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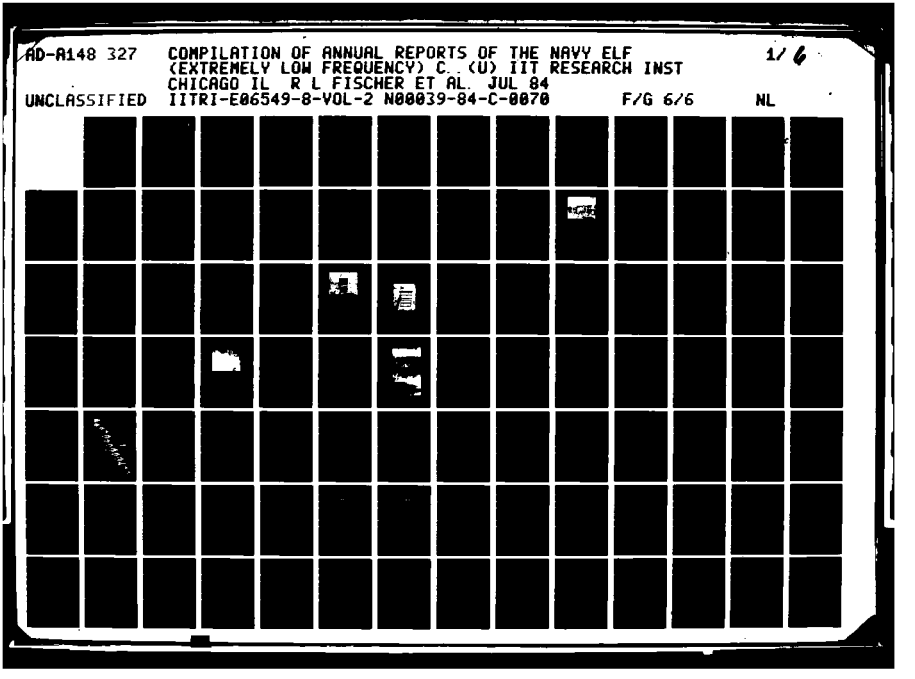

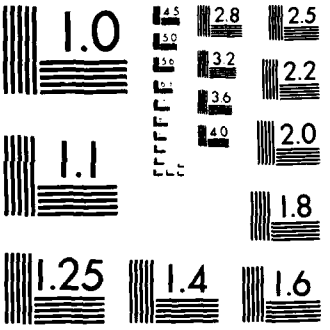

Technical Report E06549-8
Contract No. N00039-84-C-0070

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COMPILATION OF 1983 ANNUAL REPORTS OF THE NAVY ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM

Volume 2 of 2 Volumes: TABS F-J

July 1984

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A long-term program of studying ELF electromagnetic influences on ecosystems in northwestern Wisconsin and the Upper Peninsula of Michigan is being conducted. Selection of study sites, monitoring protocols, and analytical methods were initiated in 1982. Data collection was initiated in 1983. Progress is described for studying the terrestrial, aquatic, and wetland ecosystems for the 10 projects comprising the ecological monitoring program.

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Aquatic Ecosystems
Burton, T.M.; Merritt, R.W.; Stout, R.J.; Taylor, W.W.

Wetland Studies
Stearns, F.; Guntenspergen, G.; Keough, J.

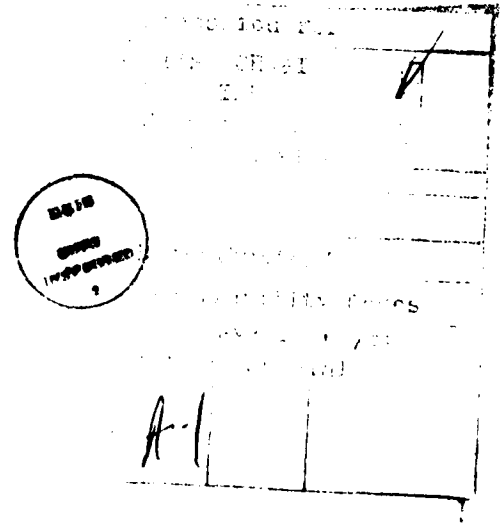
Field Studies of Effects of ELF on Migrating Birds
Larkin, R.P.

FOREWORD

This document is the second compilation of Annual Reports on the Extremely Low Frequency (ELF) Communications System Ecological Monitoring Program initially authorized under Naval Electronic Systems Command Contract N00039-81-C-0357, and being continued under Contract N00039-84-C-0070. IIT Research Institute, as coordinator for ELF ecology studies, has subcontracted for 10 monitoring projects with several universities and one state agency. This compilation summarizes the activities of those projects from November 1982 through December 1983.

The purpose of the ELF Ecological Monitoring Program is to assess the influence of electromagnetic fields associated with the ELF Communications System on major ecosystem components. Multi-year studies are planned. The first full year of pre-construction studies was completed in Michigan during this reporting period. The 1982-1983 period represents a continuation of operational studies in Wisconsin.

This document was printed from original copies of each principal investigator's annual report for 1983 without change or editing by either IIT Research Institute or the Naval Electronic Systems Command.



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J. Field Studies of Effects of ELF on Migrating Birds
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Frontis

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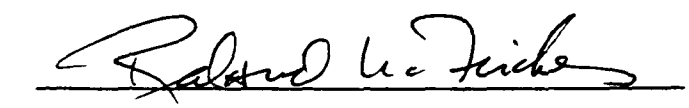

Roland L. Fischer, Principal Investigator
and Author of Report

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III. PREFACE

In the original proposal to conduct biological research on the megachilid bees the premise was made that many of their behavioral patterns are genetically imprinted in the species and as a result are somewhat stylistic by nature. There is however, a certain amount of variability within each species which allows for extrinsic factors to alter their normal or typical behavior patterns. Indeed, if this variability were not built-in to the system, the species would soon become extinct. These extrinsic factors could include numerous climatological factors, the lack of a particular species of plant in the immediate flight range or community of the bee, the lack of available nesting materials, or the lack of available nesting sites. Other extrinsic factors could possibly include human influences which might be beneficial or detrimental, depending largely on how drastic the change in the environment induced by man and the ability of the bee to adapt to any given situation. Another extrinsic factor brought about by humans could include electromagnetic waves given off by the ELF communication system. Theoretically, these might alter the bee's ability to orient to nesting areas or sites, their ability to survive under more or less constant exposures to the electromagnetic fields, or otherwise change their behavior patterns in nest architecture, pollen collection, or other nesting activity.

The research program was thus set up with a rather sophisticated ambient monitoring system to measure the climatic factors which were previously known to impinge upon the biological behavior patterns of the megachilid bees. From a scientific perspective the premise is still very sound--to monitor those factors in the environment which are either known to alter their behavior patterns or which are suspected of doing so. Thus, any serious alteration in behavior pattern, survival rate, or change in other ecological relationships between the bees and their environment might be ascribed to normally occurring phenomena within the natural environment by statistically testing

these parameters, either singly, in various combinations, or multiples. If these alterations cannot be explained on the basis of statistical analysis, further statistical testing of man-made influences such as ELF into the environment would have to be pursued.

Because of design changes made by the U. S. Navy over the past year in both the projected route of the antennal system and alteration from a partial under-and above-ground system to an entirely above-ground system our own experimental design has undergone some revision. Essentially the design change made by the U. S. Navy has eliminated one variable from our experimental plans--the underground cable system. Our current experimental design entails four sites--two in the immediate vicinity of the ELF antennal system (the experimental sites) and two approximating 13-16 kilometers distance from the cable system (the check sites). The two check sites would be far enough away from the ELF system to obviate any presumed electromagnetic influence upon the behavior mechanisms of the bees.

Four hutches (see Fig. 3), each with 20 nest blocks randomly distributed on the four shelves of the hutch, were positiond at each site. Each site thus had a potential of 180 nests per hutch or 720 per site. With four sites, 2880 potential nests would available for occupancy at any given time. To be consistent in terms of placement of the hutches at each site, two were placed in a North-South magnetic orientation and two were placed in an East-West orientation.

Once the ELF installation is in operation it is anticipated that equal time, effort and expenditure of personnel would be involved at each of the sites in obtaining data concerned with the biological ramifications of the several species of megachilids in each of the areas.

Because the bees are so dependent upon flowering plants each of the sites has been assessed both qualitatively and to a limited extent the more important pollen producing plants quantitatively to assure uniformity and similiarity between sites.

In the final analysis the data thus garnered on the some twenty more common species of megachilids of the area could be treated statistically at the species level, site, or lumped together on an "experimental" versus "check" plot area and an evaluation made as to possible causes of any deviations in biological phenomena. Among the statistical analyses which will be made are the following: T-test, rank correlation, correlation, simple one way analysis of variance, a dominance index, and co-occurrence index. When timed sequences of events occur and are possibly lumped together as units and are coupled with ambient monitoring data more sophisticated statistical analyses including nested analysis of variance, multiple regression, random processes, and canonical correlation will be made with the Cyber unit on campus.

One of the major problems with research work on univoltine species of insects is the fact that the data on behavioral habits obtained in the first season must await the following year and eventual emergence as adults to attain meaningful results. Until the Spring of 1984 and the eventual emergence of adult bees we will have no data on (1) overwintering mortality, (2) position of the sexes within the linear nests (note Fig. 1), (3) ratio of the sexes, (4) emergence dates of each sex, (5) rate of parasitism by kleptoparasitic bees or other parasitic insects, and (6) positive identification of the bee species involved with each nest. The latter (item 6 listed above) comes about with our working with a potential of over 20 species--containing complexes in the genera Megachile and Osmia which are virtually impossible to determine under field conditions. This problem may partially resolve itself with emergence and identification in the Spring of 1984 when we will have an assessment of species composition at each site.

IV. RATIONALE

The common honeybee, Apis mellifera, an imported species from Europe is thought to be the single most important pollinator of North American flowering plants. This is perhaps true of some species of flowering plants endemic to the Holarctic Region, or of differing species in North America which are closely related to others in Europe, to which the honeybee has adapted by coevolution through time for the collection of pollen and nectar. Our native American bees, of which there are about 3500 known species, have likewise coevolved through millenia of time with the native North American flowering plants. The adaptations of the bees for collection of pollen are unique and correlate with peculiarities of floral structure with native plants. These adaptations have evolved so distinctly that some native bees are known to restrict visitation to a single species of flower, a group of closely related species, or sometimes a group of closely related genera for which the term oligolectic is applied. The honeybee is a polylectic species, visiting flowers over a wide range of species whose nectar and/or pollen are readily available.

Overwintering studies on the honeybee would be excessively difficult to accomplish in the Upper Peninsula of Michigan because of the length of the winter period (days below 50°F.), extensive snow cover from mid-October through April, and excessive energy requirements for the bees to overwinter. The long period of temperatures below operable conditions for flight of the honeybee combined with snow cover negates the possibility for a cleansing flight of the honeybee during late winter period--the net result being the death of the colony!

The experimental site being situated in the heart of the contiguous Michigamme, Escanaba River and Ford River State Forests has not been disturbed by man's agricultural efforts as much as other areas of the U.P. where agriculture has continued over a period of years. Forage areas for honeybees have tended to be associated with

agricultural areas in the U.P.--near acreages of legumes and other cropping systems which have disturbed areas adjacent which has lead to a plant sucession and species of plants more conducive for honeybees to use as forage.

Apiarists in the U.P. have long been cognizant of these facts. Colonies are placed adjacent to agricultural lands where abundant forage potentials may be found, are killed in late fall, and the entire honey supply is harvested. From an economic aspect it is cheaper to begin the following season with purchased nukes from southern states than it is to attempt to overwinter the colonies and take the chance of them being dead when spring arrives.

For reasons outlined above, specifically: (1) that the honeybee is not native to North America and has not co-evolved with the native North American plants and as such are not the primary pollination agent of many plants found in the experimental site; (2) that the native bees have co-evolved with the North American plants and are thus far more efficient in their pollinating activities, with many of them being oligolectic; (3) that forage areas for honeybees in the experimental area are limited; and (4) that overwintering studies with the honeybee would be most difficult, our research efforts will be restricted to the basic biology of our native megachilid bees.

V. SCIENTIFIC APPROACH

A. GENERAL BIOLOGY OF A MEGACHILID BEE

The megachilid bees are solitary in respect to their nesting activities. The mated female may construct her own hole to make a nest by burrowing into the soil or a pithy plant stem, or make use of a previously made hole in wood such as an emergence hole of a beetle. Researchers have made use of this need for a hole in wood by drilling holes of varying diameters in wood and setting the blocks of wood out in nature in propitious places. Other techniques have included soda straws, hollow thatch, or pithy stems. The method is generally referred to as "trap-nesting."

The selection of type of nesting material and whether the hole is previously present is dependent upon the species of bee. Once selection of a proper nesting site has been made the female may clean the burrow of miscellaneous wood chips or other extraneous material. In some cases, salivary secretions may be applied to the burrow walls to further smooth them. In some members of the genus Megachile the female then departs to the field and gathers round sections of leaves which she cuts out with her mandibles and layers these in the bottom of the bore. In other species of megachilids resin, sand, soil, small pebbles, masticated leaves, plant down or mixtures of the afforementioned materials may be used. In some members of Megachile the tunnel is then lined with oblong pieces of leaves, while other megachilid species do not line their tunnels. In any case, a "cell" is delimited by the female bee (Fig. 1). Whether the cell wall is lined or not and the plant species used for these construction processes depends largely upon the species of bee involved. The time of the season and geographic area in which observations are made are obvious alterable factors for either a species of long longevity or of wide ranging geographic distribution.

With the completion of the preparation of a cell the female bee abruptly changes her activity pattern to one of foraging for pollen and/or mixtures of pollen and nectar.

Repeated trips are made to the field for gathering of pollen -- if oligolectic, from only a single species of flowering plant and assuring a high percentage of cross-fertilization of the plant; if polylectic, from a variety of plant species. When these pollen stores have reached an optimum the female bee lays an egg on the provisions and then commences to seal-off the cell with a cell partition leaving enough room for the developing larva to increase in size and complete its development. The cell partition is composed of the same material as was used at the bottom of the bore.

The entire process of cell construction and provisioning may be repeated several times along the length of the tunnel bore in a linear arrangement. Although there is a wide variation in the numbers of cells produced it is usually dependent upon the length of the original tunnel bore. A vestibule cell is sometimes formed between the last provisioned cell and the nest cap. The nest cap is constructed of the same materials as are cell partitions for the species but is usually much longer in total length. After completion of the nest cap the female abandons the nest and may seek out another suitable hole in which to begin another nest.

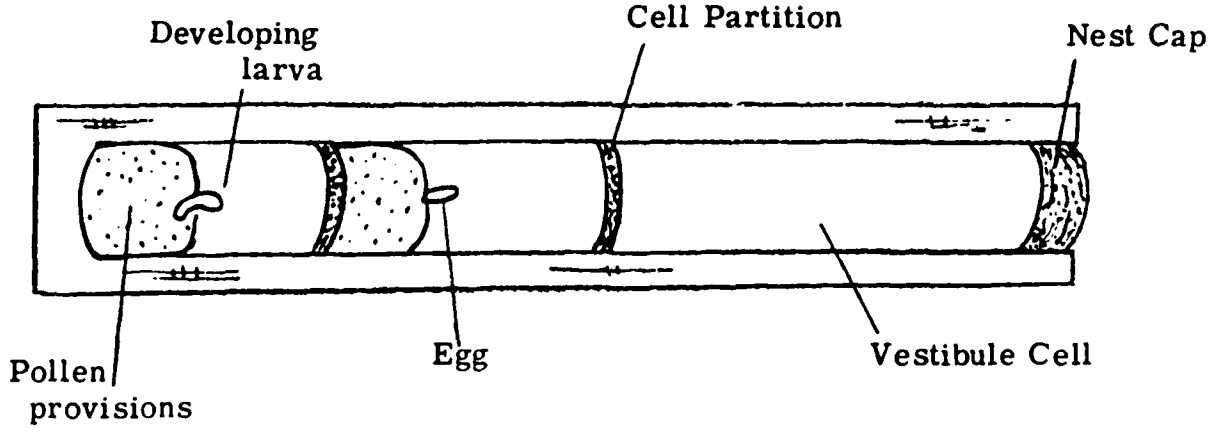


Figure 1. Longitudinal section (schematic) of a megachilid bee trap nest illustrating terminology used in text.

Environmental parameters play an important role in the length of time for any of the elucidated gathering procedures. Among the more important are ambient temperature, relative humidity, precipitation, barometric pressure, solar radiation, and wind velocity. Since these animals are poikilothermic their activities are largely governed by the ambient air temperature. Interruptions by rainfall and attendant changes in barometric pressure could also bring about changes in behavior. Bees are sensitive to changes in solar radiation so they may not be as active on a dull day versus a bright sunny day. Any of the above listed parameters could have a direct influence upon the behavior mechanisms of the bee resulting in marked differences in nest architecture, pollen collection, plant preferences, or other behavioral parameters. By correlating environmental factors with nest architecture or events in the biology of the native bee by statistical methods it could be possible to pinpoint the causal agent or demonstrate relationships.

B. TRAP NESTING METHODOLOGY

In the study site area five genera of megachilid bees are known to occur which are commonly found in trap nests. These include Osmia, Hoplitis, Megachile, Coelioxys, and Heriades - represented by 40 species. Of these 40 species, 15 are reported in the literature to occur in trap-nests, an additional eight species of Osmia possibly occur in trap-nests, five are ground nesting, one constructs its own nests in pithy plant stems, and six species of Coelioxys are kleptoparasitic in the nests of other megachilid bees.

Nesting blocks of select white pine (19 X 19 X 153 mm) were bound together in units of nine. Holes of varying diameter were drilled lengthwise of each block and randomly arranged in the pattern shown in Figure 2. The binding in units has been shown by the principal investigator to allow for easy manipulative handling, observation, recording of data, removal upon completion of the nest, and winter storage.

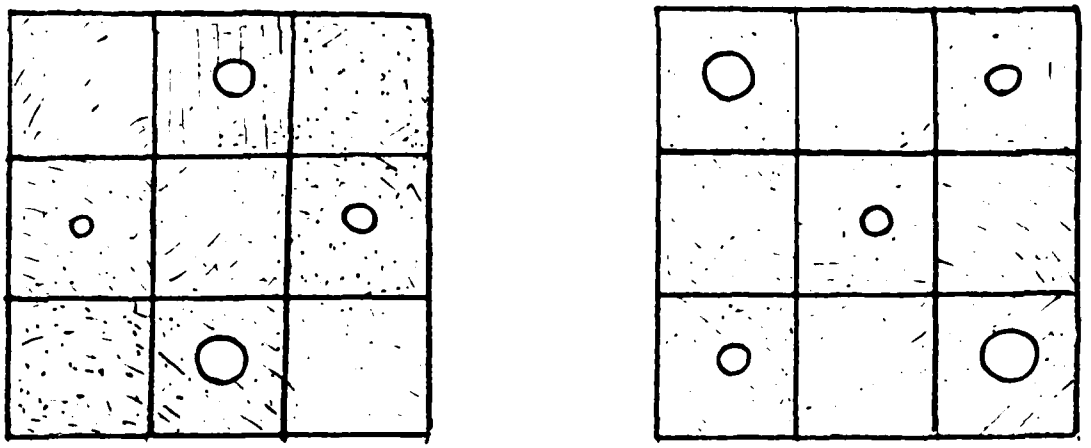


Figure 2. Schematic diagram illustrating opposing end views and random arrangement of varying size bores.

The assembled units were then placed in a randomized pattern, with four or five units per shelf, on shelves of the hutches. Construction of a 4 shelved hutch is shown in Figure 3. The randomized pattern attempts to eliminate problems with homing and the return of the bee to the proper nest. Placement of the hutch in the environment is a critical factor - semi-open areas with abundant flowering plants suitable for the leaf-cutting bees involved, other plants used by the bee in nest construction, and availability of other nesting materials being the more important.

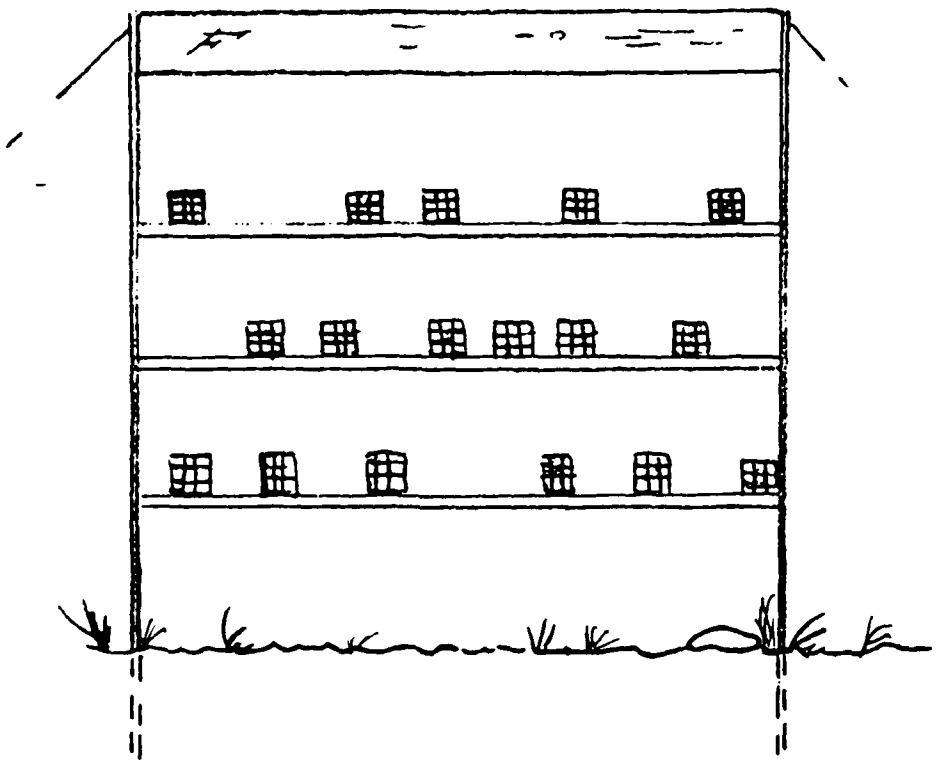


Figure 3. Side view of hutch construction and placement of nesting blocks.

C. OBSERVATIONS ON NESTING ACTIVITY

Data were obtained as to date and time at which a nest was founded and eventually completed. Daily records were kept on the progress in the nesting cycle for each nest.

A selected number of nests were monitored by the investigative team (Fig. 4) by visual observation to generate the following types of data:

1. Numbers of trips required to provision with pollen for each cell.
2. Intervals of time necessary to unload and arrange pollen within each cell.
3. Numbers of trips to secure building materials for cell partitions.
4. Intervals of time between trips in 3 to construct cell partitions.
5. Time required for egg deposition for each cell.
6. Numbers of trips to secure materials for capping the nest.
7. Intervals of time between trips in 6 above to construct the nest cap.

Figure 4. A member of the investigative team, Adam Porter, observing and recording data on nesting behavior of megachilid bees at the Ford II site.

Since data on field activity of megachilid bees concerning their nesting activity is probably the element most lacking in all previous published literature the decision was made to concentrate some of our efforts on this aspect of the project. A team of five people were trained in techniques of watching leafcutter bees as they went about their business of nest construction and provisioning. Close to 1600 man-hours of time were expended in watching, recording, and determining activity patterns of various species of Hoplitis, Megachile, and Osmia. This has amounted to some 15,000 timed events as broadly outlined above in the life history of the bees. Some 4000 visual observational notes which include incidences of marauders, parasitoids, usurpation, sunning activity, etc., were also recorded.

Each of these events are being scrutinized, categorized, and more closely defined into subsets of data approximating 50-75 letter symbols suitable for entry into the

computer. When these informational data are converted to a computer readable format it is anticipated that some 50,000 bits of information will be available for statistical analysis.

All events outlined above in the life of the bee were recorded both in actual elapsed time intervals and also standard time (CDST). Thus, should some aberration occur in bee activity it could be correlated with some event as recorded by the environmental monitoring system, or statistically analyzed to determine any causal affect brought about by the ELF installation.

Hutches were positioned at all sites in a North-South or East-West magnetic position--the trap-nests would thus respectively face in an East-West or North-South direction. Two additional parameters could eventually be analyzed statistically at each of the test sites and compared with control sites--the possible affects of the electromagnetic waves emanating from the ELF system when nest blocks are oriented in a parallel fashion with the wires of the system (the East-West hutches) or perpendicular to the wires of the system (the North-South hutches).

A complicating factor is the position of the sun and the facing of the trap-nests. All East-facing blocks receive only morning sunlight, South-facing mid-morning to mid-afternoon, West-facing mid- to late-afternoon, and North-facing no direct sunlight. Perhaps the bees, given the opportunity, may prefer to face a particular direction over another. Possibly, these preferences, if any, may be inherent within the species.

Data on the distribution of Osmia and Megachile nests at each site are presented in Tables 1 and 2; an "all sites" summary of the total numbers of nests constructed on each of the four shelves and hutch faces, is provided in Tables 3 and 4. The complex of species comprising both genera at the sites has yet to be determined; therefore the tables partiton data only to generic level. Field identification of Michigan megachilids is possible only in a few instances. Since we did not want to sacrifice or disturb the nidificating adults at our sites, the task of identificaiton was deferred to the winter of

83-84 in the case of Osmia, and to the spring and summr of '84 in the case of Megachile. It was deemed wiser in terms of fulfilling the goals of the project to gather as much behavioral data as possible on the species being observed, establishing at a later data the specific identity of the bee through the determination of its offspring. Analysis and subsequent study of the 1983 data on behavior and nest architecture for the various bee species will, in many cases, facilitate accurate field identification in the forthcoming season.

A perusal of Tables 1 and 2 suggests that there are some species in both genera that prefer to establish nests on certain shelves (i.e., at a certain height above the ground): 40% of the Osmia nests were constructed on shelf 1 (about 1 meter above ground level), and over 50% of Megachile nests were constructed on shelf 4 (about 1 decimeter above ground level). Indeed, two species of Osmia whose nests we can identify with certainty (O. lignaria and O. subaustralis) were found to exhibit marked preferences for shelf height: of 11 O. lignaria nests 9 (81.8%) occurred on shelf 1, and the remainder on shelf 2 (18.2%). All of the 12 O. subaustralis nests (100%) were built on shelf 4. Though all O. subaustralis nests were established on the south faces of the hutches, the hutch face data in Tables 3 and 4 do not suggest that any particular face was preferred by the majority of the bees.

Table 1 Summary Of Completed Megachile spp. Nests By Shelf Number At Various Sites In 1983

SITE	Shelf 1	2	3	4	total
Ford I East					
N	5	2	3	16	26
S	3	-	3	7	13
E	2	2	3	14	21
W	1	1	5	24	31
	11	5	14	61	91
Ford I West					
N	1	1	3	11	16
S	2	1	2	11	16
E	3	2	-	6	11
W	3	5	4	9	21
	9	9	9	37	64
Channing South					
N	-	1	1	2	4
S	2	-	1	7	10
E	1	-	-	5	6
W	1	-	1	3	5
	4	1	3	17	25
Channing North					
N	-	-	1	2	3
S	-	-	1	4	5
E	-	2	-	2	4
W	-	-	4	6	10
	0	2	6	14	22
County Line					
N	6	1	2	7	16
S	-	2	2	-	4
E	5	2	3	8	18
W	4	2	2	4	12
	15	7	9	19	50
Ford II East[1]					
N			4	2	6
S			3	-	3
E			2	2	4
W			2	-	2
			11	4	15
Ford II West					
N	-	1	-	-	1
S	-	-	1	1	2
E	-	-	3	1	4
W	-	1	5	1	7
	0	2	9	3	14
TOTAL	39	26	61	155	281

[1]Shelves 1 and 2 were available at this site.

Table 2 Summary Of Completed Osmia spp. Nests By Shelf Number At Various Sites In 1983

SITE	Shelf 1	2	3	4	total
Ford I East					
N	1	1	1	1	4
S	2	-	-	12	14
E	2	1	-	-	3
W	1	3	1	1	6
	6	5	2	14	27
Ford I West					
N	-	1	1	-	2
S	1	1	-	1	3
E	1	1	-	-	2
W	-	1	-	1	2
	2	4	1	2	9
Channing South					
N	4	2	-	-	6
S	3	2	-	2	7
E	1	2	-	1	4
W	3	3	-	-	6
	11	9	0	3	23
Channing North					
N	1	1	-	-	2
S	1	2	-	-	3
E	4	4	1	-	9
W	3	3	-	-	6
	9	10	1	0	20
Sagola[1]					
N	3	1	-	-	4
S	-	-	1	1	2
E	4	-	-	-	4
W	2	1	-	-	3
	9	2	1	1	13
TOTAL	37	30	5	20	92

[1] The Sagola site was discontinued on 20 July 1983.

Table 3 Summary Of Completed Megachile spp. Nests For All Sites By Shelf Number And Nest Orientation For 1983

	Shelf				
	1	2	3	4	TOTAL
Numbers Of Nests	39	26	61	155	281
%	13.7	9.8	22.1	54.4	100

	Nest Facing				
	North	South	East	West	TOTAL
Number Of Nests	72	53	68	88	281
%	25.6	18.9	24.2	31.3	

Table 4 Summary Of Completed Osmia spp. Nests For All Sites By Shelf Number And Nest Orientation For 1983

	Shelf				
	1	2	3	4	TOTAL
Number Of Nests	37	30	5	20	92
%	40.2	32.6	5.4	21.7	99.9

	Nest Facing				
	North	South	East	West	TOTAL
Number Of Nests	18	29	22	23	92
%	19.6	31.5	24	25	100.1

A total of 44 nests of various leafcutter bees were observed partially during the formation of a nest and an additional 26 were observed from founding a nest to completion. These data are summarized on Table 5. These kinds of data are extremely important for they allow us to determine the normal sequence of events in nest founding, provisioning, capping of cells, and eventual completion of a nest. In addition, activities associated with both pre- and postnesting behavior patterns may be ascertained.

In several instances data were obtained on marked bees through several successive nesting cycles. For Osmia lignaria, two different bees were observed through a partial nest and completion of a second. In one instance the same bee was observed through the completion of the first nest and completion of four additional nests within the time span of June 14 through June 26. The last nest in the sequence was abandoned by the bee. During this time span marked changes occurred in her activity patterns as compared with earlier season timed events and represent senility changes in her neural-muscular system. Considering the time span, the abandonment of the last nest before completion, and evidence of a senility our observations for this particular bee probably represent a greater portion of the adult life span of the bee.

Similar observations were made on three different individuals of Osmia subaustralis. One bee was observed for two nesting cycles, and the other two for four nests each. Time spans ranged from June 24 through July 17. The latter two probably represent the greater portion of the adult's life span.

One additional Osmia sp. was observed through two nesting cycles.

In the genus Megachile 9 bees were observed through two nesting cycles, 2 through three, and a single bee through four nesting cycles. Two different females of Megachile inermis through two nesting cycles at the end of the season (August 18-30) also exhibited senility pattern changes.

Table 5 Numbers Of Nests Of Various Megachilid Taxa On Which Nesting Observations Were Made In The 1983 Season

-	Partial Observations on a single nest	Complete Observations on a single nest
Megachile spp. (excluding M. inermis)	23	12
Megachile inermis	2	3
Hoplitis albifrons	2	--
Osmia spp.	5	1
Osmia lignaria	3	6
Osmia subaustralis	9	4
TOTAL	44	26

With the founding of each nest the female bee was marked in such a manner that she can be recognized either at the nest site or in the field at some distance from the nest. Some records were attainable on flight range, flowers visited for nectar, flowers visited for pollen, and in a few instances the source and activity mechanisms involved in the acquisition of cell partition and capping materials.

With the approach of Fall and cessation of field activity the nests were stored in boxes constructed to fit the shelves of the hutches (Figs. 5 and 6). This hopefully affords some protection to prevent marauders such as bears, blue jays, flickers, rodents and other mammals from destroying them for food. Two large screen vents were placed at the ends of the boxes to allow for circulation of air.

All nests, whether opened or not, were individually placed in 100 ml plastic centrifuge tubes and the ends closed with very fine mesh nylon by means of a rubber band. The box itself is thus exposed to rain, accumulation of snow, and alternate freezing and thawing of the winter elements--in a sense a log which might be the natural habitus of the bees but at the same time affords some protection from excessive amounts of moisture seeping between the nest blocks and the possibility of mold killing the inhabitants.

Nests of Osmia and Hoplitis were opened in September and October and nest architecture data were recorded. The overwintering nests of Megachile will be split open in late April or early May of 1984 to ascertain similar data. Megachile nests will be opened at periodic intervals to note progress toward adulthood, time and duration of pupation, the inhabitant of each individual cell will be sexed, and upon emergence as an adult the animal will be marked and released at the nest site from which it originated.

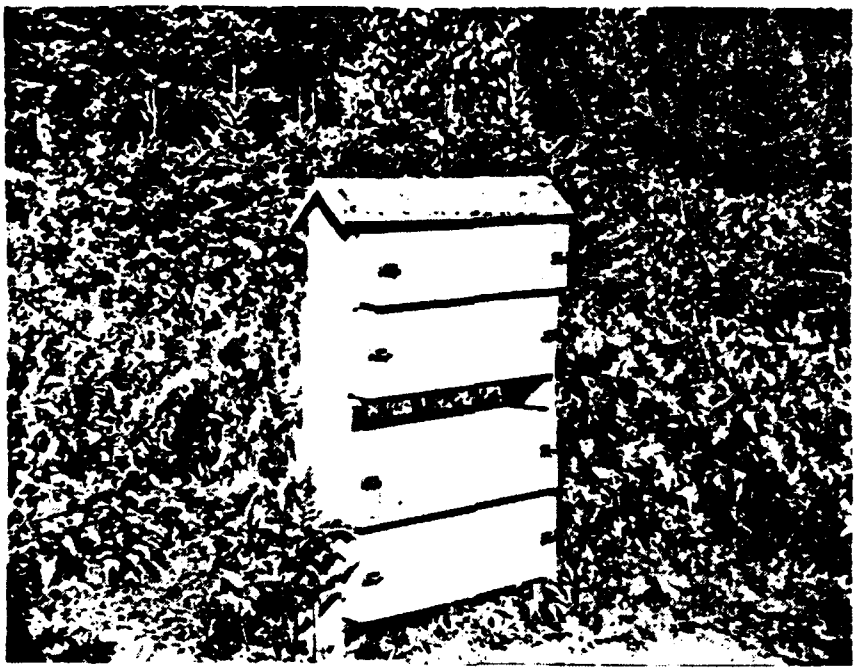


Figure 5. A hutch with boxes in position and closed for overwintering.

Selected adult specimens from each of the nests will be retained for later taxonomic verification as to the species and mounted in the usual manner for museum purposes. In addition to the usual date-locality label additional labeling would include a distinctive color label noting that it was part of project ELF and include a nest number, cell number, emergence data, and plot locality. These specimens will be placed in the Entomology Museum of Michigan State University for permanent deposition as voucher specimens.

It should be emphasized for conclusion of this section of the report that the data on behavior mechanisms cannot be fully utilized or analyzed until the Summer of 1984. Behavioral data are currently being categorized into a subset system of letter symbols applicable for entrance and retrieval from the computer for later analytical techniques. This likewise connotes the necessity of rewriting of computer programs. Such events as

emergence dates, overwintering mortality rates, sex ratios, position of sexes in linear nests and most importantly the species involved with each nest are unknown at this time and will remain so until the Spring and Summer of 1984. Once emergence of adults occurs in 1984 when positive identification for each of the nests can be made can analysis of data begin!

Figure 6. A hutch with overwintering boxes in position but with covers removed to illustrate nests enclosed in centrifuge tubes.

VI. AMBIENT MONITORING

A. INTRODUCTION

During the initial years of this investigation, it is desired to establish a data base on the unperturbed natural biological, environmental, and climatological phenomena and processes which occur in the study area. Only by comparison with such a reference data base can ecological responses to potentially disturbing influences be detected and evaluated. A discussion follows of the methodology for the acquisition of ambient environmental measurements to establish such a reference data base, and later to provide initial environmental data for analytical correlation with the studied ecosystem's reactions, if any, to ELF influences.

Two field instrumentation modules (Model Ti-5X, custom configured by the Instrumentation Division of Eco-Tech, Inc.) were purchased for automatic monitoring. These units were assembled in ruggedized, environmentally "hard" enclosures for extended field use. Due to the nature of the ELF experiments, all electronic sensing equipment is battery operated. Further, the instrumentation clusters were configured to be immune to ELF fields, and also to exhibit negligible EM radiation from instrumentation equipment and cabling.

Ambient environmental data acquired via the monitoring systems is compatible with our data management plan. A custom-configured and programmed microcomputer was operated at our field Laboratory for data entry, consolidation, preview, and preliminary analysis.

The relevant ambient environmental conditions which were monitored and recorded via the automatic Model TI-5X instrumentation modules during the active period of summer field investigation are listed in Table 6, below.

Table 6. Automatically Sampled Ambient Environmental Parameters

	Parameter	Sensor	Frequency
1)	Ambient Air Temp	Thermistor	10 mins.
2)	Relative Humidity	Elec. sensor	10 mins.
3)	Solar Radiation	Pyranometer	5 mins.
4)	Rainfall	Tipping bucket	10 mins.
5)	Barometric Pressure	Solid State sensor	5 mins.
6)	Wind Direction and Speed	Anemometer	10 mins.

The instrumentation modules were placed in an open area in the immediate vicinity of the experimental nesting sites. At each sampled location, the six parameters were monitored and logged by a TI-5X instrumentation module which contain three separate two-channel and one single channel solid state data loggers (Omnidata Datapods). These logging devices were installed in a camouflaged weatherproof enclosure installed at ground level (to discourage vandalism). The logging systems are each capable of storing 1023 sets of readings on a removable data storage module (EPROM). The systems operate on internal batteries (8AA cells) and two 12 volt auto batteries for at least two continuous months. The site microcomputer was outfitted with a data storage module reader for data transfer. The data storage modules are erasable and reusable indefinitely. Data were transferred to discs, a copy made and sent to Eco-Tech for entering on the Cyber at Michigan State University.

One module was placed at the Channing site (control site) and the other at Ford I site (experimental site). It should be pointed out that in addition to the actual logging of

data that actual time (CDST) was simultaneously recorded. Likewise, all field observations by project personnel were similarly recorded as to actual time. Thus, any single parameter, or any multiple set of factors may be statistically analyzed for affects on bee behavior patterns for a given time scale. Any deviation in the bahavior pattern of a bee from the "norm" may be similarly analyzed. From the standpoint of the project the methodology enables us to examine the normal environmental parameters which impinge upon the behavior and life of the bee as well as those which may possibly be induced by outside sources such as ELF. At the end of the 1983 season some 155,520 bits of information monitored and logged by the ambient monitoring system have been entered into the Cyber.

Ambient Air Temperature and Relative Humidity

Air temperature and relative humidity were monitored by a General Eastern R. H. and Temperature Transmitter Model 455. Eco-Tech's experience with several similar R. H. temp instruments has shown this particular device to be reliable, accurate, and compatible with the lo-power consumption, battery-operated scheme. The sensors were installed in a USWS "cotton-region type" enclosure with double roof, louvered sides and slatted bottom. Air temperature and relative humidity were recorded at 10 minute intervals.

Solar Radiation

Incident solar energy was sensed by a Li-Cor Model LI-200S pyranometer. The Datapod logging device samples the sensor value every 5 minutes.

Precipitation

Rainfall was monitored by a Weathertronics Model 6010 tipping bucket rain gauge. This device produces a momentary closure of a mercury switch for each 0.25 mm or 0.01 in. of accumulated rainfall. Each switch closure triggers the data logging device to store the time (to the nearest minute), thereby recording rate as well as total rainfall. During the winter months, data for precipitation and accumulation may be obtained from the U.S.A.F. weather station at K.I. Sawyer AFB near Gwinn, Michigan.

Barometric Pressure

The local barometric pressure was monitored by a Weathertronics Model 7115 solid state barometer. The analog pressure sensor is mounted in the same instrument shelter used for air temperature and relative humidity. The sensor output was sampled and recorded every five minutes.

VII. SITE SELECTION

The most frustrating aspect of the research project has been the selection of sites at which we will be conducting our field observations. Since our experimental design entails two sites in the immediate vicinity of the ELF system and two additional sites some 13-15 kilometers distant from the system we were restricted in our attempts to locate sites to the immediate vicinity of the antennal system and areas West of the antennal system. Areas East of the antennal system are too far distant from our base of operation in Channing, Michigan, for any area which might possibly be involved in the study would require an additional 60-75 kilometer round trip to sites on a daily basis.

Another paramount problem area for site selection involves the nature of the current plant cover. Much of southern Marquette County through which the antennal system will traverse has sandy soil and has a vegetation cover of Sweet Fern, Comptonia asplenifolia. The area has been managed in the past for grouse cover by the Department of Natural Resources. As a grouse cover it may be excellent, but as a native bee forage area it is worthless! The area contains but few isolated flowering plants for megachilid use.

Many of the other areas of both Dickinson and Marquette counties applicable to this study contain solid forested stands of several species of Aspen and/or Pine--unfortunately several years old and as a consequence canopies of trees have shaded the ground cover to such an extent that no open areas conducive to flowering plant growth are available. Thus, again, no bee forage plants.

We have literally traversed the entire proposed 90 kilometers of the antennal system by auto and much of it on foot to find suitable sites. We have, in addition, attempted to pin-point what might be suitable sites by resorting to aerial photos, vegetation cover maps, topographic maps, and by conferring with Conservation Officers in the area.

The critera for any site include the following:

1. A proper mix of flowering plant species conducive to megachilid forage. This mix of plants should contain many of the plant species found in List 11. The plants should also be represented in abundance enough to sustain a sizeable population of bees.

2. Given the fact that the monitoring program will extend for 5-6 years the area should remain relatively undisturbed for the duration of the program and should have an abundance of open areas to prevent overgrowth by tree canopy encroachment.

3. There should be some evidence of possible nesting sites for the bees in the area. Generally, since we are dealing with an area largely managed as a State Forest and is under a controlled cropping system for lumber, this would take the form of old logs, snags, and debris left after a logging operation. But generally five to ten years prior to our operation to have allowed beetles, such as buprestids and cerambycids, to have made their galleries in the wood for later use by the bees.

4. In addition to the biological requirements of the bees as defined above the following criteria for electromagnetic exposure at study sites were established in requests for proposals by IITRI:

> "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 still exist for magnetic field components between test and control plots. Electric and magnetic fields in air and earth produced by other ELF sources (e.g., power lines) shall not differ by more than one order of magnitude between paired test and control plots, and at test plots should be at least one order of magnitude below the fields produced by the ELF system."

It is also desired that the fields produced by the ELF system at the test site are at least an order of magnitude higher than the 60 Hz fields (e.g., power lines) at both the test and control sites. This is a criterion which we obviously have little control over, other than to locate our potential sites some distance from power lines, telephone lines, and buried pipe lines which may possibly induce such electromagnetic fields. On two occasions (May 25 and July 13, 1983) IIT Research Institute engineers conducted ELF

electromagnetic field tests of six potential sites. The results of the tests were received in early September, 1983, and are summarized in Tables 7 and 8. The pairings of Ford II (an experimental site) with County Line (control) were acceptable; pairings of Ford I with Channing II (control) were marginal; all others were not acceptable. As a result we will be looking, once again, for an additional control site in the Spring of 1984!

5. Our field experience this past season has shown that with the most favorable of weather conditions that some of the bees are ready to begin activity at 8:00 AM and work through the day until 8:00 PM, (CDST). If we add the bee activity time of 12 hours to a potential of two hours of travel time, round trips to site and return to our Channing laboratory, to some distant site we have a human work time period of 13-14 hours a day in the field. This is obviously unmanageable. As a result, our sites hopefully will be near to Channing to decrease wasted travel time.

6. Since sites are visited during good weather on a daily basis or have field personnel remaining on site during the entire day the site must be readily accessable after periods of inclement weather.

7. We would prefer that our sites not be visible from any main road--we have costly monitoring equipment which remains in the field as well as considerable time and effort involved with data taking to have human interference or molestation to disrupt our research efforts.

TABLE 7

ELECTROMAGNETIC FIELD INTENSITIES
AND FLUX DENSITIES (1)

SITE NO.	MEAS PT	TRANSVERSE ELECTRIC FIELD (IN THE AIR) INTENSITY (V/m)		LONGITUDINAL ELECTRIC FIELD (IN THE EARTH) INTENSITY (mV/m)		MAGNETIC FLUX DENSITY (mG)	
		MEASURED 60 Hz	ESTIMATED 76 Hz	MEASURED 60 Hz	ESTIMATED 76 Hz	MEASURED 60 Hz	ESTIMATED 76 Hz
2T1	1	<0.001	2.0	0.23	55.	0.001	3.5
2T2	1	<0.001	120.	0.071	85.	0.002	30.
2C1	1	0.045	<0.001	6.5	1.	0.023	<0.05
2C2	1	0.018	"	1.8	"	0.007	"
2C3	1	0.14	"	0.12	"	0.004	<0.1
2C4	1	<0.001	"	0.011	"	0.004	<0.05

1) Values shown are magnitudes determined as the square root of the sum of the squares of the orthogonal field components measured. Data listed for Estimated 76 Hz is based on theoretical analyses using the proposed location and operating conditions of the antenna elements along with the distance to each measurement point.

TABLE 8

FIELD INTENSITY RATIOS (1)

COMPARED SITE NO.S	TRANSVERSE ELCTRIC FIELD (AIR)				LONGITUDINAL ELECTRIC FIELD (EARTH)				MAGNETIC FIELD			
	R1>=10.	R2>=10.	R3>=10.	0.1<R4<10	R1>=10.	R2>=10.	R3>=10.	0.1<R4<10	R1>=10.	R2>=10.	R3>=10.	0.1<R4<10
2T1/2C1	>2000.	>2000.	>40.	<0.02 *	55.	240.	9.6*	0.04 *	>70.	3500.	140.	0.04 *
2T1/2C2	"	"	>120.	<0.06 *	"	"	31.	0.13	"	"	490.	0.14
2T1/2C3	"	"	>20.	<0.01 *	"	"	460.	1.9	>35.	"	875.	0.25
2T1/2C4	"	"	>2000.	1.0	"	"	5000.	21. *	>70.	"	875.	0.25
2T2/2C1	>100000.	>100000.	>40.	<0.02 *	85.	1200.	12.	0.01 *	>600.	15000.	1400.	0.09 *
2T2/2C2	"	"	>120.	<0.06 *	"	"	48.	0.04 *	"	"	4200.	0.28
2T2/2C3	"	"	>20.	<0.01 *	"	"	720.	0.60	>300.	"	7500.	0.50
2T2/2C4	"	"	>2000.	1.0	"	"	7800.	6.5	>600.	"	7500.	0.50

= Test Site (76 Hz) / Control Site (76 Hz) R1 >= 10.
= Test Site (76 Hz) / Test Site (60 Hz) R2 >= 10.
= Test Site (76 Hz) / Control Site (60 Hz) R3 >= 10.
= Test Site (60 Hz) / Control Site (60 Hz) 0.1 <= R4 <= 10.

the event that a range of values is listed for any given ratio:
High Limit ---> Maximum Numerator Value / Minimum Denominator Value
Low Limit ---> Minimum Numerator Value / Maximum Denominator Value

s not meet the exposure specification.

DESCRIPTION OF SITES

FORD I SITE. The Ford I site (Fig. 7) is a flood plain situation and occurs on the North side of a bend in the Ford River. It approximates two hectares of open area, bounded on the North by a Red Pine plantation and along the river by mature Balsam Poplar, Populus balsamifera; Black Ash, Fraxinus nigra; and Tag Alder, Alnus rugosa. Ostrich Fern, Mattericcia struthiopteris, is very common in damper shaded areas along the raised river bank. The site is ideal for megachilids for it contains an abundant variety of plant species suitable as pollen sources. The 88 possible pollen sources are given in Table 17, plant species for which quantitative phenological data were obtained in Table 18 and Table 19, of which selected plant phenologies are depicted in Fig. 10. the site is in direct line with the proposed ELF installation and is intended to be used as one of the experimental sites with hutches, once ELF is operational, moved directly beneath the wires of the project. Hutches were put in place on May 19, 1983, and removed at the end of the season on September 17, 1983.

FORD II SITE. The Ford II site is an upland area, approximately one-half kilometer South of Ford I and the Ford River. The area has been selectively cut over several years prior to this study. It is traversed with numerous old trails which are inaccessable because of the construciton of berms. As a result the trails have been invaded by native plants which are suitable for bee forage. The cut over areas were seeded with mixtures of Alsike Clover, Trifolium hybridum, Red Clover, Trifolium pratense, and White Dutch Clover, Trifolium repens, which formed the main ground cover after cutting. This ground cover is rapidly disappearing on higher ground with exposed sandy areas very common and more xeric species of plants have begun to invade. Note Fig. 8 for a general conspectus of the site.

Figure 7. General conspectus of Ford I Site looking West.

We have some reservations concerning the site, although it appears to be ideal for megachilids, for it may be difficult to reach in early Spring. From the South it may be reached by auto over approximately 10 kilometers of rough road which is possibly under water in early Spring or washed out--perhaps the road should be more aptly termed a "rough trail." From the North, our usual approach in mid-Summer, has been by fording the Ford River and walking in to gain access to the site. Since the site was not set-up until late July, we know nothing about the height of the river in late May or early June. We may have to resort to a boat or raft to gain access to the site during periods of high water.

The site is intended to be used as our second experimental site and, once the ELF installation is operational, the hutches would be moved directly beneath the wires of the antennal system.

A list of some 33 plant species suitable for bee forage is found in Table 20. It should be pointed out, however, that the list is far from complete for it lacks the vernal and early Summer species of plants.

COUNTY LINE SITE. The County Line Site (Fig. 9) was selected in mid-June so again our list of potential pollen sources is not complete for we lack the vernal species. The site is approximately two kilometers from our Channing Laboratory and 15 kilometers from the ELF installation. Hutches were placed on the site on June 28, 1983, and removed at the end of the season on September 17.

The site is quite varied with both lowland and upland areas represented. The flowering plants are likewise extremely varied with an abundant variety of mid-summer plant species. A list of 41 known entomophilous plants may be found in Tables 15 and 16. It is intended to be used as one of the control sites for it appears to be an ideal site for leafcutter bees.

CHANNING SITE. The Channing site is located immediately South of our main laboratory facilities. The area has been selectively cut for timber and is bounded by a

dense conifer forest. The area was intended as a control site. One set of ecological monitoring equipment was set-up on this site in 1983 and was to be used as a companion study of weather factors with the Ford I site. Unfortunately the site is considered as marginal on the basis of electromagnetic field intensities. We plan to continue with the site in 1984 until such time that it can be replaced and the new site tested for electromagnetic intensities.

A total of 73 entomophilous plants are known to occur on the site (see Tables 10, 11, and 12).

Figure 8. General conspectus of Ford II Site looking South.

Figure 9. General conspectus of County Line Site looking South

VIII. PLANT RELATIONSHIPS

The lives of megachilid bees are intimately associated with the biology of certain species of flowering plants. These associations with flowering plants may include portions of the plants themselves or some of their products which are used for a variety of purposes in the life history of the bee: (1) nectar is used as an energy source to sustain the adult in its numerous activities; (2) as a nesting site in the canes of Rosa, Rubus, and Rhus; (3) as a source for nest construction materials in the form of portions of leaves or flower petals--oblong and round cuts for cell construction in the genus Megachile or masticated portions of leaves in some species of Megachile and Osmia; (4) and as a source of pollen which is gathered and stored as provisions in the cells of their nests as provender for their larvae.

An intimate relationship and interdependency exists between the bee and the plant--the bee using the plant or its products for sustenance and nest construction and the plant using the bee as a means of pollen transfer in the reproductive processes of the plant. Any biological work conducted on a bee must, of necessity, concomitantly be associated with the flowering plants of the area.

Thus, a series of studies were initiated to clarify the bee-plant interrelationships. These included a botanical survey of the plant species within the immediate area of each study site, an assessment on the abundance/density of the plant species within the area, flowering phenologies of the more important plant species used commonly by the megachilid bees, devising techniques for identification of pollen used as a food source by the immature bee, and field activity of the bee in her quest for plant materials (e.g., consistency in her visitation/collection efforts to a plant species and seasonal/temporal changes which might occur, method of collection, numbers of flowers visited per pollen load, etc.).

Since the use of pollen in the life history of the bee is probably the most important entity for perpetuation of the species emphasis must be placed on this aspect in the life history of the bee. As a result a major portion of our study pertains to the interrelationships of the bees with flowering plants. From these studies it will be possible to determine, for a given time period, the complex of pollen species that was available to an individual female bee, and which elements were actually utilized. Local pollen preferences can thus be ascertained, and any pehenological synchronisms between bee species and plant species should manifest themselves. When the ELF antenna is finally operational, it will be important to notice whether or not these synchronisms are maintained, and to what degree if any, they shift.

A. FLOWER PHENOLOGIES

With a list of the species of megachilid bees derived from our taxonomic studies which potentially might occur in the study area of Marquette and Dickinson Counties (See Section IX of this report) we derived a list of plants largely from Hurd (1979) from which the bee species of the study area were previously known to visit. The list however does not distinguish between nectar and pollen collection modes but only records visitation. This plant visitation list which encompasses the entire North American continent was further restricted to include only those plants known to occur or within the range of the species for the Upper Peninsula (Table 9).

As a means of assessment and comparison of sites similar lists were made of plants used by the megachilid bees from field data for each of the study sites (Tables 10-13, Channing Site; Tables 14-16, County Line Site; Fig. 10, Tables 17-19, Ford I Site; Table 20, Ford II Site). It should be pointed out, however, that only Ford I and Channing Sites represent any degree of completeness. Reasons for these discrepancies pertain to the time scale at which sites were inaugurated, or in some cases abandoned -- Section VII pertaining to Site Selection of this report elucidates further.

Two methods were used to gather quantitative data on the flowering periods of various entomophilous plant species at the Ford I and Channing sites. The first involved m^2 quadrats which were established in May equidistant on a grid laid over the sites prior to any bee nesting activity. All quadrats at a site were assessed for flower numbers and species every 2-7 days. The second method comprised regular, systematic searches for individual plants at each site. When located, these plants were marked with tags before anthesis and examined thereafter every 2-7 days. The first method proved effective for the common species; the second was necessary to obtain data on scarce or patchily-distributed species. For a few uncommon plants, the data collected with both methods were combined. Flowers were tallied if they possessed at least one anther that was releasing pollen, or in the case of very short-lived flowers, if the anthers appeared to have been emptied earlier in the day. Flowers of polygamo-dioecious species were tabulated only if they possessed anthers. Flowers of species whose anthers were difficult to inspect in the field (Vaccinium angustifolium, V. myrtilloides, Trifolium pratense and Galeopsis tetrahit) were counted if they appeared fresh.

At the Ford I site 110 plots and at the Channing Site 25 plots were sampled. The numbers of plots were proportional to the acreage under study and comprised .6% sampled of the total cover. The primary concern in this portion of the study was to ascertain flower phenology of the plants which might be of use to the bees as a pollen source. Once the pollen relationships of the various bee species are more certainly delimited adjustments are expected to be made to increase our sample numbers and concentrate on plant species actually used by the megachilids.

Of the 92 species of potential pollen plants within .5 kilometer of the Ford I hutches (Table 17), we have quantitative phenological data for 28%; the corresponding figures from the Channing Site (Table 10) are 74 and 35%. For those species that were not studied quantitatively, the dates when their flowers were first and last observed, were recorded. Phenograms of the more important pollen plants, based on our field

observations, from the Ford I site are presented in Fig. 10. To facilitate comparison between species in the figure, the actual numbers of flowers counted for each species have been converted to percentages. The percentages are based upon the maximum number of blooms counted for a given species on a sampling date. For example, the maximum number of flowers ever tallied on a single date for Anemone canadensis was 491 on 10 July. For this species then, 491=100%, and all counts on other sampling dates are adjusted accordingly. These transformed data points were then placed on graph paper and the phenograms constructed by connecting the data points.

B. POLLEN ANALYSIS STUDIES

Assuming that pollen grains may be readily identified there are, given the time and personnel, several hypothetical methods by which pollen usage by a particular species of bee might be ascertained:

1. By sampling the pollen by means of a probe after deposition by the female in the nest. The method has the disadvantage of possible disturbance to the nesting material and subsequent disruption of the female upon return to her nest -- thus a possible disruption of her normal behavior pattern and a concordant change in her usual time sequence of events.

2. By removing samples of pollen from the scopa of the female as she returns to the nest. By necessity the female must be captured and handled to secure the sample -- her normal behavior pattern is again totally disrupted for some period of time after her release.

3. By examination of pollen stores of abortive cells. The method has considerable merit but lacks continuity in seasonal phenologies of plants.

4. By following the bee from flower to flower in the field and noting pollen collecting activity. This method can be applied in an agricultural setting such as an alfalfa field where plants are uniformly distributed over even ground, but is virtually impossible in a native field situation for plants are rarely uniformly distributed.

5. By analysis of fecal pellets which are deposited by the immature stage just prior to pupation. This method has been perfected for use in this study and is discussed further in the following section.

FECAL PELLET ANALYSIS. Larvae of the species of megachilids involved in this study void their fecal material in pellet form, and typically concentrate these in one area of the cell. Pellets, composed entirely of pollen grains, can usually be removed without much difficulty or risk to the insect. Pollen grains are very durable, and the exine (outer sculptured layer) suffers no apparent change in the larval bee gut. In most cells, 25 or more pellets can be collected, but occasionally this number is lower. Such pollen can usually be identified to family or genus level with a light or phase-contrast microscope. More precise identification is possible provided the following data are available: knowledge of the original location of the nest, the approximate date(s) during which the cell was provisioned, the daily log of nest activity, a reference collection of known pollen species for comparison, and the correlation of these facts with the phenological charts prepared for each site. Given this amalgam of data, genus or species level identification is usually possible; however, some early - season rosaceous taxa and late-season composit taxa, each have elements which are similar in pollen morphologies and overlap phenologically, making species level determination difficult.

PREPARATION OF FECAL PELLET SLIDES. All Osmia and Hoplitis nests were opened in late September and early October at the field sites to note the stage of development of the animals, record other pertinent data pertaining to nest architecture, and to prepare for winter storage. Fecal pellets were removed from the cells of the two genera at that time. Pellets were stored in small vials, labeled to indicate nest and cell number, and returned to our E. Lansing laboratories to be processed.

From a single vial a standard number (12) of pellets was randomly selected to be analyzed. Pellets were prepared for microscope analysis by placing them on a glass slide, macerating them in cold water, then breaking them apart with hydrostatic tension

applied by gently applying pressure to the cover slip. Occasionally a detergent was added to more effectively distribute the grains. The slides were allowed to dry, and a permanent mount was made with Kleermount® and a glass cover slip. The slide was labelled with the same data contained in the vial.

PREPARATION OF REFERENCE SLIDES. Reference slides were prepared in the following manner: 1) plants were identified as they came into bloom on or near the study sites; 2) flowers with unopened anthers were collected and taken to the lab for dehiscence to occur to prevent contamination with foreign pollen; 3) anthers were removed and placed on glass slides, the pollen teased from the thecae and was then labelled with the species name, site, and date collected. Over 300 slides of 155 angiosperm species were prepared in this fashion.

ANALYSIS OF FECAL PELLET SLIDES. It has been assumed that by randomly taking samples of limited numbers of fecal pellets from a cell for pollen analysis that we are attaining a true picture of pollen usage and deposition by the mother bee. This assumption is based upon several lines of evidence. The arrangement of fecal pellets on the external surface of the cocoon of some species of Osmia appears to be random and scattered. If the mother bee had used more than one species of pollen the scattered pellets should also reflect these differences. As the larva is feeding the internal movements of the digestive system would further enhance the intermix of pollen grains if a complex of species of pollen grains were originally deposited by the female bee. Lastly, the mixing of fecal pellets in the glass vials before final preparation would also tend to increase the randomness.

In the analysis of species of pollen grains found in a cell two transects are taken across a prepared slide. All pollen grains are counted and determined in each field transect of the slide. If the two transects are comparable in terms of both numbers and percentages of determined species no additional counts are made. If, however, discrepancies occur in either numbers or percentages additional transects are made.

To assure that our basic assumptions and the sampling procedures based on these assumptions are correct all fecal pellets from a few selected cells for each species of bee will be processed and similarly treated. Statistical analyses and comparisions of all fecal pellets from a cell versus random samples and two microscopic field transects should enable us to determine the validity of our sampling procedure.

It must be emphasized that the techniques outlined above have only recently been perfected -- the samples themselves not being available in our E. Lansing laboratories until mid-October. A total of 82 cells of Hoplitis and 325 cells of various species of Osmia are, at the time of this writing, being prepared for study and analysis. Preliminary results of the technique are very promising and demonstrate that the technique as devised will work and will answer many basic questions on megachilid-plant relations!

C. LEAF MATERIALS USED FOR NEST CONSTRUCTION

Field observations indicate that a given bee will return time and time again to the same plant to procure leaves for nest construction. Whether this behavior pattern remains the same throughout the entire life of the bee, or may change upon finishing a nest and selection of a new site (nest block) in the same area (same hutch) or may change with founding of a new nest some distance from her previously completed nest, or may change with the season of the year is unknown. We are currently working on techniques to ascertain plant species from which leaves were obtained for nest construction by careful disassembly of Megachile nests without doing harm to the inhabitant. The leaves of Rosa, Fragaria, Epilobium, and Viola are commonly used by members of the genus for nest construction purposes. Leaves of the above plant genera as well as a wide variety of other plant species have been collected and preserved to be used as a reference collection for determination of leaf parts found in the Megachile nests. Some of the above conjectures may thus be answered.

The disassembly of the Megachile nests will also enable us to pursue the pollen analysis for each cell for fecal pellets will be exposed for sampling and identification. As compared with species of Osmia many species of Megachile are long-lived -- living an active life as an adult for 2.5 months. A long-lived species whose span of life is greater than the "preferred" pollen source at any specific time interval must obviously select a second, or perhaps a third, plant species from which to collect pollen as the season progresses. At what stage in the availablility of pollen from two plant species does the changeover occur? Or are long-lived species pollyectic? The disassembly of Megachile nests thus has a multi-faceted approach.

