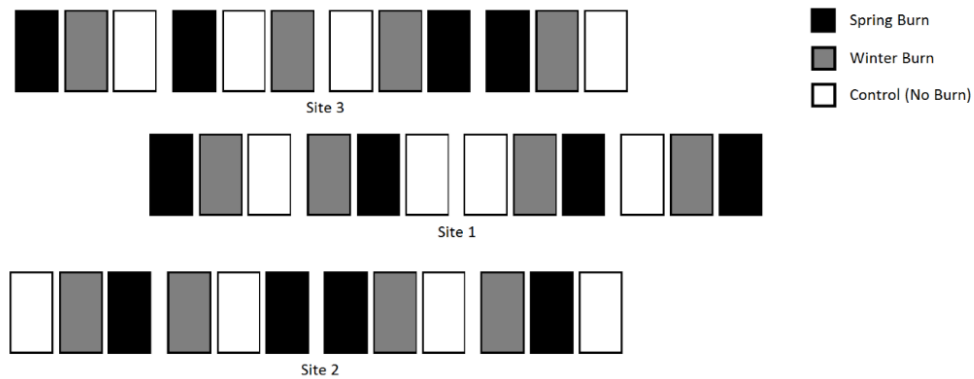


Figure 1: Plot Treatment and Layout (Adapted from Kem, 2013)

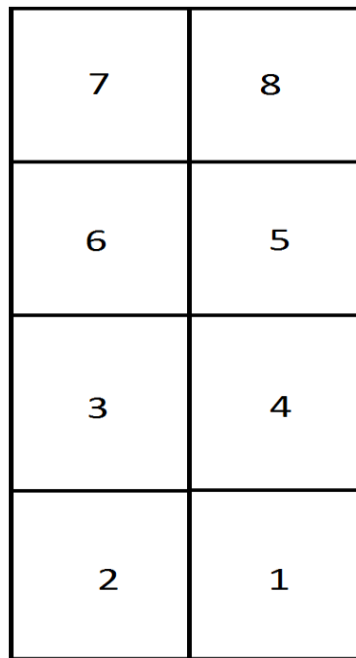


Figure 2 : Subplot Layout (Adapted from Kem, 2013)

### *Data Collection*

Data on vernal herbaceous plants was collected on April 11 and 12, 2015. Woody plants and vines were not included. Unknown or unidentified plants were identified by taking a photograph and then using plant identification guides or expert opinion. David Kem collected data on the frequency and density of herbaceous plants using the same methods. He collected data on April 9 and 10, 2010, before applying burn treatments. He also collected plant data on April 8 and 17, 2011, after spring and winter burn treatments had been applied. Soil samples from each plot were collected by David Kem using a soil corer. Samples were taken to a depth of 10 cm from each plot in two places, one at the convergence of subplots 1, 2, 3, and 4, and the other at the convergence of subplots 5, 6, 7, and 8.

### *Data Analysis*

Data on the herbaceous layer was analyzed using an ANOVA with multiple comparisons test within the R statistical program. This included a non-parametric permutation procedure with 10,000 permutations (Collyer, Sekora, & Adams, 2015). ANOVA tests were performed on the species richness of vernal herbs across the years 2010, 2011, and 2015. ANOVA tests were also performed on the overall ramet density of sites as well as the density of specific herb species. Specific herb species were chosen based on the 6 herbs present in the highest fraction of plots across 2010, 2011, and 2015. Density and species richness were also compared between specific years and sites using a pairwise comparison within the ANOVA. Both the ANOVA and the pairwise comparison utilized a null model and a full model. Soil samples were sent to the University of

Kentucky Cooperative Extension Service for analysis, as a part of David Kem's original research. Soil was evaluated for essential nutrients including phosphorous, magnesium, calcium, zinc, soil pH, and buffer pH using a Mehlich III test. Results were given in pounds per acre. A general linear model one-way ANOVA was used in the SPSS program (IBM Corp., 2012) to analyze the relationship between sites and soil.

