

APPENDIX. Continued.

Species (scientific name)	N_t^a	N_r^b	Stream		Upslope	
			\bar{x}^c	SE	\bar{x}	SE
Townsend's warbler (<i>Dendroica townsendi</i>)	1					
Vaux's swift (<i>Chaetura vauxi</i>)	9					
Wrentit (<i>Chamaea fasciata</i>)	9					

^a N_t = Total number of detections at all distances.

^b N_r = Total number of detections within 40 m of count points along transects and within 20 m of count points perpendicular to transects (i.e., restricted sampling area).

^c Mean number of detections during 6 visits/transect/year ($n = 12$) within restricted sampling area.

^d Detected on a single occasion.

BREEDING BIRD POPULATIONS IN MISSOURI OZARK FORESTS WITH AND WITHOUT CLEARCUTTING

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Abstract: Concern has arisen that forest management practices that create edge (such as clearcutting) are contributing to regional declines in neotropical migrant birds that inhabit forest interiors. Consequently, we studied breeding bird populations in an extensively forested region of southern Missouri to determine if the numbers of breeding birds differed between areas ($n = 9$) managed by the clearcutting method (CCM), and areas ($n = 9$) of mature forest with no recent timber harvest or other disturbances (NOHVST). Three forest interior migrants had lower ($P < 0.06$) mean densities on CCM sites than NOHVST sites; 3 had greater ($P < 0.03$) densities on CCM sites; and densities of 3 others did not differ ($P > 0.40$) between treatments. All early successional migrants had greater ($P < 0.01$) densities on CCM sites. Numbers of 2 avian nest predators and a brood parasite did not differ ($P > 0.20$) on CCM and NOHVST sites. Densities of 9 species differed ($P < 0.10$) among regeneration, sapling, and pole-sawtimber habitats on CCM sites. While clearcutting reduced numbers of forest interior birds that were dependent on mature forest habitats, other forest interior species made extensive use of early and mid-successional even-aged stands and occurred in greater numbers on CCM sites.

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Recent declines in populations of neotropical migrant birds in the eastern United States and Canada have been linked to forest fragmentation in the temperate zone where these species breed and destruction of tropical habitats on their wintering grounds (Robbins et al. 1989, Askins et al. 1990, Wilcove and Robinson In Press). Nearly all declining species are forest interior or interior-edge birds (Whitcomb et al. 1981). Forest fragmentation increases the proportion of forest edge to forest interior. Field studies have shown that nesting success of songbirds is lower near forest edges than in the forest interior (Gates and Gysel 1978, Chasko and Gates 1982, Brittingham and Temple 1983, Temple

and Cary 1988), and population and habitat modeling have shown that edge effects alone are sufficient to explain the distribution and decline of forest interior species in fragmented habitats (Temple 1986, Temple and Cary 1988).

Because timber management practices such as clearcutting create edge, concern has arisen that these practices are contributing to regional declines of forest interior birds (Wilcove 1988). With few exceptions, studies on the effects of forest fragmentation have been conducted in small woodlots in suburban or agricultural areas, or along permanently maintained edges. It is unclear if edges created by clearcutting in large forests could cause similar edge effects and the

decline or local extirpation of some forest interior species. Even-aged forest management also may reduce the carrying capacity for forest interior birds because a percentage of the forest is maintained over time as young even-aged stands.

Several studies have investigated use of oak-hickory forests by nongame birds (Conner and Adkisson 1975, Evans 1978, Probst 1979, Crawford et al. 1981, Horn 1984, Yahner 1986). No studies have compared breeding populations at the landscape level (a mosaic of habitats or stands) in forests managed by the clearcutting method with those in mature forest with no timber harvest. Consequently, we studied breeding bird populations in an extensively forested region of southern Missouri, much of which has been managed by the clearcutting method for 15–20 years.

Specifically, we compared breeding bird densities in forests managed by the clearcutting method (CCM) (Smith 1962) with areas of mature forest with no recent timber harvest or other disturbances (NOHVST); breeding bird densities within mature forest (pole-sawtimber) habitats of CCM sites with NOHVST sites; and breeding bird densities among regeneration, sapling, and pole-sawtimber habitats on the CCM sites. We concentrated on 3 groups of birds: forest interior–neotropical migrants, edge or early successional–neotropical migrants, and the brown-headed cowbird (*Molothrus ater*) and 2 avian nest predators (blue jay [*Cyanocitta cristata*] and American crow [*Corvus brachyrhynchos*]).

