Landscape-level Effects of Forest Management on Bird Species in the Ozarks of Southeastern Missouri

Richard L. Clawson[1], John Faaborg[2], Wendy K. Gram[3], and Paul A. Porneluzi[4]

Abstract.—This study was designed as an experiment to test how bird populations in an extensively forested landscape respond to small (group and single-tree selection) and large (clearcut) openings. Our objectives are to test the landscape-level effects of even-aged and uneven-aged forest management relative to no-harvest management on population density and reproductive success for forest-interior and early-successional bird species. Pre-treatment data were gathered during the period 1991 through 1995, treatments were applied in 1996 and early 1997, and post-treatment data have been collected from 1997 through the present. Immediately following treatment, populations of forest-interior species declined on all study sites. Post-treatment, forest-interior species responded both positively and negatively to the even-aged and uneven-aged treatments. For early-successional species, changes in density were positive in response to both even-aged and uneven-aged treatment types. Neither nest predation rates nor nest parasitism rates increased following treatment. From a landscape-level perspective, our findings indicate that the short-term effects of even-aged management are mixed, positive and negative, for forest-interior species and that the response by early-successional species is greater for even-aged than for uneven-aged management.

Planning for the MOFEP bird study began in 1989 and we have collected data since 1991. At the time this study was being planned, much of the work that had been done on migratory forest songbirds had been conducted in landscapes comprising mixtures of forest and other habitats, but in areas where forest was fragmented and a lesser component of the landscape. We were concerned that processes that affected avian populations in these landscapes also might be at work in landscapes dominated by forest, so we collaborated with scientists in related disciplines in the design and implementation of the MOFEP experiment. While we have been working on MOFEP, other researchers have turned their attention to forest-dominated landscapes and the effects of forest management on migratory forest birds. The other studies that have been done, such as Thompson *et al.* (1992), Annand and Thompson (1997), and Robinson and Robinson (1999), have been observational or correlational in nature. An important distinction to note is that MOFEP is a manipulative experiment. Thompson *et al.* (2000) recommended that, while observational studies can provide insights into the processes that affect bird populations, manipulative experiments such as MOFEP should be conducted to test and confirm key hypotheses that are generated by the observational/correlational studies. Taken together, the results of all these studies should provide forest managers with important insights into the effects of their management decisions on the forest bird community.

[1] Wildlife Research Biologist, Wildlife Research Section, Missouri Department of Conservation, Columbia, MO 65201; e-mail: clawsr@mdc.state.mo.us.

[2] Professor of Biology, Division of Biological Sciences, University of Missouri, Columbia, MO 65211; e-mail: faaborgj@missouri.edu.

[3] Director of Education, Sam Noble Oklahoma Museum of Natural History, University of Oklahoma, Norman, OK 73072; e-mail: wgram@ou.edu.

[4] Assistant Professor of Biology, Division of Science and Math, Central Methodist College, Fayette, MO 65248; e-mail: ppornelu@cmc2.cmc.edu.

The MOFEP bird study was designed to experimentally test how avian populations in an extensively forested landscape respond to even-aged and uneven-aged forest management, by examining how large (clearcut) and small (group and single-tree selection) openings affect avian abundance and demographic patterns at the landscape level, and whether or not timber harvest constitutes a negative disturbance of the habitat. Studies in central Missouri had shown that those species of migratory songbirds that required the interior of mature forest responded negatively to forest fragmentation in a number of ways. They avoided forest fragments even though the fragments often were hundreds of times larger than the typical breeding territory (Hayden *et al.* 1985). They occurred at reduced densities on the smallest of those fragments where they did occur (Wenny *et al.* 1993). They had reduced pairing success on smaller fragments (Gibbs and Faaborg 1990, Van Horn *et al.* 1995) and showed reduced nesting success of those nests that occurred as fragments got smaller in size (Donovan *et al.* 1995). Both nest predation and cowbird parasitism were shown to be mechanisms causing these patterns (O'Conner and Faaborg 1993, Donovan *et al.* 1995).

Timber harvest changes the composition of the avifauna of a forest by reducing, for a period of time, habitat quality for species that require mature trees. On the other hand, it improves habitat quality for species that use clearings or early-successional habitats, again for a period of time. Even-aged management creates large openings (clearcuts) that are unsuitable for forest-interior birds (King *et al.* 1996). In contrast, uneven-aged management produces a heterogeneous habitat of mature trees interspersed with small openings that may or may not be suitable for forest-interior birds and may or may not be sufficiently open to attract early-successional species (Dickson *et al.* 1995, Lent and Capen 1995, Thompson *et al.* 1995).

Once a clearing has been created, the interface between the forest and the clearing is an edge. Recent studies have shown that edge habitats are correlated with a number of negative effects for migrant songbirds, including increased brood parasitism and increased nest predation (Paton 1994, Faaborg *et al.* 1995). The occurrence of negative edge effects, however, is not uniform among landscapes or regions. In general, landscapes that are composed of forest and non-forest habitats, especially agriculture, often show high rates of nest parasitism and predation (Robinson 1992, Robinson and Wilcove 1994, Faaborg *et al.* 1995). Edges created by timber harvest within a forested landscape, however, generally show lower rates of nest parasitism and predation (Lent and Capen 1995, King *et al.* 1996). Strong relationships between the amount of forest cover within landscapes and nest parasitism and nest predation rates have been found by Donovan *et al.* (1997, 2000), Hartley and Hunter (1998), Hochachka *et al.* (1999), and Robinson *et al.* (1995).

Thompson *et al.* (1992) studied the effects of even-aged management on the abundance of several forest-interior and early-successional forest bird species, and Annand and Thompson (1997) compared the effects of even-aged forest management and uneven-aged forest management on the abundance of a similar set of forest bird species. These studies were conducted in the heavily forested Ozarks of south Missouri. Both studies found that individual species responded differently to the different treatments: some forest-interior species responded negatively to even-aged cuts, but some responded positively; some early-successional species were found in both smaller and larger openings, but some were found only in larger openings. Robinson and Robinson (1999) studied the effects of uneven-aged management on birds in southern Illinois. They found apparently depressed levels of two forest-interior species within treated areas. Among early-successional birds, only the species that responded to smaller openings were found.

Much of the work cited above has occurred since the MOFEP experiment began in 1989. Our goal was and continues to be to measure the landscape-level effects of even-aged and uneven-aged management on select forest songbirds via a manipulative experiment. Given the recent studies that show how landscape context plays a significant role in determining what, if any, edge effects occur, and the observational studies on forest management that have been conducted, we are in an even better position with the MOFEP bird study to assess the effects of these two forest management practices on populations of forest songbirds.

In this paper we present a synopsis of 5 years of pre-treatment data and post-treatment data from 3 years following the first set of treatments on the MOFEP sites. We discuss the successes and difficulties we have encountered during the course of our study. In an ongoing process, we are analyzing the bird study data and will report the results of these analyses in other outlets, as well. Our first paper was written prior to this symposium and was submitted as Gram *et al.*, (in prep.).

