HERPETOFAUNAL RESPONSE TO OAK-REGENERATING SILVICULTURAL PRACTICES IN THE MID-CUMBERLAND PLATEAU OF SOUTHERN TENNESSEE

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ABSTRACT

Silviculture treatments can alter landscapes, which in return can affect wildlife communities. This research examined how microhabitat differed short-term (1-2 years after disturbance) between two different oak-regenerating shelterwood treatments, a midstory-reduction (oak-shelterwood) and a first-harvested basal area removal (shelterwood), in comparison to undisturbed controls. Mechanisms responsible for influencing herpetofaunal communities were examined in the oak-hickory hardwood forests of the mid-Cumberland Plateau in Grundy County of Southern TN. Herpetofauna were captured using drift fences equipped with pitfall and box funnel traps, and microhabitat variables were collected at each trap location. Shelterwood stands had a higher amount of slash, slash pile volume, and woody and herbaceous vegetation than other stand types. Oak-shelterwood and control stands had higher litter depth, litter cover, and presence of overstory than shelterwood stands. Eastern fence lizards, eastern five-lined skinks, Fowler's toads and broad-headed skinks were all significantly more abundant in stands that received manipulation in comparison to control stands.

INTRODUCTION

Herpetofauna are important components of biological diversity, and play an ecological role as predators and prey. Understanding herpetofaunal responses to forest management practices that alter habitat conditions is important because many species have specific habitat requirements. Many herpetofaunal species use structural features of forests, ranging from the tree canopy to the forest floor, as habitat. Complex vegetation structure, such as multiple tree strata (canopy, understory, and shrub layers) and dead standing trees, also provides habitat and foraging sources for many wildlife species (Lanham and Guynn 1996). Changes in the availability of these forest features may affect the density and species composition of wildlife communities and individual species (Felix and others 2009, Wang and others 2006). Forest management techniques that affect forest structure, microhabitat, and microclimate have the potential to affect plant and animal community composition and abundance. Wildlife response to forest disturbance may vary with the type and intensity of disturbance, the forest type, and across their geographic range. Understanding vertebrate community responses to changes in forest conditions is important in predicting impacts of forest management.

The USDA Forest Service Southern Research Station, Upland Hardwood Ecology and Management Research Work Unit 4157 implemented a regional oak study (ROS) (Greenberg and others 2008, Keyser and others 2008) with partners to address how three recommended, but not widely tested, oak regeneration treatments affect oak and other hardwood species regeneration and wildlife communities across three areas within the southern Central Hardwood Region of the USA. In the ROS, effects of the following forest management treatments are being examined: 1) Shelterwood with prescribed fire (SW), 2) Oak-Shelterwood (OSW), and 3) Prescribed fire. All 3 regeneration prescriptions will have any residual trees removed 11 years after initial implementation. Studying herpetofaunal response to these treatments is one of many components of this multidisciplinary research. The herpetofaunal study examined how these disturbances affected herpetofaunal species abundance, and the mechanisms (e.g. microhabitat features) possibly responsible for influencing such communities. This study examined the short-term differences detected in microhabitat variables among SW, OSW, and control stands, and the variation of herpetofauna in relationship to treatments and habitat conditions.

STUDY SITE DESCRIPTION

The study site was located on the mid-Cumberland Plateau of southern Tennessee. This research was conducted in Grundy County, TN on property owned by Stevenson Land Company. The elevation of the site is approximately 390 m to 550 m above sea level. The forest stands are located on the eastern escarpment of Burrow's Cove, drained by Laurel

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Creek; stands are located to the north and south of Mill Hollow. Braun (1950) classified the area as being in the cliff section of mixed mesophytic forest region. The forest stands on average had a basal area (BA) of 22.5 m^2/ha and 164 stems/ha (SPHA), and they are composed of 27 different hardwood species, having yellow poplar (*Liriodendron tulipfera*), sugar maple (*Acer saccharum*), white oak (*Quercus alba*), pignut hickory (*Carya glabra*), and northern red oak (*Quercus rubra*) as their dominant overstory trees (unpublished data, Callie J. Schweitzer).