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STUDY AREA AND METHODS

We conducted our study in 1989 and 1990 on the Doniphan, Eleven-point, and Willow Springs Districts of the Mark Twain National Forest in southcentral Missouri. This region of the Ozark Plateau is the most extensively forested region in the state. The 7-county area that includes these districts is 65% forest (1.1 million ha). The area within the Forest Service district

boundaries is approximately 95% forest. The topography varies from gently sloping to very steep, highly dissected lands with narrow valley and ridge systems. Elevations range from 275 to 365 m above sea level. Oak-hickory-pine forests cover most of the area with nonforest habitats (mostly pasture) representing less than 6% of the area. Forest habitats are predominately even-aged stands that regenerated naturally following extensive timber harvest in the early 1900's. The dominant tree species are black oak (*Quercus velutina*), scarlet oak (*Q. coccinea*), white oak (*Q. alba*), post oak (*Q. stellata*), hickory (*Carya* spp.), and shortleaf pine (*Pinus echinata*). Common understory plants are flowering dogwood (*Cornus florida*), black gum (*Nyssa sylvatica*), lowbush blueberry (*Vaccinium vacillans*), farkleberry (*Vaccinium arboreum*), eastern hop-hornbeam (*Ostrya virginiana*), and fragrant sumac (*Rhus aromatica*).

Study Site Selection

We selected 9 CCM and 9 NOHVST study sites of approximately 200 ha each. We selected study sites of similar forest types and ecological land types (Miller 1981) from forest inventory data maintained by Mark Twain National Forest (Fig. 1). Study sites consisted of a group of stands; a stand being a plant community with sufficient uniformity of composition and structure to distinguish it from adjacent stands. Stands were classified by stand age as: regeneration, 0–10 years; sapling, 11–20 years; pole-sawtimber, >20 years. CCM study sites were composed of approximately 10% regeneration habitats, 10% sapling habitats, and 80% pole-sawtimber habitats, which is typical of sites under regulated even-aged management with a 100-year rotation. NOHVST study sites were located >1 km from recent timber harvests, maintained roads, early successional habitats, and agricultural lands. There had been no silvicultural treatment of pole and sawtimber stands on NOHVST or CCM sites since they were regenerated.

Bird Surveys

We focused on common birds that could be assigned to 1 of 3 groups that we hypothesized were affected by clearcutting: forest interior migrants, early successional migrants, and a brood parasite and 2 nest predators. We used the plot mapping method (Christman 1984) to survey bird populations on each study site in 1989 and 1990. Eight 500-m-long transects were located

on each study site. We located transects on each study site by randomly locating the first transect and systematically locating the remaining transects 200 m apart. Transects were occasionally further apart when a 200-m interval was skipped to avoid over- or under-sampling a habitat relative to its occurrence on each study site. The mean (SE) percent composition of habitats within the fixed-width transects on CCM sites was: 12(1)% regeneration, 13(1)% sapling, 75(3)% pole-sawtimber; and 100% pole-sawtimber in NOHVST sites.

Most bird counters had taken a college ornithology course, and all were trained for 5 days in bird identification and distance estimation the week before they began transect counts. Transects were laid out with a hand compass and tape measure and had distance markers every 25 m to allow accurate mapping of bird locations. We conducted bird counts from 0530 to 0930 hours between 16 May and 20 June. During each count, an observer spent 30 minutes walking the transect and mapping all bird observations on a transect map in the same manner as spot mapping. Eight bird counts were completed on each transect in a 10-day period, and starting times were rotated between 0530 and 0900 hours. Each observer surveyed an equal number of transects in CCM and NOHVST sites to eliminate observer bias from the treatment effect, and at least 2 observers worked at each study site to reduce observer bias in study site density estimates.

