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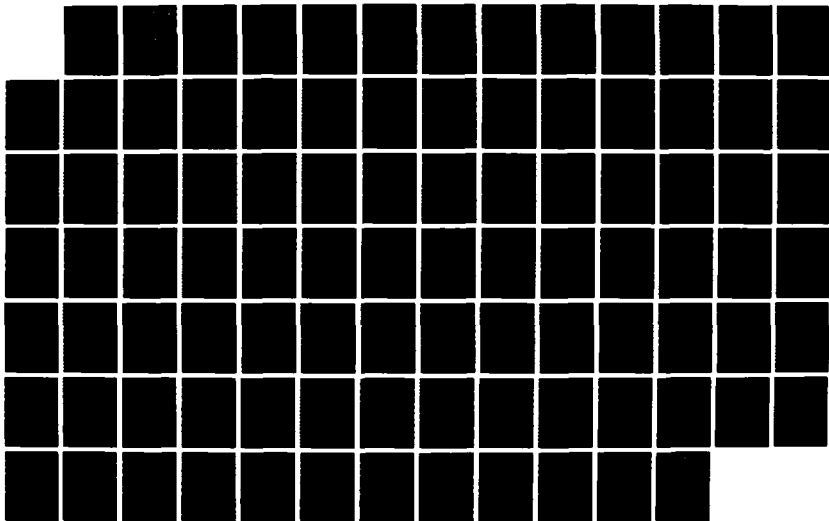
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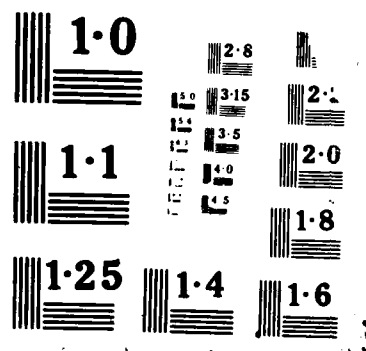
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Technical Report E06549-39
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EXTREMELY LOW FREQUENCY (ELF) COMMUNICATIONS SYSTEM
ECOLOGICAL MONITORING PROGRAM:
SUMMARY OF 1986 PROGRESS

John E. Zapotosky

December 1987

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Prepared for:

Communications Systems Project Office
Space and Naval Warfare Systems Command
Washington, D.C. 20363-5100

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DISTRIBUTION STATEMENT A

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SECURITY CLASSIFICATION OF THIS PAGE

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REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified			1b. RESTRICTIVE MARKINGS		
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION/AVAILABILITY OF REPORT		
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE			Unlimited		
4. PERFORMING ORGANIZATION REPORT NUMBER(S) E06549-39			5. MONITORING ORGANIZATION REPORT NUMBER(S)		
6a. NAME OF PERFORMING ORGANIZATION IIT Research Institute		6b. OFFICE SYMBOL (If applicable)		7a. NAME OF MONITORING ORGANIZATION	
6c. ADDRESS (City, State, and ZIP Code) Chicago, Illinois 60616-3799				7b. ADDRESS (City, State, and ZIP Code)	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Space and Naval Warfare Systems Command		8b. OFFICE SYMBOL (If applicable)		9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
8c. ADDRESS (City, State, and ZIP Code) Washington, D.C. 20363-5100		10. SOURCE OF FUNDING NUMBERS			
		PROGRAM ELEMENT NO.		PROJECT NO.	TASK NO.
				WORK UNIT ACCESSION NO.	
11. TITLE (Include Security Classification) Extremely Low Frequency (ELF) Communications System--Ecological Monitoring Program: Summary of 1986 Progress					
12. PERSONAL AUTHOR(S) Zapotosky, John E.					
13a. TYPE OF REPORT Technical		13b. TIME COVERED FROM 01/01/86 TO 12/31/86		14. DATE OF REPORT (Year, Month, Day) December 1987	
				15. PAGE COUNT 92	
16. SUPPLEMENTARY NOTATION					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB-GROUP	Extremely Low Frequency Ecology		
			Electromagnetic Fields ELF Communications System		
			Environmental Studies ELF Ecological Monitoring Program		
19. ABSTRACT (Continue on reverse if necessary and identify by block number)					
A long-term Ecological Monitoring Program is being conducted to monitor for possible effects from the operation of the U.S. Navy's ELF Communications System to resident biota and their ecological relationships. Monitoring studies were selected through a peer reviewed, competitive bidding process in mid-1982 and work on most studies began in late summer of that year. Preliminary activities of the Program consisted of site selection, characterization of critical study aspects, and validation of assumptions made in original proposals. Subsequently, increasing emphasis has been placed on the collection of preoperational and operational data bases at the Michigan and Wisconsin Transmitting Facilities. The data bases are being used to make proposed spatial and/or temporal comparisons of biological and ecological variables. This report summarizes the progress of the Ecological Monitoring Program during 1986.					
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION Unclassified		
22a. NAME OF RESPONSIBLE INDIVIDUAL			22b. TELEPHONE (Include Area Code)		22c. OFFICE SYMBOL

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FOREWORD

A long-term program to monitor for possible effects from the operation of an Extremely Low Frequency (ELF) Communications System to resident biota and their ecological relationships is being conducted by the U.S. Department of the Navy. The program is funded by the Space and Naval Warfare Systems Command under contract to IIT Research Institute (IITRI). IITRI provides engineering support and coordinates the efforts of investigators. Monitoring projects are being conducted under subcontract arrangements between IITRI and study teams.

This report summarizes the activities of the Extremely Low Frequency (ELF) Communications System Ecological Monitoring Program during 1986. This is one of a series of reports¹⁻⁴ that document the yearly progress of the Program. IITRI also compiles annual reports of subcontractor progress⁵⁻⁹ as well as reporting on engineering support activities.¹⁰⁻¹³ All reports have been submitted to the National Technical Information Service for unlimited distribution. Project personnel are also encouraged to report their findings in presentations and as publications (see Appendix A).

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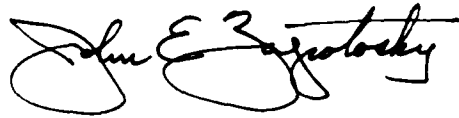
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The information presented in this summary report is based on detailed reports submitted by subcontractors. The report also includes IITRI engineering support activities as well as the results of wildlife surveys performed by the U.S. Forest Service. The surveys, although not an integral part of the Program, are generally relevant to the Program's objectives. The results of the wildlife surveys are presented in Appendix B.

Respectfully submitted,
IIT RESEARCH INSTITUTE



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**EXTREMELY LOW FREQUENCY (ELF) COMMUNICATIONS SYSTEM
ECOLOGICAL MONITORING PROGRAM: SUMMARY OF 1986 PROGRESS**

1. INTRODUCTION

1.1 Purpose

The purpose of the Ecological Monitoring Program is to determine whether electromagnetic (EM) fields produced by the Navy's ELF Communications System will affect resident biota or their ecological relationships.

1.2 ELF Communications System

The complete ELF Communications System will consist of two transmitting facilities, one located in the Chequamegon National Forest in Wisconsin and the other located in the Copper Country and Escanaba River State Forests in Michigan (see Figure 1). Each facility consists primarily of a transmitter building connected to long overhead wires (antennas) with buried ground terminals at each end. Both the antenna and grounding elements are located in cleared rights-of-way (ROW). The transmitters broadcast messages using ELF EM fields; these fields are the operational aspect of interest.

During the construction of the ELF Communications System, EM exposure can be conveniently divided into preoperational, transitional, and operational phases. During the preoperational phase, biota receive no EM exposure from the ELF Communications System. The transitional phase begins with the initiation of system testing; exposures are intermittent and are often at lower intensities than anticipated for an operational system. When the system achieves full operational capability, EM exposure will be nearly continuous and at full intensity. The achievement of a fully operational capability at the Wisconsin Transmitting Facility (WTF) occurred during the last quarter of 1985; intermittent operation of the Michigan Transmitting Facility (MTF) was initiated in the second quarter of 1986.

1.3 ELF Evaluations and Recommendations

Research on possible EM effects to biota from the operation of an ELF Communications System began in 1969. Although some ecological and wildlife studies were performed in the ensuing years, the major emphasis was on laboratory research. In 1977, the Navy and the National Academy of Sciences

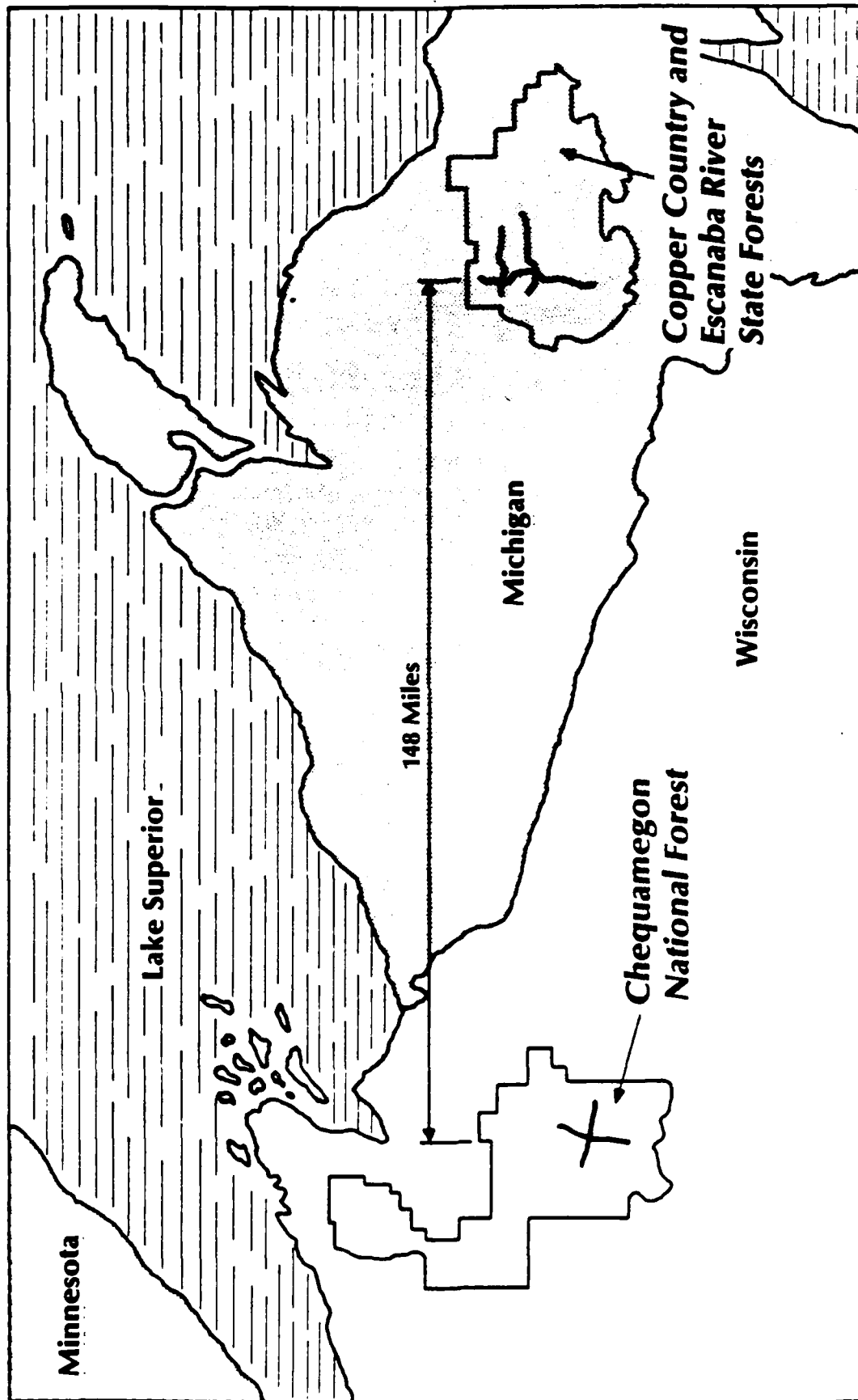


FIGURE 1. ELF COMMUNICATION FACILITIES IN WISCONSIN AND MICHIGAN.

(NAS) examined the information produced by these studies as well as studies performed at other ELF frequencies. Specific research at planned operating EM conditions of the ELF Communications System, as well as research at other ELF frequencies, showed no acute bioeffects. Those effects reported were small and/or were controversial among researchers. The Navy and the NAS concluded that adverse effects to biota from the operation of the ELF Communications System were unlikely. After reviewing similar types of information reported during the period 1977-1984, the American Institute of Biological Sciences reached the same conclusion as the Navy and the NAS. Nevertheless, all reviewing organizations recommended that a program be conducted in the ELF Communications System area to monitor for possible changes to resident biota.

The design of the recommended program was due, in part, to the limitations of research performed in the laboratory. Although laboratory research is an important approach, it emphasizes the study of select attributes of individuals; examines relatively homozygous individuals of a limited number of species over short periods of time; and does not simulate all of the potential synergistic factors present in the natural environment. In addition, the impact of environmental perturbations such as EM fields could be expressed at one or more levels of biological organization; i.e., populations, communities, and ecosystems. Our current state of understanding does not allow an accurate prediction of effects at higher levels of organization from studies of individuals, particularly if the effects are small.

1.4 Monitoring Program Design

In its 1977 environmental impact statement, the Navy outlined a preliminary plan for conducting an ecological monitoring program at those sites approved for the operation of the ELF Communications System. The initial plan was developed from the results of laboratory research, input from state agencies, and recommendations made by the NAS for long-term ecological monitoring. The elements of the initial plan were refined based on comments submitted in response to the Navy's draft environmental impact statement. In 1981, concurrently with approval to complete construction of an ELF Communications System, the Department of the Navy funded an Ecological Monitoring Program.

Ecological studies are of fundamental importance because they integrate the responses of many biota. The purpose of these kinds of studies is to examine group characteristics such as productivity, abundance, and decomposition processes. This approach is the best method for detecting possible, marked effects to the disparate species resident in the ELF Communications System area. One limitation to this approach, however, is that ecological parameters are inherently variable; therefore, a sizable effect must be manifested in order for researchers to detect it. Generally, the numbers of replicates taken for ecological parameters in this Program are adequate to ensure detection of differences of less than 40%.

The Program also includes research for possible *in situ* effects at the organismal level. These studies focus on specific attributes of abundant and ecologically significant organisms. Although narrower in scope, organismal studies are potentially more statistically sensitive than ecological studies. Large data sets can easily be collected for organismal parameters, thus enabling the detection of smaller differences than those for ecological parameters. Except for the slime mold project, every project in the Program also couples organismal level studies with monitoring at the population and/or community levels.

The general types of organisms for study were selected on the basis of ecological importance and the likelihood of their being perturbed by EM fields, irrespective of the field's intensity or frequency. Sixteen general types of organisms from three major ecosystems in the ELF Communications System area are currently being examined. The principal criterion for selecting specific biota was their presence in sufficient numbers to ensure meaningful statistical comparisons.

Both spatial and temporal comparisons of biological and ecological end points are being examined.

