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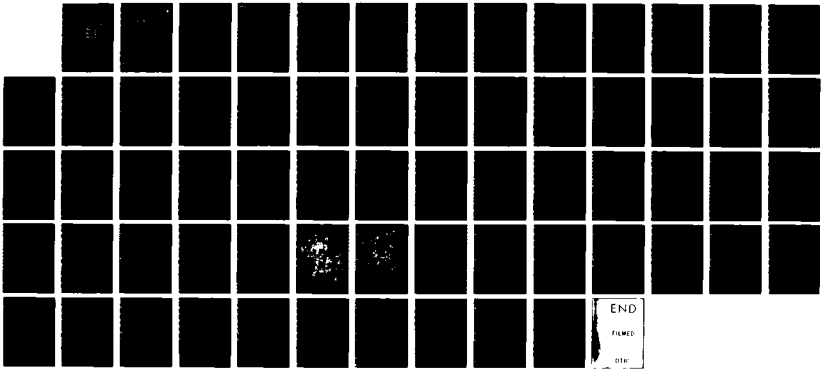

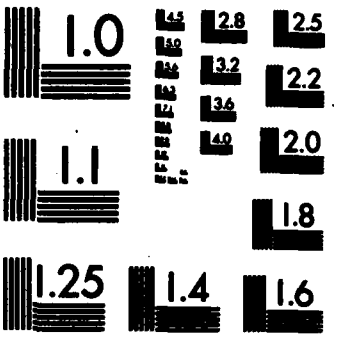

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Technical Report E06549-9
Contract No. N00039-84-C-0070

IITRI

EXTREMELY LOW FREQUENCY (ELF) COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM: SUMMARY OF 1983 PROGRESS

J. E. Zapotosky
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July 1984

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A long-term program for studying possible effects from operation of the Navy's ELF Communication System is being conducted on biota and ecosystems components in northwestern Wisconsin and the Upper Peninsula of Michigan. Sixteen general types of organisms from three major ecosystems in the ELF System area are being examined. Formulation of an ELF Ecological Monitoring Program was completed in early 1982 by the Department of the Navy. Monitoring studies were selected through a peer-reviewed, competitive bidding process in mid-1982 and studies were initiated in the late summer. Major activities of the Program during 1983 consisted of characterization of critical aspects of each study, collection of data to validate assumptions made in proposals, and selection of study sites. Progress is summarized for the 10 projects that comprise the Program.

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FOREWORD

In 1982, the Department of the Navy initiated an Ecological Monitoring Program in both Wisconsin and Michigan as part of the full-scale development of its Extremely Low Frequency (ELF) Communications System. The purpose of the Ecological Monitoring Program is to determine whether electromagnetic (EM) fields produced by the ELF Communications System will have any long-term adverse effects on resident biota or their ecological relationships. This report summarizes the progress and changes made in the program during the 1983 field season. More detailed information on the progress of each monitoring study is presented in a separate compilation of 1983 annual reports.

The Ecological Monitoring Program was authorized under Naval Electronics System Command Contract N00039-81-C-0357, and continues at present under Contract N00039-84-C-0070. IIT Research Institute coordinates and supports the efforts of investigators on 10 subcontracts.

Respectfully submitted,
IIT RESEARCH INSTITUTE

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1. INTRODUCTION

1.1 PROGRAM PURPOSE

The purpose of the Ecological Monitoring Program is to determine whether electromagnetic (EM) fields produced by the Navy's ELF Communications System will have any long-term adverse effects on resident biota or their ecological relationships.

1.2 SCOPE

The Department of the Navy has been interested in using extremely low frequency (ELF) signals for command control communications with submarines since the late 1950s, and an experimental transmitter has operated in northern Wisconsin since 1969.

In October 1981, President Reagan directed the Navy to proceed with a program for completing an operational ELF Communications System. The experimental transmitter in Wisconsin, known as the Wisconsin Test Facility (WTF), is to be upgraded to operational status, and a second transmitter is to be installed on the Upper Peninsula of Michigan. Figure 1 shows the sites of these transmitters.

During the 1970s, the Navy supported research into ELF electromagnetic (EM) effects on biota. Although several research studies were performed at the WTF, most of this research was performed in laboratory settings. The U.S. Forest Service has performed wildlife surveys in the vicinity of the WTF, and these surveys continue at present. Neither Navy-supported research nor other applicable research indicate that exposure to EM fields at the intensities or frequencies produced by the ELF Communications System is likely to adversely affect biota.[1] However, the possibility of bioeffects resulting from operation of the system cannot be fully ruled out.

The Navy conceived plans for an ecological monitoring program in 1977, and following approval of the ELF Communications Program by the President and the Congress in 1981, the Navy noted its intention to implement ecological

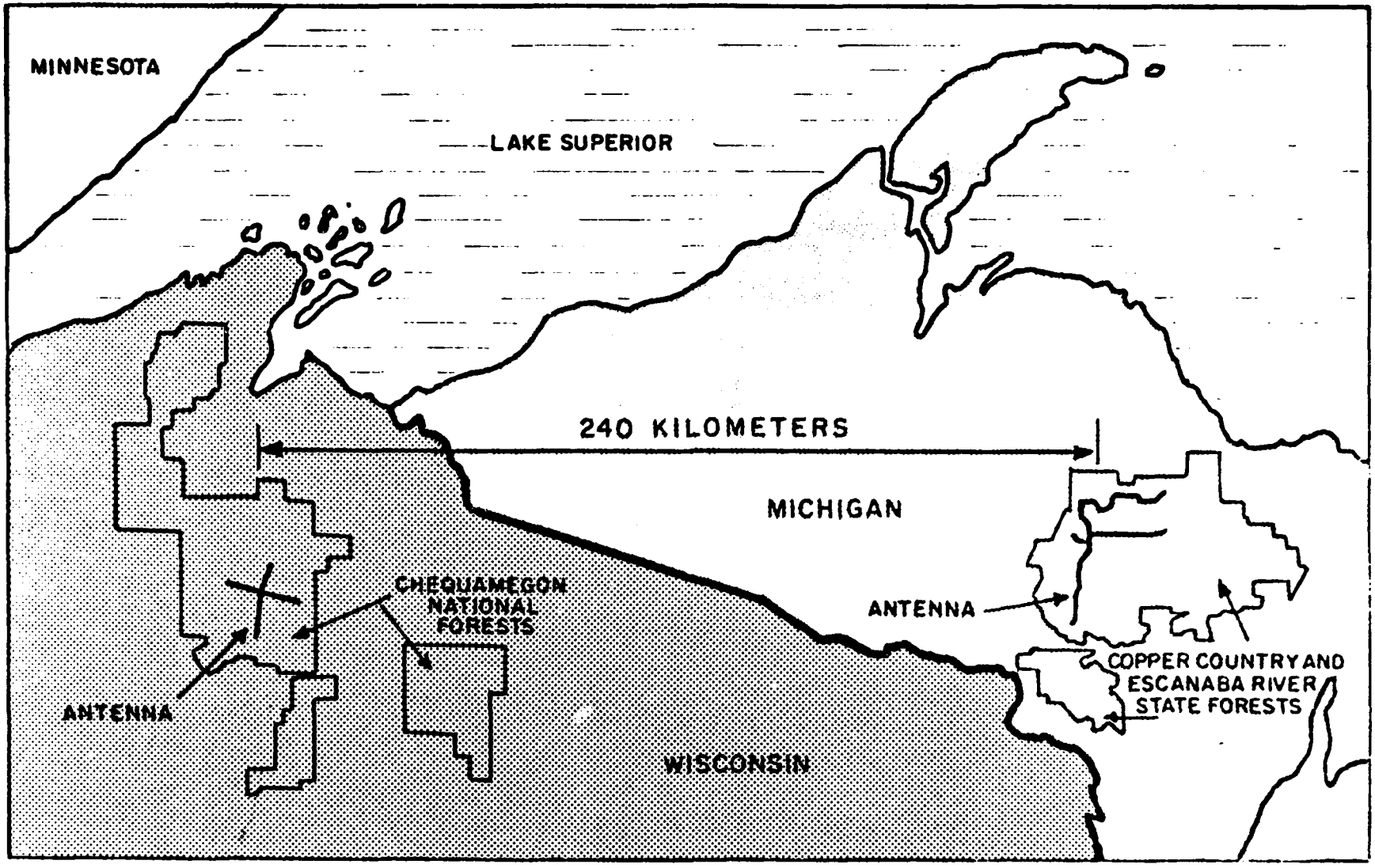

Figure 1. ELF communications facilities in Wisconsin (installed) and Michigan (planned).

monitoring in the ELF system area. The components of the ecological monitoring program were refined from comments submitted by government agencies, the public, and the National Academy of Sciences. Definition and planning of the program was accomplished during 1982.[2,3] Preliminary research activities were initiated in 1982, and were continued for most studies during 1983.[4] Studies of migrating birds and wetland flora were initiated during the spring of 1983.

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2. DEVELOPMENT OF THE PROGRAM

2.1 PERIOD OF PERFORMANCE

All ecosystems are constantly in the process of change; the change may be due to natural events or anthropogenic influences. Separation of natural change from anthropogenically caused change often requires long observation periods, particularly when influences are subtle or if there is a time lag in the response of the ecosystem. ELF effects, if present, are anticipated to be subtle, and several controversial studies suggest a time lag in acquisition of the EM effects they allege will occur. Although various groups have recommended the need for long-term, ecological/biological studies in conjunction with the ELF system, understandably, none have recommended a specific period. Now that ecological studies are ongoing, the Navy has requested a delineation of the period of performance for the monitoring program.

The possibility of confusing a natural change with an ELF-induced change is treated in part by the test/control site arrangement. If a natural change (e.g., yearly rainfall) occurs between the preoperational and operational phases of the program, it should be manifest at both the test and control sites. Statistical methods will be used to analyze the relationship of inter-site differences in parameters to pertinent natural factors. However, the period of performance should be of such a length as to permit adequate determination of the trends, variance of parameters, and the relationship of parameters at test and control sites.

The required period of performance for each study is also related to ELF electromagnetic exposure, which in turn can be conveniently divided into pre-operational, transitional, and operational phases. During the preoperational phase, biota receive no EM exposure from the ELF system. The transitional phase begins with the initiation of system testing; exposures are intermittent, and often at a lower EM intensity than anticipated for an operational system. When the system achieves full operational capability, exposure will be continuous and at full intensity. Studies should be performed to evaluate a fully operational system.