Data Analysis

We estimated the number of territories of each species and their density in each habitat on each of the 18 study sites in both 1989 and 1990. We calculated the number of territories present in a habitat type on a study site by dividing the mean number of detections by the mean probability of detection (Christman 1984). The probability of detection is derived from the frequency of detection of singing males in readily identifiable territories (clusters of 3 or more observations from 8 transect visits). Because the probability of detection may be species, time, and habitat specific, we calculated mean probabilities of detection for each species by treatment (CCM vs. NOHVST), date (first or second half of field season), and habitat (regeneration, sapling, and pole-sawtimber). We calculated the mean number of detections as the mean number of different singing males detected within 75 m

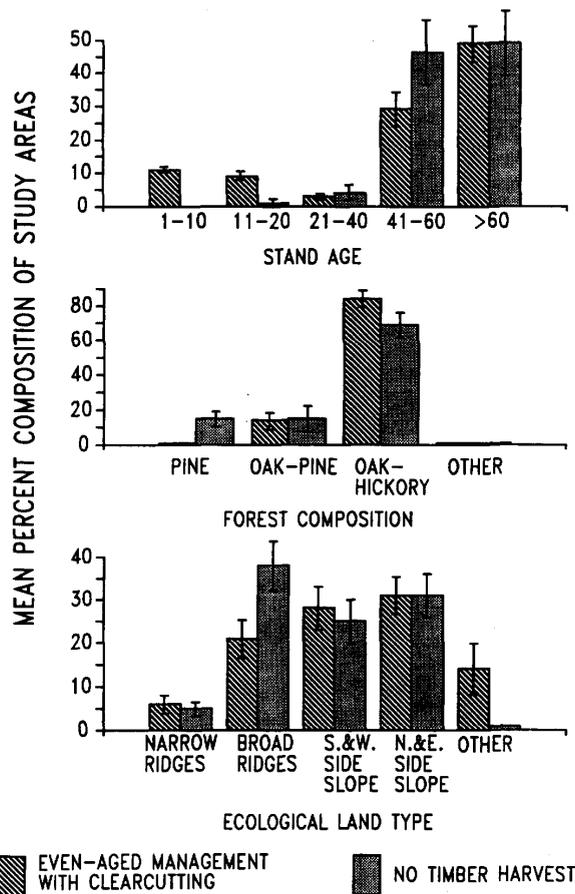


Fig. 1. Habitat characteristics of study sites managed by the clearcutting method ($n = 9$) and mature forest sites with no recent timber harvest ($n = 9$), Missouri Ozarks, 1989-90.

of the centerline of the transects during the 8 transect counts. The total number of territories of each species on a study site was the sum of the individual habitat estimates, and was expressed as territories/10 ha. We also calculated a density of each species in each habitat type by dividing the number of territories in a habitat by the area of that habitat on the transects for that study site.

Densities were not calculated for the brown-headed cowbird, American crow, and blue jay because we could not delineate territories from observations of singing males. For these species we report the mean number of individuals seen during a transect survey. We calculated the mean detections per transect for each study site as the mean number of detections during 8 visits to 8 transects. Similar to territory densities, we also calculated mean detections per transect by habitat type. Habitat specific detection rates were standardized to detections per transect.

We tested 3 null hypotheses for each species: (1) mean density on CCM sites equalled that on

NOHVST sites, (2) density in pole-sawtimber habitats on CCM sites equalled that on NOHVST sites, and (3) densities in regeneration, sapling, and pole-sawtimber habitats on CCM sites were equal. We used a repeated measures 1-way analysis of variance to test each hypothesis for each species (SAS 1990) because the abundance of a species on a study area in 1989 was likely correlated with its abundance on the same study site in 1990. In repeated measures designs, degrees of freedom are based on the number of experimental units ($n = 18$ study sites) not the number of repeated measures (18 study sites \times 2 years) (SAS 1990). In addition to treatment effects, we also tested for year effects and year-treatment interactions for hypotheses 1 and 2, and year effects and habitat-year interactions for hypothesis 3, to determine if results were consistent between years. Error rates were controlled for each hypothesis test for each species, not experiment-wide. We interpreted tests with a P -value ≤ 0.10 as significant. We chose a somewhat larger than normal P -value to reduce the probability of a type 2 error, which may be even more important than type 1 error in hypotheses concerning conservation of a species (Askins et al. 1990). Fisher's least significant difference test was used to determine which habitats had different bird densities in hypothesis 3.

