FOREST CANOPY REDUCTION AND BREEDING BIRD RESPONSES: TREATMENT- AND TEMPORAL-DEPENDENT PATTERNS

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Abstract--We examined the effects of oak regeneration forest management treatments on territorial density of breeding forest birds. The study area was located on the southern end of the mid-Cumberland Plateau in northern Jackson County, AL. Fifteen 4-ha stands were treated in 2001 with one of five target overstory retention (percentage) treatments: 0 (clearcut); 25; 50; 75; and 100 (control). In 2010-2011, the residual trees in the initial 25, 50, 75, and 100 (control) percent retention stands were harvested, and three new controls were added, which resulted in three forest stand cohorts: (1) mature (control, not harvested for 50 to 70 years); (2) 10-year-old regenerated clearcut; and (3) final harvest of the shelterwood prescriptions (25, 50, 75, and 100 percent retention stands in 2001). Breeding songbirds were surveyed 9 to 10 times per year during the peak of breeding season (April to July) of 2002, 2003, 2010, 2011, and 2012. Territory mapping was used based on detections in each year in each stand. Two-way analysis of variance (ANOVA) and Tukey test were used to compare average territory density among treatments and years. Results of temporal responses of two breeding songbird conservation concern species, Kentucky Warbler (*Geothlypis formosa*) and Worm-eating Warbler (*Helmitheros vermivorum*), to treatments showed that responses were treatment-dependent. Territory density of Kentucky Warbler (an interior-edge species) showed positive response to 50 percent retention stands. Worm-eating Warbler (an interior species) territory density responded positively to control stands.

INTRODUCTION

The importance of songbird conservation has received much attention in the ecological community, as many species are declining (Askins 2000, Sauer and others 2011). Particularly vulnerable are Neotropical migrants that breed during summer months in North America and overwinter in South and Central America, the Caribbean, and Mexico (Cornell Laboratory of Ornithology 2007). A subset of these migrants is in danger of becoming listed as threatened, having been included on the conservation concern list (Rich and others 2004) of Partners in Flight (PIF), an international bird conservation organization. Included in the PIF list are Kentucky Warbler (*Geothlypis formosa*) and Worm-eating Warbler (*Helmitheros vermivorum*) (Rich and others 2004). Research suggests that habitat alteration or loss (Askins 2000, Sauer and others 2011) and brood parasitism by cowbirds (*Molothrus* spp.), in which female cowbirds lay eggs in nests of other host species (Robinson and others 1995), are major contributors in the decline of these species and other Neotropical migratory songbirds.

Forest songbirds that breed in the southeastern United States have been particularly vulnerable as a result of massive agricultural clearing in the late 19th and early 20th centuries, followed by pine plantation reforestation, coupled with fire suppression during most of the 20th century (Rauscher 2004). These practices decreased periodic disturbance and contributed to the loss of forest understory (North American Bird Conservation Initiative U.S. Committee 2011) necessary to maintain populations of many bird species (Rich and others 2004). Despite numerous studies focusing on breeding grounds (Carpenter and others 2011, Lesak and others 2004), it is still not clear how anthropogenic disturbance affects the conservation of many species (Rich and others 2004). What has been suggested is that conservation efforts by land managers should include the production and maintenance of early successional habitat (Rich and others 2004).

Land managers of southern upland hardwood forests are faced with multiple challenges. Oak (*Quercus* spp.) is an important component of these forest systems (Hicks and others 2004). Oaks are mostly shade intolerant (Loftis 1990, Schweitzer and Dey 2011, Stringer 2006) and as juveniles expend much energy in root development and less on height growth (Hicks and others 2004). This causes oaks to be out-competed by shade-tolerant species such as sugar maple (*Acer saccharum* Marsh.) and light-responsive species such as yellow-poplar (*Liriodendron tulipifera* L.) (Schweitzer and Dey 2011). Surface fires may enable the domination of oaks over their competitors, but fire suppression during the 20th century and an increasing abundance of browsing deer (*Odocoileus virginianus*) have been major culprits in decreased oak reproduction in