Figure 10. Phenogram Of More Important Plant Species For Ford II Site For 1983 Season

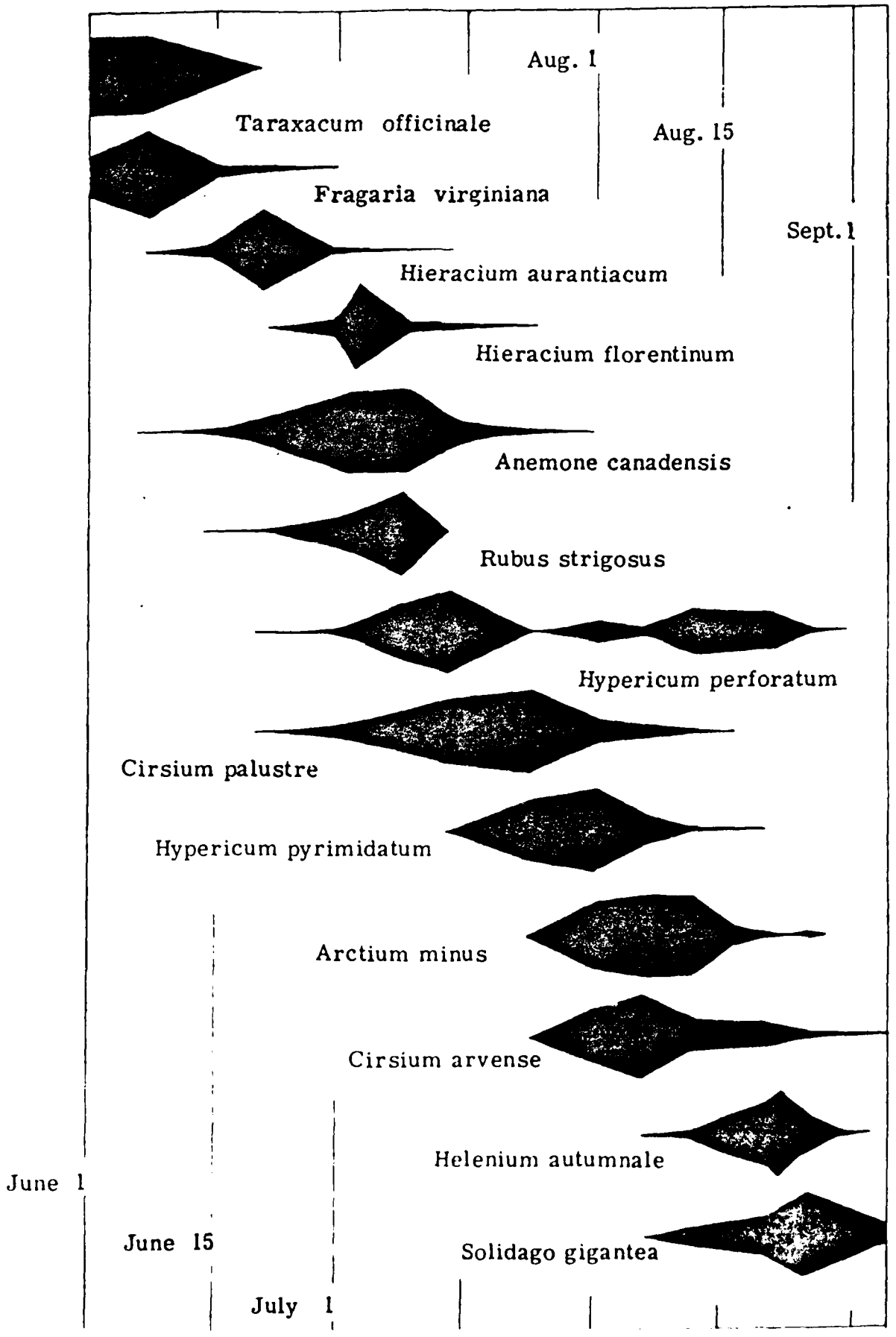


TABLE 9.

NECTAR AND POLLEN PLANTS POSSIBLY USED BY MEGACHILIDS IN UPPER MICHIGAN

*MSU Herbarium contains specimens from Marquette, Iron, Dickinson or Baraga Co.

ACERACEAE
- Acer pennsylvanicum
- A. rubrum
- A. spicatum
- A. saccharum
- A. negundo
- A. platanoides

ALISMACEAE
- Sagittaria latifolia
- S. cuneata

ANACARDIACAE
- *Rhus typhina
- *R. glabra

AQUIFOLIACEAE
- Ilex verticillata

ARISTOLOCHIACEAE
- *Asarum canadense

ARALIACEAE
- Aralia hispida
- A. nudicaulis
- A. racemosa
- Panax trifolium

ASCLEPIADACEAE
- Asclepias syriaca
- *A. exaltata
- *A. incarnata

APOCYNACEAE
- Apocynum androsaemifolium

BORAGINACEAE
- Cynoglossum boreale
- C. officinale

BORAGINACEAE (Continued)
- Echium vulgare
- Lithospermum officinale
- Mertensia paniculata
- Myosotis scorpiodes
- (2 other spp. possible)

BALSAMINACEAE
- Impatiens biflora

BERBERIDACEAE
- Berberis thunbergii

CAMPANULACEAE
- *Campanula rotundifolia
- C. uliginosa

CAPRIFOLIACEAE
- *Diervilla lonicera
- *Linnaea borealis
- *Lonicera canadensis
- *L. dioica
- *L. oblongifolia
- *L. villosa
- L. tatarica
- *Sambucus canadensis
- *Symphoricarpos albus
- Viburnum acerifolium
- V. cassinoides
- *V. opulus
- V. rafinesquianum

CARYOPHYLLACEA
- *Silene cucubalus
- *Lychnis alba

COMMELINACEAE
- Tradescantia ohiensis
- *Commelina communis

COMPOSITAE
- *Arctium minus
- Centaurea maculosa
- Cirsium arvense
- C. discolor
- C. hilli
- *C. muticum
- *C. vulgare
- C. palustre
- Cichorium intybus
- *Erigeron annus
- *E. philadelphicus
- *E. strigosus
- *Eupatorium maculatum
- *Grindelia squarrosa
- *Krigia biflora
- *Liatris aspera
- L. squarrosa
- *Petasites frigidus
- Rudbeckia laciniata
- R. hirta
- Sonchus spp. (several possible)
- Tragopogon pratensis (others possible)

CRUCIFERAE
- Arabis spp. (several possible)
- Barbarea vulgaris
- Berteroa incana
- Dentaria diphylla
- D. laciniata

CORNACEAE
- *Cornus alternifolia

CORNACEAE (Continued)
- *C. canadensis
- C. stolonifera
- C. rugosa

CONVOLULACEAE
- Convolvulus (several possible)

CRASSULACEAE
- Sedum acre
- Sedum spp. (several possible)

ELAEAGNACEAE
- *Sheperdia canadensis

ERICACEAE
- *Andromeda glaucophylla
- *Arctostaphylos uva-ursi
- *Gaultheria procumbens
- *Chamaedaphne calyculata
- Chimaphila umbellata
- *Epigaea repens
- Gaylusaccia baccata
- *Kalmia polifolia
- *Ledum groenlandicum
- Moneses uniflora
- Pyrola (several possible)
- Vaccinium angustifolium
- V. brittonii
- V. membranaceum
- V. myrtilloides
- V. macrocarpon
- *V. oxycoccus
- V. vacillans (possibly others)

FAVACEAE
- Lathyrus maritimus
- L. ochroleucus

FAVACEAE (Continued)

*L. palustris
(other escapes possible)
Lotus corniculatus
Lupinus polyphyllus
*Medicago sativa
Melilotus alba
Melilotus officinalis
Trifolium arvense
T. hybridum
T. pratense
T. repens
*Vicia sativa
*V. villosa
V. americana
(others possible)

FUMARIACEAE

*Corydalis sempervirens
Corydalis aurea
*Dicentra cucullaria
D. canadensis

GENTIANACEAE

*Menyanthes trifoliata
Gentiana
(several possible)
Halenia deflexa

GERANIACEAE

Geranium maculatum
G. robertianum

IRIDACEAE

*Iris lacustris
*Iris virginica
*Sisyrinchium angustifolium
(perhaps others)

HYPERICACEAE

*Hypericum boreale
H. canadense
*H. ellipticum
*H. perforatum
H. pyrimidataum

LABIATAE

Glecoma hederacea
Galeopsis tetrahit
Lamium purpureum
L. amplexicaule
Leonurus cardiaca
Lycopus americanus
L. uniflorus
*Mentha arvensis
*Monarda fistulosa
*Nepetea cataria
Prunella vulgaris
Satureja vulgaris
Scutellaria lateriflora
S. galericulata
Stachys palustris
S. hispida
Teucrium canadense

LYTHRACEAE

Lythrum salicaria

LILIACEAE

*Clintonia borealis
*Erythronium americanum
*Lillium philadelphicum
*L. superbum (includes michiganense)
Medeola virginiana
*Polygonatum pubescens
*Smilacina racemosa

LILIACEAE (Continued)
- *Smilacina stellata
- S. trifolia
- *Streptopus amplexfolius
- S. roseus
- *Tofieldia glutinosa
- *Trillium grandiflorum
- T. cernuum
- T. erectum
- *Uvularia grandiflora

LOBELIACEAE
- Lobelia kalmii
- L. spicata

MALVACEAE
- *Malva moschata
- M. neglecta
- *M. rotundifolia

ONAGRACEAE
- Circaea alpina
- C. quadrisulcata
- *Epilobium angustifolium
- E. coloratum
- (others possible)
- *Oenothera biennis
- *O. parviflora
- O. perennis

PAPAVERACEAE
- *Sanguinaria canadensis

PONTEDERIACEAE
- Pontedaria cordata

POLYGALACEAE
- Polygala paucifolia

POLYGONACEAE
- *Polygonum aviculare
- *P. cilinode
- *P. convolvulus
- *P. hydropiper
- *P. persicaria

POLYGONACEAE (Continued)
- P. cuspidatum
- (others possible)

PORTULACACEAE
- Claytonia caroliniana

PRIMULACEAE
- Lysimachia terrestris
- L. thyrsifolia
- L. ciliata
- Trientalis borealis (=americana)

RANUNCULACEAE
- Actea alba
- A. rubra
- *Anemone canadensis
- *A. quinquefolia
- *Caltha palustris
- *Clematis virginiana
- Coptis trifolia
- Hepatica acutiloba
- H. americana
- Ranunculus acris
- Ranunculus spp. (many possible)

RHAMNACEAE
- Rhamnus alnifolia
- (others possible)

RUBIACEAE
- Mitchella repens

SALICACEAE
- *Salix bebbiana
- S. cordata
- *S. discolor
- *S. humilus
- *S. lucida
- S. petiolaris
- S. interior
- S. rigida
- (others possible)

ROSACEAE

*Agrimonia gryposepala

Agrimonia striata

*Amelanchier laevis

*A. sanguinea

A. bartramiana

*A. spicata (includes stolonifera)

*Aronia melanocarpa

*A. prunifolia

Fragaria virginiana

*Geum aleppicum

*G. canadense

*G. rivale

G. macrophyllum

*Physocarpus opulifolius

*Potentilla argentea

*P. fruticosa

*P. *norvegica*

P. palustris

*P. simplex

*P. tridentata

Rosa blanda

Rosa palustris

R. acicularis

Rubus allegheniensis

R. parviflorus

R. odoratus

R. strigosus

R. pubescens

R. hispidus

R. pensilvanicus

*Prunus pumila

P. serotina

P. virginiana

Pyrus malus

Spirea alba
(possibly some escapes)

ROSACEAE (Continued)

*Sorbaria sorbifolia

*Sorbus americana

*S. decora

SCROPHULARIACEAE

*Castilleja coccinea

C. septentrionalis

*Chelone glabra

Linaria vulgaris

*Mimulus ringens

M. moschatus

*Melampyrum lineare

*Scrophularia lanceolata

*Verbascum thapsus

*Veronica officinalis

*Veronica
(6 others possible)

SAXIFRAGACEAE

Philadelphus spp. (escapes)

*Ribes americanum

*R. cynobasti

*R. hudsonianum

*R. oxyacanthoides

R. lacustre

R. glandulosum

*R. triste

SANTALACEAE

*Comandra umbellata

Comandra livida

SOLANACEAE

Physalis (several possibilities)

*Solanum dulcamara (perhaps others)

VALERIANACEAE

Valeriana uliginosa

VERBENACEAE

*Verbena hastata

VIOLACEAE

Viola blanda

V. adunca

*V. canadensis

*V. conspersa

*V. cucullata

*V. incognita

V. lanceolata

V. pubescens

V. renifolia

V. septentrionalis

V. sororia

UMBELLIFERAE

Cicuta bulbifera

C. maculata

Daucus carota

Heracleum lanatum

Imperatoria ostruthium

*Pastinaca sativa

Sium suave

Sanicula (several spp.)

VITACEAE

Parthenocissus vitacea

TABLE 10.

POSSIBLE POLLEN SOURCES - CHANNING SITE

Achillea millefolium
Agrimonia striata
Amelanchier spp.
Anaphalis margaritacea
Anemone quinquefolia
Antennaria spp.
Aster puniceus
A. umbellatus
Aster sp. 1
Aster sp. 2
Aster sp. 3
Barbarea vulgaris
Caltha palustris
Chrysanthemum leucanthemum
Cirsium arvense
C. muticum
C. palustre
C. vulgare
Convolvulus spithameus
Coptis trifolia
Cornus canadensis
C. stolonifera
Diervilla lonicera
Epilobium angustifolium
Erigeron annus
E. strigosus
Eupatorium maculatum
Fragaria virginiana
Geum allepicum
Hieracium aurantiacum
H. canadense
H. florentinum
Iris virginica
Lonicera tatarica
Lotus corniculatus
Lychnis alba
Lycopus uniflorus
Maianthemum canadense
Medicago lupulina
Mentha arvensis
Oenothera biennis
Pastinaca sativa
Plantago spp.
Polygala paucifolia
Potentilla recta
Prunella vulgaris
Prunus virginiana
Pyrus malus
Ranunculus acris
Rhamnus alnifolia
Ribes americanum
R. cynosbati
R. triste
Rubus pubescens
R. strigosus
Rudbeckia hirta
Salix discolor
S. petiolaris
Senecio aureus
Sisyrinchium spp.
Solidago canadensis
S. nemoralis
S. uliginosus
Sonchus uliginosus
Spirea alba
Taraxacum officinale
Trifolium agrarium
T. pratense
Vaccinium angustifolium
V. myrtilloides
Veronica spp.
Viola conspersa
V. incognita

TABLE 11.

PLANT SPECIES FOR WHICH QUANTITATIVE PHENOLOGICAL DATA WERE OBTAINED

CHANNING SITE

Anemone quinquefolia

Aster umbellatus

A. puniceus

Chrysanthemum leucanthemum

Cirsium arvense

C. palustre

Convolvulus spithameus

Coptis trifolia

Cornus canadensis

Fragaria virginiana

Hieracium aurantiacum

Polygala paucifolia

Potentilla recta

Prunella vulgaris

Prunus virginiana

Rhamnus alnifolia

Ribes cynosbati

Rubus strigosus

Senecio aureus

Sonchus uliginosus

Taraxacum officinale

Trifolium pratense

Vaccinium angustifolium

V. myrtilloides

Viola conspersa

V. incognita

TABLE 12.

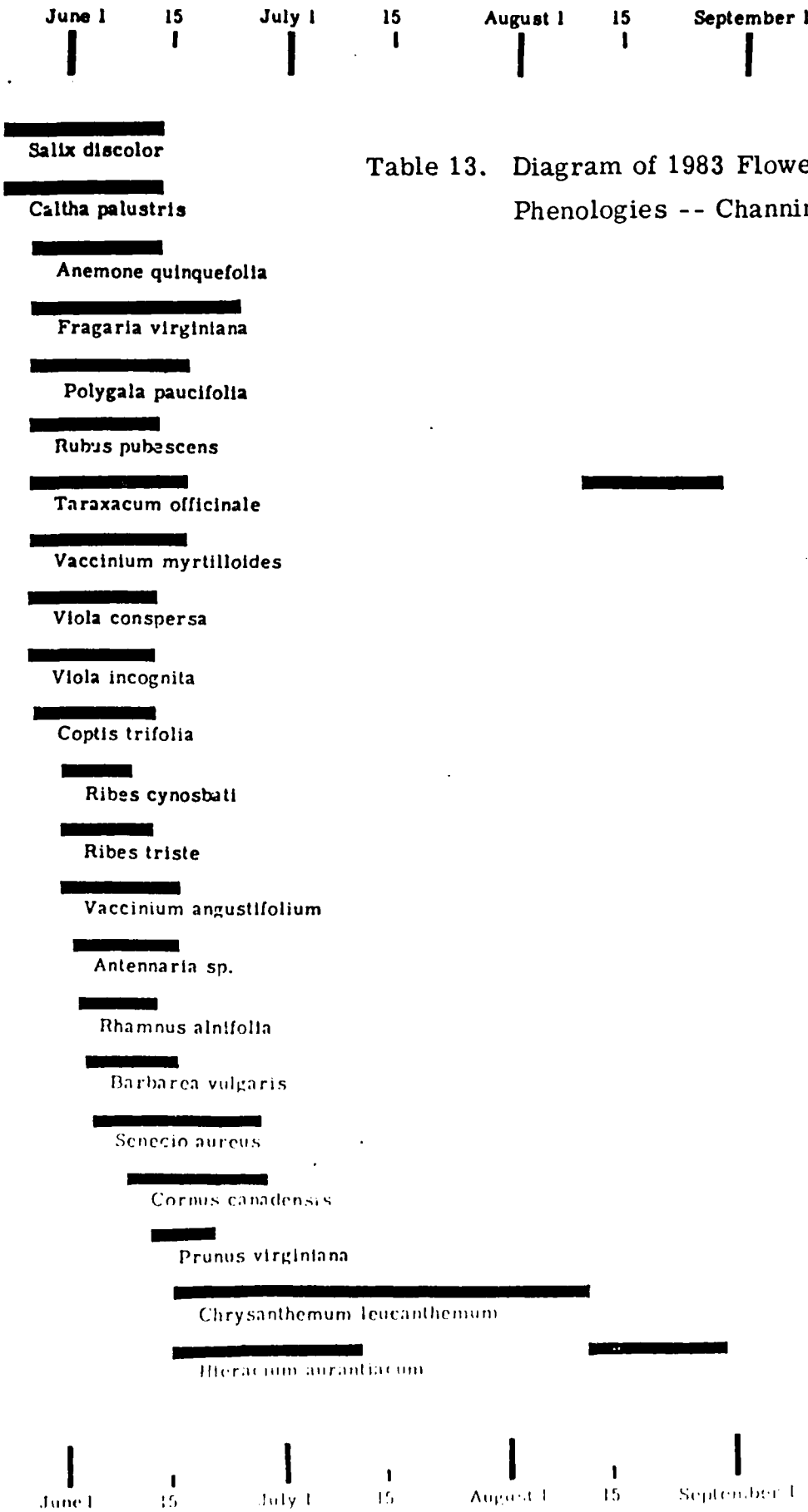
1983 SUMMARY OF FLOWER PHENOLOGIES--CHANNING SITE

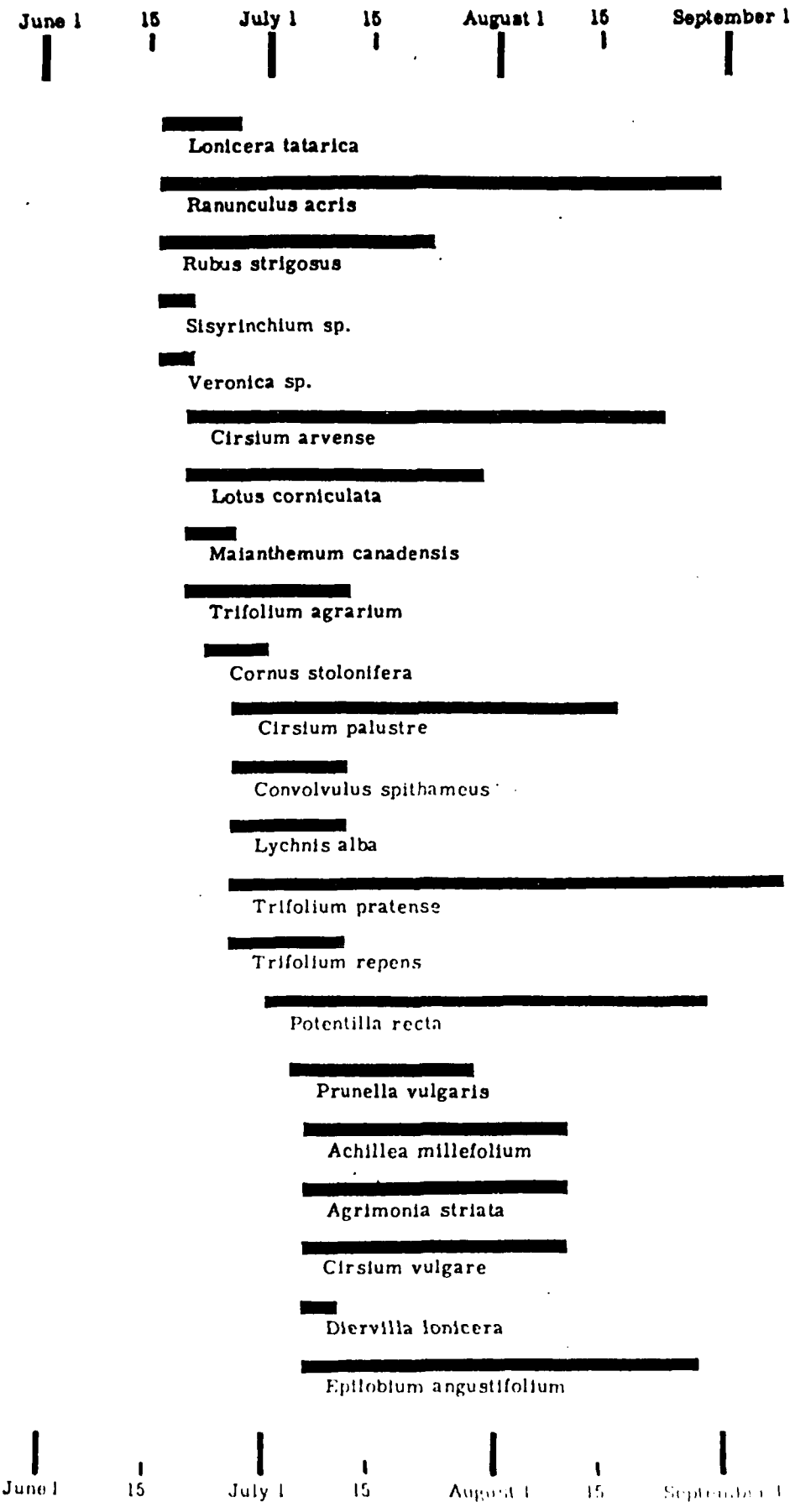
Achillea millefolium	6 July - 11 August
Agrimonia striata	6 July - 11 August
Amelanchier spp.	23 May - ? (rain)
Anaphalis margaritacea	11 August - 30 August
Anemone quinquefolia	27 May - 14 June
Antennaria spp.	3 June - 18 June
Aster puniceus	17 August - 10 September
Aster umbellatus	11 August - 10 September
Aster sp. 1 ('cordifolius')	11 August - 10 September
Aster sp. 2 ('simplex')	20 August - 10 September
Aster sp. 3 ('lateriflorus')	20 August - 10 September
Barbarea vulgaris	5 June - 18 June
Caltha palustris	23 May - 14 June
Chrysanthemum leucanthemum	14 June - 11 August
Cirsium arvense	18 June - 23 August
Cirsium muticum	?
Cirsium palustre	25 June - 17 August
Cirsium vulgare	6 July - 11 August
Convolvulus spithameus	25 June - 11 July
Coptis trifolia	28 May - 14 June
Cornus canadensis	11 June - 1 July
Cornus stolonifera	21 June - 30 June
Diervilla lonicera	6 July - 11 July
Epilobium angustifolium	6 July - 11 August
Erigeron annuus	6 July - 30 August

Erigeron strigosus	6 July - 30 August
Eupatorium maculatum	29 July - 20 August
Fragaria virginiana	27 May - 25 June
Geum allepicum	6 July - 30 July
Hieracium aurantiacum	14 June - 11 July (8/11-8/30)
Hieracium canadense	15 August - 30 August
Hieracium scabrum	11 August - ?
Hieracium florentinum	25 June - ?
Iris virginica	25 June - ?
Lonicera tatarica	14 June - 25 June
Lotus corniculata	18 June - 29 July
Lychnis alba	25 June - 11 July
Lycopus uniflorus	? - 30 August
Maianthemum canadensis	18 June - 25 June
Medicago lupulina	25 June - ?
Mentha arvensis	11 August - 30 August
Oenotherea biennis	6 July - 11 August
Pastinaca sativa	6 July - 11 August
Plantago sp.	14 June - ?
Polygala paucifolia	27 May - 18 June
Potentilla recta	30 June - 30 August
Prunella vulgaris	4 July - 29 July
Prunus virginiana	11 June - 20 June
Pyrus malus	14 June
Ranunculus acris	14 June - 30 August
Rhamnus alnifolia	4 June - 15 June
Ribes americanum	14 June

Ribes cynosbati	1 June - 11 June
Ribes triste	1 June - 11 June
Rubus pubescens	27 May - 14 June
Rubus strigosus	14 June - 22 July
Rudbeckia hirta	6 July - 29 July
Salix discolor	23 May - 14 June
Salix petiolaris	? - 14 June
Scutellaria lateriflora	11 August
Senecio aureus	6 June - 30 June
Sisyrinchium sp.	14 June - 18 June
Solidago canadensis	29 July - 30 August
Solidago nemoralis	30 August
Solidago uliginosus	30 August
Sonchus uliginosus	11 August - 10 September
Spirea alba	6 July - 29 July
Taraxacum officinale	27 May - 18 June (8/11-8/30)
Trientalis borealis	6 June
Trifolium agrarium	18 June - 11 July
Trifolium pratense	25 June - 10 September
Trifolium repens	25 June - 11 July
Vaccinium angustifolium	1 June - 18 June
Vaccinium myrtilloides	27 May - 18 June
Veronica sp.	14 June - 18 June
Viola conspersa	27 May - 14 June
Viola incognita	27 May - 14 June

Table 13. Diagram of 1983 Flower Phenologies -- Channing Site




June 1
15
July 1
15
August 1
15
September 1
Lonicera tatarica
Ranunculus acris
Rubus strigosus
Sisyrinchium sp.
Veronica sp.
Cirsium arvense
Lotus corniculata
Maianthemum canadensis
Trifolium agrarium
Cornus stolonifera
Cirsium palustre
Convolvulus spithameus
Lychnis alba
Trifolium pratense
Trifolium repens
Potentilla recta
Prunella vulgaris
Achillea millefolium
Agrimonia striata
Cirsium vulgare
Diervilla lonicera
Epilobium angustifolium
June 1
15
July 1
15
August 1
15
September 1

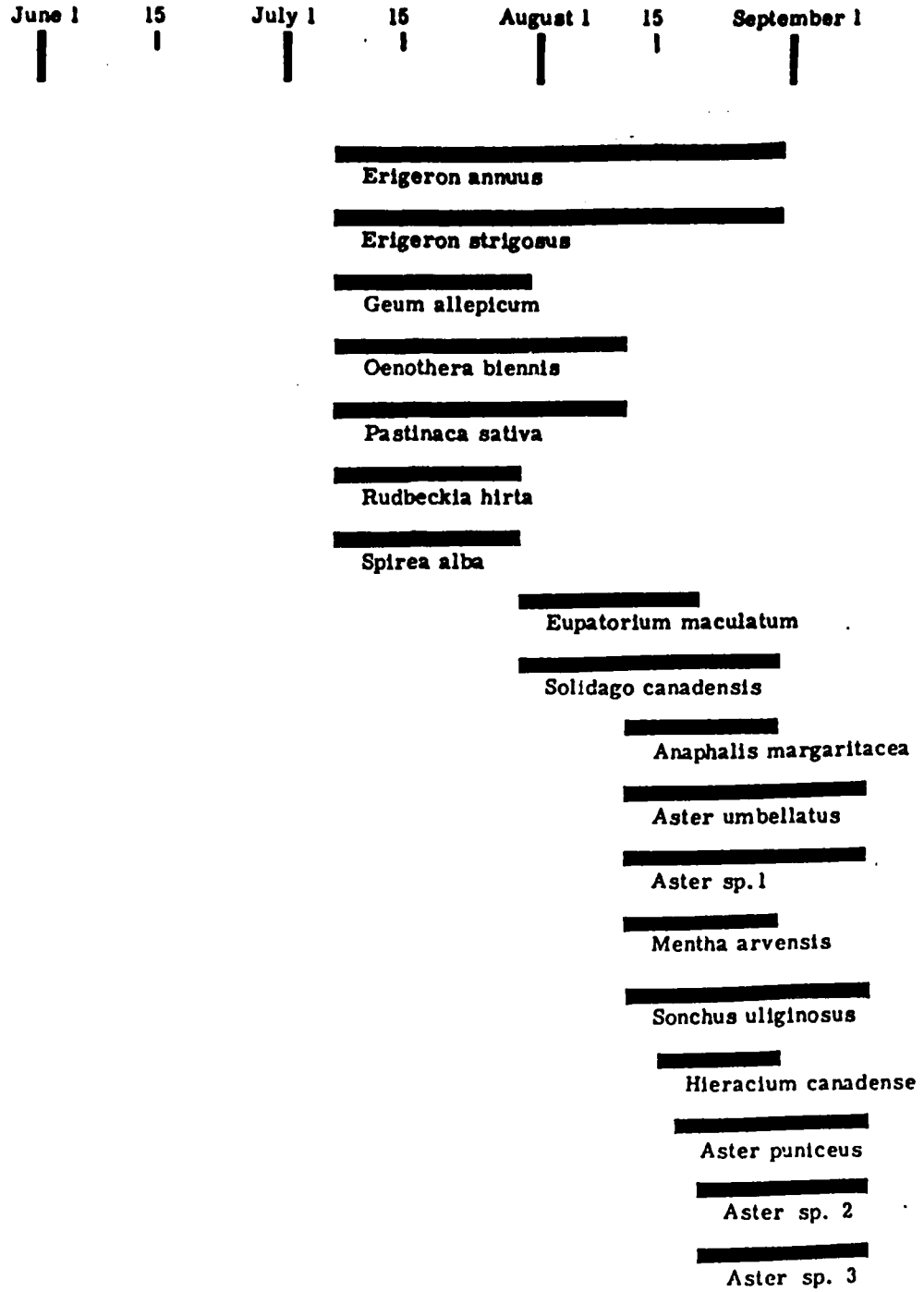

June 1
15
July 1
15
August 1
15
September 1
Erigeron annuus
Erigeron strigosus
Geum allepicum
Oenothera biennis
Pastinaca sativa
Rudbeckia hirta
Spirea alba
Eupatorium maculatum
Solidago canadensis
Anaphalis margaritacea
Aster umbellatus
Aster sp.1
Mentha arvensis
Sonchus uliginosus
Hieracium canadense
Aster puniceus
Aster sp. 2
Aster sp. 3
June 1
15
July 1
15
August 1
15
September 1

TABLE 14.

POSSIBLE POLLEN SOURCES - COUNTY LINE SITE*

Achillea millefolium
Anaphalis margaritacea
Anemone virginiana
Aquilegia canadensis
Aster puniceus
A. umbellatus
Aster sp. 1
Aster sp. 2
Campanula spp.
Chrysanthemum leucanthemum
Convolvulus spithameus
Cornus canadensis
Diervilla lonicera
Epilobium angustifolium
Erigeron annuus
E. strigosus
Fragaria virginiana
Hieracium aurantiacum
H. canadense
Hypericum perforatum
Lychnis alba
Medicago lupulina
Melampyrum lineare
Melilotus alba
Oenothera biennis
Potentilla recta
Prunella vulgaris
Prunus virginiana
Ranunculus acris
Rubus allegheniensis
R. hispidus
R. strigosus
Rudbeckia hirta
Salix spp.
Solidago canadensis
S. nemoralis
S. uliginosus
Spirea alba
Trifolium agrarium
T. hybridum
T. pratense
T. repens
Vaccinium angustifolium
V. myrtilloides
Verbascum thapsus
Viola incognita

*List incomplete; site not adopted until late June.

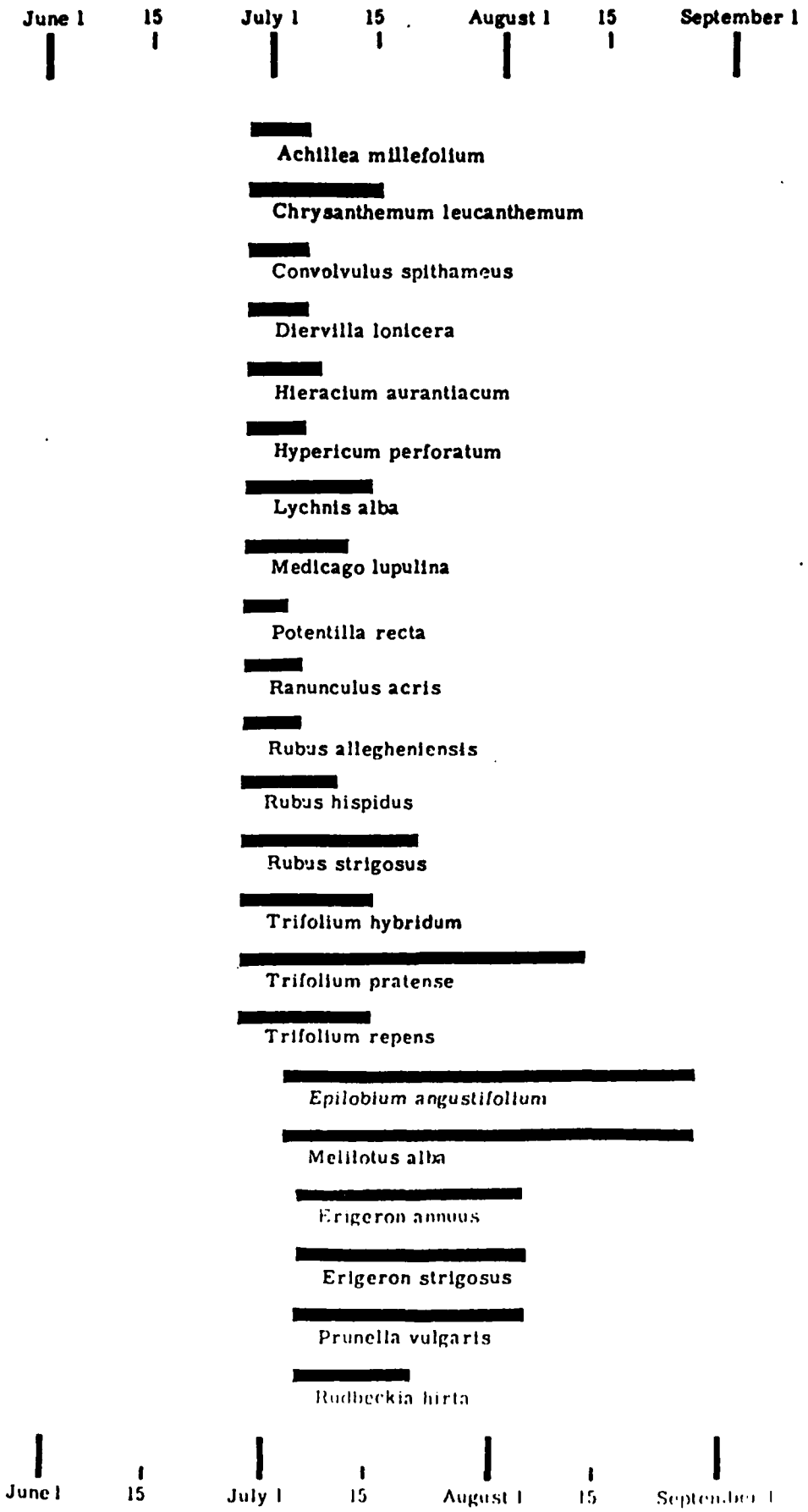
TABLE 15.

1983 SUMMARY OF FLOWER PHENOLOGIES—COUNTY LINE SITE

Achillea millefolium	28 June - 6 July
Anaphalis margaritacea	6 August - 14 August
Anemone virginiana	6 July - ?
Aquilegia canadensis	25 June - ?
Aster puniceus	14 August - 8 September
Aster umbellatus	14 August - 8 September
Aster sp. 1 ('cordifolius')	16 August - 8 September
Aster sp. 2 ('simplex')	16 August - 8 September
Aster sp. 3 ('lateriflorus')	24 August - 8 September
Chrysanthemum leucanthemum	28 June - 6 July
Convolvulus spithameus	28 June - 6 July
Cornus canadensis	28 June
Diervilla lonicera	28 June - 6 July
Epilobium angustifolium	4 July - 29 August
Erigeron annuus	6 July - 6 August
Erigeron strigosus	6 July - 6 August
Fragaria virginiana	28 June
Hieracium aurantiacum	28 June - 6 July
Hieracium canadense	16 August - ?
Hypericum perforatum	28 June - 6 July
Lychnis alba	28 June - 15 July
Medicago lupulina	28 June - 6 July
Melampyrum lineare	14 August
Melilotus alba	4 July - 29 August
Oenothera biennis	6 August

Potentilla recta	28 June - 4 July
Prunella vulgaris	6 July - 6 August
Prunus virginiana	finished prior to hutch est.
Ranunculus acris	28 June - 6 July
Rubus allegheniensis	28 June - 6 July
Rubus hispidus	28 June - 11 July
Rubus strigosus	28 June - 22 July
Rudbeckia hirta	6 July - 22 July
Salix spp.	finished prior to hutch est.
Solidago canadensis	6 August - 14 August
Solidago nemoralis	6 August - 29 August
Solidago uliginosus	6 August - 29 August
Spirea alba	16 July - 14 August
Trifolium agrarium	6 July - 22 July
Trifolium hybridum	28 June - 16 July
Trifolium pratense	28 June - 14 August
Trifolium repens	28 June - 16 July
Vaccinium angustifolium	finished prior to hutch est.
Vaccinium myrtilloides	finished prior to hutch est.
Verbascum thapsus	6 August - 14 August
Viola incognita	finished prior to hutch est.

Table 16. Diagram Of 1983 Flower Phenologies -- County Line Site



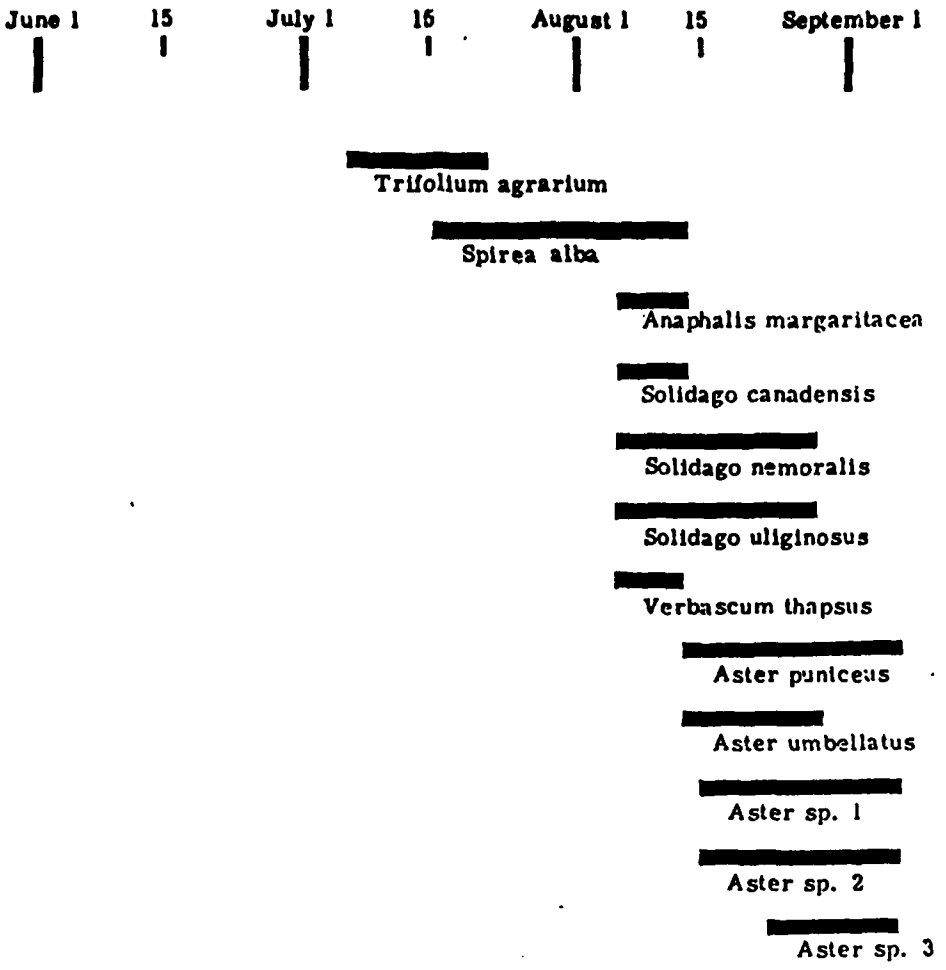

June 1
15
July 1
15
August 1
15
September 1
Trifolium agrarium
Spirea alba
Anaphalis margaritacea
Solidago canadensis
Solidago nemoralis
Solidago uliginosus
Verbascum thapsus
Aster puniceus
Aster umbellatus
Aster sp. 1
Aster sp. 2
Aster sp. 3

TABLE 17.

POSSIBLE POLLEN SOURCES - FORD I SITE

Achillea millefolium

Actaea rubra

Amelanchier spp.

Anaphalis margaritacea

Anemone canadensis

A. quinquefolia

A. virginiana

Antennaria spp.

Arctium minus

Asarum canadense

Aster puniceus

A. *umbellatus*

A. sp. 1

A. sp. 2

A. sp. 3

Centaurea maculosa

Chelone glabra

Chrysanthemum leucanthemum

Cirsium arvense

C. muticum

C. palustre

Clematis virginiana

Convolvulus spithameus

Cornus canadensis

Diervilla lonicera

Epilobium angustifolium

Erigeron annuus

E. strigosus

Erysimum cheiranthoides

Eupatorium maculatum

E. rugosum

Fragaria virginiana

Galeopsis tetrahit

Galium spp.

Geum allepicum

Helenium autumnale

Heracleum lanatum

Hieracium aurantiacum

H. florentinum

H. pratense

Hypericum perforatum

H. pyrimidatum

Iris virginica

Laportea canadensis

Linaria vulgaris

Lychnis alba

Lycopus uniflorus

Lysimachia ciliata

Melampyrum lineare

Melilotus alba

POSSIBLE POLLEN SOURCES - FORD I SITE (Cont'd)

Melilotus officinale

Mentha arvensis

Oenothera biennis

Physocarpus opulifolius

Polygala paucifolia

Polygonum (Tinaria) spp.

Potentilla norvegica

Prunella vulgaris

Prunus virginiana

Ranunculus acris

R. septentrionalis

Rhamnus alnifolia

Ribes cynosbati

R. triste

Rubus strigosus

Rudbeckia hirta

Scrophularia lanceolata

Scutellaria lateriflora

Senecio aureus

Soliadgo canadensis

S. gigantea

S. missouriensis

S. nemoralis

Spirea alba

Taraxacum officinale

Thalictrum dasycarpum

Trifolium agrarium

T. pratense

T. repens

Trillium cernuum

Urtica dioica

Vaccinium angustifolium

V. myrtilloides

Verbascum thapus

Verbena hastata

Viola conspersa

V. incognita

V. pubescens

V. septentrionalis

TABLE 18.

PLANT SPECIES FOR WHICH QUANTITATIVE PHENOLOGICAL DATA WERE OBTAINED

FORD I SITE

Anemone canadensis

Anemone quinquefolia

Arctium minus

Asarum canadense

Cirsium arvense

C. palustre

Clematis virginiana

Fragaria virginiana

Galeopsis tetrahit

Geum allepicum

Helenium autumnale

Heracleum lanatum

Hieracium aurantiacum

H. florentinum

H. pratense

Hypericum perforatum

H. pyramidatum

Potentilla norvegica

Prunus virginiana

Rubus strigosus

Solidago gigantea

Taraxacum officinale

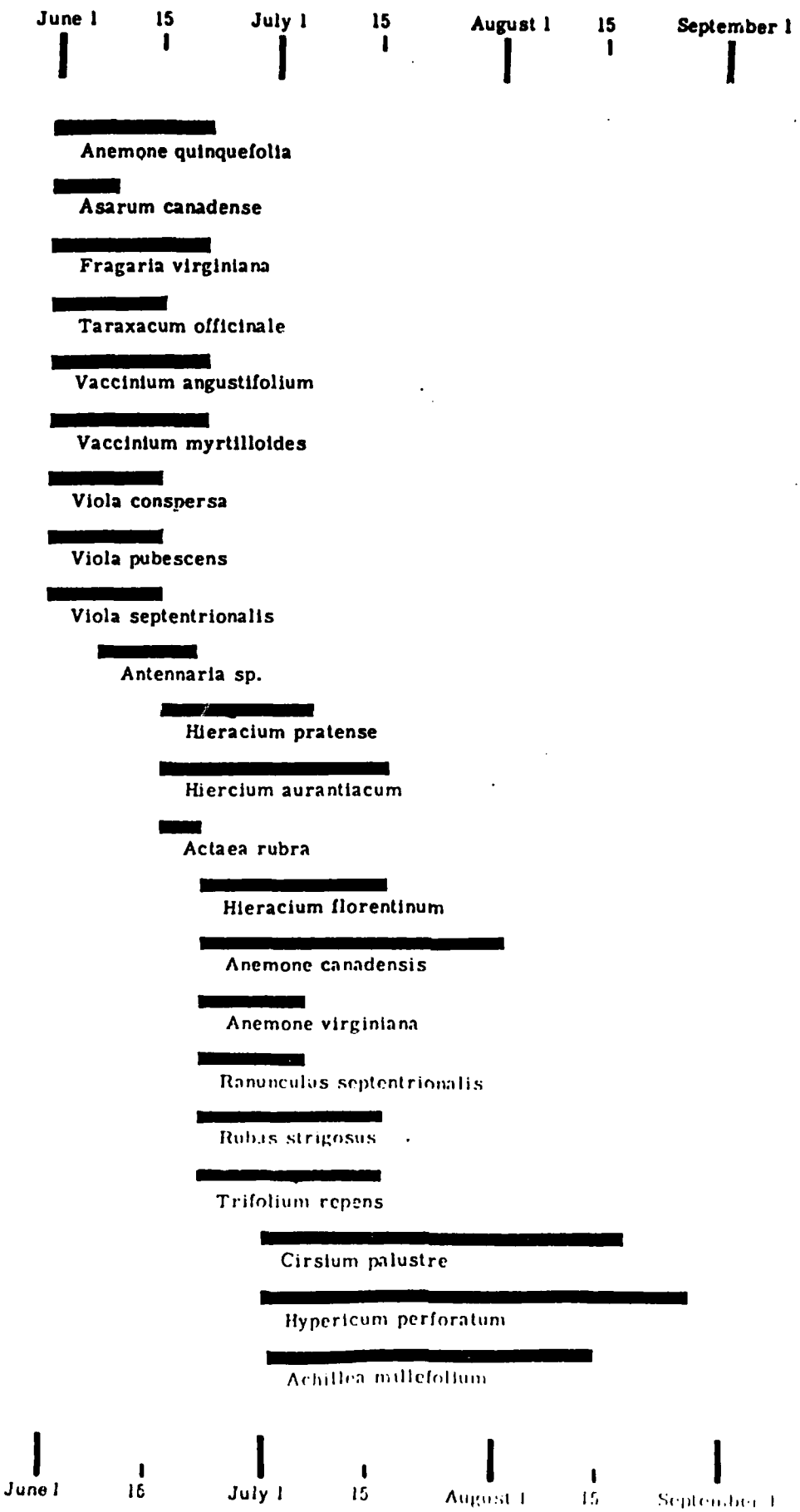
Thalictrum dasycarpum

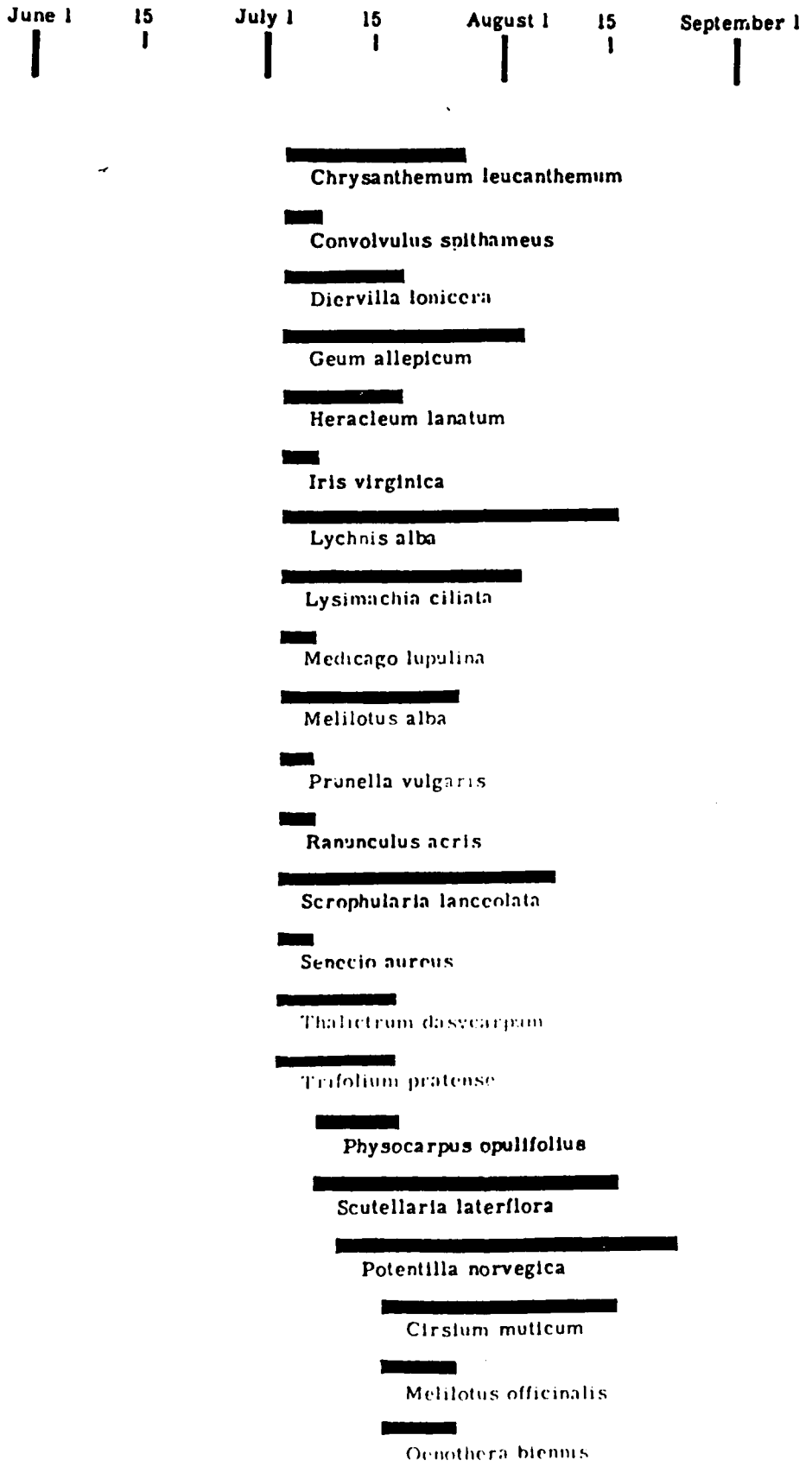
Viola conspersa

V. pubescens

V. septentrionalis

Table 19. Diagram of 1983 Flower Phenologies -- Ford I Site




June 1
15
July 1
15
August 1
15
September 1
Chrysanthemum leucanthemum
Convolvulus spithameus
Diervilla lonicera
Geum allepicum
Heracleum lanatum
Iris virginica
Lychnis alba
Lysimachia ciliata
Medicago lupulina
Melilotus alba
Prunella vulgaris
Ranunculus acris
Scrophularia lanceolata
Senecio aureus
Thalictrum dasycarpum
Trifolium pratense
Physocarpus opulifolius
Scutellaria laterflora
Potentilla norvegica
Cirsium muticum
Melilotus officinalis
Oenothera biennis

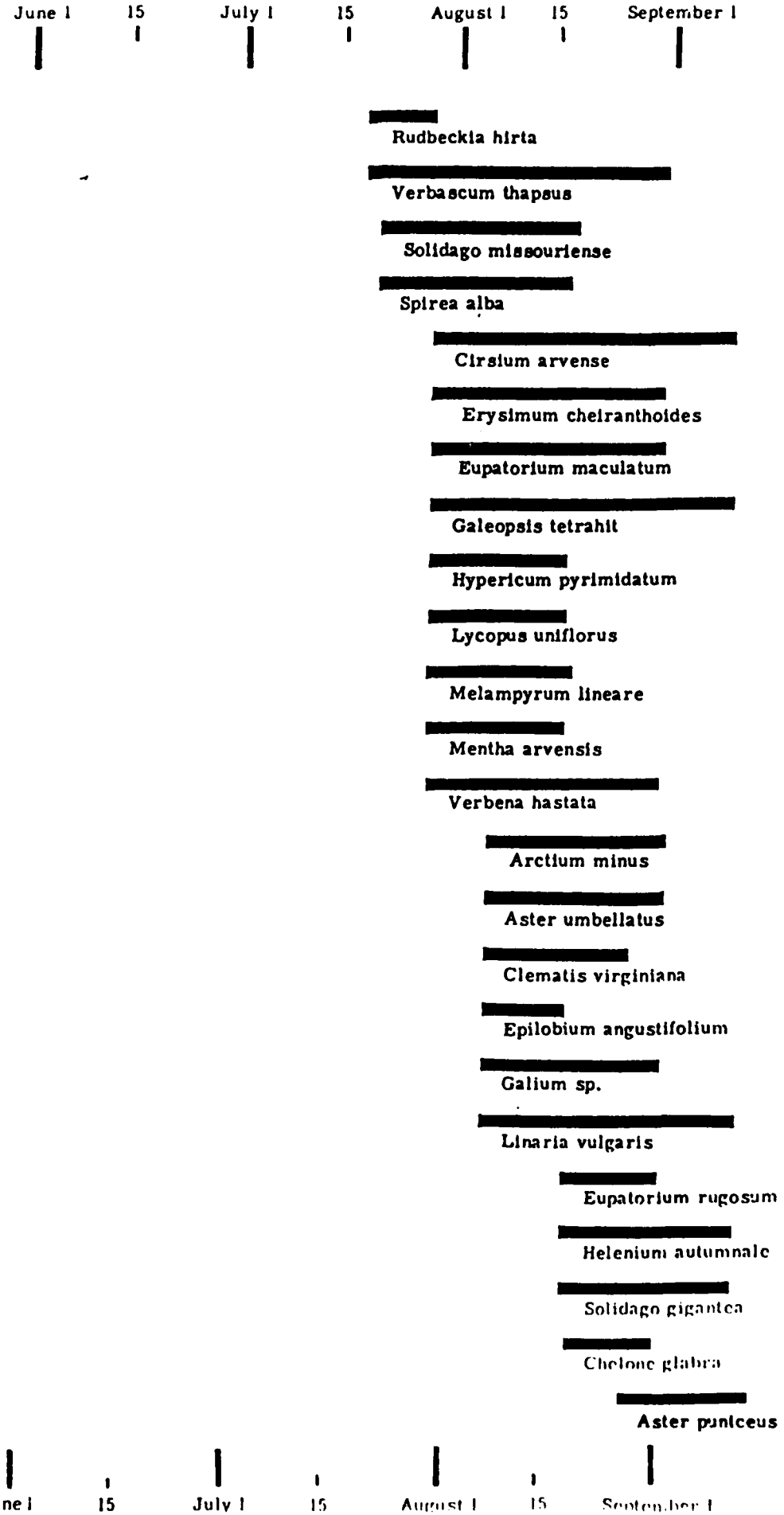

June 1
15
July 1
15
August 1
15
September 1
Rudbeckia hirta
Verbascum thapsus
Solidago missouriense
Spirea alba
Cirsium arvense
Erysimum cheiranthoides
Eupatorium maculatum
Galeopsis tetrahit
Hypericum pyrimidatum
Lycopus uniflorus
Melampyrum lineare
Mentha arvensis
Verbena hastata
Arctium minus
Aster umbellatus
Clematis virginiana
Epilobium angustifolium
Galium sp.
Linaria vulgaris
Eupatorium rugosum
Helenium autumnale
Solidago gigantea
Chelone glabra
Aster puniceus
June 1
15
July 1
15
August 1
15
September 1

TABLE 20.

POSSIBLE POLLEN SOURCES - FORD II SITE*

Achillea millefolium

Anaphalis margaritacea

Antennaria spp.

Aster umbellatus

Aster sp. 1

Centaurea maculosa

Chrysanthemum leucanthemum

Cirsium arvense

C. muticum

C. palustre

C. vulgare

Conyza canadensis

Diervilla lonicera

Erigeron annuus

E. strigosus

Eupatorium maculatum

Fragaria virginiana

Gnaphalium spp.

Hieracium canadense

Hypericum perforatum

Lychnis alba

Melilotus alba

Oenethera biennis

Prunus virginiana

Rubus strigosus

R. allegheniensis

Solidago canadensis

S. graminifolia

S. missouriense

S. nemoralis

Trifolium pratense

T. repens

Verbascum thapsus

Verbena hastata

*List incomplete; site not adopted until late July.

IX. MICHIGAN MEGACHILIDAE

Before any concentrated biological program can be initiated on any group of bees several basic avenues of information must be available. These include a list of the species in the area, their association with the plants of the area, and phenological information. As a result, a taxonomic study on the megachilid bees of Michigan was initiated. Material for study was borrowed from the University of Michigan Museum of Zoology (UMMZ), the Biology Department of Northern Michigan University (NMU), and the private collection of Dr. David P. Cowan of Western Michigan University (DPC) to augment the extensive holdings of the Michigan State University Museum (MSUC). Over 3500 megachilid bees have thus far been determined from these sources and form the basis for the accompanying annotated list and distribution maps (Figs. 12-68).

The annotations for each species include the following:

SPECIMENS EXAMINED: This includes the total number of Michigan specimens which have been determined for the species. The number of specimens will give a rough approximation of how common the bee is within the state. In those cases in which five or fewer specimens are involved, full data including the collection where housed are included. In a few instances in which no actual specimens have been seen literature records are included.

DISTRIBUTION: Reference is given to a distribution map as a Figure number for each species and are further recorded according to the biogeographical distributional zones of Michigan as follows: the Southern Lower Peninsula (SLP) which roughly transects the state from the southern borders of Mason - Gladwin Counties and is roughly coincident with a terminal glacial moraine representing the terminus of the last glaciation of the state; the Northern Lower Peninsula (NLP) which includes the area north of the terminal moraine to the Straits of Mackinac in which the vegetational cover differs markedly from SLP; the Upper Peninsula (UP); and Isle Royale (IR) -- note Fig. 11.

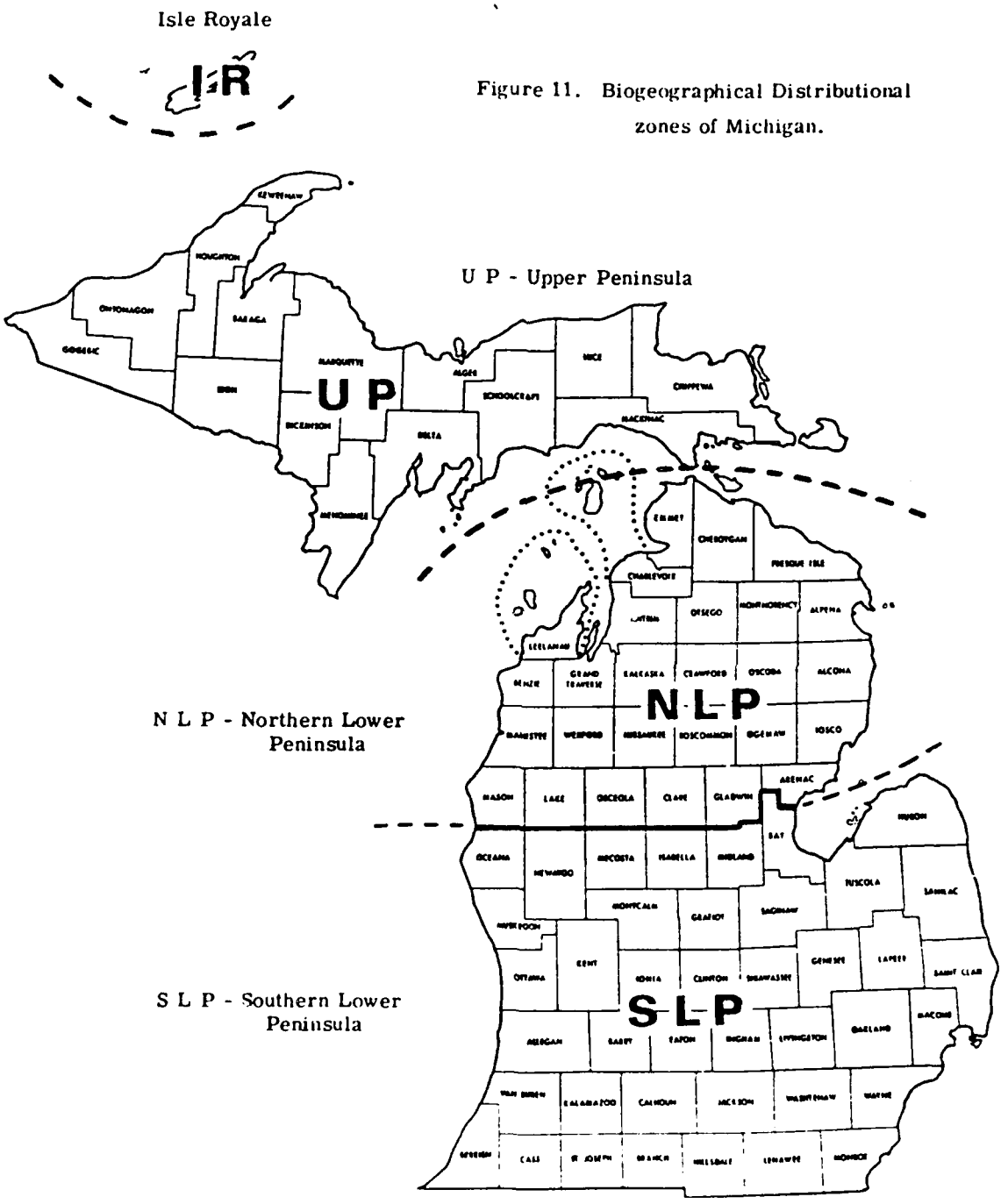


Figure 11. Biogeographical Distributional zones of Michigan.

PHENOLOGY: Inclusive dates of flight activity for species in Michigan, in some cases when numbers of specimens warrant the inclusive dates are recorded according to the four regions of the state.

FLOWER VISITATIONS: Known flower visitation records for Michigan specimens are listed and include the sex of the bee involved.

A word of caution should be engendered to the reader concerning the interpretation and adequacy of data concerning the distribution, phenology, and flower visitation records of this group of insects. This caution largely impinges upon the fact that museum collections have a number of inequities and built-in biases. Academic personnel find it difficult because of teaching commitments to get into the field in early Spring and Fall and, when it is possible, only local collections can be made because of the distance involved for travel. Specialists in museums also tend to collect the groups which most interest them and do not assiduously collect other groups. Thus, we note that counties of the state which have the greatest number of records include Washtenaw County in which the University of Michigan is located, Ingham County in which Michigan State University is located, Shiawassee and Clinton Counties which have large tracts of land for the Rose Lake Wildlife Experiment Station and adjacent to Michigan State University, Kalamazoo County and Cheboygan County where the respective biological stations for Michigan State University and the University of Michigan are located, Marquette County with Northern Michigan University, and Midland County which was the home of the late R. R. Dreisbach, an inveterate collector of the Hymenoptera.

