

Technical Report E06549-18
Contract No. N00039-84-C-0070

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IITRI

AD-A160 793

EXTREMELY LOW FREQUENCY (ELF) COMMUNICATIONS SYSTEM
ECOLOGICAL MONITORING PROGRAM:
SUMMARY OF 1984 PROGRESS

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July 1985

Prepared for:

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

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SECURITY CLASSIFICATION OF THIS PAGE

AD-A160 793

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified			1b. RESTRICTIVE MARKINGS			
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION/AVAILABILITY OF REPORT Distribution unlimited			
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE						
4. PERFORMING ORGANIZATION REPORT NUMBER(S) E06549-18			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			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			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 1984 Progress						
12. PERSONAL AUTHOR(S) J. E. Zapotosky						
13a. TYPE OF REPORT Technical		13b. TIME COVERED FROM 01/01/84 TO 12/31/84		14. DATE OF REPORT (Year, Month, Day) 1985 July		15. PAGE COUNT 72
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, and Environmental Studies, ELF Ecological Monitoring Program			
19. ABSTRACT (Continue on reverse if necessary and identify by block number)						
<p>A long-term 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; studies were initiated in late summer of that year. Currently, 16 general types of organisms from three major ecosystems in the ELF Communications System area are being examined. During 1984, the Program continued and extended those major activities initiated in 1983, consisting of site selection, the characterization of critical study aspects, and, to a lesser degree, the validation of assumptions made in original proposals. Progress is summarized for the 11 projects that comprise the Program as well as for the support activities of IIT Research Institute.</p>						
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS				21. ABSTRACT SECURITY CLASSIFICATION Unclassified		
22a. NAME OF RESPONSIBLE INDIVIDUAL			22b. TELEPHONE (Include Area Code)		22c. OFFICE SYMBOL	

DD FORM 1473, 84 MAR

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FOREWORD

This report documents the activities of the U.S. Navy's Extremely Low Frequency (ELF) Communications System Ecological Monitoring Program during 1984. The purpose of the program is to determine whether electromagnetic fields produced by the system will have adverse effects on biota or their ecological relationships. This work was funded by the Space and Naval Warfare Systems Command under Contract N00039-84-C-0070 to IIT Research Institute (IITRI). IITRI provides engineering support and coordinates the efforts of investigators. All studies are being conducted under subcontract arrangements between IITRI and study teams.

The information presented in this report is based, in large part, on detailed reports submitted annually by the subcontractors, but also includes IITRI support activities and the results of wildlife surveys performed by the U.S. Forest Service. The latter, although not an integral part of the program, is generally applicable to the program's objectives. Survey information is presented without essential editorial change as an appendix to each report.

Respectfully submitted,
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**EXTREMELY LOW FREQUENCY (ELF) COMMUNICATIONS SYSTEM
ECOLOGICAL MONITORING PROGRAM: SUMMARY OF 1984 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 DESCRIPTION OF ELF COMMUNICATIONS SYSTEM

The transmitter segments of the ELF Communications System broadcast messages using ELF EM fields; these fields are the operational components to be monitored by the Ecological Monitoring Program. The completed transmitter will consist of two facilities, one located in the Chequamegon National Forest near Clam Lake, Wisconsin, and a second located in the Escanaba River and Copper Country State Forests in Michigan (see Figure 1). The transmitter consists mainly of long overhead antenna wires with buried grounded portions at each end; all are located in cleared rights-of-way (ROWs).

1.3 EARLY ELF EVALUATION

Research on possible EM effects to biota from the operation of an ELF Communications System began in 1969 (see Figure 2). 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 examined the information produced by these studies as well as biological effects data taken at other extremely low frequencies. Specific research at planned operating conditions of the System, as well as research at other ELF frequencies, showed no acute bioeffects. Those effects reported were small and controversial among peer researchers. The Navy concluded that adverse effects to biota from the operation of the ELF System were unlikely. Nevertheless, the Navy conceptualized a monitoring program that would be conducted in the ELF Communications System area to detect any changes to resident biota caused by system operations.

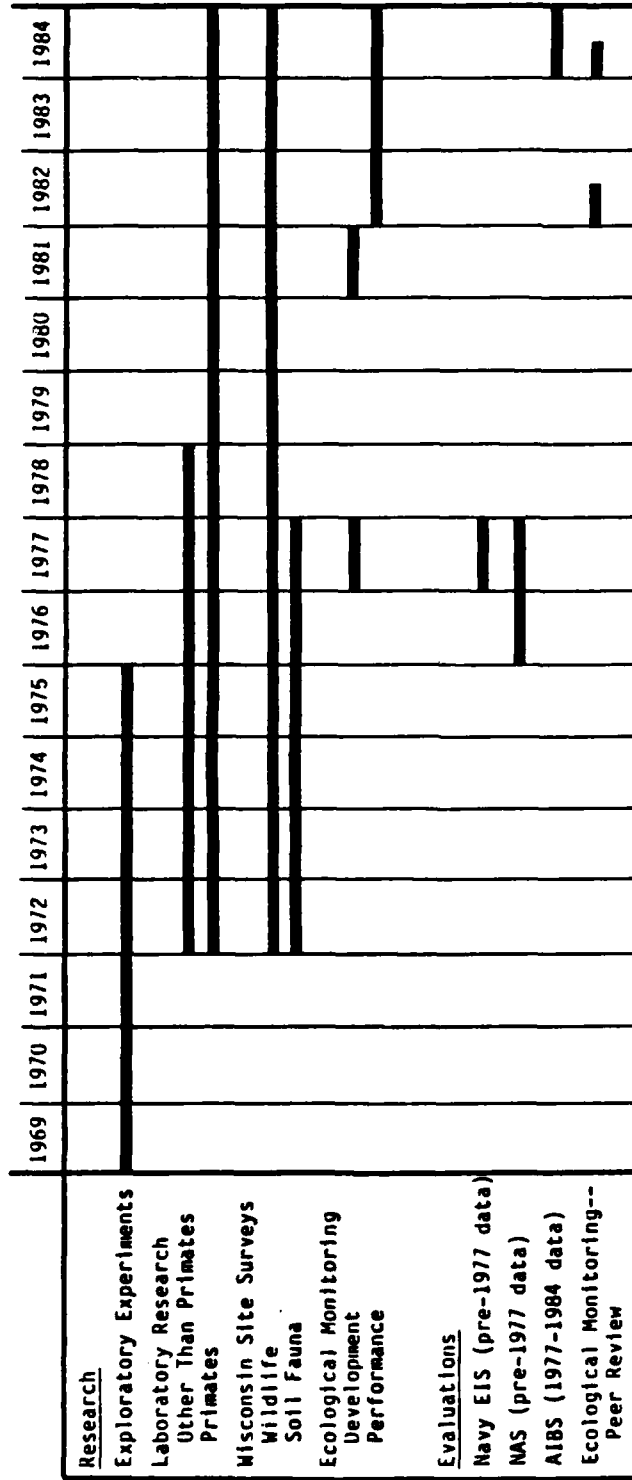


FIGURE 2. EVOLUTION OF THE ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM.

The impact of environmental perturbations such as EM fields can be expressed at one or more levels, ranging from individual (organismal) responses to responses at higher (ecological) levels of organization; i.e., populations, communities, and ecosystems. Although laboratory research is an important approach, it emphasizes select biological attributes of a limited number of species over relatively short periods of time, and it does not simulate all potentially important factors present in the natural environment. Our current state of understanding does not allow an accurate prediction of ecological effects from studies of individual responses.

In its 1977 environmental impact statement, the Navy outlined a plan for conducting an ecological monitoring program at approved ELF Communications System sites. The initial plan was developed from the results of laboratory research, input from state agencies, and recommendations made by the National Academy of Sciences for long-term environmental monitoring. The elements of the plan were subsequently refined from comments submitted by agencies and the public in response to the 1977 environmental impact statement. In 1981 the Navy noted its intention to initiate ecological monitoring at the ELF Communications System sites in Wisconsin and Michigan following the approval of the ELF Communications Program by the President and the Congress.

1.4 MONITORING PROGRAM DESIGN

Both spatial and temporal comparisons of select biological parameters to the operation of the System are being monitored. Spatial comparisons are made by obtaining data relatively close to the overhead wires and grounds (test sites) and at greater distances from these elements (control sites). The test/control site arrangements provide for a simultaneous comparison between sites that are matched except for a marked difference in the intensity of the EM fields produced by the ELF System.

Temporal comparisons of biotic parameters will be made primarily between the preoperational and operational phases of the ELF System. During the preoperational phase, biota receive no EM exposure from the System. When the System achieves full operational capability, ELF EM exposure will be continuous and at full intensity. A transitional period exists between these two phases; during this period, exposures are intermittent (see Figure 3) and

usually at lower EM intensities than anticipated for an operational ELF System.

Multiyear studies are planned so as to adequately evaluate a fully operational ELF System (see Figure 4). The achievement of a fully operational capability at the Wisconsin facility will occur during 1985, and the achievement of a similar capability in Michigan is expected by 1987. Both temporal and spatial comparisons will be made in Michigan. Comparisons planned in Wisconsin are primarily spatial, as the transmitter has been operating there in a transitional mode since 1969.

The Ecological Monitoring Program uses accepted techniques for quantifying and comparing responses of biota to differing levels of EM field intensities. The Program examines both *in situ* organismal and ecological responses.

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

Ecological studies are of fundamental importance because they integrate the responses of many biota. The objective of these studies is to examine group characteristics such as productivity, abundance, and decomposition processes. This approach is the best method for detecting 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 sizeable effect must be manifested in order for researchers to detect it. Efforts have been implemented to reduce parameter variability by the matching of sites and the refinement of data collection techniques.

