Breeding Birds of Even- and Uneven-Aged Pine Forests of Eastern Texas

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Abstract - While single-tree selection, uneven-aged management is being used increasingly on southern national forests as an alternative to clearcutting and planting of pine, its effects on wildlife are largely unknown. We compared breeding season bird abundance, species richness, diversity, and composition among uneven-aged stands and six seral stages of even-aged stands in upland pine (predominantly loblolly pine, *Pinus taeda* Linnaeus) forests of eastern Texas. Even-aged stands 18–80 years old generally had the lowest abundance, richness, and diversity of birds; uneven-aged stands and even-aged stands 1–9 years old generally had comparable values for all three of these measures. Numbers of migrants were highest in seedling, sapling, and pre-commercially thinned even-aged stands. Although many migrants were encountered in uneven-aged stands, their frequencies of occurrence there (even in the most recently harvested stands) were generally less than in early sere even-aged stands. While overall bird abundance, species richness, and diversity under single-tree selection may be comparable or higher than that found throughout most of a typical national forest even-aged rotation, our data suggest that single-tree selection management will not provide suitable habitat for many migrant species that require early succession conditions.

Introduction

Even-aged silviculture employing clearcutting, site preparation, and planting of pines (*Pinus* spp.) has dominated forest management practices on forest industry and national forest lands throughout the South for the last four decades (Baker 1989). Although young pine plantations provide habitat for wildlife species adapted to early seral stages, even-aged pine silviculture, especially under short rotations, can eliminate habitat for wildlife species that require snags and cavity trees, hardwoods, hard mast, and large down woody material unless active efforts are made to provide these structures (Melchiors 1991, Thill 1990).

Under recently adopted principles of ecosystem management (Guldin 1996, Robertson 2004), the USDA Forest Service is evaluating the effects of single-tree and group selection regeneration systems of uneven-aged silviculture as alternatives to even-aged management on both an experimental and operational basis (e.g., Baker 1994, Kitchens 1989). Considerable information is available on silvicultural aspects of

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single-tree selection (e.g., Baker 1986, Baker et al. 1996, Reynolds et al. 1984), and both loblolly (*P. taeda* Linnaeus) and shortleaf pine (*P. echinata* Miller) have been successfully managed using single-tree selection for more than four decades (Reynolds et al. 1984). In Arkansas, 17% (> 300,000 ha) of all commercial forestland under forest industry ownership is managed using uneven-aged management (Guldin 1996), and the vast majority of this is single-tree selection (J.M. Guldin, Southern Research Station, Hot Springs, AR, pers. comm.).

In uneven-aged management employing single-tree selection, pine stands are harvested frequently (e.g., every 5 to 15 years) and thinned heavily enough to achieve reproduction following at least some harvest entries. Resulting stands have an irregular canopy, recurring regeneration of the desired species, and a wide range of tree sizes/ages. When tree density by diameter (dbh) distributions are plotted for a well-structured single-tree selection stand, the result is a reverse J-shaped dbh distribution similar to the lower two graphs (pine) in Figure 1.

Few relevant citations exist on the effects on breeding birds of uneven-aged management for pine forest types (Sallabanks et al. 2001), as most of the published information on wildlife responses to single-tree selection in both hardwood and coniferous forests pertains to stands in transition to an uneven-aged stand structure; i.e., data were obtained from essentially even-aged stands that had received only one or two initial timber harvests (e.g., Medin and Booth 1989, Rodewald 1995, Szaro and Balda 1979, Ziehmer 1993). Consequently, these stands presumably lacked the characteristic vertical layering of canopies that result from repeated harvests at frequent intervals. Furthermore, most of these studies compared treated versus untreated control stands. We are aware of only one bird study (Barber et al. 2001) that compared well-structured, uneven-aged pine stands with more than one even-aged seral stage; their study evaluated nesting success, but provided no data on abundance, richness, diversity, or community composition.

There has been some research on the impacts of uneven-aged management on wildlife of hardwood forests, but its applicability to pine systems is unknown. Annand and Thompson (1997) evaluated breeding songbird populations under five treatments (both even- and uneven-age systems) in central hardwood forests of southeastern Missouri. Researchers are currently studying breeding bird densities and nesting success under even-aged, uneven-aged, and no-timber harvesting in southeastern Missouri, but this study involves oak (*Quercus* spp.)-hickory (*Carya* spp.) and oak-pine forest, the uneven-aged treatment consists of a mix of group and single-tree selection, and the study is so recent that the uneven-aged stands have yet to achieve an uneven-aged structure (Clawson et al. 1997, Clawson et al. 2002). Likewise, research in Arkansas comparing avian responses to even- and uneven-aged management (Thill et al. 2004) also involves stands that currently lack 3 distinct age/size classes, the minimum required for an uneven-aged stand structure (Smith 1962:428).

Information on the effects of uneven-aged management on wildlife is urgently needed by public land managers, many of who are

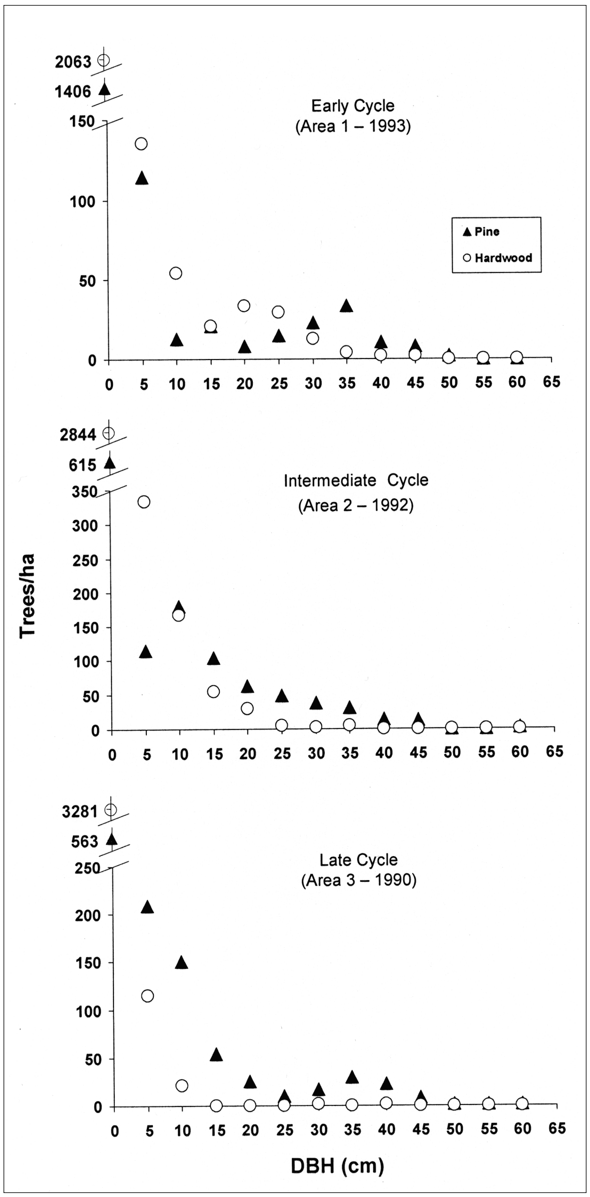

Figure 1. Pine and hardwood diameter distributions for selected early-, intermediate-, and late-cycle uneven-aged stands in eastern Texas, 1990–1995.

already implementing these practices. For the southern national forests as a whole, roughly 7% (262,000 ha) of the suitable timber-producing area is scheduled for uneven-aged management (Kitchens 1989). For southern non-industrial private forest owners, who control approximately 67% of the South's commercial timberlands, wildlife is often the second most important reason (behind timber production) for forest ownership (Nabi et al. 1983, Owen et al. 1985). Uneven-aged management offers advantages over even-aged management that may appeal to these non-industrial private forest owners (Baker and Murphy 1982, Williston 1978).