Spatial comparisons are made by obtaining data relatively close to the overhead wires and grounds of the ELF Communications System (treatment or test sites) and at greater distances from these antenna elements (control sites), as shown in Figures 2 and 3. As in classical experimental design, the control site is used to measure the environmental (ambient) conditions, while the

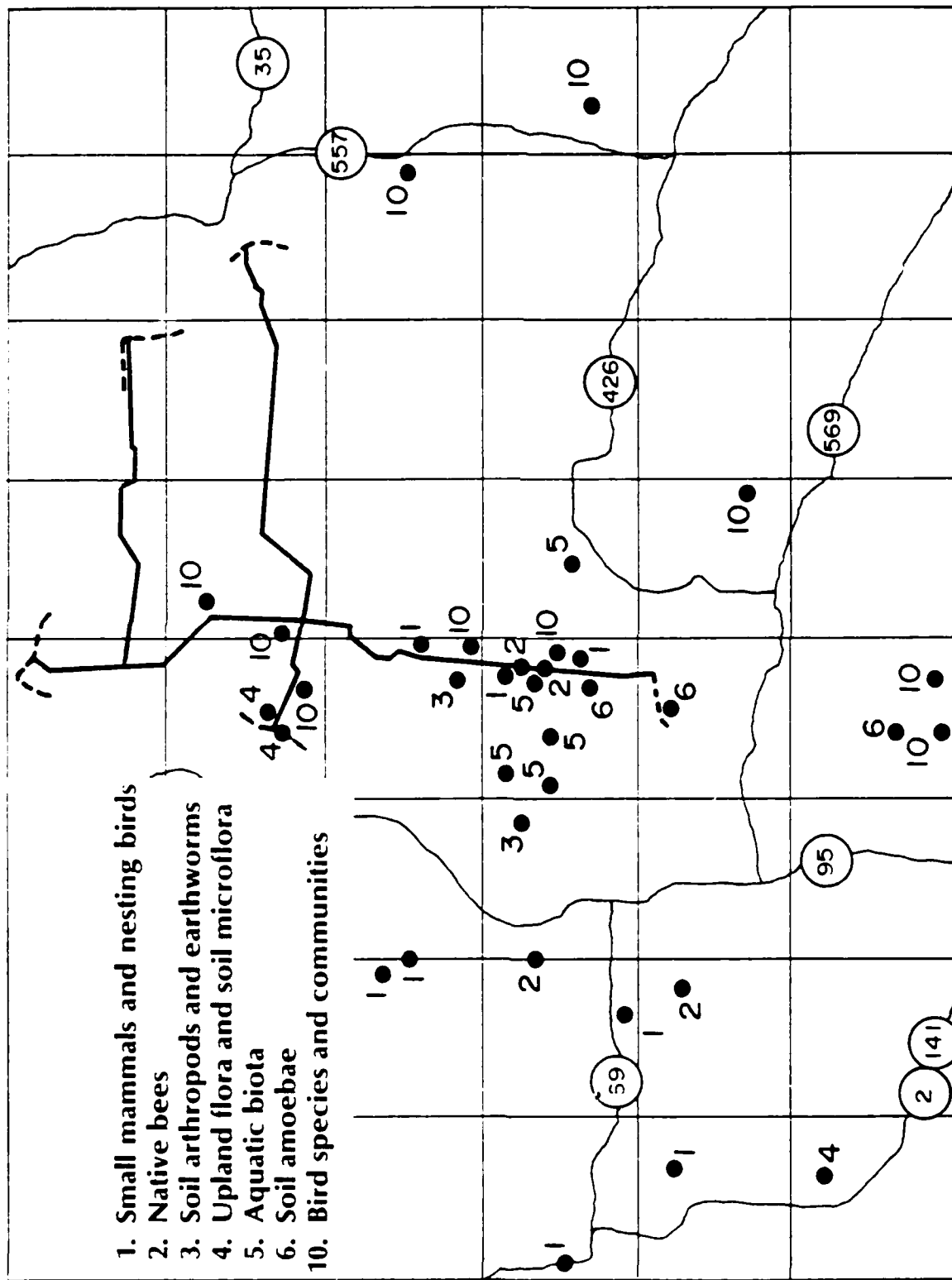
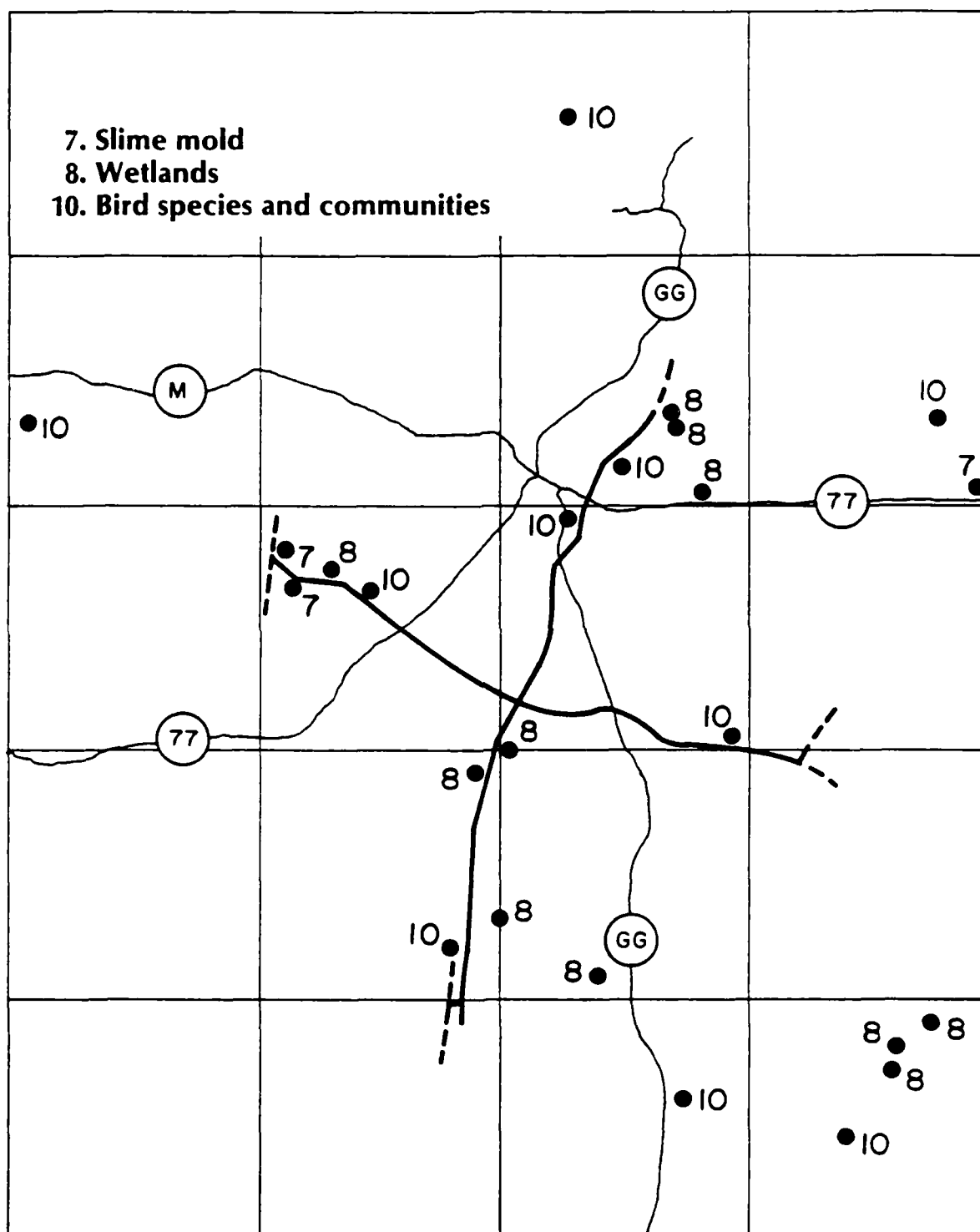


FIGURE 2. FIELD SITES FOR MICHIGAN ECOLOGY STUDIES.



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FIGURE 3. FIELD SITES FOR WISCONSIN ECOLOGY STUDIES.

treatment site is used to measure the effects of ambient conditions plus the effects of the EM fields produced by the ELF Communications System.

Temporal comparisons of biological and ecological variables will be made between the preoperational and operational phases of development of the system. Multiyear studies are planned to evaluate a fully operational ELF Communications System at both transmitting facilities (see Figures 4 and 5). Both temporal and spatial comparisons will be made in Michigan. Comparisons planned in Wisconsin are spatial only, because the transmitter there has been operating in a transitional mode since 1969 and a preoperational data base does not exist.

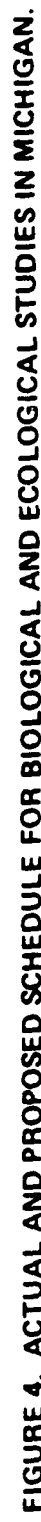
In summary, the Program emphasizes ecological studies but also includes investigation for possible *in situ* organismal effects. A program of long-term, site-specific monitoring is planned.

1.5 Program Development

Early in 1982, a competitive process was initiated to select subcontractors to participate in the Ecological Monitoring Program. A general design for studies, including the types of organisms to be examined, was provided as guidance to prospective bidders (see Reference 1, Appendix C).

By mid-1982, seven projects were funded through a peer reviewed, competitive bidding process, and studies were initiated at Wisconsin and Michigan ELF Communications System sites in late summer. Preliminary work began in 1982 for studies of upland flora, soil amoebae, soil and litter arthropods and earthworms, native bees, small mammals and nesting birds, aquatic biota, and slime molds (see Figures 4 and 5). Several unsolicited proposals were also peer reviewed and resulted in the funding of additional studies of soil microflora, wetland flora, and migrating birds. These three studies, plus the seven studies previously selected, constituted the Program during 1983.

The studies of migrating birds, begun in 1983, proposed the examination of possible short-term disorientation (radar studies) as well as long-term impacts. The long-term aspects of the study were not initiated in their entirety during 1983. During March 1984, IITRI advertised a solicitation in the Commerce Business Daily for qualifications from sources interested in conducting studies of long-term impacts to birds from the operation of the ELF



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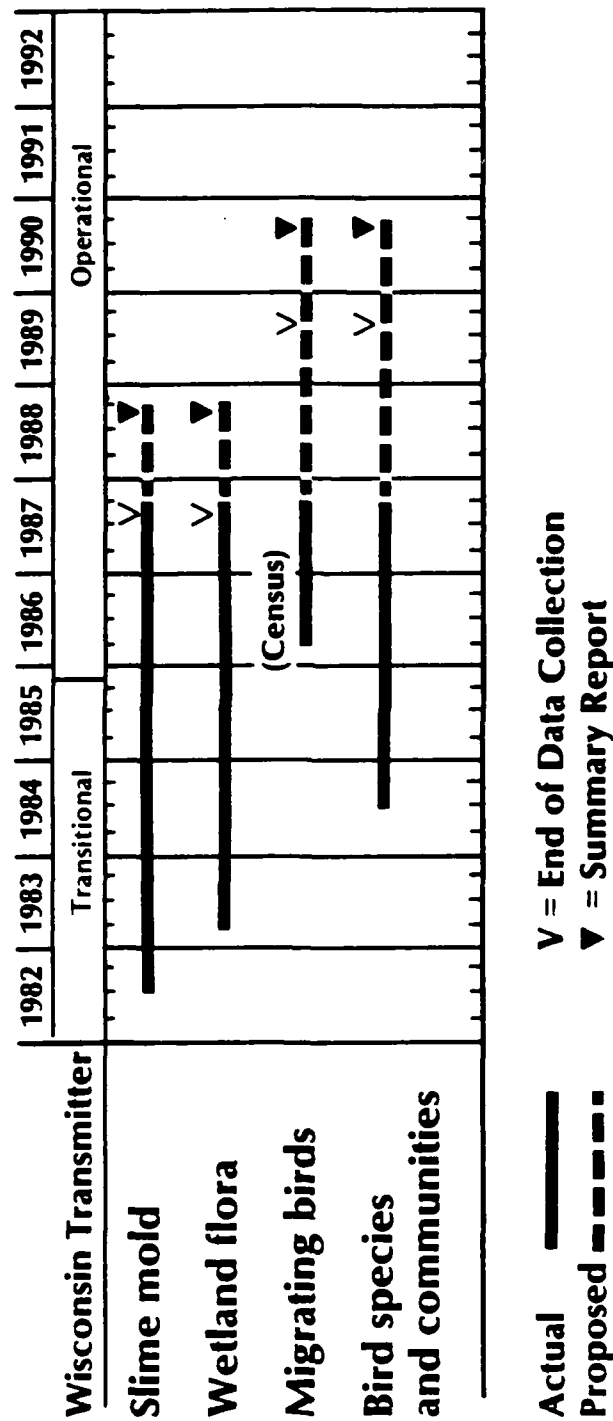


FIGURE 5. ACTUAL AND PROPOSED SCHEDULE FOR BIOLOGICAL AND ECOLOGICAL STUDIES IN WISCONSIN.

Communications System. The qualifications and proposal received from the University of Minnesota-Duluth (UMD) were selected as technically superior among those submitted, and the work was awarded to that group. With the addition of the UMD study, the Ecological Monitoring Program in 1984 consisted of 11 contracts.

In both 1983 and 1984, peer reviewers expressed serious doubt that the preoperational and operational comparisons proposed for short-term disorientation of migrating birds (radar studies) could be used successfully to detect possible effects of the ELF Communications System. The critiques were supplied to the principal investigator; however, he presented neither quantitative data nor statistical analyses in support of his approach. The study was terminated in July 1985. With the termination of this study, supplemental research was required to ensure that the migratory behavior of birds was adequately represented in the Program. IITRI requested and received a proposal from researchers at UMD to expand their bird census studies to also examine birds migrating through their existing treatment and control sites. The study of migrant birds was initiated during the 1986 spring migration period.

The major objectives of all studies during the early years (1983 and 1984) of the Ecological Monitoring Program were the selection of study sites, collection of information to validate assumptions made in proposals, and identification and characterization of critical aspects of each study. These objectives encompassed such activities as:

- identification of biota
- assessment of data collection techniques
- quantification of temporal and spatial patterns of variables
- assessment of end point variability
- description of biotic associations.

As these tasks have been accomplished, increasing emphasis has been placed on the collection of preoperational data and statistical analysis of planned comparisons (i.e., temporal and spatial).

The results of the 1986 field season were reviewed by four scientific peers during the following winter and early spring. Two of the four peers

were selected by the reporting investigator and two were selected by IITRI. In addition, IITRI initiated an overall program review by a statistician; the statistical review is ongoing. IITRI reviews, including those made by the statistician, were supplied to the investigators for their consideration. By the end of 1986, most biological and ecological variables had been evaluated for the following:

- adequacy of replication
- levels of detection
- relationship to ambient factors
- intersite differences
- interyear differences.

Except for two studies, the peer reviewers considered the technical progress of individual studies to be satisfactory to excellent. Remedial actions for select aspects of two studies will be implemented during 1987.

2. STUDY DEVELOPMENT: 1986 PROGRESS

This section summarizes the 1986 progress for each of the 10 studies that constitute the Ecological Monitoring Program. A more detailed presentation of study protocols, methodology, and progress is given in individual project reports.⁹

The general types of biota being examined are used as subsection titles, while specific study objectives are presented as underlined titles in each subsection. In order to simplify the presentation of statistical results, any difference stated as "significant" had a significance level of 5% ($P < 0.05$).

2.1 Upland Flora

Forest vegetation (trees and herbs) is the dominant biota in the ELF Communications System area. The production of organic compounds by vegetation and the subsequent degradation of these compounds comprise the main method of transfer of energy and nutrients to other organisms. Organic matter turnover and distribution are regarded as major determinants of the forest ecosystem's structure. Because the production and distribution of organic matter have been shown to be measurably affected by anthropogenic factors, these processes and associated organisms are being monitored for possible effects from the ELF Communications System. In order to examine for possible changes in forest productivity and health, the following elements are being examined:

- growth rates of established tree stands and regenerating pine stands
- phenological events of trees, herbs, and mycorrhizal fungi
- numbers and kinds of mycorrhizae on red pine seedlings
- nutrient levels of hardwood and pine foliage
- foliage production in hardwoods.

Insect damage, disease, and ambient environmental factors are also being monitored.

Upland flora and decomposers of organic matter (soil microflora) form a natural assemblage; however, these groups are being examined under separate subcontracts. Both subcontracts are with the Department of Forestry, Michigan Technological University, and both share common study sites and ambient monitoring systems. Soil microflora studies are closely tied to the mycorrhizal and litter production elements of the upland floral studies. The progress

of the upland flora studies is presented here; that of the microflora studies is presented in Section 2.2.

Treatment sites are located adjacent to the antenna and grounding elements of the Michigan Transmitting Facility. A single control site is located more than 28 miles from the nearest antenna element. The antenna and control sites each consist of overstory tree plots (existing pole-size stands), plots planted with red pine seedlings, and plots for the study of herbaceous plants. Studies of red pine are being conducted to examine for possible effects on forest regeneration. The grounding treatment site consists of plots planted with red pine only. No tree stands or herbaceous plots were established at the ELF Communications System grounds because the buffer strips required to eliminate "edge effects" would have placed the study plots at too great a distance from the grounding elements for meaningful EM exposure.

Tree Growth. The purpose of this element is to examine tree growth on both hardwood and red pine tree stands.

Diameter, height, ingrowth, and mortality are being monitored in order to gain a complete picture of tree growth and stand production at pole-size plots on study sites. The tree species being monitored on pole-size stands are oak, birch, aspen, and maple. Change in diameter increment is the primary response variable used for monitoring stand growth. As diameter is strongly correlated with total tree biomass, it is also used for estimates of stand production. Permanently installed dendrometer bands allow continual measurement of incremental growth on each tree in the stand. Bands are read weekly from 1 May until annual growth is nearly complete.

The onset and cessation of cambial activity were determined and expressed as the percent of trees growing during each weekly measurement. The onset of cambial activity was about the same in 1986 as in 1985; however, the growth period was longer in 1985.

At present, three years (1984-1986) of diameter change data has been collected at pole-size study sites. Preliminary statistical analyses (without the introduction of any covariates) were performed on the 1985 and 1986 data for each tree species. Generally, there were significant differences between years and/or between sites for diameter growth of the hardwood species. When

individual tree diameter and previous year's growth were used as covariates, there were no significant differences between sites or years for any species except maple. As tree diameter and previous growth may be affected by EM fields, meteorological and soil nutrient variables are also being examined as covariates. Development of a model to test for differences in growth patterns is continuing.

