Forest Ecology and Management 359 (2016) 277–285

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Woodland salamander responses to a shelterwood harvest-prescribed burn silvicultural treatment within Appalachian mixed-oak forests ☆

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ARTICLE INFO

Article history:
Received 11 August 2015
Received in revised form 24 September 2015
Accepted 26 September 2015

Keywords:
Plethodon ochrophaeus
Plethodon glutinosus
Plethodon cinereus
Timber harvest
Prescribed fire
Central Appalachians

ABSTRACT

Forest management practices that mimic natural canopy disturbances, including prescribed fire and timber harvests, may reduce competition and facilitate establishment of favorable vegetative species within various ecosystems. Fire suppression in the central Appalachian region for almost a century has contributed to a transition from oak-dominated to more mesophytic, fire-intolerant forest communities. Prescribed fire coupled with timber removal is currently implemented to aid in oak regeneration and establishment but responses of woodland salamanders to this complex silvicultural system is poorly documented. The purpose of our research was to determine how woodland salamanders respond to shelterwood harvests following successive burns in a central Appalachian mixed-oak forest. Woodland salamanders were surveyed using coverboard arrays in May, July, and August–September 2011 and 2012. Surveys were conducted within fenced shelterwood-burn (prescribed fires, shelterwood harvest, and fencing to prevent white-tailed deer [*Odocoileus virginianus*] herbivory), shelterwood-burn (prescribed fires and shelterwood harvest), and control plots. Relative abundance was modeled in relation to habitat variables measured within treatments for mountain dusky salamanders (*Desmognathus ochrophaeus*), slimy salamanders (*Plethodon glutinosus*), and eastern red-backed salamanders (*Plethodon cinereus*). Mountain dusky salamander relative abundance was positively associated with canopy cover and there were significantly more individuals within controls than either shelterwood-burn or fenced shelterwood-burn treatments. Conversely, habitat variables associated with slimy salamanders and eastern red-backed salamanders did not differ among treatments. Salamander age-class structure within controls did not differ from shelterwood-burn or fenced shelterwood-burn treatments for any species. Overall, the woodland salamander assemblage remained relatively intact throughout the shelterwood-burn silvicultural treatment compared to previous research within the same study area that examined pre-harvest fire effects. However, because of the multi-faceted complexities of this specific silvicultural system, continued research is warranted that evaluates long-term, additive impacts on woodland salamanders within managed central Appalachian deciduous forests.

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1. Introduction

Decades of fire suppression have contributed to a decline in oak (*Quercus* spp.) establishment and regeneration within the Appalachian region, favoring release of more shade-tolerant species including red maple (*Acer rubrum*) or fast-growing shade-intolerant species such as yellow poplar (*Liriodendron tulipifera*) (Nowacki and Abrams, 2008). In addition to vegetation encroachment, white-tailed deer (*Odocoileus virginianus*) herbivory and insect pest outbreaks are currently preventing oak reestablishment after timber harvest or natural mortality of canopy-dominant trees

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http://dx.doi.org/10.1016/j.foreco.2015.09.042
0378-1127/Published by Elsevier B.V.

(Abrams, 1992). Fire coupled with canopy cover reduction following timber harvesting is thought to facilitate oak regeneration by providing suitable conditions for seedling establishment and reducing competition from less desirable woody species. Specifically, shelterwood harvests that reduce overstory canopy by approximately 50%, followed by prescribed burns have resulted in successful oak regeneration and an associated decline in shade-tolerant vegetation in similar forest types (Brose and Van Lear, 1998). Although applying the shelterwood-burn silvicultural system to deciduous forests of the Appalachian region appears beneficial for restoring oak species and other fire-tolerant vegetation, prolonged absence of fire within these ecosystems may lead to unpredictable effects (Van Lear and Waldrop, 1989; Brose et al., 2001). In particular, repeated burning in forests that have developed over decades in the absence of fire and timber harvesting raises questions about impacts on forest floor dwelling vertebrates including woodland salamanders (Ford et al., 1999, 2010; Moorman et al., 2011).

Plethodontid salamanders rely on relatively cool, moist conditions that are associated with microhabitat characteristics indicative of mature, late-successional forests (Heatwole, 1962; Hairston, 1987; deMaynadier and Hunter, 1995; Petranka, 1998). Disturbances that reduce canopy cover, leaf litter, cover objects, or otherwise expose the forest floor to more light and higher temperatures are thought detrimental to woodland salamanders (deMaynadier and Hunter, 1995; Moorman et al., 2011). Accordingly, negative effects of timber harvest on Appalachian woodland salamanders are highest following canopy removal and associated ground disturbances after clearcutting (Ash, 1988; Petranka et al., 1993; Moorman et al., 2011). In contrast, timber harvest practices that retain some overstory (e.g., shelterwood, selection) exhibit lesser or no measurable effects on woodland salamander populations (Ford et al., 2000; Bartman et al., 2001; Homyack and Haas, 2009).

