ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM: BIRD SPECIES AND COMMUNITIES

ANNUAL REPORT: 1988-89

SUBCONTRACT NUMBER: EO6549-84-011

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Report Number: NRRI/TR-89/1

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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 includes bird censuses over a five month period from May to September, 1986-1989. Additional data were collected in June 1985 and in August-September 1984.

No consistent patterns have yet emerged to demonstrate that birds are more or less abundant on treatment relative to control segments in either state. 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.

ABSTRACT

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 includes bird censuses over a five month period from May to September (1986-1989). Additional data were collected in June of 1985 and August-September of 1984. Here we summarize results of our 1989 research activities. The Michigan transmitter began 150 amp tuning and testing intermittently in the first part of May. On the 14th of May, the transmitter began continuous 150 amp operation for 16 hrs/day on weekdays and all day on weekends. On October 7th, the Michigan transmitter began full power continuous operation. We therefore consider May 1989 to be a transitional period, and June through September to be impact periods.

Bird abundance and species diversity were highest in June and July in Michigan and in May and June in Wisconsin. No significant differences in community level parameters (total individuals, total species) were noted in either state. Considerable annual variation in numbers of individuals and species was noted.

Particularly abundant species (all seasons included) included the Nashville Warbler, Ovenbird, White-throated Sparrow, Red-eyed Vireo, Black-capped Chickadee, Hermit Thrush and Golden-crowned Kinglet. The most abundant species present on treatment and control segments varied among seasons and between states. Among "abundant" species (>1 individual observed/500 m segment), five of 34 comparisons (over all seasons) revealed a significant difference between treatment and control

segments in Michigan; four indicated a greater abundance on control segments. Six of 31 comparisons indicated a significant difference between treatment and control segments in Wisconsin; four indicated a greater abundance on control segments.

Previous analyses of vegetation on Wisconsin and 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 areas, in both states.

To account for differences in habitat between treatment and control segments in Wisconsin, we paired treatment and control segments on the basis of habitat similarity and compared bird abundances on these paired segments (N = 15 pairs). (The Michigan study is designed as a "before-and-after" experiment and, thus, differences in habitat pose less of a problem for interpretation of bird distribution patterns.) Two of 31 comparisons of abundant species showed significant differences between paired segments in Wisconsin; in both cases, numbers were higher on treatment segments. The final report for Wisconsin will consider effects of vegetation on results from previous years and on distribution patterns of guilds.

Eighteen of 105 comparisons of common species (based on prominence values) between treatment and control segments (all segments) in Michigan and 20 of 100 in Wisconsin were significant. Values were higher on control segments in Michigan in 9 cases; 6 of 20 were more abundant on control than on treatment segments in Wisconsin.

Few species were consistently and significantly more abundant on either treatment or control segments among seasons within a year or within seasons between years. Differences between treatment and control segments are 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 abundances of birds within different guilds were found between treatment and control segments. Differences were most consistent for habitat categories, providing further evidence that habitat differences are responsible for many of the observed differences in bird distribution patterns between treatment and control segments.

INTRODUCTION

Effects of extremely low frequency (ELF) electromagnetic (EM) fields on most aspects of a bird species' life history are poorly understood (National Academy of Sciences 1977; Lee et al. 1979; other references in Hanowski et al. 1987). 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; Kroodsma 1982), collison with lines (Beaulaurier et al. 1982), and audible noise generated by a transmission line (Lee and Griffith 1978). We are unaware, however, of any previous investigations that have attempted to separate effects of EM fields on bird species and communities from effects due to habitat changes along the ROW.

This investigation was designed to isolate effects of EM fields produced by 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 study encompasses spring migration (May), early (June) and late (July) breeding, and early (August) and late (September) fall migration. In this report we summarize our research activities for 1989, our sixth year of participation in the ELF ecological monitoring program. This is the fourth year in which censuses were conducted during all seasons (above). Potential effects of the ELF antenna on birds may vary among seasons. During migration, birds may be present on study areas for only brief periods. Conversely, breeding birds remain on territories longer (1-3 months), increasing their exposure to EM fields.

Two potential approaches are possible for assessing effects of the ELF antenna on bird communities. These are to (1) compare the affected area (treatment) with a similar control area; or (2) conduct a before-and-after study that incorporates both control and treatment plots. Because our study was initiated in Michigan before the antenna began operation, we can conduct a before-and-after investigation in that state. Our sampling was initiated before the antenna was operational. By following changes in bird numbers over time on areas affected by the antenna and on areas unaffected, we can separate effects of the antenna from effects of more regional variables (e.g., annual variation in rainfall). The Michigan transmitter began 150 amp tuning and testing intermittently in the first part of May. On the 14th of May, the transmitter began continuous 150 amp operation for 16 hrs/day on weekdays and all day on weekends. On October 7th, the Michigan transmitter began full power continuous operation. We therefore consider May 1989 to be a transitional period, and June through September to be impact periods. However, data are analysed in the same manner regardless of EM field impacts.

The antenna has been operating in Wisconsin periodically since 1969 and on a near continuous basis for the past several years. No pre-impact data on bird populations are available and, thus, we cannot assume that the antenna system has not already affected bird communities in Wisconsin. Consequently, we cannot compare transect segments based on similarities in bird species communities. We can, however, account for habitat differences in our analyses. By incorporating analyses of habitat, we will be able to more clearly isolate potential effects of the EM fields produced by the antenna. To this end, we conducted a detailed habitat assessment in 1986 and 1987 to document habitat differences and similarities between control and treatment segments in Wisconsin.

Our rationale for using habitat structure to compare areas is based on the premise that birds select breeding areas (and, to a lesser extent, migration stop-over points) largely on the basis of vegetation structure (Lack 1933; Hilden 1965; James 1971; Cody 1985). Areas of similar vegetation should also have similar bird communities. Although this study design is not as desirable as the before-and-after design in Michigan, studying potential effects in Wisconsin in concert with Michigan provides furthur insight into the potential long-term effects of the antenna on bird species and communities.

EXPERIMENTAL DESIGN

The experimental design for this project has been described previously in detail (Hanowski et al. 1987). Briefly, we sample birds along a series of line-transects (Jarvinen and Vaisanen 1975) located adjacent to (treatment) or away from (control) the ELF antenna. A discussion of the rationale for this procedure is in Appendix 1.

STUDY AREAS

Study areas were the same as in previous years and are described in Appendix 1. Three 500-m transect segments (two treatment and one control) in Michigan were partially logged; logging affected about 13, 27, and 36% of the three segments. Two treatment segments in Wisconsin were also partially logged, affecting approximately 18 and 41% of these segments. In an agreement reached with Michigan Department of Natural Resources, most logging along the Michigan study transects will be delayed until 1992. Analyses of annual variation in bird community composition revealed that slightly logged segments (< 5-20%) showed no greater difference between years than did unlogged sites. Segments that were logged over all or most of their length showed significantly greater differences in bird species composition between years than did unlogged segments. Consequently, our analyses of bird distribution patterns between years omit segments logged over more than 20% of their length.

METHODS

Detailed methods employed in the investigation have been described previously (Hanowski et al. 1987) and are repeated in Appendix 1. Here we review the main points and describe any changes from previous years.

BIRD CENSUSES

We censused birds using a line transect method (e.g., Järvinen and Väisänen 1975). Each 500 m segment (40 control and 40 treatment in each state) was censused during early May (spring migration and arrival of breeding residents), June (early breeding), July (late breeding), August (early fall migration), and September (late fall migration). Censuses were conducted from approximately one half hour before to approximately 4.5 hours after sunrise on days with little wind (<15 km/hr) and little or no precipitation.

We randomly assigned censuses of control and treatment transects (eight 500 m segments/transect) to each of two observers, with the restriction that each observer census the same number of control (80) and treatment (80) segments in each month. Control and treatment transects were censused simultaneously by the two observers.

Eight transect segments were censused by each observer daily. Each observer walked at a rate of 30 min/500 m segment and recorded the following information for each bird that was observed (by sight or sound) within 100 m of the segment center line: (1) species; (2) sex, when possible; (3) behavior (e.g., singing or calling); and (4) location on the segment. We classified each species by (1) nesting area, (2) food or foraging type, (3) breeding habitat preference, and (4) migration strategy (Appendix 2), using published sources (e.g., Martin et al. 1951; Bent 1963, 1964; Green and Niemi 1978; Terres 1982; AOU 1983; Blake and Karr 1984) and personal observations. Previous analyses (Blake et al. 1988) indicated that differences between treatment and control segments were most likely to occur among groups defined on the basis of foraging behavior and breeding habitat. Consequently, we used those guilds in analyses of the effects of the ELF antenna during 1989.

VEGETATION

Methods for sampling vegetation are described in Appendix 1. Habitat variables used in Wisconsin are in Appendix 3; habitat categories used in Michigan are in Appendix 4. We completed sampling of vegetation at all Wisconsin segments during 1987. Vegetation was sampled at 21 points (every 25 m) along each 500 m transect segment. Detailed results of our habitat analyses were presented in Blake et al. (1988) and are not repeated here.

STATISTICAL ANALYSES

COMMUNITY PARAMETERS AND ABUNDANT SPECIES

We used the same criteria to select variables for parametric statistical analysis that we identified in 1985 (Niemi and Hanowski 1986): (1) those species with a mean of more than one observation per 500 m segment ("abundant species") in control or treatment areas of either state in any season; (2) mean number of species observed in a 500 m segment in control or treatment areas of either state and during each season; and (3) mean number of individuals observed in a 500 m segment in control or treatment areas of either state and during each season.

We used one-way ANOVA (Sokal and Rohlf 1981) to test for differences between control and treatment segments within a season. Annual differences were examined by season for number of species and individuals using a two-way ANOVA. (Separate papers will examine annual variation in abundance in more detail [e.g., for individual species] and we do not include such analyses in this report.) Because some segments were affected by logging after the initial census in 1985, we excluded logged segments in analyses of annual variation.

Variables used in parametric statistical tests were examined for normality (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. Nonparametric tests (Kruskal-Wallis ANOVA) were used for variables that did not meet assumptions, even after transformation.

EFFECTS OF HABITAT STRUCTURE: WISCONSIN

We used a paired sample approach to control for effects on bird populations of habitat differences that exist between treatment and control segments in Wisconsin (see Blake et al. 1988 for analyses of vegetation). We paired treatment and control segments on the basis of habitat. We used a principal components analysis to reduce the 24 original variables (15 describing structural features of the habitat and 9 describing abundance of dominant tree species) (Appendix 3A) to a smaller set of uncorrelated variables that explained a substantial amount of variation in habitat. The first 7 components had eigenvalues greater than 1.0 and explained 74% of the variation in habitat (Appendix 3b). These components were used to calculate a Euclidean distance between each possible treatment-control pair:

$$D_{ij} = (\sum_{k=1} (X_{ik} - X_{jk})^2)^{0.5}$$

where D_{ij} is the distance between segments i and j and X_{ik} and X_{jk} are weighted values for principal component k (for k = 7 components) for segments i and j. Distances were calculated with each component weighted by the amount of variation it explained.

We calculated the nearest neighbor distance (i.e., most similar treatment [or control] segment to the control [or treatment] segment being compared) for each segment (N = 80 nearest neighbor distances). These distances were used to determine the mean nearest neighbor distance among all pairs. We then selected those treatment-control segment pairs that were separated by a distance that was less than the mean nearest neighbor distance among all segments. A total of 15 segment pairs met this criterion. We then used a paired sample test (t-test or Wilcoxon matched pairs signed ranks test) to compare differences in bird abundances between treatment and control segments. Here we report results from 1989 only.

COMMON SPECIES

A second group of less abundant species ("common species") was chosen based on frequency of occurrence. These species had to be present on at least six segments during a season with the restriction that they occur on at least five control or five treatment segments (e.g., a species was not included if it occurred on three control and three treatment segments).

A prominence value was calculated for each species using the formula:

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

where D = number of individuals observed and F = the relative frequency of species occurrence on treatment or control segments. Prominence values were calculated for control and treatment segments separately and differences were tested with a goodness of fit G-test or binomial test (Sokal and Rohlf 1981). The prominence value weights both the frequency of occurrence and number of individuals (Beals 1960; Blake 1982) and thus is preferable to using either total number of individuals observed or number of segments on which a species was observed to test for differences between control and treatment areas. Differences between these methods were more fully explored in a previous report (Hanowski et al. 1987). Briefly, fewer significant differences are found using prominence values than comparisons based on individuals but more than when frequency of occurrence only is used.

EDGE EFFECTS

Previous analyses have considered the possibility that differences between treatment and control segments were due to edge effects related to the right-of-way corridor. We found no indication that such an effect exists (Hanowski et al. 1987, Blake et al. 1988) and do not consider the question in this report.

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

SPECIES RICHNESS AND ABUNDANCE OF INDIVIDUALS

1989 results

Total number of species and individuals observed varied among seasons on control and treatment transects in both states (Tables 1, 2). Number of observations for all species are in Appendix 5. Total abundance was highest during June and July in Michigan and May and June in Wisconsin (Table 1). Abundance was low in Michigan during May as most migrants had not yet returned from wintering grounds. Part of the difference between states was due to differences in census date; censusing in Wisconsin began 7 to 10 days after the Michigan censusing was completed. Trends in abundance between treatment and control segments were not consistent (i.e., always greater on treatment or on control segments) across seasons in Michigan or Wisconsin (Table 2). No significant differences in mean number of individuals observed per segment were noted in either state (Table 2). When we based comparisons of individuals on paired treatment and control segments in Wisconsin (Table 3), mean number of individuals observed was greater on treatment segments in July, but not in any other month (Table 3).