At each of the three study sites, 300 red pine seedlings are permanently marked for monitoring of total height, basal diameter, terminal bud length, and physical condition. These variables are recorded at the end of each growing season. For evaluation of height growth patterns, a subsample of 100 seedlings per site is measured weekly from April until shoot elongation is complete.

Preliminary statistical analyses (without the introduction of any covariates) of 1985 and 1986 seedling height and basal diameter were performed using analysis of variance. There were significant differences between sites and years for both total seedling height and basal diameter. The use of individual seedling diameter and initial total height as covariates reduced unexplained variations; however, significant differences in seedling height persisted. Examination of other covariates for both seedling height and basal diameter is ongoing.

In order to evaluate changes in the rate or timing of growth in a given year, models have been developed to predict total growth at a given time during the growing season. A subsample of the weekly height measurements was used to validate the models. The models are apparently unbiased and provide precise estimates of seasonal height growth. Modeling results suggest that red pine is a species with deterministic growth; therefore, meteorological variables of the previous year are being evaluated for inclusion in the model.

Measurable mortality of pine due to a root disease was documented at all three plantations in 1986. Although the mortality was light, it appears that conditions at the ground and control sites may be conducive to the spread of the disease. Further analysis will proceed during 1987 once the necessary site-related information is collected.

Phenological Events. Previous studies have indicated that exposure to EM fields may alter the timing of some physiological events, e.g., mitosis. The

purpose of this element is to monitor the timing of important reproductive and vegetative events in the annual life cycle of plants in the ELF Communications System area. The timing of annual events in short-lived plants (herbs) is addressed here; the timing of annual events in long-lived plants (trees) is presented under Tree Growth, above.

The starflower, *Tridentalis borealis*, flowers frequently and is a common, abundant herb in the ELF Communications System area. The flowering and leaf expansion of at least 200 naturally growing starflower plants are followed each year on plots reserved at the antenna and control sites. When tagged plants were removed from the sample, usually due to herbivory, other plants were added to the sample so as to maintain the sample size at 200 plants. Observations were made every three days in the early part of the growing season and weekly thereafter.

In 1986, flowering was first observed at the control site on 13 May and at the antenna site on 15 May. As flowering does not occur on each plant each year, the proportion of plants in flower at each sampling date was determined. There were no significant differences between sites or between years (1985-1986) in the proportion of plants that flowered. The distribution of the proportion of plants in flower over the flowering season was not significantly different between the study sites. Models that will predict the onset of flowering based on physiological and meteorological variables are being developed. The coefficients of the model will be used to test for subtle shifts in the timing of flowering.

The rate of leaf expansion in the starflower is also being examined. Preliminary analyses indicate no differences between sites or between years (1985-1986) in the rate of leaf expansion. The relationship of meteorological information, particularly temperature, to leaf expansion is being determined. As in the case of flowering, a model for leaf expansion is being developed.

Herbaceous Plants. Herbaceous plants have been found to be a more sensitive short-term indicator of environmental perturbations than trees. Accordingly, the relative frequency of occurrence and percent cover of herbaceous plants on all study sites are being monitored for possible EM effects from the operation of the ELF Communications System.

Herbaceous plants on subplots at pole stands and plantations were identified and enumerated and their cover estimated. These surveys were conducted in August, when species diversity and plant biomass were at their maximum. Relative frequency, relative cover, and importance values for each species were calculated.

Fourteen of 17 species identified in 1985 and 1986 were common to both the antenna and control pole stand subplots. Similarly, six of 19 species were common to antenna and control plantation subplots. Except for one species, the ranking of each common species by importance (relative frequency plus relative cover) was markedly different between antenna and control sites as well as between years. Matching practical field techniques of estimating cover to effective statistical analyses has been a major problem. The researchers propose to discontinue the monitoring of these variables.

Mycorrhizae Populations and Root Growth. Mycorrhizal fungi form a symbiotic relationship with the roots of higher plants such as trees. The fungi utilize organic compounds synthesized by the tree for their growth and to "forage" for minerals and water in the soil. In turn, the fungi provide the tree with minerals and water more efficiently than the tree's roots alone. This relationship is considered essential to the satisfactory growth of nearly all tree species. Because the growth of fungal mycelia is dependent on physiologically produced intracellular currents, other sources of electrical currents, such as the ELF Communications System, may have an effect on the fungi and, indirectly, on resident plants. The population dynamics of mycorrhizae occurring on hardwood and pine trees are being examined.

The population dynamics of mycorrhizae on hardwoods are being evaluated through nondestructive monitoring of sporocarp (mushroom) production at herbaceous plant subplots located at the antenna and control sites. Weekly surveys are performed from the time that reports of fruiting are first received from field crews until fruiting has stopped. Annual counts are used to determine the dates of earliest and latest fruiting, dates by which 50% of the year's total fruiting has occurred, and dates of peak fruiting for each of 15 major species.

Sporocarps from at least 32 species have been identified from surveys made since 1984. Fifteen of these species contributed at least 5% of the

total number of sporocarps counted. Total annual sporocarp counts for each of these 15 species are being used to mathematically define the mycorrhizae community on each study plot. Statistical techniques are still being developed for comparing the time of fruiting and the fungal populations.

At pine plantation sites, the population dynamics of mycorrhizae are being characterized as the frequency of occurrence of mycorrhizae types and total number of mycorrhizal root tips per red pine seedling.

In 1986 as in 1985, type 3 was the most common and type 5 the second most common mycorrhizae on the roots of the pine seedlings. Only in October 1986 was there a significant monthly difference between sites in the total number of mycorrhizae per gram of root mass. However, the yearly average of the total number of mycorrhizae per gram of root mass decreased from 1985 to 1986. Work to date supports the conclusion that there is no difference between the study sites in the abundance of major mycorrhizal morphological types occurring on red pine.

From 1984 through 1986, mycorrhizae counting methods used the entire root system of the seedlings. Because it will not be feasible to excavate entire root systems as the seedlings grow, during 1986 a subsampling approach was compared to entire system counts. There were no significant differences in the counting methods, and subsampling will be initiated in 1987.

Preliminary analyses have shown significant correlations between mycorrhizae counts, seedling characteristics, and meteorological variables. Select seedling and meteorological variables as well as increased sample sizes will be used as covariates in future statistical analyses in order to improve the limits of detectable change.

Litter Production and Foliar Nutrients. The purpose of this element is to examine total litter weight, total leaf litter nutrient content, and the nutrient content of oak foliage during the growing season. Total litter weight and litter nutrients provide estimates of seasonal canopy production as well as an estimate of input to the decomposition system (see Section 2.2). A determination of the foliar nutrient content makes possible the detection of changes in the physiological condition of trees.

Litter is collected in one-meter-square traps on pole-size stands at the antenna and control sites. The litter is dried, sorted, and weighed according to the following categories: leaves, wood, and miscellaneous. A subsample is taken to determine the nutrient content of the leaves. Leaf samples are also taken from the crowns of red oak trees during the growing season for nutrient determinations.

In 1986, major litter fall began on 25 September and was complete by 8 October. Although the onset was the same as in 1984 and 1985, completion was 17 days earlier in 1986. Results from 1984-1986 have shown no significant differences between sites in wood and miscellaneous litter weights. Although there were no significant differences between sites in leaf litter weights in 1985, significant differences between sites occurred in both 1984 and 1986. There were no significant differences between sites in leaf litter weights when the basal areas of the trees in the stand were used as covariates.

Chemical analyses of litter and oak foliage samples taken in 1985 and 1986 have not been completed. There were no significant differences between sites for oak foliar nutrients in 1984.

2.2 Soil Microflora

Soil microflora (bacteria and fungi) play a key role in the maintenance of forest ecosystems such as those in the ELF Communications System area. Microflora transform (decompose) organic matter produced by forest vegetation (litter) and fix elements present in the atmosphere into a form available for plant uptake. Environmental factors that disrupt these processes may directly alter the flow of nutrients to vegetation and thus indirectly affect the forest community.

The purpose of this element is to monitor for possible effects of EM fields produced by the ELF Communications System on populations of streptomycetes associated with plant roots and on rates of decomposition and nutrient flux of litter. These objectives are closely related to the upland flora studies (particularly the mycorrhizal and litter production elements) described in Section 2.1.

Rhizoplane Streptomycetes. The purpose of this element is to characterize and enumerate streptomycete bacteria associated with select red pine mycorrhizae (see Section 2.1). Streptomycetes have been reported to be involved in the nutrition of mycorrhizae and may influence mycorrhizae through their production of antibiotics or growth factors.

Washed (type 3) mycorrhizal fine root samples were homogenized, serially diluted, and spread-plated onto starch-casein agar. After incubation, counts were made of total streptomycetes as well as numbers of morphological strains. All colonies with the same characteristics were considered to represent one morphological strain, and at least one colony per strain was isolated in pure culture for further characterization. Plate count data were transformed prior to analysis of variance for detection of differences between years, sampling dates, and sites.

Five morphotypes were frequently detected at all three study sites throughout the 1985 and 1986 field seasons. There were no significant differences between sites in the number of strains of streptomycetes. In 1986 as in 1985, the streptomycete designated type B was the most commonly isolated type at all sites on all sampling dates.

In order to increase the power of the statistical analyses, the number of samples was doubled in 1986. This change affords a 95% chance of detecting a difference of 25% in comparisons. There were no significant differences between sites in the numbers of streptomycetes in 1986. There were, however, significant seasonal and year-to-year differences. In both 1985 and 1986, streptomycete numbers were greater in the early part of the growing season than in the later part. A comparison of 1985 and 1986 data indicated a difference in streptomycete numbers at the control site during the early part of the growing season, but no such differences in interyear comparisons of the other sites. This difference may be due to a low sample value obtained early in the 1985 season. Overall, these results indicate that similar, relatively stable streptomycete populations have become established at all study sites.

Correlation analyses between streptomycetes and environmental variables are being conducted to determine their potential as covariates.

Litter Decomposition and Nutrient Flux. The purpose of this element is to determine the rates of decomposition and nutrient flux for the litter of

three species of trees (oak, maple, and pine) abundant in the ELF Communications System area. These variables are being used as an indicator of the overall functioning of the litter community.

Litter is collected each autumn from a single location, weighed or subsampled and analyzed for nutrient content, and then enclosed in nylon mesh envelopes. Litter samples consist of both individual foliage samples and bulk foliage samples of a single species. Samples are emplaced at study sites in December and are retrieved monthly throughout the summer and fall of the following year. Decomposition is being quantified as percent change over time in mass of dry matter and nutrients (N, P, K, Ca, and Mg). Data are expressed as the percentage of original dry matter or nutrient mass remaining at the time of retrieval. Dry matter loss data from 1984 through 1986 are complete. Nutrient data sets for 1984 and 1985 are nearly complete, while 1986 nutrient samples await laboratory analysis.

Available data were transformed and examined by analysis of variance for differences between species, sites, and years. In addition, seasonal patterns of dry matter loss were analyzed by fitting each year's data to a single exponential decay model. Comparisons of decomposition constants are planned, as are covariate analyses.

Except for maple foliage, bulk and individual samples decomposed at the same rate. Maple litter decomposition was much more rapid and variable than that of either pine or oak. For bulk samples, estimates of the minimum change in the rate of dry matter loss detectable 95% of the time are 7%, 15%, and 20% for pine, oak, and maple, respectively. Generally, the rate and variability of dry matter loss is lower on the pole stand subplots than on the plantation plots (see Section 2.1 for site arrangement). However, no differences in the rates of decomposition have been detected in intersite comparisons of plantation subplots or in intersite comparisons of pole stand subplots. At each of the study sites, all three litter species decomposed faster in 1985 than in 1986.

Preliminary correlation analyses were performed between the decomposition of bulk pine samples and environmental variables. Monthly dry matter losses were significantly correlated with mean air temperature, total precipitation, and the number of precipitation events occurring during the immediate and

previous month. In 1987, these environmental factors will be evaluated as covariates for improving the power of statistical analyses.

2.3 Slime Mold

Previous to this study, researchers reported that continuous laboratory exposure of the slime mold, *Physarum polycephalum*, to ELF EM fields depressed its rate of respiration and lengthened its mitotic cycle. They are now seeking to determine whether similar effects occur when the mold is exposed *in situ* to EM fields and environmental conditions present at an ELF Communications System facility.

This project consists of a laboratory component performed at the University of Wisconsin-Parkside (UWP) and an *in situ* component performed at the Wisconsin Transmitting Facility (WTF). The laboratory component simulates EM exposure regimes as produced at the WTF and provides for the assessment of both *in situ* protocols and previous results obtained in the laboratory. The *in situ* studies are performed at three study sites: two treatment sites located adjacent to a grounding and an aerial antenna element, and one control site located about seven miles from the nearest WTF antenna element.

The data collection protocols are essentially the same as those used in 1985 and are described in detail elsewhere.⁹ The variables examined in the laboratory were respiration rate (QO_2), adenosine triphosphate levels (ATP), and length of the mitotic cycle. Although examined in 1985, mitotic cycle length for *in situ* cultures was not measured in 1986 because the researchers felt that the QO_2 and ATP were more sensitive variables.

Results to date are not consistent between years (1983-1986). Based on these results, the researchers hypothesize that in addition to field intensity, the duration of exposure and duty cycle of the antenna should be examined. Statistical analyses to examine this premise are in progress.

The following summarizes the activities and results for 1986.

In Situ Studies. In addition to annual measurements by IITRI, EM field intensities at the study sites were measured each week before removing cultures and were readjusted following subculture to match EM fields existing in the soil. Installation of EM data logging units is planned for the 1987

field season. The units will make hourly measurements of the EM intensity in each culture chamber.

There were no significant differences between cultures exposed at treatment and control sites for QO_2 and ATP variables over a 147-day exposure period. However, preliminary analyses of fewer and more variable data indicated that a minimum number of exposure days (threshold) may be needed before significant differences become apparent.

Temperatures were measured by placing battery-operated monitors adjacent to a culture chamber at each site. In 1986 as in 1985, the culture temperature at the control site tracked 2° to 3°F higher than at treatment sites. In 1986, however, this difference became less marked from July through September, at which time the calibrations were rechecked. Calibrations showed the control monitor to be about 2°F low. The data suggest that the control monitor may have drifted beginning in July. Uncorrected measurements of the culture temperatures ranged from 40° to 68°F.

Laboratory Studies. Laboratory experiments for the QO_2 and ATP variables were performed in a manner similar to that used for the *in situ* studies. Molds were grown and subcultured on agar and then transferred to suspension (liquid) culture for analysis. Treatment cultures were continuously exposed to EM field intensities similar to those at the WTF ground site for 91 to 109 days. In 1986 as in 1985, there were no significant differences between treatment and control cultures for either variable.

Laboratory experiments on the length of the mold's mitotic cycle were performed only with suspension cultures and an EM field intensity similar to that at the WTF ground site. These cultures showed a significant lengthening of their mitotic cell cycle in 1986, but not in 1985.

Possible effects of temperature differences (40° to 68°F) on QO_2 and ATP variables at the WTF were evaluated in the laboratory by growing molds on agar substrates at 68°F and 78.4°F. After transfer to suspension culture, QO_2 and ATP were measured. No significant differences were found between the cultures grown at 68°F and 78.4°F.

2.4 Soil Amoebae

Bacteria are important to the soil ecosystem because of their ability to mobilize nutrients needed for plant growth. Soil amoebae are common soil organisms that are predators on bacteria. To the extent that protozoa affect the numbers and types of bacteria in the soil, protozoa also become a potentially important factor in soil fertility. Studies on protozoa and other related organisms have suggested possible EM effects on characteristics such as orientation, growth, and physiology.

In order to examine for possible effects from the operation of the ELF Communications System, the following aspects of soil amoebae are being studied:

- species and strain characteristics
- population size and activity
- growth and feeding.

In addition, select elements indicative of soil fertility are being monitored.

Studies on soil amoeba are being performed at three study sites in Michigan. Treatment sites are located at aerial and grounded portions of the MTF. The third site, the control, is located about nine miles from the nearest antenna element. The aerial treatment site and the control site were the same as used in 1985; however, the ground treatment site had not been used prior to the 1986 field season. The ground site was moved due to a reconfiguration of the ELF grounding system adjacent to the study.

Species and Strain Characterization. During the 1986 field season, eight types of amoebae (various generic and species levels) were isolated using soil enrichment techniques. The types of amoebae identified were the same as those found in 1984 and 1985. To date, no differences have been reported between years or sites in the types of amoebae present.

In 1986 as in 1985, the genetic diversity within a single species of soil amoeba, *Acanthamoeba polyphaga*, was determined by isoenzyme analysis. No differences were found between sites for the genetic diversity of this species in 1986. Another technique, i.e., fragment analysis of mitochondrial DNA, continues to be developed. The study of differential strain effects is

designed to detect changes at the population, rather than at the community, level.

Population Size and Activity. The size of the amoeba population is an ecological variable considered likely to influence the functioning of the soil system.

