ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM:

BIRD SPECIES AND COMMUNITIES

ANNUAL REPORT: 1992

SUBCONTRACT NUMBER: EO6595-88-C-011

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SUMMARY

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

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

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 areas 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 foraging and habitat guilds. Our monitoring program has included bird censuses over a five month period from May to September (1986-1992). Additional data were collected in both states during August and September of 1984 and during June of 1985. Research in Wisconsin was completed in 1989 (Hanowski et al. 1991), but has continued in Michigan.

Here we summarize results of our 1992 research activities in Michigan. The Michigan transmitter began 150 amp tuning and testing intermittently in the first part of May 1989. On 14 May, the transmitter began continuous 150 amp operation for 16 hrs/day on weekdays and all day on weekends. On 7 October 1989, the Michigan transmitter began continuous operation at full power.

Overall, bird abundance and species diversity were highest and approximately the same during May, June and July throughout all study areas. Bird abundance and species diversity were significantly higher on control segments in June 1992, whereas bird abundance was significantly higher on treatments in July; no other differences in community level parameters were significant. Considerable annual variation in numbers of individuals and species was noted. Particularly common species (all seasons combined) included Black-capped Chickadee, Red-breasted Nuthatch, Hermit Thrush, Red-eyed Vireo, Nashville Warbler, Black-throated Green Warbler, Ovenbird, and White-throated Sparrow. The most abundant species present on treatment and control segments varied among seasons.

Sixteen of 189 comparisons (8%) of individual species between treatment and control segments were significantly different. Abundances were higher on control segments in 12 cases (75%). Few species, however, were consistently and significantly more abundant on either treatment or control segments among seasons within a year or within seasons among years. Differences between treatment and control segments were most likely due to habitat differences.

Species were classified into guilds on the basis of foraging behavior and preferred breeding habitat. Few significant differences in abundance of birds within different guilds were found between treatment and control segments (three out of 25 comparisons, or 12 %). The same was true for habitat categories: only three out of 30 comparison (five months, six habitat groups), or 10%, were significantly different.

Previous analyses of vegetation on Michigan study sites (Blake et al. 1988) revealed differences between treatment and control plots. The difference most likely to influence bird populations was distribution of coniferous and deciduous habitats.

Treatment segments had more coniferous and lowland habitats than did control segments. It is important to note that habitat differences that exist between treatment and control areas will not affect our analysis of antenna effects. The Michigan study is designed as a before-and-after experiment; we can compare changes in bird abundance over time on treatment segments and on control segments. If electromagnetic fields produced by antenna operation affect bird distribution patterns, we expect to detect a change in patterns of abundance between treatment and control areas. Such changes, if they occur, would be independent of already present habitat differences.

To investigate this possibility, we analyzed changes in species abundances over time on treatment and control segments using a statistical technique repeated measures ANOVA. Few differences were significant: no community level parameters showed a significant difference and in only 3 cases (7.5% of those tested) were differences significant at the species level. These results indicate that the amount of change in bird abundance from pre-treatment to post-treatment conditions did not differ on treatment and control segments. Thus, there is no evidence to indicate that electromagnetic radiation produced by the ELF antenna has affected bird populations on our study sites.

INTRODUCTION

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

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

Effects of extremely low frequency (ELF) electromagnetic fields on birds are poorly understood (National Academy of Sciences 1977; Lee et al. 1979; other references in Hanowski et al. 1987, 1991). Several investigators have studied effects of transmission lines on structure and composition of bird communities; most have analyzed combined effects of habitat alteration and EM fields (Anderson et al. 1977; Anderson 1979; Dawson and Gates 1979; Meyers and Provost 1979; Stapleton and Kiviat 1979; Bell 1980; Bramble et al. 1984; Niemi and Hanowski 1984). Others have focused on effects of the right-of-way (ROW) edge (Chasko and Gates 1982; Kroodsma 1982), collison with lines (Beaulaurier et al. 1982), and audible noise generated by a transmission line (Lee and Griffith 1978). To our knowledge, our recently completed study on effects on birds of EM fields produced by the US Navy's ELF transmission facility in Wisconsin (Hanowski et al. 1991), was the first that attempted to separate effects of EM fields on bird species and communities from effects due to habitat changes along the ROW. That study produced no convincing evidence that birds were either attracted to or repelled by EM fields produced by the antenna.

The current investigation in Michigan, and the recently completed Wisconsin study, were designed to isolate effects of EM fields produced by ELF antenna systems on bird species breeding in or migrating through Wisconsin and Michigan. Our goal was to determine if distribution and abundance of bird species differed between areas that were close to the antenna and those that were far enough away to be unaffected by EM fields produced by the antenna. Our study has encompassed spring migration (May), early (June) and late (July) breeding, and early (August) and late (September) fall migration. 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.

To assess effects of the ELF antenna on bird communities we can either: (1) compare the affected area (treatment) with a similar control area; or (2) conduct a before-and-after study on both control and treatment plots. The former approach was used in Wisconsin because the antenna already was in operation at the start of our study. Research in Michigan was, in contrast, initiated before the antenna began operation. By following changes in bird numbers over time on areas affected by the antenna and on unaffected areas, we can separate any effects of the antenna on birds from effects of more regional variables (e.g., annual variation in rainfall) and from effects arising from differences in vegetation structure between control and treatment areas. The Michigan transmitter was tested intermittently, at less than full power during parts of our 1988 field season and at full power during most of our 1989 field season. Continuous operation at full power began on 7 October 1989. Therefore, 1992 represents the fourth full impact year. In the following we summarize our research activities in Michigan for 1992, the seventh year in which censuses were conducted during all seasons.

EXPERIMENTAL DESIGN

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

In an ideal experimental design, each sample unit should be randomly assigned to control and treatment areas. Logistically, 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 (each segment = one experimental or sample unit) into one long transect line (hereafter called transect; Fig. 1). Each 500 m segment was separated by a buffer of 50 m to reduce autocorrelation between the experimental units. We used Moran's I statistic (Sokal and Oden 1978) to test spatial aurocorrelation of adjacent segments. Results indicated that a 50 m buffer eliminated most autocorrelation between adjacent segments (Hanowski et al. 1990).

We grouped eight segments in a single line because our previous experience indicated that bird counts should be conducted from one half hour before to about four hours after sunrise. A total of 4 hours and 35 minutes are needed to count birds along eight segments and seven buffers (30 minutes for each segment and 3 minutes for each buffer). We estimated that 39 segments were needed in each group (control and treatment) to detect a 15% difference in number of species (Hanowski et al. 1990). This percent difference was selected based on an ability to detect a difference of one species between control and treatment areas. Therefore, we selected five transect starting points per group, for a total of 80 segments (40 treatment and 40 control segments).