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 studies, thus

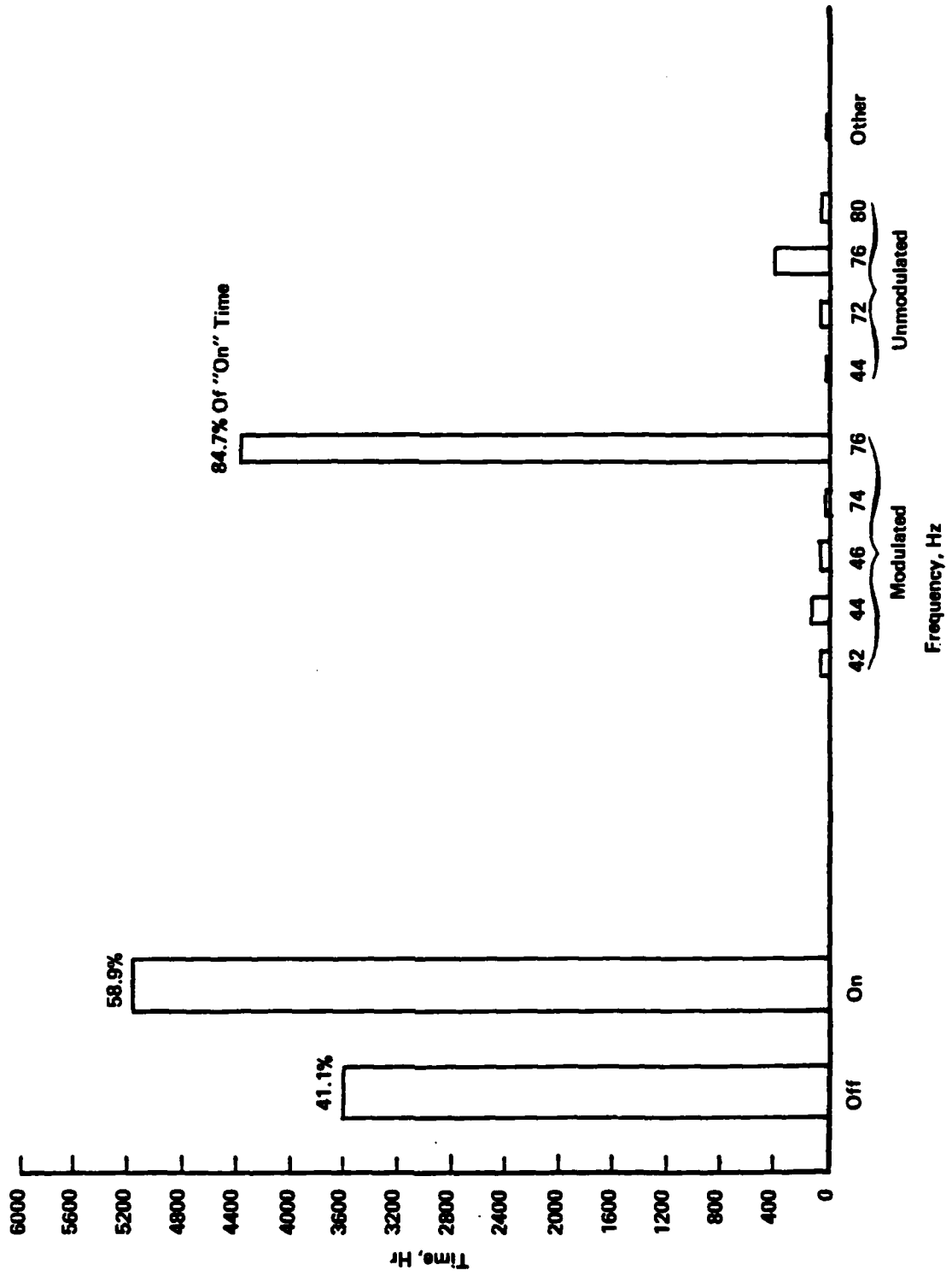


FIGURE 3. WTF OPERATING SUMMARY, 1984; NORTH-SOUTH ANTENNA.

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Michigan Transmitter											
Michigan Studies											
Upland Flora										V	U
Soil Microflora										V	U
Soil Amoebae								V	U		
Soil Arthropods and Earthworms								V	U		
Native Rees								V	U		
Small Mammals and Nesting Birds								V	U		
Aquatic Biota								V	U		
Migrating Birds								V	U		
Bird Species and Communities								V	U		
Wisconsin Transmitter											
Wisconsin Studies											
Slime Mold										V	U
Wetland Flora										V	U
Bird Species and Communities										V	U

V = End of Data Collection
U = Summary Report

FIGURE 4. PROPOSED SCHEDULE FOR THE ECOLOGICAL MONITORING PROGRAM.

enabling the detection of small differences when making comparisons. Except for the slime mold project, every project in the Program couples organismal level studies with monitoring at the population and/or community levels.

Thus, the Program emphasizes ecological studies but also includes investigation for possible *in situ* organismal effects. A long-term period of performance and monitoring of environmental factors pertinent to study parameters is planned, as are appropriate statistical analyses; these should make both approaches as sensitive as practical. Estimates of parameter variability and the number of independent measures necessary for specific levels of detection, precision, and power are being made during the preliminary phases of each project.

1.5 PROGRAM REPORTS

This report is one of a series that documents activities of the Ecological Monitoring Program. Two previous summary reports^{1,2} record the yearly progress of the program since its initiation in 1982. Those reports also provide detailed information on the background, development, and overall design of the program. IITRI has compiled reports on both the biological/ecological information submitted annually by subcontractors^{3,4} and its own engineering support activities.^{5,6} All reports are submitted to the National Technical Information Service for publication.

1.6 PROGRAM RESOURCES

The Navy has been committed to a program for 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, and Program continuity is therefore anticipated, presuming continuing Congressional approval and funding of the ELF System.

Studies are being conducted under 11 subcontracting agreements between IITRI and study teams from six institutions (see Table 1). IITRI provides engineering support and coordinates the efforts of investigators. 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

TABLE 1. ECOLOGICAL MONITORING PROGRAM: GFY 1984 AND 1985 RESOURCES

Study	Subcontractor	Principal Investigator(s) and Total Staff (1984)	Professional Staff Hours	
			1984	1985
Upland Flora	Department of Forestry Michigan Technological University	M. F. Jurgensen, Ph.D. 18 persons	12,692	13,416
Soil Microflora	Department of Forestry Michigan Technological University	J. N. Bruhn, Ph.D. 6 persons	3,337	3,337
Slime Mold	Biomedical Research Institute University of Wisconsin (Parkside)	E. M. Goodman, Ph.D. 5 persons	3,578	3,618
Soil Amoebae	Department of Zoology Michigan State University	R. N. Band, Ph.D. 7 persons	4,480	4,480
Soil Arthropods and Earthworms	Department of Zoology Michigan State University	R. J. Snider, Ph.D. R. M. Snider, Ph.D. 9 persons	12,470	12,350
Native Bees	Department of Entomology Michigan State University	R. L. Fischer, Ph.D. 9 persons	6,580	6,700
Small Mammals and Nesting Birds	Department of Zoology Michigan State University	D. L. Beaver, Ph.D. 10 persons	9,781	9,238
Migrating Birds	Illinois State Natural History Survey	R. P. Larkin, Ph.D. 7 persons	4,152	4,152
Wetland Flora	Department of Botany University of Wisconsin (Milwaukee)	F. Stearns, Ph.D. 7 persons	4,331	4,908
Aquatic Biota	Departments of Zoology, Entomology, Fisheries and Wildlife Michigan State University	T. M. Burton, Ph.D. R. J. Stout, Ph.D. W. W. Taylor, Ph.D. 13 persons	14,606	14,518
Bird Species and Communities	Department of Biology University of Minnesota (Duluth)	G. J. Niemi, Ph.D. J. M. Hanowski 4 persons	1,348	1,348
Program Integration and Engineering Support	Electromagnetics Department IIT Research Institute	J. E. Zapotosky, Ph.D. 3 persons	4,160	4,160
TOTAL			81,515	82,225

publications and expertise in areas under study by the Program. During 1984 the ELF Ecological Monitoring Program consisted of over 95 people expending a total of 81,515 staff hours. The level of effort for 1985 is anticipated to be similar to that expended during 1984.

2. PROGRAM DEVELOPMENT

The following paragraphs document significant processes and events that have affected the development of the Ecological Monitoring Program since its initiation in 1982.

2.1 1982 PROGRESS

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 derived, in large part, from the results of previous research, input from state agencies, and recommendations of the National Academy of Sciences. This design information was provided as guidance to prospective bidders (see Appendix C, reference 1). In addition, bidders were encouraged to submit proposals for study alternatives which might be preferable to those outlined for investigating biological or ecological parameters in ELF EM environments. Bidders were also encouraged to integrate studies into logical sets in order to enhance the scope of their proposed research. Eight studies were funded through a peer-reviewed, competitive bidding process in mid-1982, and were initiated at Wisconsin and Michigan ELF Communications System sites in late summer. Preliminary work began in 1982 for studies of upland flora (trees and herbaceous plants), soil microflora, soil amoebae, soil arthropods and earthworms, native bees, small mammals and nesting birds, aquatic biota (algae, aquatic insects, and fish), and slime mold. Several unsolicited proposals for additional studies were received during the latter part of 1982. After evaluation, studies of wetland flora and migrating birds were also funded. These two studies, plus the eight studies previously selected, constituted the Ecological Monitoring Program during 1983.

2.2 1983 PROGRESS

Major activities of all studies during 1983 consisted of:

- selection of study sites
- collection of information to validate assumptions made in proposals
- identification and characterization of critical aspects of each study.

Study sites were selected so as to minimize intersite variability of the biological and ecological parameters proposed for examination. The matching of sites for physicochemical and biological factors pertinent to study parameters was initially used for selection. Subsequently, IITRI made ELF EM measurements at all potential sites that were identified by investigators before and during the 1983 field season. Investigators were provided the results of these measurements during the last quarter of 1983. Several investigators requested additional site characterizations during 1984 because of logging activities, relocations of antenna or grounding elements, unacceptable EM exposure, or the failure of a site to meet other criteria.

During 1982 and in early 1983 as well, several studies employed temporary sites; this was required because precise corridors and antenna configurations were not defined until late spring and summer of 1983. The information collected at the temporary sites was used to prepare for monitoring at permanent sites.

The other major activities of the Program during 1983 were the collection of information to validate protocols and the characterization and identification of critical study aspects. Specific activities included:

- identification of biota
- assessment of data collection techniques
- quantification of temporal and spatial patterns of parameters; in particular, comparisons between study sites
- assessment of parameter variability
- description of biotic association.

The results of the 1983 season, along with planned project changes, were reported to and 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. IITRI reviews were supplied to the investigators for their consideration in planning 1984 activities and in finalizing their annual reports for 1983. Along with a presentation given at the annual technical workshop, IITRI also used its reviews for assessment purposes. The technical progress of the Program during 1983 was considered generally satisfactory.

2.3 1984 PROGRESS

The studies of migrating birds, initiated during 1983, proposed the examination of possible short-term disorientation as well as long-term impacts. The latter aspects were not initiated in their entirety during 1983. Subsequently, during March 1984, IITRI advertised a solicitation in the Commerce Business Daily for qualifications from sources interested in conducting studies of possible long-term impacts to birds from the operation of the ELF Communications System. A copy of the advertisement was also sent to the addressees of record as potentially interested bidders.

The qualifications of respondees were evaluated, and technical proposals were requested from qualified bidders. 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. The objective of the UMD study is to assess for possible effects to breeding bird species and communities due to the operation of the ELF System. The UMD study complements other bird studies funded during 1984 on nesting, behavior, and short-term disorientation. With the addition of the UMD study, the 1984 Ecological Monitoring Program included 11 subcontracts.

During 1984, the Program continued and extended those major activities initiated in 1983. Peer review of 1984 progress is planned, with particular emphasis on statistical aspects and the matching of study sites. Planned changes in objectives, protocols, and methodologies will also be assessed.

Nearly all permanent study sites have been selected. Only the UMD study should require further site selection and EM characterization effort. Additional EM field measurements are scheduled for the early spring of 1985 so as to provide UMD researchers with an entire field season for baseline data acquisition.

There have been several incidents of vandalism to study sites since the beginning of the Program, and during late October 1984, two study sites used by Michigan Technological University (MTU) were extensively damaged. The vandalism did not have a major effect on the collection of scientific data for 1984, as the field season was nearly ended. However, there will be some loss in the continuity of information between 1984 and 1985. To the extent possible, the sites were restored; however, several study elements cannot be reestablished until the spring of 1985.

Reports of 1983 study results were compiled and distributed during September 1984 to 130 individuals and organizations, including appropriate Wisconsin and Michigan libraries.³ In addition, an overview report² prepared by IITRI was distributed in November 1984.

3. STUDY DEVELOPMENT: 1984 PROGRESS

The following paragraphs summarize the 1984 progress for each of the 11 monitoring studies that constitute the Ecological Monitoring Program. The general types of biota being examined are used as paragraph titles to distinguish among the 11 studies; specific elements of each study are presented as paragraph subtitles.

