SONGBIRD COMMUNITY VARIATION AMONG FIVE LEVELS OF OVERSTORY RETENTION IN NORTHERN ALABAMA

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Abstract—We compared songbird communities among varying degrees of overstory tree retention in the oak-hickory forest of the southern Mid-Cumberland Plateau region. Three 20-ha complete block replicates of 5 experimental treatments (15 treatment units, 4 ha per unit) were used. The five treatments were operational shelterwood stands with target overstory retention levels of approximately 0, 25, 50, 75, and 100 percent. The residual basal area and resultant canopy cover of these overstory retentions were compared among treatments and both showed three distinct conditions, closed canopy, open forest, and clearcut. Territory spot-mapping was used to quantify bird species richness and density during the first post-treatment year, between mid-April and July 2002. Sixty bird species were detected with 34 of those defending territories on the sites. Clearcuts (0 percent retention) had significantly lower values than the other four treatment types for overall bird territory density, species richness, and Shannon diversity index. Territorial density of breeding songbirds was highest in the 50 percent retention treatments, while species richness and Shannon diversity peaked in the units with 25 percent basal area retention.

INTRODUCTION

Songbirds in forested landscapes have shown population decreases in recent decades, creating widespread concern in the conservation community and an interest in their management and preservation (Ambuel and Temple 1982, Askins and others 1990, Robbins and others 1989). Anthropogenic habitat alteration has been widely suspected as a causal agent in these declines. A large proportion of existing forest songbird habitat is subject to some form of use or management, whether it is under governmental, industrial, or non-industrial private ownership. As a result, the motives and operations of forestry have a significant impact on the habitat of songbirds. Land managers often have conservation and management goals for their timber resources, but water, wildlife, and soil issues have increased in importance in a move toward a more holistic approach to ecosystem management. Ultimately, we would like the findings of our research to act as a guiding tool for land managers charged with the duty of balancing the myriad goals of forest stewardship in the southern Cumberland Plateau region.

The maintenance of forest bird populations is important for many reasons other than the valuable recreational and aesthetic qualities they bring to the forest ecosystems they inhabit. As the majority of forest songbirds are insectivorous, they provide a useful service to these systems and their resources by consuming a significant number of arthropods and their larvae, some of which may be detrimental to forest health (Sherry and Holmes 1995, Williams 1936). Other species may increase the germination rates of fleshy-fruited plants through the physical removal of the skin and pulp surrounding their seeds (Greenberg and others 2001) and by gastrointestinal scarification during digestion (Traveset and others 2001). Many forest plants rely on songbirds to perform necessary seed dispersal functions and, in the case of hummingbirds, to act as pollinators. Woodpeckers, nuthatches, and other bark-foraging and excavating birds can actively contribute to the decomposition of standing dead trees and down woody debris. Forest birds can also serve as indicators of ecosystem health as some species decline or become absent when the amount, continuity, composition, and health of their habitats are changed.

A thorough understanding of the breeding habitat of a bird species or community can be very useful. The pressures of obtaining a mate and raising young, compounded by intense resource competition, greatly increases the physiological stress on birds during the breeding season (Robinson 1992). Maintaining suitable habitat for birds in their breeding range is important not only for the sustenance of the breeding adults, but these habitats also hold the potential to produce a positive input of individuals that can sustain or augment populations. Sound management and silvicultural practices on forested breeding grounds that provide for timber production while maintaining habitat integrity can be crucial to the preservation of viable populations of non-game landbirds.

Forestry practices often result in a change in density of the dominant canopy trees in the managed stand. The overstory density of a stand (i.e. the basal area of the dominant and co-dominant trees in the upper levels of a forest) is inextricably linked to canopy cover. Canopy cover, in turn, dictates the amount of light penetrating to the midstory, shrub, and ground cover layers of the forest thus affecting the entire structure and productivity of its vegetation. This affects foraging and nesting opportunities for birds as well as their exposure to predators, brood parasites, and weather. As the overstory is arguably the most ecologically important component of a forest and the most commonly altered in forest management, knowledge of the suitable overstory conditions for a songbird species, or suite of species, could help managers with the problem of applying stand-level treatments to maintain songbird habitat.

