AMPHIBIAN AND REPTILE RESPONSE TO PRESCRIBED BURNING AND THINNING IN PINE-HARDWOOD FORESTS: PRE-TREATMENT RESULTS

William B. Sutton, Yong Wang, and Callie J. Schweitzer[1]

Abstract—Analysis of pretreatment data is essential to determine long-term effects of forest management on amphibians and reptiles. We present pre-treatment amphibian and reptile capture data from April 2005 to May 2006 for a long-term study on herpetofaunal response to prescribed burning and tree thinning in the William B. Bankhead National Forest, AL, United States. Experimental design consists of a three by two factorial randomized complete block design. Drift-fence trapping arrays were used to capture 585 animals representing 12 families and 36 species (17 amphibian species and 19 reptile species) during 600 trap nights. No significant treatment difference was found for amphibians and reptiles for Shannon-Wiener indices or species richness. No significant treatment difference was found for amphibian evenness; however, a significant difference was found for reptile evenness ($p < 0.05$) in stands selected for treatment. Study results highlight the importance of collecting pretreatment data to identify pre-existing data trends in stands scheduled for forest management.

INTRODUCTION

Amphibians and reptiles, collectively known as herpetofauna, represent a diverse class of organisms. In the southeast, certain groups of these animals represent the most abundant vertebrates in forest ecosystems. Empirical evidence exists supporting the declines of amphibians (Stuart 2004) and reptiles (Gibbons and others 2000) throughout much of the world. Although increased UV-B radiation and over-collection are harmful to herpetofauna, habitat destruction and alteration represent the greatest risk to amphibians and reptiles (Dodd and Smith 2003). Habitat disturbances exist in many forms; however, not all disturbances are created equally (Pauley 2005). Conversion of forested areas to agricultural and urban areas is likely to have a greater impact upon amphibians and reptiles compared to forest management practices which allow for habitat regrowth. Nevertheless, because forest management practices alter large land areas, it is necessary to evaluate amphibian and reptile response to these disturbances. The degree to which a species will be affected depends largely on life history patterns and type of forest management practice. Amphibian response to forest thinning appears to be negligible (Brooks 1999, Messere and Ducey 1998); however, Grialou and others (2000) found a negative response of some salamanders to forest thinning. Reptiles generally appear to increase following forest thinning (Adams and others 1996) and canopy disturbances (Greenburg 2000). Amphibian response to prescribed burning is dependent on many factors, such as animal life stage, geographic province, and time of year (Pilliod and others 2003), while reptile response appears to be largely species specific (Greenburg and others 1994).

A large body of literature exists regarding the response of amphibians and reptiles to forest management (Russell and others 2004). However, no research exists regarding the effects of forest canopy reduction and prescribed burning on amphibians and reptiles in areas along the Southern Cumberland Plateau. In addition, many studies have taken a retrospective approach without examining the pretreatment herpetofaunal community parameters.

In this paper we examined pretreatment patterns of amphibians and reptiles in pine-hardwood stands scheduled for disturbance. We evaluated the hypothesis that there were no pretreatment differences between treatments for species richness, species evenness, and Shannon-Wiener indices. Data from this study provides support for the need of pretreatment data when analyzing herpetofaunal response to disturbance in forest ecosystems.

METHODS

Study Site

This study took place in the William B. Bankhead National Forest (BNF), located in Lawrence, Winston, and Franklin Counties, of northwestern AL. Bankhead National Forest is a 72 800 ha multi-use forest located in the southern Cumberland Plateau (Gaines and Creed 2003). In the 1930s, loblolly pine (*Pinus taeda*) was planted to re-establish forest conditions in abandoned agricultural and heavily timbered areas, resulting in 31 600 ha of *P. taeda* throughout BNF (Gaines and Creed 2003). Over the past decade, Southern Pine Beetle (*Dendroctonus frontalis*) infestations have affected *P. taeda* stands, producing large numbers of standing dead trees and increased fuel loads, elevating the risk of damaging wildfires. As canopy removal and fire disturbance have been prevented in forests throughout the study area for decades, BNF has initiated a Forest Restoration Plan to reduce wildfire risk and to promote natural forest growth through tree thinning and prescribed fire disturbance. The BNF has not traditionally utilized prescribed fire as a management tool, but has opted to include prescribed burning in the forest restoration plan due to administrative recommendations.