This study was initiated in 1990 to compare breeding season forest bird communities under uneven- and even-aged management in eastern Texas pine forests. This paper summarizes bird and associated habitat data for several uneven-aged (single-tree selection) stands at three cutting cycle stages with even-aged stands of six seral stages. To our knowledge, these are the only data currently available comparing bird responses to even- and uneven-aged management using single-tree selection within southeastern pine forests.

Methods

The study was conducted in West Gulf Lower Coastal Plain loblolly and shortleaf pine-hardwood forests of eastern Texas using a mix of national forests and private (industrial and non-industrial) lands. The climate of this region is characterized by hot humid summers, mild winters, average annual rainfall of 125 cm, and a frost-free growing season that typically extends from mid-March to mid-November (Dolezel 1980). The terrain is mostly level to gently rolling.

Two sets of even-aged study areas were surveyed for 2 years each: one set in 1992 and 1993, another in 1994 and 1995. Uneven-aged stands were sampled from 1990 through 1995 (Table 1). None of our study areas had been grazed for at least 10 years nor burned for at least 5 years; earlier burning records were unavailable, but these stands were likely prescribed-burned only every 15–20 years.

Uneven-aged stands

Selected stands had the following characteristics: a minimum size of 20 ha; at least 3 obvious pine age or size classes; were within 100 km of Nacogdoches, TX; were being harvested on a cutting cycle varying from about 6 to 14 years; and were privately owned. Data are presented for two stands (areas 1 and 3) immediately after they were harvested (i.e., the first two breeding seasons following harvests), four stands at an intermediate stage within their cutting cycles (areas 2, 4, 28, and 29), and one stand for 3 years prior to being harvested (area 3 from 1990 to

1992); these cutting cycle groupings will be referred to as early-, intermediate-, and late-cycle stands, respectively (Table 1). Well-structured uneven-aged stands were scarce within 100 km of Nacogdoches, TX. Consequently, following an intensive search for suitable stands, we used all stands that we could locate rather than a random sample.

Even-aged stands

Except for one late-rotation stand (which was sampled 3 years), each set of even-aged stands was sampled for two consecutive years and spanned early to late seral stages that will be referred to as seedling, sapling, pre-commercially thinned, closed-canopy, commercially thinned, and late-rotation stands (Table 1). The first four seral stages originated as planted pine plantations; the last two developed from natural regeneration following clearcutting. At the time of this study, the rotation age for loblolly pine on national forests in Texas was 70 years. Stand ages (where known) are indicated in Table 1. Areas 21 and 24 were owned by International Paper Company; all remaining even-aged stands were on the Davy Crockett (areas 26 and 27) or Angelina National Forests. Stands were randomly selected from a pool of stands that met age, size (≥ 20 ha), and shape (avoided long, narrow stands) criteria.

Table 1. Study area groupings, names, stand sizes, ages, and years birds were surveyed in eastern Texas (1990–1995).

Silvicultural system	Study area	Cutting cycle/ seral stage[A]	Stand size (ha)	Age[B] (yrs)	Survey years (19__)
Uneven-aged	1	Early	81	Unknown	91,92,93
	3	Early	49	Unknown	93,94,95
	2	Intermediate	88	Unknown	90,92,93
	4	Intermediate	32	Unknown	90,91,92
	28	Intermediate	55	Unknown	94,95
	29	Intermediate	295	Unknown	94,95
	3	Late	49	Unknown	90,91,92
Even-aged	19	Seedling	29	1	92,93
	24	Seedling	68	1	94,95
	16	Sapling	26	4	92,93
	21	Sapling	65	4	94,95
	17	Pre-commercially thinned	29	6	92,93
	26	Pre-commercially thinned	20	8	94,95
	18	Closed canopy	59	18	92,93
	22	Closed canopy	57	19	94,95
	20	Commercially thinned	62	33	92,93
	27	Commercially thinned	308	54	94,95
	12	Late rotation	66	64	90,91
	14	Late rotation	29	70	91,92,93
	23	Late rotation	61	80	94,95

[A]Cutting cycle stage for uneven-aged stands and seral stages for even-aged stands.
[B]Stand ages when first surveyed for this particular seral/cutting cycle stage.

Habitat measurements

Habitat measurements in each stand were collected within one centrally located 80- x 250-m strip transect that also was used for bird surveys. Tree and snag densities were measured within six systematically located, nested quadrats of varying sizes within each sampling area. Diameters at breast height (dbh, taken at 1.37 m above ground) of trees ≥ 25 cm dbh were measured in six 20- x 40-m plots. Trees ≥ 10 cm but < 25 cm dbh were tallied within six 20-m x 20-m plots. Trees < 10 cm dbh were counted within twelve 4- x 20-m plots. Standing dead trees (snags) > 2 m tall and ≥ 10 cm dbh were counted within six 20-m x 40-m plots. All snags and trees ≥ 25 cm dbh were tallied by 5-cm (2") dbh classes, while those < 25 cm were recorded by 1-cm dbh classes. Heights of typical pines and hardwoods ($n = 6$ each) were measured with a clinometer within their respective plots and averaged to characterize overstory canopy height.

Density board readings (MacArthur and MacArthur 1961) were used to quantify horizontal foliage density. Readings were taken at 12 systematically located points (six to the left and six to the right) along the central 250-m transect line. At each point, foliage density was ocularly estimated within four vertical zones using a 0.25-m^2 (0.5-m square) gridded board resting on the ground (zone 1) and centered at 1, 2, and 3 m (zones 2 through 4, respectively) above ground. For each reading, the board was positioned at the appropriate height and the observer backed away from the board until it was 50% obscured by live foliage, and then recorded the distance moved. On those few occasions when the board was not 50% obscured at 50 m (our maximum allowable distance), a value of 50 m was recorded. Variability among readings within each vertical zone was used as a measure of habitat patchiness (Anderson and Ohmart 1986).

