

# The Effects of Timber Harvesting on Neotropical Migrants in Cove Hardwood Forests in the Southern Appalachian Mountains<sup>1</sup>

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## Abstract

I compared avian species richness, density, and diversity for neotropical migrants, short distance migrants, and permanent residents following timber harvesting in cove hardwood forests in the Southern Appalachian Mountains of North Carolina. The forest stands were 4-103 years old, had undergone a clearcut or selective tree removal, and represented four successional stages (early, sapling/pole, mid, and late). Neotropical migrants constituted 60.5 to 69.0 percent of species richness. Mean breeding bird density for all species was 225.1 pairs/40 ha ( $\pm 16.3$  se) with an overall mean density for neotropical migrants of 186.2 pairs/40 ha ( $\pm 5.4$  se). Late successional cove hardwood forest habitats provide for a significantly more diverse avifauna with respect to the entire avifauna, and, specifically the neotropical migrants, than does sapling/pole or mid-successional forests. Neotropical migrants are the most substantial avian component of the highly diverse cove hardwood forest habitat, accounting for a minimum of 70 percent of the individual birds in each successional class. Therefore, their needs must not be overlooked in considering the consequences of habitat alterations and management activities.

*Key words:* breeding bird densities, cove hardwood forests, Neotropical migrants, Southern Appalachians, successional stage, timber harvesting.

## Introduction

Studies on neotropical migrants report declines in both distribution and overall population numbers in certain physiographic regions in North America (Terborgh 1989, Peterjohn et al. 1995, Franzreb and Rosenberg 1997). In the Southeast, the number of species that are apparently declining is the highest in the Southern Blue

Ridge Physiographic Area (Hunter et al. 1993). Given that neotropical migrants in many areas constitute the majority of the avifauna (Morse 1980); further reductions may result in substantial declining overall population levels. Observed population declines have been attributed to habitat fragmentation on the breeding grounds and to deforestation of the over-wintering areas. In the United States, habitat fragmentation has resulted from a variety of land management practices, including timber harvesting. Current forest management practices on public and private lands provide opportunities for evaluating how migrant populations respond to changing environmental conditions. Because birds are easily observed, they can be monitored relatively conveniently and, thus, can serve as a barometer of possible conditions and the status of less readily detectable species.

Cove hardwood forests are found on moist, fertile soils in concave landforms and ravines nestled well back into the sides of mountains. The vegetative component is highly diverse in all vegetative strata, from the over-story canopy to the herb layer. Much of the forested land base in the Southeast has sustained one or more entries for logging purposes. Relative to diversity and volume of timber produced, the cove hardwood forest is one of the most productive forest communities in this area. Cove hardwood forests are dominated by such species as yellow-poplar (tulip tree), sugar maple, yellow birch, black cherry, American beech, and oaks. Plant scientific names not given in the text may be found in *table 2*.

On the Pisgah and Nantahala National Forests, the largest volume of timber is removed from cove hardwood forests. Hence, evaluating this forest type with respect to birds provides an opportunity to evaluate the effects of a land management practice that is widespread over the landscape. Of the 123,940 ha of cove hardwood forests in the Pisgah and Nantahala National Forests, about 30 percent is in the 41-60 year-old age class and 50 percent is 61-80 years old (Ed Brown, US Forest Service, pers. comm.). As the rotation age for this vegetation type is approximately 80 years, much of the existing cove hardwood forest is approaching harvestable age.

The objectives of this study were to: (1) determine avian species richness, breeding bird densities and bird

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species diversity in harvested cove hardwood forests in four successional stages (early successional, sapling/pole, mid, and late successional) in the Southern Appalachian Mountains; (2) determine the proportion of the avifauna comprised of neotropical migrants, short-distance migrants, and permanent residents; and (3) provide information that may be useful in developing harvesting programs as part of an overall management plan that includes cove hardwood forests in these areas.

## Materials and Methods

### Study Area

Dominant tree species are yellow-poplar, American basswood, Carolina silverbell, sugar maple, yellow buckeye, northern red oak, white oak, yellow birch, black birch, black cherry, and American beech. Typical understory trees include eastern redbud (*Cercis canadensis*), Fraser magnolia, mountain maple (*Acer spicatum*), and flowering dogwood. Among the numerous understory shrub species are great rhododendron (*Rhododendron maximum*), flame azalea (*R. calendulaceum*), and mountain laurel (*Kalmia latifolia*). Cove hardwood forests contain a diverse array of herbaceous species with commonly encountered species including wood anemone (*Anemone quinquefolia*), red trillium (*Trillium erectum*), wild ginger (*Asarum canadense*), Solomon's-seal (*Polygonatum biflorum*), and American ginseng (*Panax quinquefolius*).

Twelve study plots were established in cove hardwood forests in the Pisgah and Nantahala National Forests in western North Carolina (Cheowah, Highlands, Appalachian, and Wayah Ranger Districts) (table 1). The plots ranged in elevation from 788 m to 1,090 m and varied in size from 19.4 to 117 ha. Slopes varied from 30-55 percent, with an average of 40 percent. The general

aspect for 10 of the plots was north or northeast and for the remaining two plots was south or southwest. Age of the plots from time of last entry for timber harvesting purposes varied from 4 to 103 years. The harvesting process varied from clear cutting in the younger stands to selective tree removal (based on minimum trunk diameter) in the older stands. Plot selection was based, in part, on road access so that all plots were within a 1-hour walk of a road. Also we selected stands that could accommodate a square or rectangular plot within the stand with minimal potential for edge effects related to adjacency of dissimilar stands.