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Relatively few studies have described the changes in songbird communities caused by intermediate levels of harvest (Thompson and others 1995). A number of past studies have described the bird populations and communities of different stages of forest development following past disturbance (e.g. Crawford and others 1981, Johnston and Odum 1956, Keller and others 2003, Odum 1950, Shugart and James 1973, Thompson and Capen 1988). However, the majority of avian research describing the direct effects of habitat alteration related to timber harvest have compared clearcut sites to untreated stands (Conner and Adkisson 1975, Thompson and Fritzell 1990, Thompson and others 1992, Welsh and Healy 1993). Conner and others (1979) explored the effects of clearcutting on winter bird populations, while Keller and Anderson (1992) and Germaine and others (1997) examined how breeding bird communities in small patch or strip clearcuts differed from those in uncut forests. We explored the relationship between songbird community structure and a gradient of stand manipulation associated with shelterwood regeneration. It was hypothesized that bird community composition and structure would change predictably with graded levels of forest canopy retention, as bird species select breeding territories on the treatments that best suit their habitat requirements. Here we report the preliminary results from the first post-treatment year.

METHODS

Study Area

This study was conducted in northern Jackson County, AL. Situated in the Mid-Cumberland Plateau of the southern Appalachian Mountains, this region's physiography is characterized by narrow, flat plateaus dissected with numerous deep valleys. Two sites were used, one located at Jack Gap (34° 56' 30" N, 86° 04' 00" W) and one at Miller Mountain (34° 58' 30" N, 86° 12' 30" W). The elevation range of the study sites was 260 to 520 m. Both sites were at middle to upper slope positions on the sides of the Plateau. Jack Gap had a northern slope aspect. Miller Mountain had generally southern to southwestern exposure.

Upland hardwood forest is the dominant land cover of northern Jackson County, with many large continuous tracts throughout. The forest cover of the sites and the surrounding areas was mature (80-100 years old) oak-hickory (*Quercus* spp. and *Carya* spp.) with yellow-poplar (*Liriodendron tulipifera* L.), sugar maple (*Acer saccharum* Marsh.), red maple (*Acer rubrum* L.), and American beech (*Fagus grandifolia* Ehrh.) as associates (Hartsell and Vissage 2001). These hardwood forests of North Alabama are largely owned by nonindustrial private forest (NIPF) landowners. Approximately 85 percent of the land area in forest cover belongs to this group, while commercial and public interests combined oversee 15 percent (Hartsell and Vissage 2001). Some of the largest and least fragmented tracts of mature upland forest in Jackson County are in a mixed matrix of state, industrial, and NIPF ownerships.

Design

This study consisted of three randomized complete block replicates of five overstory retention treatment units: 0 (clearcut), 25, 50, 75, and 100 percent (control). Jack Gap had two blocks and Miller Mountain had one. Each unit was roughly square in shape, and the units were arranged adjacently within each block. The treatment units were 4 ha in size making each replicate block 20 ha, and thus a total study area of 60 ha.

The clearcut, 25, and 50 percent treatments were accomplished by conventional chainsaw felling and skidding. In the 75 percent retention units, Arsenal® herbicide (active ingredient imazapyr) was applied mainly to the small diameter, midstory trees in order to reduce competition and increase light intensity for oak regeneration, without creating large overstory gaps. Application of the initial treatments was accomplished in cooperation with MeadWestvaco land managers and local logging crews in the fall of 2001 and winter of 2002. Each treatment unit had three bird survey transects spaced evenly across its width. Along each transect, marked reference points were placed at 25-m intervals to facilitate bird territory mapping. To adequately sample the entire treatment unit during spot-mapping, the distance between transects was ≤ 50 m, as was the distance from the outer transects to the parallel unit boundaries.

Overstory Measurements

Pre-treatment basal area was measured in each treatment unit at five systematically arranged 0.08-ha circular plots. Measurements within the plot from all overstory trees ≥ 14.2 cm diameter at breast height (1.4 m) were used to calculate initial basal area. Following treatment, diameter measurements of the remaining trees were used to determine residual basal area and the percentage of overstory retention. The same five plots within each treatment unit were used to measure the percentage of canopy cover following overstory removal. Five readings of a spherical densitometer were taken at breast height; one at plot center and one taken 3.6 m from plot center in each of the cardinal directions.

