INFLUENCES OF SHELTERWOOD PRESCRIPTIONS TO ABOVE-GROUND CARBON STORAGE AND HERPETOFAUNAL AND SMALL MAMMAL COMMUNITIES

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Abstract--We examined the response of herpetofaunal and small mammal communities to silvicultural treatments. In addition, differences between silvicultural treatments of carbon storage ratios in trees, shrubs, vines, herbaceous material, course woody debris, and fine woody debris were studied. A complete randomized design with multiple replications, 20 experimental stands of approximately 5 ha each, was used to test three prescriptions: (1) control (no alteration); (2) shelterwood (SW, 30 to 40 percent basal area retention); and (3) oak shelterwood (OSW, herbicide midstory treatment with triclopyr). Drift fences with pitfall and box funnel traps and Sherman live traps were used to assess herpetofaunal and small mammal communities. Above-ground materials for carbon quantification were either collected, dried, and weighed or derived using estimating equations to ascertain carbon ratios. We found more carbon in control and oak shelterwood compared to shelterwood. Overstory trees contained the majority of the carbon within all treatment types and accounted for most of the differences in total carbon between treatment types. In comparison between treatment types, OSW and SW had the highest herbaceous carbon content. Over both years, the most abundant reptile was eastern fence lizard (*Sceloporus undulatus*), the most abundant amphibian was American toad (*Anaxyurus americanus*), and the most abundant small mammal was the white-footed mouse (*Peromyscus leucopus*). Lizards were more abundant in the shelterwood stands in 2011 and 2012 compared to the other treatments.

INTRODUCTION

There has been a growing public awareness and political interest in the limited supply and ecological effects of using fossil fuels to generate energy. This increased awareness has raised interest in renewable bioenergy resources. Forest and agricultural residues are showing promise as a source of biofuels (Winandy and others 2008). Studies have estimated that fossil fuel consumption can be significantly offset with the use of wood product biofuels (De Vries and others 2007, Field and others 2008). This may increase demand for intensive biomass production. Much of this production in the United States could be centered in the Southeast, as it has been estimated that over one half of the nation's recoverable forestry residues are found in the Southeast and south-central regions (Gan and Smith 2006). Forests store carbon as they accumulate biomass, and active management of forests can influence carbon storage in several ways. Applied silviculture prescriptions germane to forested ecosystems result in varying ratios of carbon stocks stored in hardwoods, softwoods, woody shrubs, herbaceous growth, woody debris, and in the soil (Tilman and others 2006).

Forest above-ground structures, or forest biomass, provides habitat for a diverse array of organisms that interact with each other and the environment resulting in a number of important ecosystem functions and services (Ferris and Humphrey 1999). Total above-ground forest biomass is a complex structure that provides habitat and foraging sources for many wildlife species (Lanham and Guynn 1996). Changes in these forest features can affect the density and species composition of wildlife communities as well as individual species (Wang and others 2006). The presence and continued input of dead wood or woody debris in various states of decay are of key significance for biodiversity in managed forest systems (Hansen and others 1991). A variety of studies indicates that changes in woody debris supplies due to forest management can have strong impacts on forest biodiversity (Cromer and others 2007, Nordén and others 2004, Verschuyl and others 2011). Horner and others (2010) also found that moderate disturbance (thinning) resulted in the highest carbon standing stocks and that the lowest carbon storage was found in untreated stands. The sustainability of any short-term gain in biomass or carbon will be impacted by the age, diameter, and species distribution of the residual trees, which may or may not continue to respond over time (D'Amato and others 2011, Hoover and Stout 2007,).

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Management Research Work Unit implemented a study with partners to address how three treatments affect oak and other hardwood species regeneration and wildlife communities. Effects of the following forest management treatments are currently being examined: (1) shelterwood with prescribed fire (SW); (2) oak shelterwood (OSW); and (3) untreated control. All three treatment types will have all residual trees cut 11 years after initial implementation.