3.1 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 by microflora comprise the main method of transfer of energy and nutrients to other organisms. Organic matter turnover and distribution is regarded as a major determinant of ecosystem structure. Because the production and decomposition of organic matter have been shown to be measurably affected by anthropogenic factors, these organisms and processes merit monitoring for possible effects from the ELF System.

Upland flora and soil microflora form a natural assemblage. Due to the competitive selection process of proposals, however, they are being examined by separate subcontractors. Both subcontractors are with the Department of Forestry, Michigan Technological University, and share common; study plots and ambient monitoring systems. Soil microflora/decomposition studies are closely tied to litter production and mycorrhizal elements of the upland flora studies. The progress of the upland flora studies is presented in this section; that of the microflora studies is presented in Section 3.2.

The selection of study sites was completed in the spring of 1984. Test sites are located adjacent to the antenna and grounding elements of the planned Michigan transmitting facility, and a control site is located more than 28 miles distant from the nearest antenna element. The antenna and control sites each consist of three overstory tree plots (existing trees) and three plots cleared and planted with red pine seedlings. The ground site

consists of three plots cleared and planted with red pine. No overstory tree plots were established at the ground site, as required buffer strips would have resulted in trees being at too great a distance from the grounding element for meaningful exposures. Soil characteristics, microclimate, site history, and the vegetative community (tree plots) at the study sites were used in matching sites. Generally, the sites are matched as well as is practicable. Differences have been noted and will be addressed in future data analyses.

Tree Productivity. All trees with diameters greater than 10 cm were inventoried at the overstory plots. Tree species, total height, trunk diameter (DBH), and insect/disease damage were recorded. Comparative indexes show a strong similarity between sites. DBH, height, ingrowth (reproduction), and mortality will be monitored in the future to achieve a complete picture of possible System effects on tree and stand production. Measurements and analyses of trunk diameter growth were emphasized during 1984.

In addition to the above, regeneration studies were initiated at all sites using the growth of red pine seedlings. Sites were cleared, and all brush and slash were removed. Twenty-one thousand red pine seedlings were hand-planted immediately following the clearing operation. Three hundred seedlings were permanently marked and will be used for future growth estimates.

Phenological Events. Various phenological events were evaluated during 1984 as indicators for possible ELF effects to the physiological processes of trees and herbaceous plants. Due to parameter variability and technique problems, monitoring of the following events will not be continued in 1985:

- bud burst
- leaf out
- flowering
- seed dissemination
- litter weight.

Studies of the onset and termination of cambial activity at overstudy plots will continue in 1985. A regular schedule of phenological observations will be made on red pine seedlings starting in the spring of 1985.

Permanent quadrants were established at each site during 1984 to monitor four species of herbs. The number of plants actually producing flowers was low, thus limiting the statistical validity of the approach. Vandals later destroyed 38 of the quadrants at the control site. Leaf growth phases of six species of plant will be examined during 1985 for possible use as indicators.

Herbaceous Plants. Herbaceous plants have been found to be a more sensitive short-term indicator than trees to environmental perturbations. Species diversity, coverage, and/or biomass were originally proposed as possible indicators of changes due to ELF fields. During 1983, studies of biomass were extremely variable, making accurate prediction of herbaceous component weights prohibitively expensive. Efforts during 1984 focused on plant coverage and species diversity as possible indicators.

With the selection of a control site, surveys were performed at both the plantation and overstory plots. Thirteen to 14 species were identified, with four to five species common between sites. To further evaluate plant cover and species diversity, 36 plots were established at each site. Frequency of occurrence and coverage will be determined during the 1985 field season.

Mycorrhizal Population and Root Growth. Mycorrhizal fungi form a symbiotic relationship with the roots of higher plants. The fungi utilize organic compounds synthesized by the higher plant to "forage" for minerals and water in the soil. 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. Possible effects of System operation on this symbiotic relationship are being monitored by studies on the fruiting dynamics of ectotrophic mycorrhizal fungi and mycorrhizal root tips.

Population dynamics of sporocarp (fruiting body) production is being monitored on overstory plots as well as red pine plantation plots. Sixty-one species of fungi have been identified, of which 36 occur at both antenna and control plots. In order to determine possible underestimation of short-lived species, the longevity of sporocarps was determined. Three hundred and forty-three specimens representing 33 species were flagged during the fall of 1984 for repeat observation in 1985. Data collected in 1984 suggest that fruiting

of mycorrhizal species takes place in sufficient numbers to permit detection of population disturbances.

Mycorrhizal root tips are being quantified and characterized for red pine seedlings. Balsam fir and paper birch rootlets were previously examined but were found to be unworkable. Data for analysis will be expressed both as average mycorrhizal root tip counts per seedling and as numbers of mycorrhizae per gram of seedling root mass. The numbers and types of fungi responsible for producing the mycorrhizal types are also being investigated. During 1984, 45 randomly selected seedlings from each plantation site were processed for those endpoints just described. Data show that nursery seedlings planted initially carried large numbers of mycorrhizal fungi. Isolates taken from the nursery and subsequently at the plantation indicated that all except three species recurred at both locations. Statistical analyses showed that the only significant difference in total number of mycorrhizal root tips per seedling occurred at the time of planting. Initial differences were not found in later counts.

Litter Production and Foliar Nutrients. Litter fall and decomposition is important in the transfer of nutrients and energy within a vegetative community. Litter is collected from traps during the snow-free period of the year. Leaf litter collected in traps and foliage samples taken from the upper crown of overstory trees are also analyzed for nutrient changes. These study elements can provide an estimate of changes in canopy production and in phenological events such as leaf fall and seed dissemination. Because these physiological processes are sensitive to environmental stresses, they act as a good indicator of possible effects from the operation of the ELF Communications System.

Traps to collect litter are located at overstory tree plots at the control and antenna sites. Litter will not initially be collected on the pine plantation because of the small size of the seedlings. Significant site differences were recorded for the 1985 field season in total leaf litter production as well as periodic litter fall. Differences are thought to be related to differing species composition at each site. Covariate analysis will be used to separate possible ELF effects from inherent site differences. The standard error values are similar to other litter production studies.

Northern red oak was selected for intensive nutrient analyses in 1984. Of the four tree species previously examined, oak was found to be the least variable. Nutrient analyses of oak foliage and litter samples are being conducted.

3.2 SOIL MICROFLORA

Litter decomposition is a complex process involving a variety of organisms engaged in the degradation of complex organic compounds such as cellulose and lignin. The primary agents of organic matter decomposition are the fungi and bacteria. Recognizing the delicate balance of ecosystem functioning, it is apparent that anthropogenic factors that disrupt decomposition processes also disrupt the optimal cycling of nutrients to vegetation.

This study was originally designed to (1) quantify and characterize the major populations of soil fungi and bacteria, and (2) quantify the integrated activities of these microflora by measuring aspects of the decomposition processes such as nitrogen cycling, litter mass loss, and nutrient flux. Most of the fungi isolated in 1983 studies had a dubious role in decomposition or did not degrade complex substances such as cellulose. High variability and the interactions of plastic barriers with electric fields presented several problems in the examination of the nitrogen cycling parameter. During 1984, microflora studies were concentrated on two main areas of monitoring:

- pine litter decomposition and changes in elemental (N, P, K, Ca, Mg, and S) composition during decomposition
- populations of mycorrhiza-associated streptomycetes from red pine roots, soil, and litter.

The originally proposed studies of nitrogen cycling, fungi, and some bacteria have been eliminated due to technical and precision problems.

During 1984, data on three study sites (antenna, ground, and control) were collected for streptomycetes. However, the final selection of a control site was made too late for that site to be included in the 1984 litter decomposition and nutrient flux monitoring. Studies of litter decomposition and nutrient flux were established on the control site in December 1984 and were expanded to include studies of red oak and red maple at all sites.

Litter Decomposition and Nutrient Flux. Litter mass loss has been used as a sensitive index of organic matter cycling. It has been shown, however, that both the accuracy and precision of mass loss decline with time beyond one year, while nutrient flux provides continuous meaningful ecological information. Data from the 1984 field season show that patterns of overall mass and nutrient loss between ground and antenna sites were very similar. No significant differences were detected for overall mass loss or for change in nitrogen content. At the antenna site, litter placed in overstory tree plots lost phosphorus, potassium, calcium, and magnesium more slowly than litter placed in plantation plots. Experience gained during the 1984 season indicates that overall mass and nutrient loss by litter can be characterized with precision.

Actinomycetes. Numerous microorganisms are responsible for degrading complex organic molecules in the vicinity of root systems (rhizosphere). Although these organisms are biologically important, their frequency and occurrence have not been well established. Indeed, the ecology of the rhizosphere is only now coming under close scrutiny. Therefore, the methods being used for detection and monitoring are new, and subject to a somewhat longer phase of development than those for other studies.

Red pine roots and associated soil samples were analyzed during the 1984 field season. In order to collect background data on streptomycete numbers and types, washed root, root tip, and soil samples were similarly analyzed from red pine seedlings in place at the Toumey Nursery. Soil samples were collected at the antenna, ground, and control sites before the seedlings were planted. Samples were then collected on a monthly basis through October from each of the plantation sites in order to follow changes in streptomycete levels and types on the seedling roots and in the soil.

Based on the data collected in 1984, no differences between sites were detected for populations of streptomycetes or heterotrophic bacteria. This preliminary result is due to the large, natural variation in bacterial numbers. Although this variability is typical of complex soil systems, more statistically precise data will be required.

Work in 1985 will concentrate only on streptomycetes. Samples will be preheated to eliminate most heterotrophic bacteria prior to plating. Work will also be focused on mycorrhizal fine roots with lesser emphasis on litter. Soil samples will be deleted from the test program and emphasis will be placed on use of the enrichment techniques. In these ways, replicates can be increased, and more work can be accomplished in the area of isolate typing.

3.3 SLIME MOLD

Researchers have previously reported that continuous laboratory exposures of the slime mold, *Physarum polycephalum*, to ELF EM fields can depress its rate of respiration and lengthen the mitotic cycle. They now seek to determine whether similar effects occur when the mold is exposed to the EM fields and environmental conditions present at an ELF Communications System facility.

The project contains both laboratory and field components performed at the University of Wisconsin-Parkside (UW-P), Kenosha, Wisconsin and at the Wisconsin Transmitter Facility (WTF), respectively. The laboratory component simulates EM exposure regimes as produced by the E/F System and provides for assessments of new protocols. The results of 1983 laboratory studies on the effects of intermittent exposure durations were mixed and therefore inconclusive. No field cultures were maintained in an axenic state long enough for the expression of effects previously reported.

Field Studies. Researchers continued the development of methods for the maintenance of axenic *Physarum* cultures and the design of field culture chambers. During 1983, field cultures were not maintained in an axenic state long enough for the expression of those effects previously reported for continuous laboratory exposures. During 1984, with one exception, *Physarum* plasmodia were continuously maintained at four WTF study sites from late May through October. Cultures at one site became contaminated midway through the 1984 study season and had to be restarted. Current protocols are to periodically subsample plasmodia exposed at the WTF and to return the subsamples to UW-P for analysis. At the UW-P laboratory, plasmodia are placed into liquid culture and maintained in an incubator (free of applied electric and magnetic fields) for one week prior to analysis.

The field exposure system currently being used has undergone significant revision from that originally described.¹ Cultures are now maintained in autoclavable, polyethylene growth chambers. The electric field is collected on two buried copper plates and applied to the slime mold through electrodes buried in nutrient agar. One problem confirmed during 1984 was that the electric field intensities in the surrounding soil exceeded those in the culture chamber. Steps will be taken to address this problem prior to the 1985 field season. Those steps are described in Section 4.3 of this report.