Songbird Community Survey

To determine the species composition, overall territory density, species richness, and diversity of the songbird communities at our study sites, territory spot-mapping was used based on the methods first described by Williams (1936) and outlined by the International Bird Census Committee (1970) and Ralph and others (1993). Most forest songbirds vigorously defend nesting and foraging territories during the breeding season and display territorial behavior that is often regular and observable. Recording this behavior and its position, as well as its relative position to the territorial behavior of simultaneously-occurring conspecifics is the basis of the spot-mapping procedure. We felt the use of the spot-mapping technique to estimate the number of breeding bird territories was a good fit for this study for the following reasons:

1. The manageable treatment size (4 ha) used in this study made the intensive effort involved in accurate spot-mapping feasible.
2. The treatment units had equal areas which help to eliminate area-dependent variation in the bird community.
3. All of the treatment units were roughly square in shape, and therefore had comparatively short total edge lengths,

thus reducing edge effects on the bird communities. This fact, coupled with the equal area of the treatments gave the units similar boundary lengths and relative edge areas, diminishing this confounding influence among and within treatments. Furthermore, the straight boundaries of the square units simplified the interpretation of territories straddling the edge.

4. One person conducted all aspects of the spot-mapping duties. This reduced inter-observer bias and differences in map interpretation, while at the same time increasing the familiarity and recent knowledge of bird activity on the treatments.

Each of the 15 treatment units received 10 spot-mapping visits between mid-April and July 2002. Ralph and others (1993) suggested this amount of sampling effort is sufficient to obtain the data necessary for the interpretation of mapped territories in forested habitats. One block of five units was visited each morning. Morning mapping surveys began between 05:00 and 05:30 depending on light conditions that varied with sunrise time and cloud cover. All surveys were completed by approximately 10:30. Within each block, the treatment unit visits were ordered systematically ensuring that every unit received equal sampling at all times of the morning survey period. Each treatment unit of the block received 1 hour of surveying per visit. This gave every unit one 10-hour spot-mapping sample over the course of the breeding season in which to develop the certainty of territory occupation. While traveling along the transects of a unit during a spot-mapping visit, the species and position of singing males were recorded on a topographic map (scale 1:1400). Nest locations and behaviors (intraspecific aggression, pair feeding, copulations, nest-building, distraction displays, food-carrying, etc.) by either sex that suggested an active territory were also noted. Data recorded on the visit maps were transferred to separate species maps for each unit. The collection of registrations for the 10 visits of a unit on each species map was used to delineate territorial activity centers. Territory density per 4 ha was assigned for each species based on the number of interpreted territorial clusters in each treatment unit.

Statistical Analysis

Univariate ANOVA was used to elucidate treatment effect among the means of all measurements. These measurements included the values for pre- and post-treatment basal area and residual canopy cover as well as the songbird community indices of territory density, species richness, and Shannon diversity index. The means for the songbird community indices and basal area data were separated using the Tukey test. The Least Significant Difference (LSD) test was used to compare the means of canopy cover in order to provide the statistical power to associate the differences in canopy cover with those of basal area retention. This is an important relationship to establish if these treatments are to be used together as a guide for songbird habitat management. Trend analysis was used to determine the functional relationship between the gradient of overstory retention and the bird community indices. Analysis was performed using SPSS version 10.0 (SPSS Inc. 1999). Significant results are reported at the $p < 0.05$ level.

RESULTS

Overstory Conditions

As expected, post-treatment basal area was different among treatments ($F_{4,8} = 42.54$, $p < 0.001$). The control and 75 percent treatments had significantly higher residual basal than the other treatments (table 1). The basal area in the clearcut units was significantly lower than that in the 50 percent plots, while the 25 percent treatment was intermediate between the two. The percentage of basal area retention showed that the applied treatments closely approximated our desired retention levels, with the largest departure from the target in the 50 percent treatments.