EXPERIMENTAL DESIGN

The field experiment followed the guidelines of Greenberg and others (2008) which adopted a completely randomized design with 3 oak regenerating treatment types and 1 control, each replicated 5 times for a total of 20 experiment stands (approximately 5 ha each). Treatment units were selected by the USDA Forest Service researchers following guidelines that all treatment units have mature closed canopy stands with trees >70 years old without major anthropogenic or natural disturbances within the last 15-20 years.

The prescribed burns were not implemented during the course of this study. However, since data were collected within these unaltered stands, they were considered control stands during statistical analyses. Two out of the five SW treatments were not harvested prior to the completion of field sampling and are omitted from statistical analyses. These modifications resulted in 18 experimental stands: 10 controls, 5 OSW, and 3 SW.

SILVICULTURE TREATMENTS

Shelterwood harvest method—The SW harvest prescription followed the guidelines of Brose and others (1999). The treatment entailed harvesting of timber with a 30-40 percent basal area (BA) retention. Residual trees were based on species, diameter and quality. Trees were harvested by chainsaw felling and grapple skidding along pre-designated trails, leaving removed limbs and branches within the stands. Treatments were implemented in the fall and winter of 2008.

Oak-shelterwood method—The OSW treatment followed the guidelines of Loftis (1990). This treatment used a Garlon 3A herbicide, with the main active ingredient being Trichlopyr. Herbicide was induced into competing mid-story trees with ≥ 5 cm and ≤ 25 cm diameter at breast height (DBH) by the hack-and-squirt method. The initial treatment implementation in fall/winter of 2008 was not effective for undetermined reasons and was repeated in the fall/winter of 2009.

MATERIALS AND METHODS

MICROHABITAT

Microhabitat data were collected along line transects located at each herpetofauna sampling drift fence. At each fence two 10-m transects were installed. Transects originated 2 m from the middle of the fence to eliminate any disturbance caused by drift fence installation. Direction of the first transect was randomly determined by azimuth degree compass bearing, and the second transect used the polar opposite of the first transect on the opposite side of the fence. Variables recorded along transects included: litter depth, percent ground cover, volume of coarse woody debris (CWD) and slash, and forest stratification. Litter depth was recorded every 2 m along each transect using a ruler to the nearest millimeter. Percent ground cover was recorded every 5 m along each transect using 0.5 x 0.5 m sampling plots. Percent ground cover categories included leaf litter, bare ground, CWD, slash, rock, and herbaceous and woody vegetation. Percent cover of each category was recorded as cover within or directly above the sampling plots up to 2 m. Forest strata were visually assessed at each 5 m interval. The forest strata was assigned one of the following categories modified from Sutton (2010): 1) ground cover (≤ 2 m); 2) understory (> 2 m – ≤ 4 m); 3) midstory (> 4 m – < overstory); and 4) overstory (the main forest canopy). Volumes of CWD and slash piles were also assessed. Length and diameter at transect contact was recorded for all CWD ≥ 10 cm in diameter at the transect intercept point. Volume of CWD was calculated using the formula given by Van Wagner (1968). The volume of slash piles was roughly estimated; slash was measured if any portion of a mound intersected with the transect based on diagrams given by Hardy (1996). Canopy cover was collected at the center of each drift fence using a hand-held spherical densiometer during mid-summer when the canopy foliage was full.

