DOES FIRE AFFECT AMPHIBIANS AND REPTILES IN EASTERN U.S. OAK FORESTS?

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Abstract.—Current information about the effect of fire on amphibians and reptiles in oak forests of the Eastern and Central United States is reviewed. Current data suggest that fire results in little direct mortality of amphibians and reptiles. Fire has no effect on overall amphibian abundance, diversity, and number of species in comparisons of burned and unburned plots, though salamander numbers tend to be greater in unburned plots. Current research also suggests that fire has no effect on reptile abundance, diversity, or number of species except in several studies in which lizard abundance was or tended to be greater in burned plots. The season of burn seems to make no difference in amphibian and reptile response. Although fire generally has little effect on amphibians and reptiles in oak forests, managers need to continue to consider the potential effect of fire on amphibians and reptiles associated with streams and forest pools, and on endangered threatened species and/or those of special concern. Managers can monitor the effects of fire on their own or with help from biologists, or can consult references to surmise how management affects these animals.

INTRODUCTION

Within the last 20 years, the effects of forest management on amphibians and reptiles has received increased attention. Typically, attention has focused on the effects of even-age and uneven-age forest management (see de Maynadier and Hunter 1995 for a review), but as fire has been gaining acceptance as a forest management tool, questions have been raised about the impact of fire (Russell and others 1999; Bury and others 2000; Pilliod and others 2003; Russell and others 2004). "Altered fire regime" was one of the reasons given for the problems experienced by 7 percent of 19 frog and toad species and about 17 percent of 49 salamander species classified as "net extirpations" in the United States (Bradford 2005). Amphibians and reptiles are some of the least visible animals in the forest, yet with increasing focus on amphibian declines (Phillips 1990; Wake 1991; Lannoo 2005), forest managers need to know the effects of their practices on these animals.

There are several reasons why amphibians and reptiles should be considered when making forest management decisions. First, they comprise a significant amount of biomass in forest systems. For instance, the biomass of salamanders alone within the Hubbard Brook Experimental Forest in New Hampshire was 2.6 times that of birds and approximately equal to the biomass of mice and shrews (Burton and Likens 1975). Reported densities for just the eastern red-backed salamander (*Plethodon cinereus*), one of the most common salamanders within oak forests, have reached 11,452 per acre (Mathis 1991). Second, amphibians require moisture in the environment for breeding and respiration. Amphibians lay their eggs within water or in moist places (e.g., moss or logs) where eggs can remain moist or be covered by water. Amphibians also have permeable skin (Bury and others 2000) and are in a much greater danger of desiccation than birds or mammals. There are forest-dwelling salamanders (salamanders of the family Plethodontidae) that lack lungs and respire primarily through the skin. These species require moist environments for respiration. Third, amphibians and reptiles move relatively short distances (Bury and others 2000) such that they must deal with the changed conditions of their landscape and generally cannot escape or relocate to more favorable conditions (Szaro 1988). Amphibians and reptiles typically have small home ranges. For instance, eastern red-backed salamanders remain within an area of about 15.5 square yards (Kleeberger and Werner 1983) of the forest floor within their lifetime; by contrast, the little brown skink (*Scincella lateralis*) has a home range of 62 square yards (Brooks 1967).

Fire within a forest can alter the environment for amphibians and reptiles in several ways. Forest floor litter and coarse woody debris, which are used by amphibians

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as a moist environment (Kleeberger and Werner 1983; Herbeck and Semlitsch 2000) and by reptiles as cover and perches (James and M'Closkey 2003), could be eliminated (Bury and others 2000; Pilliod and others 2003; Vandermast and others 2004). Changes in canopy cover and ground level vegetation could result in a drier environment on the forest floor (Pilliod and others 2003). The reduction or elimination of trees around temporary or permanent pools and streams could change the water temperature and chemistry, the amount of time water remains in pools, and the pattern of stream flow, thus changing the breeding environment for amphibians (Gresswell 1999; Skelly and others 1999; Pilliod and others 2003).

In the section that follows I summarize current information with respect to the effects of fire on forest amphibians and reptiles in oak forests of the Eastern and Central United States, and suggest issues that forest managers might to consider before using fire to obtain desired forest conditions.