## CHAPTER 3

### RESULTS

The results of the ANOVA permutation procedures test showed that overall ramet density was significantly different for site, year, and to a smaller extent treatment. Some variables had significant values, but since all variables had R-squared values below 0.25, the effect the variables had were low. Year had the largest and most significant effect on overall ramet density. Sites:Year had the second highest effect and was also significant. A pairwise comparison of the significance between years and sites indicated that all three years (2010, 2011, 2015) were significantly different in site 1. Treatment and Site both had R-squared values below 0.1, so while they were significant, they had very little effect (Table 2). A comparison between the average ramet densities within sites can help give a better idea of how Year was significant. Both 2015 and 2011 had a much higher average ramet densities in site 1 than 2010 (Figure 3). However, 2015 experienced a decrease in average ramet density in site 1 compared to 2011.

Table 2: Results for an ANOVA permutation procedure using 10,000 permutations for overall ramet density of herbaceous species in plots. Plots were contained in two different sites across the years 2010, 2011, and 2015. Each plot had either a spring fire treatment, winter fire treatment, or no fire treatment (control). Sites were located at the WKU Green River Preserve.

	Df	SS	Rsq	Pr (>F)
Site	1	362952	0.098711	0.0067
Year	2	884333	0.240510	0.0001
Treatment	2	257815	0.070117	0.0203
Site:Year	2	499534	0.135857	0.0002

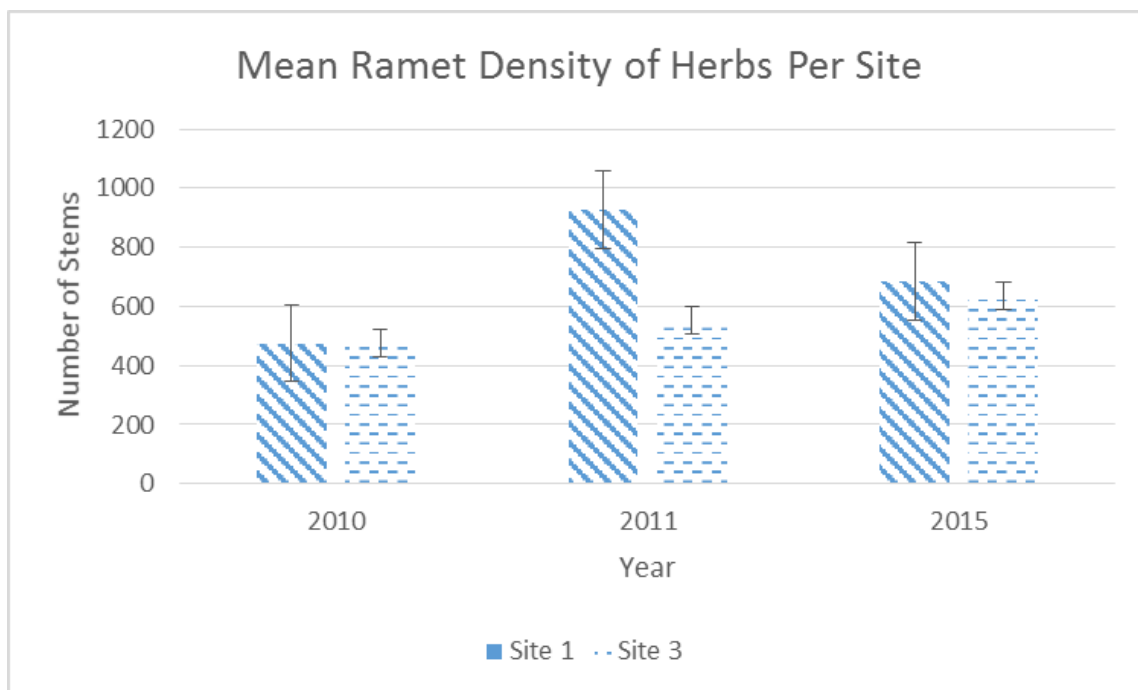


Figure 3: The average total ramet density of herbaceous species across all plots within individual sites in a mesophytic forest at the WKU Green River Preserve. Years of study included 2010, 2011, and 2015.

In 2015, there were 14 species of vernal herbs found in site 1 and 17 in site 3. In 2011, 15 vernal herb species were found in site 1 and 15 in site 3. In 2010, 17 vernal herb species were found in site 1 and 12 in site 3.

ANOVA tests for overall species richness within plots was found year to be significant, though it had only a small effect (Table 3). Results from a pairwise comparison indicate that species richness was significantly different in site 3 between 2010 and the years 2015 and 2011 (Table 4). No other comparisons of sites and years were significant. When comparing the average species richness across plots within sites, 2015 had the highest values for site 3 (Figure 4). There was a change in average species richness from 2010 to 2011 and 2010 to 2015 in site 3.