Three significantly different levels of canopy cover ($F_{4,8} = 19.52$, $p < 0.001$) were evident in our stands following treatment (table 1). As expected, the gradient displayed by residual basal area in our overstory retention treatments was closely reflected in the pattern of canopy cover. This gradient progressed from low values in the clearcuts for both measurements, to intermediate in the 25 and 50 percent treatments, until high values were retained in the

Table 1—Means of basal area for pre- and post-treatment conditions and percentage of basal area and canopy cover retained by treatment

	Basal area		Canopy cover	
Overstory treatment	Pre-treatment	Post-treatment	Retained	Retained
(*percent retained*)	- - - - - *m² per ha* - - - - -		- - - - - *percent* - - - - -	
0 (clearcut)	24.68a[a]	1.15a	4.7	32a
25	22.21a	6.14ab	27.6	76b
50	23.92a	9.05b	37.8	75b
75 (herbicide)	26.39a	18.47c	70.0	98c
100 (control)	23.90a	23.83c	99.7	100c

[a] Means in the same column followed by the same letter are not different at the $p < 0.05$ level.

75 percent and control treatments. The desired results in the 75 percent treatments were achieved by reducing an average of 30 percent of the midstory while effectively maintaining near complete canopy cover.

Songbird Community

Overall, 60 bird species were detected within the study area. Of these, 43 were present in the immediate area of the study sites during the breeding season, 12 species were strictly stopover migrants, and 5 were winter residents recorded in the early visits of the survey season. Thirty-four of the 43 breeding species held territories on our study sites and were used to determine species richness, total territory density, and diversity. Fourteen were permanent residents, 18 were long-distance (Neotropical) migrants, and 2 were short-distance (temperate) migrants. The seven most abundant species held 54 percent of the territories encountered (table 2). The most common breeding species was the red-eyed vireo which was the most abundant bird on the 100 percent (control) and 75 percent (herbicide) treatments. Indigo bunting was the second most common songbird and the most abundant species on the 50, 25, and 0 percent (clearcut) treatments.

Territory density—The overall territory density including all species of forest songbirds was significantly lower ($F_{4,8}$ = 9.40, $p < 0.005$) in clearcut plots than in the other four overstory treatments (fig. 1). No interaction was detected between block and treatment effects. Trend analysis showed that total territory density had a quadratic relationship ($p < 0.002$) with respect to overstory retention and a maximum density at the 50 percent level. Average density

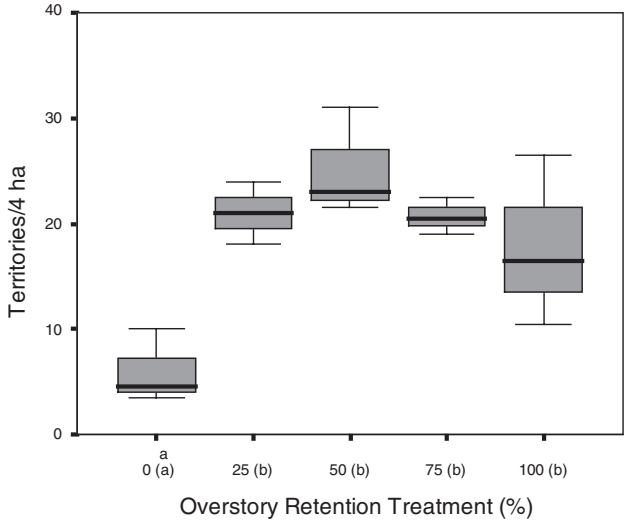

Figure 1—Average breeding bird territory density of five overstory retention treatments, different letters next to the column labels on the x-axis indicates significant difference among treatments.

was at least three times higher in the control and partial retention treatments than in the clearcut plots.