CURRENT KNOWLEDGE ABOUT FIRE EFFECTS ON AMPHIBIANS AND REPTILES

Research on the effects of fire on amphibians and reptiles within oak forests of the Eastern and central United States has been limited, though studies to date indicate that fire results in little direct animal mortality, has little effect on amphibian abundance and diversity, and may result in increases in abundance for some reptile species. Palis (1995) in Indiana and Floyd and others (2002) in South Carolina did not find evidence of direct mortality of amphibians and reptiles due to fire. Direct mortality may not have occurred because amphibians tend to reside in moist environments, such as heavy litter and duff, that cannot sustain fire, or in underground refuges, such as small mammal tunnels (Gordon 1968), that would insulate them from fire (Russell and others 1999; Pilliod and others 2003). Reptiles also likely sought refuge in tunnels or under cover objects such as rocks, or climbed trees with the advance of fire. Although unburned sites tended to have more salamanders than sites that recently burned (the results between burned and unburned plots were not significantly different in statistical tests; Floyd and others 2002; Moseley and others 2003), investigators in Georgia (Moseley and others 2003), South Carolina (Floyd and others 2002), and Virginia (Keyser and others 2004) did not detect an effect of fire on overall amphibian abundance, diversity, or the number of species (Table 1). Nor did Ford and others (1999) observe an effect of fire on salamander numbers in North Carolina (Table 1). The only reported effect on amphibians was by Kirkland and others (1996), who observed more American toads (*Bufo americanus*) on burned than on unburned tracts in Pennsylvania (Table 1). These authors did not have an explanation for this difference.

As for reptiles, some investigators have reported a greater abundance and diversity of lizards following burning (Table 1; Moseley and others 2003; Keyser and others 2004). These authors believed that the reduced litter, increased amount of bare ground, and removal of the midstory within burned forest resulted in more advantageous thermoregulatory conditions for lizards. However, others did not detect an impact of burning on lizard, snake, and turtle abundance and diversity, though lizards tended to be more abundant on burned plots (Table 1; Floyd and others 2002). Also, in preliminary analyses of more recent work, there were no effects of fire on amphibians in oak-hickory-poplar forests in South Carolina (K.R. Russell, University of Wisconsin-Stevens Point, pers. commun.) or on amphibian abundance (but perhaps on reptile abundance) in North Carolina oak-hickory forests (C. Greenberg, USDA Forest Service, pers. commun.). The season of burning also had no effect on amphibians and reptiles. Although spring and summer burns resulted in less forest shrub cover than winter burns, winter, spring, and summer burns did not differ in their effect on amphibian and reptile abundance (Keyser and others 2004). No investigators reported local disappearances of species or the appearance of new species on study plots following burning (Kirkland and others 1996; Ford and others 1999; Floyd and others 2002; Moseley and others 2003).

In nearly all of the studies reporting the effects of fire on amphibians and reptiles in eastern oak forests, few discussed the intensity and type of fire (Table 1). The fires ranged from intense wildfires (Kirkland and others 1996) and light prescribed burns (Floyd and others

Table 1.—Details of fires and amphibian and reptile responses to those fires in the eastern oak forests of the US.

Location and reference	Type of fire treatments	Fire intensity	Fuel consumption	Patchiness of consumption	Species evaluated	Animal r80esponse
Indiana (Palis 1995)	April burn; Prescribed burn set at 1615 hrs	Nighttime fire	NA[a]	80 percent of 1,000 acres burned	Amphibians and reptiles of that region	No direct mortality observed; resulting amphibian and reptile numbers and assemblage appeared typical
Pennsylvania (Kirkland and others 1996)	Burned in November	Charred tree trunks; killed many saplings; charred vegetation in ground and shrub layers	NA	NA	American toad	More toads on burned than unburned sites
North Carolina (Ford and others 1999)	Burned in April	High intensity prescribed fire	NA	NA	Woodland salamanders	No difference in salamander abundance detected between burned and unburned sites
South Carolina Piedmont (Floyd and others 2002)	First round of fires in February - March 1999; strip head fires set 15 to 30 feet apart; second round of fires in April 2000; strip head fires set 10 to 20 feet apart;	First round average flame length was >1 foot; second round average flame length < 1 foot	NA	NA	Total herpetofauna, frogs, toads, salamanders, newts, lizards, turtles, snakes	No difference in abundance, diversity, and eveness in total herpetofauna or by taxonomic groups

Table 1.—continued.