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southern upland hardwood forests (Hicks and others 2004). The resultant mature, even-aged forests with closed canopies do not provide adequate light conditions that are required for oak reproduction (Larsen and Johnson 1998). Because of the difficulties of recruiting oak into competitive and dominant positions within mixed species forests, managing these forests to sustain demand for oak and other wildlife-dependent (McShea and Healy 2002) and economically-valuable hardwoods has become the focus of some forest researchers (e.g. Rathfon 2011, Schweitzer 2004, Schweitzer and Dey 2011). To address the lack of sufficient competitive oak reproduction, managers are altering regeneration techniques to facilitate development of sustainable levels of oak stocking. One such technique is the oak shelterwood method, which involves removing undesirable midstory species, allowing more light penetration to the forest understory and encouraging oak seedling height growth (Loftis 1990, Stringer 2006).

Forest managers also need to monitor forest ecosystem health and consider the effects of management actions on forest birds, since forest health is partially maintained by birds (Connor and others 1999, Greenberg and others 2001, Traveset and others 2001), and songbirds rely on forests for suitable habitat (Lesak and others 2004, Rich and others 2004, Wang and others 2006). PIF and other conservation organizations recognize the need for examination of the influence of silvicultural practices on forest songbirds (Rich and others 2004). Studying forest bird response to anthropogenic disturbance can help managers formulate strategies that will help maintain healthy populations of forest birds. Studies observing the long-term effects of shelterwood treatments on songbirds have been limited (e.g. Augenfeld and others 2008) and have not included songbird response to multiple ages (e.g. clearcut + oak-shelterwood + control). Since Alabama contains the third largest commercial forest industry and the second largest private forest landholdings in the nation (Alabama Forestry Commission 2009), it is important that land managers be equipped with the knowledge and tools to sustain healthy forests for multiple uses.

Clearcut Harvesting

Clearcut harvesting often abruptly changes species composition (Chambers and others 1999, Costello and others 2000, Lesak and others 2004) and provides habitat for early successional species (Costello and others 2000, Lesak and others 2004). Previous studies examining forest bird response to management practices often compared clearcut stands with untreated stands (Conner and Adkisson 1975, Thompson and others 1992, Thompson and Fritzell 1990). Relatively short-term studies revealed that clearcuts often negatively impacted the forest-interior-nesting Worm-eating Warbler (Conner and Adkisson 1975, Gram and others 2003, Thompson and others 1992). The interior-edge-nesting Kentucky Warbler appeared less sensitive to clearcut stands and re-inhabited these stands in a relatively short amount of time (Thompson and others 1992). Intermediate- and long-term responses of forest birds to clearcut harvesting are limited (e.g. McDermott and Wood 2009).

Shelterwood Harvesting

Studies showing the effects of shelterwood harvesting on forest bird species were short-term and limited, and few compared shelterwood stands with clearcut stands (Annand and Thompson 1997, King and DeGraaf 2000, Lesak and others 2004). Even less studied are the responses of conservation priority species (Rich and others 2004) to both shelterwood and clearcut treatments in the Cumberland Plateau region (e.g. Lesak and others 2004), especially in multiple phases. By the second year after shelterwood harvesting, Lesak (2004) noticed favorable response to all shelterwood treatments by Kentucky Warbler and similar responses by Worm-eating Warbler to treatments of 25 percent overstory retention. However, there still remain gaps in intermediate- and long-term temporal response patterns of these and other forest bird species on the Cumberland Plateau.

Certain forest management prescriptions can create early successional habitat that may be beneficial for some early successional avian species (Askins 2000, Lesak and others 2004) and interior-edge species, such as Kentucky Warbler. However, other species, such as Worm-eating Warbler, may suffer immediate decline due to loss of mature forest habitat (Askins 2000). With sufficient re-growth of the forest vegetation structure, disturbance may eventually provide sustainable resources for mature forest species (Lesak and others 2004). In this study, we examined how different stages of regenerating forests contributed to habitat creation conducive to particular birds. In alignment with recommendations made by PIF for conservation priority forest birds, we monitored the territory density of selected species with high conservation concern such as Kentucky Warbler and Worm-eating Warbler (Rich and others 2004) on the forest stands with canopy reduction treatments.

