PINE 10

BIRD DIVERSITY AND COMPOSITION IN EVEN-AGED LOBLOLLY PINE STANDS RELATIVE TO EMERGENCE OF 13-YEAR PERIODICAL CICADAS AND VEGETATION STRUCTURE[1]

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Abstract—In southern Arkansas, 13-year periodical cicadas (*Magicicada* spp.) were expected to emerge in late April and early May of 1998. Presence of a superabundant food source, such as periodical cicadas, may attract greater numbers of birds and more species of birds than is usually present in a particular area. Three even-aged loblolly pine (*Pinus taeda* L.) stands were surveyed for birds by using a fixed-width transect before, during, and after emergence of the periodical cicadas. Emerging cicada nymphs were trapped and counted to obtain an estimate of cicada density. The density of cicadas in these pine stands was considerably lower than densities reported for other forest stands in the Eastern U.S. Bird diversity was variable between months and stands but did not appear to be strongly influenced by the presence of periodical cicadas. Bird composition in these managed loblolly pine stands was similar to that in unmanaged, even-aged pine and pine/hardwood stands of similar ages.

INTRODUCTION

Emergence of periodical cicadas (Homoptera: Cicadidae: *Magicicada*) is a highly predictable occurrence. The 13-year race of periodical cicadas that occurs in Arkansas is a group of three species including *Magicicada tredecim* (Walsh and Riley), *M. tredecassini* (Alexander and Moore), and *M. tredecula* (Alexander and Moore). Adult cicadas synchronously emerge from the ground every 13 years, ascend the nearest tree, and cast their nymphal skin. Adult males aggregate in the forest canopy and form chorusing centers to attract females for mating (Williams and Smith 1991). Adults complete their reproductive cycle and die within 4 to 6 weeks.

Adult populations of periodical cicadas can be very dense. Populations in previous emergences have been estimated at tens of thousands to hundreds of thousands of individuals per acre (Dybas and Davis 1962, Rodenhouse and others 1997, White and others 1982). This type of ephemeral, high density occurrence of insects can provide a superabundance of food that may attract greater numbers and more species of insectivorous birds than is usually present in a particular location. In this study, we investigated the influence of 13-year periodical cicadas on bird diversity in even-aged stands of loblolly pine (*Pinus taeda* L.) in southern Arkansas where periodical cicadas were observed during a previous emergence (personal observation, M.D. Cain, 1985).

The study also provided an opportunity to examine bird composition relative to vegetation structure of loblolly pine stands that were managed to maximize pine development. Others have examined bird composition relative to vegetation structure in unmanaged, even-aged pine and pine/hardwood stands (Childers and others 1986, Conner and others 1979, Conner and others 1983, Dickson and Segelquist 1979, Kellner 1996), but this information is lacking for managed stands. Recent concern over declining populations of neotropical migratory songbirds and an increasing interest in managing forests at the ecosystem level warrants an examination of bird communities inhabiting forests managed for timber production (Finch and Stangel 1993).

METHODS

Study Sites

Three plots were surveyed for birds and cicadas on the Crossett Experimental Forest, Ashley County, Arkansas. Merchantable-sized trees (>3.5 in. d.b.h.) on all plots were primarily loblolly pine, but a few shortleaf pine (*Pinus echinata* Mill.) and assorted hardwood species were present. Plot 5 is a 10-acre, 25-year-old stand measuring 1,320 ft long and 330 ft wide. This stand was precommercially and commercially thinned and periodically prescribe burned in winter (Cain 1996). Burning was initiated in the ninth year to control understory vegetation. The most recent burn was conducted in February 1998. Plot 5 also had patches of unmanaged pine and openings that supported grasses and forbs. Plots 37N and 37S are both 15-year-old loblolly pine stands. Plot 37N is 1,000 ft long and 165 ft wide (3.8 acres), and plot 37S is 660 ft long and 330 ft wide (5.0 acres). As part of one ongoing study, plots 37N and 37S have been similarly managed (Cain 1997). Both plots were precommercially and commercially thinned and competing vegetation was controlled with herbicides, manual removal, or both during the first 5 years of pine development. These two plots also had patches of unmanaged pine. All plot boundaries were well-defined by mowed fire lanes.

Bird Survey

Birds were surveyed using a fixed-width transect (Mikol 1980). A transect was established through the center of each plot. Bird surveys were conducted along each transect for 2 days each in early-April, mid-May, and mid-June of 1998. Each 2-day survey was completed within a 4-day period. All birds detected by sight or sound within the plot boundary were recorded and plotted on a map as the observer slowly traversed the transect. In addition, all birds detected within 80 ft outside the plot boundary were recorded and mapped for two reasons. First, birds were not confined to our artificially-defined boundaries. Second, birds in the periphery were observed using the study plots.