OBJECTIVES

The overall, long-term objectives of the MOFEP bird study are:

1. To determine differences in breeding densities of some common forest songbirds in forest managed by the even-aged, uneven-aged, and no-harvest methods,
2. To determine rates of nest parasitism, nest predation, and reproductive success for these songbirds in forests managed by the even-aged, the uneven-aged, and no-harvest methods.

METHODS

The MOFEP sites have been described in detail elsewhere (Brookshire *et al.* 1997). Bird data were gathered during the periods 1991-1995 and 1997-the present. Treatments were applied during 1996 and early 1997.

Initially, we selected five forest-dwelling species for intensive study: Ovenbird (see table 1 for scientific names), worm-eating warbler, Kentucky warbler, wood thrush, and Acadian flycatcher. Data also were gathered on other neotropical migrant forest birds, including species such as indigo bunting and blue-winged warbler that are associated with forest edge or second growth. These were selected because:

1) they are territorial and vocal, thus allowing estimates of their densities via spot-mapping;
2) their nests are generally accessible for monitoring of reproductive success;
3) we had comparable data on abundance and demography of these species from fragmented habitats in prior or concurrent studies.

In fact, we gathered data on all forest birds, including species such as scarlet tanager, yellow-throated warbler, and eastern wood pewee. The list is extensive (table 1). However, for most of these species, we gathered only

Table 1.—*Bird species for which density data were collected*

Focal Forest-Interior Species

Acadian flycatcher (*Empidonax virescens*)
Wood thrush (*Hylocichla mustelina*)
Worm-eating warbler (*Helmitheros vermivorus*)
Ovenbird (*Seiurus aurocapillus*)
Kentucky warbler (*Oporornis formosus*)

Focal Early-successional Species

Blue-winged warbler (*Dendroica pinus*)
Prairie warbler (*Dendroica discolor*)
Yellow-breasted chat (*Icteria virens*)
Hooded warbler (*Wilsonia citrina*)
Indigo bunting (*Passerina cyanea*)

Other Forest-Interior Species for which Density Data Were Collected

Pileated woodpecker (*Dryocopus pileatus*)
Yellow-billed cuckoo (*Coccyzus americanus*)
Great crested flycatcher (*Myiarchus crinitus*)
Eastern wood pewee (*Contopus virens*)
Eastern phoebe (*Sayornis phoebe*)
Carolina chickadee (*Parus carolinensis*)
Eastern tufted titmouse (*Parus bicolor*)
White-breasted nuthatch (*Sitta carolinensis*)
Carolina wren (*Thryothorus ludivicianus*)
Blue-gray gnatcatcher (*Polioptila caerulea*)
Yellow-throated vireo (*Vireo flavifrons*)
Red-eyed vireo (*Vireo olivaceus*)
Black-and-white warbler (*Mniotilta varia*)
Northern parula (*Parula americana*)
Cerulean warbler (*Dendroica cerulea*)
Yellow-throated warbler (*Dendroica dominica*)
Pine warbler (*Dendroica pinus*)
Louisiana waterthrush (*Seiurus motacilla*)
Scarlet tanager (*Piranga olivacea*)
Summer tanager (*Piranga rubra*)

Other Early-successional Species for which Density Date Were Collected

Mourning dove (*Zenaida macroura*)
Eastern bluebird (*Sialia sialis*)
White-eyed vireo (*Vireo griseus*)
Common yellowthroat (*Geothlypis trichas*)
Northern cardinal (*Cardinalis cardinalis*)
Rufous-sided towhee (*Pipilo erythrophthalmus*)
Field sparrow (*Spizella pusilla*)

spot-mapping density data because their nests are located in the forest canopy where we cannot monitor them to determine reproductive success.

To facilitate study, each of the nine study areas was laid out in a grid system for orientation and subdivision. Grid lines run E-W and N-S and were approximately 300 m apart. Trees along grid lines were permanently marked with orange paint. Junctions were flagged and identified as to location on the grid. To equalize effort among the nine study sites, the exterior portions of the larger sites (study areas 1 - 4, 6, 7, and 9) were excluded from study, resulting in sampling areas per site that ranged from 278 to 355 ha.

Bird densities were determined through spot-mapping (Robbins 1970). Each study area was divided into seven spot-mapping plots, each of which was approximately 45 ha in size. Each plot was visited 8 to 10 times at 2- to 3-working-day intervals from mid-May through the end of June. Mappers used enlarged topographic maps of the spot-map plots to orient themselves and marked all detections of birds on their maps, along with the path used in making the map. Workers were instructed to use a different route across the plot from the one used in the prior visit. One map was produced each day a spot map plot was visited; most maps took 3 to 4 hours to complete. To determine densities, composite maps were compiled for each species. To locate territories, we looked for clusters of observations ($\geq$3). In addition to the density data for each plot each year, territory locations have been entered into a GIS system.

To determine reproductive success, nests were located and monitored while spot-mapping and by deliberate searching from mid-May through July. Nest locations were recorded on enlarged topographic maps and marked on-site by flagging. Nests were monitored every 3-5 days until nest fate was determined. Evidence of predation and parasitism was noted as part of data collection procedures. This produced reproductive data and a permanent record of nest locations. Daily survival rates were calculated using the methods of Mayfield (1961, 1975) as modified and categorized by the protocol for the Breeding Biology Research Database (BBIRD) program (Martin *et al.* 1997).

Birds also were captured in mist nets and banded to examine movements and return rates. During the pre-treatment phase of the study, 13 mist net lines, each containing 12 nets (36-mm mesh) set 50 m apart, were placed systematically throughout each study area on the east-west grid lines. Following treatment on the even-aged sites, two of the net lines were modified as follows: instead of following grid lines, nets were placed at 50-m intervals along the border of a clearcut, with one end attached to a tree at the edge and the net strung towards the interior of the cut. Net lines (and net locations) were marked on the topographic maps to ensure consistent placement of nets on an annual basis. Each net line was run for two consecutive mornings from dawn to noon. All birds captured in the nets were identified, aged, sexed, banded with U.S. Fish and Wildlife Service bands, and released.

Each summer, 24-27 field assistants helped us conduct the bird study. The students were enrolled in an Undergraduate Research Internship through the University of Missouri-Columbia, which provided a stipend, research credit, and a chance to do independent projects.

RESULTS

Avian Density

In this paper, we have focused our attention on five forest-interior species (ovenbird, worm-eating warbler, Acadian flycatcher, wood thrush, and Kentucky warbler) and four species of early-successional birds (indigo bunting, hooded warbler, yellow-breasted chat, and prairie warbler). We were interested in answering two questions: 1) Do treatments affect the densities of forest-interior birds? 2) To what extent do early-successional birds respond to the treatments?