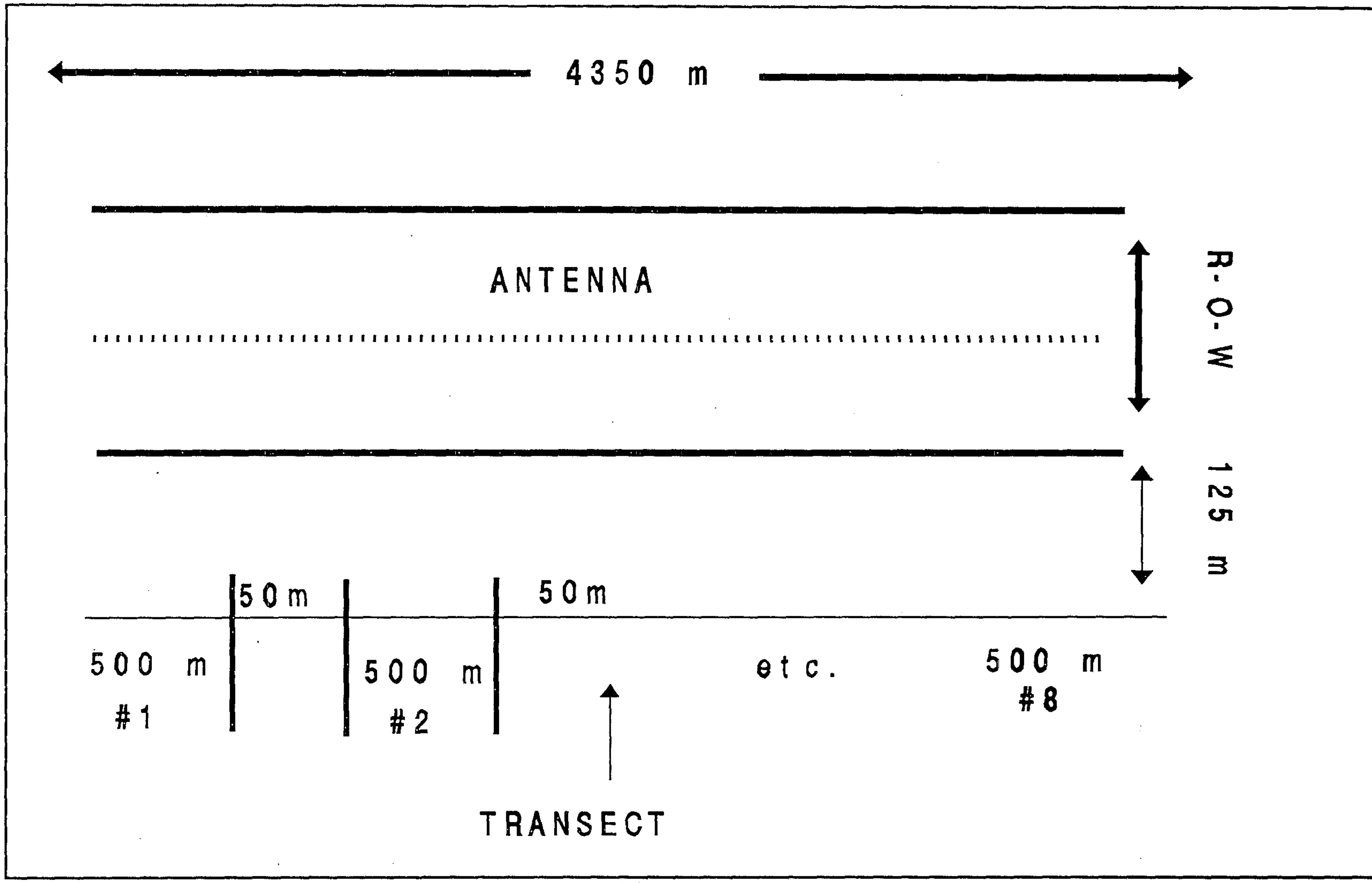

Figure 1. Schematic of a treatment transect layout. ROW = right-of-way.

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 25 m from the edge of the ELF antenna ROW (Fig. 1). This achieved a 25 m buffer from the limits of where we recorded birds (100 m) to 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).

STUDY AREAS

Starting locations for five control and five treatment transects were randomly selected (Fig. 2; see Niemi and Hanowski 1986, Hanowski et al. 1991 for details). 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 be 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). Eight of 25 transect pairs in Michigan were determined to be "conditionally acceptable" with respect to EM field ratios established by IITRI, 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. Five control and five treatment transect segments were scheduled for logging in Michigan effective through 1992 (Table 1). Several 500-m transect segments in Michigan have been partially logged since this study started (Table 1). The Michigan Department of Natural Resources agreed to delay most additional logging until 1994. Analyses of annual variation in bird community composition revealed that segments logged over <20% of total length showed no greater difference in bird populations 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

We counted birds along each 500 m segment (40 control and 40 treatment) 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). Counts were started approximately one half hour before sunrise and lasted up to approximately 4.5 hours after sunrise on days with little wind (<15 km/hr) and little or no precipitation.

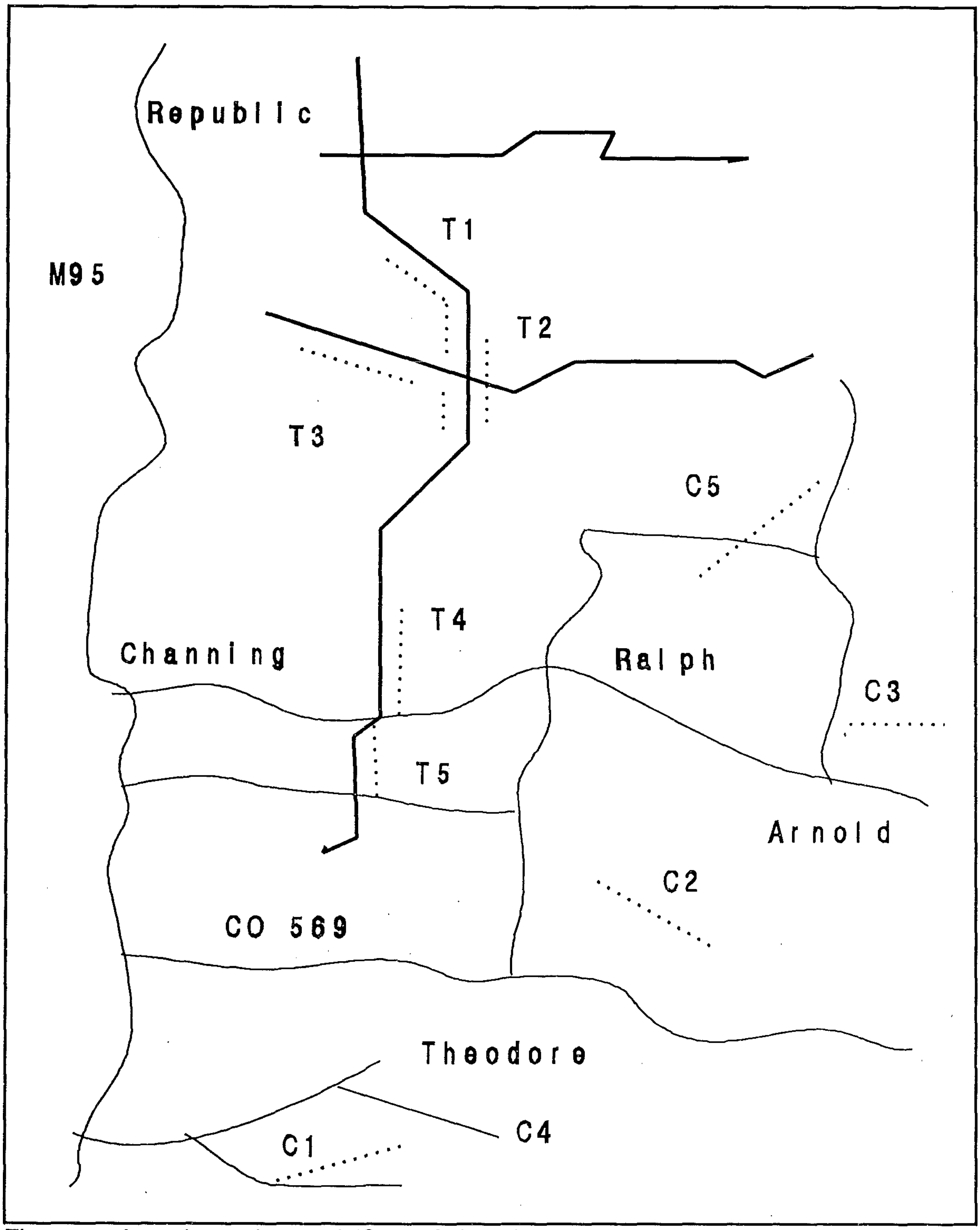

Figure 2. Locations of control (C1 to C5) and treatment (T1 to T5) transects in Michigan.

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

Number and Name		Township	Range	Sections	Number of 500 m segments affected
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 ****
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

Eight transect segments were censused by each observer daily. Each observer walked at a rate of 30 min/500 m segment and recorded the indentity and location of all birds observed (by sight or sound) within 100 m of the segment center line.

We randomly assigned counts of control and treatment transects (eight 500 m segments/transect) to each of two observers, with the restriction that each observer sample the same number of control and treatment segments. Control and treatment transects were sampled simultaneously by the two observers.

We used the number of individuals observed in all data analyses instead of attempting to calculate a density value. Density could be calculated with a variety of formulae (Emlen 1971, 1977; Järvinen and Väisänen 1975; Burnham et al. 1981), but there are several assumptions that must be met before these methods can be used. A critical assumption is that distances are measured accurately; such measurements are difficult to obtain when birds are heard but not seen, as is true for most birds recorded during counts. Without accurate distance estimates, these methods do not provide valid density estimates. Instead, density estimates provide an index that may be no better than the original counts (Wilson and Bart 1985). In addition, estimates of density are not needed in most investigations, especially when comparisons of "relative density" are less costly and allow the investigator to meet the objectives of the experiment (see Verner 1985). Here, we only assumed that the number of birds recorded was related to the density of birds in an area (Raphael 1987) and that bird detectability was similar within control and treatment areas.

We classified each species by (1) nesting area, (2) food or foraging type, (3) breeding habitat preference, and (4) migration strategy (Appendix 1), 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 1992.

STATISTICAL ANALYSES

WITHIN YEAR COMPARISONS

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

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

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

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

where D = number of individuals observed and F = the relative frequency of species occurrence on treatment or control segments. The prominence value weights both the frequency of occurrence and number of individuals (Beals 1960; Blake 1982) and therefore provides a useful description of bird distribution patterns. However, because the count data are transformed, it is not strictly correct to compare differences based on G-tests. Consequently, we decided to use Kruskal-Wallis tests in this (and all future reports) to compare differences in abundance on treatment and control segments of these less abundant species; the large sample size (40 segments per treatment or control) permitted us to do this. To facilitate comparisons with previous years, we reanalyzed results previously based on prominence values.