The results of this study indicate that a total of 69 species of Megachilidae are currently known for the State. Of these, 53 are anthophilous or use pollen and nectar for sustenance for their young, and 13 are kleptoparasitic or lay their eggs in the nest of anthophilous species. It should be further pointed out that the list is not entirely complete -- specimens of the genus Stelis have not, as yet, been determined so literature records of Mitchell (1962) are used for the list. In addition, approximately 200 additional

specimens of Megachile and Osmia await determination, and another 300 specimens which were collected largely in areas adjacent to the study sites during the 1983 season are currently being labeled. This latter group should aid immeasurably in our understanding of the study site areas both in terms of the species complexes present and flower visitation records.

In regards to Upper Peninsula distribution 39 species of megachilids have been verified to occur in the area. Of these, four species are known only in Mackinac County, perhaps a reflection of the movement of commerce across the Straits of Mackinac and their establishment in the Upper Peninsula. Ten species are known to occur in both Marquette and Dickinson Counties, while a total of 21 are known from Marquette County and only 13 from Dickinson County. The majority of museum records from Marquette County are from the city of Marquette or immediate vicinity reflecting the influence of Northern Michigan University. A few of the species from both the northern portion of Marquette and Alger Counties may possibly be associated with maritime plants adjacent to Lake Superior and as a consequence have a limited distributional pattern.

In the accompanying annotated list of species known to occur in Michigan those which are known to occur in Marquette and/or Dickinson Counties or thought to occur because of their known distributional pattern are denoted by an asterisk(*).

Annotated List of Species of Megachilidae Known to Occur in Michigan

Anthidium psoraleae Robertson

Only three specimens are known from the State: Berrien Co., Warren Dunes State Park, 17 July 1982, M. A. O'Brien, ♂ (UMMZ); 1 ♂ , 1 ♀ Washtenaw Co., Stinchfield Woods, 28-30 June 1971, from Malaise Trap. (UMMZ) (Fig. 12)

Dianthidium simile (Cresson)

SPECIMENS EXAMINED: 34

DISTRIBUTION: SLP, NLP (Fig. 13)

PHENOLOGY: 24 June - 16 August

FLOWER VISITATION: None

Heteranthidium zebratum (Cresson)

Known only from a single ♀ . Lake Co., 10 August 1941, R. R. Dreisbach (MSUC). (Fig. 3)

Stelis (Chelynia) labiata (Provancher)

Recorded by Mitchell (1962) as to occur in Michigan.

Stelis (Chelynia) michiganensis Mitchell

Known only from the Holotype specimen: Luce Co., 8 July 1946, R. R. Dreisbach. (Fig. 77)

Stelis (Microstelis) lateralis Cresson

Recorded by Mitchell (1962) as to occur in Michigan.

Stelis (Microstelis) vernalis Mitchell

Recorded by Mitchell (1962) as part of the paratype series as follows: Cheboygan Co., Douglas Lake, (7 June or July 6) 1930. C. J. D. Brown, ♀; Mason Co., (date obliterated), R. R. Dreisbach, ♂ , (MSUC); Huron Co., 29 June 1922, R. H. Hussey, ♀ ; Charlevoix Co., 3 July 1939, D. S. Bullock and R. R. Dreisbach, ♂ . (Fig. 78)

***Heriades (Physostetha) carinata Cresson**

SPECIMENS EXAMINED: 131

DISTRIBUTION: SLP, NLP, UP (Fig 15)

PHENOLOGY: SLP, 13 June - August 9; NLP, 21 June - September 5; UP, 2 July - August 30.

FLOWER VISITATION: Asclepias syriaca ♂♀ , Melilotus alba ♀ , Monarda fistulosa ♀ , Rhus glabra ♀

Heriades (Neotrypetes) leavitti Crawford

SPECIMENS EXAMINED: 10

DISTRIBUTION: SLP, NLP, (Fig. 16)

PHENOLOGY: 1 July - August 13

FLOWER VISITATION: None

Heriades (Neotrypetes) variolosa variolosa (Cresson)

SPECIMENS EXAMINED: 8

DISTRIBUTION: SLP, NLP (Fig. 17)

PHENOLOGY: 9 July - August 19

FLOWER VISITATION: None

Ashmeadiella (Ashmeadiella) bucconis bucconis (Say)

A single male specimen known from the State: Otsego Co., 7 July 1959, R. and K. Dreisbach (MSUC). (Fig. 18).

Prochelostoma philadelphi (Robertson)

SPECIMENS EXAMINED: 50

DISTRIBUTION: SLP, NLP, (Fig. 19)

PHENOLOGY: 31 May - July 18

FLOWER VISITATION: Philadelphus grandiflorus ♀♂, Potentilla recta ♀

***Hoplitis (Monumetha) albifrons (Kirby)**

SPECIMENS EXAMINED: 17

DISTRIBUTION: NLP, UP, (Fig. 20)

PHENOLOGY: 29 May - July 29

FLOWER VISITATION: Epilobium angustifolium ♀ , Rubus allegheniensis ♀

***Hoplitis (Andronicus) cylindrica (Cresson)**

SPECIMENS EXAMINED: 75

DISTRIBUTION: SLP, NLP, UP, IR (Fig. 21)

PHENOLOGY: SLP, 20 May - August 11; NLP, 28 May - August 7; UP, 7 July - August 4; IR, 3 July - August 10.

FLOWER VISITATION: Arctium minus ♀ , Fragaria ♂ , Melilotus alba ♀ , Rubus allegheniensis ♀ , Rubus ♂

Hoplitis (Alcidamea) pilosifrons (Cresson)

SPECIMENS EXAMINED: 50

DISTRIBUTION: SLP, NLP (Fig. 22)

PHENOLOGY: SLP, 5 June - July 23

FLOWER VISITATION: Fragaria ♂♀, Melilotus alba ♀, Monarda fistulosa ♀, Penstemon hirsutus ♀, Potentilla recta ♀, Rubus ♂♀, Trifolium repens ♀, Trifolium ♂♀, Vicia villosa ♂

***Hoplitis (Alcidamea) producta producta (Cresson)**

SPECIMENS EXAMINED: 161

DISTRIBUTION: SLP, NLP, UP, IR (Fig. 23)

PHENOLOGY: SLP, 17 May- July 24; NLP, 18 May - August 8;, UP, 22 June - July 29.

FLOWER VISITATION: Apocynum androsaemifolium ♀, Melilotus ♂, Monarda fistulosa ♀, Rhus glabra ♀, Rhus typhina ♀, Rubus allegheniensis ♂, Rubus strigosus ♀, Rubus ♂♀, Trifolium repens ♂♀

Hoplitis (Alcidamea) truncata truncata (Cresson)

SPECIMENS EXAMINED: 13

DISTRIBUTION: SLP, NLP (Fig 24)

PHENOLOGY: 9 June - July 28

FLOWER VISITATION: None

***Osmia (Osmia) lignaria lignaria Say**

SPECIMENS EXAMINED: 39

DISTRIBUTION: SLP, NLP, UP (Fig. 36)

PHENOLOGY: SLP, 18 April - June 22; NLP, May 21 - 23; UP, 5 May-June 29.

FLOWER VISITATION: Prunus tomentosa ♂, Salix ♂

Osmia (Chalcosmia) coerulescens (Linnaeus)

SPECIMENS EXAMINED: 81

DISTRIBUTION: SLP, NLP, UP (Fig. 28)

PHENOLOGY: SLP, 3 May - July 26; NLP, 5 June - July 15; UP, 9 - 23 July.

FLOWER VISITATION: Fragaria ♀, Lonicera tatarica ♂, Trifolium ♂, Viola americana ♀, Weigelia ♂

Osmia (Chalcosmia) georgica Cresson

SPECIMENS EXAMINED: 8

DISTRIBUTION: SLP (Fig. 32)

PHENOLOGY: SLP, 1 May - July 12

FLOWER VISITATION: None

Osmia (Chalcosmia) texana Cresson

SPECIMENS EXAMINED: 6

DISTRIBUTION: SLP (Fig.44)

PHENOLOGY: SLP, 20 May - August 11

FLOWER VISITATION: None

*Osmia (Cephalosmia) subaustralis Cockerell

SPECIMENS EXAMINED: 12

DISTRIBUTION: NLP, UP (Fig. 42)

PHENOLOGY: 9 June - July 28

FLOWER VISITATION: None

*Osmia (Centrosmia) bucephala Cresson

SPECIMENS EXAMINED: 38

DISTRIBUTION: SLP, NLP, UP, IR (Fig. 27)

PHENOLOGY: SLP, 5 May - July 4; NLP, 24 May - July 22; UP, 8 June - July 6; IR, 2 - 18 July.

FLOWER VISITATION: Rubus allegheniensis ♀ , Viola ♀

*Osmia (Centrosmia) nigriventris (Zetterstedt)

Two specimens are known from the State; Marquette Co., McCormick Tract, , 18 May 1982; , 19 May 1982; both at flowers of Amelanchier bartramiana and collected by M. Arduser (Fig. 38) (MSUC).

*Osmia (Acanthosmioides) integra Cresson

SPECIMENS EXAMINED: 6

DISTRIBUTION: UP (Fig 35)

PHENOLOGY: UP, 6 June - July 3

FLOWER VISITATION: Arabis lyrata ♀ , Hieracium ♀ , Hudsonia ♀ , Linnaea ♀

*Osmia (Nothosmia) albiventris Cresson

SPECIMENS EXAMINED: 62

DISTRIBUTION: SLP, NLP, UP (Fig 25)

PHENOLOGY: SLP, 24 April - August 14; NLP, 27 May - June 30; UP, 11 June - August 5.

FLOWER VISITATION: Epilobium angustifolium ♀, Fragaria ♀, Robinia pseudoacacia ♀, Rubus ♂♀, Trifolium repens ♀, Vicia villosa ♂

Osmia (Nothosmia) distincta Cresson

SPECIMENS EXAMINED: 77

DISTRIBUTION: SLP, NLP (Fig 31)

PHENOLOGY: 23 April - July 13

FLOWER VISITATION: Penstemon hirsutus ♀, Rubus ♀, Trifolium hybridum ♀, Trifoluim ♀, Vicia americana ♀, Vicia villosa ♂♀, Viola americanum ♀, Viola ♂

*Osmia (Nothosmia) inspergens Lovell & Cockerell

SPECIMENS EXAMINED: 16

DISTRIBUTION: SLP, NLP, UP (Fig.34)

PHENOLOGY: 21 May - July 18

FLOWER VISITATION: None

Osmia (Nothosmia) michiganensis Mitchell

Mitchell (1962) described this species from a single male specimen from Grand Traverse Co., 27 May 1950, R. R. Dreisbach. Two additional male specimens of what appear to be this species have been identified from MSUC material: Missaukee Co., 29 May 1959, R. R. Dreisbach and Montmorency Co., 24 - 30 May 1966, P. C. Kennedy, EX: Window Pane trap. (Fig 37).

*Osmia (Nothosmia) pumila Cresson

SPECIMENS EXAMINED: 106

DISTRIBUTION: SLP, NLP (Fig. 40)

PHENOLOGY: SLP, 21 April - August 19; NLP, 4 May - July 5.

FLOWER VISITATION: Fragaria ♀, Potentilla recta ♀, Prunus ♂, Rubus ♀, Salix ♂♀, Taraxacum officinalis ♂, Trifolium repens ♀, Viola ♀

*Osmia (Chenosmia) atriventris Cresson

SPECIMENS EXAMINED: 236

DISTRIBUTION: SLP, NLP, UP, IR (Fig. 26)

PHENOLOGY: SLP, 23 April - July 29; NLP, 28 April - August 16; UP, 15 May - July 24; IR, 10 - 29 July.

FLOWER VISITATION: Amelanchier canadensis ♂ , Fragaria ♀ , Prunus tomentosa ♂, Rosa ♀ , Rubus allegheniensis ♀ , Rubus ♀ , Salix ♂ , Trifolium ♀ , Vaccinium ♀ , Vicia villosa ♂♀, Viola ♂

Osmia (Chenosmia) collinsiae Robertson

SPECIMENS EXAMINED: 10

DISTRIBUTION: SLP, NLP, UP (Fig. 29)

PHENOLOGY: 30 June - July 18

FLOWER VISITATION: None

*Osmia (Chenosmia) inermis (Zetterstedt)

Known from four female specimens: Oscoda Co., Luzerne, 28 June 1966, L. F. Wilson; Montmorency Co., 5 July 1966, P. C. Kennedy (all above from window pane traps); Marquette Co., Ishpeming, 9 June 1940. (all MSUC) (Fig. 33)

*Osmia (Chenosmia) proxima Cresson

SPECIMENS EXAMINED: 71

DISTRIBUTION: SLP, NLP, UP, IR, (Fig. 39)

PHENOLOGY: SLP, 3 May - June 27; NLP, 21 May - June 29; UP, 27 May -July 29; IR, 3 July - August 1.

FLOWER VISITATION: Trifolium repens ♀ , Viola canadensis ♂ , Viola papilionacea ♀

*Osmia (Chenosmia) tersula Cockerell

SPECIMENS EXAMINED: 21

DISTRIBUTION: NLP, UP (Fig. 43)

PHENOLOGY: NLP, 24 May- July 17; UP, 11 June - July 6.

FLOWER VISITATION: Rubus allegheniensis ♀

Osmia (Chenosmia) virga Sandhouse

Known only from a single male: Schoolcraft Co., Manistique, 28 May 1960, R. L. Fischer (MSUC). (Fig. 45).

*Osmia (Monilosmia) simillima Smith

SPECIMENS EXAMINED: 108

DISTRIBUTION: SLP, NLP, UP, IR, (Fig. 41)

PHENOLOGY: SLP, 22 April - August 6; NLP, 27 May - 19 July; UP, 6 June - August 6, IR, 30 June - August 8.

FLOWER VISITATION: Fragaria , Trifolium hybridum ♂, Trifolium repens ♀ , Vicia americana ♂♀ , Vicia villosa ♂♀, Viola ♂

Osmia (Diceratosmia) conjuncta Cresson

SPECIMENS EXAMINED: 68

DISTRIBUTION: SLP, NLP, UP (Fig. 30)

PHENOLOGY: SLP, 27 April -July 12; NLP, 1 May - July 13; UP, 29 May.

FLOWER VISITATION: Fragaria ♀ , Salix ♂ , Vicia villosa ♀

*Megachile (Litomegachile) brevis brevis Say

SPECIMENS EXAMINED: 63

DISTRIBUTION: SLP, NLP, UP (Fig. 47)

PHENOLOGY: SLP, 13 June - September 21; NLP, 6 July - September 5; UP, 26 August.

FLOWER VISITATION: Melilotus alba ♂ , Potentilla recta ♂ , Vicia americana ♂

*Megachile (Litomegachile) mendica mendica Cresson

SPECIMENS EXAMINED: 235

DISTRIBUTION: SLP, NLP, UP (Fig. 55)

PHENOLOGY: SLP, 30 May - October 15; NLP, 25 June - September 2; UP, 7 June - July 22.

FLOWER VISITATION: Asclepias tuberosa ♂ , Hypericum punctata ♀ , Melilotus alba ♂ , Monarda fistulosa ♂ , Rhus glabra ♀ , Rudbeckia hirta ♂ , Trifolium hybridrum ♂ , Trifolium repens ♂ , Verbena ♂ , Vicia americana ♂

Megachile (Litomegachile) texana Cresson

SPECIMENS EXAMINED: 95

DISTRIBUTION: SLP, NLP, UP (Fig. 60)

PHENOLOGY: SLP, 18 June - August 22; NLP, 17 June - August 24; UP, 15 -23 July.

FLOWER VISITATION: Asclepias tuberosa ♂♀

*Megachile (Megachile) centuncularis (Linnaeus)

SPECIMENS EXAMINED: 38

DISTRIBUTION: SLP, NLP, UP (Fig. 48)

PHENOLOGY: SLP, 4 June - August 30; NLP, 21 June - September 4; UP, 20 July - September 26.

FLOWER VISITATION: Cirsium vulgare ♂, Melilotus officinalis ♀, Philadelphus grandiflorus ♀

*Megachile (Megachile) inermis Provancher

SPECIMENS EXAMINED: 115

DISTRIBUTION: SLP, NLP, UP, IR (Fig. 52)

PHENOLOGY: SLP, 25 June - September 21; NLP, 22 June - September 5; UP, 25 June - August 31; IR, 1 July - August 3.

FLOWER VISITATION: Cirsium palustre ♂, Epilobium angustifolium ♀

*Megachile (Megachile) montivaga Cresson

SPECIMENS EXAMINED: 32

DISTRIBUTION: SLP, NLP, UP, IR (Fig. 56)

PHENOLOGY: SLP, 13 June - September 6; NLP, 17 July - August 15; UP, 28 June - August 3; IR, 3-7 August.

FLOWER VISITATION: Chrysanthemum leucanthemum ♀, Helianthus ♂, Rhus glabra ♀

*Megachile (Megachile) relativa Cresson

SPECIMENS EXAMINED: 229

DISTRIBUTION: SLP, NLP, UP, IR (Fig. 59)

PHENOLOGY: SLP, 30 May - October 15; NLP, 5 June - September 7; Up, 18 June - September 28; IR, 3 July - August 29.

FLOWER VISITATION: Chrysanthemum leucanthemum ♂♀, Hieracium ♂, Lythrum salicaria ♀, Melilotus officinalis ♀, Potentilla recta ♀, Rubus ♀, Rudbeckia hirta ♂, Solidago ♀, Trifolium repens ♂♀

Megachile (Eutricharaea) concinna Smith

Three female specimens are known from the State: Ingham Co., Lansing, 31 August 1956, 5 September 1956, R. W. Hodges; and Clinton Co., Bath, 2 June 1956, R. L. Fischer. (Fig. 49)

Megachile (Eutricharaea) pacifica (Panzer)

SPECIMENS EXAMINED: 21

DISTRIBUTION: SLP (Fig. 57)

PHENOLOGY: SLP, 13 June - September 7

FLOWER VISITATION: Pyracantha coccinea ♂

*Megachile (Addendella) addenda Cresson

SPECIMENS EXAMINED: 50

DISTRIBUTION: SLP, NLP, UP (Fig. 46)

PHENOLOGY: SLP, 14 May - July 17; NLP, 21 June - July 29; UP, 15 July

FLOWER VISITATION: Asclepias syriaca ♂, Medicago sativa ♀, Vicia americana ♂♀

*Megachile (Delomegachile) frigida frigida Smith

SPECIMENS EXAMINED: 119

DISTRIBUTION: SLP, NLP, UP, IR, (Fig. 50)

PHENOLOGY: SLP, 10 June - September 13; NLP, 10 June - August 6; UP, 15 June - September 2; IR, 4 July - August 9.

FLOWER VISITATION: Campanula rotundifolia ♀, Epilobium angustifolium ♀, Lathyrus maritimus ♂

*Megachile (Delomegachile) gemula gemula Cresson

SPECIMENS EXAMINED: 112

DISTRIBUTION: SLP, NLP, UP, IR (Fig. 51)

PHENOLOGY: SLP, 30 May - 3 October; NLP, 23 May - July 28; UP, 11 June - September 2; IR, 10 July - August 8.

FLOWER VISITATION: Barbarea ♀, Campanula rotundifolia ♀, Epilobium angustifolium ♂, Linnaea borealis ♂, Rhus ♂, Rubus ♂, Vicia americana ♀

*Megachile (Delomegachile) melanophoea melanophoea Smith

SPECIMENS EXAMINED: 169

DISTRIBUTION: SLP, NLP, UP, IR, (Fig. 54)

PHENOLOGY: SLP, 30 May - July 11; NLP, 5 June - August 14; UP, 7 June - August 7; IR, 30 June - August 18.

FLOWER VISITATION: Anemone canadensis ♀, Epilobium angustifolium ♀, Lathyrus maritimus ♂, Trifolium repens ♂♀, Vicia americana ♂♀ Vicia villosa ♂♀

*Megachile (Xanthosarus) latimanus Say

SPECIMENS EXAMINED: 384

DISTRIBUTION: SLP, NLP, UP, IR, (Fig. 53)

PHENOLOGY: SLP, 14 June - October 12; NLP, 29 June - September 9; UP, 1 July - September 11; IR, 23 August

FLOWER VISITATION: Asclepias tuberosa ♀, Centaurea maculosa ♀, Chrysanthemum leucanthemum ♂, Cirsium vulgare ♀, Coreopsis ♀, Melilotus alba ♂♀, Rhus glabra ♀, Rudbeckia hirta ♂

*Megachile (Xanthosarus) perihirta Cockerell

Mitchell (1962) records a single male specimen from the State as follows: Schoolcraft Co., Manistique, 1 July 1922, S. Moore. (Fig. 58).

Chalicodoma (Chelostomoides) campanulae campanulae (Robertson)

SPECIMENS EXAMINED: 42

DISTRIBUTION: SLP, NLP, (Fig. 61)

PHENOLOGY: 2 July - September 3

FLOWER VISITATION: Asclepias syriaca ♂, Asclepias tuberosa ♂, Melilotus alba ♀, Nepeta cataria ♂

Chalicodoma (Chelostomoides) rugifrons (Smith)

A single male specimen is known from the State: Midland Co., June 1934, R. R. Dreisbach (MSUC). (Fig. 62)

Megachiloides (Xeromegachile) dakotensis (Mitchel)

SPECIMENS EXAMINED: 24

DISTRIBUTION: SLP, NLP, (Fig. 63)

PHENOLOGY: 10 - 21 July

FLOWER VISITATION: None

Eumegachile (Sayapis) frugalis frugalis (Cresson)

SPECIMENS EXAMINED: 6

DISTRIBUTION: SLP (Fig. 64)

PHENOLOGY: SLP, 28 June - July 23

FLOWER VISITATION: Centaurea cybnus ♂

Eumegachile (Sayapis) inimica sayi (Cresson)

Four specimens are known: Kalamazoo Co., Gull Lake Biological Station, 15 August 1964, , at flowers of Helianthus, R. L. Fischer; 2 , same data as above, R. W. Matthews (MSUC). Kalamazoo Co., no date, N. Becker (UMMZ). (Fig. 65)

*Eumegachile (Sayapis) pugnata pugnata (Say)

SPECIMENS EXAMINED: 61

DISTRIBUTION: SLP, NLP, UP, IR, (Fig. 66)

PHENOLOGY: SLP, 27 June - September 12; NLP, 4 July - August 24; UP, 15 July - July 26; IR, 5 July.

FLOWER VISITATION: Apocynum androsaemifolium ♂, Helianthus ♂, Nepeta cataria ♂, Rhus glabra ♂, Rudbeckia hirta ♀

AD-A148 327 COMPILATION OF ANNUAL REPORTS OF THE NAVY ELF (EXTREMELY LOW FREQUENCY) C.. (U) IIT RESEARCH INST CHICAGO IL R L FISCHER ET AL. JUL 84 2/6

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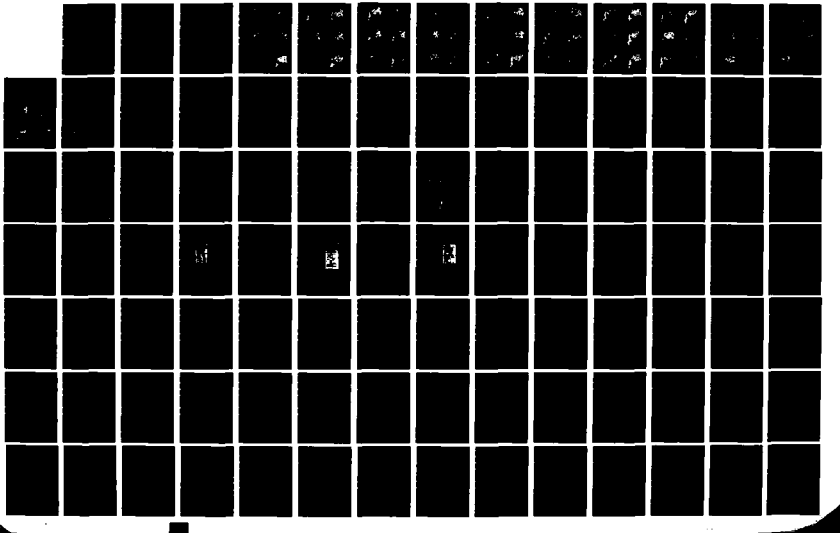
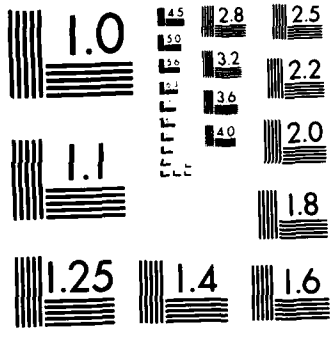




Pseudocentron (Leptorachis) petulans (Cresson)

SPECIMENS EXAMINED: 11

DISTRIBUTION: SLP, (Fig. 67)

PHENOLOGY: SLP, 4 July - August 14

FLOWER VISITATION: None

Coelioxys (Coelioxys) sodalis Cresson

SPECIMENS EXAMINED: 20

DISTRIBUTION: SLP, NLP, (Fig. 68)

PHENOLOGY: 5 June - July 29

FLOWER VISITATION: None

Coelioxys (Boreocoelioxys) moesta Cresson

Four specimens are known from the State as follows: Huron Co., 12 September 1927, ♀ , F. M. Gaige; Mecosta Co., 24 July 1948, ♂, R. R. Dreisbach; Arenac Co., 3 June 1939, ♂, R. R. Dreisbach; Iosco Co., 22 July 1950, ♂ , R. R. Dreisbach - (all MSUC). (Fig. 69).

***Coelioxys (Boreocoelioxys) octodentata Say**

SPECIMENS EXAMINED: 36

DISTRIBUTION: SLP, NLP, UP (Fig. 70)

PHENOLOGY: 9 June-September 6

FLOWER VISITATION: Asclepias tuberosa ♂♀ , Rubus ♂

***Coelioxys (Boreocoelioxys) porterae Cockerell**

SPECIMENS EXAMINED: 20

DISTRIBUTION: SLP, NLP, UP, IR (Fig. 71)

PHENOLOGY: 1 June - August 19

FLOWER VISITATION: Rubus ♂

Coelioxys (Boreocoelioxys) rufitarsis Smith

SPECIMENS EXAMINED: 62

DISTRIBUTION: SLP, NLP, UP, IR, (Fig. 72)

PHENOLOGY: SLP, 21 June - September 26; NLP, 4 July - 19 August; UP, 29 June - August 15; IR, 29 July.

FLOWER VISITATION: Anaphalis margaritacea ♀ , Asclepias syriaca ♂ , Asclepias tuberosa ♂ , Cirsium vulgare ♀ , Solidago ♂

Coelioxys (Boreocoelioxys) sayi Robertson

SPECIMENS EXAMINED: 39

DISTRIBUTION: SLP (Fig. 73)

PHENOLOGY: SLP, 29 May - September 16

FLOWER VISITATION: Melilotus alba ♂, Rubus ♂, Rudbeckia hirta ♂

*Coelioxys (Schizocoelioxys) funeraria Smith

Four female specimens are known from the State: Sanilac Co., 7 August 1927; Dickinson Co., 28 August 1959, R. and K. Dreisbach; Isle Royale, 1 August 1957, R. W. Hodges (all MSUC); Marquette Co., Ishpeming, 2 September 1979 (NMU). (Fig. 74).

Coelioxys (Syncoelioxys) alternata Say

SPECIMENS EXAMINED: 12

DISTRIBUTION: SLP, NLP (Fig. 75)

PHENOLOGY: 8 July - August15

FLOWER VISITATION: None

*Coelioxys (Crytocoelioxys) modesta Smith

SPECIMENS EXAMINED: 5

DISTRIBUTION: SLP, UP (Fig. 76)

PHENOLOGY: 13 July - August 30

FLOWER VISITATION: None

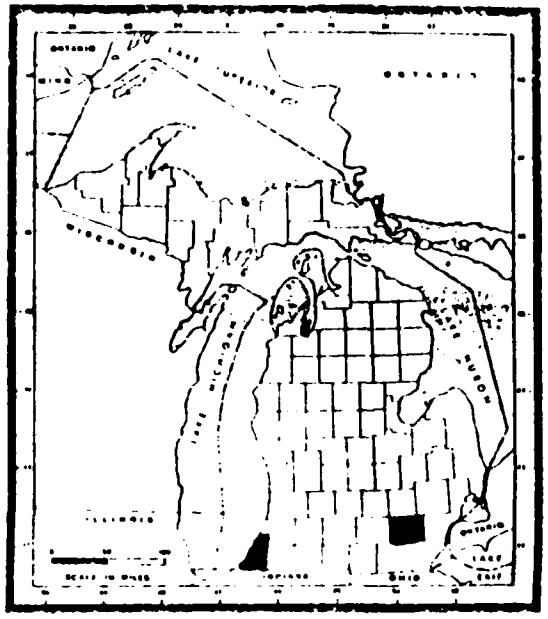


Figure 12. Anthidium psoraleae

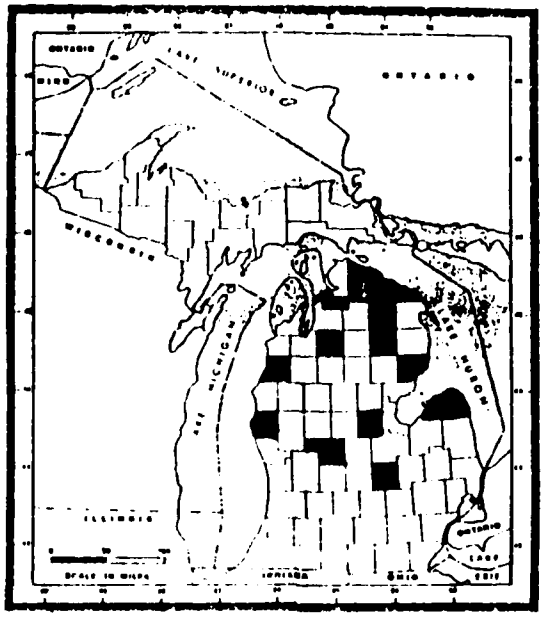


Figure 13. Dianthidium simile

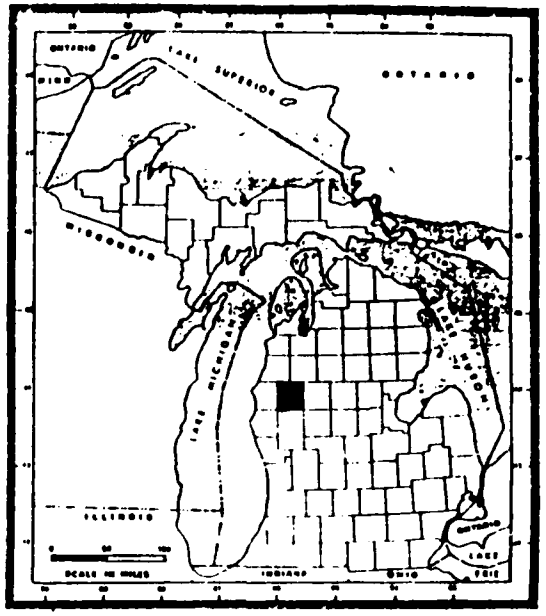


Figure 14. Heteranthidium zebratum

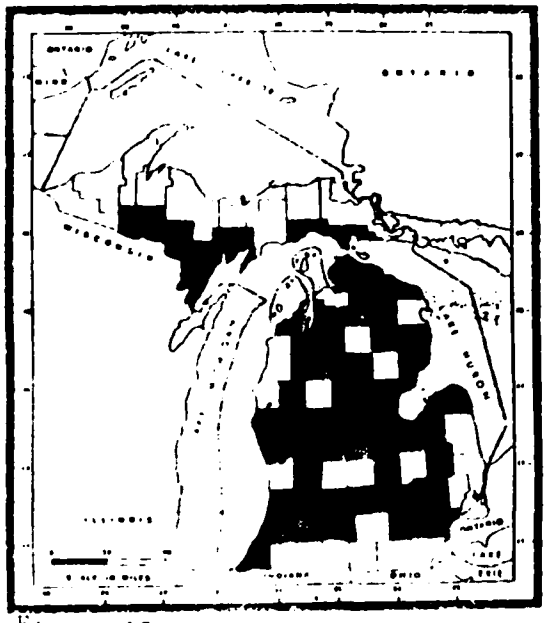


Figure 15. Heriades carinata

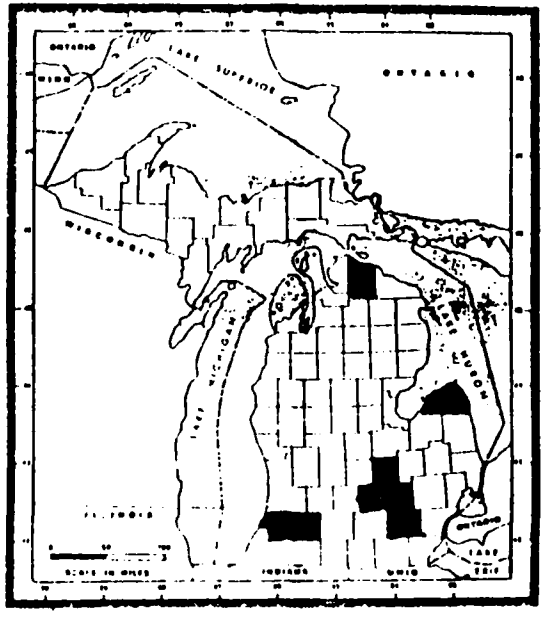


Figure 16. Heriades leavitti

Figure 17. Heriades variolosa

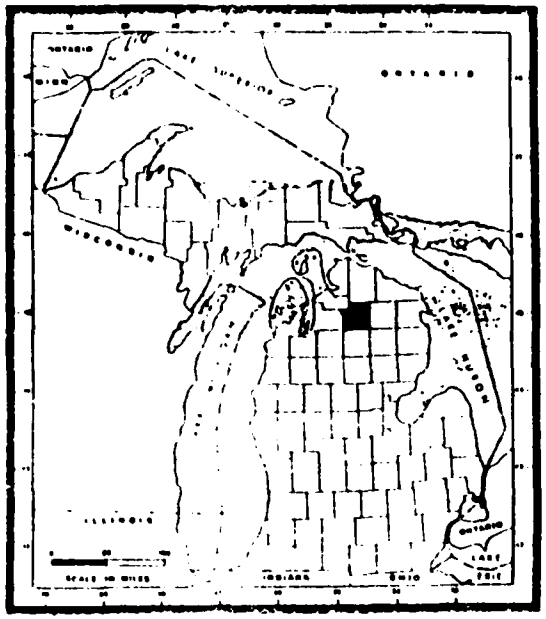


Figure 18. Ashmeadiella bucconis

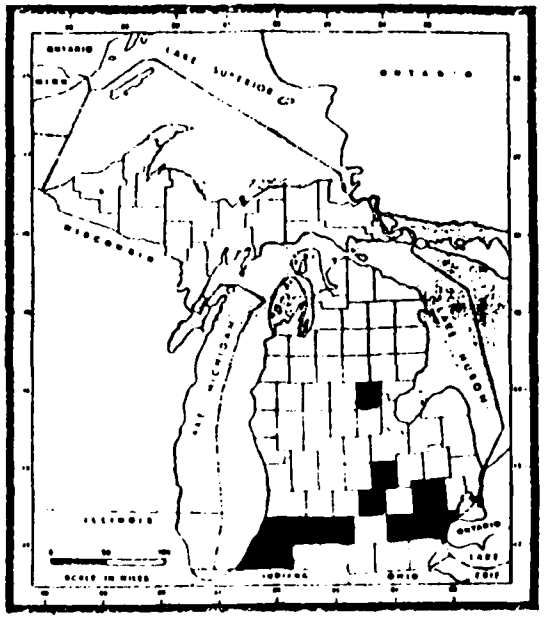


Figure 19. Prochelostoma philadelphi

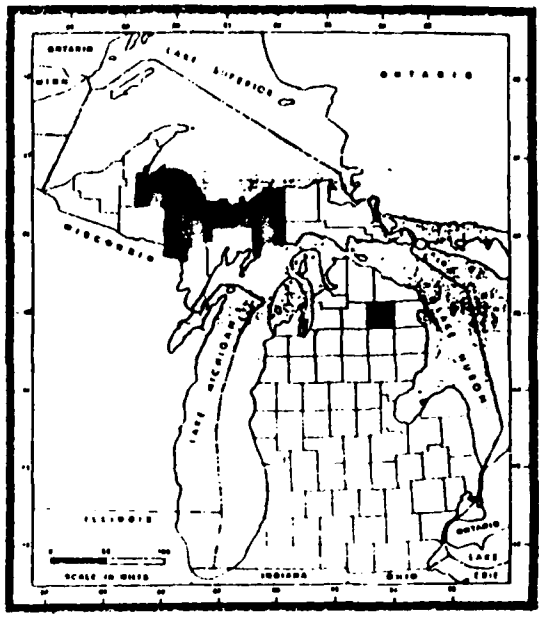


Figure 20. Hoplitis albifrons

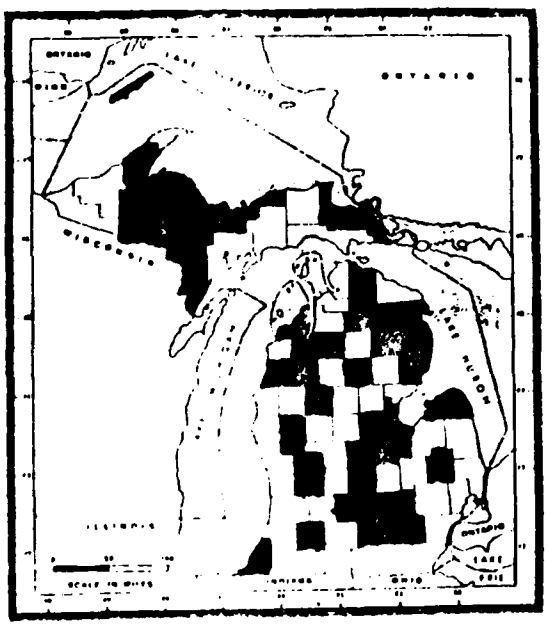


Figure 21. Hoplitis cylindrica

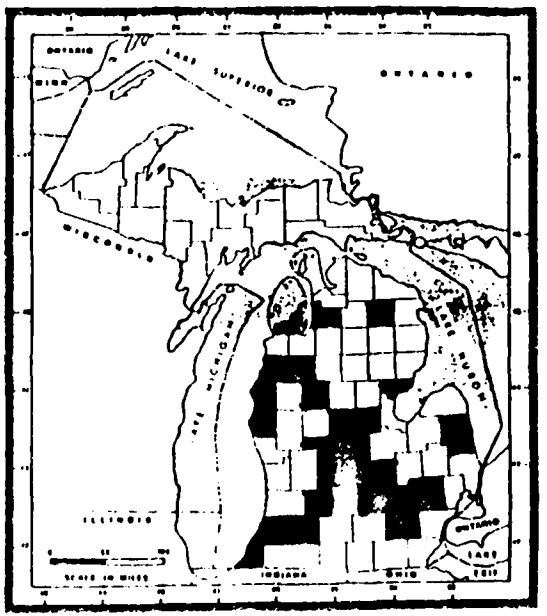


Figure 22. Hoplitis pilosifrons

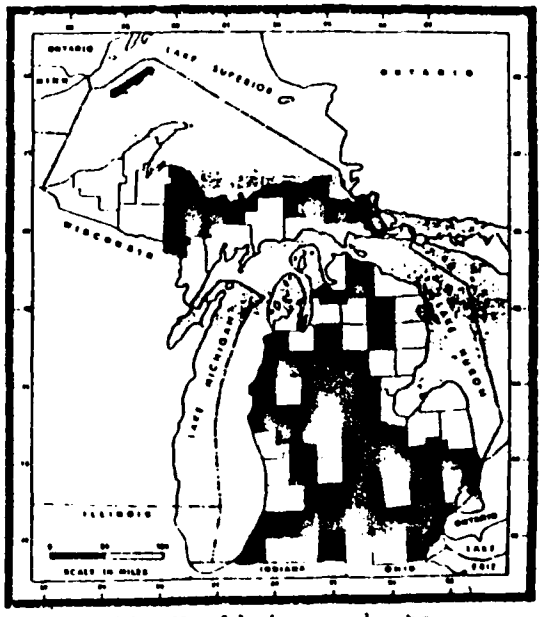


Figure 23. Hoplitis producta

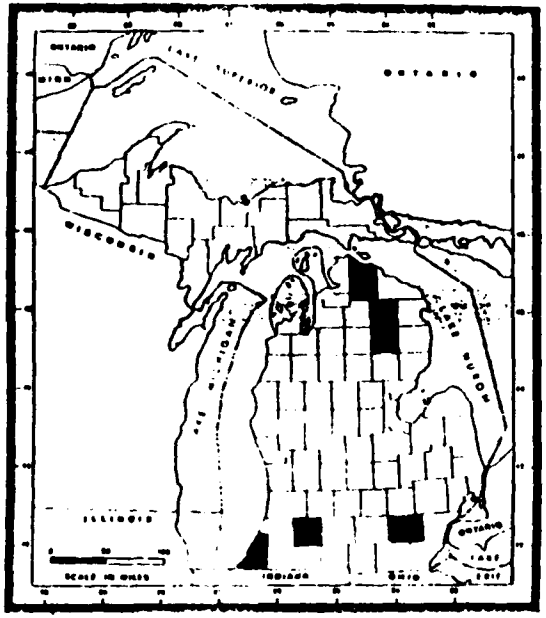


Figure 24. Hoplitis truncata

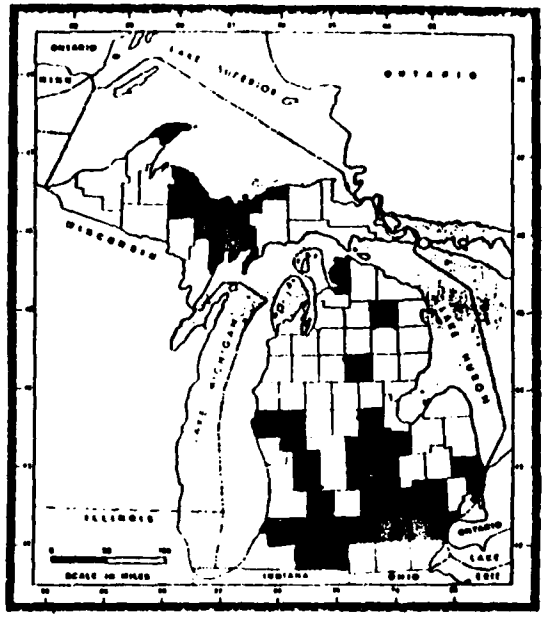


Figure 25. Osmia albiventris

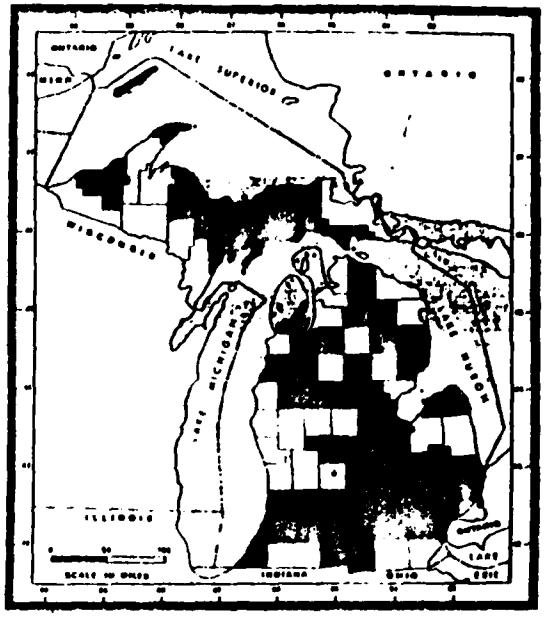


Figure 26. Osmia atriventris

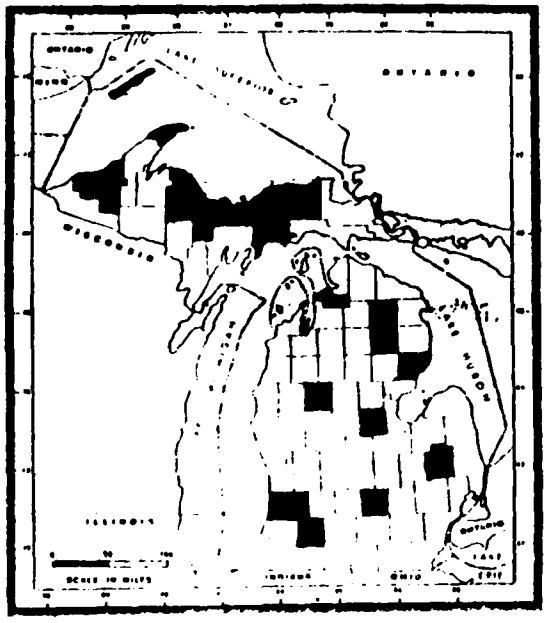


Figure 27. Osmia bucephala

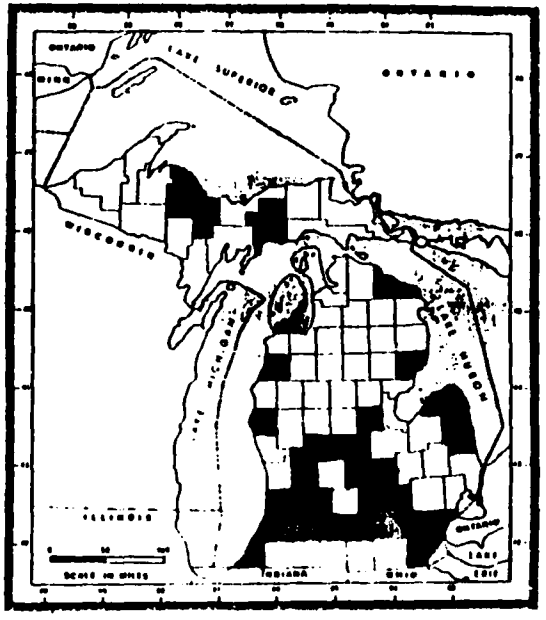


Figure 28. Osmia coerulescens

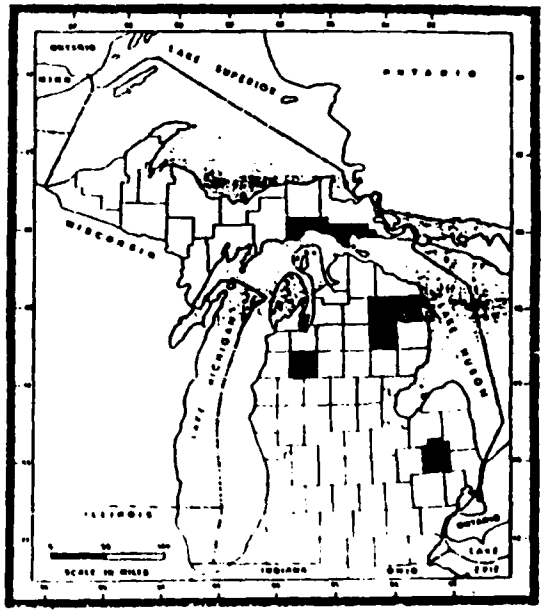


Figure 29. Osmia collinsiae

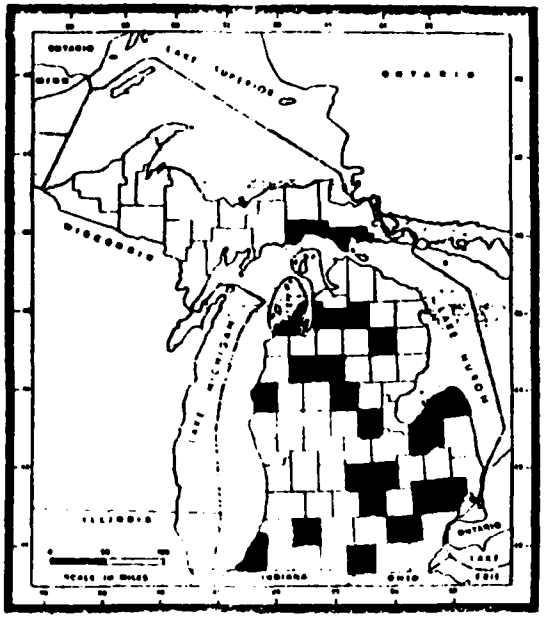


Figure 30. Osmia conjuncta

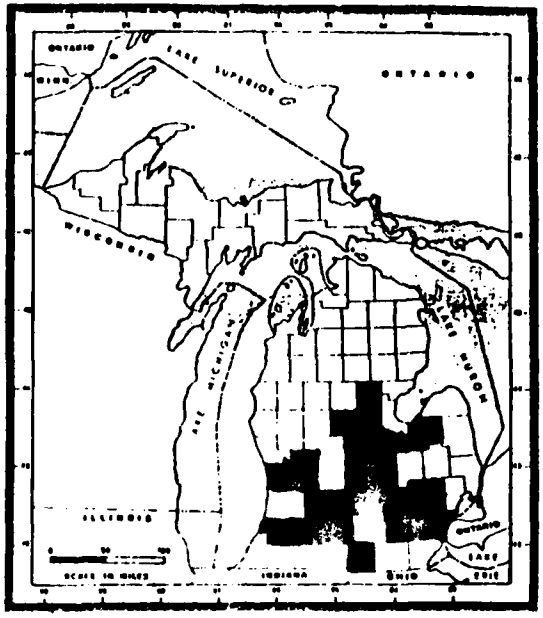


Figure 31. Osmia distincta

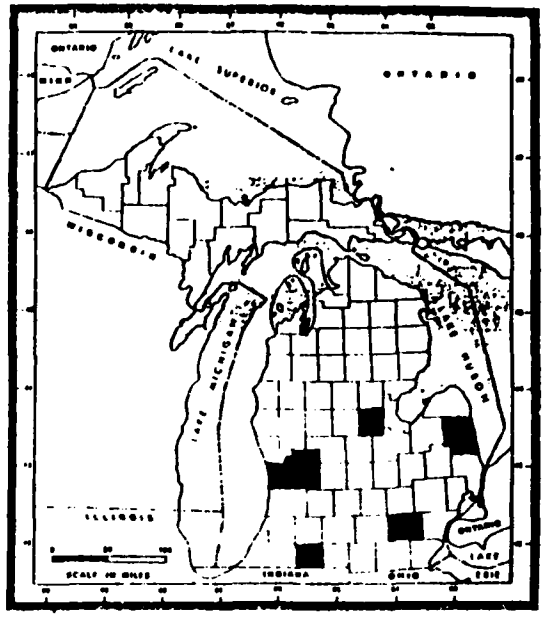


Figure 32. Osmia georgica

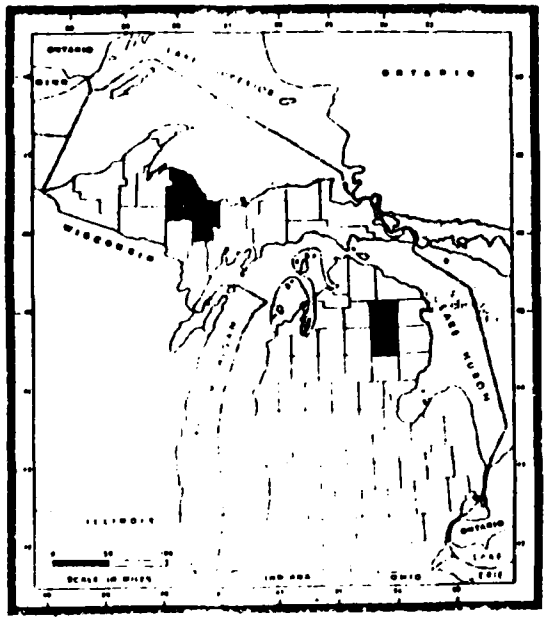


Figure 33. Osmia inermis

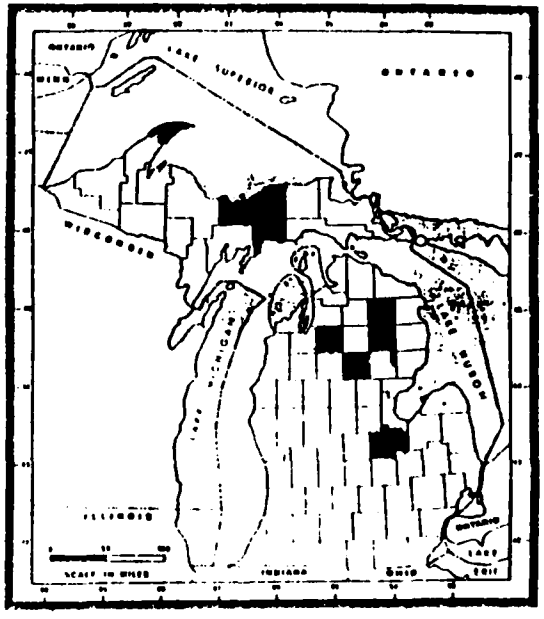


Figure 34. Osmia inspergens

Figure 35. Osmia integra

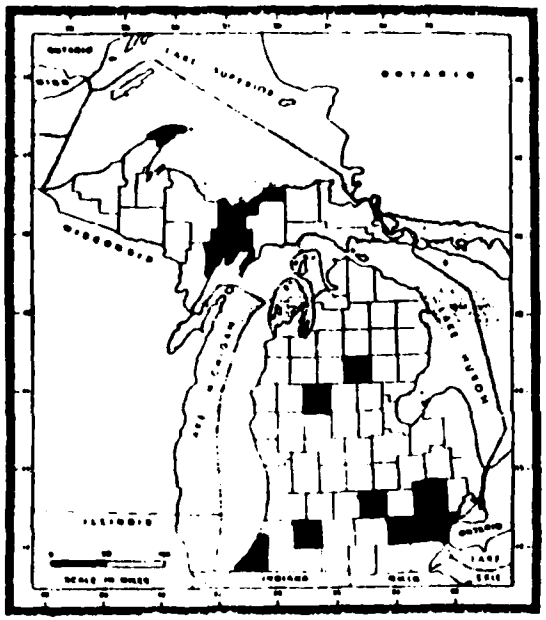


Figure 36. Osmia lignaria

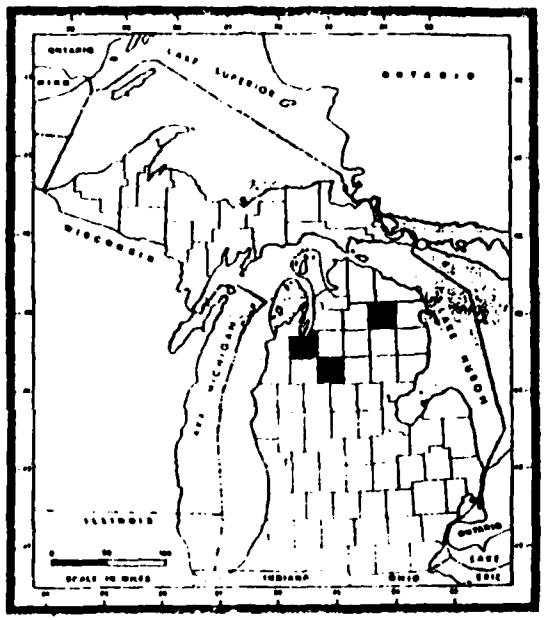


Figure 37. Osmia michiganensis

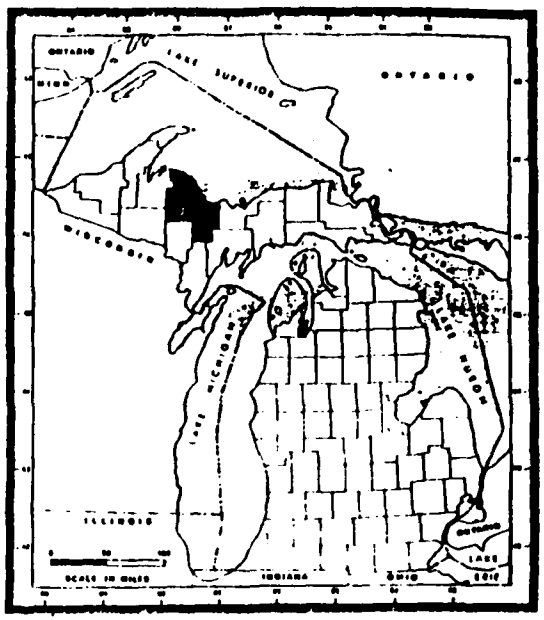


Figure 38. Osmia nigriventris

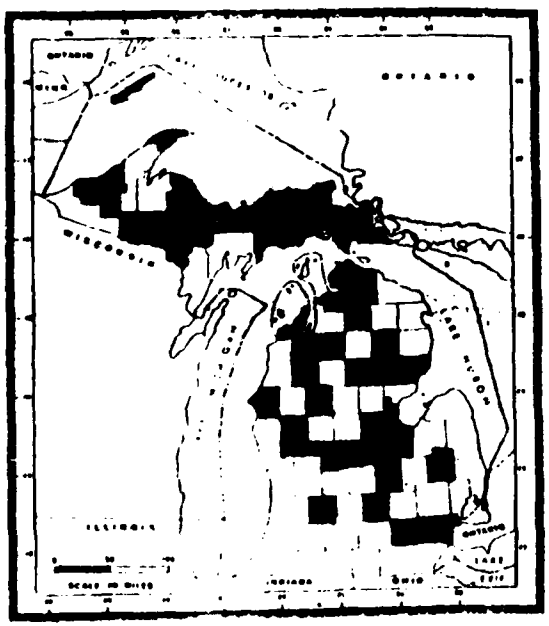
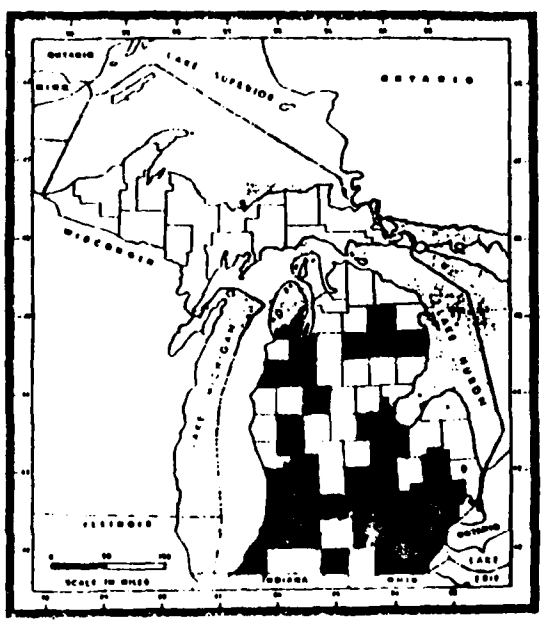


Figure 39. Osmia proxima



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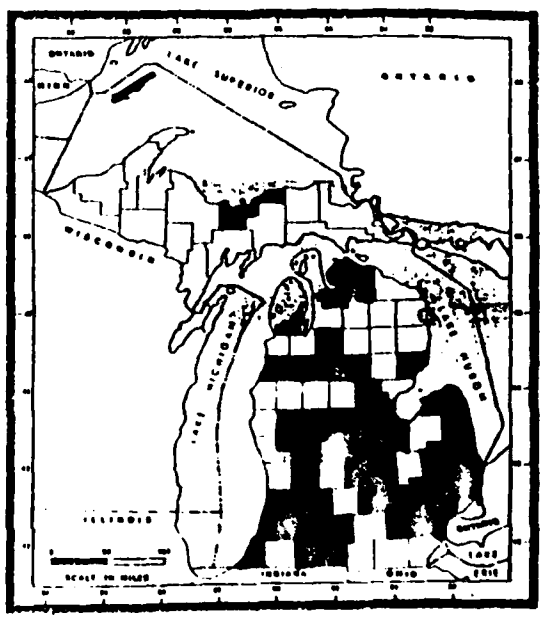

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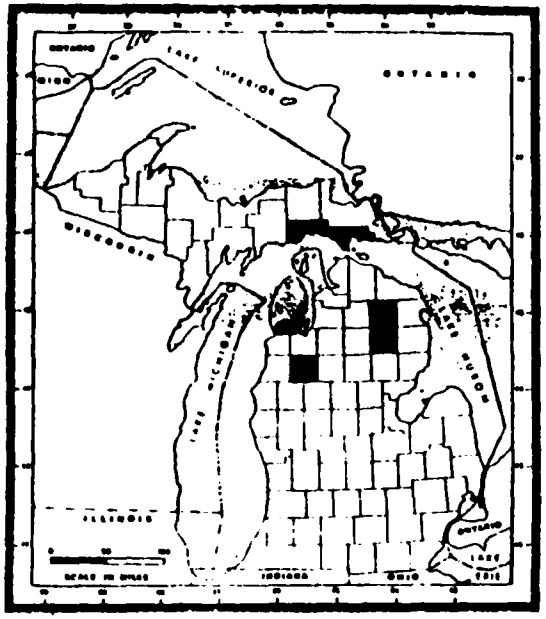

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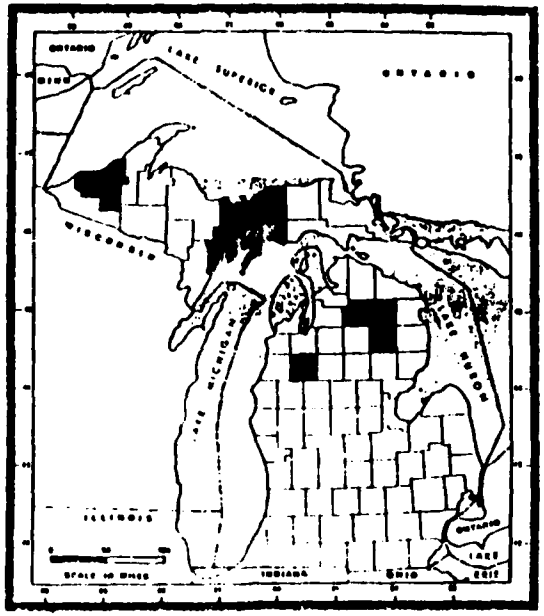