Foliage density from 7 to 20 m above ground was quantified by sighting vertically through a 400 mm telephoto lens on a reflex camera (MacArthur and Horn 1969). Foliage density > 20 m was estimated from the proportion of the vertically directed camera lens obscured by foliage above 20 m. These data, collected at 18 systematically located points, were used to compute an index of foliage height diversity for each study area (MacArthur and MacArthur 1961). Habitat data were collected during the summer immediately following the first year that each area was surveyed for birds (Table 1).

Bird surveys

Breeding season surveys were conducted by three observers three times (nine visits/area/year) between 22 April and 3 June within the 80- x 250-m strip transect used for habitat measurements. Two of the three observers were the same for most years, but the third birder varied most years. Birds heard or seen within 40 m of either side of the 250-m center line were recorded. Surveys were uniformly distributed throughout this sampling period, with each observer completing surveys of all study areas before beginning subsequent replications. Insofar as possible, the order of each 25- to 30-min survey was changed for each of the three visits, and 98% of all surveys were conducted within 4 hours of sunrise. Species heard or observed off the transect (but within the same stand) also were recorded; however, unless otherwise noted, data presented are from strip transects only. The total number of birds seen/heard per visit is used as an index of relative abundance; data for males and females were combined.

Data summaries

Relative abundance (mean number of birds/visit), species richness, and Shannon's diversity index (Shannon 1948) are reported. Richness and diversity values are based on composited data across observers and visits; values for each stand were computed separately by year and then averaged across years and study areas within the nine uneven-aged cutting cycles/even-aged seral stages (treatments henceforth) shown in Table 1. Data for migrants and residents are presented separately and combined. Data for migrants that typically do not breed in this area were excluded. Habitat data are averaged across study areas within each treatment category.

Data for our nine treatments are presented as descriptive statistics, as there were too few uneven-aged stands to permit a more rigorous experimental design. However, we pooled stands into three groups (all uneven-aged stands, young even-aged stands, and older even-aged stands) and compared abundance, richness, and diversity data for migrants, residents, and all birds combined using a one-way ANOVA and Tukey's HSD. The young even-aged group consisted of all the seedling, sapling and pre-commercially thinned stands (spanning 1 to 9 years of age); the older even-aged group consisted of all the closed canopy, commercially thinned, and late-rotation stands (spanning 18 to 81 years of age). Given our low samples sizes, all tests were made at the 0.10 significance level.

Similarities in bird community composition among treatments were quantified by comparing nesting guild composition (using Hamel's [1992] species assignments) and using Kulcyznski's coefficient of similarity (Oosting 1956:77), which indicates the percent overlap in species composition between two treatments. To derive these coefficients, species composition percentages were computed (by combining data for all observers and dates) for each sampling area for each measurement year. Species composition means were then computed by averaging across years and sampling areas within each of the nine treatments. Using these composited data, coefficients of similarity were derived for all possible pairs of treatment combinations.

Results

Habitat characteristics

Given the differences in ownership/past management and timing of harvesting entries in the uneven-aged stands, high within-treatment variation in some habitat variables is not surprising; the same holds true for even-aged stands due especially to within-treatment differences in stand ages (except for seedling and sapling treatments) and timing/frequency of past prescribed burning. Hardwood basal area on the privately owned uneven-aged stands ranged from 2.9 to 11.5 m^2/ha, comprising from 14.2 to 44.0% of the total basal area (Table 2). Hardwood basal area in the eight youngest even-aged stands was consistently lower (≤ 2.7 m^2/ha) than the uneven-aged stands, but hardwood basal area on the five oldest even-aged stands was relatively high, comprising 17.1 to 35.7% of the total basal area.

Snag densities varied widely among treatments (Table 2). Snags

Table 2. Habitat characteristics (means with SE in parentheses below) of uneven- (first three rows of data) and even-aged stands in eastern Texas (1990–1995).[A]

Cutting cycle/ seral stage[B]	No. of study areas	Basal area (m^2/ha)		Snag density (no./ha)	Average canopy height (m)[C]		Foliage height diversity
		Pine	Hardwood		Pine	Hardwood	
Early	2	13.6	5.6	25.0	25.2	17.2	0.56
		(2.1)	(2.4)	(10.4)	(1.0)	(3.8)	(0.01)
Intermediate	4	17.2	7.8	8.4	23.2	18.2	0.78
		(1.0)	(1.5)	(2.9)	(2.0)	(0.4)	(0.13)
Late	1	17.5	2.9	25.0	26.1	13.4	1.18
Seedling	2	0.2	0.2	39.6	-[D]	-	-
		(0.1)	(0.1)	(37.5)			
Sapling	2	2.3	1.0	0.0	4.2	6.7	-
		(0.1)	(0.3)		(0.2)	(1.1)	
Pre-commercially thinned	2	9.8	2.0	0.0	9.0	6.8	-
		(4.0)	(0.2)		(0.4)	(0.8)	
Closed canopy	2	38.8	2.1	6.2	17.4	13.0	0.62
		(0.9)	(0.6)	(4.2)	(0.8)	(2.8)	(0.16)
Comercially thinned	2	21.0	5.4	16.7	27.4	20.2	0.58
		(1.4)	(0.8)	(12.5)	(2.8)	(2.1)	(0.11)
Late rotation	3	25.8	11.3	30.5	27.2	19.4	0.75
		(2.3)	(1.9)	(5.1)	(0.7)	(1.5)	(0.10)

[A]Data were collected the first year birds were surveyed (see Table 1).
[B]Cutting cycle stage for uneven-aged stands and seral stages for even-aged stands.
[C]With the exception of areas 2, 3, 4, and 12 (which were measured in 1991), heights shown are for the first survey year listed in Table 1.
[D]Not measured in these young plantations.

meeting our minimum size criteria were not encountered in four of the even-aged stands. Area 24, an even-aged forest industry plantation, had the highest density of snags (77.1/ha), but 92% of these snags were ≤ 20 cm dbh and all were ≤ 25 cm dbh.

Average canopy heights for overstory pines and hardwoods for the uneven-aged stands were similar to those for the five oldest even-aged stands (Table 2). Areas 2 and 3, which had been harvested more frequently than the other uneven-aged stands, had the smoothest reverse-J pine diameter distributions and the highest foliage height diversity. Pine diameter distributions for the other uneven-aged stands were more similar to area 1 (Fig. 1).

Foliage height diversity, horizontal foliage density, and habitat patchiness were highly variable among areas within treatments (Table 3), reflecting differences in timing, intensity, and frequency of past harvesting and burning practices as well as site quality differences. Highest foliage densities (indicated by low mean distances to 50% obscurity) near the ground (zones 1 and 2) tended to occur in the most recently thinned stands (i.e., seedling, sapling, pre-commercially thinned, and most of the uneven-aged stands). Compared with older even-aged stands, uneven-aged stands had substantially lower densities of larger trees (Fig. 1), yielding lower overstory canopy coverage.