Species' abundance patterns generally followed those for individuals (Table 2). Species richness was highly correlated with individuals per segment in Michigan ($r = 0.95$) and Wisconsin ($r = 0.96$). Mean number of species recorded per 500 m segment did not differ between treatment and control segments in any season (Table 2). No significant differences in number of species were noted between paired segments in Wisconsin (Table 3).

Table 1. Total numbers of individuals (indiv.) and species observed on treatment (T) and control (C) transects in Michigan and Wisconsin, 1985-1989. A combined species total for treatment and control segments is in parentheses.

	1985			1986			1987			1988			1989		
	T		C	T		C	T		C	T		C	T		C
MICHIGAN															
May:															
indiv.				949		1210	775		888	815		939	570		607
species				54	(76)	69	50	(67)	62	53	(66)	56	44	(60)	46
June:															
indiv.	1629		1327	1098		1169	1131		1162	1061		1014	983		1020
species	70	(81)	72	60	(74)	68	71	(81)	73	70	(89)	77	70	(83)	71
July:															
indiv.				938		978	1136		1258	891		907	994		1039
species				59	(75)	63	68	(81)	73	69	(83)	68	63	(77)	68
August:															
indiv.				380		478	682		610	564		469	791		551
species				53	(61)	46	59	(68)	54	50	(66)	51	62	(69)	52
September:															
indiv.				402		627	634		501	469		574	505		435
species				36	(55)	48	46	(55)	41	46	(60)	47	48	(60)	45
WISCONSIN															
May:															
indiv.				1396		1452	1305		1302	1105		1142	1011		1065
species				67	(78)	62	72	(83)	62	68	(82)	69	68	(79)	65
June:															
indiv.	1548		1348	1207		1050	1358		1439	818		839	979		1016
species	76	(81)	66	66	(72)	57	69	(76)	65	68	(82)	62	65	(79)	67
July:															
indiv.				858		808	861		761	644		693	805		690
species				50	(64)	54	66	(81)	63	53	(67)	55	49	(64)	54
August:															
indiv.				522		477	606		653	400		461	486		451
species				40	(47)	38	51	(63)	50	47	(57)	44	47	(56)	40
September:															
indiv.				682		644	819		880	403		426	729		654
species				31	(48)	39	46	(56)	42	36	(50)	43	46	(55)	44

Table 2. Mean observations in a 500m segment on control (C) and treatment (T) segments, 1985-89; 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		ANOVA		
	T	C	T	C	T	C	T	C	T	C	T	Y	I
MICHIGAN													
May:													
indiv.			23.7**	30.3	19.4	22.2	20.4 *	23.5	14.3	15.2	***	***	
species			9.7**	12.9	8.1**	10.8	9.5	11.0	7.7	8.2	***	***	
June:													
indiv.	40.8**	33.3	27.5	29.2	28.3	29.1	26.5	25.4	24.6	25.5		***	**
species	14.2	14.0	11.1	12.5	12.5	12.9	12.4	13.1	11.7	12.9	*	***	
July:													
indiv.			23.5	24.5	28.4	31.5	22.1	22.7	24.9	26.0		***	
species			9.6	10.4	11.8	14.4	11.1	11.0	10.8	11.8	**	***	
August:													
indiv.			9.6	12.0	17.1	15.3	14.1	11.7	19.8	13.8		***	
species			4.6	5.2	7.3	6.7	6.1	5.8	7.7	6.5		***	
September:													
indiv.			10.1 *	15.7	15.9	12.5	11.7	14.4	12.6	10.9			*
species			4.0	5.6	5.4	5.1	5.0	5.6	5.0	4.7			*
WISCONSIN													
May:													
indiv.			34.9	36.3	32.6	32.5	27.6	28.6	25.3	26.6		***	
species			13.4	12.8	13.1	12.2	13.3	13.6	11.5	12.3		*	
June:													
indiv.	38.7**	33.8	30.2 *	26.3	34.0	36.0	20.5	21.0	24.5	25.4		***	*
species	15.0 *	13.0	12.3	11.3	14.3	14.4	11.4	10.6	12.0	11.2	*	***	
July:													
indiv.			21.5	20.2	21.5	19.0	16.1	17.3	20.1	17.3		**	
species			8.4	7.8	9.7	8.8	7.7	7.9	8.8	7.8	*		
August:													
indiv.			13.1	12.2	15.2	16.3	10.0	11.5	12.2	11.3		***	
species			5.3	4.8	5.8	6.5	4.6	4.6	5.1	5.0		**	
September:													
indiv.			17.1	16.0	20.5	22.0	10.1	10.7	18.2	16.4		***	
species			5.3	5.3	6.1	6.8	4.1	4.2	5.9	5.8		***	

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

Table 3. Mean number of observations in Wisconsin in 1989 on all treatment (T) and control (C) segments and on paired segments; Segments were paired (N = 15 pairs) on the basis of similarities in vegetation. Differences between paired segments were tested with paired t-tests. Mean values are given for species only if they showed a significant difference between paired segments. See Tables 2 and 4 for results based on all segments.

Species	All Segments		Paired Segments		
	T	C	T		C
MAY[1]					
Total species	11.5	12.3	12.9		11.5
Total individuals	25.3	26.6	24.5		24.4
JUNE[2]					
Total species	12.0	11.2	12.7		11.3
Total individuals	24.5	25.4	22.1		24.3
JULY[3]					
Total species	8.8	7.8	9.1		7.9
Total individuals	20.1	17.3	20.3	*	15.5
Black-throated Green Warbler	0.9	1.0	1.2	*	0.2
Golden-crowned Kinglet	1.0	0.5	1.7	*	0.4
AUGUST[4]					
Total species	5.1	5.0	5.3		5.3
Total individuals	12.2	11.3	12.3		12.5
SEPTEMBER[5]					
Total species	5.9	5.8	6.6		5.5
Total individuals	18.2	16.4	14.5		14.5

[1] 7 species tested.
[2] 6 species tested.
[3] 7 species tested.
[4] 4 species tested.
[5] 7 species tested.

* $P < 0.05$

Annual variation and treatment effects on species and individuals

Considerable annual variation in abundance of individuals and species was noted in both states (Tables 2, 4). Abundance tended to be lowest in 1988, reflecting the severe drought that affected much of the region (see Blake et al., in review; Table 4). Treatment effects were noted in Michigan during May (individuals and species), June (species only), and July (species only; Table 2); individuals and species were more abundant on controls. A treatment effect was noted for species in Wisconsin during June and July, but no other treatment effects were noted when results from all years were included in the analyses (Table 2). The significance of these results is considered in the discussion section (see pages 19 and 22).

DISTRIBUTION OF ABUNDANT SPECIES

Spring migration

The Black-capped Chickadee was the most abundant species on treatment and control segments in Michigan (Appendix 5a). Seven species were recorded with an average abundance of at least one bird per segment (treatment or control) in Michigan, but only Yellow-bellied Sapsuckers showed a significant difference (more abundant on controls) between controls and treatments (Table 5). The Ovenbird was the most abundant species in Wisconsin on both control and treatment segments (Appendix 5b). Four of eight abundant species differed in abundance between control and treatment segments in Wisconsin (Table 5); all four were more abundant on controls. When comparisons were based on paired treatment and control segments, however, no species differed in abundance between treatment and control segments (Table 3).

Early breeding

The Ovenbird was the most abundant species in June in both states and on both control and treatment segments (Appendices 5a, 5b). Nashville Warblers were more abundant on treatment segments and Black-throated Green Warblers and Rose-breasted

Table 4. Summary of differences among years and among treatment (T) and control (C) segments, by season and year (85, 86, 87, 88, 89). (See Table 2 for ANOVA results.) Year and segment combination (e.g., C86 = control segments in 1986) are arranged from left to right in decreasing order of abundance. Year-segment combination not underlined by the same line are significantly different ($P < 0.05$). For example, for individuals in Michigan in June, abundance was higher on treatment segments in 1985 than at any other time.

Month	Abundance of Individuals	Abundance of Species
Michigan		
May	C86 T86 C88 C87 T88 T87 C89 T89	C86 C88 C87 T86 T88 C89 T87 T89
June	T85 C85 C87 C86 T87 T86 T88 C89 C88 T89	T85 C85 C88 C87 C89 C86 T87 T88 T86 T89
July	C87 T87 C89 T89 C86 T86 C88 T88	C87 T87 C89 C88 T88 T89 C86 T86
August	T89 T87 C87 C89 T88 C88 C86 T86	T89 C87 T87 C89 C88 T88 C86 T86
September	C86 T87 C88 T89 C87 C89 T88 T86	C86 T87 C88 T89 C87 C89 T88 T86
Wisconsin		
May	C86 T86 C87 T87 C88 T88 C89 T89	C88 T86 T88 T87 C86 C89 C87 T89
June	T85 C87 C85 T87 T86 C86 C89 T89 C88 T88	T85 C87 T87 C85 T86 T89 T88 C86 C89 C88
July	T86 T87 C86 T89 C87 C88 C89 T88	T87 C87 T89 T86 C88 C86 C89 T88
August	C87 T87 T86 C86 T89 C88 C89 T88	C87 T87 T86 C88 T89 C89 T88 C86
September	C87 T87 T89 T86 C89 C86 C88 T88	C87 T87 T89 T86 C89 C86 C88 T88

Table 5. Mean number of individuals per segment for abundant species (those with an average of at least one individual per treatment or control segment) that showed a significant difference (one-way ANOVA) in abundance between treatment (T) and control (C) segments in 1989.

Species	Michigan			Wisconsin		
	T		C	T		C
MAY[1]						
Yellow-bellied Sapsucker	0.3	**	1.1			
Winter Wren				0.5	**	1.2
Black-throated Green Warbler				1.2	*	1.9
Black-and-white Warbler				0.8	*	1.2
Ovenbird				3.6	*	5.0
JUNE[2]						
Nashville Warbler	2.8	*	1.8			
Black-throated Green Warbler	0.8	*	1.5			
Rose-breasted Grosbeak	0.5	*	1.0			
JULY[3]						
Black-capped Chickadee				2.1	*	1.1
Ovenbird	2.2	*	3.5			
AUGUST[4]						
SEPTEMBER[5]						
Yellow-rumped Warbler				1.0	**	0.2

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[1] Species tested: 7 in Michigan; 8 in Wisconsin.
[2] " " 9 " " 7 " "
[3] " " 9 " " 8 " "
[4] " " 6 " " 3 " "
[5] " " 3 " " 5 " "

* $P < 0.05$; ** $P < 0.01$

Grosbeaks were more abundant on control segments in Michigan (Table 5). No species differed in abundance between treatment and control segments in Wisconsin either when comparisons were based on all segments or on matched segments (Tables 3, 5).

Late breeding

The Ovenbird was the most abundant species in Michigan and the Hermit Thrush and Red-eyed Vireo were most abundant in Wisconsin (Appendices 5a, 5b). The Ovenbird was more abundant on control segments in Michigan and the Black-capped Chickadee was more abundant on treatment segments in Wisconsin (Table 5), but no other abundant species showed a significant difference between treatment and control segments in July when comparisons were based on all segments. Black-throated Green Warblera and Golden-crowned Kinglets were more abundant on treatment segments in Wisconsin when comparisons were based on paired segments (Table 3). Black-capped Chickadee abundance did not differ between paired treatment and control segments.

Early fall migration

Bird communities in both states were dominated by Black-capped Chickadees during early fall migration (Appendices 5a, 5b). No abundant species in either state showed a significant difference in abundance between control and treatment segments (Tables 3, 5).

Late fall migration

Bird communities during late fall migration were dominated by Red-breasted Nuthatches (particularly in Wisconsin) and Black-capped Chickadees (particularly in Michigan) (Appendices 5a, 5b). No abundant species showed a significant difference in abundance between control and treatment segments in Michigan (Table 5). Yellow-rumped Warblers were more abundant on treatment segments in Wisconsin when comparisons were based on all transects (Table 5) but not when based on paired transects (Table 3).

DISTRIBUTION PATTERNS OF COMMON SPECIES

Abundances of common species (as indexed by prominence values) differed between treatment and control transects in 18 of 105 comparisons (17%) during 1989 in Michigan (Table 6). In 9 cases, prominence values were higher on control than on treatment segments. Winter Wren was more common (higher prominence value) on control segments in both May and June, but no other species showed a significant difference in more than one season in Michigan.

Twenty of 100 comparisons of common species showed significant differences between control and treatment transects during 1989 in Wisconsin (Table 6). In 14 comparisons, prominence values were higher on treatment segments. Three species showed a significant difference in more than one season (Golden-crowned Kinglet, Chipping Sparrow, Indigo Bunting); all were more common on treatment segments. The biological significance of these results, and those for abundant species, are discussed later (see page 24).

GUILD COMPOSITION

Few significant differences [4 of 50 tests (8%)] between treatment and control segments existed in abundance of members in different foraging guilds (Table 7). No foraging guild showed a significant difference in more than one season in either state (Table 7).

Differences were more pronounced among habitat guilds (14 of 60 tests 23%; Table 7). Birds preferring deciduous forest habitats were more common on control segments in Michigan and Wisconsin; the reverse was true for birds preferring coniferous habitat, particularly in Wisconsin (Table 7). Birds preferring early successional and open habitats were more abundant on treatment segments in Michigan (Table 7).

Table 6. Prominence values (see text) for species showing significant differences (G-test) between treatment (T) and control (C) segments in 1989.

