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Prescribed Fire Impacts to Amphibians and Reptiles in Shelterwood-harvested Oak-dominated Forests

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ABSTRACT

As part of a larger study examining the role of prescribed fire in regenerating upland oaks (*Quercus* spp.), seasonal prescribed burns (winter, spring, summer, and unburned control) were applied to first-stage shelterwood-harvested stands on Horsepen Wildlife Management Area in the Virginia Piedmont in 1995. Because fire impacts are poorly documented for herpetofaunal communities, we surveyed these stands in 1996 capturing 133 individuals of ten species during over 12,720 pitfall trapnights. We found no significant differences in relative abundance of Eastern Red-backed Salamanders (*Plethodon cinereus*) ($P = 0.26$), American Toads (*Bufo americanus*) ($P = 0.93$), or all amphibians combined ($P = 0.25$) among unburned shelterwood stands and those treated with winter, spring, or summer burns. Three species of reptiles (Northern Fence Lizard [*Sceloporus undulatus*], Ground Skink [*Scincella lateralis*], and Southeastern Five-lined Skink [*Eumeces inexpectatus*]) combined were captured more frequently in burned versus unburned stands ($P = 0.02$). Based on a stepwise multiple regression model, Eastern Red-backed Salamander captures were more strongly influenced by landscape variables ($P = 0.0320$), including distance to permanent water and mesic (i.e., eastern-northern) aspects, than by fire treatments ($P = 0.26$). Similar landscape models were not significant ($P < 0.05$) for toads or reptiles. Based on these results, prescribed fire may not be detrimental to herpetofaunal communities in oak dominated forests in the Virginia Piedmont.

INTRODUCTION

Over the past decade, considerable interest has developed in understanding relationships between herpetofaunal communities and forest management (deMaynadier and Hunter 1995). Prescribed burning as it relates to the local herpetofauna, however, is one aspect of forest management that has not been well studied (Russell et al. 1999). Cole et al. (1997) examined amphibian responses to clearcutting followed by broadcast prescribed burns in the Oregon Coast Range and reported increases in capture rates for Western Red-backed Salamanders (*Plethodon vehiculum*), no change for three species, and declines for two others. Unfortunately, their design did not allow them to isolate the effects of burning from logging.

Burning effects on amphibians and reptiles have been studied to a limited extent in the Coastal Plain of the Southeastern United States (Brennan et al. 1998, Russell et al. 1999). Old field pine (*Pinus* spp.) treated with understory prescribed burns on the Maryland Coastal Plain had lower capture rates for a number of amphibian species, including Eastern Red-backed Salamanders (*Plethodon cinereus*) and six species of frogs and toads than did unburned sites (McLeod and Gates 1998). As was the case in the Oregon Coast Range study, however, the burned areas also had been harvested (in this case only partial overstory removal), thus confounding fire effects. Greenberg (2002) reviewed several studies involving prescribed fire in xeric pine uplands of the Coastal Plain in Florida and concluded that with respect to amphibians, population responses to fire were difficult to detect due to the confounding influence of aquatic habitats on the landscape. She did report that some work on reptiles showed positive responses to intense disturbances including burning and salvage logging, indicating that for some species (e.g., Mole Skink [*Eumeces egregius*], Six-lined Racerunner [*Cnemidophorus sexlineatus*], and Scrub Lizards [*Sceloporus woodi*]) these disturbances may have mimicked natural regimes for which these animals were adapted. Mushinsky (1985), also working in Florida uplands, reported that among four fire rotations that he examined (one, two, seven years and an unburned control), both one and seven year fire intervals had higher densities of *C. sexlineatus* and higher species diversity than the control. He attributed these differences to improved habitat structure and increased solar radiation resulting from the burns. His results were strongly influenced by a single species, *C. sexlineatus*, which comprised 32% of the total sample and was abundant on the annually burned plots.

Two studies in eastern hardwood forests indicate that fire may not be detrimental to amphibians (Kirkland et al. 1996, Ford et al. 1999). Another study, however, documented reduced amphibian numbers in burned versus unburned sites in Virginia (Mitchell 2000).