Table 2 lists the focal species and displays the number of study sites on which they were detected each year throughout the study. Four of the five focal forest-interior species have been observed on all nine sites every year. The exception, Kentucky warbler, has been detected on a majority of the sites each year, but exists in low densities and was observed on all nine sites only in one year, 1992. Three of the four focal early-successional species were detected on some or all of the study sites prior to the treatments, but all four have been observed much more consistently since then.

Table 2.—*The number of study sites on which the focal species were detected each year*

Species	1991	1992	1993	1994	1995	1997	1998	1999
Acadian flycatcher	9	9	9	9	9	9	9	9
Wood thrush	9	9	9	9	9	9	9	9
Ovenbird	9	9	9	9	9	9	9	9
Worm-eating warbler	9	9	9	9	9	9	9	9
Kentucky warbler	7	9	6	5	8	6	7	7
Yellow-breasted chat	1	3	2	6	5	6	7	7
Prairie warbler	0	2	2	0	2	2	4	4
Hooded warbler	0	0	0	0	0	4	5	6
Indigo bunting	2	8	8	9	9	9	9	9

Figures 1-5 show the observed densities of the forest-interior species during the pre-treatment phase of the study, 1991-1995, and during the first 3 years of observed densities following treatment, 1997-1999. The populations of all five forest-interior species dropped from the pre-treatment period to the post-treatment period, including those on the untreated (control) sites. It is possible that the timber harvest activity constituted a disturbance in a large area, and that it had effects beyond the boundaries of the treated sites, even to the point of affecting populations on the nearby control sites. Gram *et al.* (2001) reported that many species showed evidence of changes in density in the post-treatment period, with both declines and increases in densities across all species groups and treatments following the timber harvest in 1996. Even so, we are able to see possible treatment effects on several species.

The response to the treatments varied among the forest-interior species. Ovenbirds declined more on both the even-aged and uneven-aged treatments than on the control sites (fig. 1). Wood thrushes initially declined on both treatments and the controls, but have increased on the even-aged sites during the post-treatment period (fig. 4). Kentucky warblers have never been found in high densities on any of the MOFEP sites, but seem to have responded to the treatments and increased on both treatment sites after timber harvest (fig. 5). Worm-eating warblers declined initially on both treatment types and the control sites, but since have rebounded on all three (fig. 2). Acadian flycatchers declined on both types of treatment and the controls (fig. 3).

A number of early-successional birds responded positively and dramatically to the newly available habitat created by the treatments on the 10-12 percent of the study sites that were disturbed (see figs. 6-9). However, because we are examining bird populations at the landscape (study site) scale, conversion of densities to number of territories per 100 ha for entire study sites diluted the numbers, making total increases relatively small. Indigo buntings responded dramatically to both treatments, increasing their densities many fold in the post-treatment period on both even-aged and uneven-aged sites (fig. 6). Yellow-breasted chats responded to both treatments, especially the even-aged treatment, by increasing density on both treatment types (fig. 8). Prairie warblers seemed to respond only to the even-aged treatment (fig. 9). Hooded warblers were practically non-existent on the study areas prior to treatment and have moved into the cuts produced by both treatments (fig. 7). No species showed greater density increases on the uneven-aged treatment sites versus the even-aged sites, but several species showed greater increases on the even-aged sites versus the uneven-aged sites.

Avian Reproduction

To this point in the study, we have found and monitored over 1,600 nests. However, when these data are divided by species, year, and treatment, the number of nests per category can be too small to be useful for examination. For this paper, therefore, we grouped the data from all of the nests that we have monitored into three guilds: 1) tree-nesting forest-interior birds, 2) ground-nesting forest-interior birds, and 3) shrub-nesting early-successional birds.

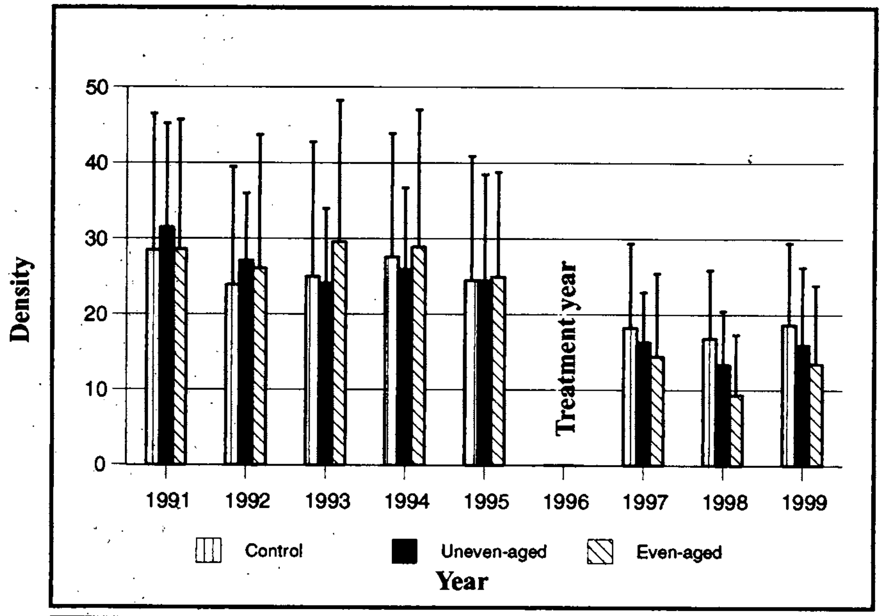


Figure 1.—*Mean densities (number of territories per 100 ha) and standard errors for overnbird, 1991-1995 and 1997-1999.*

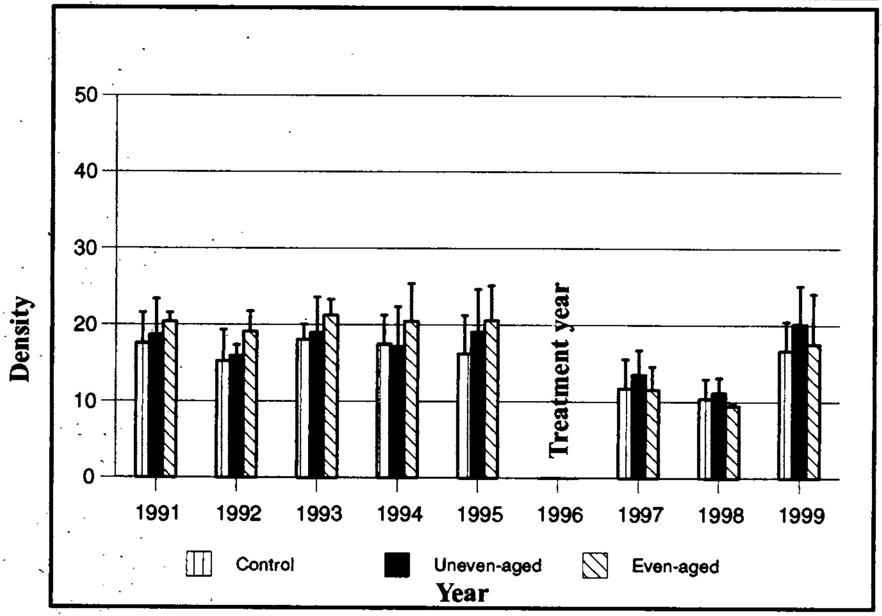


Figure 2.—*Mean densities (number of territories per 100 ha) and standard errors for worm-eating warbler, 1991-1995 and 1997-1999.*