Based on the considerations discussed and the comments received from principal investigators, the following recommendations are made for continuation of the Ecological Monitoring Program (also see Figure 2):

Michigan

The preoperational phase in Michigan will be determined by the construction schedule. Currently, a preoperational phase of three years (i.e., 1983, 1984, 1985) seems probable. An operational phase equal in length to the preoperational phase should satisfy the statistical needs of most studies. Assuming a transitional phase of 9-12 months (1986), monitoring during the operational phase would include 1987, 1988, and 1989 for most studies. Studies of trees require additional time due in part to their longevity.

Wisconsin

Achievement of a fully operational capability during 1986 is probable at the Wisconsin Test Facility. If possible, the field portions of the slime mold study and wetlands studies should be performed here during the fully operational phase of the WTF. At a minimum, both studies should be performed during 1986 and 1987.

General

After the recommended data collection period, an additional year is required for work-up of biological samples and analyses of data. Upon completion, a final report covering the entire period of performance should be submitted to the Navy for its evaluation.

2.2 PROGRAM RESOURCES

The Navy has been publicly committed to a program for long-term ecological monitoring since the ELF Communications System site selection process was initiated. The ELF 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 Communications System.

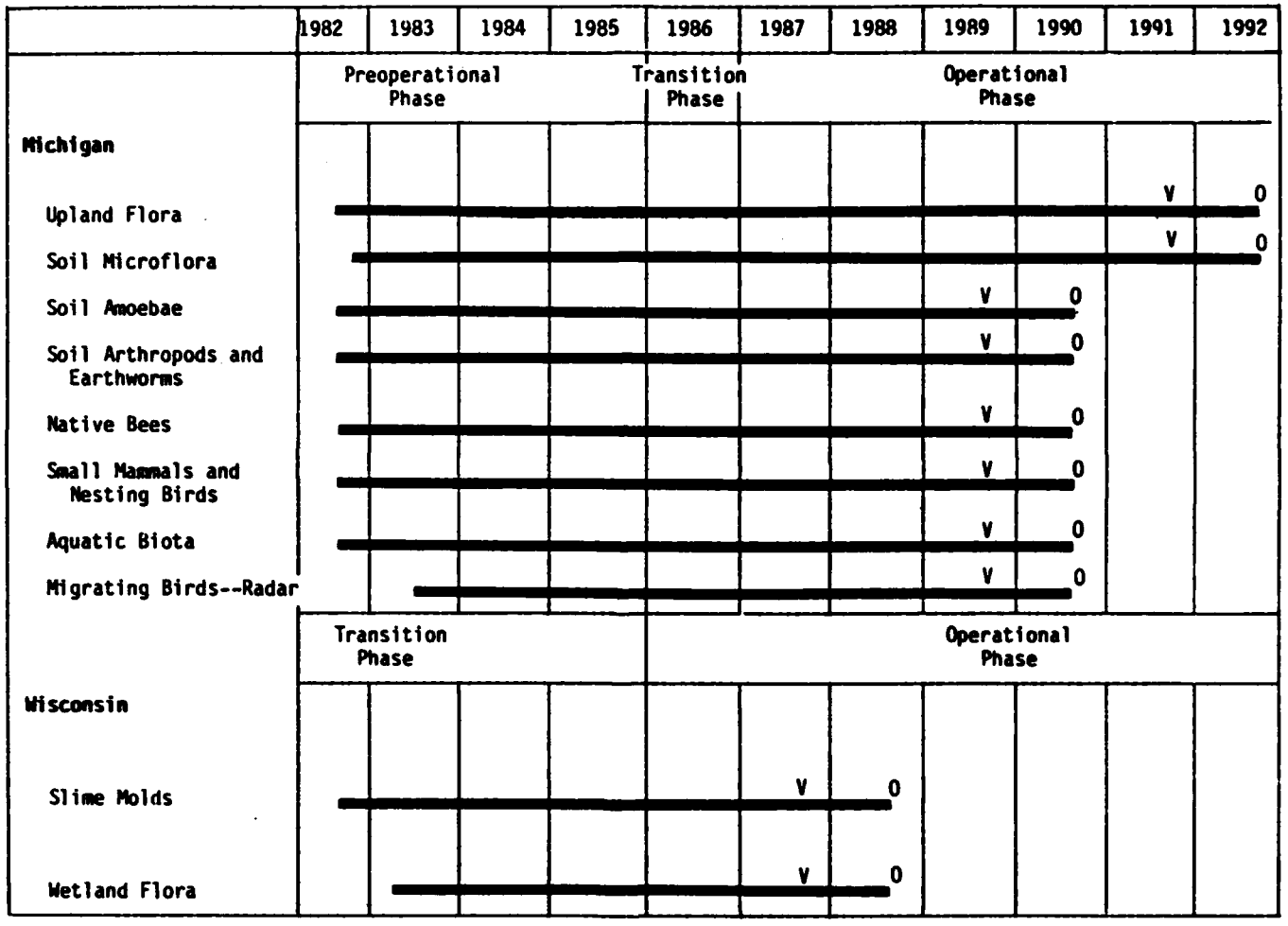

Figure 2. Proposed schedule for ecological monitoring program.

Funds for Department of Defense activities are authorized and appropriated by the Congress on a yearly basis. During 1983, the Navy agreed to subcontracting arrangements by IIT Research Institute (IITRI) that will permit ecology studies renewed in 1984 to be continued for a four-year period without the need for new proposals each year. Presuming successful performance by investigators and continuing Congressional approval of the program, this arrangement will ensure funding continuity.

Resources for the Ecological Monitoring Program for Fiscal Years 1983 and 1984 are listed in Table 1. Resources continued to expand, from about 10 staff years expended in 1982 to 35 staff years in 1983, and 37 staff years are projected for 1984.

Planned GFY 1984 efforts represent a 7 percent increase in staff hours over efforts expended in GFY 1983. Most studies plan small to modest increases (200-900 staff hours) in 1984. The effort for studies of upland flora will increase by about two staff years. This represents a preplanned increase in the level of sampling and analyses that will be maintained throughout the remaining period of performance. Increases in effort in wetland studies are also required. Original estimates were made prior to the first field season, and underestimated the effort required for chemical analyses.

2.3 QUALITY CONTROL

A peer review process specified in 1982 subcontracts was used in 1983 to ensure a high technical standard. Each annual report included in the 1983 compilation[4] has been examined by four reviewers with appropriate expertise. Two reviewers were selected for each report by each principal investigator, and two were selected by IITRI. Reviewers' comments have been considered by the investigators in preparing the final versions of their annual reports. Additional peer review is anticipated through journal publications and investigator presentations at scientific meetings.

A yearly symposium was planned when the ELF Ecological Monitoring Program was initiated, the symposium to be conducted in the fall of each year. The purpose of the symposium was to provide a forum for an exchange of information among the numerous investigators, IITRI, and the Navy. The 1982 symposium in

TABLE 1. GFY 1983 AND RESOURCES - ECOLOGICAL MONITORING PROGRAM

Study	Subcontractor	Principal Investigator(s) and Total Staff (1984)	Professional Staff Hours 1983	Professional Staff Hours 1984
Upland Flora	Department of Forestry Michigan Technological University	M. F. Jurgensen, PhD 18 persons	7,900	12,400
Soil Microflora	Department of Forestry Michigan Technological University	J. N. Bruhn, PhD 6 persons	3,200	3,200
Slime Molds	Biomedical Research Institute University of Wisconsin (Parkside)	E. M. Goodman, PhD 5 persons	3,300	3,500
Soil Amoebae	Department of Zoology Michigan State University	R. N. Band, PhD 7 persons	3,700	4,100
Soil Arthropods and Earthworms	Department of Zoology Michigan State University	R. J. Snider, PhD R. M. Snider, PhD 9 persons	12,600	12,500
Native Bees	Department of Entomology Michigan State University	R. L. Fischer, PhD 9 persons	5,700	6,100
Small Mammals and Nesting Birds	Department of Zoology Michigan State University	D. L. Beaver, PhD 10 persons	9,500	9,800
Migrating Birds	Illinois State Natural History Survey	R. P. Larkin, PhD 7 persons	4,100	4,200
Wetland Flora	Department of Botany University of Wisconsin (Milwaukee)	F. Stearns, PhD 7 persons	2,500	4,400
Aquatic Biota	Department of Zoology Michigan State University	T. M. Burton, PhD R. W. Merritt, PhD R. J. Stout, PhD W. W. Taylor, PhD 10 persons	13,700	14,600
Program Integration and Electromagnetics Engineering	IIT Research Institute	J. E. Zapotosky, PhD 3 persons	5,700	2,400
		Total	**71,900**	**77,200**

Wisconsin showed that the fall of the year was inappropriate, as there was insufficient time for investigators to analyze data obtained during the previous summer.

The symposium concept has been changed to that of a workshop, and the schedule has been changed to late winter. The workshop arrangement is more conducive to critical review and discussion. The schedule change permits investigators to report more fully on what was accomplished the previous year and on what is planned for the current year in the field. A workshop will be conducted in Michigan in March 1984.

2.4 1983 PROGRAM ACTIVITIES

Major activities of the Ecological Monitoring Program during 1983 consisted of:

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

The information collected during 1983 has been used to evaluate proposed protocols and parameters, and to provide a basis for appropriate alterations to monitoring activities in 1984. During 1982, and in early 1983 as well, temporary sites were used by several studies. The use of temporary sites was required because precise corridors and antenna configurations were not defined until the spring and summer of 1983. Information collected at the temporary sites was used to prepare for monitoring at permanent study sites.

EM exposure, physicochemical criteria, and biological criteria were used in selection of study sites. These criteria are presented in Section 4, Site Selection. Intersite comparisons of biological parameters are presented in Section 3, 1983 Achievements/Study Changes.

3. 1983 ACHIEVEMENTS/STUDY CHANGES

This section addresses two of the major 1983 activities, the collection of information to validate protocols and identification/characterization of critical study aspects. Specific activities include:

- assessment of techniques
- assessment of parameter variability including sources
- quantitative comparisons of parameters between sites
- temporal and spatial patterns of parameters
- identification and enumeration of biota
- descriptions of biotic associations.

In some cases, particularly those studies of population and community levels, information presented was collected during 1982 and analyzed during 1983. These studies generally have a one-year reporting lag due to the time required for sorting, identification, enumeration, and subsequent analyses. Changes in proposed activities based on preliminary studies are also presented.