AMONG YEAR COMPARISONS

We used two approaches to analyze distribution patterns among years. (Because some segments were affected by logging after the initial census in 1985, we excluded logged segments [>20% logged] in analyses of annual variation.) First, we examined annual differences by season for number of species and individuals using a two-way ANOVA. Second, we compared changes among years in abundances of birds on treatment segments to changes that occurred on control segments. If antenna operation affected bird distribution patterns, we would expect a greater mean change per segment on treatment than on control segments. In earlier reports, combined data from 1986 and 1987 from each segment were used to provide a pre-treatment basis for comparison. The average difference in abundance on treatment and control segments were then compared; comparisons were made between pre-treatment values and those of all subsequent years (t-tests). The antenna was in partial operation during, and full treatment years begin in 1989.

In this report the analysis (before-and-after) is done using a repeated measures ANOVA procedure because several measurements (counts) are taken on each study unit and the measurements are correlated (data from consecutive years). The results are also more easily interpreted when using this technique. The procedure is basically a multivariate technique designed to reveal any treatment effects and it takes into account (possible) correlations between the dependent variables (Freund et al. 1986). An assumption in repeated measures ANOVA (for multivariate tests) is that the variables in the model have a multivariate normal distribution. This assumption is not strictly met here in all the cases. However, if the groups to be compared have relatively equal sample sizes and the samples are large, the analysis is not sensitive to slight deviations from the assumption (see Freund et al. 1986, Hanowski et al. 1992).

PROBABILITY VALUES

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

RESULTS

WITHIN-YEAR COMPARISONS

Species Richness and Abundance of Individuals

Total number of species and individuals observed varied among seasons on control and treatment transects (Tables 2, 3). Observations for all species are in Appendix 2. Total abundance was highest and approximately equal during May, June and July (Table 2). Bird abundance and species diversity were significantly higher on control segments during June and total abundance in July. No other differences between treatment and control segments were significant at the community level in 1992 (Table 3).

Individual Species

Particularly common species during spring migration (May; Appendix 2) included Nashville Warbler and Ovenbird both on treatment and control segments as well as White-throated Sparrow on treatments and Black-throated Green Warbler on controls. Two species (5% of 37 tested) showed a significant difference in abundance between controls and treatments (Table 4) both were more abundant on controls.

The Ovenbird, Nashville Warbler and Red-eyed Vireo were the most numerous species in June (early breeding season) on both treatment and control segments. Seven species (14% out of 51 species tested) showed a significant difference in abundance between treatment and control segments (Table 4); all of them were more abundant on control segments.

The most abundant species during July (late breeding) included the Nashville Warbler and Red-eyed Vireo on treatments and the Red-eyed Vireo and Ovenbird on control segments. Three species were significantly more abundant on treatment and one on control segments (Table 4; 4 significant cases out of 46 species tested, 9%).

Black-capped Chickadees, Red-breasted Nuthatches and Red-eyed Vireos were abundant during August on both treatment and control segments. Two species (7% of 30 tested) had a significant difference in abundance between treatments and controls; both of them were more abundant on control segments (Table 4).

Table 2. Total numbers of individuals and species observed on treatment (T) and control (C) transects in Michigan, 1985-1992. A combined species total for treatment and control segments is in parentheses.

	1985			1986			1987			1988			1989			1990			1991			1992		
	T		C	T		C	T		C	T		C	T		C	T		C	T		C	T		C
May:																								
individuals				949		1210	775		888	815		939	570		607	847		858	578		778	1045		1060
species				54	(76)	69	50	(67)	62	53	(66)	56	44	(60)	46	65	(76)	65	55	(72)	60	66	(81)	69
June:																								
individuals	1629		1327	1098		1169	1131		1162	1061		1014	983		1020	877		880	895		907	981		1189
species	70	(81)	72	60	(74)	68	71	(81)	73	70	(89)	77	70	(83)	71	66	(81)	71	63	(76)	66	65	(77)	68
July:																								
individuals				938		978	1136		1258	891		907	994		1039	772		818	892		1104	1132		964
species				59	(75)	63	68	(81)	73	69	(83)	68	63	(77)	68	65	(75)	54	59	(72)	65	68	(77)	58
August:																								
individuals				380		478	682		610	564		469	791		551	323		353	558		556	488		468
species				53	(61)	46	59	(68)	54	50	(66)	51	62	(69)	52	38	(52)	45	47	(64)	50	53	(57)	44
September:																								
individuals				402		627	634		501	469		574	505		435	398		489	612		510	394		371
species				36	(55)	48	46	(55)	41	46	(60)	47	48	(60)	45	43	(56)	44	43	(51)	44	35	(50)	42

Table 3. Mean observations in a 500m segment on control (C) and treatment (T) segments in Michigan, 1985-92; significance of one-way ANOVAs between treatment and control segments is shown for each year. For two-way ANOVAs, T = treatment effect, Y = year effect, and I = interaction. Two-way ANOVAs were calculated with logged segments excluded.

Month	1985		1986		1987		1988		1989		1990		1991		1992		ANOVA		
	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	Y	I
May:																			
individuals			23.7	** 30.3	19.4	22.2	20.4	* 23.5	14.3	15.2	21.2	21.4	14.5	* 19.5	26.8	26.5	XX	XXX	
species			9.7	** 12.9	8.1	** 10.8	9.5	11.0	7.7	8.2	9.9	11.3	7.7	* 9.8	11.6	12.1	XXX	XXX	
June:																			
individuals	40.8	** 33.3	27.5	29.2	28.3	29.1	26.5	25.4	24.6	25.5	21.9	22.0	22.4	22.7	24.5	** 29.7		XXX	XX
species	14.2	14.0	11.1	12.5	12.5	12.9	12.4	13.1	11.7	12.9	10.4	*12.1	10.5	11.7	10.4	*** 13.2	XXX	XXX	
July:																			
individuals:			23.5	24.5	28.4	31.5	22.1	22.7	24.9	26.0	19.3	20.4	22.3	** 27.6	28.3	* 24.1		XXX	
species			9.6	10.4	11.8	14.4	11.1	11.0	10.8	11.8	9.2	9.7	9.7	** 12.3	11.7	10.9	XX	XXX	
August:																			
individuals			9.6	12.0	17.1	15.3	14.1	11.7	19.8	13.8	8.1	8.8	14.0	13.8	13.0	12.4		XXX	
species			4.6	5.2	7.3	6.7	6.1	5.8	7.7	6.5	4.0	4.5	5.3	6.2	6.0	5.8		XXX	
September:																			
individuals			10.1	* 15.7	15.9	12.5	11.7	14.4	12.6	10.9	9.7	12.2	15.3	12.8	10.7	9.9		XX	X
species			4.0	5.6	5.4	5.1	5.0	5.6	5.0	4.7	4.7	* 6.0	5.2	5.7	3.9	4.0	XX	XX	

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

Table 4. Mean number of individuals per segment for species that showed a significant difference in abundance between treatment (T) and control (C) segments in Michigan in 1992.

Month	Species	T		C
MAY[1]	Great Crested Flycatcher	0.1	*	0.3
	Northern Parula	0.1	*	0.5
JUNE[2]	Yellow-bellied Sapsucker	0.2	*	0.4
	Great Crested Flycatcher	0.1	**	0.4
	Black-capped Chickadee	0.3	*	0.9
	Winter Wren	0.2	*	0.4
	Black-and-white Warbler	0.4	*	0.8
	Common Yellowthroat	0.2	*	0.7
	Song Sparrow	0.2	*	0.5
	Red-winged Blackbird	0.0	*	0.2
JULY[3]	Golden-crowned Kinglet	1.3	*	0.4
	Cedar Waxwing	0.7	**	0.0
	Nashville Warbler	2.7	***	1.1
AUGUST[4]	White-breasted Nuthatch	0.1	**	0.4
	Brown Creeper	0.6	*	0.2
SEPTEMBER[5]	-			

[1] 37 species tested. * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$
[2] 51 species tested.
[3] 46 species tested.
[4] 30 species tested.
[5] 25 species tested.

Abundant species during late fall migration (September) included Black-capped Chickadees and Red-breasted Nuthatches. There were no significant differences between control and treatment segments among 25 species tested (Table 4).

Guild Composition

Few significant differences in abundance of different foraging guilds were noted between treatment and control segments (Table 5; 12%, 3 of 25 tests; five months x five foraging guilds). Differences in abundance were significant in June (more abundant on controls) and July (more abundant on treatments) for foliage insectivores and in September for flycatchers (more on controls).

Differences were of similar magnitude among habitat guilds (10% or 3 of 30 tests were significant; Table 5; five months x six habitat guilds). Birds preferring deciduous forest habitats were more common on control segments during June. Birds preferring early successional habitats were more abundant on treatment segments during July and birds preferring lowland conifers were more abundant during August.

