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**ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM:  
BIRD SPECIES AND COMMUNITIES**

**ANNUAL REPORT: 1991**

**SUBCONTRACT NUMBER: EO6549-84-011**

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**TABLE OF CONTENTS**

	<b>Page</b>
List of Figures . . . . .	vi
List of Tables . . . . .	vi
Summary . . . . .	vii
Abstract . . . . .	ix
Introduction . . . . .	1
Experimental Design . . . . .	3
Study Areas . . . . .	6
Methods . . . . .	8
Statistical Analyses . . . . .	11
Results . . . . .	13
Discussion . . . . .	22
Literature Cited . . . . .	33
Appendix 1 . . . . .	39
Appendix 2 . . . . .	51
Appendix 3 . . . . .	69
Appendix 4 . . . . .	77

## SUMMARY

This investigation was designed to isolate effects of electromagnetic (EM) fields produced by extremely low frequency (ELF) antenna systems on bird species breeding in or migrating through Wisconsin and Michigan. Specifically, we seek to determine if bird species richness and abundance differ between areas that are close to the antenna and those that are far enough away to be unaffected by the antenna. We are pursuing this question at both the community and species level. Characteristics examined include total species richness and abundance, abundances of common bird species, and abundances of birds within selected guilds. Our monitoring program has included bird censuses in both states over a five month period from May to September, 1986-1991. Additional data were collected in August-September 1984 and in June 1985, in both states. Bird censuses were terminated in Wisconsin after 1989 but are continuing in Michigan.

No consistent patterns have yet emerged to demonstrate that birds are more or less abundant on treatment relative to control segments in either state after effects of habitat are accounted for. Further, few significant differences have been found at the community or species level; differences in one season or year are not always repeated in subsequent years or seasons. Most differences that exist between treatment and control transects can be attributed to habitat differences or chance rather than to electromagnetic field differences.

crowned Kinglet, Hermit Thrush, Red-eyed Vireo, Nashville Warbler, Black-throated Green Warbler, Ovenbird, and White-throated Sparrow. The most abundant species present on treatment and control segments varied among seasons.

Twenty-seven of 193 comparisons (14%) of individual species between treatment and control segments were significantly different. Abundances were higher on treatment segments in 20 cases (74%). Few species, however, were consistently and significantly more abundant on either treatment or control segments among seasons within a year or within seasons among years. Differences between treatment and control segments were most likely due to habitat differences.

Species were classified into guilds on the basis of foraging behavior and preferred breeding habitat. Few significant differences in abundance of birds within different guilds were found between treatment and control segments. Differences were most consistent for habitat categories (e.g., birds that prefer deciduous forest were more abundant on control segments in 4 of 5 months), providing further evidence that habitat differences were responsible for many of the observed differences in bird distribution patterns between treatment and control segments.

Previous analyses of vegetation on Michigan study sites (Blake et al. 1988) revealed differences between treatment and control plots. The difference most likely to influence bird populations was distribution of coniferous and deciduous habitats. Treatment segments supported more coniferous and lowland habitats than did control segments. It is important to note that habitat differences that exist between treatment and control areas will not affect our analysis of antenna effects. The Michigan study is designed as a before-and-after experiment; we can compare changes in bird abundance over time on treatment segments and on control segments. If

## INTRODUCTION

Natural disturbances are increasingly recognized as integral components of most, if not all, biotic communities (Pickett and White 1985). Disturbances vary on both temporal and spatial scales and can substantially affect structure and organization of communities as well as the population dynamics of individual species. Anthropogenic disturbances also influence most, if not all, communities; these latter disturbances frequently are cause for concern because of their potential to disrupt population dynamics and community structure.

The types of disturbances caused by human activities are numerous and, like natural disturbances, differ in level of intensity and effects on populations and communities. One of the most ubiquitous disturbances is the network of transmission lines that crisscross the country. These transmission lines form long, linear breaks in the natural cover and emit electromagnetic (EM) radiation of different intensities. Potential effects of EM radiation, from various sources, have been the subject of much recent attention (Carstensen 1987, Pool 1990a-c).

Effects of extremely low frequency (ELF) electromagnetic fields on birds are poorly understood (National Academy of Sciences 1977; Lee et al. 1979; other references in Hanowski et al. 1987, 1991). Several investigators have studied effects of transmission lines on structure and composition of bird communities; most have analyzed combined effects of habitat alteration and EM fields (Anderson et al. 1977; Anderson 1979; Dawson and Gates 1979; Meyers and Provost 1979; Stapleton and Kiviat 1979; Bell 1980; Bramble et al. 1984; Niemi and Hanowski 1984). Others have focused on effects of the right-of-way (ROW) edge (Chasko and Gates 1982;

study. Research in Michigan was, in contrast, initiated before the antenna began operation. By following changes in bird numbers over time on areas affected by the antenna and on unaffected areas, we can separate any effects of the antenna on birds from effects of more regional variables (e.g., annual variation in rainfall) and from effects arising from differences in vegetation structure between control and treatment areas. The Michigan transmitter was tested intermittently, at less than full power during parts of our 1988 field season and at full power during most of our 1989 field season. Continuous operation at full power began on 7 October 1989. Therefore, 1991 represents the third full impact year. In the following we summarize our research activities in Michigan for 1991, the sixth year in which censuses were conducted during all seasons.

### EXPERIMENTAL DESIGN

The first steps in the experimental design were to (1) evaluate techniques for sampling birds; and (2) determine sample sizes required to detect a specified difference between control and treatment areas. We examined four potential sampling techniques: transect counts, point counts, territorial mapping, and mist-netting. Territorial mapping and mist-netting were eliminated from consideration because of the amount of effort required to obtain statistically reliable results. We selected transect counts instead of point counts because the ELF communications system consists of a long, linear network of antenna and ROW and transects could be run parallel to this network. Transects also included a larger sample area than would have been included in point counts.