Laboratory Studies. The laboratory component of this project provides for the development of new protocols and the assessment of exposure regimes. During 1983 and 1984, project personnel developed methods to perform oxygen analyses on agar cultures. The instrument used in previous experiments for the oxygen analysis of liquid laboratory cultures is incompatible with oxygen measures of cultures maintained on an agar surface in the field. To date, exposed and control plasmodia from the WTF have not shown any statistically significant differences in oxygen consumption. During 1985, researchers will continue the development of protocols to reduce scatter in the data and increase the number of trials.

In view of the close metabolic correlation between oxygen consumption and ATP synthesis, researchers are also examining the feasibility of using ATP as a biological end point. The data obtained to date indicates that this approach is feasible. Further development during 1985 is warranted.

In the laboratory, microplasmodia were exposed to a continuous 76 Hz, modulated, 1.0 G, 1.0 V/M field. During 1984, it was decided to examine the time from inoculation to the third metaphase (M-III) of the cell's mitotic cycle. Although it was thought that inherent differences in the cell's mitotic cycle would be magnified, the scatter in the data was also magnified. There were major outliers in each day's data set. The magnitude of the difference between exposed and control cultures was small or not statistically significant. The time to M-III oxygen consumption showed no difference between exposed and control cultures.

Both the time to M-III and M-II were examined for plasmodia placed in the vicinity of the WTF. The scatter in the M-II data appears to be less than

that encountered in the laboratory. In general, the results were mixed for both cell cycle and respiration.

3.4 SOIL AMOEBAE

Soil amoebae are common soil organisms that play an important role in soil mineralization. Their main ecological role is believed to be as predators on soil bacteria. Studies on related organisms have suggested possible direct effects on characteristics such as orientation, growth, and physiology. Indirect effects by action on other soil components important to amoebae also seem possible. The main objective of the study is to determine possible effects due to operation of the ELF System on:

- species and strain diversity
- physiological changes
- population size and activity
- growth and feeding.

During 1984, a major effort was to select and compare study sites for physicochemical and biological similarity. Another major accomplishment was the characterization of the population size and activity of soil amoebae for the field season. Continued progress was reported on preliminary studies of species and strain diversity, growth and feeding characteristics, and physiological changes.

Site Selection. The design of this study is based on two test sites (ground and antenna) and a control site. Although two of the needed sites were established in 1983, a permanent ground site was not possible because of design changes at Ground No. 4, and a temporary site was established for preliminary studies. Early in the 1984 season, a site was established at Ground No. 4 that satisfied EM exposure criteria. Subsequently, physicochemical and biological data were collected to determine the similarity of sites for 14 characteristics. Those characteristics included acidity, bulk density, and soil chemistry.

No statistically significant differences between sites were found for acidity, bulk density, or total numbers of amoebae. In addition, 12 other soil parameters were characterized. Statistical comparisons between sites for

these latter characteristics were not performed as there were no statistically significant differences in numbers of amoeba.

Ambient Monitoring. Soil temperature and moisture were continually monitored during 1984 using transducers and electronic data loggers. This 1984 information was used to indicate general trends. In addition, replicate samples were taken for soil moisture (determined as a weight/weight mean percent) at the same time as samples for population estimates. Although fluctuating soil moisture has been demonstrated to be important to amoebae in soil, numbers of vegetative amoebae did not appear to directly correlate with soil moisture. There were no significant differences in soil moisture between sites.

Species and Strain Differences, Physiological Changes. Species composition between sites and between years (1983 and 1984) were the same.

During 1984, researchers continued preliminary studies examining the use of isoenzyme analysis as a possible indicator for physiological changes within soil amoebae. The use of *Naegleria gruberia* for isoenzyme analysis, begun in 1983, was abandoned in favor of *Acanthamoeba polyphaga*. *A. polyphaga* has a very distinctive cyst morphology which makes it easy to retrieve from soil dilution, enrichment plates. If it can be demonstrated that the cyst structure is the same for clones, and that there is overlay between isoenzyme patterns, this should provide sufficient evidence that the investigator is dealing in strains of the same species.

Population Size and Activity. Procedures for estimating protozoan populations in soil have been found to work well. The results of the 1984 season indicate that although the study sites have the same total numbers of amoebae per gram of soil, the numbers of vegetative (growing) amoebae differ between sites.

Growth and Feeding Characteristics. During 1984, preliminary growth rate experiments were performed at the Michigan study sites using *in situ* growth chambers. The results indicate no differences between the growth rates of *Kalavalia balamuthi* at the three study sites. Because these studies did not employ electrical inputs, additional studies with such inputs will be attempted during 1985 at the Wisconsin transmitter facility.

3.5 SOIL AND LITTER ARTHROPODS AND EARTHWORMS

Arthropods and earthworms significantly affect vegetative decomposition. These invertebrates generally shred plant remains and redistribute the remains within the soil habitat. Vegetative remains are subsequently further degraded by the soil microflora (see Section 3.2). For the purposes of detecting possible ELF effects to this system, process-oriented monitoring of organic matter and nutrient cycling is underway, as is the characterization of the litter and soil invertebrate communities.

From 7 May to 15 October 1984, test and control sites were sampled. The resulting faunal material has not been completely identified, so that analyses other than preliminary site comparisons are pending. A number of potential sources of error were quantified. Results, conclusions, and changes follow.

Site Surveys. Site surveys were intensified in 1984. Soil textural profiles were found to be similar, with fine sandy loam predominating at both sites. Macronutrients and pH did not differ significantly. Only extractable phosphorus, as measured by a more sensitive method than in 1983, was significantly higher at the control site.

Vegetation surveys were completed, including a midsummer analysis of ground cover composition. Despite some slight differences, the sites are well matched.

Ambient Monitoring. Automatic logging of soil temperature and moisture was plagued by equipment breakdowns. In view of the importance of these data, the investigators decided to add sensing/recording devices of a different design in 1985, including a backup monitoring system. Sampling was expanded to include soil and litter moisture by weight loss after drying. Litter moisture data promise to be an excellent tool for explaining faunal fluctuations. Environmental monitoring which included precipitation showed that rainfall was essentially synchronous at both sites.

Arthropods. Soil and litter arthropod populations, where identifications are available, were found to be very similar in species composition. Relative abundances of members of major groups often differed between sites, and showed discrepant seasonal density fluctuations. Using mites as an example, a need for greater in-depth analysis of selected groups was shown. This redirection

of effort (from working with all material in semi-detail) will yield a more sensitive data base on the dynamics of selected populations.

Surface-active arthropods at test and control sites were similar in species composition, although some taxa, e.g., carabid beetles, were more diverse at the control site. Pit-trapping and barrier-trapping techniques were further tested. Data showed that barrier-trapping magnified catches over pit-trapping to a degree that varied with taxon (e.g., > 5x for carabids, > 2x for Collembola). Previous estimates of surface-active fauna must therefore be interpreted with caution; barrier-trapping will be used in 1985.

Earthworms. Earthworms were sampled at shorter (two-week) intervals in 1984 than in 1983, while fewer samples were taken per date. With the possible exception of cocoons, a reduced replication of 10 was shown to have little effect on the accuracy of population estimates. The calculation of live worm biomass from preserved specimens was quantified for five species; all regressions were highly significant statistically and differed between species.

Lumbricid associations differed between sites in terms of species composition, although each species at the test site has its ecological equivalent at the control site. Of two litter-dwelling species shared between sites, *Dendrobaena octaedra* is prevalent at the control site, *Lumbricus rubellus* at the test site. One medium-sized soil-dwelling species (*Aporrectodea turgida* at the control site, *A. tuberculata* at the test site) dominates numerically at each site and contributes most of the biomass. Each site also harbors a moderately common deep-living form. As all life stages are being accurately sampled, the potential effects of ELF on lumbricid biology should be reflected in population dynamics that are detectable irrespective of site differences in species composition.

Litter Decomposition. Litter inputs to the forest floor were essentially equal at both sites, as was the response of trees to climatic conditions (gradual abscission in 1983, abrupt and late denudation in 1984). Of all decomposition criteria monitored, standing crop estimates proved the most

variable. In 1985, additional samples will be taken at critical times of the season.

Litterbag studies were expanded to a large-mesh (5 mm) series of bags in addition to a replicate series of 1 mm bags. 1984 data (first year of decomposition studies) indicated a site difference, with control litter retaining more of its initial weight than test litter. Continued (second year) and replicate (second series of 1 mm bags) sampling will be used to validate these results. In the case of arthropods extracted from litterbags, the value of genus- and species-level analyses is questionable because they are expected to be highly site-specific. Researchers have tentatively decided that arthropod densities, also likely to differ between sites, should still be obtained for all major groups present, since they represent a factor potentially affecting decomposition rates.

The trotline technique was proven unsuccessful because of the fragility of maple leaf petioles. Despite the resulting low sample replication, decomposition of unconfined leaves promised to be a good tool for assessing breakdown rates. Two major sources of variation were identified in 1984: the position of leaves with respect to surrounding litter (vertical stratification) and leaf type (sun, shade). A revised experiment (leafpacks) was initiated in November 1984 that accommodates both variables as factors in future analysis of decomposition rates.

3.6 NATIVE BEES

Bees are important pollinators of flowering plants and are therefore important to the continued reproductive cycle of these plants. Magnetically-sensitive structures have been reported in the abdomen of bees, and fluctuations in the strength of the earth's magnetic field have been cited as affecting the communicative behavior of honey bees. This study examines behavioral aspects of native bees, particularly as they relate to the nesting cycle. Theoretically, ELF EM fields might alter the bees' ability to orientate to nesting areas or otherwise change their behavior patterns in nest architecture, pollen collection, or other nesting activities. Native bees are being studied because they have coevolved with resident plants and overwinter in the ELF Communications System area.

Nesting Activities. Nest architecture and bee development are being studied using "trap-nesting" techniques. Some native bees make use of existing holes to construct solitary nests. Researchers set predrilled blocks of wood in propitious places to study occupying bee species. Over 40 species of native (megachilid) bees have been known to occur in the ELF Communications System area, 20 of which have been reported to occur in trap nests. During 1983 and 1984, bees constructed 1,183 nests at study sites. Based on the numbers of individuals and general distribution of species between test and control sites, 1985 efforts will be concentrated on five species.

Plant Relationship. The lives of megachilid bees are intimately associated with the biology of select species of flowering plants. The bee uses the plant for sustenance and nest construction, while the plant utilizes the bee as a means of pollen transfer. A series of study elements, i.e., flowering phenologies, pollen analysis, and nest construction materials, are devoted to describing the bee/plant relationship.

The primary concern in this portion of the study was to ascertain flower phenology of those plants used by bees as a pollen source. A list of plants that bee species of the study area were known to visit was derived from the literature. During 1984, several methods were used to gather quantitative data on the flowering of listed plant species at a test/control site pair. Of the 92 species of potential pollen plants, flower counts were conducted at three- to four-day intervals for 29 to 32% of the species listed. The dates when flowers were first and last observed were recorded for the remaining species.

A picture of pollen usage and deposition by the mothering bee is being determined by light and electron microscopic examination of randomly selected fecal pellets taken from nest cells. Reference slides were prepared from identified plants as they came into bloom. During 1984, over 300 slides of 155 plant species were prepared. Despite the reference collection, some pollen grains taken from fecal pellets could not be identified to species level.

