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Effects of fuel reduction treatments on movement and habitat use of American toads in a southern Appalachian hardwood forest

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ABSTRACT

Prescribed fire is a commonly used management technique for maintaining fire-adapted ecosystems, yet empirical data regarding its effects on amphibians are limited and contradictory. Anurans (frogs and toads) may be the amphibian taxa most negatively affected by fire due to their extensive use of the forest floor; however, short-term abundance studies suggest that terrestrial toads (e.g., *Anaxyrus* [*Bufo*] *americanus*) may benefit from fire-based ecosystem management. We used radio-telemetry to examine the effects of prescribed fire on movements, home range characteristics, mortality, and habitat selection of *A. americanus* in a southern Appalachian upland hardwood forest. We tracked 26 adult *A. americanus* between 27 January and 30 May 2012. Toads exhibited high non-breeding site fidelity and traveled 993.5 m (±265.9 m) mean (±SD) route distance between the breeding ponds and the last recorded location within their summer habitat. We found no evidence of direct mortality of *A. americanus* from a prescribed fire that occurred on 13 February 2012. Forward stepwise discriminant analysis (DA) revealed that the availability of coarse woody debris (CWD) was a significant discriminator between microhabitats used (i.e., location plots) and random plots (Wilk's lambda = 0.9852, $F_{1,\ 661} = 9.9414$, $p = 0.002$). Forward stepwise DA revealed that burned and unburned location plots were significantly different (Wilk's lambda = 0.2713, $F_{1,\ 221} = 593.6863$, $p < 0.001$) based on the percent of plot ground cover comprised of charred material (%char). When %char was excluded from the analysis due to its short-term nature, the percent of plot ground cover comprised of deciduous leaves, a cover item commonly used by toads in unburned locations, was the variable with the most discriminatory power (Wilk's lambda = 0.4243, $F_{1,\ 221} = 299.8741$, $p < 0.001$). Toads maintained greater distances from CWD in the unburned (mean ± SD = 119.50 ± 109.64 cm) than in the burned locations (mean ± SD = 86.05 ± 104.81 cm; $\chi^2_1 = 9.7055$, $p = 0.002$). Our results indicate that prescribed fire as implemented in this study did not cause direct mortality, nor did it appear to inhibit migratory movements of adult *A. americanus*. However, fire reduced the diversity and availability of refugia, especially deciduous leaves, though the availability of alternative cover objects (e.g., CWD) in burned treatments allowed toads to inhabit those areas, suggesting the importance of noncombustible or semi-permanent refugia for *A. americanus* in fire-managed forests.

1. Introduction

Fire has been a predominant force influencing the structure and function of many ecosystems (Noss, 1989; Spetich et al., 2011). Methods of prescribed burning have been developed to restore and maintain native fire-adapted ecosystems (Stanturf and Madsen, 2002). Fire as a management tool is commonly used to maintain a specific ecosystem type (Boyer and White, 1990; Waldrop et al., 1992), enhance habitat for wildlife (Kern et al., 2012), reduce fuel loads and the associated risk of damaging wildfire (McCandliss, 2002; Agee and Skinner, 2005; Agee and Lolley, 2006; Waldrop et al., 2008), and eradicate exotic or invasive species (Higgins et al., 1989; Miller et al., 1999; Miller, 2003; Kyser et al., 2008). Numerous empirical studies and reviews conducted to elucidate the effects of fire on wildlife have yielded equivocal results that were largely dependent on species, life history, and fire frequency, extent, and intensity (Russell et al., 1999; Ford et al., 2000; Moritz et al., 2011). Vegetation responses to fire largely structure long-term population responses for many wildlife species, but the immediate effects of a burn are less understood (Russell et al., 1999). Movement and habitat selection studies of wildlife species in response to fire are rare and most wildlife-fire studies assess species presence or population-level changes. Among vertebrates,

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birds and mammals are best studied in relation to fire; until recently little information was available for reptiles and amphibians (Russell et al., 2009; Zwolak, 2009).

Amphibians may be vulnerable to the negative effects of fire due to their limited vagility and susceptibility to desiccation, a characteristic associated with their dependence on moisture and their sensitive, permeable skin (Pilliod et al., 2003; Greenberg and Waldrop, 2008). However, fire-maintained ecosystems, such as longleaf pine savannas, harbor a variety of amphibian species considered habitat specialists, demonstrating that fire in some ecosystems can enhance amphibian habitat and, by extension, populations (Means, 2006). Studies examining the effects of prescribed fire on amphibians report conflicting results which may reflect differences in species' life histories in relation to fire, but may also in part be due to limitations associated with study design (Bury, 2004; Greenberg and Waldrop, 2008; Matthews et al., 2010). For example, many relevant studies have been limited to comparisons of pre- and post-fire abundance and/or richness estimates (e.g., Kirkland et al., 1996; Schurbon and Fauth, 2003; Greenberg and Waldrop, 2008; Matthews et al., 2010). Because many prescribed burns are implemented in the winter or spring, pre-and post-burn amphibian sampling is often conducted in the fall prior to and in the summer following the burn (e.g., Ford et al., 1999; Greenberg and Waldrop, 2008). The results of such studies may be confounded by seasonal differences in abundance and/or detection rates as many amphibians undergo seasonal migrations and changes in activity states (e.g., torpor; Conant and Collins, 1998; Wells, 2007). Furthermore, the short-term duration of abundance and richness studies will not elucidate the longer-term effects of fire that may result from indirect impacts (e.g., the effects of changes in the distribution of fine-scale structure that serve as amphibian habitat; Matthews et al., 2010; Perry et al., 2012). Complimentary studies that examine amphibian movement patterns, use of space, and post-fire habitat selection provide critical information regarding longer-term and/or sublethal effects (e.g., behavioral response to disturbance) of prescribed fire on amphibians, yet such studies are rare (but see Guscio et al., 2008; Hossack et al., 2009).