Stand selection criteria required that stands be similar in structure (basal area and stems/ha) and ratio of pine to hardwood tree species. Pretreatment basal area and stems/

[1]Graduate student, Professor, Alabama A&M University, Normal AL; Research Forester, USDA Forest Service, Southern Research Station, Huntsville AL, respectively.

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ha ranged as follows: block 1 (24-28 m^2/ha; 539-804 stems/ha), block 2 (20-29 m^2/ha; 552-720 stems/ha), and block 3 (28-34 m^2/ha; 506-920 stems/ha).

Experimental Design

We used a before-after and control-impact (BACI) randomized complete block design. Forest manipulation treatments consist of three thinning levels (no thin, 11 m^2/ha residual basal area), and 17 m^2/ha residual basal area) along with two burn treatments (no burn and burn). The experiment was replicated three times across the landscape. Each plot was approximately 9 ha and was blocked accordingly by time of treatment (year) and location in accordance with the BNF's forest restoration plan. Because we only evaluated pretreatment data in this study, study plot designations were only used to illustrate future treatment conditions.

Herpetofaunal Sampling

Amphibians and reptiles were sampled using drift-fence trapping arrays (Renken and others 2004). A single trapping array composed of three drift fences (61 cm high aluminum flashing) 15 m in length radiating from a triangular box trap was installed in each plot. A central box trap was used because it has proven successful for sampling large bodied snakes (Burgdorf and others 2005). In addition, one large box trap was placed at the terminus of each drift fence (three per array), while two pitfall traps were installed at the midpoint of each drift fence (six per array).

Traps were opened with the block number and order of traps randomly determined *a priori*. Number of trap nights was recorded to determine trapping effort (one trap night is equal to one trap unit being open for a 24 hour period). Traps were checked daily between 0700 and 1200 hours (Central Standard Time) to reduce animal mortality. Upon capture, animals were identified to species, measured (snout-vent length and total length, mm) with a dial caliper (0.1-mm), and weighed with an Ohaus digital scale (0.1 g). Animals were given a trap specific mark to assure that recaptured animals were not counted. Frogs, salamanders, and lizards were toe-clipped, while snakes and turtles were marked via sub-caudal scale-clipping and marginal scute marking, respectively. After marking, animals were released on the opposite side of the drift fence in which capture occurred. We trapped animals between April 2005 and May 2006.

Data Analysis

Species captures were compared using the following bio-diversity measures: species richness, Shannon-Wiener diversity index, and species evenness. Species richness refers to the number of different species found within a community. Shannon-Wiener index is a biodiversity measure that takes into account species richness and species evenness (the relative abundance with which each species is represented in an area). The Shannon-Wiener index was calculated based on

$$H' = -\sum_{i=1}^{s} (p_i)(\ln p_i) \quad (1)$$

where H' = diversity of species, s = number of species, and p_i = proportion of total sample belonging to the i^{th} species. Shannon-Wiener diversity scores usually fall between 1.5 and 3.5 and are relative to the tested sample (Magurran 1988). Species evenness represents the relative distribution of individuals among species. Evenness is calculated based on

$$E = H' / H\max \quad (2)$$

where E = evenness measure, H' = Shannon-Wiener function, and H_{max} = maximum value of H' = ln s (number of species). Evenness scores range between 0 and 1, with 1.0 representing a situation in which all species are equally abundant (Magurran 1988).

A general linear model (GLM) was used to compare mean values for species richness, Shannon-Wiener diversity index, and evenness across treatment plots. An alpha level of 0.05 was used for all GLM tests. Tukey tests were used for mean separation. Amphibians and reptiles were analyzed separately due to differences in life history characteristics. Statistical Package for the Social Sciences v. 10.0 (SPSS Inc., USA) was used for all statistical analyses.

RESULTS

A total of 585 unique amphibians and reptiles representing 14 families and 36 species (17 amphibian species and 19 reptile species) were captured during 600 trap nights (Appendix A). The Mississippi slimy salamander (*Plethodon mississippi*) and green frog (*Rana clamitans melanota*) were the most commonly captured amphibians with 206 and 24 individual captures, respectively, while the ground skink (*Scincella lateralis*) and green anole (*Anolis carolinensis*) were the most commonly captured reptiles, with 70 and 33 individual captures, respectively (Appendix A).