Species	Michigan			Wisconsin		
	T		C	T		C
MAY[1]						
Yellow-bellied Sapsucker				5.2	*	13.9
Northern Flicker	16.8	*	6.3			
Brown Creeper	8.0	**	22.8			
Winter Wren	6.8	*	16.3			
Golden-crowned Kinglet				28.3	***	7.1
Red-eyed Vireo				15.3	*	28.3
Common Yellowthroat				16.5	*	7.1
Chipping Sparrow				14.3	***	0.7
Dark-eyed Junco	5.0	*	0.2			
Brown-headed Cowbird				0.8	*	6.3
JUNE[2]						
Yellow-bellied Sapsucker	2.1	*	9.7			
Great Crested Flycatcher	0.4	**	10.1			
Black-capped Chickadee	5.4	*	16.0			
Winter Wren	4.5	**	16.3			
Golden-crowned Kinglet	26.1	*	13.1	19.3	**	6.3
Cedar Waxwing				0.2	*	4.3
Yellow-rumped Warbler				11.8	**	1.3
Mourning Warbler				24.0	*	11.0
Common Yellowthroat	1.1	**	10.0			
Indigo Bunting				4.2	*	0.2
Chipping Sparrow				5.7	*	0.2
Red-winged Blackbird	0.2	**	7.1			
JULY[3]						
Great Crested Flycatcher	0.4	**	7.1			
Golden-crowned Kinglet				23.7	*	10.0
Chestnut-sided Warbler				8.9	*	2.1
Mourning Warbler	14.0	*	4.2			
Indigo Bunting				5.9	*	0.2
Chipping Sparrow	9.0	*	1.6			
Swamp Sparrow				7.1	**	0.3
AUGUST[4]						
Eastern Wood Pewee	3.3	**	16.4			
Blue Jay				3.8	*	12.4
American Robin	11.2	*	2.5			
Cedar Waxwing	20.5	**	4.6			
Rufous-sided Towhee	4.6	*	0.2			
SEPTEMBER[5]						
Downy Woodpecker				0.3	**	8.4
Golden-crowned Kinglet				19.7	*	8.5
Nashville Warbler				5.4	*	0.4

[1] Species tested: 16 in MI; 27 in WI.

[2] Species tested: 33 in MI; 28 in WI.

[3] Species tested: 28 in MI; 19 in WI.

[4] Species tested: 18 in MI; 12 in WI.

[5] Species tested: 10 in MI; 12 in WI.

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

Table 7. Mean number of individuals in foraging and habitat guilds that showed a significant difference (One-way ANOVA) between control (C) and treatment (T) in Michigan and Wisconsin in 1989.

Guild	Month	Michigan			Wisconsin		
		T		C	T		C
FORAGING GUILDS							
Foliage insects	July				9.7	*	7.5
Ground invertebrates & seeds	July				2.7	*	1.4
	August	2.9	*	0.7			
Flycatchers	August	0.7	*	1.2			
HABITAT GUILDS							
Deciduous forest	May	3.7	*	5.0	8.1	*	10.5
	June	7.7	*	10.5			
	July	7.2	**	11.1			
	September				5.5	*	7.0
Coniferous forest	May				3.0	*	1.6
	June				2.2	*	1.3
	September				7.7	*	5.5
Lowland coniferous	May	0.5	*	0.0			
Mixed deciduous & coniferous	May				6.2	*	7.7
Early successional	June	4.1	*	2.6			
	July	4.6	*	2.3			
	August	3.3	*	0.8			
Fields, meadows	August	2.2	*	0.9			

DISCUSSION

SPECIES DISTRIBUTION AND ABUNDANCE PATTERNS

No consistent patterns have yet emerged during this study (1985-1989) to demonstrate that birds are more or less abundant on treatment relative to control segments in either state. 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. Differences between treatment and control segments are most noticeable in Michigan during May; four of the six significant differences found for individuals (Fig. 1) and species (Fig. 2) are in Michigan during May. Patterns are less consistent in subsequent months, however. Individuals were significantly more abundant on treatment segments in June 1985 and on control segments in September 1986, but no other significant differences have been demonstrated at the community level (Table 2, Figs. 1, 2).

The Michigan facility was operated well below full strength in 1987 and half of 1988 (15 amperes, 8 hr/day, weekdays, starting June 1 1987 through 2 July 1988) and at 75 amperes (8 hr/day, weekdays) for the remainder of 1988. It was operated at 150 amperes for 16-24 hr/day during most of the 1989 sampling period. There has been, however, little noticeable change in bird populations on treatment relative to control segments. Populations were lower overall in 1988 relative to 1987, and remained low or increased slightly in 1989. As this pattern in abundance was observed on both treatment and control segments, it is most likely attributable to some factor other than the antenna operation. 1988 was extremely dry and hot (National Oceanic and Atmospheric Administration) and the weather conditions may have had an adverse impact on birds (e.g., reduced reproductive success; early emmigration from study areas; see Blake et al., in review). The drought was not as severe in 1989 (pers. obs.) and further declines were not noted for most species; some species increased slightly in abundance from 1988 to 1989.

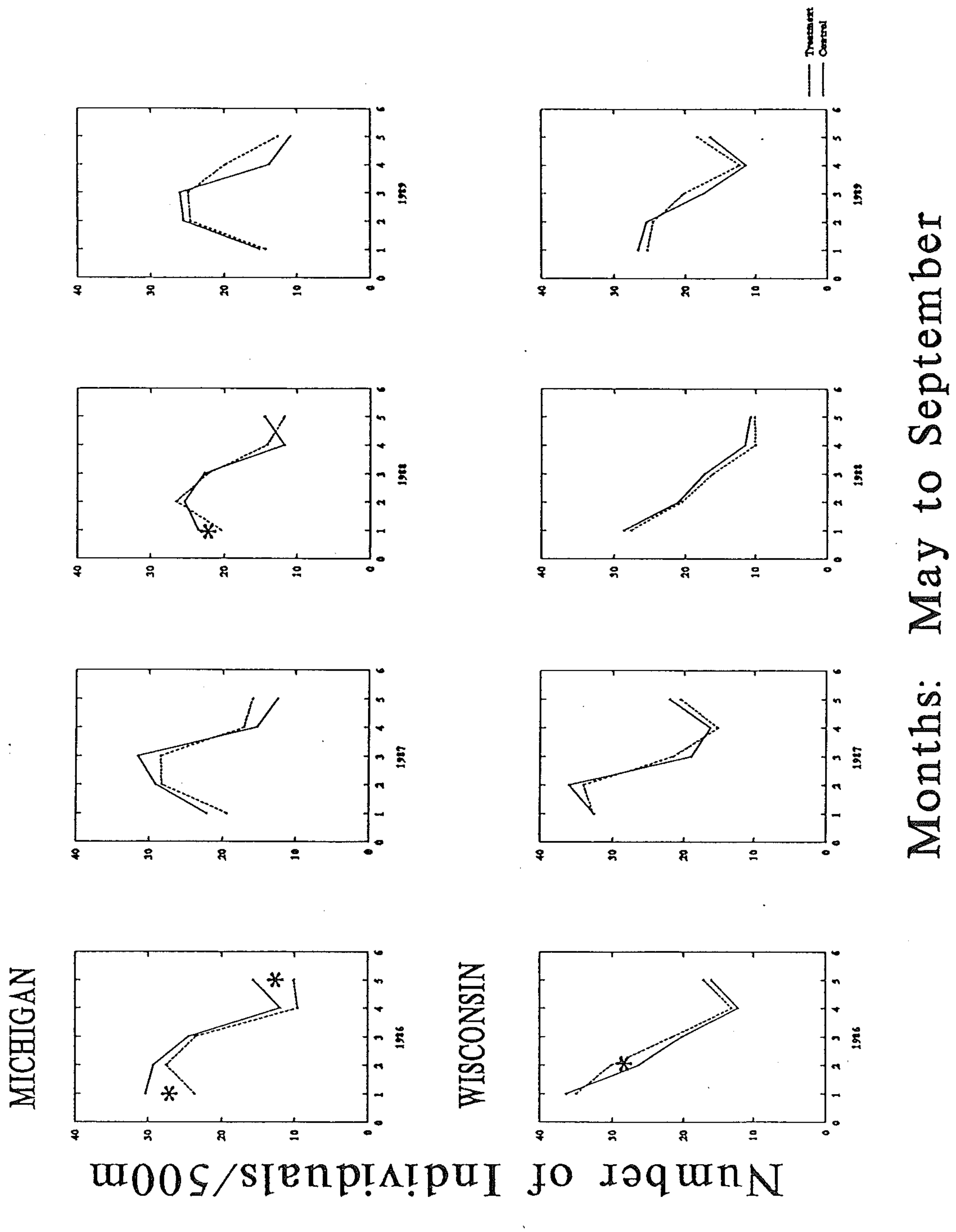

Figure 1. Mean number of individuals recorded per 500m segment on treatment and control segments, May (1) to September (5), 1986-1989.

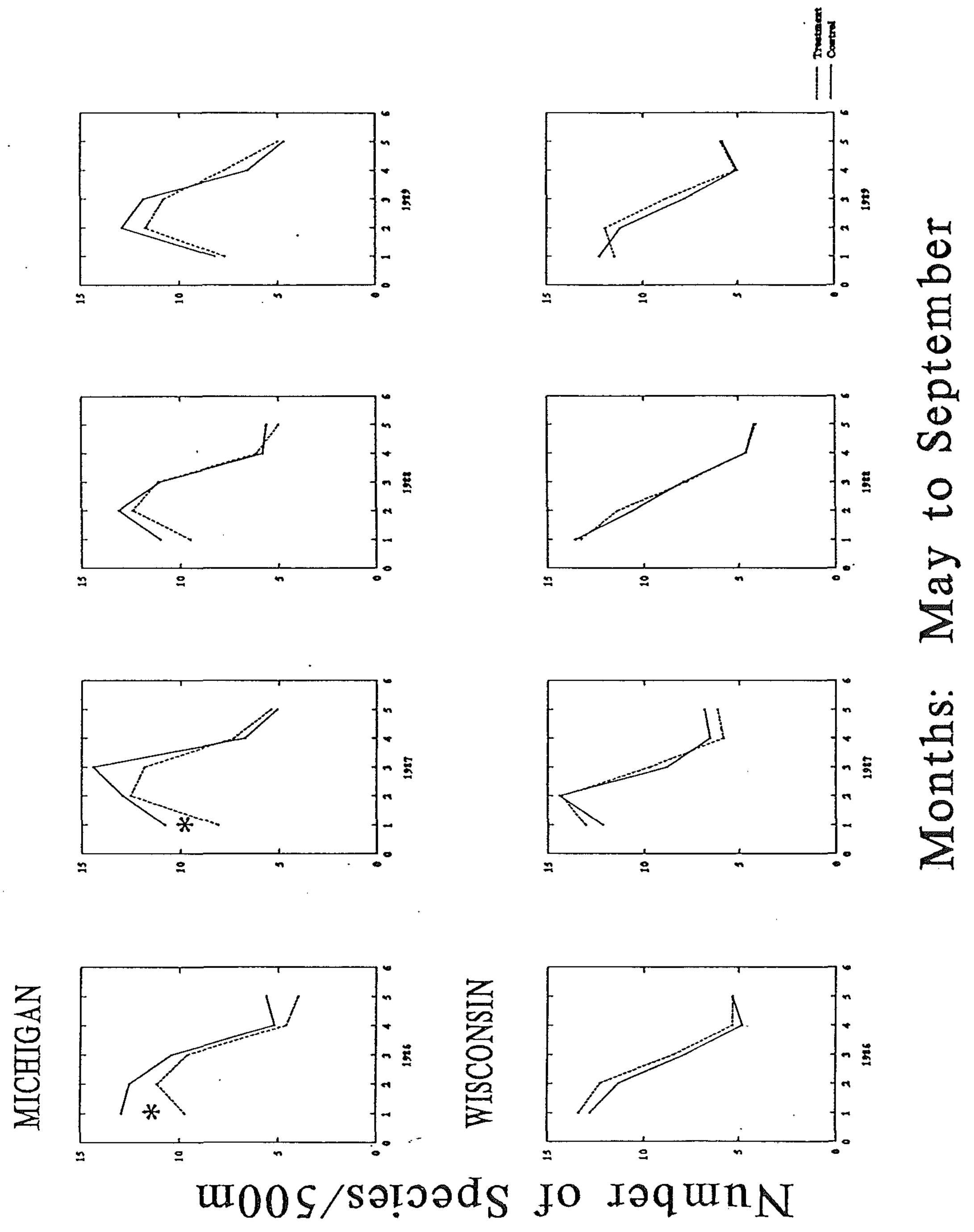

Figure 2. Mean number of species recorded per 500m segment on treatment and control segments, May (1) to September (5), 1986-1989.

Results from Wisconsin showed little consistency between years or among seasons in species richness or number of individuals. If the ELF transmitter was strongly influencing bird distribution patterns, one might expect that relative abundance of birds on treatment and control segments would remain the same from one year to the next, particularly during the breeding season, and from one season to the next. There was, however, little evidence for such an effect (Table 2, Figs. 1, 2). Species and individuals were more abundant on treatment segments in 1985 and individuals in 1986, but no other significant difference at the community level has been noted. In fact, throughout 1986-1989, species richness and abundance of individuals have been remarkably similar on treatments and controls (Figs. 1, 2).

The effect of the drought in 1988 also was seen in the generally lower values for 1988 relative to 1987 in Wisconsin. Rainfall during 1989 in Wisconsin, particularly during the breeding season, was closer to normal and abundances of several species increased. The fact that bird populations were lower in both states in 1988 provides further support for the suggestion that operation of the Michigan facility had little immediate effect on bird populations in that state.