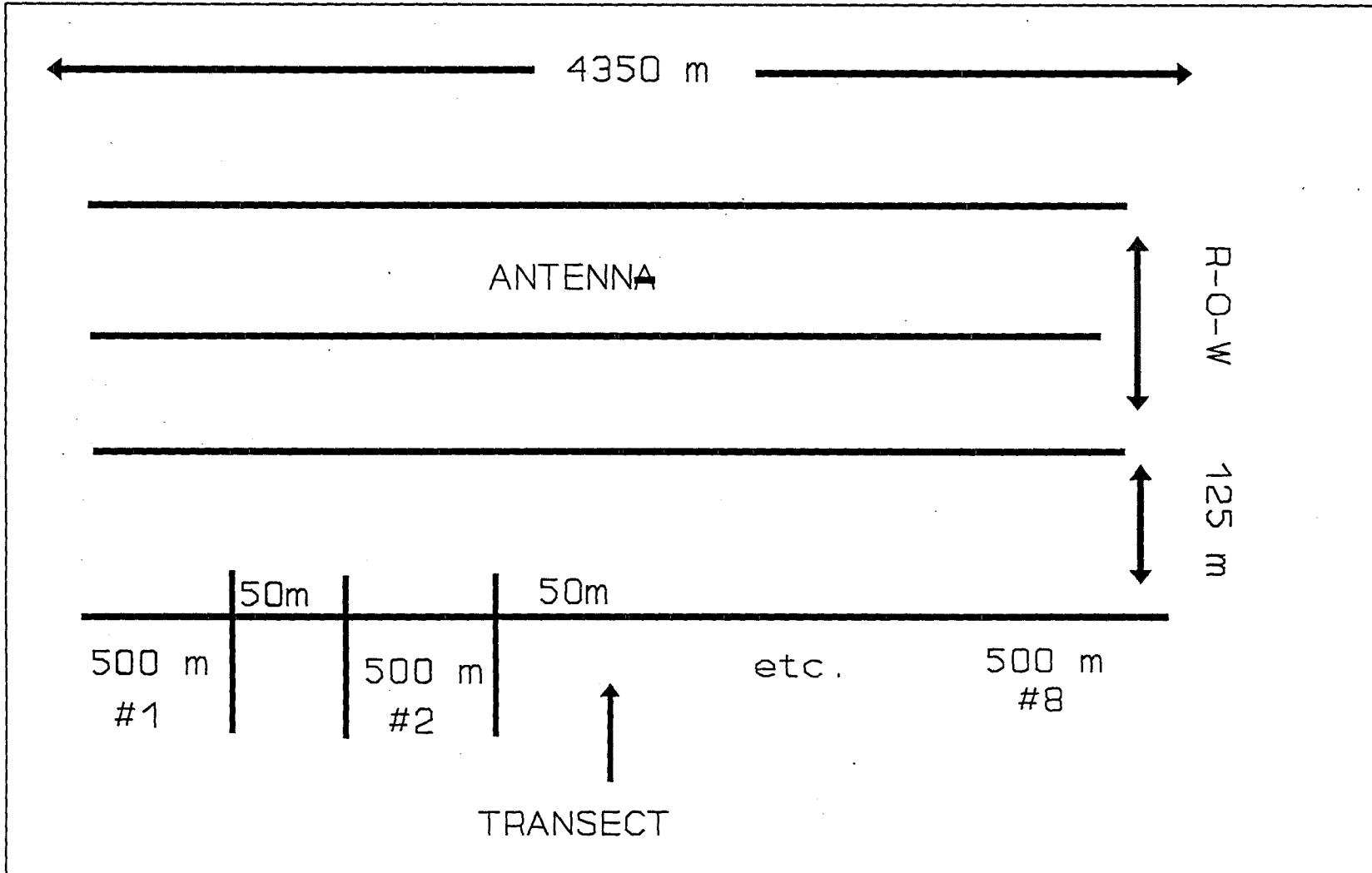


Figure 1. Schematic of a treatment transect layout. ROW = right-of-way.

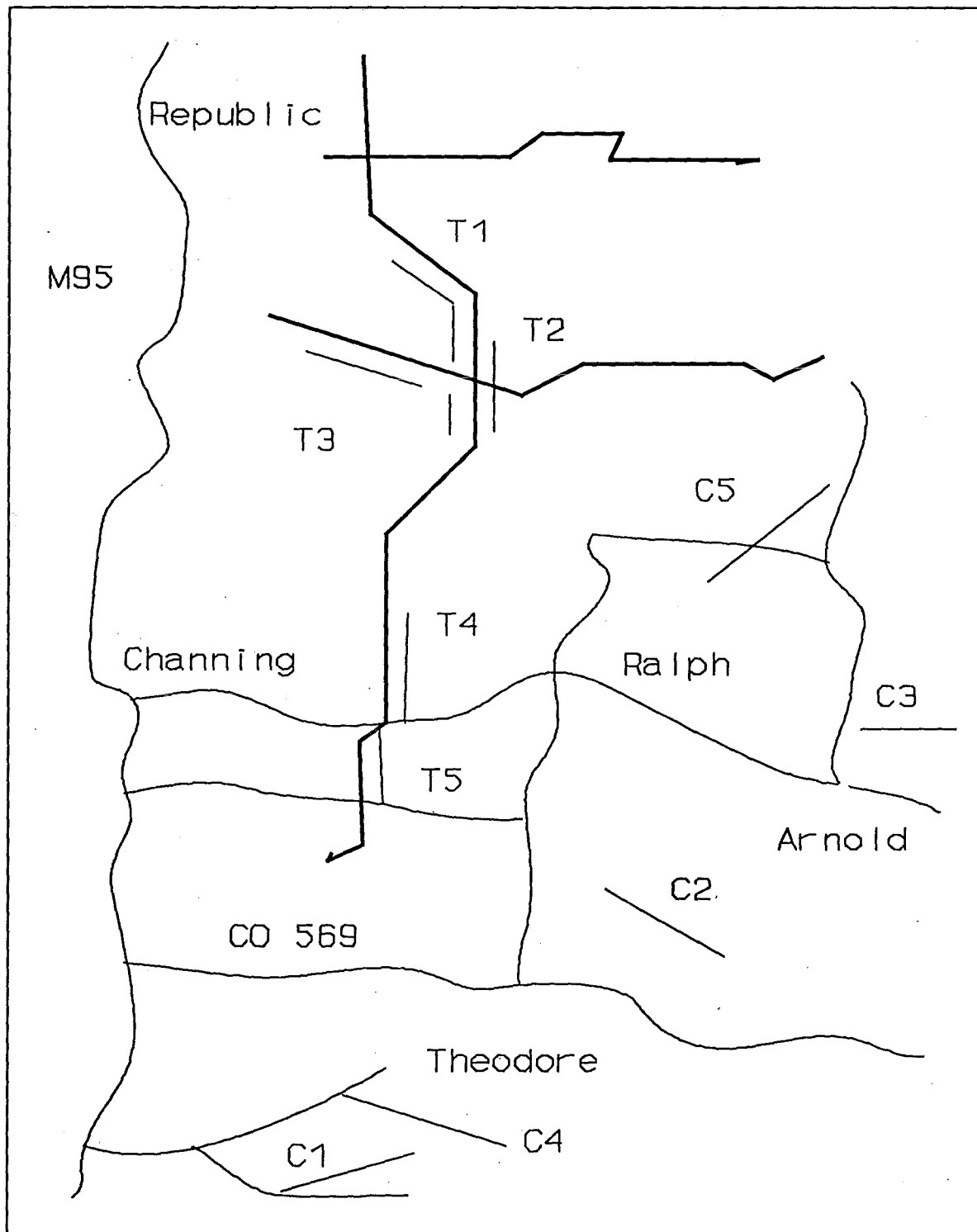


Figure 2. Locations of control (C1 to C5) and treatment (T1 to T5) transects in Michigan.

Table 1. Summary of Michigan transect locations and proposed logging of study areas effective through 1991. Asterisks denote sections that were logged in 1987 (\*), 1988 (\*\*), 1989 (\*\*\*), and 1990 (\*\*\*\*). No additional study areas in Michigan are scheduled to be logged before the end of the study.

Number and Name affected	Township	Range	Sections	Number of 500 m segments
C1 Carney Lake	41N	29W	33,34,35,36	2 (1992)
C2 Skunk Creek	42N 42N	28W 27W	14,23,24 19,30	2 (1992)
C3 Arnold	43N 43N	25W 25W	31,32,33,34 32	1 * 1 ***
C4 Lost Lake	41N	29W	21,26,27,28,35	2 **
C5 Bob's Creek	44N	26W	13,23,24,26	1 ****
T1 Heart Lake	45N 45N	28W 28W	7,18 19	1 1 ***
T2 Flat Rock Creek	44N 45N	28W 28W	6 19,30,31	3 *
T3 Schwartz Creek	45N 45N	28W 29W	31 26,27,35,36	2 **
T4 Turner Road	43N 44N	29W 29W	1,11,12 36	0
T5 Leeman's Road	43N	29W	14,23,26,35	0

behavior and breeding habitat. Consequently, we used those guilds in analyses of the effects of the ELF antenna during 1991.

## STATISTICAL ANALYSES

### WITHIN YEAR COMPARISONS

We used one-way analysis-of-variance (ANOVA) or Kruskal-Wallis test (Sokal and Rohlf 1981) to test for differences between control and treatment segments for the following variables: (1) mean number of individuals observed in a 500 m segment in control or treatment areas during each season; (2) mean number of species observed in a 500 m segment in control or treatment areas during each season; and (3) mean abundance of individual species on control or treatment areas.

Variables were examined for normality of residuals (Wilk-Shapiro test; skewness and kurtosis) and homogeneity of variance (Bartlett's test) prior to statistical analyses (Sokal and Rohlf 1981). Variables were transformed where necessary (e.g., logarithmic, square root) to reduce skewness, kurtosis, and heterogeneity of variances. A nonparametric test (Kruskal-Wallis test) was used when assumptions were not met, even after transformation.

In previous years (e.g., Blake et al. 1991), we used G-tests to compare distribution and abundance of less common species on treatment and control segments on the basis of prominence values:

$$PV = D * F^{0.5},$$

where D = number of individuals observed and F = the relative frequency of species occurrence on treatment or control segments. The prominence value weights both the frequency of occurrence and number of individuals (Beals 1960; Blake 1982) and

post-operational analyses, results of analyses through 1990, and a summary of antenna operation are in Appendix 2.