Bird abundance

Within uneven-aged treatments, relative abundance of all breeding birds was 1.6 and 1.3 times higher during the first 3 years after

Table 3. Density board measurements and habitat patchiness by four vertical sampling zones for uneven- (first three rows of data) and even-aged study areas in eastern Texas (1990–1995).[A]

Cutting cycle/ seral stage	No. study areas	Mean (SE) distance (m) to 50% obscurity by zone				Patchiness[B] by zone			
		1	2	3	4	1	2	3	4
Early	2	4 (< 1)	11 (5)	20 (10)	24 (14)	3 (1)	60 (49)	136 (106)	101 (67)
Intermediate	4	8 (2)	12 (4)	16 (4)	21 (6)	26 (13)	74 (38)	72 (29)	87 (24)
Late	1	5	7	10	15	8	12	68	213
Seedling	2	2 (< 1)	10 (2)	44 (6)	50 (< 1)	2 (0)	64 (24)	118 (118)	8 (8)
Sapling	2	3 (1)	5 (1)	6 (2)	13 (2)	2 (2)	4 (1)	17 (10)	106 (68)
Pre-comm. thinned	2	6(4)	9 (0)	12 (2)	12 (4)	12 (9)	15 (2)	54 (30)	104 (102)
Closed canopy	2	18 (2)	28 (2)	26 (2)	19 (2)	114 (4)	178 (34)	128 (28)	70 (1)
Commercially thinned	2	7 (3)	21 (4)	35 (10)	36 (14)	24 (22)	149 (13)	184 (84)	121 (121)
Late rotation	3	16 (7)	29 (14)	36 (12)	36 (9)	59 (50)	111 (60)	137 (36)	116 (98)

[A]Zones 1 through 4 correspond to a 0.25-m^2 board resting on the ground and centered at 1, 2, and 3 m, respectively. All values rounded to whole units.
[B]Variance among distances (n = 12) to 50% obscurity.

harvest ("early-cycle") than intermediate- and late-cycle stands, respectively (Fig. 2). These differences were due to higher numbers of both residents and migrants in the early-cycle stands. As a percentage of the total number of birds recorded/visit, migrants comprised about a third of the birds recorded, ranging from 24.2% in the late-cycle stand just prior to thinning to 35.0% in the early-cycle stands the first 3 years after harvest.

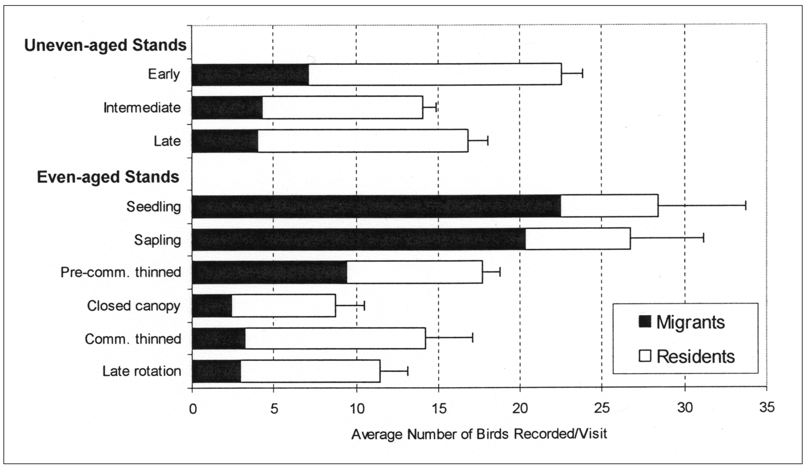

Figure 2. Relative abundance of migrant and resident birds within even- and uneven-aged stands of eastern Texas during the breeding season, 1990–1995. Standard error bars are for the total number of birds.

Table 4. Abundance, richness, and diversity of migrants, residents, and all birds combined in uneven-aged stands and young (1 to 9 years old) and older (18 to 81 years old) even-aged stands of eastern Texas (1990–1995).[A]

		Uneven-aged (n = 7)		Young even-aged (n = 6)		Older even-aged (n = 7)			
Variable	Group	Mean	SE	Mean	SE	Mean	SE	F	P
Abundance									
	Migrants	5.1A	0.6	17.4B	3.5	2.9A	0.5	1.8	0.0001
	Residents	11.8A	1.3	6.9B	1.0	8.5AB	1.3	0.7	0.0197
	All	16.9A	1.6	24.3B	3.7	11.4A	1.7	0.9	0.0050
Species richness									
	Migrants	10.3A	1.1	12.1A	0.6	5.2B	0.5	1.5	0.0001
	Residents	9.4	0.6	10.2	1.1	8.2	0.7	0.4	0.2462
	All	19.7A	1.6	22.2A	1.3	13.4B	0.9	1.1	0.0005
Diversity									
	Migrants	1.9A	0.1	1.9A	0.1	1.2B	0.1	1.6	0.0001
	Residents	1.8	0.1	1.8	0.2	1.6	0.1	0.3	0.4781
	All	2.4A	0.1	2.4A	0.1	2.1B	0.1	1.0	0.0021

[A]Means within rows followed by the same letter are not significantly different (1-way ANOVA and Tukey's HSD, $P \leq 0.10$).

Within even-aged treatments, total bird abundance in seedling and sapling stands averaged roughly two to three times higher than that observed in the three oldest seral stages (Fig. 2). Migrant abundance within pre-commercially thinned stands was less than half that of the seedling and sapling stands (Fig. 2). Although even-aged seedling and sapling stages (encompassing just the first 5 years of roughly a 70-year rotation) had highest numbers and higher percentages of migrants, these differences were short-lived; migrants were least abundant in closed-canopy stands and relatively scarce in commercially thinned and late-rotation stands (Fig. 2).

Comparing even- and uneven-aged treatment groups, abundance of migrants and all birds combined were greater in the young even-aged group than in the uneven-aged or older even-aged treatment groups (Table 4). Resident birds were more abundant in the uneven-aged group than in the young even-aged group. Relative abundance of migrants, residents, and all birds combined were consistently higher (though not significantly so) in the uneven-aged treatments than that of the oldest four even-aged treatments, which encompass most of a saw log rotation (Table 4).

Species richness and diversity

The average number of species encountered in uneven-aged treatments ranged from 17.4 to 24.7. Migrants comprised nearly identical proportions (range 51.7 to 53.4%; mean = 52.5%) of the species recorded in these three treatments (Fig. 3).