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All surveys were performed by one observer within 3 hours after sunrise on days without rain and with minimal wind. On the first sampling day, all plots were surveyed from north to south in the following sequence: plot 5, plot 37N, plot 37S. To diminish the effect of time of day on bird activity, the plots were surveyed in the reverse direction (south to north) and reverse order (37S, 37N, 5) on the second sampling day. Only species that were breeding residents of the Crossett Experimental Forest and were regularly observed in the vicinity of the survey plots were included in the data analyses. Only data on male occurrence were used in the analyses because the majority of the observations were of male birds.

Estimation of bird density (D) from a fixed-width transect was calculated by using the following equation (Mikol 1980):

$$D = n/LW, \tag{1}$$

where
n = the number of territorial males detected within a strip of a specified transect length (L) and total width (W).

The W is twice the detection width (w) that extends from the central transect to the outer survey boundary (plot boundary + 80 ft). Density is reported as the number of territorial males per 100 acres so plots of different sizes can be compared to each other.

Bird diversity was calculated with the Shannon-Weaver diversity function (Shannon and Weaver 1949):

$$H' = -\sum p_i \log p_i \tag{2}$$

where
p_i = the proportion of individuals in the ith species.

For calculation of the diversity index, each male was assumed to represent one resident pair of birds (Emlen 1971). A t-test (Hutcheson 1970, as provided in Zar 1984) tested for differences in bird diversity between months and plots.

Cicada Sampling

Thirteen-year periodical cicada nymphs were expected to begin emerging in late April 1998. The bird surveys were timed to coincide with cicada pre-emergence, peak activity, and post-emergence periods. To obtain an estimate of cicada density, wire-mesh traps were systematically placed within each plot (75 traps on plot 5 and 40 traps each on plots 37N and 37S). Traps were checked twice weekly for cicada adults or cast skins beginning April 30, and these checks continued until cicada emergence was complete. Cicada density was estimated by multiplying the average number of cicadas per trap by 20,000 to obtain the number of cicadas per acre for each study site (one trap = 1/20,000 acre).

Vegetation

In accordance with the protocol for ongoing silvicultural studies being conducted in the survey areas, both woody and herbaceous vegetation was measured in the fall of 1998, and the data are presented in this paper to quantitatively describe vegetation on the study plots. On plot 5, five sample points were systematically established within each of fifteen 0.4-acre experimental subplots (75 sample points total). At each point, percent ground cover on 1-milacre (3.72-ft radius) quadrats was estimated for herbaceous (vines, forbs, grasses, and semi-woody plants) and woody (all pines, hardwoods, and shrubs) vegetation. In addition, stem counts of sapling-size (1-, 2-, and 3-in. diameter classes) pines, hardwoods, and shrubs were tallied within five 0.01-acre circular quadrats (11.77-ft radius) per subplot. Within each 0.4-acre subplot, a sample of 40 merchantable (>3.5 in. d.b.h.) pines was measured for d.b.h. and 10 of these were also measured for total tree height. On plots 37N and 37S, ten 1-milacre circular quadrats were systematically established within each of sixteen 0.25-acre experimental subplots (160 sample points total) to estimate percent ground cover of both herbaceous and woody vegetation and to count sapling-size stems of pines, hardwoods, and shrubs. On each subplot, a sample of 20 merchantable pines was measured for d.b.h. and total height. On plots 5, 37N, and 37S, sample pines were selected for measurement based on crown class, tree quality, and spacing.

RESULTS AND DISCUSSION

Bird Diversity and Periodical Cicadas

The 13-year periodical cicada nymphs began emerging on April 29, 1998 and completed emergence within 2 weeks. As cicada emergence subsided, adult activity increased and peaked during the second week of May, and adults had died by the first week in June. Overall, density of emerging cicadas was low with ≤3,500 per acre (table 1). By comparison, Williams and others (1993) estimated an average of 164,213 cicadas per acre in an upland hardwood forest in northwestern Arkansas, and Dybas and Davis (1962) estimated an average of 133,000 cicadas per acre in an upland hardwood forest in Illinois. The low densities on plots in the present study may have occurred because *Magicicada* species are typically more prolific in hardwood forests than in pine forests (Dybas and Lloyd 1974, James and others 1986).