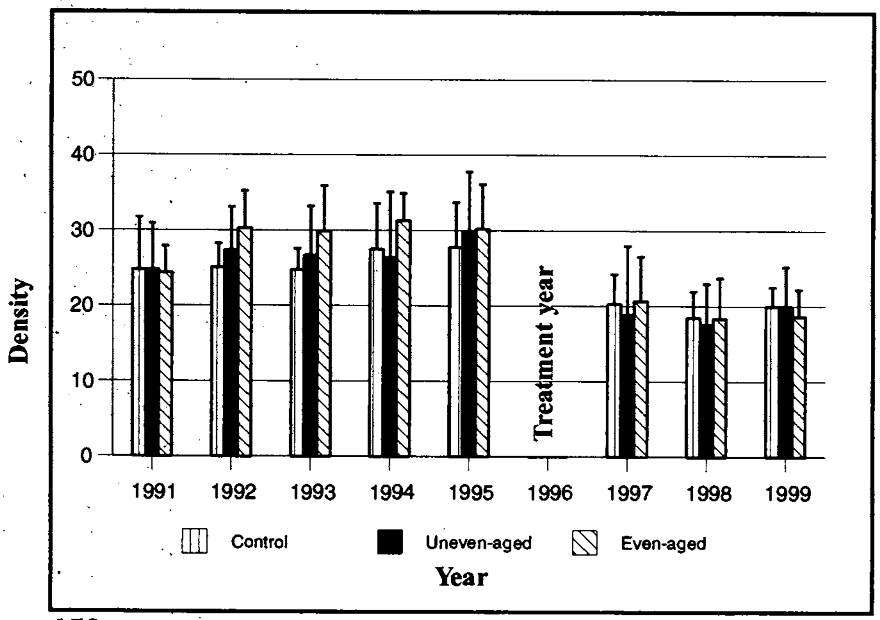


Figure 3.—*Mean densities (number of territories per 100 ha) and standard errors for Acadian flycatcher, 1991-1995 and 1997-1999.*

Figure 4.—*Mean densities (number of territories per 100 ha) and standard errors for wood thrush, 1991-1995 and 1997-1999.*

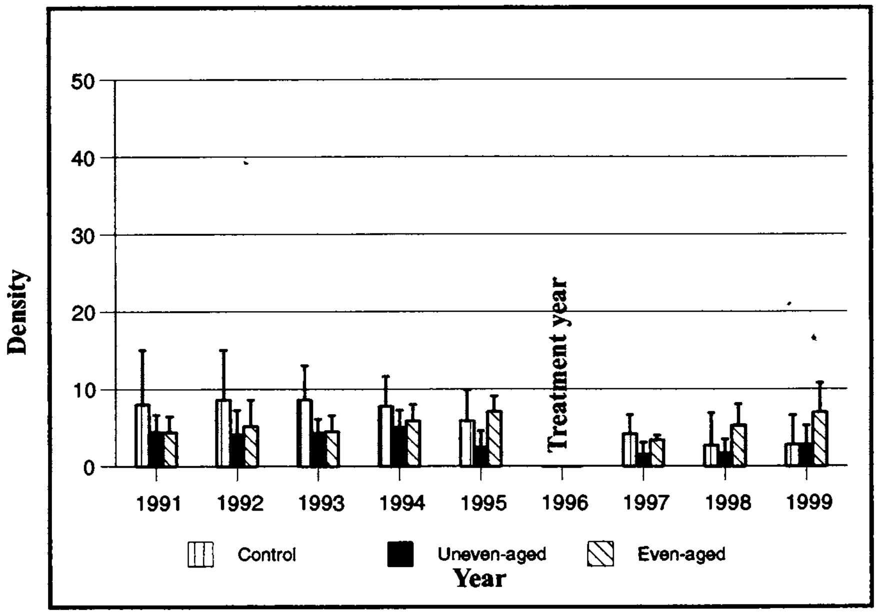


Figure 5.—*Mean densities (number of territories per 100 ha) and standard errors for Kentucky warbler, 1991-1995 and 1997-1999.*

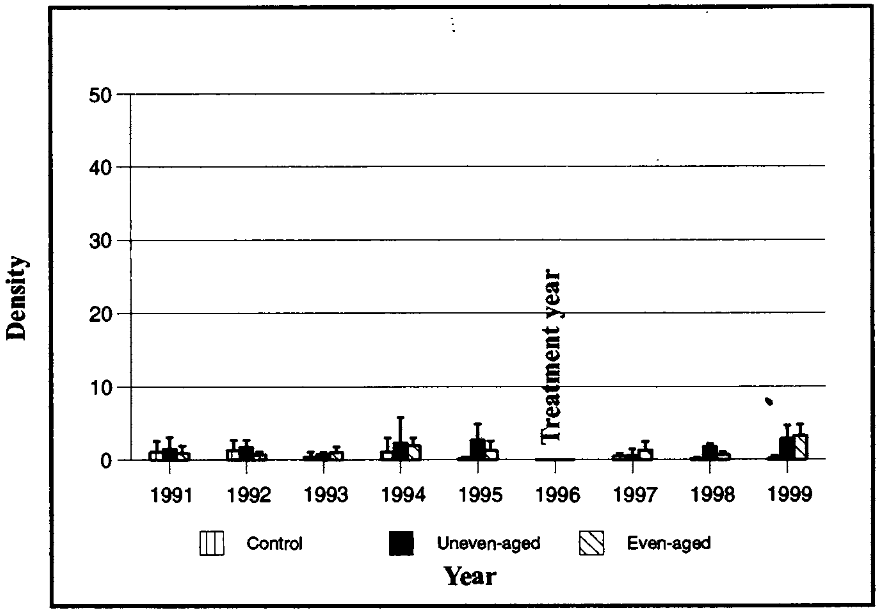
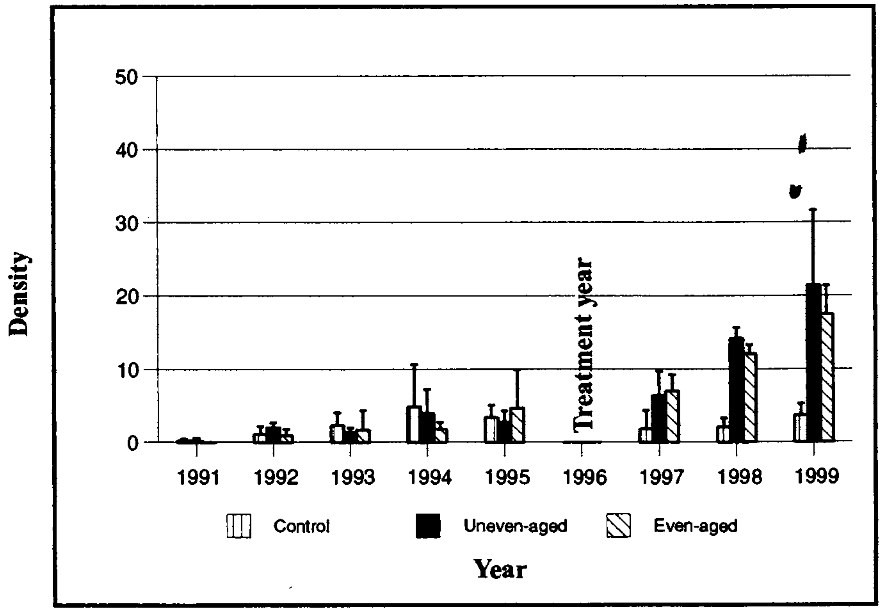