Study Site Description

The study site is located in Grundy County, TN, situated on the Mid-Cumberland Plateau. This property is owned and managed by Stevenson Land Company. The treatment stands are located on the eastern escarpment of Burrow's Cove. The site is just east of the Eastern Highland rim (Smalley 1982). The site is classified as being a true plateau with strongly dissected margins (Smalley 1982), and additionally described by Braun (1950) as being in the Cliff section of Mixed Mesophytic Forest region. Stands were situated on the escarpment. Upland oak site index (SI) is 23 to 24 m, and yellow poplar SI is 30 m (Smalley 1982). Soil classification is Bouldin Stony Loam (NRCS 2007), which is deep and well drained, consisting of 30 percent rocky slopes. The hardwood forest within the stands is comprised of 27 different species with yellow poplar (*Liriodendron tulipfera* L.), sugar maple (*Acer saccharum* Marsh.), white oak (*Quercus alba* L.), pignut hickory [*Carya glabra* (Mill.) Sweet], and northern red oak (*Quercus rubra* L.) as the dominant overstory trees (Cantrell and others 2013). For stems over 25 cm in diameter, the stands have a basal area (BA) of 22.5 m^2/ha and 1,000 stems per ha (SPHA). Following treatment, the basal area (for stems > 25 cm in diameter) of the control stands was 22.8 m^2/ha with 993 SPHA. The OSW had a basal area of 24.0 m^2/ha and 1,060 SPHA, and the SW had 9.7 m^2/ha of basal area and 613 SPHA. For the OSW, the average treated stem diameter was 10.5 cm, and 1,500 SPHA were treated. (Personal communication. 2013. Callie Schweitzer, Research Forester, USDA Forest Service, Southern Research Station, 730-D Cook Avenue, Huntsville, AL 35801).

Experimental Design

The field experiment was originally designed targeting three regeneration treatments and one control replicated five times resulting in 20 experiment units or stands (approximately 5 ha each). Treatment stands were selected by the Forest Service researchers so as to have mature closed canopy stands with trees > 70 years old and without any major anthropogenic or natural disturbances within the last 15 to 20 years.

Modifications were made to the original experimental design. The prescribed burn was not implemented therefore we incorporated these unaltered stands as control stands. One of the oak shelterwood stands and two of the controls were partially harvested on the bottom slope and were not used due to the impact on the animal sampling protocols. One prescribed burn stand was harvested at the same level as the other shelterwoods and was considered a shelterwood stand. These modifications resulted in 17 experimental units: 6 shelterwood stands (SW), 4 oak shelterwood stands (OSW), and 7 control stands.

Shelterwood

The shelterwood method is an even-aged forest management practice that allows the regeneration of a new tree cohort under a partial over-story (Spetich and Graney 2003) due to increased light availability to the understory. The shelterwood harvest prescription used the guidelines of Brose and others (1999). The treatment entailed harvesting of timber with 30 to 40 percent of the original BA retained. Residual trees were retained based on species, diameter, and quality. Trees were harvested by chainsaw felling and grapple skidding. Many dominant and co-dominant oak species were retained in the residual stand. Trees harvested had their crown, limbs, and branches removed on site, leaving the majority of slash within the stand (Cantrell and others 2013).

Oak Shelterwood

The oak shelterwood method is a modified silviculture practice that is used specifically for the purpose of regenerating oak (Loftis 1990). This method reduces the midstory structure via the use of herbicides, with a goal of reducing competition from shade-tolerant trees and increasing light to the understory. In this process, the herbicide treatment is followed by overstory removal once the regenerating oaks reach a height which will allow them to compete with other species upon release (Cantrell and others 2013).