Species richness—Species richness of territorial breeding birds (fig. 2) showed a pattern similar to territory density. Control, 75, 50, and 25 percent retention treatments had similar numbers of species while the clearcuts had lower mean richness ($F_{4,8}$ = 10.39, $p < 0.005$). There was no interaction between block and treatment effects. Trend

Table 2—Territory abundance and density of seven species of songbirds accounting for 54 percent of mapped territories in five overstory retention treatments in northeastern Alabama

Species		Treatment				
		100	75	50	25	0
	n	- - - - - - - - - - -		*percent*	- - - - - - - - - - -	
Vireo olivaceus L.	33[a]	3.3[b]	3.3	2.5	1.8	—
Red-eyed vireo		(1)[c]	(1)	(2)	(3)	
Passerina cyanea L.	26.5	—	1.0	3.0	2.8	2.0
Indigo bunting			(5)	(1)	(1)	(1)
Baeolophus bicolor L.	20.5	2.0	1.7	1.8	1.2	0.2
Tufted titmouse		(2)	(2)	(4)	(6)	(7)
Thryothorus ludovicianus Lath.	18	0.8	0.7	2.2	1.3	1.0
Carolina wren		(5)	(6)	(3)	(5)	(2)
Piranga rubra L.	17	0.5	1.2	1.5	1.7	0.8
Summer tanager		(7)	(4)	(6)	(4)	(3)
Piranga olivacea Gmel.	16	1.5	1.7	1.7	0.5	—
Scarlet tanager		(3)	(2)	(5)	(9)	
Contopus virens L.	15.5	0.3	0.7	1.7	2.0	0.5
Eastern wood-pewee		(8)	(6)	(5)	(2)	(5)

[a] Total territories of species.

[b] Mean territories per 4 ha.

[c] Rank of importance within community by treatment.

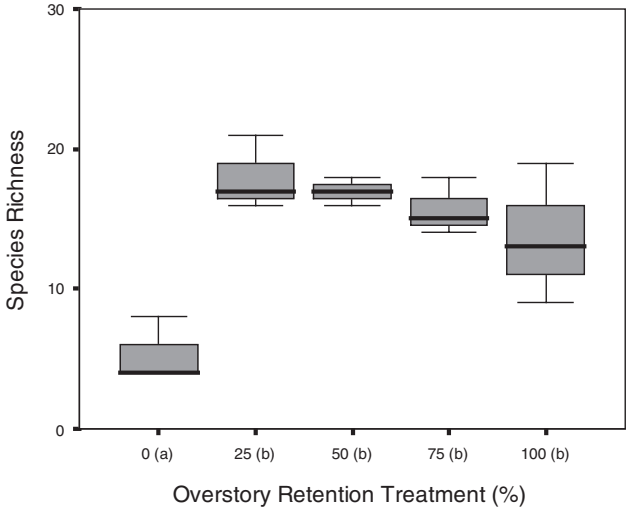

Figure 2—Means of species richness of five overstory retention treatments, different letters next to the column labels on the x-axis indicates significant difference among treatments.

analysis also revealed a quadratic relationship ($p < 0.002$) between species richness and overstory treatment. Maximum species richness was observed in the 25 percent treatments. In the control, 75, 50, and 25 percent treatments, mean species richness was at least twice that of the clearcut units.

Shannon diversity index—The Shannon diversity index was calculated for breeding songbirds holding territories on our treatments using a logarithm with base 10. Shannon diversity is a descriptive index, which in this case, takes into account the bird abundance distributed across the species richness of a particular treatment type. Treatment effect was significant ($F_{4,8} = 12.93$, $p < 0.002$) with no block-treatment interaction. Reflecting the results of territory density and species richness, the Tukey test yielded one separation for the means of Shannon diversity (fig. 3).

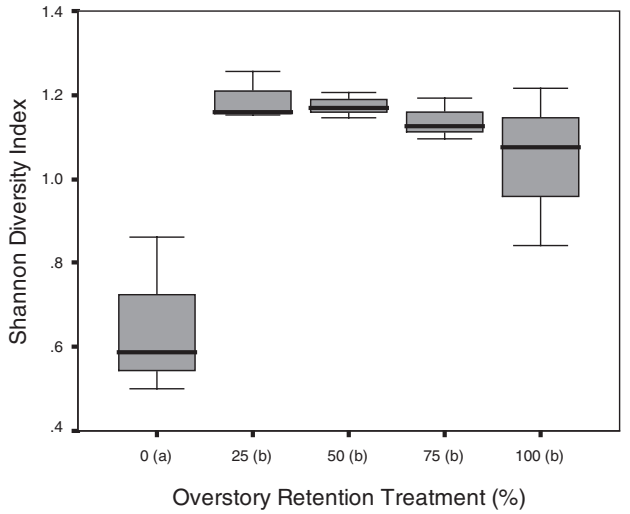

Figure 3—Means of Shannon diversity index of five overstory retention treatments, different letters next to the column labels on the x-axis indicates significant difference among treatments.