METHODS

Study Site

The study area was located on the southern end of the mid-Cumberland Plateau in northern Jackson County, AL. Average temperature in this region is approximately 13 °C and average annual precipitation is 149 cm (Smalley 1982). Two sites were used, one located at Miller Mountain (MM) (34” 58’ 30” N, 86” 12’ 30” W) and one at Jack Gap (JG) (34” 56’ 30” N, 86” 04’ 00” W) (Lesak 2004). Miller Mountain has a southern to southwestern aspect and JG has a northern aspect. Elevation for both sites varies between 260 to 520 m, with slopes ranging from 15 to 30 percent. Upland hardwood is the primary forested land cover type, composed mainly of oak and hickory (*Carya* spp.) with yellow-poplar, sugar maple, red maple (*Acer rubrum* L.), and American beech (*Fagus grandifolia* Ehrh.) (Schweitzer 2004).

Experimental Design

In 2000, two blocks of 10 stands were established at JG and one block of 5 stands at MM, for a total of three blocks and 15 stands. Each stand was approximately square in shape and 4 ha in size (Schweitzer 2004). Each block was approximately 20 ha, for a total study area (in 2010) of 60 ha. All stands were arranged adjacently within each block (Schweitzer 2004). In 2011, 3 new stands (2 at JG and 1 at MM) were added to the study for a total of 18 stands comprising a 72-ha study site. Five 0.01-ha circular plots were established in each stand for vegetation characterization. All trees 3.8 cm in diameter at breast height (d.b.h.) were monumented with a permanent tag, and species and d.b.h. were recorded.

Silvicultural treatments--The USDA Forest Service Southern Research Station-initiated study consisted of a randomized complete block replicate design with five overstory retention treatment units replicated three times. The five treatments consisted of stands with the following target overstory retention percentages: 0 (clearcut); SW25; SW50; SW75; and SW100 (control, not harvested for 40 years or greater), and were blocked by location. Trees in the SW25 to 50 percent retention stands were marked and retained according to species (preference was given to oak, ash, and persimmon), vigor, class, and crown position (Schweitzer 2004). Initial tree harvesting was accomplished by chainsaw felling and grapple skidding. Stands of SW75 percent retention were treated with an herbicide injection (Arsenal®, containing active ingredient imazapyr) in 2001 to remove the midstory. The intermediate harvest intensity stands (SW25-75 percent retention) were initiated as shelterwood stands to investigate the relationship between varying levels of overstory retention and oak regeneration. Stands of 0 percent retention were treated with a single clearcut prescription, which was completed in 2002 (Schweitzer 2004).

All 15 original stands were allowed to grow for approximately 10 years prior to final harvest in 2011, when the overstory canopies in these stands were removed. At that time, residual trees in the initial overstory retention (percentage) treatment stands of SW25, SW50, SW75, and SW100 (control) were harvested with the use of chainsaw felling and grapple skidding. Stands of SW100 percent retention (controls for bird surveys) were also harvested. Three new stands, Control2010 (not harvested for 50 to 70 years), were added for bird survey controls. Once 2011 treatments were completed and new control stands were established, there were approximately three forest stand cohorts: mature (Control2010), 10-year-old regenerated clearcut, and new shelterwood harvests (SW25, SW50, SW75, and SW100 percent retention treatment in 2001).

Basal area data--Pre-treatment basal area data were collected from five measurement plots that were systematically located within each treatment unit (Schweitzer 2004). At these locations, all overstory trees ≥ 14.2-cm d.b.h. were tallied to estimate initial basal area in 2001, prior to treatment. In 2002, post-treatment residual trees were measured and used to determine residual basal area and overstory retention. Following treatments, these locations were also used for measuring canopy cover with a handheld spherical densitometer.

Avian territory mapping--Three transects were established within each stand. Each transect was spaced evenly across its width and parallel with the slope; there were ≤ 50 m between transects, and between transects and stand boundaries. Each transect had marked reference points every 25 m which were used to facilitate bird territory mapping (Lesak 2004).