Successional stages were defined as early successional (grass/forb and shrub/seedling, up to 10 years old, one plot), sapling/pole (11-40 years old, five plots), mid-successional (41-80 years old, three plots), and late successional (81-120 years old, three plots) (U.S. Forest Service 1999). As a result of the limited amount of recent logging on Forest Service lands on these forests, I was unable to locate more than one suitable stand to assess the early successional stage. In a landscape context, the cove sites were in concave landforms that were surrounded by other types of hardwood stands such as oak-hickory, white pine-hemlock, and maple-beech-birch. There was little information available on a site-specific basis that described land use changes on these sites from historic times to the present day. Eight of the plots were treated post-logging either by chain saw site preparation (Brush Creek in 1991 and Rattler Ford in 1974), thinning (Appletree in 1966, Rhinehart Creek in 1978, Ash Flats in 1968 and 1991, and White Oak in 1989), grape removal (Rattler Ford in 1983), and herbicide application (Jutts Creek in 1978 and 1980 and Bee Cove in 1976). The three oldest plots and one of the mid-successional (Sugarhouse) stage plots received no post-harvesting treatments. Also, I did not sample any old-growth plots (those more than 120 years of age).

**Table 1**—Description of cove hardwood forest study plots, southern Appalachians.

Plot name	Stand age (years)	Successional stage	Mean elev. (m)	Mean slope (%)	General aspect	USGS quad name
Brush Creek	4	Early	1090	55	N	Highlands, NC/GA
Jutts Creek	15	Sapling/pole	955	45	NE	Hewitt, NC
White Oak	18	Sapling/pole	1076	35	S	Celo, NC
Rattler Ford	21	Sapling/pole	879	55	NE	Santeetlah Creek, NC
Bee Cove	23	Sapling/pole	970	40	N	Fontana Dam, NC
Appletree	37	Sapling/pole	970	30	N	Topton, NC
Rhinehart	56	Mid-	1000	30	NE	Wayah Bald, NC
Sugarhouse	56	Mid-	1030	40	SW	Mt. Mitchell-Barnardsville, NC
Ash Flats	68	Mid-	1030	40	NE	Rainbow Springs, NC
Cherry Gap	93	Late	1030	40	NW	Sylva South, SC
Joyce Kilmer A	103	Late	788	35	NE	Santeetlah Creek, NC
Joyce Kilmer B	103	Late	1000	35	NE	Santeetlah Creek, NC

## Vegetation

I used the plotless point-quarter method (Cottam and Curtis 1956) to sample trees with diameter at breast height (dbh) >12.7 cm. In the summer of 1994, twenty-five points with four trees each were sampled in 11 of these 12 study plots. There were no trees with dbh > 12.7 cm in the early successional stage. Points were at least 50 m apart and counted from a random starting point along the transect. In each quadrant, the following information was recorded for the tree in each quadrant closest to the center stake: distance to the center point, tree species, height, dbh, and length of the live branch closest to the ground. These data were analyzed to provide tree species density, frequency, dominance, and importance values. Species richness reflects the number of species. Dominance values were derived from basal area figures that rely on measurements of dbh and were expressed as m<sup>2</sup>/ha. I estimated the importance value by summing the relative density, relative dominance, and relative frequency of tree species in each plot. Points were selected from those used for establishing the spot map grid (see avian sampling below). Likewise I sampled four saplings (defined as dbh < 12.7 cm) at each of ten points for a total of 40 saplings per study plot. A total of 1,100 trees (n = 11 stands) and 480 saplings (n = 12 stands) were measured. Plant species diversity and structural characteristics that contributed to avian species richness and densities are being analyzed (Franzreb, unpubl. data<sup>1</sup>).

## Avian Sampling

Each study plot was 10 ha in size and contained a series of labeled stakes placed 50 m apart along parallel transect lines, which in turn were 50 m from other transect lines. Birds were surveyed using the spot mapping method (Williams 1936, Kendeigh 1944), whereby locations of individual birds were recorded on a map that had a grid system that corresponded to the labeled stakes. Territory boundaries were delineated and the number of territories was estimated for each species, with the assumption that each territory represented one breeding pair. Eight visits were made in each plot for each year of the study. Data for each species were collated for all visits and transferred to a map for each individual species prepared for each breeding season. Densities are reported as the number of breeding pairs per 40 ha for ease of comparing with results of other studies. Estimates of partial territories overlapping with the area outside the plot were included as a percentage of a complete territory. Birds were surveyed from May 27 - July 15 in 1992, May 27 - July 5 in 1993, and May 16 - July 7 in 1994, by the observer systematically walking along the transects and recording the following for each observation: species, activity (singing, foraging, etc.), sex, map location on the grid, date, time,

and<sup>1</sup> weather conditions. Distances were estimated using a range finder and with the aid of flagging placed at specific distances parallel to the transect lines. Observations were begun approximately at sunrise and continued up to three hrs. The order that the transects were walked was randomized for each visit. There were a total of five observers, each of whom surveyed one plot per survey day.