RESULTS

Three forest interior migrants (scarlet tanager [*Piranga olivacea*], red-eyed vireo [*Vireo olivaceus*], and pine warbler [*Dendroica pinus*]) had lower ($P < 0.06$) mean densities in CCM sites than NOHVST sites (Fig. 2, Appendix). Red-eyed vireos, however, were still extremely abundant on CCM sites where they occurred at densities 3 times higher than the next most abundant species. Black-and-white warblers (*Mniotilta varia*), worm-eating warblers (*Helmintheros vermivorus*), and Kentucky warblers (*Oporornis formosus*) had greater ($P < 0.03$) densities in CCM sites, and densities of acadian flycatchers (*Empidonax vireescens*), ovenbirds (*Seiurus aurocapillus*), and wood thrushes (*Hylocichla mustelina*) did not differ ($P > 0.40$) between treatments (Fig. 2, Appendix). The forest interior species that occurred in greater numbers on CCM sites used early successional stands created by clearcutting (Table 1). The indigo bunting (*Passerina cyanea*), blue-winged warbler (*Vermivora pinus*), prairie warbler (*Dendroica discolor*), and yellow-breasted chat (*Ic-*

teria virens) all were considered early successional migrants and attained greater ($P < 0.01$) densities on CCM sites. Blue jays, American crows, and brown-headed cowbirds occurred in similar ($P > 0.20$) numbers on CCM and NOHVST sites (Fig. 2, Appendix). Mean study area densities of 6 species varied (ANOVA; $P < 0.1$; 1,16 df) between years. The yellow-breasted chat had a significant year-treatment interaction (ANOVA, $P < 0.1$; 2,16 df); but in both years, mean density was greater on CCM sites (Appendix).

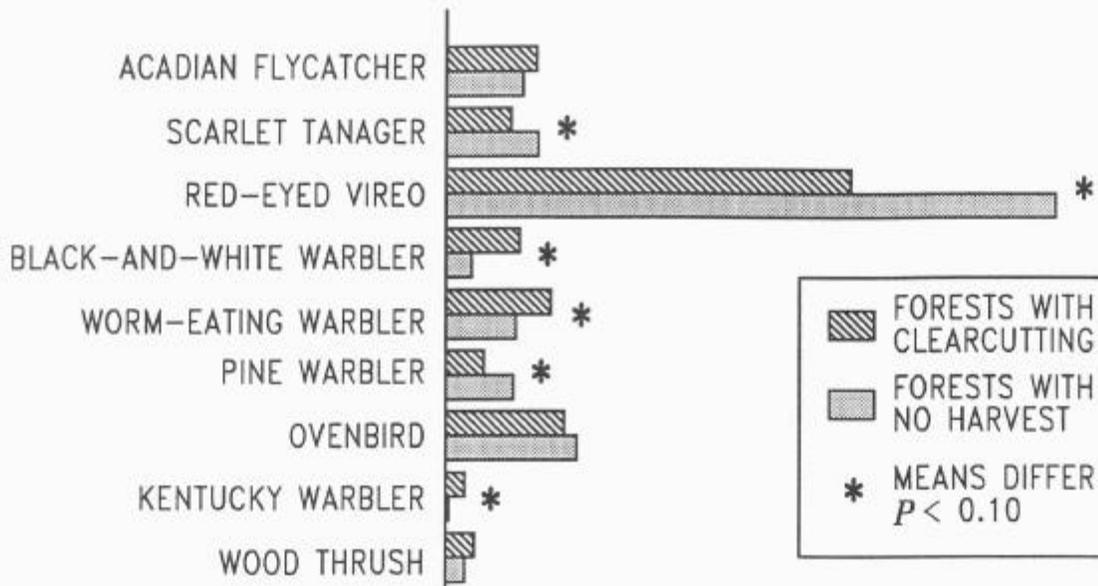
Seven species occurred at different ($P < 0.10$) densities in pole-sawtimber habitats on CCM sites than on NOHVST sites (Table 1). Densities of 6 species varied (ANOVA; $P < 0.1$; 1,16 df) between years, but there were no treatment-year interactions. Densities of 9 species differed ($P < 0.05$) among regeneration, sapling, and pole-sawtimber habitats on CCM sites (Table 1). Six species had year effects (ANOVA; $P < 0.1$; 1,24 df). The yellow-breasted chat and brown-headed cowbird had habitat-year interactions (ANOVA; $P < 0.1$; 2,24 df), but densities were consistently higher within regeneration habitats in both years.

