Effects of Selected Timber Management Practices on Forest Birds in Missouri Oak-Hickory Forests: Pre-treatment Results

Richard L. Clawson[1], John Faaborg[2], and Elena Seon[1]

Abstract.—Our goal is to understand the repercussions of two different forest management techniques on Neotropical migrant birds in the heavily forested landscape of the Missouri Ozarks. Our objectives are to determine breeding densities of forest birds under even-aged and uneven-aged management regimes and to determine the effects of these practices on songbird demographics. Our methods included spot mapping, nest monitoring, and mist-netting and banding. Analyses of our pre-treatment data show some variation both spatially and temporally, but do suggest that we have adequate baseline data for future comparisons. The data will allow us to see the immediate avian response to cutting, although decades and subsequent cutting cycles will be needed to evaluate the complete response. They also will allow us to examine avian population demographics on a scale that is unsurpassed for migrant songbirds.

Recent concerns about possible declines in populations of Neotropical migrant birds led to two major international symposia (the Manomet Symposium published as Hagan and Johnston [1992] and the Estes Park Meeting published both as Finch and Stangel [1993] and Martin and Finch [1995]) and to the development of the Neotropical Migratory Bird Conservation Program (also known as Partners in Flight). Three major factors have been cited as possible causes of these purported declines: winter habitat limitation, stopover habitat limitation during migration, and habitat loss and fragmentation in the breeding grounds. Although declines in wintering populations have been documented (Faaborg and Arendt 1992), the role of winter habitat limitation in causing overall population declines in most species is very controversial (see Rappole and McDonald [1994] and Latta and Baltz [1997] for an introduction to the problem). The role of stopover habitat loss in causing population-wide declines is even more difficult to document, although habitat loss can be at least locally critical for birds dealing with barriers such as the Gulf of Mexico and the Great Lakes (Moore and Simons 1992, Ewert and Hamas 1996).

In contrast, numerous studies have shown that fragmented breeding habitats have lower species diversity and reduced breeding success among those species that still occur. Primarily due to increased nest predation and cowbird parasitism (Robinson 1996, Thompson 1996), it appears that many fragmented regions have populations of migrant birds living in population "sinks" that exist only because of regular "rescue" from population "sources" (Donovan *et al.* 1995a, 1995b). It appears that potential source regions for forest migrants in the Midwest are those areas that still contain large areas of forest with little non-forest habitat, including such areas as the Missouri Ozarks, northern Wisconsin and Minnesota, and, perhaps, southern Indiana (Robinson *et al.* 1995).

If the Missouri Ozarks are crucial to maintaining populations of migrant birds across a large area of the Midwest, it is critical that we understand what habitat manipulations such as

[1] Wildlife Research Biologist and Wildlife Research Assistant, respectively, Missouri Department of Conservation, 1110 S. College Ave., Columbia, MO.
[2] Professor of Biology, University of Missouri-Columbia, Columbia, MO.

timber management might do to the demography of migrant birds within this region. Several studies in central Missouri have shown that those species of migrants that required the interior of mature forest responded negatively to forest fragmentation by avoiding forest fragments even though many of those fragments were hundreds of times larger than the typical breeding territory (Hayden *et al.* 1985), by occurring at reduced densities on the smallest of those fragments where they did occur (Wenny *et al.* 1993), by having reduced pairing success on smaller fragments (Gibbs and Faaborg 1990, Van Horn *et al.* 1995), and by showing reduced nesting success of those nests that occurred as fragments got smaller in size (Donovan *et al.* 1995a). Data supported both nest predation and cowbird parasitism as mechanisms causing these patterns (Donovan *et al.* 1995a, O'Conner and Faaborg 1993) and it was clear that most bird populations on these fragments were not producing enough offspring to replace the mortality of the adults.

As our data on fragmented populations grew, we realized that knowledge about populations in this fragmented situation was of limited value for providing management guidelines for the heavily forested Ozarks of southern Missouri. This region is not characterized by large gaps between populations, great amounts of edge, or small tracts of forest surrounded by fields or pastures. Rather, the Ozarks are 80 percent or more forested; when disturbance does occur, it is the cutting of a small portion of a large tract of forest. While such cutting may negatively affect the migrants that require mature forest, patterns of avian demography that apply to a landscape of agriculture with isolated woodlots do not transfer to a landscape of woodlands with isolated openings (Donovan *et al.* 1996).

At the time we developed our ideas with regard to MOFEP (the late 1980's), forest management studies had collected primarily correlational information to examine species-habitat relationships. Only Thompson and Fritzell (1990) had conducted experiments on forest-bird interactions in Missouri, and their study was within the fragmented region of central Missouri. When the idea for MOFEP was developed (Kurzejeski *et al.* 1993), we were enthusiastic because we felt that an experimental approach would allow us to better understand all of the interactions occurring with birds during timber management and it would permit us to better assess the impacts of management decisions on avian populations in the future.

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 method, the uneven-aged method, and forests with no timber harvest.
2. To determine rates of nest parasitism, nest predation, and reproductive success for these songbirds in forests managed by the even-aged method, the uneven-aged method, and forests with no timber harvest.