AMONG-YEAR COMPARISONS

Considerable annual variation in abundance of individuals and species was noted (Table 2). Abundance has tended to decline during much of this study (Figs. 3, 4), perhaps reflecting the series of droughts that have affected much of the region (see Blake et al. 1992). A slight increase in numbers was noted in 1991 and this trend continued in 1992. Relatively strong treatment effects have been noted for individuals during May and for species during May, June, and July (Tables 2, 3). Overall, annual variation in abundance and species richness has been considerably greater than variation associated with treatments.

There were few significant differences between treatment and control segments in the abundances of birds during the study period, from pre-impact years (1986, 1987) to full impact years (repeated measures ANOVA). There were no differences when changes were examined at the community level (total individuals or species) and only 3 when individual species were examined (Table 6; 40 species tested). As this represents only 7.5% of the number of species tested, it is no more than might be expected by chance.

DISCUSSION

SPECIES DISTRIBUTION AND ABUNDANCE PATTERNS

No consistent patterns have yet emerged during this study (1985-1992) to demonstrate that distribution patterns of birds are affected by electromagnetic fields produced by ELF antennas in Wisconsin or Michigan (Hanowski et al. 1991, Niemi and Hanowski 1991, Blake et al. 1991, this report). Few significant differences in abundance between treatment and control segments have been found at the community or species level; differences that existed in one season or year were not necessarily present in subsequent years or seasons. Differences between treatment and control segments were

Table 5. Mean number of individuals per segment in foraging and habitat guilds that showed a significant difference (one-way ANOVA) between treatment (T) and control (C) segments in Michigan in 1992.

Guild	Month	T		C
FORAGING GUILDS				
Foliage insects	June	12.9	*	15.0
Foliage insects	July	14.3	*	11.5
Flycatchers	September	0.0	*	0.1
HABITAT GUILDS				
Deciduous forest	June	9.5	*	13.3
Early successional	July	3.5	**	1.0
Lowland, conifer	August	0.3	*	0.1

* = P < 0.05; ** = P < 0.01

Table 6. Species showing a significant different change in abundance between treatment and control segments during the study period. Differences were tested by a repeated measures ANOVA (see also text). The total number of species tested 40.

	F	P
Red-breasted Nuthatch	2.692	0.03
Golden-crowned Kinglet	3.029	0.02
Song Sparrow	3.829	0.02

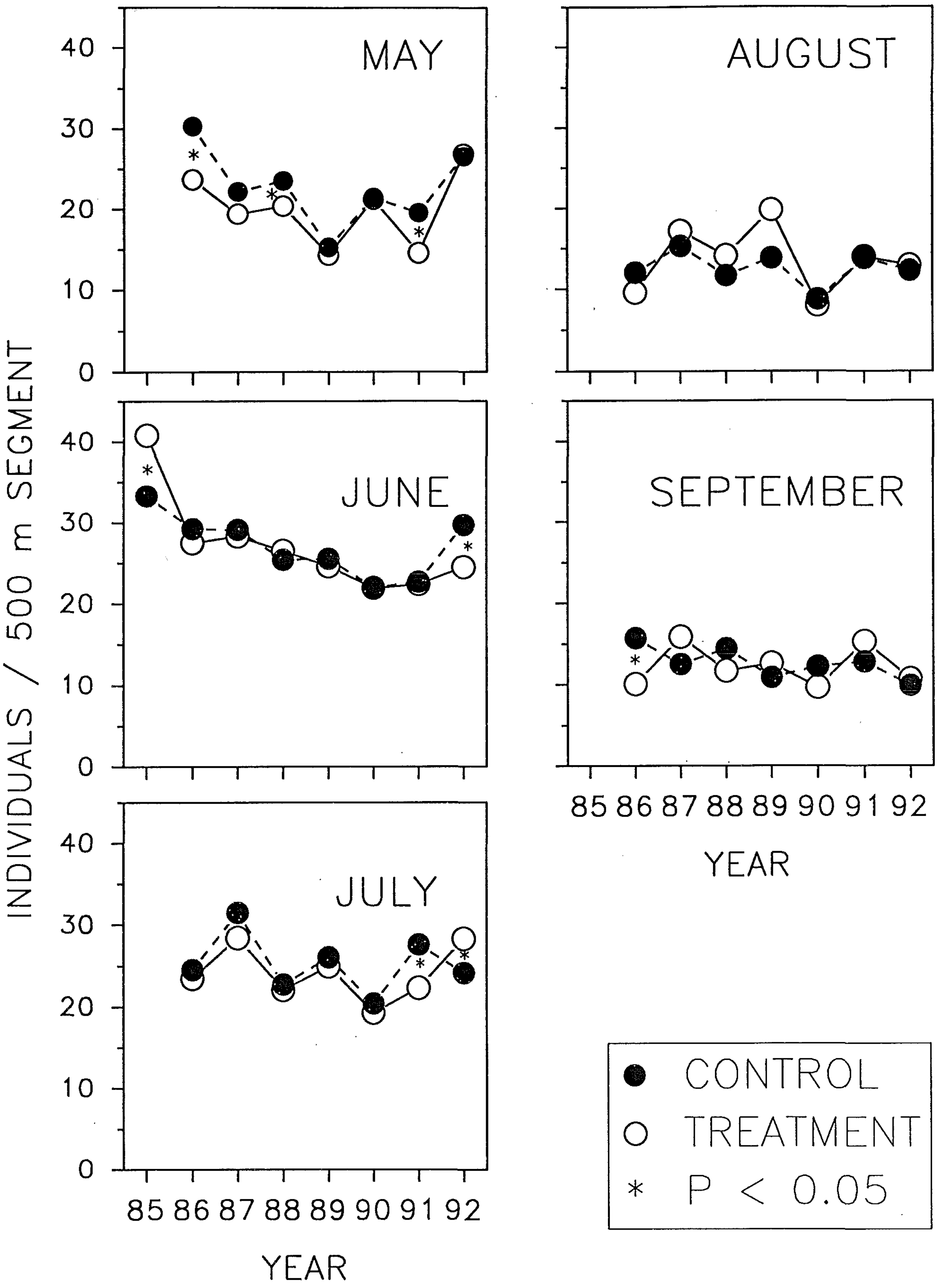

Figure 3. Mean number of individuals recorded per 500 m on treatment and control transects.