3.1 UPLAND FLORA

Tree Productivity, Biomass, Disease, and Insect Infestation

During 1983, a 100 percent inventory was conducted of all trees at three candidate sites. Tree species, total height, diameter (at breast height), disease, and insect infestations were recorded for each tree. The most widely accepted tree growth measurements are diameter and height. A strong correlation exists between these measures (especially diameter) and total biomass. Based on estimated variance, all trees in all diameter classes warrant banding to measure yearly increases in growth. About 35 percent of the trees at the antenna (test) site have been banded; the remaining trees will be banded during 1984.

A primary change in 1984 will be the study of red pine (Pinus resinosa) seedlings to replace, in part, naturally occurring trees. The study of seedlings addresses concerns of the Michigan Department of Natural Resources about forest regeneration after timber removal. Young trees have a rapid growth

rate, which may more clearly exhibit possible effects of the ELF system than would the growth rate of older trees. Studies on pole-size stands of existing vegetation will continue as originally proposed.

Phenological Events

Methodologies for describing phenophases were developed during 1983. For all hardwood species on study plots (i.e., test and control), bud burst, leaf out, full foliage, flowering, cambial activity, seed dissemination, and leaf fall were recorded. Originally trembling aspen, bigtooth aspen, sugar maple, paper birch, and balsam fir were to be studied. Based on 1983 estimates of abundance, red maple, red oak, bigtooth aspen, and paper birch will be examined in 1984. Bud burst and candle elongation will be recorded for red pine seedlings. Initial, average, and terminal date of occurrence will be recorded for each event.

Herbaceous Growth, Species Dominance, and Biomass

A preliminary reconnaissance of candidate study sites determined the relative abundance of herbaceous plants. Three herb species were found to be abundant enough at the control and antenna plots to be used in a statistically valid study of herbaceous productivity. The percent cover of all ground species was estimated (line-intercept method). Indices indicate a moderate to strong similarity in the degree of diversity within each site. Portions of the abundant plant species were measured and weighed. Regressions were then made for estimates of biomass. Because two new sites must be selected in 1984, similar measurements will be made at each of the new sites.

Mycorrhizal Populations and Root Growth

During 1983, the fruiting bodies of ectomycorrhizal fungi were inventoried at irregular intervals between late August and late October. A reference collection was established for subsequent identifications. Based on 1983 collections, it has been determined that such monitoring of mycorrhizal fungus populations on study plots should be continued. A systematic method of periodic monitoring will be adopted for the 1984 season in order to facilitate evaluation of fruiting dynamics for spatial and temporal comparisons.

Sections of feeder roots of paper birch and red pine were examined for ectotrophic mycorrhizae. Balsam fir rootlets were to be examined as well, but few such trees were found on study plots. Because paper birch roots proved to be unworkable, red pine was chosen for intensive root studies. The roots of red pine trees both on or near study sites and at the parent nursery have been intensively sampled for mycorrhizal fungi. During 1984, root systems of planted red pine seedlings will be sampled at bud burst (early June) and leaf fall (late September-early October). Mycorrhizal types will be quantified for seasonal and annual comparison of taxonomic richness and population density. Root growth will be quantified as the change in number and biomass of active mycorrhizae per unit terminal root length.

Litter Production and Foliar Nutrients

Prior to leaf fall in late September-early October, foliage was obtained for nutrient analysis from dominant and codominant northern red oak, bigtooth aspen, paper birch, and red maple. Litter traps were placed randomly on each permanent measurement plot at the antenna and control sites in August. Trapped litter was collected at weekly intervals after the onset of leaf fall.

Foliar nutrient concentrations showed considerable variability among tree species, but little difference between sites. Intersite differences found in litter fall rate and total litter weight probably reflect variations in climatic conditions and stand composition between sites. A new control site will be selected in 1984. The litter will continue to be collected in traps monthly during the snow-free period. Foliage samples will also be taken monthly from the upper crown of overstory trees.

3.2 SOIL MICROFLORA

Non-mycorrhizal Fungi (Population Characteristics)

Approximately 53 non-mycorrhizal fungi have been isolated into culture from field and nursery red pine roots. Of these, 32 represent identifiable genera. Most of the remainder failed to produce structures in culture that would permit efficient routine recognition. Many of the identified fungi are genera that are dependent on simple carbohydrate energy sources. These genera are less important in the decomposition/nutrient flux scheme than fungi that degrade more complex substrates such as cellulose. The ecological role of the

unidentified isolates is unclear. Due to these factors, work on this study element will be discontinued in 1984.

Actinomycetes (Population Characteristics)

From November 1982 to October 1983, soil and root samples from various sites were analyzed for heterotrophic bacteria and streptomycete densities and types. Samples were used to check isolation, enumeration, and identification techniques. Samples associated with red pine, balsam fir, and paper birch from ELF study sites and from Toumey Nursery were analyzed to provide comparisons of *in situ* bacterial populations for plantings.

Two improvements in isolation methodology were developed during 1983. As negligible numbers of actinoymcetes were found to be associated with surface-sterilized mycorrhizae, studies have shifted to washed mycorrhizae and mycorrhizal influenced soil. In addition, isolated actinomycetes are being tested for their ability to degrade oxalates as well as cellulose and lignocellulose. Rhizosphere actinomycetes may have a nutritional relationship to mycorrhizae through their ability to metabolize oxalates.

Because of their reproduction by spore, streptomycete densities could not be quantitatively determined using serial dilution plate count techniques as originally proposed. However, the different types present in different samples can be determined by their relative incidence (i.e., number of colonies per type); this will provide an indication of each type's activity and dominance.

During 1984, actinomycete studies will concentrate on sampling of red pine seedlings twice annually. Diversity-related features of actinomycete populations will be used to monitor for possible ELF effects.

Litter Decomposition and Nutrient Flux

Freshly fallen red pine and paper birch foliar litter was collected in the autumn of 1982. Envelopes containing preweighed litter were placed on study plots near an ELF ground during December 1982. Half of the envelopes were retrieved after snowmelt in May 1983, and the remainder were retrieved in October. This preliminary experiment was designed to estimate parameter variability and to estimate loss of litter via envelopes and individually tethered pine fasciles. Chemical analysis of bulk litter samples was

completed for the elements nitrogen, phosphorous, potassium, calcium, and magnesium; determination of sulfur content remains to be done.

Efforts in 1984 will be concentrated on litter decomposition of red pine, but will be expanded later in the year to include a broad-leafed species. Red pine weight loss will be studied by the tethered fascile method. Nutrient flux will be analyzed for bulk litter samples of pine and birch. Statistical emphasis will shift from characterization of litter fall beneath individual trees to characterization of litter at the study plot level. More frequent (monthly) sampling of litter envelopes is planned.

Nitrogen Cycling

Five trenched areas were established on each study plot to monitor nitrogen mineralization during 1983. Rates of nitrogen fixation were estimated, and nitrogen and ammonium concentrations were determined from samples taken in October.

Based on peer review comments, resources used for these determinations will be redirected to an increased study effort of litter decomposition and nutrient flux.

3.3 SLIME MOLDS

Mitotic Cell Cycle and Oxygen Consumption

The task researchers have previously reported that continuous laboratory exposure of the slime mold, Physarum polycephalum, to 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 EM fields and environmental conditions present at the ELF Communications System-Wisconsin Test Facility (WTF). The WTF has been operated, and is currently operating, on an intermittent basis. Since earlier work by the investigators involved only continuous ELF exposures, efforts in 1983 were directed toward determining whether intermittent exposure was capable of altering the mold's physiology.

The 1983 research program contains both laboratory and field studies performed at University of Wisconsin-Parkside, at Kenosha, Wisconsin, and at Clam Lake, Wisconsin respectively.

The field exposure system consists of culture chambers (nutrient agar) buried at various distances from the antenna. No field culture was maintained axenically long enough during 1983 for expression of those effects reported in laboratory studies. In order to obtain reliable data, culture must be maintained in an axenic state.

Laboratory exposures were intermittent and in liquid, shake culture regimen during 1983. The following results were reported for the laboratory studies:

- The mitotic cell cycle is apparently altered following ELF exposure. Differences between controls and exposed cultures were -4 to +6 percent depending on the experimental protocol used.
- The respiratory quotient (consumption of oxygen) was 3 to 9 percent higher in exposed than in control cultures; in only two of the four experiments were the test and control differences considered statistically significant ($p < 0.01$).

During 1984, researchers will be making a concerted effort to maintain axenic cultures at the WTF. In the laboratory, researchers will attempt to approximate more closely the conditions found at the WTF. Molds cultured on nutrient agar (WTF-technique) as well as the liquid culture regimen (laboratory technique) will be exposed under laboratory conditions. EM exposure in the laboratory will be modulated 16 Hz, 1.0 G, and 1.0 V/m. Laboratory experiments in liquid media will be designed to ascertain the minimal exposure cycle required to induce previously reported changes in mold respiration and mitotic cycle. When changes have been observed to occur and have been recorded, the tests will be repeated with progressively shorter exposure periods until no effects are observed.

3.4 SOIL AMOEBAE

Spatial Distribution

Replicate samples (10 per site) taken in 1983 did not reveal sufficient variation in amoeba numbers to indicate clustering at the macrolevel. Clustering at a microlevel will not affect data needed to detect differences between test and control sites. Cluster analysis will not be performed in 1984.

Species and Population Characterization

During 1983, soil samples were placed on non-nutrient agar plates with the bacterium Escherichia coli as the added food. Isolates from the 1983 field season are in progress, but species other than those identified in 1982 have not been observed to date. Preliminary (morphological) identifications have failed to reveal species unique to a given site or particular soil horizon. The isolation of mitochondrial DNA and the study of DNA restricted fragments are in progress, with emphasis on the genus Naegleria. Taxonomic studies of DNA will enable studies of species and strain diversity at study sites, and will continue during 1984.

Population counts of amoebae were also performed in 1983. Ten replicate samples per site, each subdivided into an organic and a mineral horizon, were taken and compared to a second, 10 sample count, a month later. Counts revealed significant differences at the 5 percent confidence level for the organic horizon between sites. There were high numbers of amoebae at the control site. Mineral horizons at all three sites (antenna, ground, and control) were not significantly different at the 5 percent level. Sample sizes were considered adequate after determination of coefficients of variation.

Differential counts of vegetative and encysted forms were done in duplicate at the three sites: Data were too scattered for analysis, and 8 to 10 replicates at each site for each sampling are planned for 1984.