At the end of the pre-treatment phase of MOFEP, comparison of the data from all of the study sites over a 5-year period allows us to understand how bird populations and nesting success may vary over both time and space. It also allows us a detailed look at the spatial distribution of various species within the study sites. The distributional data can be used as a template to see the precise effects of the different treatment practices on bird distributions within each study site, whereas the density and reproduction summaries from each area can provide information on the demographic consequences of management practices within the scale of the study area.

MATERIALS AND METHODS

The MOFEP sites have been described in detail elsewhere in this volume (Brookshire *et al.* 1997). We were able to do all of our sampling activities on all nine sites for 5 years before treatment (1991-1995); we anticipate intensive studies on these sites for at least 3 years post-treatment (1997-1999).

We selected five forest-dwelling species as focal species (ovenbird [*Seiurus aurocapillus*], worm-eating warbler [*Helmitheros vermivorus*], Kentucky warbler [*Oporornis formosus*], wood thrush [*Hylocichla mustelina*], and Acadian flycatcher [*Empidonax virescens*]). 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.

Data also were gathered on 13 additional species of Neotropical migrant forest birds (e.g., yellow-throated vireo [*Vireo flavifrons*]), five Neotropical migrant species that are associated with forest edge or second growth (e.g., blue-winged warbler [*Dendroica pinus*]), and three permanent resident species (e.g., Carolina wren [*Thryothorus ludovicianus*]). To date, data for these species have not been analyzed but are available for future study. For example, sample sizes for second-growth habitat species were very small, but should increase following treatment, at which time the comparative nature of the pre-treatment datasets should increase their value despite their small size.

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. Differences in size posed a problem for equalizing effort among the nine study areas. To standardize, more or less, the area actually studied on the various study sites, exterior edges of sites 1 through 4, 6, 7, and 9 were excluded from study during the pre-treatment phase of the project. The entire area of sites 5 and 8 was studied. As a result, the amount of area studied in each of the nine sites ranged from 287 to 353 ha (table 1).

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 10 times at 2 to 3 working-day intervals (excluding weekends) 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.

Table 1—*Amount of each study area surveyed via spot mapping and searched for nests, 1991-1995.*

Site	Number of hectares in the study area
1	335
2	315
3	287
4	321
5	313
6	323
7	318
8	339
9	353

To determine densities, composite maps were compiled for each species. To locate territories, we looked for clusters of observations (≥3). In addition to the density data for each plot each year, a file of territory locations will be maintained that will be used to ascertain bird response to treatments; at some point, all this will be put into a GIS system.

To determine reproductive success, as well as parasitism and predation rates, we located and monitored nests while spot mapping and by deliberate searching from mid-May through July. Nest locations were recorded on the enlarged topographic maps and marked on-site by flagging. Nests were monitored every 3 to 5 days until nest fate was determined. 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 BBIRD program.

Birds also were captured in mist nets and banded to examine movements and return rates. Thirteen 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. Net lines (and net locations) also were marked on the topographic maps to ensure consistent placement of nets on an annual basis. Such consistent placement also was aided by the use of aluminum nails put into a tree to attach one end of each net. This also reduced the number of net poles that had to be carried up and down the Ozark slopes. 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.

We used 25 to 27 field assistants each summer to conduct the bird study. This was done as an Undergraduate Research Internship through the University of Missouri-Columbia, which offered the students a stipend, research credit, and a chance to do independent projects.

Statistical methodology used to analyze avian density data and nest survival data is contained in Littell *et al.* (1996). The analytical approach used for the mist netting capture/recapture data is documented in Pollock *et al.* (1990).

PRE-TREATMENT RESULTS AND DISCUSSION

Spot Mapping

During 1991-1993 and 1995, each spot-map plot was visited 10 times. In 1994, due to weather and personnel problems, each spot-map plot was run nine times. We were able to compute densities (number of territories per 100 ha) of the five focal species on a scale we feel is unmatched by any other study (table 2). Ovenbird and Acadian flycatcher were the most abundant species, and Kentucky warblers occurred only in low densities.

Both ovenbird and worm-eating warbler had significant patterns of density variation by study site (block effect of tables 3 and 4), as did all birds combined (table 8). The Acadian flycatcher showed significantly increasing populations through the study (a year effect, table 6). The worm-eating warbler, Kentucky warbler, wood thrush, and all birds combined had significant relationships between both year and study site (year*block; tables 4, 5, 7, and 8). The finding of significance in analyses involving block effects suggests that developing MOFEP with a block design was a wise decision. The lack of significant relationships between density of birds and assigned treatment suggests that these study sites will serve adequately for post-treatment analysis.