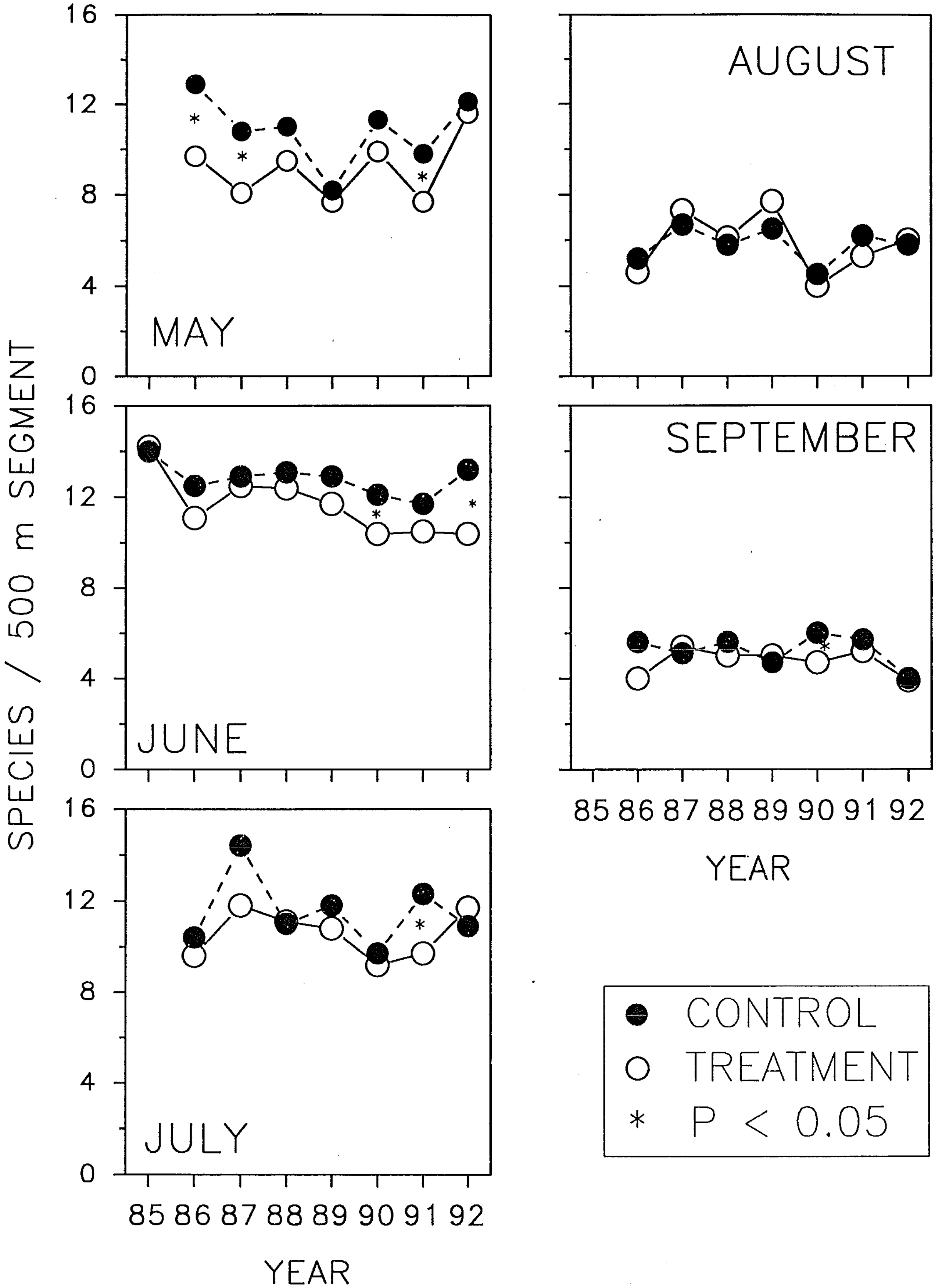

Figure 4. Mean number of species recorded per 500 m on treatment and control segments.

most noticeable in Michigan during May, both for individuals (Fig. 3) and species (Fig. 4) (four significant differences in both cases out of 36 comparisons, or 11%). Apart from May, significant differences in abundance within a single year have been noted four times for number of species (twice in June, once in July and September) and five times for number of individuals (twice in June and July, once in September). Overall treatment effects (all years combined) tend to be more pronounced for number of species than for individuals; more species per segment typically are recorded on control segments than on treatment segments.

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 and during all of 1990. There has been, however, little noticeable change in bird populations on treatment segments relative to those on control segments. Populations of many species have declined in abundance (e.g., Fig. 5) but declines have occurred on both treatment and control segments, often in concert. Further, major declines occurred before the antenna began operation in 1988. Finally, no consistent pattern is yet evident to indicate that changes in abundance on treatment segments have been more pronounced than on control segments since the antenna became fully operational. That is, after the antenna became fully operational in 1989, trends in abundance on treatment and control segments have not been significantly altered.

Results from Wisconsin also showed little consistency among years or seasons in species richness or number of individuals (Hanowski et al. 1991). If the ELF transmitter strongly influenced bird distribution patterns, one might expect that changes in relative abundance of birds on treatment and control segments would be somewhat consistent (within each group) from one year to the next, particularly during the breeding season, and from one season to the next. There was, however, little or no evidence for such a pattern. Species and individuals were more abundant on treatment segments in 1985 and individuals were more abundant on treatment segments in 1986, but no other significant difference at the community level were noted. In fact, throughout 1986-1989, species richness and abundance of individuals were remarkably similar on treatment and control segments in Wisconsin (Hanowski et al. 1991).

GUILD DISTRIBUTION PATTERNS

Species that belong to the same "guild" share some biological characteristics. Thus, if the ELF antenna system influenced the distribution patterns of birds, 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 Michigan in 1992 or either state in previous years (Blake et al. 1991, 1992, Hanowski et al. 1991). Differences that did exist likely reflected differences in habitat that exist between treatment and control segments. Treatment segments in Michigan have more early successional habitats than do control

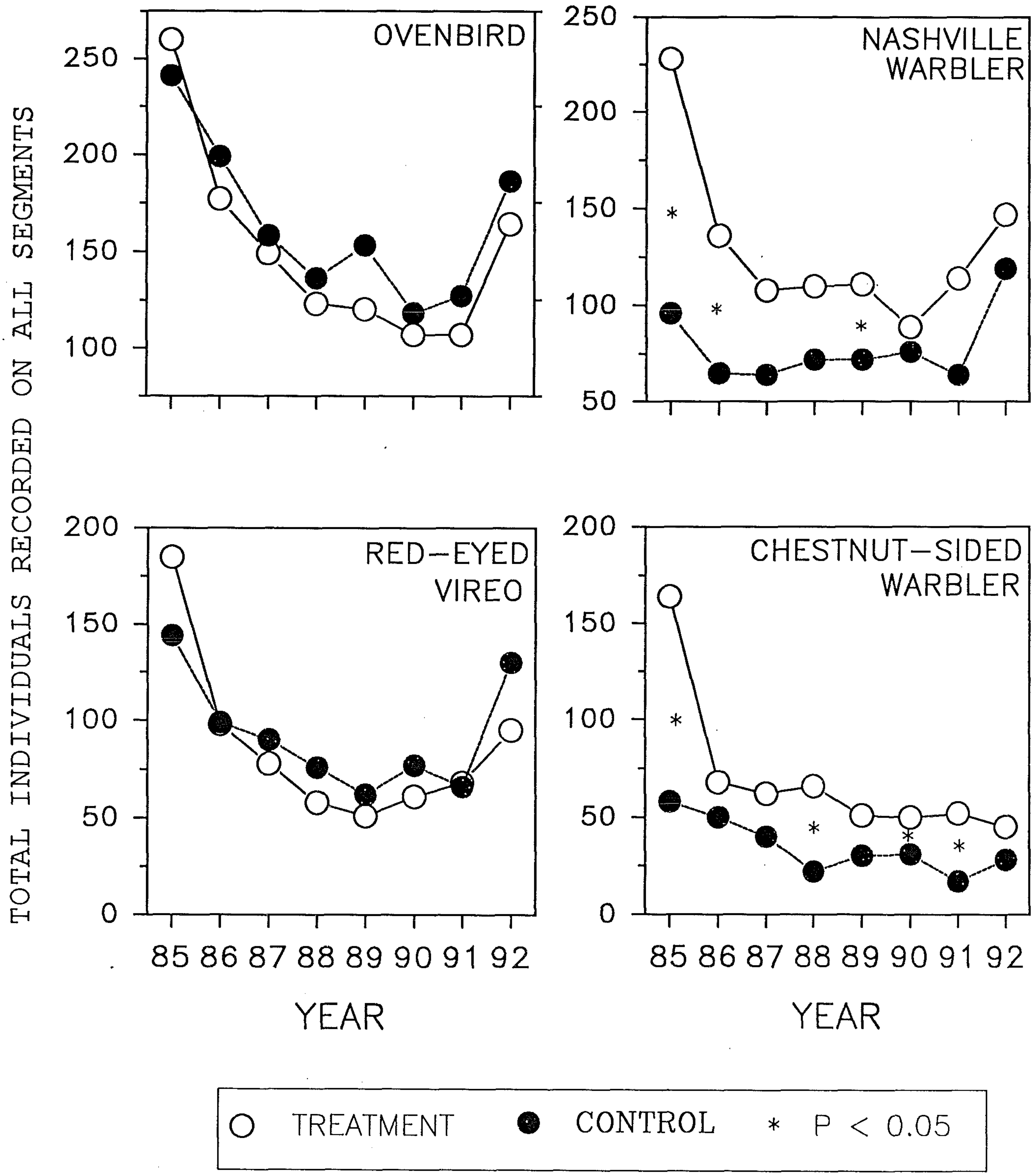

Figure 5. Total number of individuals of four abundant migrants recorded during June, 1985-1992, on all treatment and control segments.

areas and birds breeding in such habitats showed the strongest treatment effect, being more abundant on treatment segments (e.g., Chestnut-sided Warbler, Fig. 5). A similar result was noted for earlier years (Blake et al. 1991). Deciduous forest habitat is more common in control areas and coniferous habitats more common in treatment segments in both states (Blake et al. 1988); distribution of birds preferring deciduous habitat followed a similar trend.

INDIVIDUAL SPECIES

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

There have, however, been relatively few cases where differences in abundance of a species between treatment and control segments have remained consistently significant among seasons and years in Michigan (Table 7; Fig. 5). A total of 50 species in Michigan have shown a significant difference in abundance between treatment and control segments in at least one season and year. Somewhat more species (27) were more abundant on control than on treatment segments (15) (Table 7). However, 12 species have shown a significant difference in only one season in one year (Table 7) and eight species have been more abundant on treatment segments in one season and on control segments in another. The total number of cases showing a siginificant difference between control and treatment segments is 177 which is 15% of all the comparisons (11% for treatments and 18% for controls). For example, the Chipping Sparrow was more abundant on treatment segments during June in two years but was more common on control segments during May and August in other years. Such changes in distribution 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 more consistent pattern of distribution between treatment and control segments. White-throated Sparrows, for example, have been consistently more abundant on treatment segments, particularly in June (Table 7). Chestnut-sided and Nashville Warblers also have been consistently more abundant on treatment segments (Fig. 5). Several species (e.g., Yellow-bellied Sapsucker, Winter Wren, Ovenbird [Fig. 5], and Red-winged Blackbird) consistently have been more abundant on control segments.

