THE EFFECTS OF PRESCRIBED BURNING AND THINNING ON HERPETOFAUNA AND SMALL MAMMALS IN THE UPPER PIEDMONT OF SOUTH CAROLINA: PRELIMINARY RESULTS OF THE NATIONAL FIRE AND FIRE SURROGATE STUDY

Eran S. Kilpatrick, Dean B. Kubacz, David C. Guynn, Jr., J. Drew Lanham, and Thomas A. Waldrop[1]

Abstract—Due to heavy fuel loads resulting from years of fire suppression, upland pine and mixed pine hardwood forests in the Upper Piedmont of South Carolina are at risk of severe wildfire. The National Fire and Fire Surrogate Study (NFFS) was conducted on the Clemson Experimental Forest to study the effects of prescribed burning and thinning on a multitude of factors, including herpetofauna and small mammals. Drift fence/pitfall arrays, modified pitfalls, unmodified pitfalls, and hand captures were used to sample herpetofauna. We captured 1,317 reptiles and amphibians representing 40 species from September 9, 2000 to January 9, 2002. There were no significant treatment effects on abundance within five major taxa (frogs/toads, salamanders, turtles, lizards, and snakes). However, there were treatment effects on two lizard species. When comparing richness, the thin treatment had a significantly higher number of snake species than the burn treatment. Live traps, snap traps, and herpetofauna traps were used to sample small mammals. No small mammals were caught in live traps for 9,600 trap nights. Snap trap success was 0.10 percent for 27,000 trap nights. Small mammals were captured at low levels in herpetofuana traps (0.06 percent trap success) for 163,968 trap nights. Treatment effects could not be determined for small mammals due to the low number of captures. Although treatment effects were limited, prescribed burning and thinning have been found to alter herpetofauna and small mammal communities.

INTRODUCTION

Herpetofauna response to forest management practices is an important issue in current wildlife research (Bury and others 1980, deMaynadier and Hunter 1995, Gibbons 1988, Lyon and others 2000, Russell and others 1999). This interest is partly due to reported declines in amphibian and reptile populations across the United States and other countries (Gibbons and others 2000, Pechmann and Wilbur 1994, Wyman 1990). The natural history and physiology of herpetofauna makes them valuable research subjects alone or in conjunction with avifauna, mammals, plants, and arthropods. Some amphibians are completely aquatic obligates while others use aquatic and terrestrial habitat in their life cycles. Consequently, forest management activities in terrestrial areas may affect the amphibian component (Bennett and others 1980). Amphibian's permeable skin is sensitive to acid rain, herbicides, pesticides, and other pollutants. This sensitivity, their use of aquatic and terrestrial environments, short life spans, and small home ranges makes amphibians good indicators of environmental quality (Pechmann and Wilbur 1994).

More than 130 species of reptiles and amphibians have been documented in South Carolina (Conant and Collins 1998, Martof and others 1980). High species density (Kiester 1971) coupled with extensive forest management in a variety of habitats (Sharitz and others 1992) makes South Carolina ideal for the study of herpetofauna response to forest management. This issue has been studied in the Coastal Plain and Appalachian Mountains but is lacking in the South Carolina Piedmont.

Southeastern forests with historically short interval, low- to moderate- severity fire regimes, have become denser and the quantity of forest fuels has increased greatly. Fuel accumulation is mostly due to successful fire suppression efforts, which degraded ecosystem integrity and increased the risk of large-scale wildfires. Each year, South Carolina suppresses nearly 4,500 wildfires. Most of these fires (80 percent) are caused by negligent debris burning or by arson. Since 1970, an average of one catastrophic wildfire of 1,000 acres or more has occurred each year in South Carolina. This average increases during droughty years. In 1985, there were 10 wildfires that averaged over 2,000 acres in size.