Nest Monitoring

Even with a large crew, it was difficult to find nests. During 1991-1995, we found the nests of 27 species of birds, of which 23 (85 percent) were Neotropical migrants. We have amassed a dataset with nearly 1,800 nests overall (table 9). Of these, approximately 880 nests proved useful for extraction of information on reproductive success. In addition to the impressive number of nests and nests found at the egg stage, it is noteworthy that cowbird parasitism rates were exceptionally low in the Ozarks, ranging from 1.3 to 3.6 percent annually. These figures are minuscule compared to parasitism rates in mid-Missouri, Illinois, and elsewhere in the Midwest (Robinson 1996).

To date, we have been able to conduct only two major analyses of our nest success data. In an attempt to see if our study sites were uniform in nest success characteristics, we computed daily nest survival rates for all nests of all species by year in each of the treatment groups (table 10). Despite a range of values from 0.945 in blocks 7-8-9 in 1991 to 0.970 in block 1-2-3 in 1991, the mean of the three treatment groups over the 5-year sample differed by only 0.01. These values were subjected to analysis of variance, for each year, to test for block or treatment effects (table 11). No block effects were observed, but a treatment effect was noted in 1995, although the difference in nest success rates in the treatment groups was small (table 11). We also subjected the combined daily nest success rate data to repeated measure analysis, with year as the repeated factor (table 12). No year, block, or treatment effects were found. As a result, we feel the data provide useful results to compare with the post-treatment data we will gather in the future.

We also have computed annual variation in daily nest success rates for the four focal species for which we had adequate data (excluding the Kentucky warbler) for the study area blocks. Daily nest survival rates for ovenbirds ranged from 0.917 in block 4-5-6 in 1993 to 1.000 for block 1-2-3 in 1994 (for only five nests; table 13). The mean daily nest survival rate for ovenbird nests for all years combined was 0.949(+/-0.007 SE). For this species, block 4-5-6 shows consistently low nest success rates, but the smaller sample sizes by species confound statistical comparison.

Daily nest survival rates for the worm-eating warbler ranged from 0.879 to 1.0 in different years and blocks (table 14), although the mean daily nest success rates over the 5-year period were more consistent between blocks for this

Table 2.—*Densities (number of territories per 100 ha) of ovenbirds, worm-eating warblers, Kentucky warblers, wood thrushes, and Acadian flycatchers on the MOFEP study areas, 1991-1995.*

Year	Study area	Ovenbird	Worm-eating warbler	Kentucky warbler	Wood thrush	Acadian flycatcher
1991	1	33.73	17.91	0.30	5.27	26.07
1992	1	26.37	11.94	0.60	5.37	26.17
1993	1	25.77	20.40	0.00	6.87	27.46
1994	1	33.08	21.79	3.28	8.66	31.14
1995	1	28.66	18.21	0.30	3.88	32.70
Mean(SE)		29.52(3.71)	18.05(3.77)	0.90(1.35)	6.01(1.82)	28.71(3.03)
1991	2	35.00	22.86	3.17	6.67	29.74
1992	2	29.34	16.19	1.90	7.62	29.13
1993	2	29.61	19.37	0.95	5.05	26.98
1994	2	34.92	21.90	6.35	7.06	34.29
1995	2	38.31	24.60	4.13	4.44	37.75
Mean(SE)		33.44(3.87)	20.98(3.28)	3.30(2.09)	6.17(1.36)	31.58(4.36)
1991	3	23.00	21.84	0.70	2.09	27.87
1992	3	16.03	16.03	0.35	1.39	30.84
1993	3	20.64	21.69	0.00	3.14	31.71
1994	3	22.30	25.09	4.18	8.01	34.76
1995	3	21.60	25.09	1.05	9.41	35.66
Mean(SE)		20.71(2.76)	21.95(3.70)	1.26(1.68)	4.81(3.65)	32.17(3.14)
1991	4	43.09	19.63	1.25	4.36	26.79
1992	4	34.67	17.34	0.62	1.56	31.96
1993	4	29.98	23.36	0.62	2.18	33.10
1994	4	28.91	18.03	0.62	2.49	27.73
1995	4	24.87	19.31	3.66	0.31	29.80
Mean(SE)		32.30(6.97)	19.53(2.33)	1.35(1.32)	2.18(1.48)	29.88(2.69)
1991	5	47.71	19.49	1.92	6.07	24.28
1992	5	46.30	20.55	1.17	6.18	25.18
1993	5	47.63	23.00	1.28	3.35	23.24
1994	5	49.26	21.09	1.46	3.83	31.52
1995	5	40.19	20.77	2.68	5.75	23.96
Mean(SE)		46.22(3.53)	20.98(1.28)	1.70(0.62)	5.04(1.34)	25.64(3.36)
1991	6	43.34	21.37	2.79	16.10	30.96
1992	6	38.03	19.84	0.31	16.14	28.79
1993	6	42.44	17.13	0.00	13.70	21.98
1994	6	40.34	16.10	0.00	11.24	30.86
1995	6	38.29	20.12	0.00	10.53	33.44
Mean(SE)		40.49(2.39)	18.91(2.20)	0.62(1.22)	13.54(2.63)	29.21(4.36)
1991	7	16.35	13.52	0.00	2.20	17.92
1992	7	17.61	14.56	2.52	3.14	21.07
1993	7	12.74	14.15	0.94	5.56	20.02
1994	7	13.98	11.68	0.00	5.35	17.13
1995	7	10.38	13.52	0.31	2.83	22.01
Mean(SE)		14.21(2.87)	13.49(1.10)	0.75(1.06)	3.82(1.54)	19.63(2.07)
1991	8	8.55	13.42	0.29	2.65	17.40
1992	8	7.18	14.16	2.95	4.42	23.30
1993	8	6.78	16.81	1.18	5.25	25.07
1994	8	9.26	14.50	0.00	3.54	20.53
1995	8	6.39	10.62	0.29	3.24	21.77
Mean(SE)		7.63(1.22)	13.90(2.23)	0.94(1.21)	3.82(1.02)	21.61(2.90)
1991	9	15.01	20.02	0.00	5.10	20.96
1992	9	15.81	20.77	0.57	8.33	34.84
1993	9	11.40	19.12	1.56	6.94	34.75
1994	9	14.98	15.30	0.00	5.84	27.48
1995	9	13.19	16.01	0.09	6.18	30.88
Mean(SE)		14.08(1.78)	18.24(2.45)	0.44(0.67)	6.48(1.23)	29.78(5.80)