## PROBABILITY VALUES

To simplify and condense the results section, we eliminated all probability ( $P$ ) values from the text. Any difference stated in this section was significant to at least the  $P < 0.05$  level.

## RESULTS

### WITHIN-YEAR COMPARISONS

#### *Species Richness and Abundance of Individuals*

Total number of species and individuals observed varied among seasons on control and treatment transects (Tables 2, 3). Observations for all species are in Appendix 3. Total abundance was highest and approximately equal during June and July (Table 2). Bird abundance and species diversity were significantly higher on control segments during May and July, but no other differences between treatment and control segments were significant at the community level in 1991 (Table 3).

#### *Individual Species*

Particularly common species during spring migration (May; Appendix 3) included Black-capped Chickadee, Yellow-rumped Warbler, and White-throated Sparrow on treatment segments; Ovenbirds and Black-throated Green Warblers were abundant on controls. Six species (16% of 38 tested) showed a significant difference in abundance between controls and treatments (Table 4); only the White-throated Sparrow was more abundant on controls.

Table 3. Mean observations in a 500m segment on control (C) and treatment (T) segments in Michigan, 1985-91; significance of one-way ANOVAs between treatment and control segments is shown for each year. For two-way ANOVAs, T = treatment effect, Y = year effect, and I = interaction. Two-way ANOVAs were calculated with logged segments excluded.

Month	1985		1986		1987		1988		1989		1990		1991		ANOVA		
	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	Y	I
May:																	
individuals			23.7	**30.3	19.4	22.2	20.4	*23.5	14.3	15.2	21.2	21.4	14.5	*19.5	xxx	xxx	
species			9.7	**12.9	8.1	**10.8	9.5	11.0	7.7	8.2	9.9	11.3	7.7	*9.8	xxx	xxx	
June:																	
individuals	40.8	**33.3	27.5	29.2	28.3	29.1	26.5	25.4	24.6	25.5	21.9	22.0	22.4	22.7		xxx	x
species	14.2	14.0	11.1	12.5	12.5	12.9	12.4	13.1	11.7	12.9	10.4	*12.1	10.5	11.7	xx	xxx	
July:																	
individuals			23.5	24.5	28.4	31.5	22.1	22.7	24.9	26.0	19.3	20.4	22.3	**27.6	x	xxx	
species			9.6	10.4	11.8	14.4	11.1	11.0	10.8	11.8	9.2	9.7	9.7	**12.3	xxx	xxx	
August:																	
individuals			9.6	12.0	17.1	15.3	14.1	11.7	19.8	13.8	8.1	8.8	14.0	13.8		xxx	
species			4.6	5.2	7.3	6.7	6.1	5.8	7.7	6.5	4.0	4.5	5.3	6.2		xxx	
September:																	
individuals			10.1	*15.7	15.9	12.5	11.7	14.4	12.6	10.9	9.7	12.2	15.3	12.8			x
species			4.0	5.6	5.4	5.1	5.0	5.6	5.0	4.7	4.7	*6.0	5.2	5.7	x		

\* P < 0.05; \*\* P < 0.01; \*\*\* P < 0.001

The Ovenbird was the most abundant species in June on control and the Nashville Warbler was the most abundant on treatment segments (Appendix 3). Three species were significantly more abundant on control segments and three on treatment segments (Table 4; 6 significant differences out of 52 species tested; 12%).

Abundant species during July (late breeding) included the Nashville Warbler and Ovenbird on treatment segments and Ovenbirds, Red-eyed Vireos, and Black-capped Chickadees on control segments (Appendix 3). Six species (13% of 46 tested) showed a significant difference in abundance between controls and treatments (Table 4); all were more abundant on treatments.

Cedar Waxwings were common on treatment segments and Black-capped Chickadees were common on both treatment and control segments during July (Appendix 3). Seven species (24% of 29 tested) showed a significant difference in abundance between control and treatment segments (Table 4). Four species were more abundant on treatment segments and three on controls.

Bird communities during late fall migration (September) were dominated by Black-capped Chickadees and Red-breasted Nuthatches (Appendix 3). Only two species, Winter Wren and Black-and-white Warbler, differed in abundance between control and treatment segments (Table 4; 7% of 28 tested); both were more abundant on treatment segments.

#### *Guild Composition*

Few significant differences (3 of 25 tests) in abundance of different foraging guilds were noted between treatment and control segments (Table 5). Differences in abundance were significant in May and July for foliage insectivores and in July for

bark insectivores. In all three cases, birds within these guilds were more abundant on treatment segments.

Differences were slightly more pronounced among habitat guilds (20% or 6 of 30 tests were significant; Table 5). Birds preferring deciduous forest habitats were more common on control segments during May and July. Birds preferring early successional habitats were more abundant on treatment segments during May, June, and August.

### **AMONG-YEAR COMPARISONS**

Considerable annual variation in abundance of individuals and species was noted (Table 3). Abundance has tended to decline during much of this study (Figs. 3, 4), perhaps reflecting the series of droughts that have affected much of the region (see Blake et al. in press), although a slight upturn in numbers was noted in 1991. Although some treatment effects have been noted for individuals during May and for species during May, June, and July (Table 2). Overall, annual variation in abundance and species richness has been considerably greater than variation associated with treatments.

There were few significant differences between treatment and control segments in the average change in abundance of birds from pre-impact years (1986, 1987) to 1991, a full impact year. There were no differences when changes were examined at the community level (total individuals or species) and only 7 when individual species were examined (Table 6). As this represents only 5.3% of the number of species tested, it is no more than might be expected by chance.