During the peak of breeding season in 2002 and 2003 (late April to beginning July), the territory spot-mapping technique (Bibby and others 2000, International Bird Census Committee 1970, Ralph and others 1993, Williams 1936) was used to survey the original 15 forest stands 10 times, an appropriate amount of sampling effort to obtain reliable breeding-territory data (Ralph and others 1993). Between approximately 05:30 and 10:30 every survey morning, one block of five units was visited. Each block was visited once before the next rotation was started. Order of visits within blocks was assigned uniquely for each rotation to ensure that all stands were visited equal amounts at all possible morning times, and approximately 1 hour was spent in each unit. Stand entrance and exit locations were also rotated. During surveys, territorial defense displays (songs, calls, distraction displays) and other behaviors indicative of an active territory were recorded on topographic maps and were later transposed onto transparency films (Lesak 2004). These steps were replicated in 2010. Each stand was visited 9 to 10 times between approximately May 1 and June 30 in 2010, 2011, and 2012. In 2011 and 2012, topographic data maps were scanned for territory delineation in ArcMap (ArcGIS 10.0). All territory spot-mapping was conducted by one or two observers per season, and stands were rotated between observers to reduce inter-observer bias.

Due to unfavorable weather conditions, logging activity was postponed, and final harvest of shelterwood and control stands at JG could not be completed prior to the bird breeding season of 2011. As a result, only 7 of the original 15 stands (all 5 original stands at MM and 3 prior clearcut stands at JG) plus the 3 new control stands were available for bird surveys. This resulted in inadequate replications. Therefore, these data were omitted from this analysis; control stand data were retained and used.

Statistical Analyses

Bird data from 2002, 2003, 2010, and 2012 were analyzed using two-way factorial repeated-measures analysis of variance (ANOVA, SPSS v 20.0) with year as the within-subjects repeated factor and effects of block and treatment as between-subject factors. Tree data were used to compute basal area (BA) and stems per ha (SPH) of each stand, and statistics were applied as with the bird data. Normality and homogeneity of variance assumptions of the data were tested with Shapiro-Wilk and Levene test, respectively, at the significance level of $p > 0.05$. We tested the effect of treatment, year, and their interactions on the territory density. If there was no interaction between year and treatment, we directly examined the year and treatment main effect, followed by Tukey multiple comparison tests. If there was an interaction between year and treatment, we examined treatment effect by each year separately, followed by Tukey multiple comparisons for each year.

RESULTS AND DISCUSSION

Tree Basal Area and Stems per Hectare

Following initial treatment application, a gradient of three different BAs resulted (Schweitzer and Dey 2011). For the SW100 and SW75, BA remained relatively unchanged from pre-treatment values. The herbicide treatment targeted the midstory trees, and few overstory trees were treated. The number of SPH of trees ≥ 3.8 cm d.b.h. was reduced from 791 to 290 in the herbicide treatment; conversely, the SW100 treatment gained stems, from 719 SPH pre-treatment to 779 SPH in 2010. The clearcut resulted in the lowest residual BA, 1.4 m^2 ha^{-1}, but went from 217 SPH immediately post-harvest to 1,054 SPH in 2010. The clearcut BA was significantly different from all other treatments except the SW25 ($F_{4,2} = 37.31$, $P = 0.0001$). The SW50 left 10.1 m^2 ha^{-1}, which was significantly different from all other treatments except the SW25. The SW25 had a residual BA of 8.5 m^2 ha^{-1}, and this was only significantly different than the control and 75SW. By 2010, the SW50 and SW25 had 871 and 1,102 SPH and BAs of 13.5 m^2 $ha^{-1}$and 11.9 m^2 $ha^{-1,}$ respectively. Following the second phase of the shelterwood treatments, all merchantable stems were harvested from the SW100, SW75, SW50, and SW25. The SW75 had the lowest SPH (53) and BA (3.3 m^2 ha^{-1}), reflective of the missing midstory (deadened 10 years prior and thus no sprouting). The SW50 and SW25 had SPH of 1,392 and 1,412, respectively, although the residual BA of the SW50 was 10.6 compared to 6.3 m^2 ha^{-1} for the 25SW m^2 ha^{-1}. Both the SW50 and SW25 were dominated by trees 4 cm d.b.h.; there were no SPH > 28 cm in the SW25,