HERPETOFAUNAL TRAPPING

The herpetofaunal community was assessed from mid-May until the end of September in 2010 via drift fences with pitfall and double funnel box traps, a commonly used technique to capture terrestrial reptile and amphibian species (Dodd 1991). In each unit four drift fences of 7.6 m long aluminum flashing were installed by excavating trenches approximately 15.2 cm deep and 15.2 cm wide and secured using wooden stakes. Two drift fences were installed at the lower slope region (bottom 1/3 of the stand) and the other two drift fences were installed at the upper slope region (top 1/3 of the stand). A pitfall trap (a 19 L bucket) was installed into the ground at each end of the drift fence. Each drift fence also had a funnel box trap at the center along each side of the fence. Traps were opened continuously except for a few days at the end of August and beginning of September. All traps were checked four to six days a week. Each time a single drift fence was checked it was recorded as being a single trap night.

STATISTICAL ANALYSIS

Species and microhabitat data were analyzed using general linear model analysis of variance (ANOVA) for a completely randomized design to determine if there were any differences among treatment types. Post-hoc Tukey multiple range tests (HSD) were used to identify differences between specific treatments if ANOVA tests were significant. Principal component analysis (PCA) was used to simplify microhabitat variables into components, which allowed the interpretation of possible relationships among microhabitat variables. A constrained ordination technique, canonical correspondence analysis (CCA), was used to explore the relationship between herpetofaunal species and microhabitat variables (McGarigal and others 2000). Microhabitat variables represented by vectors in CCA that did not show a strong relationship with either axis were excluded. Species with < 10 captures were excluded from CCA and ANOVA analyses. All tests were performed with $\alpha = 0.1$.

RESULTS

MICROHABITAT

Several microhabitat variables differed among treatments in 2010 (Table 1). Canopy cover was the only variable significantly different among all three treatment types, which averaged 92 percent for control stands, 86 percent for OSW stands, and 67 percent for SW stands. Oak-shelterwood and control stands had higher litter depth, litter cover and presence of overstory than SW stands. Shelterwood stands had a higher amount of slash, slash pile volume, and woody and herbaceous vegetation than control and OSW treatment stands. Shelterwood stands had more bare ground than OSW and control stands. Understory and midstory structure was reduced in SW and OSW treatments compared to control stands.

Principal component analysis extracted 5 separate components (eigenvalue >1) that accounted for 74.2 percent of total habitat variance (Table 2). Component one was positively related to canopy cover, overstory structure, litter depth, and ground litter cover, and negatively related to the amount of slash, ground cover, and woody and herbaceous vegetation covers. Component two was positively related to canopy cover and understory and midstory vegetation cover, and negatively related to ground cover vegetation. Component three was positively related to slash and slash pile volume, and the amount of bare ground, and negatively correlated with litter depth. Component four was positively related to the presence and volume of CWD, but negatively related to the amount of ground cover vegetation. The last component, component five, was positively related to the rock coverage and negatively related to the litter depth.

HERPETOFAUNA

There were 96 days of trapping during the 2010 field season, which resulted in 6,912 trap nights. A total of 4,108 individuals of 28 species were captured. American toads (*Anaxyrus americanus*) made up 84.6 percent of the individuals captured. The abundance of four hereptofaunal species differed among treatments. Eastern fence lizards (*Sceloporus undulatus*), Eastern five-lined skinks (*Plestiodon fasciatus*), and Fowler’s toads (*Anaxyrus fowleri*) were more abundant in SW stands than oak-shelterwood and control stands (Table 3). Broad-headed skinks (*Plestiodon laticeps*) were more abundant in OSW stands (Table 3).

MICROHABITAT AND HERPETOFAUNAL RELATIONSHIP

For amphibians, CCA eigenvalues accounted for 84.9 percent of total variance of species-environment relationship (Figure 1). Axis 1 was positively correlated to the percent cover of rock and bare ground, and negatively related to litter cover and presence of overstory; the second axis was positively related to the covers of woody vegetation, slash, and overall ground cover, and negatively related to the mid and upper story vegetations, slash pile volume, litter depth, and CWD volume. Eastern spadefoot toads (*Scaphiopus holbrookii*) had a strong positive relationship with high coverage of herbaceous vegetation, and slash. Other species such as southern leopard frogs (*Lithobates sphenocephala*), pickerel frogs (*Lithobates palustris*), American toads, and Fowler’s toads appeared to be habitat generalists and occurred at the center of the CCA plot. Eastern red spotted newts (*Notophthalmus v.viridescens*) occurred more often in sites with high rock coverage, whereas green frogs (*Lithobates clamitans*) occurred more often at sites with more bare ground. Cave salamanders (*Eurycea lucifuga*) appeared to have a strong association with the second axis, and occurred at sites with high ground cover.