DISCUSSION

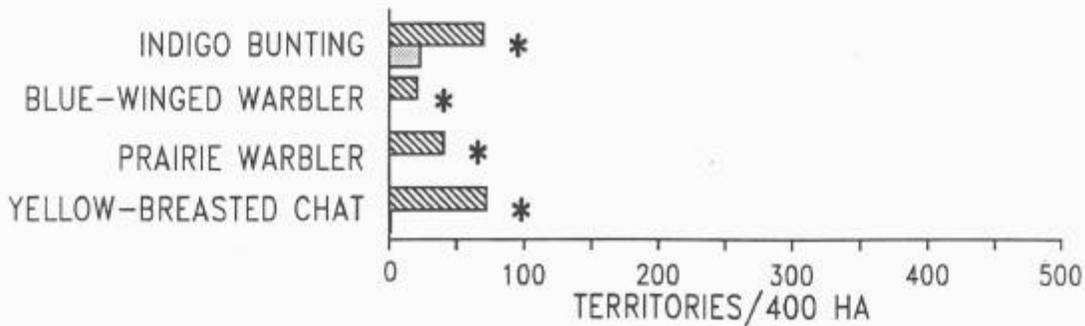
We hypothesized that densities of forest interior species would be lower on the CCM sites than NOHVST sites. Densities of 3 forest interior species (scarlet tanager, red-eyed vireo, and pine warbler) were lower on CCM sites (Fig. 2, Appendix) because they made minimal use of regeneration and sapling habitats (Table 1), and previously have been shown to prefer mature forest habitats in the Missouri Ozarks (Evans 1978). All forest interior species, including those that increased on CCM areas (Fig. 2, Appendix), are considered area sensitive in Missouri (Hayden et al. 1985) and often are associated with mature forest habitats (Evans 1978, Thompson and Fritzell 1990). However, black-and-white and Kentucky warblers also have been associated with early or mid-successional forests (Thompson and Capen 1988, Thompson and Fritzell 1990), and typically select habitats with dense understories. These species may use young even-aged forest habitats because these sites have high woody-stem densities even though they do not have a mature overstory. Similarly, Whitcomb et al. (1981) observed some forest interior birds breed in early stages of forest succession.

Differences in species densities between pole-

FOREST INTERIOR MIGRANTS



EARLY SUCCESSIONAL MIGRANTS



NEST PREDATORS AND BROOD PARASITE

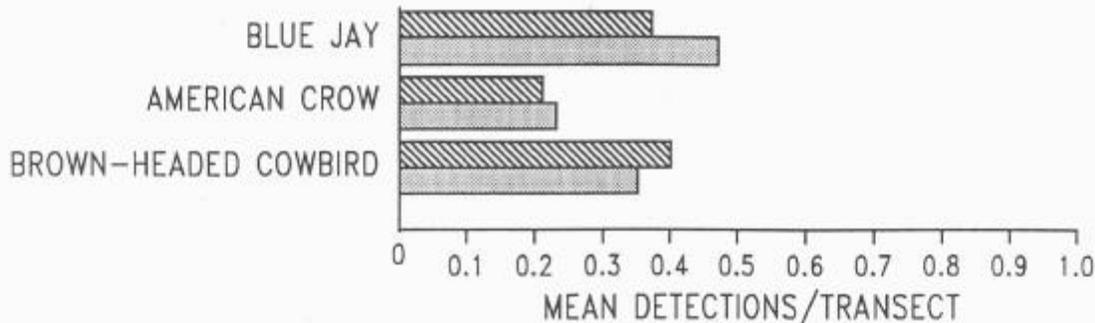


Fig. 2. Mean breeding bird abundance on study sites managed by the clearcutting method ($n = 9$) and mature forest sites with no recent timber harvest ($n = 9$), Missouri Ozarks, 1989-90.

Table 1. Mean breeding bird abundance in 3 forest size classes on sites managed by the clearcutting method, and pole-sawtimber stands on sites with no recent timber harvest, Missouri Ozarks, 1989–90.