Bird diversity was variable between months (table 2) and plots (table 3). Bird diversity on plot 5 increased ($P<0.001$) from April to May, then decreased ($P<0.001$) from May to June. This peak in bird diversity occurred during maximum cicada activity in May, but plots 37N and 37S did not show a similar trend in bird diversity (fig. 1). In addition, the density of emerging cicadas was highest on plot 37S (table 1) where no change in bird diversity was observed ($P>0.05$) from April to May, although a decrease ($P<0.05$) occurred from May to

Table 1—Summary of results from cicada sampling including total number of cicadas trapped per plot, calculated number of cicadas per square yard, and estimation of cicada density per acre

Plot	Total no. cicadas	No. cicadas per yd^2	No. cicadas per acre
5	12	0.64	3,200
37N	4	0.40	2,000
37S	7	0.72	3,500

Table 2—Comparison of bird species diversity between months for each plot

Comparison of months	Plot number	Bird diversity by month H'	Bird diversity by month H'	t	P[a]
		April	**May**		
April vs May	5	0.76	1.17	7.26	***
	37N	.83	.96	2.09	*
	37S	.88	.88	.044	ns
		May	**June**		
May vs June	5	1.17	.90	4.61	***
	37N	.96	1.02	1.44	ns
	37S	.88	.73	2.52	*

[a] Probability values are as follows: ns = not significant at α = 0.05, *<0.05, ** <0.01, *** <0.001.

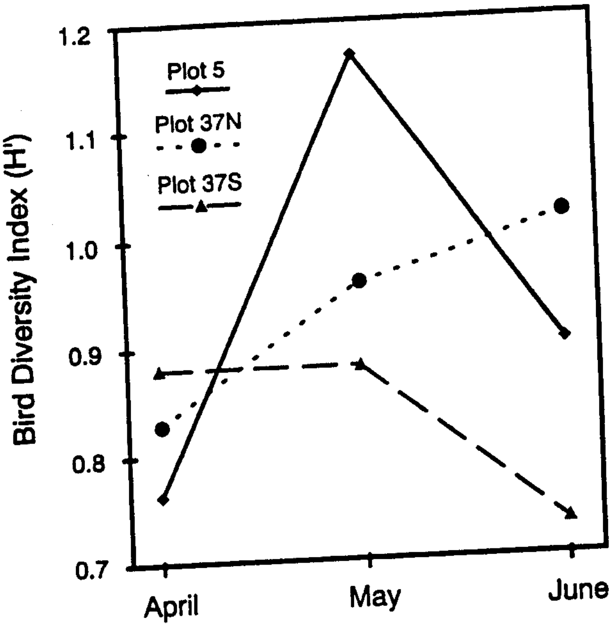

Figure 1—Monthly changes in bird diversity (H') by plot.

Table 3—Comparison of bird species diversity between plots for each month

Comparison of plots	Month	Bird diversity by plot H'	Bird diversity by plot H'	t	P[a]
		5	**37N**		
5 vs 37N	April	0.76	0.83	0.93	ns
	May	1.17	.96	5.18	***
	June	.90	1.02	2.00	*
		5	**37S**		
5 vs 37S	April	.76	.88	1.99	ns
	May	1.17	.88	6.90	***
	June	.90	.73	2.30	*
		37N	**37S**		
37N vs 37S	April	.83	.88	.77	ns
	May	.96	.88	1.79	ns
	June	1.02	.73	5.09	***

[a] Probability values are as follows: ns =not significant at α = 0.05, *< = 0.05, ** < = 0.01, *** < = 0.001.

June. Furthermore, bird diversity on plot 37N increased ($P<0.05$) from April to May, as in plot 5, but had the lowest density of emerging cicadas (table 1), and bird diversity did not subsequently decrease ($P>0.05$) in June. Therefore, the monthly variation in bird diversity observed on these plots does not appear to have been strongly influenced by emergence of 13-year periodical cicadas.

Two factors may account for a lack of cicada influence on bird diversity. First, the density of emerging cicadas in these managed pine stands was considerably lower than densities reported for other forests in the Eastern U.S. (Dybas and Davis 1962, Rodenhouse and others 1997, Williams and others 1993) and therefore, may have been too low to induce a change in bird diversity. However, Karban (1982) failed to find a relationship between density of birds and density of cicadas in eight isolated forest patches in New York where cicada densities were generally higher than in this study. Densities in New York ranged from about 2,500 to 57,200 cicadas per acre, although five of the eight sites had between 12,000 and 25,000 cicadas per acre. Birds were not counted before or after cicada emergence in the Karban (1982) study.

