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Amphibian and reptile responses to thinning and prescribed burning in mixed pine-hardwood forests of northwestern Alabama, USA

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ABSTRACT

We evaluated the response of amphibians and reptiles to two levels of prescribed burning and three levels of thinning using a field experiment consisting of a before–after, control-impact, and factorial complete block design over a four year period in the William B. Bankhead National Forest located in northwestern Alabama. We captured 2643 individuals representing 47 species (20 amphibians and 27 reptiles) during 3132 trap nights. Pre-treatment captures varied widely for both amphibians and reptiles among the stands designated for management, which was likely due to forest structural changes caused by tree mortality resulting from Southern Pine Beetle (*Dendroctonus frontalis*) infestations. Within each amphibian and reptile species assemblage, we observed species-specific associations with specific treatments and environmental characteristics. In regards to individual species responses, Eastern Fence Lizards (*Sceloporus undulatus*) increased in thin-with-burn treatments and Green Anoles (*Anolis carolinensis*) tended to increase in all thinned stands. North American Racers (*Coluber constrictor*) increased in thin-only plots primarily during the second post-treatment year. Mississippi Slimy Salamander (*Plethodon mississippi*) captures tended to decrease in all treatment stands throughout the study period, which may been due to either drier environmental conditions during post-treatment sampling or natural population cycling. Pool-breeding amphibian captures were more likely related to the hydroperiod of aquatic breeding environments within 290 m of survey locations rather than forest treatments. Our results illustrate that forest restoration through tree thinning can positively influence certain reptile species with limited impacts on amphibians in upland, pine-dominated forests of northern Alabama. However, as our forest stands are scheduled to be burned every 3–5 years, continued monitoring is necessary to understand the impacts of repeated disturbances.

1. Introduction

Ecological disturbances are events that disrupt ecosystem, community, or population structure and change resource and substrate availability in the physical environment (White and Pickett, 1985). Understanding the relationship between disturbances and animal responses is essential for longterm species conservation, and factors such as spatial and temporal scale, frequency, and intensity all play important roles in determining species responses to disturbance (Petraitis, 1989). Anthropogenic disturbances (e.g., fragmentation, forest conversion, disturbance suppression) not consistent with an ecosystems disturbance history may have long-lasting negative impacts on species conservation because they alter habitat conditions in a manner inconsistent with the environmental conditions of which particular species has evolved (Turner et al., 1989). In areas where the historical patterns of disturbance have been disrupted by anthropogenic means, management practices such as burning and tree removal can be used as a surrogate for stochastic disturbance events to increase habitat connectivity and maintain or restore focal habitats (Drever et al., 2006).

There has been heightened interest in the response of amphibians and reptiles to disturbances, including forest management (Hawkes and Gregory, 2012; Russell et al., 2004; Semlitsch et al., 2009; Steen et al., 2010), which is most likely due to the importance of herpetofauna in ecological food webs (Fitch, 1949; Burton and Likens, 1975; Wyman, 1998) and the apparent worldwide declines of these species (Gibbons et al., 2000; Stuart et al., 2004). Due to the range of impacts from forest management, it is important to consider the type of management strategy when evaluating amphibian and reptile responses. With respect to amphibians, clearcut harvesting has been shown to have the greatest negative impacts to terrestrial plethodontid salamanders (e.g., Homyack

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and Haas, 2009; Karraker and Welsh, 2006; Knapp et al., 2003; Perkins and Hunter, 2006) due to alteration of environmental characteristics that increase the risk of dessication. Pool-breeding amphibians that have evolved in forested ecosystems with a relatively long time between disturbances are also particularly sensitive to the environmental changes caused by clearcutting forest management (Fredenfields et al., 2011; Patrick et al., 2006; Semlitsch et al., 2009). The effects of even-age shelterwood harvesting (Harpole and Haas, 1999; Knapp et al., 2003) and thinning operations (Naughton et al., 2000; Grialou et al., 2000) on plethodontid salamanders appear to be species-specific, whereas uneven-aged management, such as group and single tree selection, either has minimal (Messere and Ducey, 1998; McKenny et al., 2006) or negative effects (Cromer et al., 2002; MacCracken, 2005). Although fewer studies have evaluated reptile response to forest management practices compared to amphibians in the eastern and southeastern United States (Greenberg, 2001), reptiles tend to exhibit species-specific responses to most tree harvesting operations (e.g., Adams et al., 1996; Greenberg and Waldrop, 2008; Renken et al., 2004; Steen et al., in press a) and generally benefit from management and disturbance conditions that mirror the ancestral habitat conditions in which a given species has evolved (Steen et al., 2010, in press b).