Growth and Feeding Activity/Cell Cycle Analysis

This technique involves suspending a known amoeba species previously isolated from study sites in a physiological saline with a food bacterium. Direct counts of amoebae and bacteria are made microscopically to determine temporal changes. Designs of soil culture vessels have been reviewed by IITRI and will be tested during 1984. The relationship of internal to external electric field characteristics is of particular concern. Culture chambers will also be used in determining the time between mitotic divisions.

3.5 SOIL AND LITTER ARTHROPODA AND EARTHWORM STUDIES

Forest floor invertebrate fauna continued to be surveyed at a temporary site established in 1982. Permanent test and control sites were selected and surveyed from August through October 1983. Preliminary surveys showed that the two permanent sites shared many arthropod and lumbricid species, and that both sites also faunistically resembled the temporary sites monitored in 1982. Information obtained at temporary sites in 1982 and 1983 helped in the interpretation of faunal dynamics at permanent sites. Litter decomposition studies were initiated at permanent sites in November 1983.

Major accomplishments during 1983 include:

- description of the Turner Rd. (temporary) soil and litter arthropod community (1982 and partial 1983 data); i.e., distribution, density, and dominance relations of common taxa
- analysis of a 1982 pit-trapping experiment designed to quantify the technique's potential for out-trapping surface-active arthropods
- an improved and validated technique for sampling lumbricid populations
- description of population dynamics (lumbricids) characteristic of permanent sites
- identification of potential sources of variation
- compilation of a checklist of species and families (lumbricids and arthropods) so far encountered in deciduous forests in the ELF system area.

Population Characteristics and Validation of Techniques

An experiment was established during the period from August through October 1982 to assess the possible over-trapping of surface-active fauna. Over-trapping could result in depletion of surface fauna and could distort monitoring results. Organisms were identified and enumerated during the winter of 1982-1983. Many of the species identified at the temporary site were also found at permanent test and control sites. Generally, no consistent depletion of surface-active arthropods was found along linear transects. The data were used to validate the experimental plot design adopted during 1983.

Soil and litter arthropod assemblages were determined primarily from samples taken from August through October 1982. Subsequently, major taxa and peak densities were determined. The data indicate a typical clumped distribution for the organisms. Mites and collembola are numerically dominant, and few groups show a preference for either litter or soil.

During 1982 and 1983, major methodological modifications and validation of earthworm collection techniques were determined. A two-step process of sorting and sieving gave recoveries estimated at 97.7 percent of the worms and 96.7 percent of the cocoons from soil. A modified formalin technique was perfected for litter sampling. Initial results indicate that earthworm data can be tested only by parametric statistics after logarithmic transform.

Major and minor earthworm species based on numbers and biomass were identified for permanent test and control sites. Neither abundance nor biomass differed between sites. Analyses of the stage structure of earthworm populations were begun on these sites. This information will provide estimates of population growth, extent of recruitment, and seasonal and stage-specific mortality. Based on limited samples from the test and control sites, population densities were correlated to humus depth and litter weight and no quadrat (sampling area) specific sources of variation were found.

3.6 NATIVE BEES

The 1983 objectives for this study include:

- taxonomic studies of megachilid bees, with special emphasis on those known to occur in the Upper Peninsula of Michigan
- listing of plant species utilized by megachilids
- identification of plant species at study sites that are known to be of value to megachilids
- qualitative and quantitative determination of pertinent flowering phenologies
- development of qualitative and quantitative techniques for pollen analysis present in fecal pellets of larvae
- collection of nesting behavior of resident bees.

On the Upper Peninsula of Michigan, native bees produce only a single generation per year. Many of these species enter the winter period in a

"quiescent" larval or pupal stage to emerge as an adult the following spring or early summer. With the emergence of adults in 1984, data on nesting behavior (e.g., winter mortality, emergence dates) will be collected and positive identification of species will be made. Approximately 250,000 bits of 1983 behavior data await species identification before further analysis. Field activities during 1984 will shift from technique development to technique application and data analyses.

Taxonomic Studies

A taxonomic study of the megachilid bees of Michigan was initiated in 1983 with specimens borrowed from various Michigan universities and from one private collector. Based on these efforts, researchers estimate a working potential of over 20 species that cannot be determined at present under field conditions. This problem may partially resolve itself with emergence and identification performed in the spring of 1984.

Nesting Activity

During 1983, more than 1600 man hours were used in observing, recording, and determining activity patterns of various species of native bees. This amounted to the recording of some 15,000 life history events and about 4,000 observational notes (e.g., incidence of marauders, sunning activity, etc.). Analyses of these data await further identification of megachilid species.

Differing nest orientation (north-south, east-west) and height above the ground were analyzed for bee preferences. Some species exhibited preference for height location, but no preferences in orientation were indicated. Marked bees were used to determine the normal sequence of nesting events, and several activities associated with both pre- and post-nesting behavior were ascertained. Some records were also obtained on flight range, flowers visited for pollen, and source of nesting material. Nests of two bee genera were opened in September and October 1983, and architectural data were recorded. Some overwintering nests will be opened in late April or early May 1984 to determine similar data.

Plant Relationships

A major portion of the study pertains to the relationship of bees to flowering plants. The use of pollen by bees is a factor in perpetuation of

the species. During 1983, study elements were designed to determine the complex of plant species that was available and which plant species were utilized at study sites. Once the ELF Communications System is operational, it will be important to determine if synchronisms are maintained or shifted.

A list of plants that the bee species of the study area were previously known to visit was derived from the literature. As a means of assessment and comparison of study sites, similar lists were made from field data at one pair (test and control) of study sites. Two methods were used to gather quantitative data on the flowering periods of various entomophilous plants at the study sites. Once the pollen relationships of the various bee species are determined, researchers will increase sample size and concentrate on those plant species used by the megachilids.

To further define the bee-plant relationship, fecal pellets of larvae in nests were examined. Pellets were collected and the pollen was identified. A total of 407 nest cells were examined for fecal pellets. Preliminary results have shown this to be a viable technique. Currently, techniques are being examined to ascertain plant species from which leaves were obtained for nest construction.

3.7 SMALL MAMMALS AND NESTING BIRDS

Research activities for 1983 were directed toward the collection of preliminary data and evaluation of protocols. Baseline data was obtained for avian population distribution and density; avian (tree swallow) embryo growth rates, clutch size, hatching success, nestling growth, parental incubation, care of nestlings, and fledging success; and mammalian population distribution and density, parental care, growth of young, and tolerance of implanted radio telemetry transmitters and continuously recording, passive identification detector (CRPID) coils. Researchers evaluated the suitability of proposed test animals, protocols, and sample sizes for statistical tests.

Preliminary evaluations of test animals were carried out in 1982 and continued during 1983. Two criteria of major importance were that study animals must occupy and rear their young in nest boxes and that they be abundant on the study sites. The former criterion is important because many of the study elements will be carried out on nesting animals. As a result of

evaluation, three species of vertebrates have been selected for specific studies during 1984. The tree swallow (Tachycineta bicolor) will be the subject for studies of parental care, fecundity, maturation, development, homing, and activity patterns. The black-capped chickadee (Parus atricapillus) will be used for studies of metabolic physiology but will not be used in any other study objective. Mammalian studies will be limited to the deer mouse (Peromyscus maniculatus).

Population Characteristics (Surveys)

Bird census transects were established on one pair of study sites in June 1983. Thirty-six species were identified and recorded. In general, species abundances were similar for each plot.

Due to problems in the selection of suitably matched plots, censusing of small mammals was carried out on plots other than those originally proposed. In addition to the deer mouse, five other rodent species and one shrew species were captured. Density estimates for deer mice were considerably different for each study site. However, estimated densities appear normal and are within the range of extremes reported in the literature.

Parental and Nesting Behavior, Maturation, and Fecundity

During 1983, parents and young in 34 swallow nests were monitored by continuously recording temperatures and by direct observation. Time spent in the nest, clutch size, hatching rate, fledgling success, and morphometric observations were made. Generally, values were similar to others reported in the literature.

From June through September 1983 nest boxes at various locations in the study site were checked for deer mice. Monitoring revealed that few nest boxes were occupied at any given time and that the residence time was short. Because researchers feel that data cannot be obtained from unrestrained nests, plexiglas enclosures were constructed to restrict the movements of those deer mice to be used for fecundity and developmental studies. Evaluation of this technique will continue in 1984.

Parental behavior of breeding mice and swallows and homing/activity patterns (in part) will be monitored using a continuously recording, passive identification detector (CRPID) system. Extensive work was done during 1983 in further perfecting a coil design and surgical implanting procedures. Subcutaneous implantation in adult and nestling mice was unsuccessful; however, intraperitoneal implants offer much promise. Implantation of coils in birds also proved futile, and CRPID coils will now be placed on leg bands. Tests of the first prototype CRPID unit showed unacceptably large errors. Subsequent tests of a redesigned second unit indicated that it is functioning in a error-free manner.

Homing and Activity Patterns

Because of developmental problems associated with the CRPID system, no homing studies were carried out on nesting birds during 1983. Data on homing behavior of swallow species suggest a considerable variability in homing after displacement from the nest. Data must be collected in 1984 before a sample size can be estimated that will meet statistical sufficiency.

Due in part to delays in site selection, homing of mice was not carried out as proposed. However, radio transmitters were successfully implanted in three adult mice. Post-surgical observations of the mice revealed no apparent ill effects on behavior due to the surgery or transmitter.

Developmental Studies

Eggs in various stages of development were collected from the nests of tree swallows. Techniques for collection and analysis were perfected and a protocol was delineated for a single blind experiment. Based on 1983 collections, the frequency of abnormalities in tree swallow embryos was about 15 percent. This frequency is similar to reports in the literature.

Physiology Studies

The components of the metabolic studies apparatus have been calibrated and tested, and are fully operational. Protocols for single blind tests have been delineated. Although no data have been collected for winter acclimatized

mice, the collection of baseline data on the peak metabolism rates of deer mice is currently in progress.

No tests of birds have yet been accomplished. The species of choice is the black-capped chickadee, as tree swallows do not overwinter on the Upper Peninsula.

3.8 MIGRATING BIRDS

This study was initiated during the spring of 1983. The principal investigator proposed studies of possible short-term disorientation as well as long-term impact. Long-term impact studies were to examine migrating birds, population abundance, and species composition using observational surveys, mist netting, and ceiliometer (light and radar) techniques. Short-term disorientation was to be examined using radar and radiotracking techniques.