The OSW treatment followed the guidelines of Loftis (1990). The treatment used triclopyr herbicide (Garlon 3A, Dow AgroSciences, LLC) applied to the trunk via the hack and squirt method. Herbicide was applied to competing mid-story trees with > 5 cm and < 25 cm in diameter at breast height (d.b.h.). Initial treatment was repeated in fall/winter of 2009 due to defective active ingredient in the original chemical used.

Herpetofaunal Sampling

The herpetofaunal community was sampled using drift fences with box funnel traps. Each stand contained four drift fences made of 7.6-m lengths of aluminum flashing with funnel traps placed centrally on both sides of the fence. In addition, 19 L buckets were dug in flush with the ground surface at each end of the fence. Each pitfall had drainage holes to minimize mortality (Cantrell and others 2013).

Trapping was conducted from mid-May until the end of September in 2011 and 2012. Traps were open continuously except for 1 week in August. Captured animals were measured, identified, and released. Captured herpetofauna were marked using toe clips. Clip corresponded to treatment type and year captured. All animals were released a few meters away from their capture site.

Small Mammal Sampling

The small mammal community was surveyed using Sherman live traps (7.7 x 9.0 x 23.3 cm) (Cantrell 2010). In addition, mammals found in the drift fence arrays were recorded. Sherman live trapping was conducted from June and through August with each stand sampled twice. Each sampled stand had 60 Sherman live traps placed 10 m apart within a 50- by 90-m grid. All traps were baited with peanut butter and re-baited each day. To avoid possible sample time bias, four stands were sampled concurrently for each trapping period, one stand of each treatment type (control, SW, OSW), as well as one additional stand of one of the treatment types. All traps were opened continuously for five nights and checked each morning. After the five-night trapping period, the traps were moved to the next set of stands. After all stands have been sampled once, the process was repeated resulting in 10-trap nights of sampling per stand. While the stands that were sampled concurrently remained the same, the order in which the groups of stands were chosen for sampling was randomized during both sampling periods to minimize time bias. Captured mammals were measured, identified, and released. All animals were released a few meters away from their capture site. Captured mammals were marked using toe clips. Clip corresponded to treatment type and year captured.

Carbon Sampling

In the summer of 2012, field samples were collected to determine the amount of dried mass and to model the carbon stored within trees (d.b.h. > 1 cm.); woody vegetation (d.b.h. ≤ 1cm at 1 to 30 cm above ground level); herbaceous vegetation; coarse woody debris [small end diameter > 7.62 cm (Woodall and Williams 2005)]; fine woody debris (small end diameter ≤ 7.62 cm); and vines.

Vines, woody vegetation, and herbaceous vegetation were harvested from 1- by 1-m quadrats by clipping at ground level at 10 m from the center of each drift fence at two randomly generated azimuths. If the quadrat fell within a permanent vegetation sample plot or directly on a large standing tree then the next azimuth was used. The quadrat was constructed using 3.8-cm-diameter PVC pipe and was measured from the inside edge. Sampling at the four traps resulted in eight total samples per stand. All vegetation with d.b.h. > 1 cm within the plot was excluded. Collected material was bagged and oven dried at 105 ºC until a consistent weight was achieved before being weighed to determine biomass (Davies and others 2011). Biomass was converted to carbon weight by multiplying by 0.5 (Namayanga 2002).

Coarse and fine woody debris were sampled in the same 1- by 1-m quadrats at 10 m from the center of each drift fence at two randomly generated azimuths. Samples were collected, brought into the laboratory, dried, and weighed. Materials too large to weigh (logs) had their volume calculated using measurement of diameter at both ends as well as length of the log. Using the average diameter, volume was calculated assuming log shape as a cylinder. A section of the log was collected using a handsaw. This section was brought back to the lab for analysis. Wet volume was determined by wrapping the section in plastic and submerging in water to test displacement. The section was dried and weighed to determine density which was used to estimate total mass of the log (Scott and others 2004).