Annual variation in abundance

Substantial variation occurred among years in abundance of many bird species. Overall, abundance has tended to decline from 1985 to 1988; a slight rebound was noted in 1989 in Wisconsin. Although the precise causes of such variation largely are unknown, they are likely related to the severe drought in 1988; the drought followed by two relatively dry years (1986-1987). An analysis of annual variation in bird populations (June data, 1985-1989) was completed and is under review (Blake et al., in review). By the completion of this project we will be able to analyze such variation in greater detail in Michigan, where seven years of data will be available for analysis.

A potentially confounding factor in examination of annual variation in bird communities relates to sampling. Particularly during spring migration, changes in weather may profoundly influence the abundance of birds in a particular area (Richardson 1978). Differences in weather from one year to the next may produce apparent (as well as real) differences in abundance of birds. We attempt to minimize this problem by sampling over a five to six day period each season. Thus, weather patterns may not be as likely to strongly influence results of that sample. Similarly, we attempt to sample each season during the same calendar time period each year. It is likely, however, that differences of as much as a week from one year to the next have a considerably smaller influence on abundance than differences that may occur as a consequence of weather. This was particularly noticeable during the May sample in Michigan, where cold weather, including snow, probably delayed arrival of many migrants. Overall abundances were much lower in May 1989 than in previous years.

Guild distribution patterns

Species that belong to the same "guild" share some biological characteristics. Thus, if the ELF antenna system influences distributions of bird species we might expect members of a particular guild to be influenced in a similar fashion. Similarly, habitat related effects may be evident from the distribution patterns of guild members.

Relatively few differences in abundance of birds in different guilds were noted between treatment and control segments in either state in 1989 or previous years (Blake et al. 1989). Differences that did exist likely reflected differences in habitat that occur between treatment and control segments. Treatment segments in Michigan had more early successional habitats than did control areas and birds breeding in such habitats showed the strongest treatment effect, being more abundant in treatment segments. A similar result was noted for earlier years (Blake et al. 1989). 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 or coniferous 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 been relatively few cases where differences in abundance of a species between treatment and control segments have remained consistently significant among seasons and years (Tables 8, 9; Fig 3). A total of 41 species in each state have shown a significant difference in abundance between treatment and control segments in at least one season and year. Somewhat more species (21) were more abundant on control than on treatment segments (13) in Michigan (Table 8). The number of species showing a difference in Wisconsin was equally split between treatment (17 species) and control (20 species) segments (Table 9). However, many species have shown a significant difference in only one season in one year (Fig. 3). Moreover, seven species in Michigan and four in Wisconsin have been more abundant on treatment segments in one season and on control segments in another (Tables 8, 9). For example, the Yellow-rumped Warbler was more abundant on treatment segments in June 1985 and 1986 in Michigan but was more common on control segments during September 1986 (Table 8). Such reversals may reflect seasonal changes in habitat selection. For example, a species may breed in one habitat but then move into a different habitat following breeding. If distribution of breeding and nonbreeding habitats differ between treatments and controls, a switch in abundance between treatment and controls also may occur.

Several species have shown a consistent pattern of distribution between treatment and control segments. Yellow-bellied Flycatchers in Michigan, for example, have been

Table 8. Summary by year and month[a] of species that were significantly more abundant on treatment or control segments in Michigan. Underlined months indicate that differences were tested by ANOVA (i.e., "abundant" species; see text). Differences for common species (not underlined) were based on goodness-of-fit G-tests.

Species	More abundant on treatment					More abundant on control				
	1985	1986	1987	1988	1989	1985	1986	1987	1988	1989
Northern Flicker					M					
Yellow-bellied Flycatcher	Ju	Ju	Ju							
Golden-crowned Kinglet	Ju		S	Jy	Ju					
Hermit Thrush		Jy								
American Robin	Ju			JyA	A					
Cedar Waxwing				A	A					
Golden-winged Warbler			Ju							
Nashville Warbler	Ju	JuJy	Jy		Ju					
Chestnut-sided Warbler	Ju			JuJy						
Mourning Warbler	Ju				Jy					
Rufous-sided Towhee					A					
White-throated Sparrow	Ju	S	JuJyA	JuJyS						
Dark-eyed Junco					M					
Blue Jay		Ju					S		M	
Black-capped Chickadee				Jy				MJu		Ju
Winter Wren				M		Ju	M		Ju	MJu
Yellow-rumped Warbler	Ju	Ju					S			
Rose-breasted Grosbeak	Ju	M								Ju
Chipping Sparrow	Ju			Ju	Jy		M			
Song Sparrow				MJu		Ju				
American Woodcock								Jy		
Ruffed Grouse							Jy	Jy	Jy	
Yellow-bellied Sapsucker							M	MJyA	MJyS	MJu
Downy Woodpecker							A			
Eastern Wood-Pewee								A		A
Least Flycatcher							Jy			
Great Crested Flycatcher								Ju		JuJy
Brown Creeper								Jy	MJy	M
Red-breasted Nuthatch									S	
Veery								Jy		
Northern Parula									Jy	
Black-throated Green Warbler								M	M	Ju
Blackburnian Warbler								Ju		
Black-and-white Warbler							M	M	M	
American Redstart							S			
Ovenbird							MS	M	MS	Jy
Common Yellowthroat							JuJy	Jy	Jy	Ju
Swamp Sparrow								MJy		
Red-winged Blackbird							MJu	MJuJy	M	Ju
Brown-headed Cowbird							MJu		Ju	
Purple Finch								M		

[a] M - May; Ju - June; Jy - July; A - August; S - September.

Table 9. Summary by year and month[a] of species that were significantly more abundant on treatment or control segments in Wisconsin. Differences in habitat structure between treatment and control segments have not been incorporated in these results. Underlined months indicate that differences were tested by ANOVA (i.e., "abundant" species; see text). Differences for common species (not underlined) were based on goodness-of-fit G-tests.

Species	More abundant on treatment					More abundant on control				
	1985	1986	1987	1988	1989	1985	1986	1987	1988	1989
Alder Flycatcher	Ju									
Black-capped Chickadee					Jy					
Red-breasted Nuthatch			Jy	Ju						
Golden-crowned Kinglet		Ju	Jy		MJuJyS					
Nashville Warbler		A			S					
Chestnut-sided Warbler	Ju		Ju	MJuJy	Jy					
Magnolia Warbler		M	M							
Cape May Warbler		M								
Yellow-rumped Warbler	Ju				JuS					
Mourning Warbler					Ju					
Common Yellowthroat		M			M					
Indigo Bunting		Ju			JuJy					
Chipping Sparrow	Ju	Ju	Ju	MJu	MJu					
Song Sparrow		M		Ju						
Swamp Sparrow	Ju	Ju	Jy		Jy					
White-winged Crossbill			Jy							
Evening Grosbeak	Ju									
Blue Jay			M				Jy		Jy	A
Ruby-crowned Kinglet				S				A		
Hermit Thrush		A							Ju	
American Robin	Ju							Ju		
Ruffed Grouse						Ju	S		S	
Yellow-bellied Sapsucker										M
Downy Woodpecker										A
Eastern Wood-Pewee								Ju	Ju	
Yellow-bellied Flycatcher						Ju				
Least Flycatcher						Ju		M	Ju	
Great Crested Flycatcher						Ju	Ju	M		
Brown Creeper									A	
Winter Wren						Ju		Jy		M
Veery							Ju			
Cedar Waxwing									A	Ju
Red-eyed Vireo								A		M
Northern Parula							M			
Black-throated Green Warbler										M
Blackburnian Warbler									Ju	
Black-and-white Warbler							M			M
Ovenbird							Jy	JuJy		M
Canada Warbler							Ju	M		
Rose-breasted Grosbeak							MJu	M		
Brown-headed Cowbird										M

[a] M - May; Ju - June; Jy - July; A - August; S - September.

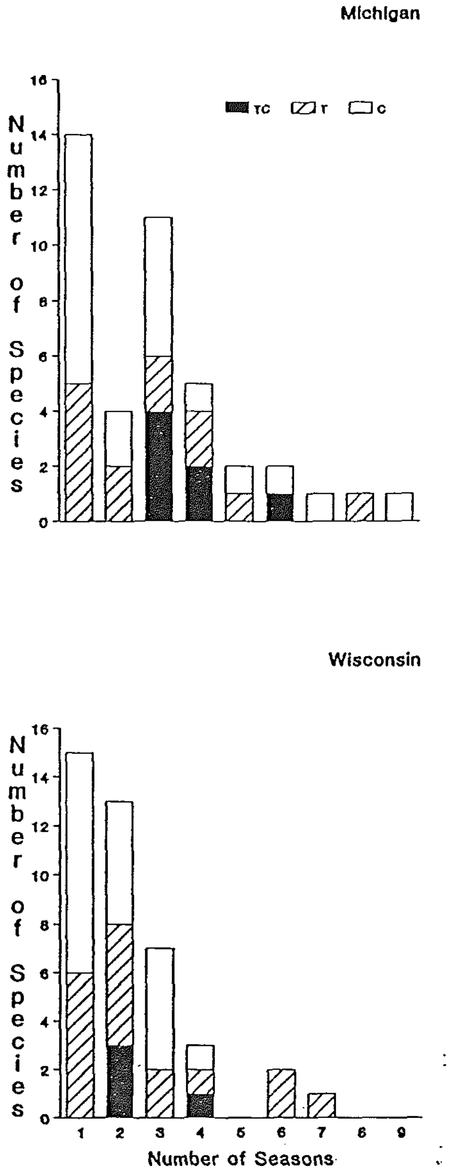

Figure 3. Number of species more abundant on treatment or control segments during 1 or more seasons, all years combined (i.e., a possible maximum of 21 "seasons" if a significant difference occurred in every season in each year). T = always more abundant on treatment; C = always more abundant on control; TC = more abundant on treatment in 1 (or more) season(s) and more abundant on control in another season.

more abundant on treatment segments in three of five Junes sampled (Table 8). White-throated Sparrows and Nashville Warblers also have been consistently more abundant on treatment segments. Several species (e.g., Yellow-bellied Sapsucker, Common Yellowthroat, Red-winged Blackbird) consistently have been more abundant on control segments in Michigan. Similarly, in Wisconsin, several species were consistently more abundant on treatment segments (e.g., Chestnut-sided Warbler, Chipping Sparrow, Golden-crowned Kinglet) (Table 9).

Differences in abundance of species that showed a consistent difference between treatment and control segments likely are related to habitat in many cases. White-throated Sparrows, for example, favor early successional habitats. Such habitats were more common on treatment segments than on controls in Michigan. In contrast, deciduous woods are more common on control segments in Michigan (and Wisconsin) and Yellow-bellied Sapsuckers were more frequently observed on control segments.

HABITAT STRUCTURE ON TREATMENT AND CONTROL SEGMENTS

Habitat structure influences the composition of bird communities in many ways (see Cody 1985 for a recent review). Our sample design (long linear transects) was established to sample habitats in approximate proportion to their availability in the study areas in each state. Treatment and control segments in Michigan and Wisconsin sample a wide range of habitats, including deciduous and coniferous woods, bogs, meadows, marshes, and logged areas of different ages. This diversity of habitats ensures that a diverse assemblage of birds will be sampled. The predominant influence of habitat structure on many aspects of bird communities means, however, that areas that differ in structure and species composition of the vegetation will differ (to a greater or lesser extent) in species composition and abundance of birds present.

Placement of treatment segments was constrained by the location of the ELF transmission lines. Thus, our sampling is not strictly random with respect to habitats in the study regions. In both states for example, treatment areas support more coniferous habitat, particularly lowland coniferous habitats, whereas control areas support more deciduous habitats (Blake et al. 1988). Differences in a variety of other habitat features also occur, but the deciduous-coniferous difference was most pronounced and, as has been discussed above, likely influenced composition of related bird communities. Several differences in bird community characteristics observed between treatment and control segments likely were due to differences in habitat and we are accounting for many of these differences with our analyses.

Habitat structure on Wisconsin segments

The experimental design in Michigan (before-and-after) will allow us to detect changes due to EM fields, apart from those due to habitat differences, if such changes occur. Because the antenna has been operating in Wisconsin since before this project started, we may not be able to detect effects of the EM fields without accounting for differences in habitat structure. To account for such habitat effects, we paired treatment and control segments on the basis of vegetation. We reasoned that if habitat structure on treatment and control segments being compared was similar, then differences in bird populations, if they occur, might be due to factors other than habitat.

No comparisons based on paired segments revealed a significant difference between treatment and control segments for total species or individuals. Only two significant differences were noted among abundant species; in both cases, correcting for habitat increased abundances on treatment segments. No difference in abundance that was significant when all segments were included also was significant when segments were paired on the basis of habitat. Thus, when habitat differences are accounted for, there is even less evidence to indicate a significant treatment effect in Wisconsin.

These analyses were done for 1989 only; results for 1988 were treated in last year's report (Blake et al. 1989). The significance of observed patterns may be more apparent when results from all years are examined, as will be done for the final report for Wisconsin (Hanowski et al., in prep.). Similarly, we will reexamine distribution patterns of different guilds (e.g., species preferring deciduous habitat).

OBJECTIVES

Our major objective for 1989 was to complete bird censuses during all seasons in both states; that objective was met. Our objectives for 1990 and beyond are to continue our sampling of bird communities in Michigan, following our established procedures. We also will complete a thorough analysis of all Wisconsin data for incorporation into a final report for that state.

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Appendix 1. Summary of Experimental Design, Study Areas, and Methods used in the design and execution of research on effects of the ELF transmitter on bird communities and populations.

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EXPERIMENTAL DESIGN

The first steps in the experimental design were to (1) evaluate techniques for quantifying bird community parameters and (2) determine sample sizes required to detect a specified difference between control and treatment areas. Four potential techniques were examined: transect counts, point counts, territorial mapping, and mist-netting (Table A1). Territorial mapping and mist-netting were eliminated from consideration because of the amount of effort required to obtain statistically reliable results.

