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Oak savanna management strategies and their differential effects on vegetative structure, understory light, and flowering forbs

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ABSTRACT

High quality oak savanna communities were once abundant in the North American Midwest, but have become exceedingly rare. Where remnant savannas remain, fire suppression and resulting woody encroachment have dramatically altered vegetative structure, resulting in reduced understory light levels and precipitating declines in herbaceous understory diversity. Restoration of fire suppressed oak savannas generally involves the reintroduction of fire, but questions remain regarding the necessity and impact of mechanical woody vegetation reduction in addition to fire. We report here on initial short-term results of a long-term experiment in a remnant fire-suppressed oak savanna in Southern Michigan to compare a gradient of oak savanna management intensities including; (1) unmanaged reference plots, (2) burning alone (low management intensity), and (3) progressive mechanical thinning combined with burning (high management intensity). We measured several metrics of restoration success: understory, shrub, and canopy cover, understory light levels, understory floral resources, and flowering forb diversity, in the first two growing seasons after initiation of restoration treatments. We found that increasing management intensity largely corresponded with increased understory light availability, abundance of floral resources (i.e. forb bloom abundance and diversity), and with decreased shrub and canopy cover. Low management intensity did not increase light availability, or decrease vegetative or canopy cover relative to unmanaged references, while high management intensity achieved both management goals. Both burning alone and thinning + burning generally increased diversity of flowering forbs, where the effect was greatest with high intensity management. These increases were most pronounced in the second growing season after burning, when we saw sharp increases in richness and abundance of flowering forbs. In restored plots, the flowering forb community consisted of pre-existing shade tolerant species, native and exotic ruderals, as well as savanna indicator species. In sum, low-intensity management can achieve some restoration objectives over the short-term; however, we show a clear initial advantage of coupling thinning with burning, relative to burning alone. We suggest that these differing intensities of oak savanna restoration may be appropriate under different temporal, financial, and ecological scenarios. Our work highlights the potential for restoration of understory forb communities by low or high intensity approaches, where relict populations and/or viable seedbanks exist.

1. Introduction

Temperate savanna ecosystems are among the rarest and least-protected biomes on Earth today (Hoekstra et al., 2005). Oak savannas were once widespread in the Midwestern United States, but have all but disappeared (Nuzzo, 1986). Most of these lands have been directly converted for agricultural or residential purposes, making rehabilitation difficult and unlikely. Most remaining savannas exist as remnants in altered ecological states due to disruption of their historical disturbance regimes (Nuzzo, 1986; O'Connor, 2006; Nowacki and Abrams, 2008). Thus, restoration efforts on remnants are key to the persistence of savannas in the Midwestern landscape.

Midwestern oak savannas were formerly abundant and share structural and vegetative characteristics with both tallgrass prairie and eastern deciduous forest biomes, including well-developed herbaceous understories and scattered overstory oak trees. Spanning the ecotone between prairie and Eastern deciduous forest, oak savannas display wide variation in plant species composition, soil type, disturbance regime, and structure. A defining feature is

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the co-dominance of the overstory and understory plant community (Curtis, 1959; Packard and Mutel, 2005; Chapman and Brewer, 2008), with tree canopy cover typically ranging from 10–60% (Curtis 1959, Kost et al., 2007). Importantly, oak savanna understories are also noted for their high proportion of forbs relative to graminoids, opposite that of grassland understories (Pruka, 1994; Leach and Givnish, 1999).

The structure and biological communities of Midwestern oak savannas are maintained through disturbance, particularly frequent low-intensity surface fires that were historically largely ignited by humans (Heikens and Robertson, 1994; Wolf, 2004; O'Connor, 2006; Nowacki and Abrams, 2008). Fires act to suppress encroachment of woody vegetation, promoting a scattered canopy and the higher light levels necessary to maintain a dense herbaceous understory (Bowles and McBride, 1998; Leach and Givnish, 1999; Reich et al., 2001; Pavlovic et al., 2006). Records of regional historical fire return intervals in oak savannas are uncommon and, where available, appear highly dependent on local conditions (e.g. annual precipitation, human activity). Fire return intervals maintained by Native Americans are thought to range from one to ten years (Abrams, 1996), with documented pre-European settlement mean intervals of 2.8 (Cutter and Guyette) and 3.7 years (Dey et al., 2004; Wolf, 2004). In these studies, the majority of burns occurred during the dormant or late growing season, with occasional early season burns. European settlement and subsequent cessation of historical fire regimes resulted in a number of key changes in abiotic conditions and biological communities. Fast-growing mesophytic tree species, once marginalized by frequent fire, rapidly colonized savannas in the absence of fire. This "mesophication" process increases occurrence of mesophytic tree species, woody plant density and soil moisture, decreased light availability, and produces a shift to less-flammable litter (Nowacki and Abrams, 2008). Thus, many oak savanna remnants today exist in a fire-suppressed state with a closed canopy, dominance by mesophytic tree species, declining prevalence of oaks, a relatively thick, moisture-retaining litter layer, and reduced density and diversity of the understory plant community (Nowacki and Abrams, 2008).