Table 3: Results for an ANOVA permutation procedure using 10,000 permutations for overall species richness of herbaceous species in plots. Plots were contained in two different sites across the years 2010, 2011, and 2015. Each plot had either a spring fire treatment, winter fire treatment, or no fire treatment (control). Sites were located in a mesic forest at the WKU Green River Preserve.

	dF	SS	Rsqr	Pr(>F)
Site	1	0.125	0.000571	0.87555
Year	2	41.333	0.188844	0.01775
Treatment	2	5.801	0.026503	0.3302

Table 4: P-values resulting from a pairwise comparison between sites and year of species richness of herbaceous species within plots. Plots were contained within site 1 and site 3. Below is a comparison of site 3 in the years 2010, 2011, and 2015. Sites were located in a mesic forest at the WKU Green River Preserve. Bolded P-values indicate species richness was significantly different between those years for site 3.

	3:2010	3:2011	3:2015
3:2010	1.0000	-	-
3:2011	<b>0.04590</b>	1.0000	-
3:2015	<b>0.00100</b>	0.19955	1.0000



Figure 4: The mean species richness of herbaceous species across all plots within individual sites. Years of study included 2010, 2011, and 2015. Sites were located in a mesic forest at the WKU Green River Preserve.

ANOVA tests were performed on the 5 herb species most present across plots between 2010, 2011, and 2015. Tests indicated that the density of *Dentaria laciniata*, *Viola sororia*, *Claytonia virginica*, and *Erythronium americanum*, were significantly

different across years. The density of the herb *Glechoma hederacea* was only significant in regards to site. Tests indicated that treatment was not a significant or meaningful variable for any of these species.

The results for the density of *D. laciniata* showed that Year was the most significant variable and accounted for the highest amount of variation (Table 5). A pairwise comparison between years and sites of *D. laciniata* indicated that site 1 in 2011 was significantly different compared to site 1 in 2010 and 2015, and that site 3 in 2015 was significantly different compared to site 3 in 2010. Results of the Pairwise comparisons of *D. laciniata* can be seen in tables 6 and 7. When comparing average densities across plots in site 3, 2015 actually had a decrease in the average ramet density of *D. laciniata* compared to 2011 and 2010, with 64.42 ramets per plots in 2015 compared to 121 ramets per plot in 2011 and 162.67 ramets per plot in 2010. In site 1, 2015 had the lowest average number of ramets as well, with only 124 ramets per plot. 2010 had 164.4 ramets per plot in site 1, and 2011 had the highest average, with 305.67 ramets per plot.

Results also indicated that Year was the most significant variable and had the greatest effect on the common vernal herb *V. sororia* (Table 8). A pairwise comparison for *V. sororia* showed that 2015 was significantly different from 2010 and 2011 in site 1. Comparison of average densities of *V. sororia* in site 1 between all three years found that there was an increase from 2010 to 2011, with the average ramet density of *V. sororia* in 2010 being 34 ramets per plot, and 2011 having an average of 49.08 ramets per plot. There was then a decrease in 2015, with plots in site 1 only having an average ramet density of 5.75 ramets per plot for *V. sororia*.



Results for the density of *C. virginica* had Year and Site:Year as the most significant variables. Year had the largest effect, with an R-squared value equaling 0.38192. Results can be seen in Table 9. A pairwise comparison of *C. virginica* indicated that 2011 was significant from 2010 and 2015 in site 1, and 2010 was significant from 2011 and 2015 in site 3. Results for the pairwise comparison can be seen in Tables 10 and 11. The average ramet density of *C. virginica* in site 1 for 2011 was much higher than both 2015 and 2010. 2011 had 191.75 ramets of *C. virginica* on average per plot, while 2010 had 63.42 and 2015 had 60.92. For site 3, the average ramet density of *C. virginica* increased every year, with an average of 20.333 in 2010, 75.42 in 2011, and 85.08 in 2015.

*Erythronium americanum* had several significant variables, including Site, Year, and Site:Year. Site:Year was the most significant and had the largest effect, though since the R-squared value was only 0.15, the effect was not particularly large (Table 12). A pairwise comparison indicated that all three years were significant from each other in both sites. For site 1, 2011 had the highest average ramet density of *E. americanum*, with 211.33 ramets per plot. 2010 had the lowest, with 62.17 ramets of *E. americanum* on average per plot, and 2015 had 88.25 ramets on average per plot. Site 3, unlike site 1, had an increase in the average density of *E. americanum* across every year of study, with 2010 having 138.42 stems on average per plot, 2011 having 177.75 ramets on average per plot, and year 2015 having 340.75 ramets on average per plot.