Deciduous hardwood forests cover much of the eastern United States and provide important habitats for a wide range of wildlife species. Additionally, these forests provide substantial economic benefits. An emerging management technique that employs prescribed fire as a tool to help regenerate oaks (*Quercus* spp.), a major component of these forests critical for numerous wildlife species, may lead to increased use of prescribed fire after decades of suppression (Clark 1993, Lorimer 1993). Recent research in the Virginia Piedmont has indicated that oak regeneration responds well to prescribed burns, whereas other woody competitors are less tolerant of fire (Keyser et al. 1996, Brose and Van Lear 1998, Brose et al. 1999). As a result, oaks can increase their competitive position following prescribed fire.

A silvicultural approach that seems particularly promising to regenerate oak involves partial canopy removal, or shelterwood harvest, followed several years later by prescribed fire (Van Lear et al. 2000). If this system gains wide acceptance and becomes relatively common, it will be necessary to understand the impacts of this silvicultural technique on a wide array of forest organisms, particularly non-game wildlife. This information gap may present problems for land managers when implementing shelterwood-burn practices where concerns for wildlife are high, or management guidelines require extensive environmental assessments.

If prescribed fire has negative impacts on the herpetofauna, effects could cascade across trophic levels to species such as medium-sized mammalian predators and avian predators that depend on amphibians and reptiles as a prey base. Salamanders in particular may be a critical component of the food chain in forested ecosystems (Burton and Likens 1975, Jaeger 1980). Therefore, we examined the effects of prescribed fire on herpetofaunal communities in shelterwood-harvested upland oak stands in the Virginia Piedmont. Specifically, our objective was to determine if prescribed fire, and season of burn, effected relative abundance for amphibians and reptiles in oak-dominated shelterwood-harvested forests in the Virginia Piedmont.

METHODS

We conducted our research at the 1,200-ha Horsepen Wildlife Management Area, a property managed by the Virginia Department of Game and Inland Fisheries (VDGIF). The property is located in Buckingham County, Virginia in the Piedmont physiographic province (lat. 37° 30' N, long. 78° 33'W). Mixed stands of scarlet oak (*Quercus coccinea*), white oak (*Q. alba*), northern red oak (*Q. rubra*), and black oak (*Q. velutina*) dominated the area. Other important associates were yellow-poplar (*Liriodendron tulipifera*), red maple (*Acer rubrum*), blackgum (*Nyssa sylvatica*), and American beech (*Fagus grandifolia*). Climate was warm continental with an annual growing season of 190 days and 104 cm of evenly distributed annual precipitation. The topography was rolling with elevations from 130-190 m and soils dominated by Typic Hapludults.

As part of a larger study designed to assess impacts of seasonal prescribed fire effects on oak regeneration (Brose and Van Lear 1998), four burning treatments were completed in 1995: winter (February), spring (April), summer (August), and a control. Each burn treatment was replicated three times, one replicate located on each of three isolated timber sale units, in a randomized complete block design. Treatment units were 2-5 ha in size. First-stage shelterwood harvests had been completed 3-5 years earlier on all sites including the control, leaving approximately 11 m^2 of basal area/ha comprised of better form oaks and a few scattered yellow-poplars. We selected three uncut reference stands that were similar in all respects (age, species composition, soils, management history, stocking levels, and understory condition) in 1996 in the vicinity of the treatment stands for supplemental sampling. They were not, however, used in any way for the control treatment data.

Fire intensity was measured by placement of tiles treated with heat-sensitive paint strips suspended 1 m above the ground. Two tiles were placed on each of 15 0.04-ha plots centered within each burn unit. Residence time was not recorded (Brose 1995). Fuel loads and duff (Oa horizon) thickness were measured in late 1994 prior to burning, and again in 1995 following burning and prior to leaf fall. Litter (Oi) horizon was assessed 1-3 days before burning and again in fall 1995 prior to leaf fall (Brose 1995). Understory stem (>30 cm tall and < 10 cm DBH) density was measured annually from 1994 through 1996. We obtained distance from the plot center to nearest permanent water (in all cases, first order streams) and prevailing aspect of the plot from the examination of USGS 7.5' quadrangle topographic maps.