Studies examining herpetofaunal responses to prescribed burning in the eastern US have generally focused on certain ecoregions (e.g., southeastern Coastal Plain; e.g., Bishop and Haas, 2005; Schurbon and Fauth, 2003; Means et al., 2004) or species groups (e.g., amphibians, Ford et al., 2010; Russell et al., 2004). Overall, prescribed fire appears to have negative short-term effects on amphibians that inhabit ecosystems that are not fire prone (Cole et al., 1997; Kirkland et al., 1996; Mcleod and Gates, 1998) or forest stands where the natural fire regime has been suppressed (Schurbon and Fauth, 2003; Means et al., 2004). Other studies have found that fire has negligible impacts (Ford et al., 1999; Moseley et al., 2003; Greenberg and Waldrop, 2008) or short-term positive effects (Mushinsky, 1985; Wilgers and Horne, 2006) on certain amphibian species. Prescribed burning appears to have either positive impacts for some reptile species (Moseley et al., 2003; Wilgers and Horne, 2006; Greenberg and Waldrop, 2008; Perry et al., 2012) or no measurable impacts (Mcleod and Gates, 1998). In longleaf pine ecosystems of the southeast, prescribed burning is essential to maintain habitat for herpetofauna native to these ecosystems (Russell et al.,1999; Means et al., 2004; Yager et al., 2007). The disparity of amphibian and reptile species responses to fire disturbance is primarily related to whether a species has evolved in an ecosystem that experiences periodic disturbances through fire (Pilliod et al., 2003; Means et al., 2004; Steen et al., 2010). However, our knowledge of herpetofaunal responses to fire throughout most areas of the United States remains insufficient (Bury, 2004) and inconsistencies among studies including fire characteristics (e.g., intensity, fire return interval), specific taxa examined, and study design make it difficult to compare management implications among studies (Russell et al., 1999).

Most studies of herpetofaunal responses to forest management have taken a retrospective approach without data from pre-harvest conditions (Russell et al., 2004). The lack of pre-treatment data limits study inference and effective evaluation of forest management practices for ecosystem restoration and wildlife habitat management. In addition, few studies have evaluated the impacts of simultaneous thinning and prescribed burning forest management on amphibians and reptiles. In this study, we took a large-scale, replicated, stand-level approach to evaluate herpetofaunal responses to forest management practices (thinning and prescribed burning) as a part of a larger study evaluating ecosystem response to forest restoration. Because forest thinning results in canopy cover reduction and increased air and soil temperatures, we expected to see positive changes (i.e., increases in abundance) for many reptile species, specifically in thinning treatments. Additionally, we expected that amphibian responses would decline greatest in thin with burn treatments due to the simultaneous reduction of canopy cover and the forest litter layer. Overall, we predicted that the impacts of forest restoration on amphibians and reptiles would be related to the behavioral and physiological adaptations (e.g., thermoregulation, moisture requirements) that particular species have acquired in relation to the disturbance history of the southern Cumberland Plateau.

2. Materials and study area

2.1. Study area

We conducted this study in the northern portion of the William B. Bankhead National Forest (BNF), located in Lawrence, Winston, and Franklin Counties of northwestern Alabama (Fig. 1). The BNF is a 72,800 ha multi-use forest located along the highly dissected portion of the southern Cumberland Plateau (Smalley, 1982; Gaines and Creed, 2003). Soils within this region are typically composed of Hartsells-Rock and limestone-Hector (Smalley, 1982). Mixed forests of the southern Cumberland Plateau tend to be dominated by oak-hickory forest types (McWilliams, 1991) except in areas where pines were planted for commercial purposes. Loblolly Pine (*Pinus taeda*), which is a native tree species in the southeastern United States, was used to re-establish forest conditions in abandoned agricultural and heavily timbered areas during the 1930s (Gaines and Creed, 2003). Reforestation efforts along with natural growth have resulted in 31,600 ha of *P. taeda* throughout the BNF (Gaines and Creed, 2003). For the past decade, Southern Pine Beetle (*Dendroctonus frontalis*) infestations have affected *P. taeda* stands, producing large numbers of standing dead trees and increased fuel loads, elevating the risk of damaging wildfires. In 2003, the BNF initiated a forest restoration plan (FRP) to reduce wildfire risk and promote growth of natural upland, hardwood forest communities through tree thinning and prescribed fire (Gaines and Creed, 2003). The BNF's FRP mirrors regulations in the Healthy Forest Restoration Act, which authorizes advanced vegetation management projects when specified conditions (e.g., existence of insect or disease epidemic) pose a threat to ecosystem health (Healthy Forest Restoration Act, 2003). In 2004 the BNF began a partnership with Alabama A&M University to evaluate the impacts of restoration strategies (i.e., thinning and burning) on the overall forest ecosystem through a multi-disciplinary (i.e., wildlife, soils, vegetation, molecular studies, and human dimensions) approach.

The forest stands examined in this study were located on upland sites composed of loblolly pine 25–50 years of age that also possessed a hardwood component (Gaines and Creed, 2003; Schweitzer and Tadesse, 2004). At the time of this study, these stands had not been harvested for approximately 30 years and each stand had varying levels of damage from *D. frontalis* (Gaines and Creed, 2003).

2.2. Experimental design and forest treatments

Our experiment consisted of a before-after, control-impact (BACI), complete block design with a 2×3 factorial arrangement of three thinning levels (no thin, 11 $m^2\ ha^{-1}$ residual basal area [BA], and 17 $m^2\ ha^{-1}$ residual BA) and two burn levels (no burn and burn), which resulted in six treatments that included a control [no thin and no prescribed burn], burn [prescribed burn and no thin], light thin [17 $m^2\ ha^{-1}$ BA retention and no burn], heavy thin [11 $m^2\ ha^{-1}$ BA retention and no burn], light thin with burn [17 $m^2\ ha^{-1}$ BA retention with prescribed burn], and heavy thin