Soil samples for population studies are taken with a coring device. Coring locations within study sites are determined randomly using a numbered grid system and a random number generator. The soil profile at study sites is typical of northern hardwood soils, i.e., with a sharp difference between the upper, organic horizon and the lower, mineral horizon. In a typical core the 1- to 2-in. organic horizon is taken as one sample, and the top 2 in. of the underlying mineral horizon is taken as a second sample. A soil-dilution counting technique is used to determine the population size of each sample.

Studies to date have shown that the total amoeba population at any given moment consists of both vegetative (actively reproducing) and encysted forms. During the growing season there are cyclic changes in the total number of amoebae present, often increasing or decreasing by two orders of magnitude, with the vegetative form generally predominating. In 1984 and 1985, large increases in the total number of amoebae occurred during the period 8 to 10 August, while in 1986 comparable increases or timing were not detected. The researchers speculate that the number of amoebae was depressed in 1986 by the lack of rain during the early part of the growing season. However, no direct statistical correlation of amoeba numbers to ambient environmental factors such as temperature or moisture has been reported.

The cyclical changes in total amoeba population indicated to the researchers that both the vegetative and encysted forms were being actively destroyed. In an attempt to identify those organisms possibly affecting amoeba population dynamics, the researchers isolated bacteria and fungi from study site soils. In 1985, it was found that of 300 isolates, about a dozen were toxic, and two were lethal to soil amoebae. This work was to continue in 1986; however, no results were reported.

In 1986 as in the past, the total number of amoebae in the mineral soil horizon was less than, and varied in a manner similar to, the total number in the organic horizon. There were no significant differences between sites for

the total number of amoebae in a comparable horizon. There were significant differences between sites for the number of encysted forms present on a given date, but no consistent pattern was apparent. No statistical comparisons for interyear differences were reported.

Growth and Feeding Activity. The purpose of this element is to determine the in situ growth and feeding activity (i.e., predation on bacteria) of soil amoebae in buried culture chambers.

The project involves suspending a known species of amoeba (*A. polyphaga*) with a food bacterium in a physiological saline, all contained in a culture chamber. In order to produce electric fields and electric currents similar to those in the surrounding soil, the chambers are connected to buried collecting electrodes. Periodic counts of amoebae and bacteria are to be made with a microscope to determine changes in the number of organisms over time. Cropping activity will be determined by varying the number of bacteria for amoeba growth and then following the growth rate and maximum yield. It is felt that this approach will allow the examination of an important ecological function of amoebae (i.e., bacteria predation) by eliminating some of the variability inherent in the soil environment.

In 1984, preliminary studies of amoeba growth in culture chambers at Michigan study sites indicated no significant differences between sites for amoeba growth rates without EM fields. Circuits for electrical exposure and measurement in the growth chambers were designed and constructed by IITRI for use at the WTF during the 1985 field season. Although the evaluation of electrical exposure of amoebae was not accomplished during 1985, brief studies were performed in 1986. Studies at the WTF did not indicate a significant difference between exposed and unexposed chambers in the growth rate of the enclosed amoebae.

2.5 Soil and Litter Arthropods and Earthworms

Arthropods and earthworms play a major role in the decomposition of vegetation. These invertebrates shred plant material such as leaves and redistribute the remains in the soil habitat. The vegetative remains are then further degraded by soil microflora (see Sections 2.2 and 2.3). For the purpose of detecting possible effects of the ELF Communications System on major agents of litter decomposition, this element is monitoring both the

structural and functional aspects of the litter and soil invertebrate community.

The project employs one treatment site located adjacent to the antenna ROW at the Michigan Transmitting Facility and one control site located at a distance west of the antenna. Both sites are situated in a maple-dominated deciduous forest. Although there are faunal differences between the sites, the sites have similar soils, vegetation, and climate.

In order to address faunal differences between sites, community indices and the characteristics of major populations common to both sites are emphasized. In addition to dominant groups, populations representing various roles in the soil habitat, such as predators and detritivores, are examined. To accommodate the various roles of the soil fauna may require intersite comparisons of ecological equivalents and/or preoperational and operational comparisons of populations unique to the treatment site. Litter decomposition rates will provide an overall indication of the functional aspects of the soil community.

The following is a summary of the status of each project element. Except for the litter element, the findings have not been extensively examined by statistical means. An extensive statistical treatment of the variables under study will be presented in the 1987 annual report.

Arthropods. This element examines the major arthropod fauna inhabiting the soil, litter, and surface layers at each site.

Diel and seasonal activity patterns of surface-active arthropods are being assessed by consecutive, day and night, pit-trap samples taken once a week. Data collected throughout the year are combined to provide an estimate of the community structure. Major groups being examined as candidates for further study are collembolans (spring tails), acari (velvet mites), carabidae (ground beetles), and spiders.

Pit-trap data taken during 1984 and 1985 at both sites and for all major groups except spiders were used for preliminary comparisons. At the time of reporting, 1985 data for spiders were being entered into a computer for analysis, and the identification of arthropods in 1986 samples had begun. Based on the available data, sites differed in the relative dominance of major

species and in the occurrence of a few rare species. Activity patterns of the major species present at the study sites are synchronous.

In order to increase catches of surface-active arthropods, pit traps were provided with barriers in 1985 that increase the effective area sampled by diverting moving arthropods toward the pit. As a result, the number of individuals and species collected in 1985 was greater than that collected in 1984. Meaningful year-to-year comparisons of community structure and activity will therefore require a second year (1986) of barrier trapping data.

The population and community dynamics of soil and litter arthropods are being determined from samples taken biweekly during the growing season. Litter and soil are sampled separately. The arthropods are then extracted by heat and sugar flotation techniques. Data for the 1984 and 1985 growing seasons were available for analysis. Data for most 1986 samples are complete; however, select taxonomic groups require further identification. Based on the available data (1984 and 1985), the collembola and acari are the most abundant taxa in the litter and soil of both sites and are the major groups of interest.

The diversity and yearly mean density of the collembolan community are comparable to those of other deciduous forest communities with similar mean annual temperatures and soil characteristics. However, both diversity and density are apparently different between study sites. Because only two years of data are available for analysis and comparable information has not been reported in the literature, it is difficult to interpret the differences between sites. These variables will continue to be studied to determine if the intersite differences persist. In addition, ambient conditions at each study site will be examined as possible factors influencing density and diversity.

The population density of four species, each representing a different family of collembolans, is also being monitored. Stage-specific density estimates, reproductive patterns, and recruitment patterns are being examined as possible variables. Preliminary analyses are ongoing and have been focused on one abundant species that occurs in the litter and soil of both sites. Depending on the results obtained, use of the same variables for the other species will be considered.

The bulk of the acari in both sites belong to the orders Orbatida, Prostigmata and Mesostigmata, Astigmata being negligible. The density of mites at the study sites is comparable to other deciduous forest communities with similar mean annual temperatures and soil characteristics. However, the density of mites is apparently different between sites. In addition to examining the seasonal and yearly summaries of mite density of the higher taxa, the researchers have selected three species for population analyses. Of the population characteristics being examined, population structure may prove to be an important and statistically acceptable parameter. Using multivariate analysis, the population structure (five developmental stages) for two of the three mite species was examined. Despite seasonal and year-to-year density differences, the stage structure for the two species was significantly similar between sites and between years. Assessment of all variables for the acari will be continued.

Earthworms. The purpose of this element is to examine the major earthworm fauna inhabiting the soil and litter of the study sites.

Population and community characteristics of earthworms are being determined from samples of soil and litter 25 cm by 25 cm by 40 cm deep. Earthworms are extracted from litter using weak formalin, while those in soil are obtained by hand sorting followed by wet sieving.

Sample data taken from 1984 through 1986 were used for preliminary analyses and site characterization of the earthworm community. Average yearly density of all worms is estimated at more than 400/m² at both sites. This is higher than most reports in the literature. Eight species of earthworms have been identified, of which three are common to both sites. As expected, species diversity indices are low but are comparable to Canadian worm communities. There were no significant differences between sites for community diversity when total numbers of worms per species were averaged over all three years. Preoperational and operational comparisons of community diversity are planned.

Only one species of earthworm, *Dendrobaena octaedra*, occurs at both sites in sufficient numbers for direct intersite comparisons. Two dominant species of *Aporrectodea* (*A. tuberculata* at the treatment site and *A. turgida* at the control site) are also being evaluated for possible intersite comparisons.

These species are similar in their biology and are considered by European researchers as forms of a single species. Population variables being examined include distribution, density, reproductive activity, and recruitment.

Litter Decomposition. This element examines the input, decomposition, and standing crop of leaf litter at each study site. These variables provide a direct estimate of the overall functioning of the soil and litter community.

Litter inputs were determined by collection of leaf and other litter from twenty 0.25 m² traps per site. Traps were emptied weekly during the time of greatest leaf fall and monthly at other times. These samples were then sorted by category (e.g., maple, basswood, flowers, seeds, etc.), oven-dried at 50°C, cooled, and weighed. Total litter inputs in 1986 were 295 gm/m² and 315 gm/m² at treatment and control sites, respectively. Maple leaves constituted the bulk of the litter inputs. There were no statistically significant differences between sites or years for total litter inputs from 1984 through 1986. Input values are consistent with data reported for similar forests and latitudes.

In previous years, standing crop estimates were obtained every two weeks from litter samples initially taken for the determination of litter moisture content and the extraction of arthropod fauna. After the determination of moisture content or extraction of arthropods, the litter was dried and weighed. Because these samples were contaminated with soil and other materials, it was determined that previous standing crop values were over-estimated. In 1986, some samples were washed prior to drying and weighing. Although mass loss due to leaching of soluble materials in the litter remains to be determined, preliminary analyses indicate that washing reduces sample mass by 20% to 30%. Maximum standing crop (fall) estimates, based on unwashed samples, were 414 g/m² and 446 g/m² at treatment and control sites, respectively. There were no significant differences between sites or between years (1984-1986) for this variable. Exponential decay rates of forest floor litter are being calculated based on total annual litter inputs and maximum standing crop after leaf fall.

In addition to inputs and standing crop, several litterbag methods and variations (e.g., mesh size, mixed leaves, leafpacks, etc.) have been evaluated for estimates of litter decomposition. Large mesh litterbags containing

maple leaves have been selected for continued use. Samples of dried maple litter are weighed and placed in 20 mm mesh netting on the soil surface at both study sites. At monthly intervals, 10 samples per site are retrieved, dried, and weighed. Correction for soil contamination is determined by combustion of ground samples and weighing the residue. Data obtained from this method were less variable than data obtained from other methods and produced decay rates similar to those estimated from standing crop and litter inputs.

Nutrient loss analyses have been eliminated. This step will allow a greater focus on fauna-related variables.

Ambient Monitoring. In general, the data collected to date have shown that study sites are well matched for the climatic variables being monitored. Air temperatures and soil temperatures through the soil profile are similar at both sites. Litter and soil moisture at both sites reflect the frequency and intensity of rainfall. In three years, litter moisture has differed between sites only on one date. Substrate moisture and temperature data are being used as independent variables in regression analyses and as covariates in analyses of variance.

2.6 Native Bees

Fluctuations in the earth's magnetic field and the EM environment beneath high voltage transmission lines have been reported as affecting honeybees. Enervated cells containing iron granules have been found in the abdominal segments of adult, foraging honeybees. It has been speculated that these iron structures may be used in orientation and otherwise provide a mechanism for the sensing of EM fluctuations by honeybees. Behavioral changes such as:

- greater dispersal
- greater levels of activity
- lower overwintering survival
- modification of nest structure

have been described.

Honeybees are rare in the forested areas in which the ELF Communications System is located. Native bees are, however, abundant and are of particular importance to ecological communities in the area as the main pollinators of resident flowering plants. Native bees have coevolved with resident plants

and are able to overwinter in the study area. Therefore, native bees, rather than honeybees, are being monitored for possible EM effects from the operation of the ELF Communications System.

For the past four years three general types of data on native bees have been collected:

- nesting activity
- nest architecture and orientation
- emergence and mortality.

The latter two types of data have been collected using "trap nesting" techniques, and the former by direct observation as the bees are constructing their nests.

Because native bees make use of existing holes to construct nests, pre-drilled blocks of wood are set on shelved hutches at study sites in order to study the biological aspects of the occupying bee species. Each nest consists of a series of reproductive (cell) and nonreproductive (basal and vestibular) spaces within the bore of the hole. The ends of the nonreproductive spaces are closed with a series of plugs using rounded leaves or other material. Individual cells are also separated by partitions consisting of rounded leaves. Each cell is lined with elongate leaves and is provisioned with pollen. After an egg is deposited in a cell, the open end is closed by another partition. The egg hatches and the larva molts through a series of stages to overwinter as a prepupa.

Over 40 species of native bees are known to occur in the ELF Communications System area, 20 of which are known to use trap nests. Based on information collected since 1983, further data collection and analysis will focus on two abundant species, *Megachile inermis* and *M. relativa*. Both species overwinter as prepupae and emerge as adults in mid-June at the study sites.

Nesting Activity. Previously, an extensive effort was made to observe, record, and determine the different activity patterns of various species of native bees. For example, during 1983 over 1600 hours were used to record 15,000 life history events and about 4,000 observational notes (i.e.,

incidence of marauders, sunning activity, etc.). Similar types of efforts and data collection have been performed every year to date.

From this extensive data base, the time spent foraging for nest materials and the time spent manipulating the materials in constructing the nest were considered to be of particular relevance. Disorientation or agitation of bees while foraging or building nests may be reflected in the time taken to construct a nest and/or in the number or duration of foraging trips made by the bees. Data are available for the two species of interest; therefore, preliminary statistical analyses were performed to evaluate these behaviors for further study.

The preliminary analyses of foraging behavior focused on the duration of trips to collect round leaf pieces (L0), elongate leaf pieces (LR), and pollen (P). The distribution of durations for a given type of foraging trip and the durations of times in the nest after a collecting trip are skewed with a wide tail (indicating a few trips of long duration). Based on the distribution of the data, appropriate data transformations were attempted. Only L0 trips could be adequately normalized. Transformed (log-log) L0 durations were examined using analysis of variance techniques. No significant differences were found between years, dates, time of day, or sites. Using the coefficient of variation calculated in the analysis of variance, researchers should be able to detect either a twofold change in L0 duration with 60 replicates or a threefold change with 27 replicates. A search is ongoing for a transformation that will normalize the other two foraging behaviors.

Based on these preliminary analyses, protocols will be changed during the 1987 field season. Planned changes include:

- emphasis on the above foraging behaviors
- more systematic sampling (i.e., equally over locations, season, and time of day)
- examination of a few trips for many different individuals (previously many trips for a few individuals were recorded)
- correlation of behaviors with ambient environmental factors.

Disorientation in the collection of materials or attempts to modify the nest structure could also be reflected in the number of foraging trips and/or

the time taken to build a nest (or its components). In order to examine this premise, behaviors marking the onset and termination of construction activities were delineated. Although sparse, some data were available on the number of trips and the subsequent duration of manipulating foraged materials in lining cells, provisioning cells, and constructing cell caps. Analyses indicate that the duration of cell cap construction is highly variable. The time required to deposit foraged pollen within a given cell ranged from two to nine hours. The researchers feel that it would be more efficient to monitor the number of leaves used to line cells, rather than spending excessive amounts of time recording construction events or counting trips.

Nest Architecture and Orientation. When exposed to EM fields produced by a high voltage transmission line, honeybees increased the amount of propolis at their nest entrance. If native bees respond to the EM fields produced by the ELF Communications System in a similar manner, they may produce thicker cell caps, thicker nest caps, or larger nonreproductive spaces. Although no data analyses were presented, researchers feel that these variables can easily be analyzed using a nested analysis of variance for caps and a chi-square contingency table for nonreproductive spaces. Reproductive spaces may also be affected if native bees are disoriented by the EM fields produced by the ELF Communications System. The native bees are likely to respond by producing fewer or smaller cells.

The available nest architecture data have been compiled, and most of the data have been entered into the computer. Inconsistencies in methods of nest measurement and data entry into the computer prior to 1986 remain to be resolved. Nests constructed in 1986 will not be opened until the spring of 1987. Despite these difficulties, the researchers feel that cell size should be a particularly good end point. Cell size does not vary greatly within a given species and a given bore diameter. Furthermore, as each nest consists of a number of cells, variability can be analyzed within and between components of cell size. For these reasons, the potential for detecting changes in cell-related variables is considered high.

Since honeybees may use the earth's magnetic field to orient their comb, it is possible that fluctuating ELF magnetic fields could disturb any preference that native bees have in orienting their nests. Previous analyses

showed no preference of native bees for any cardinal compass point in orienting their nests. Analysis of data will continue. Future comparisons of the relative acceptability of different nest orientations will use testing for independence of discrete categorical data. The latter comparisons generally require a minimum of five nests per hutch.