Statistical Analysis

General linear model (GLM) analysis of variance (ANOVA) for a completely randomized split plot design (CRSPD) was used to test the treatment difference and interaction on study species. Species with < five captures in each year were excluded from the analysis to avoid the effect of small sample bias. Post-hoc Tukey multiple range test (HSD) was used to identify differences between specific treatments if ANOVA tests were significant. Statistical tests were declared significant when $p < 0.1$ (SPSS.v20.0).

RESULTS AND DISCUSSION

Data were collected for the 2011 and 2012 field seasons. Data presented here were preliminary results. Sampling will continue in 2013. Data for midstory trees have not yet been analyzed.

Total aboveground carbon storage (not including midstory) for control and OSW were similar (table 1). SW treatments had approximately half the stored carbon compared to control and OSW. Overstory trees contained the majority of the carbon within all treatment types and accounted for most of differences in total carbon between treatment types. Herbaceous biomass/carbon among treatment types showed that control had the lowest amount while OSW and SW had similar carbon content within the herbaceous layer. Control stands had the lowest amount of carbon within woody vegetation while SW had the highest amount. Control had the highest amount of carbon stored in CWD while OSW had the lowest.

Control and OSW stands both had nearly twice the amount of carbon stored above ground (excluding midstory) compared to SW stands. This mirrors the differences seen in carbon stored within the overstory trees, with control and OSW having more than twice the amount of stored carbon in this component compared to SW. The most rapid change in the carbon pool has been found in the above-ground tree biomass (Fahey and others 2010). These initial assessments are subject to change, as others have found that carbon storage rates are higher in disturbed stands compared to untreated stands (Horner and others 2010). Because the SW treatment removed 60 to 70 percent of the overstory trees while OSW retained the overstory, we expect that the amount of carbon stored will remain higher in the OSW compared to the SW, although the rate of storage may not follow that same pattern. Increased light and growing space created by tree removal created conditions within the SW stands that favored growth of herbaceous and small woody plants.

Table 1--Carbon sampling results showing amounts of carbon stored in 2012 within stands treated with three different forest management practices at Burrow Cove in Grundy County, TN

Treatment	Classes[a]	Mean	Total
		------*Mg/ha carbon*------	
Control	CWD	11.62	114.0911
	FWD	4.58	
	HERB	0.01	
	LL	3.84	
	VINE	0.40	
	WOODY	0.08	
	Overstory	93.56	
Oak shelterwood	CWD	3.71	115.8632
	FWD	5.99	
	HERB	0.17	
	LL	4.87	
	VINE	1.40	
	WOODY	0.15	
	Overstory	99.57	
Shelterwood	CWD	6.29	58.41753
	FWD	5.84	
	HERB	0.14	
	LL	3.53	
	VINE	0.12	
	WOODY	0.31	
	Overstory	42.18	

[a]Classes described are: coarse woody debris (CWD), fine woody debris (FWD), herbaceous vegetation (HERB), leaf litter (LL), vines (VINE), woody vegetation (WOODY), and overstory trees (overstory).

Table 2--Means ± standard deviations of herpetofaunal response to three different forest management practices at Burrow Cove in Grundy County, TN, 2011. ANOVA (F) test was followed with post-hoc Tukey tests. Different letters in columns indicate significant difference (Tukey p < 0.1)

Species	Scientific name	Control	SW	OSW	F	P
Eastern five-lined skink	*Plestiodon fasciatus*	1.00±1.65a	4.33±1.50b	2.0±1.58a	7.928	0.004
Eastern fence lizard	*Sceloporus undulatus*	0.56±0.52a	6.50±4.41b	1.60±2.30a	6.703	0.007
Broadhead skink	*Plestiodon laticeps*	1.22±0.67a	5.33±2.50b	3.20±3.27ab	9.411	0.002

Table 3--Means ± standard deviations of herpetofaunal and small mammal response to three different forest management practices at Burrow Cove in Grundy County, TN, 2012. ANOVA (F) test was followed with post-hoc Tukey tests. Different letters in columns indicate significant difference (Tukey p < 0.1)