Table 5: Results for an ANOVA permutation procedure using 10,000 permutations for stem density of *Dentaria laciniata* in plots. Plots were contained in two different sites across the years 2010, 2011, and 2015. Each plot had either a spring fire treatment, winter fire treatment, or no fire treatment (control). Sites were located in a mesic forest at the WKU Green River Preserve.

	dF	SS	Rsq	Pr(>F)
Site	1	120050	0.181326	0.0010
Year	2	85235	0.257481	0.0001
Treatment	2	11042	0.033357	0.1182
Sites:Years	2	51835	0.156586	0.0001

Table 6: Pairwise comparison between sites and years of the ramet density of *Dentaria laciniata* within plots. Plots were contained within site 1 and site 3. Below is a comparison of site 1 in the years 2010, 2011, and 2015. Bolded P-values indicate stem density was significantly different between those years for site 1. Sites were located in a mesic forest at the WKU Green River Preserve.

	1:2010	1:2011	1:2015
1:2010	1.00000	-	-
1:2011	<b>0.00020</b>	1.0000	-
1:2015	0.26700	<b>0.0001</b>	1.0000

Table 7: Pairwise comparison between sites and years of the stem density of *Dentaria laciniata* within plots. Plots were contained within site 1 and site 3. Below is a comparison of site 3 in the years 2010, 2011, and 2015. Bolded P-values indicate stem density was significantly different between those years for site 3. Sites were located in a mesic forest at the WKU Green River Preserve.

	3:2010	3:2011	3:2015
3:2010	1.0000	-	-
3:2011	0.2451	1.0000	-
3:2015	<b>0.0044</b>	0.1157	1.0000

Table 8: Results for an ANOVA permutation procedure using 10,000 permutations for stem density of *Viola sororia* in plots. Plots were contained in two different sites across the years 2010, 2011, and 2015. Each plot had either a spring fire treatment, winter fire treatment, or no fire treatment (control). Sites were located in a mesic forest at the WKU Green River Preserve.

	dF	SS	Rsq	Pr(>F)
Site	1	6309	0.174362	0.0002
Year	2	3699.5	0.204474	1e-04
Treatment	2	98.0	0.005418	0.7485
Site:Year	2	2204.2	0.121829	0.0004

Table 9: Results for an ANOVA permutation procedure using 10,000 permutations for stem density of *Claytonia virginica* in plots. Plots were contained in two different sites across the years 2010, 2011, and 2015. Each plot had either a spring fire treatment, winter fire treatment, or no fire treatment (control). Sites were located in a mesic forest at the WKU Green River Preserve.

	dF	SS	Rsq	Pr(>F)
Site	1	36585	0.13384	0.0012
Year	2	52198	0.38192	0.0001
Treatment	2	678	0.00496	0.7020
Site: Year	2	29628	0.21678	0.0001

Table 10: Pairwise comparison between sites and years of the ramet density of *Claytonia virginica* within plots. Plots were contained within site 1 and site 3. Below is a comparison of site 1 in the years 2010, 2011, and 2015. Sites were located in a mesic forest at the WKU Green River Preserve. Bolded P-values indicate ramet density was significantly different between those years for site 1.

	1:2010	1:2011	1:2015
1: 2010	1.0000	-	-
1: 2011	<b>0.0001</b>	1.00000	-
1: 2015	0.9179	<b>0.0001</b>	1.00000

Table 11: Pairwise comparison between sites and years of the ramet density of *Claytonia virginica* within plots. Plots were contained within site 1 and site 3. Below is a comparison of site 3 in the years 2010, 2011, and 2015. Sites were located in a mesic forest at the WKU Green River Preserve. Highlighted P-values indicate ramet density was significantly different between those years for site 3.