Transect and point counts are closely related techniques that differ primarily in a) whether the observer is moving (transects) or stationary (point counts) and b) in the size (area) of the experimental unit. For our comparison, we assumed that we could census an area 100 m from the point or transect line (both sides). The point count method would result in an effective census area of about 6.28 ha (assuming two point counts completed in the same time as one 500 m transect); a 500 m transect would cover about 10 ha. We decided to use transect counts because the ELF communications system consists of a long, linear network of the antenna and ROW and transects could be run parallel to this network. Point counts also could have been run adjacent to this network, but because we would walk along the swath adjacent to the ELF network, we decided to use the method that would include the larger census area (transects). In addition, if our estimates of the mean and variances are correct, transect counts are slightly more efficient in terms of effort (Table A1).

Table A1. Comparison of statistics for four bird census methods using the number of species as the community parameter of interest. Difference detectable was set at 15% of the mean and determination of sample size necessary to detect that difference was based on a probability of 0.05 and a power of 80% (Snedecor and Cochran 1967, p. 113). Formula used was: $n = (15.8 \times S^2)/d^2$ where d=the absolute difference detectable or 15% of the mean (Snedecor and Cochran 1967). Statistics were estimated for forested habitats in the upper-midwestern United States based on the authors personal data.

Method	Mean number of species	Variance	Absolute difference detectable	N	Effort per n in hr	Initial effort per n in hr	Total effort in hr
Point count [1]	6.0	10.0	0.90	195	0.25	0.60	169
Transect count [2]	12.0	8.0	1.80	39	0.60	3.00	144
Territory mapping [3]	18.0	25.0	2.70	54	16.00	16.00	1728
Mist-netting [4]	1.6	1.8	0.24	494	0.50	0.25	371

[1] Estimates are for all species observed during 10 min count period.

[2] Estimates are for the number of species observed during a 30 min census of a 500 m transect.

[3] Estimates are for the total territorial males mapped in a 12.5 ha area.

[4] Estimates are for the number of species caught in a 12 m mist-net during a 5 hr period.

In an ideal experimental design, each segment should be randomly assigned to control and treatment areas. From the perspective of censusing in the field, however, this arrangement would be inefficient. To balance statistical rigor with the practicalities of working in the field, we decided to group eight 500 m segments into one long transect line (hereafter called transect). Each segment was separated by a buffer of 50 m to reduce autocorrelation between the experimental units (Figure A1). We grouped eight segments because our previous experience indicated that bird censuses should be conducted from one half hour before sunrise to about four hours after sunrise. A total of 4 hours and 35 minutes are needed to census eight segments and seven buffers (30 minutes for each segment and 3 minutes for each buffer). We estimated that 39 segments (Table A1) were needed in each group (control and treatment for each state) to detect a 15% difference in number of species. This percent difference was selected based on the ability to detect a difference of one species between control and treatment areas. Therefore, we selected five transect starting points per group or a total of 160 segments (40 segments per group).

Placement of treatment transects with respect to the ELF antenna system was designed to achieve two goals: (1) to reduce or eliminate potential effects of the ROW edge on the bird community (Chasko and Gates 1982), and (2) to maintain an appropriate EM field within the treatment area. We placed the transects parallel to and 125 m from the edge of the ELF antenna ROW (Figure A1). This achieved a 25 m buffer from the limits of where we recorded birds (100 m) from the ROW edge. Although this placement reduced the intensity of EM fields within treatment areas, EM fields were still high enough to achieve the 10:1 ratio between treatment and control areas required in the study specifications (Brosh et al. 1986).

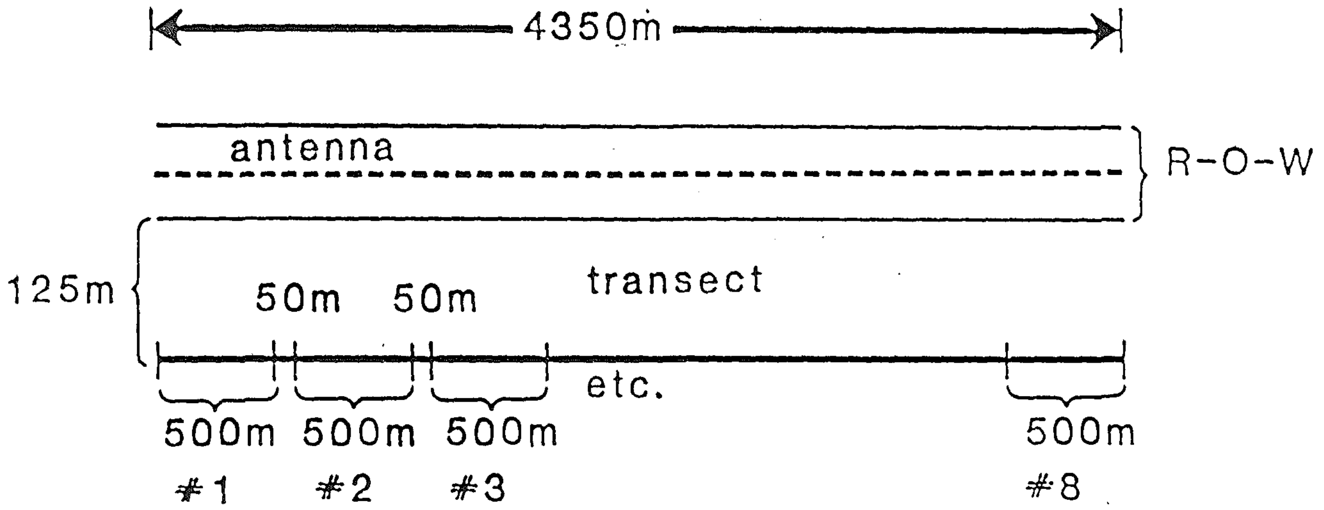

Figure A1. Schematic of a treatment transect layout. ROW = right-of-way.

STUDY AREAS

Starting locations for 10 control and 10 treatment transects were randomly selected in Michigan and Wisconsin (Figures A2 and A3) with methods described previously (Niemi and Hanowski 1986). Electromagnetic fields were measured to insure that 76 Hz EM fields at a treatment site were significantly larger than: (1) 76 Hz EM fields at control sites, (2) 60 Hz fields at treatment sites, and (3) 60 Hz fields at control sites. In addition, exposure criteria required that there was no substantial difference in the ambient 60 Hz EM fields between control and treatment transects (Brosh et al. 1986). Electromagnetic fields were measured at the beginning and ending points for each transect; they were not completed for each transect segment because most were not easily reached (e.g., most are 1-4 km from a road). However, in 1988 and 1989 EM fields were measured along three entire transects in Wisconsin and at various perpendicular distances from the antenna (Haradem et al. 1989). These measurements will provide a measure of how EM fields vary both along and perpendicular to the antennna.

All transect pairs (control versus treatment) in Wisconsin fall within the "acceptable" category for EM field ratios established by IITRI. Eight of 25 transect pairs in Michigan were determined to be "conditionally acceptable" based on data collected in 1986. Previous data placed all pairs in the "acceptable" category (Haradem et al. 1987). All transects still satisfy the EM exposure criteria and will be used for the remainder of the monitoring period.

Information regarding proposed logging along the transects was obtained from Department of Natural Resources in Michigan and the U.S. Forest Service in Wisconsin. Five control and five treatment transect segments were scheduled for

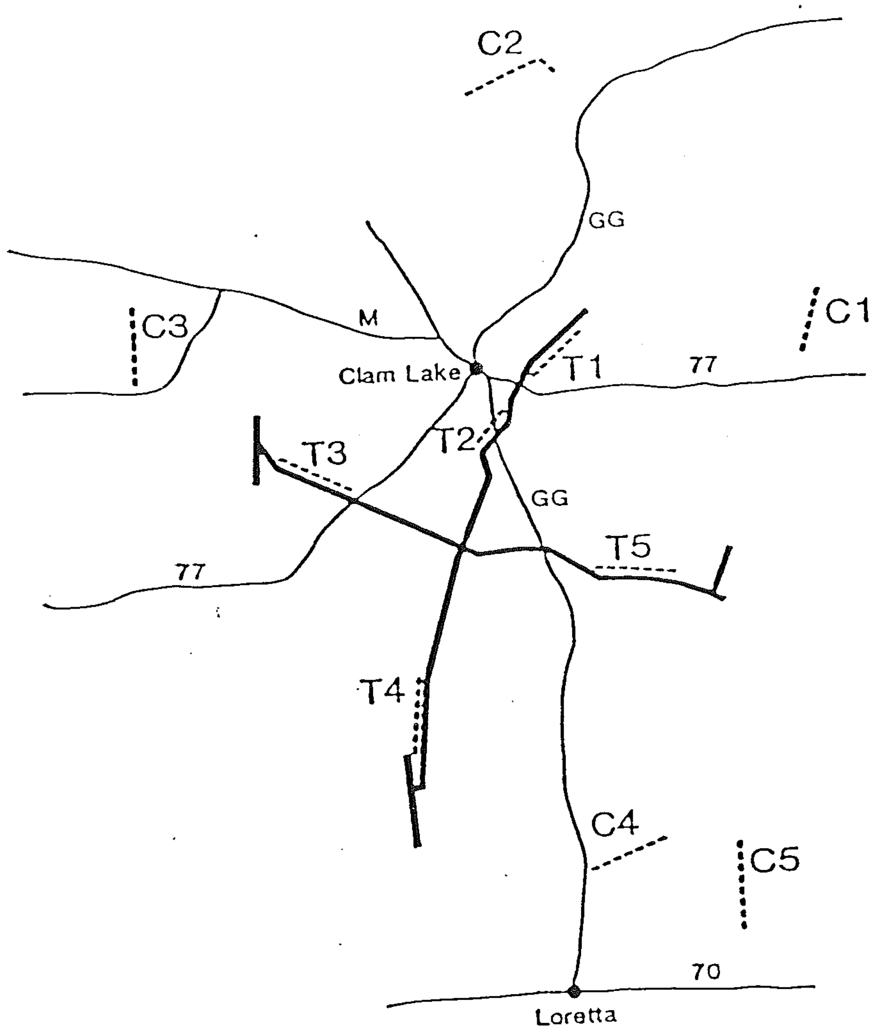

Figure A2. Location of Wisconsin antenna and study transects.

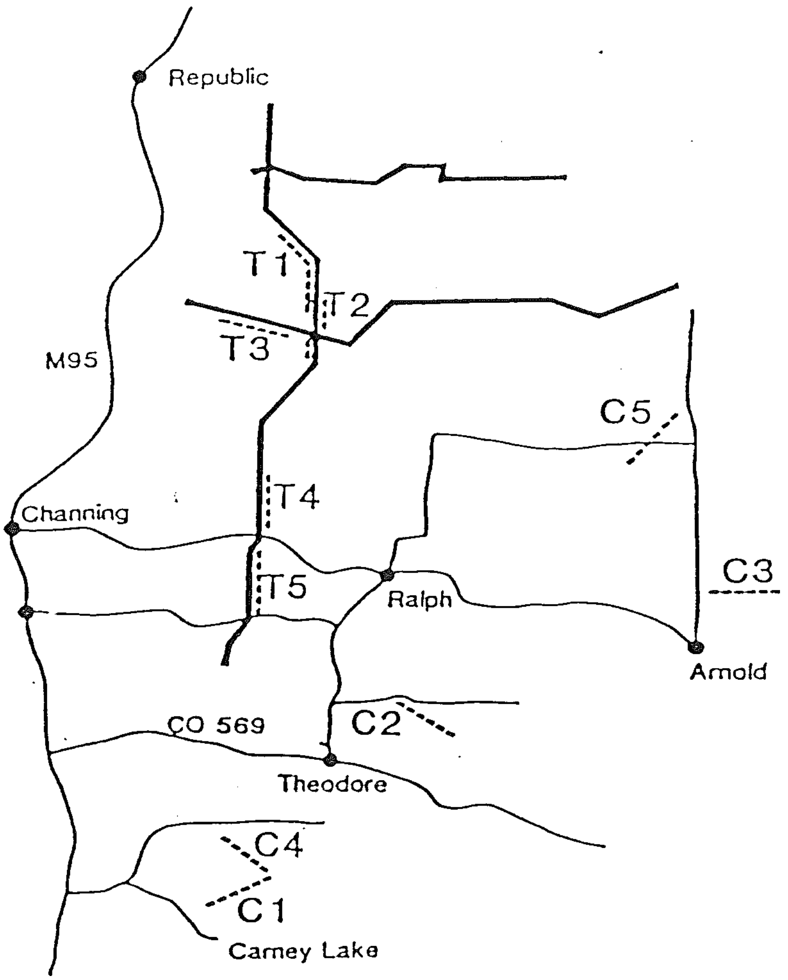

Figure A3. Location of Michigan antenna and study transects.

logging in Michigan effective through 1990 (Table A2). However, in an agreement reached with Michigan DNR (September 1988), logging on Carney Lake and Skunk Creek will not be completed until 1992 (Table A2). In 1989 three Michigan segments were affected by logging (Heart Lake, Leemans Road, and Arnold Road)(Table A2). In Wisconsin, two control and eight treatment transect segments will be affected; however, all of these sites will be selectively cut or thinned (Table A2). In 1989 two Wisconsin segments were affected by logging activity (both in Moose River)(Table A2). Because of the length of our transects, it is probably impossible to avoid areas affected by logging. We will be sensitive to disturbances along transects in subsequent analyses and if necessary, affected transect segments can be removed from analyses. This will allow us to assess potential affect of logging or other disturbances on results of the investigation.