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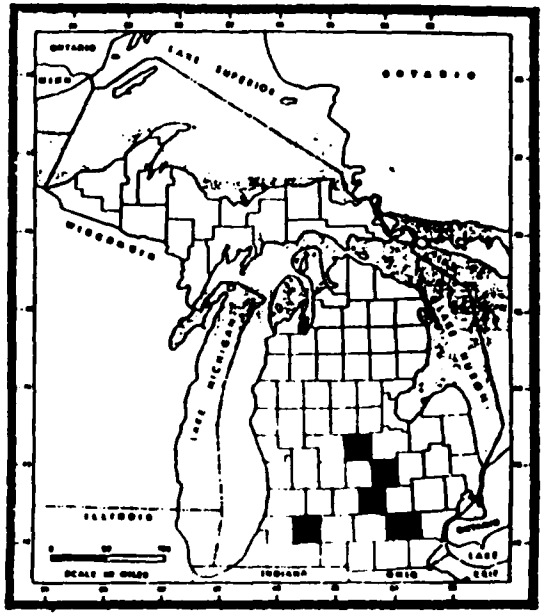
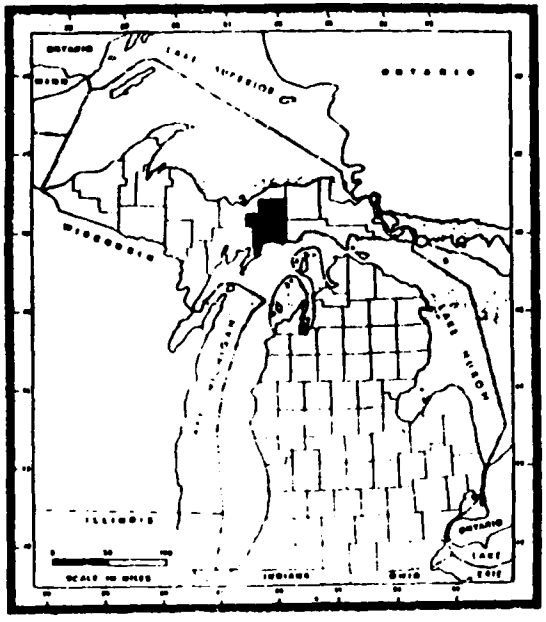


Figure 44. Osmia texana



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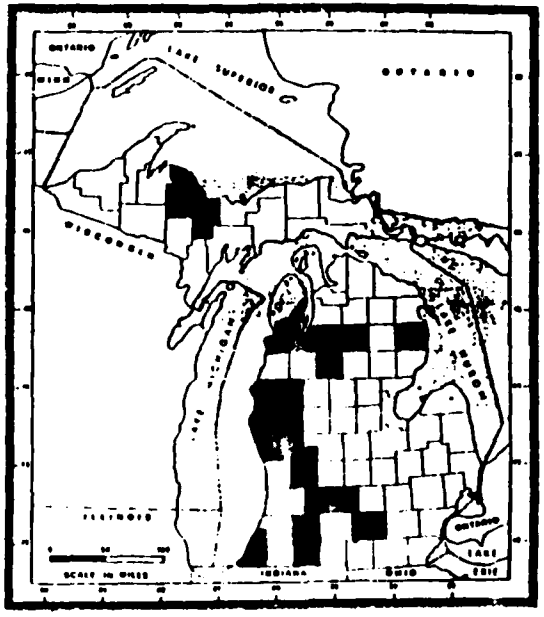
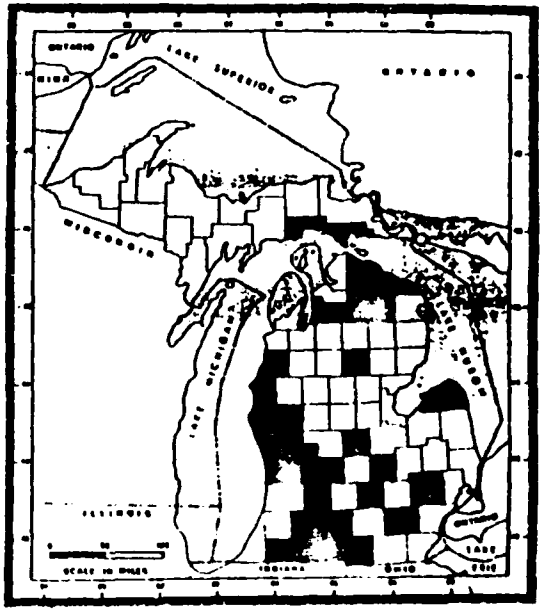


Figure 46. Megachile addenda



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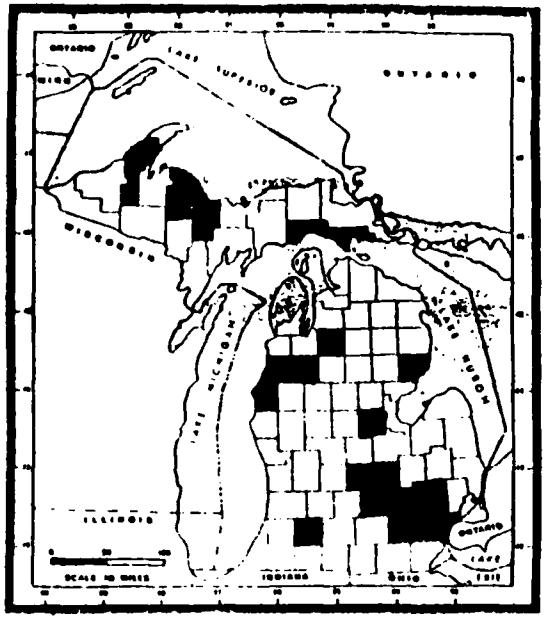


Figure. 48. Megachile centuncularis

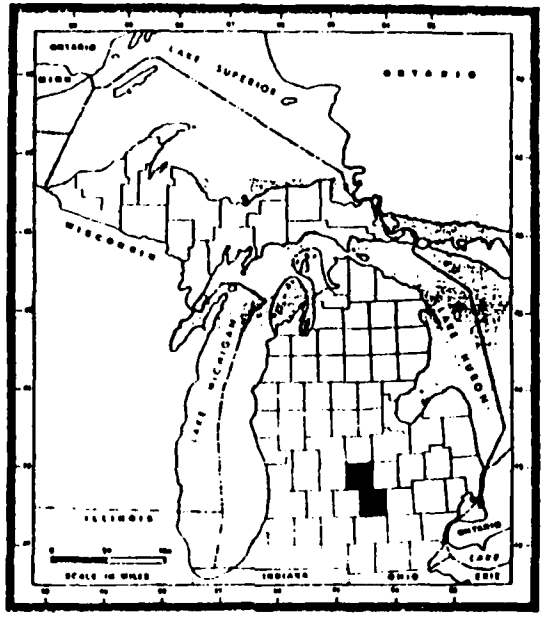
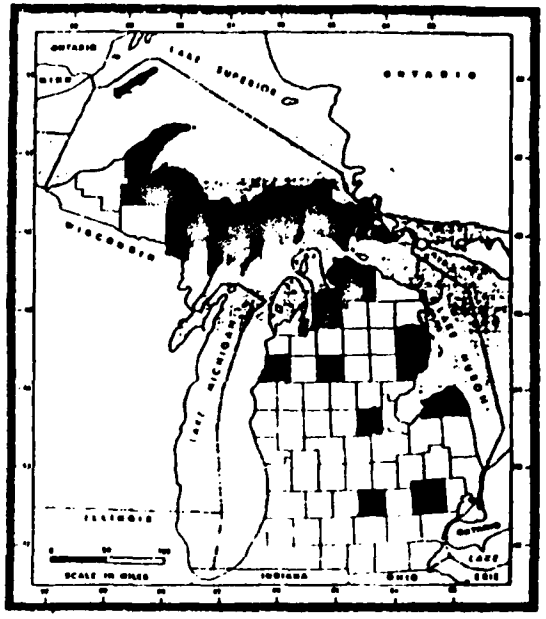


Figure 49. Megachile concinna



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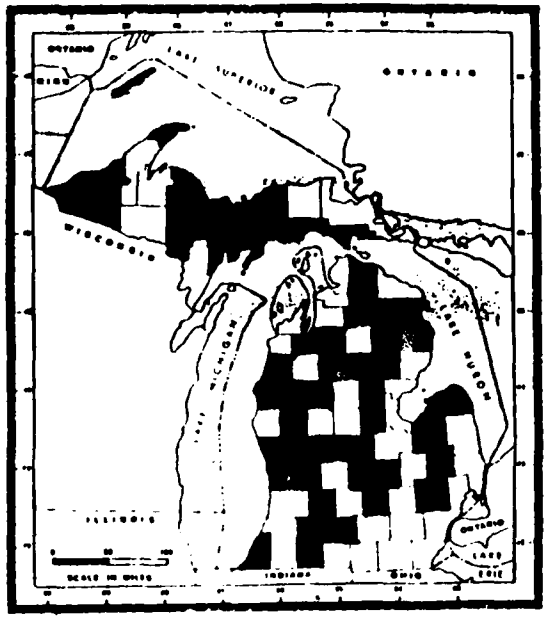
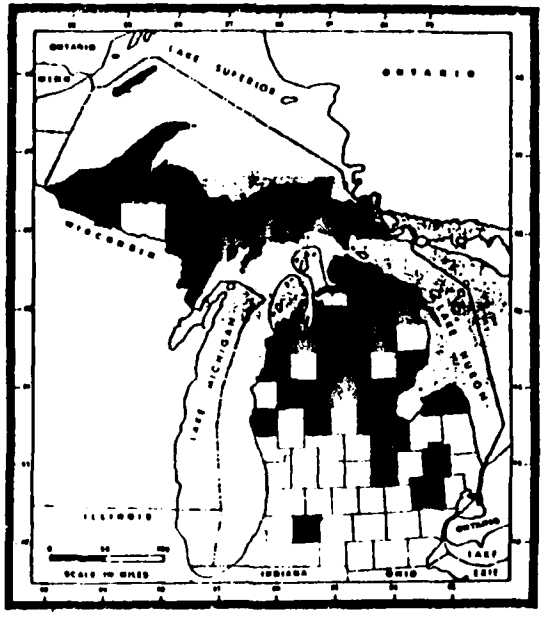


Figure 51. Megachile gemula



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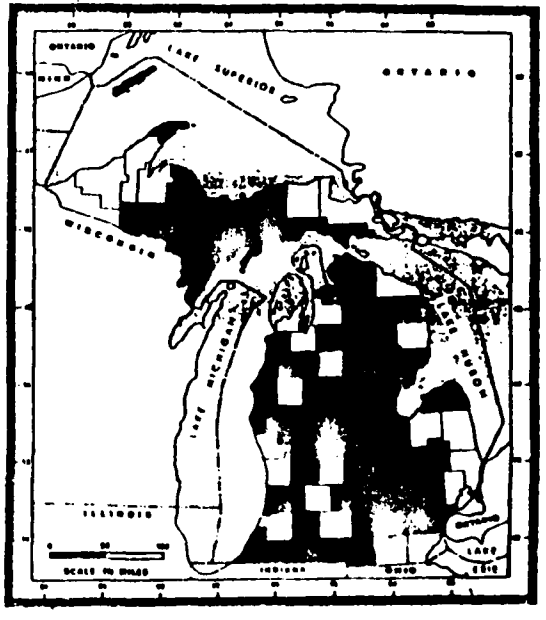


Figure 53. Megachile latimanus

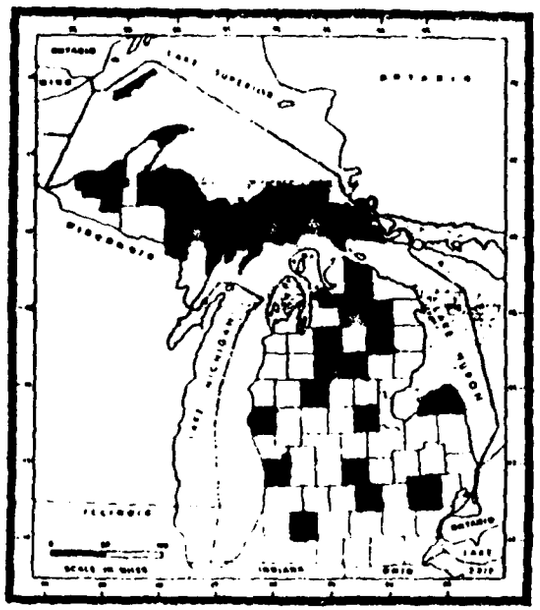


Figure 54. Megachile melanophoea

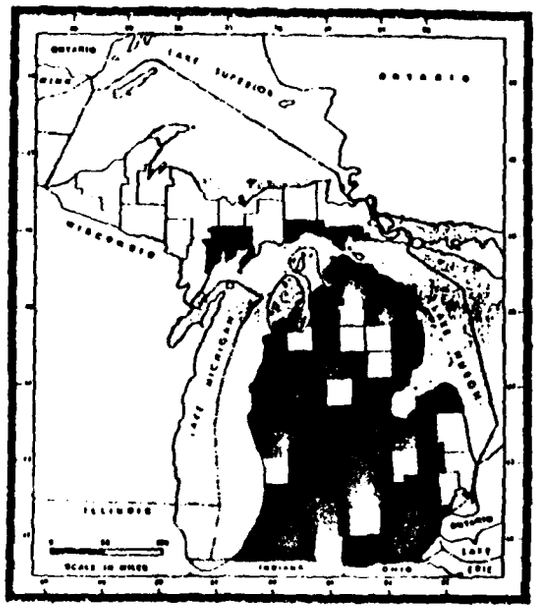


Figure 55. Megachile mendica

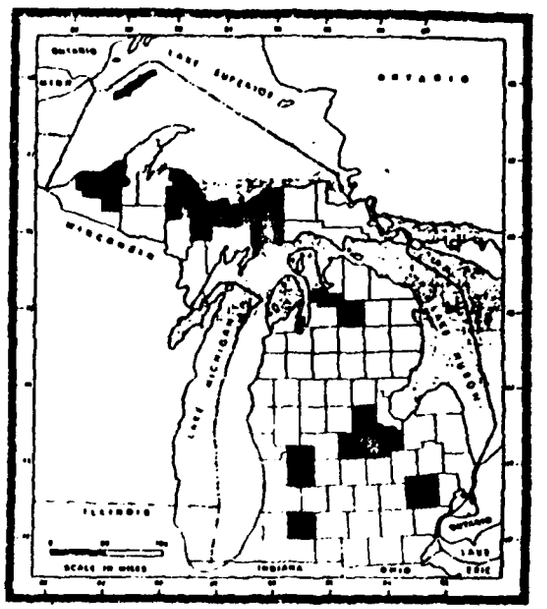


Figure 56. Megachile montivaga

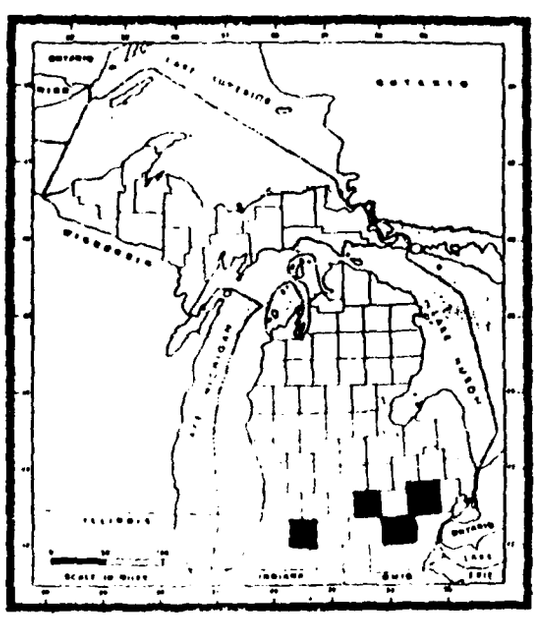


Figure 57. Megachile pacifica

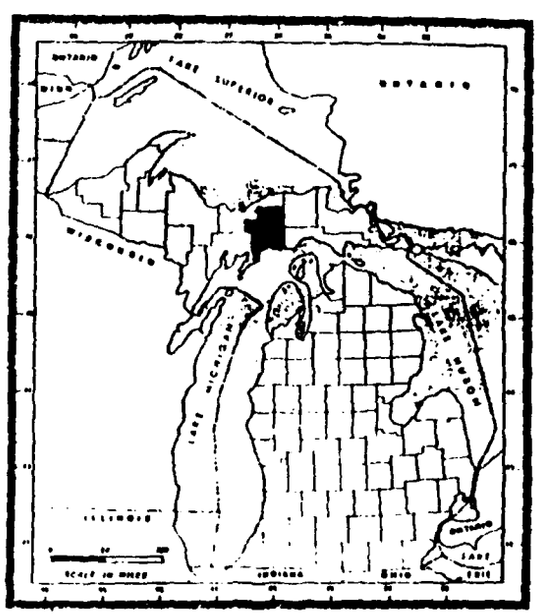


Figure 58. Megachile perihirta

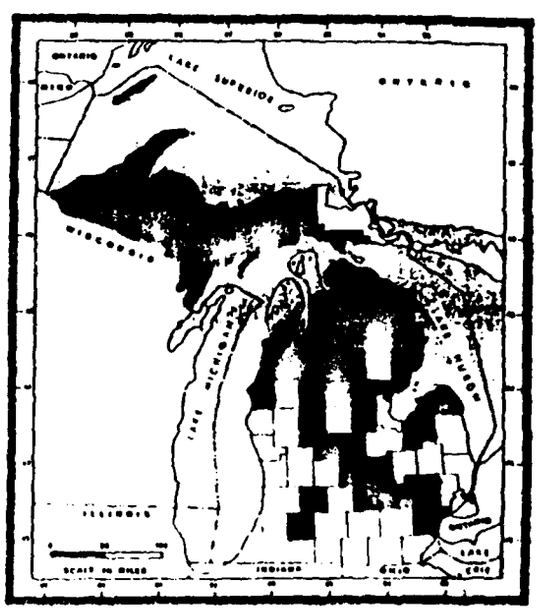


Figure 59. Megachile relativa

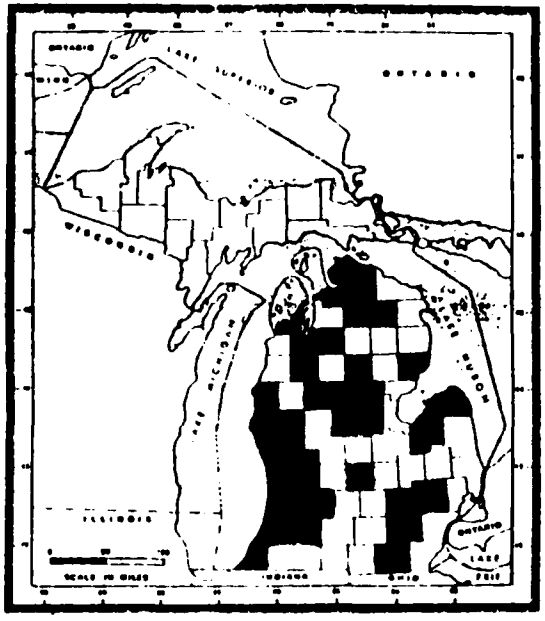


Figure 60. Megachile texana

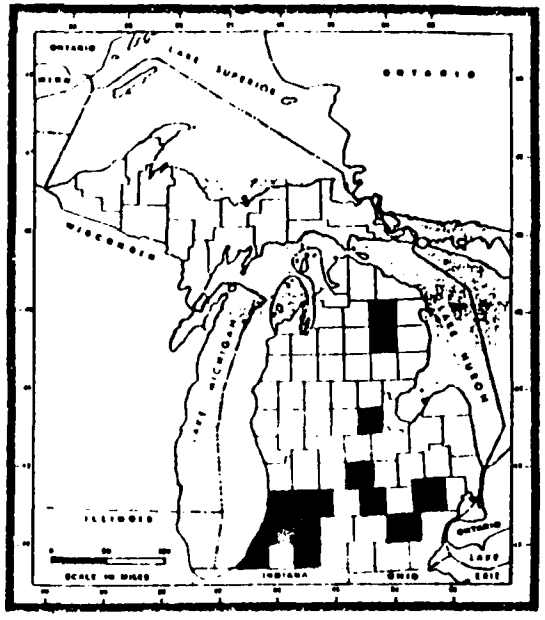


Figure 61. Chalicodoma campanulae

Figure 62. Chalicodoma rugifrons

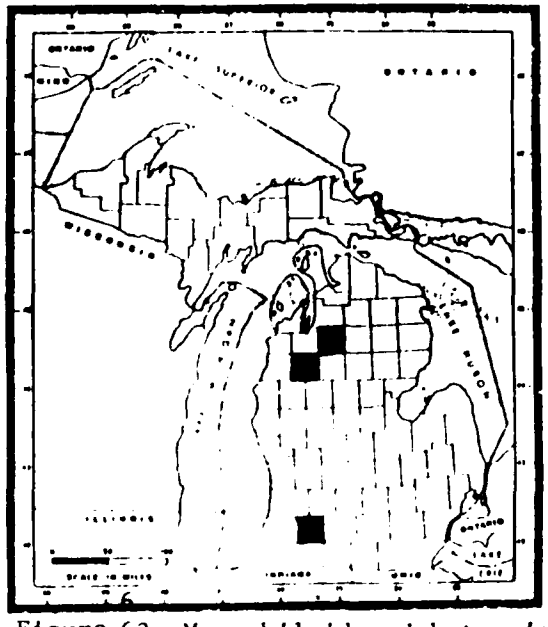


Figure 63. Megachiloides dakotensis

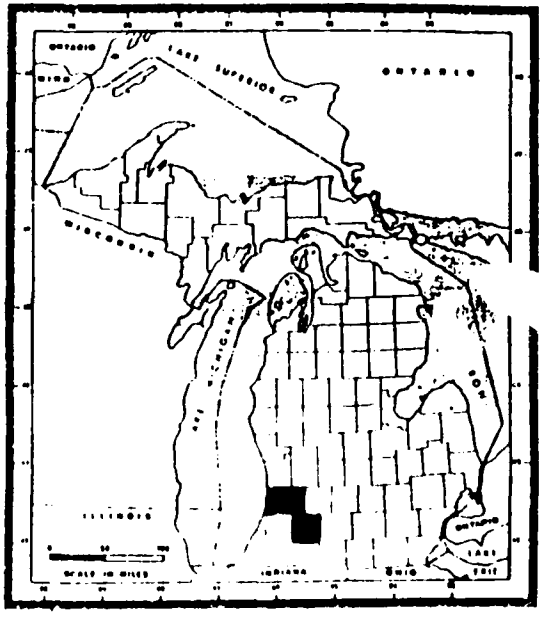


Figure 64. Eumegachile frugalis

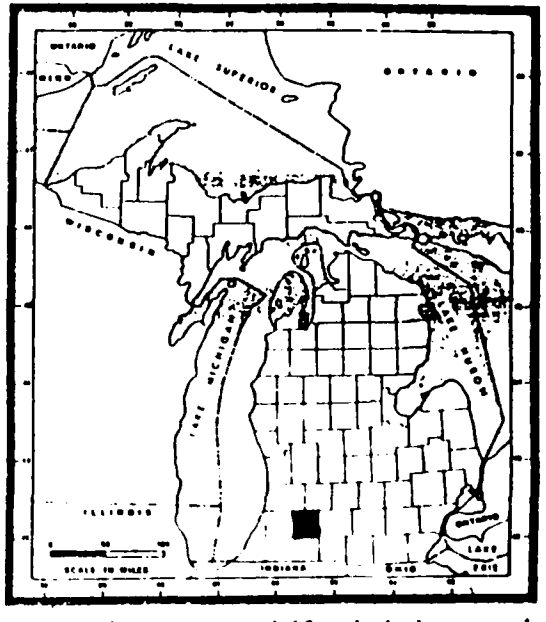


Figure 65. Eumegachile inimica sayi

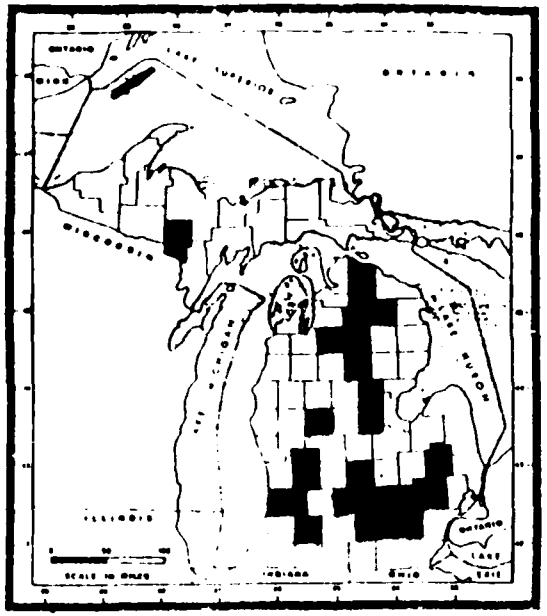


Figure 66. Eumegachile pugnata

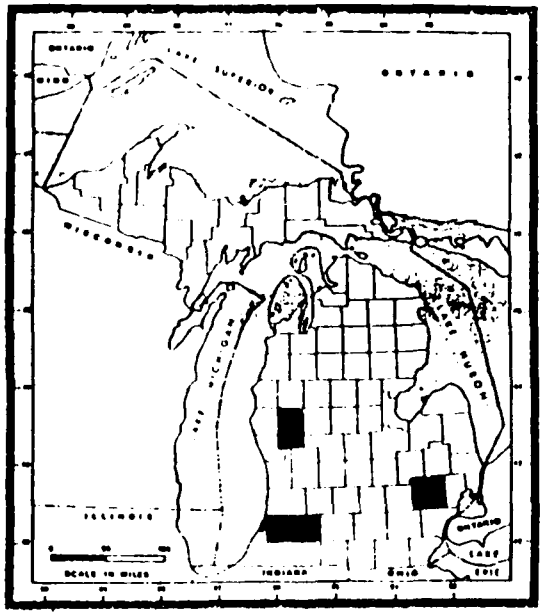


Figure 67. Pseudocentron petulans

Figure 68. Coelioxys sodalis

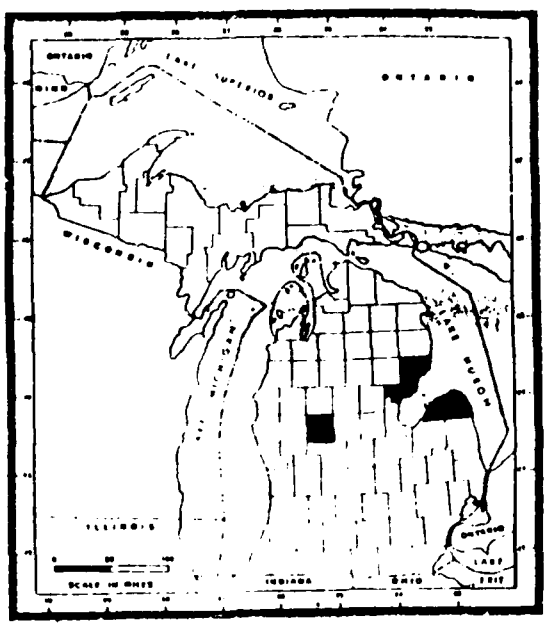


Figure 69. Coelioxys moesta

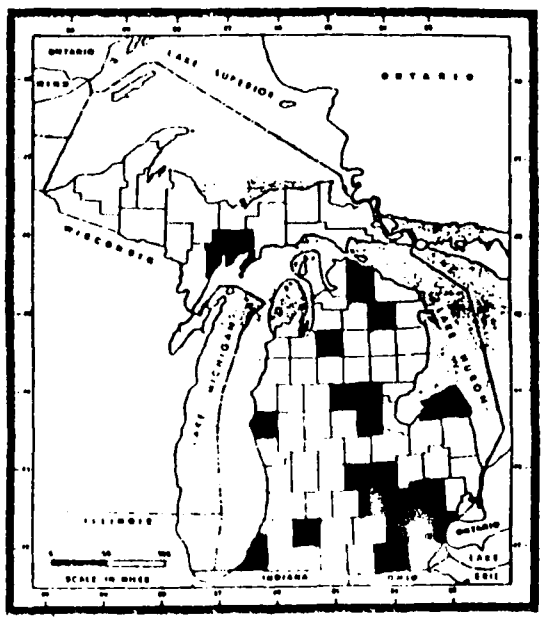


Figure 70. Coelioxys octodentata

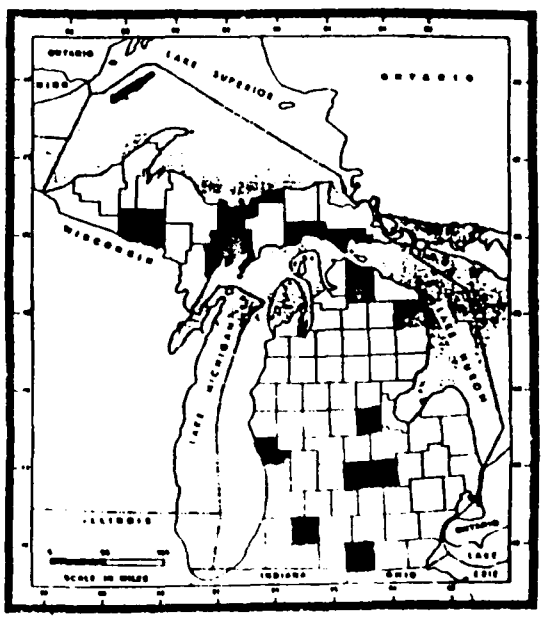


Figure 71. Coelioxys porterae

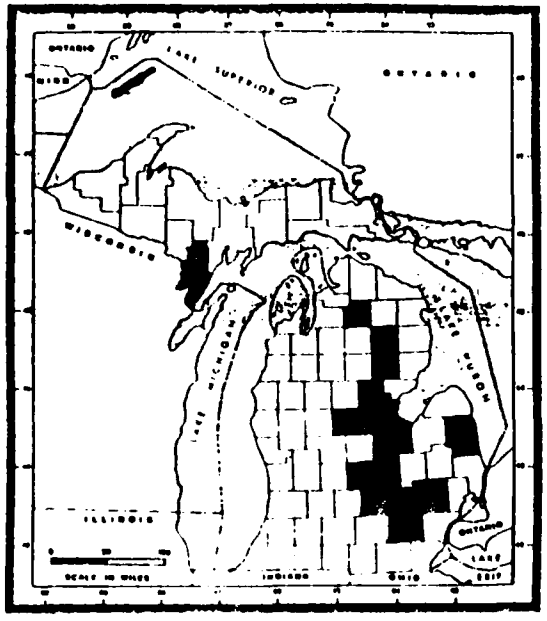


Figure 72. Coelioxys rufitarsis

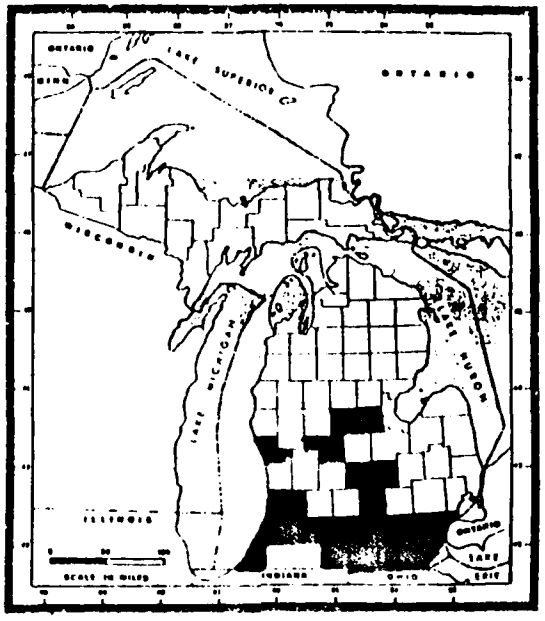


Figure 73. Coelioxys sayi

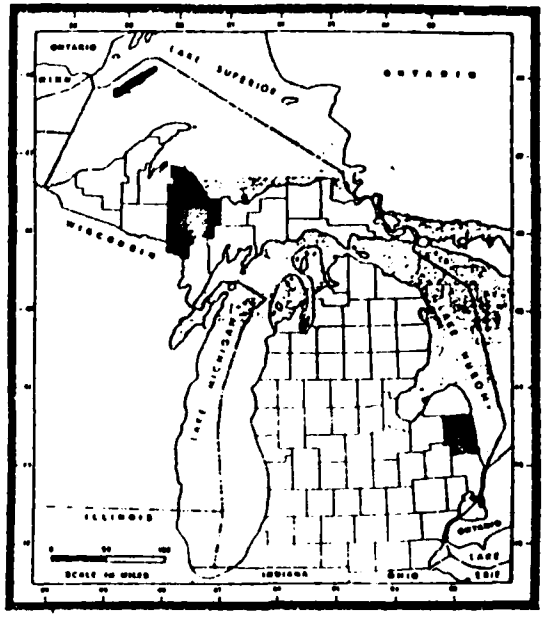


Figure 74. Coelioxys funerarea

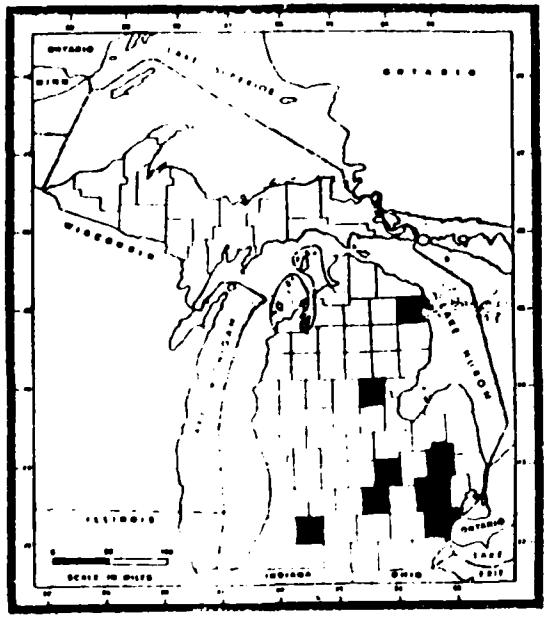


Figure 75. Coelioxys alternata

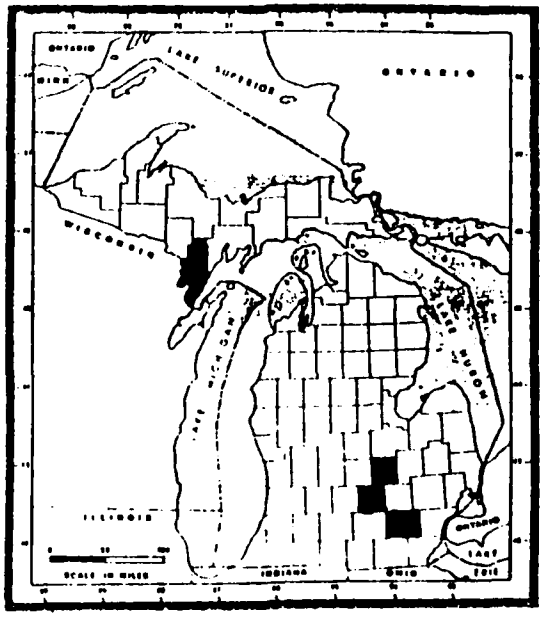


Figure 76. Coelioxys modesta

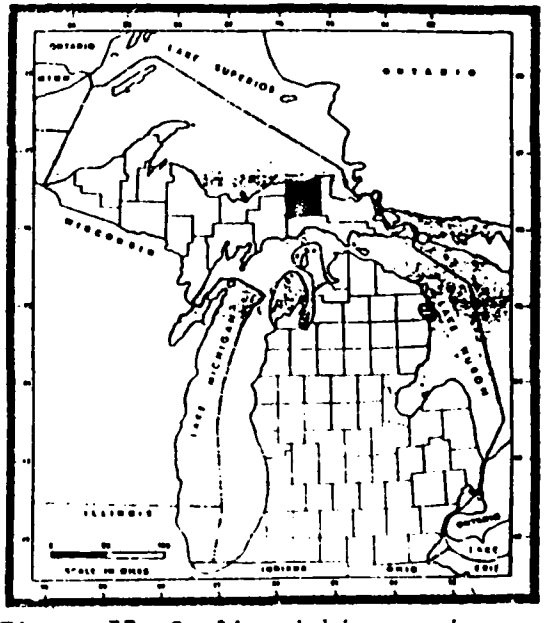


Figure 77. Stelis michiganensis

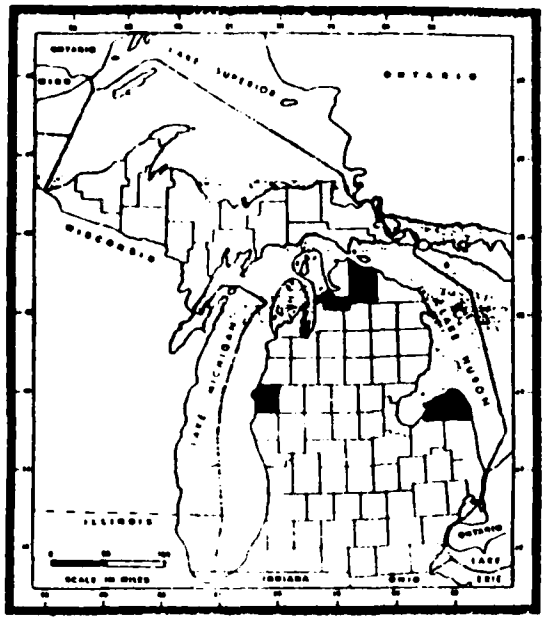
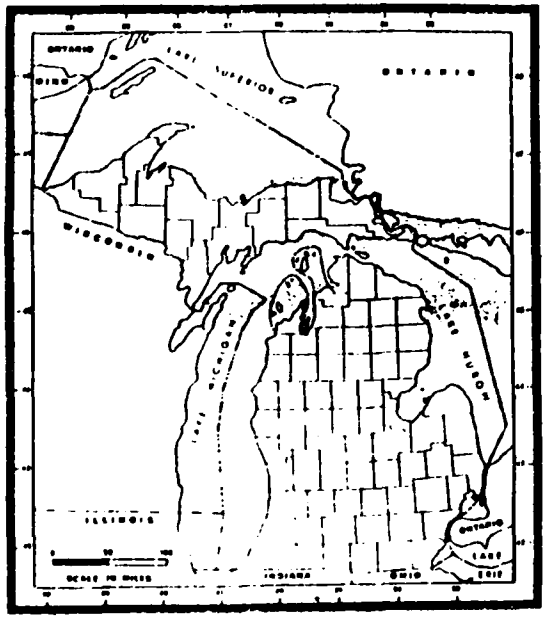


Figure 78. Stelis vernalis



X. LITERATURE CITED

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XIII. OUTLINE OF RESEARCH EFFORTS FOR FISCAL 1983-1984

November 1983

1. Pursue pollen analysis of fecal pellets of Osmia and Hoplitis.

December 1983

2. Ascertain a method of opening Megachile nests with leaf lining to secure fecal pellets, without undue disturbance to the inhabitants, for pollen analysis.

3. Trip to Channing site to secure a male and female adult Osmia from each nest so that each of the nests can be placed to species. Assuming that our techniques for recovery of fecal pellets from Megachile nests have been perfected some of these nests will be sampled.

4. Identification of Osmia specimens from nests.

5. Continuance of pollen analysis of Osmia fecal pellets.

6. Rewriting of computer programs of input and field notes pertaining to Osmia and Hoplitis. Additional programming will be necessary for nest architecture and pollen analysis data.

January 1984

7. Completion of pollen analysis studies on Osmia and Hoplitis.

8. Begin fecal pellet analysis of Megachile nests.

9. Input into the computer of nest data of Osmia and Hoplitis as outlined in 6.

February 1984

10. Hopefully with rewritten programs, the Osmia specimens identified, field and nest architecture data, and pollen analyses all completed and entered into the main Cyber computer we can begin some analyses of our data. The only element lacking would be actual emergence dates.

11. Continue pollen analysis studies on Megachile.

12. Begin input of field data on Megachile into the computer.

13. Begin preparation on nest blocks for summer 1984 season.

March 1984

14. Completion of 10.

15. Continue 11.

16. Continue 12.

17. Continue 13.

18. Attendance at annual conference, with possible side-trip to our Channing Field Station to check on nests of Megachile and to attain additional fecal pellet samples.

April 1984

19. Continue 11.

20. Continue 12.

21. Completion of 13.

May 1984

22. Continue 11.

23. Completion of 12.

24. Two research affiliates will be at our Channing Field Station to set up our monitoring equipment, hutches, and field-oriented ecological plots for vegetational studies.

25. Remaining overwintering Megachile nests will be opened, nest architecture data recorded, samples of fecal pellets removed.

26. Two or three additional control sites will be selected so they may be tested for electromagnetic fields in June.

27. Marking, release, and recording of data on emerged bees.

June-July-August 1984

28. Data taking at all sites on the field activity of various species of Megachile.

29. Shifts in the program which will differ from 1982-83 which have come about largely from our data of the prior season include:

    a. A greater emphasis on the flowering phenologies of those plants actually used by the several species of megachilids at each site. This would include a greater number of samples and more frequent sampling.

    b. The rewritten computer programs for field nesting activity will allow us to input these data into the microcomputer on a daily basis--a copy being made and one sent to E. Lansing for entry on the Cyber without the delay we had in 1982-83.

    c. Certain selected nests of Osmia and Hoplitis and perhaps Megachile will be opened immediately upon completion to ascertain position of the egg, hatching, feeding, and other features in the biology of the immature stage.

September 1984

30. With emergence data from 1982-83 nests completed, voucher specimens determined, and pressures of 1983-84 field activities on the wane we can complete entry into the computer of all Megachile data and begin analyses of data.

31. Begin to close up our Channing field facilities and prepare nests for winter.

October 1984

32. Continuance of 30.

33. Final close-up of Channing facilities and preparation of specimens for wintering.

34. Collection of voucher specimens from Osmia nests, data recording of nest architecture, and sampling of fecal pellets for pollen analyses.

35. Begin analysis of pollen in 1983-1984 nests.

XII. SUMMARY OF 1983 RESULTS

From year to year, slight shifts in emphasis might be expected on a seasonal basis to be made on the direction of the project, depending to some extent on the expertise of the personnel involved, but more importantly on what had been ascertained in the analysis of data from the prior season—this is the nature of science. Since this is our first full season in the field, we lack any prior analysis of data to make any adjustments in the program. Rather, we have had to rely upon our original proposal, the prior knowledge and previous experience of personnel associated with the project, and previous published literature records.

Nevertheless, a set of objectives were outlined for the 1983 summer season. These objectives, with a few reservations, have largely been met during this past season and were discussed or amplified upon in prior sections of this report. Briefly, these include: (1) selection of four experimental sites; (2) taxonomic studies on the megachilid bees of Michigan with special emphasis on the distribution of those known to occur in the Upper Peninsula; (3) a list of potential plant species known to be of value to the megachilid bees; (4) a list of plant species for each site which were previously known to be of value to the megachilids involved; (5) flowering phenologies, both a qualitative and quantitative sense, of the plants so involved for each site; (6) develop techniques for pollen analysis, again both qualitative and quantitative, by analyzing fecal pellets of larvae; (7) monitor numerous climatological events that might impinge on bee activity; and (8) observational data concerning timed-events in the nesting behavior of the various species of megachilids which will inhabit trap-nests.

In the Upper Peninsula of Michigan, the megachilid bees are univoltine, or have but a single generation per year. This leads to complications in terms of attempting any analysis of data for a univoltine species accomplishes only a portion of its life cycle during the active summer season: emerging as a adult in the spring or early summer,

mating, nest selection, provisioning the nest, laying eggs, the larvae hatching from the eggs and the larva feeding on the pollen provisions, and for many species entering the winter season in a "quiescent" stage as a larva, prepupa, or pupa. In these species, transformation would occur to the adult stage in late Spring or early Summer followed by emergence as an active adult. Data on ratio of sexes, overwintering mortality, and actual species involved with construction of each nest from the prior season must await the following Spring before analyses can be made on field observations of the previous season. Portions of these data could conceivably be worked ahead--provided we knew with certainty which species were involved with each nest under observation. However, this is not the case. Positive field identification to species level can be made on approximately 10 per cent of the animals involved in the study at the moment. This may change as we know the animals better through "quircks" in behavioral patterns, specificity to pollen plants, seasonality, specificity in use of nesting materials, and species complexes associated with each experimental site.

Thus, while we have data approximating 200-250,000 bits of information which will be loaded into the computer system before the Spring of 1984, the data cannot be analyzed by species until emergence occurs in late Spring or early Summer of 1984. For reasons outlined above, this current report contains a modicum of definitive analyzed data.

The avowed purpose of this current study on the biology of the leafcutter bees is to ascertain any possible affect the installations of the ELF submarine communication system and the subsequent electromagnetic waves emanating from the system may have in altering their behavior patterns and total biology. The experimental design includes four experimental plots--two approximating 12-14 kilometers distance from the proposed installation which will serve as controls since they are outside the realm of any electromagnetic influence generated, and two which will be directly below the lines of the ELF installation and will serve as experimental sites. All four sites are subject to

review by the U.S. Navy or subcontractors to ascertain the incidence of electromagnetic waves which may be present from other sources.

All four sites were tested by IITRI engineers for levels and incidence of background electromagnetic flux densities and field intensity ratios. One control site and two experimental sites met the criteria as originally proposed in the contract. However, the Channing site is considered marginal. We shall, however, continue to use the site in the 1984 season as a safeguard, hoping to locate another control site in the Channing area. Other criteria which we have been concerned with regarding site selection include the proper mix of flowering plants, accessibility to the site with a minimum of travel time, that megachilids be present in the immediate vicinity, previous natural nesting areas be present to have allowed a resident population of bees to have maintained themselves, that the sites be varied ecologically in terms of flowering plants throughout the season to sustain a number of species of bees but yet at the same time be similar to each other that they could be used as paired plots if we desire to handle the data in such a manner at some later time, and somewhat off the pathways of usual human traffic to prevent malicious destruction of equipment.

Weather factors which could alter the behavior patterns of bees are numerous. A monitoring system was installed at the Channing (control) site and Ford I site (experimental). Records were automatically taken every 5-10 minutes on atmospheric pressure, precipitation, solar radiation, relative humidity, ambient air temperature, and wind direction and speed. Changes or alterations in biological behavior patterns of the bees in response to changing climatic factors or perhaps to the ELF installation may thus be determined through statistical analysis of data.

Four hutches were installed at each site, each hutch provided with four shelves and equal numbers of nest blocks (trap-nests) with randomized pre-drilled holes of varying sizes placed upon them. Two hutches at each site were oriented in a North-South geomagnetic direction and two in an East-West direction. Since the fields which will

emanate from the ELF system are both transverse and longitudinal there is a theoretical possibility that there may be an affect upon the bees and their orientation to the hutches and the trap nests. An additional set of parameters for later statistical analysis has been added to the study.

Because the species complexes of the leafcutter bees for the State of Michigan were unknown and, more importantly, also unknown for the Upper Peninsula at the commencement of this study, a taxonomic study was initiated on the group. Over 3000 museum specimens of Michigan megachilids have been examined and identified. The results of the study have given us some ideas on how common the various species are in the Upper Peninsula, the species complexes present, and some information on the phenology of the various species. The data on the genus Osmia is perhaps the least substantive for members of the genus predominate in the early Spring--a time of year when the vagaries of the weather are not conducive for collecting and a difficult time for personnel from the Lower Peninsula to form collecting forays to the Upper Peninsula. A total of 69 species of leafcutter bees are currently known to occur in Michigan. Of these, 53 are anthophilous and 13 are kleptoparasitic.

While admittedly these data are not complete, because of the paucity of available specimens for study from the Upper Peninsula, we now know that at least 40 species of megachilid bees are represented. Of these, 10 species are known to occur in both Marquette and Dickinson counties, and an additional 13 in Dickinson County and 21 species in Marquette County--a total of 31 in Marquette County and 23 in Dickinson County.

Bees use plants, products thereof, or portions of plants per se, for three general purposes: (1) for collection of pollen which is used as stored materials or provisions for their young; (2) as a nidification habitus or certain plant parts (leaves or portions thereof, plant down or resins) may be used as construction materials in founding a nest; or (3) as a ready energy source in the form of nectar for individual sustenance or in some

instances for manipulation as an admixture with pollen to bring about a proper consistency of the provisions. Some species of bees prefer certain species, or groups of closely related species, of plants as either nectar or pollen sources.

We have placed considerable emphasis upon these relationships in an attempt to understand the phenological phenomena between the plants of the Upper Peninsula and the associated megachilid bee fauna. On two sites (Ford I and Channing) our data on flowering phenology is excellent--with the flowering activity of over 70 plant species known both qualitatively and quantitatively. On the Ford II and County Line sites the phenological data on flowering plants are not as complete since the sites were not established until late in the season and lack the vernal species. These kinds of data are an aid to understanding bee biology for they can be correlated with other events in the life of the bee. Is she polylectic or oligolectic? What happens with a long-lived bee which provisions a series of nests over a long period of time? Is she capable of moving to another flowering plant after her initial "favorite" ceases to bloom? To answer some of these types of questions we embarked upon a study of fecal pellets of the bee larvae.

Prior to forming a pupal cell the larva defecates on the inner walls of the tunnel. Pollen grains in these voided elongate fecal pellets pass through the gut of the bee with but little distortion. They may be treated and mounted on microscope slides and later determined to plant group and in many istances to species. When only to group the phenological plant data and timed events in nest construction on the part of the bees have allowed us to determine the initial pollen source. The pollen grains can then be counted and a percentage value of various plant species ascertained as provisions for each cell. Currently we are conducting a series of studies to determine numbers of pellets necessary in the preparation of a slide from each cell, and the numbers of counting transects which must be made to obtain valid results.

Visual observations including recording of elapsed time for a variety of bee activities in the field and nesting site as well as actual time for each event were

conducted by a team of five personnel. Close to 1600 man hours were spent on this activity resulting in some 15,000 timed events and an additional 4000 observational notes. These data are being refined into subsets of data suitable for computer language entry. It is anticipated that this will result in some 50,000 computer bits of information.

At the close of the season a total of 385 nests of various species of megachilids were recovered. Of these, 281 were of various species of Megachile sensu latu), 92 of Osmia and 12 of Hoplitis albifrons. All nests were placed in centrifuge tubes in boxes and replaced on the hutches for overwintering studies. We await the coming of spring for completion of our first year of work on the project and the beginning analysis of data.

SMALL VERTEBRATES: The Michigan Study Site
Tasks 5.6, Small Mammals, and 5.12A, Nesting Birds

ANNUAL REPORT
1982-1983

SUBCONTRACT NUMBER: E06516-82-C-20015

SUBCONTRACTED TO:

THE BOARD OF TRUSTEES, MICHIGAN STATE UNIVERSITY

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INTRODUCTION - ANNUAL REPORT 1982-1983

The research activities for 1982-83 are summarized in this report, along with analyses of preliminary data, discussion of changes in research protocol, and other activities that have been necessitated by various factors encountered to date. All research tasks are referenced to the original research proposal, especially where there have been changes in technique, protocol or sample design or size.

Research activities for 1983 were organized around three goals. The first of these was to locate suitable test-control pairs of plots. Matching of plots was based on major activites planned for them, and on gross habitat similarity. The second goal was to obtain preliminary data on as many tasks as possible. We were successful in obtaining baseline data for: avian population distribution and density; tree swallow (Tachycineta bicolor) embryo growth rates and abnormality rates, clutch size, hatching success, nestling growth (weight, growth of limbs, age at eye opening, age at feather eruption), parental incubation, care of nestlings and fledging success; small mammal population distribution and density, parental care, growth of young and tolerance of implanted radio telemetry transmitters and CRPID coils. Thirdly, we wished to evaluate the suitability of proposed test animals, research protocols and sample sizes for statistical tests so that changes could be made prior to a major commitment of funds and effort.

As will be detailed in the following report, we have been able largely to meet these goals. There are still a few study elements and procedures

that will require attention in the coming year of research. These will be discussed in detail in this report.

ACCOMPLISHMENTS IN 1983

Selection of Study Plots - One of the main activities in the early summer of 1983 was the selection of the test and control plots for the various tasks of the research program. The criteria for selection were extensively described in the original proposal and will only be summarized here. First, the size of the plots was determined entirely by our projected sample size requirements for study animals for the various tasks we proposed to undertake. In all tasks, except the population survey study, the original criterion (see Technical Volume, 1982) for determining sample size was that statistical tests be able to detect at least a 10% change in the variable under study with a 90% certainty at the 5 % level of significance. Our preliminary estimates, based on literature values only, of sample sizes yielded a maximum requirement of about 60 nesting animals per plot for both the birds and small mammals to be studied. Plots were scaled in size to produce these numbers of animals based on estimated home range and territory size. The population survey studies were known by us initially to be too variable to apply this stringent a statistical requirement. Therefore, none was applied.

The selection of plots was also based on the extent to which background readings of electrical and magnetic fields were matched. Since construction of the antenna itself had not begun, the only source of any electrical or magnetic fields was from utility lines.

Test plots were located immediately adjacent to proposed above ground

portions of the antenna right-of-way. This design produces maximum levels of exposure for test animals while still permitting a habitat buffer between the antenna right-of-way and the plot. Three plots in similar tracts of upland hardwood habitat were selected along the antenna right-of-way in 1983, one of which may not be suitable (see below). The two test plots and their paired control plots are shown in Figure 1. Control plots were matched in habitat with their corresponding test plot. Measurements were made by personnel from IITRI in early June and in July of electrical and magnetic fields on all test and control plots being considered at the time. Guidelines for the evaluation of electric fields on the plots were established by IITRI in the Request for Proposals as follows:

> Control plots shall be selected at locations where electric fields in the 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 magentic fields in the air and earth produced by other ELF sources (e.g., power lines) shall not differ by more than one order of magnitude between paired test and control plots, and at test plots should be at least one order of magnitude below the fields produced by the ELF system.

The values obtained by IITRI's sampling are shown in Table 1. The findings were that our two main plot pairs, T1 (Leeman's Road: parental care) and C1 (North Michigamme Reservoir: parental care), and T3 (Well's Grade: embryology, homing and energy metabolism) and C3 (South Michigamme Reservoir: embryology, homing and energy metabolism) were within acceptable limits for all components. However, the census plot pair, T2 (Cleveland

Figure 1. Location of study plots for small mammal and nesting birds near the Michigan ELF facility. Experimental sites are designated as "T" and control sites as "C". Dark lines represent the antenna configuration.

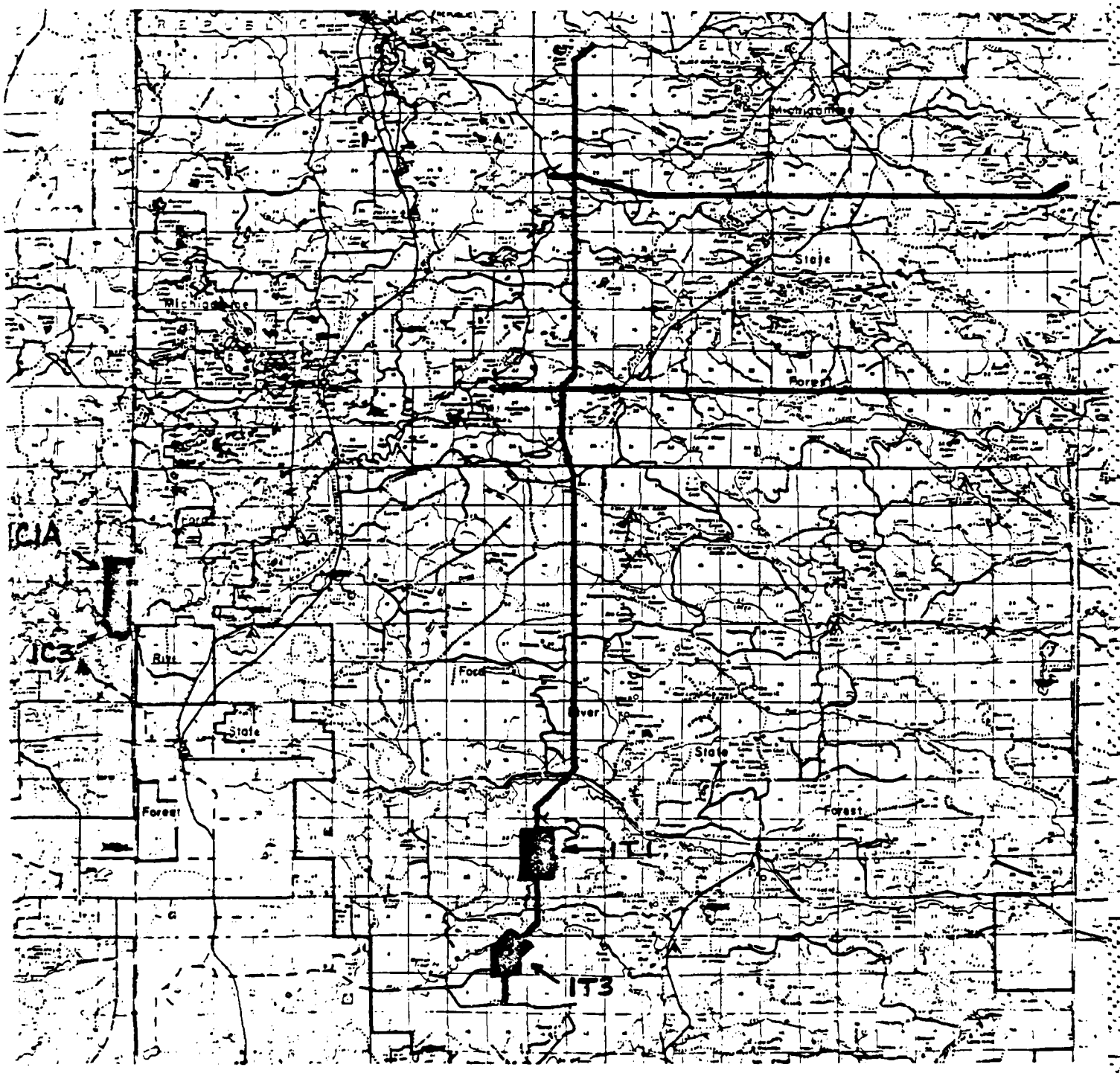

ICIA
IC3
IT3
Forest
State
Forest
State
Forest

Table 1. Values for field intensity ratios between proposed experimental and control plots. (Data from report by IITRI, October, 1983)

FIELD INTENSITY RATIOS (1)

COMPARED SITE NO.S	TRANSVERSE ELECTRIC FIELD				LONGITUDINAL ELECTRIC FIELD				MAGNETIC FIELD			
	R1>=10.	R2>=10.	R3>=10.	0.1<R4<10	R1>=10.	R2>=10.	R3>=10.	0.1<R4<10	R1>=10.	R2>=10.	R3>=10.	0.1<R4<10
1T1/1C1A	>35000.	>35000.	>35000.	1.0	>35.	>380.	>590.	2.2-->0.4	>100.	>500.	>1000.	2.0
1T1/1C1B	*	*	*	*	>17.	*	>230.	0.8-->0.1	*	*	*	*
1T2/1C2A	*	*	>2500.	14. *	>35.	>200.	>60.	0.3	>50.	>1000.	>500.	0.5
1T2/1C2B	*	*	>35000.	1.0	*	*	>130.	3.7-->0.6	*	*	>300.	1.0-->0.3
1T2/1C2C	*	*	*	*	*	*	>1400.	7.7-->6.0	>100.	*	>1000.	1.0
1T2/1C2D	*	*	*	*	*	*	>1600.	170.->7.*	*	*	*	*
1T3/1C3	*	*	*	*	*	>95.	>260.	3.3-->2.0	*	>250.	*	4.0

1) R1 = Test Site (76 Hz) / Control Site (76 Hz) R1 >= 10.
R2 = Test Site (76 Hz) / Test Site (60 Hz) R2 >= 10.
R3 = Test Site (76 Hz) / Control Site (60 Hz) R3 >= 10.
R4 = Test Site (60 Hz) / Control Site (60 Hz) 0.1 <= R4 <= 10.

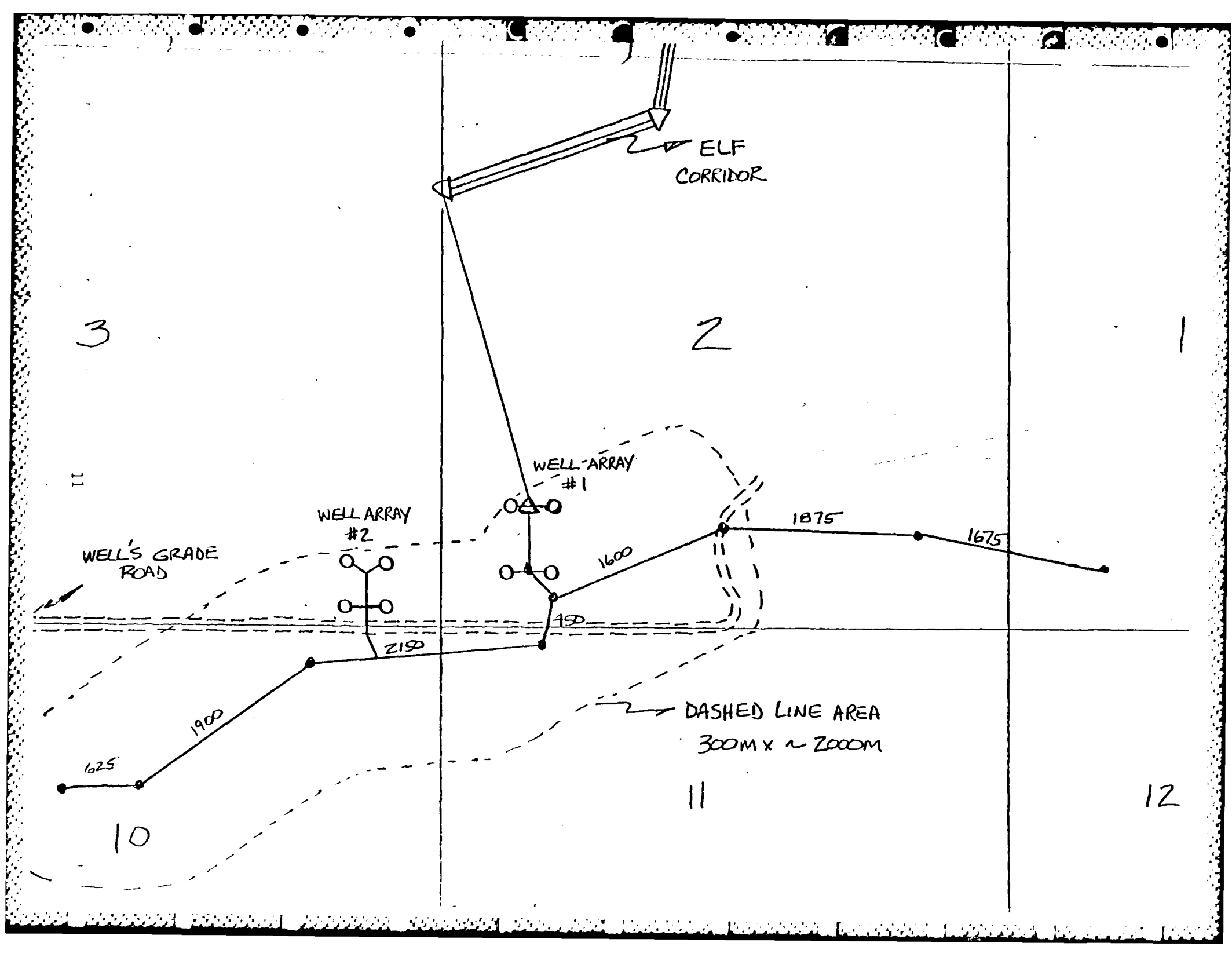
In the event that a range of values is listed for any given ratio:
High Limit ---> Maximum Numerator Value / Minimum Denominator Value
Low Limit ---> Minimum Numerator Value / Maximum Denominator Value

* Does not meet the exposure specification.