Data were averaged over the three years for each of the 12 plots, segregated by migratory class and then consolidated for each successional stage as needed to perform specific statistical tests. A mean for the consolidated data for a successional stage was obtained by averaging the densities for individual species over the three year period. Species were segregated into groups according to their migratory status (neotropical migrant, short-distance migrant, and permanent resident) as per the Breeding Bird Survey classification system (see Sauer et al. 2001). Short-distance migrants were defined as those who do not migrate outside the boundaries of the United States.

Species richness, breeding bird species densities, bird species diversity, and evenness values were obtained for each migratory class in each of the plots. To determine the overlap in species presence from one successional stage to the next, I used the Sorensen index (Sorensen 1948). Comparisons of species overlap (similarity) included early versus sapling/pole, sapling/pole versus mid-successional, and mid-successional versus late successional stages. Single classification analysis of variance (ANOVA) was performed to detect differences between the successional stages for three variables: species richness, density, and bird species diversity. Each of these variables was analyzed on an overall population basis and then separately for neotropical migrants, short distance migrants, and permanent residents. ANOVA tests were followed by Turkey's studentized range tests to compare results between successional stages. One of the assumptions of ANOVA is homogeneity of variances and in cases that involve only one plot, it is not possible to calculate the variance and, hence, not possible to check this assumption. Because the early successional stage was represented by only one plot, thus precluding estimating a variance, it was not included in the ANOVA.

Bird species diversity was calculated using the Shannon formula (Shannon 1948). Evenness (or relative diversity) was calculated as  $J = H/H_{max}$  where H is the diversity value,  $H_{max} = \log k$  and k is the number of species in the data set (Pielou 1966). In this study, k = 45 species. Pearson correlation coefficients were obtained to test the relationship of bird species diversity

<sup>1</sup> Unpublished data on file at Southern Appalachian Cooperative Ecosystems Studies Unit, Knoxville, TN.

versus successional stage for the entire avifauna and for each individual migratory class for all 12 plots, including the youngest plot.

The potential power of the statistical tests was low because of the small sample size. Thus, to reduce the type II error, all ANOVA tests were performed at the 0.10 significance level and subsequent pairwise comparisons were performed at an experimentwise 0.10 level. Statistical analyses were done using SAS (1999-2000).

## Results

### Vegetation

All plots had diverse flora typical of hardwood forests in the Southern Appalachians. As the Brush Creek plot was only four years-old when the study was initiated, it contained a large number of saplings (3,846/ha), but no trees (Franzreb, unpubl. data). The importance values for tree species (relative density + relative frequency + relative dominance) showed that yellow-poplar was the most influential species in nine of the 12 plots. It was replaced in importance in the oldest two plots by black cherry, sugar maple, and American basswood (table 2). Black birch also was an important tree species in the young and middle-aged stands.

### Species Composition and Richness

Successional stage was nonsignificant for species richness for all birds ( $P = 0.11$ ), neotropical migrants ( $P = 0.29$ ), short distance migrants ( $P = 0.81$ ), or permanent residents ( $P = 0.19$ ). Species richness in the four successional stages ranged from  $18.7 \pm 1.8$  se in the mid-

successional stage to  $24.3 \pm 0.9$  se in the late successional stage (fig. 1, table 3).

The mean number of neotropical migratory bird species varied from  $13.3 \pm 0.3$  se in the mid-successional stage to a high of  $15.3 \pm 0.3$  se in the late successional stage. Neotropical migratory birds constituted 60.5 - 69.0 percent of the breeding bird species in the successional stages, representing the majority of species present compared to short distance migrants (5.2 - 13.6 percent) or permanent resident species (18.2 - 34.2 percent) (fig. 2). The highest proportion of permanent resident species was found in the late-successional stage and short distance migrants in the early successional stage.

Of the migratory classes, the short distance migrants had the lowest degree of species overlap between the successional stages (table 4). Species overlap for neotropical migrants increased slightly (0.74 to 0.84) with age of the successional stage. For permanent residents, species overlap increased consistently with age of the successional stage, ranging from 0.50 in the early stage compared to the sapling/pole stage to a high of 0.95 in the mid- compared to late successional stage. When all species are considered, species overlap increased with successional stage.

### Avian Species Density

The overall mean number of breeding birds in the four successional stages for the three year period was 225.1 pairs/40 ha ( $\pm 16.29$  se) and varied from a low of 203.5 pairs/40 ha ( $\pm 13.5$  se) in the sapling/pole stage to a high of 272.7 pairs/40 ha in the early successional stage (fig. 3).

