Forest Ecology and Management 409 (2018) 808–816

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Reptile and amphibian response to season of burn in an upland hardwood forest

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ARTICLE INFO

Keywords:
Amphibians
Growing-season burn
Herpetofauna
Lizard
Prescribed fire
Plestiodon fasciatus
Reptiles
Terrestrial salamanders
Season of burn

ABSTRACT

Growing-season burns are increasingly used in upland hardwood forest for multiple forest management goals. Many species of reptiles and amphibians are ground-dwelling, potentially increasing their vulnerability to prescribed fire, especially during the growing-season when they are most active. We used drift fences with pitfall traps to experimentally assess how herpetofaunal species and communities responded to early, growing-season burns, dormant-season burns, and unburned controls. We documented no adverse effects of either growing-season burns or dormant-season burns on any common herpetofaunal taxa, but capture rates of total, adult, and juvenile five-lined skinks (*Plestiodon fasciatus*) were greater following growing-season burns. Most measurements reflected little or transient change in forest structure. However, canopy cover decreased by an average of 16% in growing-season burns within four growing-seasons of burning, with some tree mortality in patches where fire temperature likely was hotter. Our study suggests that even modest reductions in canopy cover may positively affect relative abundance and reproductive success of *P. fasciatus*. We cautiously suggest that a higher mean ground-level fire temperature and the physiologically active condition of vegetation in growing-season burns interacted to damage a greater proportion of trees, resulting in more canopy thinning than in dormant-season burns. However, weather, fuel types and condition, vegetation structure, and topography interact to affect fire intensity and the level of mortality or damage to canopy trees within and among stands, regardless of season conducted. We suggest that herpetofaunal response, for the species we studied, is more closely linked to change in canopy cover than to season of burn *per se*.

1. Introduction

Prescribed burning, a common management tool in eastern deciduous forests, is most commonly conducted during dormant-season due to drier fuels and more predictable environmental conditions (Sparks et al., 2002). As burning has become a preferred tool in restoration of disturbance-adapted ecosystems, forest managers are increasingly widening the ‘burn window’ to include growing-season burns. However, little is known about how growing-season burns impact the wide diversity of wildlife taxa. Many species of reptiles and amphibians are ground-dwelling, potentially increasing their vulnerability to prescribed fire, especially during the growing-season when they are most active. Land managers need to know how season of burn affects herpetofauna to inform and direct wildlife conservation in conjunction with ecosystem restoration, or other forest management objectives.

In the southern Appalachians, many terrestrial reptile and amphibian species retreat belowground and become dormant during winter, with aboveground activity occurring primarily during the warmer spring and summer months (Camp, 1988; Fitch and von Achen, 1977; Greenberg, *unpubl. data*). Increased surface activity during spring and summer months could potentially increase amphibian and reptile vulnerability to growing-season prescribed burns. In addition, most herpetofaunal species have small home ranges and poor dispersal abilities, potentially limiting their ability to evade fire. For example, the home range of Plethodontid salamanders in the southern Appalachians is estimated to be $\leq 14.5\,m^2$ (Merchant, 1972). Whereas box turtles (Howey and Roosenberg, 2013; Melvin, 2017) and some snakes (Beaupre and Douglas, 2012) may be vulnerable to fire-caused injury or mortality, many herpetofaunal species may exhibit adaptive behaviors in response to fire that could minimize mortality (O’Donnell et al.,

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https://doi.org/10.1016/j.foreco.2017.12.016
Received 19 September 2017; Received in revised form 2 December 2017; Accepted 9 December 2017
0378-1127/ Published by Elsevier B.V.

2016; Pitt et al., 2013). Although difficult to gauge and poorly studied, evidence suggests that direct mortality from fire is rare, and unlikely to affect most reptile and amphibian species at the population level (Harper et al., 2016).

In contrast, fire-caused change to forest structure may indirectly influence relative abundance of some reptile and amphibian species by altering microhabitats such as availability of leaf litter or coarse woody debris, or microclimatic conditions such as light, moisture, and temperature at the forest floor. Research shows that low-intensity dormant-season prescribed burns in upland hardwood forest generally have a negligible impact on herpetofauna (e.g., Greenberg et al., 2016, 2017; O'Donnell et al., 2015; Perry et al., 2009; Raybuck et al., 2015), whereas high-severity dormant-season burns that kill overstory trees result in greater relative abundance of lizards (Greenberg et al., 2017; Fouts et al., 2017). Because of seasonal differences in fuel condition, air and fire temperature, and physiological activity of vegetation, dormant-season and growing-season burns are likely to differ in their effects on forest structure, and thereby indirectly affect relative abundance of some herpetofaunal species.

Reptiles and amphibians are important components of biological diversity, and play important ecological roles as predator and prey (Greenberg et al., 2017). In general, terrestrial reptiles and amphibians differ considerably in their microhabitat requirements due to phylogenetic and physiological differences (Moorman et al., 2011). Reptiles have dry scaly skin, require warmer temperatures associated with higher light levels for thermoregulation and egg incubation, and lay their eggs on land (Moorman et al., 2011). In contrast, most amphibians have moist, permeable skin that increases their susceptibility to desiccation; they require moist microenvironments, and water bodies for egg deposition (Moorman et al., 2011). These physiological distinctions between reptiles and amphibians likely influence their response to altered forest structure and microclimate after fire or other disturbances (Moorman et al., 2011). Despite their importance, relatively little is known about how season of burn, and especially growing-season burns, affect herpetofauna in upland hardwood forests. To the best of our knowledge, our study is the first to experimentally compare season of burn effects on relative abundance of reptile and amphibian species, as measured by surface activity.