We conducted herpetofaunal sampling one year after burning using pitfall trapping for a total of 53 nights during June, July, and October 1996. We placed twenty 1-liter pitfalls near cover objects at regular spacing (5 m) along transects centered in each treatment area (240 total) following Ford et al. (1994). Sampling effort was equal across all block/treatment levels.

We analyzed capture data by species and/or taxonomic group using a one-way ANCOVA with each of three replicates treated as a blocking factor, season of burn as the main effect, and mean stand burn temperature as a covariate. We used least square means to test for differences in treatment means (SAS 1993, Neter et al. 1996). Due to small sample sizes and their similarity in habitats and habitat use, we combined three species of lizards (Northern Fence Lizard [*Sceloporus undulatus*], Ground Skink [*Scincella lateralis*], and Southeastern Five-lined Skink [*Eumeces inexpectatus*]) for analysis. Eastern Red-backed Salamanders (*Plethodon cinereus*) and American Toads (*Bufo americanus*) were analyzed separately. We also analyzed all amphibians as a group. We rank transformed data for Eastern Red-backed Salamanders and all amphibians combined because these data were not normally distributed (Proc Univariate (SAS 1993)). Data for the lizards and toads were normally distributed and were analyzed without transformation. Furthermore, we conducted a stepwise multiple regression analysis with a selection criterion that maximized the coefficient of determination (SAS 1993, Neter et al. 1996) to determine the ability of habitat variables to explain capture frequencies for Eastern Red-backed Salamanders, American toads, and the combined lizard species among the individual burn units ($n = 12$). Variables used in the model were selected from among those collected for the study after removal of those that were correlated and included, understory stem density, basal area, mass of thousand-hour (woody debris 7.62-20.32 cm in diameter) fuels, litter mass, distance to permanent water, and aspect. Non-normal variables were natural log transformed. Criteria for model selection were inclusion of significant variables ($P < 0.15$) and *Mallow's C*(p).

RESULTS

All fires reduced fine (< 2.54 cm diameter), medium (2.54-7.62 cm diameter), and coarse (> 7.62 cm diameter) fuel loads ($P < 0.05$), but the duff layer remained intact in all cases (Brose 1995). Most fine fuels were completely eliminated, whereas coarse fuels generally were only partially reduced. Nevertheless, medium and coarse fuel loads on burned sites remained, respectively, at levels greater than and equal to those found in the reference stands. Understory vegetation shifted from shrub-dominated to herbaceous-dominated for sites treated with spring and summer fires (Brose 1995). Sites treated with winter fires retained a shrub-dominated understory. Overall plant coverage and species richness increased following fire regardless of season of burn (Brose 1995). Mean fire temperatures measured 1 m above the ground were 274.7° C (winter burns), 342° C (spring burns), and 252° C (summer burns).

Pitfall sampling resulted in 12,720 trap-nights with 133 amphibian and reptile captures or 1.05 captures/100 trap-nights. We captured ten species, including three lizards, one snake, one toad, and five salamanders (Table 1). The most abundant species were Eastern Red-backed Salamanders, followed by American Toads, with the remaining eight species comprising 20% of the captures, collectively (Table 1).

We failed to detect a significant difference for season of burn on captures for American toads ($F_{3,5} = 0.14$, $P = 0.93$), Eastern Red-backed Salamanders ($F_{3,5} = 1.82$, $P = 0.26$), or all amphibian species combined ($F_{3,5} = 1.87$, $P = 0.25$). For the three

TABLE 1. Summary of amphibian and reptile captures using pitfalls at Horsepen Wildlife Management Area, Buckingham County, Virginia during June-October 1996. Results are for all four burn categories: spring, summer, winter, and control. Unadjusted means and standard errors are presented for the four categories with sample sizes large enough to permit statistical analysis. Means within rows with different letters are significantly different ($P < 0.05$), while means within rows with no letters do not have significant differences.