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,

Table 7. Number of years per month[a] (1986 - 1992; 1985 - June only) that species were significantly (Kruskal Wallis test) more abundant on treatment or control segments.

Species	More on treatment					More on control				
	M	Ju	Jy	A	S	M	Ju	Jy	A	S
American Woodcock					1					
Northern Flicker	1	1								
Yellow-bellied Flycatcher		3								
Gray Jay				2						
Golden-crowned Kinglet		1	3	1	1					
Hermit Thrush	1		1							
American Robin			1	3						
Brown Thrasher		2								
Solitary Vireo		1								
Nashville Warbler		3	4							
Chestnut-sided Warbler		4	2							
Yellow-rumped Warbler	1	2								
Rufous-sided Towhee		1								
White-throated Sparrow	1	5	2	1	2					
Dark-eyed Junco	2									
Ruffed Grouse		1								1
Downy Woodpecker				1		1		1		1
Blue Jay				1		1			1	
Cedar Waxwing			1	2			1			
Mourning Warbler		1						1		
Indigo Bunting				1			1		1	
Chipping Sparrow		2				1			1	
Song Sparrow	2	1		1		1	1			
Yellow-bellied Sapsucker						5	3	3	2	1
Hairy Woodpecker							1			
Eastern Wood-Pewee									1	
Least Flycatcher							1	1		
Great Crested Flycatcher						2	4	2		
Black-capped Chickadee						1	2	1		
Red-breasted Nuthatch										1
White-breasted Nuthatch								2	2	
Brown Creeper						2		1	1	
Winter Wren						3	4	1		1
Sedge Wren								1		
Veery								1		
Red-eyed Vireo								1		1
Northern Parula						4	1	2		

Table 7 (continued).

Species	More on treatment					More on control				
	M	Ju	Jy	A	S	M	Ju	Jy	A	S
Black-throated Green Warbler						2	1			
Blackburnian Warbler								1		
Black-and-white Warbler						3	1			1
Ovenbird						3		2		
Common Yellowthroat							3	1	1	
Canada Warbler							1			
Scarlet Tanager							1	1		
Rose-breasted Grosbeak						1	2	1		
Swamp Sparrow						1		1		
Red-winged Blackbird						2	6	3		
Common Grackle							1			
Brown-headed Cowbird						1	2			
Purple Finch						1				
Number of species	6	14	6	9	3	18	17	20	8	7
Number significant differences	8	28	14	13	4	35	37	28	10	7

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

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

If the antenna operation adversely affected bird species, we might have expected the number of species on treatment segments to decline after operation began. Birds have been sampled during all five months since 1986. Both 1986 and 1987 can be considered pre-impact years (although the antenna was tested at low power during part of 1987). The antenna was tested at half strength during 1988 and was at full strength during most of 1989 and all of 1990, 1991, and 1992. Thus, we consider 1988 a transitional year and 1989-1992 as impact years. During 1986-1987, species were significantly more abundant on treatment segments in 18 instances and more abundant on control segments 35 times (Fig. 6). (We are not including 1985 here as samples were collected only during June.) During 1989-1992, species were more abundant on treatment segments 28 times and 63 times on controls. Thus, a similar proportion of significant differences were noted for species more abundant on treatment segments both before (34%) and after (31%) antenna operation reached full strength. The difference in distribution between the pre- (1986-1987) and post-impact (1989-1992) periods was not significant (comparing number of species more abundant on treatment or control segments during each of the two periods [i.e., pre- and post-impact]; $\chi^2 = 0.04$, $P > 0.80$, 1 df). Similarly, if the distribution of significant differences is compared among all years, no difference exists among years ($\chi^2 = 4.34$, $P > 0.60$, 6 df). The increase from 1987 to 1988 in number of species more abundant on treatment segments (Fig. 6) may reflect the effect of the 1988 drought (Blake et al. in press). Lowland (i.e., wet) habitats are more common on treatment segments than on controls and such habitats may have provided a refuge for birds, particularly in relation to the drier upland habitats more common in control areas. There is no correlation between the number of species showing a significantly higher abundance on controls and that on treatments among years (r=0.070, P>0.5), that is, a high number of significant differences in favor of controls is not associated with a high or low number of opposite cases. The regression lines fitted to the number of significant differences in favor of either controls or treatments do not significantly differ from zero (see Fig. 6). The number of species showing significantly higher abundance on treatments has a slightly decreasing trend during the study period, but it is not statistically signicant (P=0.10).

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

OBJECTIVES

Our major objectives for 1992 were to complete bird censuses during all seasons, to initiate comparisons based on pre- and post-impact data, and to complete this annual report. Additionally, several manuscripts derived from previous work have been submitted for publication or are in preparation (Appendix 3). Our objectives for 1993 and beyond

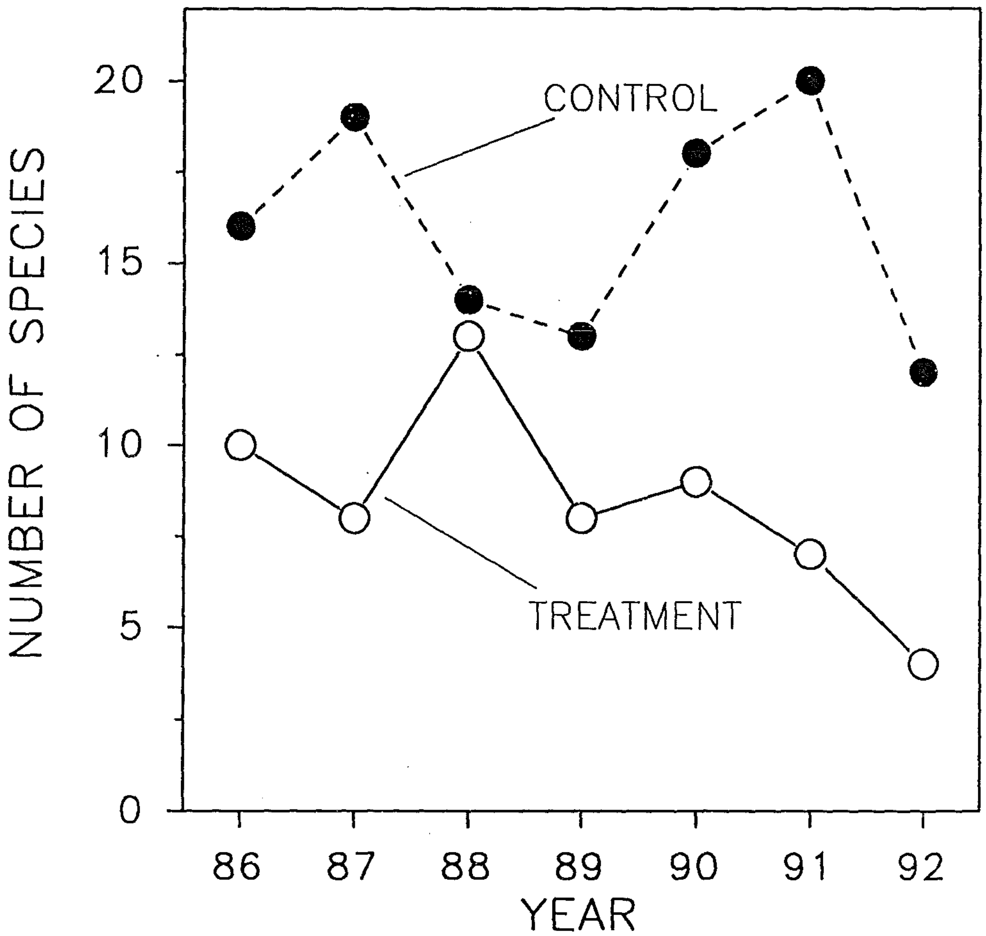

Figure 6. Number of cases per year when species were significantly more abundant on treatment or control segments.