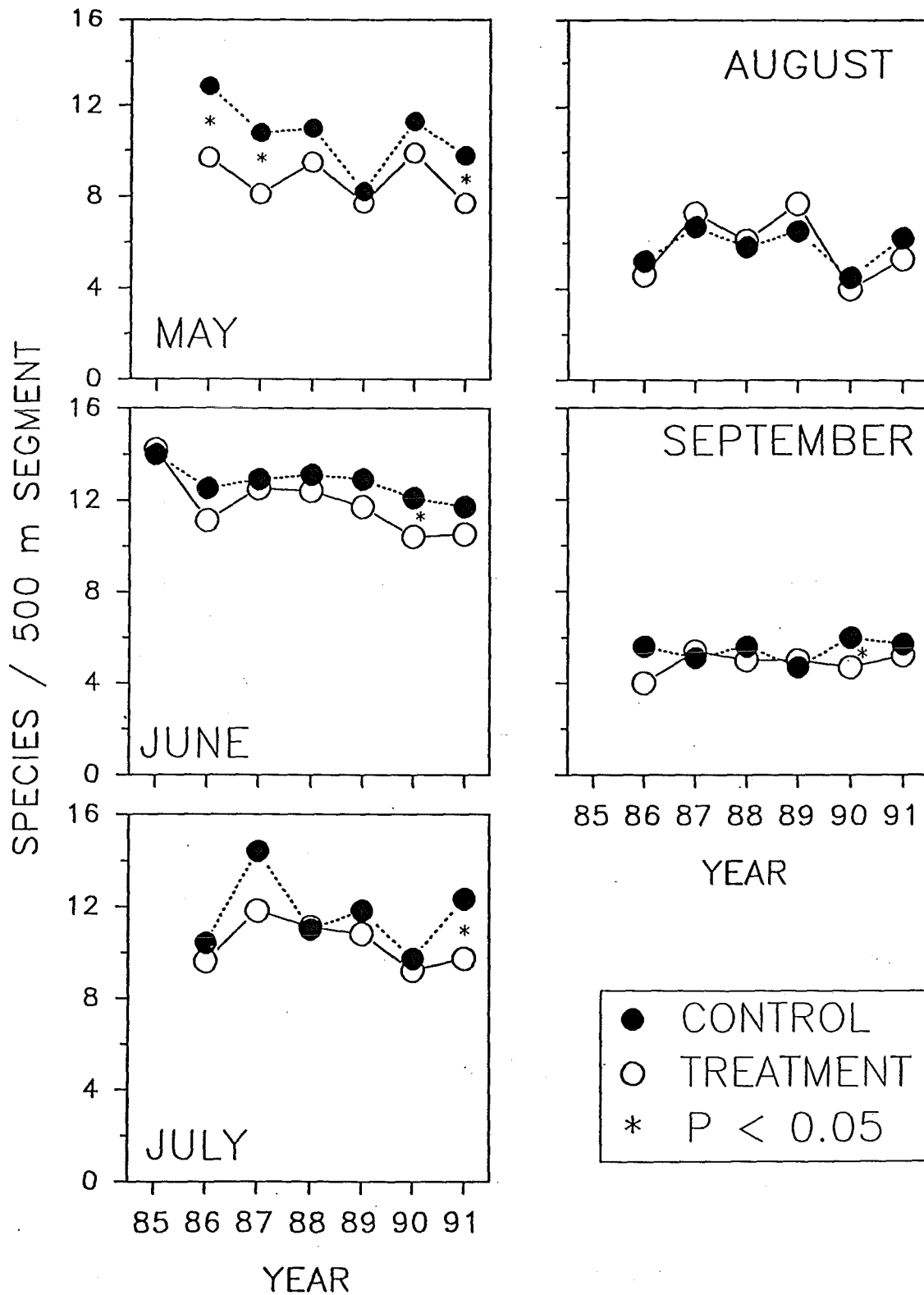


Figure 4. Mean number of species recorded per 500 m on treatment and control segments in Michigan.

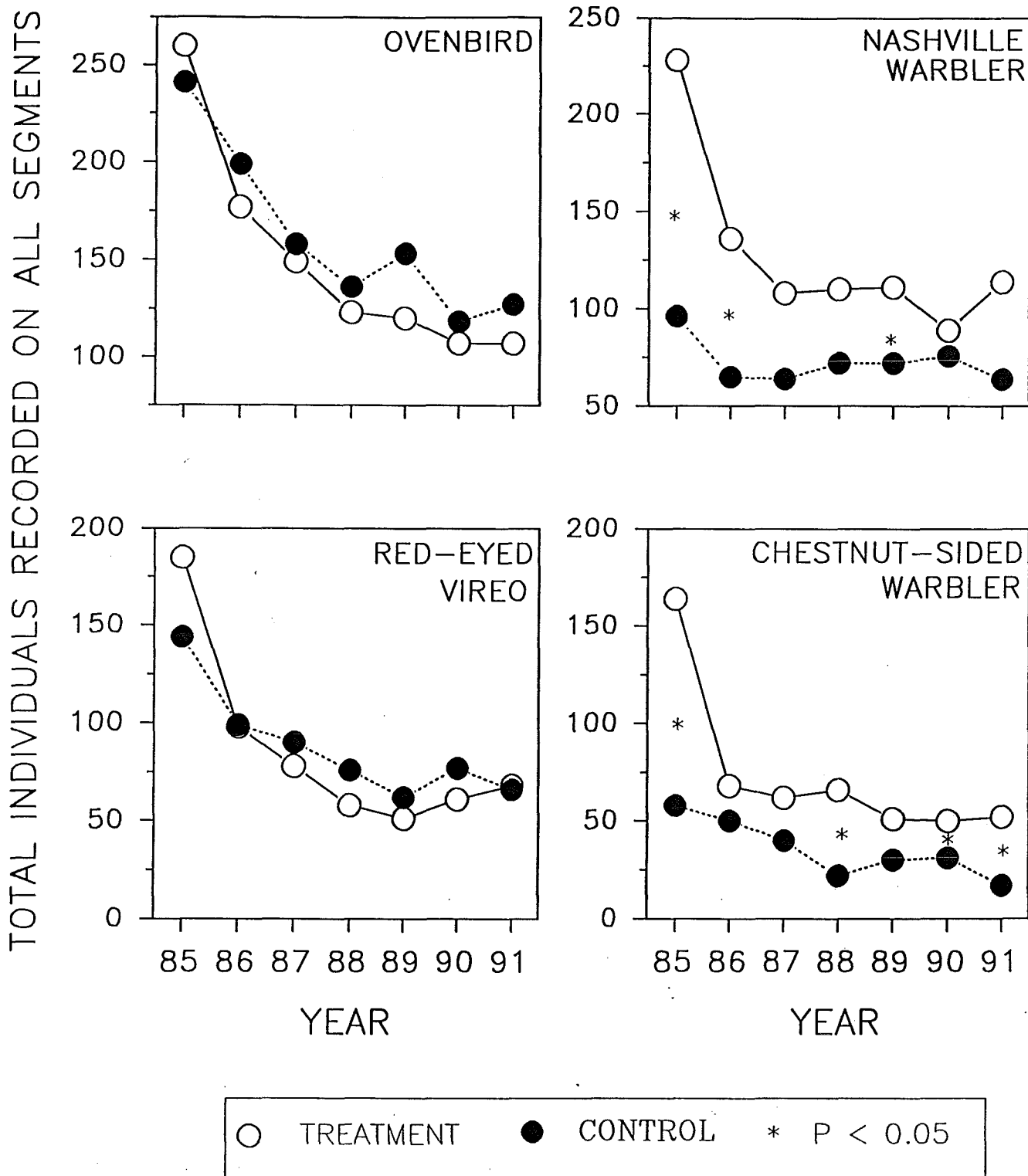


Figure 5. Total number of individuals of four abundant migrants recorded during June on all treatment and control segments in Michigan.

Relatively few differences in abundance of birds in different guilds were noted between treatment and control segments in Michigan in 1991 or either state in previous years (Blake et al. 1991, Hanowski et al. 1991). Differences that did exist likely reflected differences in habitat that exist between treatment and control segments. Treatment segments in Michigan have more early successional habitats than do control areas and birds breeding in such habitats showed the strongest treatment effect, being more abundant on treatment segments (e.g., Chestnut-sided Warbler, Fig. 5). A similar result was noted for earlier years (Blake et al. 1991). Deciduous forest habitat is more common in control areas and coniferous habitats more common in treatment segments in both states (Blake et al. 1988); distribution of birds preferring deciduous habitat followed a similar trend.

#### **INDIVIDUAL SPECIES**

Habitat or EM related differences that exist between treatment and control segments may not influence all bird species in the same manner. If some species are more abundant on control and others on treatment segments, then such differences might cancel each other, producing nonsignificant results at the community level. If differences between treatment and control segments (either related to habitat or EM fields) are primary factors influencing distribution patterns of individual species, then we might expect those species to show similar patterns among years and seasons.

There have, however, been relatively few cases where differences in abundance of a species between treatment and control segments have remained consistently significant among seasons and years in Michigan (Table 7; Fig. 5). A total of 50 species in Michigan have shown a significant difference in abundance between

Table 7 (continued).

Species	More on treatment					More on control				
	M	Ju	Jy	A	S	M	Ju	Jy	A	S
Black-throated Green Warbler						2	1			
Blackburnian Warbler								1		
Black-and-white Warbler						3				1
Ovenbird						3		2		
Common Yellowthroat							2	1	1	
Canada Warbler							1			
Scarlet Tanager							1	1		
Rose-breasted Grosbeak						1	2	1		
Swamp Sparrow						1		1		
Red-winged Blackbird						2	5	3		
Common Grackle							1			
Brown-headed Cowbird						1	2			
Purple Finch						1				
Number of species	6	14	6	9	3	18	17	20	8	7
Number significant differences	8	28	11	12	4	33	29	27	9	7

<sup>a</sup> M = May; Ju = June; Jy = July; A = August; S = September.

contrast, deciduous woods are more common on control segments and Yellow-bellied Sapsuckers, which prefer deciduous forests, were more frequently observed on control segments.