Mist Netting

In Wisconsin, the capture of birds in mist nets was used as an index of the volume of migrating birds passing over study sites. From May 15 to June 6 field work was conducted in the Chequamegon National Forest near the south leg of the ELF antenna. A total of 15 birds were captured during 603 mist net hours. Researchers believe that the large expanse of homogeneous forested habitat that exists in the Chequamegon National Forest was a major factor contributing to the inability to capture the large numbers of birds needed for the study.

Radio Tracking

Radio tracking was used to determine possible side effects such as temporary disorientation (over the antenna array), chronic disorientation (flight after leaving array), and time of departure of migrants.

One migrant bird captured in Wisconsin was fitted with a back-mounted radio transmitter. Radio contact was maintained for 9 days and 8 nights in late May and early June, during which time the bird remained in a localized area of less than 0.15 square miles. On June 7 and 8, potential study areas near the planned Michigan ELF antenna were reconnoitered. The initial

impression of the researchers was that radio tracking of migrants would be more difficult there than at the Chequamegon study site in Wisconsin.

Mist netting and radio tracking studies were to be entirely shifted to Michigan sites during August and September 1983. Researchers for these elements had difficulty in finalizing a contract with the prime subcontractor, and declined further participation. These elements, along with the waterfowl survey element, will be evaluated for further study during 1984.

Radar Tracking

A total of two megabytes of data on migrating birds was collected at the Michigan antenna site from August 26 to September 10. These data include 751 individual bird tracks, 38 counts of target densities totaling several thousand birds, and 26 records of wingbeat signatures. Data reduction was initiated in 1983 and will be continued during 1984.

The following are select conclusions from preliminary analyses:

- the weather during the study period was atypical and generally unfavorable for large-scale migrations
- most birds fly straight and level, although the proportion of bird targets that climb, drop, or turn was greater than at other sites examined by the principal investigator
- directions of bird travel were quite variable, both within a night and between nights
- insect-like targets were common, and there was difficulty in distinguishing them from bird targets.

During 1984, observations will be shifted to the fall migration season exclusively. There will be an increased emphasis on data analysis and better data collection techniques for nonlinear bird tracks and insect targets.

Waterfowl Survey

Estimates were to be made of the density and diversity of migrating waterfowl at predetermined bodies of water within and outside the ELF Communications System area. Statistical analyses would take the form of analysis of variance across species and locations.

A waterfowl survey was conducted during October 1983 at 25 lakes ranging from 0.2 to 10.5 miles from the Michigan antenna. Biologists from the Michigan Department of Natural Resources and the Seney National Wildlife

Refuge supplied supplementary information. Results indicate that peak numbers of waterfowl are present from October 1 to October 10 and that some mallards, black ducks, and mergansers nest in the small lakes of the area. Most other waterfowl nest in the larger lakes such as those within the Seney National Wildlife Refuge. As the ELF Communications System area is not in a major flyway, this element will be critically evaluated for further study in 1984.

3.9 WETLAND FLORA

During 1983, preliminary data were collected on the cation content of plant foliar tissue and cellulose decomposition. Initial estimates of cation content are considered adequate. Sample size estimates for cellulose decomposition must await results of the 1984 field season. Studies on leaf diffusion resistance are still in the developmental stage.

The direction and emphasis of the overall 1984 study remain unchanged; studies of cellulose decomposition, cation analysis of foliar tissue, and diffusive resistance of Wisconsin wetland flora are planned. During 1984, exploratory work on nitrogen fixation will be initiated. Cloning of a nitrogen-fixing shrub with re-establishment at study sites will be attempted. Investigators will initiate studies on the decomposition of natural leaf material, cation analysis of moss, and, if warranted, other studies of water stress in plants.

Decomposition

The decomposition of standard cellulose as an index of microbial activity was examined during the 1983 growing season. The data from samples left in wetlands for one month show high variability for some samples. Larger sample sizes and longer residence in the bags will be examined during the 1984 field season. In addition, blocking (a statistical technique) of samples within each wetland will be attempted to increase the precision of this parameter.

Stomatal Resistance

The stomatal resistance of select northern wetland flora are being examined to determine the overall physiological status of EM-exposed plants. During 1983, instrument operation and associated problems were discussed with personnel from the Botany Department of Duke University. A major problem is

the conversion of transpiration output from a conifer to loss on an areal basis. A sampling protocol has been developed based on the advice of the Duke personnel. During 1984, preliminary data including sample size, temporal variation, and variance among individuals will be tested.

Foliar Cations

Cations are assimilated by plants through the formation of electrostatic or coordinate bonds. During 1983, leaves were collected for analysis of three cations: calcium, magnesium, and potassium. Two sets of samples were collected, one in August and one in late September, for each of four plant species: one tree, one shrub, and two herb species. Mean cation concentrations from the eleven study sites have been analyzed for several species and all tree samples. Coefficients of variation are considered high (15-20%) but comparable to analyses of other multiple populations. Based on the variation present and the biological significance of differences in cation concentration, investigators feel that a sample size of 20 is appropriate. However, several other approaches will be investigated in 1984. A large sample (N>100) of one species from one site with a large amount of variation will be examined. Researchers will also investigate the subdivision of study sites into blocks from which both foliar samples and ambient data will be taken.

3.10 AQUATIC BIOTA

The research plan is directed at determining the effects on aquatic plants and animals of low-level, long-term EM fields produced by the ELF Communications System. The integrated approach taken is to combine the major interrelated and interactive components of aquatic systems (i.e., periphytic algae, aquatic insects, and fish) and to monitor sensitive life history events and community processes critical to the basic structure and function of stream ecosystems.

In 1982 and 1983, 22 study elements were defined in order to meet the initial objectives. During 1984, 14 study elements will be used. These reductions are based on 1982-83 data resulting in appropriate reorganization of work effort, elimination of preliminary tasks (e.g., site selection, physical characterization of sites, optimization of techniques, etc.), and elimination of marginally productive study elements (e.g., developmental

studies of fish). Appropriate changes in techniques such as sampling frequency and sample sizes are also planned. Generally, the objectives originally proposed have been retained.

3.10.1 PERIPHYTIC ALGAE

Population and Community Characteristics

During 1983, a comparison was made of periphyton communities on natural substrates with those on artificial substrates. Glass slides appear to give a good overall representation of the community, but are less variable than natural substrates, especially for relative abundance patterns. Sampling periods of either 14 or 28 days (depending on the parameter) represent a reasonable regime to achieve a "mature" community characteristic of rock substrates.

A total of 304 diatom taxa were enumerated from riffle and pool samples taken on the Ford River in Michigan between August 1982 and August 1983. Algae other than diatoms were identified, but densities were markedly less than diatom species. Monthly cell densities for test and control sites have not been completely analyzed. However, samples from one site show the anticipated seasonal differences in density. When combined to provide a single yearly mean, density data show no difference between riffle and pool habitats. Data were collected during 1983 for calculations of cell volume and density, but analyses have not yet been performed.

Study elements have been completed for determining optimal exposure time for colonization of artificial substrates and comparison of periphytic communities on artificial and natural substrates. Species composition, numbers, diversity, biomass production, cell volume, and chlorophyll a/phaeophytin a production will be monitored in 1984 using larger sample sizes than were used in 1983: six samples for chlorophyll a/phaeophytin a and biomass, and three samples for the remaining parameters.

3.10.2 INVERTEBRATES

Population and Community Characterization

Aquatic invertebrates were collected and identified during 1983 to establish a reference collection for subsequent studies. At least 100 species of insects have been identified. Artificial substrates were emplaced to determine the optimal colonization time, pattern, and variance. No asymptote occurred for numbers of individuals over a maximum 28-day period. Structural community indices did not stabilize until day 14, and by day 28 variance was low. Based on these data, at least four samples from each study site will be examined for 30-day exposure periods during 1984. Data collected on the number of insects show more similarity between the selected test and control sites than pairings of other control sites with the test site. The test site will be moved closer to the planned antenna in order to reduce intersite EM variability.

Migration

Movement patterns and habitat preferences of an insect predator and crayfish were monitored. Crayfish exhibited both local and long distance movements. Statistical correlations between numbers of crayfish, particle size of substrate, and stream velocity were low. The movement patterns and density of crayfish at test and control sites were more similar than other pairings.

Preliminary data on the life history of an insect predator (mayfly) has been collected as background for movement studies in 1984. These data will be combined with movement studies and gut analyses during 1984 at both the test and control sites.

Leaf Litter; Colonization, Feeding, and Processing

Leaves are important sources of energy to streams in the ELF Communications System area. Studies to determine the actual processing and the biological community responsible are considered important.

Initially, the Ford River and Swartz Creek were examined as possible test and control sites. Riparian vegetation, leaf area loss rate, and community indices were significantly different between these streams. A major macroinvertebrate (mayfly) was selected for preliminary examination. Enclosures

with similar stream substrates, diatometer, leaf material, and mayflies were placed at the Ford River test site in July 1983. Periphyton colonization, mayfly length/weight data, production estimates, and feeding habits were examined. To date, the periphyton analysis and the mayfly length/weight relationship have been determined, and values agree with previously published data.

Studies in 1984 will estimate preoperational rates of transfer of periphytic production to one major grazer (mayfly). The relative importance of periphyton in the diet of the grazer will be assessed by gut sampling techniques. Colonization, feeding, and processing study objectives will be combined with leaf litter processing studies because of the overlap of these elements.

Drift

Drift studies, originally proposed in 1982, were deleted during contract negotiations. Some preliminary data were nevertheless collected in 1982; based on these data, drift patterns of aquatic invertebrates will not be investigated during 1984.

3.10.3 FISH

Generally, those objectives proposed to monitor possible ELF electromagnetic effects on fish have been retained for the 1984 field season. Studies on fish development were dropped during 1983. Select homing and food consumption parameters, although initially proposed, will not be studied during 1984. The related parameters of food habits and migration will be continued.

Community Characteristics

Preliminary data were collected on fish community structure from test and control sites on the Ford River. Twenty species were collected representing two families of fish. Results indicate that the planned study sites are similar in species composition and abundance of both the mobile and sedentary fish community.

During 1983, the efficiency of various fish sampling techniques was assessed. Five types of gear and visual observations (snorkeling) were

compared. Regular seining was found to be ineffective. Both fyke netting and kick sampling worked well, but both are selective in their catch and must be geared to target species. The box sampler and visual estimates will be retested in 1984.

Vital Statistics

The growth, fecundity, survival, and distribution of sculpins and brook trout were to be examined in 1983. Brook trout will not be examined in 1984 because of the small number of fish available. However, available data is presented and will be further analyzed. The longnose dace was selected as a replacement for brook trout.