During 1984, preliminary studies were undertaken of the nesting activity of three species of bee in relation to flowering activity. It was shown that the bees are switching their activity patterns as seasonal changes occur in

the flowering of various plant species, and that the same species of bee is using different plant species at the different sites under study. Although the three bee species overlap in nesting activity, nesting activity peaked at different periods.

Once the pollen relationships of the various bee species are delimited, researchers will concentrate on those plant species actually used, and increased sample numbers are planned. Plans for 1985 are to pursue plant phenological data at all four sites and to increase the accuracy of pollen identification.

Overwintering Studies. Completed nests are routinely removed and encapsulated into glass tubes with cloth ends. Nests are checked for nest interlopers, excessive moisture, and vertebrate predation. The encapsulated nests are returned to study sites. During the spring, the encapsulated nests are removed from the overwintering boxes and are split open, and data on nest architecture are recorded. The nests are returned again to await final emergence. With emergence, factors relating to mortality are scored. Preliminary studies concerning the mortality factors for a single species of bee were quantitatively enumerated. Similar studies on those five species selected for continued study are currently under investigation.

3.7 SMALL MAMMALS AND NESTING BIRDS

Population characteristics of small mammals and birds are being examined, as are attributes of individuals. Individual attributes to be monitored include parental and nestling behavior, fecundity, growth and maturation, homing and activity patterns, embryological development, and metabolic physiology. The three main research animal species selected for the study of individual attributes are the tree swallow, the woodland deer mouse, and the black-capped chickadee.

During 1984, researchers continued efforts begun in 1983 toward the collection of preliminary data, evaluation of protocols, and selection of study sites. The 1985 field season should produce preoperational data for the comparison of test and control sites.

Site Selection. Five test sites immediately adjacent to or underneath the antenna have been paired with four control sites of similar habitat. The

clearing of forest areas on the control plots as share right-of-way will be performed during the summer of 1985. The approval of these sites and clearing activities by the Michigan Department of Natural Resources is also anticipated during 1985.

Population Surveys. Census routines were performed during the 1984 field season to monitor species and population size of nesting birds and small mammals. The high temporal variability of population sizes suggests that such censusing will not be able to detect possible operational effects of the ELF Communications System unless the effects are large.

During 1983, bird census transects were established on one test and control site pair. Five censuses were performed during 1984. For the three most abundant species, both plots had similar densities, similar diversity, and equitability. During 1984, researchers at the University of Minnesota were contracted to provide avian population studies. Their protocols provide the necessary sample sizes for detecting small differences in temporal and spatial comparisons. Therefore, bird censusing will not be performed by this subcontractor during 1985.

Plots at test and control sites were established to census small mammals (squirrel-sized or smaller). Monthly censuses were performed in July, August, and September 1984. On both plots, the most abundant small mammal was the deer mouse. The results of the first full year of small mammal trapping have shown high levels of variation within and between plots.

Parental and Nestling Behaviors, Growth and Maturation, and Fecundity. The postnatal growth and development of young reared in nest boxes is also being monitored. Any effects that the operation of the ELF Communications System might exert on the young could be reflected in altered rates of growth and development. Alternatively, any disturbances of parental attentive behavior could be influential, because the rates of growth and development of nestlings are dependent on the extent to which parents provide not only food but warmth.

Fecundity is also an important parameter to study, not only because it is demographically significant, but also because it is influenced by a number of factors that may be affected by EM fields. Fecundity in both swallows and

deermice is being monitored by counting the number of broods or litters produced per year and the number of viable young per brood or litter.

Temporary trips made away from the nest by nestling mammals are significant because the young learn to find food and to orient during these trips. Impairment of such leaving could decrease the probability of survival once weaning has taken place. In birds, nestlings typically remain in the nest until they fledge, and thereafter they do not return to the nest. Researchers are determining the age of fledging in swallows and the age of weaning in deermice. Nestling activities (deermice) and parental attentiveness (mice and swallows) are being determined by the distribution of time spent in and out of the nest. These data are collected using a continuously recording passive identification detector (CRPID) system. Attentiveness data are being collected at the same time as maturation data using the same animals and nests.

During 1984, researchers monitored 157 swallow nests, of which 77 had egg laying activity. In all, higher mean clutch sizes, higher hatching rates, and fledging rates were found in 1984 than in 1983, but landmark events such as eye opening and feather eruption occurred at the same time. Nestling weight was significantly higher in 1984 than in 1983. The difference appears real, as there does not appear to be an observer effect that could explain the difference.

Data could not be obtained in 1983 on postnatal growth and maturation in unrestrained nests of young deermice. Mice would abandon the nest boxes when disturbed by researchers collecting data on the young. During 1984, data were collected on two nesting pairs of adults restrained within a Plexiglas field enclosure. Data on postnatal weights, age at eye opening, and eruption of incisors compared favorably with data in the open literature. The construction of enclosures at test and control sites is nearly complete. Data collection will proceed during 1985.

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 to return to their home range after displacement is being assessed for swallows and deermice in the ELF Communications System area. During 1984, protocols were perfected and preliminary data were collected on homing.

Adult birds were captured on nests brooding young shortly after sunset and driven to a release site 20 to 22 km distant. Ten of 11 birds successfully returned. Two birds displaced 296 km failed to return. Some mortality of the brooding young suggests that displaced adults were either not flying back to the nest at night or not entering the nest boxes upon their return. More data, are needed to determine whether swallows are returning at night and to estimate the sample size required for statistical sufficiency. These data will be collected during 1985.

Homing and telemetry studies of deermice were conducted from August through November 1984. Mark and recapture livetrapping, marking with fluorescent pigments, and radiotelemetry were used to determine the home range of mice near the planned ELF antenna. Mice were captured and displaced from their home range in the early evening. Both livetrapping and telemetry techniques were found to be reliable in determining homing ability. Adult deermice were found to be good homers from displacement distances of 400 to 500 m.

Developmental Studies. Prenatal development stages are especially sensitive to environmental perturbations. At present, there is conflicting evidence of direct EM effects on embryonic or fetal developmental. However, it has been established that brooding temperatures can be extremely important for normal development. Should incubation behavior be disturbed by the operation of the ELF system, developing embryos might experience abnormal reductions in temperature. In combination with preliminary data from 1983, data collected in 1984 establish a baseline from which to assess possible effects of the ELF Communications System on various aspects of the embryology of tree swallows.

A total of 163 embryos were examined during the 1983 and 1984 field seasons. From a Chi-square analysis, the frequency of developmental abnormalities is not significantly different between the two field seasons.

Pooling both embryonic and hatching data for the two field seasons, a frequency of 15.1% abnormalities were observed.

In addition to development, researchers examined the onset and temperature of incubation as well as the phenomenon of "developmental catch-up." The data suggest that parents begin incubation with the production of the second egg out of a clutch of six. They gradually increase the nest temperature over time until a day or so following the production of the last egg. Researchers plan to continue monitoring nest temperatures and to collect additional information concerning the onset of incubation. During the course of 1984 studies, it was found that developmental differences between the first and last egg laid decreased with incubation time. This phenomenon of "developmental catch-up" will be studied further to determine whether it is caused by parental behavior or is an inherent property of developing embryos.

In general, observations to date indicate that the development of the tree swallow appears to proceed much like the development of the domestic chicken, which is a model often used in bioelectromagnetic and avian embryology studies.

Physiological Studies. Deficits in an animal's physiological ability to cope would be expected to decrease the probability of survival to the next reproductive season. Possible synergism between ELF EM fields and cold stress is being assessed by measurements of peak metabolism in birds and mammals. Several hundred measurements of peak metabolism were carried out on laboratory populations of deermice to perfect protocols and familiarize field personnel with the equipment. The collection of baseline data on the peak metabolic rates of deermice is currently in progress.

No metabolic measurements on birds have yet been accomplished. The species of choice for this study is the black-capped chickadee. Researchers have maintained temporary feeding stations and have found these birds to be easy to attract and capture.

3.8 MIGRATING BIRDS

The original purpose of this study was to determine possible short-term disorientation as well as long-term impacts to migrating birds. Long-term impacts were to examine species composition and population abundance using

waterfowl survey, mist netting, and ceilometer (light and radar) techniques. Short-term disorientation was to be examined using radar and radio tracking techniques. Mist netting, radio tracking, and a waterfowl survey were attempted during 1983, but were not satisfactorily accomplished. These latter aspects were opened to rebid during the spring of 1984. Based on the scientific merit of the proposals, a study of populational and community aspects of migrant and resident birds using censusing techniques was selected for the assessment of possible long-term impacts (see Section 3.9).

Radar Tracking. The originally proposed paired-plot design, in which alternative tracks (over the antenna array and adjacent unaffected areas) would be compared, has been replaced with a preoperational/operational comparison only. The selected site is located such that fall-migrating birds cannot approach the radar site without flying over part of the antenna. North and south of the site are broadcast towers for stations WNMU and WLUC. The radar site is also in an area of numerous magnetic anomalies.

For the before-and-after comparison, researchers are gathering data on departure times (onset of nocturnal migration), straightness and consistency of altitude of long bird tracks, and numbers of bird targets passing over the area per unit time. In support of the information, data are being gathered to assess the variability in numbers, altitude, and orientation of bird targets over the site. Winds near the ground are being monitored by a wind vane and anemometer 10 m above the ground. Wind characteristics at height are determined by tracking targets suspended from balloons.

Data collected in the Fall of 1984 showed migrating birds flying along expected southward tracks with fewer nonlinear tracks than in the previous season. The data were collected during 18 nights and included 1,365 individual bird tracks, 95 counts of target density, and 43 wind measurements of balloon radar targets. Wingbeat signatures were collected on most bird targets.

Aside from data collection, work during 1984 emphasized the development of analytical techniques for discriminating birds from other targets and for a geographic information system to correlate pertinent geographic features to bird tracks.

3.9 BIRD SPECIES AND COMMUNITIES

This study tests for possible effects to population and community characteristics of resident and migrating bird species that nest in the ELF Communications System area. The study is in addition to the studies of the biology of a resident species (see Section 3.7) and short-term disorientation of migrating species (see Section 3.8) that are currently underway. A rationale for the study of birds in general was presented in an earlier report.¹

Methods. Data have been collected using census techniques on variable width transects following procedures outlined by Jarvinen and Vaisanen.⁷ The transect method is a proven method for monitoring bird population and for obtaining statistically reliable results. These methods were used recently by the principal investigators to assess the impact of a 500 kV transmission line on bird populations in northern Minnesota.

End Points. In assessing ELF exposures, the investigations are pursuing the following end points:

- species richness (number of species/500 m transect)
- relative density of all species
- relative density of specific species
- relative frequency of specific species (applicable to uncommon species).

Study Sites. The project consists of 20 study transects (five test and five control) in both Wisconsin and Michigan. Each transect consists of eight 500 m segments separated by 50 m (i.e., 4350 m, or 2.7 mi long). Test transects are parallel to and more than 125 m from the edge of the antenna ROW. Control transects are variously oriented and generally at distances greater than 10 km from the antenna.

Statistical Design. Data, such as numbers, species, sex, behavior, and position, are transferred directly from field sheets to computer files. The information is then tabulated using a statistical package (SPSS). Subprograms are used to examine for normality and homogeneity of variances.

A two-way analysis of variance (ANOVA) is planned for comparing exposed and control transects. Initially, the Michigan and Wisconsin study areas will

be considered separately, but the possibility of pooling data between study areas will be examined. Unless substantial differences exist between the two regions, most data suggest that geographic variation of bird communities or nesting biology should be minimal across a few hundred kilometers.