METHODS

Bird censuses

We used the line-transect method to census all transects (Emlen 1971, 1977; Jarvinen and Vaisanen 1975). Census data were gathered during morning hours (one half hour to four and one half hours after sunrise) on days when wind speed was < 15 km/hr and when there was little or no precipitation. Control and treatment transect segments were censused simultaneously by two observers to eliminate differences that could occur by censusing at different times. Censuses of control and treatment transects were randomly assigned to each of two observers with the restriction that each observer census the same number of control (80) and treatment (80) segments in each census period. This was done to control for potential differences in observers.

Table A2. Summary of Michigan and Wisconsin transect locations and proposed logging of study areas effective through 1990. Asterisks denote sections that were logged in 1987 (*) 1988 (**) and 1989 (***). No additional study areas in Michigan are scheduled to be logged before the end of the study.

Number and Name		Township	Range	Sections	Number of 500 m segments affected
MICHIGAN					
C1	Carney Lake	41N	29W	33,34,35,36	2 (1992)
C2	Skunk Creek	42N	28W	14,23,24	2 (1992)
		42N	27W	19,30	
C3	Arnold	43N	25W	31,32,33,34	1 *
		43N	25W	32	1 ***
C4	Lost Lake	41N	29W	21,26,27,28,35	2 **
C5	Bob's Creek	44N	26W	13,23,24,26	1 (1989)
T1	Heart Lake	45N	28W	7,18	1
		45N	28W	19	1 ***
T2	Flat Rock Creek	44N	28W	6	3 *
		45N	28W	19,30,31	
T3	Schwartz Creek	45N	28W	31	2 **
		45N	29W	26,27,35,36	
T4	Turner Road	43N	29W	1,11,12	0
		44N	29W	36	
T5	Leeman's Road	43N	29W	14,23,26,35	0
WISCONSIN					
C1	Spillerberg Lake	43N	3W	23,26,35	0
C2	Mineral Lake	44N	4W	15,16,17,18	0

Table A2 continued

Number and Name		Township	Range	Sections	Number of 500 m segments affected
C3	Rock Lake	42N	6W	6	1 (thinning)
		43N	6W	19,30,31	
C4	Blaisdell Lake	40N	4W	13,14,22,23	0
		40N	3W	18	
C5	Brunette River	40N	3W	16,21,28	1 (thinning)
T1	Woodtick Lake	43N	4W	22,23,27,28,33	0
T2	Little Clam Lake	42N	4W	5,8,17	3 (thinning)
T3	Christy Lake	42N	5W	7,8,15,16,17	1 (thin part) * 1 (thin all) *
T4	Black Lake	41N	5W	24,25,36	0
T5	Moose River	42N	3W	31	1 (thin part) * 2 (thin all) *
		42N	4W	35,36	2 ***

Eight transect segments were censused daily by each observer. Each observer walked the designated transect segment at a rate of approximately 16.7 m/min and recorded the following for each bird observed: (1) species; (2) sex when possible; (3) behavior (e.g., singing or calling); (4) estimated perpendicular distance from the segment center line, in meters; (4) position relative to the segment center line (e.g., right or left side); and (5) distance, in meters, from the start of the segment. Information for each individual bird observed was recorded on microcomputer files. Birds flying over (i.e., above the canopy) were not included. Data were checked for accuracy after entry.

We used the number of individuals observed up to 100 m from the segment center line in all data analyses instead of attempting to calculate a density value. Relative density could be calculated with a variety of formulae (Emlen 1971, 1977; Jarvinen and Vaisanen 1975; Burnham et al. 1981) but at the present we have no basis for using one formula over another. We only assume that the number of birds recorded is related to the density of birds in an area. A disadvantage to using a density formula (e.g., LINETRAN; Burnham et al. 1981) is the number of observations required to obtain a reliable density estimate. For example, at least 30 observations/species are recommended to calculate densities with the Fourier series estimator. Such a sample size is prohibitive for this study because we do not observe this many individuals of one species on a 500 m segment. To obtain the specified sample, our segments would have to be about five times longer (about 2500 m) than they are now. This design is not feasible because of the large sample size (number of segments) needed to detect the desired difference between control and treatment areas. It may be possible to use this technique at a later date if we pool data among years or among different experimental units.

An advantage of using total number of observations is that we reduce potential variability between observers in ability to estimate distance (Svensson 1977). Here we only assume that the ability to detect individuals is similar between observers and, therefore, between control and treatment sites because each observer censuses the same number of control and treatment segments.

Bird guilds

We listed all bird species observed in Michigan and Wisconsin and all species that could potentially occur in our study areas. Each species was classified by 1) nesting area, 2) food or foraging type, 3) breeding habitat preference, and 4) migration type (Appendix 2). Classifications were based on published sources (e.g., Martin et. al. 1951; Bent 1963, 1964; Green and Niemi 1978; Terres 1982; AOU 1983, 1985) and personal observations. A hierarchical classification scheme was used if a species occurred in more than one category. When this occurred, we identified primary, secondary, and tertiary areas of use for these species; primary being the predominant category of use. We use this information in analyses to address any differential effects of the ELF antenna on species that use particular feeding strategies, specific nesting areas, or different migration patterns (see Verner 1984). These analyses allow us to test for differences between control and treatment transects for species that have similar life history characteristics and therefore, similar exposures to ELF EM fields.

Wisconsin vegetation

Vegetation on all 80 control and treatment segments was measured over a two year period (1986 and 1987). A two year period was selected to more efficiently use personnel and to better control for seasonal variation in vegetation growth. A representative portion of segments measured in 1986 were remeasured in 1987 to quantify annual differences in vegetation growth and/or variation in sampling efficiency.

Vegetation samples were collected at 25 m intervals to describe changes that occur within each segment. Sample points were positioned two meters from the transect line to avoid biases in where flag markers for transects were placed. We used methods that we have successfully used in past investigations to assess habitat characteristics (Niemi and Hanowski 1984; Niemi 1985); methods were modified from Wiens (1969) and Wiens and Rotenberry (1981). Densities of trees, shrubs, forbs, and graminoids were calculated with the point-centered quarter method (Cottam and Curtis 1956). Vegetation variables measured and their description are in Appendix 3A. All vegetation data were entered onto microcomputer files and checked for accuracy by someone other than the original data entry person.

Michigan vegetation

We classified habitats of the Michigan study areas at 25 m intervals along each segment. Nineteen habitat types were used for classification (Appendix 4) and percentage of occurrence of each type on control and treatment areas was calculated. We did this to identify gross habitat differences between control and treatment segments that might potentially explain differences in bird populations. For example, before the antenna is turned on in Michigan we would expect that any differences between control and treatment transects would be due to some other source of difference between these areas (i.e., habitat). We collected 1750 vegetation samples in Michigan and entered these data onto microcomputer files. A goodness-of-fit G-test was used to test for differences between control and treatment transects using the frequencies of the 19 habitat types observed.

Appendix 2. Nesting, feeding, habitat, and migration classification for bird species observed in Michigan and Wisconsin.

Appendix 2. 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 2 (continued)

Species	Nesting	Food	Habitat	Migration
Sora	3	19,18	8,6	2
Sandhill Crane	1	5	8,5,10	2
Solitary Sandpiper	2,3	19	9	3
Spotted Sandpiper	1	19	9	2,3
Common Snipe	1	19	8,6,5	2
American Woodcock	1	6	6,5,4,1	2
Mourning Dove	2,3	7	5,7	2
Black-billed Cuckoo	3	10	1,4,6	3
Yellow-billed Cuckoo	3	10	1,4,6	3
Great Horned Owl	2	2	3,2,1	1
Barred Owl	2	2	1,3	1
Common Nighthawk	1	11	3,7,4	3
Whip-poor-will	1	11	1,3,4	2
Chimney Swift	4	11	7,3,1	3
Ruby-throated Hummingbird	2	17	5,7,4	3
Belted Kingfisher	4	1	9	2
Yellow-bellied Sapsucker	4	17,16	1,3,2	2
Downy Woodpecker	4	16	1,4,3	1
Hairy Woodpecker	4	16	1,3,4	1
Black-backed Woodpecker	4	16	2,11,3	1
Northern Flicker	4	9	1,3,2	2
Pileated Woodpecker	4	16	1,3,2	1

Appendix 2 (continued)

Species	Nesting	Food	Habitat	Migration
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
Sedge Wren	3	10	8,6,5	2
Marsh Wren	3	10	8	2

Appendix 2 (continued)

Species	Nesting	Food	Habitat	Migration
Golden-crowned Kinglet	2	10	2,11	2,1
Ruby-crowned Kinglet	2	10	2,11,4,6	2
Veery	1	9	1,4,3,6	3
Gray-cheeked Thrush	3	9	4,11,2	3
Swainson's Thrush	2,3	9	11,2,4	3
Hermit Thrush	1	9	3,11,1,2	2
Wood Thrush	3,1	9	1,3	3
American Robin	2,3,1	9	5,7,4,1	2,1
Gray Catbird	3	13	4,6,7	2,3
Brown Thrasher	3	9	4,7	2
Bohemian Waxwing	2	14	4,3,1	4
Cedar Waxwing	2	14	4,3,1	1,2
European Starling	4	9	7,3	1
Solitary Vireo	2	10	3,11,2	3,2
Yellow-throated Vireo	2	10	1,3	3
Warbling Vireo	2	10	4,3,1	3
Philadelphia Vireo	2,3	10	1,3,6	3
Red-eyed Vireo	2,3	10	1,3,4	3
Golden-winged Warbler	1,3	10	4,6	3
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

Appendix 2 (continued)

Species	Nesting	Food	Habitat	Migration
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
Mourning Warbler	1,3	10	4,3	3
Common Yellowthroat	3	10	6,8,4	2,3
Wilson's Warbler	3	10	6	3
Canada Warbler	3	10	3,4	3

Appendix 2 (continued)

Species	Nesting	Food	Habitat	Migration
Scarlet Tanager	3	10	1,3	3
Rose-breasted Grosbeak	3,2 13	1,4,3	3	
Indigo Bunting	3	15	5,4	3
Rufous-sided Towhee	1,2,3	8	4	2
American Tree Sparrow	3	7	5	4,2
Chipping Sparrow	2	8	2,3,4,11	2
Clay-colored Sparrow	3	8	5,6	2,3
Field Sparrow	1,3	8	5	2
Savannah Sparrow	1	8	5,8,10	2
Fox Sparrow	1,3	8	4,5	2
Song Sparrow	3	8	5,4,6	2
Lincoln's Sparrow	1	8	10,8,4	2
Swamp Sparrow	3	8	6,8	2
White-throated Sparrow	1	8	4,3,2,11,1	2
White-crowned Sparrow	1,3	8	4,6,5	2
Dark-eyed Junco	1	8	11,2,3,4	2,1
Snow Bunting	5	7	5	4
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

Appendix 2 (continued)

Species	Nesting	Food	Habitat	Migration
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

A. Nesting

1 Ground

2 Canopy or canopy vegetation (tree but not necessarily tree top)

3 Subcanopy or shrub

4 Cavity, hole or bank

Appendix 2 (continued)

5	Ledge or platform
6	Cavity - tree roots
7	Nest parasite

B. Food

1	Aquatic vertebrates, including fish or other aquatic vertebrates
2	Birds, small mammals, large insects
3	Carrion
4	Vegetation such as buds, pine needles, and seeds but excluding species concentrating on seeds or fruits
5	Various small vertebrates (including eggs and young), invertebrates, plants, carrion, etc. (e.g., Omnivores)
6	Ground invertebrates
7	Seeds (plus a smaller amount of fruit by some species)
8	Ground invertebrates and seeds
9	Ground invertebrates and fruit
10	Foliage invertebrates
11	Aerial insects - taken while in continuous flight
12	Aerial insects - taken in sallies from a perch
13	Foliage invertebrates and fruit
14	Fruit
15	Foliage invertebrates and seeds
16	Bark insects
17	Nectar and sap

Appendix 2 (continued)

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

2 Short-distance migrant; generally includes breeders; individuals generally winter south of study areas but most winter north of the tropics

3 Long-distance migrant; generally winter south of the U.S.

4 Winter resident

Appendix 3A. Description of habitat variables used to quantify habitat characteristics of Wisconsin study areas.

Appendix 3A. Description of habitat variables used to quantify habitat characteristics of Wisconsin study areas.

Habitat Variable	Description
Ground Cover	Estimate of percent of green vegetation less than 10 cm high in m^2 surrounding the center point
Water Cover	Estimate of percent of standing water in m^2 surrounding the center point
Water Depth	Depth at center point
Overall Height	Estimate of the average height of vegetation in 25 m^2 surrounding center point
Tree Density	Density of trees greater than 2.5 cm diameter breast height (dbh) measured by the point-centered quarter method
Tree Height	Height of four trees measured for tree density; measured with a clinometer
Tree Species	Identification of four trees measured for tree density
Tree Diameter	Measured dbh of four trees measured for tree density
Canopy Cover	Average of four readings taken with a spherical densiometer in NE quarter of point-centered plot
Log Density	Density of fallen logs greater than 2.5 cm diameter measured by the point-centered quarter method
Log Species	Identification of four logs measured for log density
Log Diameter	Measured diameter of four logs measured for log density. Diameter was measured at point where log was closest to center point.
Shrub Density	Density of shrubs greater than 30 cm high and less than 2.5 cm dbh measured by the point-centered method. Shrubs were defined as any plant species that was persistent in the environment year round at a height of at least 30 cm (e.g., woody shrubs and cattails)
Shrub Height	Height of four shrubs measured for shrub density

Appendix 3A (continued)

Habitat Variable	Description
Shrub Species	Species of four shrubs measured for shrub density
Forb Density	Density of forbs > 10 cm high measured by the point-centered method
Forb Species	Species of four forbs measured for forb density
Grass-Sedge Density	Density of grasses and sedges > 10 cm high measured by the point-centered quarter method

Appendix 3B. Proportion of variation explained and important variables (in order of importance) for seven factors calculated with principal components analysis of vegetation data from Wisconsin. Weighted factor scores for each transect segment were used to pair control and treatment transects (see text for detail).