Values were lowest in the clearcut units while the other four treatments had higher diversity indices. Shannon diversity was quadratically related ($p < 0.002$) to overstory retention with a maximum mean diversity in the 25 percent treatments.

Treatment selection—Six species defended territories in just one of the retention treatments (table 3). A few species selected only one or two of the treatment types, while other generalist species held territories over a range of overstory conditions. Interestingly, 12 species that maintained territories in all but one treatment type excluded either the control or clearcut plot in their range of habitat selection. Five songbird species—Carolina wren (*Thryothorus ludovicianus* Lath.), eastern wood-pewee (*Contopus virens* L.), tufted titmouse (*Baeolophus bicolor* L.), northern cardinal (*Cardinalis cardinalis* L.), and summer tanager (*Piranga rubra* L.)—held territories in all treatment types. No single breeding bird species was unique to the clearcut treatments. Common, year-round generalists such as northern cardinal, Carolina wren, tufted titmouse, and Carolina chickadee (*Poecile carolinensis* Audu.) occurred more frequently in 25 and 50 percent treatment units.

Table 3—Breeding habitat association of 10 species with a limited range of treatment use

Species	Habitat type	
	Closed canopy forest[a]	Open canopy forest[b]
	- - - - - - - *percent* - - - - - - -	
Wilsonia citrina Bodd. Hooded warbler	X[c]	
Hylocichla mustelina Gmel. Wood thrush	X[c]	
Empidonax virescens Viei. Acadian flycatcher	X	
Cyanocitta cristata L. Blue jay	X	
Seiurus aurocapillus L. Ovenbird	X	
Passerina caerulea L. Blue grosbeak		X[d]
Sayornis phoebe Lath. Eastern phoebe		X[d]
Zenaida macroura L. Mourning dove		X[d]
Vireo griseus Bodd. White-eyed vireo		X[d]
Oporornis formosus Wils. Kentucky warbler		X

[a] 75 and 100 percent retention.
[b] 25 and 50 percent retention.
[c] Occurred only on control treatments.
[d] Occurred only on 25 percent treatments.

DISCUSSION

Our data suggested highest bird territory density in the 50 percent overstory level while richness and diversity was highest in the 25 percent overstory retention level. Although richness, abundance, and diversity were nearly as high in the 100 percent (control) and 75 percent treatments, the species composition of these closed canopy units was quite different from that of the open canopy intermediate basal area treatments (25 and 50 percent). There was some overlap between these two habitat types, but each had their own set of unique bird species. This suggests species composition may be a function of the conditions caused by the basal area and canopy cover conditions following the treatments applied in this study.

The intermediate treatments (25 and 50 percent) had six unique species, many habitat generalists, and 16 species that occurred in either the control or clearcut plots. Three species with closed canopy preferences, the scarlet tanager (*Piranga olivacea* Gmel.), red-eyed vireo (*Vireo olivaceus* L.), and tufted titmouse persisted in the intermediate treatments but declined in abundance and importance as overstory retention decreased (table 2). These points illustrate the species overlap and turnover expected with a graded change in stand retention. Dickson and others (1995) reported that bird diversity in shelterwood and seed-tree regenerated stands can be higher as a result of the immigration of early-successional species into the stands while some late-successional species remain and utilize the residual overstory. Wood and Nichols (1995) found that two-aged stands, with residual overstory and a regenerating cohort underneath, harbored greater numbers of birds and species than clearcuts or untreated stands. Our results appear to be congruent with these studies as our intermediate retention units had the greatest community indices and have high species overlap with the alternative treatments.