Table 3.—*Multivariate repeated measurement analysis (year as repeated variable) of ovenbird densities on the MOFEP study areas, 1991-1995.*

Between site effects

Source	df	Mean square	F	P-value
Block	2	2897.9	11.09	0.0233*
Treatment	2	4.9	0.02	.9813
Error	4	261.3		

Within site effects

Source	Pillai's Trace Statistic	F	Numerator df	Denominator df	P-value
Year	0 .985	16.3	4	1	0.184
Year*Block	1.738	3.3	8	4	.131
Year*Treatment	1.231	.8	8	4	.636

* Significant

Table 4.—*Multivariate repeated measurement analysis (year as repeated variable) of worm-eating warbler densities on the MOFEP study areas, 1991-1995.*

Between site effects

Source	df	Mean square	F	P-value
Block	2	118.9	16.50	0.012*
Treatment	2	93.1	6.46	.056
Error	4	7.2		

Within site effects

Source	Pillai's Trace Statistic	F	Numerator df	Denominator df	P-value
Year	.948	4.5	4	1	0.337
Year*Block	1.865	6.9	8	4	.040*
Year*Treatment	1.407	1.2	8	4	.464

* Significant

Table 5.—*Multivariate repeated measurement analysis (year as repeated variable) of Kentucky warbler densities on the MOFEP study areas, 1991-1995.*

Bewteen site effects

Source	df	Mean square	F	P-value
Block	2	4.6	1.42	0.343
Treatment	2	3.8	1.17	.398
Error	4	3.2		

Within site effects

Source	Pillai's Trace Statistic	F	Numerator df	Denominator df	P-value
Year	.981	12.8	4	1	0.206
Year*Block	1.895	9.0	8	4	.025*
Year*Treatment	1.681	2.6	8	4	.183

* Significant

Table 6.—*Multivariate repeated measurement analysis (year as repeated variable) of Acadian flycatcher densities on the MOFEP study areas, 1991-1995.*

Between site effects

Source	df	Mean square	F	P-value
Block	2	196.243	2.49	0.198
Treatment	2	30.452	.39	.702
Error	4	78.709		

Within site effects

Source	Pillai's Trace Statistic	F	Numerator df	Denominator df	P-value
Year	1.000	1,043.0	4	1	0.023*
Year*Block	1.560	1.8	8	4	.304
Year*Treatment	1.439	1.3	8	4	.431

* Significant

Table 7.—*Multivariate repeated measurement analysis (year as repeated variable) of wood thrush densities on the MOFEP study areas, 1991-1995.*

Between site effects

Source	df	Mean square	F	P-value
Block	2	18.5	0.27	0.774
Treatment	2	53.5	.79	.515
Error	4	67.9		

Within site effects

Source	Pillai's Trace Statistic	F	Numerator df	Denominator df	P-value
Year	.944	4.2	4	1	0.348
Year*Block	1.968	31.2	8	4	.002*
Year*Treatment	1.839	5.7	8	4	.055

* Significant

Table 8.—*Multivariate repeated measurement analysis (year as repeated variable) of densities for all birds combined on the MOFEP study areas, 1991-1995.*

Between site effects

Source	df	Mean square	F	P-value
Block	2	6,421.048	10.5	0.026*
Treatment	2	147.475	0 .2	.797
Error	4	611.949		

Within site effects

Source	Pillai's Trace Statistic	F	Numerator df	Denominator df	P-value
Year	0 .835	1.3	4	1	0.575
Year*Block	1.925	12.9	8	4	.013*
Year*Treatment	1.204	0 .8	8	4	.660

* Significant

Table 9.—*Total number of nests, number of nests with eggs, and number of nests that were parasitized, 1991-1995.*

Year	**Total found** *Number*	**With eggs** *Number*	**Parasitized** *Number (Percent)*
1991	353	149	2 (1.3)
1992	323	173	6 (3.5)
1993	398	197	7 (3.6)
1994	269	197	4 (2.0)
1995	423	250	6 (2.4)