The decline of oak savanna understory communities is well documented. Research from Wisconsin (Cottam, 1949), Illinois (Bowles and McBride, 1998), Iowa (Brudvig and Mabry, 2008), and the larger Eastern United States (Nowacki and Abrams, 2008) all note reductions in remnant oak savanna understory plant diversity and/or cover following fire suppression. Increased canopy cover and shifts in tree species composition following fire suppression are two of the presumed mechanisms causing this understory decline (Nowacki and Abrams, 2008). Moreover, the understory plant communities in fire-suppressed savanna remnants support more shade-tolerant species characteristic of woodland or forest, with light-loving plant species historically prevalent in savannas confined to edges, canopy openings, the seed bank, or absent altogether (Bowles and McBride, 1998; Brudvig and Mabry, 2008).

Biodiversity in oak savanna communities in the Midwest can be restored by reversing the effects of mesophication in fire-suppressed remnants (Leach and Givnish, 1999; Davis et al., 2000). An overarching goal of these efforts is to return historical savanna structure and biological diversity by decreasing canopy cover and increasing herbaceous understory plant communities (Asbjornsen et al., 2005). Prescribed fire during oak ecosystem restoration can reduce canopy and overall woody cover (Faberlangendoen and Davis, 1995, Haney et al. 2008), increase understory light availability (Kay et al., 2007), promote a dense herbaceous understory plant community (Nuzzo et al., 1996; Leach and Givnish, 1999), and facilitate recruitment of understory plant species through stimulation of the seed bank (Glasgow and Matlack, 2007). However, burning alone may not achieve some restoration objectives, such as canopy cover reduction, particularly at fire-suppressed sites where encroaching mesophytic tree species have achieved high densities and large diameters (White, 1983; Abella et al., 2004). Therefore, some managers advocate direct removal of mesophytic trees and shrubs through mechanical harvest and subsequent herbicide treatment (Nielsen et al., 2003; Brudvig and Asbjornsen, 2007; Abella, 2010). This practice can accelerate savanna restoration by more rapidly increasing understory light availability, shifting woody species composition and abundance, and facilitating the development of the understory plant community (Brudvig and Asbjornsen, 2009). However, woody vegetation removal is costly relative to prescribed fire and, if carried out too quickly, could result in stress or mortality of remaining overstory oak trees, or invasion by exotic or aggressive native understory plant species. Either of these unintended impacts could compromise the core goals of promoting characteristic savanna overstory structure and understory plant communities during restoration.

The objectives of this study were to measure the effects of two oak savanna restoration strategies on (1) structural metrics of vegetation which define savannas (i.e. 10–60% canopy cover, low shrub cover, high understory cover), (2) understory light availability, and (3) flowering response of understory forb species. This study examines the first two-years of a 10-year effort to examine the long-term ecological effects of utilizing burn only and thinning and burning management approaches to oak savanna restoration. Specifically, we monitored the effects of prescribed burning-alone, as well as tree thinning coupled with prescribed fire on understory and canopy cover, shrub layer cover, light availability, and abundance and richness of understory forb species in flower. We did not include a "thin only" treatment as previous research has demonstrated that thinning by itself may yield short-term benefits but ultimately prescribed burning is necessary for these benefits to persist (Brudvig and Asbjornsen, 2007). Forb species are important to pollinators and comprise a large percentage of the ground layer in oak savannas – both in terms of richness and abundance, yet effects of savanna management on flowering forbs is lacking (Leach and Givnish, 1999; Huffman and Werner, 2000; Pavlovic et al., 2011). We focused on forbs in bloom because flowering is necessary for sexual reproduction of forbs, flowering rates are likely to influence the recovery of relict forb populations, and because of our broader interest in the role of pollinators in ecological restoration. We hypothesized that many heliophytic (light-loving) savanna forb species are suppressed due to decades of mesophication and resultant shading, but that these effects may be ameliorated through restoration. Specifically, we predicted that with increasing management intensity, light availability, floral abundance, and richness of forbs in flower would increase, while shrub and canopy cover would decrease.

2. Material and methods

2.1. Study site

The study site was located on the ~165 ha Michigan State University MacCready Reserve in Jackson County, MI (42°07′36″ N, 84°23′38″). The reserve lies in the Jackson Interlobate Region, an area formed at the intersection of three separate glacial lobes (13–16,000 years ago). Glacial landscape features such as outwash plains and moraines, as well as ice-contact topography such as eskers, kettles, and kames characterize the region (Albert, 1995). This diversity of landscape features in the region has led to a diversity of natural communities, which are well represented at the study site. These include oak opening savannas, hillside prairies, prairie fen wetlands, and southern wet meadows (Michigan Natural Features Inventory, www.mnfi.anr.msu.edu/communities).