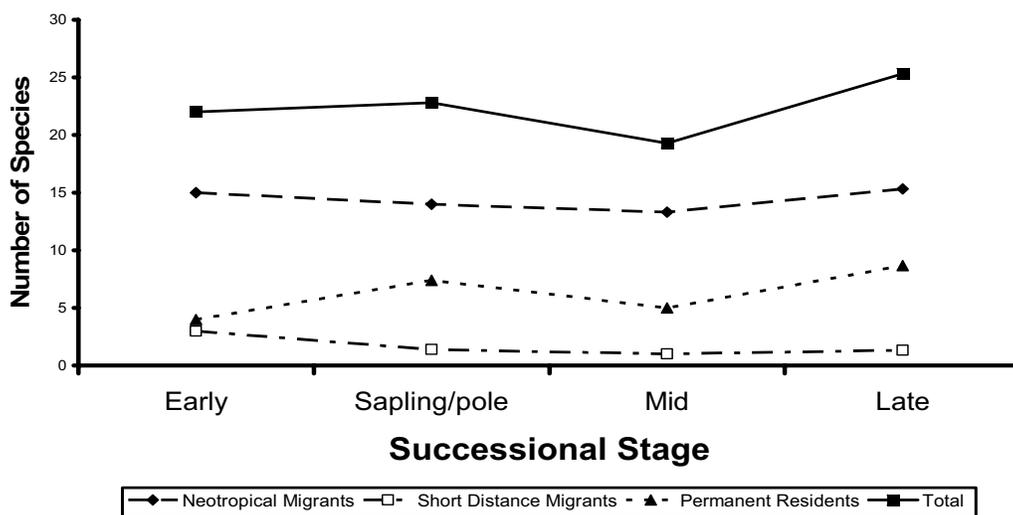


Figure 1—Number of species of birds by migratory class and stand age in cove hardwood forests in the southern Appalachians.

Table 2—Importance values<sup>1</sup> for trees in cove hardwood forest plots, southern Appalachians (1992–1994).

Plant name	Scientific name	Importance Value										
		Jutt's Creek	White Oak	Rattler Ford	Bee Cove	Apple Tree	Rhinehart	Sugar-house	Ash Flats	Cherry Gap	Joyce Kilmer A	Joyce Kilmer B
Eastern hemlock	<i>Tsuga canadensis</i>		11.7								21.3	15.4
White pine	<i>Picea strobus</i>		2.9									
Mockernut hickory	<i>Carya tomentosa</i>	3.0	3.0		3.6	55.1		26.4		76.0	66.6	2.4
Black birch	<i>Betula lenta</i>	43.0	9.3	63.0	54.5	5.8	53.0	5.8		27.3	18.3	43.0
Yellow birch	<i>Betula alleghaniensis</i>							2.5				
Eastern hophornbeam	<i>Ostrya virginiana</i>							3.1				
American beech	<i>Fagus grandifolia</i>					3.3	8.3	12.6				20.3
White oak	<i>Quercus alba</i>		3.1			29.0		6.2				
Chestnut oak	<i>Quercus montana</i>		47.5					30.7		4.4	8.0	
Northern red oak	<i>Quercus rubra</i>		30.9	5.3	3.1	25.2	20.0	36.8		39.9	28.7	17.0
Cucumber-tree	<i>Magnolia acuminata</i>	26.2	3.2	54.4	59.3	22.6		5.4				
Fraser magnolia	<i>Magnolia fraseri</i>	5.8				2.6	3.0					
Yellow-poplar	<i>Liriodendron tulipifera</i>	15.4		106.5	100.8	40.8	108.9	76.2		71.2	58.3	4.4
Sassafras	<i>Sassafras albidum</i>	79.7	114.6		3.0			2.6				
Black cherry	<i>Prunus serotina</i>	13.6	26.2		6.3		4.1			3.0	2.8	52.0
Black locust	<i>Robinia pseudoacacia</i>	19.2	18.4	36.2	32.1	2.6	4.7	12.9		18.4	23.1	
Red maple	<i>Acer rubrum</i>	10.2	20.6	7.8	14.4	36.7	15.8	18.1		14.5	29.8	20.2
Sugar maple	<i>Acer saccharum</i>	10.5	2.8	12.2	11.9	7.6		12.1		6.2	10.3	56.1
Striped maple	<i>Acer pensylvanicum</i>	2.6	3.0		3.0					2.8	2.6	
Yellow buckeye	<i>Aesculus octandra</i>									9.2	5.8	21.5
American basswood	<i>Tilia glabra</i>	18.4		9.0	5.0	3.1	39.5	11.2		18.3	35.0	37.9
Blackgum (bk. tupelo)	<i>Nyssa sylvatica</i>	5.4				2.7						2.3
Flowering dogwood	<i>Cornus florida</i>	5.3				5.5		17.0		2.6	7.1	4.6
Sourwood	<i>Oxydendrum arboreum</i>	7.2				28.0		7.7		2.7		
Carolina silverbell	<i>Halesia carolina</i>	31.8		5.3	3.0	19.1	4.2			3.7	3.6	7.6
White ash	<i>Fraxinus americana</i>	2.7	2.8				7.5	9.5			2.8	2.9