For reptiles, CCA eigenvalues accounted for 88.9 percent of total variance for species-environment relationship (Figure 2). Axis 1 represented a gradient from higher percentage of bare ground, CWD, and volume of slash, and negatively related to canopy cover, litter cover and depth, and understory. Axis 2 represented a gradient from higher percentage of rock, presence of overstory, and CWD volume, and was negatively related to woody vegetation, presence of ground cover and midstory. Most reptile species appeared to be habitat specialists and were associated with specific microhabitat features. For example, eastern fence lizards had strong positive relationship with the first axis, characterized by habitats with more slash piles and increased bare ground, whereas broad-headed skinks had a strong negative association with the first axis, with more litter cover and understory. Copperheads (*Agkistrodon contortrix*) and eastern five-lined skinks were associated with sites that had a higher presence of overstory and litter depth. Species such as the midwest worm snake (*Carphophis a. helenae*) and eastern garter snake (*Thamnophis s. sirtalis*) were not strongly associated with any of the tested microhabitat variables.

DISCUSSION

This study examined herpetofaunal response to the habitat changes created by different forest management prescriptions for oak regeneration. Only the first phase of each SW was implemented and studied, however each created uniquely different microhabitat characteristics. Only the SW treatment involved a commercial harvest, which resulted in a 42 percent reduction in overstory basal area. The OSW treatment did not alter the overstory basal area but did change the composition and structure of the midstory.

Several reptile species were more abundant in SW stands compared to OSW and control stands. This can be attributed to the subsequent changes in forest canopy cover. The opening of the forest canopy increased the amount of light available for thermal regulation by reptiles. This coincides with findings by Felix (2007) who also found an overall increase in reptilian species richness and abundance in response to canopy removal. Results of this study indicated that abundance of most amphibians was either unchanged or increased in disturbed forest habitats. This may be due to several factors, including the increased heterogeneity and complexity within these stands.

Canonical correspondence analysis showed the habitat associations of reptile and amphibian species regardless of the treatment by examining habitats associated with specific trapping locations. Most species in this study were habitat specialists and were associated with specific habitat features. The gradients demonstrated in CCA also helped verify the microhabitat conditions presented by PCA and ANOVA. For example, in the CCA conducted using reptiles and habitat associations, high canopy cover, litter cover, and litter depth were correlated, and were associated with control stands in ANOVA. These associations are also seen in PCA. These same variables using CCA were inversely related to percent coverage of woody, herbaceous, and slash covers, which corresponded to ANOVA results showing these variables to be more abundant in SW treatment stands.

CONCLUSIONS

Results from this study showed that several microhabitat features in both the SW and OSW silviculture treatments differed from control stands in the short-term. These differences, either directly or indirectly, influenced the composition and abundance of herpetofaunal communities. The SW and OSW method created openings in the canopy and changes in the vertical structure of vegetation that likely resulted in more woody and herbaceous vegetation ground cover. The SW method resulted in more open areas, less canopy cover, and increased light availability. These increases were beneficial for species that depend on sunlight for thermoregulation. The SW treatment removed both the midstory and overstory, which resulted in less litter cover and litter depth due to a decrease in the source. However, litter cover and depth will likely increase over time as the vegetation responds, regeneration occurs, and the system inputs leaves and twigs as part of the deciduous vegetation process. Shelterwood stands also had higher amounts of CWD and slash on the forest floor, which provided cover not found in the other treatments. All of these factors contributed to increased complexity and heterogeneity of the forest floor environment and microenvironments, providing increased habitat diversity that appeared to benefit some reptile and amphibian species and subsequently change species abundance compared to OSW and control stands.