Pretreatment Shannon-Wiener indices were not different among the plots, although reptiles had more variability and tended to be highest in 11 m^2/ha plots (mean score = 1.7 ± 0.32), while amphibians were relatively consistent among selected plots (fig. 1). Pretreatment evenness was not different among plots for amphibians, but was different for reptiles ($F = 4.14$; df = 5, 10; $p < 0.03$) (fig. 2); pretreatment reptile evenness was lowest on control plots (mean score = 0.82 ± 0.006) and highest on burn plots (mean score = 0.96 ± 0.003) (fig. 2). Species richness was not different among selected plots, although it tended to have the greatest value on 11 m^2/ha plots for reptiles (mean score = 7.3 ± 1.8) and amphibians (6.7 ± 0.33) (fig. 3).

DISCUSSION

Thirty-six species were captured during the pretreatment survey period. Similar species estimates (43 species) were obtained over a six year period in a Missouri Ozark Forest (Renken and others 2004). The four most common species captured during this study, Mississippi slimy salamander, green frog, ground skink, and green anole, use a variety of habitats and are common throughout the region. Mississippi slimy salamanders are one of the most abundant amphibians that inhabit upland pine-hardwood forests and are able to exploit almost all terrestrial habitats throughout their range, while green frogs inhabit wet areas ranging from ponds to slow moving streams (Mount 1996). Ground skinks are common in upland forest types, while green anoles are common in open and disturbed areas (Mount 1996).

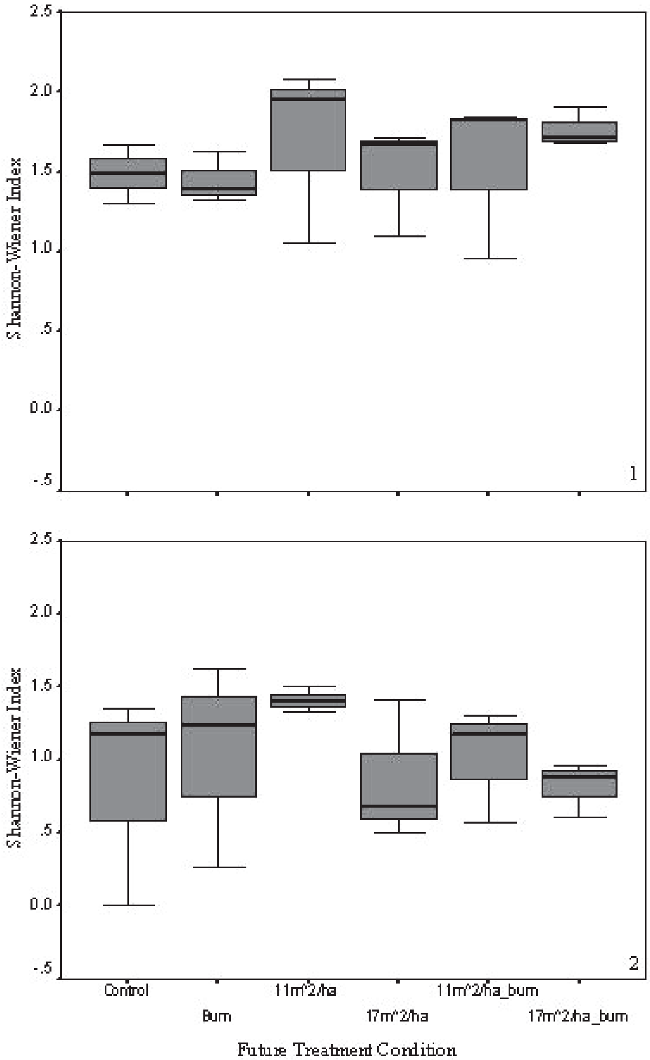

Figure 1—Pre-treatment Shannon-Wiener biodiversity indices for reptiles (1) and amphibians (2) in forest stands of the Bankhead National Forest, AL, U.S.A. No significant differences existed between treatments.