This study offered an interesting look into the bird community characteristics of a clearcut in the first year following treatment. Similar to Conner and Adkisson (1975) we found that bird abundance, species richness, and diversity was the lowest in clearcuts during the first post-treatment year, likely due to limited vegetative regrowth before the beginning of the breeding season. It has been widely reported that regenerating clearcuts can support abundant and diverse bird communities. Baker and Lacki (1997) showed that songbird communities in clearcuts and high- and low-leave two-aged forests had greater diversity, species richness, and abundance than in unharvested stands. However, we found that clearcut stands had the lowest density, richness, and diversity, and control stands showed values similar to the intermediate retention treatments. Keller and others (2003) reported that values of avian density and species richness for 6 year old clearcuts in the northeast were over two times that of mature stands. Our results were quite different, but it is important to stress that we studied the bird communities of clearcuts in the breeding season directly following the dormant season harvest. It is anticipated that the vegetative structure and composition in the clearcut plots will change considerably in coming years, likely leading to greater species richness and density.

From a management perspective, the results of this research would suggest the mature closed canopy habitat retained in the control and 75 percent treatments may be necessary to maintain a few unique species (table 3); the wood thrush (*Hylocichla mustelina Gmel.)* and hooded warbler (*Wilsonia citrina Bodd.)* were absent and the ovenbird (*Seiurus aurocapillus L.) was* less abundant in the 75 percent treatments. It is important to remember that most of the midstory of the 75 percent treatment was deadened using an herbicide injection. If the preservation of a species dependent on a fully-developed and living midstory is a management priority, this should be taken into consideration. On the other hand, the standing dead trees produced in the 75 percent treatment provided increased foraging opportunities for bark foraging and excavating birds that may benefit from this type of shelterwood.

The open forest habitat of the 25 and 50 percent retention treatments harbored a number of unique species and had the highest abundance, richness, and diversity. These open forest sites could be prescribed to increase richness and diversity by supporting a mixture of closed canopy, open forest, and scrub species. The clearcut plots had very low community indices and no unique species during the first breeding season following harvest. This is expected to change as years pass and further vegetative growth occurs. Perhaps forest management practices that retain some overstory and minimize understory disturbance while allowing vegetation to regenerate beneath them may be beneficial to forest songbird communities. These could be prescribed to promote desirable timber species and at the same time maintain high community indices for forest songbirds throughout a managed forest rotation by avoiding periods of low abundance and richness as in the early stages of a clearcut.

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LITERATURE CITED

Ambuel, B.; Temple, S.A. 1982. Songbird populations in southern Wisconsin forests: 1954 and 1979. Journal of Field Ornithology. 53(2): 149-58.

Askins, R.A.; Lynch, J.F.; Greenberg, R. 1990. Population declines in migratory birds in eastern North America. Current Ornithology. 7: 1-57.

Baker, M.D.; Lacki, M.J. 1997. Short-term changes in bird communities in response to silvicultural prescriptions. Forest Ecology and Management. 96: 27-36.

Conner, R.N.; Adkisson, C.S. 1975. Effects of clearcutting on the diversity of breeding birds. Journal of Forestry. 73: 781-785.

Conner, R.N.; Via, J.W.; Prather, I.D. 1979. Effects of pine-oak clearcutting on winter and breeding birds in southwestern Virginia. Wilson Bulletin. 91(2): 301-316.

Crawford, H.S.; Hooper, R.G.; Titterington, R.W. 1981. Songbird population response to silvicultural practices in central Appalachian hardwoods. Journal of Wildlife Management. 45(3): 680-692.

Dickson, J.G.; Thompson, F.R., III; Conner, R.N.; Franzreb K.E. 1995. Silviculture in central and southeastern oak-pine forests. In: Martin, T.E.; Finch, D.M., eds. Ecology and management of neotropical migratory birds: a synthesis and review of critical issues. New York, NY: Oxford University Press: 245-266.

Germaine, S.S.; Vessey, S.H.; Capen, D.E. 1997. Effects of small forest openings on the breeding bird community in a Vermont hardwood forest. The Condor. 99: 708-718.