The NFFS was initiated on the Clemson Experimental Forest (CEF) in spring 2000 to study the ecological and economic consequences of four fuel reduction treatments over a 5 year period. The NFFS is a national study, taking place on 13 replicated study sites in the United States. It has been proposed that fuel reduction treatments, such as prescribed fire, and fire surrogates, such as cutting and mechanical fuel treatments, could restore historical ecosystem processes and increase forest sustainability. The objective of the NFFS is to use prescribed fire and thinning to understand how fuel reduction treatments affect vegetation, fuel and fire behavior, soils, wildlife, entomology, pathology, and treatment cost and utilization economics. The goal of this paper was to assess the effects of prescribed fire and thinning for fuel reduction on herpetofauna and small mammals in the Upper Piedmont of South Carolina.

METHODS

Twelve treatment areas were established in the CEF during spring 2000 based on stand age, size, tree composition, and wildfire vulnerability. Treatment areas ranged in age

[1] Graduate Research Assistant, Graduate Research Assistant, Professor, and Associate Professor, Department of Forest Resources, 261 Lethotsky Hall; and Research Forester, USDA Forest Service, Southern Research Station, 233 Lethotsky Hall, Clemson University, Clemson, SC 29634, respectively.

Citation for proceedings: Connor, Kristina F., ed. 2004. Proceedings of the 12th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–71. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 594 p.

from 15 to 60 years and were blocked by tree size to reduce variability. Each of three blocks contains four treatment areas composed primarily of pulpwood sized trees diameter at breast height (d.b.h.) (15 to 25 cm), sawtimber sized trees (d.b.h. > 25 cm), and a mixture of pulpwood and sawtimber sized trees.

Minimum block size was 14 ha to accommodate the 10-ha study plot and a buffer area of about 20 m. Tree composition was primarily planted loblolly pine (*Pinus taeda* L.) with some shortleaf pine (*Pinus echinata* Mill.), Virginia pine (*Pinus virginiana* Mill.), and various hardwood species. The last thinning occurred at least 10 years ago, and the last prescribed or wild fire occurred at least 5 years ago.

Treatments

The four treatments were randomly assigned to each block using a random number table. Treatments included thinning, prescribed burning, and an untreated control. The prescribed burn for the thin/burn treatment was not applied until data collection for this study was completed; therefore thin/burn treatments are designated as T2 in this study to distinguish them from the thin only treatment (T1). Thinning and burning levels were prescribed that reduced fuels and followed standard silvicultural practices for managed stands in the Piedmont. Thinning operations were conducted in the winter of 2000 and 2001 and prescribed burning was conducted in the spring of 2001 and 2002.

Trapping Methods

Herpetofauna was sampled using 24 drift fence/pitfall trap arrays, 120 modified pitfall traps, 120 unmodified pitfall traps, and area-constrained searches. Pitfall traps were buried 19 L plastic buckets. Two drift fence/pitfall arrays (Crosswhite and others 1999) constructed of nylon silt fencing were randomly located in the upper and lower half of the treatment area. Drift fence/pitfall arrays were Y-shaped with 10-m arms spaced 120^{o} from each other. Each array had four pitfalls, one pitfall in the center and one at each arm end. Modified pitfalls were placed every 200 m and alternated with unmodified pitfalls. Pitfalls were modified by burying three 1-m sections of aluminum flashing at 120^{o} angles to the pitfall opening. Any herpetofauna captured by hand or heard vocalizing within the treatment areas were counted as hand captures.

Marking Techniques

All herpetofauna captured were identified to species, marked, sexed, weighed, and measured. Taxonomy followed that of Conant and Collins (1998), Highton and Peabody (2000), and Martof and others (1980). Frogs/toads, salamanders, and lizards were marked by toe clipping the fourth outermost toe on the right rear foot with a pair of small scissors (Donnelly 1989). Snakes were marked by scale clipping the end of the fifth ventral plate. Turtles were marked by marginal scute filing. Scale clipping and scute notching methods were modifications of those used by Woodbury (1953).