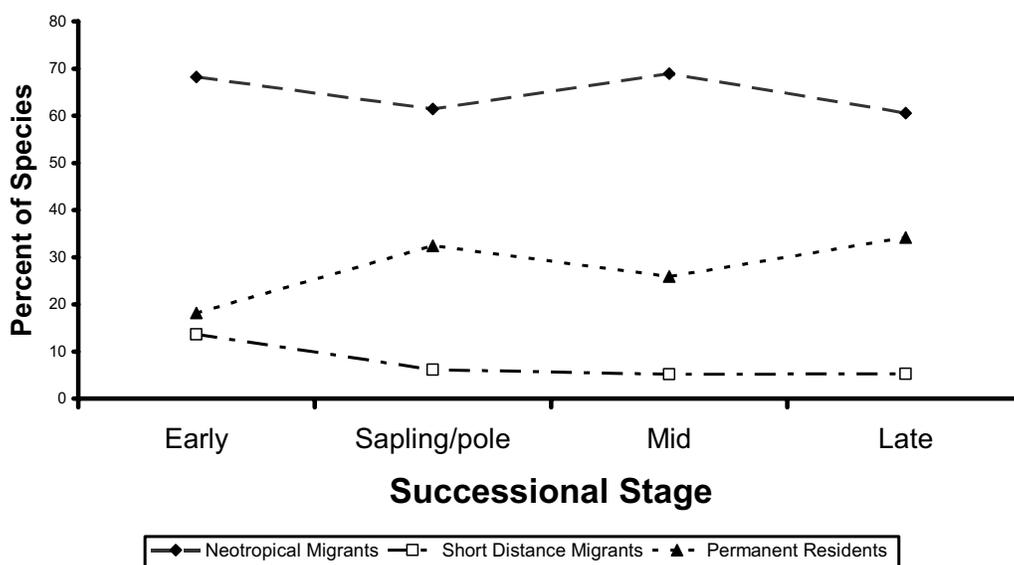
<sup>1</sup>Importance Value = relative density + relative frequency + relative dominance (max. = 300, min. = 0).

**Table 3**—Relationship of successional stage to species richness, species densities, and bird species diversity in cove hardwood forests.

	ANOVA <sup>1</sup>		Mean ± se and Tukey's test <sup>2</sup>		
	F	P	Sapling/pole	Mid-successional	Late successional
<b>Species Richness</b>					
Neotropical migrants	1.45	0.29	14.0 ± 0.89 <sup>a</sup>	13.3 ± 0.33 <sup>a</sup>	15.3 ± 0.33 <sup>a</sup>
Short distance migrants	0.21	0.81	1.4 ± 0.51 <sup>a</sup>	1.0 ± 0 <sup>a</sup>	1.3 ± 0.33 <sup>a</sup>
Permanent residents	2.05	0.19	7.4 ± 0.93 <sup>a</sup>	5.0 ± 1.52 <sup>a</sup>	8.7 ± 0.88 <sup>a</sup>
All Birds	2.92	0.11	22.6 ± 1.54 <sup>a</sup>	18.7 ± 1.76 <sup>a</sup>	24.3 ± 0.88 <sup>a</sup>
<b>Species Densities</b>					
Neotropical migrants	0.45	0.65	176.7 ± 12.3 <sup>a</sup>	198.0 ± 27.12 <sup>a</sup>	182.8 ± 3.64 <sup>a</sup>
Short distance migrants	0.72	0.52	4.6 ± 2.00 <sup>a</sup>	1.78 ± 0.22 <sup>a</sup>	3.2 ± 0.77 <sup>a</sup>
Permanent Residents	6.75	<b>0.02</b>	22.1 ± 3.72 <sup>a,b</sup>	8.11 ± 5.28 <sup>b</sup>	34.2 ± 5.22 <sup>a</sup>
All Birds	0.20	0.82	203.5 ± 13.50 <sup>a</sup>	207.9 ± 32.5 <sup>a</sup>	220.2 ± 9.59 <sup>a</sup>
<b>Bird Species Diversity</b>					
Neotropical migrants	5.22	<b>0.04</b>	0.94 ± 0.02 <sup>b</sup>	0.94 ± 0.04 <sup>b</sup>	1.04 ± 0.01 <sup>a</sup>
Short distance migrants	0.62	0.56	0.08 ± 0.05 <sup>a</sup>	0 <sup>a</sup>	0.09 ± 0.09 <sup>a</sup>
Permanent residents	2.21	0.17	0.76 ± 0.06 <sup>a</sup>	0.53 ± 0.16 <sup>a</sup>	0.80 ± 0.06 <sup>a</sup>
All birds	8.96	<b>0.01</b>	1.09 ± 0.01 <sup>b</sup>	1.01 ± 0.06 <sup>b</sup>	1.20 ± 0.02 <sup>a</sup>

<sup>1</sup> Numbers in bold = significant difference at P ≤ 0.10. All df = 2.

<sup>2</sup> Means in a row with the same letter are not significantly different based on Tukey's studentized range test at the 0.10 significance level.



**Figure 2**—Percent species of birds by migratory class and successional stage in cove hardwood forests in the southern Appalachians.

The youngest stand, 4-year-old Brush Creek, had the highest bird density (272.7 pairs/40 ha), primarily the result of the presence of three high density species, Chestnut-sided Warbler (*Dendroica pensylvanica*) (73.0 pairs/40 ha), Eastern Towhee (*Pipilo erythrophthalmus*) (53.0 pairs/40 ha), and Indigo Bunting (*Passerina cyanea*) (50.7 pairs/40 ha). With the exception of the youngest plot, which had only one pair, Ovenbirds (*Seiurus aurocapillus*) were the most common breeding bird on all plots, ranging in density from 36.0 to 63.7 pairs/40 ha. Black-throated Green

Warblers (*Dendroica virens*) and Black-throated Blue Warblers (*D. caerulescens*) were among the most common breeding birds on plots that were 21 years of age or older.