Three distinct age classes were found for both the sculpin and dace. No statistically significant difference was found in mean size of dace at test and control sites. Pairing of test and control sites for dace was more similar than other possible pairings. Growth of sculpins and trout are significantly different at the study sites. Analysis of fecundity data will be completed in early 1984.

Preliminary data, based on a small sample size, indicate that sculpins had higher survivorship at the test site than at the control site. No clear trends were found between sites in dace survivorship. More reliable estimates based on movement data and microhabitat modeling will be investigated in 1984.

In order to compare possible future ELF effects on fish populations, sculpins were investigated during 1983. Per unit area estimates appeared to be the least biased. Mark and recapture estimates were biased by violation of at least two necessary assumptions (i.e., no immigration or recuitment, and a random distribution). Per unit area estimates will continue to be used. A combined mark-recapture and microhabitat model approach will be tested in 1984. Per unit area estimates indicate a significantly greater population size at the test site than at the control site.

Food Habits

Problems were encountered in identifying those organisms consumed by the sculpin. Based on a small sample size, data indicate that the sculpin and dace eat different food items. Identification problems will be addressed during 1984, in part by increasing sample sizes.

Development

No unusual developmental patterns or deformities were noted in fish taken during the 1982-83 field seasons. As developmental abnormalities due to the ELF electromagnetic exposure appear unlikely, resources will be used during 1984 for examination of other parameters.

Parasites and Pathogens

Types and numbers of the parasitic fauna of sculpins and dace were comparable between study sites. Fifteen individuals of each host fish will be collected monthly from April through November 1984 to further determine population characteristics of the parasitic fauna.

4. SITE SELECTION

Spatial comparisons of biological/ecological parameters are being made by obtaining data both relatively close to the ELF Communications System (test plots) and at greater distances (control plots). The test/control arrangement allows for test/control differences in EM exposure intensity (as a function of distance) in the actual environmental setting of the ELF system area. Two studies are not using the paired plot design; migrating bird studies will rely on temporal comparisons, and wetland studies employ a gradient design, i.e., test, control, and a number of sites receiving an intermediate exposure. EM exposure criteria for site pairs were presented in the Request for Proposals and subsequently were refined. Ambient and other site factors (physicochemical and biological) can cause intersite variations in biological/ecological parameters. Matching of sites for physicochemical and biological factors helps to reduce intersite variability for given parameters.

EM measurements and estimates were made at candidate sites from May through August 1983. Comparisons to exposure criteria were made, and investigators were informed of the results during the period September-November 1983. Study sites in Wisconsin are scattered throughout the ELF system area. In Michigan, study sites are generally clustered in Dickinson County, and to a lesser extent in Marquette and Iron Counties. Several additional sites remain to be selected during the early 1984 field season.

4.1 ELECTROMAGNETIC EXPOSURE

Exposure Criteria

The ELF Communications System produces EM fields that can be described in terms of the following components:

- a magnetic field, the same in air and earth, which is generated by the current in the antenna element
- an electric field in the earth that is produced by the magnetic field as it intersects the earth, and the flow of current from the buried wire elements of the antenna ground terminals

- an electric field in the air that is produced as a result of the potential difference between the antenna element and the earth.

These three components also describe those EM fields produced by electric power transmission and distribution lines. It is therefore important to account for the EM fields produced by commercial power (60 Hz) systems as well as those produced by the ELF Communications System.

In an effort to establish a method of selecting these test and control site pairs, ELF electromagnetic field exposure criteria were developed and presented in the Request for Proposals (March 1982).[2]

> Control plots shall be selected at locations where electric fields in soil near the surface of the earth produced by the ELF system are on the average at least one order of magnitude and preferably two orders of magnitude less than those at paired test plots. The same relationship shall exist for magnetic field components between test and control plots. Electric and magnetic fields in air and earth produced by other than ELF sources (e.g., power lines) shall not differ by more than one order of magnitude between paired test and control plots, and test plots should be at least one order of magnitude below the fields produced by the ELF system.

In addition, it is desirable that the 76 Hz fields produced by the ELF system at the test site be higher (at least one order of magnitude) than the 60 Hz fields at both the test and control sites.

To provide an easier way of determining whether a site pair satisfied the EM exposure criteria, a mathematical representation was developed. It was assumed for this representation that one order of magnitude or greater would constitute a significant difference. The following four inequalities illustrate this mathematical representation.

(1) Test (ELF)/Control (ELF) > = 10.

(2) 0.1 > = Test (60)/Control (60) < = 10.

(3) Test (ELF)/Test (60) > = 10.

(4) Test (ELF)/Control (60) > = 10

where

Test (ELF) is the field intensity at the operating frequency of the ELF system at the test site.

Control (60) is the field intensity at a frequency of 60 Hz at the control site.

The first inequality requires that the ELF system EM fields at the test site be significantly higher than at the paired control site. The requirement that the 60 Hz fields be comparable between paired test and control sites is illustrated by the second inequality. Looking at the third and fourth inequalities together, the ELF system fields at the test site are required to be significantly higher than the 60 Hz fields at either the test site or the control site. The application of these exposure criteria is discussed later in this section.

Site Locations

Each principal investigator was responsible for selecting potential field sites that satisfied his or her requirements. During the 1983 field season, IITRI field crews documented the sites identified by the investigators and selected measurement locations within each site. Figures 3 and 4 illustrate the site locations at which field crews evaluated ELF electromagnetic fields.

ELF Electromagnetic Field Measurements

EM field intensity measurements were taken at each measurement location identified. The magnetic flux density and the electric field intensity both in air and in the earth were measured at 60 Hz. In Wisconsin, where an ELF test system exists, measurements were also made at 76 Hz.

In order to evaluate a particular test and control site pair for Michigan studies, estimates of the 76 Hz EM field intensities were analytically calculated for each measurement location. These estimates were based on calculations utilizing proposed operating conditions of the antenna and the distance to each measurement location.

1983 Measurement Locations

Table 2 lists the number of test and control sites identified by the principal investigators as potential field study sites. The ELF electromagnetic fields at each of these sites were measured during 1983. For each test or control site, one or more measurement locations were selected. As indicated in Table 2, a total of 116 measurement locations were used to characterize 68 candidate sites.

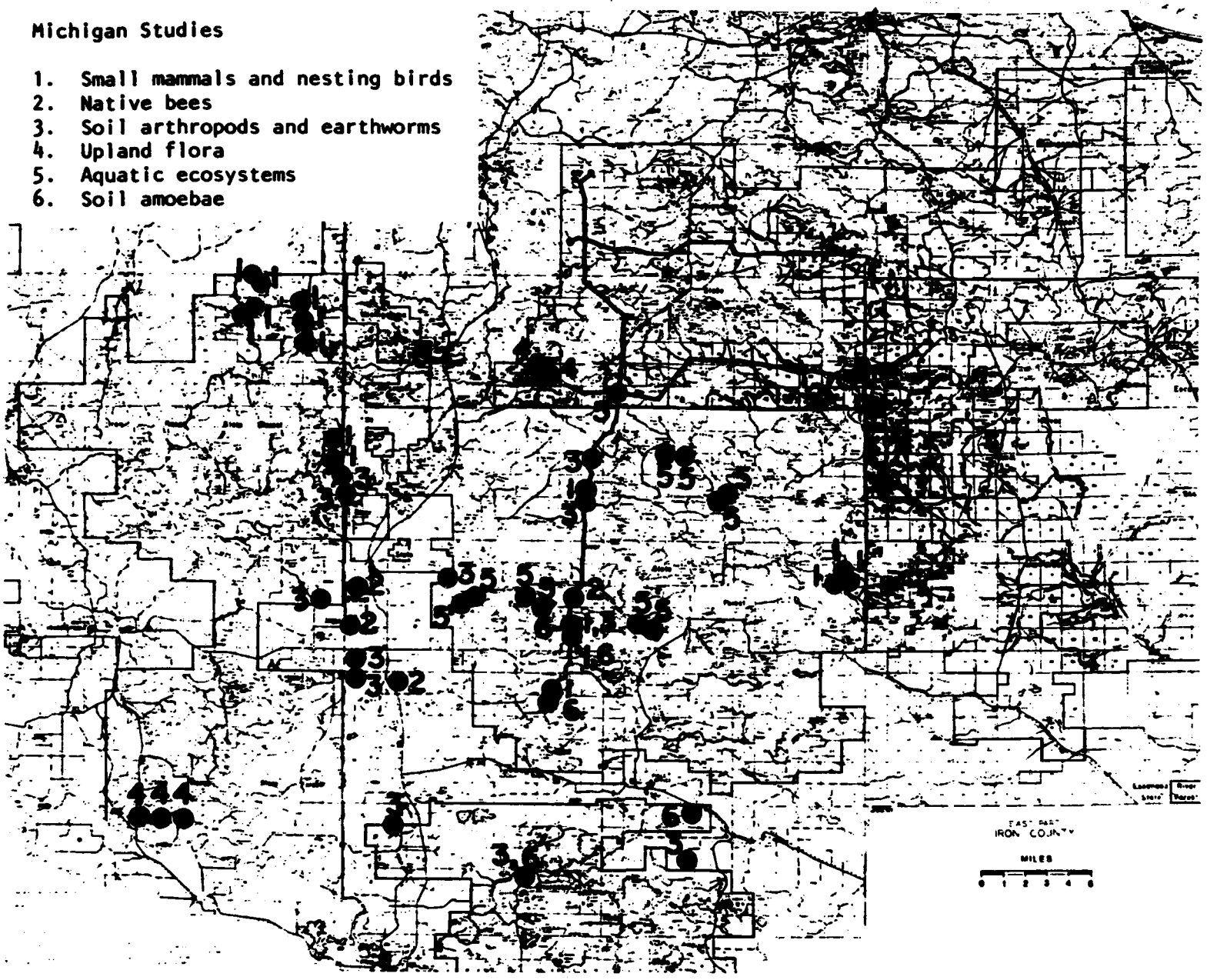

Figure 3. 1983 EM measurement sites in Michigan.