1984 Progress. The 1984 season represented the pilot stage of the investigation, and the objectives for this preliminary phase were to:

- select study transects (randomly)
- establish transects for further EM and biological evaluation
- gather census data
- analyze data.

These activities were required to assess the feasibility of proposed protocols and to determine whether sample sizes were adequate to detect differences between exposed and control areas. All objectives were accomplished.

Due to the timing of the subcontract award (June 1984) and the subsequent establishment of transects, census data were gathered during the migration season. Variance of the data for the migration season is larger (as expected) than that for the breeding season. Therefore, the differences that can be detected between test and control transects is larger than could be detected if variances were small. The researchers plan to reassess sample size requirements based on census data for the 1985 breeding season. It is anticipated that tests will be more powerful as the parameters will be less variable during the breeding season.

The migration data collected did, however, allow a preliminary assessment of the methodology to be used during the breeding season. Census data on the numbers of individual (total) species and individuals of select species were analyzed. With few exceptions, Michigan control and treatment transects were the same for all parameters tested. Tests for the Wisconsin data indicated six significant differences out of 28 comparisons. Although some differences were detected between control and treatment transects, there were no consistent patterns for any of the migration variables considered.

3.10 WETLAND FLORA

The overall goal of this study is to determine whether long-term exposure to ELF EM fields can significantly influence the stability and functioning of peatland ecosystems. End points being examined include decomposition, foliar cations, nitrogen fixation, and select ambient monitoring parameters. Preliminary studies were initiated in 1983 to evaluate the effectiveness of analytical and sampling procedures, determine within-site variability for study parameters, and test the adequacy of sample size in the experimental design. The results indicated large within-site variations in both decomposition and foliar cation parameters. Based on those results, the analytical techniques and sampling regimes were appropriately modified for 1984 efforts.

Study Sites. Three categories of antenna sites were selected based on ELF EM intensity and the requirements for a gradient. In 1983, a series of 11 similar peatland sites were located along an EM gradient at the Wisconsin Transmitting Facility. These peatlands have similar plant species and environmental characteristics.

Because samples are collected many times during the growing season, human disturbance of plant cover is of concern. All plots were relocated 5 to 10 m prior to 1984 sampling. Site disturbance was still of concern upon evaluation in the fall of 1984. A limited boardwalk system will be installed during 1985 to further ameliorate site damage.

Ambient Monitoring. During 1983, researchers collected data on several water quality parameters (temperature, pH, conductivity, and cation concentration). In 1984, redox potential, water color (dissolved organic material), and depth to water table were added. The 1984 data were collected from wells permanently placed in the peat. In addition, three peat cores were collected from each bog during the summer of 1984. The cores have been appropriately stored and will be analyzed during the winter of 1985.

Both within-site variations and variations between sites are present. Water quality data will be used in regression and multivariate analysis along with biological parameters and EM field intensities during early 1985.

Decomposition. The decomposition of plant material, a major process in bog development and change, is accomplished by microorganisms that are potentially susceptible to ELF radiation. During 1983 and 1984, researchers examined the loss of weight of cellulose squares as an index of microbial activity.

The first set of decomposition samples was placed in study sites in August 1983. Samples were retrieved after one, two, and eight months of emplacement, and weight loss was determined. Samples emplaced for a year could not be handled for analysis due to the extent of degradation.

The variability of weight loss in one-month samples was very high. Much of this variability is assignable to an initial weight gain by several samples, probably due to microbial colonization and/or the accumulation of debris. The variability was greatly reduced in two-month samples. The variability increased only slightly after eight months of emplacement.

Data from two-month and eight-month emplacements were analyzed using nested ANOVA. In both analyses, there was a significant difference in variability between bogs, but no significant differences among the ELF EM groups. Comparison of the variability between two- and eight-month samples indicates that placement technique or location within the study site may be an important source of variation. In 1985, cellulose squares will be placed on the peat surface rather than inserted into the peat. In addition, researchers will test the leaves of resident vegetation.

Foliar Cations. The foliar cations calcium, potassium, and magnesium play important roles in plant physiology as active constituents of a number of biochemical reactions. ELF fields may affect the transport of these mineral nutrients across the root cell membrane, or the cation concentrations may otherwise indicate a stressed condition for the examined plant.

Because the utilization of these ions may change, foliage samples from leatherleaf and black spruce were collected for analysis several times during the growing season. In addition, samples from three other species of plants were collected only once from a subset of the 11 study sites to determine within-site variability and the suitability of these other species.

The mean cation concentration for each of the species examined is within the range of values reported in the literature for such species in other bog sites. There are distinct differences in the cation makeup of the five species examined. Calcium proved to be the most variable cation examined; generally, coefficients of variability ranged between 15 and 25 percent. Statistical tests were also performed to determine whether foliar tissue concentrations were correlated with interstitial water chemistry. None of the environmental measures produced high correlation with the foliar cation data.

The leatherleaf and spruce cation data were analyzed using a nested analysis of variance. Although there were several instances of significant differences between bogs, only one instance of significance was due to the treatment (ELF) effects. Because there were no other consistent differences, the researchers concluded that a Type II error occurred for the treatment effect. In addition, a discriminant analysis was performed to evaluate for possible ELF effects using the entire set of ions. Discriminant analysis makes use of a set of characteristics to distinguish between groups. The researchers found no significant effects from ELF fields on foliar nutrients.

Nitrogen Fixation. Nitrogen fixation is an important process in wetlands. The process involves a symbiotic relationship between a bacterium and a flowering plant. The bacterium converts atmospheric nitrogen into ammonia which is then available for uptake by the flowering plant. The roots of alder, a common shrub of wet areas in northern Wisconsin, have such a relationship with the nitrogen fixing bacterium, *Frankia*. The relationship is considered possibly sensitive to ELF exposure effects through membrane permeability and/or cellular reproduction.

In the spring and summer of 1984, tests were performed to determine appropriate inoculation and assay procedures. Alder cuttings and bacteria nodules were collected from one study site. The cuttings were rooted, inoculated with crushed nodules, and grown in a greenhouse. These cuttings will be transplanted onto all study sites in June 1985. Acetylene reduction is the method of choice for estimating nitrogen fixation rates.

Stomatal Resistance. The researchers continued to address major problems with this technique during 1984.

3.11 AQUATIC BIOTA

The energy structure of streams consists of three essential trophic levels:

- primary producers, consisting of periphytic algae, rooted aquatic plants, and riparian vegetation
- primary consumers, such as insects, crustaceans, and other macroinvertebrates
- secondary consumers, such as fish and other higher vertebrates.

In headwater streams such as exist in the ELF Communications System area, only a portion of the energy supply to the ecosystem is supplied by aquatic plants and diatoms. The maintenance of community structure and function is largely dependant on the input of organic materials from riparian vegetation. Macroinvertebrate consumers are in turn largely responsible for the processing of the organic material, making it available to the higher trophic levels (i.e., fish).

The approach of the aquatic biota studies is to examine aspects of each trophic level and to determine pertinent interactions between the levels. Various study elements occupy adjacent stream segments at test and control sites. No major intervening tributary occurs between the study sites.

3.11.1 Periphytic Algae

Both structural (e.g., species diversity and evenness) and functional (e.g., productivity) aspects of the periphyton community are being monitored as indicators of possible stress from the operation of the ELF Communications System. Artificial substrates (glass slides) are being used to establish the periphyton community. During 1983, researchers compared periphyton communities on natural substrates with those establishing themselves on glass slides. The artificial substrates gave a good overall representation of the community and were less variable than other substrates.

Studies to determine appropriate sampling periods were begun in 1982 and were analyzed during 1983 and 1984. Colonization periods of 14 days were needed for production estimates (chlorophyll productivity and organic matter accumulation), while 28-day colonization periods were found to be most

indicative of "mature" natural communities (chlorophyll, organic matter, standing crop, and diatom density, diversity, and evenness).

Chlorophyll productivity between study sites was comparable; however, the chlorophyll content of mature communities showed significant differences between sites and between years. The disposition of the latter awaits comparisons with test results on biomass and cell density. Biomass (production and standing crops) was not significantly different between sites or years (1983-1984). Biomass production will be used in the future when comparing sites for a possible ELF effect. Standing crop will be used primarily in correlation with cell density and community characterization. Statistical analyses of diatom density are similar to biomass standing crops.

Comparing the changes in the periphyton community through the use of diversity and evenness indexes can indicate subtle shifts in community structure unnoticed by other tests, such as chlorophyll, biomass, or density. A one-way analysis of variance, contrasting mean evenness and mean species diversity from June 1983 through June 1984, showed no significant difference between sites. These calculations will continue to be examined as possible indicators.

3.11.2 Aquatic Insects

Aquatic insects are being studied at two different levels of organization. Community level responses include:

- insect colonization of substrates
- structural descriptions of community change
- functional aspects of leaf litter processing.

Possible changes at the organismal level include:

- movement patterns
- feeding activities.

These studies include representatives of the more important invertebrate functional groups, such as shredders (large particle ingestors), collectors (fine particle ingestors), predators, and grazers (scrapping algal feeders). Particular emphasis has been placed on studies of the grazer food chain.

Insect Colonization of Substrates. Researchers are monitoring qualitative and quantitative changes in the benthic invertebrate community at paired study sites to determine optimum colonization periods and temporal colonization patterns of macroinvertebrates on artificial substrates. The information will be used as a data base for complementary elements, such as community dynamics.

Chironomids have been counted and measured for 80% of the samples, and the remaining groups have been separated to the order level. The results will be presented in the next annual report.

Community Characterization. Artificial substrates emplaced for one-month intervals were used to indicate structural and functional aspects of the benthic community. Macroinvertebrates were collected, identified, and counted. Statistical analyses were performed for individuals identified at the family and species levels.

Diversity and evenness indexes of the benthic community were similar at both study sites except during the winter months. Species and family richness values were similar at both sites throughout the year. At least 46 species of macroinvertebrates were found at both sites. Ten species were collected exclusively at the antenna site, whereas 14 species were collected exclusively at the control site.

Biomass was estimated for individuals in each sample, utilizing length-weight ratios. Mean biomass per individual taxon for each sampling period and site was calculated for selected species, as was overall biomass for each sample. Values for mean biomass per individual were computed for insect species that met two or more of the following criteria:

- consistent temporal pattern of abundance at both study sites
- species having high numerical abundance
- species having high biomass dominance
- species needed to represent a functional feeding group.

Researchers selected eight species or genera from different families for long-term monitoring. Mean biomass values will be reported in 1985, as will percent numerical dominance for each functional feeding group.

Leaf Decomposition. Leaf decomposition and invertebrate colonization patterns using "leaf pack" bioassay are being evaluated for use as an indicator of possible ELF Communications System effects. Measures of community structure, such as diversity, evenness, and richness, are also being used to characterize colonization patterns. Initial efforts during 1982 and 1983 were diverted to adapting this technique using two streams in the the planned ELF Communications System area. Autumn dried leaves are most used by researchers in the temperate zone. It was observed, however, that fresh leaves do enter the streams throughout the summer and fall. During 1983, both fresh and autumn leaves were added to both streams. These studies showed that fresh leaves were processed faster and accumulated a more diverse fauna than abscessed leaves. Unfortunately, the two types of leaves were emplaced in the streams at different times.

In 1984, both fresh and abscessed leaves were simultaneously emplaced at test and control sites in the Ford River. Those insects colonizing the leaf packs have not yet been identified. Leaf processing rates over a 54-day period are consistent with data from the 1982-1983 period. Based on the 1982-1983 data, future studies cannot exceed 100 days.