Neotropical migrants comprised the majority of the overall breeding bird population in terms of densities and percent of each successional category (Figs. 3, 4). The mean density of neotropical breeding birds varied from 176.7 pairs/40 ha (±12.3 se) in the sapling/pole stage to a high of 198.0 pairs/40 ha (±27.12 se) in the mid-successional stage, with an overall mean of 186.2

± 5.4 se (table 3). The percent of the population consisting of neotropical migrants ranged from 70.1 percent in the early successional stage to a high of 95.2 percent in the mid-successional stage. Successional stage was not significantly related to the density of neotropical migrants (P = 0.65) (table 3).

Short-distance migrants had a mean density ranging from 1.8 pairs/40 ha (± 0.2 se) in the mid-successional stage to a high of 20.7 pairs/40 ha in early successional stage (fig. 3, table 3). The overall mean density for short-distance migrants in the four successional stages was 7.6 pairs/40 ha ± 4.4 se. Short-distance migrants comprised from 0.9 to 7.6 percent of the density of breeding birds (fig. 4). Successional stage was not significant for the density of short distance migrants (P = 0.52) (table 3).

Densities of permanent residents ranged from a low of 8.1 pairs/40 ha (± 5.3 se) in the mid-successional stage to a high of 60.7 pairs/40 ha in the early successional stage (fig. 3, table 3), with an overall mean of 31.3 pairs/40 ha ± 11.2 se. Permanent residents comprised from 3.9 to 22.3 percent of the breeding bird density in the four stages (fig. 4). The density of permanent

residents was influenced by successional stage (P = 0.02). Mean densities of permanent residents was significantly lower in the mid- versus the late successional stage (8.1 pairs/40 ha vs. 34.2 pairs/40 ha, respectively) (table 3).

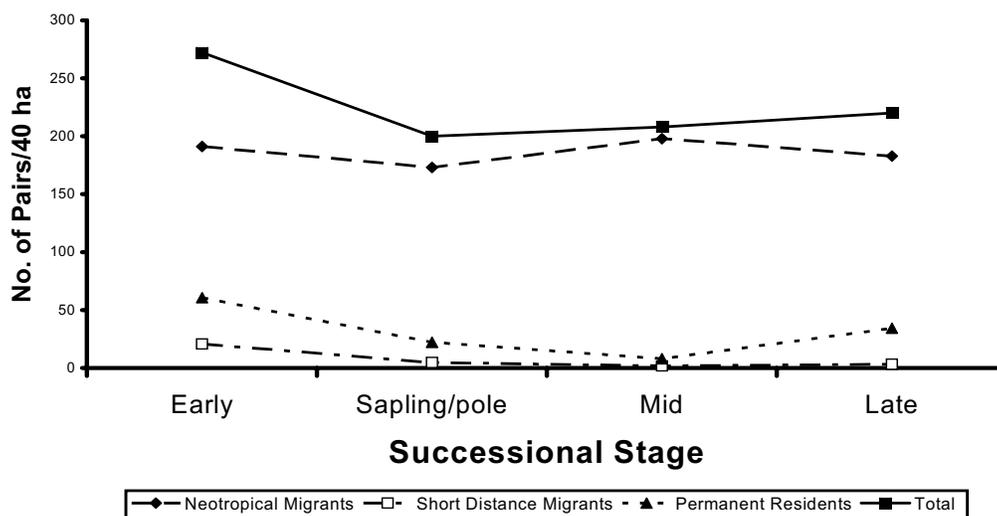
**Bird Species Diversity**

Bird species diversity for all birds ranged from a low of 0.62 in the early successional stage, which included one 4 year-old plot, to a high of 1.20 ± 0.02 se in the late successional stage (n = 3) consisting of Cherry Gap (93 years) and Joyce Kilmer A and B (each 103 years old) (table 5). The bird species diversity for the 12 plots was 1.06 ± 0.05 se. Species diversity was significantly different between stages when considering all migratory classes together (P = 0.01) (table 3). According to Tukey’s studentized range tests, bird species diversity for all birds was significantly lower in the sapling/pole versus the late successional stages and significantly lower in the mid-successional versus the late successional stages (tables 3 and 5). Bird species diversity and evenness for all birds were positively correlated with stand age (r = 0.54, P = 0.07 and r = 0.54, P = 0.07, respectively).