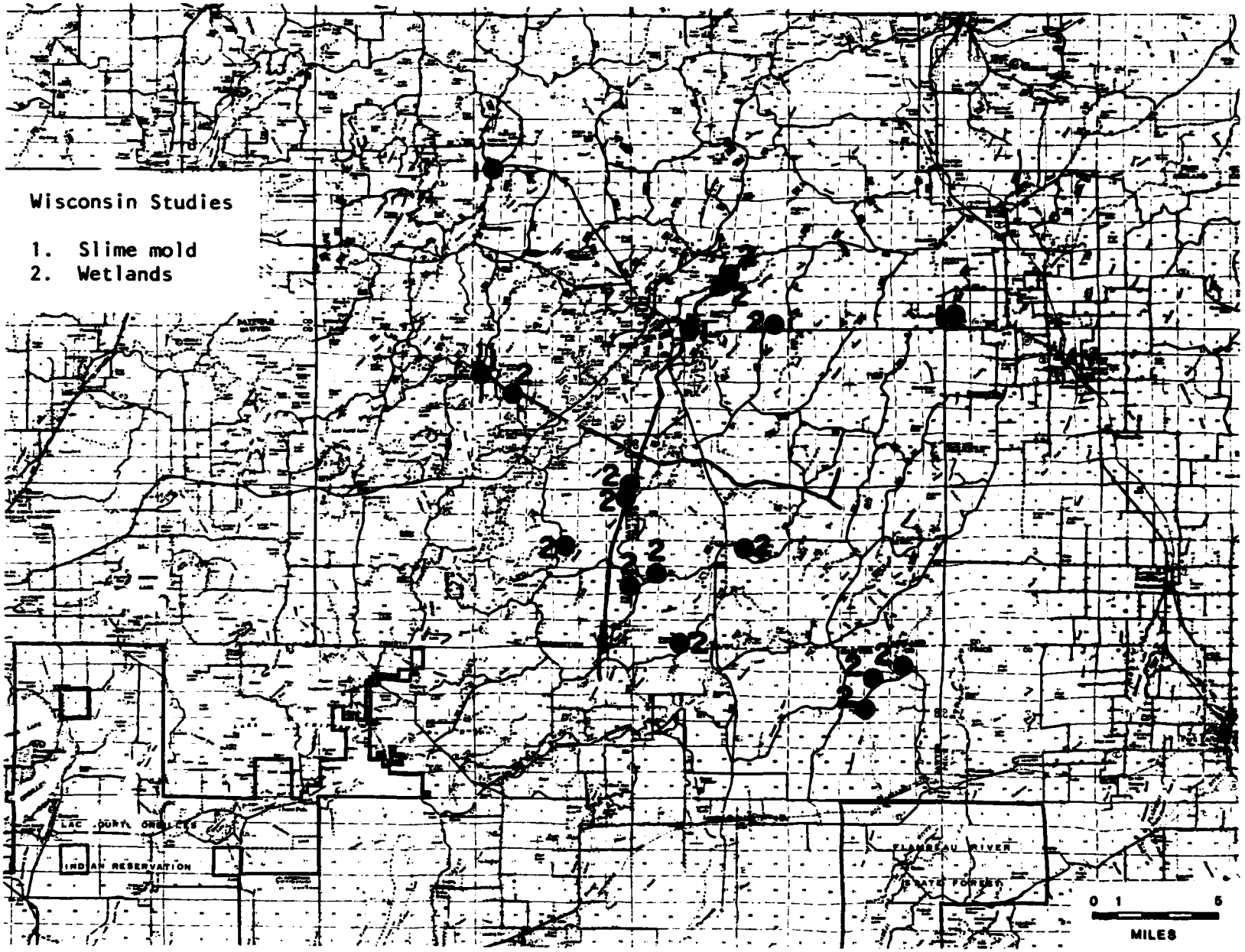

Figure 4. 1983 EM measurement sites in Wisconsin.

TABLE 2. SUMMARY OF 1983 MEASUREMENT LOCATIONS

Study	Test and Control Sites	Measurement Locations
Upland Flora and Soil Microflora	5	12
Slime Molds	4	4
Soil Amoebae	5	5
Soil Arthropods and Earthworms	12	12
Native Bees	6	6
Small Mammals and Nesting Birds	10	21
Migrating Birds	(Radar measurement needs to be determined)	
Wetland Flora	15	42
Aquatic Biota	11	14
Totals	**68**	**116**

Application of Exposure Criteria

The EM field exposure criteria were applied using the measured (Wisconsin) and calculated (Michigan) data. In order to sort out the site pairs in terms of EM exposure acceptability, the following categories were defined:

Acceptable. A test/control site pair was placed in this category if it satisfied all exposure criteria applicable to the study. That is, all four of the previously listed inequalities (mathematical representation of the exposure criteria) were satisfied for all fields; however, if a field that was not expected to have any impact on the study failed to satisfy the exposure criteria, the pair was nevertheless termed acceptable as long as all other fields satisfied the four inequalities. The soil amoebae study would be an example of such a situation. The electric field in air, since it terminates at the earth's surface, is not expected to have any impact on biota existing in the soil.

Conditionally acceptable (or marginal). A test/control site pair was placed in this category if it approached but did not meet the conditions for acceptability. This category was established to take into account two uncertainties: first, one order of magnitude or greater was chosen as a criterion,

but without knowing a priori what effects, if any, will be experienced; second, the 76 Hz field data in Michigan were estimated based on a set of probable electrical conditions (e.g., earth conductivity).

Unacceptable. A test/control site pair was placed in this category if it did not satisfy the applicable criteria for acceptability and if it did not qualify for conditional acceptability.

EM field intensity data were collected at candidate sites, and the ELF field exposure criteria were applied to all possible combinations of test/control site pairs. Table 3 summarizes all possible site pairs and their categories. These categories reflect the ELF electromagnetic field exposure component for site selection, but not other physicochemical or biological criteria.

A summary of the ELF electromagnetic field measurements was sent to the principal investigators of each of the ecology studies during last quarter of 1983. With regard to overall site pair acceptability for study, it was indicated in this information that a particular site pair falling in the unacceptable category was unacceptable for further study because of the ELF electromagnetic exposure alone. The final decision on choice or selection of any of the study site pairs falling in the acceptable or conditionally acceptable categories, after weighing the combined effects of the EM component and other (physicochemical and biological) components, was left up to the investigator.

EM Measurement Plan for 1984

A tentative 1984 schedule was established at the end of 1983 field season based on the remaining site selection work and measurement requirements. Two weeks at the end of May were set aside for the completion of the site selection process for all of the ecology studies so as to provide the study investigators an entire field season for baseline data acquisition. Six weeks in the latter part of the summer and early fall were tentatively scheduled for performing the annual field verification measurements at each of the selected test/control site pairs of ecology studies.

Specific EM engineering support to the ecology studies will be scheduled when requested, as was the case during the 1983 field season.

TABLE 3. ACCEPTABILITY OF CANDIDATE SITE PAIRS

Study	Planned Test/Control Pairs	Number of Possible Test/Control Pairs	Acceptable	Conditionally Acceptable (marginal)	Unacceptable
Upland Flora	2	6	3	1	2
Soil Microflora	2	6	3	1	2
Slime Molds	2	4	1	2	1
Soil Amoebae	2	6	2	0	4
Soil Arthropods and Earthworms	1	27	19	2	6
Native Bees	4	8	1	3	4
Small Mammals and Nesting Birds	2	7	5	1	1
Migrating Birds		(Radar measurement needs to be determined)			
Wetland Flora	15	15	14	1	0
Aquatic Biota	1	6	0	2	4

4.2 PHYSICOCHEMICAL AND BIOLOGICAL SITE CHARACTERISTICS

4.2.1 Upland Flora

Site Configuration

Two types of test sites (antenna and ground) are matched to a common control site. The antenna and control sites each consist of six plots, three (30 x 15 m) plots of pole-size trees and three plots of planted red pine seedlings. Pole-size trees and planting plot sites are separated by a cleared corridor. At the ground site, three plots (30 x 35 m) of planted red pine seedlings are located immediately adjacent to the planned corridor.

Sites were selected during the summer of 1983. One of the desired sites subsequently was rejected on EM exposure criteria, and one site (ground) had to be relocated. Two new sites will be selected during the spring of 1984. Detailed soil and physiographic data were collected at the three initial candidate sites.

Site Characteristics

Percent slope, aspect range, slope position, elevation, and habitat type were recorded. Vegetation at the initial study sites represents an Acer-Querus-Vaccinium habitat type.

Soil Characteristics

Bulk density samples and soil samples for physical and chemical analyses were obtained for select soil horizons. Analyses were conducted by the Soil Research Laboratory, Michigan Technology University, using standard analytical techniques. Physical characteristics analyzed included particle size, moisture retention, and natural fabric properties. Chemical analyses performed were: pH, extractable acidity, cation exchange capacity, extractable bases, calcium, magnesium, sodium, potassium, iron, aluminum, total nitrogen, and total carbon. Horizon thickness, horizon identification, rock abundance, and the presence of earthworms were noted.

Ambient Monitoring

Ambient monitoring is designed to provide climatological and soils data that affect plant growth processes. The chemical and physical characteristics of soil are presented above. The original proposal for collection of ambient

climatological data, as well as soil moisture and temperature, provided for three plots on each of three study sites. Changes in 1983 have resulted in 15 plots divided among the three study sites so as to include planned red pine regeneration. Equipment has been purchased and will be deployed in 1984. Intersite comparisons of ambient conditions will be available at a later date.

4.2.2 Soil Microflora

Microfloral and litter decomposition studies are being conducted at the sites that were established for studies of upland flora. Plot selection and collection of ambient monitoring data have been coordinated to ensure meeting the needs of both projects.

4.2.3 Slime Molds

The investigation of ELF electromagnetic exposure on the slime mold Physarum polycephalum includes laboratory studies at the University of Wisconsin-Parkside as well as field studies at the Wisconsin Test Facility. Field work is being done at two test sites (antenna and ground) and a control site. The antenna test site is located near a buried part of the antenna (road crossing). In 1984, researchers will relocate the road crossing site to a site adjacent to an overhead portion of the antenna.

Because this study uses buried cultures in chambers, site characterization other than of EM intensities is generally not required. Mechanical temperature measurements will be made during 1984 at the Wisconsin field sites.

4.2.4 Soil Amoebae

Site Configuration

The design of this study is based on two test sites and a common control site. The dimension of each site is not expected to exceed 10 x 20 m. A test site will require relocation due to design alterations to Ground Number 4. The preliminary design of this ground was changed during the summer of 1983 and it was not surveyed until the end of the field season. A temporary site was established in the area; selection of a permanent site is planned for 1984.

Major selection criteria other than EM exposure included forest type and soil characteristics.

Site Characteristics

All of the study sites were on high ground, with similar shrubs and herbaceous plants. The density and species of mature trees was similar, dominated by sugar maple with some basswood, elm, ash, and leatherwood. None of the plants included pioneer species (indicative of recent clearing activities).