Homestead: census) and C2 (Camp 1 Road: census) was found to have high ratios for the electric field in the air, and for the electric field in the earth. Discussions are underway with IITRI concerning the future use of these plots. This problem, coupled with logging and relocation of the antenna at the Well's Grade test plot resulted in reconsidering plot configurations. We are considering establishing a plot along the ground line near our former Well's Grade plot. This will be done following the same plot layout used for all plots, provided there will be sufficient length along the ground to allow it, and that the method of construction of the ground (e.g. above ground lines) is not too dissimilar to that to be used for the above ground portion of the line. Should we decide to establish a plot along the Well's Grade ground, the configuration would appear as in in Figure 2. We further propose to move the avian and small mammal census tasks to Leeman's Road and North Michigamme Reservoir plots (T1:C1). We will interface our census techniques with the planned studies of parental care on these plots. The only remaining planned activities for the T2:C2 plot pairs is placement of tree swallow nest boxes to meet the needs for embryological studies.

Other plot changes from the original design consist of establishing plots for tree swallows (Tachycineta bicolor) and not for black-capped chickadees (Parus atricapillus). The reason for this change in research design is because of our finding during this summer's research that chickadees did not use nesting boxes, whereas tree swallows did readily. Plots for tree swallows must be in openings, such as will be created by the

Figure 2. Well's Grade test plot showing proposed experimental area, as indicated by dashed lines.


ELF
CORRIDOR
3
2
1
WELL ARRAY
#1
WELL ARRAY
#2
WELL'S GRADE
ROAD
1875
1675
1600
150
2150
1900
1625
DASHED LINE AREA
300M x ~ 2000M
10
11
12

antenna right-of-way, and in natural clearings along the antenna route. Tree swallow plots will be established along and within the antenna right-of-way and in the sham corridor on the control plots, according to our original plan. Therefore, it is essential that the sham corridor and the antenna corridor be constructed in the same year (1984, hopefully) and that the future maintenance of it and of the antenna right-of-way be identical. Furthermore, the maintenance must produce continuous, open areas so that all fast growing trees and brush are kept below about one foot in height.

Population-Survey Studies of Birds- Bird census transects were established on T2 and C2 plots in early June. (The problem of the electrical field readings was not known until after the breeding season.) Bird census data for 1983 are summarized in Table 2. Tree swallows were not recorded in the census because the survey was conducted in forested plots, and although swallows are locally abundant, they prefer an open habitat. In general, species found abundant on one plot are also abundant on the other, and if they are rare on one, they are rare on the other. The abundances are greater on the Cleveland Homestead plot for the abundant species. However, we are unable to apply statistical tests to these data because only four censuses were possible due to the time of season that the plot locations were finalized. The data are presented in Table 2 without statistical interpretation.

Population-Survey Studies of Mammals- Due to problems that arose during summer with the selection of suitably matched census plots (T-2, C-2 in Technical Volume) that also met the permissible levels of background

Table 2. Results of 1983 bird census showing species on each plot, the number of samples for each species, mean samples per day, and estimated densities per hectare.

Plots: 1) Cleveland Homestead experimental plot, area sampled 2300' X 200', 10.56 acres, 4.28 hectares.
2) Camp One control plot, area sampled 2600' X 200', 11.93 acres, 4.83 hectares.

	CLEVELAND HOMESTEAD EXPERIMENTAL			CAMP ONE CONTROL		
SPECIES	n	X n/day	X/ha	n	X n/day	X/ha
Ovenbird	36	9.00	2.10	18	4.50	0.93
Red-eyed vireo	17	4.25	0.99	20	5.00	1.04
Rose-breasted grosbeak	13	3.25	0.76	6	1.50	0.31
American robin	10	2.50	0.58	8	2.00	0.41
Chestnut-sided warbler	9	2.25	0.53	7	1.75	0.36
Veery	9	2.25	0.53	2	0.50	0.10
Least flycatcher	9	2.25	0.53	3	0.75	0.16
Yellow-shafted flicker	9	2.25	0.53	0	0.00	0.00
Great-crested flycatcher	9	2.25	0.53	1	0.25	0.05
White-throated sparrow	7	1.75	0.41	15	3.75	0.78
Nashville warbler	1	0.25	0.06	9	2.25	0.47
Black-throated green warbler	5	1.25	0.29	7	1.75	0.36
Yellow-bellied sapsucker	5	1.25	0.29	5	1.25	0.26
Song sparrow	5	1.25	0.29	0	0.00	0.00
Wood pewee	3	0.75	0.18	0	0.00	0.00
Black-capped chickadee	1	0.25	0.06	3	0.75	0.16
Scarlet tanager	0	0.00	0.00	3	0.75	0.16
Chipping sparrow	0	0.00	0.00	3	0.75	0.16
Blue jay	2	0.50	0.12	3	0.75	0.16
Brown-headed cowbird	0	0.00	0.00	3	0.75	0.16
Mourning warbler	0	0.00	0.00	3	0.75	0.16
Black and white warbler	2	0.50	0.12	0	0.00	0.00
Pileated woodpecker	2	0.50	0.12	0	0.00	0.00
Red-breasted nuthatch	1	0.25	0.06	2	0.50	0.10
Chimney swift	0	0.00	0.00	2	0.50	0.10
Golden-crowned kinglet	0	0.00	0.00	2	0.50	0.10
Connecticut warbler	0	0.00	0.00	2	0.50	0.10
Hermit thrush	1	0.25	0.06	0	0.00	0.00
Raven	1	0.25	0.06	0	0.00	0.00
Purple finch	1	0.25	0.06	0	0.00	0.00
Rufous-sided towhee	0	0.00	0.00	1	0.25	0.05
Black-throated blue warbler	0	0.00	0.00	1	0.25	0.05
Yellow-rumped warbler	0	0.00	0.00	1	0.25	0.05
Magnolia warbler	0	0.00	0.00	1	0.25	0.05
Hairy woodpecker	0	0.00	0.00	1	0.25	0.05
Cedar waxwing	0	0.00	0.00	1	0.25	0.05

electromagnetic fields, the census of small mammal populations as intended per the original proposal was not carried out. Small mammal censusing was to have begun in May 1983 but by June it was obvious that finalization of the census plots might not occur until later in the summer - after the period allotted for population surveys was over.

Hence, a decision was made to direct the trapping efforts first to the Turner Road demonstration plot (Figure 3) and later to the parental care plots (Figures 4-5) with the intention of discovering what may be responsible for the low incidence of nest box occupancy by deer mice (see below). If the low occupancy rates at the Turner Road plot were in any way related to low population density, for instance, it was important for us to know the density of deer mice at both parental care plots before we established a grid of nest boxes there.

Since the measurement of population density of deer mice was the primary objective of the summer census efforts, only the mouse-sized Leather live-traps were used. Live-trapping and the calculation of population density for Peromyscus were carried out as described by O'Farrell et al. (1977).

Trapping at the Turner Road, Leeman's Road (T-1) and Michigamme (C-1) plots took place successively over a period of 33 days from 30 June to 1 August. Captures of deer mice on the census lines and along the assessment lines are summarized for each plot in Table 3. Five other rodent species, Glaucomys volans (northern flying squirrel), Napeozapus insignis (woodland jumping mouse), Zapus hudsonius (meadow jumping mouse),

Figure 3. Turner Road demonstration plot. Unshaded box represents the boundaries of the nest box grid. The shaded box represents the boundaries of the census and assessment lines.

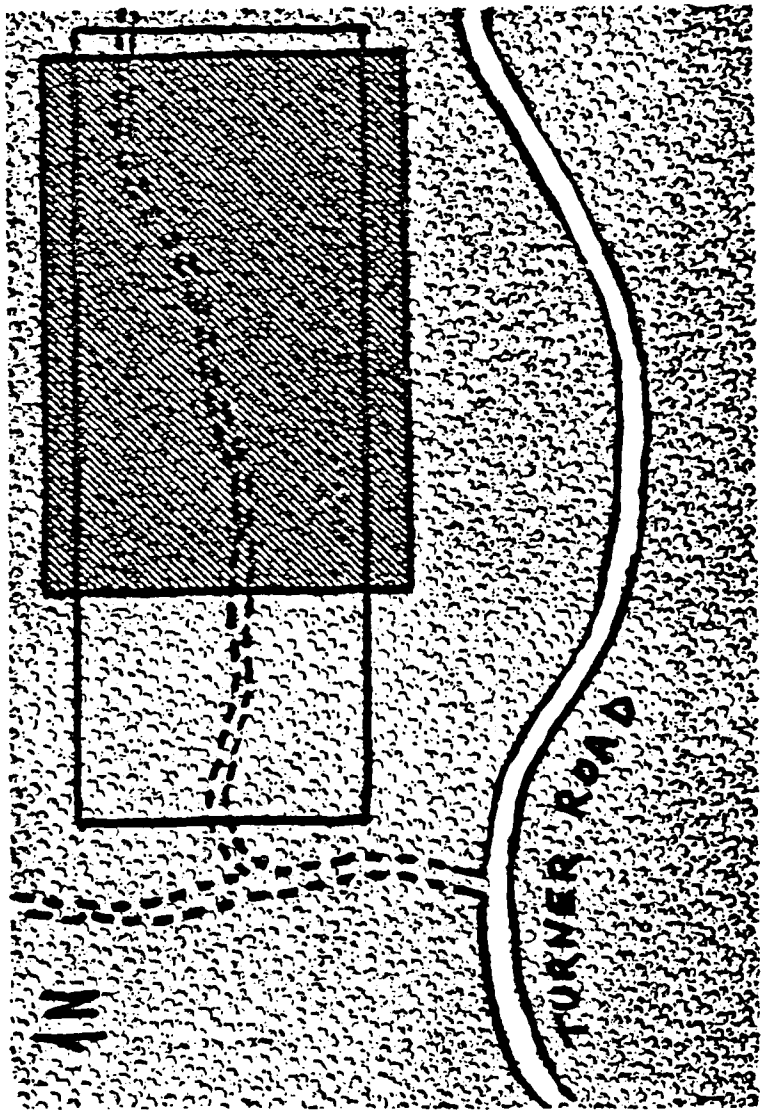

TURNER ROAD

Figure 4. Leeman's Road (T-1) plot. The shaded box represents the boundaries of the census and assessment lines.

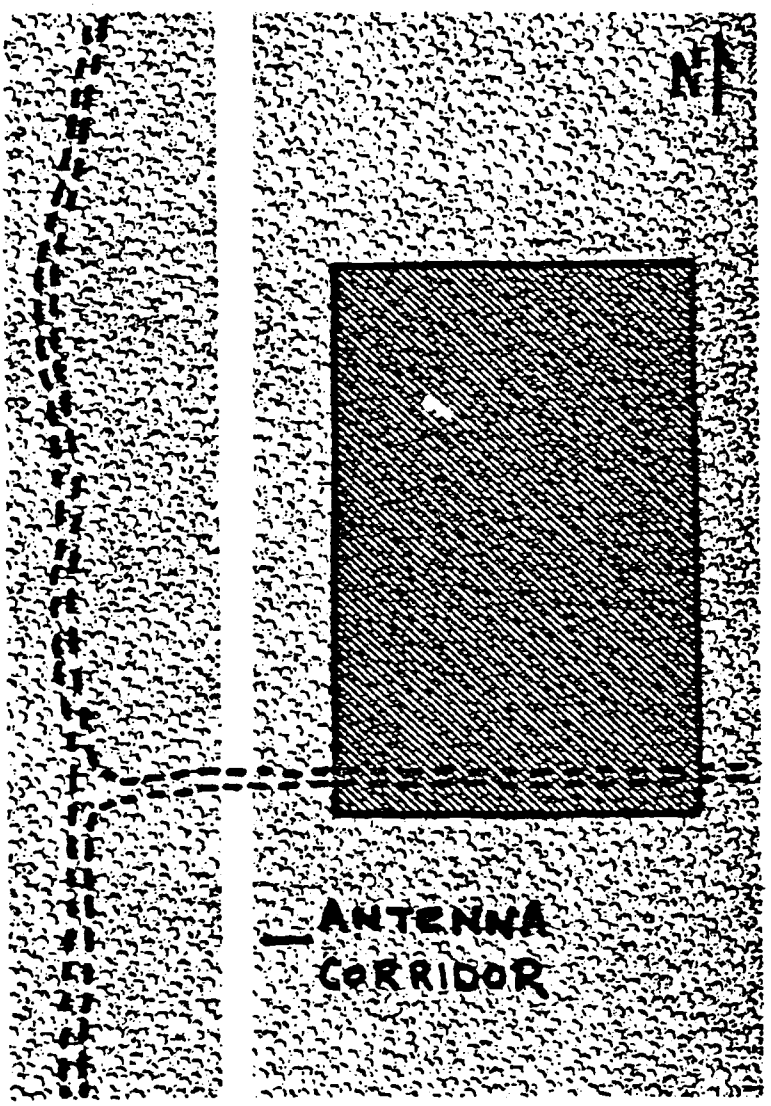

N
ANTENNA
CORRIDOR

Figure 5. Michigamme (C-1) plot. Shaded box represents the boundaries of the census assessment lines.

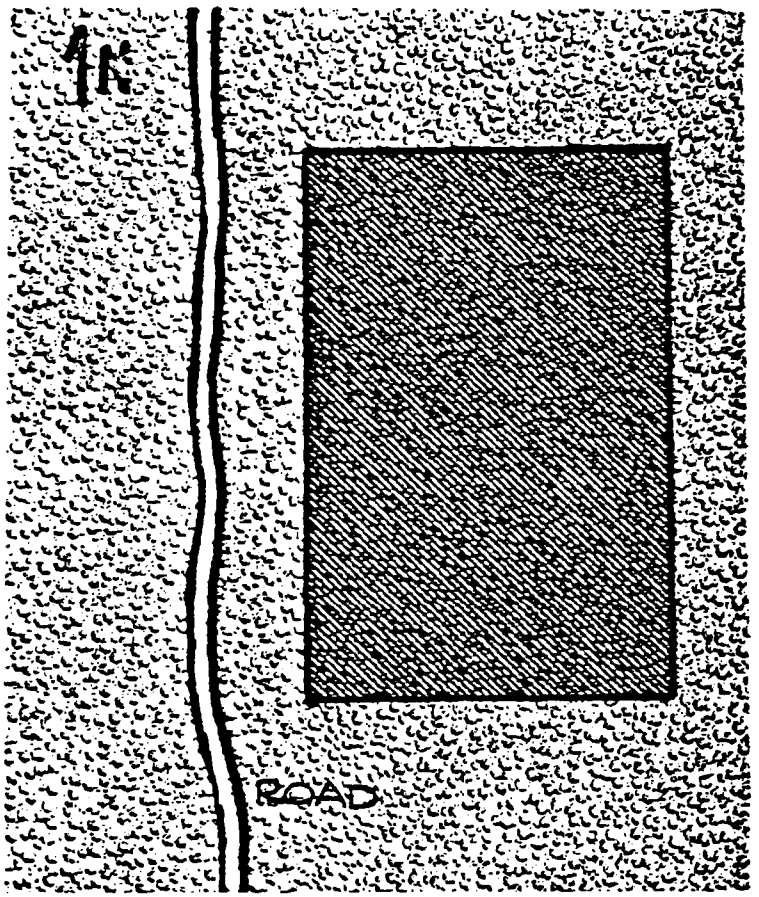

N
ROAD

Table 3. Capture summaries of Peromyscus maniculatus gracilis on census lines (N) and assessment lines at three plots. First captures of all mice as well as unmarked mice (not previously captured on census lines) are accumulated from the outer end (Station 1) to inside the census lines.

	TURNER ROAD		LEEMAN ROAD		MICHIGAMME	
	Live-Trap N=15		Live-Trap N=38		Live-Trap N=15	
Station	All	Unmarked	All	Unmarked	All	Unmarked
1	1	1	6	6	3	3
2	1	1	7	7	4	4
3	1	1	7	7	8	6
4	1	1	8	8	8	6
5	3	3	10	10	9	7
6	7*	5	15	15	9	7
7	8	6	18	18	10*	7
8	8	6	21*	20	13	7
9	8	6	28	26	14	8
10	11	9	30	28	18	11
11	12	10	35	31	18	11
12	13	11	37	32	19	11
13	13	11	40	33	20	11
14	13	11	45	34	22	12
15	15	13	49	37	22	12
16	15	13	50	37	23	12
17	17	13	52	38	24	12
18	18	13	55	38	24	12

* First station inside the area of effect (used in calculation of area for density estimates).

Tamias striatus (eastern chipmunk), Clethrionomys gapperi (red-backed vole), and 1 shrew, Sorex cinereus (masked shrew) were captured but their numbers were insufficient to allow density estimation.

Density estimates for deer mice from the three plots were considerably different (Table 4). Although comparisons with other studies may be meaningless due to differences in procedures, it should be noted that estimated densities in the present study appear to be normal and are within the range of extremes (1 - 27 mice/hectare) reported earlier by other authors (Blair, 1941; Manville, 1949; from Terman, 1968).

The relevance of deer mouse population densities in the parental care plots to the proposed nest box studies is discussed in the section below.

Parental and Nestling Behavior, and Fecundity, Growth, and Maturation Studies of Birds- We studied parents and young of tree swallows in 34 nests, six of which were renests. Parental care was monitored by continuously recording temperatures in the nests of two pairs during the period of incubation of eggs. Monitoring was supplemented by direct observation on several days. The parameter of concern in this monitoring was time spent in the nest by the parent birds each day. Data for two nests during the incubation of eggs are shown in Table 5. The data were obtained from a combination of temperature records (recorded automatically by A/D temperature probe system and OS3 data loggers) and direct, simultaneous observation by personnel. These data indicate a coefficient of variation (20% to 40%) in time spent in the nest which exceeds our original estimate of about 20%. This problem, and others regarding

Table 4. Density estimates for Peromyscus maniculatus gracilis at three plots in summer 1983.

PLOT	DENSITY (number of mice/hectare)
TURNER ROAD	4.59
LEEMAN ROAD (T-1)	10.39
MICHIGAMME (C-1)	2.53

Table 5. Data from five nests on days when manual observations were recorded. Total time spent in and out of the nest by both parents during the observations was used to extrapolate to the entire day's time. A 14L and 10D daylight pattern was assumed. This figure was chosen following perusal of the OS-3 temperature data showing an increase in ambient temperature following sun-up and a decrease following sun-down. It was also assumed that one of the parents was inside the nest at all times during the 10 hr night. All times recorded are in seconds.

		DURING OBSERVATIONS		REMAINDER OF DAY		NIGHT	TOTALS		
DATE	NEST#	Time In	Time Out	Time In	Time Out	Time In	Total Time In	% Time In	Hrs/day
7/2	14	4432.0	401.0	41784.9	3782.1	36000	82216.9	95.2	22.85
7/3	19	13934.6	2917.7	27743.9	5803.8	36000	77678.5	89.9	21.58
7/7	19	18160.9	2964.6	25176.1	4098.4	36000	79337.0	91.8	22.03
7/9	19	14400.5	983.5	32775.0	2241.0	36000	83175.5	96.3	23.11
7/10	19	14525.5	400.7	34515.6	957.8	36000	85041.1	98.4	23.62
									Mean = 22.64
	Mean	13090.7		Mean	32399.1				
	S.D.	5127.5		S.D.	6452.8				
	C.V. %	39.2		C.V. %	19.9				

statistical sufficiency will be dealt with in a later section on data analysis (See Data Base Management; Table 8).

Clutch size was measured in 34 nests, 6 of which were renests. Birds that renest after a failure or attempt a second nesting are known, in general, to have smaller clutches than first nests. We therefore present paramaters for the mean and standard deviation for first nesting attempts only. For 28 first nestings, the mean clutch size was 5.26 eggs, standard deviation = 0.742 and coefficient of variation = 13.3%. These values are similar to those in the literature for the tree swallow (Paynter, 1954).

Hatching rate for first nestings was 66.2% (N=14). Of the available hatchlings, 64.5% fledged. These values are similar to literature values (Paynter, 1954).

After hatching, young birds were weighed daily to within 0.1 g using a spring scale. Body weight (Figure 6) followed a very similar pattern to that reported in other studies (Zach and Mayoh, 1981; Paynter, 1954) with asymptotic weight being reached on day 13 at about 21 g. Both tarsi (tarsometarsus) and ulnae were measured daily using dial calipers to within 0.1 mm for all young after the 5th day in age (hatching day was assigned as day 0). Prior to this, selected young were measured as part of the testing of the measurement procedure. Thus, while we present data from day 0 to day 21, it should be pointed out that the adjustments in measurement technique as we learned the best way to do the measures makes days 0 to 5 qualitatively different from the remaining days. Data on tarsi and ulnae length are presented in Figures 7 through 10. We could not find data on

Figure 6. Mean daily weights (g) of nestling tree swallows. Vertical bars represent ± one standard deviation.

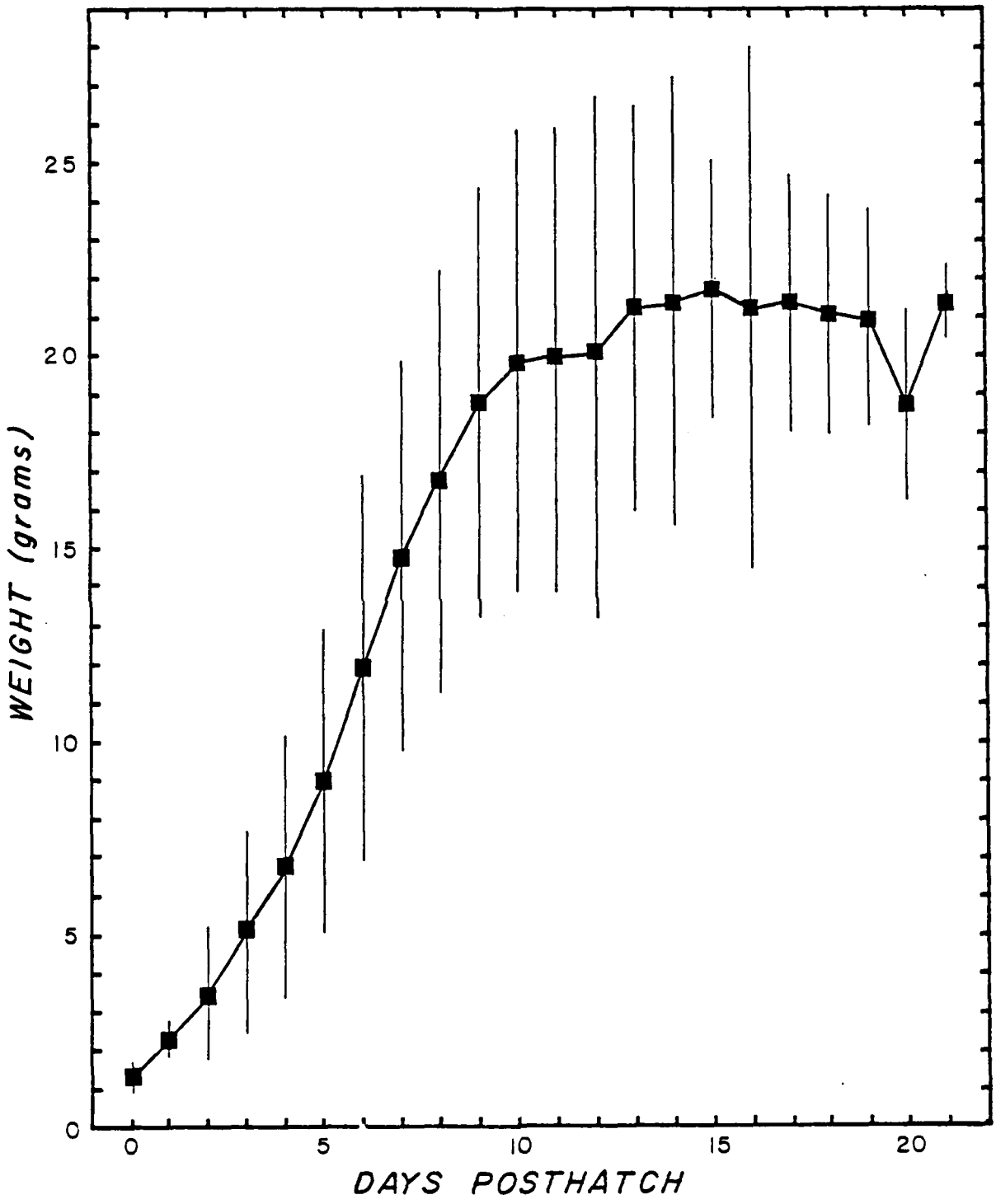

WEIGHT (grams)
0
5
10
15
20
25
0
5
10
15
20
DAYS POSTHATCH

Figure 7. Mean daily values for length (mm) of right tarsi in nestling tree swallows. Vertical bars represent ± one standard deviation.

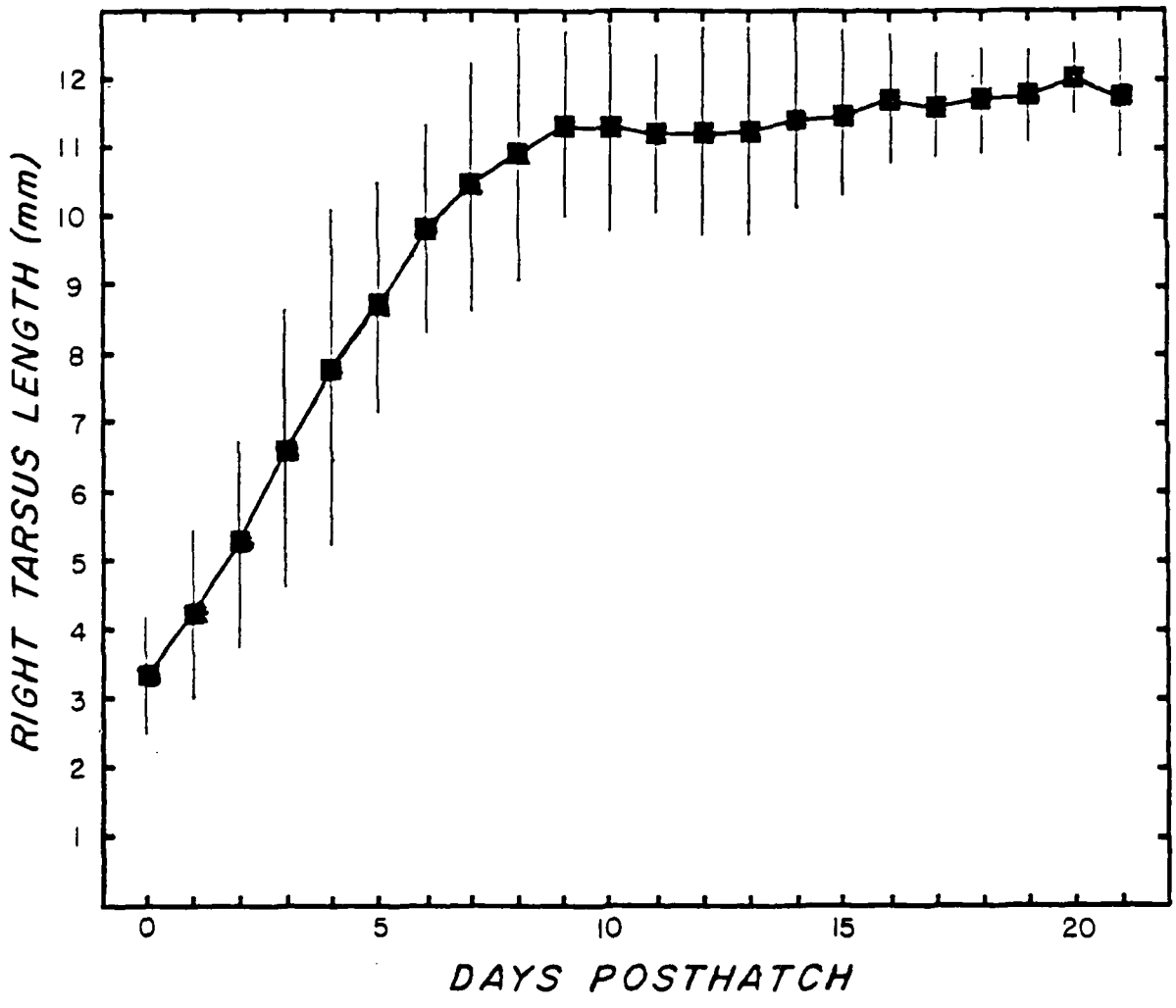

RIGHT TARSUS LENGTH (mm)
1
2
3
4
5
6
7
8
9
10
11
12
0
5
10
15
20
DAYS POSTHATCH

Figure 8. Mean daily values for length (mm) of left tarsi in nestling tree swallows. Vertical bars represent ± one standard deviation.

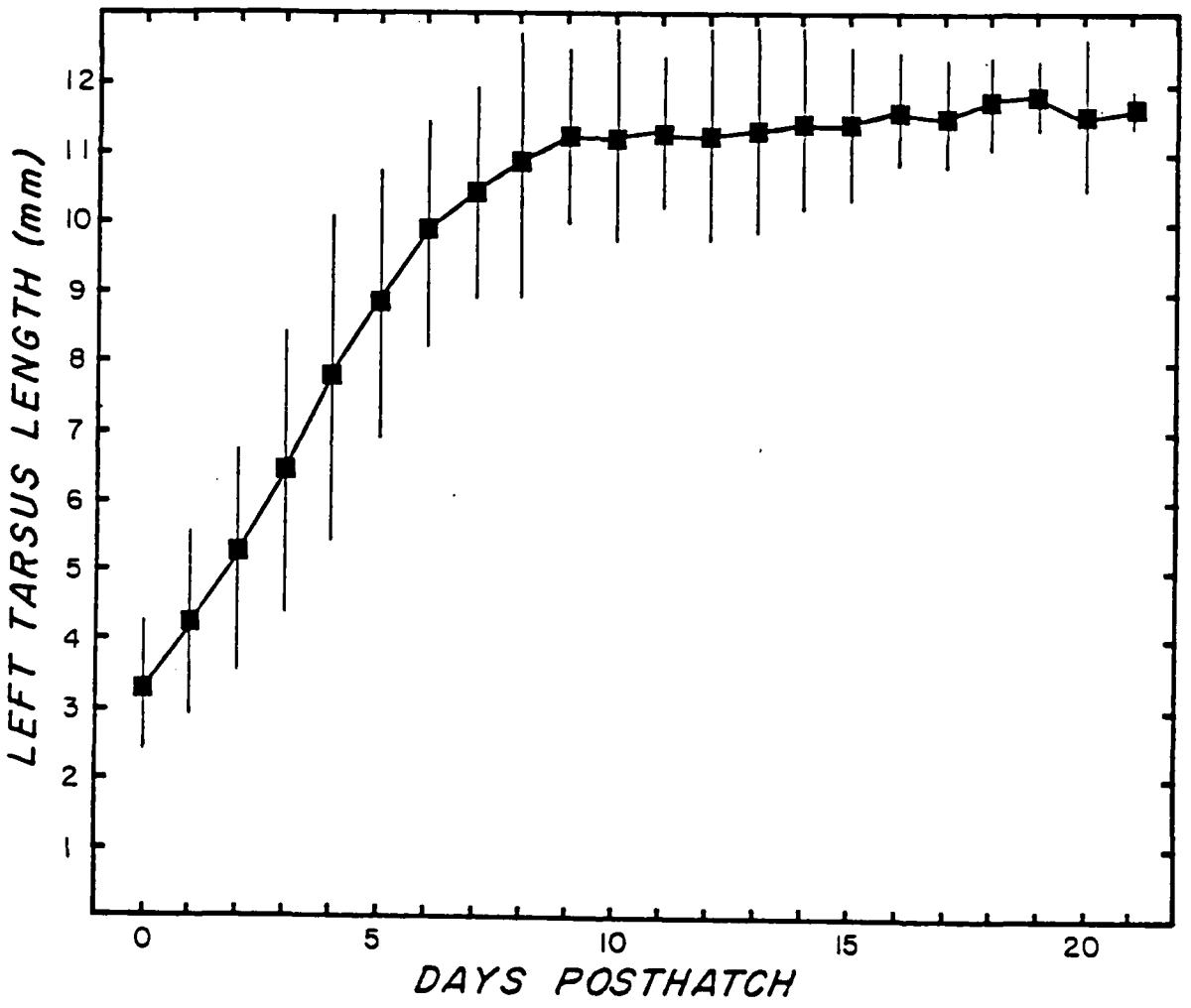

LEFT TARSUS LENGTH (mm)
1
2
3
4
5
6
7
8
9
10
11
12
0
5
10
15
20
DAYS POSTHATCH

Figure 9. Mean daily values for length (mm) of right ulnae in nestling tree swallows. Vertical bars represent ± one standard deviation.

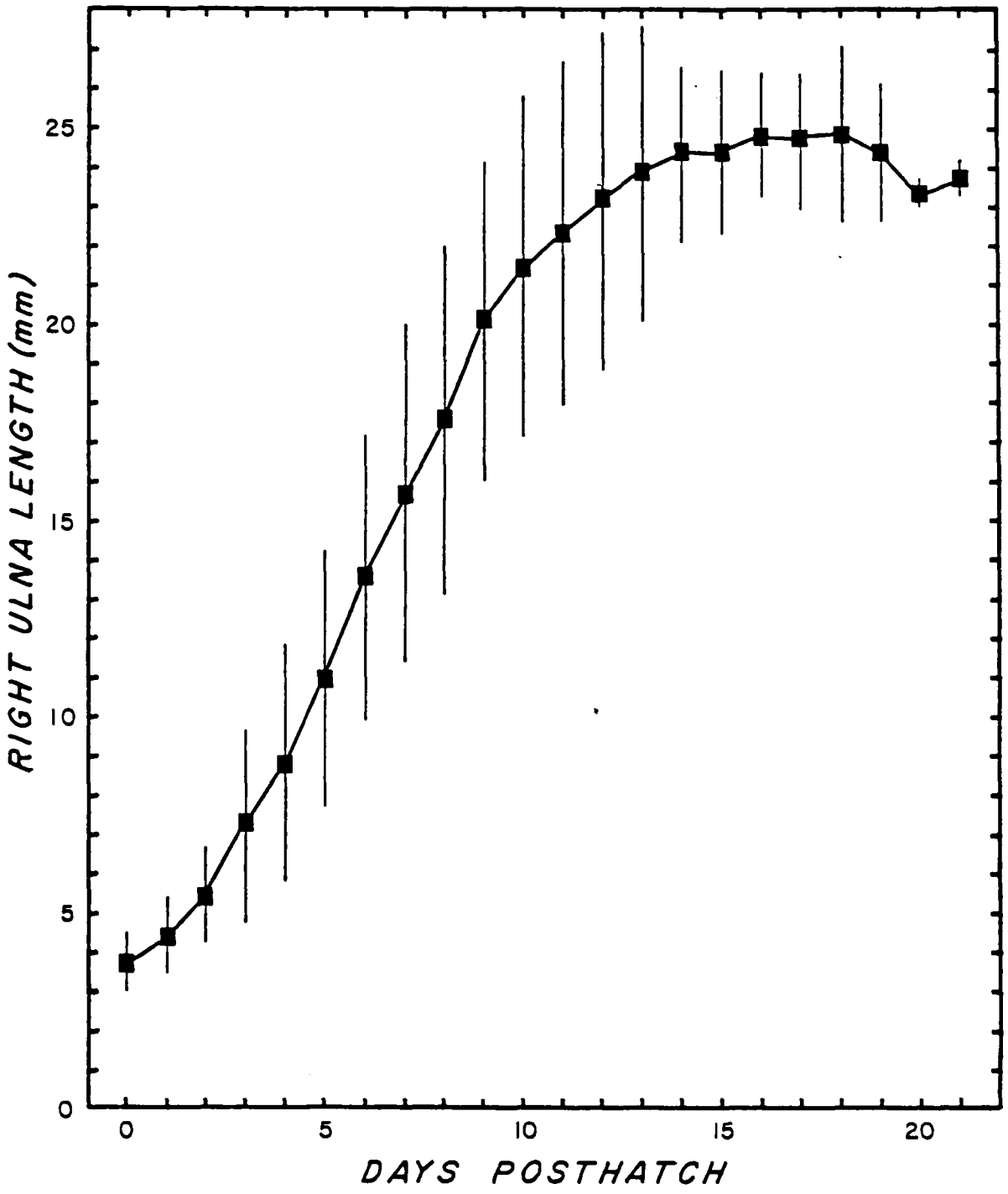
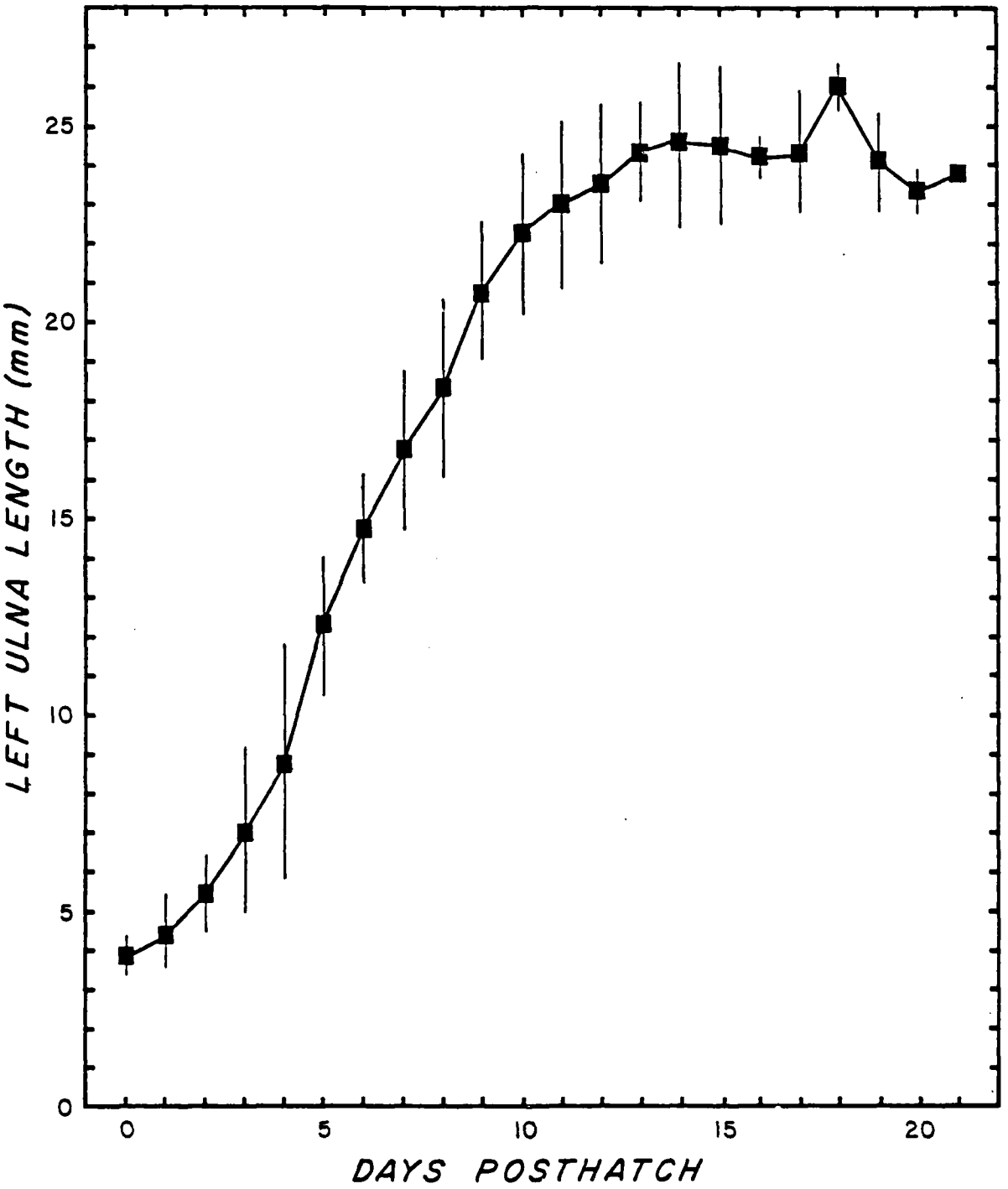

RIGHT ULNA LENGTH (mm)
0
5
10
15
20
25
0
5
10
15
20
DAYS POSTHATCH

Figure 10. Mean daily values for length (mm) of left ulnae in nestling tree swallows. Vertical bars represent ± one standard deviation.


LEFT ULNA LENGTH (mm)
0
5
10
15
20
25
0
5
10
15
20
DAYS POSTHATCH

these morphological features for tree swallows in the literature. However, Stoner (1945) presents data for the cliff swallow, and the lengths and variation on each day of nestling life are very similar. Feather eruption occurred on about day 6 (hatch day = 0) of nestling life (we do not report standard deviations for these data as we feel our technique in 1983 was unreliable). The time of eruption is similar to reports in the literature for tree swallows (7.3 ± 0.82 days with day of hatching assigned as day 1; Zach and Mayoh, 1981) and for the cliff swallow (Stoner, 1945). (We have written Zach and Mayoh requesting their original data; these would allow us to compare our findings with theirs in an analysis of variance). The age at eye opening averaged 5.64 ± 1.05 days. We could not locate data for comparison in the literature. Of all the mensural data collected, body weight was the most variable, with a maximum coefficient of variation of 26.5 % on day 4 of nestling life.

Parental and Nestling Behavior, Fecundity, Growth and Maturation Studies of Mammals- Beginning on 7 June and again on every third day through 5 September 1983, all nest boxes at the Turner plot were checked for the presence of deer mice. Installed at the site (see Figure 3) were 26 large, bird-size cement boxes, 48 small, mouse-sized cement boxes, 16 cement building-block boxes, and 4 mouse-sized wooden boxes. By monitoring a variety of nest box styles and positions we hoped to determine which were most attractive to mice.

The bird boxes were distributed into three rows and mounted on trees at a height of 1.2-1.5 m. The rows were spaced 100 m apart, and boxes in each

row were spaced 50 m apart. The 48 cement mouse boxes were distributed in three rows of 16 per row. The mouse box rows were spaced 40 m apart, and the boxes in each row were also spaced 40 m apart. The boxes were installed at four different types of locations on or near trees within the grid. Twenty-five percent of the cement mouse boxes were mounted on trees at a height of 1.5 m. Equal proportions were placed in three other positions: 1) 0.6 m high on a tree, 2) on the ground at a tree base, and 3) buried half underground in an area adjacent to a tree. The 16 building block boxes were distributed into two rows of 8 each. In each row of building blocks, the nest boxes were alternatively placed on or below the ground surface. The four wooden boxes were installed on trees at a height of 1.2 m. All mouse boxes were provisioned with cotton nesting material that was replaced when wet or badly soiled. Most of the bird boxes had a shallow bed of sawdust (intended originally for use by black-capped chickadees) and some were left completely empty. On a few occasions we added a few sunflower seeds to each of the nest boxes in hope of attracting deer mice to the boxes. By examining the boxes afterwards for seed shells and mouse feces, we were able to obtain a measure of nest box visitation by the mice. All mice found occupying a nest box were identified by toe-clipping, sexed, aged, and returned to the nest box.

During the three month monitoring period, 57 different free ranging mice (juveniles, subadults, or adults) occupied nest boxes. Of these, 30 made only one visit to a box (20 males, 10 females). Some mice made more than one visit. Thirteen mice (6 males, 7 females) visted a box twice, 9

(2 males, 7 females) made three visits, 3 mice made 4 visits, and only 2 mice made 5 visits. In general, nest box occupancy rates were low. A mean of only 1.26 (of 94 available) boxes was occupied on any given census day. Each occupied nest box contained a mean of just 2.92 mice (range: 1 - 8). Boxes with a large number of mice were invariably occupied by an adult lactating female and her suckling litter. Nevertheless, only two females with litters were found in a nest box.

Sixty-seven percent of all nest box occupancies were in bird or mouse cement boxes mounted 1.2 m high on trees. In comparison, only 18 percent were found in boxes at the 0.6 m height, 13 percent at the ground level, and only 2 percent in boxes located underground.

In summary, the monitoring of nest boxes at the Turner Road plot revealed that, overall, few mice occupied nest boxes at any given time, and that the occupations were often short-lived. These findings were discouraging for two reasons. First, our parental care and nestling growth studies require us to sample approximately 30 litters and their parents per year. The chance of finding 30 breeding female nest occupants in any given breeding season with the present nest box grid arrangement would appear to be small. Second, a necessary condition for the parental care and nestling growth studies is long-term nest box residency by the young mice and their parents. Clearly, the Turner Road data give little reason to hope that this condition could be met.

The problems described above could be attributed to several factors, two of the most likely will be discussed. First, the low occupancy rates

could be a result of the rather low population density of deer mice at the Turner Road plot. Mouse density (4.58 mice/hectare, see Table 4) was only half the density of nest boxes at the site (8.33 boxes/hectare). Although few occupied nest boxes were observed, there was ample evidence that an unknown number of deer mice frequently visited the boxes to feed (when sunflower seeds were provided). For example, on two occasions in which sunflower seeds were added to the nest boxes, 90% or more of the boxes exhibited signs of mouse activity within 3 days after the seeds were added.

Second, the low occupancy rates and the lack of long-term residency could be attributed to features of the nest boxes that the mice find undesirable. In spite of the variety of box positions, designs and materials, free-ranging mice were reluctant to maintain long-term residency in the boxes provided.

Proposed Small Mammal Enclosures and Justification- The first-year field data demonstrate conclusively that nest boxes are not intensively used by animals living in the forests near the planned ELF Communication System. These findings lead to the conclusion that if the growth, development, and behavior of mammals are to be productively studied at all, the animals will have to be constrained in their movements. Thus, we propose to carry out our work in large enclosures, which will be open at the top to allow free passage of atmospheric electromagnetic fields. As in our amended original proposal, we again opt to make P. maniculatus gracilis the subject of our intensive work on mammals, for three reasons:

(1) It remains desirable to study a small mammal because small mammals tend to have much smaller home ranges than large and, thus, a greater fraction of their home range can be encompassed by an enclosure of given size. (2) Results obtained on P. m. gracilis will apply to the most abundant small mammal living in forests surrounding the System. (3) The genus Peromyscus has been subject to a greater amount of previous study in large outdoor enclosures than any other genus of mammals found in Michigan forests; thus, prior experience with the genus in enclosures, albeit limited, is exceptional.

An obvious question is whether Peromyscus in enclosures are similar in their behavioral patterns to mice free-roaming in forests. This question cannot be answered in detail because very little is known about free-roaming behavior. Two previous studies have shown, however, that P. maniculatus retain known habitat preferences when living in enclosures. Fitch (1975) found that P. m. gracilis captured in forested or open habitats continued to exhibit a clear bias toward occupancy of their home habitat when given a choice of both habitats in enclosures. Wecker (1963) showed that P. m. bairdii from fields continue to live preferentially in field when placed in enclosures that provide a choice of field or forest. It is to be stressed that Wecker's enclosures measured 16 ft by 100 ft, and Fitch's measured just 8.9 ft by 10.5 ft. These enclosures were small enough that a mouse could conceivably travel their full extent in seconds or minutes. Yet, still, the mice continued to exhibit their native habitat preferences by restricting their activities to just parts of the

enclosures. Even relatively small enclosures are seen to be compatible with expression of important known behavioral patterns.

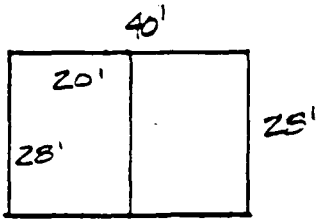
Another important question is whether enclosures have advantages over simple cages. Specifically, are Peromyscus more likely to show their normal free-roaming behaviors when confined in a large enclosure than in a small laboratory cage? (If not, the expense of constructing enclosures would be unjustified.) Again, definitive answers cannot be given for lack of a good understanding of free-roaming behavior. However, Hill (1972) made a direct comparison of maternal-care behavior in small laboratory arenas and moderately large (10 ft x 20 ft) outdoor enclosures, and he found that the behavioral patterns of P. leucopus in the enclosures were dramatically different from those of the same species in the laboratory arenas. Furthermore, the direction of the differences was that to be expected; mothers occupying a large, diverse environment in enclosures spent much more time away from their young each day than ones occupying small, homogeneous environments. Hill's data clearly suggest that large, outdoor enclosures elicit a better approximation of natural free-roaming behavior than small, laboratory arenas.

We propose, on the basis of the information presented above, to construct enclosures in the field on the test and control plots. These enclosures (see Figure 11) will be made of plexiglas material so that electrical fields will be allowed to penetrate the walls (engineers at IITRI have informed us that plexiglas is the only material permeable to electric fields in air). The plexiglas is ideally suited to containing the

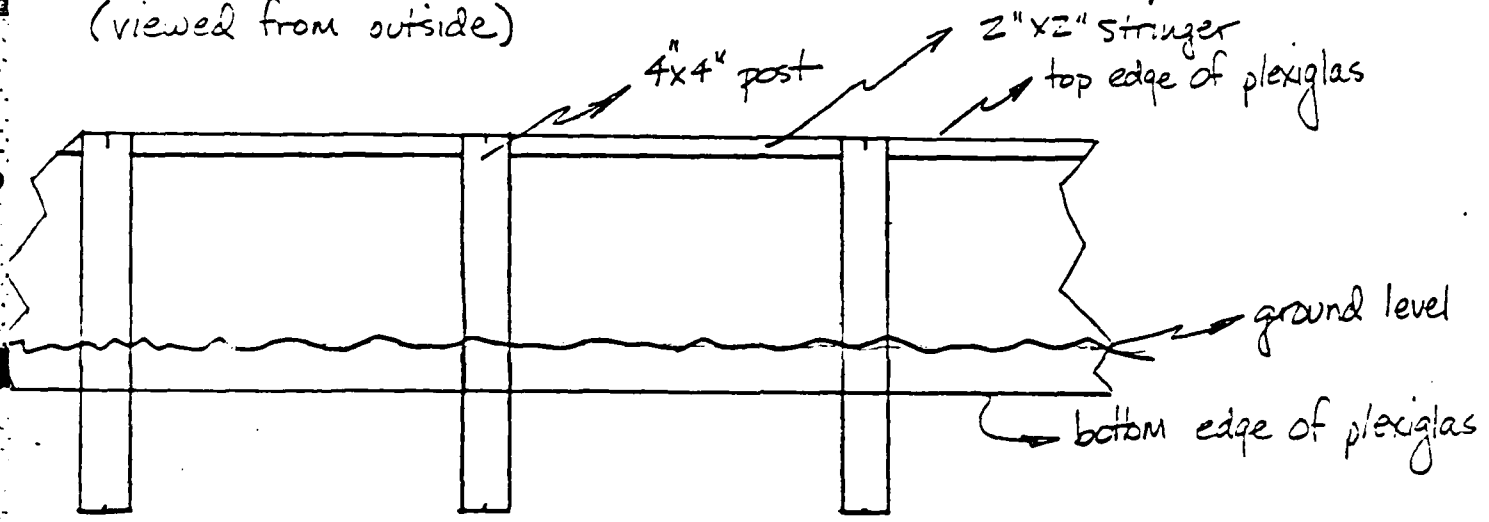
Figure 11. Diagram of the proposed deer-mouse enclosure.

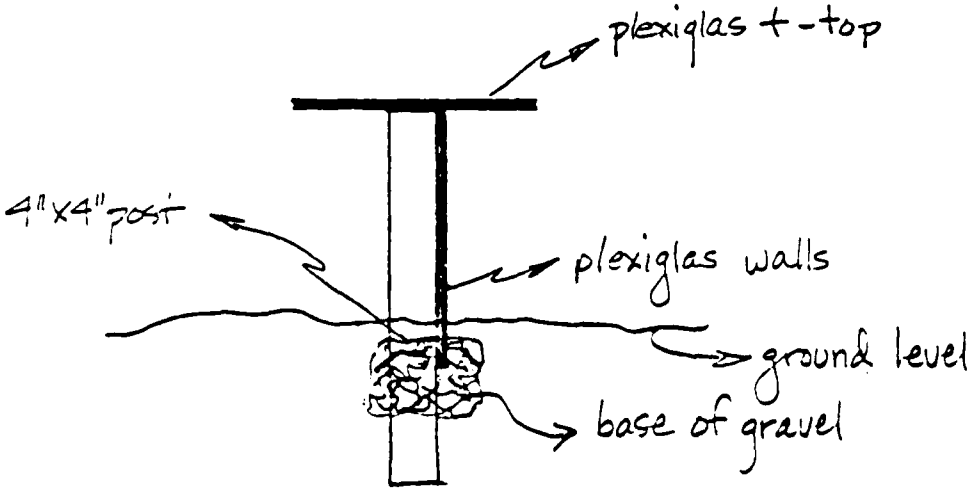
Enclosures will be built in pairs (diagrams not to scale)

erview



Side view of section of wall
(viewed from outside)



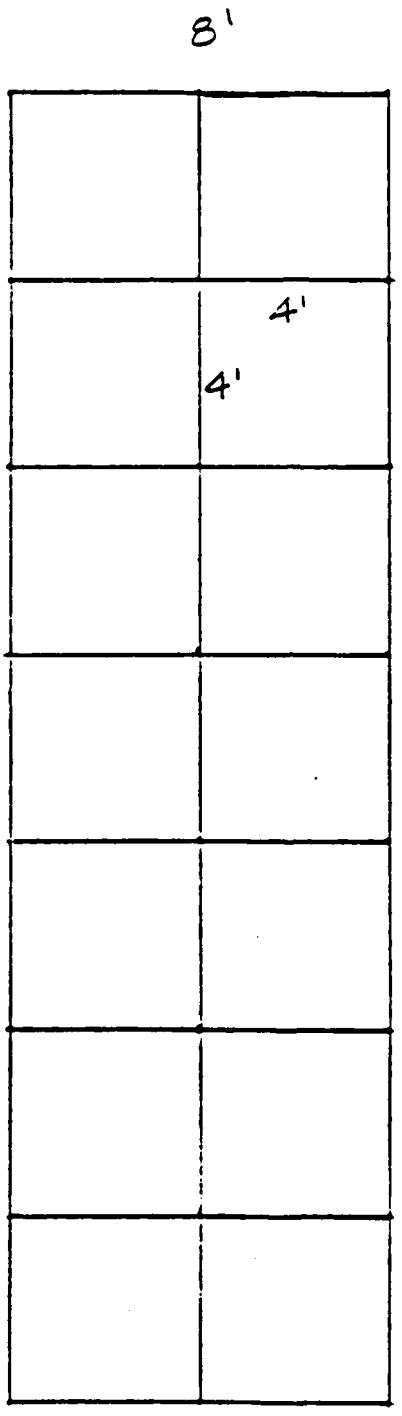


mice because of its slick surface. The walls of the enclosures will be kept to about 2 ft above ground level to allow free air circulation so as to minimize any effects this might have on the air temperature within. All walls will have a 20-inch-wide sheet of plexiglas mounted horizontally on their top to prevent the enclosed animals from escaping (Figure 11, Wecker, 1963). Except for these horizontal sheets, the tops of the enclosures will be open. An absolute minimum of cutting or destroying of vegetation in the enclosures will be observed during construction. Any trees in the enclosures will be encircled with polyethelyene sheeting to prevent the mice from climbing out, something P. m. gracilis is prone to do. The dimensions of the enclosures will be 20 ft x 28 ft, or about 52 m sq. A nest box and ad libitum food and water will be provided for enclosed mice. Mice to be used in the enclosure will be housed until use in a large open-top outdoor holding facility (each compartment 4 x 4 foot) constructed on the same plan and of the same materials as the enclosures (Figure 12).

It is important to consider the size of the enclosures relative to the normal home range of P. m. gracilis. The home range of this subspecies was estimated by Blair (1942) and by Manville (1949) (Table 6). A similar woodland species, P. leucopus, was studied by Flemming (1977), Mineau and Madison (1977) and Madison (1977) (Table 6). The methods and results of these works vary considerably, but we can obtain at least a crude estimate of the area that will be supplied by our enclosures relative to the range of free-roaming mice. The enclosures provide from less than one percent (0.5%) to about 7% of the estimated total home range size. We suspect that

Figure 12. Diagram of deer-mouse holding facility.

Mouse holding facility.



Constuction will be the same as for the enclosure.

One pair of mice will occupy each compartment.

Table 6. Home range estimates for P. m. gracilis, and for P. leucopus which is a congener with similar habitat preference. All estimates of home range area are given in hectares. M = male, F = female, A = adult, J = juvenile.

SPECIES	SEX	AGE	AREA hectares	METHOD	REFERENCE
P.m. gracilis	M	A	.94 ± .12	Mark & recapture Incl boundary strip	Blair, 1942
	F	A	.57 ± .07		
	M	J	.36 ± .04		
	F	J	.44 ± .07		
	M	A	.08	Mark & recapture Excl boundary strip	Manville, 1949
	F	A	.07		
		J	.07		
P. leucopus	M		.53	Mark & recapture 95% confidence ell.	Flemming, 1977
	F		.31		
	M	A	1.26	Radio tracking of 1 male & 1 female	Mineau & Madison, 1977
	F	A	0.91		
	M	A	0.1	Radio tracking of 9 males & 6 females	Madison, 1977
	F	A	0.1		

these percentages are underestimates of the effective size of the enclosures because free-roaming mice spend much of their time within areas--"centers of activity"--much smaller than their total home ranges (Metzgar, 1973; Myton, 1974). Unfortunately the areas of the centers of activity are not known. However, our enclosures encompass a greater fraction of the centers of activity than of entire home ranges.

Work with CRPID Units and Resonant coils- Extensive work was done perfecting surgical procedures for implantation of resonant coils in animals. We were assisted in these efforts by a surgeon from the Michigan State University College of Veterinary Medicine, Dr. Charles DeCamp.

Originally we had hoped that coils could be placed subcutaneously on mice, so as to avoid the invasiveness of intraperitoneal surgery. We discovered, however, that coils placed subcutaneously on nestlings were often immediately chewed out by the parents; and coils placed subcutaneously on adults sometimes caused weakening of the overlying skin over the course of weeks or months, with the result that the skin would break open, creating a site of infection and allowing the coils to drop out. We concluded that coils would have to be placed in the peritoneal cavity of both nestling and adult mice. Extensive work was done on perfecting techniques for this insertion, and further work of this sort is planned for 1984. Using sterile technique, including draping of the surgical site, adults show little or no set back from surgery. Nestlings have tended to show some retardation of growth for a number of days after surgery, but there is good reason to hope that these effects can be

eliminated. The technique of subcuticular suturing has been mastered so that sutures will not be exposed on the outer body surface at the surgical site. Use of the technique has proved necessary since mice will chew exposed sutures.

Attempts at surgical implantation of coils in birds proved futile (using zebra finches as test species). Birds are reputed to be difficult to anesthetize, and our results confirmed this observation. We were able to perfect our technique to the point that few deaths occurred due to anesthesia, but we then found that room in the peritoneal cavity was too limited to insert coils without trauma to the visceral organs or air sacs. Subcutaneous implantations inevitably broke through the thin skin of the birds within days.

The failure of surgical implantation in birds prompted us to consider attaching the coils to leg bands. Efforts in this direction proved successful. Thus, an external placement of the coils will be used on birds (external placement cannot be used on mice because they will chew at objects attached to their bodies).

Coils that are to be surgically implanted must be encapsulated in a physiologically inert material. We have selected Dow-Corning 382 medical-grade elastomer for this purpose and have perfected the techniques for encapsulation.

Toward the end of the contract period, coils were redesigned to give greater electrical stability. Instead of consisting of several turns of thin copper wire (as originally), they now consist of a single wire loop

interrupted by a microcapacitor. This redesign promises to help also with an encapsulation problem: prevention of trapped air bubbles. The multiple loops of the original coils tended to retain air bubbles, making degassing (under vacuum) a slow process. The new coils have no parts where air bubbles could become trapped.

Engineering consultant Tracy Allen was slow to deliver the first prototype CRPID unit, and the unit proved to make unacceptably large numbers of errors once tested. Thus, data were not acquired using CRPIDs in the contract period. However, testing of the first prototype provided numerous, invaluable design insights, and toward the end of the contract period Dr. Allen completed a second prototype. Preliminary tests of this new prototype indicated it to function in an error-free manner.

Homing and Telemetry Studies- No homing studies were carried out on nestng birds this year due to the CRPID equipment not being completed before the end of the breeding season. For tree swallows, no adequate literature values could be found concerning homing behavior after displacement from the nest. Data on other species in the family Hirundinidae suggest there is considerable variability in return rates after displacement, but the distances displaced and the technique of study also varied (Southern, 1959; 1968). We therefore must obtain data in 1984 before we can estimate a sample size that will meet statistical sufficiency. Nest site fidelity can only be investigated between years. We expect to obtain data in the coming years of study.

Due, in part, to delays in the final approval of the homing and

telemetry test plot (T-3), time limitations did not permit deer mouse homing studies to be carried out as intended. Nonetheless, work was done in September on perfecting procedures for encapsulation of AVM SM-1 style radiotransmitters and their implantation in deer mice.

To insure waterproofing, radiotransmitters were encapsulated with Elvax (Mini-Mitter Co.), a paraffin-based material that has been used successfully by other radio telemetry specialists (Dale Madison, personal communication). The encapsulated transmitters were implanted intraperitoneally following the surgical procedures described above for the implantation of CRPID coils in mice.

Three radio transmitters were successfully implanted in three adult deer mice. Post-surgical observations of two of these three mice in a field enclosure revealed no apparent ill effects on behavior due to the surgery or the transmitter. One transmitter, however, failed to operate one day after implantation. A close examination of the transmitter revealed a problem with battery attachment, which can be corrected by improved soldering techniques. Monitoring revealed that the other transmitters operated normally for up to two weeks, which will allow more than adequate time to carry out plannned homing studies in the field.

Data on homing in deer mice are few, and can be used only as a rough indication of what we may expect in the forests near the System. Furrer (1973), Griffo (1961) and Murie (1963) provide estimates of returns for P. maniculatus and P. gossypinus. When released at 500 meters or less from their home range, the rate of return was 72 %. However, the studies

were either in a different habitat (Furrer; Murie) or on a different species (Griffo). It is therefore not certain what we can expect in forests near the System in Michigan; and as is the case for the tree swallows, we will not propose an estimated sample size until we have obtained data from the field in 1984.

Developmental Studies- Embryos collected during the early summer were all from nests of tree swallows. Eggs were collected in various stages of development, as determined by monitoring the temperature of the eggs to determine the start of incubation, and by noting the laying sequence. The frequency of abnormal embryos and the type of abnormality are shown in Table 7. There are few problems distinguishing dead and resorbing embryos from live normal ones. The category that would be most likely to cause interpretational errors is the one of live but abnormal embryos. This category represented only 6.5% of all embryos examined in 1983, but was more frequent than either dead or resorbed embryos. It is apparent that care must be taken to avoid observer bias in evaluating the living abnormal embryo category because of the difficulty in interpretation. We have proposed a single-blind experiment that will eliminate this difficulty.

We will produce a log book containing a set of 1000 random numbers. Since there will be only two personnel involved in the entire experiement, one (P. Lederle) will keep this log and assign numbers to eggs as they are collected. All embryos will receive the number on the egg when they are prepared by placing the number on the slide, or in the collecting vial. Mr. Lederle will record all of the pertinent data about each egg in the log

Table 7. Summary of conditions of embryos of tree swallows collected during the 1983 field season.