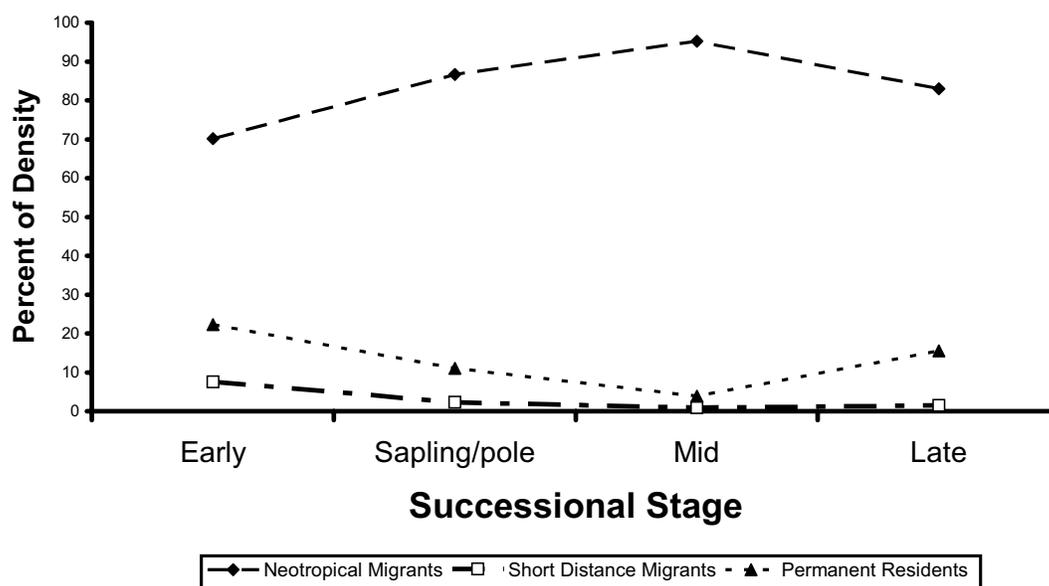
**Table 4**—Species overlap by migratory class and successional stage based on Sorensen index<sup>1</sup>.

Species Overlap	Early successional vs. sapling/pole	Sapling/pole vs. mid-successional	Mid- vs. late successional
Neotropical migrants	0.74	0.76	0.84
Short distance migrants	0.57	0.67	0.50
Permanent residents	0.50	0.76	0.95
All birds	0.66	0.75	0.85

<sup>1</sup>See Sorensen (1948) (max = 1.0, min = 0).



**Figure 3**—Breeding bird density by migratory class and successional stage in cove hardwood forests in the southern Appalachians.



**Figure 4**—Percent of breeding bird density by migratory class and successional stage in cove hardwood forests in the southern Appalachians.

**Table 5**—Bird species diversity and evenness by successional stage and migratory class. Parameter estimates are reported as mean ± se.

Parameter	Successional Stage				Overall (n = 12)
	Early (n = 1)	Sapling/pole (n = 5)	Mid (n = 3)	Late (n = 3)	
<b>Mean bird species diversity<sup>1</sup></b>					
Neotropical migrants	0.78	0.94 ± 0.02	0.94 ± 0.04	1.04 ± 0.01	0.95 ± 0.03
Short distance migrants	0.38	0.08 ± 0.05	0.00	0.09 ± 0.09	0.09 ± 0.04
Permanent residents	0.20	0.76 ± 0.06	0.53 ± 0.15	0.80 ± 0.06	0.67 ± 0.07
All species	0.62	1.09 ± 0.01	1.01 ± 0.06	1.20 ± 0.02	1.06 ± 0.05
<b>Evenness<sup>2</sup></b>					
Neotropical migrants	0.47	0.57 ± 0.01	0.57 ± 0.03	0.63 ± 0.003	0.58 ± 0.01
Short distance migrants	0.23	0.05 ± 0.03	0.00	0.05 ± 0.05	0.05 ± 0.02
Permanent residents	0.12	0.46 ± 0.03	0.32 ± 0.09	0.48 ± 0.04	0.40 ± 0.04
All species	0.38	0.66 ± 0.007	0.61 ± 0.04	0.73 ± 0.01	0.64 ± 0.03

<sup>1</sup> Shannon-Weiner formula (see Methods).

<sup>2</sup> J = H/H<sub>max</sub> (see Methods).

Mean bird species diversity for neotropical migrants for all successional stages was 0.95 ± 0.03 se versus 0.09 ± 0.04 se for short-distance migrants and 0.67 ± 0.07 se for permanent residents. Neotropical migrants attained their highest species diversity of 1.04 ± 0.01 se (n = 3) in the late stage and their lowest in the early successional stage (0.78, n = 1). Species diversity for neotropical migrants was significantly different between stages for neotropical migrants (P = 0.04), being significantly higher comparing the late successional to either the sapling/pole or mid-successional stages (tables 3 and 5). Bird species diversity and evenness

for neotropical migrants were positively correlated with stand age (r = 0.73, P = 0.01 and r = 0.75, P = 0.01, respectively).

## Discussion

Avian community structure is largely determined by the structure and physiognomy of the plant community including the vertical and horizontal heterogeneity (MacArthur and MacArthur 1961, Willson 1974, Balda 1975, Niemi and Hanowski 1984). Silvicultural activi-

ties influence the vegetation and, therefore, have a profound influence on the avian community (Maurer et al. 1981, Thompson et al. 1995). Increased public concern regarding the potential impacts of timber harvesting on wildlife support the need to more fully understand how components of the ecosystem, such as the avifauna, respond to changes in the landscape following harvesting.

Wilcove (1988) censused birds in 10-ha plots using the spot-map method in three cove hardwood forests in the Great Smoky Mountains National Park. One plot was logged sometime in the 19th Century (Lower Ramsey) and, therefore, may correspond to my late successional plots. Because the other two cove plots were virgin forest, they do not have an analog in my study. In Lower Ramsey, the breeding bird density was 218.4 pairs/40 ha of which 186.4 pairs/40 ha were neotropical migrants (Wilcove 1988). My results are strikingly similar to those of Wilcove in overall breeding bird densities in the late successional stage (220.2 pairs/40 ha and 218.4 pairs/40 ha, respectively), in densities of neotropical migrants (182.8 pairs/40 ha and 186.4 pairs/40 ha, respectively), and in the percent of neotropical migrants in the breeding population (83.9 percent and 85.5 percent, respectively). These comparisons are particularly interesting because the census method and plot size were the same.