Table 10.—*Daily survival rates for all nests in each block of study areas, 1991-1995.*

	Study area block			
Year	**1-2-3**	**4-5-6**	**7-8-9**	**Overall**
1991	0.970 (40)[1]	0.950 (55)	0.945 (44)	0.956 (139)
1992	0.963 (40)	0.952 (66)	0.953 (40)	0.956 (146)
1993	0.962 (55)	0.964 (97)	0.955 (32)	0.962 (184)
1994	0.968 (35)	0.953 (79)	0.966 (61)	0.960 (175)
1995	0.967 (65)	0.963 (87)	0.960 (81)	0.963 (233)
Mean [SE]	0.966 [0.003]	0.956 [0.007]	0.956 [0.008]	0.959 [0.003]

[1]( )=Number of nests

Table 11.—*Analysis of variance for block or treatment effects in daily survival rates for nests of all species combined, 1991-1995.*

Year	**Source**	**df**	**Mean square**	**F**	**P-value**
1991	Block	2	0.0005	3.14	0.151
	Treatment	2	.0005	2.95	.163
	Error	4	.0002		
1992	Block	2	.0002	1.83	.272
	Treatment	2	.0005	3.87	.116
	Error	4	.0001		
1993	Block	2	.0003	.92	.470
	Treatment	2	.0007	2.01	.249
	Error	4	.0004		
1994	Block	2	.0002	.77	.521
	Treatment	2	.0001	.39	.699
	Error	4	.0003		
1995	Block	2	.0001	2.83	.171
	Treatment	2	.0003	15.73	.013*
	Error	4	.0000		

*Significant

Table 12.—*Multivariate repeated measurement analysis (year as repeated variable) of daily survival data for all species combined, 1991-1995.*

Between site effects

Source	df	Mean square	F	P-value
Block	2	0.0007	1.91	0.261
Treatment	2	.0006	1.51	.324
Error	4	.0004		

Within site effects

Source	Pillai's Trace Statistic	F	Numerator df	Denominator df	P-value
Year	0 .874	1.735	4	1	0.510
Year*Block	1.268	.867	8	4	.601
Year*Treatment	1.480	1.422	8	4	.389

Table 13.—*Daily survival rates for ovenbird nests in each block of study areas, 1991-1995.*

	Study area block			
Year	1-2-3	4-5-6	7-8-9	Overall
1991	0.939 (6)[1]	0.940 (13)	0.958 (4)	0.942 (23)
1992	0.968 (5)	0.944 (11)	0.972 (3)	0.956 (19)
1993	0.971 (6)	0.917 (11)	0.943 (2)	0.943 (19)
1994	1.000 (5)	0.928 (15)	0.983 (4)	0.957 (24)
1995	0.976 (3)	0.938 (14)	0.944 (6)	0.947 (23)
Mean [SE]	0.971 [0.022]	0.933 [0.011]	0.960 [0.017]	0.949 [0.007]

[1]( )=Number of nests

species than for the ovenbird. The mean daily nest survival rate for worm-eating warbler nests for all years combined was 0.957 (+/-0.026 SE).

The wood thrush showed daily nest survival rates ranging from 0.914 to 0.977 (table 15), but the mean values of the treatment blocks were remarkably similar. The mean overall daily survival rate for all years combined was 0.961 (+/-0.008 SE).

Daily nest survival rates for the Acadian flycatcher ranged from 0.924 to 0.979 (table 16), with block 1-2-3 showing consistently higher success rates than the other treatment blocks. The mean overall daily nest survival rate for this species was 0.959 (+/-0.004 SE).

To date, we have computed only preliminary estimates of the source/sink status of these populations by year and treatment block. Because these estimates rely heavily on measures of both adult and juvenile mortality, both of which are not accurately known for this area, they can be difficult to calculate. A study by Donovan *et al.* (1995a) that used a subset of MOFEP nests during 1991-1992 showed that ovenbird and wood thrush populations produced young at a rate that qualified for source status, but not all treatment blocks in all years show this trend. For example, a subset of wood thrush nests analyzed by Anders *et al.* (1997) for the years 1994 and 1995 showed lower nest success and possible sink status for this species at that time.