Condition of Embryo	Number	Percent
Normal	65	84.42
Resorbed	4	5.20
Dead and Abnormal	2	2.59
Dead, apparently normal Did not hatch	1	1.30
Alive, abnormal	5	6.49
Infertile	0	0.00
TOTALS	77	100.00

book. Dr. Asher will then remove and preserve the embryos. No analysis will be done until later in the season when specimens are taken to Michigan State University by Dr. Asher for weighing and preparation for microscopic examination. During the entire process of weighing, preparation and evaluation, only the random number will be associated with its specimen. Mr. Lederle will keep separate and private (at the Channing field lab) the log of numbers and their corresponding embryo data as to the plot they came from. Only after all analyses on the embryos have been comp ted by Dr. Asher will the embryos be resorted into test versus control. The statistical tests prescribed for the various parameters measured will then be performed. (This protocol is limited to a single-blind experiment by our limited labor force as it would take three persons to do a double-blind experiment.)

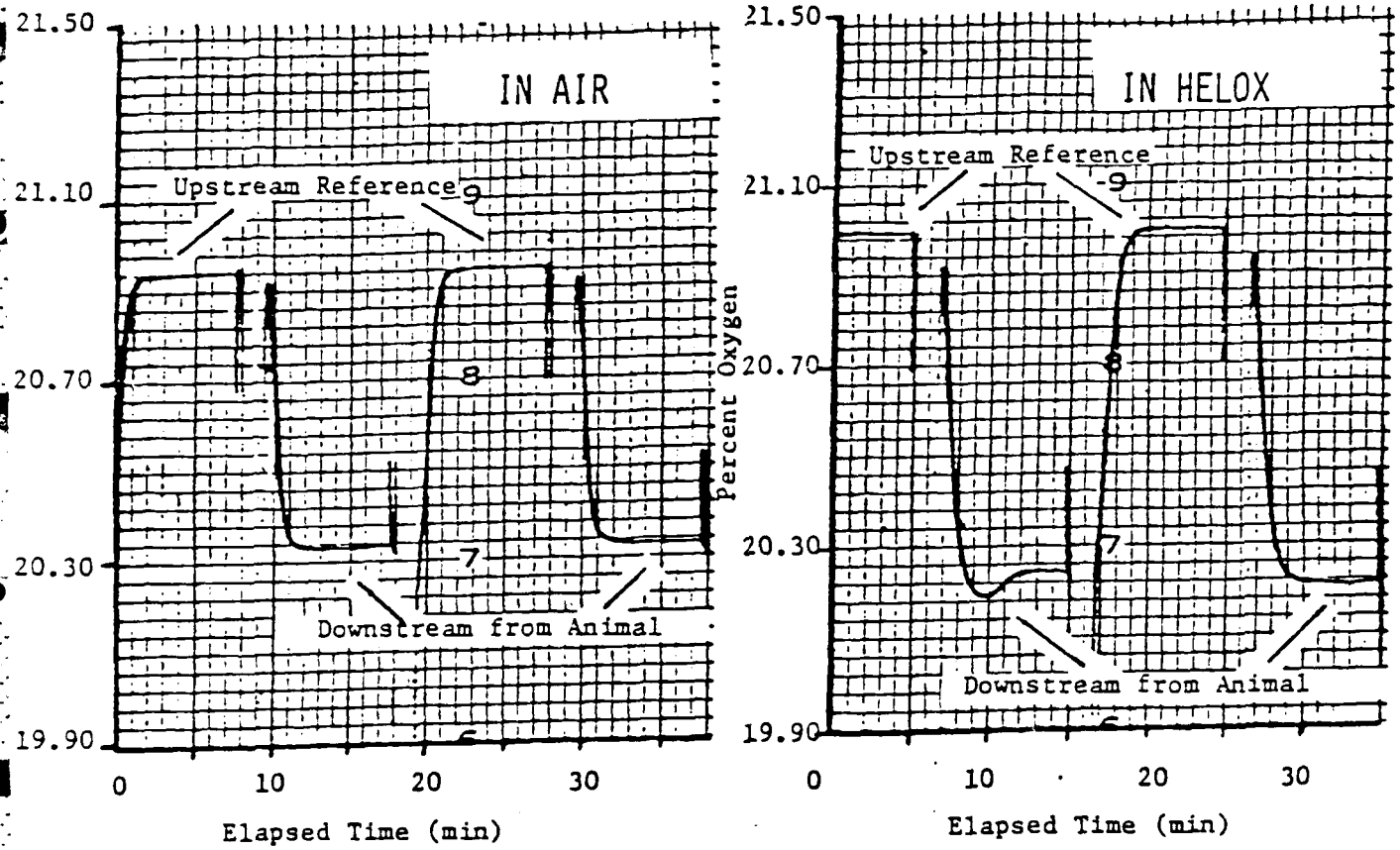
The frequency of abnormalities in tree swallow embryos based on our 1983 collections is about 15%. This frequency is similar to a literature report of eggs that were incubated but failed to hatch in a population of tree swallows on Kent Island, New Brunswick (Paynter, 1954; p 50, 15.04 %). However, no mention of the condition of the embryos was made, nor what percentage were infertile as opposed to abnormal in development.

Physiology Studies- The components of the metabolic studies apparatus have been calibrated and tested, and are fully operational (although warranty repairs on the Leeds and Northrup thermocouple recorder remain to be done). The collection of baseline data on the peak metabolic rates of Peromyscus is currently in progress.

Among the metabolic characteristics currently being evaluated is the temperature at which the maximal rate of oxygen consumption in a helium-oxygen (helox) atmosphere occurs for deer mice. Because helium has a greater thermal conductivity than nitrogen, an individual's heat loss and its corresponding oxygen consumption occur at greater rates in a helox atmosphere than in air at any given ambient temperature. Sample data in Figure 13 illustrate this principle. At 20° C, oxygen consumption in the animal exposed to helox in this example is approximately 33% greater than it is in air. Results so far indicate that maximum oxygen consumption in helox occurs between 15° and 0° C in warm-acclimated laboratory Peromyscus. Cold-acclimated deer mice are also to be tested.

We do not as yet have data on the variation in maximum oxygen consumption for winter acclimatized Peromyscus maniculatus. However, using data from Wickler (1980) on a similar species, P. leucopus, tested in a helox atmosphere between -3° and -9° C, we compute a mean maximal rate of oxygen consumpton of 18.1 ml per gram-hr with a standard deviation of 1.98. The computed coefficient of variation is 10.9%. It is not clear if the animals used by Wickler all maintained normal levels of body temperature. Extensive lowering of body temperature can diminish the peak oxygen consumption attained. Thus, the variation in peak oxygen consumption from animal to animal tends to be greater if some animals suffer extensive lowering of their body temperature than if all maintain high body temperatures. We will disregard data from animals that become markedly hypothermic, and thus, the coefficient of variation in our work may prove

Figure 13. Sample recordings from the oxygen analyzer during preliminary studies with Peromyscus maniculatus gracilis. The difference in percent oxygen between upstream and downstream sources is approximately proportional to the oxygen consumption of the animal tested. Data are from one individual exposed to air or helox at 20 degrees C.


IN AIR
Upstream Reference
Downstream from Animal
21.50
21.10
20.70
20.30
19.90
Percent Oxygen
0
10
20
30
Elapsed Time (min)
IN HELOX
Upstream Reference
Downstream from Animal
21.50
21.10
20.70
20.30
19.90
0
10
20
30
Elapsed Time (min)

to be lower than that evident in Wickler's work.

No runs on birds have yet been accomplished. The species of choice for this work is the black-capped chickadee, since tree swallows do not overwinter in the upper peninsula. We have maintained temporary feeding stations near the field laboratory and have found these birds to be easy to attract and capture.

To avoid researcher bias, a single-blind procedure will be implemented in the analysis of data from Peromyscus and the chickadee. Here, it will not be possible to blind the field part of the experiment since animals will have to be obtained from the field, one plot at a time, tested, and then returned. The blind procedure will be applied in the analysis of the data. The output of the metabolic apparatus is a strip-chart recording of the oxygen-analyzer output for a particular animal, along with records of associated body and metabolic chamber temperatures. These strip-charts will be assigned a random number as they are produced . As in studies of development, only one person will know the location of origin of the animal, and all data relevant to the collection of the animal and its testing will be kept in a log unavailable to the person analyzing the charts. All analysis of the data will done by a researcher with reference only to the random number on the strip-chart. Only after all charts have been analyzed will the data be assembled according to plot location and statistical testing commence.

All blind tests will be supervised by the project director in the field and during later statistical analysis. We believe that following the

outlined procedures will reduce if not completely eliminate experimenter bias.

Data Base Management- We have succeeded in developing data storage and retrieval systems for data collected in the field, and for the timely transfer and analysis of data at Michigan State University. As we are still in the early stages of data collection and analysis, we do not have full tests (ANOVA, etc.) to report on data collected in 1983. We have collected enough data to provide a reasonably complete estimate of the required sample sizes for statistical sufficiency for the various tasks under study.

Estimates of Samples Sizes and Statistical Sufficiency- In this section we will discuss sample effort and design aspects to achieve statistically meaningful data. For study elements with pilot data, we will present estimates of sample N required to meet prescribed statistical power. Table 8 lists each study element with the estimated sample size required to meet statistical sufficiency with a 90% certainty of detection of a 20% change at the 5% level. We have chosen this standard (and dropped the standard stated earlier of 90% certainty of dectecting a 10% change at the 5% level) so that all study elements, including inherently more variable behavioral measures, can be compared on the same basis. Certainly some study elements, such as measures of growth, will produce data that can be examined at higher standards; and where higher standards can be met, they will be. However, all study elements now proposed for intensive research will meet the standard stated above. The data used in Table 8 are derived

Table 8. Minimum sample size requirements estimated for various study elements to meet the statistical standard of 90 % certainty of detecting a 20 % change at the 5 % level of significance.

Study Element	Species	Parameter	Estimated N
Parental care, fecundity, growth, and maturation	Peromyscus	litter size	36
		weight	21
		age eye open	6
	tree swallow	clutch size	21
		egg weight	17
		hatching success	113
		weight	38
		growth: tarsi	15
		growth: ulnae	17
		feather eruption	8*
		age eye open	20
		fledge success	112
		time to fledge	14
Developmental Abnormalities	tree swallow	embryo wt after 4th day	89
		frequency of normal embryos	48**
Physiology	Peromyscus	peak metabolism	8
	black-capped chickadee	peak metabolism	8

* Data from Zach and Mayoh (1981).

** Estimated using Chi Square statistic.

from our own research in 1983, unless otherwise stated. The procedure used was that of a comparison of the ratio of the % expected change and the coefficient of variation as described in Sokal and Rholf (1969, pg 247) and the data used are presented in the appendix of this report. We used a Chi Square statistic to estimate the sample size required to detect differences in frequencies of abnormal embryos (the procedure simply computes sample sizes necessary to show statistical significance at the levels we specify above; it is not a power function).

In addition, we have developed the analytical techniques that we propose to use in examining the data generated by the studies of parental behavior and the maturation of young to be carried out on Peromyscus in enclosures. The proposed approach is outlined on the following pages.

Statistical Design for Enclosure Studies

General Experimental Design

In Peromyscus, parental behavior and the maturation of young will be monitored by studying animals in large, open-topped, outdoor enclosures. Animals will be trapped in the field and placed into open-topped, outdoor holding pens until they are to be used in the study. Parental behavior will be monitored continuously using automatic data-logging CRPID equipment. Growth and maturation of young will be accomplished by direct observation and measurement. Behavioral maturation of young (e.g., departures from nest) will be monitored with CRPID equipment.

An experimental run will commence when a mated pair, including a pregnant female, is placed into one of the large test arenas. The run will conclude upon the weaning (or loss) of the litter. Each run should take no more than five weeks to complete. With a total of twenty enclosures (ten experimental and ten control) and with a twenty-week field season, each season should include approximately 80 experimental runs.

Analysis of Data

Each experimental run can be characterized by the place of capture (origin) of the test animals and by the place of testing (location). Thus, all data will fall naturally into a two-by-two factorial design. The data will be examined first using exhaustive orthogonal contrasts in analysis of variance. This will be followed with additional planned, non-orthogonal contrasts. The use of multiple comparisons is believed to be justified by the charge of the research--the detection of any effects due to the antenna. Under this charge, minimizing Type II error is more important than minimizing Type I error.

The use of orthogonal contrasts will allow an examination of the data for any effects that might be occurring. The orthogonal contrasts are given below.

origin:	E		C	
location:	E	C	E	C
origin	+ 1	+ 1	- 1	- 1
location	+ 1	- 1	+ 1	- 1
origin x location	+ 1	- 1	- 1	+ 1

An a priori consideration of the system under study indicates that at least three different types of antenna effects are conceivable:

1. Long-term changes, due to continuous exposure to the antenna. These effects are presumed to be due to long-term exposure to the antenna and are presumed to persist for some time following cessation of exposure to the antenna. These effects should be detectable in all animals captured in the experimental plots, regardless of the location of their testing.
2. Short-term effects, due to immediate exposure to the antenna. These effects are presumed to be due to the immediate effects of the antenna and as such would be expressed only during exposure to the antenna. These effects should be detected in all animals tested in the experimental plots, regardless of their origin.
3. Long-term changes that require immediate exposure to the antenna for expression. These effects are presumed to require long-term exposure to the antenna for their generation and immediate exposure to the antenna for their expression. These effects

should be detectable only in animals captured and tested in the experimental plots.

This *a priori* consideration allows the development of a specific model to explain the behavior of each of the four different experimental groups. This model can then be used to construct specific tests for these different effects.

To begin, first let

M = the overall mean measurement expected in the absence of any antenna effects,

L = the additive effect of long-term changes (as in note 1, above),

S = the additive effect of short-term exposure (note 2),

L/S = the additive effect due to long-term changes that require short-term exposure for their expression (note 3), and

e = error in measurement.

Then, assuming homogeneity of errors, we can calculate the expected mean measurement for each experimental group. Using E/C to indicate animals captured in the experimental plot and tested in the control plot, these values are as follows.

group	expected mean measurement
E/E	M + L + S + L/S + e
E/C	M + L + e
C/E	M + S + e
C/C	M + e

Under this model, specific contrasts among means may be constructed to provide direct tests for the occurrence of each of these three hypothesized effects. The contrast vectors used for these estimates are as follows.

factor being estimated	contrast vector E/E	E/C	C/E	C/C
L	0	+ 1	0	- 1
S	0	0	+ 1	- 1
L/S	+ 1	- 1	- 1	+ 1

As is apparent from a comparison of these contrast vectors with the proposed model, each vector allows the direct estimation of the additive increment attributable to each specific hypothesized effect.

Additional Considerations

Existing data obtained by one of us (R. Hill) indicate that some aspects of maternal behavior (e.g., time spent in the nest per night) may vary considerably between mothers while being fairly stable between nights within mothers. If this proves to be true within mothers across litters (across-litter data are not currently available), considerable power could be added to our analysis if we conducted paired tests, where each set of parents would be tested once at the experimental site and once at the control site. (For balance, half of the animals should be tested in the E/C order, half in the C/E order.)

The actual increase in power attainable from such a design would depend upon at least two factors: (a) the actual difference in the between-mothers vs. within-mothers measurements across litters and (b) the loss in sample size that would result from mothers failing to produce a second litter following their first experimental run. Since neither of these can be estimated in the absence of data, we propose to obtain estimates by carrying out as many paired tests as possible during our first field season. The resulting data will then be examined to determine the expected increase in power that would occur is we restricted our analysis to paired comparisons. If this gain in power is

appreciable, our experimental designs will be modified accordingly in future seasons.

If paired designs are employed, it is also possible that a significant difference might be observed in the measurements between first and second litters, regardless of origin of capture or location of test. In our analysis of the first season's data, this will be investigated by adding another dimension to allow for sequence to the two-by-two factorial design. A detection of any direct or interactive effects due to sequence will be accomplished via the following set of orthogonal contrasts for the resulting two-by-two-by-two factorial design.

ORIGIN:	E				C			
LOCATION:	E		C		E		C	
SEQUENCE:	1	2	1	2	1	2	1	2
origin	+1	+1	+1	+1	-1	-1	-1	-1
location	+1	+1	-1	-1	+1	+1	-1	-1
sequence	+1	-1	+1	-1	+1	-1	+1	-1
origin x location	+1	+1	-1	-1	-1	-1	+1	+1
origin x sequence	+1	-1	+1	-1	-1	+1	-1	+1
location x sequence	+1	-1	-1	+1	+1	-1	-1	+1
ori x locat x sequence	+1	-1	-1	+1	-1	+1	+1	-1

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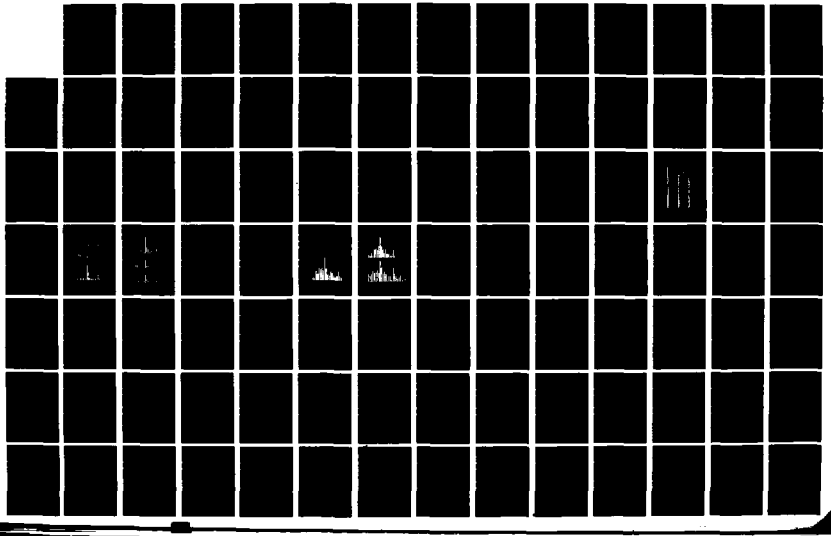

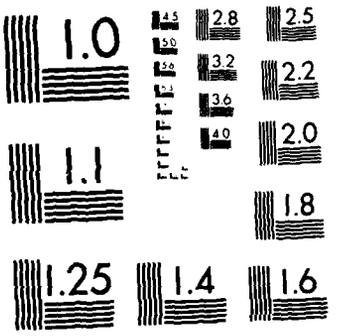

APPENDIX

Table 1. Body weight of tree swallow (*Tachycineta bicolor*) nestlings from the day of hatching to fledging.

Days Posthatch	N	Mean Wt, gms	Standard Deviation	Coefficient of Variation(%)
0	41	1.539	0.2673	17.3
1	51	2.2137	0.4837	21.8
2	55	3.4327	0.8722	25.4
3	56	5.1339	1.3096	25.5
4	57	6.7965	1.8014	26.5
5	52	9.0308	1.9843	21.9
6	52	11.9308	2.5046	20.9
7	50	14.7600	2.5654	17.3
8	48	16.7729	2.7431	16.3
9	48	18.7167	2.8047	14.9
10	46	19.8130	3.0404	15.3
11	43	20.007	2.9484	14.7
12	43	20.1488	3.3389	16.5
13	40	21.2425	2.6134	12.3
14	38	21.3974	2.9044	13.5
15	33	21.7727	1.6773	7.7
16	38	21.2105	3.3819	19.9
17	35	21.4486	1.6541	7.7
18	26	21.0923	1.5829	7.5
19	13	20.5308	1.4121	6.8
20	2	18.7000	1.2728	6.8
21	2	20.4500	0.4950	2.4

Days 19-21 are the period of fledging; thus the smaller samples.

Table 2. Length of the right tarsus of tree swallow (*Tachycineta bicolor*) nestlings from the day of hatching to fledging.

Days Posthatch	N	Mean Length, mm	Standard Deviation	Coefficient of Variation(%)
0	39	3.3405	0.4381	13.1
1	44	4.2425	0.6347	14.9
2	54	5.2550	0.8140	15.4
3	55	6.5744	1.0245	15.5
4	56	7.7189	1.2363	16.0
5	51	8.7424	0.9353	10.6
6	52	9.7863	0.8310	8.4
7	50	10.3954	0.8795	8.4
8	48	10.9250	0.8660	7.9
9	46	11.3252	0.6644	5.8
10	46	11.3333	0.7357	6.4
11	43	11.2753	0.6300	5.5
12	41	11.2600	0.7675	6.8
13	40	11.2725	0.7861	6.9
14	38	11.4455	0.6897	6.0
15	33	11.5479	0.6193	5.3
16	37	11.7181	0.4207	3.5
17	35	11.6183	0.3645	3.1
18	26	11.7173	0.3713	3.1
19	10	11.7820	0.3402	2.8
20	2	12.0200	0.2546	2.1
21	2	11.7700	0.3818	3.2

Days 19-21 are the main period of fledging; thus the small sample size.

Table 3. Length of the left tarsus of tree swallow (*Tachycineta bicolor*) nestlings from the day of hatching to fledging.

Days Posthatch	N	Mean Length, mm	Standard Deviation	Coefficient of Variation (%)
0	39	3.3254	0.4566	13.7
1	44	4.2652	0.6654	15.6
2	54	5.2044	0.7812	15.0
3	55	6.4624	0.9775	15.1
4	56	7.7211	1.1699	15.1
5	51	8.8318	0.9492	10.7
6	52	9.8196	0.7511	7.6
7	50	10.4136	0.7690	7.3
8	48	10.8925	0.8536	7.8
9	46	11.2857	0.6236	5.5
10	46	11.2867	0.7330	6.4
11	43	11.3051	0.5978	5.2
12	41	11.2380	0.7912	7.0
13	40	11.3162	0.7487	6.6
14	38	11.4203	0.6766	5.9
15	33	11.4424	0.5693	4.9
16	37	11.6200	0.4033	3.4
17	35	11.5923	0.4077	3.5
18	26	11.7173	0.3061	2.6
19	10	11.8260	0.2946	2.4
20	2	11.5900	0.5798	5.0
21	2	11.6700	0.0707	0.6

Days 19-21 are the main period of fledging; thus the small sample size.

Table 4. Length of the right ulnae of tree swallow (Tachycineta bicolor) nestlings from the day of hatching to fledging.

Days Posthatch	N	Mean Length,mm	Standard Deviation	Coefficient of Variation(%)
0	9	3.7511	0.3543	9.4
1	4	4.4750	0.4579	10.2
2	5	5.4880	0.6632	12.0
3	7	7.3743	1.1499	15.5
4	5	8.8540	1.5078	17.0
5	8	10.9987	1.6182	14.7
6	17	13.6171	1.8173	13.3
7	29	15.6855	2.0715	13.2
8	30	17.5860	2.2375	12.7
9	32	20.1050	2.0838	10.3
10	33	21.4694	2.1433	9.9
11	34	22.3182	2.2058	9.8
12	32	23.2119	2.1611	9.3
13	33	23.9103	1.8933	7.9
14	33	24.4394	1.1875	4.8
15	33	24.4085	1.0782	4.4
16	37	24.8127	0.8204	3.3
17	34	24.7468	0.9154	3.6
18	22	24.8214	1.1115	4.4
19	9	24.3989	0.8619	3.5
20	2	23.3850	0.0919	0.3
21	2	23.8900	0.0707	0.2

Days 19-21 are the main period of fledging; thus the small sample size. Days 0-5 are lower in sample size than later ages because we were testing the efficacy of ulna measures during those days.

Table 5. Length of the left ulnae of tree swallow (Tachycineta bicolor) nestlings from the day of hatching to fledging.

Days Posthatch	N	Mean Length, mm	Standard Deviation	Coefficient of Variation(%)
0	9	3.8289	0.2602	6.7
1	4	4.4575	0.5347	11.9
2	5	5.3980	0.4999	9.2
3	4	7.0775	1.0630	15.0
4	5	8.8160	1.4911	16.9
5	3	12.3300	0.8700	7.0
6	4	14.7400	0.6956	4.7
7	12	16.765	0.9790	5.8
8	13	18.3562	1.1290	6.1
9	13	20.8731	0.9220	4.4
10	14	22.2721	1.0703	4.8
11	18	23.0206	1.0934	4.7
12	19	23.5495	1.0479	4.4
13	18	24.3250	0.6356	2.6
14	17	24.6159	1.0986	4.4
15	17	24.5641	1.0058	4.0
16	14	24.2550	0.4789	1.9
17	12	24.3758	0.7869	3.2
18	2	26.1250	0.3182	1.2
19	3	24.1900	0.6295	2.6
20	2	23.3750	0.3182	1.3
21	1	23.3400	0.0	-

Days 19-21 are the main period of fledging; thus the small sample size. Days 0-6 were used as a test period for the measuring technique and are therefore also of lower sample size.

Table 6. Body weight in grams for deermice (Peromyscus leucopus) nestlings from the day of birth to independence. Data are from Hill (Unpub).

Days Postbirth	N	Mean Wt, gms	Standard Deviation	Coefficient of Variation(%)
2	25	2.5252	0.3765	14.9
4	23	3.3265	0.4573	13.7
6	28	4.2514	0.5314	12.5
8	32	5.3150	0.6760	12.7
10	35	5.7589	0.8219	14.2
12	32	6.4200	1.1065	17.2
14	35	7.0957	1.2774	18.0
16	31	7.8287	1.4949	19.1
18	34	8.1874	1.2556	15.3
20	32	8.8622	1.6052	18.1

Table 7. Time (hours) mothers of the deermouse (Peromyscus leucopus) spend out of the nest from age 4 to 14 days of the young. Data are from Hill (Unpub).

Days Postbirth	N	Mean Time,hrs	Standard Deviation	Coefficient of Variation(%)
4	5	6.06	0.6580	10.8
6	5	6.82	1.6529	24.2
8	5	6.32	1.9486	30.8
10	5	7.14	1.7855	25.0
12	5	5.18	1.5090	29.1
14	5	6.10	3.0952	50.7

Table 8. Time (minutes) young of the deermouse (Peromyscus leucopus) spend out of the nest from age 16 to 29 days. Data are from Hill (Unpub).

Days Postbirth	N	Mean Time,min	Standard Deviation	Coefficient of Variation(%)
16	5	9.8	8.4971	86.7
17	5	36.4	25.4617	69.9
18	5	93.6	41.8426	44.7
19	6	138.7	66.3013	47.8
20	6	215.0	68.1821	31.7
21	6	525.2	70.0121	27.7
22	6	307.7	69.2031	22.4
23	6	323.5	81.7307	25.3
24	6	360.2	59.4489	16.5
25	5	377.4	51.6362	13.6
26	6	390.3	91.5394	23.4
27	5	382.2	68.5689	17.9
28	5	385.6	109.5162	28.4
29	3	350.3	113.9181	32.5

Data are for 16-20° C.

Table 9. Time (minutes) young of the deermouse (Peromyscus leucopus) spend out of the nest from age 16 to 29 days. Data are from Hill (Unpub).

Days Postbirth	N	Mean Time,min	Standard Deviation	Coefficient of Variation(%)
16	5	5.4	5.6833	105.2
17	8	9.6	17.6144	183.0
18	9	27.9	28.7073	102.9
19	9	65.8	34.6907	52.7
20	10	93.9	54.2985	57.8
21	10	148.9	82.8485	55.6
22	10	217.0	111.4829	51.3
23	10	226.6	105.9614	46.7
24	10	282.2	100.9563	35.7
25	10	387.5	98.4494	34.2
26	10	309.9	84.3925	27.2
27	10	330.3	98.8006	29.9
28	10	316.1	81.8419	25.8
29	4	309.5	165.0969	53.3

Data are for 7-10° C.

Table 10. Mean weights of tree swallow (Tachycineta bicolor) embryos without extraembryonic tissue, from the 1983 field season.

Age (days)	N	Mean Wt, gms	Standard Deviation	Coefficient of Variation(%)
3.00	1	.00253	-	-
3.25	1	.01251	-	-
3.75	1	.02554	-	-
4.00	1	.02163	-	-
4.50	2	.022	.009	40.9
4.75	4	.037	.004	10.8
5.25	1	.04838	-	-
5.75	4	.073	.018	24.6
6.25	2	.061	.007	11.4
6.75	4	.122	.011	9.0
7.50	2	.143	.018	12.5
8.75	5	.211	.027	12.7
10.00	2	.315	.003	0.9
11.00	2	.689	.018	2.6
12.00	3	.779	.086	11.0
13.00	5	.816	.055	6.7
14.00	2	1.270	.092	7.2

Table 11. Mean weights of tree swallow (Tachycineta bicolor) embryos with extraembryonic tissue, from the 1983 field season.

Age (hours)	N	Mean Wt, gms	Standard Deviation	Coefficient of Variation(%)
18.5	1	.00112	-	-
20.5	1	.00560	-	-
27.5	3	.00679	.00297	43.7
31.0	2	.01069	.00298	27.8
35.5	2	.00964	.00216	22.4
51.5	1	.01204	-	-
52.5	4	.01200	.00305	25.4
53.5	1	.01340	-	-
78	3	.03068	.00653	21.2
86	2	.04116	.01481	35.9

Table 12. Peak rates of O_2 consumption measured on eight winter-caught Peromyscus leucopus in helox atmosphere. Data are from Wickler, 1980.

Mouse Number	Mean Oxygen Consumption (ml/g-hr)
1	15.3
2	16.1
3	16.5
4	18.2
5	18.6
6	19.5
7	20.0
8	20.8
	X = 18.1
	SD = 1.98
	CV = 10.9%

The mean oxygen consumption in helox for winter Peromyscus leucopus in an ambient temperature range of -3° to -9° C.

I. COVER PAGE

A. SUBCONTRACTOR: MICHIGAN STATE UNIVERSITY
EAST LANSING, MICHIGAN 48824

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IV. SUMMARY

The following is a summary of the data base collected from 10 July 1982, to 31 October, 1983, summarized by the final negotiated work plan element:

Element 1 - Paired Plot Selection

Two sites on the Ford River, Dickinson County, Michigan were chosen as our paired plot selection. Ford Experimental Site (FEX) (IITRI's 5T1) (T43N:R29W:Sec. 11) is at the ELF corridor crossing. Ford Control Downstream (FCD) (IITRI's 5C1) (T43N:R28:Sec. 21) is an excellent control for FEX with similar biological and physical characteristics and closely matched background electromagnetic radiation exposure. Other potential sites investigated are listed and discussed including a potential upstream control site on the Ford River (FCU) used in 1983 that is being abandoned for reasons discussed in other elements.

Element 2 - Inventory Physical Characteristics of Stream Sites

Measurements of pool and riffle lengths, substrate particle size, riparian vegetation, discharge, width and depth, and physical parameters used in fisheries research are summarized. In general, these physical characteristics are similar for FEX and FCD but differ greatly for FCU.

Element 3 - Establish and Conduct Ambient Monitoring Program

Summaries of water chemistry for various sites on the Ford River are presented. FEX and FCD are very similar with respect to water quality while FCU differs with higher alkalinity, conductivity, and hardness. Nutrient analyses for 1982 demonstrated that water quality for the Ford River is excellent with very low levels of nitrogen, phosphorus, and other essential nutrients. Samples for 1983 are frozen and await processing. Automatic ambient monitoring stations were installed in June, 1983, and worked reasonably well. Data analyses await development of computer programs for summarization.

Element 4 - Effects of Exposure Period on Periphytic Colonization of Artificial Substrates

On the basis of all criteria examined, we concluded the following:

(1) A 28 day sampling period represents a reasonable sampling regime for species composition, dominance, diversity, evenness, richness, and density to achieve our goal of sampling a "mature" community characteristic of rock substrates in the river.

(2) A 14 day sampling period during the active growing season should be used to determine productivity parameters such as chlorophyll a and organic matter biomass accumulation rate. However, we will sample these same parameters on a 28 day sampling period as well as the 14 day period in order to correlate these parameters with the "mature" community parameters listed above.

(3) The downstream control site (FCD) is an excellent control for the experimental site (FEX) at the ELF corridor while the upstream control site (FCU) is unacceptable. The FCD-FEX comparison will be further enhanced in future studies by more careful matching of environmental parameters such as light exposure, water depth, and flow rates in the coming year.

Element 5 - Compare Periphyton Communities on Natural Substrates with those on Artificial Substrates

Comparisons of natural substrate periphyton against the glass slide periphyton showed similar species composition but different relative species abundances. No species were identified from natural substrates that were not also recorded from the glass slides. The glass slides thus appear to give a good overall picture of the periphyton community.

Element 6 - Monitoring of Species Composition, Numbers, Diversity Biomass

Chlorophyll a (Chl a) values showed mid-summer (July) peaks at the three sites FCD, FEX, & FCU. This coincided with peaks in organic biomass accumulation observed in mid-summer at these sites and correspondingly high cell densities measured from late spring through the summer period for FSI site. Close agreements between Chl a and organic biomass accumulations were observed between FEX and FCD while significant differences in these same parameters occurred between FEX and FCU. FCU thus appears unacceptable as a control site for future periphyton comparisons against FEX.

Three hundred and four diatom taxa were enumerated from August 1982 - August 1983. Non-diatom algae appeared at densities much below diatom cell densities. Initial length and width measurements of algal cells have been made for all species but Biovolume calculations have not as yet been performed. Species diversities have not yet been finished for the yearly analysis.

Diatom cell densities for FSI indicated May-June as a period of maximum growth and late February as a period of minimum production. Cell density differences between riffle and pool habitats appeared greatest during spring and fall corresponding

with rapid water flow fluctuations. A comparison of yearly cell density means for pool and riffle habitats however showed no significant density differences.

Element 7 - Stream Invertebrate Collection and Identification

One hundred and two species of insects were identified from the Ford River sites. Additional species of chironomids are currently being identified because they are numerically dominant in leafpack and substrate samples. Any new species from future samples will be added to the reference collection. Element 7, per se, is now terminated: Insect collections and identification will come from samples described in other elements.

Element 8 - Effects of Exposure Period on Invertebrate Colonization of Artificial Substrates

Results from the insect colonization study showed that richness, diversity, evenness, and proportion of individuals among trophic groups stabilized by Day 28; however, absolute numbers of individuals were still increasing by that time. If this study is repeated next summer, five rather than three replicates will be taken and the study will span a two-month period.

Element 9 - Species Richness and Biomass of Stream Macroinvertebrates in Riffles and Pools from Artificial Substrates

Insects from substrate samples at FEX and FCD were more similar to each other than were insects from FEX and FCU substrate samples. The specific location for samplers in FEX was changed in September of 1983 to more closely match the location of samplers at FCD. The FCU site will be dropped from this study as of January 1984. Five replicates per sampling date were shown to be sufficient for data analysis.

Element 10 - Movement Patterns of Selected Aquatic Invertebrates

Crayfish, by mark-recapture methods, moved over longer distances at FEX than at FCU. Crayfish were more abundant at FCU than at the FEX and FCD sites. More detailed work on crayfish local movement patterns and microhabitat preferences will be done during the field season of 1984. Samples of the dragonfly, Ophiogomphus carolus, showed two distinct size groups; the slow-growing pattern within the size class groups suggested that the population is hemivoltine. Densities were higher at FEX than at FCU. Next summer, the FCD site will be added and the FCU site will be dropped from the study. Also, studies on larval growth, movement patterns and food preferences will continue during the 1984 field season. Additional species of insects will also be added for studies on movement patterns.

Element 11 - Colonization Patterns and Processing by Invertebrates on Autumnal Freshly Fallen Leaves

Fresh leafpacks supported a more diverse, more equitable and richer insect fauna than did dried autumn leaves in Schwartz Creek, a sandy bottom site having white cedar as the primary leaf input. Leaf loss was faster for fresh than for dried leaves there. The same experimental design was used in the Ford River, and yielded different results. Fresh leaves contained three times the number of individuals; yet, diversity and equitability of insects on the two types of leafpacks were similar (richness was higher for the fresh leaves). Dried and fresh leaves lost their mass at about the same rate in the Ford River at a cobble site where Tag Alder & Balm of Gilead leaves were the primary inputs. Although chironomids numerically dominated all leafpacks, only in the Schwartz was there significantly lower dominance by chironomids on fresh versus dried leaves. Dominance remained the same for fresh and dried leaves in the Ford. The numbers of replicates (5) per sampling date and location was sufficient for data analysis.

Element 12 - Drift Patterns of Aquatic Invertebrates

This work element was included even though it had been deleted in the best and final offer. Preliminary work in 1982 demonstrated that this labor intensive project could not be done with available manpower and commitment. It was dropped after the 1982 season.

Element 13 - Leaf Litter Processing Experiments Using Natural Leaf Packs and Cages

A caged experimental design was used to study effects of a major shredder, Tipula abdominalis, on leaf loss rates. The study began late in September of 1983; the experiment will run until February or March of 1984 and analyses will be done at that time.

Element 14 - Feeding Activity of Grazer Populations

This element concentrates on assessing the importance of periphyton in the feeding and growth of the mayfly Stenonema vicarium (Walker) (Heptageniidae), a common grazer during the summer in the Ford River. Published information indicates that S. vicarium is specialized on periphyton grazing. If this is true, one would expect production of S. vicarium to be low where periphyton production is also low, since S. vircarium may not be able to feed effectively on other food resources (e.g., detritus). The overall hypothesis is that production of S. vicarium, and grazers in general, is positively correlated with periphyton production. The results of this study could be used to assess the indirect effects of ELF electromagnetic radiation on grazers via the periphyton community. Studies of other grazer populations will be added next season.

Element 15 - Fish Species Composition, Relative Abundance and Habitat Relationships

A) Species composition and relative abundance

Twenty species representing ten families and five orders were collected from ELF sites. FCU had 15 species, FEX had 16 species, and FCD had 17 species. Differences in taxa appeared to be caused by the addition and/or replacement of species with downstream distance, and was influenced by habitat differences between sites and the effect of migration from Lake Michigan. Overall, the fish species collected at the ELF sites was similar.

Night fyke net catches of the mobile fish component showed that this fish community component was dominated by the Cyprinidae (in particular creek chubs and common shiners) with the Salmonidae (brook trout), Catostomidae (white suckers) and Gadidae making up the majority of the remaining catch. The cyprinid family was similar at FCU and FEX, and changed in composition at FCD. No changes were seen in the other families between sites in percent composition. Catch per unit effort did show the sites differing by the number of each species caught, but none of these differences was significant.

Kick sampling of the benthic fish component showed the FCU benthic fish community dominated by the longnose and blacknose dace whereas FEX and FCD were dominated by mottled sculpins. FCD and FEX were similar in catch composition but differed in numbers caught.

B) Habitat relationships

Longnose dace and mottled sculpin catch in number was related to physical parameters and these relationships were best seen at the FCD and FEX sites. This suggested that the more uniform distribution of the catch was caused by the more stable habitat complex at those sites. These relationships will be further developed into a habitat preference model and then expanded to all species.

Element 16 - Assessment of Equipment Efficiency for Capture of Selected Fish Species

Night fyke netting combining both 1/4" and 1/2" meshes worked well for catching mobile fish populatins and kick sampling worked well for catching benthic fish. Both methods are selective in their catch and must be geared to the target fish and study objectives. Fyke netting is appropriate to examine fish movement, age and growth, fecundity and parasites of mobile fish. If examining population dynamics, food habits, microhabit use,

fecundity and parasites of non-mobile benthic fish is the objectiv, then kick seining is an appropriate technique. The box sampler has the potential to work well for benthic fish work and will be retested in a modified form next field season. Visual observation will be retested at night next year for sampling suitability since daytime sampling was ineffective. Regular seining was found to be ineffective and will not be used in the coming field season. Additional visual observation of all techniques and electroshocking efficiency tests of kick sampling will be done in the coming field season.

Element 17 - Age-Length-Weight Relationships; Growth, Fecundity, Survival, and Distribution of Selected Fish Species

A) Age and growth

Three age groups were displayed by longnose dace and mottled sculpin at all sites using an age-length key. The age 0+ fish appeared in the August catch and ranged in length from 35 to 45 mm for longnose dace and from 23 to 32 mm for mottled sculpins. The age 1+ fish were present throughout the sampling year, and ranged in length from 50 to 70 mm for longnose dace and from 45 to 65 mm for mottled sculpin. The age 2+ fish were infrequently caught and were over 80 mm in length. FCD and FEX were the most similar in mean size and FCU fish were larger.

B) Length-weight relationships

All length-weight regression lines were significant. Longnose dace demonstrated little difference between sites in terms of the length-weight relationship. Mottled sculpins and brook trout both showed significant different relationships of length to weight between sites.

C) Fecundity

Fecundity analyses are in progress and will be discussed in a later report.

D) Survival

Yearly survival for age 0+ to 1+ ranged from 22.9 to 44% for mottled sculpins and from 5.1 to 38.1% for longnose dace. Estimates of from 3.0 to 21.4% were found for age 1+ to 2+ mottled sculpins and longnose dace displayed 12.5 to 50% survivorship for age 1+ to 2+ fish. Survival estimates were more similar between FCD and FEX than between FCU and FEX although no significant differences were detected.

Monthly survivorship estimates were only available for age 1+ fish, and ranged from 52 to 95.5% for mottled sculpin and from 10.4 to 97.8% for longnose dace. These estimates were highly variable and displayed no significant differences between sites.

Element 18 - Diurnal Food Habits and Consumption Rates of Selected Fish Species

Preliminary survey data from non-ELF sites indicated that mottled sculpin and longnose dace utilized different taxa in their diet, with Ephemeroptera dominant numerically for mottled sculpins and Diptera dominant numerically for longnose dace. Further ELF site analysis, taxonomic classification and fish size class analysis will be completed by spring and will be discussed in a future report.

Element 19 - Mark-Recapture Studies of Sculpin

Per unit area estimates appeared less biased than mark-recapture estimates, and showed that FEX had the largest population of mottled sculpins although not significantly larger than the other sites. The population estimates ranges were 60.8-85 at FCU (321 m^2), 89-269 at FEX (541 m^2), and 90-172 fish at FCD (541 m^2). Mark recapture estimates were biased by assumption violations and thus were not statistically tested. A combined approach using mark recapture techniques and microhabitat modeling will be tested this coming field season. Per unit area estimates will continue to be used and compared to the other methods tested.

Element 20 - Studies of Patterns of Development from Egg to Adult for Selected Fish Species

No unusual development patterns or deformities were seen in any of the fish examined.

Element 21 - Parasite Loads of Selected Fish Species

The parasitic faunas of mottled sculpins and longnose dace between sites were comparable taxonomically and generally in species numbers. The number of species found infecting sculpins from the FCU, FCD and FEX sites were four, six, and six respectively. Parasitic species from longnose dace numbered five at the FCD site, seven at the FCU site, and eight at the FEX site. Strigeoid metacercariae and P.m. minimum metacercariae were the most prevalent endohelminths found in sculpins and dace, respectively, at each site. The endohelminth faunas of sculpins and dace at each site were characterized by being composed of larval parasites which mature in fish-eating birds and mammals; only R. cotti and R. canadensis mature in sculpins and dace, respectively (Hoffman 1967). Of the external parasites found on both sculpins and dace at each site, Epistylus sp. was the most common.

Element 22 - Data Analysis and Report Writing

This Annual Report represents the summary of data analysis performed to date.

V. PROJECT RATIONALE AND APPROACH

In our original research plan, we proposed an integrated study of stream ecosystems involving three aquatic components for monitoring the potential effects of ELF. These components were: 1) periphytic algae; 2) aquatic insects; and 3) fish. The design incorporated studies of ecosystem properties with studies of behavior and biology of individual species so that any effects of ELF would be quantified at the population, community and ecosystem levels.

We selected stream ecosystems as representative aquatic ecosystems rather than lakes or marshes because: (1) upstream-downstream paired plots on the same system would provide less variability than between lake comparisons; (2) migratory behavior was more likely to be important in stream organisms; and (3) our local expertise and interests were oriented more toward stream ecology.

We planned to test the effects of ELF on stream ecosystems by using a paired "plots" design on selected sections of a chosen stream. Specific control and experimental sites were to be selected after the final ELF cable corridors were established. We planned to select a stream section containing pools and riffles in an area of forest just upstream of the cable corridor with maximum exposure to extremely low frequency electromagnetic radiation (ELF). This section was to be compared to a physically similar site (with regard to depth, width, flow rates, canopy cover, etc.) on the same stream far enough away from the ELF cable to receive at least an order of magnitude less exposure to ELF. The two stream sections constituted our paired "plot" design. Thus we planned to have two plots of intensive stream studies: a control site and an experimental site at the cable corridor. We expected these studies to continue for a least 3 years of preconstruction background data collection followed by at least 2-3 years of post construction data collection.

For each site, we planned to continuously monitor stream velocity and water depth so the discharge could be calculated. Water and air temperatures, dissolved oxygen, pH, solar radiation at the water surface and at the stream bottom, and relative humidity were also be continuously monitored. We planned to sample all other chemical parameters required in the RFP as detailed in the work plan submitted in 1982/83.

In conclusion, our research plan is directed at determining the effects of low-level, long term electromagnetic fields and gradients produced by the ELF Communications System on aquatic plant and animal life. The integrated approach we have 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. These include: periphyton and stream invertebrate colonization, migration, diversity, trophic level changes in density and biomass, as well as primary productivity; organic matter processing by macroinvertebrates; dynamics of fish population growth, reproduction, and survival; fish behavior including movement patterns of homing and migration, and fish pathogen and parasite loads. Since many of these processes and events are mutually dependent on one another and the interactions are complex, we feel that a holistic approach with a multi-disciplinary effort is imperative.

The data generated from this research should: (1) determine whether the ELF Communications System affects aquatic plant and animal life in stream systems; and (2) contribute to a better understanding of stream organism processes which will help clarify a number of important aspects of current conceptual models of stream ecosystem structure and function.

During the last year, we made significant progress. We selected sites on the Ford River, Dickinson County, Michigan for intensive study after an initial selection process which included many other streams in what was originally suggested as an area where the final ELF corridor would be located. After final siting of the corridor in early 1983, our research was concentrated on potential sites on the Ford River. Our results for 1982/83 are detailed by our original work plan elements in Section VI. This report format should facilitate review of progress for each original work plan element.

VI. LITERATURE REVIEW

After a thorough literature review and computer retrieval search, we have found no published studies on the effects of extremely low frequency electromagnetic fields on aquatic organisms. A few studies dealing with electromagnetic radiation heretofore have investigated the response of different arthropods to various wavelengths of the electromagnetic spectrum, often with control possibilities in mind (Teel et al. 1976. Eldumiati and Levengood 1972, Crum et al. 1974). Greenberg's (1972) Wisconsin study was the first published research which investigated the impact of extremely low frequency electromagnetic fields on soil arthropods. In general, he found that arthropod species and abundance were unaltered when exposed to 10,000 times the normal electrical field. A continuation of the above study (Greenberg 1973) showed no demonstrable effects on natural populations of soil arthropods after two years of exposure. Interestingly, he noted that if small, subtle changes caused by ELF did exist, they would be obscured by the multiple of environmental variables and obliterated by the elasticity of the populations under study. He also indicated from his studies that species are not a reliable long-term indicator of an ELF effect, because species succession could occur at a surprisingly high rate in an undisturbed situation. This is a major reason why our Aquatics group chose "community processes" to examine rather than rely solely on changes in species numbers or diversity.

Further studies by Greenberg and Ash (1974, 1976) also demonstrated no significant effect of the Navy's Project Saguine/ Seafarer (ELF) system on soil arthropods and the surrounding flora after 6 years' exposure. To our knowledge, the aquatic studies underway are the first to assess the effects of ELF on any aquatic fauna.

VII. OVERALL OBJECTIVES AND SPECIFIC TASK OBJECTIVES

OVERALL OBJECTIVE

Our major objective in this study is to determine the effects of low level, long term electromagnetic fields and gradients produced by the ELF Communication System on aquatic plant and animal life in streams. The study will incorporate studies of ecosystem properties with studies of behavior and biology of individual species so that any effects of ELF will be quantified at the population, community and ecosystem level.

SPECIFIC TASK OBJECTIVES

A. Periphytic Algal Studies

The objectives of the periphytic algal studies are:

(1) to quantify any changes in species diversity, algal density, and chlorophyll a that occur as a result of ELF electromagnetic fields;

(2) to quantify any changes in primary productivity that might occur as a result of ELF; and

(3) to monitor algal cell volume and chlorophyll a to phaeophytin a ratio, thereby providing an index to physiological stress of periphytic algal cells that might occur as a result of ELF electromagnetic fields.

B. Aquatic Invertebrate Studies

The objectives of the studies of aquatic invertebrates are:

(1) to quantify any changes in organic matter processing rates that occur as a result of ELF;

(2) to quantify changes in species richness, individual abundances, and species diversity of the aquatic invertebrate communities associated with leaf packs and inorganic stream bottom substrates;

(3) to quantify changes in upstream-downstream movements of selected aquatic invertebrates that might occur as a result of ELF; and

(4) to quantify trophic, behavioral, and community level changes in selected species of aquatic insect "grazers" or "scrapers" which feed on algae or periphyton attached to stream substrates.

C. Fish Studies

The objectives of the study are to determine the effects of electromagnetic radiation using 2 to 3 species of fish on:

(1) feeding, growth and production;

(2) fecundity;

(3) rates of parasitism;

(4) migration;

(5) behavioral habitat selection; and
(6) recruitment and survivorship.

The above studies and objectives will be coordinated and integrated with the ambient monitoring program.

VIII. PROGRESS BY WORK ELEMENT

Element 1 - Paired Plot Selection

Synopsis - Paired plots will be selected on each of two separate stream systems. The general stream systems to be included in this study will be selected early in July with final plot selection contingent upon final siting of ELF right-of-way. After we are told the exact location of the right-of-way, final selection of an experimental plot in the vicinity of the ELF right-of-way and a control plot will be completed.

Changes from Original Synopsis - Paired plots were selected on only one stream system as explained below. Final plot selection was not completed until late 1983 after electromagnetic radiation exposure data were received from IITRI and initial biological data were analyzed.

Contributing Staff - T.M. Burton, Associate Professor (PI)
R.W. Merritt, Associate Professor (PI)
R. Jean Stout, Research Associate (PI)
W.W. Taylor, Assistant Professor (PI)

Objectives

The objective of this element was to select a plot (section of river) at or near the proposed ELF corridor as an experimental site and a control plot meeting all the criteria set forth in the contract to serve as a control (e.g. similar rates of exposure to electromagnetic radiation at present; an expected order of magnitude less radiation exposure once the system is operable; and similar biotic community dynamics).

Materials and Methods

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. Final site selection awaited data on the present electromagnetic fields at each site from IITRI and initial comparisons of biological data between sites. This comparison of biological data is the primary focus of this annual report.

Results and Discussion

A. Abandoned Sites

Preliminary data were collected on several sites in 1982 prior to final ELF corridor siting. These now abandoned sites include the following (descriptions excerpted with modifications from J.O. Enk's letter from IITRI of September 27, 1983, listing electromagnetic data measurements for each site).

(1) Ramshackle Site on the Ford River (IITRI's 5C4) (T43N:R29W:Sec. 16/17) approximately 6 miles east of the intersection of Turner Road and the Escanaba and Lake Superior Railroad tracks. The site is accessed by walking south from Turner Road across abandoned property (Ramshackle) and the railroad tracks to the river, ∿30 yards south of the railroad tracks.

This site was abandoned in early 1983 because it was not far enough away from the ELF corridor to meet the order of magnitude difference in expected exposure criterion. Preliminary fish and insect population sampling procedures were tested here.

(2) Ford Site 1 (FS 1) (IITRI's 5C5) (T43N:R29W:Sec.16).

This site is located on the Ford River approximately 8.2 miles east of Highway M95 along Turner Truck Road, ∿8.6 miles west of Ralph, and ∿2 miles east of the intersection of Turner Road and the Escanaba and Lake Superior Railroad tracks. The site is accessed by driving south from Turner Road along a dirt track (∿0.35 miles) to the railroad tracks.

This site is also too close to the ELF right-of-way to meet the order of magnitude difference in expected ELF exposure criterion. We collected one year of background data on periphyton and aquatic insects from this site prior to its abandonment. These data are summarized in the following elements. Comparisons between FEX, FCD, and this site suggest that these data will be useful in providing background data on the Ford River since there are no significant differences between sites for many of the biological parameters examined (see the following elements).

(3) Ford Site 2 (FS 2) (IITRI's 5C6) (T43N:R28W:Sec.20).

This site is located on the Ford River approximately 2.2 miles west of Ralph along Turner Truck Road. A power distribution line crosses Turner Road heading south towards a hunting lodge at this point. The site is accessed by following the footpath, near this distribution line, south across the railroad tracks (∿100 yards) to the river.

This site is also too close to the ELF corridor to meet the order-of-magnitude criterion but is only about one mile upstream of FCD. Thus, data from this site on water chemistry and periphyton may provide useful data for 1982 for comparison with 1983 data from FCD.

(4) West Branch of the Escanaba at the Flat Rock Creek Camp (WBE 1) (IITRI's 5C 11) (T44N:R28W:Sec. 11).

This site is located on the West Branch of the Escanaba River. The site is accessed by following County Road 581 north from Ralph 6.4 miles and turning west on a dirt road. Proceed west on this dirt road for 0.25 miles and turn north onto another dirt road. Take this dirt road north for ∿3 miles, past a log bridge across McGregor Creek (at 0.4 miles), to a dirt road leading to the Flat Rock Club lodge.

Final ELF corridor selection did not cross this branch of the Escanaba River as originally anticipated. We collected data on water chemistry, leaf pack degradation rate, leaf pack insects, substrate samples of insects and initial fish population data from this site. Many of these analyses are incomplete since site abandonment.

(5) West Branch Campground (WBE2) (IITRI's 5C 13) (T44N:R27W: Sec.19). This site was meant to be the downstream control for WBE 1 as initial data indicated an ELF crossing at WBE 1 (4 above). It is located on the West Branch of the Escanaba River in West Branch Campground 2. The site is accessed by following County Road 581 north from Ralph ∿7.5 miles, past West Branch Campground 1, to West Branch Campground 2.

Data were collected on this site for water chemistry. Periphyton samples were taken but never analyzed.

(6) Schwartz Creek Experimental Site (IITRI's 5C 12) (T44N:R28W: Sec. 10). This site is located on Schwartz Creek which feeds the West Branch of the Escanaba River. It is less than a mile upstream of WBE 1 in the general area where the ELF corridor was originally expected to cross. This site is accessed by following County Road 581 north from Ralph 6.4 miles and turning west on the dirt road. Proceed west on this dirt road for 0.25 miles and turn north onto another dirt road. Take this dirt road north-northwest for ∿4 miles, past a log bridge across McGregor Creek (at 0.4 miles), past the dirt road to the Flat Rock Club lodge (at ∿3 miles), to a dirt road heading north and across Schwartz Creek.

Data were collected from this site on water chemistry, periphyton and aquatic insects. Data for a complete year of monitoring has been completed for some of these studies. Since the ELF corridor will not cross near this site, these data are useful only in providing general comparative data for smaller streams of the area. This site has now been abandoned.

(7) McGregor Creek Experimental Site (IITRI's 5C 10) (T44N:R28W: Sec. 25). This site is located on McGregor Creek which feeds the West Branch of the Escanaba River. The site is accessed by following County Road 581 north from Ralph 6.4 miles and turning west on a dirt road. Proceed west on this dirt road for 0.25 miles and turn north onto another dirt road. Take this dirt road north for 0.4 miles to a log bridge which crosses McGregor Creek.

Data were collected from this site for water chemistry, periphyton, and fish populations before abandonment.

B. Final Tentative Sites

After the ELF right-of-way became final in early 1983, we selected four tentative sites on the Ford River. The Ford River is the only river crossed by the ELF corridor that flows far enough away from the corridor without major changes to provide a control. Most streams have major tributary inputs near the corridor or are near existing transmission lines. After an extensive survey of the area, we concluded that the Ford River was the only possible stream suitable for our studies.

The four tentative sites selected on the Ford River are described below.

(1) Ford Experimental Site (FEX) (IITRI's 5T1)(T43N:R29W: Sec.11). This site is located on the Ford River, approximately 6 miles west of Ralph and 10.6 miles east of Highway M95 along Turner Truck Road. The site is accessed by walking from Turner Road south, across the railroad tracks, along a red flagged foot path. It is ~ 100 yards from Turner Road to the Ford River.

(2) Ford Control Downstream (FCD)(IITRI's 5C1)(T43N:R28W: Sec. 21). This site is located on the Ford River approximately 1.2 miles west of Ralph. It is accessed by traveling west on a petroleum pipeline haul road which intersects County Road 581 ~ 2.1 miles southwest of Ralph. After traveling 0.1 miles on the pipeline road, turn north along a dirt trail and proceed ~ 1.3 miles while following signs to Servia (a hunting lodge).

(3) Ford Control Upstream (FCU)(IITRI's 5C3)(T43N:R29W: Sec. 18). This site is located on the Ford River approximately 5.8 miles east of Highway M95 along Turner Truck Road and 0.2 miles west of the intersection of Turner Road and the Escanaba and Lake Superior Railroad tracks. The site is accessed by following a dirt track south from Turner Road 0.1 miles to an old tree stump, walking west down a small hill, and then south ~ 25 yards to the river.

(4) Ford Control Upstream (FCU2)(IITRI's 5C2)(T43N:R30W: Sec. 13). This site is located on the Ford River approximately 5.2 miles east of Highway M95 along Turner Truck Road and 0.8 miles west of the intersection of Turner Road and the Escanaba and Lake Superior Railroad tracks. The site is accessed by walking south from Turner Road along a ridge for 200 yards to the Ford River.

Even on the Ford River, we are constrained by changes in the river as we move east or west of the corridor. West of the corridor, the Ford River is joined by Two Mile Creek at a point where the order of magnitude differences in exposure to ELF radiation called for in the RFP are not met. Above this confluence, significant changes in width, discharge, and other parameters make this stream segment less than an optimum control site. Even so, we sampled this site (5C3 or Ford Control Upstream) as a potential control during the past summer. Preliminary indications are that this site is enriched by nutrients from upstream communities and a feedlot and is not comparable for many of the biological parameters. The report on electromagnetic field measurement data from Joe Enk of IITRI on September 27, 1983, indicated that this site was marginal. A move upstream to 5C2 or further upstream encounters problems in matching 60 HZ fields with the test site and/or exacerbates the nutrient enrichment problem.

Our second major pair (5T1/5C1 or FEX/FCD) is also deemed marginal with postioning of our experimental site upstream of the actual corridor (as is currently the case) because of failure to meet the predicted order of magnitude difference in ELF radiation exposure. As a result of our biological sampling discussed in detail in the rest of this report, we conclude that this control site is the only feasible site which will allow matching of biological parameters with the test site. A move downstream (to the East) nearer Ralph moves the site out of the gravel riffle/sand pool configuration characteristic of the test site since the river changes gradient and actually becomes a swamp east of Ralph. No gravel riffle of any size exists East of FCD (5C1).

Our alternatives to the FEX/FCD pairing, thus, are all unacceptable from either a biological and/or an electromagnetic radiation matching criteria basis. Therefore, we plan to continue to use the FEX/FCD pair as our primary experimental and control sites. One suggestion to improve acceptability of this pairing from Joe Enk's report was to move our test site directly under the antenna. That is possible for certain work elements but not for others. We have recently moved our periphyton sampling to areas very near the corridor. We will also move much of our invertebrate work to very near the corridor next spring. However, the fish task and elements of the invertebrate work cannot be moved closer. The fish are wide-ranging but tend to concentrate in riffle areas. Thus, our population work with fish has to be in large riffle areas to generate sample size and numbers needed for statistical reliability. We are now working as near the corridor as is possible because of this limitation. We have also selected the last large riffle in the stream as a control site (FCD). No suitable riffle exists for at least 15 miles downstream (east) of this site. We have traveled the entire stretch by canoe looking for other sites. The movement work with invertebrates also has to be located over several hundred meters of stream so cannot be just directly under the ELF antenna. Movement of fish is sampled with Fyke nets which could be moved further downstream of FCD.

In conclusion, we plan the following. First, the FEX/FCD pair will be our test and control sites. Second, we will move as much of our work as possible to areas very near or under the proposed antenna crossing. Third, we ask IITRI and the Navy to accept the FEX/FCD pair as it exists for fish work and for invertebrate movement studies. We realize that 76 HZ fields are only predicted to be 6.3 times greater at the test than at the control site for this pairing but can come up with no acceptable alternative site that comes even close to matching biological community parameters. For the periphyton and much of the invertebrate work, the order of magnitude criterion will be met by this site selection.

Starting in 1984, we plan to abandon FCU and FCU2. As described in detail below, these stations are simply not similar enough biologically to FEX to serve as a control. Thus, our final site selection will be for the FEX/FCD pair with all future monitoring work done at these sites.

Element 2 - Inventory Physical Characteristics of Stream Sites

Original Synopsis - Determine general physical characteristics of the two study streams including width, depth, shape, and velocity. Determine particle size distribution for bottom sediments in riffle and pools of each stream as well as length of pools and riffles (riffle/pool length ratio). Determine riparian vegetation along the stream margin including species composition and dominance of forest vegetation and canopy coverage of stream.

Changes from Original Synopsis - None

Contributing staff - R. Jean Stout, Research Associate (PI)
Thomas M. Burton, Associate Professor (PI)
Michael O'Malley, Field Research Tech. II
William Taft, Field Research Tech. II
Gary Whelan, Field Research Tech. II

Objectives

1) To describe physical characteristics of the presently proposed experimental and control sites on the Ford River. 2) To describe physical characteristics of the potential control and experimental sites designated in 1982 (Schwartz Creek and Ford I). 3) To compare and contrast physical characteristics in the experimental and control sites. 4) To use data as correlation variables for biotic data from the control and experimental sites.

Materials and Methods

Lengths of pools and riffles were taken at FEX, FCD, and FCU sites. The junction between a pool and riffle was defined, using breakwater points and changes in substrate. Stream bottom particle sizes were collected from pools and riffles in FEX, FCD, FCU, Ford I and Schwartz Creek, using a 30 x 30 x 15 cm sampler with a 60 mesh bag at the rear. Large rocks were hand-picked from the sample area; then remaining sediments were removed to a depth of 8 cm. Collected sediments in the bag were added to the sample. Three replicates from each site were brought back to the lab. Large rocks were washed over seven, graded soil sieves (16.0, 4.0, 2.36, 1.0, 0.25, 0.075, and 0.045 mm openings); the remaining sediments were washed through the sieve. Each fraction was dried at 60°C for 48 hr and weights were taken. Rocks greater than 16 mm in diameter were individually weighed, and presence or absence of periphyton was recorded. Sieved sediments were analyzed, using proportion values (percent in each category over total weight, with means and standard error values for the three replicates). Larger

sediments were tabulated as numbers of rocks in each weight class.

The riparian vegetation survey consisted of traversing stream banks and recording the three to four most common plants and then recording less common plants encountered. Those data are present as lists, with the most common species appearing first. In addition, catch traps above the water line were put in the Ford I and Schwartz Creek sites in the fall of 1981. Leaves collected during the fall showed that the major species along the stream were also supplying the majority of the leaf inputs. Natural leafpacks in the streams were also sampled and they reflected inputs in the catch traps.