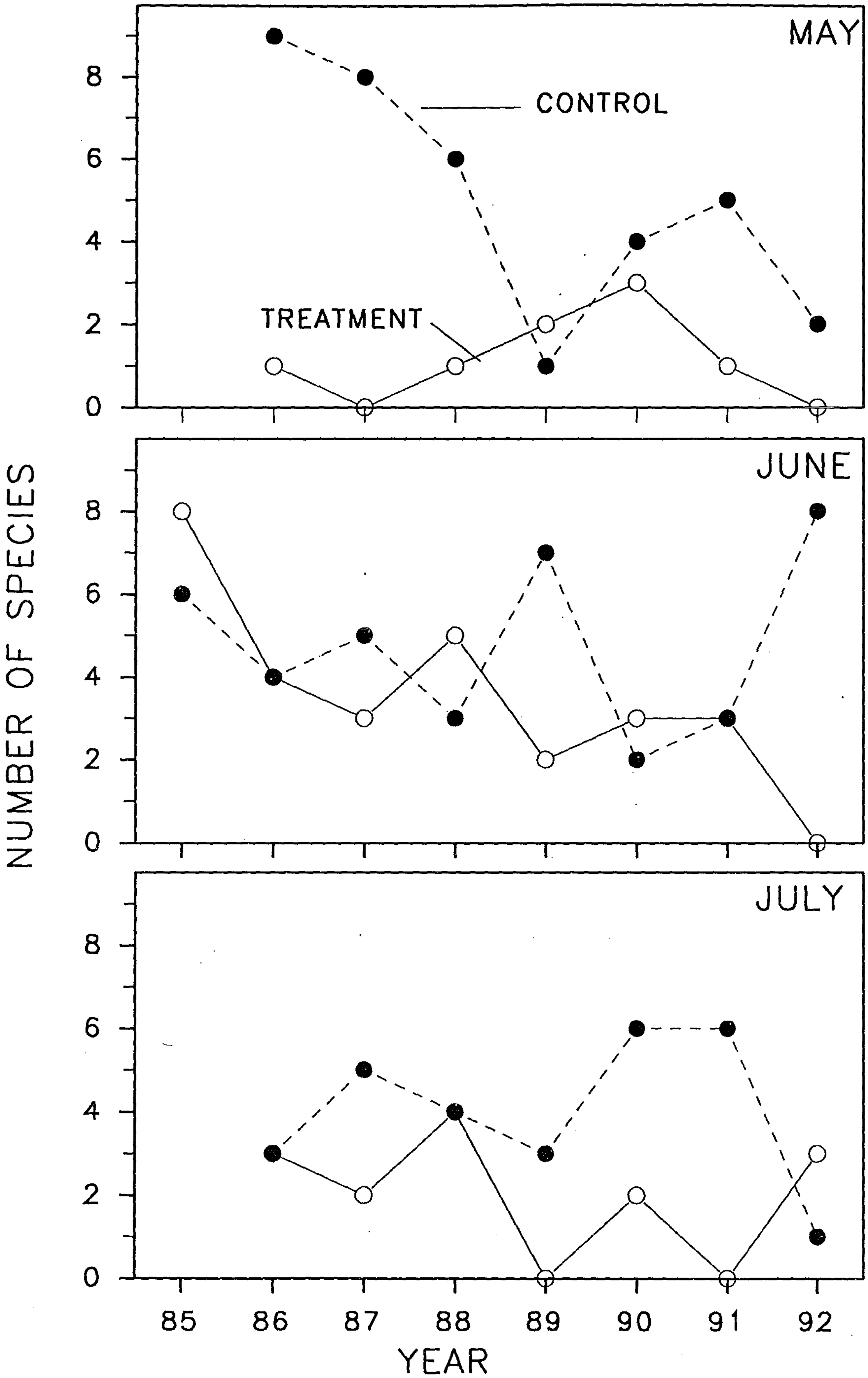

Figure 7. Number of species significantly more abundant on treatment or control segments during May, June, and July, 1985-1992.

are to continue our sampling of bird communities in Michigan, following our established procedures.

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

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

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

Appendix 1 (continued)

Species	Nesting	Food	Habitat	Migration
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

Appendix 1 (continued)

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

Appendix 1 (continued)

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

Appendix 1 (continued)

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

Appendix 1 (continued)

Species	Nesting	Food	Habitat	Migration
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
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

Appendix 1 (continued)

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

Appendix 1 (continued)

A. Nesting

1 Ground

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

3 Subcanopy or shrub

4 Cavity, hole or bank

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

Appendix 1 (continued)

13 Foliage invertebrates and fruit

14 Fruit

15 Foliage invertebrates and seeds

16 Bark insects

17 Nectar and sap

18 Aquatic vegetation

19 Aquatic invertebrates

C. Habitat

1 Deciduous forest

2 Coniferous forest

3 Mixed deciduous - coniferous forest

4 Early successional deciduous - coniferous forest

5 Fields and meadows

6 Shrub swamp

7 Urban

8 Open wetlands (e.g., sedge fen, cattail)

9 Ponds, lakes, rivers, and streams

10 Muskeg

11 Lowland coniferous forest

D. Migration

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

Appendix 1 (continued)

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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 2. Total number of individuals and species observed on control (C) and treatment (T) transects in Michigan during five census periods in 1992. English and scientific names follow AOU (1983).

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Appendix 2. Total number of individuals and species observed on control(C) and treatment(T) transects in Michigan during five census periods in 1992. English and scientific names follow AOU (1983).

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
American Bittern _Botaurus lentiginosus_	0	2								
Great Blue Heron _Ardea herodias_	0	1								
Wood Duck _Aix sponsa_	2	0	0	1	0	2				
Mallard _Anas platyrhynchos_	0	4							0	2
Hooded Merganser _Lophodytes cucullatus_	0	3								
Red-breasted Merganser _Mergus serrator_					0	6				
Turkey Vulture _Cathartes aura_									0	2
Sharp-shinned Hawk _Accipiter striatus_	0	1			2	2			0	1
Northern Goshawk _Accipiter gentilis_	1	0								
Broad-winged Hawk _Buteo platypterus_	2	0	2	0	0	2	3	3	0	1
Red-tailed Hawk _Buteo jamaicensis_	0	1	0	1	0	1			0	1
American Kestrel _Falco sparverius_	2	1								
Merlin _Falco columbarius_							0	2		
Ruffed Grouse _Bonasa umbellus_	6	8	4	3	3	8	2	10	4	3
Killdeer _Charadrius vociferus_	1	0								
American Woodcock _Scolopax minor_	0	3	1	0	0	2	2	0	1	1
Mourning Dove _Zenaida macroura_							1	0		
Black-billed Cuckoo _Coccyzus erythropthalmus_			1	1	3	0				
Yellow-billed Cuckoo _Coccyzus americanus_			0	1			1	1		
Barred Owl _Strix varia_							1	1		
Common Nighthawk _Chordeiles minor_					1	0				
Chimney Swift _Chaetura pelagica_					0	2				
Ruby-throated Hummingbird _Archilochus colubris_			0	2						

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
Yellow-bellied Sapsucker <u>Sphyrapicus varius</u>	11	27	6	17	7	23	2	9	3	4
Downy Woodpecker <u>Picoides pubescens</u>	7	7	1	1	5	12	4	3	5	10
Hairy Woodpecker <u>Picoides villosus</u>	3	4	2	4	4	6	6	7	3	3
Black-backed Woodpecker <u>Picoides arcticus</u>			2	0					2	0
Northern Flicker <u>Colaptes auratus</u>	11	3	5	4	12	7	7	7	13	6
Pileated Woodpecker <u>Dryocopus pileatus</u>	4	3	1	1	2	1	2	2	2	4
Olive-sided Flycatcher <u>Contopus borealis</u>	0	1			4	0				
Eastern Wood-Pewee <u>Contopus virens</u>			7	14	10	11	14	15	0	3
Yellow-bellied Flycatcher <u>Empidonax flaviventris</u>	0	2	26	18	9	2	1	0		
Alder Flycatcher <u>Empidonax alnorum</u>			11	7	3	1	4	5		
Least Flycatcher <u>Empidonax minimus</u>	40	67	12	32	4	12	2	1		
Eastern Phoebe <u>Sayornis phoebe</u>	1	0	1	0	1	0	1	0		
Great Crested Flycatcher <u>Myiarchus crinitus</u>	2	12	3	17	4	11	1	5	0	1
Eastern Kingbird <u>Tyrannus tyrannus</u>			2	1	2	2	3	4		
Tree Swallow <u>Tachycineta bicolor</u>	0	2			1	0				
Gray Jay <u>Perisoreus canadensis</u>	2	1	4	0	3	0	4	2	7	7
Blue Jay <u>Cyanocitta cristata</u>	32	15	24	23	17	19	21	10	24	26
American Crow <u>Corvus brachyrhynchos</u>			0	4	2	0	1	1	0	1
Common Raven <u>Corvus corax Linnaeus</u>	5	2	3	7	2	4	0	1	1	1
Black-capped Chickadee <u>Parus atricapillus</u>	47	71	10	36	91	93	82	94	63	64
Boreal Chickadee <u>Parus hudsonicus</u>	5	2	6	1	6	0	8	0	2	2
Red-breasted Nuthatch <u>Sitta canadensis</u>	25	24	10	11	59	29	44	26	51	50
White-breasted Nuthatch <u>Sitta carolinensis</u>	1	4	1	1	2	4	3	16	1	4
Brown Creeper <u>Certhia americana</u>	8	11	8	8	15	14	9	19	8	15