		BURN TREATMENT									
			Control		Winter		Spring		Summer		
SPECIES		n	Mean (SE)	n	Mean (SE)	n	Mean (SE)	n	Mean (SE)	TOTAL	%
Marbled Salamander	*Ambystoma opacum*	0		0		0		1		1	0.6
Sourthern Two-lined Salamander	*Eurycea cirrigera*	1		0		0		0		1	0.6
Red-spotted Newt	*Notophthalmus viridescens*	1		2		0		0		3	1.9
White-spotted Slimy Salamander	*Plethodon cylindraceus*	1		0		0		0		1	0.6
Eastern Red-backed Salamander	*Plethodon cinereus*	9	3.0 (0.577)	20	6.7 (1.202)	33	11.0 (8.021)	34	11.3 (10.349)	96	60.8
American Toad	*Bufo americanus*	5	1.7 (0.882)	8	2.7 (1.667)	8	2.7 (0.882)	10	3.3 (0.882)	31	19.6
Subtotal1		7	5.7 (0.667)	30	10.0 (1.528)	41	13.7 (7.219)	45	15.0 (11.533)	133	84.1
Species Richness		5		3		2	3		6		
Eastern Worm Snake	*Carphophis amoenus*	1		0		0		1		2	1.3
Northern Fence Lizard	*Sceloporus undulatus*	1		0		1		4		6	3.8
Ground Skink	*Scincella lateralis*	2		3		2		1		8	5.1
Southeastern Five-lined Skink	*Eumeces inexpectatus*	0		4		2		3		9	5.7
Subtotal (lizards)		3	1.0 (0.0) A	7	2.3 (1.453) B	5	1.7 (0.882) B	8	2.7 (0.667) B	23	14.5
Subtotal		4		7		5		9		25	15.8
Species Richness		3		2		3		4		4	

species of lizards combined, season of burn was significant ($F_{3,5} = 9.55$, $P = 0.02$) with more animals captured on the burned sites than on the unburned sites (Table 1).

Regression models for Eastern Red-backed Salamanders proved to be significant ($r^2 = 0.069$, $P = 0.0320$) with the best model based on the stepwise procedure including distance to permanent water (DIST), understory stem density (STEMS), and aspect (ASPECT) (captures = 5.55470 – 0.00057214(DIST) – 0.00031576(STEMS) – 0.34959 (ASPECT)). No model was significant ($P < 0.05$) for either toads or lizards.

DISCUSSION

Our spring and summer burns were particularly intense and consumed virtually all fine fuels, reducing leaf litter to minimal depths and shifting ground-layer vegetative communities from primarily woody to those dominated by herbaceous vegetation. Despite this, no amphibian or reptile species or species group was negatively impacted by any burn regardless of season. Our finding is consistent with results of a study of an intense community restoration fire in the Southern Appalachians (Ford et al. 1999). In that study, no differences in amphibian captures were detected between burned and unburned areas leading the authors to conclude that the amount of functional refugia was adequate to protect animals during and after fire. Cole et al. (1997) likewise speculated that on the treated sites the amount of residual woody debris might have provided enough cover for amphibians to persist. There was a large amount of slash still on site in our study as the result of the initial shelterwood harvest (Brose 1995, Brose and Van Lear 1998). This debris may have mitigated any loss of cover due to the consumption of leaf litter and small woody debris by the fires. Indeed, the medium and coarse fuels remained more abundant on burned sites than on unharvested reference areas (Brose 1995). Furthermore, the duff layer, an important component of diurnal cover for amphibians (Taub 1961, Heatwole 1962), remained intact. Thus, despite gross floristic changes to the sites as a result of burning, the critical habitat components for these taxa remained largely intact. Greenberg (2002), in her review of fire responses of herpetofaunal communities in the Coastal Plain, likewise concluded that the variable nature of burns on habitat structure make it difficult to detect fire-mediated responses in amphibian communities.

Mitchell (2000), working in the upper Coastal Plain of Virginia, noted fewer amphibians, principally of the genus *Plethodon*, in sites that had just been burned versus sites without recent burns. However, he does not discuss the fire history of the burned and unburned sites in enough detail to evaluate the influence of past burning on his results. Without the benefit of pre-treatment data or such a history, it is not clear that the burning is the cause of the apparent differences that he observed.