Statistical Analysis

Herpetofauna data were summarized for all captures from September 9, 2000 to January 9, 2002 and for post-treatment captures from April 11, 2001 to January 9, 2002. Captures were totaled for each species within five major taxa for each sampling period, trap type, and month. Only captures from April 11, 2002 to January 9, 2002 were used to test for treatment effects. Tests for treatment effects on abundance and richness were conducted on treatment and major taxa totals and for 11 individual species with the highest abundance: green anole (*Anolis carolinensis* Voigt), Fowler's toad (*Bufo fowleri* Hinckley), eastern worm snake (*Carphophis a. amoenus* Say), five-lined skink (*Eumeces fasciatus* L.), eastern narrowmouth toad (*Gastrophryne carolinensis* Holbrook), southern appalachian salamander (*Plethodon teyahalee* Hairston), bullfrog (*Rana catesbieana* Shaw), ground skink (*Scincella lateralis* Say), northern fence lizard (*Sceloporus undulatus hyacinthinus* Green), southeastern crowned snake (*Tantilla coronata* Baird and Girard), and eastern box turtle (*Terrepene c. carolina* L.). Captures from September 9, 2000 to January 9, 2002 were used for trap efficiency analysis.

The General Linear Model (GLM) procedure and Least Significant Difference (LSD) tests in SAS (1999) were used to test for treatment effects and differences in trap efficiency. The level of significance was set at $\alpha = 0.05$ for all statistical tests.

RESULTS AND DISCUSSION

Herpetofauna

During the overall sampling period, we captured 1,317 reptiles and amphibians representing 40 species in 163,968 trap nights. Lizards (49.1 percent) were the most abundant taxon followed by frogs/toads (23.5 percent), snakes (13.7 percent), salamanders (9.2 percent), and turtles (4.6 percent). The majority of captures, 52.8 percent reptiles and 28.6 percent amphibians, occurred from April 2001 to October 2001. Total post-treatment sampling produced 1,146 captures representing 40 species for 92,064 trap nights. Lizards (47.7 percent) were the dominant taxon followed by frogs/toads (25.7 percent), snakes (14.2 percent), salamanders (7.9 percent), and turtles (4.5 percent).

S. u. hyacinthinus was the most abundant species overall and in post-treatment sampling, representing 25.5 percent and 24.3 percent of total captures, respectively. *B. fowleri*, *A. carolinensis*, *E. fasciatus*, and *T. coronata* were the next four dominant species forming a group representing 34 percent of total captures overall and 36 percent in the post-treatment sampling period. No significant treatment effects on abundance were found for the five major taxa (table 1). Although post-treatment sampling occurred throughout the peak months of activity (April to October) more sampling is needed during this time over successive years to detect treatment effects.

When comparing richness, T1 had significantly higher number of snake species than the burn treatment (table 2). However, 50 percent of snake richness was made up of species represented by only one capture per plot. The difference in snake richness pertained more to random encounter with a trap rather than the effects of the burn. There were no significant treatment effects when comparing the total treatment abundance and richness. Of the

Table 1—Mean herpetofauna abundance (captures/treatment) for post-treatment sampling

Treatment	Frogs and toads	Salamanders	Turtles	Lizards	Snakes	Overall
Burn[a]	12.6 a[b]	3.0 a	3.6 a	39.7 a	9.6 a	13.7 a
Control	37.3 a	8.3 a	4.3 a	27.7 a	14.3 a	18.4 a
T1	26.0 a	7.0 a	4.0 a	54.7 a	18.0 a	21.9 a
T2	22.0 a	12.0 a	5.0 a	60.3 a	12.3 a	22.3 a

T1 = thin only treatment; T2 = thin/burn treatment.
[a] Burn only treatment.
[b] Means not followed by the same letter within columns differ significantly at $p < 0.05$.