Figure 6.—*Mean densities (number of territories per 100 ha) and standard errors for indigo bunting, 1991-1995 and 1997-1999.*



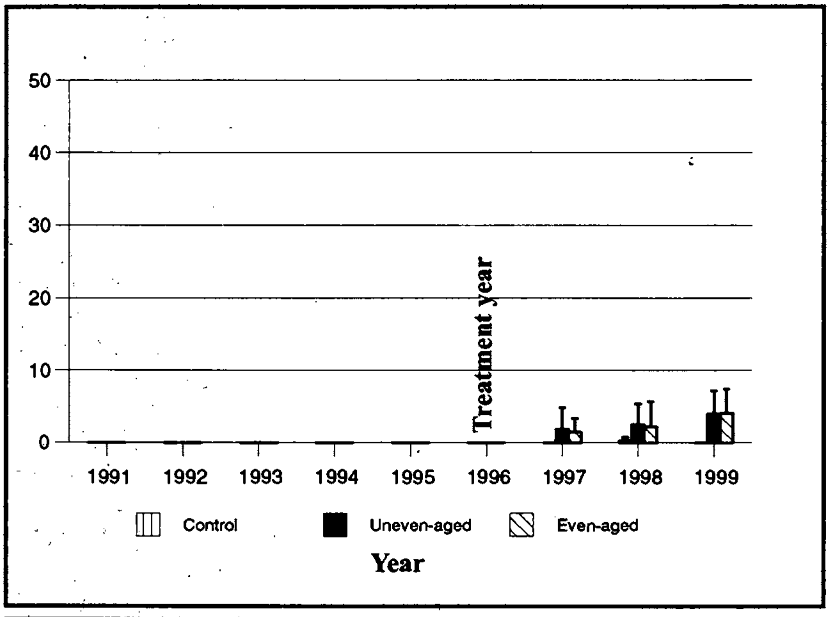


Figure 7.—*Mean densities (number of territories per 100 ha) and standard errors for hooded warbler, 1991-1995 and 1997-1999.*

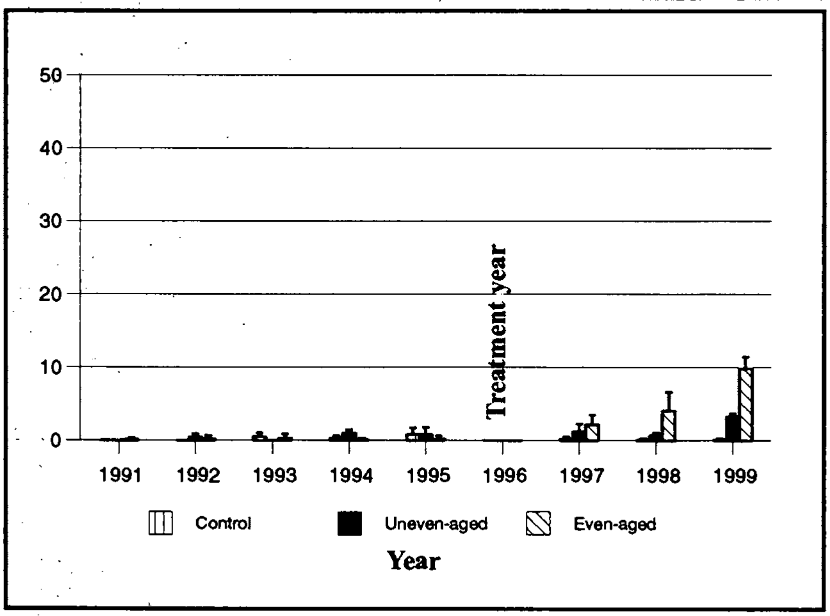


Figure 8.—*Mean densities (number of territories per 100 ha) and standard errors for yellow-breasted chat, 1991-1995 and 1997-1999.*

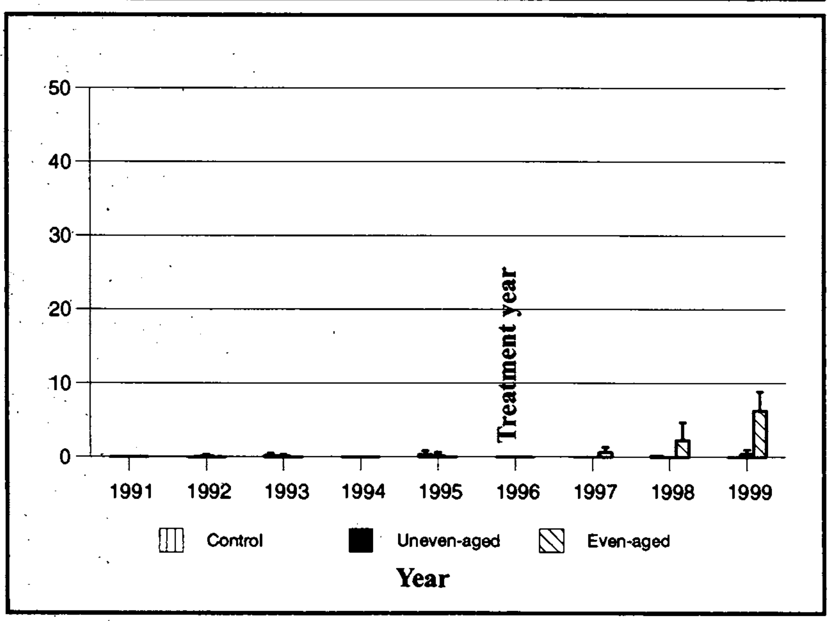


Figure 9.—*Mean densities (number of territories per 100 ha) and standard errors for prairie warbler, 1991-1995 and 1997-1999.*

We calculated daily survival rates and rates of brood parasitism for these groups, subdividing the data for the study sites by treatment type during the pre-treatment and post-treatment periods (see tables 3-5).