Second, adult cicada chorusing centers were numerous and scattered across the Crossett Experimental Forest. In fact, multiple chorusing centers were located either on or around the study sites. Therefore, birds would not have to travel long distances to forage on cicadas. Williams and Smith (1991) mapped from 29 to 48 chorusing centers within a 40-acre forest stand in northwest Arkansas and found that the distribution and size of these chorusing centers varied temporally. Given the abundance and dynamic nature of cicada chorusing centers, an examination of the distribution and size of chorusing centers across a larger area in relation to bird distribution and abundance may reveal an influence on bird populations that is not discernable on small forest plots.

Seasonal variation in bird abundance and mating behavior due to spring migration and the progression of the breeding season are additional factors that can affect variation in bird diversity and detectability within forest stands (Ralph and Scott 1981). These factors limited the ability of Kellner and others (1990) to detect any effect of 13-year periodical cicadas' presence on the foraging behavior of four species of birds inhabiting an upland hardwood forest in the Arkansas Ozarks even though over 1 million cicadas emerged on the 40-acre study site (25,000 per acre). Seasonal variation may have influenced bird diversity in the present study given that the survey periods corresponded with early migration, late migration/early breeding, and mid-breeding periods of birds in southern Arkansas. However, only those species that breed in the vicinity of the study area and only data from singing males were used in the data summary and analyses to partially compensate for this variation.

Bird Composition and Stand Characteristics

A total of 21 species of breeding birds—15 neotropical migrants and 6 permanent residents—were recorded in the survey areas (table 4). The density of each species, reported as the number of territorial males per 100 acres, was calculated for each plot (fig. 2).

Table 4—Common and scientific names of bird species present in managed, loblolly pine stands

Common name	Scientific name	4-letter code[a]
Yellow-billed cuckoo	*Coccyzus americanus*	YBCU
Ruby-throated hummingbird	*Archilochus colubris*	RTHU
Eastern wood-pewee	*Contopus virens*	EAWP
Acadian flycatcher	*Empidonax virescens*	ACFL
Carolina chickadee	*Poecile carolinensis*	CACH
Tufted titmouse	*Baeolophus bicolor*	TUTI
Carolina wren	*Thryothorus ludovicianus*	CARW
Blue-gray gnatcatcher	*Polioptila caerulea*	BGGN
Wood thrush	*Hylocichla mustelina*	WOTH
White-eyed vireo	*Vireo griseus*	WEVI
Red-eyed vireo	*Vireo olivaceus*	REVI
Pine warbler	*Dendroica pinus*	PIWA
Black-and-white warbler	*Mniotilta varia*	BAWW
Kentucky warbler	*Oporornis formosus*	KEWA
Common yellowthroat	*Geothlypis trichas*	COYE
Hooded warbler	*Wilsonia citrina*	HOWA
Yellow-breasted chat	*Icteria virens*	YBCH
Summer tanager	*Piranga rubra*	SUTA
Northern cardinal	*Cardinalis cardinalis*	NOCA
Indigo bunting	*Passerina cyanea*	INBU
Eastern towhee	*Pipilo erythrophthalmus*	EATO

[a] Four-letter codes used in figure 2. Birds are listed according to American Ornithologists' Union (1998) sequence.

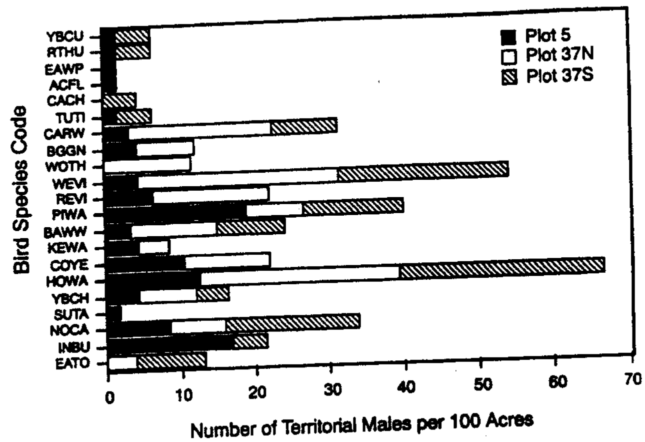

Figure 2—Density of bird species by plot (see table 4 to interpret 4-letter species codes).