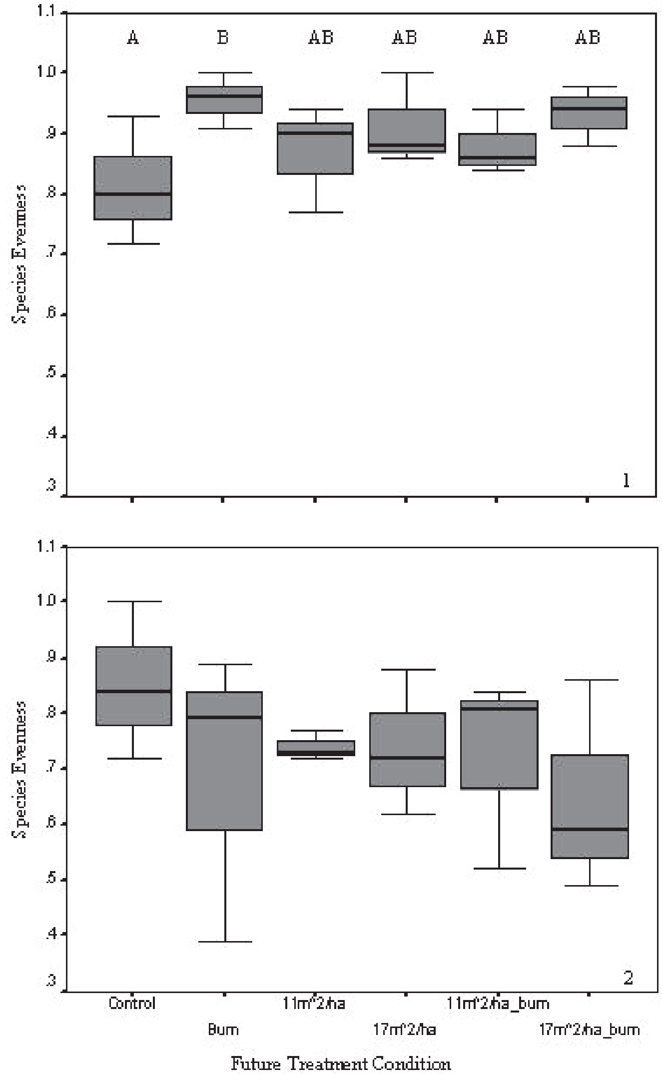

Figure 2—Pre-treatment species evenness biodiversity indices for reptiles (1) and amphibians (2) in forest stands of the Bankhead National Forest, AL, U.S.A. Different letters above boxplots indicate significant differences.

Mean pretreatment biodiversity indices were comparable among plots scheduled for treatments. We found no significant treatment effect for Shannon-Wiener indices, species richness, and evenness for amphibians. This is not surprising, because surveyed stands represent forest stands that were in a "pretreatment" condition and were randomly assigned. Selection criteria required that forest stands in this study had similar disturbance regimes, were between 15 and 45 years of age, were between 210 and 300 m elevation, and were not located along riparian areas. Although all stands examined in this study have been exposed to some type of past forest management disturbance, the study stands had not been exposed to anthropogenic disturbance for at least five years. However, the significant treatment effect found for reptile evenness indicates there is considerable variation between the control and burn plots. Reptile evenness was highest on burn plots indicating that species were represented more evenly than those on control plots. This does not indicate that one plot provides better habitat than another. It indicates that species structure is quite different between these plots. Control stand selection was more constrained than that for other treatment plots. Due to the BNF's forest restoration plan, there were few stands that could be set aside as untreated (control) stands. Therefore, control stands were located in the Sipsey Wilderness Area, which has not seen anthropogenic disturbances since the wilderness designation in 1975. Therefore, pretreatment species evenness differences may be due the longer time to disturbance in control stands when compared to other stands. This significant difference must be taken into account when comparing the post-treatment data.

Most studies of herpetofaunal response to forest management lack true experimental manipulations, treatment replication, and pretreatment data collection. Russell and others (2004) found only six forest management studies