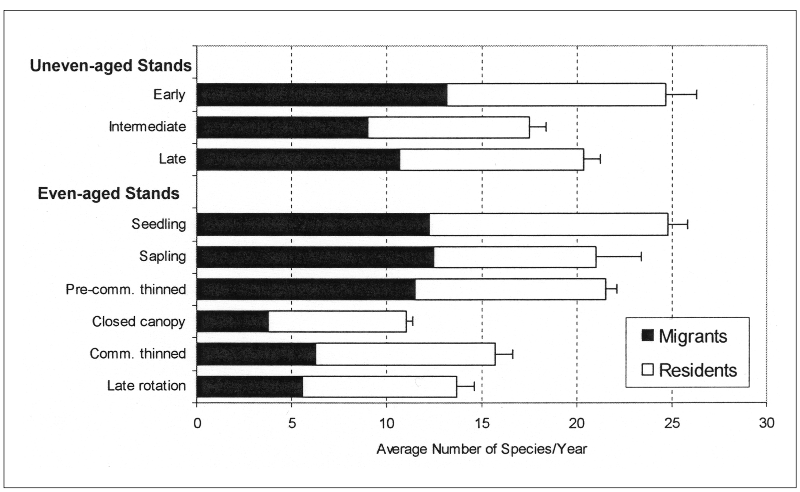

Figure 3. Species richness of migrant and resident birds in even- and uneven-aged stands in eastern Texas during the breeding season, 1990–1995. Standard error bars are for the total number of species.

The average number of species encountered in even-aged treatments ranged from 11.0 to 24.8 (Fig. 3). On a percentage basis, migrants comprised 34.1% (closed canopy stands) to 60.2% (sapling stands), with the three youngest even-aged seral stages averaging 2.3 times as many migrants as the three oldest even-aged seral stages (Fig. 3). The number of migrant species encountered in pre-commercially thinned stands was comparable to seedling and sapling stands. Unlike uneven-aged stands, the percent contribution of migrant species varied widely among even-aged seral stages, comprising > 75% of the birds recorded in seedling and sapling stands, 53.3% in pre-commercially thinned stands, and 22.9 to 27.4% in the three oldest seral stages. Relatively high levels of species richness were maintained through year 9 using pre-commercial thinning, but richness declined substantially thereafter (Fig. 3).

Comparing treatment groups (Table 4), the number of migrant species and all species combined did not differ between uneven-aged stands and young even-aged stands, but both of these groups averaged more species than older even-aged stands. Numbers of resident species were not different among these groupings.

Diversity data generally mirrored those for species richness (Fig. 4). Relatively low diversity in the three oldest even-aged seral stages was the most apparent and consistent pattern observed. Comparing treatment groups, there was no difference in diversity of resident species among groups, but diversity of migrants and all birds

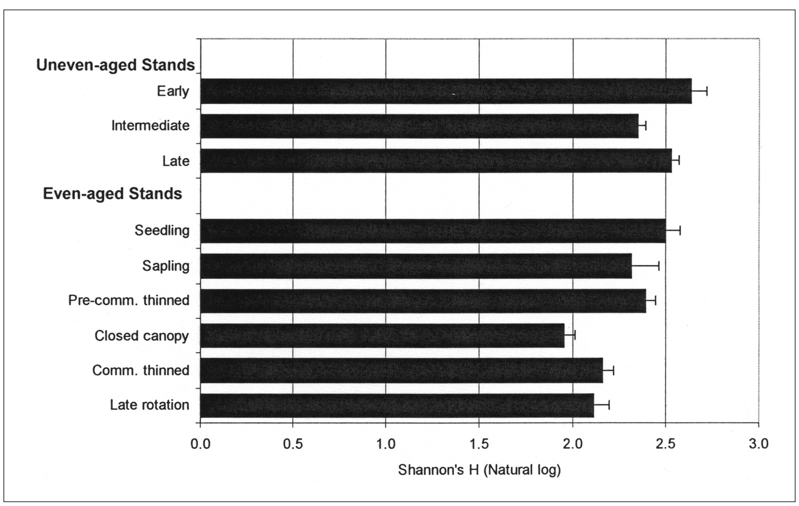

Figure 4. Diversity of bird communities in even- and uneven-aged stands in eastern Texas during the breeding season, 1990–1995. Migrants and residents are combined, and standard error bars are for all birds.

combined were higher for the uneven-aged and young even-aged groups than the older even-aged group (Table 4); mean diversity for the former two groups were identical.

Migrant responses

Twenty-seven migrant species had frequency of occurrence values of ≥ 5% in one or more treatments (Table 5). Seven of these species were encountered in even-aged stands, but were not recorded in uneven-aged stands: Chimney Swift (scientific names in Table 5), Dickcissel, Eastern Kingbird, Orchard Oriole, Painted Bunting, Prairie Warbler, and Wood Thrush (Table 5). Three early succession species that were common in younger even-aged stands occurred less frequently in uneven-aged stands: Blue Grosbeak, Common Yellowthroat, and Yellow-breasted Chat. Four species that occurred infrequently in uneven-aged stands were not encountered in even-aged stands: Chuck-will's-widow, Louisiana Waterthrush, Yellow-throated Warbler, and American Redstart (Table 5, footnote A). Five migrant species occurred in both even-aged and uneven-aged stands, but at somewhat higher frequencies of occurrence in at least one uneven-aged cutting cycle stage: Black-and-white Warbler, Blue-gray Gnatcatcher, Eastern Wood-Pewee, Kentucky Warbler, and Yellow-billed Cuckoo. Four species were relatively common under both silvicultural systems: Hooded Warbler, Red-eyed Vireo, Summer Tanager, and White-eyed Vireo (Table 5).

Seventeen of the migrant species listed in Table 5 are considered species of moderate (8 Tier II species, footnote c) or high (9 Tier I species, footnote E) conservation concern within the West Gulf Coastal Plain (Panjabi 2001). Thirteen of these were discussed above; the remaining four (Acadian Flycatcher, Ruby-throated Hummingbird, Worm-eating Warbler, and Yellow-throated Vireo) were encountered too infrequently to suggest any preferences for silviculture treatments.

Resident bird responses

Twenty-one species of resident birds had frequency of occurrence values of ≥ 5% in one or more treatments (Table 5). Four of these species (American Goldfinch, Bachman's Sparrow, Field Sparrow, and Wood Duck) were not encountered in uneven-aged stands, but were recorded (though infrequently) in one or more even-aged treatments. None of the resident species were found exclusively within uneven-aged treatments, but four species (Blue Jay, Brown-headed Cowbird, Carolina Wren, and Tufted Titmouse) tended to occur more frequently within uneven- than even-aged treatments.

Northern Bobwhite, a National Forest System management indicator species in Texas and a species of conservation concern within

Table 5. Percent frequency of occurrence for migrant (first 27 species) and resident breeding birds in uneven- and even-aged stands of eastern Texas (1990–1995).