Emergence and Mortality. Completed nests are routinely removed from study sites to another outdoor holding site to overwinter near the field station. Nests are checked for interlopers, excessive moisture, and vertebrate predation. During the spring, the nests are split open and data on nest architecture are recorded. The nests are then returned to the study sites to await final emergence. With emergence, factors relating to development and mortality are scored.

The current experimental protocol presents several problems in comparing the mortality at treatment and control sites. Confounding factors such as removal from study sites and differential frequency of parasitism at the study sites will be examined in 1987.

2.7 Small Mammals and Nesting Birds

Laboratory studies at intensities and ELF frequencies similar to those produced by the ELF Communications System have reported effects to small vertebrates. Although the reported effects have been controversial, many species of small mammals and birds are resident in the ELF Communications System area, and, in principle, any could be affected by the operation of the system.

As in the case of other studies in the Ecological Monitoring Program, this study examines several levels of biological organization for possible effects from the ELF Communications System. Because it is impossible to monitor all aspects of all species, community characteristics are being used to assay for possible effects to many different species of mammals. Two species of mammals are also being monitored for possible changes in populational aspects, such as density. Avian population and community studies are being provided by other researchers (see Section 2.8).

Population and community studies are inherently variable; therefore, only pronounced effects are detectable. Laboratory research indicates that if the

operation of the ELF Communications System produces any effects on vertebrates, the effects will be small. Therefore, to complement the population and community approach, studies of specific attributes of individuals are also being conducted. The purpose of this approach is to gather a sufficiently large set of data to detect small differences in exposure comparisons. The individual attributes being examined are based on previous research and include reproductive, developmental, behavioral, and physiological characteristics of select species.

Those species selected for studies of population attributes and most individual attributes are the deermouse, chipmunk, and tree swallow. The black-capped chickadee is being examined solely for physiological variables. These studies employ five treatment sites in, or immediately adjacent to, the antenna ROW and four control sites with similar habitat. Areas on the control sites have been cleared and are being treated the same as the antenna ROW.

Population and Community Studies. The purpose of this element is to monitor the small mammalian community and select mammalian populations for possible effects from the operation of the ELF Communications System.

Live trapping was the primary method used to characterize the community and select populations of small mammals at study sites. In order to detect species that were not likely to be trapped, sign surveys and pitfall traps were also employed. Indices of species richness, diversity, and composition were determined and used for intersite and interyear comparisons of the mammalian community. Population density of deermice and chipmunks was used to monitor for possible effects at the population level.

Indices of species composition and richness at the treatment and control sites were quite similar, and there were no significant differences between sites in the diversity of small mammal species trapped during either 1985 or 1986. There were significant differences between sites in the density of chipmunks in 1986; however, there were no similar differences in the density of deermice. Both species were much lower in abundance in 1986 than in 1985.

The researchers anticipate that interyear comparisons will be of little value in assessing possible ELF Communications System effects on population variables, although intersite comparisons within a single year will be useful.

It is estimated that a 20% change in either community indices or population densities will be detectable using current protocols.

Embryonic Development. Prenatal developmental stages are especially sensitive to environmental perturbations. At present, there is conflicting evidence of direct EM effects on embryonic or fetal development. In addition, possible effects of the ELF Communications System on parental behavior could also have an indirect effect on development. The purpose of this element is to determine the incidence of the abnormalities in embryonic development of tree swallows at treatment and control sites and to test for possible effects of the ELF Communications System on the incidence of these abnormalities.

Embryos of tree swallows are collected at four treatment and two control sites after four days of incubation. The embryos are dissected from the egg, preserved, and initially scored for normality. The preserved specimens are later cleared, stained, mounted whole on glass slides, and examined in detail for normality. The final determination of normality is carried out according to a "blind" procedure.

Chi-square analysis of embryos collected at treatment and control sites during both 1985 and 1986 (i.e., during the preoperational period) showed that the frequency of developmental abnormalities was not uniform among the sites; one site had an extremely high incidence (39%) of abnormalities. Reanalysis of the data without this site showed no significant differences between the treatment and control sites. The frequency of abnormalities for the pooled treatment and control sites (without the high-incidence site) was 8.0%. The researchers will continue to monitor all sites, including the site demonstrating a high incidence of abnormalities.

Parental and Nestling Behavior, Fecundity, Growth and Maturation: Tree Swallows. The purpose of this element is to monitor important aspects of the reproductive and postnatal growth processes in the tree swallow. Variables are parental attentiveness to eggs and young, number of eggs per clutch, hatching success within clutches, rates of postnatal growth, development of hatchlings, and nestling mortality.

Studies are carried out in natural or artificial clearings where the researchers have erected arrays of nest boxes. The boxes can be opened to permit inspection and weighing of the young. Active nests are checked daily

or every other day to determine the dates that eggs are laid, the number of eggs, hatching dates, and overall hatching success. Monitoring nestling growth and mortality then continues until all young fledge (16 days). Parental attentiveness to eggs is monitored using temperature probes, and attentiveness to nestlings is monitored with video recording devices.

Mean clutch size was significantly larger at the treatment study site (5.3 eggs per nest) than at the control site (4.9 eggs per nest); however, there was no difference in the distribution of clutch sizes between treatment and control sites. The difference noted was the same in 1986 as in 1985. The researchers are examining available food supply as one possible factor for this difference.

In 1986, hatching success (percent of eggs that hatch) was significantly greater at the treatment site than at the control site. When 1985 and 1986 data were pooled, the likelihood of hatching was shown to be independent of both plot and year.

Fledging success (percent of hatchlings that survive to fledge) was not significantly different between sites in 1986. However, when 1985 and 1986 data were pooled, the differences between sites were highly significant. The number of young that survived to fledge in 1986 was extremely low due to one episode of inclement weather that caused about a 60% mortality of fledglings. The values of fledging success, hatching success, and clutch size obtained in these studies are similar to those reported in the literature for other studies of tree swallows.

There was no significant difference between sites in the postnatal landmark of eye opening; however, the mean number of days to feather eruption was significantly longer at the control site than at the treatment site. As in the case of clutch size, the difference in time to feather eruption is being examined in relation to food supply.

In order to examine growth variables, measured values were fit to models. Data taken in 1986 on body mass and tarsus and ulna growth best fit logistic models, while wing growth best fit an exponential model. Models were then used to produce values for an analysis of variance. In general, the rates for each growth variable showed that nests differed significantly among themselves, but pooled rates did not differ between treatment and control sites.

Although data were accumulated during 1986 with respect to parental attentiveness to eggs, the data were not fully analyzed at the time of reporting, and only representative analyses were presented. The variables examined were total time spent incubating eggs, average egg temperature during incubation, and average time of incubation event. Of these, the best variable for statistical analysis was the total time spent incubating (expressed as the percentage of time on the eggs per day). Using dispersion statistics from the data analyzed, it is estimated that 10 nests per study site need to be monitored in order to detect a 20% difference between sites.

In order to quantify parental attentiveness to nestlings, several variables were measured from video recordings of male and female activity at nests during 1986. Of the variables examined, only visits per hour was considered sufficient to meet statistical requirements for further study. When visits are pooled over nests, females have slightly lower visitation rates than males. The pooled data for females yield a coefficient of variation of about 18%. Eighteen nests per site will need to be monitored in order to detect a 20% difference in visits per hour. Because this sample size is larger than anticipated, additional video recording equipment will be used during the 1987 field season.

Parental and Nestling Behavior, Fecundity, Growth and Maturation:

Deermice. The purpose of this element is to monitor important aspects of the reproductive and growth processes in deermice. Variables are maternal attentiveness to nestlings, number of young born per litter, proportion of young surviving until weaning, rate of postnatal growth, and rate of development of nestlings. (Note: the prenatal development of mammals is not being studied because reproductive females would have to be killed in order to examine the fetuses. The removal of the number of females required to meet statistical sufficiency for these studies would have adverse effects on the local population.)

Large (20 ft by 28 ft), open enclosures are being used to restrict the movements of deermice during studies of behavior, fecundity, and growth. The deermice to be studied are captured in mixed deciduous forest near the enclosure sites. The animals are paired, and when the female is pregnant, she is transferred to the large enclosure to give birth and rear the young to

weaning. The attentive behavior of the mother is monitored by using treadles attached to nest boxes and feeding stations.

Litter size, age at eye opening, and age at incisor eruption were similar between sites in 1986 but, as in 1985, were highly variable. The possibility of increasing the number of visits to nests in order to better resolve these developmental landmarks is being examined. Studies to date have shown that growth curves of nestling body mass are different between litters. Therefore, growth rates have been estimated using linear regression analyses for growth of each individual and combined growth of all individuals in each litter. Nested analysis of variance of growth rates indicated significant differences between mothers, but not between animals at treatment and control sites.

Preliminary studies are underway to measure maternal attentiveness by examining number of visits to the nest or feeder, percent of day spent in the nest or feeder, and amount of time spent in each visit to the nest or feeder. These data, recorded for two females from the time of birthing to 16 days after birthing, are currently being analyzed.

Homing Studies. Published information suggests that magnetic fields are one of several cues used in the orientation of some birds and mammals. Animals are able to find food and escape predators more effectively in their home range or territory than in less familiar areas. Thus, any disturbance of the ability to return to a home range could decrease the probability of survival. The ability of tree swallows and deermice to return to their home range after displacement in the ELF Communications System area is being assessed. The variables being examined are the percentage of displaced individuals that return home and the amount of time taken to return home.

Adult birds from treatment and control sites were captured at nest boxes while brooding their young. Captured birds were banded, color-marked, and taken to release sites. (Release sites are located in open areas 30 km from the capture site.) The direction of the release points from the nest sites requires birds returning to their nests at treatment sites to cross both east-west antenna elements. Birds taken from control sites are displaced at angles and distances similar to those used for birds taken from the treatment sites, but do not cross or come near any of the antenna elements. Observers located near the nest boxes record the times at which the displaced birds return.

There were no significant differences between sites in 1986 in either the frequency of return of displaced birds or the mean time required for the return of displaced birds.

Chipmunks and deermice were captured on a trapping grid at treatment and control sites. Displacements took place during, or just prior to, the next activity period following capture; deermice were displaced at dusk and chipmunks in the morning. Individuals were displaced either to the south or west of the trapping grid, with each animal displaced 450 m from the trap at which it was captured. The displacements to the south were through relatively continuous forest, while displacements to the west required the returning animals to cross the antenna ROW or sham ROW. Once an animal was displaced, traps on the grid were checked morning and evening for at least five days.

In the frequency of return of chipmunks, there were no significant differences between males and females, between west- and south-displaced individuals, or between sites. The frequency of returning chipmunks was greater in 1986 than in 1985, due in part to a reduction in the displacement distance. The data for deermice were not analyzed due to the small number trapped in 1986. The data collected in 1985 showed no significant differences between sites for the direction of displacement or frequency of return.

Physiology: Peak Aerobic Metabolism. The purpose of this element is to determine peak aerobic metabolism of chickadees and deermice. This variable is measured during periods of severe stress (winter) at treatment and control sites. Peak metabolism provides a general index of an animal's health, and a deficit would indicate that some attribute of the animal's system involved in oxygen supply had been adversely affected.

Black-capped chickadees and deermice collected along the ELF Communications System ROW and at a control site are taken to a screened outdoor holding facility at Crystal Falls, Michigan. Food and water are provided ad libitum. To elicit a peak rate of oxygen consumption, a version of the helium-oxygen method is used; an animal must produce heat more rapidly in helium-oxygen than in air if it is to maintain a stable body temperature. Animals in a metabolism chamber are cooled in a water bath using ethanol. Helium-oxygen is pumped through the chamber, and the reduction in oxygen content is measured.

There were no significant differences between animals captured at test or control sites or between pooled 1985 and pooled 1986 peak aerobic metabolism values for a given species. Experiments performed over a four- to 20-day period indicate that there is no difference in peak metabolism due to length of captivity. Generally, five to seven days of captivity are required for routine measurements.

2.8 Bird Species and Communities

Many species of birds migrate from a nesting range to an overwintering area and back again. Successful migratory movement requires a mechanism that permits judgment of direction in order to arrive at the appropriate location. Many experiments have indicated that birds are sensitive to magnetic cues and use such cues, along with others, for orientation during migration. The magnetic environment in which a bird is raised may also be important in its development of orientation ability.

This study monitors for possible effects to resident birds, migratory birds that breed in, and birds that migrate through, the ELF Communications System area. The study concentrates on community characteristics such as species richness, community density, density of common species, and relative frequency of occurrence of uncommon species. A line transect method (variable width) is used to census these community characteristics. Observers walk the designated transect and record information directly from sightings or indirectly from bird songs. The variables recorded include species, sex, behavior, perpendicular distance from transect, and distance along transect.

Study sites consist of 10 transects in Wisconsin (five treatment and five control) and 10 transects in Michigan. Treatment transects are parallel to and more than 125 m from the edge of the antenna ROW. Control transects are variously oriented and are generally at distances greater than 10 km from the antenna. Control transects do not have sham corridors located adjacent to them.

Although pilot data on bird species and communities were taken in 1984, the 1985 season was the first in which the collection of data on birds breeding in the ELF Communications System area was possible. During 1985, each study transect was censused at least once in June. In addition, 16 treatment and control segments were censused twice in each state in order to

document day-to-day and observer differences (see below). In 1986, the characteristics of both the breeding and migrant bird communities were examined for each of five periods: spring migration (May), early breeding (June), late breeding (July), early fall migration (August), and late fall migration (September).

Three summer resident species (Nashville warbler, red-eyed vireo, and ovenbird) were the most common species on both control and treatment transects throughout the spring migration and early and late breeding periods in both states. A permanent resident species, the black-capped chickadee, was the most abundant species during the early fall and late fall migration periods in both states.

Annual Trends. The only period sampled in both 1985 and 1986 was the early breeding period (June). The total number of species and the number of individuals were examined, as were those species considered abundant (more than one individual per transect segment in either 1985 or 1986).

On both treatment and control transects in Wisconsin and Michigan, the total number of species and the total number of individuals were significantly lower in 1986 than in 1985. Changes in the number of individuals of abundant species varied in both magnitude and direction. The overall decline in the number of individuals was largely due to decreases in a few abundant species. The ovenbird, red-eyed vireo, and Nashville warbler showed the greatest declines in the number of individuals on both treatment and control transects in both states.

Seasonal Patterns. Because only one year of data on migrating bird communities has been collected, this section compares observations made on treatment and control sites during 1986. There will be a more extensive examination of seasonal patterns in community characteristics for consistency between years when similar data are available in 1987.

The researchers observed a pattern of high (or increasing) numbers of species and individuals during migratory periods and relatively low (or decreasing) numbers of species and individuals during the breeding season. Because the majority of observations were based on sound, and because singing drops throughout the breeding season, the apparent decline in numbers over the period June-August may be an artifact of the observation method.

In Wisconsin, where the antenna was operational in 1986 and where the ELF Communications System has operated intermittently since 1969, the total numbers of species and individuals were generally higher on control than on treatment transects. In June, there were significantly more individuals on treatment transects; except for June, however, there were no significant differences between treatment and control transects for total numbers of species or individuals. The researchers discerned the following pattern of species distribution among sites: five species were observed to have consistently more individuals on control transects; four species were observed to have consistently more individuals on treatment transects; and four species showed no consistency. Differences among sites in the number of individuals for a given species were either not statistically significant or were significant for only one or two of the five monthly censuses.

In Michigan, where the antenna was energized at low currents in 1986, the total numbers of species and individuals were higher on control transects than on treatment transects. These site differences were statistically significant only during the spring and late fall migration periods. Of the 17 species recorded, seven species were observed to have consistently higher numbers of individuals on control transects; two species were observed to have consistently higher numbers on treatment transects; and eight species showed no consistency. As in Wisconsin, site differences in the number of individuals per species for a given month were either not statistically significant or were significant for only one or two of the five censuses.

Edge Effect. The presence of a cleared ROW is a potential source of error when comparing the characteristics of treatment and control (no ROW) bird communities. Both the variety and density of birds are known to be larger at the edges of plant communities. Vegetation changes associated with clearing of the ROW are different than undisturbed habitats on control transects or in undisturbed areas adjacent to the antenna. Because clearing of sham corridors on control transects was not feasible, treatment transects were placed at a distance from the antenna ROW in an attempt to eliminate edge effect variability from the study design. The data are being examined to determine the effectiveness of this design aspect.

If there is an edge effect, there should be more individuals observed on the side of the transect adjacent to the ROW. If birds are distributed evenly, there should be no differences between sides on control transects. Analysis of 1985 and 1986 data collected on transects in both Wisconsin and Michigan showed 12 significant differences in 84 side-to-side comparisons.

The findings suggest that birds are not distributed randomly on control transects, and therefore most likely are not distributed randomly on treatment transects. Because of the distribution, it cannot be concluded that there was a positive effect of the edge for those species that had more individuals on the ROW side of the treatment transects. These analyses will continue during 1987.