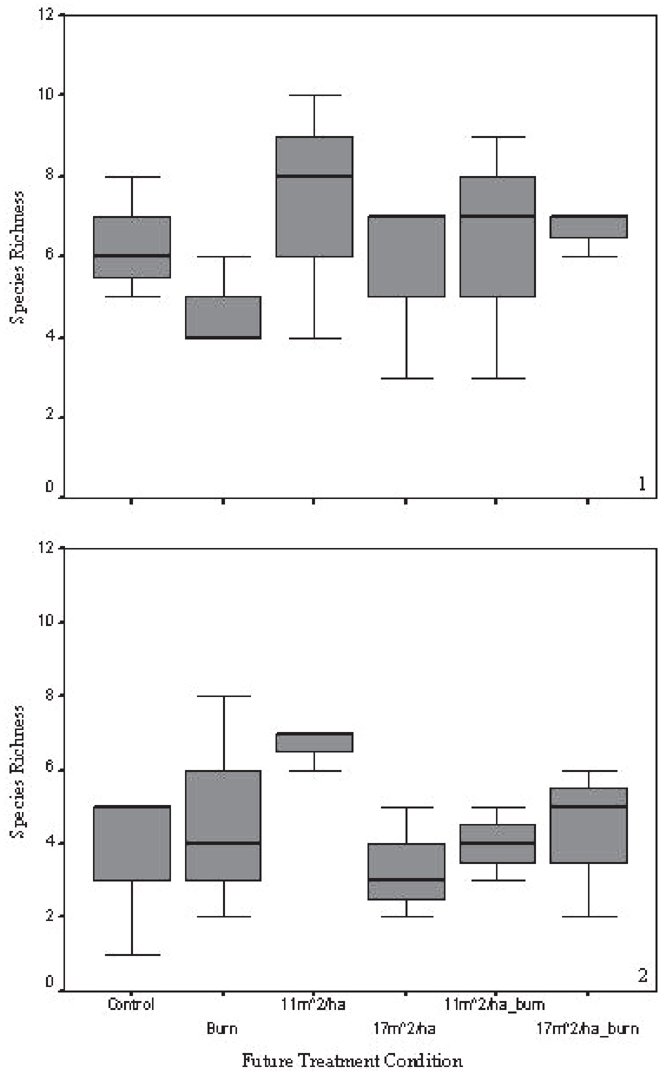

Figure 3—Pre-treatment species richness for reptiles (1) and amphibians (2) in forest stands of the Bankhead National Forest, AL, U.S.A. No significant differences existed between treatments.

that met these criteria. Attempts should be made to include these criteria into future forest management studies; this will increase strength of conclusions from these studies (Sallabanks and others 2000). Our findings indicate the importance of pretreatment data for large-scale forest management studies. We recommend that researchers who wish to implement similar studies should work closely with land managers during project planning periods to assure that pretreatment data can be collected.

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Appendix A—Pre-treatment amphibian and reptile species captures in Bankhead National Forest, Alabama, U.S.A.

Species List	Number Captured
Order Anura	
Family Bufonidae	
Fowler's toad (*Bufo fowleri*)	14
Family Hylidae	
barking treefrog (*Hyla gratiosa*)	1
grey treefrog (*Hyla chrysoscelis*)	1
mountain chorus frog (*Pseudacris brachyphona*)	3
Family Microhylidae	
eastern narrowmouth toad (*Gastrophryne carolinensis*)	9
Family Pelobatidae	
eastern spadefoot (*Scaphiopus holbrookii*)	
Family Ranidae	
American bullfrog (*Rana catesbeiana*)	14
green frog (*Rana clamitans melanota*)	24
pickerel frog (*Rana palustris*)	7
southern leopard frog (*Rana sphenocephala*)	9
Order Caudata	
Family Ambystomatidae	
marbled salamander (*Ambystoma opacum*)	3
spotted salamander (*Ambystoma maculatum*)	4
Family Plethodontidae	
northern red salamander (*Pseudotriton r. ruber*)	14
northern zigzag salamander (*Plethodon dorsalis*)	19
Mississippi slimy salamander (*Plethodon mississippi*)	206
southern two-lined salamander (*Eurycea cirrigera*)	2
Family Salamandridae	
red-spotted newt (*Notophthalmus v. viridescens*)	1
Order Squamata	
Suborder Lacertilia	
Family Phrynosomatidae	
fence lizard (*Sceloporus undulatus*)	12
Family Polychridae	
green anole (*Anolis carolinensis*)	33
Family Scincidae	
broad-headed skink (*Eumeces laticeps*)	17
five-lined skink (*Eumeces fasciatus*)	21
ground skink (*Scincella lateralis*)	70
Suborder Serpentes	
Family Colubridae	
black king snake (*Lampropeltis getula nigra*)	5
black racer (*Coluber c. constrictor*)	9
eastern corn snake (*Elaphe guttata*)	4
eastern garter snake (*Thamnophis s. sirtalis*)	10
eastern worm snake (*Carphophis a. amoenus*)	4
midland brown snake (*Storeria dekayi wrightorium*)	1
midland rat snake (*Elaphe spiloides*)	6
midland water snake (*Nerodia sipedon pleuralis*)	1
red-bellied snake (*Storeria o. occipitomaculata*)	1
red milk snake (*Lampropeltis triangulum syspila*)	1
southern ringneck snake (*Diapdophis p. punctatus*)	4
Family Viperidae	
southern copperhead (*Agkistrodon c. contortrix*)	32
timber rattlesnake (*Crotalus horridus*)	4
Order Testudines	
Family Emydidae	
eastern box turtle (*Terrapene c. carolina*)	3