Species[A]	Uneven-aged Early (54)[B]	Uneven-aged Intermed. (90)	Uneven-aged Late (27)	Even-aged Seedling (36)	Even-aged Sapling (36)	Even-aged Pre-comm. thinned (36)	Even-aged Closed canopy (36)	Even-aged Comm. thinned (36)	Even-aged Late rotation (63)
Acadian Flycatcher (*Empidonax virescens* Vieillot)[C]	7.4	-[D]	-	-	-	-	-	-	4.8
Black-and-white Warbler (*Mniotilta varia* L.)[C]	31.5	26.7	44.4	-	8.3	25.0	11.1	2.8	7.9
Blue Grosbeak (*Passerina caerulea* L.)	7.4	-	3.7	86.1	47.2	2.8	-	-	-
Blue-gray Gnatcatcher (*Polioptila caerulea* L.)[C]	20.4	8.9	7.4	5.6	11.1	2.8	-	-	1.6
Chimney Swift (*Chaetura pelagica* L.)	-	-	-	2.8	8.3	2.8	-	-	3.2
Chuck-will's-widow (*Caprimulgus carolinensis* Gmelin)[E]	13.0	-	3.7	-	-	-	-	-	-
Common Yellowthroat (*Geothlypis trichas* L.)	3.7	-	-	61.1	36.1	2.8	-	-	-
Dickcisse (*Spiza americana* Gmelin)l[C]	-	-	-	36.1	5.6	-	-	-	-
Eastern Wood-Pewee (*Contopus virens* L.)[C]	25.9	7.8	7.4	5.6	2.8	5.6	-	8.3	1.6
Eastern Kingbird (*Tyrannus tyrannus* L.)	-	-	-	69.4	19.4	-	-	-	-
Gray Catbird (*Dumetella carolinensis* L.)	-	-	3.7	2.8	5.6	8.3	-	-	-
Great Crested Flycatcher (*Myiarchus crinitus* L.)	16.7	10.0	-	11.1	-	11.1	2.8	19.4	11.1
Hooded Warbler (*Wilsonia citrine* Boddaert)[E]	29.6	25.6	48.2	2.8	5.6	33.3	50.0	5.6	20.6
Indigo Bunting (*Passerina cyanea* L.)	74.1	26.7	40.7	94.4	97.2	77.8	5.6	13.9	-
Kentucky Warbler (*Oporornis formosus* Wilson)[E]	25.9	10.0	37.0	-	-	5.6	-	-	3.2
Orchard Oriole (*Icterus spurius* L.)[E]	-	-	-	66.7	44.4	-	-	-	-
Painted Bunting (*Passerina ciris* L.)[E]	-	-	-	-	30.6	-	-	-	-
Prairie Warbler (*Dendroica discolor* Vieillot)[E]	-	-	-	83.3	97.2	30.6	-	-	-
Purple Martin (*Progne subis* L.)	3.7	4.4	3.7	-	2.8	-	2.8	5.6	1.6
Red-eyed Vireo (*Vireo olivaceus* L.)	37.0	72.2	18.5	-	5.6	25.0	33.3	83.3	76.2
Ruby-throated Hummingbird (*Archilochus colubris* L.)[C]	3.7	2.2	-	8.3	19.4	2.8	-	-	-
Summer Tanager (*Piranga rubra* L.)[C]	55.6	46.7	33.3	8.3	2.8	19.4	5.6	55.6	39.7
White-eyed Vireo (*Vireo griseus* Boddaert)[E]	57.4	31.1	37.0	11.1	83.3	80.6	5.6	-	-
Worm-eating Warbler (*Helmitheros vermivorus* Gmelin)[E]	1.9	8.9	3.7	-	-	-	5.6	-	1.6
Yellow-billed Cuckoo (*Coccyzus americanus* L.)[E]	13.0	15.6	22.2	-	-	8.3	8.3	5.6	19.0
Yellow-breasted Chat (*Icteria virens* L.)	22.2	3.3	-	88.9	100.0	80.6	-	-	-
Yellow-throated Vireo (*Vireo flavifrons* Vieillot)[C]	16.7	2.2	-	2.8	-	8.3	-	2.8	1.6
American Crow (*Corvus brachyrhynchos* Brehm)	-	5.6	-	-	-	11.1	11.1	11.1	14.3
American Goldfinch (*Carduelis tristis* L.)	-	-	-	8.3	2.8	-	-	-	1.6

Table 5, continued.

	Uneven-aged			Even-aged					
Species[A]	Early (54)[B]	Intermed. (90)	Late (27)	Seedling (36)	Sapling (36)	Pre-comm. thinned (36)	Closed canopy (36)	Comm. thinned (36)	Late rotation (63)
Bachman's Sparrow (*Aimophila aestivalis* Lichtenstein)[E]	-	-	-	8.3	-	-	-	-	-
Blue Jay (*Cyanocitta cristata* L.)	33.3	18.9	55.6	2.8	2.8	16.7	16.7	13.9	15.9
Brown-headed Cowbird (*Molothrus ater* Boddaert)	59.3	38.9	70.4	16.7	41.7	11.1	-	13.9	17.5
Carolina Chickadee (*Poecile carolinensis* Audubon)[C]	48.2	42.2	44.4	19.4	11.1	27.8	27.8	36.1	39.7
Carolina Wren (*Thryothorus ludovicianus* Latham)	90.7	65.6	92.6	5.6	44.4	77.8	44.4	75.0	50.8
Common Grackle (*Quiscalus quiscula* L.)	1.8	-	-	5.6	-	-	-	-	1.6
Downy Woodpecker (*Picoides pubescens* L.)	11.1	-	7.4	-	-	8.3	2.8	2.8	-
Eastern Bluebird (*Sialia sialis* L.)	-	1.1	-	30.6	2.8	-	-	-	-
Field Sparrow (*Spizella pusilla* Wilson)[C]	-	-	-	27.8	13.9	-	-	-	-
Hairy Woodpecker (*Picoides villosus* L.)	3.7	-	-	8.3	-	2.8	-	-	4.8
Mourning Dove (*Zenaida macroura* L.)	11.1	7.8	-	27.8	19.4	5.6	-	-	3.2
Northern Bobwhite (*Colinus virginianus* L.)	-	1.1	-	33.3	27.8	11.1	-	-	-
Northern Cardinal (*Cardinalis cardinalis* L.)	94.4	86.7	88.9	52.8	83.3	97.2	69.4	83.3	71.4
Pileated Woodpecker (*Dryocopus pileatus* L.)	3.7	2.2	7.4	-	-	5.6	-	8.3	3.2
Pine Warbler (*Dendroica pinus* Wilson)[C]	94.4	95.6	92.6	-	2.8	27.8	80.6	97.2	92.1
Red-bellied Woodpecker (*Melanerpes carolinus* L.)[C]	35.2	8.9	44.4	22.2	2.8	11.1	2.8	13.9	11.1
Red-headed Woodpecker[E] (*Melanerpes erythrocephalus* L.)[E]	7.4	-	-	38.9	-	-	-	-	1.6
Tufted Titmouse (*Baeolophus bicolor* L.)	74.1	58.9	66.7	2.8	-	19.4	36.1	47.2	44.4
Wood Duck (*Aix sponsa* L.)	-	-	-	-	-	-	-	5.6	-

[A]Nomenclature follows AOU checklist (http://www.aou.org/checklist/index.php3) through 45[th] supplement. Includes only those species with a frequency of occurrence of ≥ 5% in one or more columns. Raptors were excluded. Four migrants had values of < 5% within a single column: American Redstart (*Setophaga ruticilla* L., 1.8%, early uneven-aged); Louisiana Waterthrush[C] (*Seiurus motacilla* Vieillot, 3.7%, late UEA [uneven-aged]); Wood Thrush[C](*Hylocichla mustelina* Gmelin, 2.8%, pre-commercially thinned), and Yellow-throated Warbler (*Dendroica dominica* L.), 1.9%, early UEA [uneven-aged])).