Mist Netting

Of the 13 mist net lines designated per study area, 11 were run in 1991, 12 in 1992 and 1993, and all 13 in 1994 and 1995. The increased intensity of netting in the latter years reflected our operating more concurrent net lines at that time, in part because of the low capture rates discovered in the earlier part of the study. We caught 41 species of birds in the

Table 14.—*Daily survival rates for worm-eating warbler nests in each block of study areas, 1991-1995.*

Year	Study area block 1-2-3	4-5-6	7-8-9	Overall
1991	0.960 (8)[1]	0.949 (2)	0.926 (12)	0.940 (22)
1992	0.962 (8)	0.945 (13)	0.978 (5)	0.958 (26)
1993	0.949 (7)	0.949 (2)	0.879 (5)	0.923 (14)
1994	0.946 (5)	0.985 (9)	1.000 (4)	0.983 (18)
1995	0.965 (5)	0.987 (9)	1.000 (4)	0.980 (18)
Mean [SE]	0.956 [0.008]	0.963 [0.021]	0.957 [0.053]	0.957 [0.026]

[1]( )=Number of nests

Table 15.—*Daily survival rates for wood thrush nests in each block of study areas, 1991-1995.*

Year	Study area block 1-2-3	4-5-6	7-8-9	Overall
1991	0.914 (4)[1]	0.957 (15)	0.973 (5)	0.953 (24)
1992	0.970 (7)	0.956 (13)	0.938 (6)	0.957 (26)
1993	0.977 (10)	0.977 (18)	0.943 (6)	0.973 (34)
1994	0.960 (3)	0.953 (10)	0.961 (14)	0.958 (27)
1995	0.961 (8)	0.953 (14)	0.971 (22)	0.964 (44)
Mean [SE]	0.956 [0.025]	0.959 [0.010]	0.957 [0.016]	0.961 [0.008]

[1]( )=Number of nests

Table 16.—*Daily survival rates for Acadian flycatcher nests in each block of study areas, 1991-1995.*

Year	Study area block 1-2-3	4-5-6	7-8-9	Overall
1991	0.979 (19)[1]	0.924 (15)	0.930 (15)	0.954 (49)
1992	0.962 (12)	0.954 (15)	0.954 (14)	0.956 (41)
1993	0.947 (20)	0.972 (27)	0.961 (9)	0.964 (56)
1994	0.966 (12)	0.962 (22)	0.959 (10)	0.962 (44)
1995	0.965 (26)	0.955 (22)	0.956 (16)	0.960 (64)
Mean [SE]	0.964 [0.011]	0.953 [0.018]	0.952 [0.013]	0.959 [0.004]

[1]( )=Number of nests

nets, of which 31 (76 percent) were Neotropical migrants. The red-eyed vireo (*Vireo olivaceus*) was the most caught species, with the Acadian flycatcher next most abundant (table 17). Only three cowbirds were captured in 5 years of netting. Captures varied by treatment block (table 18), but given the annual variation in total captures (708 birds in 1995 vs. 1,425 in 1994), it is difficult to determine what this variation means.

Capture rates per net line were low, which is typical of breeding season netting in mature forest. After mid-July, they were even lower, and it was common to catch no birds in mist net lines run after this time. This precipitated our concentrating the netting effort in late June and early July in 1994 and 1995. Although the 1994 totals suggested this was a wise move, the lack of captures in 1995 was puzzling. Results from a radio-tracking study of wood thrush

Table 17.—*Numbers of the five focal species, two commonly caught species, and other birds caught in mist nets, 1991-1995.*

	Species							
Year	Ovenbird	Worm-eating warbler	Kentucky warbler	Acadian flycatcher	Wood thrush	Red-eyed vireo	Scarlet tanager	Other
1991	64	90	37	110	82	239	46	274
1992	50	41	10	120	97	238	81	332
1993	64	47	18	115	62	244	74	262
1994	94	92	19	120	90	412	106	492
1995	49	30	17	108	27	196	45	236

Table 18.—*Numbers of birds (all species) caught in mist nets and banded in each study area and block, 1991-1995.*

Study area	1991	1992	1993	1994	1995	Totals
1	86	133	108	129	70	526
2	195	116	160	228	102	801
3	119	110	65	212	71	577
Block total	400	359	333	569	243	1,904
4	88	116	67	145	48	464
5	103	71	87	95	46	402
6	81	100	91	148	61	481
Block total	272	287	245	388	155	1,347
7	75	95	110	163	101	544
8	83	96	81	151	124	535
9	112	132	117	154	85	600
Block total	270	323	308	468	310	1,679
Totals	942	969	886	1,425	708	4,930
No. recaptured	—	24	70	104	65	263
Percent recaptured		2.5	7.9	7.3	9.2	5.3

(Anders *et al.* 1997) and several intern projects suggest that the forest birds move into the denser cover of clearcuts and riparian vegetation later in the breeding season, which may account for our lower capture rates in late July.

Recapture rates of previously banded birds also were low, although they increased annually (table 18). The low value in 1992 reflects a smaller pool of banded birds from which recaptures could occur.

The mist netting data were subjected to capture/recapture analysis using program JOLLY (Pollock *et al.* 1990). Unfortunately, we did not have enough data for any of the individual species to obtain species-specific estimates, so we tried to combine the data. The attempted groupings were: (1) all birds, regardless of species, and (2) a "guild" approach, combining the five focal species plus red-eyed vireo, scarlet (*Piranga olivacea*) and summer (*P. rubra*) tanagers, and indigo bunting (*Passerina cyanea*). Even after grouping, however, the data were too sparse to obtain reasonable estimates at the study area or block level. The only two groupings of the data that were successfully run through the program were for all study areas combined. Given the number of species that were represented in these analyses, assumptions of homogeneous capture and survival probabilities across individuals and among species would be more than suspect. Therefore, models of population dynamics cannot be developed using these data.

