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Reptile and amphibian response to oak regeneration treatments in productive southern Appalachian hardwood forest

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ABSTRACT

Forest restoration efforts commonly employ silvicultural methods that alter light and competition to influence species composition. Changes to forest structure and microclimate may adversely affect some taxa (e.g., terrestrial salamanders), but positively affect others (e.g., early successional birds). Salamanders are cited as indicators of ecosystem health because of their sensitivity to forest floor microclimate. We used drift fences with pitfall and funnel traps in a replicated Before-After-Control-Impact design to experimentally assess herpetofaunal community response to initial application of three silvicultural methods proposed to promote oak regeneration: prescribed burning; midstory herbicide; and shelterwood harvests (initial treatment of the shelterwood-burn method) and controls, before and for five years post-treatment. Species richness of all herpetofauna, amphibians, reptiles, frogs, salamanders, or snakes was unaffected by any treatment, but lizard species richness increased in the shelterwood harvest. Capture rate of total salamanders decreased post-harvest in shelterwood units after a 2–3 year delay; *Plethodon teyahalee* decreased post-harvest in shelterwoods, but also in control units. In contrast, capture rate of total lizards and *Plestiodon fasciatus* increased in shelterwood stands within the first year post-harvest. Prescribed burn and midstory herbicide treatments did not affect any reptile or amphibian species. A marginally lower proportion of juvenile to adult *P. teyahalee*, and a higher proportion of juvenile *P. fasciatus* in shelterwood than control units suggested that heavy canopy removal and associated change in microclimate may differentially affect reproductive success among species. Our study illustrates the importance of longer-term studies to detect potential changes in herpetofaunal communities that may not be immediately apparent after disturbances, and highlights the importance of including multiple taxa for a balanced perspective when weighing impacts of forest management activities.

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1. Introduction

Silvicultural methods often are used to facilitate forest restoration goals, but the resulting changes in forest structure may differentially affect vertebrate taxa. Variable responses by different taxa correspond with the type and intensity of disturbance and changes in macro- and microhabitat conditions such as canopy cover, leaf litter, shade, ground-level temperature, and moisture (DeMaynadier and Hunter, 1995; Moorman et al., 2011). Response to silvicultural disturbances are also likely to differ among taxa with different life history and microclimate requirements (Moorman et al., 2011). For example, shelterwood harvests or high-severity burns that substantially reduce canopy cover provide habitat for some early successional bird species (Askins, 2001; Greenberg et al., 2013) and butterflies and other pollinating insects (Campbell et al., 2007; Haddad and Baum, 1999; Lanham and Whitehead, 2011; Whitehead, 2003), but changes in the forest floor microclimate may negatively affect some salamander species (see DeMaynadier and Hunter, 1995; Matthews et al., 2010). Because of their abundance (Burton and Likens, 1975; Semlitsch et al., 2014), their role as predator and prey (Pough et al., 1987), and sensitivity to changing forest conditions, salamanders have been suggested to be indicators of overall ecosystem health

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(e.g., Welsh and Droege, 2001). A balanced metric of overall forest condition(s) should include a diverse suite of taxa with different habitat requirements rather than salamanders alone.

Restoration of structure and function of mixed-oak (*Quercus* spp.) forest is a focal issue of forest land managers in the eastern United States. Widespread oak regeneration failure – the failure of oak seedlings or saplings to attain canopy status- is problematic, especially on intermediate and highly productive sites after canopy release because of competition from faster-growing species such as yellow-poplar (*Liriodendron tulipifera*) (Aldrich et al., 2005). Historically, mostly anthropogenic disturbances such as frequent burning, livestock grazing, loss of American chestnut (*Castanea dentata*), and widespread logging may have promoted understory light conditions conducive to oak development (Abrams, 1992; McEwan et al., 2011), and have been largely eliminated (Greenberg et al., 2015). Silvicultural treatments to facilitate oak forest restoration involve altering forest structure to change light conditions and competition from other hardwood tree species to promote the growth of oak seedlings before canopy release, giving them a head-start against faster-growing competition.

Amphibians (class *amphibia*) and reptiles (class *reptilia*) are phylogenetically, physiologically, and ecologically distinct from one another and, therefore, should respond differently to changes in forest structure following restoration practices (Moorman et al., 2011). A growing body of literature suggests that heavy canopy removal and associated lighter, drier and warmer microclimate with reduced leaf litter cover or depth adversely affect salamander populations (see DeMaynadier and Hunter, 1995; Moorman et al., 2011) and micro-distribution (O'Donnell et al., 2015) of plethodontid salamanders. In contrast, silvicultural treatments that retain canopy cover do not appear to adversely affect salamander abundance (e.g., Harpole and Haas, 1999; Homyack and Haas, 2009). Several studies show that even one (Ford et al., 1999; Greenberg and Waldrop, 2008) or two (Matthews et al., 2010) low-severity winter prescribed burns, have little effect on salamanders. Typically, prescribed fire and other midstory treatments in upland hardwood forest do not eliminate canopy cover, coarse woody debris, or duff, which provide cover and ameliorate forest floor temperature fluctuations and moisture.