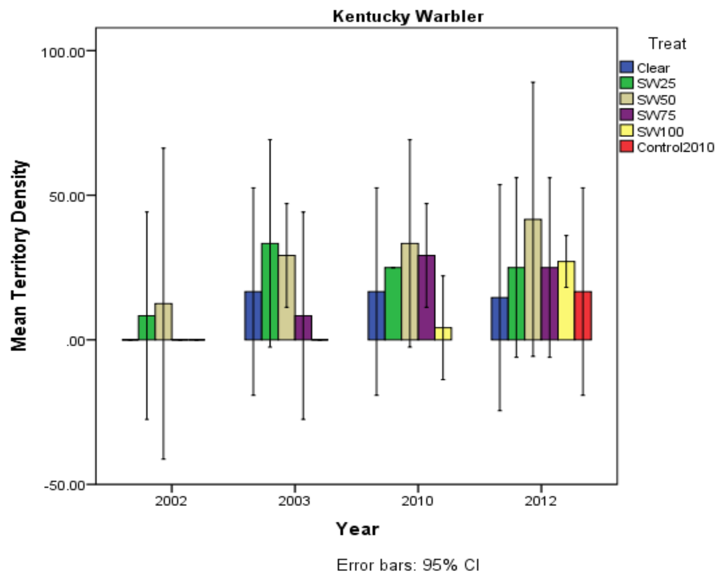

Figure 1--Mean territory density [(territories/4-ha)*100] of Kentucky Warbler (*Geothlypis formosa*) displaying treatment and year effects in 2002, 2003, 2010, and 2012 at Miller Mountain and Jack Gap, Jackson County, AL. Treatments were as follows: clear = clearcut in 2002; SW25 = shelterwood with 25 percent target overstory retention level in 2001; SW50 = shelterwood with 50 percent target overstory retention level in 2001; SW75 = shelterwood with 75 percent target overstory retention level in 2001; SW100 = shelterwood with 100 percent target overstory retention level in 2001, used as bird survey control for 2002, 2003, and 2010; Control2010 = control installed for 2012 bird surveys. Residuals in all SW stands were harvested after 2010 bird surveys.

and 8 SPH of trees > 28cm in the SW50. These treatments were predominately populated with new stump sprouts. Control2010 had a BA of 26.9 m^2 ha^{-1} with 845 SPH, and the now 11-year old clearcut had 9.8 m^2 ha^{-1} with 2,481 SPH.

Kentucky Warbler

Treatment (*P* = 0.001) and year (*P* = 0.0001) had significant effects on the territory density but not the treatment and year interactions (table 1). Territory density increased in all treatments except control between 2002 and 2010 after treatments were implemented and was the highest in SW50 stands in 2010 before the residual trees were removed from the treatment stands (fig. 1). After the removal of the residual trees in 2010, there was a sharp increase in territory density in the initial control (SW100) stands in 2012. The territory density was the highest at initial SW25 stands and was the lowest in clearcut stands and new control (Control2010) stands in 2012.

Worm-eating Warbler

The treatment (*P* = 0.0003) and the interaction between year and treatment (*P* = 0.051) significantly affected the territorial density of Worm-eating Warbler (table 2). The clearcut negatively affected the density of this species after the initial treatment, but the density gradually increased between 2002 and 2012, though it was still lower than the density in control stands. Other shelterwood treatments (SW25, SW50, and SW70) all had lower densities of Worm-eating Warblers compared to the control but higher than the clearcut after initial treatment and in 2010 before the removal of the residual trees. After the removal of residual trees, the territory density in initial control (SW100), SW75, and SW25 all declined, with the initial control (SW100) and SW75 having the faster rate of decline. Territory density was highest in control (SW100) stands for all years except 2012, when it was highest in Control2010 stands (fig. 2). In 2012, approximately 10 years after initial harvest, clearcut stands had the second highest territory density.