Georgia upper Coastal Plain (Moseley and others 2003)	Winter burns; stands had been burned every 2-3 years in the previous 9 years	Low intensity	More litter in unburned; more bare ground in burned; no difference in coarse woody debris volume between burned and unburned	NA	Total herpetofauna; amphibians, anurans, salamanders, reptiles	No difference in overall amphibian and reptile, salamander, or anuran abundance, richness, and diversity between burned and unburned; reptile abundance and diversity were greater in burned than unburned sites
Virginia Piedmont (Keyser and others 2004)	Seasonal prescribed burns (winter, spring, summer) applied to first-stage shelterwood-harvested stands (to 48 ft^2 basal area per acre) cut 3 to 5 years prior to burns	Average fire temperature 39 inches above the ground was 526 °F in winter burn, 648 °F in spring burn, and 485 °F in summer burn	All fires reduced fine, medium, coarse fuel loads (fine fuels were eliminated; coarse fuels were partially reduced), yet duff layer remained intact	Spring and summer burns caused a shift from shrub dominated to herbaceous dominated understory	All amphibians and reptiles, especially eastern red-backed salamanders, American toads, northern fence lizards (*Sceloporus undulatus*), little brown skinks, and southeastern five-lined skinks (*Eumeces inexpectatus*)	No difference in abundance of salamanders, toads, and all amphibians between controls and different seasonal burns; lizard abundance was greater in burned than unburned stands

a Not Available

Figure 1.—Results of a prescribed burn where not all the litter and woody debris was eliminated.

2002; Moseley and others 2003) to high-intensity prescribed burns (Ford and others 1999; Keyser and others 2004). The effects of fire on amphibians and reptiles generally were similar among these studies.

Researchers may not have detected an effect of fire on amphibians and many reptiles due to short-term changes in the physical features important to these animals or the effects were not significant. Unless conditions are extremely dry, some coarse woody debris remains after a fire (Palis 1995; Van Lear and Harlow 2000; Moseley and others 2003; Trammell and others 2004) and can serve as cover for both amphibians and reptiles. Fire causes a temporary reduction in ground flora cover and litter depending on the frequency and intensity of fire, but ground flora cover rebounds quickly, sometimes within the next growing season (Kirkland and others 1996; Vandermast and others 2004). Not all litter or duff is consumed (Fig. 1; Kirkland and others 1996; Floyd and others 2002; Keyser and others 2004; Trammell and others 2004) and burns may create a mosaic of vegetation on the forest floor (Ford and others 1999). Litter seems to accumulate to unburned plot levels within 3 years after fire (Gagan 2002). Also, unless the objective of burning is to dramatically reduce the density of trees and greatly open the canopy, trees remaining following infrequent fires provide shade to reduce the amount of temperature variation at the forest floor, and the canopy helps soil and any remaining litter retain moisture (Ford and others 1999). Moisture within soil, litter, and coarse woody debris allows salamanders to remain active at the forest floor surface. In dry environments, amphibians, particularly salamanders, retreat underground and remain there until conditions on the forest floor are more suitable (Heatwole 1960; Heatwole 1962; Jaeger 1980; Feder 1983). For lizard species that experience an increase in abundance with fire, the temporary benefits of more bare ground and more basking sites probably boost survival rates (Parker 1994). However, populations probably return to pre-burn levels as post-fire forest conditions return to conditions of unburned forest.

OTHER CONSIDERATIONS CONCERNING THE EFFECTS OF FIRE

Do we need to be aware of other considerations concerning the use of fire as a tool and its effect on amphibians and reptiles? One is the possible indirect effects of fire on streams and stream-associated amphibians. There have been no studies on the indirect effects of fire on streams in eastern oak forests, but it is possible that streams could be affected by increased rates of sedimentation, increases in temperature due to reduced canopy cover, increases in amount of woody debris into the stream, which could change the flow and course of the stream, and increased concentrations of chemicals from the leaching of ash and the diffusion of smoke (Gresswell 1999; Pilliod and others 2003). Increased rates of sedimentation, increased concentrations of chemicals such as potassium and nitrogen, and increases in woody debris may change stream productivity and habitats, thus changing the flow and quality of streams. Stream-associated amphibians may be sensitive to such changes (Bury and others 2000; Pilliod and others 2003), which also can affect the foods and reproduction of stream-side dwelling amphibians, such as the northern dusky salamander (*Demognathus fuscus*). A reduced canopy cover might result in increased water temperature, which also could affect foods (e.g., macroinvertebrates) and reproduction of these animals (Pilliod and others 2003).