Observer Differences. Another potential source of error in censusing is the variability between observers in detecting and recording bird species and numbers.

This source of variability has been checked annually since 1984. In 1986, two observers 12 minutes apart censused the same eight transect segments during the early breeding period. There was only one significant difference between the two observers, with no significant differences between them in 12 other variables. To account for the one difference between observers, the possibility that the first observer's passage caused ovenbirds to stop singing is being examined. Annual checks will continue.

Vegetation Studies. In Wisconsin, there are no data on bird communities prior to the initiation of intermittent testing of the transmitting facility. In principle, current studies cannot assume that intermittent operation of the antenna since 1969 has not altered the bird communities.

It has been reported in the literature that birds select their breeding areas based on vegetation; therefore, areas of similar vegetation should have similar breeding bird communities. In order to determine whether the ELF Communications System affects the bird communities, it is necessary to account for differences on or "pair" control and treatment transects based on the habitat of the transects.

The vegetation on all 80 segments that constitute the control and treatment transects will be measured over a two-year period (1987 and 1988).

Samples are being collected at 25 m intervals to describe the vegetation that occurs on each segment. Densities of trees, shrubs, forbs, and grasses will be calculated using the point-centered quarter method. Twenty-five tree, 47 shrub, and 73 forb species were identified along the transects measured in 1986. Sampling on the remaining segments is planned for 1987. A representative portion of segments measured in 1986 will be remeasured in 1987 in order to estimate changes from 1986 to 1987.

Preoperational differences have been noted in the bird communities of Michigan between treatment and control transects. In order to examine these differences, the habitats on Michigan transects were determined at 25 m intervals along each segment. A chi-square test was used to test for differences between treatment and control transects using the proportions of the 19 habitats observed.

In Michigan, control transects had significantly more maple and cedar habitats, while treatment transects had significantly more lowland conifer habitats. When categories were combined on a general scale to compare percentages of lowland and upland forests, and lowland and upland shrub habitats, the treatment and control transects were relatively similar. Unique habitats present were (1) recently logged habitats in treatment but not control areas and (2) pond and cattail habitats in control but not treatment areas.

Guild Analysis. All bird species observed have been classified based on nesting area, food or foraging type, habitat preference, and migration type. The classifications are based on published sources. This information will be used in comparing or matching specific treatment and control transects.

2.9 Wetland Flora

In addition to upland ecosystems (see Section 2.1), wetland ecosystems are also found in the ELF Communications System area. Wetlands play a valuable role in supporting diverse food chains, providing wildlife resources, and, under some conditions, maintaining natural hydrologic systems. They are sensitive ecosystems that are easily modified by environmental perturbations.

Laboratory studies at ELF frequencies and intensities higher than those produced by the ELF Communications System have affected plants. It has been

hypothesized that EM fields may affect biota by altering the transport of materials across their cell membranes. Therefore, variables important to the stability and functioning of wetland systems and which could be affected at the membrane level are being monitored. The three variables being examined are foliar nutrient content, stomatal resistance, and litter decomposition. A fourth variable, nitrogen fixation, was dropped from the 1986 studies because of low rates of nitrogen fixation and a large variability in these rates between sites.

A common type of wetland found in the ELF Communications System area is the peatland. Three types of peatland plants (herbs, shrubs, and trees) are being examined in a series of 11 peatland sites near the Wisconsin Transmitting Facility. There are four EM exposure types: antenna, ground, intermediate, and control. The antenna and ground sites (treatment) are located adjacent to the transmitter elements they describe. The control sites are located at a distance from the transmitting elements and have EM intensities two orders of magnitude less than the antenna and ground sites. Intermediate sites are located so as to have EM intensities between those of the treatment and control sites.

Each site is a 15 m by 75 m rectangular plot oriented with the long side parallel to the nearest transmitter element. Each plot is subdivided into six subplots, with a shallow well at the center of each subplot. Ambient environmental factors (e.g., ground water chemistry and temperature) are taken at the well, while biological samples and measurements are taken from areas immediately adjacent to the well.

Foliar Cations. ELF EM fields may directly affect the transport of cations across cell membranes. Foliar cations are important in plant physiology as active constituents of a number of biochemical reactions.

Four species of wetland plants are being monitored for their foliar cation content (i.e., K, Ca, and Mg). Thirty-six foliar samples were collected from 36 different individuals of each species in each bog at various times during the 1986 growing season. Samples were digested and then analyzed by atomic absorption techniques.

Analysis of 1985 data from solomon's seal, leatherleaf, labrador tea, and black spruce all indicated seasonal changes in cation content. Nested

analysis of variance was used to compare the four types of bogs (based on EM exposure) for the cation content of solomon's seal. No differences were found among EM exposure types; however, statistically significant differences were found among sites and subplots. These results were essentially the same as those found for leatherleaf and black spruce in analyzing 1984 data.

Labrador tea was sampled for the first time in 1986 as a possible replacement for two sedges previously examined. The sedges were discontinued because they were not present in sufficient numbers for statistically significant comparisons. Labrador tea was collected in only four bogs (representing the four types of EM exposure) to determine the variations associated with the nutrient content of this species. Based on the coefficients of variation (11% and 19%) these plants are a reasonable substitute.

Stomatal Resistance. The possibility of EM field effects to the transport of ions across biological membranes has been noted. The transport of ions, in turn, may indirectly affect water uptake through osmotic processes or may directly restrict stomatal opening. In some plants even a mild potassium deficiency can hamper stomatal opening. Therefore, the stomatal resistance is being examined to determine the physiological status of wetland plants exposed to EM fields from the ELF Communications System.

Efforts previous to 1986 were devoted to the development of an appropriate protocol for measuring stomatal opening using a steady state diffusion porometer. After examining four species of plants as possible test organisms, the researchers chose leatherleaf for further studies. Only expanded new leaves were used, and measurements were taken only when the photosynthetically active radiation was above 400 microeinsteins/m²/sec. Thirty readings were taken in each of the 11 bogs under study. Each sampling period lasted several days; samples were taken in both July and August 1986.

Initial analyses examined data from both months using nested analysis of variance. This analysis detected significant differences between the four types of EM exposure, bogs (11 sites), and plots (subplots within sites) for the July data. No significant differences between EM exposure types were found for the August data. Then, using "unplanned multiple comparisons, test of means" for the July data, a significant difference was shown between the antenna and control exposure types; however, there were no significant

differences among other exposure comparisons. July 1986 porometer readings were significantly correlated with both the 1985 ELF electric field in the soil and with the 1985 ELF magnetic field, but not with light intensity. The 1986 EM data were not available at the time of analysis.

Because the results of the July and August measurements were inconsistent, greater effort will be expended on this variable in 1987. The researchers plan to more closely examine sampling techniques, increase sample size so as to increase the power of these analyses, and increase the number of covariates in the statistical analyses.

Decomposition. The decomposition of plant material, a major process in bog development and change, is accomplished by microorganisms. As a group, microorganisms have been shown to be affected by ELF EM fields at intensities greater than those produced by the ELF Communications System.

In September 1984, senescent leaves from labrador tea plants were collected from a control bog site, air-dried, and weighed. Leaves were randomly selected, enclosed in 2-mm mesh fiberglass bags, and then emplaced on the peat surface of each study bog in June 1985. After one year, the bags were retrieved and the leaves were dried and reweighed to obtain percentage weight loss.

Nested analysis of variance showed no significant difference between ELF treatment types for leaves emplaced over the period June 1985 through June 1986. There were, however, significant differences between sites, indicating a heterogeneity among bogs for this variable. In the future, the overgrowth of litterbags by moss will be examined in an attempt to reduce some of the variability in the measured weight loss.

2.10 Aquatic Biota

In headwater streams such as exist in the ELF Communications System area, energy is supplied to the streams primarily by organic materials from periphyton and riparian vegetation. Macroinvertebrate consumers feed on the organic materials of the plants, making energy and invertebrate organic material available to higher trophic levels such as fish. The purpose of this study is to monitor a riverine ecosystem for possible effects from the long-

term exposure to the low level EM fields produced by the ELF Communications System in Michigan.

Two similar sections of the Ford River are used as matched study sites. One site is located adjacent to the antenna ROW (treatment); the other is located more than 10 km downstream (control). No major tributary occurs between the sites. At each site, ambient environmental factors are monitored and ecological experiments occupy adjacent stream segments. In order to determine the migration pattern of fish, four additional sites are located upstream of the control site.

2.10.1 Periphytic Algae

Periphyton are a community of microscopic plants and animals associated with the surfaces of submerged objects. Unlike the structural and functional aspects of organisms suspended in the water column, those of the periphyton community at a given location are governed by conditions at that point. Periphyton, therefore, are useful in assessing the effect of perturbations on streams because they show responses immediately at the source of the perturbation. Structural and functional aspects of the periphyton community are being monitored for possible changes due to the operation of the ELF Communications System.

Because of the periphytons' association with surfaces, quantitative determinations require the collection of periphyton from a known surface area such as that provided by an artificial substrate. Preliminary studies in the Ford River have found that the periphyton established on glass slides gave a good representation of the community found on natural substrates.

As the periphyton are dominated by periphytic algae (diatoms), these organisms are emphasized in monitoring of the structural aspects of the community. However, functional aspects such as chlorophyll, biomass, photosynthesis, and respiration are determined for the entire community, i.e., diatoms, other plants, and animals.

Structural Aspects. The purpose of this element is to monitor select variables of the diatom community. Indices for species diversity, evenness, and abundance allow the detection of subtle shifts in the community's makeup,

while total cell density and biovolume provide an indication of any overall change in the diatom community.

Glass slides emplaced at study sites for 28 days were used to identify and enumerate colonizing diatoms. The community that develops on emplaced slides most often consists of 50 to 70 species of diatoms. Because diatoms vary greatly in their size distribution, the number of individuals (total cell density) alone does not give an adequate picture of the community's makeup. Therefore, cell volume measurements for the dominant diatoms were also determined. Volume estimates were multiplied by the density of each species and summed to provide an estimate of the total biovolume for all cells present.

Since 1983, the seasonal pattern has continued to be high diversity and evenness during winter, with lower values in summer. Diatom cell density showed wintertime lows, with sustained high densities throughout the summer. For a given species, cell volume tends to be larger in the winter than in the summer. As in the past, no statistically significant differences between study sites in species diversity, species evenness, or density of diatoms were found during 1986. Individual cell volumes of 20 dominant species of diatoms were also not significantly different between treatment and control sites. In 1986 as in 1985, the total biovolume of the dominant diatom species was significantly larger at the control site.

Previously, multiple regressions were performed to examine possible relationships between untransformed community and ambient environmental variables. At that time, multiple regression analyses of cell density resulted in no significant equations for either site when regressed against ambient factors. Various transformed--e.g., $1/x$, $\ln(x+1)$, etc.--and untransformed data from 1985-1986 were again examined using multiple regressions in 1986. The $\ln(x+1)$ transform resulted in more correlations of diatom cell density with biological, chemical, and physical variables than other transforms or untransformed data.

Functional Aspects. As indicated previously, numbers or types of diatoms alone do not provide a complete characterization of the periphyton community. The purpose of this element is to monitor such aspects as chlorophyll a, organic matter accumulation, photosynthesis, and respiration, which represent the functioning of the entire community.

Slides were emplaced in the Ford River for 14 days for determinations of accrual rates and 28 days for determinations of standing crop estimates of chlorophyll a, phaeophytin a, and organic matter biomass. Fluorometric methods were used for analyses of chlorophyll and phaeophytin. Organic matter biomass was determined using changes in ash-free dry weight per unit area.

Annual patterns for chlorophyll a standing crop and accrual were similar. The annual pattern was one of winter lows, with a peak value occurring in July or August. There was considerable year-to-year variability in both standing crop and accrual rates, due to the presence (or absence) of a secondary peak occurring from late March through June and the magnitude of the summer peak. The secondary peak occurs when spring conditions are dry, i.e., low stream flows and relatively warm temperatures. Although there were differences between sites in 1983 and 1984, no significant differences between sites were detected in 1985 and 1986 for standing crop or accrual rates.

Organic matter standing crop and accrual rates showed the same annual pattern as chlorophyll. In 1986 as in the past, there were no significant differences between sites for organic matter standing crop and accrual rates.

In order to estimate community productivity and respiration, light/dark chambers with periphyton-covered substrates were used to determine changes in dissolved oxygen concentrations. There were no significant differences between sites in net production, respiration, and gross production of the community over the period 1984-1986 when using this methodology.

Results of multiple regressions with other variables were the same as for the structural aspects. Multiple regressions for June 1983 to June 1985 data sets gave strong correlations between chlorophyll a and above-water photosynthetically active radiation, water temperature, and stream flow. Stepwise regressions for chlorophyll a and ambient factors in 1986 indicated that water temperature explained 61% of the variance and was followed in importance by conductivity (33%). Water temperature was also the most important factor for organic matter standing crop. Researchers will examine the cumulative effects (e.g., degree days) of these variables in 1987. The use of "before and after, control and impact" analysis techniques is also being examined.

2.10.2 Aquatic Insects

As part of the integrated studies of the aquatic ecosystem, insects are being monitored as representative of the primary and secondary consumer levels in the aquatic food chain. These studies examine the important functional insect groups, such as shredders, collectors, predators, and grazers. Both community and individual aspects of organization are being monitored. The community aspects being monitored are leaf litter processing; insect colonization patterns on leaf litter and artificial substrates; and the frequently used structural descriptors of community change such as species richness, individual abundance, and species diversity. The monitoring of individual aspects emphasizes changes in individual behavior such as alterations in movement patterns and feeding activity.

Feeding Activity of Grazers. The purpose of this element is to monitor the relationship between the producer and primary consumer trophic levels. This is accomplished by examining the periphyton community for effects from insect grazing.

The study approach uses streamside chambers to which are added tiles precolonized with periphyton and grazing insects. The chambers are subdivided so as to allow the introduction of a different number of grazers (0 to 30) per experimental run. After a period of time the tiles are removed and the periphyton are analyzed for chlorophyll *a*, organic matter biomass, and diatom cell counts. Techniques were developed during 1985, and at that time studies were conducted at one site per experimental run. In 1986, experiments were conducted simultaneously at both treatment and control sites.

Preliminary studies performed during 1985 indicated that grazing by the caddisfly, *Glossosoma*, caused species and diversity shifts in the diatom community even though these shifts were not reflected in chlorophyll *a* or organic matter standing crop. In 1986 as in 1985, grazing caused no significant differences between sites for shifts in standing crop of chlorophyll *a* or organic matter. Species counts had not been completed at the time of reporting.

Benthic Insect Community. The purpose of this element is to monitor the major organisms constituting the primary and secondary consumer trophic levels, i.e., benthic insects, for changes in community structure and function.

Riverine substrates contained in sample baskets were emplaced for one-month periods at study sites. Insects were collected from the substrates, identified, and counted. Numbers of individuals, diversity, richness, evenness, and percent numerical dominance for selected species were determined for each replicate. Total sample biomass and the biomass for functional feeding groups were determined. For those insects with high numerical abundance mean dry weight per individual was also computed.

Taxon diversity and evenness have an annual pattern of lower winter values than those measured at other times of the year. During the winter of 1985-86, there were significantly higher values for diversity and evenness indices at the treatment site than at the control site. At other times of the year, there were no statistically significant differences between sites in diversity or evenness. Chironomids are present in high numbers in the Ford River, and their abundance has a marked effect on both diversity and evenness values. The high number of chironomids at the control site relative to the treatment site during the winter months may account for the significant differences between sites during this period.

Taxon richness tends to be lowest in the spring (March-May) and to have two peaks occurring during the June-September period. The timing of the annual pattern is most probably determined by stream flow and temperature conditions. Taxon richness values were not significantly different between sites over the period July-October 1985; were significantly higher at the control site over the period November-April 1986; and were significantly higher at the treatment site over the period May-July 1986. Differences in substrates and stream flows at the sites may be responsible for the statistical pattern observed.

The annual pattern of insect biomass showed both spring (February-April) and summer (July-August) peaks, with troughs over the October-December period. Insect biomass data collected over the period 1983-1986 showed a significant correlation with water temperature and diatom density. Graphical presentations indicate higher insect biomass at the treatment site than at the control site. Collector-gatherer, collector-filterer, and predator biomass had the most influence on total insect biomass. Shredders had less influence on total biomass, and their seasonal pattern was different than that of total biomass.

Leaf Litter Processing. In headwater streams such as exist in the ELF Communications System area, only a portion of the energy supply to the ecosystem is provided by aquatic plants and algae. The maintenance of community structure is largely dependent on the input of organic materials (i.e., leaves) from riparian vegetation. Macroinvertebrate consumers such as shredders process the leaves, making their biomass available to higher trophic levels (predators).