	3: 2010	3: 2011	3: 2015
3: 2010	1.0000	-	-
3: 2011	<b>0.0171</b>	1.0000	-
3: 2015	<b>0.0040</b>	0.6824	1.0000

Table 12: Results for an ANOVA permutation procedure using 10,000 permutations for stem density of *Erythronium americanum* in plots. Plots were contained in two different sites across the years 2010, 2011, and 2015. Sites were located in a mesic forest at the WKU Green River Preserve. Each plot had either a spring fire treatment, winter fire treatment, or no fire treatment (control).

	dF	SS	Rsqr	Pr(>F)
Site	1	174247	0.104717	0.0048
Year	2	178600	0.107333	0.0091
Treatment	2	17034	0.020474	0.4063
Site:Year	2	124971	0.150207	0.0002

## CHAPTER 4

### DISCUSSION

Despite species richness and density showing a significant change across years, fire treatment had little to no influence. There was no effect on density and species richness whether plots had a winter burn, spring burn, or no burn. Fire treatment also did not have any specific effects on densities of the most common herb species found in both sites across all years, including both vernal and invasive species. This differs from findings that correlated higher species richness and density to use of prescribed fire (Elliott, Hendrick, Major, Vose, & Swank, 1999). Elliot et al. (1999) found a greater amount of species richness after a prescribed burn took place on a xeric, ridge site, unlike this study, which took place in a mesic forest. However, the results presented here are partly supported by more recent studies, such as Elliot and Vose (2010), who found no effect of fire on species richness of the herb layer, and in some cases no effect of fire on herb cover. The study by Elliot and Vose (2010) took place on an intermediate to sub-mesic mixed oak forest, which is more similar to this study. A 5-year study by Hutchinson et al. (2005) found that vegetation in the herbaceous layer of forests was not significantly altered by prescribed fires, though their study took place over mixed oak forests with xeric, intermediate, and mesic moisture regimes. Any significant changes in herb species richness due to fire in the Hutchinson et al. (2005) study were found to be

relatively small, with fire having less of an influence than other environmental factors, such as topography. Unlike this study, Hutchinson et al. (2005) involved the use of multiple prescribed fires, with some plots being burned either two times, four times, or not at all. The plots in this study had only been burned one time.

The effectiveness of prescribed fires could be influenced by the moisture regimes and topography of the environment. All sites in this study took place in a mesic forest. Mesic sites are much higher in moisture, and have less of a history of burning. Studies have indicated that fire effects on both soil quality and composition of the herbaceous layer are less pronounced on mesic sites compared to drier sites (Iverson & Hutchinson, 2002; Hutchinson, et al., 2005).

Differences in fire intensities and subsequent effects on herb richness and density on sites can also depend on topography (Elliott, et al., 1999). More intense fires could have greater effects on the herb layer. Prescribed fires in this study were of low intensity. Philips et al. (2007) showed that prescribed fire used in tandem with vegetation thinning led to more intense fires and greater effects on the herb layer than burning alone did. Low-intensity fires do not have as great of an effect on overstory composition and cover as high-intensity fires (Hutchinson, Sutherland, & Yaussy, 2005), so effects on the herbaceous layer from a reduced canopy are expected to be more pronounced from the use of higher intensity fires.

Fire may also benefit summer herb species more than vernal species, since summer herb species are more influenced by canopy cover (Hutchinson, et al., 2005). Fires in dormant seasons (such as winter) have less of an effect on density and richness than burns in growing or active seasons (such as spring) (Schwartz & Heim, 1996;

Hutchinson , 2006;). This study differed in that neither had any effect. Elliot and Vose (2010) involved burns of a low to moderate intensity, and took place during the dormant season. Their study also found no increase in species richness of herb species. The burns in this study were only prescribed once and were of low intensity, however increased frequency or intensity of prescribed burns may lead to more significant but potentially different results. Therefore more frequent, higher intensity burns may be necessary for significant effects to occur in a mesic forest environment.

Overall results of density of herb species and species richness within sites were most affected by years. Differences in environmental conditions within each year could account for how vernal herb density and species richness significantly changed across the years of study. Light, nutrients, and moisture most regularly affect herb growth (Muller, 2014). Within these factors, variations in soil moisture could have a significant impact on vernal species of herbs. Gilliam, et al. (2006) found that fluctuations in soil moisture had a stronger effect on vernal herb diversity in forests than other factors. Overstory composition, which is known to control light availability for herb species on the forest floor, is less influential on vernal herbs because their main period of growth takes place before overstory closure (Rogers, 1982). Higher amounts of soil moisture are linked to increased herb species abundance, richness, and cover (Whittaker, 1956; Graves, Peet, & White, 2006; Hutchinson, et al., 1999). Therefore, fluctuations in soil moisture amounts within different years could have a strong influence on the growth of vernal herb species within this study.