Bird species diversity reflects not only the number of species but also the proportional distribution of densities of those species. The early successional plot (Brush Creek) had the lowest bird species diversity, primarily because of the presence of three species in high densities - Chestnut-sided Warbler, Eastern Towhee, and Indigo Bunting. Together these three species comprised a total of 176.7 breeding pairs/40 ha out of a total of 272.8 pairs/40 ha. Short-distance migrants were most numerous in the early successional plots primarily the result of the presence of large numbers of Dark-eyed Juncos (*Junco hyemalis*) and American Goldfinches (*Carduelis tristis*), which were less numerous in older successional stages.

King and DeGraaf (2000) found that number of species and bird species diversity were significantly higher in shelterwood harvested sites than in either clearcut or mature forests. The results of my study are in partial agreement with their findings. Bird species diversity was significantly lower in younger and mid-successional stands than in mature forest for all species combined and for neotropical migrants. Bird species diversity and evenness for all birds and neotropical migrants were positively correlated with successional stage over the full length of successional classes. This is partly explained by the younger stands having been clearcut, whereas the older stands were subjected to harvesting of trees that had attained a minimum trunk

diameter (as in high-grading). As trees had not developed yet in the youngest stand, the vegetation structure and diversity in that plot was substantially less than what was present in the other, older stands.

It has been shown that some species of neotropical migrants in the Southern Appalachians responded to habitat gradients representing both microclimate features (tree species, tree basal area, dbh, percent cover, canopy height, height range of vegetation layers, elevation, stand age, and canopy height) and landscape features (proportion of stand types within the landscape) (Lichstein et al. 2002). Early successional species appeared to be most sensitive to landscape composition, perhaps the result of the relative lack of early successional forest in this area (Lichstein et al. 2002). In fact, the scarcity of early successional stage forest habitat made it difficult for me to locate more than one plot in the youngest successional class that was suitable for obtaining data on absolute avian densities. Results from a study on northern hardwood forests in the Northeast suggest that timber harvesting may benefit early successional species as 11 of the 20 species that were observed only on managed areas were associated with early successional habitats (Welsh and Healy 1993). Analysis of long-term breeding bird survey data for the Southern Appalachians indicated that many early successional species in this region appear to have experienced significant population declines (Franzreb and Rosenberg 1997). Therefore, the importance of timber harvesting as a strategy to enhance habitat quality for these species should not be underestimated. I am presently undertaking a more detailed analysis of the vegetation components in my plots to assess how local attributes may have influenced species richness, densities, and diversity (Franzreb, unpubl. data).

Analyzing the responses of birds to timber harvesting as was done in this study advances our understanding of the interactions of harvesting and the avifauna. However, it should be noted that this particular study was limited in three ways. First, limitations on logging of Forest Service land in the forests of western North Carolina precluded me from being able to locate more than one suitable early successional stage plot. Second, although the Joyce Kilmer area has been referred to as old growth, it does not technically meet the definition of old growth for this stand type (>120 years), as it was only 103 - 106 years old when this study was conducted. Hence, there were no plots in this study that were defined as true old growth. Third, all plots were not subjected to the same type of timber harvesting, nor were post-harvesting management actions similar in all the plots. Harvesting of the stands was done over a period in excess of 100 years. When the first plots were logged, clear-cutting had not yet been implemented as a harvesting strategy. It was not until the 1960s that clearcutting became prevalent in this area (John

Blanton, U.S. Forest Service, pers. comm.). Therefore, it should not be surprising that these 12 plots have been dealt with differently. However, it should be emphasized that the logging approach and post-logging treatments in these plots is typical and widespread in this area. Eight of the 12 plots in this study were subjected to some kind of management treatment (e.g., site preparation using chain saws, thinning, and herbicide application) post harvest, whereas four plots sustained no such treatment. It is not known what influence such treatments may have had on the avian community. Because many hectares of Forest Service lands in this area have been subjected to similar logging patterns and treatments, it is worthwhile to explore and examine the bird populations in these sites to try and assess possible differences in the avifauna.

One goal of the Forest Service's forest management plans that cover part of the Southern Appalachians will be to, "Provide breeding, wintering, and migration staging and stop-over habitat for migratory birds in ways that contribute to their long-term conservation." (U.S. Forest Service-FWRBE Team, in prep.). The results of this study demonstrate that neotropical migrants constitute the majority of the bird species present and the bulk of the breeding bird population in all successional forest stages examined. To provide suitable quality breeding habitat for all neotropical migrants will require a variety of management strategies, possibly including various forms of timber harvesting. Logging would be particularly beneficial to species that prefer disturbed forest, including the Partners in Flight category II Golden-winged Warbler (*Vermivora chrysoptera*) (Hunter et al. 1999) that was found in this study. Such harvesting may be useful for early successional species if sufficient tree removal is undertaken, whereas some stands should be maintained in relatively undisturbed condition to provide for those species that are more common in older, mature habitats. It is anticipated that the forest management plans currently being revised will address the conservation of neotropical migrants as a valid management concern.

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