Another consideration is the direct effect of fire on vegetation structure around amphibian breeding ponds. Frequent fires open the canopy around pools and the increased light can change amphibian use of the pools. Depending on how isolated the pool is from other pools and the amount of time water is in the basin in a year, amphibian species more characteristic of open pools may start using formerly closed-canopy pools. Amphibian species such as spring peepers (*Pseudacris crucifer*) prefer open habitats and more open canopies around breeding pools (Skelly and others 1999; Halverson and others 2003), and may invade formerly closed-canopy pools if other spring peeper populations are nearby. Pools in closed canopies typically have lower oxygen levels and water temperatures, and shorter periods when water is in the basin than open-canopy pools of the same category (Skelly and others 1999, 2002; Pilliod and others 2003). The reason for this is that trees shade the water and use the water within the basin (Skelly and others 1999). Lower water temperatures reduce tadpole growth rates for some amphibian species (Skelly and others 2002; Halverson and others 2003). Reduced growth rates and faster drying pools in closed canopies make it difficult for tadpoles to develop into terrestrial-living juveniles before the pools dry. In a study examining amphibians using ponds in Michigan between 1988 and 1992, Skelly and others (1999) noted that tree growth and maturation around pools that were open-canopy pools from 1967 to 1974 resulted in fewer amphibian species using the pools. The composition of the amphibian community was less diverse and species that preferred more open habitats stopped using the closed-canopy pools. The remaining amphibians were considered forest species and generally tolerated of a wider range of canopy conditions than open-habitat species.

A third consideration is the use of fire for forest management in the presence of endangered or threatened species and/or those of special concern. Although direct mortality does not seem to be an issue, managers may want to be aware of these species' habitat needs and seasonal and daily activity patterns so that fire does not result in direct mortality (e.g., burning outside the months of the year when that species is active), and that required habitat remains or is improved following burning.

A fourth consideration is that while current information suggests that infrequent fires in eastern oak forests result in little direct mortality or in insignificant impacts to amphibians and limited changes to reptile communities, future data may point to impacts that have not yet been measured. I found few published studies on the effects of fire on amphibians and reptiles in eastern oak forests, yet I am aware that several other studies that are in progress or that recently were completed (C. Greenberg, USDA Forest Service, pers. commun.; D. Miles, Ohio University, pers. commun. part of the National Fire and Fire Surrogate Study; K. Russell, University of Wisconsin-Stevens Point, pers. commun.).

CONCLUSIONS

Currently available information indicates that fire has little effect on amphibians and reptiles in oak forests of the Eastern and Central United States. Some researchers have noted fewer salamanders in burned areas than unburned areas, though significant changes in amphibian abundance, diversity, and number of species have not been detected. Researchers have also reported that fire generally does not affect reptile abundance and diversity but that there is evidence that lizard abundance increases following burning. The lack of significant effects likely is due in part to the incomplete elimination of moisture-holding litter, duff, and coarse woody debris, the continued canopy cover provided by remaining trees, and the quick regrowth of ground vegetation (Palis 1995; Moseley and others 2003; Keyser and others 2004).

Forest managers must consider many factors when contemplating management goals on properties under their care. In an ideal situation, a manager would monitor the impacts of management actions on amphibians and reptiles along with such monitoring as necessary to determine whether the desired forest conditions are obtained. Few managers have the luxury of time and money to monitor amphibian and reptile communities. The next best option is to work with a biologist who can monitor amphibian and reptile responses or provide information to help guide decision making. If this option is not available, the manager can consult general references related to the biology and habitat needs of nontarget animals. Examples include "A field guide to reptiles and amphibians of eastern and central North America" (Conant and Collins 1991), "A guide to amphibians and reptiles" (Tyning 1990), and "Salamanders of the United States and Canada" (Petranka 1998). "Amphibian declines: the conservation status of United States species" (Lannoo 2005) provides information on the life history, natural history, and conservation status of all amphibians in the United States. Other helpful references include state or regional publications such as "The amphibians and reptiles of Missouri" (Johnson 2000)

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