Appendix 3B. Proportion of variation explained and important variables (in order of importance) for seven factors calculated with principal components analysis of vegetation data from Wisconsin. Weighted factor scores for each transect segment were used to pair control and treatment transects (see text for detail).

Factor	Proportion of Variation	Important Variables
1	.2588	Tree Height, overall height, deciduous basal area, sugar maple (Acer saccharum) importance value
2	.1262	Black ash (Fraxinus nigra) importance value, water cover, northern white cedar (Thuja occidentalis) importance value
3	.1065	Coniferous basal area, tree density
4	.0707	Number of shrub species, number of tree species
5	.0673	Balsam fir (Abies balsamea) importance value, density of trees 15-23 cm dbh, coniferous basal area
6	.0570	Density of trees 15-23 cm dbh
7	.0489	Shrub density

Appendix 4. Description of habitat types used to classify Michigan study areas.

Appendix 4. Description of habitat types used to classify Michigan study areas.

Habitat Type	Description
Upland Conifer Forest	Upland forest with > 90% conifer species (e.g., pine)
Lowland Conifer Forest	Lowland forest with > 90% conifer species (e.g., black spruce (Picea mariana))
Upland Deciduous Forest	Upland forest with > 90% mixed deciduous species
Maple Forest	Upland deciduous forest with > 90% maple sp.
Lowland Deciduous Forest	Lowland forest with > 90% deciduous species (e.g., black ash)
Upland Mixed Forest	Upland forest with mixed deciduous and coniferous species
Lowland Mixed Forest	Lowland forest with mixed deciduous and coniferous species
Cedar Forest	Lowland forest with > 90% Northern white cedar
Wet Shrub	Alder/willow wetland with no or few trees
Tree Shrub	Alder/willow wetland with trees (e.g., black ash or tamarack)
New Cut	Logged area < 5 years old
Young Cut Aspen	Logged area with aspen spp. < 3m
Young Cut Mixed	Logged area with mixed species < 3m
Short Aspen	Logged area with aspen spp. > 3m but < 10m
Short Mixed	Logged area with mixed species > 3m but < 10m
Open	Forest opening
Sedge	Wet sedge meadow
Pond	Small pond
Cattail	Wet area with > 90% cattail

Appendix 5A. Total number of individuals and species observed on control (C) and treatment (T) transects in Michigan during five census periods in 1987. English and scientific names follow AOU (1983, 1985).

Appendix 5A. Total number of individuals and species observed on control (C) and treatment (T) transects in Michigan during five census periods in 1989. English and scientific names follow AOU (1983,1985).

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
Canada Goose _Branta canadensis_	0	1	0	0	0	0	0	0	0	0
Wood Duck _Aix sponsa_	0	5	0	2	0	0	0	0	0	1
Mallard _Anas platyrhynchos_	1	1	0	0	0	0	0	0	0	0
Hooded Merganser _Lophodytes cucullatus_	0	3	0	0	0	0	0	0	0	0
Turkey Vulture _Cathartes aura_	2	0	0	0	0	0	0	0	0	0
Bald Eagle _Haliaeetus leucocephalus_	0	1	0	0	0	0	0	0	0	0
Northern Harrier _Circus cyaneus_	0	0	0	0	0	0	0	1	0	0
Sharp-shinned Hawk _Accipiter striatus_	0	0	0	1	0	1	0	1	1	1
Broad-winged Hawk _Buteo platypterus_	0	0	0	2	0	1	0	1	0	0
Red-tailed Hawk _Buteo jamaicensis_	0	0	0	1	0	0	0	0	3	0
American Kestrel _Falco sparverius_	0	2	2	2	0	0	3	0	0	0
Spruce Grouse _Dendragapus canadensis_	0	0	0	0	0	0	0	0	0	1

Appendix 5A (continued)

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
Ruffed Grouse Bonasa umbellus	23	13	7	2	6	14	21	7	4	0
American Woodcock Scolopax minor	1	1	3	0	4	3	1	5	7	0
Black-billed Cuckoo Coccyzus erythropthalmus	0	0	0	0	1	0	0	0	0	0
Yellow-billed Cuckoo Coccyzus americanus	0	0	1	4	0	0	0	0	0	0
Barred Owl Strix varia	0	0	0	0	0	0	0	1	0	0
Whip-poor-will Caprimulgus vociferus	0	1	0	0	0	0	1	0	0	0
Chimney Swift Chaetura pelagica	0	0	0	0	0	2	0	0	0	0
Ruby-throated Hummingbird Archilochus colubris	0	0	1	0	0	2	2	2	0	2
Belted Kingfisher Ceryle alcyon	0	1	0	0	0	1	0	0	0	0
Yellow-bellied Sapsucker Sphyrapicus varius	13	46	6	17	9	18	5	11	0	4
Downy Woodpecker Picoides pubescens	7	7	4	0	3	3	4	2	0	5
Hairy Woodpecker Picoides villosus	2	4	3	3	3	1	2	6	4	4
Black-backed Woodpecker Picoides arcticus	1	0	0	0	0	3	1	2	1	0
Northern Flicker Colaptes auratus	25	14	8	7	12	12	21	8	6	6
Pileated Woodpecker Dryocopus pileatus	1	0	0	1	2	3	1	0	3	0

Appendix 5A (continued)

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
Olive-sided Flycatcher _Contopus_ _borealis_	0	0	2	1	1	1	1	1	2	1
Eastern Wood-Pewee _Contopus_ _virens_	0	0	7	18	5	11	8	26	5	6
Yellow-bellied Flycatcher _Empidonax_ _flaviventris_	0	0	17	9	11	8	1	0	0	0
Alder Flycatcher _Empidonax_ _alnorum_	0	0	9	12	2	2	6	6	0	0
Least Flycatcher _Empidonax_ _minimus_	0	0	29	31	20	37	2	4	0	1
Eastern Phoebe _Sayornis_ _phoebe_	1	2	0	0	0	0	1	1	0	0
Great Crested Flycatcher _Myiarchus_ _crinitus_	0	2	2	17	2	19	1	2	0	1
Eastern Kingbird _Tyrannus_ _tyrannus_	0	0	2	2	4	1	6	8	0	0
Tree Swallow _Tachycineta_ _bicolor_	1	0	0	0	0	0	0	0	0	0
Gray Jay _Perisoreus_ _canadensis_	2	0	2	1	7	1	7	5	8	4
Blue Jay _Cyanocitta_ _cristata_	16	11	16	17	20	14	14	19	36	24
American Crow _Corvus_ _brachyrhynchos_	1	0	1	0	1	0	0	1	0	0
Common Raven _Corvus_ _corax_ _Linnaeus_	2	2	1	4	1	1	1	3	1	1
Black-capped Chickadee _Parus_ _atricapillus_	68	75	13	28	29	52	96	97	97	99
Boreal Chickadee _Parus_ _hudsonicus_	5	0	4	0	2	1	10	2	2	1

Appendix 5A (continued)

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
Red-breasted Nuthatch Sitta canadensis	10	10	5	14	18	23	54	42	77	61
White-breasted Nuthatch Sitta carolinensis	1	4	0	0	0	1	3	7	0	3
Brown Creeper Certhia americana	16	35	3	8	5	14	13	21	1	7
Winter Wren Troglodytes troglodytes	13	25	10	25	17	24	11	10	4	3
Sedge Wren Cistothorus platensis	0	0	1	3	5	1	0	0	2	0
Marsh Wren Cistothorus palustris	0	2	0	0	0	0	0	1	0	0
Golden-crowned Kinglet Regulus satrapa	59	39	40	24	40	24	67	17	46	44
Ruby-crowned Kinglet Regulus calendula	24	35	6	1	3	1	7	1	2	0
Eastern Bluebird Sialia sialis	1	0	2	1	0	0	0	0	0	0
Veery Catharus fuscescens	0	0	20	18	17	25	1	0	2	0
Swainson's Thrush Catharus ustulatus	0	0	0	2	0	0	0	0	0	0
Hermit Thrush Catharus guttatus	41	31	26	41	91	81	46	45	16	14
Wood Thrush Hylocichla mustelina	0	0	2	0	0	1	0	0	0	0
American Robin Turdus migratorius	29	39	22	18	17	25	19	7	9	6
Gray Catbird Dumetella carolinensis	0	0	0	1	2	0	2	0	0	0

Appendix 5A (continued)

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
Brown Thrasher Toxostoma rufum	4	0	6	2	3	0	2	0	1	0
Cedar Waxwing Bombycilla cedrorum	0	0	7	3	26	14	36			
European Starling Sturnus vulgaris	1	4	2	0	0	0	5	0	0	0
Solitary Vireo Vireo solitarius	0	2	9	2	3	1	2	1	0	1
Yellow-throated Vireo Vireo flavifrons	0	0	0	1	1	1	0	0	0	0
Philadelphia Vireo Vireo philadelphicus	0	0	1	0	0	0	0	0	0	0
Red-eyed Vireo Vireo olivaceus	0	0	51	62	61	82	34	43	7	16
Golden-winged Warbler Vermivora chrysoptera	0	0	6	11	1	0	0	0	0	0
Tennessee Warbler Vermivora peregrina	0	0	0	2	0	0	0	0	2	0
Nashville Warbler Vermivora ruficapilla	0	1	111	72	94	49	18	11	3	3
Northern Parula Parula americana	0	0	5	8	4	8	0	0	1	1
Yellow Warbler Dendroica petechia	0	0	0	0	0	1	1	0	0	0
Chestnut-sided Warbler Dendroica pensylvanica	0	0	51	30	41	25	6	4	2	1
Magnolia Warbler Dendroica magnolia	0	0	3	0	0	0	1	0	0	0
Black-throated Blue Warbler Dendroica caerulescens	0	0	0	2	0	0	0	0	1	0

Appendix 5A (continued)

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
Yellow-rumped Warbler Dendroica coronata	43	39	17	14	19	16	0	1	0	4
Black-throated Green Warbler Dendroica virens	0	1	32	59	31	47	11	14	2	2
Blackburnian Warbler Dendroica fusca	0	0	11	8	1	6	2	0	0	0
Pine Warbler Dendroica pinus	0	0	4	1	0	0	0	0	0	0
Palm Warbler Dendroica palmarum	1	0	0	0	1	0	0	0	0	0
Black-and-white Warbler Mniotilta varia	0	0	15	17	9	14	4	1	2	4
American Redstart Setophaga ruticilla	0	0	0	1	0	0	0	0	1	1
Ovenbird Seiurus aurocapillus	0	0	120	153	87	140	7	11	17	8
Northern Waterthrush Seiurus noveboracensis	0	2	0	7	0	4	0	0	0	0
Connecticut Warbler Oporornis agilis	0	0	1	0	2	0	0	0	0	0
Mourning Warbler Oporornis philadelphia	0	0	23	11	28	10	0	0	0	0
Common Yellowthroat Geothylpis trichas	0	0	4	21	11	22	6	1	5	5
Canada Warbler Wilsonia canadensis	0	0	1	7	3	4	1	1	2	3
Scarlet Tanager Piranga olivacea	0	0	9	14	8	8	0	0	1	1
Rose-breasted Grosbeak Pheucticus ludovicianus	0	0	18	39	12	10	4	1	1	4

Appendix 5A (continued)

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
Indigo Bunting *Passerina cyanea*	0	0	12	8	24	17	12	0	3	0
Rufous-sided Towhee *Pipilo erythrophthalmus*	2	0	9	3	10	3	11	1	0	1
Chipping Sparrow *Spizella passerina*	7	13	19	9	18	5	11	3	2	0
Vesper Sparrow *Pooecetes gramineus*	2	0	0	0	2	0	0	0	0	0
Song Sparrow *Melospiza melodia*	15	16	13	10	18	17	16	6	3	0
Swamp Sparrow *Melospza georgianna*	5	9	7	9	7	15	4	4	5	5
White-throated Sparrow *Zonotrichia albicollis*	58	35	56	40	73	41	72	15	14	6
Dark-eyed Junco *Junco hyemalis*	13	1	4	0	2	0	2	0	1	0
Red-winged blackbird *Agelaius phoeniceus*	0	12	1	20	0	12	0	0	0	0
Rusty Blackbird *Euphagus carolinus*	0	1	0	0	0	0	0	0	0	0
Common Grackle *Quiscalus quiscula*	9	11	2	2	2	7	1	0	0	0
Brown-headed Cowbird *Molothrus ater*	9	18	1	5	2	2	0	0	0	0
Northern Oriole *Icterus galbula*	0	0	4	3	0	2	0	0	0	0
Purple Finch *Carpodacus purpureus*	21	20	4	3	0	1	3	0	0	0
Red Crossbill *Loxia curvirostra*	1	0	0	0	0	0	0	0	0	0

Appendix 5A (continued)

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
White-winged Crossbill *Loxia leucoptera*	0	0	37	0	0	0	23	0	9	7
Pine Siskin *Carduelis pinus*	0	4	0	0	0	0	0	0	0	0
American Goldfinch *Carduelis tristis*	1	0	6	2	1	1	9	4	8	1
Evening Grosbeak *Coccothraustes vespertinus*	4	1	0	1	0	3	1	0	0	1
Unidentified passerine *Unidentified passerine*	7	5	23	18	23	14	42	39	59	51
Unidentified woodpecker *Unidentified woodpecker*	1	0	1	2	6	5	5	6	3	1
Unidentified raptor *Unidentified raptor*	0	0	0	0	0	0	0	0	1	0
Total individuals	570	607	983	1020	994	1039	791	551	505	435
Total species	44	46	70	71	63	68	62	52	48	45

Appendix 5B. Total number of individuals and species observed on control (C) and treatment (T) transects in Wisconsin during five census periods in 1989. English and scientific names follow AOU (1983, 1985).