Anurans (i.e., frogs, toads) may be among the amphibian taxa most likely affected by fire as many anuran species travel extensively across the forest floor and occupy shallow burrows or cavities during times of inactivity (Baldwin et al., 2006; Elliott et al., 2009). Research targeting the effects of fire on anurans has shown that fire may have no effect, positive effects, or negative effects. For example, Moseley et al. (2003) found no significant differences in anuran abundance, diversity, or richness between burned and unburned bottomland hardwood forest in the upper Coastal Plain of Georgia. Kirkland et al. (1996) found that amphibian abundance, driven to a great extent by the presence of American toads (*Anaxyrus* [*Bufo*] *americanus*), was greater in a burned than in an unburned oak forest in Pennsylvania. However, because the burn was the result of wildfire, Kirkland et al. (1996) did not have pre-burn capture data to establish whether the observed patterns of amphibian abundance were preexisting or a result of the fire. The effects of fire on boreal toad (*Anaxyrus boreas*) breeding habitat revealed that *A. boreas* selected wetlands subjected to higher severity fires over wetlands exposed to lower severity fires (Guscio et al., 2008; Hossack et al., 2009). The authors concluded that the selection of wetlands subjected to higher severity fires may have been due to possible fitness benefits (e.g., higher growth rate, greater fertility) associated with higher burrow temperatures observed in the wetlands subjected to higher severity burns. In contrast, Humphries and Sisson (2012) found that a gopher frog (*Lithobates capito*) undergoing spring migration from its breeding habitat suffered direct mortality from a prescribed burn in North Carolina.

Fire played a primary role in shaping the species composition and structure of hardwood forests of the eastern United States for thousands of years (Spetich et al., 2011). In the southern Appalachian Mountains, oak-dominated hardwood forests were historically common due to the frequent fires that occurred as a result of Native Americans' activities (Waldrop et al., 2008). Fire resulted in open woodland and early successional forest habitats (Waldrop et al., 2008). However, land use changes and fire suppression policies resulted in altered species composition, denser forests, and higher fuel loads that increased the likelihood of catastrophic wildfire (Spetich et al., 2011). One of the best documented cases of the use of forest management techniques, including prescribed fire, to restore open woodland habitats and decrease fuel loads in the southern Appalachian Mountains is the result of the National Fire and Fire Surrogate (NFFS) study. The NFFS study is a nationwide program designed by an interdisciplinary team of government, university, and private scientists and land managers to quantify the ecological and economic effects of fire across a variety of forest types (Youngblood et al., 2005). The goals for the southern Appalachian Mountains NFFS site are to decrease the severity of wildfires through fuel reduction, increase oak regeneration, and improve wildlife habitat including creating early successional habitat (Waldrop et al., 2008). These goals are expected to be achieved by restoring open woodland habitats through prescribed fire, mechanical understory removal, and a combination of the two techniques (Waldrop et al., 2008). The NFFS program provides the opportunity to study the effects of forest management techniques, used alone and in combination, on a variety of species including amphibians. Previous studies at the southern Appalachian Mountain NFFS site revealed no differences in relative abundance of amphibian species with the exception of *A. americanus*, following mechanical understory removal and a prescribed burn (Greenberg and Waldrop, 2008). *A. americanus* were more abundant in treatments subjected to fire, but the authors warned that the result may not have been an effect of treatment but rather proximity to breeding habitat and study timing corresponding with juvenile dispersal as the majority of individuals captured were juveniles (Greenberg and Waldrop, 2008). A subsequent study following a second prescribed fire yielded no significant differences in capture rates among treatments for all anuran species pooled or *A. americanus*, but lower salamander abundance in treatments that received both mechanical understory removal and prescribed fire relative to control and burn-only treatments (Matthews et al., 2010). As a third prescribed fire was scheduled for 2012, we sought to extend these studies by examining the effects of fuel reduction treatments on the movements, home range, mortality, and habitat selection of the most abundant and terrestrial anuran species at the site, *A. americanus*. As toads are habitat generalists, we predicted that toads would not avoid burned areas as they moved through the landscape. As toads are relatively hardy to arid conditions and have behavioral adaptations that would allow them to avoid and survive low intensity fires, we predicted that few, if any, toads would suffer direct mortality from fire. We predicted that habitat selection analyses would reveal that toads may select for microhabitat features (e.g., refugia) that provided security from predators and/or allowed them to better regulate their physiological status and that these features may differ between burned and unburned locations. As in all fine-grained radio-telemetry analyses, we sought to add to general natural history and movement knowledge, and apply that to forest management.

2. Methods

2.1. Study area

The Green River Game Land (GRGL), Polk County, North Carolina (35°17′9″N, 82°19′42″W), located in the southern Appalachian Mountains, is a 5841-ha mixed-use recreation area. The area is pri-