If the antenna operation adversely affected bird species, we might have expected the number of species more abundant on treatment segments to decline after operation began. Birds have been sampled during all five months since 1986. Both 1986 and 1987 can be considered pre-impact years (although the antenna was tested at low power during part of 1987). The antenna was tested at half strength during 1988 and was at full strength during most of 1989 and all of 1990 and 1991 (Appendix 2). Thus, we consider 1988 a transitional year and 1989 - 1991 as impact years. During 1986-1987, species were significantly more abundant on treatment segments in 18 instances and more abundant on control segments 35 times (Fig. 6). (We are not including 1985 here as samples were collected only during June.) During 1989-1991, species were more abundant on treatment segments 24 times and 51 times on controls. Thus, a similar proportion of significant differences were noted for species more abundant on treatment segments both before (34%) and after (32%) antenna operation reached full strength. The difference in distribution between the pre- (1986-1987) and post-impact (1989-1991) periods was not significant (comparing number of species more abundant on treatment or control segments during each of the two periods [i.e., pre- and post-impact];  $\chi^2 = 0.05$ ,  $P > 0.80$ , 1 df). Similarly, if the distribution of significant differences is compared among all years, no difference exists among years ( $\chi^2 = 3.59$ ,  $P > 0.60$ , 5 df). The increase from 1987 to 1988 in number of species more abundant on treatment segments (Fig. 6) may reflect the effect of the

1988 drought (Blake et al. in press). Lowland (i.e., wet) habitats are more common on treatment segments than on controls and such habitats may have provided a refuge for birds, particularly in relation to the drier upland habitats more common in control areas.

Number of species more abundant on control or treatment segments also showed little consistency over time when examined among years by month (Fig. 7). (August and September were omitted because too few differences were noted.) This was particularly true during June, the main breeding period, when effects of antenna operation should be most strongly felt (i.e., because birds are strongly tied to territories and are less apt to wander).

## **OBJECTIVES**

Our major objectives for 1991 were to complete bird censuses during all seasons, to initiate comparisons based on pre- and post-impact data, and to complete this annual report. Additionally, several manuscripts derived from previous work have been submitted for publication or are in preparation (Appendix 4). Our objectives for 1992 and beyond are to continue our sampling of bird communities in Michigan, following our established procedures.

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Appendix 1. Nesting, feeding, habitat, and migration classification for bird species observed in Michigan and Wisconsin.

Appendix 1. Nesting, feeding, habitat, and migration classification for bird species observed in Michigan and Wisconsin.

Species	Nesting	Food	Habitat	Migration
Common Loon	1	1	9,8	2
Pied-billed Grebe	1	1	9,8	2
American Bittern	3	1	6,9	2
Great Blue Heron	2	1	9,1,2,3	2
Wood Duck	4	18	9,1	2
Mallard	1	18	9,8	2
Blue-winged Teal	1	18	9,8	3,2
Turkey Vulture	1	3	3,1,5	2,3
Osprey	2	1	9,3	2,3
Bald Eagle	2	1	9,3	2,1
Northern Harrier	1	2	8,5,10	2,3
Sharp-shinned Hawk	2	2	2,3,11	2
Cooper's Hawk	2	2	1,3	2
Northern Goshawk	2	2	2,3	4,1
Broad-winged Hawk	2	2	3,1	3
Red-tailed Hawk	2	2	5,1	2
American Kestrel	4	2	5,4	2,3
Spruce Grouse	1	4	2,11	1
Ruffed Grouse	1	4	1,3,4	1
Virginia Rail	3	19	6,8	2

## Appendix 1 (continued)

Species	Nesting	Food	Habitat	Migration
Pileated Woodpecker	4	16	1,3,2	1
Olive-sided Flycatcher	2	12	4,11,2	3
Eastern Wood-Pewee	2	12	3,1,2	3
Yellow-bellied Flycatcher	1	12	11,2	3
Alder Flycatcher	3	12	6	3
Least Flycatcher	2	12	1,3,4	3
Eastern Phoebe	5	12	9,7	2
Great Crested Flycatcher	4	12	1,3	3
Eastern Kingbird	2,3	12	5,4,10,8	3
Tree Swallow	4	11	5,7,4,9	2,3
Gray Jay	2	5	11,3,2	1
Blue Jay	2	5	1,3,2	1
American Crow	2	5	5,1,3,7	2,1
Common Raven	2	5	2,3,7	1
Black-capped Chickadee	4	10	1,3,11,2	1
Boreal Chickadee	4	10	11,2	1
Red-breasted Nuthatch	4	16	2,3,11,1	1
White-breasted Nuthatch	4	16	1,3	1
Brown Creeper	4	16	1,3,2,11	2,1
House Wren	4	10	7,4	2
Winter Wren	1,6	10	3,11,4,2	2

## Appendix 1 (continued)

Species	Nesting	Food	Habitat	Migration
Tennessee Warbler	1	10	3,2,6,4	3
Orange-crowned Warbler	1	10	6,4,3	2,3
Nashville Warbler	1	10	3,4,11,2	3
Northern Parula	2	10	11,3,2	3
Yellow Warbler	3	10	6,5,7	3
Chestnut-sided Warbler	3	10	4,3	3
Magnolia Warbler	2,3	10	4,2,3	3
Cape May Warbler	2	10	2,3	3
Black-throated Blue Warbler	3	10	1,3,4	3
Yellow-rumped Warbler	2	13	2,3,11,4	2,3
Black-throated Green Warbler	2	10	3,1	3
Blackburnian Warbler	2	10	2,3	3
Pine Warbler	2	10	2	2
Palm Warbler	1	6	11,10	2,3
Bay-breasted Warbler	2	10	2,3	3
Blackpoll Warbler	2	10	2,4,3	3
Black-and-white Warbler	1	16	3,4,6,1	3
American Redstart	2,3	12,10	4,1,6	3
Ovenbird	1	6	1,3,2,4	3
Northern Waterthrush	1,6	6	9	3
Connecticut Warbler	1	10	11	3

## Appendix 1 (continued)

Species	Nesting	Food	Habitat	Migration
Bobolink	1	8	5,8	3
Red-winged Blackbird	3	8	8	2
Eastern Meadowlark	1	6	5	2
Western Meadowlark	1	6	5	2
Yellow-headed Blackbird	3	8	8	2
Rusty Blackbird	3	8	9	2
Brewer's Blackbird	3,1	8	5	2
Common Grackle	3	5	5,9,7	2
Brown-headed Cowbird	7	8	5,4,1,7	2
Northern Oriole	2	13	1,3	3
Pine Grosbeak	2	7	2,11	4
Purple Finch	2	7	3,2,4	2,1
Red Crossbill	2	7	2,11,3	4,1
White-winged Crossbill	2	7	2,11,3	4,1
Common Redpoll	3	7	5	4
Hoary Redpoll	3	7	5	4
Pine Siskin	2	15	2,3	1,4
American Goldfinch	3,2	7	5,6,4	2
Evening Grosbeak	2	15	3,2,7	1,4
House Sparrow	4	7	7	1

Appendix 1 (continued)

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- 13 Foliage invertebrates and fruit
- 14 Fruit
- 15 Foliage invertebrates and seeds
- 16 Bark insects
- 17 Nectar and sap
- 18 Aquatic vegetation
- 19 Aquatic invertebrates

**C. Habitat**

- 1 Deciduous forest
- 2 Coniferous forest
- 3 Mixed deciduous - coniferous forest
- 4 Early successional deciduous - coniferous forest
- 5 Fields and meadows
- 6 Shrub swamp
- 7 Urban
- 8 Open wetlands (e.g., sedge fen, cattail)
- 9 Ponds, lakes, rivers, and streams
- 10 Muskeg
- 11 Lowland coniferous forest

**D. Migration**

- 1 Permanent resident; populations may be augmented during winter or during summer

**Appendix 2. ELF Communications System Ecological Monitoring Program: Breeding and Migrating Birds. Technical Summary.**

**ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM:  
BREEDING AND MIGRATING BIRDS**

- 1) TECHNICAL SUMMARY
- 2) FY 92 SUBCONTRACT MODIFICATION
- 3) FY 93-94 PROPOSAL

SUBCONTRACT NUMBER: E06549-84-C-011

Submitted to:

IIT Research Institute  
ELF Communications Program  
10 West 35th Street  
Chicago, Illinois 60616

By:

Gerald J. Niemi and JoAnn M. Hanowski  
Natural Resources Research Institute  
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218-720-4311

September 1991

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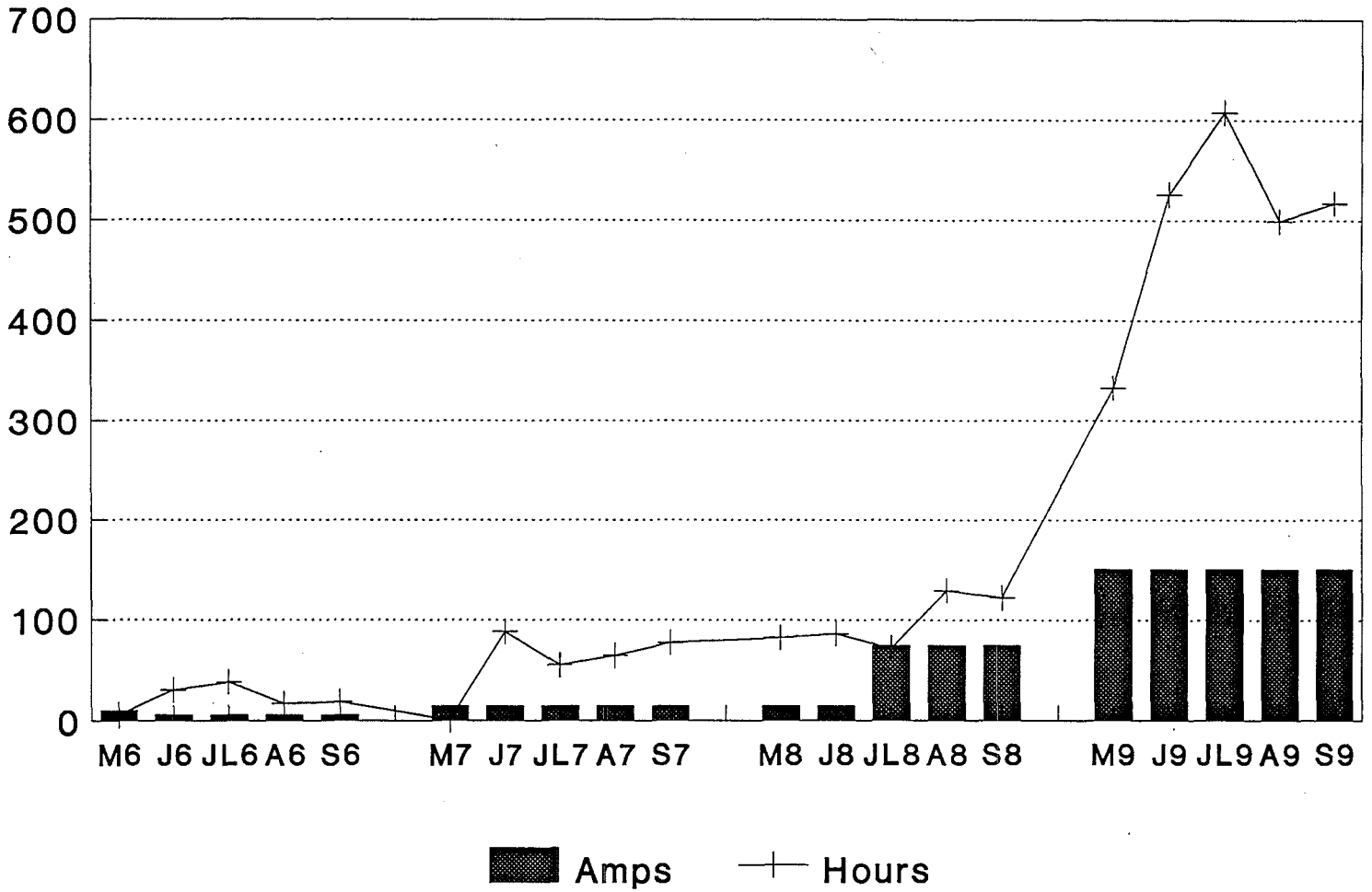


Figure 1. Power (amps) of operation and number of hours antenna was operated in each month (M = May; J = June; JL = July; A = August; S = September) from 1986 (6) to 1989 (9) in Michigan.

an order of magnitude. Therefore, because there was an order of magnitude change in EM field exposure between 1987 and 1988 we consider 1986 and 1987 as pre-full operational data, 1988 as transitional, and 1989, 1990, and 1991 as post-full operational data.

#### Statistical model for pre and post-operational comparisons

We are testing the hypothesis that there is no difference in the magnitude and direction of change in control versus treatment study areas between the pre-full operational years and post-full operational years for bird species and community parameters. The before-and-after statistical model (Equation 1) that we used to test the hypothesis calculates the difference between each post-operational ( $post_j$ ) year and the mean of the pre-operational years ( $pre_{x86,87}$ ).

$$\text{Equation 1. } \Delta = post_j - pre_{x86,87}$$

This difference ( $\Delta$ ) is calculated for each 500 m transect and the mean difference among control ( $\Delta C$ ) and mean difference among treatment ( $\Delta T$ ) transects is compared with a t-test (two-tailed).

This model is preferred over a standard t-test or two-way ANOVA (treatment and year) that tests for differences in mean number of individuals in control and treatment transects in each year because it directly tests the null hypothesis (e.g., there is no difference in  $\Delta C$  and  $\Delta T$  in pre and post-operational years between control and treatment areas). A t-test or two-way ANOVA using mean values would not allow us to separate inherent differences between control and treatment (e.g., due to habitat) from EM field induced changes. For example, we observed differences in bird parameters between control and treatment areas before the antenna was operated (June 1985). Differences in

post-year minus mean of pre-years) values in these analyses. We present data for community parameters (number of individuals and species), the three most abundant guild categories for migration, nesting, feeding, and habitat, and the most abundant individual bird species for each month (May to September). Sample size, mean, and coefficient of variation values presented are the mean values of control and treatment study areas in 1988, 1989, and 1990. Sample sizes reported in the tables are the mean number of study areas where the species occurred in 1988, 1989, and 1990 (Tables 1 to 5).

Power of t-tests (two-tailed) are presented for levels of change in terms of number of birds. For example, a power of 0.83 for American Robin in May for change of one bird indicates that we would have an 83% chance of detecting a difference in change between control and treatment of one bird. Therefore, if abundance of this species changed from 2.1 (pre-operational) to 1.1 (post-operational) on treatments and did not change (e.g., pre and post-operational difference = 0) in control areas the t-test would indicate a significant difference for this bird ( $P < 0.05$ ). The power for each variable is in bold in the tables when it reaches or exceeds 0.80. This is the value used by our statistical tests when determining if the difference between control and treatment study areas is significant (alpha 0.05).

The difference in power in terms of change in number of birds for each group of variables primarily reflects the magnitude of the variance of the variable. For example, the mean value for total number of individuals is highest and the power of 0.80 is not reached until there is a difference of five or more birds between control and treatment areas. Variance values for individual species are lower and a power of 0.80 is reached when there is a difference in change between control and treatments of one or two birds.

Table 2. Mean (control and treatment 1988, 1989, 1990), coefficient of variation sample size (mean of segments where individual occurred over 3 years), and power of t-test (two-tailed) based on the difference between post- and pre-operational antenna bird parameters for June. Transects with zero counts during pre and post years are not included. Logged sites were also excluded. For example, the power of detecting a difference in post- and pre-operational numbers of one Hermit Thrush individual between control and treatment study areas is 0.86 (if such a difference exists).