During the pre-treatment period, we monitored between 84 and 142 nests of tree-nesting forest-interior species annually (table 3). Daily survival rates ranged from 0.95 to 0.98 per year and the rate of brood parasitism ranged from 0 to 16.7 percent. During the post-treatment period we found between 107 and 172 nests annually. Post-treatment daily survival rates ranged from 0.95 to 0.98; they were similar among treatments and were comparable to those observed prior to treatment. Rates of brood parasitism in the several treatment categories ranged from 0 to 10.1 percent and were within the pre-treatment range of observations. The predominant species in our sample were Acadian flycatcher, wood thrush, and red-eyed vireo, but we also have data from yellow-billed cuckoo, summer and scarlet tanagers, eastern wood pewee, and eastern phoebe.

Nests of ground-nesting forest-interior birds were somewhat harder to find than those of tree-nesters, and not as many species placed their nests on or near the forest floor. As a result, we monitored fewer ground nests, between 38 and 63 annually, during the pre-treatment period, and 39 to 102 nests annually post-treatment (table 4). Daily survival rates pre-treatment ranged from 0.89 to 0.97 and brood parasitism rates ranged from 0 to 14.3 percent. Post-treatment daily survival rates ranged from 0.94 to 0.98; as above, they were similar among treatments and were comparable to those observed prior to treatment. Rates of brood parasitism post-treatment ranged from 0 to 7.1 percent and most were within the range observed prior to treatment. The predominant species in our sample were ovenbird, worm-eating warbler, and black-and-white warbler, but we also have data from Kentucky warbler, Louisiana water thrush, and Carolina wren.

Nests of shrub-nesting early-successional species were uncommon prior to treatment, but the number that we found and monitored was rising during the pre-treatment period and rose dramatically post-treatment (table 5). Most of the nests found in the pre-treatment period were indigo bunting. The rising number of nests found in 1993-1995 did not represent an increase in density of buntings (see figure 6), but instead represented increased attention to the species in anticipation of the upcoming treatment. Pre-treatment daily survival rates ranged from 0.86 to 1.00, but sample sizes were low. Brood parasitism rates ranged from 0 to 7.7 percent. Post-treatment, daily survival rates ranged from 0.92 to 1.00 and brood parasitism rates ranged from 0 to 25.0 percent. The predominant species in our sample were indigo bunting and northern cardinal, but we also have data from mourning dove, hooded warbler, yellow-breasted chat, common yellowthroat, blue-winged warbler, prairie warbler, and white-eyed vireo.

Table 3.—*Daily survival rates (DSR) and parasitism rates for tree-nesting forest-interior songbirds, 1991-1995 and 1997-1999*

	Control			Uneven-aged			Even-aged		
	No. Nests	# Par. (%)	DSR	No. Nests	# Par. (%)	DSR	No. Nests	# Par. (%)	DSR
1991	39	1 (2.6)	0.96	18	3 (16.7)	0.97	27	0 (0)	0.95
1992	37	1 (2.7)	0.95	30	0 (0)	0.95	25	0 (0)	0.97
1993	64	4 (6.3)	0.96	35	1 (2.9)	0.95	36	1 (2.8)	0.98
1994	35	1 (2.9)	0.96	28	0 (0)	0.95	32	0 (0)	0.96
1995	64	5 (7.8)	0.96	29	1 (3.4)	0.95	49	2 (4.1)	0.97
1997	69	7 (10.1)	0.95	47	2 (4.3)	0.95	56	2 (3.6)	0.96
1998	44	1 (2.3)	0.95	27	1 (3.7)	0.95	36	1 (2.8)	0.97
1999	33	0 (0)	0.98	35	0 (0)	0.96	44	1 (2.3)	0.95

Table 4.—*Daily survival rates (DSR) and parasitism rates for ground-nesting forest-interior songbirds, 1991-1995 and 1997-1999*

	Control			Uneven-aged			Even-aged		
	No. Nests	# Par. (%)	DSR	No. Nests	# Par. (%)	DSR	No. Nests	# Par. (%)	DSR
1991	15	0 (0)	0.92	17	0 (0)	0.97	19	0 (0)	0.95
1992	18	0 (0)	0.96	19	1 (5.3)	0.95	16	1 (6.3)	0.96
1993	18	0 (0)	0.94	14	1 (7.1)	0.94	6	0 (0)	0.89
1994	15	1 (6.7)	0.97	19	0 (0)	0.97	21	1 (4.8)	0.95
1995	21	3 (14.3)	0.95	21	1 (4.8)	0.96	21	0 (0)	0.97
1997	34	1 (2.9)	0.94	29	1 (3.4)	0.95	39	2 (5.1)	0.96
1998	21	0 (0)	0.98	14	1 (7.1)	0.95	21	0 (0)	0.94
1999	7	0 (0)	0.94	10	0 (0)	0.95	22	0 (0)	0.98

Table 5.—*Daily survival rates (DSR) and parasitism rates for shrub-nesting early-successional songbirds, 1991-1995 and 1997-1999*

	Control			Uneven-aged			Even-aged		
	No. Nests	# Par. (%)	DSR	No. Nests	# Par. (%)	DSR	No. Nests	# Par. (%)	DSR
1991	0	--	--	1	0 (0)	1.00	1	0 (0)	1.00
1992	0	--	--	0	--	--	1	0 (0)	1.00
1993	3	0 (0)	0.96	7	0 (0)	0.98	1	0 (0)	0.90
1994	10	0 (0)	0.97	5	0 (0)	0.98	5	0 (0)	0.95
1995	6	0 (0)	0.86	4	1 (25.0)	0.93	17	0 (0)	0.98
1997	7	0 (0)	0.92	11	1 (9.1)	0.93	10	0 (0)	0.96
1998	3	0 (0)	1.00	24	2 (8.3)	0.94	15	0 (0)	0.97
1999	7	0 (0)	0.95	58	5 (8.6)	0.97	44	3 (6.8)	0.97

To biologically interpret daily survival rate, one can convert the figure into "nesting success" as follows: the probability that a nest will survive the entire nesting cycle is calculated by raising the figure to the exponent of the number of days in the nesting cycle for a particular species. However, because the data presented herein are composites for guilds that are composed of species with different lengths of nesting cycles, nest success cannot be calculated for the guilds. We have calculated nesting success elsewhere (Gram *et al.*, in prep.) and calculated that nest success rates averaged 29 percent for the five species for which there were 50 or more nests in the data (Acadian flycatcher, ovenbird, worm-eating warbler, wood thrush, and indigo bunting). There did not appear to be any distinguishable changes in nest success from pre- to post-treatment.