Soil Characteristics

Soil chemistry (phosphorus, potassium, calcium, magnesium, zinc, iron, manganese, copper, sodium, chlorine, and percent organic nitrogen) was determined on organic and mineral horizons from 20 pooled samples from each site. Bulk density measurements were done on four samples from each site. Each sample was subdivided into organic and mineral horizons. Soil pH was measured at each site over a period of 14 days. Generally, soil analyses of the three plots indicated that they are chemically similar.

Ambient Monitoring

Soil moisture and temperature were monitored and evaluated for part of the 1983 season. Soil temperatures were similar between sites, indicating to the principal investigator a site-to-site similarity of cover vegetation. Soil moisture data was collected to show general trends.

4.2.5 Soil and Litter Arthropods and Earthworms

Site Configuration

Two preliminary study sites were selected and used during 1982 to improve initial study designs. A permanent site pair (overhead antenna and control) was selected in 1983 that met EM and other criteria.

Sites consist of 32 to 34 (10 x 10 m) quadrats separated by walkways (1.5 m) located in the most uniform portion of the overstory tree stand. Twenty-six quadrats at the test site and a similar number at the control site are reserved for long-term monitoring. Six quadrats at each site will remain undisturbed to provide a photographic record of physical conditions. Twenty quadrats will be used for sampling. The remaining quadrats (six at the test

site, eight at the control site) are not being used because surface and/or soil conditions do not conform with desired study characteristics (e.g., presence of boulders, low tree density). The non-conforming quadrats are interspersed throughout each site. Remote sensors and recording devices used to monitor ambient soil conditions are located in a central quadrat at both the test site and the control site.

Site Characteristics

Detailed surveys of tree and shrub populations were performed as part of a detailed vegetation mapping program. In addition to identification and mapping, density, frequency, and cover were also determined. Although some differences between sites were noted, sites generally did not differ to any significant degree.

Soil Characteristics

Soils at both sites are classified as Emmett sandy loams. With the possible exception of phosphorus, none of the major soil chemical parameters (pH, percent organic material, potassium, calcium, and magnesium) differed significantly between sites.

Ambient Monitoring

A set of remote sensors (soil temperature and moisture) and recorders were buried at three depths in a central quadrat at each site in August 1983. Due to equipment malfunction, however, no data were recorded during 1983.

4.2.6 Native Bees

Site Configuration

The megachilid bees are solitary in respect to their nesting activities. The mated female often makes use of a previously made hole in wood. Researchers use this need of a hole for nesting by drilling holes of varying diameter in blocks of wood and setting the blocks out in nature. The method is called trap-nesting and is used in this study. Nest blocks in units of nine are bound together, with four or five units per shelf placed on multi-shelved hutches. At present, hutches are placed in line but lateral to the

planned antenna corridor. Once the ELF Communications System is operational, hutches will be moved directly beneath the overhead antenna.

Site Characteristics

Two test and two control sites were selected for study. One test site is located on a flood plain with approximately two hectares of open area. The site is ideal for megachilids because it contains an abundant variety (88) of plant species suitable as pollen sources. The other test site is an upland area immediately south of Test Site 1. Although incomplete, a list of 33 plant species suitable for bee forage has been identified. County Line Control Site is approximately 15 kilometers from the ELF antenna. Both lowland and upland areas are represented. Over 41 species of entomophilous plants are present. The Channing Control Site is about 14 kilometers from the ELF antenna. On the basis of exposure criteria, this site is considered conditionally acceptable. Researchers plan to continue with this latter site but to attempt replacing it with another control site in 1984. A total of 73 entomophilous plants are known to occur on the site.

Ambient Monitoring

During 1983, ambient climatological parameters were monitored at one test site and one control site. These parameters included air temperature, relative humidity, solar radiation, rainfall, barometric pressure, wind speed, and wind direction. Data have been entered into a mainframe computer for analysis. Intersite comparisons of ambient parameters should be available during 1984.

4.2.7 Small Mammals and Nesting Birds

The two major criteria for pairing of study sites were similarity in composition/abundance of study species and suitable vegetation. The size of the plots was determined by projected sample size requirements for each study objective and the density of study animals at each site. During 1984, five candidate plot pairs was reduced to three site pairs. Changes in study design and locating of appropriately sized plots have left selection of permanent plots unresolved. Final selection of study sites will be determined in 1984. Additional EM characterizaton may be required because of the use of field enclosures for studies of nesting activities in small mammals.

4.2.8 Migrating Birds (Radar Tracking)

Site Configuration

The initial physiographic criteria used in the selection of a study site included a line-of-sight vantage point that would cover the ELF right-of-way as well as land distant from the ELF right-of-way, and a location free from nearby human activity (i.e., away from towns or heavily-traveled roads).

Site selection took place in late July 1983. The site selected is a former jack pine stand, recently clear-cut, with a regrowth of pines about 2 meters tall. The site is located south of an east-west corridor and east of the north-south corridor. Birds cannot approach the radar site (except from 100°) without flying over part of the right-of-way. This location does not, however, allow tracking of birds at a distance from the ELF antenna.

Ambient Monitoring

This study does not employ a test and control site arrangement, and therefore intersite comparisons are not made. Ambient monitoring consists of observations of local weather conditions that may have an effect on bird migration. Of primary interest to the study are wind speed and direction. Wind characteristics at height are monitored by tracking radar targets suspended from balloons. Surface winds are monitored using an anemometer.

4.2.9 Wetland Flora

Site Configuration

Primary factors used in the selection of sites were similarity of species, structural similarity of vegetation, density of vegetation, and environmental parameters (i.e., pH, conductivity, temperature, water table depth, and aqueous cations). Forty-five candidate sites were selected for visitation and preliminary observations were made. After culling of these sites based on the selective criteria and ordination analysis, 11 study sites were chosen for preliminary studies during the summer of 1983. During the fall the upland area surrounding one of the control sites was logged; a replacement control site will be found during 1984.

Study plots are 60 m long and 4 m wide, and are oriented parallel to the closest antenna element (WTF). Plots were located at each site in an area with representative vegetation for that site.

Site Characteristics

All of the study sites have an organic, relatively undecomposed peat substrate, low pH, low conductivity, and low cation water concentration. Sites are dominated by an overstory of black spruce and an understory of ericaceous shrubs and sedges.

4.2.10 Aquatic Biota

Site Configuration

In 1982, several tentative sites were selected, and data collection was initiated prior to final siting of the ELF right-of-way. After final siting, a riffle and pool section of stream was selected near the ELF corridor and similar sites were sought at upstream and downstream sites to serve as controls. After the ELF right-of-way was finalized in early 1983, researchers selected four such tentative sites on the Ford River. The Ford River is the only river crossed by the antenna without major physicochemical changes over the distance required for EM exposure criteria to be met. Most other streams in the ELF Communications System area have major inputs between possible test and control sites or are influenced by the local power system. Paired study sites on the Ford River were selected during 1983.

Site Characteristics

General physical characteristics used as criteria in the selection of study sites on streams included width, depth, shape, velocity, sediment particle size, and length of pools and riffles. The composition and dominance of riparian vegetation and canopy coverage of candidate study locations were also determined. Based on biotic criteria and most physical criteria, the selected Ford River sites were more similar than other pairings. The sites were less similar than other pairings for substrate particle size and pool/riffle length ratios.

Ambient Monitoring

Ambient monitoring consists of both continuous electronic monitoring of select physicochemical parameters and periodic sampling/analysis for select nutrients. Over the course of the study, investigators have monitored water quality conditions on three streams in the ELF Communications System area. Data for the Ford River have been partially analyzed for candidate site comparisons. No substantial differences were found between the selected test and control sites. Water parameter values typical of excellent water quality are suitable for most organisms sensitive to chemical pollutants.

5. REFERENCES

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APPENDIX A
WILDLIFE SURVEYS AT CLAM LAKE, WISCONSIN

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WILDLIFE SURVEYS AT CLAM LAKE, WISCONSIN

Wildlife surveys by the U.S. Forest Service were continued during 1983. Results do not indicate any effects from the ELF Communications System on the wildlife monitored. Background information on the wildlife surveys was presented in 1983.[2] Results of the 1983 surveys are summarized in this appendix.

DEER TRACT SURVEY

The deer tract method of determining a trend in the deer population within the general area of the ELF transmission lines was established in 1982 and censused again in 1983. Sixteen 2-mile transects were censused. Each transect was censused twice during August, with at least a one-week interval between censuses.

The average number of tracts per transect is somewhat less than in 1982. Because this is only the second year of the survey, a trend cannot be established.

TRAIL TRANSECT DEER POPULATION ESTIMATE

The ELF Deer Management Unit, established in 1974, was surveyed in early November 1983 using the same method used in previous years. The results of the suvey indicated a fall population of about 11 deer per square mile. In 1983, the Wisconsin Department of Natural Resources did not conduct a pellet or deer trail survey in either Deer Management Unit 13 or 14, the units that include the ELF Deer Management Unit. However, the Department sex-age-kill data for the 1982 fall population were estimated at about 12 deer per square mile for the area. There are many variables that impact the Trail Transect Survey. Weather seems to have the greatest impact on the results. Trail development does not seem to start much before the first heavy frost. This year the frost was very late; leaf fall was about the last week in October. The estimate of 11 deer per square mile is probably a little below the actual population.

BALD EAGLE NEST PRODUCTION

All known bald eagle nesting territories within the boundary or one mile outside the boundary of the Chequamegon National Forest were checked for activity in late March and for production in late May.

Twenty territories were checked; one territory was considered abandoned after being inactive for five years. Fifteen territories were classified as active, showing some degree of activity; six failed to produce young. The nine active territories that were successful in producing young produced 14 eaglets. The rate of production was 0.9 eaglets per active territory, slightly less than 1982 production.

Within a 10-mile radius of the ELF transmitter site there are five known nesting territories. Three appeared inactive; one showed some degree of activity but failed to produce young, and one produced one young. No new territories were located within the ELF system area this past year.

RUFFED GROUSE DRUMMING TRANSECTS

Seven ruffed grouse drumming transects were censused in late April and early May to determine the trend in the number of drumming male grouse along an established route. Transects were censused twice if proper weather conditions could be met during the census period. The largest number of drumming birds continues to be along those transects partially or entirely within the ELF Communications System area. Ruffed grouse are considered cyclic and are at or near the low population level in the cycle throughout northern Wisconsin.

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