Appendix 5B. Total number of individuals and species observed on control (C) and treatment (T) transects in Wisconsin during five census periods in 1989. English and scientific names follow AOU (1983, 1985).

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
Pied-billed Grebe <u>Podilymbus</u> <u>podiceps</u>	0	0	1	0	0	0	0	0	0	0
American Bittern <u>Botaurus</u> <u>lentiginosus</u>	1	0	1	0	0	0	0	0	0	0
Great Blue Heron <u>Ardea</u> <u>herodias</u>	0	0	0	0	0	0	0	1	0	1
Wood Duck <u>Aix</u> <u>sponsa</u>	1	0	0	0	0	9	0	0	0	2
Mallard <u>Anas</u> <u>platyrhynchos</u>	0	4	0	1	0	0	0	0	0	0
Hooded Merganser <u>Lophodytes</u> <u>cucullatus</u>	0	3	0	0	0	0	0	0	0	0
Sharp-shinned Hawk <u>Accipiter</u> <u>striatus</u>	0	0	0	0	2	0	0	0	0	0
Broad-winged Hawk <u>Buteo</u> <u>platypterus</u>	2	2	1	2	0	1	0	0	0	1
Red-tailed Hawk <u>Buteo</u> <u>jamaicensis</u>	0	0	1	0	0	0	0	0	0	1
Ruffed Grouse <u>Bonasa</u> <u>umbellus</u>	11	18	4	6	5	12	2	0	8	16
Common Snipe <u>Gallinago</u> <u>gallinago</u>	0	1	0	0	0	0	0	0	0	0
American Woodcock <u>Scolopax</u> <u>minor</u>	2	1	2	1	0	0	1	1	0	2
Yellow-billed Cuckoo <u>Coccyzus</u> <u>americanus</u>	0	0	0	0	0	0	0	0	4	0

Appendix 5B (continued)

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
Barred Owl *Strix varia*	1	1	0	0	0	0	1	0	0	2
Chimney Swift *Chaetura pelagica*	1	0	1	2	0	0	0	0	0	0
Ruby-throated Hummingbird *Archilochus colubris*	0	0	1	0	0	0	0	0	0	0
Belted Kingfisher *Ceryle alcyon*	0	1	0	1	0	1	1	3	1	0
Yellow-bellied Sapsucker *Sphyrapicus varius*	11	22	15	14	1	2	3	1	5	11
Downy Woodpecker *Picoides pubescens*	0	2	0	1	0	2	2	0	2	16
Hairy Woodpecker *Picoides villosus*	3	2	3	2	0	2	3	7	5	4
Black-backed Woodpecker *Picoides arcticus*	1	3	0	1	0	0	1	0	0	1
Northern Flicker *Colaptes auratus*	1	3	5	7	5	2	2	2	6	5
Pileated Woodpecker *Dryocopus pileatus*	3	1	0	1	1	2	1	1	2	1
Olive-sided Flycatcher *Contopus borealis*	1	1	4	1	2	5	0	1	0	0
Eastern Wood-Pewee *Contopus virens*	0	3	5	10	2	8	3	11	1	6
Yellow-bellied Flycatcher *Empidonax flaviventris*	10	11	28	31	21	20	4	1	0	0
Alder Flycatcher *Empidonax alnorum*	2	0	3	3	3	0	1	0	0	0
Least Flycatcher *Empidonax minimus*	21	31	32	23	3	1	0	1	0	0

Appendix 5B (continued)

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
Eastern Phoebe *Sayornis phoebe*	1	0	0	0	0	0	0	0	0	0
Great Crested Flycatcher *Myiarchus crinitus*	6	12	5	4	0	1	0	0	0	0
Eastern Kingbird *Tyrannus tyrannus*	0	0	0	1	2	3	0	0	0	0
Tree Swallow *Tachycineta bicolor*	0	5	0	0	0	3	0	0	0	0
Gray Jay *Perisoreus canadensis*	3	1	1	0	1	0	3	4	3	5
Blue Jay *Cyanocitta cristata*	34	25	21	19	9	14	9	21	32	48
American Crow *Corvus brachyrhynchos*	0	2	1	0	0	0	0	0	0	0
Common Raven *Corvus corax Linnaeus*	0	0	0	3	0	1	0	0	0	0
Black-capped Chickadee *Parus atricapillus*	26	24	18	28	84	44	93	91	104	98
Boreal Chickadee *Parus hudsonicus*	0	0	0	0	0	1	1	0	2	0
Red-breasted Nuthatch *Sitta canadensis*	14	7	14	9	13	8	30	28	196	184
White-breasted Nuthatch *Sitta carolinensis*	2	1	0	3	0	1	1	5	2	6
Brown Creeper *Certhia americana*	6	12	12	18	6	12	10	13	21	25
Winter Wren *Troglodytes troglodytes*	20	47	29	35	24	32	10	7	4	3
Sedge Wren *Cistothorus platensis*	5	0	0	0	3	0	0	0	0	0

Appendix 5B (continued)

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
Marsh Wren Cistothorus palustris	0	0	2	0	0	0	0	0	0	0
Golden-crowned Kinglet Regulus satrapa	40	17	28	14	40	21	45	38	36	22
Ruby-crowned Kinglet Regulus calendula	1	0	2	1	0	0	0	0	3	0
Veery Catharus fuscescens	1	0	12	4	2	2	0	3	0	0
Swainson's Thrush Catharus ustulatus	0	0	0	0	0	0	0	0	4	4
Hermit thrush Catharus guttatus	40	30	55	58	91	76	9	10	11	14
Wood Thrush Hylocichla mustelina	0	0	0	1	0	0	0	0	0	0
American Robin Turdus migratorius	10	10	6	12	4	6	7	4	0	0
Gray Catbird Dumetella carolinensis	0	0	0	0	0	1	2	0	0	0
Brown Thrasher Toxostoma rufum	1	0	0	1	0	0	1	0	0	0
Cedar Waxwing Bombycilla cedrorum	0	0	1	11	14	13	43	23	7	4
Solitary Vireo Vireo solitarius	4	11	5	1	0	3	2	0	1	2
Philadelphia Vireo Vireo philadelphicus	2	1	0	0	0	0	0	0	0	0
Red-eyed Vireo Vireo olivaceus	28	39	78	108	73	92	30	37	10	6
Golden-winged Warbler Vermivora chrysoptera	14	6	6	6	0	1	0	0	0	0

Appendix 5B (continued)

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
Tennessee Warbler *Vermivora peregrina*	2	1	1	1	0	0	3	0	6	0
Nashville Warbler *Vermivora ruficapilla*	92	68	56	75	53	25	5	3	13	2
Northern Parula *Parula americana*	13	21	12	17	2	3	0	2	0	0
Yellow Warbler *Dendroica petechia*	4	1	3	0	0	0	1	0	0	0
Chestnut-sided Warbler *Dendroica pensylvanica*	77	56	70	50	17	6	0	3	6	3
Magnolia Warbler *Dendroica magnolia*	4	1	4	4	6	2	0	0	0	1
Cape May Warbler *Dendroica tigrina*	0	0	1	0	0	0	0	0	0	0
Yellow-rumped Warbler *Dendroica coronata*	30	18	20	4	9	2	0	2	41	7
Black-throated Green Warbler *Dendroica virens*	47	77	47	57	34	38	3	4	5	8
Blackburnian Warbler *Dendroica fusca*	7	16	13	18	0	0	1	0	1	1
Pine Warbler *Dendroica pinus*	0	0	0	1	0	0	0	0	0	0
Palm Warbler *Dendroica palmarum*	3	1	2	0	0	1	0	0	9	0
Bay-breasted Warbler *Dendroica castanea*	1	0	0	0	0	0	0	0	1	0
Black-and-white Warbler *Mniotilta varia*	30	48	21	23	6	2	3	4	2	3
American Redstart *Setophaga ruticilla*	0	1	4	1	1	0	0	1	1	0

Appendix 5B (continued)

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
Ovenbird *Seiurus aurocapillus*	144	199	119	162	47	61	18	23	20	46
Northern Waterthrush *Seiurus noveboracensis*	2	1	2	0	0	0	0	0	1	1
Connecticut Warbler *Oporornis agilis*	0	0	2	2	1	0	0	0	0	0
Mourning Warbler *Oporornis philadelphia*	5	9	34	20	11	4	3	0	0	0
Common Yellowthroat *Geothylpis trichas*	29	15	14	7	24	14	9	2	9	2
Canada Warbler *Wilsonia canadensis*	4	8	10	10	0	1	2	4	0	1
Scarlet Tanager *Piranga olivacea*	2	8	4	3	2	4	0	0	0	0
Rose-breasted Grosbeak *Pheucticus ludovicianus*	21	22	8	14	4	7	5	1	4	1
Indigo Bunting *Passerina cyanea*	0	0	10	1	14	1	4	0	0	0
Rufous-sided Towhee *Pipilo erythrophthalmus*	0	0	1	0	0	0	0	0	0	0
Chipping Sparrow *Spizella passerina*	25	3	12	1	7	0	0	0	2	0
Lark Sparrow *Chondestes grammacus*	3	0	0	0	0	0	0	0	0	0
Song Sparrow *Melospiza melodia*	10	4	12	11	17	9	7	1	1	4
Lincoln's Sparrow *Melospiza lincolnii*	1	0	0	0	2	0	0	0	0	0
Swamp Sparrow *Melospza georgianna*	13	1	7	1	20	2	0	0	3	0

Appendix 5B (continued)

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
White-throated Sparrow *Zonotrichia albicollis*	63	64	53	47	62	45	23	13	37	28
Dark-eyed Junco *Junco hyemalis*	0	1	0	6	0	0	0	0	0	0
Red-winged Blackbird *Agelaius phoeniceus*	3	4	6	5	0	0	0	0	0	0
Common Grackle *Quiscalus quiscula*	0	5	0	5	2	0	0	0	0	0
Brown-headed Cowbird *Molothrus ater*	3	14	1	2	0	0	0	0	0	0
Northern Oriole *Icterus galbula*	1	0	0	0	1	1	2	0	0	0
Purple Finch *Carpodacus purpureus*	8	5	2	2	1	0	1	0	0	0
White-winged Crossbill *Loxia leucoptera*	0	0	0	0	10	19	6	8	14	6
Pine Siskin *Carduelis pinus*	1	0	0	0	0	0	0	4	14	0
American Goldfinch *Carduelis tristis*	2	1	5	8	1	3	7	4	1	1
Evening Grosbeak *Coccothraustes vespertinus*	1	7	0	2	0	0	0	0	2	3
Unidentified passerine *Unidentified passerine*	30	21	16	7	36	30	59	53	61	46
Unidentified woodpecker *Unidentified woodpecker*	0	4	4	5	4	8	3	5	5	0
Total individuals	1011	1065	979	1016	805	690	486	451	729	654
Total species	68	65	65	67	49	54	47	40	46	44

Appendix 6. Presentations and manuscripts based on work conducted as part of the ELF monitoring program.

Presentations

Hanowski, J.M. and G.J. Niemi. 1987. Statistical perspectives and experimental design in bird censusing. American Ornithologists Union; San Francisco State University; August 1987.

Hanowski, J.M. and G.J. Niemi. 1987. Assessing the effects of an extremely low frequency (ELF) antenna system on bird species and communities in northern Wisconsin and Michigan. Lake Superior Biological Conference; University of Minnesota-Duluth; September 1987.

Blake, J.G., J.M. Hanowski, G.J. Niemi, and P.T. Collins. 1988. Seasonal and annual variation in the influence of time of day on bird censuses. Cooper Ornithological Society, Asilomar, California; March 1988.

Blake, J.G., G.J. Niemi, and J.M. Hanowski. 1989. Annual variation in bird populations: some consequences of scale of analysis. Cooper Ornithological Society, Moscow, IL; June 1989.

Blake, J.G., G.J. Niemi, and J.M. Hanowski. 1989. Drought and annual variation in bird populations: effects of migratory strategy and breeding habitat. Symposium on Ecology and Conservation of Neotropical Migrant Landbirds, Woods Hole, Massachusetts; December 1989.

Manuscripts (in review)

Blake, J.G., J.M. Hanowski, G.J. Niemi, A.R. Lima, and P.T. Collins. Hourly variation in transect counts of birds: regional, monthly, and annual effect. Submitted to Condor.

Hanowski, J.M., G.J. Niemi, and J.G. Blake. Statistical perspectives and experimental design in counting birds with line transects. Submitted to Condor.

Blake, J.G., G.J. Niemi, and J.M. Hanowski. Drought and annual variation in bird populations: effects of migratory strategy and breeding habitat. "Ecology and conservation of neotropical migrant landbirds."

Blake, J.G., J.M. Hanowski, and G.J. Niemi. Correlations between birds and habitat: annual variation in species-habitat relationships. Submitted to Condor.

Manuscripts (in preparation)

Collins, P.T., G.J. Niemi, J.G. Blake, and J.M. Hanowski. Lateral distance distribution patterns for northern forest birds.

Hanowski, J.M., J.G. Blake, G.J. Niemi, and P.T. Collins. Effects of extremely low frequency electromagnetic fields on breeding and migrating bird species and communities.

Hanowski, J.M., J.G. Blake, and G.J. Niemi. Seasonal bird distribution patterns along habitat edges in northern Wisconsin and Michigan.