Future work will be done on the previous year's autumn abscessed leaves and the present year's summer leaves. Leaf packs will continue to be emplaced each September. Statistical analyses will include three-way ANOVAS with factors being days (five levels), stations (two levels), and treatments (two levels). The parameters for analysis will include processing coefficients, numbers of individuals, richness, biomass, and numbers of the chironomid, *Brillia flavifrons*.

Movement Patterns. The objective of this element of the study is to determine possible changes in upstream-downstream movements of select aquatic invertebrates. Efforts during 1982 and 1983 were directed toward the selection of appropriate study organisms and the identification of ambient conditions pertinent to their movement patterns.

During 1984, individuals of a dominant dragonfly predator were studied using mark and recapture techniques. Niads of this species either remained at the release site or were found downstream within the current flow line, thus indicating that this species, at least in August, is rather sedentary. In

1985, movement studies on an additional predator will be initiated. The results at both the test and control sites will be compared, using Mann Whitney U Tests for numbers of animals recaptured along the transects of each recapture.

Feeding Activity of Grazer Populations. This element of the study concentrates on assessing the importance of periphyton in the feeding and growth of a common grazer. The overall hypothesis is that production of grazers in general is positively correlated with periphyton production. The results will be used to assess possible indirect effects of EM field exposures on grazers via the periphyton community. The initial emphasis of this element has been on estimating the rate of transfer of periphyton production to macroinvertebrate production.

Efforts during 1984 consisted of descriptive studies of *Stenonema vicarium* feeding and production in areas of natural differing periphyton production in conjunction with laboratory studies. Feeding and production of *S. vicarium* are being monitored in Schwartz Creek and at the Ford River test site. Periphyton biomass, chlorophyll, standing crop, and production (on glass slides as well as natural substrates) are being monitored to ensure differences between the two sites. Although production at the Ford River site was more rapid than at Schwartz Creek, standing crop was similar in both streams.

Laboratory experiments to measure the growth of *S. vicarium* nymphs feeding on either natural periphyton or leaves with no available algae were conducted at Michigan State University. The experiment was conducted in two thermally controlled artificial streams. In three separate tests of the experiment, the mean growth rate on periphyton was greater than on leaves, but this difference was statistically significant only for one test.

3.11.3 Fish

Originally, five fishery elements were proposed for examination. Many of the measured biological end points were highly variable even when using standard netting techniques. At the suggestion of peer reviewers, 1984 studies were refocused on possible behavioral interaction with the anticipated fields produced by the ELF Communications System. The researchers are continuing to collect data on several characteristics of the mobile fish

community (i.e., fish production, population statistics, and community structure), but emphasis has been placed on migratory behavior and other fish movements, particularly those of brook trout. All of these aspects are addressed under the fish migration element of the study. Study of the parasitic fauna of resident fish will continue in its originally proposed form.

Fish Migration and Community Characteristics. Some species of fish have an extraordinary ability to perceive electromagnetic fields, which they use for prey detection and/or as orientation cues. This element of the study seeks to determine whether the EM fields produced by the ELF Communications System will interfere with these normal behaviors.

Fyke nets and a weir have been deployed across the width of the Ford River drainage at five sites in or near the ELF antenna corridor. All moving fish are collected, and both community characteristics and movements through the ELF Communications System area are recorded. Seventeen species from five orders and nine families were collected in 1984 sampling. Several species that were collected in 1983 were not collected in 1984, and four species were added. This was attributed to the change to 1/2 in. bar fyke nets and the susceptibility of those species to the capture gear.

The community catch displayed a strong seasonal trend in both composition and diversity, which was similar at the downstream control and test sites. The direction of this catch was determined to be largely upstream. This movement included both localized and long distance (between sites) movement components which were variable seasonally as to importance.

Brook trout and burbot were chosen to determine movement rates through the ELF corridor. A total of 945 brook trout were marked with site-specific fin clips and/or streamer or disc tags. Brook trout recaptures indicated that the majority of the trout moved upstream through the ELF corridor during June and early July. Individual rates of movement were higher than literature values and strongly directional, with a mean rate of 2.6 km/day during the spring migration. With additional data from future field seasons, the influence of abiotic factors on this movement will be determined, and a sound baseline of migration data will be accumulated to determine the effects of ELF on brook trout movement patterns.

A total of 510 burbot were marked with site-specific fin clips and/or streamer or disc tags. Burbot recaptures were low (n = 33) and were mostly at the marking site. Because of the low recapture rate, the burbot program will be assessed for continued study; the results of that assessment will be reported in the next annual report.

Fish Parasite Fauna. If stressed, fish may die or become more susceptible to parasites and disease as their physiological condition deteriorates. Researchers are monitoring the fish parasite loads of two species of resident fish as indications of possible stress induced by the ELF Communications System.

A total of 397 longnose dace and 368 mottled sculpins were collected from test and control sites on the Ford River. The parasitic faunas of both fish species were taxonomically similar and comparable in species number. Nine parasite species were found to occur only sporadically, while seven species were found to be common. The endoparasitic faunas were composed primarily of larval parasites that mature in fish-eating birds and mammals. Only two species of parasite mature sexually in the host fish.

Due to the nonsignificant differences between host sexes regarding infestation parameters of the common parasite species, data for male and female hosts of the same species were combined for statistical analyses. Trends in seasonal occurrence for the common parasites were not apparent. Except for one species of parasite, the highest densities and mean numbers of parasites were found in the upstream control site, followed by the antenna and downstream control sites.

During 1985 studies, 15 dace and 15 sculpin will be collected monthly from April through December at test and control sites. The prevalence, density, mean numbers, seasonal occurrence, and species diversity of the infesting parasites will be calculated and analyzed statistically.

4. ENGINEERING SUPPORT

In addition to coordinating the research efforts of investigators, IITRI performs EM field analyses and verification measurements and provides technical services and consultation. These efforts are to ensure that credible research results are obtained and found acceptable and factual by peer groups and the public. This section summarizes the measurement of EM field exposures at study sites and also presents special engineering activities carried out in support of the Ecological Monitoring Program. Detailed information on these activities is found elsewhere.^{5,6}

4.1 ELECTROMAGNETIC FIELD MEASUREMENTS

Each investigator has been responsible for selecting candidate study sites that satisfy the biological requirements of his study. During the 1983 field season, IITRI personnel documented the sites initially identified by the investigators and made measurements at selected locations within each site. Calculated ratios of the 1983 EM data⁵ indicated several sites that needed relocation in order to meet the EM exposure criteria. Several other sites were deemed unacceptable by investigators because of nearby logging activities or other factors.

During 1984, the ELF EM fields at 42 new ecological study sites were characterized for the first time, and 30 existing sites were remeasured to study year-to-year variability. A total of 183 measurement sets were taken.⁶ All potential study sites that were identified by investigators during the 1984 field season were visited by IITRI field crews, ELF EM field measurements were made, and the results were documented. The principal investigators for all of the ecological studies were provided with details of the measurement site locations, summaries of the measured electromagnetic fields, and analyses of the EM exposure acceptability of each of their test/control site pairings.

In summary, only one study, that of bird species and communities, which was begun late in the 1984 season, should require further site selection and EM characterization efforts. Figures 5 and 6 illustrate the locations of the

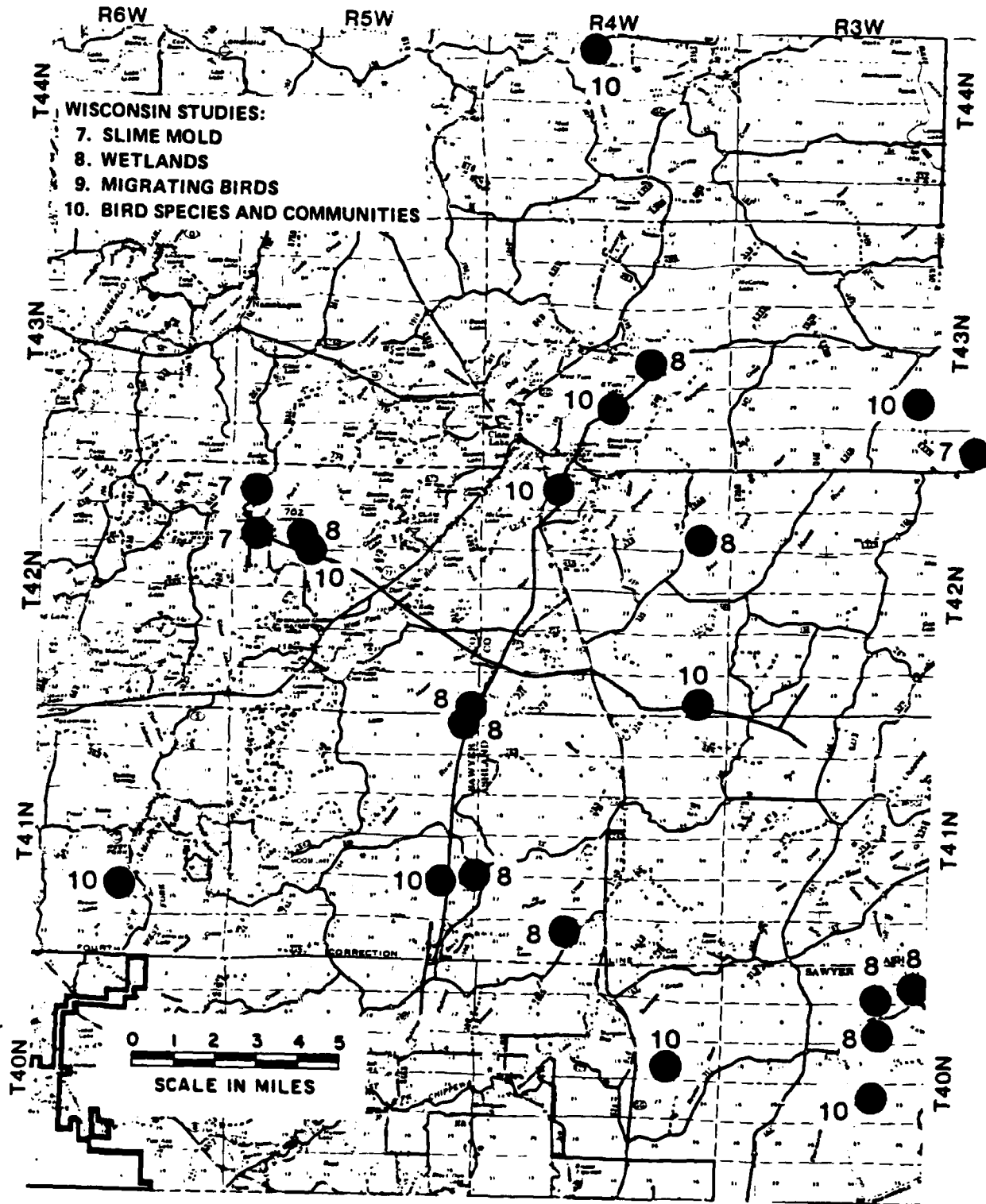


FIGURE 6. FIELD SITES FOR WISCONSIN ECOLOGY STUDIES.

field sites in use at the end of 1984. Additional EM field measurements are scheduled for early spring 1985 so as to provide the study investigators with an entire field season for baseline data acquisition. The annual measurement and verification of ELF EM fields at all permanent sites is scheduled for the third quarter of 1985.