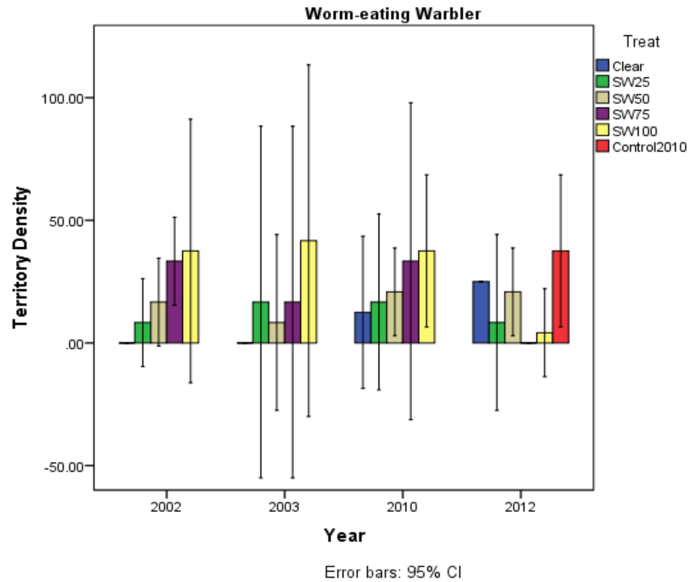

Figure 2--Mean territory density [(territories/4-ha)*100] of Worm-eating Warbler (*Helmitheros vermivorum*) displaying treatment*year interaction in 2002, 2003, 2010, and 2012 at Miller Mountain and Jack Gap, Jackson County, AL. Treatments were as follows: clear = clearcut in 2002; SW25 = shelterwood with 25 percent target overstory retention level in 2001; SW50 = shelterwood with 50 percent target overstory retention level in 2001; SW75 = shelterwood with 75 percent target overstory retention level in 2001; SW100 = shelterwood with 100 percent target overstory retention level in 2001, used as bird survey control for 2002, 2003, and 2010; Control2010 = control installed for 2012 bird surveys. Residuals in all SW stands were harvested after 2010 bird surveys.

Table 1--Tests of between-subjects effects for Kentucky Warbler (*Geothlypis formosa*) territory density at Miller Mountain and Jack Gap, Jackson County, AL[a]

Source	Type III sum of squares	df	Mean square	F	Significance
Treat	0.380	5	0.076	5.179	0.001
Year	0.416	3	0.139	9.439	0.0001
Treat x Year interactions	0.200	13	0.015	1.046	0.428
Error	0.646	44	0.015		

[a]Tests of between-subjects effects for Kentucky warbler and dependent variable: territory density.

Table 2--Tests of between-subjects effects for Worm-eating warbler (*Helmitheros vermivorum*)

Source	Type III sum of squares	df	Mean square	F	Significance
Treat	0.673	5	0.135	5.866	0.0003
Year	0.151	3	0.050	2.194	0.103
Treat x Year interactions	0.582	13	0.045	1.949	0.051
Error	0.987	43	0.023		

[a]Tests of between-subjects effects for Worm-eating Warbler and dependent variable: territory density.

Creating and altering habitat conditions through active forest management is an on-going practice in the Cumberland Plateau region. Forest structure and composition has changed with disturbance or lack thereof, causing suitable bird habitat to also fluctuate. We are more acutely aware of the need to have a mosaic of habitats, spatially and temporally distributed, in order to sustain the highest diversity of birds (Augenfeld and others 2008, Lesak 2004, Lesak and others 2004). Studying bird response to active forest management is often done within a short time frame, with the loss of knowledge about how successional dynamics influence habitat creation and subsequent bird activities. Although certainly not long-term, this on-going study is providing insight into those dynamics as related to two bird species of conservation concern.

In productive forest systems such as those found on more mesic escarpment sites on the Cumberland Plateau, the vegetation response to disturbance is vigorous (Schweitzer and Dey 2011). Within 8 years following the initial harvests, the SW25, SW50, and clearcuts had a densely occupied under- and midstory. The response of the targeted bird species in this study was reflective of this growth. From these data, it appears that SW50 is most favorable for the territory density of the Kentucky Warbler. For the Worm-eating Warbler, controls created the most favorable habitat. This report does not take into account overall breeding success (i.e. nesting success/failure) of the targeted bird species; future analyses of these data will help provide more information on how the bird species are responding to the treatments in this study. In addition, the examination of the understory composition data will allow us to identify possible relationships that exist between the targeted bird species and their respective flora.

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