Parameter	N	Mean	CV	Change in number of individuals (post-pre)					
				0.5	1	2	3	4	5
Total individuals	70.00	23.75	34.57	0.05	0.08	0.21	0.41	0.63	0.82
Total no. species	70.00	11.77	30.79	0.10	0.26	<b>0.80</b>	0.98	1.00	1.00
Permanent resident	67.67	2.06	90.36	0.15	0.46	<b>0.96</b>	1.00	1.00	1.00
Short distance migrant	69.67	6.14	80.21	0.09	0.25	<b>0.80</b>	0.97	1.00	1.00
Long distance migrant	70.00	15.16	43.77	0.05	0.11	0.30	0.58	<b>0.82</b>	0.95
Ground nests	70.00	9.97	45.74	0.07	0.18	0.54	<b>0.87</b>	0.99	1.00
Canopy nests	70.00	6.89	57.07	0.09	0.23	0.69	<b>0.96</b>	1.00	1.00
Subcanopy nests	68.33	4.44	103.88	0.08	0.20	0.61	<b>0.92</b>	0.99	1.00
Ground ins. & seeds	57.67	2.32	109.48	0.17	0.53	<b>0.98</b>	1.00	1.00	1.00
Foliage insects	70.00	11.05	42.87	0.07	0.15	0.44	<b>0.80</b>	0.95	0.99
Ground invertebrates	70.00	5.37	58.33	0.12	0.33	<b>0.87</b>	1.00	1.00	1.00
Deciduous habitat	70.00	9.61	66.27	0.07	0.15	0.46	<b>0.80</b>	0.96	1.00
Coniferous habitat	57.33	2.67	94.19	0.16	0.50	<b>0.97</b>	1.00	1.00	1.00
Mixed habitat	70.00	5.81	57.06	0.11	0.32	<b>0.85</b>	0.99	1.00	1.00
Yellow-bellied Flycatcher	27.33	0.85	103.20	0.26	<b>0.80</b>	1.00	1.00	1.00	1.00
Least Flycatcher	21.67	2.76	142.53	0.06	0.12	0.34	0.64	<b>0.87</b>	0.97
White-throated Sparrow	43.33	1.61	112.84	0.18	0.54	<b>0.98</b>	1.00	1.00	1.00
Rose-breasted Grosbeak	48.67	1.18	104.76	0.23	0.69	<b>1.00</b>	1.00	1.00	1.00
Red-eyed Vireo	62.00	1.94	105.82	0.20	0.61	<b>1.00</b>	1.00	1.00	1.00
Black-and-white Warbler	42.67	0.78	119.04	0.27	<b>0.80</b>	1.00	1.00	1.00	1.00
Nashville Warbler	57.67	2.68	81.36	0.14	0.43	<b>0.95</b>	1.00	1.00	1.00
Chestnut-sided Warbler	44.67	1.54	118.35	0.11	0.30	<b>0.82</b>	1.00	1.00	1.00
Black-throated Green Warbler	50.00	1.74	98.86	0.19	0.57	<b>1.00</b>	1.00	1.00	1.00
Ovenbird	70.00	3.36	72.17	0.21	0.62	<b>1.00</b>	1.00	1.00	1.00
Mourning Warbler	43.67	0.43	177.17	0.17	0.51	<b>0.98</b>	1.00	1.00	1.00
Black-capped Chickadee	35.33	1.12	111.22	0.17	0.53	<b>0.98</b>	1.00	1.00	1.00
Golden-crowned Kinglet	36.67	1.49	101.27	0.21	0.63	<b>1.00</b>	1.00	1.00	1.00
Hermit Thrush	53.67	1.14	94.64	0.33	<b>0.86</b>	1.00	1.00	1.00	1.00
American Robin	47.67	0.53	165.89	0.44	<b>0.95</b>	1.00	1.00	1.00	1.00

Table 4. Mean (control and treatment 1988, 1989, 1990), coefficient of variation, sample size (mean of segments where individual occurred over 3 years), and power of t-test (two-tailed) based on the difference between post- and pre-operational antenna bird parameters for August. Transects with zero counts during pre and post years are not included. Logged sites were also excluded. For example, the power of detecting a difference in post- and pre-operational numbers of one Hermit Thrush individual between control and treatment study areas is 0.85 (if such a difference occurred).

Parameter	N	Mean	CV	Change in number of individuals (post-pre)					
				0.5	1	2	3	4	5
Total individuals	70.00	12.12	71.83	0.05	0.09	0.25	0.48	0.73	0.89
Total no. species	70.00	5.58	55.01	0.12	0.35	0.88	1.00	1.00	1.00
Permanent resident	69.67	4.46	102.71	0.09	0.25	0.73	0.97	1.00	1.00
Short distance migrant	69.00	4.20	110.84	0.07	0.16	0.47	0.81	0.97	1.00
Long distance migrant	65.00	2.52	99.24	0.15	0.45	0.95	1.00	1.00	1.00
Ground nests	63.67	2.42	107.68	0.12	0.35	0.88	1.00	1.00	1.00
Canopy nests	67.67	4.14	90.75	0.09	0.25	0.73	0.97	1.00	1.00
Subcanopy nests	44.00	1.16	156.89	0.20	0.61	1.00	1.00	1.00	1.00
Ground ins. & seeds	40.67	1.26	186.13	0.11	0.33	0.86	1.00	1.00	1.00
Foliage insects	69.00	4.82	93.07	0.08	0.21	0.63	0.93	1.00	1.00
Ground invertebrates	63.33	1.68	98.67	0.19	0.59	1.00	1.00	1.00	1.00
Deciduous habitat	70.00	4.47	97.01	0.08	0.21	0.63	0.93	1.00	1.00
Coniferous habitat	56.67	2.77	127.31	0.10	0.26	0.80	0.98	1.00	1.00
Mixed habitat	63.33	1.98	97.11	0.21	0.59	1.00	1.00	1.00	1.00
Red-eyed Vireo	38.67	1.13	120.49	0.26	0.80	1.00	1.00	1.00	1.00
Red-breasted Nuthatch	45.00	1.33	131.40	0.20	0.62	1.00	1.00	1.00	1.00
Black-capped Chickadee	63.00	2.18	115.10	0.14	0.41	0.93	1.00	1.00	1.00
Golden-crowned Kinglet	40.67	1.79	148.17	0.09	0.23	0.68	0.96	1.00	1.00
Hermit Thrush	39.67	1.14	92.56	0.32	0.85	1.00	1.00	1.00	1.00

The coefficient of variation better reflects the sensitivity of our tests in detecting a percentage difference between control and treatment mean differences. Coefficients of variation were lowest for community parameters (number of individuals and species) and highest for individual species (Tables 1 to 5). Overall, coefficients of variation for most parameters were lowest in May, June, and July and higher during the fall migration period (August and September).

Power of statistical tests presented here differ from previous reports primarily because we are using a different statistical model to test for EM exposure effects. The power of the before-and-after test is generally lower than the power calculated with a standard t-test or two-way ANOVA with means. For example, with previous calculations we determined that we could detect a difference of one species between control and treatment areas (if such a difference occurred). With the before-and-after model, we can detect a change of two species between control and treatment study areas. For example, if  $\Delta T$  (post-pre species) was 3.1 and  $\Delta C$  was 1.1 we would have a > 84% chance of detecting this change in each season (Tables 1 to 5). Fewer differences between control and treatment study areas were observed when we used the before-and-after statistical model. However, many of the differences detected with the standard t-test or two-way ANOVA were present before the antenna was operational (probably due to inherent differences in habitat between control and treatment areas). We prefer the before-and-after test because it compares each study area to itself; controlling for habitat differences. In addition, this model directly tests our null hypothesis (see page 2).

Table 6. Summary of major findings by parameter for pre- and post-operational comparisons of change in control ( $\Delta C$ ) and change in treatment ( $\Delta T$ ) study areas.