[B]Maximum number of occurrences (e.g., 54 = 2 areas x 3 years of data/area x 9 visits/area/year).

[C]Denotes species of moderately high (Tier II, Panjabi 2001) conservation concern (Partners in Flight, physiographic area S42, June 30, 2003: http://www.rmbo.org/pif/scores/scores.html).

[D]Dashes indicate no occurrences within strip transects.

[E]Denotes species of highest (Tier I, Panjabi 2001) conservation concern (Partners in Flight, physiographic area S42, June 30, 2003: http://www.rmbo.org/pif/scores/scores.html).

many of the southeastern US Partners in Flight physiographic regions (Trani 2002), were only recorded in one uneven-age stand: an intermediate-cycle stand in 1992, but not in 1990 and 1993. When averaged across years and areas, bobwhites comprised 2.5% of the species composition for both the seedling and sapling treatments and 0.7% for the pre-commercially thinned treatment. However, bobwhites were not recorded on transects in any of the three older even-aged treatments.

Pileated Woodpecker, another management indicator species for many southern national forests, were not recorded within transects of seedling, sapling, or closed canopy treatments, and comprised < 1% of the species composition for the other six treatments. They were most abundant in commercially thinned (0.9% of species composition) and late rotation (0.4%) even-aged and late-cycle uneven-aged stands (0.4%).

Brown-headed Cowbirds generally were encountered more frequently in uneven-aged than even-aged treatments (Table 5), and the number of cowbirds seen per visit was higher (ranging from 0.58 to 1.24 for intermediate- and early-cycle stands, respectively) in uneven-aged than even-aged stands, except for sapling stands (1.1 cowbirds/visit). Cowbirds were not encountered (even off transects) in either closed canopy plantation.

American Crows were not encountered within transects of seedling, sapling, and early- or late-cycle uneven-aged stands (Table 5), but were encountered off the transects in these stands. Frequency of occurrence of Blue Jays generally was higher in uneven- than even-aged stands. Likewise, the number of Blue Jays seen/visit also tended to be higher in uneven- than in even-aged stands.

Community composition

Similarities in species composition were high within the three uneven-aged treatments, within the three oldest even-aged treatments, and between all uneven-aged treatments and the four older even-aged treatments (Table 6). Seedling and sapling stands differed markedly (≤ 31% overlap in species composition) from both the three older even-aged treatments and the three uneven-aged treatments. These differences are also reflected in nesting guild composition (Fig. 5). Shrub, tree, and cavity nesters were well represented in all of the uneven-aged stands. Within even-aged stands, shrub nesters dominated the three younger seral stages, while tree nesters were the most common group within the three older seral stages. Cavity nesters were least abundant in the three youngest even-aged seral stages, which generally lacked larger snags. Ground nesters comprised a small percentage of the birds encountered across all treatments.

Discussion

At the stand level, the primary distinctions between conventional even-aged management employing clearcutting and single-tree selection is that single-tree selection stands will always have an overstory of

Table 6. Kulcyznsk's coefficients of similarity (percentages) for breeding bird communities within different seral stages of uneven- and even-aged pine forests of eastern Texas (1990–1995). Seral stage column heading abbreviations: E = early, I = intermediate, L = late, Se = seedling, Sa = sapling, Pt = pre-commercially thinned, Cc = closed canopy, Ct = commmercially thinned, Lr = late rotation.

	Uneven-aged			Even-aged					
Seral stage	E	I	L	Se	Sa	Pt	Cc	Ct	Lr
Uneven-aged									
Early									
Intermediate	79								
Late	83	78							
Even-aged									
Seedling	20	13	13						
Sapling	31	25	24	67					
Pre-commercially thinned	66	58	58	40	52				
Closed canopy	63	75	68	10	17	49			
Commercially thinned	68	79	68	10	16	49	72		
Late rotation	65	82	66	11	17	47	78	85	

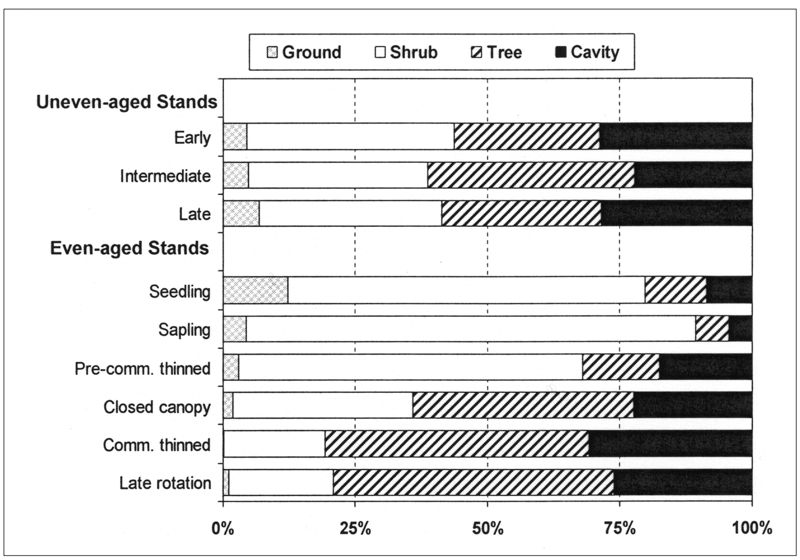

Figure 5. Nesting guild associations in even- and uneven-aged stands in eastern Texas during the breeding season, 1990–1995.

older trees and at least three distinct tree age or size classes. With frequent harvest entries, plant succession within single-tree selection stands is constantly being re-adjusted within a relatively narrow successional framework. This contrasts markedly with even-aged stands that begin with young pine regeneration and culminate (many years later) in some final successional stage governed by the desired forest management objective (typically saw logs on National Forest System lands). Thus, we would expect a fairly constant avian community composition within uneven-aged stands and a continually changing avian composition throughout much of the rotation under even-aged management; our data supports this expectation (Table 6).

Harvest intervals for single-tree selection can vary widely depending on site productivity and landowner objectives. On better sites, harvests may be economical as often as every 3 years (Baker et al. 1996). While the length of the cutting cycle has little effect on timber growth/ha/year (Reynolds 1969), it would influence snag availability, stand patchiness, and extent of site disturbance, all of which influence bird communities. Under a short (e.g., 3-year) cutting cycle, less volume is removed (so openings tend to be smaller), less of the site is typically disturbed (since fewer trees are removed), and more of the natural mortality in merchantable trees can be salvaged, thus reducing snag availability. Conversely, a longer cutting cycle results in heavier cuts (with larger openings), more site disturbance, and reduced salvage of dead or dying trees (Williston 1978). Thus, longer cutting cycles would likely have more dramatic impacts on bird communities, though this topic has not been researched.