Although the banding results have been disappointing in many ways, this aspect of the study will not be abandoned. Our dataset represents one of the largest breeding ground banding efforts in North America. With the addition of harvest treatments and the expected increase in nettable birds, the MOFEP bird banding effort may achieve more definitive results in the future.

CONCLUSIONS AND PREDICTIONS

MOFEP is designed to be a long-term experiment. Our goal during 1991 through 1995 was to understand the spatial and temporal variation in avian characteristics of our study sites so that we could truly measure the effects of the forest treatments that will occur on them; we feel we are in an excellent position to do that during the coming years.

At the time we developed our protocol for MOFEP, we had some ideas about how the different timber harvest practices might affect bird communities following the treatments, but these were general hunches. During the pretreatment phase of MOFEP, several papers were published that improved our ability to predict which species will be most affected by the conditions that will occur post-treatment. Thompson *et al.* (1992) surveyed birds in forests with and without clearcutting elsewhere in the Ozarks, while Annand and Thompson (1997) surveyed species in a variety of forest regeneration types. Wenny *et al.* (1993) provided detailed measures of habitat preferences of two of the focal species. All of these studies provide insight into how different species may respond to different treatments. In a more general way, Thompson (1993) modeled how birds with negative responses to the creation of edge may respond differently to the even-aged and uneven-aged harvest techniques tested in MOFEP.

These articles suggest that forest interior species living in the three study sites receiving even-aged treatments should lose the percentage of territories located in stands that were harvested. This percentage varies by species, but, for example, was 15 percent for ovenbirds on study site 5. It is possible some sort of edge effect might reduce densities in forest around the clearcuts, but this remains to be seen. If site faithfulness prevails, it is possible that densities of birds in the uncut forest might increase, at least for awhile. For even-aged management, the negative effects of forest management on forest interior birds should be confined to the cut areas and their immediate vicinity.

Sites with even-aged treatments also must be studied for the potential positive effects that clearcuts will have on second-growth habitat species that invade clearings sometime in the first year or two after cutting. Species such as prairie warbler (*Dendroica discolor*), yellow-breasted chat (*Icteria virens*), and indigo bunting, to name just a few, will become abundant in these sites where they were rare or nonexistent before. There is some evidence that these species have much lower parasitism and nest predation rates in the Ozarks than elsewhere in Missouri, which may mean that these clearcuts are important source habitats for these species. Although the positive benefit of these clearcuts may take longer to measure, it is very possible that it will be quite pronounced for certain species.

The effects of uneven-aged treatment will be harder to predict, in part because less work has been done on this management technique, and because it involves more subtle changes in vegetation structure without the addition of large areas of a new habitat. The results of Annand and Thompson (1997) suggest that abundances of hooded warbler (*Wilsonia citrea*) will go up dramatically following uneven-aged treatment, while densities of worm-eating warbler and black-and-white warbler (*Mniotilta varia*) may increase somewhat. It is less clear if the increase in edge caused by the many clearings associated with uneven-aged management will reduce nesting success of the remaining species appreciably. In general, the Ozarks have low densities of cowbirds, so parasitism rates will be lower than in more fragmented regions. The data of Annand and Thompson (1997) also suggest that densities of Acadian flycatcher and ovenbird will be reduced in areas with uneven-aged management. Given that as many as 70 percent of ovenbird territories may occur where at least some trees are removed in an area with uneven-aged management, negative effects on these forest interior species could be measurable. It is quite possible, though, that there may be a 1- or 2-year time lag in some of these effects, because some birds may return to territories where they previously occurred despite the loss of trees, while subsequent males may be unwilling to use these areas for establishing breeding territories because of their changed vegetation structure.

Although we can make some quantitative predictions of possible effects based on the area of mature forest that is harvested, and some qualitative predictions from prior studies in different habitats, the beauty of MOFEP is the combination of its experimental design, its large scale, and long-term nature. Over the next 3 years and more, we should be able to measure in detail the distributional shifts of forest birds in response to the cuts, the addition of new birds in clearcuts and, perhaps, group and single tree openings, and the demographic effects of the two management schemes on all the birds common in these forests. With the strength of our 5 years of preliminary data, we and subsequent researchers should have a chance to gain unprecedented insight into the effects of these forest management techniques on the demography of migrant and resident birds. The pre-treatment data will allow us to see the immediate avian response to cutting, although decades and subsequent cutting cycles will be needed to evaluate the complete response. If the Ozarks truly are a population source region for other parts of the Midwest, we should be able to design a management plan that maintains the integrity of this resource for future generations of both songbirds and humans.

ACKNOWLEDGMENTS

We acknowledge a debt of gratitude to the many people who have helped us conduct this research. An accurate accounting of everyone who has contributed to the bird study would produce a list too extensive to include in this report. To those whom we have not named, our apologies. Major on-site assistance was rendered by Randy Jensen and Jenny Grabner. Carol Bruce coordinated paper work for the student interns at the University of Missouri. Paul Porneluzi lived with the students on-site and helped tremendously in all aspects of the study. Zhuoqiong He and Steve Sheriff assisted with data analysis. And, of course, we couldn't have accomplished this study without the 100+ students who spent their summers working in the Ozark hills.