Leaf decomposition and insect colonization patterns using "leaf pack" bioassay techniques are being used to monitor for possible EM effects to this energy pathway. Species diversity, evenness, and richness are used to characterize colonization patterns. Leaf processing rates (mass loss) are used to quantify the feeding activities of the colonizing organisms.

Processing rates of both fresh and dried green leaves were examined by emplacement during both the fall of 1985 and the summer of 1986. Fresh and dried green leaves were processed significantly faster at the treatment site during the fall of 1985. There were no differences between sites in the processing of fresh green leaves during the summer (June-August) of 1986; nor were there differences between sites for the processing rates of fresh and abscised leaves during the fall of 1984. Leaf mass loss differences between sites during the fall of 1985 may have been due to extensive scouring at the treatment site and sand deposition at the control site. An analysis of covariance for the processing rates of fresh and abscised leaves will be presented in the 1987 annual report.

The annual pattern for structural community parameters for organisms colonizing leaf packs consisted of an initial, variable phase (three weeks) followed by a period of general decline. The percent dominance of chironomids generally increased over the period of emplacement of leaf packs. The steady decrease in taxon diversity and evenness during the latter part of emplacement was attributed to the steady increase in numerical dominance by chironomids. During the fall of 1985 and the winter of 1985-86, numbers of individuals peaked at about three weeks emplacement, declined, and then generally increased. There were no significant differences between sites in diversity and evenness after the first week of emplacement during 1985-1986; however,

there were significant differences between sites for taxon richness and numbers of individuals from days 3 through 54.

Functional community parameters for colonizing organisms include total insect biomass (adjusted to leaf biomass), biomass of functional groups, and the mean (dry) weight per individual for representative species within each functional group. The latter showed the most consistent and similar pattern between 1984 and 1985. For the period fall 1985 to early winter 1985-86, total biomass values showed a consistent increase through day 54 of emplacement. In both 1984 and 1985, there was significantly greater insect biomass at the treatment site than at the control site. The mean weight per individual of a collector gatherer and predator were similar in 1984 and 1985; similar values for a representative shredder were not consistent between years.

Insect Movement Patterns. Other riverine studies have used the behavioral drift of aquatic invertebrates as a measure of community response to stressed conditions. In order to monitor for possible effects from the operation of the ELF Communications System, mark and recapture techniques are being used to discern the movement patterns of displaced dragonfly naiads.

Naiads of *Ophiogomphus colubrinus* (dragonfly) traveled downstream for short distances. Their lateral movements were related to flow patterns at each of the sites. The only difference between sites was that the naiads tended to move farther at the control site. This difference was attributed to the higher mean stream velocity at the control site. Recapture success indicates a high probability in detecting possible alterations in the movement pattern of the dragonfly due to the operation of the ELF Communications System.

2.10.3 Fish

An extraordinary ability of some species of fish to perceive EM fields has been reported in the literature. It is believed that fish use this perceptive ability to orient themselves and to detect prey. Fish also represent the tertiary consumers in the aquatic food chain; therefore, the characteristics of the mobile fish community, and the migratory behavior of trout in particular, are being monitored for possible effects from the operation of the ELF Communications System in Michigan. In addition, the parasitic populations

of two "nonmotile" species of fish are being monitored. Changes in the parasitic populations are being used as an indicator of possible stress to the fish.

Mobile Fish Community. Fyke nets and weirs have been deployed across the width of the Ford River drainage at five sites in or near the ELF Communications System. All fish are collected, and both community characteristics and movement through the area are recorded. Community characteristics recorded are species composition, species abundance, and biomass.

In 1986 as in the past, the number of species collected was higher at the downstream control site than at the treatment site. In 1986, 16 species were collected at the control site versus 13 at the treatment site. The difference between sites in the number of species is attributed to the presence of a few rarely found species at the control site that are not found at the treatment site. The control site is also located closer to a warm water marsh than the treatment site.

The fish community at both sites is dominated by five species. During 1986, common shiners and creek chubs made up 55% and 45% of the catch at control and treatment sites, respectively. These percentages were consistent from year to year. The other common species are the burbot, brook trout, and white sucker. Percent catch by biomass showed the same five species as most abundant; however, brook trout and burbot were the dominant species. Percent catch by biomass was more variable than percent catch by numbers. From 1983 through 1986, there were no significant differences between sites in the diversity of the mobile fish community, and the diversity at each site was generally similar.

Although the recapture frequency (about 20%) was similar, the movement of fish through the ELF Communications System area was lower in 1986 than in previous years. Site-to-site movements declined for common shiners and creek chubs in 1986, but increased for white suckers and burbot. Differences in fish movement were attributed to a significantly lower flow rate for the Ford River in 1986 than during 1984 and 1985.

In order to assess for possible direct effects of the ELF Communications System on the mobile fish community, analyses were initiated in 1986 to examine the growth and condition of captured fish. The common shiner, creek

chub, white sucker, and brook trout were selected as indicator species for the community. For 1983, the analyses showed better than average growth for common shiners, creek chubs, and brook trout, and lower than average growth for white suckers. Analysis of 1984-1986 growth data is continuing. Statistical analysis of fish condition has been initiated and will be reported, along with 1984-1986 growth data, in the 1987 annual report.

Brook Trout Movement. Magnetic cues have been shown to be used by fish in their migratory movements. In a thermally unstable stream such as the Ford River, it is particularly important to determine any possible disorientation of fish in their search for an optimal temperature regime.

The general pattern of trout migration has been an upstream movement in the spring to early summer, with a varied intensity and timing of peak movement from year to year. In 1984, the peak catch occurred during the first week of June (15.8 trout/day); in 1985, the peak occurred during the first week of July (11.7 trout/day); and in 1986, the peak occurred during the first week in June (about 6 trout/day). Trout migrate through the ELF Communications System area (control and treatment sites) to the confluence of the Ford River and Two Mile Creek. Virtually all trout migrate up Two Mile Creek; optimal growth temperatures appear to be responsible for the movement of trout up the creek. No downstream movement from Two Mile Creek was found for sampling periods lasting through November in 1984 and September in 1985 and 1986. Factors affecting this pattern appear to be water temperature, stream velocity, and population size.

Due to low catch rates, only 82 trout were tagged in 1986. The recapture frequency for the tagged trout in 1986 was 0%, down from a frequency of about 15% in both 1984 and 1985. Because there were no recaptures in 1986, movement rates could not be determined; however, previous data indicate mean rates of 1.2 to 5.0 km/day for movement of trout through the ELF Communications System area.

Fish Parasites. If stressed, fish may become more susceptible to parasites as their physiological condition deteriorates. The parasitic fauna of two "nonmotile" fish species are being monitored at treatment and control

sites as indicators of possible stress induced by the operation of the ELF Communications System.

Since 1983, a total of 929 mottled sculpins and 1115 longnose dace have been collected from treatment and control sites on the Ford River in Michigan. Fish were preserved in 10% formalin at the time of capture, and later they were necropsied at Michigan State University. At necropsy, fish characteristics were recorded and each fish was examined for both internal and external parasites.

The parasitic fauna infesting fish from treatment and control sites were comparable. The parasitic fauna was composed primarily of larval parasites that mature in fish-eating predators (birds or other fish). The parasitic fauna of the dace consisted of nine species of helminths (worms) and three protozoan species, while the fauna of the sculpin consisted of 11 species of helminths, three protozoan species, and one species of mollusca. Diversity indices for the parasitic fauna of both the sculpin and dace were similar to those reported in the literature for other fish species.

The infestation frequency and prevalence of the parasitic fauna were extremely variable. Because of the variability of the data, age/cohort analyses will be performed for the three most common parasites associated with each fish species.

3. ENGINEERING SUPPORT

Accurate data are needed to evaluate cause/effect relationships between EM exposure and biological/ecological end points. As part of the Ecological Monitoring Program, IITRI assists university investigators by providing annual EM measurements and other EM engineering support. EM engineering support includes such activities as analysis of EM aspects of research protocols; design, fabrication, and installation of special EM exposure equipment; and review of EM aspects of investigator reports in the context of environmental protection or risk.

This section summarizes both the measurement of EM field exposures at study sites and those engineering activities carried out in support of the program during 1986. A more extensive presentation of this information appears elsewhere.¹³

3.1 Transmitter Operations

In order to evaluate the effect of the operation of the ELF Communications System, investigators will need to examine the intensity as well as other characteristics of EM exposure as covariates in their statistical analyses. This section summarizes the operational characteristics, particularly duration, of the transmitting facilities in both Wisconsin and Michigan. EM intensities experienced at study sites are discussed in Section 3.2.

Data on antenna operations have been provided to IITRI by the Navy on a minute-by-minute basis, and included all changes in operational frequency, modulation, power, and phasing for each antennal element. This information has been provided to investigators as graphical and tabular summaries and, when requested, in detailed tabular form.

The Wisconsin Transmitting Facility (WTF) was transmitting for about 60%, 40%, and 91% of the time available during 1984, 1985, and 1986, respectively. The WTF became fully operational during the last quarter of 1985. In 1986, the WTF was not energized 9% of the available time due to scheduled maintenance (four hours per week) and unanticipated repairs. When on, the WTF was operated at full power in both antenna elements during 1986.

The Michigan Transmitting Facility (MTF) was intermittently operated for the first time during 1986. Intermittent operation of the MTF was necessary for testing of electronic hardware and for collection of information for utility interference mitigation and safety. The MTF was operated at low power with each antenna element energized separately. The antenna was energized about 2% of the available time during 1986.

3.2 EM Field Measurements

EM measurements were made at all 69 active Wisconsin and Michigan study sites from August-October 1986. These measurements have been performed annually since 1983 to document major changes and to characterize the temporal variability of the EM exposure. With intermittent operation of the MTF in 1986, additional measurement points were used to characterize the spatial variation across large treatment sites.

The EM measurement protocol at Michigan study sites included 60 Hz characterization (all antenna elements off) as well as 76 Hz values (each antenna element measured separately). The 60 Hz fields at treatment sites changed markedly between 1985 and 1986. Typically, the magnetic flux density increased and the longitudinal (in soil) electric field decreased. These changes are due to coupling of EM fields produced by the power distribution system to the newly constructed antenna. The 76 Hz values measured at the low antenna currents were extrapolated to planned operational currents for comparison to estimated values used in site selection. The extrapolated values were similar to previous estimates.

With the WTF fully operational in 1985, manipulation of the antenna to measure each antenna element separately was not possible. EM measurements are now made with both antenna elements operating and with the intensity of the electrical current out of phase in each element. Therefore, a new measurement protocol was developed and used in 1985 and again in 1986. Generally, 60 Hz fields at treatment sites cannot be accurately measured under operational conditions. Year-to-year variation in 76 Hz EM fields at the Wisconsin study sites has been small, although there were marked changes in the 76 Hz EM field intensity at three study sites due to a redistribution of electrical currents at grounding elements. An intensive study of seasonal changes in the longitudinal electric field is planned for 1987.

3.3 Other Support Activities

Although site selection is complete, site pairs were reexamined for Michigan study sites using EM measurements made during 1986. Except for aquatic biota, all studies met the EM guidelines established in the design of the program (Reference 1, Appendix C). Physical limitations in available site locations for the aquatic studies make it impossible to meet the guidelines in a strict sense. Nevertheless, all studies have an adequate number of electromagnetically acceptable or conditionally acceptable site pairings.

The soil amoeba and slime mold studies both employ culture chambers that isolate the study organisms from the surrounding soil. The culture chambers are buried in the earth at shallow depths. Ambient electrical exposure is provided to the chambers by buried electrodes in conjunction with control and monitoring circuitry. This *in situ* technique allows close monitoring of biotic variables without contamination from other soil organisms.

In 1983, IITRI personnel reviewed the proposed design of the chambers. At that time, the matching of internal to external electric fields and the measurement internal electrical fields were two areas of concern. Subsequently, IITRI helped to design, fabricate, and install chamber and control apparatus. Protocols for the setup and measurement of electric fields were provided to the investigators. Culture chambers for slime mold studies were established and have been in use since 1984. Exposure control was added in 1985. Electrodes were emplaced at the WTF for amoeba studies in 1985 and preliminary biological studies were performed during 1986 (see Section 2.4). Technical support by IITRI for these studies continued during 1986.

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APPENDIX A

ECOLOGICAL MONITORING PROGRAM: LIST OF
PUBLICATIONS/PRESENTATIONS, 1982-1986

Upland Flora (Michigan Technological University)

1. Brooks, R. H.; Cattelino, P. J. Determining fine soil bulk density in rocky soils. (In preparation.)
2. Fuller, L. G.; Reed, D. D. A model of seasonal diameter growth development for four northern hardwood species. (In preparation.)
3. Jones, E. A.; Reed, D. D.; Cattelino, P. J.; Mroz, G. D. Seasonal height growth in young red pine plantations. (In preparation.)
4. Liechty, H. O.; Mroz, G. D. Changes in microclimate after clear cutting a northern hardwood coverytype. (In preparation.)
5. Richter, D. L.; Bruhn, J. N. Shifts in mycorrhizal fungus populations on red pine seedlings following outplanting on clear hardwood sites in Michigan's Upper Peninsula. (In preparation.)
6. Fuller, L. G.; Cattelino, P. J.; Reed, D. D. Correction equations for dendrometer band measurements of five hardwood species. Northern Journal of Applied Forestry. (Submitted for publication.)
7. Mroz, G. D.; Cattelino, P. J.; Becker, C. A. Terminal buds can be a useful indicator of early red pine planting survival. Northern Journal of Applied Forestry. (Submitted for publication.)
8. Jurgensen, M. F.; Larsen, M. J.; Mroz, G. D.; Harvey, A. E. Timber harvesting soil organic matter and site productivity. In: C. T. Smith, ed., Proceedings: Productivity of Northern Forests Following Biomass Harvesting, University of New Hampshire, Durham, New Hampshire, 1987, pp. 43-52.
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10. Fuller, L. G. Modeling northern hardwood diameter growth using weekly climatic factors in northern Michigan. M.S. thesis, School of Forestry and Wood Products, Michigan Technological University, Houghton, Michigan, 1986.
11. Becker, C. A. The effects of plant moisture stress on red pine (*Pinus resinosa*) seedling growth and establishment. M.S. thesis, School of Forestry and Wood Products, Michigan Technological University, Houghton, Michigan, 1986.
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16. Cattelino, P. J.; Mroz, G. D.; Jones, E. A. Soil/climatic factors affecting red pine seedling growth in Northern Michigan. Presented at the American Society of Agronomy annual meeting, Chicago, Illinois, December 1985.
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18. Cattelino, P. J. An overview of the Ecological Monitoring Program: Trees and Herbaceous Plants Study. Presented to Rotary International, Hancock, Michigan, 1984.
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5. Bruhn, J. N.; Bagley, S. T. Actinomycetes associated with red pine mycorrhizae in the field versus nursery stock. Presented at the Third International Congress on Microbial Ecology, East Lansing, Michigan, 1983.

Slime Mold (University of Wisconsin-Parkside)

1. Goodman, E. M.; Greenebaum, B. A field and laboratory study of the effects of weak electromagnetic fields. Presented at the Eighth Annual Meeting of the Bioelectromagnetics Society, Madison, Wisconsin, June 1986.
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1. Hanowski, J. M.; Niemi, G. J. Statistical perspectives and experimental design in bird censusing. (In preparation.)
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APPENDIX B

WILDLIFE SURVEYS AT THE WISCONSIN TRANSMITTING FACILITY,
CLAM LAKE, WISCONSIN

Deer Track Survey

Following a discussion with the Forest Game Research Group of the Wisconsin Department of Natural Resources, a deer track survey was developed in 1982 to measure a trend in the deer population within the influence of the ELF Communications System.

Sixteen two-mile transects were established, four in each quarter of the influence area (see Figure B-1). All transects were located on ground or dirt roads. The transects are to remain unchanged unless road conditions change. Each transect is traversed twice during August: once during the second full week and again during the third full week. The afternoon before censusing, each transect is dragged with equipment that will leave a relatively smooth surface 3 to 4 ft wide in the center or along one side of the road.

Weather conditions should be relatively stable. Temperature variation should not be more than 15°F above or below normal. The census is not conducted when a cold front is near or over the area. Light rain does not affect deer activity.

Usually half the transects are dragged one day and censused the next.

A track that enters the dragged area, follows it for some distance, or crosses immediately is counted as one. A track that follows just outside the dragged area, but does not enter the area, is not counted.

The field work is done by District personnel. Approximately 28 man days are involved in preparation, dragging, censusing the transects, and reporting the data to the Supervisor's Office. Approximately two additional man days are needed in the Supervisor's Office to consolidate the data and prepare reports for the biological survey report to the Navy.

Table B-1 presents deer track data collected since 1982.