Kirkland et al. (1996) reported an increase in amphibian populations following a dormant-season burn on an oak-dominated site in Pennsylvania. This was largely driven, however, by the increase in American Toad captures, the only species abundant enough to test individually. Their study lacked pre-treatment sampling and replication, and the apparent differences could have been present prior to burning or have been an artifact of the site. It is possible that changes reported by Kirkland et al. (1996) during the spring months were present in Virginia as well. If so, we may have failed to detect these changes because we did not sample at that time of year.

Logistical constraints prevented us from initiating sampling during spring months when a broader sample of the amphibian community, specifically ambystomid salamanders and various anurans, may have been collected. Although failure to sample at this time of year may have reduced sample sizes and over-simplified the species composition, we do not believe it was a significant problem. Piedmont/upland hardwood forest amphibian assemblages typically are not very diverse and are dominated by the species represented in our sample (Skeen et al. 1993, Brooks 1999, Herbeck and Larsen 1999).

Although the differences we detected in reptile captures among the burned and unburned areas may have been a function of small sample sizes, changes induced by burning likely altered the site in a manner favorable to reptiles. For example, the increase in solar radiation due to the removal of the hardwood midstory would have created more favorable conditions for these reptiles (Mitchell 1994). Indeed, McLeod and Gates (1998) found a highly significant increase in skink (*Eumeces* spp.) captures in partially harvested (versus intact) hardwood stands that resembled our shelterwood harvests, but not between burned and unburned pine stands. In their case, the harvest seemed to be of greater importance in skink response than the fire. Both Greenberg (2002) and Mushinsky (1985) reported that reptiles were more abundant in areas treated with fire, a result that they related to changes in the structure of the habitat. Specifically, they both believed that the increased solar radiation and structural diversity of the habitat were important fire-mediated contributors to improved habitat quality for reptiles.

For Eastern Red-backed Salamanders, two landscape variables, distance to permanent water and aspect, influenced capture frequency whereas fire treatments did not. Greenberg (2002) also reported that distance to water was a more important variable than stand age or disturbance treatment for anurans. Ford et al. (1999) observed a similar response for many amphibian species, including plethodontid salamanders, and distance to water. Thus, mesic environment seemed to be important for Eastern Red-backed Salamanders.

Because we did not sample the herpetofauna in the year of the burn (1995), we recognize that there may have been some short-term changes that had disappeared by 1996. With respect to amphibians, however, we think this is unlikely because two critical habitat components, the duff layer and large woody debris, were largely intact in both 1995 and 1996. The only change, beyond normal plant regrowth in the spring of 1996, would be the leaf litter accumulation of fall 1995. Although this is not irrelevant, it may be of less importance than duff and large woody debris (Heatwole 1962). In any case, the possibility remains that we missed some short-term responses to the burns.

Undisturbed oak-dominated hardwood forests in the Piedmont are likely to change markedly due to the suppression of fire, and be replaced by forests dominated by beech, yellow-poplar, and maple (Kellison 1993). The shelterwood-burn technique shows promise for maintaining a substantial oak component in eastern hardwood forests in the face of decades of limited regeneration success. Given the rate of development and loss of forested habitats in many parts of the Southeast and mid-Atlantic, the importance of maintaining as many acres of quality, ecologically healthy, hardwood forests as possible undoubtedly will increase. Our results suggest that the prescribed burns associated with this technique are unlikely to adversely affect two of the more common amphibian species in the Piedmont.

The results of our study and the limited number of other studies that have investigated the effects of fire on these communities suggest that fire, by itself, is not a detrimental factor in many upland systems. The benefits that can be realized from a stand-level and ecosystem-level perspective to eastern hardwood forests from maintaining or restoring a substantial oak component are notable. That we were unable to detect measurable negative impacts on the herpetofaunal community despite the application of fairly intense growing season fires, may suggest that this could be a viable technique for achieving those goals. Given the serious concerns about the loss of fire as an ecosystem component and its effects on biota in the Southeast and elsewhere (Brennan et al. 1998, Delcourt and Delcourt 1998, Frost 1998) this tool may have additional merit for maintaining healthy and diverse ecosystems.

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