Soil moisture levels are determined by the inflow of water, with precipitation often having the largest influence (Ma, et al., 2014). Precipitation is directly correlated

with subsequent soil moisture conditions, and Findall and Eltahir (1997) indicated that precipitation and soil moisture conditions may have a positive feedback loop. There is significant variability in precipitation over sites during the spring months of each year of this study. 2010 was the driest year, with only 16.36 cm of rain recorded from February to April 10 (the period during which herb data were collected for that year). 2011 had over twice the amount of precipitation with 34.72 cm recorded from February to April 8. 2014 had 30.73 cm of rain from February to April 7, 2015 had 43.23 cm from February to April 12. The mean value for precipitation amounts between March 1 – April 7 at the National Climactic Data Center station at Mammoth Cave, KY in the years 1981-2010 was 24.08 cm (Western Regional Climate Center, 2016) When compared to this mean, 2010 was a very dry year for that area while 2011, 2014 and 2015 were wetter years. Different amounts of precipitation could have caused significantly different soil moisture conditions within sites during each year, and coincidentally may explain the change in density and species richness of herbs across these years. Results from the pairwise comparison of data for species richness show that species richness in site 3 increased from 2010 to 2011, and from 2011 to 2015. Average species richness in site 1 decreased from 2010 to 2011, and increased from 2011 to 2015, with 2015 having the highest value of the three years. 2011 and 2015 both being wetter than average, and 2010 being drier could explain this result, especially for site 3. Analysis between years and sites was different for herb density, which only found a significant increase in average herb density of site 1 between 2010 and 2011, and a decrease between 2011 and 2015, though 2015 still had a higher value than 2010. Experimental research is needed to examine this relationship.



Another factor to consider is how precipitation is changing across the US, including the area of this study. Climate change is leading to changes in precipitation across the eastern United States, with a trend towards overall increase in the amount of wet days and annual precipitation amounts (Knapp, et al., 2008). This includes frequency and intensity of precipitation events as well, with an increase in the occurrence of intense precipitation events (Karl & Knight, 1998; Knapp, et al., 2008). Further studies have indicated that an increase in intense precipitation will be more focused in spring months, a time when rainfall is already higher (Groisman, Knight, & Karl, 2001). This could have major effects on the growth of those herb species with higher rates of reproduction in mesic environments, particularly vernal species. Results of this study showed a change in the density of several common native vernal herb species, including *Dentaria laciniata*, *Claytonia virginica*, *Viola sororia*, *Erythronium americanum*, and *Galium aparine*. Pairwise comparisons of these species all had a variety of results, with some such as *C. virginica* experiencing an increase in density from 2010 to 2011 to 2015 within site 3, while others such as *D. laciniata* decreased in average density on site 3 from 2010 to 2011 to 2015. If soil moisture conditions are the main cause of change in herb densities, then the wide variance in results could be explained by differing responses of each species to soil moisture conditions due to life histories. Shorter-lived herb species or herb species with higher reproductive rates may respond more quickly or intensely to changes in soil moisture compared to longer-lived species or species with lower reproductive rates. Another factor to consider is how herb species respond to precipitation events. Some herb species may respond differently to increased moisture brought about by occasional, very intense precipitation compared to more frequent, less

intense precipitation. The difference in these responses could account for variations in how individual herb species densities changed across years. Of the five most common herbs within sites, only *G. hederacea* did not change in density across years, but changed significantly by site. A possible factor contributing to this could be sampling time, with *G. hederacea* flowering in late spring to early summer. This is unlike the other common vernal herb species studied, which bloom in early spring. In addition, *G. hederacea* is an evergreen species that grows throughout the year, not just spring, unlike many of the other herb species studied. *G. hederacea* is also an invasive species, while the other herb species are native. It could be that *G. hederacea* responds less quickly or differently to changes outside its original range or habitat.

Another factor that could contribute to changes in herb densities and species richness is variations in topography. Site, and the Site:Year were both significant factors affecting herb density, though to a lesser degree than Year alone did. Site was also a significant factor affecting several common vernal herb species, including *Dentaria laciniata*, *Claytonia virginica*, *Viola sororia*, *Erythronium americanum* and *Glechoma hederacea*. Site 1 and Site 3, though they both were on upland sites, differed in terms of grade, distance from the forest edge, and soil type. Rogers (1982) linked microtopography and soil type to influencing growth of vernal herb species. Further study is needed on how exactly these factors influence herb growth, particularly in terms of species richness and density.