These findings give forest resource managers and private land owners in the region the knowledge of how herpetofauna respond to these two forest management practices compared to no management in the short-term. Results suggest that these two active management practices for oak regeneration do not adversely affect reptiles or amphibian populations, and may benefit some of these species. However, the scale and intensity of such operations combined with differences in geographic locations should be considered. It should also be considered that these results are indicative of only one-year of response data, and responses over longer temporal and broader spatial scales should be investigated.

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Table 1—Comparison of microhabitat variables for three management treatments in Grundy County, TN, 2010. ANOVA (F) test was followed with post-hoc Tukey tests. Means in the same row (Means ± Standard Deviation) with different superscript letters indicate significant difference (Tukey p<0.1)

Variable	Control	Oak-Shelterwood	Shelterwood	F	P
Canopy Cover %	92.3± 3.02 ^{a}	86.1±5.18^{b}	67.4±9.91^{c}	101.12	0.000
Litter Depth (cm)	3.2± 1.15 ^{a}	3.4±1.14^{a}	2.2±0.77^{b}	4.61	0.013
Litter Cover %	62.5± 12.54 ^{a}	60.2±8.85^{a}	23.3±9.89^{b}	58.95	0.000
Bare Ground Cover %	0.9± 1.77 ^{ab}	0.7±0.91^{b}	2.3±2.38^{a}	3.386	0.040
Slash %	4.0± 2.07 ^{b}	4.0±1.74^{b}	7.9±4.28^{a}	12.31	0.000
Slash Pile Volume (m^3/ha)	0.0±0.00 ^{b}	0.0±0.00 ^{b}	87.61±98.3 ^{a}	24.91	0.000
Woody Vegetation %	13.0± 8.5 ^{b}	14.4±9.18^{b}	30.2±11.92^{a}	16.25	0.000
Herbaceous Vegetation%	8.9± 8.13 ^{b}	9.9±6.79^{b}	24.1±10.45^{a}	16.55	0.000
Understory	0.6± 0.31 ^{a}	0.1±0.2^{b}	0.2±0.19^{b}	23.58	0.000
Midstory	0.7± 0.23^{a}	0.2±0.18^{b}	0.4±0.29^{b}	37.87	0.000
Overstory	01.0± 0.13^{a}	1.0±0.05^{a}	0.8±0.18^{b}	10.28	0.000

Table 2—Component loadings based on principal component analysis for microhabitat variables in Grundy County, TN, 2010

	Component				
Variable	PC1	PC2	PC3	PC4	PC5
Litter %	.85	.29	-.16	-.09	-.20
Overstory	.78	-.23	-.24	-.10	-.05
Woody %	-.81	-.18	-.02	-.25	-.04
Canopy Cover %	.76	.44	-.30	-.15	.04
Herbaceous %	-.74	-.27	-.05	.14	-.15
Slash %	-.49	.06	.48	.02	.20
Ground Cover %	-.45	-.42	-.11	-.52	.11
Understory	.13	.90	-.14	-.04	.06
Midstory	.18	.82	.02	-.02	-.27
CWD %	-.02	-.04	.27	.73	-.09
CWD Volume (m^3/ha)	-.17	-.08	-.12	.80	.15
Slash Piles Volume (m^3/ha)	-.40	-.25	.65	.18	.16
Bare Ground %	.03	-.05	.92	.09	-.07
Litter Depth (cm)	.42	-.13	-.40	.27	-.48
Rock %	.08	-.18	.01	.07	.89
Percent of Variance	26.52	14.73	13.01	11.2	8.57
Cumulative Percent	26.52	41.25	54.26	65.46	74.0

Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kaiser Normalization

Table 3—Herpetofaunal response to three different forest management practices at Burrow Cove in Grundy County, TN, 2010. ANOVA (F) test was followed with post-hoc Tukey tests. Means in the same row (Means $\pm$ Standard Deviation). Different superscript letters indicate significant difference (Tukey p<0.1)

Species	Scientific Name	Control	Oak-Shelterwood	Shelterwood	F	P
Eastern Five-Lined Skink	*Plestiodon fasciatus*	0.6 ± 0.76^{b}	0.8 ± 1.03^{b}	1.8 ± 0.98^{a}	4.951	0.013
Eastern Fence Lizard	*Sceloporus undulatus*	0.1 ± 0.31^{b}	0.5 ± 0.53^{b}	4.3 ± 3.78^{a}	18.569	0.000
Broadheaded Skink	*Plestiodon laticeps*	0.2 ± 0.52^{b}	1.2 ± 1.81^{a}	0.7 ± 0.82^{b}	2.923	0.068
Fowler's Toad	*Anaxyrus fowleri*	0.6 ± 0.68^{b}	1.3 ± 1.57^{ab}	1.8 ± 1.17^{a}	3.615	0.038

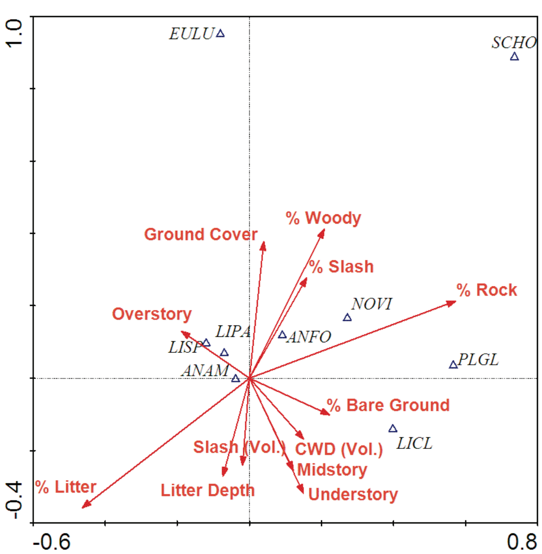

Figure 1—Canonical correspondence analysis ordination plot representing the relationship between amphibian species and microhabitat variables at Burrow Cove in Grundy County, TN, 2010. Four-lettered abbreviations accompanied with triangles represent the Garrison code of species scientific names and arrowed lines represent microhabitat variables.

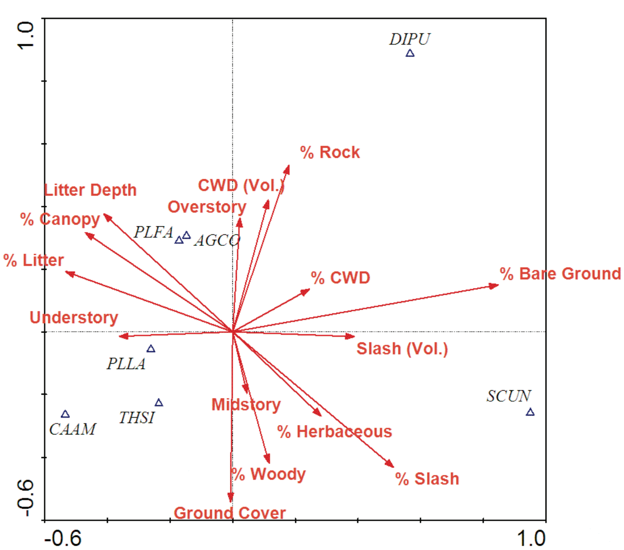

Figure 2—Canonical correspondence analysis ordination plot representing the relationship between reptile species and microhabitat variables at Burrow Cove in Grundy County, TN, 2010. Four-lettered abbreviations accompanied with triangles represent the Garrison code of species scientific names and arrowed lines represent microhabitat variables.