4.2 SUMMARY OF WISCONSIN TRANSMITTER OPERATION

During 1984 as in previous years, the Wisconsin Transmitter Facility (WTF) operated with numerous frequency and modulation conditions in order to accommodate fleet operations, the testing of new hardware, the testing of utility interference mitigation, etc. Wisconsin ecological investigators have requested some type of summary of the modes and hours of operation of the WTF to correlate, if possible, to their studies. To address this need, IITRI personnel have placed the 1984 WTF operating log entries in a computer data base, where they can be manipulated via standard data base or spread sheet software commands. A summary of WTF operation during 1984 was provided to Wisconsin researchers.

4.3 CULTURE CELLS

Soil amoeba and slime mold studies both employ culture cells that isolate the study organisms from the surrounding soil. This *in situ* procedure allows close monitoring of biotic end points without contamination from other soil organisms. Culture cells are buried in the earth at shallow depths, and ambient electrical exposure is provided by similarly buried electrodes. However, electrical exposure in the culture cell is complicated by a mismatch between the conductivities of the culture media and the surrounding soil. It was found that a culture cell directly connected to the earth would have a lower electric field and a higher current density than in the surrounding soil. This difference in conductivity also means that the electric field and current density in any given culture cell cannot be matched to the surrounding soil.

Engineering support was provided for the soil amoeba and slime mold studies to assure proper EM exposure in the culture cells used for the *in situ* portions of these investigations. During 1984, laboratory measurements were

made to determine the conductivity of various soil layers and culture growth media. Field measurements were made to determine earth source voltages, currents, and impedances at study sites. Drive circuitry was then designed and prototyped to control the electric field or current density in culture cells deployed in the field. Test protocols were developed to aid the study investigators in setting up and adjusting the EM exposure control apparatus.⁶

The fabrication and setup of EM exposure control apparatus, along with further engineering support, is planned for the spring of 1985.

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APPENDIX
WILDLIFE SURVEYS AT 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 project.

Sixteen two-mile transects were established, four in each quarter of the influence area (see Figure A-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 A-1 presents deer track data collected since 1982.

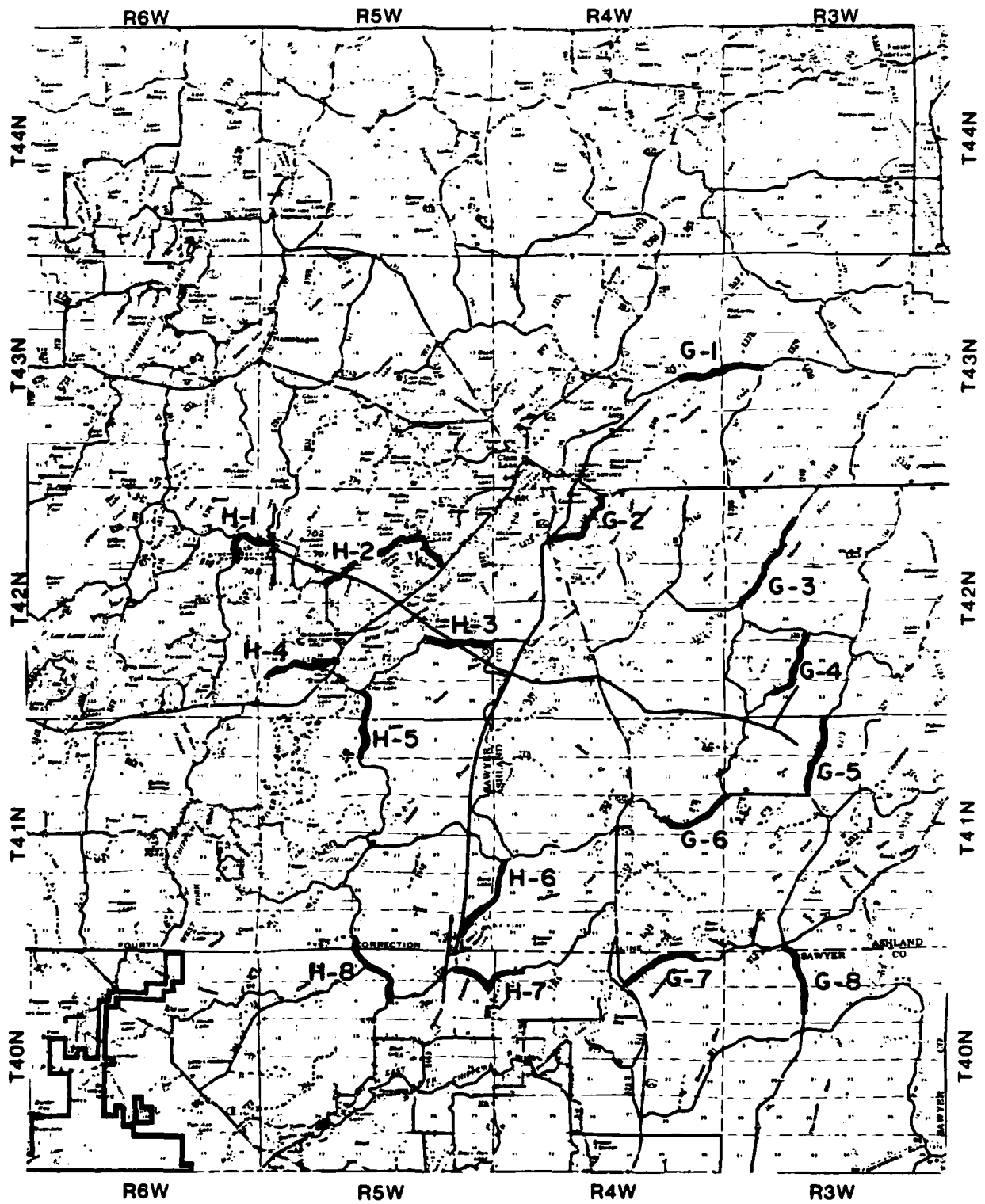


FIGURE A-1. TRANSECTS FOR DEER TRACK SURVEY.

TABLE A-1. DEER TRACK SURVEY

Transect	1982	1983	1984
G-1	11.5	7.5	21.5
G-2	18	17	10.5
G-3	6	6	15.0
G-4	7	8	13.5
G-5	2	4.5	22.5
G-6	12	20.5	8.5
G-7	14.5	35.5	12.5
G-8	18.5	27.0	7.5
H-1	43	33	17
H-2	29.5	14.5	39
H-3	21	15.5	18.5
H-4	18	12.5	6.5
H-5	53.5	30.5	10
H-6	5	9.5	17
H-7	18	10.5	21.5
H-8	17	11.5	28
Average Tracks Per Transect	18.4	15.8	16.8

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 A-2) are within what is considered the influence area of the ELF project. 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 area of the ELF project. An additional one man day is required to consolidate the data and prepare the annual report for ELF and any other reports required.

Table A-2 presents the results of the data collected over the past 11 years when two extra transects were established in the ELF 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.

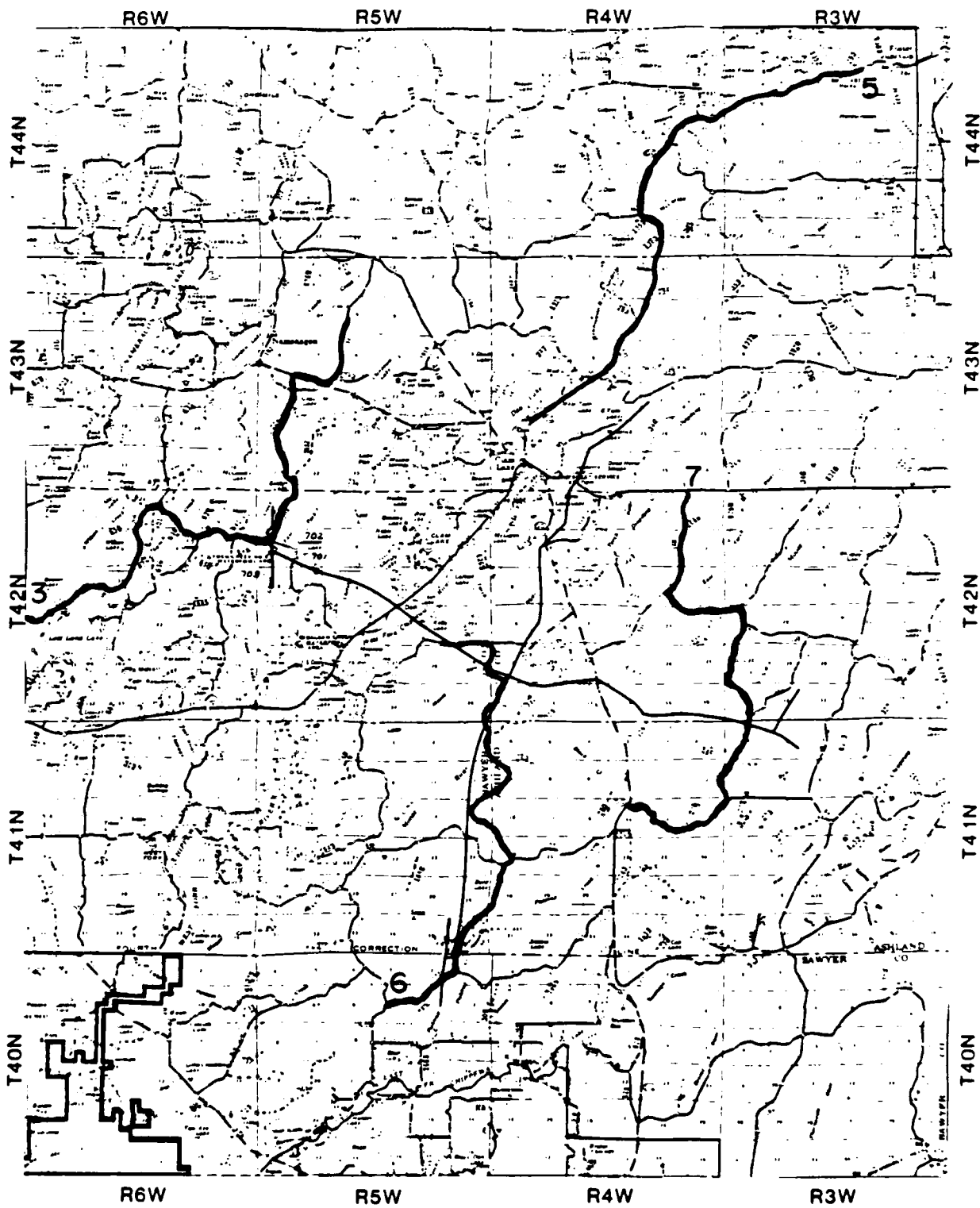


FIGURE A-2. RUFFED GROUSE DRUMMING TRANSECTS.

TABLE A-2. RESULTS OF THE SEVEN RUFFED GROUSE DRUMMING TRANSECTS
ON THE FOREST OVER THE PAST 11 YEARS

Year	1	2	3 ^a	4	5 ^a	6 ^a	7 ^a	Average No. of Birds 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
Average No. of Birds Heard	7.1	7.0	10.3	5.9	23.8	12.8	13.8	

^aTransects within influence of ELF

^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 A-3 and A-4 show eagle nest production on the Forest over the past ten years.

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 influence zone, 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 ELF area are a very small number to average.

TABLE A-3. FOREST-WIDE EAGLE PRODUCTION OVER THE PAST TEN 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

TABLE A-4. EAGLE NEST PRODUCTION WITHIN TEN 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

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