Mist Netting

As with the other data, we subdivided the mist netting data by treatment type for the pre-treatment and post-treatment periods (see table 6). The number of birds caught per net line (a net line consists of 12 nets that have been run for two consecutive mornings) ranged from 5.18 (± 1.52) to 13.74 (± 3.36) birds during the pre-treatment period. The rate of recapture of previously banded birds ranged from 2.5 to 9.2 percent. Post-treatment, the number of birds caught per net line remained low (in fact, dropped) on the control sites to 3.84 (± 1.77) to 6.51 (± 0.67) birds per line, while the capture rate climbed somewhat to 11.88 (± 3.96) to 15.79 (± 3.92) birds on the uneven-aged sites. In 1997 the slash from the timber harvest prevented us from placing any nets in the

Table 6.—*Mist netting results, 1991-1995 and 1997-1999*

	Control			Uneven-aged			Even-aged				
	No. Birds Net-ted	No. Caught Per Net Line (SE)		No. Birds Net-ted	No. Caught Per Net Line (SE)		No. Birds Net-ted	No. Caught Per Net Line (SE)		No. recaptured	
1991	250	7.58	(0.23)	358	10.85	(5.99)	334	10.12	(0.73)	—	
1992	329	9.14	(1.69)	327	9.09	(1.01)	313	8.70	(2.57)	24	(2.5%)
1993	280	7.78	(1.14)	337	9.36	(3.88)	269	7.47	(2.17)	70	(7.9%)
1994	428	10.97	(0.92)	536	13.74	(3.36)	461	11.82	(4.50)	104	(7.3%)
1995	255	6.54	(2.62)	251	6.44	(2.38)	202	5.18	(1.52)	65	(9.2%)
1997	215	6.51	(0.67)	392	11.88	(3.96)	328	9.94	(2.54)	18	(1.9%)
1998	162	4.91	(0.90)	478	14.48	(2.42)	560	16.97	(5.89)	23	(1.9%)
1999	92	3.84	(1.77)	379	15.79	(3.92)	624	26.00	(12.83)	36	(3.3%)

clearcuts on the even-aged sites and our capture rate was similar to pre-treatment numbers at 9.94 (± 2.54) birds per line. After nets were placed around the borders of clearcuts in 1998, however, the capture rate shot up to 16.97 (± 5.89) birds and climbed further to 26.00 (± 12.83) birds in 1999. Post-treatment, the rate of recapture of banded birds on all sites was low and remained low, ranging from 1.9 to 3.3 percent.

DISCUSSION

We have generated a very large set of data describing the composition, abundance, and reproductive success of the forest bird community of the Ozarks of southeastern Missouri, and have data in hand with which to begin developing an understanding of the response of these species to two types of forest management applied to the MOFEP sites. We have density data for forest songbirds at the level of an entire study site for the nine MOFEP sites. This level of data is unique in the country. We have accompanying data from monitoring the nests of these birds. These data will allow us to consider both abundance and reproductive success when we seek to determine the effects of forest management on the bird community.

We have, however, encountered unanticipated difficulties that must be addressed as the MOFEP experiment and the bird study continue. The most serious of these difficulties arose in the even-aged sites, where the downed material (mostly felled tree tops) and the explosion of growth (the most problematic of which was grape vine) prevented our workers from penetrating the interior of the largest of the clearcuts. This was not a big problem initially, because observers could scan all the way across the cuts. By the third year post-treatment, however, the newly sprouted trees grew beyond head height, severely limiting our capability to spot-map the entire opening. The tangle of downed material and vines, and the profusion of small stems, also prevented our personnel from searching for nests beyond the edges of the openings. When we recognized that we had a problem, we created narrow paths through several of the clearcuts as a possible solution. From these paths we were better able to survey the cuts and doubled or nearly doubled the number of observed territories for early-successional species within the openings. We therefore recommend that, after subsequent rounds of treatment, paths be cleared immediately following treatment in large, even-aged cuts, and that these paths be marked and maintained in the post-treatment years. As the stands that were treated in 1996 grow, we will continue to monitor the situation so that we also will be able to recommend the time period through which such paths must be maintained. We have taken steps to eliminate or reduce the likelihood that these "bird paths" will negatively affect the results of our study or the other MOFEP studies by 1) avoiding the sampling plots for the other studies, 2) creating narrow paths, 3) making the paths meander through the cuts, and 4) siting the paths so they do not open at the edges of the cuts.

Another difficulty that we encountered concerned mist netting in the forest. Although we have captured and banded thousands of birds during the course of the study, it is only because of the very large number of nets employed across the landscape that we have captured very many birds at all. When examined critically, the capture rates for our mist netting effort in mature forest have been disappointingly low and raise questions as to the return in data for the effort required to collect it. Since the treatments were applied, capture rates have picked up in both even-aged and uneven-aged treatment types, especially in the even-aged openings. We speculate that this has occurred for two reasons: 1) the influx of early-successional birds, and 2) the dense vegetation in the openings also attracts family groups of forest-interior species once the young have fledged. We recommend that future mist netting be targeted to address specific issues and needs of the bird study, rather than conducted generally across the landscape.

Because MOFEP is a long-term experiment that will go on for 100 years or longer, it would be premature in the extreme to draw final conclusions based upon only 3 years of data following the very first treatment. There are, however, trends in the composition and the demographics of the avifauna that can be discerned and reported, even at this early point in the experiment. First of all, it appears that the treatments have not caused the dire consequences that might have been predicted 10 years ago. The forest-interior species that were of concern when the study was initiated remain dominant and important parts of the species composition of the study sites. Reproductive success, as measured by daily survival estimates for nests, did not decline. Brood parasitism did not increase. In addition, early-successional species have responded to the habitat created by the treatments, resulting in an increase in the diversity of the avifauna on the study sites.

As the MOFEP experiment continues, it will be important to continue monitoring birds for a number of reasons. Determining the responses of the different species to the different treatments will be critical to understanding the functioning of the Ozark forest and the implications of active management. The first treatments affected only a small percentage of the overall area. The openings that were created will close in with regenerated forest, and the composition of the avifauna within those openings will be dynamic and changing. It can be assumed that the early-successional species will plateau and then decline as the new forest begins its long maturation process; at some point, the forest-interior species will begin to reoccupy the space (Johnston and Odum 1956). Knowledge about when and how these changes take place will help us predict what will happen in subsequent treatments.

As treatments are applied at intervals through time, a mosaic of different-aged forest will be created on the study sites. It will take a number of cutting cycles before the age composition of the forest and the interspersion of treated stands will approximate the long-term condition that will be attained after a full rotation of 100 years. The composition and demographics of the avifauna probably will remain in flux until that time, so regular, if not constant, monitoring of the bird population will be required to remain on top of the situation. We hope that the data we have gathered and the techniques we have tried and implemented will be valuable to the researchers who will follow us, and will allow them to make informed decisions about data collection and interpretation in the future. Ultimately, of course, the goal of this study is to provide to forest managers the information they need to manage the birds and all the other components of the Ozark forest ecosystem.

ACKNOWLEDGMENTS

We thank the hundreds of interns who have gathered data for this project through the years. The Missouri Department of Conservation, in cooperation with the Division of Biological Sciences at the University of Missouri-Columbia (MU), provided primary funding for the study. The National Fish and Wildlife Foundation (with thanks to Peter Stangel and Alison Dalsimer), Missouri Federal Aid in Wildlife Restoration Project W-13-R, USGS Biological Resources Division (through the BBIRD program headed by Dr. Tom Martin), and the University of Missouri-St. Louis contributed additional funds for parts of the study. Finally, we thank members of the Avian Ecology Laboratory at MU for providing support and inspiration throughout the project.