Fire treatment had little to no effect on the density and species richness of vernal herbs in this study. However, the density and species richness of vernal herbs was found to have significantly changed across years. This is mostly likely due to changes within

environmental conditions within different years. Soil moisture conditions have a strong influence over vernal herb species. Precipitation has been correlated with subsequent soil moisture conditions. There has been significant differences in precipitation across the years in this study, and these differences could correlate with the significant changes in herb species density and richness in this study. Further study would be needed to analyse the relationship between herb species and changes in precipitation.

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## Appendix A:

Burn Severity data. Site 2 and control plots excluded. Each burned plot contained two dowel rods, one placed between subplots 1, 2, 3, and 4, marked with a “D”, and the other placed between subplots 5, 6, 7, 8, and marked with a “U”. Scorch height was recorded for each dowel rod and then designated with a code. A “UB” means that the dowel rod was unburned and was coded as 1. An “X” means the dowel was burned to the point of falling into the fire. Code 2 = 0.1-27.5 cm, code 3 = 21.76-43.5 cm, code 4 = 43.6-65.25 cm, code 5 = 65.26 +.

Plot Number	Site	Replicate	Plot	Scorch Height	Coded
209-U	1	1	1	UB	1
209-D	1	1	1	UB	1
210-U	1	1	2	UB	1
210-D	1	1	2	7.50 cm	2
212-U	1	2	1	11.20 cm	2
212-D	1	2	1	9.00 cm	2
213-U	1	2	2	41.00 cm	3
213-D	1	2	2	8.00 cm	2
216-U	1	3	2	UB	1
216-D	1	3	2	18.00 cm	2
217-U	1	3	3	UB	1
217-D	1	3	3	UB	1
219-U	1	4	2	13.00 cm	2
219-D	1	4	2	UB	1
220-U	1	4	3	87.00 cm	5
220-D	1	4	3	X	5
234-U	3	1	2	UB	1
234-D	3	1	2	UB	1
235-U	3	1	3	UB	1
235-D	3	1	3	UB	1
236-U	3	2	1	X	5
236-D	3	2	1	X	5
237-U	3	2	2	UB	1
237-U	3	2	2	UB	1
239-U	3	3	1	UB	1
239-D	3	3	1	UB	1
241-U	3	3	3	UB	1
241-D	3	3	3	UB	1
243-U	3	4	2	UB	1
243-D	3	4	2	UB	1
244-U	3	4	3	87.00 cm	5



Data on Ramet Density of Herbs, 2011																	
Treatment	Plot	<i>S. pubera</i>	<i>V. sororia</i>	<i>C. virginica</i>	<i>E. americanum</i>	<i>D. ladiniata</i>	<i>As. canadense</i>	<i>G. hederacea</i>	<i>Al. canadense</i>	<i>G. aparine</i>	<i>T. sessile</i>	<i>E. bitematum</i>	<i>A. triphyllum</i>	<i>D. canadense</i>	<i>S. diphyllum</i>	<i>P. peltatum</i>	<i>R. abortivus</i>
Winter Burn	209	84	75	174	502	202	0	127	0	0	0	0	0	4	0	0	0
Spring Burn	210	0	0	198	39	334	0	75	0	0	0	0	0	0	0	0	120
Control	211	0	34	162	594	269	0	49	0	0	0	0	0	0	0	0	1
Winter Burn	212	0	61	245	659	388	0	24	14	0	0	0	0	0	0	0	3
Spring Burn	213	0	13	162	47	469	0	5	0	2	0	0	0	0	0	0	0
Control	214	0	98	194	26	402	0	16	5	2	0	0	0	0	0	0	0
Control	215	223	36	239	93	296	0	0	0	2	2	0	0	0	0	0	59
Spring Burn	216	20	40	171	0	332	0	0	0	2	0	0	0	0	0	0	120
Winter Burn	217	359	54	212	0	318	0	1	0	1	1	4	0	0	3	0	62
Control	218	75	95	204	109	244	0	16	0	5	0	64	0	0	0	0	76
Winter Burn	219	297	57	195	202	202	21	0	0	1	0	21	0	1	0	0	20
Spring Burn	220	25	26	145	265	200	0	17	0	0	1	0	0	0	3	0	6
Control	233	0	6	8	72	182	0	0	0	10	3	118	0	0	0	0	0
Winter Burn	234	0	22	71	276	90	0	0	0	2	3	0	0	5	0	0	0
Spring Burn	235	5	18	166	155	163	0	0	0	9	1	0	0	67	0	0	3
Spring Burn	236	0	10	59	189	169	0	0	0	1	0	9	0	9	0	0	0
Winter Burn	237	0	15	67	132	79	0	0	0	3	9	0	0	262	27	0	0
Control	238	0	0	80	21	82	0	15	0	7	0	0	10	130	0	22	0
Winter Burn	239	0	8	59	199	231	0	0	0	8	1	364	4	0	0	0	0
Control	240	0	11	60	314	219	0	0	0	2	0	0	10	0	0	2	0
Spring Burn	241	0	14	120	201	91	0	0	0	3	21	0	0	12	0	0	0
Winter Burn	242	0	11	42	117	53	0	0	0	1	22	2	0	293	0	1	0
Winter Burn	243	0	22	67	218	37	9	32	0	1	4	5	0	291	0	19	0
Spring Burn	244	0	26	106	239	56	8	0	0	0	5	1	0	82	0	24	0