Despite abundant research investigating effects of timber harvest on woodland salamanders, responses of these species to natural or prescribed fire in deciduous and Appalachian forests remains poorly understood (Russell et al., 1999, 2004; Pilliod et al., 2003; Renken, 2006; Moorman et al., 2011). Woodland salamanders in the central Appalachians, where natural fires were less frequent and intense than in other areas of the United States (e.g., Coastal Plain pine forests), may respond negatively to the introduction of prescribed burning after decades without fire (Pilliod et al., 2003; Ford et al., 2010). In addition, salamanders may be more vulnerable to direct mortality from fire than other vertebrates because of their restricted mobility and susceptibility to desiccation (Russell et al., 1999; Renken, 2006). However, single and consecutive prescribed burns in deciduous forests of the eastern United States to date appear to negligibly affect woodland salamanders (Kirkland et al., 1996; Ford et al., 1999, 2010; Keyser et al., 2004; Greenberg and Waldrop, 2008).

The shelterwood-burn silvicultural system involves multiple treatments and stand entries that, in many cases, may take a decade or more to complete (Burns and Honkala, 1990). Each stand entry has the potential to negatively impact salamander assemblages individually or cumulatively (Moseley et al., 2008; Moorman et al., 2011). Previous studies have typically evaluated the individual impacts of shelterwood harvesting (Sattler and Reichenbach, 1998; Harpole and Haas, 1999; Bartman et al., 2001; Knapp et al., 2003; Homyack and Haas, 2009; Raybuck et al., 2015) or prescribed fire (Kirkland et al., 1996; Ford et al., 1999, 2010; Floyd et al., 2002; Raybuck et al., 2015). However, there is limited information on the combined impacts of both forest management practices (Keyser et al., 2004; O'Donnell et al., 2015). Also, many of these studies were conducted within 1–3 years of application (Sattler and Reichenbach, 1998; Harpole and Haas, 1999; Ford et al., 1999, 2010; Bartman et al., 2001; Pilliod et al., 2003; Raybuck et al., 2015), thereby not accounting for enduring impacts to salamander populations. Woodland salamanders are relatively long-lived species that may reproduce only every other year or longer (Duellman and Trueb, 1986; Hairston, 1987; Pilliod et al., 2003), and as a result, potential direct effects of silvicultural practices on salamanders or indirect effects from alterations in vegetation may take several years to become evident (Russell et al., 2004; Ford et al., 2010), especially when applying multiple forest management practices over time.

Evaluating woodland salamander responses for the duration of this complex silvicultural system will provide a unique opportunity to address the current lack of information regarding impacts of long-term, additive forest management practices on salamander populations in central Appalachian mixed-oak forests. The objective of our study was to determine how woodland salamanders respond to shelterwood harvests within a previously burned central Appalachian mixed-oak forest. Specifically, we evaluated whether post-harvest changes in habitat variables associated with woodland salamanders influence salamander relative abundance and age-class structure. We also evaluated long-term, additive impacts of shelterwood-burn treatments on salamanders by comparing our results to those of Ford et al. (2010), who assessed effects of consecutive prescribed fires on woodland salamanders at the same sites between 2001 and 2007.

2. Methods

Our study was conducted in the Fernow Experimental Forest, located within the Monongahela National Forest in Tucker County, West Virginia. The Fernow Experimental Forest consists of approximately 1900-ha managed by the USDA Forest Service Northern Research Station for long-term silviculture and hydrologic research. This area is within the unglaciated Allegheny Mountains section of the Appalachian Plateau Physiographic region at elevations of 530–1100 m (Adams et al., 2008). The Fernow Experimental Forest was extensively logged during 1903–1911 (Trimble, 1977). As a result of these activities, the forest is best described today as a second-growth mixed mesophytic hardwood type (Braun, 1950), containing a mix of species: northern red oak (*Quercus rubra*), chestnut oak (*Quercus prinus*), white oak (*Quercus alba*), shagbark hickory (*Carya ovata*), bitternut hickory (*Carya cordiformis*), yellow poplar, American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), red maple, black gum (*Nyssa sylvatica*), and eastern hemlock (*Tsuga canadensis*).

Our research was conducted within the Canoe Run watershed and consisted of 24 0.20-ha plots, including 14 on upper slopes and 10 on lower slopes. These plots were previously established for earlier studies evaluating the effects of two consecutive prescribed fires on oak regeneration (Schuler et al., 2010) and woodland salamander populations (Ford et al., 2010). The plots were generally on southwestern-facing aspects (180–325°) with variation in elevation (600–775 m) and slope steepness (4–19%). Upper slope sites were thinned 30 years ago to a 60–75% stocking level, whereas lower slopes remained fully stocked (Schuler and Miller, 1995). Twenty plots were burned using two prescribed fires. Poor weather conditions interrupted the first prescribed fire in April 2002 with only partial coverage on the upper slope. Lower slope plots were burned successfully the following spring in 2003 (Schuler et al., 2010). In April 2005, 20 lower and upper slope plots were burned a second time with adequate intensity and coverage to reduce small diameter tree stocking. Sites were burned using strip head fire with hand-held drip torches. Fires were generally of moderate or low intensity during all prescribed burns (Ford et al., 2010). Four plots remained as unburned controls with two