Overall, plots 37N and 37S had similar vegetation and differed from plot 5 by having three to four times as many hardwood saplings and shrubs in the understory and a greater ground cover of hardwoods (table 5). As expected, plots 37N and 37S generally supported higher densities of bird species that are typically associated with low, shrubby

Table 5—Mean vegetation characteristics

Vegetation variables	Plot number 5	37N	37S
Pine overstory			
Tree height (feet)	60.9	49.8	48.3
D.b.h. (inches)	9.2	8.3	8.5
Basal area (ft^2/acre)	87.6	77.1	81.6
Hardwood saplings and shrubs[a]			
Total	145	588	426
1-inch saplings	80	325	238
2-inch saplings	41	188	125
3-inch saplings	24	75	63
Pine saplings[a]			
Total	28	38	26
1-inch saplings	0	25	13
2-inch saplings	3	13	13
3-inch saplings	25	0	0
Percent ground cover[b]			
Pine	74	67	61
Hardwood	3	35	30
Semi-woody	14	2	2
Grass	34	11	10
Forbs	17	9	4
Vines	50	50	47

[a] Values for hardwood saplings and shrubs and for pine saplings are the mean number of stems per acre.
[b] Percent ground cover values are the mean percent coverage on 1-milacre quadrats.

vegetation (Carolina wren, common yellowthroat, northern cardinal, eastern towhee, white-eyed vireo, and yellow-breasted chat) or a deciduous understory with some merchantable-sized hardwood trees (black-and-white warbler, hooded warbler, and wood thrush). All these species, except black-and-white warbler, are dependent upon the presence and amount of deciduous vegetation in the understory for foraging and nesting (Conner and others 1983, Crawford and others 1981, Dickson and Noble 1978, Hamel 1992, Thompson and Capen 1988). Black-and-white warblers depend more on the presence of deciduous vegetation in the midstory and canopy layers (Conner and Dickson 1997, Conner and others 1983, Dickson and Segelquist 1979). Both plots, particularly 37N, had some merchantable-sized hardwoods in the unmanaged areas of the plot.

Compared to plots 37N and 37S, plot 5 generally had larger pines, fewer hardwood saplings and shrubs, and a greater coverage of forbs and grasses (table 5). This plot supported bird species that are typically associated with mature forests such as Acadian flycatcher, blue-gray gnatcatcher, eastern wood-pewee, Kentucky warbler, pine warbler, red-eyed vireo, and summer tanager. All these species, except pine warbler, were present at very low densities and are more commonly associated with hardwood or pine/hardwood forests. These species may have been attracted to the pine/hardwood forest bordering plot 5 on the south and west. In contrast, pine warblers were the most common species in this stand and prefer mature pine forests for nesting and foraging (Conner and others 1983, Hamel 1992). Indigo buntings and common yellowthroats also were fairly common in this 25-year-old stand and were associated with the open, herbaceous areas and the few patches of dense, deciduous understory within the stand. These species usually occur at high densities in the open, shrubby habitat of recent clearcuts and then decrease as the canopy begins to close (Childers and others 1986, Kellner 1996, Thompson and Capen 1988).

In general, bird composition in these managed loblolly pine stands was similar to that found in unmanaged, even-aged pine and pine/hardwood stands of similar ages (Childers and others 1986, Conner and others 1979, Dickson and others 1993, Kellner 1996) and was related to vegetation structure. Therefore, managing stands for maximum development of loblolly pine by precommercial thinning, commercial thinning, and competition control during early development stages does not appear to negatively affect the breeding bird population. Commercial thinning of plots 37N and 37S in December 1997, opened the canopy and stimulated growth of a deciduous understory that was used by the majority of bird species present in those stands. In contrast, a prescribed burn during February 1998 on plot 5, immediately preceding the bird surveys, top-killed most of the shrubs and small sapling hardwoods resulting in an open understory with a greater coverage of grasses and forbs. This type of habitat was more attractive to indigo buntings and less attractive to the other understory species that prefer a dense, deciduous understory. Presence of deciduous vegetation is important for many species of birds (Conner and others 1983, Crawford and others 1981, Dickson and others 1993, Thompson and Capen 1988). Allowing deciduous vegetation to grow after pines have become established will increase vertical foliage diversity and attract more species of birds. More research is needed to clarify the effect of commercial thinning and techniques for controlling competing vegetation on bird populations inhabiting pine stands.

SUMMARY

Emergence of 13-year periodical cicadas did not strongly influence bird diversity within managed loblolly pine stands. Low cicada density and abundant, widely distributed cicada chorusing centers may contribute to the lack of a bird/cicada relationship in this study.

Bird composition in these managed loblolly pine stands was similar to that found in unmanaged, even-aged pine and pine/hardwood stands of similar ages. Managing stands for maximum development of loblolly pine by precommercial/commercial thinning and competition control during early development stages does not appear to negatively affect the breeding bird population. Bird composition could be explained by vegetation structure, and the majority of the bird species present generally depend on some type of deciduous vegetation for nesting and/or foraging.

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