We surveyed the best structured single-tree selection stands (i.e., those approximating a reverse-J distribution of pine diameters) that we could locate after a fairly intensive search within 100 km of Nacogdoches, TX. All of these uneven-aged stands were privately owned, and some contained more hardwoods than desirable from a strictly silvicultural standpoint due to landowner perceptions of aesthetics and wildlife habitat needs. These hardwoods added structural and compositional diversity, and presumably contributed positively to observed bird abundance, richness, and diversity. More intensively managed stands containing fewer hardwoods and snags likely would have compared less favorably with our even-aged stands.

Higher incidence of cowbirds in our uneven-aged than even-aged stands was likely due to differences in landscape settings rather than silvicultural treatments. Cowbirds are more abundant in forested stands that are near pastures and other short-grass areas (Coker and Capen 1995). With the exception of intermediate-cycle stands 28 and 29, our uneven-aged stands lie within a mixed landscape of forests and grazed woodlands and pastures. In contrast, our even-aged stands were within relatively large blocks of national forest and industry lands with few agricultural inclusions. Similarly, somewhat higher Blue Jay numbers in uneven-aged treatments may have resulted from these landscape differences, as corvid numbers are positively correlated with the amount of agricultural habitat (Andrén 1992). The one encounter of a single Louisiana Waterthrush in the late-cycle uneven-aged stand is likely attributable to habitat conditions off the study area (rather than this silvicultural treatment), as we intentionally selected stands without streams or ponds to avoid confounding treatments.

Whiting and Fleet (1987) studied breeding bird communities in even-aged seedling, sapling, pole, and saw log loblolly-shortleaf pine stands of eastern Texas, and also generally found higher species richness and abundance in seedling stands, and declining richness and abundance with advancing stand ages due to rapid canopy closure. Intensively managed, short-rotation pine plantations in this region reach canopy closure rapidly (Dickson et al. 1993) and often remain unthinned until final harvest. Lacking structural and tree-species diversity, these stands contain few numbers and species of birds, as demonstrated in our 18- to 20-year-old closed canopy plantations. Although included here for comparative purposes, pre-commercial thinning is seldom practiced under short (pulp) rotations, but is occasionally used under saw log rotations when initial pine stocking exceeds desired levels. Early thinning (whether pre-commercial or commercial) should help to maintain bird numbers, species richness, and diversity, as did pre-commercial thinning in this study through stand age 9.

The three late-rotation saw log stands in this study, which appeared representative of many other local national forest stands of this age, had abundance, richness, and diversity values that were not much higher than observed in our closed-canopy stands; these two seral stages also had 78% overlap in species composition (Table 6). Nevertheless, we did encounter 9 species of moderately high and 5 species of highest conservation concern utilizing these mature stands (Table 5). We also found relatively low bird numbers, richness, and diversity in late rotation (≥ 60 years) shortleaf pine-hardwood stands in the Ouachita Mountains of Arkansas (Thill et al. 2004) under similar management to that used in eastern Texas; there, just 9 species comprised nearly 80% of the composition during 4 survey years (R.E. Thill, unpubl. data).

The avian communities of these older, closed canopied, infrequently burned stands in Texas (like those in Arkansas) consisted primarily of canopy-associated species (e.g., Red-eyed Vireo, Pine Warbler, Summer Tanager, and Yellow-billed Cuckoo) and forest generalists like Northern Cardinals, Tufted Titmice, Carolina Chickadees, Carolina

Wrens, American Crows and Blue Jays. Of the species that are often common to abundant in mature loblolly/shortleaf pine-hardwoods stands across the Southeast (Dickson et al. 1995), eight were absent or infrequently encountered in our three mature stands: Yellow-throated Vireo, Acadian Flycatcher, Wood Thrush, Eastern Wood-Pewee, Blue-gray Gnatcatcher, Worm-eating Warbler, Ovenbird, and Eastern Towhee (*Pipilo erythrophthalmus* Linnaeus). Our three sites were more xeric than the first three listed species prefer, and were generally too dense for the Eastern Wood-Pewee. The last three listed are uncommon breeders in East Texas.

If relative abundance, richness, and diversity values for our three oldest even-aged seral stages (encompassing 18 to 80+ years of a 80-year rotation) are representative, any management practices that will boost these values would have a significant impact on substantial national forest acreage.

The absence or scarcity of a number of early succession species (e.g., Prairie Warbler, Common Yellowthroat, Eastern Kingbird, and Blue Grosbeak) in all our uneven-aged stands (and especially the most recently thinned ones) suggests that this system may not be appropriate for their management. However, this system may provide suitable habitat for two early-succession species (Yellow-breasted Chat and Indigo Bunting) and at least acceptable habitat for a number of migrants that prefer patchy, shrubby habitat and/or multiple strata such as Black-and-white Warbler, Hooded Warbler, Kentucky Warbler, Yellow-billed Cuckoo, and White-eyed Vireo. Our uneven-aged stands also were utilized by many mature-forest species, including Red-eyed Vireo and Summer Tanager. In mixed oak and oak-pine forests of the Missouri Ozarks, Annand and Thompson (1997) found comparable numbers of several mature-forest species (e.g., Red-eyed Vireo, Summer Tanager, and Scarlet Tanager) in mature forest and single-tree selection stands; Hooded Warbler, Black-and-white Warbler, and Northern Parula numbers were significantly higher in single-tree selection than clearcut, shelterwood, group selection, or mature-forest stands.

Too few data are currently available to assess the impacts of single-tree selection management on avian nesting productivity and survival. While data from Barber et al. (2001) suggest that nesting productivity and survival for at least some species may be higher under single-tree selections than under even-aged management employing clearcutting, additional research is warranted.

In conclusion, while additional research on the effects of single-tree selection management on reproductive success is warranted, our data suggest that single-tree selection stands (similar in structure to those we studied) may have comparable or higher avian abundance, species richness, and diversity to that achieved throughout most of a typical national forest even-aged rotation. However, those bird species that are dependent on larger forest openings or early seral conditions created by more intensive site disturbances (as occurs following clearcutting and seed-tree cutting) may be adversely affected if extensive areas were managed under single-tree selection. With sufficiently long rotation lengths, even-aged management can be tailored to accommodate most forest birds by providing a complete spectrum of successional stages. Data presented here suggest that this may not be possible using only single-tree selection, because even the most recently thinned stands were unacceptable to a number of early succession species. Nevertheless, single-tree selection stands were readily utilized by a number of migrants, including several species of conservation concern, and several species of conservation concern occurred more frequently in uneven- than even-aged stands. Consequently, to better emulate naturally occurring ecological processes and disturbance sizes, a mix of even- and uneven-aged management could achieve bird conservation objectives.

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