We used a replicated, completely randomized design with repeated measures to experimentally assess how herpetofaunal species and communities responded to early growing-season burns (GSB), dormant-season burns (DSB), and controls (C). Our objective was to determine if, and how, species richness or capture rate of common reptile and amphibian taxa differed among the season of burn treatments.

2. Methods

2.1. Study area

Our study was conducted at the Bent Creek Experimental Forest, a part of the Pisgah National Forest in Buncombe County, North Carolina (Fig. 1). Located within the Southern Appalachian region of western North Carolina, the area encompasses 2500 ha with annual precipitation averaging 140 cm (Owenby and Ezell, 1992) and elevations ranging from 700 m to 1070 m (McNab et al., 2004). Monthly average temperatures range −4.2° to 8.6 °C in January, to 16.0° to 28.9 °C in July (Owenby and Ezell, 1992). Common tree species in this upland hardwood forest site include black oak (*Quercus velutina*), chestnut oak (*Q. montana*), scarlet oak (*Q. coccinea*), white oak (*Q. alba*), sourwood (*Oxydendrum arboreum*), red maple (*A. rubrum*), dogwood (*Cornus florida*), and interspersed shortleaf pine (*Pinus echinata*) (McNab et al., 2004).

2.2. Study design

We established nine, approximately 5 ha (range 3.5–7.0) units (two treatments and control, three replicates each) within the Bent Creek Experimental Forest (Fig. 1). Units were separated by fires lines as needed. All units were comprised of mature (> 70 years old), oak-dominated closed canopy stands, and portions of each were within 500 m of perennial streams. Randomly assigned treatments were: (1) growing-season prescribed burn (GSB), (2) dormant-season prescribed burn (DSB), and (3) control (C). We defined growing-season based on vegetation phenology, including the presence of new, small leaves on several deciduous tree species such as white oak, dogwood, yellow poplar (*Liriodendron tulipifera*), and red maple, and full flowering by dogwood and several oak species. We defined dormant-season as the absence of live leaves on any deciduous tree species. We conducted the three growing-season burns on 26 April 2013, and the three dormant-season prescribed burns on 5 March 2014.

2.3. Forest structure and fire temperature measurements

We tagged all live overstory trees ≥25 cm diameter at breast height (dbh) within three, 0.05 ha, randomly located, permanent circular vegetation plots separated by > 30 m, within each treatment unit; we also tagged live midstory trees ≥5 cm and < 25 cm dbh within a 0.01 ha subplot concentrically nested within the 0.05 ha plot. We recorded status (live or dead) of all tagged trees each year (2013–2016) to assess treatment effects on live tree density. We measured additional forest structure variables in GSB and C during summer 2013, and in DSB, GSB, and C in summers 2014, 2015, and 2016. We measured percent cover of shrubs (woody understory) and leaf litter depth along each of four 15 m transect lines. Transects originated from a center line bisecting each unit, at a randomly chosen distance along the center line, oriented in a randomly selected perpendicular direction out. We recorded 'start' and 'stop' distance for shrubs along each transect, summed the total distance, and divided the sum by the transect length to obtain percent cover. We used average percent cover across all transects within treatment units for data analyses. We measured litter depth at 7.5 m and 15 m along each transect line. We used a spherical densiometer at the center bucket of each trapping array in each unit (see Section 2.4) to measure percent canopy cover. We measured fire temperatures at ground level using temperature-sensitive paints on tags placed at two locations, 8 m apart, in each of the three vegetation plots spaced throughout each GSB and DSB unit.

2.4. Herpetofaunal sampling

We installed two drift fence arrays in each GSB and C unit in 2013. Arrays were located at least 35 m from unit boundaries and ≥75 m apart using a randomly chosen direction and distance (0–50 m) perpendicular to a center transect bisecting each unit. In 2014, a third array was added to each GSB and C unit, and three arrays were established in DSB (Fig. 1). We determined the location of the third array in each unit using a randomly chosen azimuth from the center bucket of each second array, and set 75 m apart. We constructed arrays with three 7.6 m, 50 cm high sections of aluminum flashing positioned at approximately 120° angles (in a "Y" configuration), with one, 19-l bucket buried at the center, and at the end of each "arm," for a total of four pitfall traps per array. We placed a double-ended funnel trap, constructed from aluminum screening, along both sides of each arm for six funnel traps total per array. We drilled holes in the bottoms of pitfalls to prevent flooding. We shaded all traps with a small board, and placed a sponge in pitfall traps that was moistened as needed to provide cover and humidity for captured animals; we additionally placed a small piece of styrofoam in buckets that were frequently flooded, for flotation.

We identified, weighed, measured (snout-vent and total length), and sexed (when possible) all reptiles and amphibians. We marked animals by year and treatment by toe-clips (lizards, frogs, and salamanders), scale-clips (snakes), or scute-notching (turtles). We trapped during late