Species	Scientific name	Control	SW	OSW	F	P
Eastern five-lined skink	*Plestiodon fasciatus*	0.71±0.76a	2.67±1.75b	1.25±1.50ab	3.491	0.059
Eastern fence lizard	*Sceloporus undulatus*	0.14±0.38a	3.67±2.88b	1.00±1.15a	6.354	0.011
Masked shrew	*Sorex cinereus*	0.43±0.54a	1.67±1.03b	0.75±0.96ab	3.675	0.052

In the 2011 field season we captured a total of 2,469 herpetofauna individuals encompassing 26 species (13 amphibian and 13 reptile). We also had 347 mammal captures comprised of 15 species. During the 2012 field season we captured a total of 1,170 individuals. Reptile captures yielded 12 different species and 111 individuals. Amphibian captures yielded 15 different species and 906 individuals. Mammal captures yielded 10 species and 153 captures. In both years American toad (*Anaxyrus americanus*) was the most abundant species overall. The most abundant mammal species was the white footed mouse (*Peromyscus leucopus*) in both years. The most abundant reptile in 2011 was the broadhead skink (*Plestiodon laticeps*). In 2012 the most abundant reptile was the eastern fence lizard (*Sceloporus undulatus*). Data for both years combined showed the most abundant reptile was the eastern fence lizard.

In 2011, eastern five-lined skink (*Plestiodon fasciatus*), broadhead skink, and eastern fence lizard all showed greater abundance in SW stands (table 2). In 2012, eastern five-lined skink, eastern fence lizard, and masked shrew (*Sorex cinereus*) all showed greater abundance in SW stands (table 3).

The most commonly captured species was the American toad. This is a common and ubiquitous species in Tennessee and the large numbers can likely be attributed to breeding pools created by road ruts in the logging road that the treatment stands all border (Cantrell and others 2013). American toad showed no response to treatment, but the numbers did fluctuate. In 2011 there were 1,316 captures of this species while in 2012 there were only 610 captures. This difference may be due to a prolonged drought during breeding season as well as logging activity that destroyed many road rut pools.

There were four total lizard species captured, but one species, Ground Skink (*Scincus lateralis*), had too few captures (< 3 captures per year) to warrant analysis. Three species, five-lined skink, broadhead skink, and eastern fence lizard, showed response to treatment. All of these lizard species were more abundant in SW stands compared to OSW and control stands. This is due to the removal of canopy cover and subsequent changes in the understory environment. The opening of the forest canopy increased the amount of light that reached the forest floor, creating basking sites for thermoregulation. Slash piles and CWD created habitat as well. This is supported by findings by Greenberg (2001) and Cantrell and others (2013) who also found an overall increase in reptilian species richness and abundance in response to removal of canopy.

Abundance changed for only one mammal species in response to the treatments. Masked shrew showed higher abundance in SW stands compared to control, but there was no difference in abundance between SW and OSW. This could be due to the increased light associated with the removal of canopy allowing herbaceous and small woody plants to increase. A flush of herbaceous and woody growth created habitat for the shrews as well as habitat for insects on which the shrew feeds. The carbon data show that both the SW and OSW treatments created conditions which increased the herbaceous and woody plants.

Preliminary results show that the SW treatments created conditions favorable to certain lizard species, as they showed consistently greater abundance in SW stands compared to the other treated stands. Masked shrew also responded with higher abundance in the SW compared to other treatments in 2012.

These findings give forest resource managers and private land owners in the region better understanding of how herpetofauna and small mammals respond to these three forest management decisions 2- to 4- years post-harvest. Results suggest that the active management treatments do not adversely affect reptiles or amphibian populations and may provide some benefit to a few species. Conversely, the control, or the decision to 'do nothing' may not be an optimal choice for some shrew and lizard species.

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