LITERATURE CITED

Anders, A.D.; Faaborg, J.; Thompson, F.R., III. 1997. Juvenile survival in a population of Neotropical migrant birds. Conservation Biologist. (In press).

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

Brookshire, B.L.; Jensen, R.; Dey, D.C. 1997. The Missouri Ozark Forest Ecosystem Project: past, present, and future. In: Brookshire, Brian L.; Shifley, Stephen R., eds. Proceedings of the Missouri Ozark Forest Ecosystem Project symposium: an experimental approach to landscape research; 1997 June 3-5; St. Louis, MO. Gen. Tech. Rep. NC-193. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 1-25.

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

Donovan, T.M.; Lamberson, R.H.; Thompson, F.R. III; Faaborg, J. 1995b. Modeling the effects of habitat fragmentation on source and sink demography of Neotropical migrant birds. Conservation Biologist. 9: 1396-1407.

Donovan, T.M.; Clark, D.A.; Howe, R.W.; Danielson, B.J. 1996. Metapopulations, sources and sinks, and the conservation of Neotropical migratory birds in the Midwest. In: Thompson, F.R., III, ed. Management of Midwestern landscapes for the conservation of Neotropical migratory birds; 1995 December 5; Detroit, MI. Gen. Tech. Rep. NC-187. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 41-52.

Ewert, D.N.; Hamas, M.J. 1996. Ecology of migratory landbirds during migration in the Midwest. In: Thompson, F. R., III, ed. Management of Midwestern landscapes for the conservation of Neotropical migratory birds; 1995 December 5; Detroit, MI. Gen. Tech. Rep. NC-187. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 200-208.

Faaborg, J.; Arendt, W.J. 1992. Long-term declines of winter resident warblers in a Puerto Rican dry forest: which species are in trouble? In: Hagan, J.M.; Johnston, D.W., eds. Ecology and conservation of Neotropical migrant landbirds. Washington, DC: Smithsonian Institute Press: 57-63.

Finch, D.M.; Stangel, P.W. 1993. Status and management of Neotropical migratory birds. Gen. Tech. Rep. RM-229. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 422 p.

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 Biologist. 4: 193-196.

Hagan, J.M.; Johnston, D.W., eds. 1992. Ecology and conservation of Neotropical migrant landbirds. Washington, DC: Smithsonian Institute Press. 609 p.

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.

Kurzejeski, E.W.; Clawson, R.L.; Renken, R.R.; Sheriff, S.L.; Vangilder, L.D.; Hauser, C.; Faaborg, J. 1993. Experimental evaluation of forest management: the Missouri Ozark Forest Ecosystem Project. Transactions of the 58th North American Wildlife and Natural Resource Conference: 599-609.

Latta, S.C.; Baltz, M.E. 1997. Population limitation in Neotropical migrant birds: a comment on Rappole and McDonald (1994). Auk. (In press).

Littell, R.C.; Milliken, G.A.; Stroup, W.W.; Wolfinger, R.D. 1996. SAS system for mixed models. Cary, NC: SAS Institute Inc. 633 p.

Martin, T.E.; Finch, D.M. 1995. Ecology and management of Neotropical migratory birds. Oxford: Oxford University Press. 489 p.

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.

Moore, F.R.; Simons, T.R. 1992. Habitat suitability and stopover ecology of Neotropical landbird migrants. In: Hagan, J.M.; Johnston, D.W., eds. Ecology and conservation of Neotropical migrant landbirds. Washington, DC: Smithsonian Institute Press: 345-355.

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.

Pollock, K.H.; Nichols, J.D.; Brownie, C.; Hines, J.E. 1990. Statistical inference for capture-recapture experiments. Wildlife Monographs. 107: 1-97.

Rappole, J.H.; McDonald, M.V. 1994. Cause and effect in population declines of migratory birds. Auk. 111: 652-660.

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.; 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, S.K. 1996. Threats to breeding Neotropical migratory birds in the Midwest. In: Thompson, F.R., III, ed. 1996. Management of Midwestern landscapes for the conservation of Neotropical migratory birds; 1995 December 5; Detroit, MI. Gen. Tech. Rep. NC-187. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 1-21.

Thompson, F.R., III. 1993. Simulated responses of a forest-interior bird population to forest management options in central hardwood forests of the United States. Conservation Biologist. 7: 325-333.

Thompson, F.R., III, ed. 1996. Management of Midwestern landscapes for the conservation of Neotropical migratory birds; 1995 December 5; Detroit, MI. Gen. Tech. Rep. NC-187. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 207 p.

Thompson, F.R., III; Fritzell, E.K. 1990. Bird densities and diversity in clearcut and mature oak-hickory forest. Res. Pap. NC-293. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 7 p.

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: 23-30.

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.