Data for Density of Herbs, 2010																		
Treatment	Plot	<i>S. pubera</i>	<i>V. sororia</i>	<i>C. virginica</i>	<i>E. americanum</i>	<i>D. laciniata</i>	<i>As. canadense</i>	<i>G. hederacea</i>	<i>Al. canadense</i>	<i>G. aparine</i>	<i>T. sessile</i>	<i>E. biternatum</i>	<i>D. canadensis</i>	<i>S. diphyllum</i>	<i>P. peltatum</i>	<i>R. abortivus</i>	<i>C. flavula</i>	
Winter Burn	209	53	39	91	152	152	2	149	0	0	0	0	0	0	0	0	2	0
Spring Burn	210	1	54	84	24	253	0	91	0	0	0	0	0	0	0	0	12	0
Control	211	0	25	74	135	194	0	53	0	0	0	0	0	0	0	2	22	0
Winter Burn	212	0	19	93	203	231	0	66	13	0	0	0	0	0	0	3	0	0
Spring Burn	213	0	27	87	8	222	7	18	0	0	0	0	0	0	0	0	8	0
Control	214	0	57	85	11	219	0	5	0	0	0	0	0	0	0	0	0	0
Control	215	152	14	49	21	116	0	0	0	0	1	4	0	0	0	0	9	6
Spring Burn	216	18	42	49	0	218	0	11	0	0	0	0	0	0	0	0	39	0
Winter Burn	217	250	21	37	0	123	0	22	0	5	1	0	0	0	0	0	24	0
Control	218	212	59	30	43	85	9	56	0	0	0	10	0	0	0	0	9	10
Winter Burn	219	96	44	43	77	68	21	21	0	0	0	8	0	0	0	0	10	0
Spring Burn	220	240	7	39	72	92	28	19	0	0	0	0	0	3	0	0	0	0
Control	233	0	0	15	87	241	0	0	0	9	0	69	0	0	0	0	6	0
Winter Burn	234	0	5	50	141	105	0	0	0	0	0	1	1	0	0	0	0	0
Spring Burn	235	0	10	44	221	306	0	0	0	1	0	0	51	0	0	0	0	0
Spring Burn	236	0	14	68	207	211	0	0	0	1	0	5	11	2	0	0	0	0
Winter Burn	237	0	1	19	47	161	0	2	0	0	0	6	200	15	0	0	0	0
Control	238	0	1	18	54	154	0	4	0	1	0	0	159	22	18	0	0	0
Winter Burn	239	0	0	0	105	149	0	0	0	1	0	243	0	0	0	0	0	0
Control	240	0	5	0	142	264	0	0	0	0	0	0	3	0	0	1	0	0
Spring Burn	241	0	3	7	169	116	0	0	0	0	0	0	11	0	0	0	0	0
Winter Burn	242	0	6	17	76	120	0	0	0	0	0	2	303	0	1	0	0	0
Winter Burn	243	0	29	6	173	40	2	13	0	0	0	12	358	0	22	0	0	0
Spring Burn	244	0	60	0	239	85	0	0	0	2	0	5	67	40	28	0	0	0