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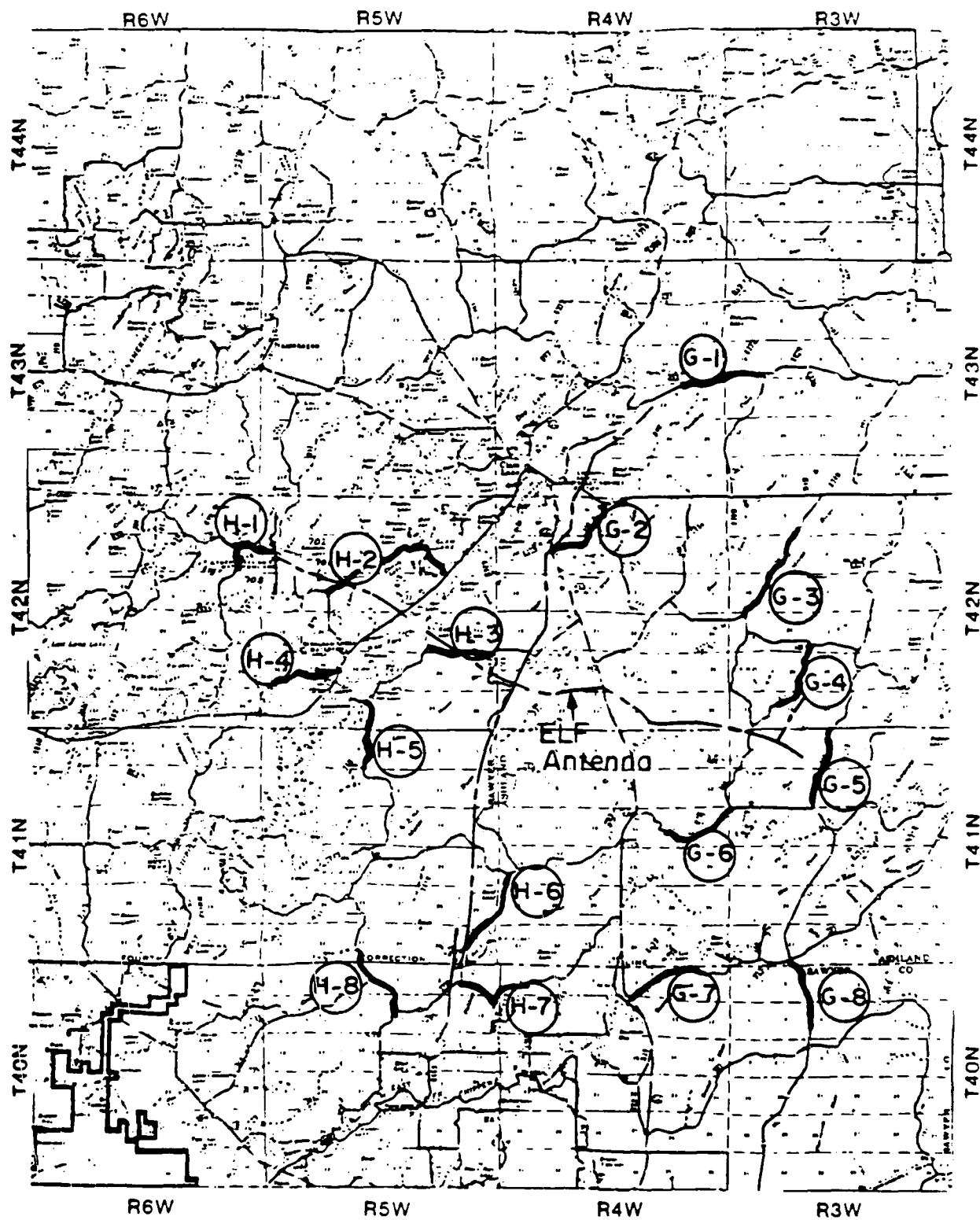


FIGURE B-1. TRANSECTS FOR DEER TRACK SURVEY.

TABLE B-1. DEER TRACK SURVEY

Transect	1982	1983	1984	1985	1986
G-1	11.5	7.5	21.5	7.5	6
G-2	18	17	10.5	23.5	26
G-3	6	6	15	9.5	4
G-4	7	8	13.5	3.5	--
G-5	2	4.5	22.5	7	--
G-6	12	20.5	8.5	11	17
G-7	14.5	35.5	12.5	33	19.5
G-8	18.5	27	7.5	29.5	9.5
H-1	43	33	17	14	19
H-2	29.5	14.5	39	7.5	18.5
H-3	21	15.5	18.5	10	16.5
H-4	18	12.5	6.5	10	8.5
H-5	53.5	30.5	10	39.5	19.5
H-6	5	9.5	17	16	10
H-7	18	10.5	21.5	5	13.5
H-8	<u>17</u>	<u>11.5</u>	<u>28</u>	<u>10.5</u>	<u>15</u>
Average Tracks per Transect	18.4	15.8	16.8	14.8	14.5

-- = transects G-4 and G-5 were rained out on both attempts.

Ruffed Grouse Drumming Transects

The Forest has seven established ruffed grouse drumming transects to follow the population trend of drumming males. All transects are on all-weather Forest roads through typical forested habitat. Four of these transects (see Figure B-2) are within what is considered the influence area of the ELF Communications System. Each transect is 14 mi long, with 15 listening stations 1 mi apart. Each transect is run twice during the period of 20 April to 5 May, if weather conditions permit. The listening period is 4 min. Starting time is 1/2 hr before local official sunrise. The survey is conducted only on calm, clear mornings. The person or persons doing the census work are instructed to reach the first stop well ahead of the starting time. At the proper time, the person stops the vehicle engine (if not done previously), steps from the car (being careful not to slam the door), and listens. During the 4-min listening period, the number of individual birds and drums are recorded. At the end of the listening period, the person immediately drives to the next listening station at approximately 30 mph and repeats the listening and recording procedure. Usually two people go on each census to assist in counting drumming birds. This is the procedure established by the Wisconsin Department of Natural Resources. The data are sent to the Department to be included in their state-wide survey.

All transects are run by District wildlife technicians. Approximately eight man days are required to conduct the survey on the four transects within the ELF Communications System area. One additional man day is required to consolidate the data and prepare the annual report for ELF and any other reports required.

Table B-2 presents the results of the data collected since 1974 when two extra transects were established in the area.

The data collected within the Forest compare quite favorably with state-wide data, identifying a low in the ruffed grouse population cycle about 1975-1976 and again about 1983. Because the Forest data are limited, with only seven transects, there will be a slight variation with the state-wide data.

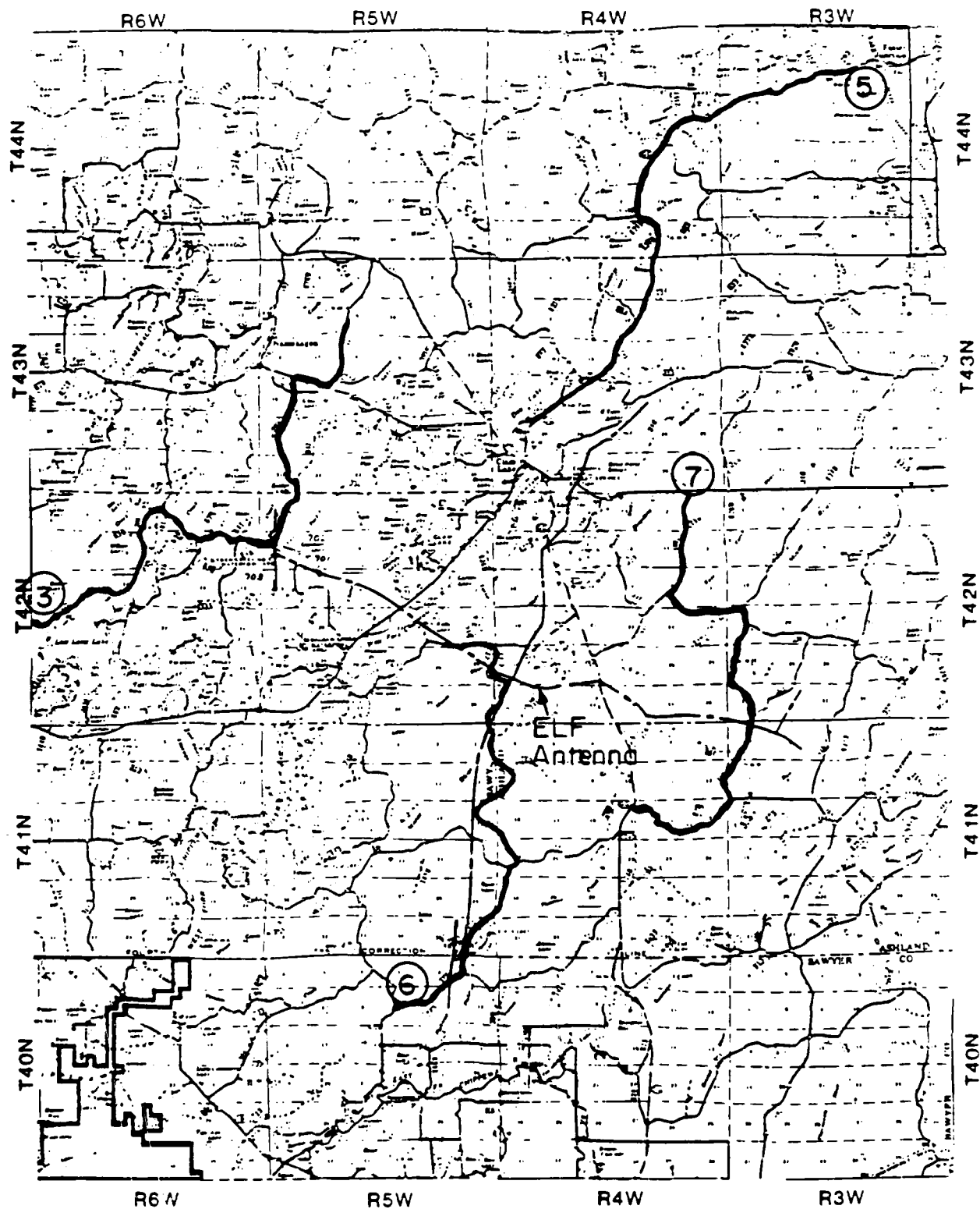


FIGURE B-2. RUFFED GROUSE DRUMMING TRANSECTS.

TABLE B-2. RESULTS OF THE SEVEN RUFFED GROUSE DRUMMING TRANSECTS
ON THE FOREST OVER THE PAST 13 YEARS

Year	1	2	3 ^a	4	5 ^a	6 ^a	7 ^a	Average No. of Birds Heard Per Transect
1974	8	1	7	4	21	5	24	10
1975	4	5	10	4	21	8	14	9.5
1976	4	6	2	2	19	9	14	8
1977	10	7	9	10	23	12	10	11.5
1978	13	12	19	4	24	9	11	13
1979 ^b								
1980	12	8	--	--	37	C	C	19
1981	8	4	16	3	25	C	C	10
1982	6	9	8	0	29	21	13	14
1983	2	9	5	4	16	15	11	9
1984	9	8	14	28	--	24	15	16
1985	8	5	13	3	21	28	17	14
1986	4	8	14	3	28	25	14	14

^aTransects within influence of ELF Communications System.

^bRecords not available.

^cNot financed.

Eagle Nest Survey

The eagle nest survey is done in two parts. The first survey is made in late March or early April to determine nesting activity. Activity is determined by the presence of adult eagles on the nest or near the nest tree. A second survey is done in late May or early June to determine nest production. Both surveys are done from the air at 500 ft or less. The Forest Service hires a pilot and aircraft to fly the early survey. The Forest biologist and a District wildlife technician accompany the pilot as observers for locating nests, determining activity, and searching potential nesting sites. All known nests within the Forest boundary or 1 mi outside the Forest boundary are checked.

The nesting activity data are forwarded to the Wisconsin Department of Natural Resources or to a specified individual who rechecks the nests for production in late May. The Department checks the nests within the Forest for production and provides the results to the Forest. Forest Service regulations prohibit flying less than 500 ft above ground level; the production survey requires flying at less than 500 ft. Consequently, this survey, if done, must be done by someone other than the Forest Service.

The results of the two surveys constitute a part of the biological survey done for the Navy. Approximately four man days are involved in the first survey. An additional three or four man days are spent preparing flight plans, reports to Wisconsin Department of Natural Resources and District personnel, consolidating the data, and preparing the final report to the Navy.

Tables B-3 and B-4 show eagle nest production on the Forest and within 10 miles of the ELF Communications System since 1975.

Comparing the Forest-wide data with the state-wide data, the Forest active nest production is slightly higher most years than the state-wide average. Within the ELF Communications System area, the average young per active nest is very comparable to the state-wide average. It should be noted that the three to five nesting territories within the area are a very small number to average.

TABLE B-3. FOREST-WIDE EAGLE PRODUCTION OVER THE PAST 12 SEASONS

Year	Territories Checked	Active	Failed	Successful	Young	Young per Active Territory	State-Wide Young per Active Territory
1975	16	14	6	8	11	0.8	1.0
1976	16	14	3	11	15	1.1	0.9
1977	16	15	4	11	17	1.5	1.2
1978	17	16	8	8	11	0.7	1.2
1979	17	15	4	11	19	1.7	1.2
1980	20	18	7	11	20	1.8	1.3
1981	22	19	6	13	19	1.5	1.2
1982	23	17	7	10	17	1.7	1.2
1983	21	15	6	9	14	0.9	1.3
1984	22	16	2	14	22	1.6	1.2
1985	25	17	5	12	16	0.9	1.1
1986	27	20	8	12	19	1.0	1.1

TABLE B-4. EAGLE NEST PRODUCTION WITHIN 10 MILES OF ELF SITE

Year	Territories Checked	Active	Failed	Successful	Young	Young per Active Territory	State-Wide Young per Active Territory
1975	3	1	2	1	1	1.0	1.0
1976	3	2	0	2	2	1.0	0.9
1977	3	3	1	2	3	1.0	1.2
1978	3	2	1	1	1	0.5	1.2
1979	3	2	0	2	4	2.0	1.2
1980	3	3	1	2	3	1.0	1.3
1981	4	3	1	2	3	1.0	1.2
1982	5	3	1	2	3	1.0	1.2
1983	5	2	1	1	1	0.5	1.3
1984	5	3	2	1	1	0.3	1.2
1985	6	4	2	2	2	0.5	1.1
1986	6	4	1	3	5	1.2	1.1

APPENDIX C

ECOLOGICAL MONITORING PROGRAM: FY 1986 RESOURCES

ECOLOGICAL MONITORING PROGRAM: FY 1986 RESOURCES

The Navy has been committed to a program of long-term ecological monitoring since the ELF Communications System site selection process was initiated. The Ecological Monitoring Program is identified separately from other environmental protection work for future year budgeting purposes; therefore continuity of the Program is anticipated, presuming continued Congressional approval and funding of the ELF Communications System.

During 1986, studies were conducted under 10 subcontracting agreements between IITRI and study teams from five universities (see Table C-1). IITRI provides engineering support and overall program management. Each study team is headed by a principal investigator with academic training to the doctoral level. Most of the staff also have advanced degrees, with expertise and publications in the areas under study. During 1986 the Ecological Monitoring Program consisted of over 88 people expending a total of 91,230 staff hours.

TABLE C-1. ECOLOGICAL MONITORING PROGRAM: FY 1986

Study	Subcontractor	Principal Investigator(s) and Total Staff (1985)	Professional Staff Hours 1986
Upland Flora	Department of Forestry Michigan Technological University	M. F. Jurgensen, Ph.D. 18 persons	15,958
Soil Microflora	Department of Forestry Michigan Technological University	J. N. Bruhn, Ph.D. 6 persons	3,868
Slime Mold	Biomedical Research Institute University of Wisconsin (Parksides)	E. M. Goodman, Ph.D. 5 persons	3,578
Soil Amoeba	Department of Zoology Michigan State University	R. N. Band, Ph.D. 6 persons	4,840
Soil Arthropods and Earthworms	Department of Zoology Michigan State University	R. J. Snider, Ph.D. R. M. Snider, Ph.D. 9 persons	13,070
Native Bees	Department of Entomology Michigan State University	K. Strickler, Ph.D. M. Scriber, Ph.D. 7 persons	6,808
Small Mammals and Nesting Birds	Department of Zoology Michigan State University	D. L. Beaver, Ph.D. 11 persons	11,370
Bird Species and Communities	Natural Resources Institute University of Minnesota (Duluth)	G. J. Niemi, Ph.D. J. M. Hanowski 6 persons	6,456
Wetland Flora	Department of Botany University of Wisconsin (Milwaukee)	F. Stearns, Ph.D. 6 persons	6,662
Aquatic Biota	Departments of Zoology, Entomology, F sheries and Wildlife Michigan State University	T. M. Burton, Ph.D. R. J. Stout, Ph.D. W. W. Taylor, Ph.D. 11 persons	14,460
Program Integration and Engineering Support	Electromagnetics and Electronics Department IIT Research Institute	J. E. Zapotosky, Ph.D. 3 persons	4,160
TOTAL			91,230

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