Parameter	Result <sup>1</sup>	Month	Year
Total individuals	$\Delta T < \Delta C$	May	1989
	$\Delta T > \Delta C$	August	1989
Total species	$\Delta T < \Delta C$	May	1989
	$\Delta T > \Delta C$	August	1989
Ground nesters	$\Delta T > \Delta C$	June	1989
Subcanopy nesters	$\Delta T < \Delta C$	May	1988, 1989
	$\Delta T < \Delta C$	June	1988, 1990
Cavity nesters	$\Delta T < \Delta C$	July	1989, 1990
	$\Delta T < \Delta C$	August	1990
Permanent residents	$\Delta T < \Delta C$	July	1990
Short-distance migrants	$\Delta T < \Delta C$	August	1989
Long-distance migrants	$\Delta T < \Delta C$	May	1989, 1990
Coniferous habitat	$\Delta T < \Delta C$	August	1989
	$\Delta T > \Delta C$	September	1988
Mixed upland habitat	$\Delta T > \Delta C$	June	1989
Lowland conifer habitat	$\Delta T < \Delta C$	May	1989
Ground insects & seeds	$\Delta T < \Delta C$	June	1988
Ground invertebrates	$\Delta T < \Delta C$	May	1989, 1990
Flycatchers	$\Delta T > \Delta C$	July	1989
Bark insects	$\Delta T > \Delta C$	July	1988
	$\Delta T < \Delta C$	July	1990
	$\Delta T < \Delta C$	August	1990
Nashville Warbler	$\Delta T > \Delta C$	May	1988, 1989
Ovenbird	$\Delta T < \Delta C$	May	1990
Hermit Thrush	$\Delta T < \Delta C$	May	1990
Least Flycatcher	$\Delta T < \Delta C$	June	1989, 1990
Mourning Warbler	$\Delta T > \Delta C$	June	1989, 1990
Red-eyed Vireo	$\Delta T < \Delta C$	July	1988
Blue Jay	$\Delta T < \Delta C$	September	1989

<sup>1</sup>  $\Delta T < \Delta C$  = change in treatment less than change in control

$\Delta T > \Delta C$  = change in treatment greater than change in control

Appendix 3. Total number of individuals and species observed on control(C) and treatment(T) transects in Michigan during five census periods in 1991. English and scientific names follow AOU (1983).

## Breeding and migrating birds

-71-

Appendix 3. Total number of individuals and species observed on control(C) and treatment(T) transects in Michigan during five census periods in 1991. English and scientific names follow AOU (1983).

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
Pied-billed Grebe <u>Podilymbus podiceps</u>	0	0	0	0	0	1	0	0	0	0
American Bittern <u>Botaurus lentiginosus</u>	1	1	0	0	0	0	0	0	0	1
Canada Goose <u>Branta canadensis</u>	0	2	0	0	0	0	0	0	0	0
Wood Duck <u>Aix sponsa</u>	0	0	0	3	0	0	0	3	0	0
Mallard <u>Anas platyrhynchos</u>	1	4	0	0	0	0	0	0	0	0
Blue-winged Teal <u>Anas discors</u>	0	2	0	0	0	0	0	0	0	0
Sharp-shinned Hawk <u>Accipiter striatus</u>	0	1	0	1	0	1	0	2	0	0
Northern Goshawk <u>Accipiter gentilis</u>	0	0	1	0	0	0	0	0	0	0
Broad-winged Hawk <u>Buteo platypterus</u>	0	2	2	0	0	2	5	0	0	0
Red-tailed Hawk <u>Buteo jamaicensis</u>	0	0	0	0	0	0	1	1	0	0
American Kestrel <u>Falco sparverius</u>	1	2	2	2	5	1	6	0	1	0
Merlin <u>Falco columbarius</u>	0	0	0	0	0	0	0	1	0	0
Ruffed Grouse <u>Bonasa umbellus</u>	17	10	3	0	3	15	1	5	10	7
Virignia Rail <u>Rallus limicola</u>	0	1	0	0	0	0	0	0	0	0
Sandhill Crane <u>Grus canadensis</u>	0	1	0	2	0	0	0	0	0	0
Killdeer <u>Charadrius vociferus</u>	0	0	0	1	0	0	0	0	0	0
Greater Yellowlegs <u>Tringa melanoleuca</u>	0	1	0	0	0	0	0	0	0	0
Spotted Sandpiper <u>Actitis macularia</u>	0	0	0	0	0	1	0	1	0	0

## Breeding and migrating birds

-73-

## Appendix 3 (continued)

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
Great Crested Flycatcher <u>Myiarchus crinitus</u>	1	5	9	14	6	9	1	5	0	3
Eastern Kingbird <u>Tyrannus tyrannus</u>	0	0	3	0	1	3	1	3	0	0
Tree Swallow <u>Tachycineta bicolor</u>	0	5	0	0	0	0	0	0	0	0
Gray Jay <u>Perisoreus canadensis</u>	2	0	0	6	2	0	0	2	6	9
Blue Jay <u>Cyanocitta cristata</u>	24	18	15	15	19	15	35	14	35	26
American Crow <u>Corvus brachyrhynchos</u>	1	0	0	0	2	0	0	1	0	0
Common Raven <u>Corvus corax</u>	1	4	0	1	2	2	2	0	2	0
Black-capped Chickadee <u>Parus atricapillus</u>	50	39	21	20	42	86	73	83	66	70
Boreal Chickadee <u>Parus hudsonicus</u>	6	4	3	0	1	1	2	0	2	0
Red-breasted Nuthatch <u>Sitta canadensis</u>	3	5	3	2	10	12	11	18	82	50
White-breasted Nuthatch <u>Sitta carolinensis</u>	2	3	1	1	3	7	2	16	0	0
Brown Creeper <u>Certhia americana</u>	9	27	8	15	1	6	3	15	13	10
House Wren <u>Troglodytes aedon</u>	1	0	0	0	1	4	1	0	0	0
Winter Wren <u>Troglodytes troglodytes</u>	17	37	15	24	16	38	4	10	0	6
Sedge Wren <u>Cistothorus platensis</u>	0	2	1	8	1	5	0	7	0	1
Golden-crowned Kinglet <u>Regulus satrapa</u>	46	36	48	31	49	40	7	12	15	11
Ruby-crowned Kinglet <u>Regulus calendula</u>	19	9	4	2	1	0	0	0	1	0
Eastern Bluebird <u>Sialia sialis</u>	0	0	3	2	0	0	0	0	3	0
Veery <u>Catharus fuscescens</u>	2	0	9	12	12	19	1	0	0	2

## Breeding and migrating birds

-75-

## Appendix 3 (continued)

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
Pine Warbler <u>Dendroica pinus</u>	1	0	0	0	1	1	0	0	0	0
Palm Warbler <u>Dendroica palmarum</u>	2	2	1	0	2	2	0	0	0	0
Black-and-white Warbler <u>Mniotilta varia</u>	8	16	13	19	6	10	5	0	0	4
American Redstart <u>Setophaga ruticilla</u>	0	0	0	0	0	0	1	0	0	3
Ovenbird <u>Seiurus aurocapillus</u>	37	60	107	127	93	131	11	11	12	10
Northern Waterthrush <u>Seiurus noveboracensis</u>	4	3	0	0	0	0	0	0	0	0
Mourning Warbler <u>Oporornis philadelphia</u>	0	0	21	17	2	16	5	0	0	0
Common Yellowthroat <u>Geothlypis trichas</u>	0	0	15	24	17	25	3	16	9	2
Canada Warbler <u>Wilsonia canadensis</u>	0	0	1	5	0	1	0	0	0	0
Scarlet Tanager <u>Piranga olivacea</u>	1	6	5	9	10	15	0	2	1	1
Rose-breasted Grosbeak <u>Pheucticus ludovicianus</u>	10	17	12	22	3	32	2	1	2	0
Indigo Bunting <u>Passerina cyanea</u>	0	0	12	13	20	30	3	2	0	0
Rufous-sided Towhee <u>Pipilo erythrophthalmus</u>	4	5	6	3	6	2	1	1	2	0
Chipping Sparrow <u>Spizella passerina</u>	5	18	6	6	3	11	0	7	0	10
Vesper Sparrow <u>Poocetes gramineus</u>	0	0	0	0	1	0	1	0	0	0
Song Sparrow <u>Melospiza melodia</u>	0	9	13	12	4	13	0	1	2	0
Lincoln's Sparrow <u>Melospiza lincolni</u>	0	0	1	0	0	0	1	0	0	0
Swamp Sparrow <u>Melospiza georgiana</u>	9	10	6	23	8	10	3	3	0	0
White-throated Sparrow <u>Zonotrichia albicollis</u>	54	23	39	20	46	23	13	14	19	15

Appendix 4. Presentations, publications, and manuscripts based on work conducted as part of the ELF monitoring program.

### **Presentations**

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