Stream surface substrate sizes for fish community analyses were measured concurrently with microhabitat sampling in Element 15. Substrate size was examined using a ruler transect on which all substrates touching one side were measured to the nearest 0.50 cm. These data were grouped by phi particle sizes using a modified Wentworth classification (Table 2.1) and converted to area percentages for analysis. Bottom and mid water velocities were measured using a Swoffer current meter and percent vegetation was estimated visually. Preliminary August, 1983 data will be reported on here as data analysis is in progress and will compare the means of a 1126 physical parameters by site using either ANOVA or Kruskel-Wallis tests depending upon normality. Chi-square analysis will also be used to compare the whole substrate complex between sites.

Results and Discussion

A. Pool and riffle lengths

Graph 2.1 shows the variation between pool and riffle lengths for the three sites selected on the Ford River in the spring of 1983. Certainly, the Downstream Control Site (FCD) has longer pool sections than either of the other two sites. Substrate particle size data presented below show that FCD also had proportionately more sand (between 1.0 and 0.25 mm) in pools and riffles than did the other sites. As one goes from the downstream to the upstream sites, the pool/riffle ratio decreases (FCD = 3.80; FEX = 2.56 and FCU = 1.94) as well as the widths (data presented).

B. Substrate particle size comparisons

1. Comparisons among sites on the Ford.-- Pools at FCD contained an extremely high proportion of sand and a low proportion of pebbles (between 16.0 and 4.0 mm). Ninety-seven percent of the sediments in the pools at FCD were sand; whereas, the other two sites contained only 60 to 64% sand (Fig. 2.2). Conversely, riffles at the three sites were rather similar to one another

FIGURE 2.1

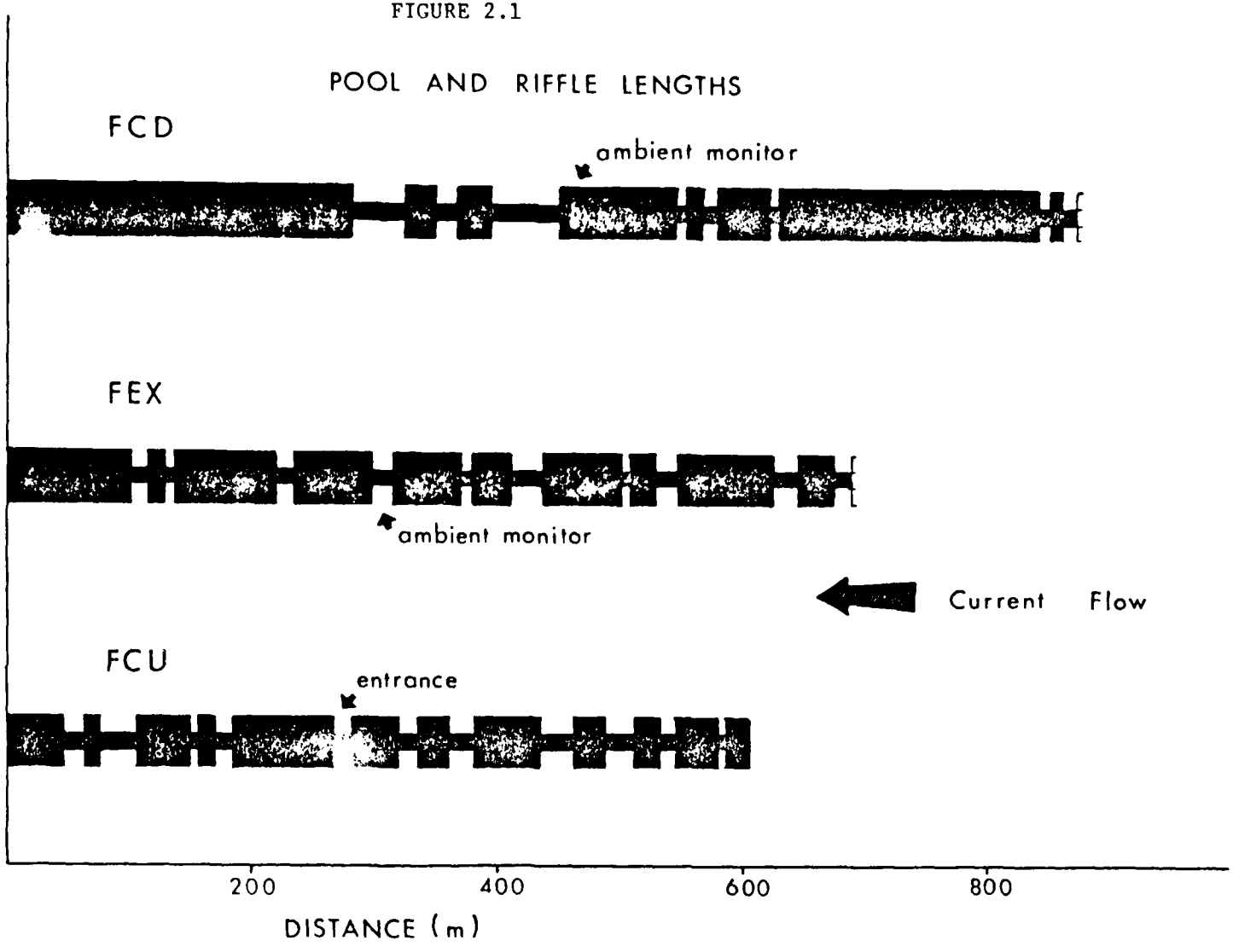
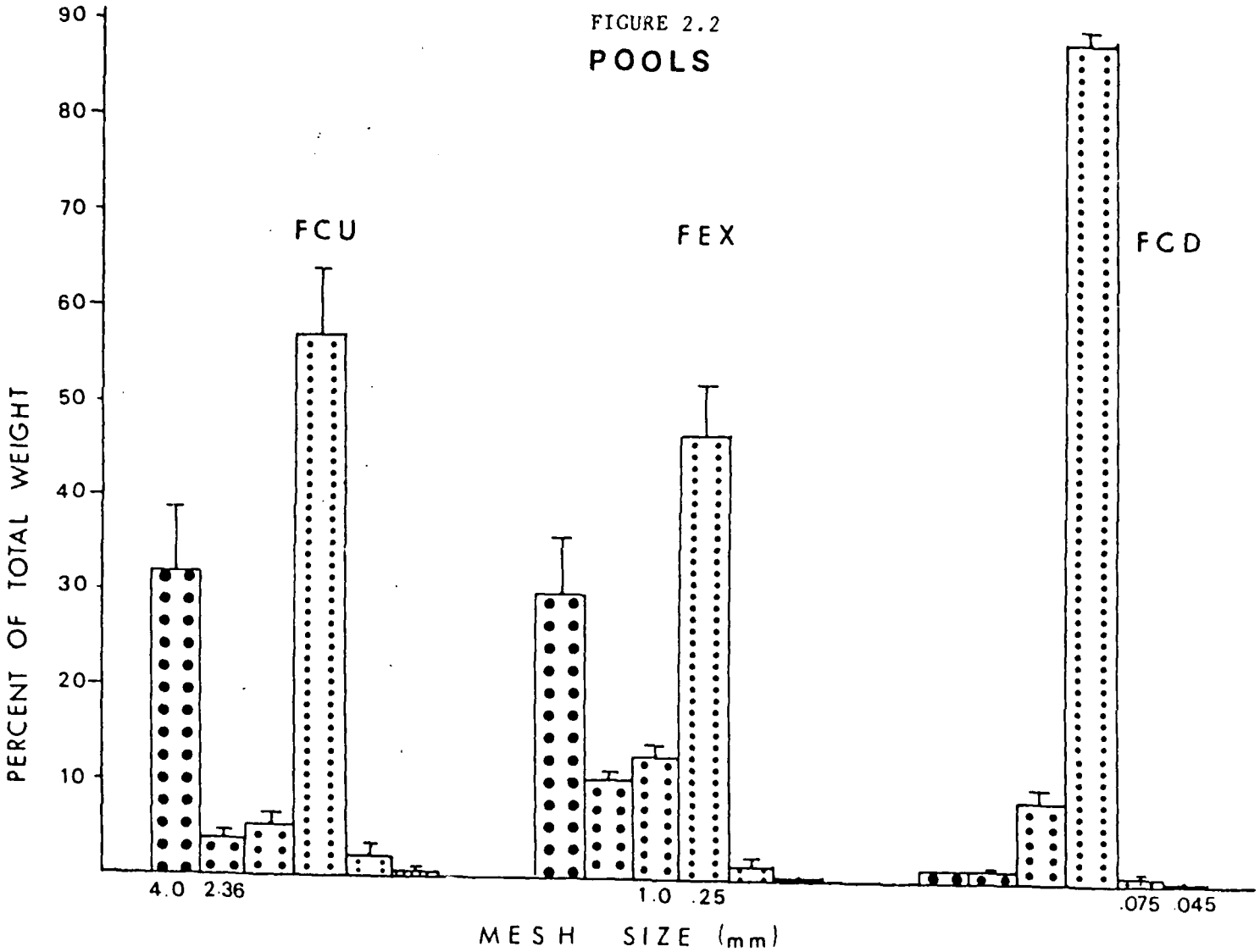

POOL AND RIFFLE LENGTHS
FCD
ambient monitor
FEX
ambient monitor
Current Flow
FCU
entrance
200
400
600
800
DISTANCE (m)

FIGURE 2.2

POOLS



Bars = S.E.

(Fig. 2.3). However, FCD contained significantly more sand and significantly fewer pebbles and fine gravel (between 4.0 and 2.36 mm). The FEX and FCU sites were not significantly different from one another for any size category.

Pools at FCU contained many more rocks greater than 16 mm in diameter than did the other two sites (Fig. 2.4). In fact, the pool samples from FCU were similar to riffle samples from the same site (Fig. 2.5). The pool/riffle ratio at FCU is low relative to the other sites. The pools there may be more affected by bedload movements during spates, resulting in transfer of larger substrates into pools. Both FEX and FCU contained more rocks in the larger weight values than did FCD. In all samples, there is a decided peak at the 10 to 19.9 gm wt and at the 100 to 199 gm wt. Those peaks could be due to the parent rock fracture patterns or to seasonal stream flow characteristics.

In summary, based on substrate particle size and an pool/ riffle ratios, FEX and FCU were more similar to one another than was FCD to either. However, based on other biotic criteria (periphyton, water chemistries and insect assemblages in substrates), FCD was determined as being a more appropriate control site than was FCU. There were locations at FEX and FCD that were more similar to each other than the sites from which substrates were taken. We, therefore, selected the most similar sites at both locations whenever possible for biological and chemical studies. Because FCU is narrower and has more large rocks throughout its riffle and pools, it was more difficult to match locations there with FEX locations than it was to match locations at FEX with those at FCD.

2. Comparisons between Ford I and Schwartz Creek.-- Pools at Schwartz Creek were almost entirely composed of sand and silt; whereas, Ford I pools contained pebbles and gravel as well as sand (Fig. 2.6). The sieved sediments from pools in Schwartz (except for the silt fraction) were similar to those taken at FCD, and sediments from Ford I and FEX were similar. Sediments from Schwartz Creek riffles were nearly 80% sand and were not comparable with those from Ford I (Fig. 2.7). Visual distinctions between pools and riffles at Schwartz Creek were difficult to make. Often, wood debris created riffle areas rather than gradient or curvatures in the stream. This lack of distinction was reflected in the particle size distributions.

Larger sized fractions (rocks greater than 16 mm in diameter) were not found in pools at Schwartz Creek but were found in high numbers at the Ford I riffle site (Fig. 2.8). There were rocks in riffles from both Schwartz and Ford sites; however, the Ford contained more rocks weighing 100 gm or more (Fig. 2.9).

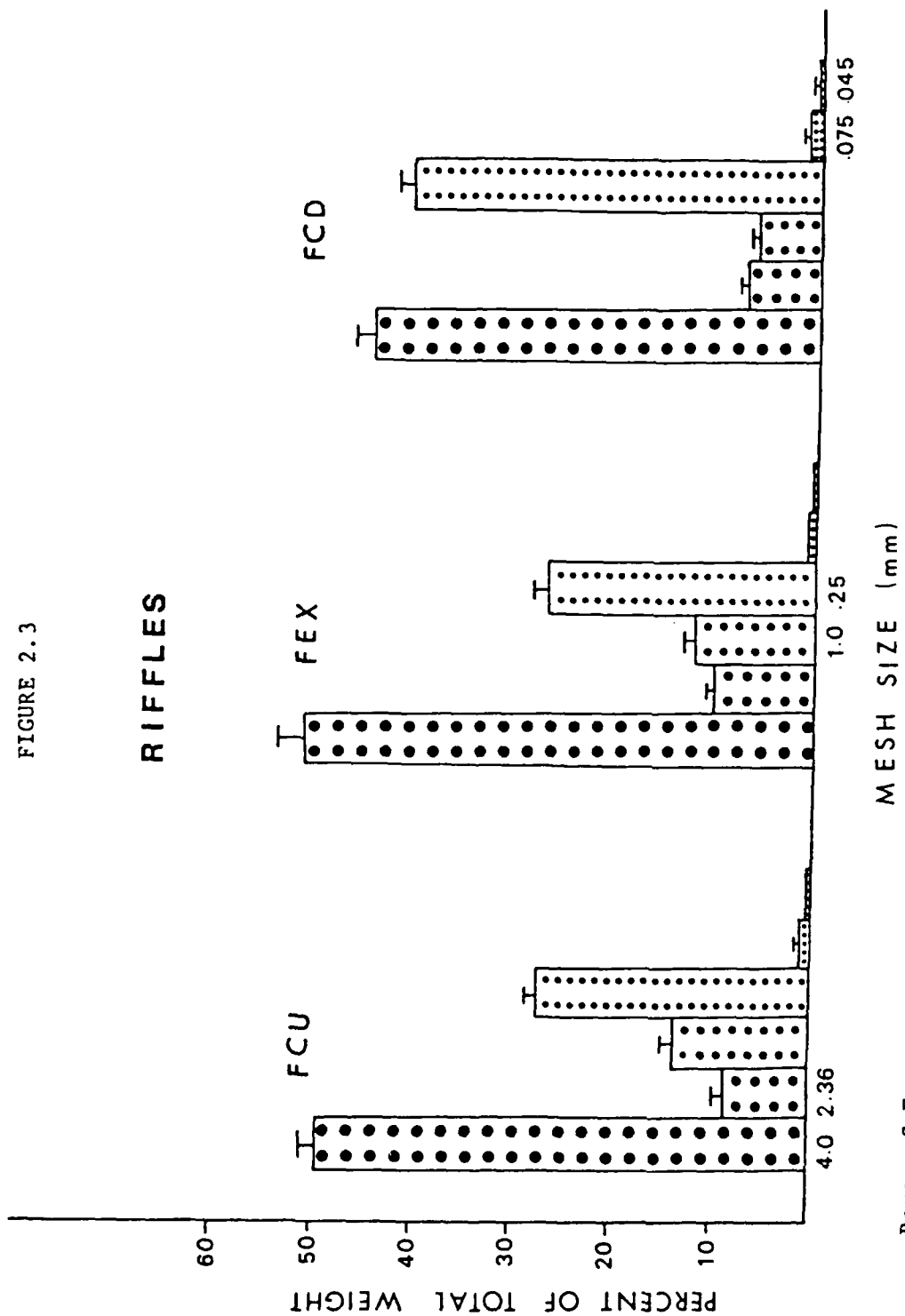
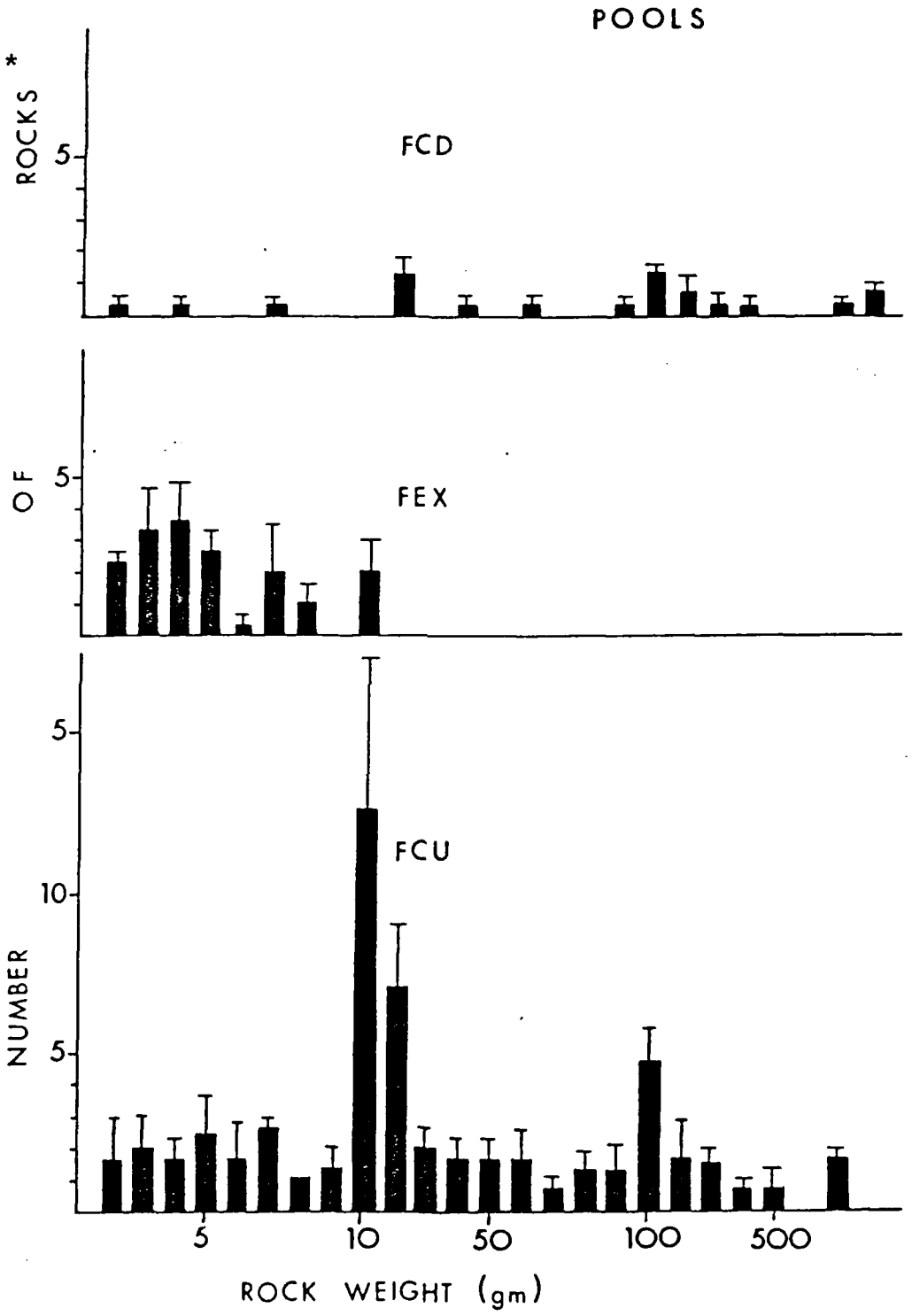

RIFFLES
FCU
FEX
FCD
PERCENT OF TOTAL WEIGHT
60
50
40
30
20
10
4.0
2.36
1.0
.25
.075
.045
MESH SIZE (mm)
Bars = S.E.

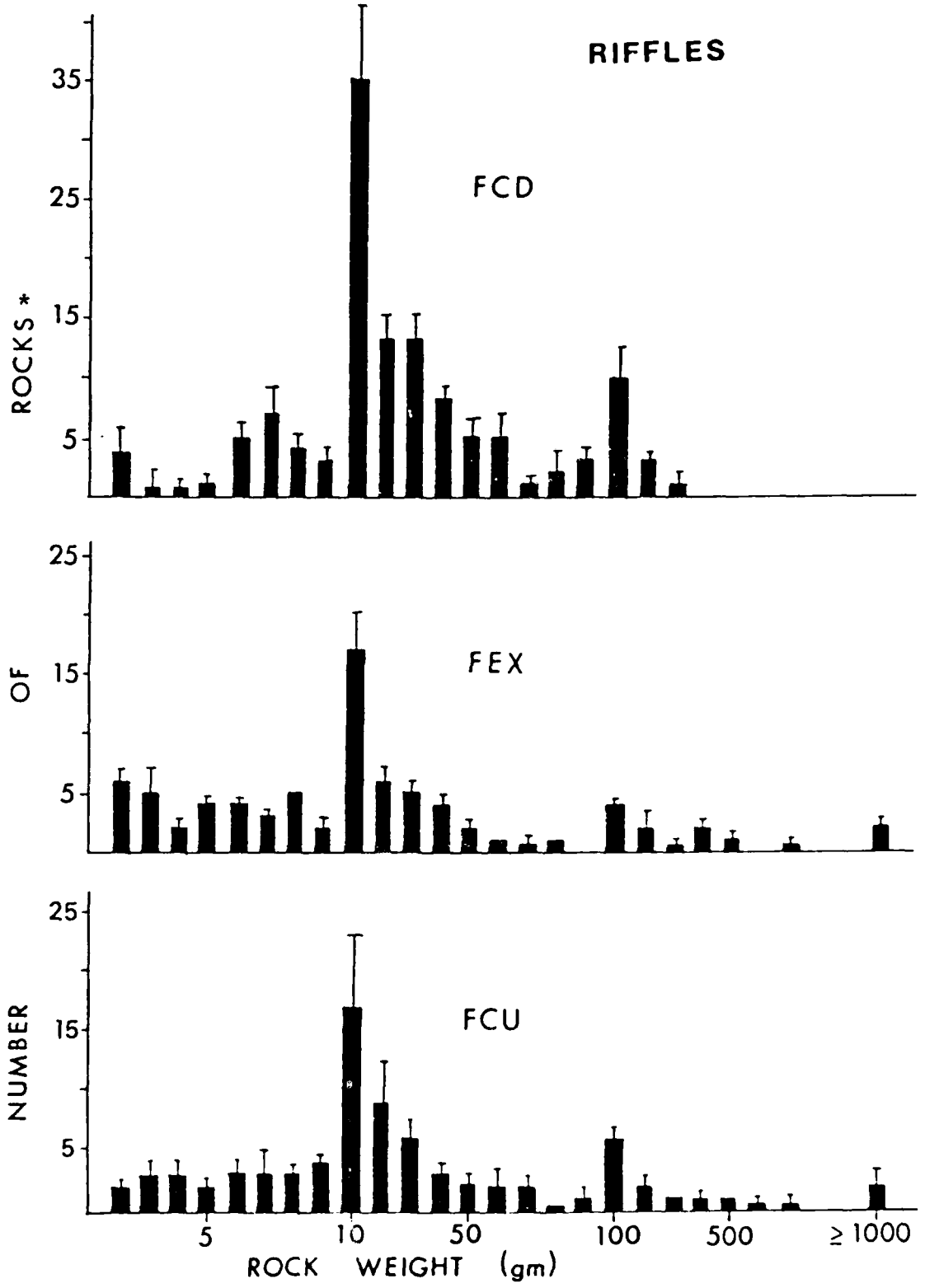
FIGURE 2.3

FIGURE 2.4



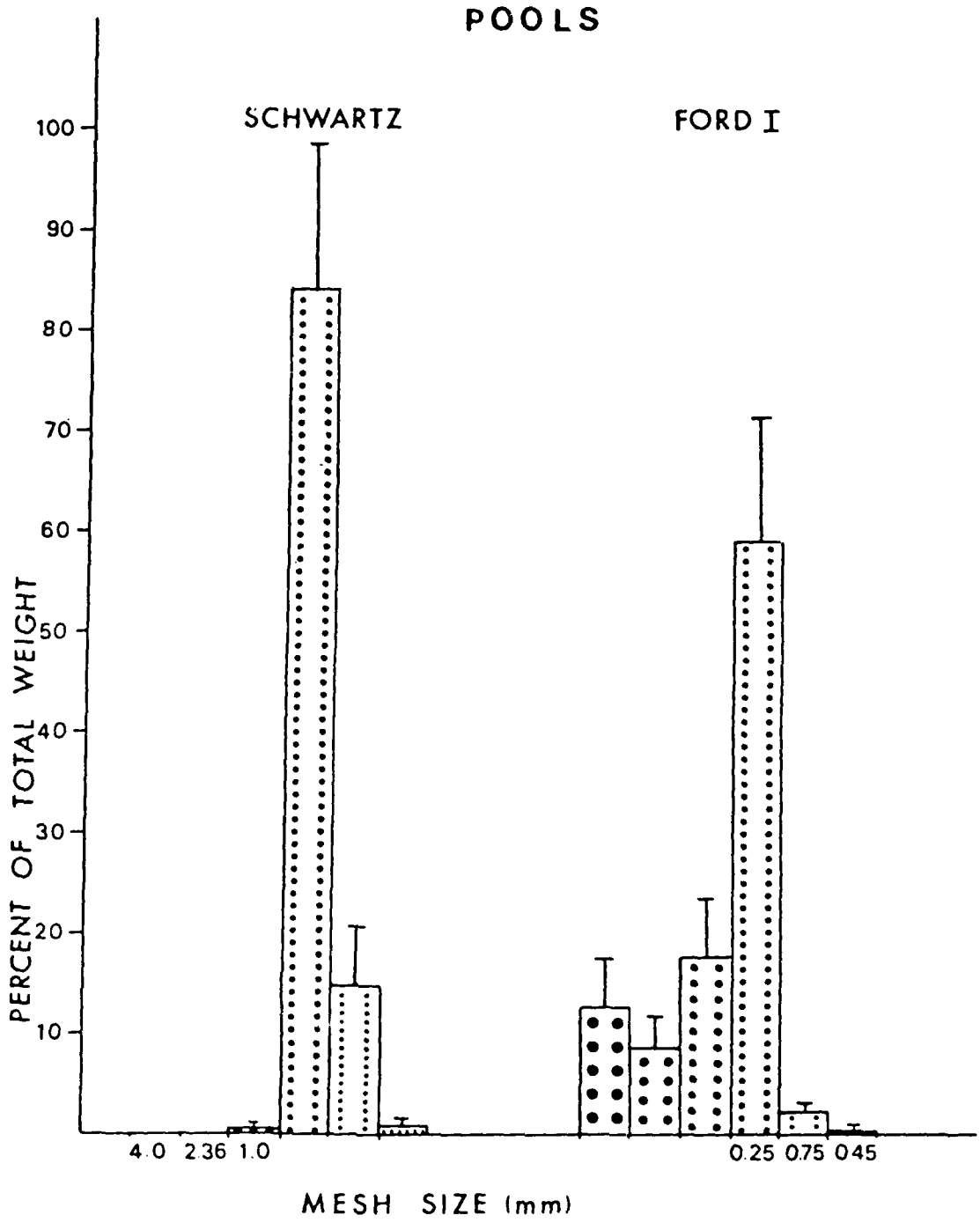
Bars = S.E.
* = Rocks greater than 16 mm.

FIGURE 2.5



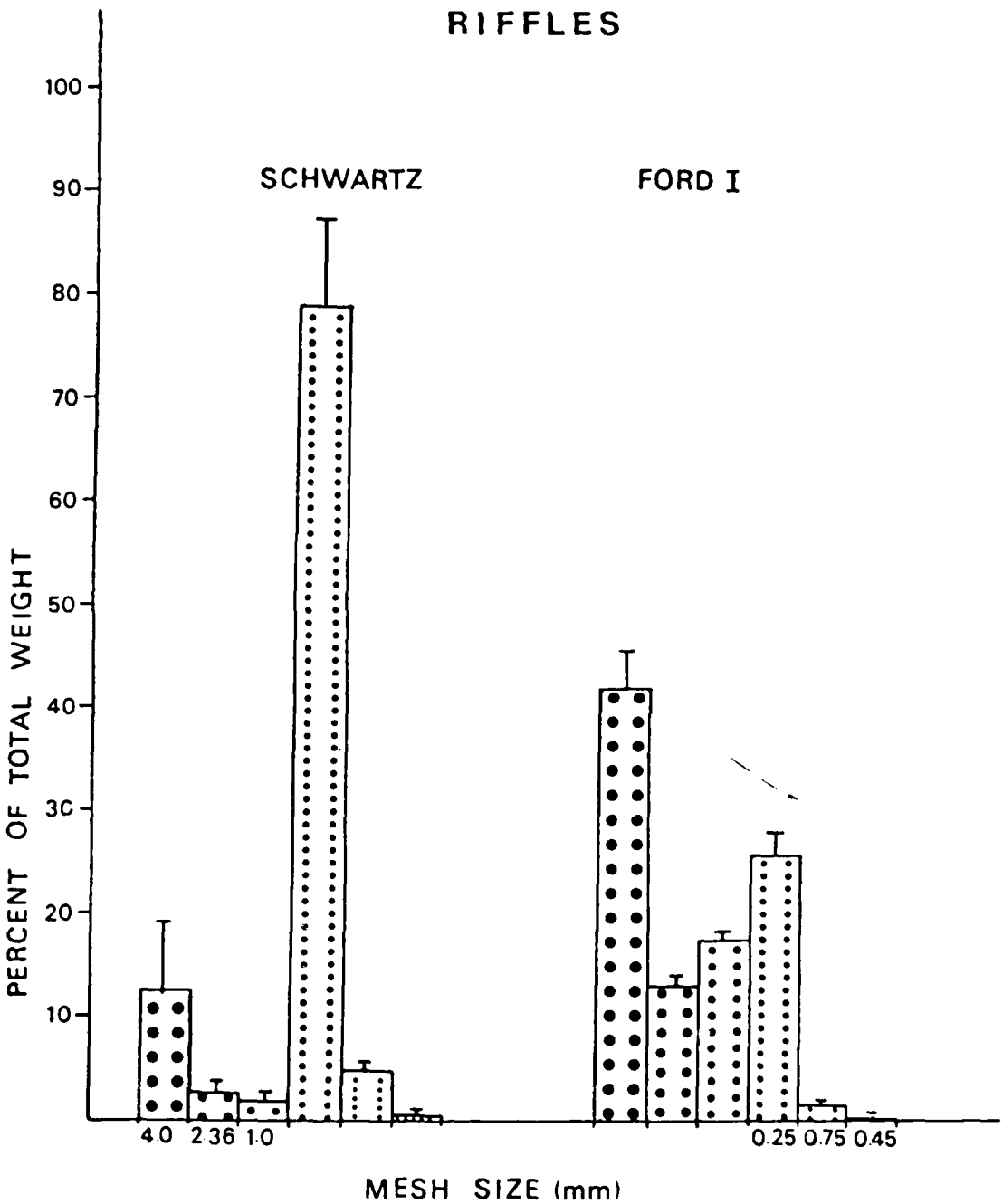
Bars = S.E.
* = Rocks greater than 16 mm.

FIGURE 2.6



Bars = S.E.

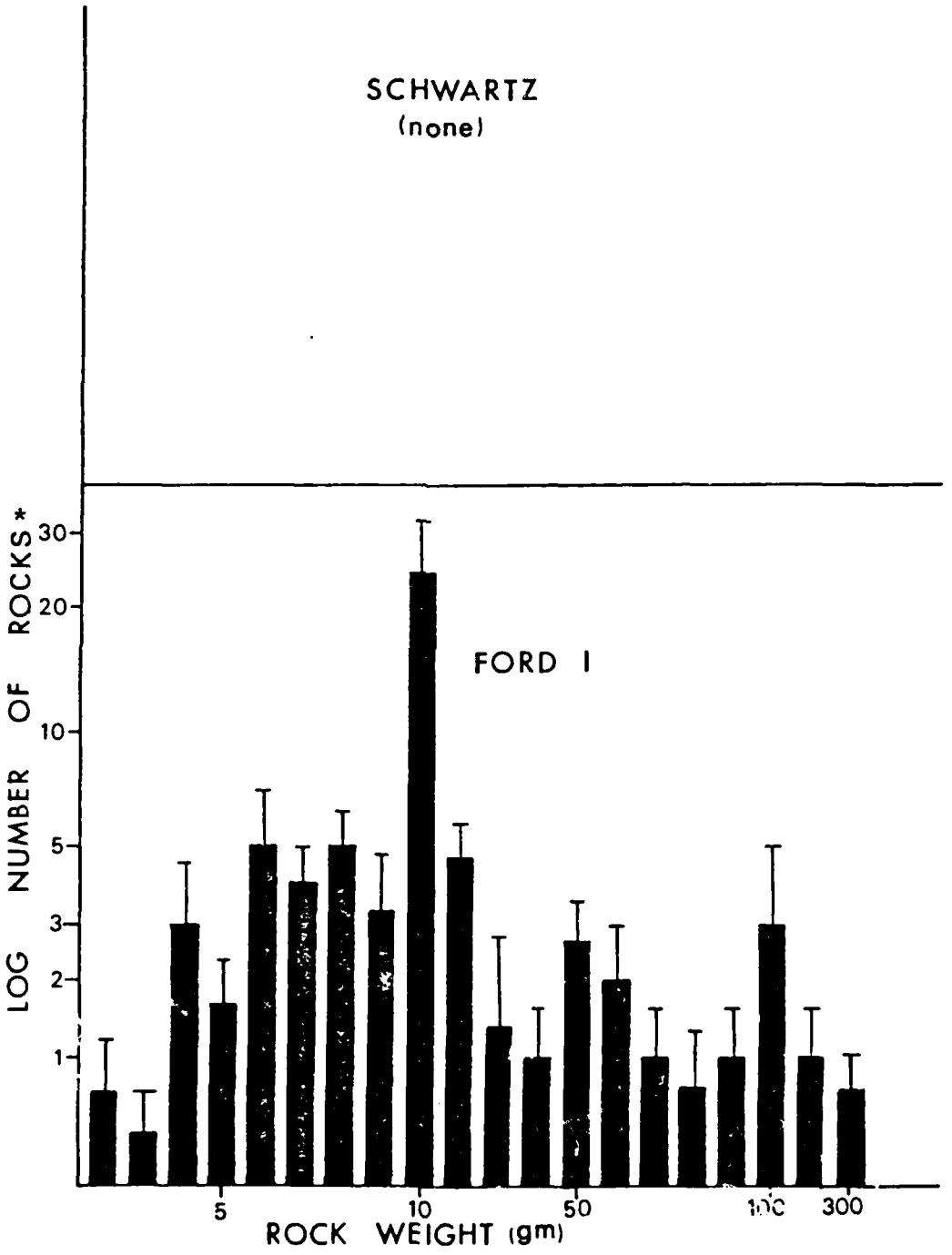
FIGURE 2.7



Bars = S.E.

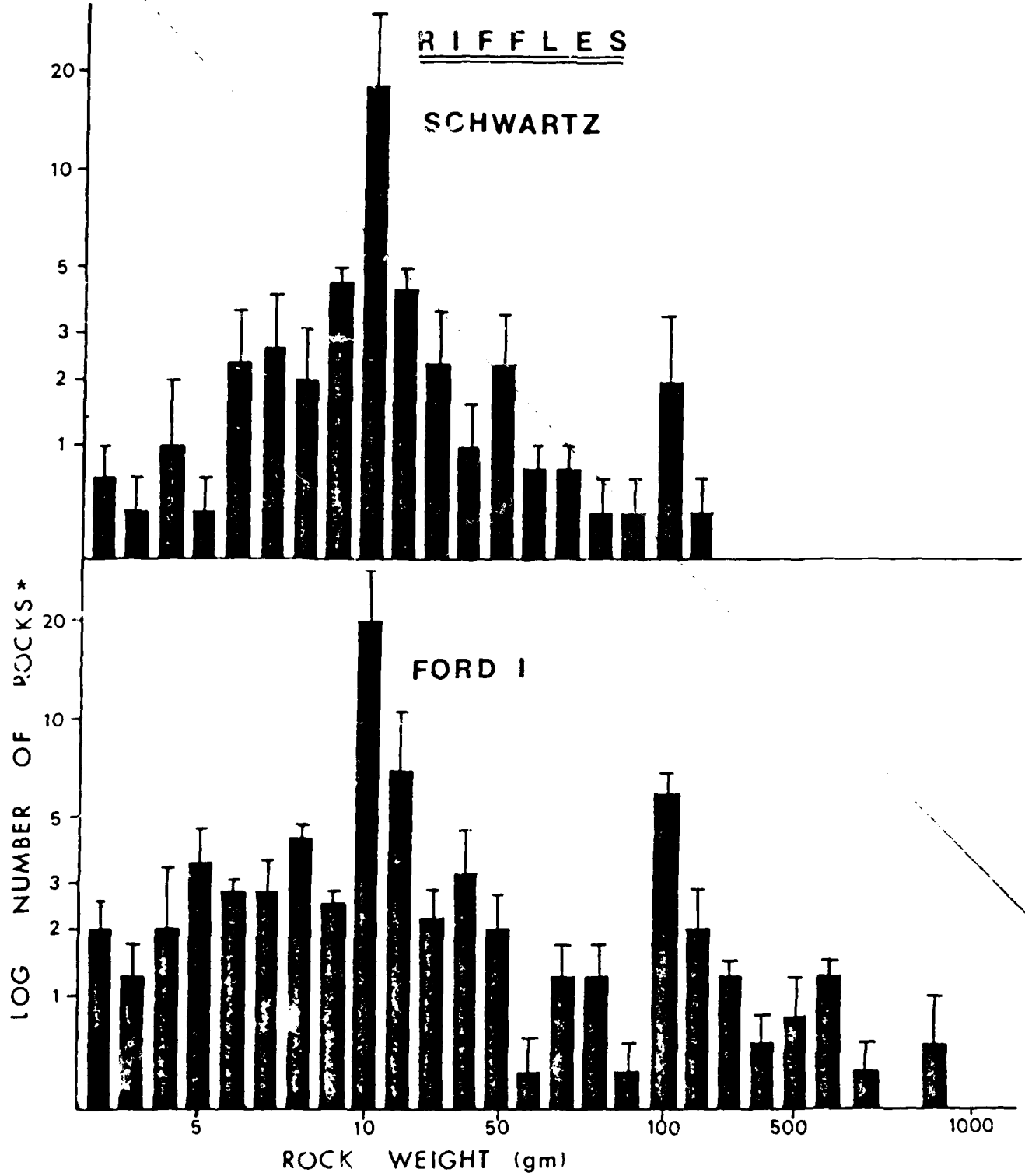
FIGURE 2.8

POOLS



Bars = S.E.
* = Rocks greater than 16 mm.

FIGURE 2.9



Bars = S.E.
* = Rocks greater than 16 mm

In summary, substrates in Schwartz Creek and the Ford River, Site I differed considerably. These differences, coupled with differences in allochthonous inputs (see next section C.) led us to ask the question, "How does processing of allochthonous inputs differ between the two stream types?" (See results in Element 11). Schwartz Creek, at one time, was selected as a potential control site (1981-82), but is no longer a part of our study. We have since ceased research at that site.

C. Riparian vegetation survey

The following is a listing of common plants associated with each sampling site for 1982 and 1983. The plants are listed in decreasing order of importance.

Ford I (1982)	Speckled Alder (Alnus rugosa) Balm of Gilead (Populus gileadensis) Quaking Aspen (Populus tremuloides) Red-osier Dogwood (Cornus stolonifera) Goldenrod (Solidago sp.) Meadowrue (Thalictrum dasycarpum) Angelica (Angelica atropurpurea)
Schwartz Creek (1982)	Northern White Cedar (Thuja occidentialis Eastern Hemlock (Tsuga canadensis)) Speckled Alder (Alnus rugosa) Balm of Gilead (Populus gileadensis)
Ford Downstream Control (FCD) (1983)	Speckled Alder (Alnus rugosa) Balm of Gilead (Populus gileadensis) Green Ash (Fraxinus pennsylvanicus) Angelica (Angelica atropurpurea)
Ford Experimental Site (FEX) (1983)	Speckled Alder (Alnus rugosa) Green Ash (Fraxinus pennsylvanicus) Balm of Gilead (Populus gileadensis) Angelica (Angelica atropurpurea) Wood Nettle (Laportea canadensis) Joe-pye Weed (Eupatorium maculatum) Meadowrue (Thalictrum dasycarpum) Virgin's Bower (Clematis virginiana) Northern White Cedar (Thuja occidentalis) Sneezeweed (Helenium autumnale) White-topped Aster (Aster umbellatus)
Ford Upstream Control (FCU) (1983)	Speckled Alder (Alnus rugosa) Joe-pye Weed (Eupatorium maculatum) Sedge (Carex sp.) Meadowrue (Thalictrum dasycarpum) Balm of Gilead (Populus gileadensis)

D. Discharge

Only limited discharge data are available at the three Ford River sites as yet. Continuous monitoring of stream water level, begun in late June, 1983, will enable us to calculate discharge for the entire ice-free season (April to November) as soon as stage-discharge relationships are established. Measurements of discharge in the fourth order segment of the Ford River (FSI, FSII, FEX, FCD) have varied from 15 to 64 CFS for the 8 discharge values determined to date. The value of 15 CFS represents one of the lowest flow periods ever observed according to local people, so low flow discharge is unlikely to ever be much below this value. The 64 CFS only represents moderately high water and peak discharge values between 100 to 200 CFS are to be expected during spring snow melt periods. For example, the U.S. Fish and Wildlife Service recorded peak discharges of 101-120 CFS for this stream reach on May 4, 1983, after a mild winter with minimal snow pack (Harry Moore, U.S. FWS, Marquette, Michigan, personal communication). Discharge during most of the active growing season in the summer probably falls in the 15 to 50 CFS range. The highest flow rate recorded during lamprey surveys and lampricide treatments by the U.S. Fish and Wildlife Service for the Ford River west of Ralph, Michigan was 525 CFS on June 2, 1980, with most recorded values during moderately high water falling between 40 and 90 CFS for the stream reach just west of Ralph (unpublished computer printout of chemical and physical data obtained from the U.S. Fish and Wildlife Service Office, Marquette, Michigan).

Comparative discharge measurements under similar flow conditions demonstrated that the flow rate at FCD was consistently slightly higher than FEX but usually varied by less than 2 CFS above values recorded for FEX. Discharge at FCU was much lower than at FEX or FCD. In fact, velocity in pools under late summer low flow conditions were too low for use of the Gurley pygmy current meter. Using the float method, we recorded a value of 4 CFS on 8/28/83. Using the pygmy current meter at slightly higher flows on 8/4/83 resulted in a discharge measurement of 7 CFS. All U.S. Fish and Wildlife Service flow rate data on computer printout from the Marquette, Michigan Office for the reach of the Ford River that included FCU fall in the range of 4-8 CFS. Comparative values for the reach which includes FCD were 4 to 8 times higher (e.g. 4 vs 27 CFS; 6 vs 25 CFS). Thus, the flow rate at FCU is only 15-25% of the flow rate at FEX and FCD under low flow conditions.

Under the peak discharge conditions recorded for 1983 by the U.S. Fish and Wildlife Service (Harry Moore, personal communcation), 34% of discharge at FEX was derived from the Ford River above its confluence with Two Mile Creek, 52% of discharge was derived from Two Mile Creek, 6% from Turner Creek, and the other 8% was presumed to have been derived from overland flow or seepage directly into

the river below the Two Mile Creek - Ford River confluence. Thus, discharge at FCU is only 15-35% of discharge at FEX, and FCU is not a representative control for FEX on the basis of discharge. FCD is a reasonable control for FEX.

Discharge measurements for other sites included a discharge of 25 CFS for Schwartz Creek on 9/3/82 and values between 56 and 68 CFS for 4 measurements for the West Branch of the Escanaba River (WBE 1) taken between 9/3 and 10/5/82.

E. Width and Depth

No systematic determination of width and depth were made other than those associated with flow rate measurements. These measurements indicated that mean depth for FEX and FCD under low to moderate flow conditions varied from 0.15 in riffle to 0.5 meters in moderate pools and width varied from 5 m in narrow riffles to 10-11 meters for most areas. The widest point at FCU was 9 meters with widths as narrow as 3 meters for riffles. In most areas, FCU was 5-6 m wide with depths from 10 to 90 cm. In most areas the stream at FCU varied from 20 to 35 cm average depth. On average, width and depth were similar for FEX and FCD with both width and depth being less for FCU.

F. Physical Parameter Survey For Fisheries Research

Table 2.2 shows the results of the August, 1983 site physical parameter survey as measured by the fisheries section. FCD and FEX were similar in mean percent vegetation, vegetation mat size, and rock substrate size. These sites differed in mean water velocity, depth and woody substrate size with FEX demonstrating higher velocities and depth, and greater amounts of woody substrate. FEX and FCU differed in all physical parameters except for woody substrate size. In summary, FCD and FEX were more similar in physical characteristics than FCU and FEX. This data will be further statistically analysed and reported on in a future report.

TABLE 2.1: Modified Wentworth particle size scale as used in this study from Hynes, H.B.N. 1970. The ecology of running waters. Univ. Toronto Press, Toronto, Can. 555p.

Name of Particle	Range of Size in mm	Phi Scale
Boulder	>256	-8
	128-256	-7
Cobble	64-128	-6
Pebble	32-64	-5
	16-32	-4
Gravel	8-16	-3
	4-8	-2
Sand and finer particles	<4	-1

TABLE 2.2: Mean site values (± 1 S.D.) of physical parameters measured concurrently with fish microhabitat assessment in Element 15 for August 1983.

Physical Parameter	Site		
	FCU (N=44)	FEX (N=40)	FCD (N=40)
Depth (cm)	19.7 ± 7.6	46.9 ± 13.4	30.8 ± 10.8
Bottom velocity (cm/sec)	2.0 ± 5.8	5.0 ± 4.0	1.6 ± 1.0
Midwater velocity (cm/sec)	10.0 ± 13.7	20.0 ± 10.0	10.0 ± 13.7
Percent vegetation	0 ± 0	13.2 ± 22.0	14.0 ± 25.9
Percent rock phi particle size			
phi-7	3.1 ± 11.5	0 ± 0	0 ± 0
phi-6	50.4 ± 19.8	11.1 ± 14.5	13.6 ± 15.5
phi-5	20.2 ± 10.9	22.5 ± 13.4	14.9 ± 9.2
phi-4	11.7 ± 8.6	24.7 ± 11.2	19.6 ± 11.9
phi-3	2.2 ± 2.4	7.7 ± 4.8	7.2 ± 5.5
phi-2	1.1 ± 2.4	4.2 ± 3.5	4.4 ± 3.6
phi-1	8.9 ± 10.5	24.3 ± 16.6	33.1 ± 21.1
Percent vegetation mat phi size			
phi-7	0 ± 0	1.5 ± 9.5	1.7 ± 11.1
phi-6	0 ± 0	0.4 ± 2.8	3.1 ± 13.9
phi-5	0 ± 0	0.5 ± 2.4	0.8 ± 3.6
phi-4	0 ± 0	0.6 ± 2.2	0.4 ± 1.9
phi-3	0 ± 0	0.1 ± 0.4	0 ± 0
phi-2	0 ± 0	0 ± 0	0 ± 0
phi-1	0 ± 0	0 ± 0	0 ± 0
Percent wood phi particle size			
phi-6	0 ± 0	0.3 ± 2.2	0 ± 0
phi-5	0.5 ± 2.1	0.2 ± 1.2	0 ± 0
phi-4	0.4 ± 1.5	0.1 ± 0.6	0.1 ± 0.6
phi-3	0.2 ± 0.8	0.1 ± 0.3	0.1 ± 0.3
phi-2	0.1 ± 0.3	0 ± 0	0 ± 0
phi-1	0 ± 0	0 ± 0	0 ± 0

Element 3 - Establish and Conduct Ambient Monitoring Program

Original Synopsis - The ambient monitoring programwill consist of daily sampling of all water chemistry parameters for each plot as well as continuous monitoring of several ambient parameters (D.O, pH, etc.) detailed in the proposal. The automatic monitoring stations will be ordered in July, 1982 but will not be installed until final plot selection after the exact right-of-way is known. All other monitoring will begin August, 1982 and continue on a daily basis (5 day/week) through October, 1982. Theywill be reduced to monthly samples from November 1, 1982 to April 1, 1983 when daily sampling will resume.

Changes from Original Synopsis - Existing manpower precluded daily sampling as originally envisioned. Also, changes in most parameters were slow with less day to day variability than expected. Sampling was reduced to two to three days per week in 1982 and to one day per week after installation of monitoring stations in June, 1983.

Contributing staff - Thomas M. Burton, Associate Professor (PI)
Michael O'Malley, Field Research Tech. II

Objectives:

The objective of this work element is to provide the background data on physical and chemical parameters needed to correlate observations on biological community dynamics with environmental parameters. A second objective is to monitor stream chemistry to determine whether or not water quality changes are the primary determinants of changes in community structure rather than ELF radiation induced changes and to provide data for factoring out these different influences.

Materials and Methods

All chemical analyses follow procedures outlined in Standard Methods (American Public Health Association 1980) or approved techniques of the U.S. Environmental Protection Agency (U.S. EPA 1979). The quality control program recommended by the U.S.

Environmental Protection Agency (U.S EPA 1979) was initiated at the start of the field season in 1983. Laboratory nutrient analyses (N, P, SI, etc.) were conducted using auto-analyzer techniques as outlined in the U.S. EPA manual (1979).

Results and Discussion

Much of the ambient monitoring program in 1982 dealt with Schwartz Creek, the West Branch of the Escanaba River, and sites on the Ford River that were abandoned after final ELF corridor selection. Data for the ford River are partially reported here but only as they relate to the three sites selected in 1983 after corridor selection. Weekly field chemistry for 1983 was similar for all the 4th order stream sites (FSI, FEX, FCD) (Table 3.1). Monthly averages for all parameters differed very little from FSI to FEX to FCD in a downstream direction (Table 3.1). This similarity was not surprising since no major tributary enters the Ford River between these three sites.

The upstream control site (FCU) is the Ford River prior to its concluence with Two Mile Creek, another third order stream. It receives run-off from a small feedlot about 11-12 km upstream as well as some runoff from the community of Channing. The field chemistry for 1983 differed from this station compared to the three fourth order stations (FSI, FEX, and FCD) in that alkalinity, hardness, and conductivity, alkalinity, and hardness may be related to upstram pollution sources. At any rate, FCU differs enough from the downstream stations to bring into question its use as a control for FEX. There was no substantial difference in field chemisry between FCD and FEX, the two station comparison that we presently emphasizing.

All chemical constiuents for all sites (Table 3.1-3.3) fall within ranges typical of excellent water quality. Dissolved oxygen is always near saturation (Table 3.1), pH is neutral to slightly basic, and turbidity is very low. Soluble reactive phosphorus at FSI and FSII was always below the detection limit of 5 μg P/ℓ. and both inorganic and organic N were low for a reverine environment. With such low N and P levels, productivity of periphyton would b expected to be low. Water quality parameters all indicate that the Ford River has water quality suitable for the most sensitive organisms.

The automatic ambient monitoring stations were installed in June, 1983, at FCD and FEX. They performed reasonably well except for pH probes. These probes will have to be replaced with different types better suited for long term outdoor monitoring. Data are stored in the computer data base, and we are presently designing programs to integrate and summarize these data. Reports on these data will have to await development of these programs.

TABLE 3.1. Monthly Summaries of Water Chemistry Conducted on Site for the Ford River Sites May-November, 1983. Values are Means ± One Standard Deviation.

	Dissolved Oxygen mg/ℓ	Alkalinity mg $CaCO_3$/ℓ	Hardness mg $CaCO_3$/ℓ	pH	Specific Conductance umhos/cm	Turbidity NTU's	Water Temperature Range °C	Number of Samples
FORD CONTROL DOWNSTREAM (FCD)								
May, 1983	9.5±0.6	81±13	91±10	7.2±0.7	105±34	2.5±1.3	8-11	3
June, 1983	8.7±1.1	119±24	127±23	8.2±0.1	184±51	1.7±1.1	12-20	4
July, 1983	8.3±0.5	160±9	174±13	7.7±0.1	257±35	1.7±0.3	15.5-22.5	4
August, 1983	8.0±0.7	160±11	188±44	7.9±0.3	236±24	1.6±0.7	19-22	5
September, 1983	9.6±1.1	158±42	176±43	7.6±0.3	235±49	1.3±0.2	95-18	4
October, 1983	10.3±1.3	106±23	130±24	7.4±0.2	175±36	1.0±0.4	1.5-14.5	4
November 13, 1983	13.1	121	142	7.7	195	0.9	0	1
FORD EXPERIMENTAL (FEX)								
May, 1983	9.8±0.3	78±13	89±10	7.2±0.8	104±44	2.0±1.1	8-10.5	3
June, 1983	9.3± 0.6	114±25	124±23	8.3±0.1	185±52	1.8±1.2	11-19.8	4
July, 1983	8.6±0.7	160±9	170±13	7.7±0.1	261±40	1.9±0.9	16-22.5	4
August, 1983	8.6±0.4	159±13	185±44	8.0±0.3	270±19	1.6±0.4	19.5-23.5	5
September, 1983	9.6±0.7	149±35	164±28	7.7±0.2	229±41	1.7±0.9	10-18.5	4
October, 1983	10.5±1.3	106±25	128±25	7.3±0.2	175±36	0.9±0.2	4.5-9	4
November 13, 1983	13.4	113	130	7.7	210	1.3	0	1
FORD CONTROL UPSTREAM (FCU)								
June, 1983	8.6±0.9	148±11	162±6	8.2±0.1	236±63	1.3±0.3	20.5-22	2
July, 1983	8.9±0.2	189±17	202±21	7.9±0.2	328±49	1.8±0.1	17-26.5	4
August, 1983	8.4±0.2	192±24	227±61	8.0±0.4	320±37	1.8±0.5	18-22	5
September, 1983	9.9±1.1	177±58	200±54	7.6±0.3	274±63	1.4±0.4	10.5-18	4
October, 1983	10.6±1.4	114±31	145±25	7.3±0.1	197±36	1.0±0.3	4-14.5	4
November 13, 1983	13.5	131	168	7.8	235	0.6	0	1

TABLE 3.1 continued...

FORD SITE I (FSI)

	Dissolved Oxygen mg/ℓ	Alkalinity mg $CaCO_3$/ℓ	Hardness mg $CaCO_3$/ℓ	pH	Specific Conductance umhos/cm	Turbidity NTU's	Water Temperature Range °C	Number of Samples
May, 1983	9.8±0.6	67±7	80±2	7.3±1.0	97±18	2.4±0.9	8-10	2
June, 1983	9.1±0.7	109±24	119±19	8.3±0.2	175±45	1.8±1.4	10.5-20.5	4
July, 1983	9.1±0.2	155±10	165±14	7.9±0.2	262±41	1.5±0.5	16-22.5	4
August, 1983	8.6±0.2	158±13	199±62	7.7±0.3	268±23	1.6±0.4	18-22	3

TABLE 3.2 Chemistry of Ford Site I, 1982-83. Values are Means ± One Standard Deviation; N is Indicated in Parentheses.

	NO_3-N mg N/ℓ	NO_2-N mg N/ℓ	NH_4-N mg N/ℓ	Total P* mg P/ℓ	Total Kjeldahl Nitrogen mg N/ℓ	Si mg Si/ℓ	Cl mg Cl/ℓ
August, 1982	(17) 0.025±0.014	(17) 0.013±0.003	(16) 0.024±0.025	(14) 0.020±0.008	(13) 0.41±0.09	(17) 8.53±1.03	(17) 3.40±0.79
September, 1982	(16) 0.033±0.028	(16) 0.013±0.004	(16) 0.056±0.051	(23) 0.030±0.015	(15) 0.60±0.18	(16) 8.13±0.95	(16) 4.28±0.68
October , 1982	(7) 0.030±0.017	(7) 0.022±0.015	(7) 0.043±0.025	(7) 0.041±0.033	(3) 0.66±0.09	(7) 8.27±0.17	(7) 4.36±1.05
November 18, 1982	0.068	0.017	0.060	0.031	-	9.60	2.50
January 16, 1983	0.158	0.017	0.085	0.022	-	9.84	3.40
February 12, 1983	0.210	0.009	0.055	0.020	-	9.95	4.97

*Soluble reactive phosphorus was always below 0.005 mg P/ℓ.

TABLE 3.3: Chemistry of Ford Site II, 1982-83. Values are Means ± Standard Deviation; N is Indicated in Parentheses.

	NO_3-N mg N/ℓ	NO_2-N mg N/ℓ	NH_4-N mg N/ℓ	Si mg Si/ℓ	Cl mg Cl/ℓ
August, 1982	(15) 0.039±0.007	(15) 0.006±0.003	(14) 0.043±0.014	(14) 9.8±0.3	(15) 1.80±0.45
September, 1982	(14) 0.037±0.008	(14) 0.005±0.002	(14) 0.052±0.016	(14) 9.4±0.3	(14) 2.92±0.74
October, 1982	(7) 0.055±0.029	(7) 0.003±0.00	(7) 0.055±0.013	(7) 9.5±0.2	(7) 3.16±0.79
November 18, 1982	0.118	0.003	0.065	9.6	2.6
December 16, 1982	0.195	0.003	0.050	11.1	2.3
January 16, 1983	0.225	0.003	0.050	11.3	2.9
February 12, 1983	0.248	0.005	0.060	11.3	3.4

Element 4 - Effects of Exposure Period on Periphytic Colonization of Artificial Substrates

Synopsis - Artificial glass slide substrates will be placed in pools and riffles of the two study streams. Substrates will be removed daily to assess the impact of exposure period on species composition, numbers of individuals, diversity, biomass accumulation, and chlorophyll a/phaeophytin a production.

Changes from Original Synopsis - The sampling interval was reduced from daily after an initial experiment at Ford Site I and Schwartz Creek proved it unnecessary in 1982. Studies were concentrated on the Ford River after final ELF corridor selection proved it to be the only stream offering adequate experimental control sites.

Contributing Staff - T.M. Burton, Associate Professor (PI)
M.P. Oemke, Research Associate
M. O'Malley, Field Research Tech II

Objectives

The pattern of colonization of periphytic algae on artificial substrates in streams may vary in response to such environmental parameters as light, temperature, nutrient availability, and velocity and turbulence of flow around the substrate. Since these factors are likely to vary seasonally, one must determine seasonal colonization rates in order to design the most efficient monitoring regime for a suspected perturbation such as ELF on riverine periphyton communities.

Since artificial substrates are used to simulate rock substrates on the river bed, different points in the colonization cycle may need to be sampled depending on the community parameter being studied. If one wants to determine production on rock surfaces, one needs to sample the algal community during active growth where losses are minimal rather than at an equilibrium point where production is offset by losses to physical abrasion, sloughing, grazing, etc. Conversely, if the goal is to use the substrate to study species composition, diversity, species density, and species relative abundance of the "mature" riverine periphyton community, the correct sampling point in the colonization cycle may well be at the equilibrium point where production is offset by losses.

The objective of the research conducted in this element was to establish seasonal colonization patterns for the periphyton community at three potential monitoring sites in the Ford River so that an efficient routine monitoring program could be designed.

Materials and Methods

Plexiglass slide racks were designed to hold 8 standard 3 x 1 inch glass slides in a vertical placement oriented facing the current in the river. These slide racks were fastened to bricks and placed in pool and riffle habitats at each site investigated. Slides were removed after different exposure periods in the stream ranging up to 56 days exposure. As many slide racks were placed in the river as were needed to perform analyses on species composition and cell counts and volumes, chlorophyll *a* and phaeophytin *a*, and organic matter biomass accumulation. Different slides from within the same subset of slide racks were used for each of these analyses as follows.

For species composition, cell counts, and cell volume determinations, two slides were removed on each sampling period from each habitat. One slide was air dried and the other placed in a mixture of 6 parts water, 3 parts 95% alcohol and 1 part formalin. The field preservative was latter switched to 4% glutaraldehyde as this solution was determined to be less disruptive to algal cellular contents and structures. The air dried slides were later scraped in the lab with razor blades to remove the diatoms for further specimen cleaning and slide preparation.

Slides were prepared for specimen identification by cleaning the diatoms removed from the exposed glass slides in concentrated hydrogen peroxide (30%) followed by further oxidation of the cellular contents with the addition of small amounts of potassium dichromate. The cleaned diatoms were then rinsed with distilled water and settled in graduated cylinders. The final volume of concentrate containing the cleaned diatom frustules was then measured and 1 ml subsamples pipetted onto 22 mm^2 coverslips, until an adequate counting density was achieved. The coverslips were air dried and permanently mounted on glass slides using Hyrax® medium.

Counting was done at 1250 X magnification on a Zeiss microscope equipped with phase contrast illumination and an oil immusion 100 x NEOFLUAR phase objective with numerical aperture of 1.30. Transects were taken moving across the coverslip until between 250-450 frustules were counted. Estimates of diatom densities were made from quantitative samples via the equation:

$$\text{cells } m^{-2} = \frac{\text{number of valves counted} \cdot (22\ mm)^2 \cdot \text{volume concentrate}}{2 \cdot \text{area coverslip counted} \cdot \text{subsample volume} \cdot (.00375m)^2}$$

Diatom species composition was recorded for the 250-450 frustules for determination of species richness, diversity using the Shannon-Wiener formula (Southwood 1978), evenness, and dominance. Cell volume measurements were taken by measuring lengths and widths and recording shapes of dominant diatoms for later calculation of cell volume.

Initially, three slides were taken for chlorophyll a and phaeophytin a determinations for each exposure period from each habitat at each site. This number was increased to four at the start of the 1983 growing season because of considerable variability in these parameters. Analyses for both chlorophyll a and phaeophytin a followed the fluorometric determination described in Standard Methods (American Public Health Association 1980). Because the fluorometer had to be ordered and procedures worked out after receipt of the contract, the 1982 samples were frozen for subsequent analyses. Extremely high variability with the chlorophyll a to phaeophytin a ratio for these stored samples suggested that long term storage of these samples was a problem so all 1982 samples were discarded. The 1983 samples were analyzed within a month of collection as specified in Standard Methods. Initial analyses suggested that there were no differences in chlorophyll a and phaeophytin a between samples where the cells had been scraped from the slide and ground to facilitate cell rupture and samples with the grinding step eliminated. Subsequently, slides were collected, frozen for at least 24 hours to promote cell rupture, and extracted in 90% buffered acetone. Chlorophyll a and phaeophytin a were then determined following procedures outlined in Standard Methods.

Three additional slides in 1982, four in 1983, were taken from each habitat at each site for organic matter biomass determination. Analyses were conducted following procedures 1003 C and 1003 D in Standard Methods (American Public Health Association 1980). Again, long term storage of 1982 samples led us to suspect results so they were discarded. All 1983 samples were analysed on frozen slides within 30 days of collection time. Early 1983 samples were more variable than later samples since invertebrates were not all removed before ash-free dry weight determination. This problem was rectified in June, 1983, and all data subsequent to that time are of organic matter on slides after removal of invertebrates such as black flies from the slides.

During 1982, ELF corridor selection had not been completed. Thus, we sampled several streams in the general area of the project. After corridor selection, three potential sites on the Ford River were selected for study in 1983. Most results reported are from these three sites, Ford Control Upstream (FCU), Ford Experimental (FEX) near the ELF corridor, and Ford Control Downstream (FCD). Some data are reported from Ford Site I, a station between FCU and FEX but closer to FEX with no major

tributaries entering between it and FEX. We also collected data from Schwartz Creek, the West Branch of the Escanaba River, and Ford Site II (between FEX and FCD) but data analyses are incomplete and are not reported here since these sites have been abandoned.