Greenberg, C.H.; Smith, L.M.; Levey, D.J. 2001. Fruit fate, seed germination and growth of an invasive vine: an experimental test of 'sit and wait' strategy. Biological Invasions. 3: 363-372.

Hartsell, A.J.; Vissage, J.S. 2001. Forest statistics for north Alabama, 2000. Resour. Bull. SRS-64. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 50 p.

International Bird Census Committee. 1970. An international standard for a mapping method in bird census work recommended by the International Bird Census Committee. Audubon Field Notes. 24: 722-726.

Johnston, D.W.; Odum E.P. 1956. Breeding bird populations in relation to plant succession on the piedmont of Georgia. Ecology. 37: 50-62.

Keller, J.K.; Richmond, M.E.; Smith C.R. 2003. An explanation of patterns of breeding bird species richness and density following clearcutting in northeastern USA forests. Forest Ecology and Management. 174: 541-564.

Keller, M.E.; Anderson, S.H. 1992. Avian use of habitat configurations created by forest cutting in southeastern Wyoming. The Condor. 94: 55-65.

Odum E.P. 1950. Bird populations of the Highlands (North Carolina) Plateau in relation to plant succession and avian invasion. Ecology. 31: 587-605.

Ralph, C.J.; Geupel, G.R.; Pyle, P. [and others]. 1993. Handbook of field methods for monitoring landbirds. Gen. Tech. Rep. PSW-144. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 41 p.

Robbins, C.S.; Sauer, J.; Greenberg, R.; Droege, S. 1989. Population declines in North American birds that migrate to the Neotropics. Proceedings of the National Academy of Science. 86: 7658-7662.

Robinson, S.K. 1992. The breeding season: introduction. In: Hagen, J.M., III; Johnston, D.W., eds. Ecology and conservation of neotropical migrant landbirds. Washington, D.C.: Smithsonian Institution Press: 405-407.

Sherry, T.W.; Holmes, R.T. 1995. Summer versus winter limitation of populations: what are the issues and what is the evidence? In: Martin, T.E.; Finch, D., eds. Ecology and management of Neotropical migratory birds: a synthesis and review of critical issues. New York, NY: Oxford University Press: 85-120.

Shugart, H.H., Jr.; James, D. 1973. Ecological succession of breeding bird populations in northwestern Arkansas. Auk. 90: 62-77.

SPSS Inc. 1999. SPSS Base 10.0 applications guide. Chicago, IL: SPSS Inc. 426 p.

Thompson, F.R., III; Capen D.E. 1988. Avian assemblages in seral stages of a Vermont forest. Journal of Wildlife Management. 52(4): 771-777.

Thompson, F.R., III; Dijak, W.D.; Kulowiec, T.G.; Hamilton, D.A. 1992. Breeding bird populations in Missouri Ozark forests with and without clearcutting. Journal of Wildlife Management. 56(1): 23-30.

Thompson, F.R., III; Fritzell, E.K. 1990. Bird densities and diversity in clearcut and mature oak-hickory forest. Res. Pap. NC-293. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 7 p.

Thompson, F.R., III; Probst, J.R.; Raphael, M.G. 1995. Impacts of silviculture: overview and management recommendations. In: Martin, T.E.; Finch, D.M., eds. Ecology and management of neotropical migratory birds: a synthesis and review of critical issues. New York, NY: Oxford University Press: 201-219.

Traveset, A.; Riera, N.; Mas, R.E. 2001. Passage through bird guts causes interspecific differences in seed germination characteristics. Functional Ecology. 15(5): 669-675.

Welsh, C.J.E.; Healy, W.M. 1993. Effect of even-aged timber management on bird species diversity and composition in northern hardwoods of New Hampshire. Wildlife Society Bulletin. 21: 143-154.

Williams, A.B. 1936. The composition and dynamics of a beech-maple climax community. Ecological Monographs. 6: 317-408.

Wood, P.B.; Nichols, J.V. 1995. Effects of two-age management and clearcutting on songbird density and reproductive success. In: Gottschalk, K.W.; Fosbroke, L.C., eds. Proceedings of the tenth central hardwood forest conference. Gen. Tech. Rep. NE-197. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station: 225.