Table 2—Mean herpetofauna richness (number of species and treatment) for post-treatment sampling

Treatment	Frogs and toads	Salamanders	Turtles	Lizards	Snakes	Overall
Burn	2.7 a[a]	2.0 a	1.3 a	4.6 a	3.0 a	2.7 a
Control	5.7 a	2.0 a	1.0 a	5.0 a	4.7 ab	3.7 a
T1	4.0 a	3.7 a	1.0 a	5.0 a	5.0 a	3.9 a
T2	4.3 a	4.0 a	1.0 a	5.3 a	5.3 ab	4.0 a

T1 = thin only treatment; T2 = thin/burn treatment.
[a] Means not followed by the same letter within columns differ significantly at $p < 0.05$.

11 individual species chosen for analysis, there were significant treatment effects on *A. carolinensis* and *E. fasciatus* (table 3). T2 had significantly more *A. carolinensis* captures than the burn or control. There were significantly more *E. fasciatus* captures in the T2 and T1 than in the control. *A. carolinensis* and *E. fasciatus* activity increased due to the conditions created by overstory removal. Thinning reduced basal area within the treatment area (Phillips and others, in press). Thinning increased the amount of sunlight reaching the forest floor resulting in a higher proportion of area available for thermoregulation.

Much of the amphibian abundance and richness in this study can be explained by the presence of adjacent breeding habitat. Amphibians made up 33.6 percent of post-treatment captures and were primarily composed of species uncharacteristic of upland pine plantations. This could be due to the presence of adjacent breeding habitat to the treatment areas. Beaver ponds, perennial streams, and intermittent streams are in close proximity to treatment areas. Different habitat among blocks may have produced enough variability to mask significant differences among treatments.

Table 3—Average abundance of individual species by treatment

Species	Burn	Control	T1	T2
Anolis carolinensis	5.0 a[a]	2.0 a	7.3 ab	17.7 b
Bufo fowleri	9.0 a	2.7 a	20.3 a	12.7 a
Carphophis a. amoenus	1.3 a	4.7 a	3.3 a	4.4 a
Eumeces fasciatus	7.0 ab	4.3 a	11.7 b	9.6 b
Gastrophyrne carolinensis	2.0 a	3.0 a	3.0 a	4.7 a
Plethodon teyahalee	1.7 a	8.7 a	1.7 a	5.7 a
Rana catesbieana	1.3 a	9.0 a	5.2 a	2.3 a
Scincella lateralis	5.2 a	3.3 a	4.6 a	3.0 a
Sceloporus undulatus hyacinthinus	22.7 a	14.7 a	27.7 a	28.0 a
Tantilla coronata	7.0 a	5.7 a	9.3 a	4.3 a
Terrapene c. carolina	3.3 a	4.3 a	4.0 a	5.0 a

T1 = thin only treatment; T2 = thin/burn treatment.
[a] Means not followed by the same letter within columns differ significantly at $p < 0.05$.

Trap Efficiency

Drift fence/pitfall arrays accounted for 32.3 percent of total captures while modified pitfalls accounted for 30.4 percent. Unmodified pitfalls and hand captures made up 19.2 and 18.0 percent of total captures, respectively. Both drift fence/pitfall arrays and modified pitfalls caught 30 species. Twenty-five species were caught in unmodified pitfalls and 19 species were caught by hand.

There were no significant differences in capture efficiency among trap types for frogs/toads, salamanders, or lizards or for overall capture abundance (table 4). Significantly higher numbers of *T. c. carolina* were caught by hand than by array, modified pitfall, and unmodified pitfall. Modified pitfalls caught significantly more *T. c. carolina* than unmodified pitfalls. Arrays caught significantly higher numbers of snakes than modified pitfalls, unmodified pitfalls, and hand capture.

Array efficiency for snakes, especially *T. coronata*, supported the findings of other trap efficiency studies. Preferred prey for this species are centipedes and insect larvae (Conant and Collins 1998, Martof and others 1980). Arrays may capture more of the preferred *T. coronata* prey than the other trap designs. Abundant species such as *S. u. hyacinthinus* were caught in all trap types with the same relative efficiency. This may be due to the diurnal nature of this species and the amount of area it covers during active periods. During peak breeding activity in the spring, male *S. u. hyacinthinus* are actively seeking females and cover more area. Evidence of this increased activity was reflected by the increase in multiple male captures per pitfall. There were several instances where four or five different males were caught in a single pitfall during the spring. For most of the study, one capture per pitfall was usual.