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
House Wren *Troglodytes aedon*	1	1	1	3	0	4				
Winter Wren *Troglodytes troglodytes*	20	32	7	17	18	22	4	9	4	7
Sedge Wren *Cistothorus platensis*	1	8	2	4	2	5	0	1	2	0
Marsh Wren *Cistothorus palustris*					1	0				
Golden-crowned Kinglet *Regulus satrapa*	45	13	30	21	50	14	20	6	16	8
Ruby-crowned Kinglet *Regulus calendula*	11	6	5	0	5	0	2	0	3	0
Eastern Bluebird *Sialia sialis*							4	0		
Veery *Catharus fuscescens*	1	0	16	22	12	8				
Gray-cheeked Thrush *Catharus minimus*	2	0								
Swainson's Thrush *Catharus ustulatus*	3	1								
Hermit Thrush *Catharus guttatus*	29	22	14	27	75	79	14	17	3	2
Wood Thrush *Hylocichla mustelina*	5	0							0	1
American Robin *Turdus migratorius*	18	27	17	12	20	18	23	6	9	5
Brown Thrasher *Toxostoma rufum*	3	0	3	0	1	0				
Cedar Waxwing *Bombycilla cedrorum*			7	16	27	0	9	2		
European Starling *Sturnus vulgaris*			1	0						
Solitary Vireo *Vireo solitarius*	8	10	9	6	2	10			0	1
Yellow-throated Vireo *Vireo flavifrons*			2	2			0	1		
Philadelphia Vireo *Vireo philadelphicus*					1	0				
Red-eyed Vireo *Vireo olivaceus*	14	4	95	130	94	98	30	35	2	5
Golden-winged Warbler *Vermivora chrysoptera*	4	1	1	2	1	0				
Tennessee Warbler *Vermivora peregrina*	2	2							1	1
Nashville Warbler *Vermivora ruficapilla*	152	127	147	119	108	44	7	1	2	2
Northern Parula *Parula americana*	3	21	3	7	0	6				

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
Chestnut-sided Warbler *Dendroica pensylvanica*	15	13	45	28	33	13	2	2	1	0
Magnolia Warbler *Dendroica magnolia*	2	7	2	3	2	2				
Cape May Warbler *Dendroica tigrina*	1	0	2	1	3	1				
Black-throated Blue Warbler *Dendroica caerulescens*									0	1
Yellow-rumped Warbler *Dendroica coronata*	65	45	27	17	36	12	3	2	3	0
Black-throated Green Warbler *Dendroica virens*	65	87	57	85	56	62	7	9	0	1
Blackburnian Warbler *Dendroica fusca*	3	6	7	18	3	4				
Pine Warbler *Dendroica pinus*	1	0	0	1			1	0		
Palm Warbler *Dendroica palmarum*	0	4								
Bay-breasted Warbler *Dendroica castanea*	1	5	1	1						
Black-and-white Warbler *Mniotilta varia*	16	27	16	33	8	17	4	3	6	3
American Redstart *Setophaga ruticilla*	0	3			2	1			0	1
Ovenbird *Seiurus aurocapillus*	102	116	164	186	86	98	4	6	7	6
Northern Waterthrush *Seiurus noveboracensis*	2	6	0	1						
Mourning Warbler *Oporornis philadelphia*			12	17	11	3				
Common Yellowthroat *Geothylpis trichas*	6	6	7	26	19	37	7	8	9	5
Wilson's Warbler *Wilsonia pusilla*	0	1								
Canada Warbler *Wilsonia canadensis*			8	9	1	0			0	1
Scarlet Tanager *Piranga olivacea*	4	1	6	10	7	12				
Rose-breasted Grosbeak *Pheucticus ludovicianus*	35	27	24	34	17	13	4	0		
Indigo Bunting *Passerina cyanea*	0	1	8	13	25	14	1	4		
Rufous-sided Towhee *Pipilo erythrophthalmus*	5	3	3	2	7	3	1	0	1	0
Chipping Sparrow *Spizella passerina*	14	18	8	7	9	15	1	3	1	0
Vesper Sparrow *Pooecetes gramineus*							1	0	0	1

	May		June		July		August		September	
	T	C	T	C	T	C	T	C	T	C
Song Sparrow *Melospiza melodia*	14	9	7	20	13	14	5	2		
Lincoln's Sparrow *Melospiza lincolnii*	1	0								
Swamp Sparrow *Melospza georgianna*	12	11	6	9	8	11	1	5		
White-throated Sparrow *Zonotrichia albicollis*	95	50	31	22	50	19	26	7	12	6
Dark-eyed Junco *Junco hyemalis*	3	2			3	0				
Red-winged blackbird *Agelaius phoeniceus*	2	9	0	9	2	0				
Common Grackle *Quiscalus quiscula*	5	1	0	3	4	2				
Brown-headed Cowbird *Molothrus ater*	1	4	0	1						
Northern Oriole *Icterus galbula*	0	1	0	1	0	3				
Purple Finch *Carpodacus purpureus*	6	3	1	3	2	0				
White-winged Crossbill *Loxia leucoptera*			10	0	6	0	1	0	3	0
American Goldfinch *Carduelis tristis*	1	7	1	2	9	6	10	15	9	16
Evening Grosbeak *Coccothraustes vespertinus*			0	1			3	0		
Unidentified non-passerine	26	25	9	14	17	18	60	68	104	70
Unidentified sparrow	1	0					1	3	1	4
Unidentified thrush									0	1
Unidentified woodpecker	1	5	6	8	2	0	2	5	1	2
Unidentified woodpecker							1	4	4	7
Unidentified vireo									0	2
Total individuals	1045	1060	981	1189	1132	964	488	468	394	371
Total no. species	66	69	65	68	68	58	53	44	35	42

Appendix 3. Presentations, publications, and manuscripts based on work conducted as part of the ELF monitoring program.

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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, Idaho; 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.

Hanowski, J. M., J. G. Blake, and G. J. Niemi. 1990. Seasonal bird distribution patterns along habitat edges in northern Wisconsin. Lake Superior Biological Conference, Ashland, Wisconsin; September 1990.

Hanowski, J. M., G. J. Niemi, J. G. Blake, and P. T. Collins. 1990. Effects of extremely low frequency electromagnetic fields on bird species and communities.
- Annual Review of Research on Biological Effects of 50/60 Hz Electric and Magnetic Fields, Denver, Colorado; November 1990.
- 52nd Midwest Fish and Wildlife Conference, Minneapolis, Minnesota; December 1990.
- XX Congressus Internationalis Ornithologicus, Christchurch, New Zealand; December 1990.

Collins, P.T. 1990. Birds and invertebrates in northern Wisconsin forests: Are they related?
- University of Minnesota, Duluth; May 1991.
- American Ornithologists' Union; McGill University, Montreal; September 1991.

Blake, J. G., J. M. Hanowski, and G. J. Niemi. 1992. Annual variation in bird populations of mixed conifer-northern hardwood forests. American Ornithologists Union, Ames, Iowa; June 1992.

Blake, J. G. 1992. Temporal and spatial variation in migrant bird populations. Department of Ecology, Ethology, and Evolution, University of Illinois; April 1992.

Helle, P.J. 1992. Bird community dynamics in boreal forests. IUFRO Centennial Meeting (International Union of Forestry Research Organizations), Berlin, Germany; September 1992.

Publications

Hanowski, J. M., J. G. Blake, G. J. Niemi, and P. T. Collins. 1993. Effects of extremely low frequency electromagnetic fields on breeding and migrating birds. American Midland Naturalist 129:96-115.

Collins, P. T. 1992. Length-biomass relationship for terrestrial gastropods and Oligochaetes. American Midland Naturalist 128:404-406.

Blake, J.G., G.J. Niemi, and J.M. Hanowski. 1992. Drought and annual variation in bird populations. pgs. 419-430. In J. Hagan and D. W. Johnston, eds., Ecology and conservation of neotropical landbird migrants. Smithsonian Institution Press, Washington, DC.

Blake, J.G., J.M. Hanowski, G.J. Niemi, and P.T. Collins. 1991. Hourly variation in transect counts of birds. Ornis Fennica 68:139-147.

Collins, P.T. 1991. Relationships between invertebrate biomass and bird abundance in northern Wisconsin forests. MS thesis, University of Minnesota.

Hanowski, J.M., G.J. Niemi, and J.G. Blake. 1990. Statistical perspectives and experimental design in counting birds with line transects. Condor 92:328-337.

Manuscripts (in review)

Blake, J. G., et al. Annual variation in bird populations of mixed conifer-northern hardwoods forests. submitted to Ecology.

Helle, P. and G. Niemi. Bird community dynamics in boreal forests. Submitted to: R. M. DeGraaf (ed.), Wildlife conservation in forested landscapes. Elsevier Publishing.

Manuscripts (in preparation)

Hanowski, J. M., J. G. Blake, and G .J. Niemi. Seasonal abundance and composition of bird communities adjacent to forest edges in northern Wisconsin.

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