LITERATURE CITED

Annand, E.M.; Thompson, F.R., III. 1997. Forest bird response to regeneration practices in central hardwood forests. Journal of Wildlife Management. 61(1): 159-171.

Brookshire, B.L.; Jensen, R.; Dey, D.C. 1997. The Missouri Ozark Forest Ecosystem Project: past, present, and future. In: Brookshire, B.L.; Shifley, S.R., eds. Proceedings of the Missouri Ozark Forest Ecosystem Project symposium: an experimental approach to landscape research. Gen. Tech. Rep. NC-193. St. Paul, MN: U.S. Department of Agriculture, Forest Service: 1-25.

Dickson, J.G.; Thompson, F.R., III; Conner, R.N.; Franzreab, K.E. 1995. Silviculture in central and southeastern oak-pine forests. In: Martin, T.E.; Finch, D.M., eds. Ecology and management of neotropical migratory birds. Oxford, England: Oxford University Press: 245-266.

Donovan, T.M.; Thompson, F.R., III; Faaborg, J. 2000. Ecological trade-offs and the influence of scale on brown-headed cowbird distribution. In: Smith, J.N.M.; Cook, T.L.; Rothstein, S.I.; Robinson, S.K.; Sealey, S.G., eds. Ecology and management of cowbirds and their hosts. Austin, TX: University of Texas Press: 255-264.

Donovan, T.M.; Jones, P.W.; Annand, E.M.; Thompson, F.R., III. 1997. Variation in local-scale edge effects on cowbird distribution and nest predation. Ecology. 78: 2064-2075.

Donovan, T.M.; Thompson, F.R., III; Faaborg, J.; Probst, J.R. 1995. Demography of migratory birds in habitat sources and sinks. Conservation Biology. 9: 1380-1395.

Faaborg, J.; Brittingham, M.C.; Donovan, T.M.; Blake, J.G. 1995. Habitat fragmentation in the temperate zone. In: Martin, T.E.; Finch, D.M., eds. Ecology and management of neotropical migratory birds. Oxford, England: Oxford University Press: 357-380.

Gibbs, J.P.; Faaborg, J. 1990. Estimating the viability of ovenbird and Kentucky warbler populations occupying forest fragments in central Missouri, U. S. A. Conservation Biology. 4: 193-196.

Gram, W.K.; Porneluzi, P.A.; Clawson, R.L.; Faaborg, J. (In prep.) Short-term, landscape-level effects of experimental forest management on density and nesting success of bird species in Missouri Ozark forests.

Gram, W.K.; Sork, V.L.; Marquis, R.J.; Renken, R.B.; Clawson, R.L.; Faaborg, J.; Fantz, D.K.; LeCorff, J.; Lill , J.; Porneluzi, P. 2001. Evaluating the effects of ecosystem management: a case study in a Missouri Ozark forest. Ecological Applications. 11(6): 1667-1679.

Hartley, M.J.; Hunter, M.L., Jr. 1998. A meta-analysis of forest cover, edge effects and artificial nest predation rates. Conservation Biology. 12: 465-469.

Hayden, T.J.; Faaborg, J.; Clawson, R.L. 1985. Estimates of minimum area requirements for Missouri forest birds. Transactions of the Missouri Academy of Science. 19: 11-22.

Hochachka, W.M.; Martin, T.E.; Artman, V.; Smith, C.R.; Heijl, S.J.; Andersen, D.E.; Curson, D.; Petit, L.; Mathews, N.; Donovan, T.; Klaas, E.E.; Wood, P.B.; Manolis, J.C.; McFarland, K.P.; Nichols, J.V.; Bednarz, J.C.; Evans, D.M.; Duguay, J.P.; Garner, S.; Tewksbury, J.; Purcell, K.L.; Faaborg, J.; Goguen, C.B.; Rimmer, C.; Dettmers, R.; Knutson, M.; Collazo, J.A.; Garner, L.; Whitehead, D.; Geupel, G. 1999. Scale dependence in the effects of forest coverage on parasitization by brown-headed cowbirds. Studies in Avian Biology. 18: 80-88.

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

King, D.I.; Griffin, C.R.; DeGraaf, R.M. 1996. Effects of clearcutting on habitat use and reproductive success of the ovenbird in forested landscapes. Conservation Biology. 10: 1380-1386.

Lent, R.A.; Capen, D.E. 1995. Effects of small-scale habitat disturbance on the ecology of breeding birds in a Vermont (USA) hardwood forest. Ecography. 18: 97-108.

Martin, T.E.; Paine, C.R.; Conway, C.J.; Hochachka, W.M.; Allen, P.; Jenkens, W. 1997. BBIRD field protocol. Missoula, MT: Montana Cooperative Wildlife Research Unit, University of Montana.

Mayfield, H. 1961. Nesting success calculated from exposure. Wilson Bulletin. 73: 255-261.

Mayfield, H. 1975. Suggestions for calculating nest success. Wilson Bulletin. 87: 456-466.

O'Conner, R.J.; Faaborg, J. 1993. The relative abundance of the brown-headed cowbird (*Molothrus ater*) in relation to exterior and interior edges in forests of Missouri. Transactions of the Missouri Academy of Science. 26: 1-9.

Paton, P.W.C. 1994. The effect of edge on avian nest success: how strong is the evidence. Conservation Biology. 8: 17-26.

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

Robinson, S.K. 1992. Population dynamics of breeding neotropical migrants in a fragmented Illinois landscape. In: Hagan, J.M., III; Johns, D.W., eds. Ecology and conservation of neotropical migrant landbirds. Washington, DC: Smithsonian Institution Press: 408-418.

Robinson, S.K.; Wilcove, D.S. 1994. Forest fragmentation in the temperate zone and its effects on migratory songbirds. Bird Conservation International. 4: 233-249.

Robinson, S.K.; Thompson, F.R., III; Donovan, T.M.; Whitehead, D.R.; Faaborg, J. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science. 267: 1987-1990.

Robinson, W.D.; Robinson, S.K. 1999. Effects of selective logging on forest bird populations in a fragmented landscape. Conservation Biology. 13: 58-66.

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

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

Thompson, F.R., III; Brawn, J.D.; Robinson, S.; Faaborg, J.; Clawson, R.L. 2000. Approaches to investigate effects of forest management on birds in eastern deciduous forests: how reliable is our knowledge? Wildlife Society Bulletin. 28(4): 1111-1122.

Van Horn, M.A.; Gentry, R.M.; Faaborg, J. 1995. Patterns of ovenbird (*Seirus aurocapillus*) pairing success in Missouri forest tracts. Auk. 112: 98-106.

Wenny, D.G.; Clawson, R.L.; Sheriff, S.L.; Faaborg, J. 1993. Population variation, habitat selection, and minimum area requirements of three forest interior warblers in central Missouri. Condor. 95: 968-979.