There were no significant differences in capture efficiency for richness among trap types for frogs/toads, salamanders, and turtles (table 5). Unmodified pitfalls caught significantly more lizard species than hand capture. Significantly more snake species were caught in the array and modified pitfalls than by unmodified pitfalls and hand capture. Overall, there were significantly fewer species caught by hand and unmodified pitfalls than by the other two trap types.

Richness analysis found that trap efficiency varied for lizards, snakes, and the overall number of species captured. Unmodified pitfalls were more efficient for lizards than hand capture because this trap type consistently caught more species of *Eumeces* (Wiegmann). *A. carolinensis*, *S. u. hyacinthinus*, and *S. lateralis* were species common to both hand and unmodifed pitfall traps. However, unmodified pitfalls were more efficient at catching *Eumeces* than hand capture. For each replication, unmodified pitfalls consistently caught two or three species of *Eumeces*, but no more than one of three species was ever caught by hand. *Eumeces* are alert and very active lizards (Contant and Collins 1998) and are much more difficult to capture by hand than *A. carolinensis*, *S. u. hyacinthinus*, and *S. lateralis*.

Table 4—Capture abundance for array, hand, modified, and unmodified trap types

Treatment	Frogs and toads	Salamanders	Turtles	Lizards	Snakes	Overall
Array	34.3 a[a]	20.0 a	3.8 a	53.0 a	32.3 b	30.5 a
Hand	18.7 a	—	13.0 b	42.3 a	5.0 a	19.8 a
Modified	35.0 a	14.0 a	3.7 a	68.0 a	13.0 a	26.7 a
Unmodified	15.0 a	9.5 a	1.3 a	52.0 a	9.7 a	17.8 a

— = Taxon was not present.
[a] Means not followed by the same letter within columns differ significantly at $p < 0.05$.

Table 5—Species richness for array, hand, modified, and unmodified trap types

Treatment	Frogs and toads	Salamanders	Turtles	Lizards	Snakes	Overall
Array	5.3 a[a]	4.0 a	1.5 a	5.3 ab	6.0 a	4.6 a
Hand	3.7 a	—	1.0 a	4.0 a	3.3 b	3.0 b
Modified	5.0 a	5.3 a	1.0 a	5.3 ab	4.0 a	4.1 a
Unmodified	3.7 a	3.2 a	1.0 a	5.7 bc	3.3 b	3.4 b

— = Taxon was not present.
[a] Means not followed by the same letter within columns differ significantly at $p < 0.05$.

CONCLUSIONS

Prescribed burning and thinning for fuel reduction had minimal effects on herpetofauna in upland pine plantations of the Piedmont. Opening the forest canopy by thinning (Phillips and others 2004) created favorable conditions for two lizard species (*A. carolinensis* and *E. fasciatus*). Adjacent breeding habitat appears to have influenced the abundance and richness of amphibians in a treatment area more than did prescribed fire and thinning. These findings are based on intensive sampling of herpetofauna with a variety of methods and knowledge of land use adjacent to treatment areas. Because prescribed burning and timber harvest have been documented as having definite effects on herpetofauna, further post-treatment research should be conducted to expand on the baseline data collected thus far.

ACKNOWLEDGMENTS

The authors thank Peter R. Kapeluck, Ross J. Phillips, and Victor B. Shelburne for their insightful comments on the manuscript. Zack Featherstone, Anna P. Kilpatrick, Shaun C. Worley, and Luara A. Zebehazy assisted in field work, and James Williams assisted in data analyses. This is contribution Number 27 of the National Fire and Fire Surrogate Project (NFFS), funded by the U.S. Joint Fire Science Program.

