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Effects of dormant and growing season burning on surface fuels and potential fire behavior in northern Florida longleaf pine (*Pinus palustris*) flatwoods

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ABSTRACT

Prescribed fire is widely used to manage fuels in high-frequency, low-severity fire regimes including pine flatwoods of the southeastern USA where prescribed burning during the growing season (the frost-free period during the calendar year) has become more common in recent decades. Growing season prescribed fires address ecological management objectives that focus on increasing herb cover and decreasing shrub cover. The shift from shrub to herb dominance due to burning in the growing season corresponds to a change in surface fuels that could affect fire behavior, yet little has been done to assess the potential effects. We examined the effects of season-of-burn on shrub and herbaceous fuel layers and predicted fire behavior at replicate plots on frequently burned mesic pine flatwoods for two season-of-burn treatments (growing and dormant season prescribed fires) in two geographic regions in northern Florida. The Fuel Characteristic Classification System was used to construct a representative fuelbed for each plot at each sampling time to predict fire behavior. Predicted fire behavior was tested for correlation with measured surface fuel properties to determine if there was an effect from differences in fuels characteristics across treatments. In addition, fire temperature was measured *in situ* as a proxy for fire intensity and tested for treatment effects on the re-growth of live surface fuels. Compared to single dormant season burns, our single growing season burns caused no changes to live understory fuels and had no detectable effect on fire behavior, although predicted rate of spread and flame length were significantly reduced after all prescribed burns. Shrub cover and predicted fire behavior were, however, significantly different between geographic regions, and shrub height was significantly affected by fire temperature. Predicted fire behavior was strongly correlated with measures of the litter and herb strata. Results from this study suggest that land managers should not initially expect large changes in understory fuel properties or potential fire behavior from a shift to burning during the growing season and show that geographic location and fire intensity had significant effects on live fuels and potential fire behavior.

1. Introduction

Throughout the USA, prescribed fire is used to manage fuels (Schwilk et al., 2009; Stephens et al., 2012) and is recommended to counter the negative ecological effects of human activities, such as fire suppression and climate change, in ecosystems with high-frequency, low-severity fire regimes (Stephens and Ruth, 2005; Ryan et al., 2013). Using prescribed fire requires an understanding of how variation in its application affects ecosystem properties, fuel characteristics, and potential fire behavior (Agee and Skinner, 2005; O'Brien et al., 2010). Shifting season-of-burn from the dormant season to the growing season has been gaining attention as a treatment option because doing so can affect vegetation dynamics and produce ecological benefits (Knapp et al., 2009). In the southeastern USA, prescribed fire is widely used to control fuels, particularly understory shrubs and hardwood trees in fire-adapted pine forests (Melvin, 2012). While much research has been focused on the ecological effects of season-of-burn (e.g. Robbins and Myers, 1992), scant attention has been given to the effects on fuels and fire hazard, important considerations given that managing fire potential is often a primary goal of prescribed burning in this region (Marshall et al., 2008; O'Brien et al., 2010).

The pine flatwoods ecosystem is widespread throughout the coastal plain of the southeastern USA. When frequently burned,

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it is characterized by an open canopy of pines, most commonly longleaf pine (*Pinus palustris* Mill.), and a biologically diverse understory of herbs and shrubs (Hardin and White, 1989). Prior to European settlement, the mean fire-return interval for longleaf pine forests was 2.2–3.2 years, with a shorter median, and most fires occurred during the growing season (Bale, 2009; Henderson, 2006; Stambaugh et al., 2011). Fire frequency drives understory composition in pine flatwoods with herbs favored at shorter fire-return intervals (Brockway and Lewis, 1997). This effect is enhanced by growing season fires when fire-return intervals are less than two years, however, the magnitude of the seasonal effect appears to vary geographically (Haywood et al., 2001; Glitzenstein et al., 2003).

The use of prescribed fire in the pine flatwoods ecosystem has shifted seasonally over the past several decades. The dormant season was the preferred burning period when fire was reintroduced as a management tool in the 1940s (Stanturf et al., 2002). Burns during the dormant season were favored because dry air and predictable winds following wetting rains produced manageable fire behavior and good smoke dispersion. A more recent focus on endangered species preservation and maintenance of biological diversity has prompted land management agencies to increase the frequency of burning and extend burning operations into the growing season with the goal of reducing the shrub component and increasing abundance of bunchgrasses and other herbaceous species (Ferguson, 1998; McWhite et al., 1999). This shift in understory composition is desirable because herb-dominated understories have greater plant diversity (Glitzenstein et al., 2012), and provide habitat for the gopher tortoise (*Gopherus polyphemus*; Cox et al., 1987) and the red cockaded woodpecker (*Picoides borealis*; Van Balen and Doerr, 1978; James et al., 1997), two vulnerable keystone species (Eisenberg, 1983; Conner et al., 2004); and the bobwhite quail (*Colinus virginianus*), an important game species (Schroeder, 1985).