Reptile response to heavy forest canopy reduction is less studied, but some research suggests that lizards in particular may increase in sites with reduced canopy cover due to natural disturbance (Greenberg, 2001) or high-severity fire (Matthews et al., 2010). The majority of studies examining herpetofaunal response to silvicultural disturbances focus on plethodontid salamanders, likely because they are common and easy to capture compared with many other species. Yet, more comprehensive study of how silvicultural treatments affect reptiles and a wider range of amphibians is needed to direct wildlife conservation in conjunction with ecosystem restoration or other forest management objectives.

We used a replicated Before-After-Control-Impact (BACI) design to experimentally assess how herpetofaunal species and communities responded to initial application of three silvicultural methods proposed to promote oak regeneration: prescribed burning; midstory removal with herbicide (henceforth referred to as 'midstory herbicide;' initial treatment of the oak shelterwood method (Loftis, 1990); and shelterwood harvest (initial treatment of the shelterwood-burn method; Brose et al., 1999) and controls, prior to treatments (2008) and for five years (2010–2014) after initial treatments were fully implemented. Our objective was to determine if, and how, species richness or capture rate of reptiles and amphibians differed before and after treatments, or among treatments and controls. Regional Oak Study installations using the same experimental design and intended to test the same treatments (Keyser et al., 2008) are also located in the Ozark Highlands of Missouri (O'Donnell et al., 2015) and the Cumberland Plateau in Tennessee (Cantrell et al., 2013).

2. Methods

2.1. Study area

Our study was conducted in Haywood County, North Carolina on Cold Mountain Game Land (CMGL), which encompassed 1333 ha of second growth, upland mixed-oak forests with elevations ranging from 940 to 1280 m. CMGL was managed by the North Carolina Wildlife Resources Commission for diverse wildlife habitat and was located in the Blue Ridge Physiographic Province. Terrain was mountainous with gentle to steep slopes with predominant overstory trees of oak, hickory (*Carya* spp.), and yellow-poplar. Species composition in the midstory consisted primarily of shade-tolerant species, including sourwood (*Oxydendrum arboreum*) flowering dogwood (*Cornus florida*) silverbell (*Halesia tetraptera*) blackgum (*Nyssa sylvatica*), and red maple (*Acer rubrum*). The climate was characterized by warm summers and cool winters and precipitation averaged 1200 mm annually.

2.2. Study design

In 2008, we established five, 5-ha units (approximately 225 × 225 m) of three oak regeneration treatments plus a control for a total of 20 units. In 2013, we reduced replication to n = 4 units per treatment for logistical reasons. We randomly assigned treatments (prescribed fire, midstory reduction using herbicide, and shelterwood harvest) and controls to each unit resulting in a completely randomized design. All units were between 940 and 1240 m in elevation and separated by a >10-m buffer. Each contained mature (>70 years old), fully stocked, closed-canopied stands where oaks comprised at least 10% of the overstory tree BA (⩾25.0-cm diameter at breast height (dbh)). We selected stands that contained abundant oak seedlings, few ericaceous shrubs, a well-developed midstory canopy layer (stems 5–25-cm dbh), and no substantial disturbance within the last 15–20 years. All treatment units were intermediate- to high-quality sites, with site index ranging 23.0–30.4 m (base-age 50).

2.3. Treatments

Treatments for the Regional Oak Study were designed to evaluate three oak regeneration practices on productive sites: (1) oak shelterwood, consisting of a midstory herbicide followed by overstory removal after about 10 years (Loftis, 1990); (2) three prescribed burns at approximately 4-year intervals, followed by overstory removal after 10–11 years, and; (3) shelterwood-burn, consisting of a heavy establishment cut with 6.8–9.0 m^2/ha of BA retention followed by a prescribed fire after 4–5 years (Brose et al., 1999), and overstory removal 2–3 years post-burn. All three treatments are designed to promote advanced oak regeneration, followed by canopy release.

Our study encompassed one year before (2008) and five years after initial treatments were fully implemented (sampled in 2010, 2011, 2013, 2014). In midstory herbicide treatment units, herbicide was applied in early fall 2008, prior to leaf fall. Trees within the midstory strata except oak or hickory (e.g., red maple, sourwood, blackgum, flowering dogwood) ⩾5.0 cm and <25.0 cm dbh were treated with herbicide (~1 ml of diluted Garlon 3A solution) using the hack-and-squirt method (Loftis, 1990). Prescribed burns were conducted in all burn treatment units (two units were burned on 25 February 2009, and again on 2 April 2014; the other three units were burned only once during the study period,