LITERATURE CITED

Bennett, S.H.; Gibbons, J.W.; Glanville, J. 1980. Terrestrial activity, abundance and diversity of amphibians in differently managed forest types. American Midland Naturalist. 103(2): 412-416.

Bury, R.B.; Campbell, H.W.; Scott, N.J., Jr. 1980. Role and importance of nongame wildlife. Transactions of the North American Wildlife and Natural Resource Conference. 45: 197-207.

Conant, R.; Collins, J.T. 1998. A field guide to the reptiles and amphibians of eastern and central North America, 3rd edition. Boston, MA: Houghton Mifflin. 616 p.

deMaynadier, P.G.; Hunter, M.L., Jr. 1995. The relationship between forest management and amphibian ecology: a review of the North American literature. Environmental Reviews. 3: 230-261.

Donnelly, M.A. 1989. Demographic effects of reproductive resource supplementation in a territorial frog, *Dendrobates pumilio* (Schmidt). Ecological Monographs. 59: 207-221.

Gibbons, J.W. 1988. The management of amphibians, reptiles, and small mammals in North America: historical perspective and objectives. In: Szaro, R.C.; Severson, K.E.; Patton, D.R., tech. coords. Management of amphibians, reptiles, and small mammals in North America. A symposium proceedings. Gen. Tech. Rep. RM-166. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 1-3.

Gibbons, J. W.; Scott, D.E.; Ryan, T.J. [and others]. 2000. The global decline of reptiles, déjà vu amphibians. Bioscience. 50(8): 653-665.

Highton, R.; Peabody, R.B. 2000. Geographic protein variation and speciation in salamanders of the *Plethodon jordani* (Blatchley) and *Plethodon glutinosus* (Green) complexes in the southern Appalachian mountains with the description of four new species. In: Bruce, R.C.; Jaeger, R.G.; Houck, L.D., eds. The biology of plethodontid salamanders. New York, NY: Kluwer Academic/ Plenum Publishers: 31-78.

Kiester, A.R. 1971. Species density of North American amphibians and reptiles. Systematic Zoology. 20: 127-137.

Lyon, L.J.; Huff, M.H.; Hooper, R.G. [and others]. 2000. Direct effects of fire and animal responses. Chapter 3. In: Wildland Fire in Ecosystems: Effects of Fire on Fauna. Gen. Tech. Rep. RMRS-42. Denver, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 83 p.

Martof, B.S.; Palmer, W.M.; Bailey, J.R.; Harrison, J.R., III. 1980. Amphibians and reptiles of the Carolinas and Virginia. Chapel Hill, NC: University of North Carolina Press. 264 p.

Pechmann, J.H.K.; Wilbur, H.M. 1994. Putting declining amphibian populations in perspective: natural fluctuations and human impacts. Herpetologica. 50: 65–84.

Phillips, R.J.; Waldrop, T.A.; Chapman, G.L. [and others]. [In press] . Effects of fuel reduction techniques on vegetative composition of Piedmont loblolly-shortleaf pine communities: preliminary results of the National Fire and Fire Surrogate Study. In: Connor, K.F., ed. Proceedings of the 12th biennial southern silvicultural research conference. Gen. Tech. Rep. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.

Russell, K.R.; Van Lear, D.H.; Guynn, D.C., Jr. 1999. Prescribed fire effects on herpetofauna: review and management implications. Wildlife Society Bulletin. 27(2): 374-384.

SAS Institute, Inc. 1999. SAS user's guide: statistics. Cary, NC: SAS Institute, Inc.

Sharitz, R R.; Boring, L.R.; Van Lear, D.H.; Pinder, J.E. 1992. Integrating ecological concepts with natural resource management of southern forest. Ecological Applications. 2: 226-237.

Woodbury, A.M. 1953. Methods of field study in reptiles. Herpetologica. 9(2): 87-92.

Wyman, R.L. 1990. What's happening to the amphibians? Conservation Biology. 4: 350-352.