Manipulating season-of-burn to alter the understory has implications for potential fire behavior because the amount and structure of surface fuels differ between shrub- and herb-dominated types (Anderson, 1982). Measures of fire behavior can be high for shrub-dominated vegetation (Saglam et al., 2008; Hough and Albini, 1978; Andreu et al., 2012). Because biomass of fine-dead and volatile-live fuels accumulates rapidly, shrub-dominated fuelbeds can support intense fires that are difficult to control. In forested areas, taller shrub-dominated fuelbeds decrease the gap between surface fuels and the tree canopy, increasing the probability of crown fire. In pine flatwoods, the shrub understory component can be managed with regular prescribed burning. Without regular burning, however, the rapid growth of shrubs (Fig. 1) contributes to surface fuel levels that can support high-intensity fires (Brose and Wade, 2002; Kreye et al., 2014). In contrast, herb-dominated fuel types tend not to support high-intensity fires because herb biomass does not accumulate to the same level as shrubs and fuel height remains relatively low (Yospin et al., 2012). Herb-dominated fuel types can affect fire behavior in other respects, however. Higher surface area-to-volume (SAV) ratio and near-optimal packing of continuous herbaceous fuelbeds can support high rates of fire spread. In addition, as herbaceous fuels cure and their moisture content decreases toward the end of their phenological growth cycle, they can have a high probability of ignition.

The goal of this study was to determine how season-of-burning influences live fuel characteristics and therefore potential fire behavior in the pine flatwoods ecosystem. The objectives were: (1) to quantify the effects of prescribed burning in the dormant and growing seasons on post-burn fuel loading, cover, and height of live understory fuels, and (2) to determine the extent to which differences in post-burn live surface fuel recovery influences fire behavior in stands managed with prescribed fire in different seasons.

We hypothesized that, relative to dormant season burns, growing season burns would cause a small shift toward herbs and away from shrubs with a similarly minor decline in fire behavior. The hypothesized direction and magnitude of expected change in live understory fuels was based on results from other published experiments in similar ecosystems in the southeastern USA where the effects of dormant season and growing season burns have been compared. Although the effects were minor, single growing season burns were found to increase herb production in an upland longleaf pine forest in central Louisiana (Grelen and Epps, 1967), decrease understory hardwoods in an oak-hickory (*Quercus–Carya*) forest in central Virginia (Brose, 2010), and decrease saw palmetto (*Serenoa repens* (W. Bartram) Small) in pine flatwoods in central and southern Florida (Willcox and Giuliano, 2010). The direction and magnitude of our hypothesized shift in live understory fuels is also suggested by long-term studies of season-of-burning in fire-adapted loblolly (*Pinus taeda* L.) and longleaf pine ecosystems (Waldrop et al., 1987; Haywood et al., 2001; Glitzenstein et al., 2003). These long-term studies show that individual growing season fires cause incremental shifts that favor herbs, and when applied consistently at short intervals, in some cases, can cause a large shift from shrub- to herb-dominated understory vegetation. Relative to dormant season fires we expect predicted fire behavior following growing season fires to decline based on known differences in fire behavior between shrub- and herb-dominated fuel types, namely that herbaceous fuel loading is typically lower than shrub fuel loading which tends to reduce measures of fire intensity (Brose and Wade, 2002; Kreye et al., 2014).

2. Methods

2.1. Study area

The study area encompasses mesic, mature pine flatwoods on federally managed lands in northern Florida (Fig. 2). The climate in northern Florida is humid-subtropical (Kottek et al., 2006) and temperatures range from an average minimum of 5 °C in January to an average maximum of 33 °C in July. Average annual precipitation is 1525–1650 mm with peak rainfall in July associated with convective thunderstorm activity. Dry periods occur in October–November and April–May. Eglin Air Force Base (EAFB) is characterized by broad plateaus dissected by dendritic streams to the north and flat coastal lowlands to the south; soils in pine flatwoods are generally somewhat poorly to moderately well-drained Entisols (Overing and Watts, 1989; Overing et al., 1995). Topography of the Apalachicola National Forest and St. Marks National Wildlife Refuge (APSM) is flat and, where pine flatwoods are present, soils are commonly poorly drained sandy Spodosols (Sanders, 1981; Allen, 1991). Pine flatwoods in the study area are characterized by an overstory dominated by longleaf pine, an open midstory, and an understory of shrubs and herbs, including saw palmetto, gallberry (*Ilex glabra* (L.) A. Gray), dwarf live oak (*Quercus minima* (Sarg.) Small), Darrow's blueberry (*Vaccinium darrowii* Camp), wiregrass (*Aristida stricta* Michx.), bluestem (*Andropogon* L. and *Schizachyrium* Nees), hairy trilisa (*Carphephorus paniculatus* (J.F. Gmel.) Herb.), and silk-grass (*Pityopsis graminifolia* (Michx.) Nutt.).

2.2. Study design

Growing and dormant season burn treatments were replicated eight times across the study and evenly allocated between two geographic regions (i.e., four replicates per region; Fig. 2). Repeated measurements of understory fuels were conducted during the dormant season no more than five months before treatment, and immediately (within one month), one year, and two years post-treatment. The dormant season was defined as the