Species	Clearcutting						No harvest	
	Regeneration		Sapling		Pole & sawtimber		Pole & sawtimber	
	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE
Forest interior migrants (territories/10 ha)								
Acadian flycatcher ^a	0.03 A ^b	0.03	0.09 A	0.06	2.09 B	0.37	1.43	0.32
Scarlet tanager	0.79 A	0.34	0.97 A	0.32	1.29 A	0.17	1.71	0.17
Red-eyed vireo	3.25 A	0.62	8.44 B	1.66	7.95 B	0.79	*c	11.33
Black-and-white warbler	2.77 A	0.61	3.24 A	0.67	0.97 B	0.21	*	0.47
Worm-eating warbler	1.28 A	0.41	2.20 A	0.62	2.00 A	0.21	*	1.29
Pine warbler	0.00 A	0.00	0.00 A	0.00	0.89 B	0.20		1.24
Ovenbird	0.29 A	0.19	1.92 B	0.47	2.47 B	0.29		2.43
Kentucky warbler	0.46 A	0.31	0.14 A	0.07	0.36 A	0.11	*	0.06
Wood thrush	0.40 A	0.20	1.33 A	0.54	0.44 A	0.10		0.36
Early successional migrants (territories/10 ha)								
Indigo bunting	5.56 A	0.85	2.96 B	0.58	1.06 C	0.24		0.56
Blue-winged warbler	3.08 A	0.90	0.98 B	0.46	0.13 B	0.04	*	0.00
Prairie warbler	5.10 A	1.41	1.31 B	0.69	0.41 B	0.10	*	0.01
Yellow-breasted chat	9.72 A	2.30	3.03 B	1.42	0.55 B	0.13	*	0.02
Nest predators and brood parasite (detections/transect)								
Blue jay	0.47 A	0.14	0.63 A	0.18	0.32 A	0.05		0.47
American crow	0.14 A	0.05	0.32 A	0.10	0.20 A	0.20		0.23
Brown-headed cowbird	1.31 A	0.22	0.52 B	0.10	0.27 B	0.27		0.35

^a Data collected in 1990 only.

^b Means for size classes under the clearcutting method followed by the same letter are not different (Fisher's least significant difference test, $P \leq 0.05$, 24 df).

^c Means for pole-sawtimber under the clearcutting method and no timber harvest with an asterisk between them differ (Repeated measures ANOVA, $P \leq 0.10$, 1,16 df).

sawtimber habitats in CCM and NOHVST sites might have been due to increased amounts of edge caused by timber harvest, or habitat differences not related to management. The Kentucky warbler, black-and-white warbler, and worm-eating warbler likely were more abundant in pole-sawtimber habitats on CCM sites than NOHVST sites because they reached their highest densities in regeneration or sapling habitats, and their territories extended into adjacent pole-sawtimber habitats on CCM sites. This also may explain why 3 of the 4 early successional migrants attained greater numbers in pole-sawtimber habitats on CCM sites than NOHVST sites.

The lower densities of red-eyed vireos and pine warblers in pole-sawtimber habitats on CCM sites probably was not caused by edge-related reductions in reproductive success because brown-headed cowbirds, blue jays, and American crows were no more abundant there than on NOHVST sites. Pine warblers were probably less abundant on CCM sites because CCM sites had less pine habitat than NOHVST sites (Fig. 1).

Forest interior species could exist on CCM sites with significant edge related reductions in

reproductive success, if their populations were supported by immigration. However, the lack of a significant difference in mean abundance of brown-headed cowbirds, blue jays, and American crows between CCM and NOHVST sites suggests brood parasitism and nest predation by these species was not higher on CCM sites, and that these were not population sinks. Cowbirds were more abundant in regeneration than sapling and pole-sawtimber habitats on CCM sites, but the presence of regeneration habitats did not appear to increase the overall abundance of cowbirds on a study site.

Concerns for biological diversity in eastern forests have often, and appropriately, focused on species that require unfragmented mature forests, because these habitats are becoming scarce. However, on our study sites in the Missouri Ozarks, species dependent on early successional forest had the most limited distributions and were dependent on natural disturbances or timber harvest to create habitat.

MANAGEMENT IMPLICATIONS

Forests managed by the clearcutting method will have lower numbers of some forest interior species than mature forests with no timber har-

vest. Species dependent on mature forest habitats will be less abundant because some of these habitats will be regenerated into young, even-aged forest. However, numbers of many forest interior birds may remain unchanged or increase because they make substantial use of young, even-aged stands. While forest interior bird populations may be reduced in forest fragments due to edge-effects, this did not appear to be the case in extensive forests managed by clearcutting in Missouri. Our study suggests that in extensively forested areas, forest management by the clearcutting method is compatible with the goal of maintaining viable populations of neotropical migrant birds, although some species will be less abundant, and others more abundant than in forests with no timber harvest.

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