Results and Discussion

A. Chlorophyll a

Although we were able to conduct a 15 and 25 day exposure study of two of the Ford River sites (FEX and FCD) starting on May 12, 1983 (Tables 4.1 and 4.2), our first complete colonization study for these two sites was initiated on May 30, 1983. Colonization for both pool and riffle exposures was very slow for the first 7 days (Figures 4.1, 4.2) under conditions of very high flow and relatively high tubdibity, followed by more rapid colonization thereafter as flow and turbidity decreased. The primary difference between the experimental (FEX) and downstream control (FCD) site occurred for pool samples after 28 days (Figure 4.2) with the experimental site attaining much higher chlorophyll a values than FCD. The rapid increase in chlorophyll a for pool exposures after 21 days was probably related to lower flow and turbidity as well as a sustained period of high sunlight.

Colonization under conditions of low flow and high sunlight from late June through early August was very rapid for the first 14 days for both pool and riffles followed by slower accumulation of chlorophyll a thereafter (Figures 4.3, 4.4). The exception to this pattern was the Experimental Site (FEX). The slower accumulation of chlorophyll a at this site likely resulted from substrate placement in a shaded backwater pool and shallow "riffle" area rather than real inter-site differences between FEX and FCD. We will be much more careful in the upcoming year to match FEX with a FCD in terms of flow rate and light exposure. The exceptionally high accumulation of chlorophyll a at the upstream control (FCU) compared to the other two sites reflects real inter-site differences. We suspect that this increased upstream production is linked to lower flow rates in this third order stream segment compared to the two 4th order downstream sites as well as greater nutrient availability from the upstream community of Channing and a feedlot on the Ford River near Channing. Analyses of frozen, stored water samples over the winter should demonstrate whether differences in nutrient availability really exist or not.

It is unfortunate that the mid-summer colonization series included the highest 14 day value for FCD which occurred throughout the growing season (Figure 4.5). We are unable to explain why this value was so high. However, if this value were more in line with other values for the summer (Figure 4.5), the shape of the curve for FEX and FCD would be very similar.

TABLE 4.1: Chlorophyll a Accumulation (mg/m^2 ± One Standard Error) on Glass Slides in Pools for the Three Ford River Sites in 1983. N=4 unless otherwise indicated.

Date out of River	Days Exposure	FCU	FEX	FCD
6/6/83	7	-	0.40 ± 0.004(N=3)	0.08 ± 0.01(N=3)
6/13/83	7	-	0.61 ± 0.06(N=5)	0.75 ± 0.04
6/20/83	7	-	0.69 ± 0.04	0.79 ± 0.13
6/27/83	7	4.20 ± 0.16	0.71 ± 0.19	0.42 ± 0.04
5/27/83	15	-	0.88 ± 0.03	2.00 ± 0.18
6/13/83	14	-	0.85 ± 0.06(N=3)	1.18 ± 0.06(N=3)
6/27/83	14	-	1.29 ± 0.11	1.10 ± 0.51
7/11/83	14	20.54 ± 1.37	1.82 ± 0.22	0.72 ± 0.03(N=2)
7/25/83	14	30.93 ± 0.83	4.41 ± 0.43	15.17 ± 0.79
8/8/83	14	16.32 ± 1.71	3.44 ± 0.25	2.96 ± 0.48
8/22/83	14	7.03 ± 0.55	1.89 ± 0.10	3.81 ± 0.26
9/6/83	15	5.89 ± 0.36	1.89 ± 0.10	3.45 ± 0.17
9/19/83	13	4.14 ± 0.85	1.03 ± 0.15	1.73 ± 0.14
10/03/83	14	1.77 ± 0.11	0.86 ± 0.43	0.50 ± 0.05
10/18/83	15	1.77 ± 0.08	0.40 ± 0.13	0.79 ± 0.44(N=3)
6/3/83	22	-	1.04 ± 0.10(N=3)	1.51 ± 0.21(N=3)
6/20/83	21	-	1.78 ± 0.19	1.16 ± 0.16
6/6/83	25	-	2.11 ± 0.43	2.72 ± 0.67
6/27/83	28	-	6.41 ± 1.44	2.77 ± 0.15
7/25/83	28	35.00 ± 1.96	12.19 ± 0.84	10.42 ± 0.83
8/22/83	28	27.36 ± 0.39	9.78 ± 0.58	13.97 ± 1.13
9/06/83	29	10.67 ± 0.78	3.87 ± 0.40	10.18 ± 0.86
9/19/83	28	16.00 ± 0.66	3.96 ± 0.57	7.86 ± 0.62
10/18/83	29	8.77 ± 0.76	1.06 ± 0.20	0.97 ± 0.32
8/8/83	42	33.43 ± 1.89	12.40 ± 1.39	18.85 ± 1.75
10/18/83	42	6.80 ± 1.54	2.33 ± 0.19	4.43 ± 0.04(N=3)

TABLE 4.2: Chlorophyll a Accumulation (mg/m^2 + One Standard Error) on Glass Slides in Riffles for the Three Ford River Sites in 1983. N=4 unless otherwise indicated.

Date out of River	Days Exposure	FCU	FEX	FCD
6/6/83	7	-	0.07 ± 0.03(N=3)	0.08 ± 0.004(N=3)
6/13/83	7	-	0.92 ± 0.27	0.83 ± 0.03
6/20/83	7	-	0.72 ± 0.05	0.80 ± 0.15
6/27/83	7	3.43 ± 0.11	0.75 ± 0.05	1.31 ± 0.95
5/27/83	15	-	1.09 ± 0.28	1.59 ± 0.56
6/13/83	14	-	1.09 ± 0.12(N=3)	1.00 ± 0.10(N=3)
6/27/83	14	-	1.90 ± 0.21	0.94 ± 0.14(N=5)
7/11/83	14	21.30 ± 1.22	2.49 ± 0.11	1.77 ± 0.22
7/25/83	14	29.92 ± 0.86	2.14 ± 0.19	17.44 ± 1.27
8/8/83	14	26.10 ± 1.11	3.16 ± 0.58	3.09 ± 0.23
8/22/83	14	16.09 ± 2.52	1.63 ± 0.34	2.82 ± 0.30
9/6/83	15	12.92 ± 1.28	3.03 ± 0.35	5.10 ± 0.80
9/19/83	13	5.30 ± 0.25	2.16 ± 0.37	1.70 ± 0.35
10/03/83	14	1.23 ± 0.19	0.55 ± 0.06	0.50 ± 0.05
10/18/83	15	1.60 ± 0.16	0.23 ± 0.01	0.48 ± 0.05
6/3/83	22	-	3.58 ± 0.80(N=3)	2.26 ± 0.41(N=3)
6/20/83	21	-	2.58 ± 0.37	1.79 ± 0.018
6/6/83	25	-	3.70 ± 0.89	2.11 ± 0.28(N=6)
6/27/83	28	-	2.56 ± 0.11	2.79 ± 0.16
7/25/83	28	24.50 ± 2.47	13.29 ± 2.82	20.57 ± 0.36
8/22/83	28	32.10 ± 0.51	5.71 ± 1.02	16.50 ± 1.41
9/06/83	29	33.00 ± 1.45	4.21 ± 0.34	14.56 ± 0.90
9/19/83	28	31.51 ± 3.59	3.45 ± 0.37	8.35 ± 0.85
10/18/83	29	6.57 ± 0.47	1.01 ± 0.06	3.25 ± 0.44
8/8/83	42	26.63 ± 2.21	22.88 ± 0.89	23.25 ± 1.25
10/18/83	42	9.14 ± 0.50	1.80 ± 0.38(N=3)	4.96 ± 1.09(N=3)

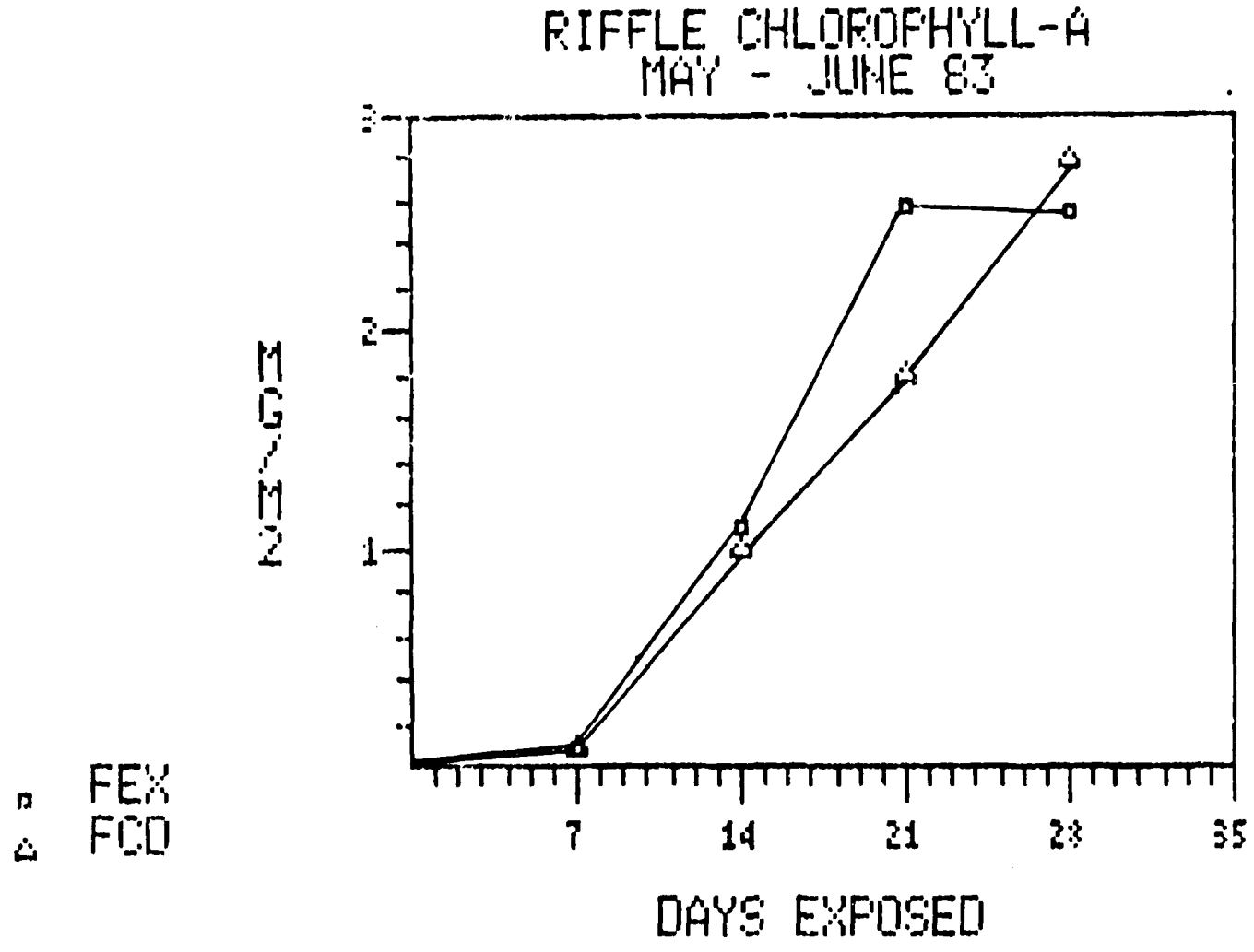

RIFFLE CHLOROPHYLL-A
MAY - JUNE 83
MG/M2
3
2
1
7
14
21
28
35
DAYS EXPOSED
FEX
FCO

FIGURE 4.1

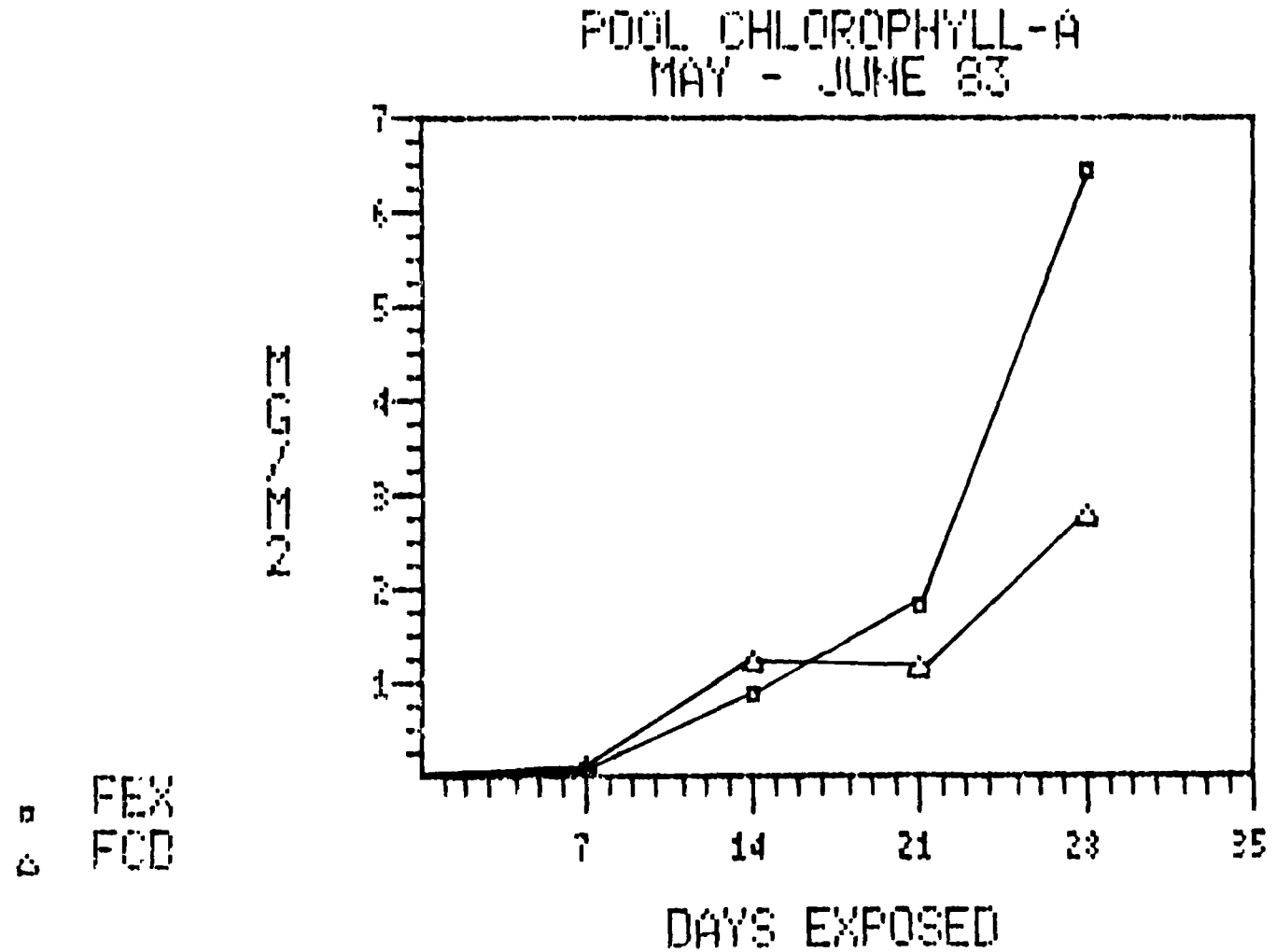

POOL CHLOROPHYLL-A
MAY - JUNE 83
MG/CM
1
2
3
4
5
6
7
7
14
21
28
35
DAYS EXPOSED
FEX
FCO

FIGURE 4.2

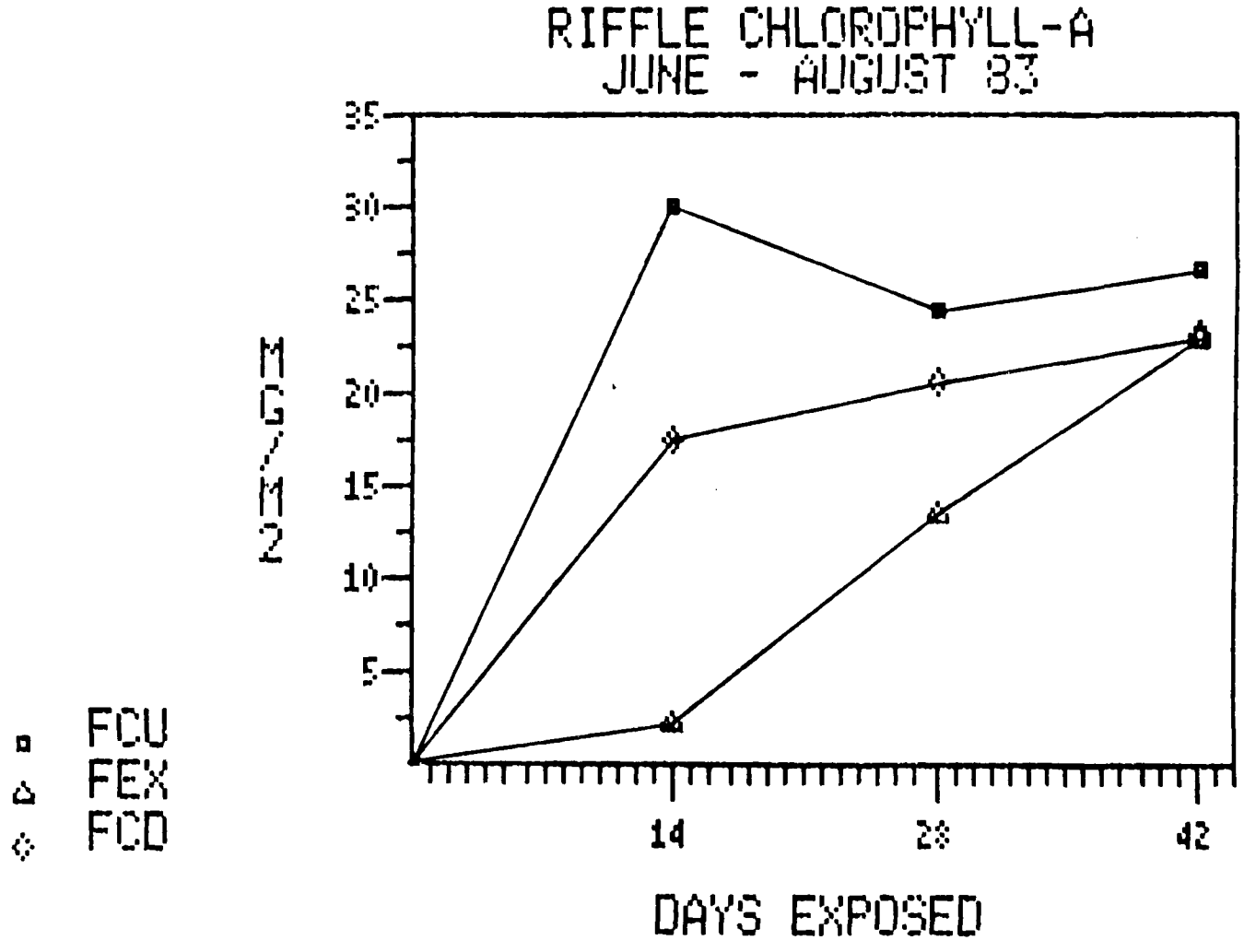

RIFFLE CHLOROPHYLL-A
JUNE - AUGUST 83
MG/SQM
35
30
25
20
15
10
5
14
28
42
DAYS EXPOSED
FCU
FEX
FCD

FIGURE 4.3

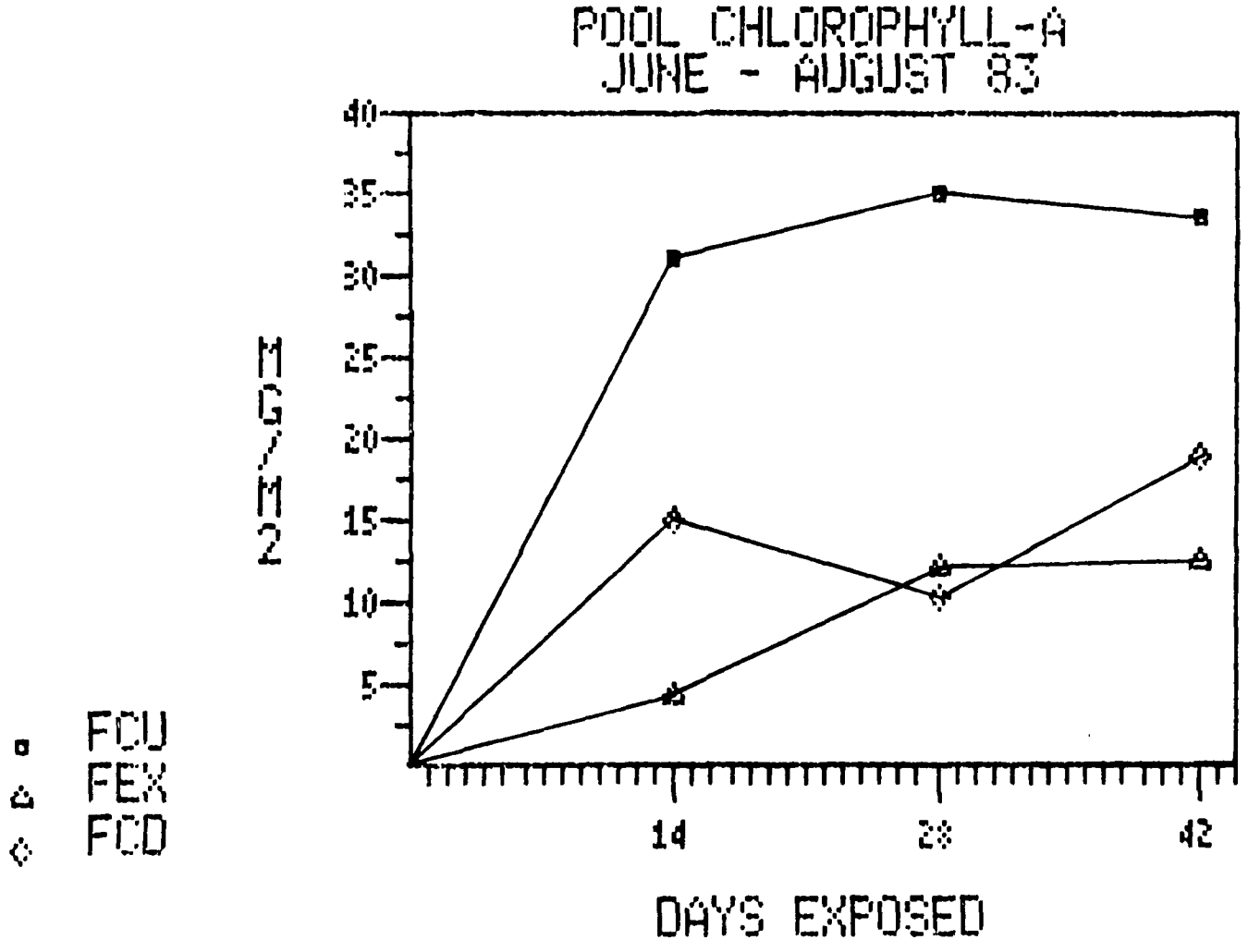

POOL CHLOROPHYLL-A
JUNE - AUGUST 83
MG/M2
40
35
30
25
20
15
10
5
14
28
42
DAYS EXPOSED
FCU
FEX
FCD

FIGURE 4.4

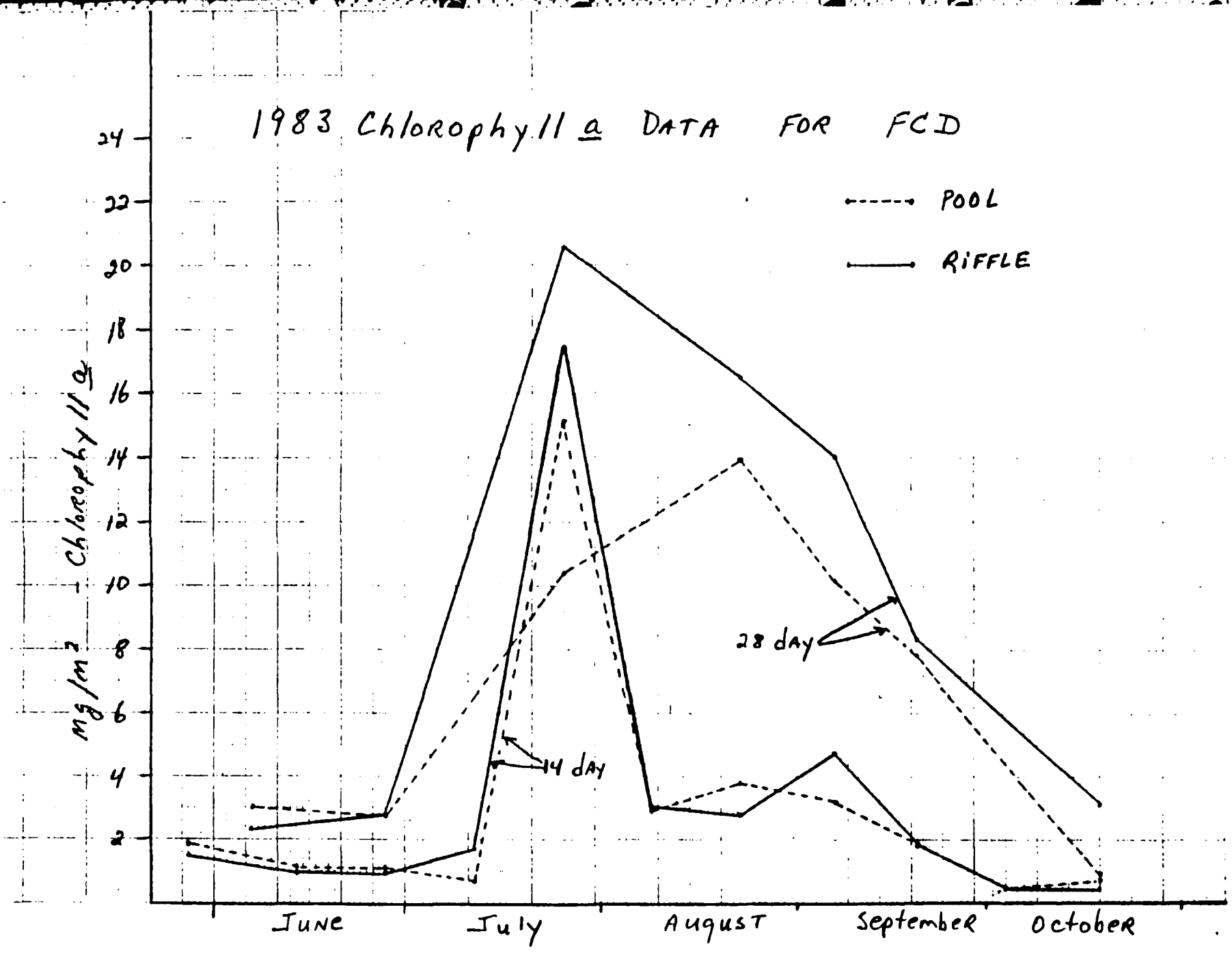

1983 Chlorophyll a DATA FOR FCD
POOL
RIFFLE
mg/m² Chlorophyll a
24
22
20
18
16
14
12
10
8
6
4
2
28 day
14 day
June
July
August
September
October

FIGURE 4.5

The fall colonization series was characterized by increases through day 28 for all sites for both pool and riffle followed by a decline in chlorophyll a between the 28 and 42 day exposure periods (Figures 4.6, 4.7). Both the 14 and 28 day exposures were removed on September 19, 1983, after an exposure to 10-12 days of significant precipitation during the previous 14-16 days exposures. Continued periods of high water and decreasing temperatures during the next 28 days may have resulted in the decline in chlorophyll a for the 42 day exposure removed on October 18, 1983.

Over all seasons, the 28 day exposure period seems to represent an exposure period near peak chlorophyll a accumulation or a period of slight decline of chlorophyll a. The Spring exposures may be an exception to this trend and longer colonization periods are needed to establish the trend. We conclude that chlorophyll a should be sampled at two exposure period for the Ford River during the primary growing season (May-October). A 14 day sampling period will ensure that chlorophyll a is still in the rapid accumulation phase with minimal losses. This sampling period will be used as an indicator of site productivity. A 28 day exposure period sample will enable us to correlate chlorophyll a with "equilibrium" community parameters such as density, diversity, etc. as will be discussed below. Only a 28 day exposure period will be used for Winter sampling (November-April).

Even though the experimental site (FEX), typically had lower chlorophyll a values than did the downstream control, these differences were not significant when averaged over the entire growing season (Table 4.3). However, the upstream control (FCU) had much higher chlorophyll a production than did FEX. Thus, we conclude that FCU is not a reasonable control for FEX in terms of chlorophyll a accumulation while FCD is.

TABLE 4.3: T-test Results From Comparisons of Pool and Riffle Mean Chlorophyll a Values (mg/m^2) for 28 Day Exposure Periods for Three Sites on the Ford River, May-October, 1983 ($\bar{x} \pm$ S.E.,N Indicated in Parentheses).

	FCU	FEX	Significance
Riffle	25.53 ± 2.43(20)	5.04 ± 0.91(24)	*** p <0.001
Pool	19.25 ± 2.40(20)	6.21 ± 0.84(24)	*** p <0.001

	FCD	FEX	
Riffle	11.01 ± 1.42(24)	5.04 ± 0.091(24)	N.S. p > 0.2
Pool	7.90 ± 1.01(22)	6.21 ± 0.84(24)	N.S. p > 0.2

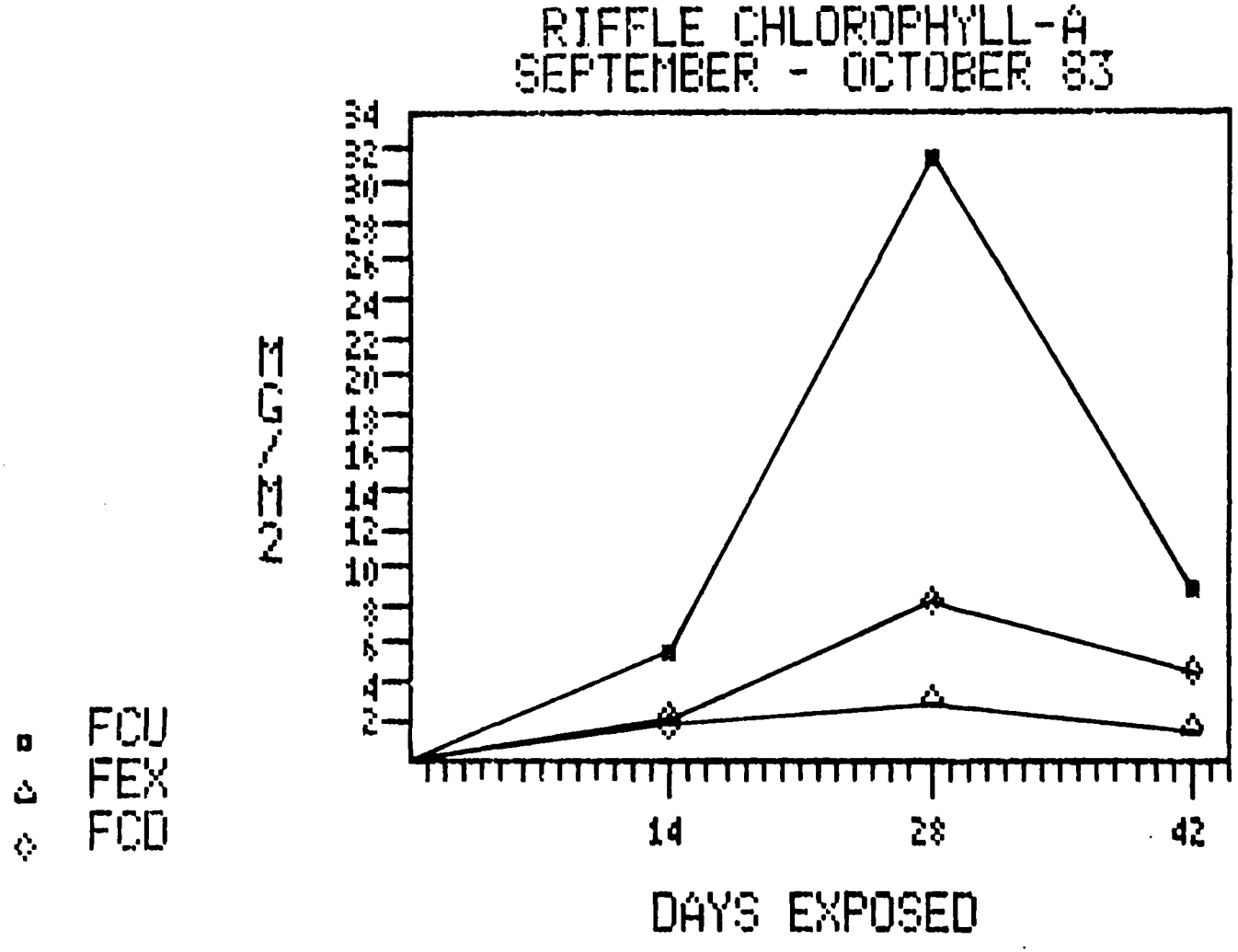

RIFFLE CHLOROPHYLL-A
SEPTEMBER - OCTOBER 83
MG/SQM
FCU
FEX
FCD
14
28
42
DAYS EXPOSED

FIGURE 4.6

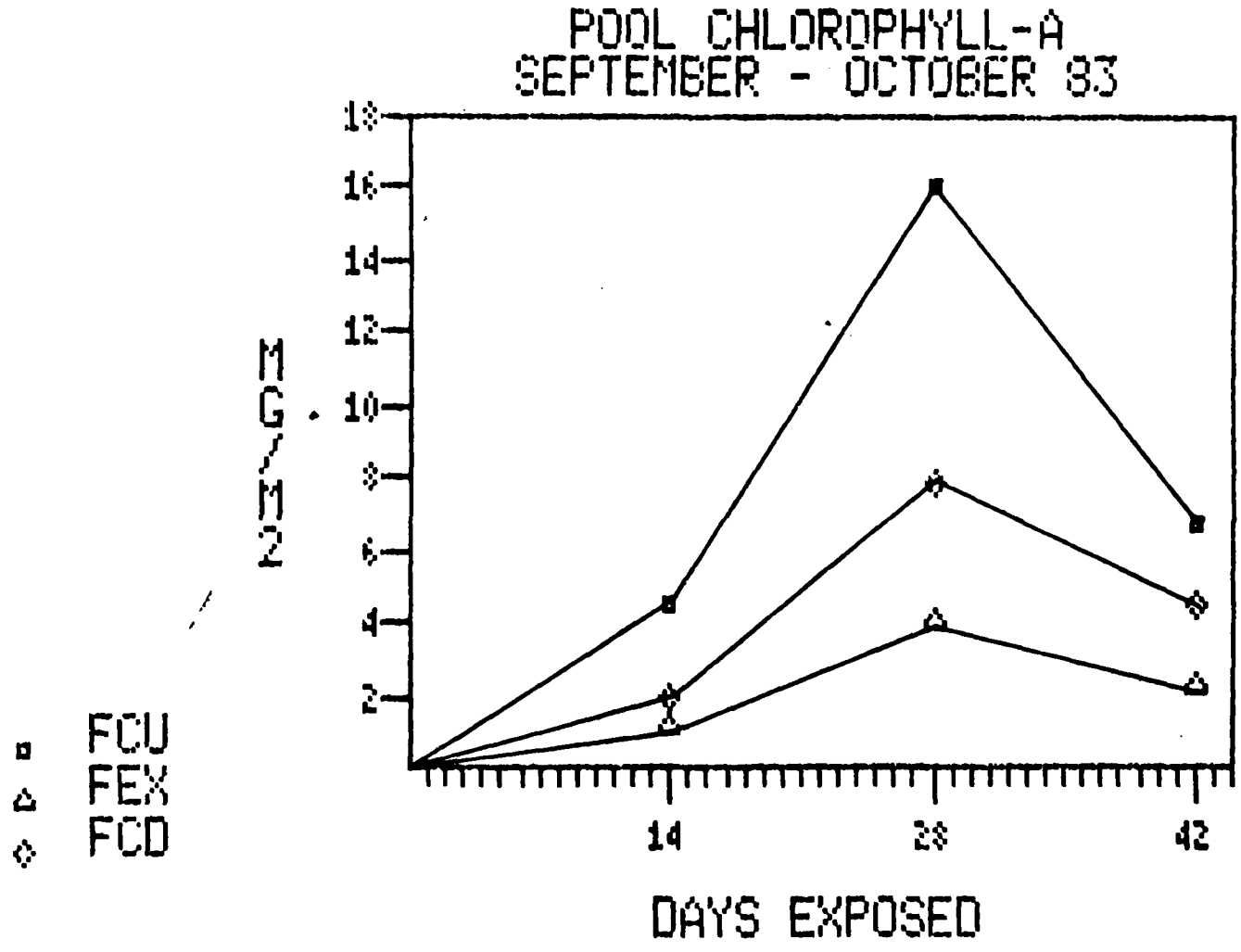

POOL CHLOROPHYLL-A
SEPTEMBER - OCTOBER 83
MG/M2
16
14
12
10
8
6
4
2
14
28
42
DAYS EXPOSED
FCU
FEX
FCD

FIGURE 4.7

B. Biomass Accumulation

The rate of accumulation of organic matter on glass slides is one means of estimating productivity of streams (American Public Health Association 1980). Productivity in this instance includes both algal and microbial productivity and in practice is expressed as gain in ash free dry weight per unit area from one collection period to the next. Correlation of ash free dry weight biomass accumulation with chlorophyll a, cell counts, etc. enables one to crudely separate periphytic algal production from microbial production. Thus, it is important to sample biomass accumulation at the same time as other periphyton parameters are sampled. If the goal is to ascertain rates of production, then the sampling period should be designed to sample biomass during a rapid expansion phase. On the other hand, correlation with "equilibrium" periphyton community dynamics requires sampling after rapid colonization of glass slides is essentially complete. Thus, the sampling regime for biomass accumulation needs to be intermeshed with the sampling regime for chlorophyll a, cell counts, and other periphyton community parameters as has been discussed for chlorophyll a.

We sampled biomass accumulation on the same schedule as chlorophyll a. All data are summarized in Tables 4.4 and 4.5. Specific colonization studies were also conducted at the same times as have already been reported for chlorophyll a. Data for the May 30 to June 27 colonization study suggested that a rapid rate of colonization continues for 14 days for pools and 21 days for riffles with a flattening or decline in rate of accumulation thereafter for all three sites, (Figures 4.8, 4.9). The June 27-August 8 colonization study was also characterized by a rapid rate of colonization through day 14 for all sites for both pool and riffle followed by continued rapid accumulation through day 28 for riffles but a decline for pools between day 14 and 28 (Figures 4.10, 4.11). This decline for pools may well reflect two significant summer storms received on July 17 and July 21 prior to the July 25 removal date for the 28 day set. Rapid biomass accumulation continued for pools from day 28 to day 42 even though significant precipitation did occur on July 31 and August 3 prior to the August 8 removal date for the 42 day set. The September-October colonization period also was characterized by rapid accumulation of biomass for the first 14 days followed by a flattening or decline in rate of biomass accumulation thereafter (Figures 4.12, 4.13).

We conclude that a 14 day colonization period is ideal for all sites on the Ford River for sampling the biomass accumulation rate as an indicator of site productivity during the primary growing season. We also plan to continue a year round 28 day sampling program as a means of correlating organic matter biomass with periphyton community dynamics.

TABLE 4.4: Accumulation of Organic Matter Biomass (mg/m^2 Ash Free Dry Weight ± One Standard Error) on Glass Slides in Pools for the Three Ford River Sites in 1983. N=4 unless otherwise indicated.

Date out of River	Days Exposure	FCU	FEX	FCD
6/6/83	7	-	80 ± 26(N=2)	151 ± 69(N=3)
6/13/83	7	-	520 ± 121	367 ± 33
6/20/83	7	-	827 ± 431(N=3)	173 ± 93(N=2)
5/27/83	15	-	419 ± 58	987 ± 85
6/13/83	14	-	470 ± 49(N=3)	560 ± 27(N=3)
6/27/83	14	-	667 ± 94(N=2)	258 ± 18(N=3)
7/11/83	14	1300 ± 187	780 ± 327	360 ± 23
7/25/83	14	1406 ± 98	487 ± 68	1260 ± 89
8/8/83	14	826 ± 63	827 ± 139	600 ± 39
8/22/83	14	553 ± 98	667 ± 42	400 ± 3
9/6/83	15	520 ± 280(N=2)	1100 ± 329	347 ± 106
9/19/83	13	473 ± 111	267 ± 11	307 ± 64(N=2)
10/03/83	14	573 ± 49	467 ± 110	249 ± 39(N=3)
10/18/83	15	193 ± 13	193 ± 13	213 ± 151(N=2)
6/3/83	22	-	307 ± 173	613 ± 174
6/20/83	21	-	527 ± 72	380 ± 71
6/6/83	25	-	667 ± 160	926 ± 109
6/27/83	28	-	533 ± 267(N=2)	507 ± 73
7/25/83	28	1360 ± 23	1073 ± 28	840 ± 93
8/22/83	28	1320 ± 172	1031 ± 406(N=3)	760 ± 228
9/06/83	29	-	933 ± 160(N=2)	1067 ± 31(N=3)
9/19/83	28	773 ± 85	580 ± 119	1040 ± 216(N=3)
10/18/83	29	880 ± 37	293 ± 74(N=3)	353 ± 40
8/8/83	42	2453 ± 37	2367 ± 185	2427 ± 494(N=3)
10/18/83	42	693 ± 86	700 ± 95	1067 ± 320(N=2)

TABLE 4.5: Accumulation of Organic Matter Biomass (mg/m^2 Ash Free Dry Weight ± One Standard Error) on Glass Slides in Riffles for the Three Ford Rive Sites in 1983. N=4 unless otherwise indicated.

Date out of River	Days Exposure	FCU	FEX	FCD
6/6/83	7	-	275 ± 77 (N=3)	364 ± 99(N=3)
6/13/83	7	-	740 ± 61	373 ± 82(N=3)
6/20/83	7	-	413 ± 3	-
5/27/83	15	-	372 ± 72	707 ± 166
6/13/83	14	-	840 ± 67(N=2)	596 ± 131(N=3)
6/27/83	14	-	660 ± 103	320 ± 56(N=3)
7/11/83	14	1804 ± 49(N=3)	540 ± 5	527 ± 51
7/25/83	14	1826 ± 165	400 ± 92	1053 ± 52
8/8/83	14	1973 ± 188	673 ± 206	1100 ± 123
8/22/83	14	1150 ± 160	684 ± 78(N=3)	533 ± 107
9/6/83	15	1201 ± 733	1413 ± 627	613 ± 271
9/19/83	13	587 ± 72	573 ± 69	313 ± 79
10/03/83	14	680 ± 208	480 ± 8	233 ± 107
10/18/83	15	613 ± 255	613 ± 255	276 ± 64(N=3)
6/3/83	22	-	611 ± 41(N=3)	676 ± 329(N=3)
6/20/83	21	-	1013 ± 215	1007 ± 186
6/6/83	25	-	2773 ± 912	1727 ± 857
6/27/83	28	-	393 ± 145	360 ± 28
7/25/83	28	2680 ± 691	1747 ± 201	1687 ± 171
8/22/83	28	2550 ± 143(N=3)	1233 ± 67	1236 ± 50(N=3)
9/06/83	29	-	1440 ± 201(N=3)	1413 ± 162
9/19/83	28	2160 ± 187	500 ± 74	1013 ± 66
10/18/83	29	586 ± 552	547 ± 73	947 ± 138
8/8/83	42	2780 ± 1430(N=3)	2747 ± 112	2500 ± 377
10/18/83	42	927 ± 107	507 ± 15(N=3)	1013 ± 241

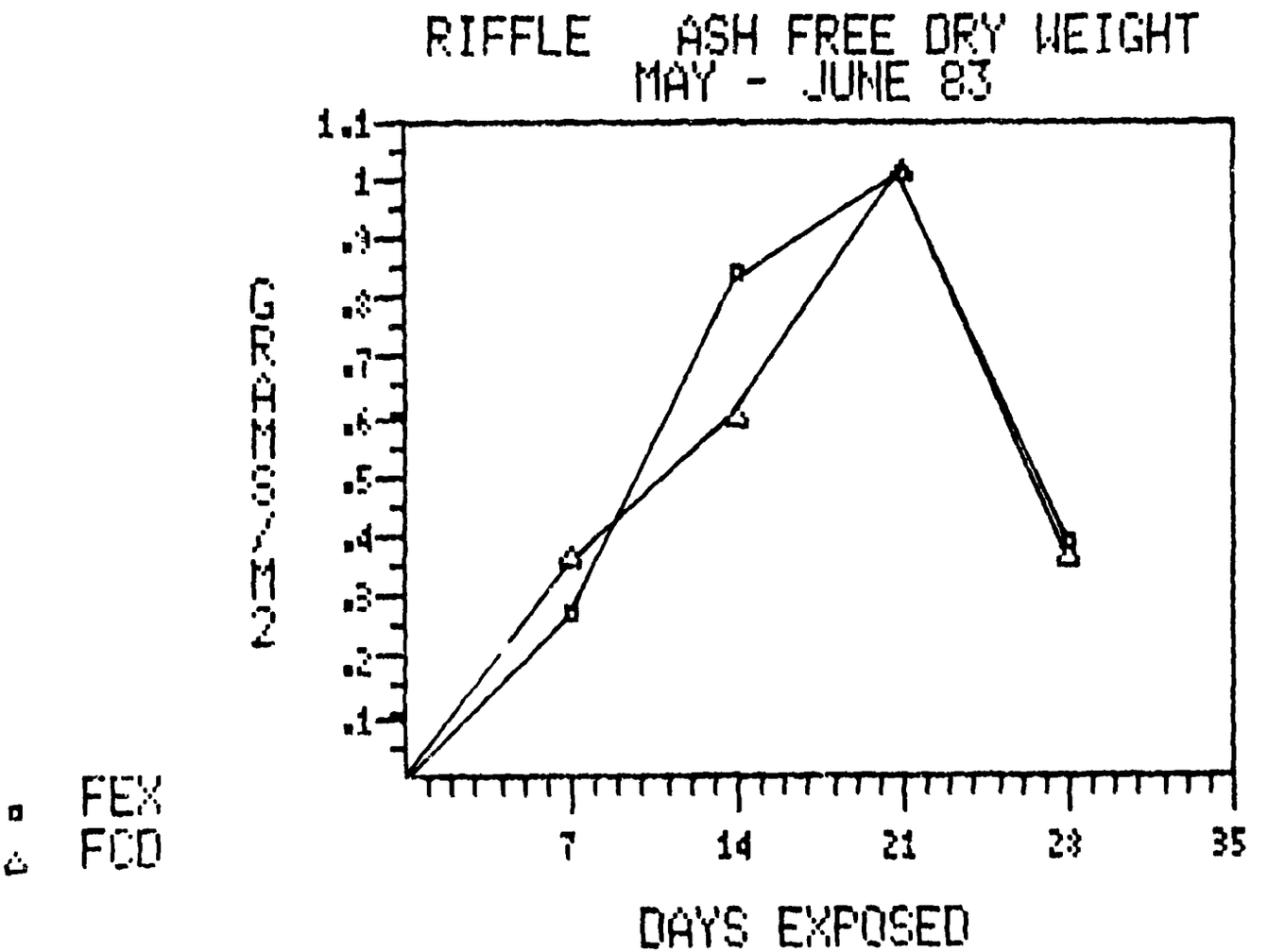

RIFFLE ASH FREE DRY WEIGHT
MAY - JUNE 83
GRAMS/M2
1.1
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
7
14
21
28
35
DAYS EXPOSED
FEX
FCO

FIGURE 4.8

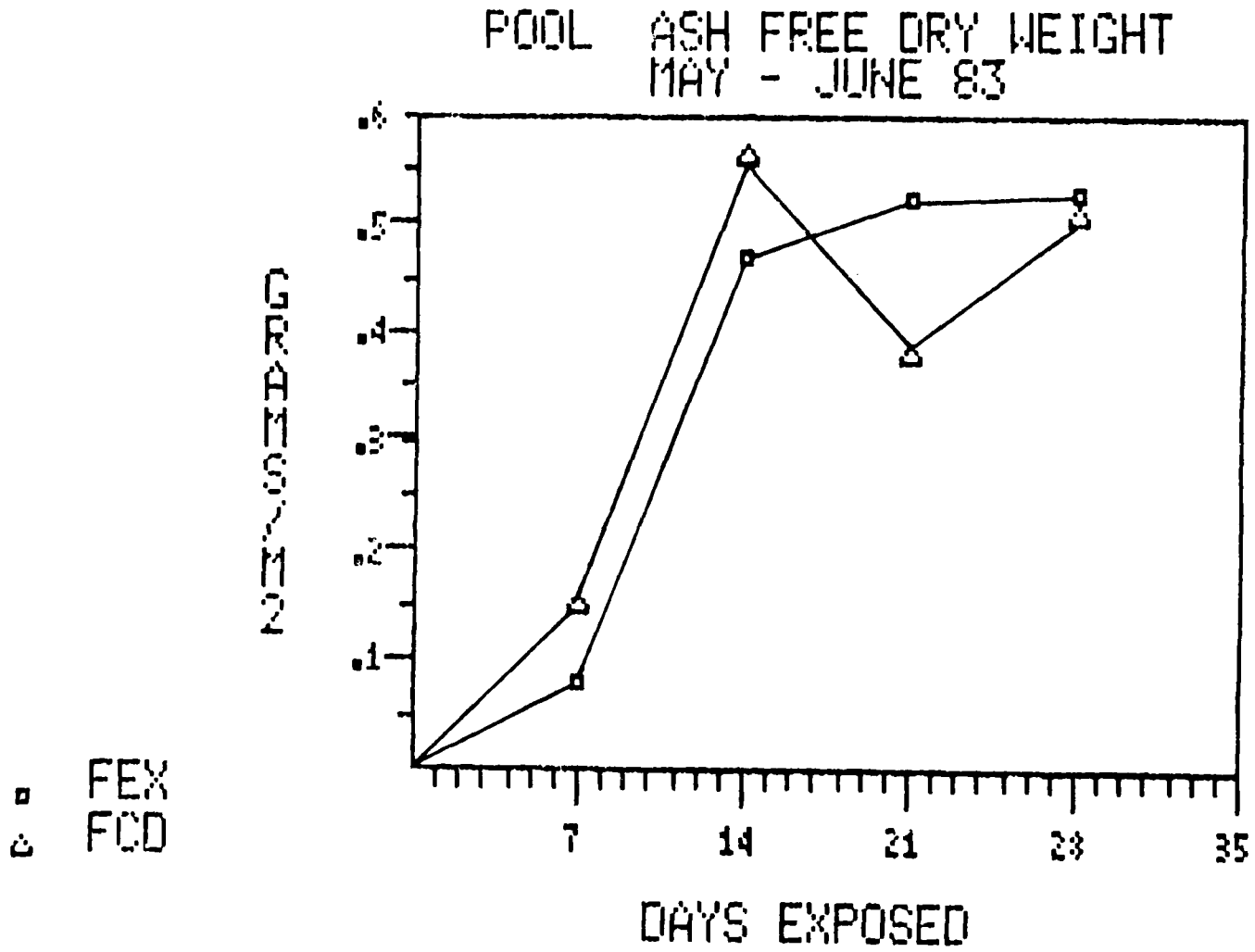

POOL ASH FREE DRY WEIGHT
MAY - JUNE 83
GRAMS/SQ METER
.6
.5
.4
.3
.2
.1
7
14
21
28
35
DAYS EXPOSED
FEX
FCD

FIGURE 4.9

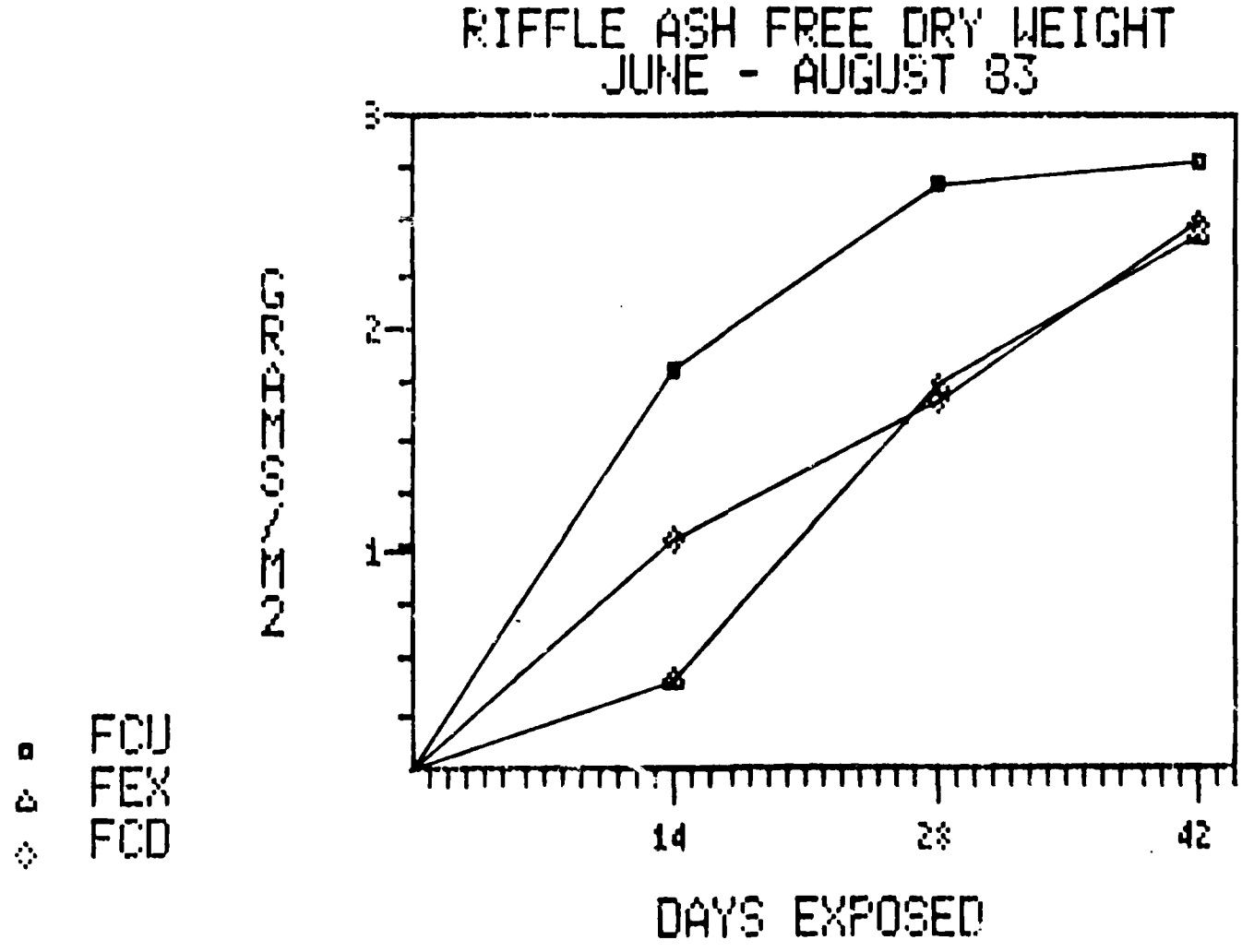

RIFFLE ASH FREE DRY WEIGHT
JUNE - AUGUST 83
GRAMS/M2
3
2
1
14
28
42
DAYS EXPOSED
FCU
FEX
FCD

FIGURE 4.10

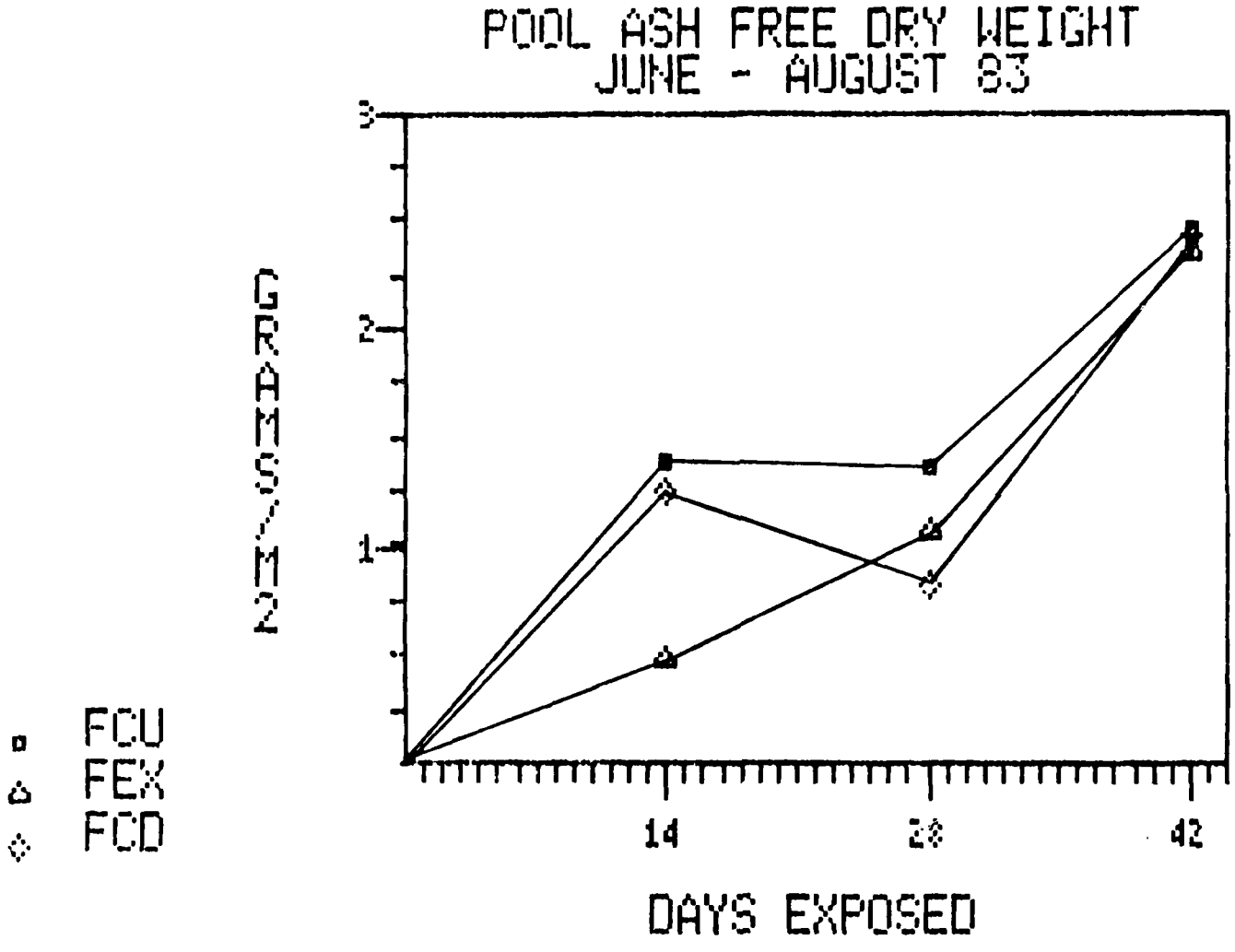

POOL ASH FREE DRY WEIGHT
JUNE - AUGUST 83
MG/SQUARE
3
2
1
14
28
42
DAYS EXPOSED
FCU
FEX
FCD

FIGURE 4.11

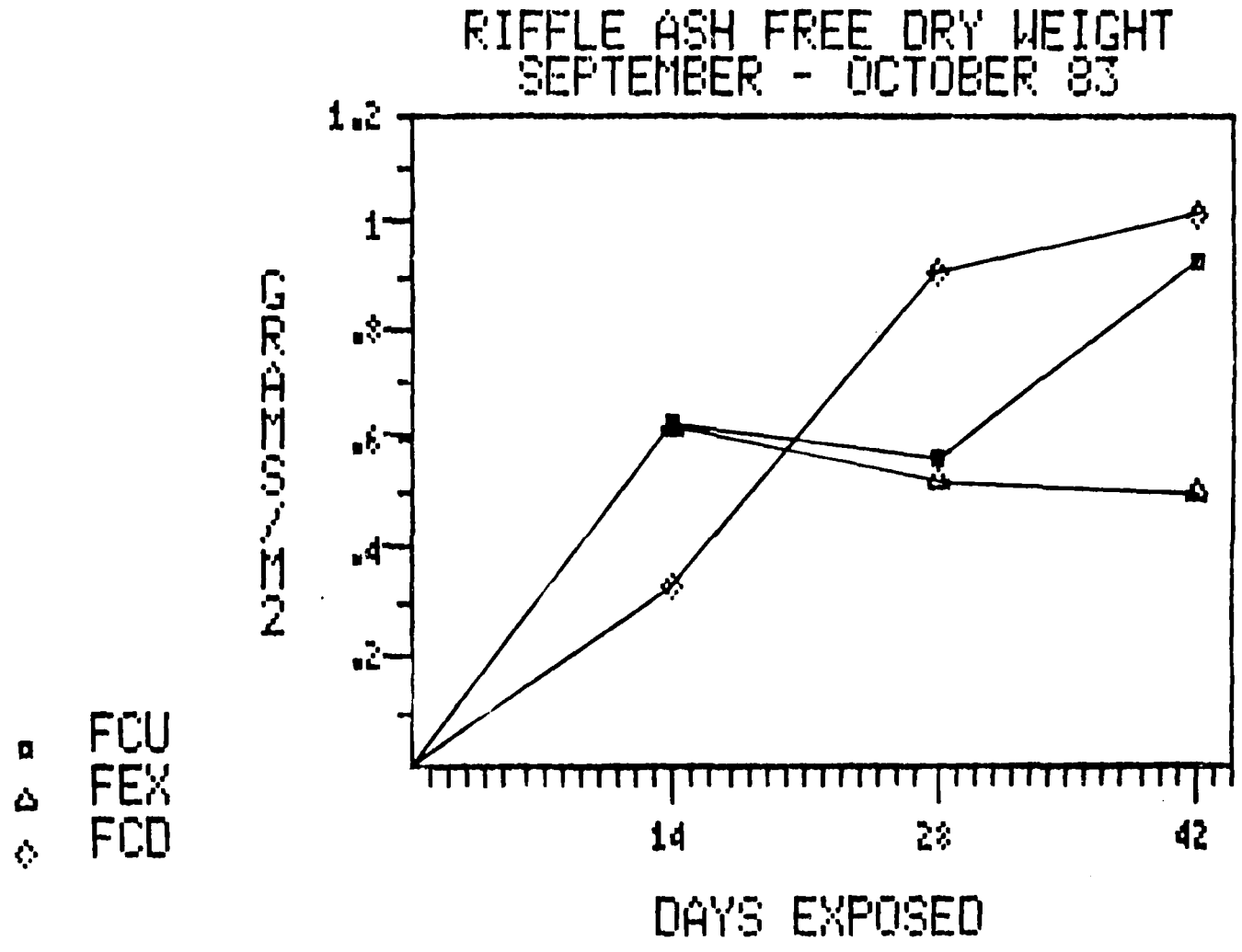

RIFFLE ASH FREE DRY WEIGHT
SEPTEMBER - OCTOBER 83
GM/SQ METER
1.2
1
.8
.6
.4
.2
14
28
42
DAYS EXPOSED
FCU
FEX
FCD

FIGURE 4.12

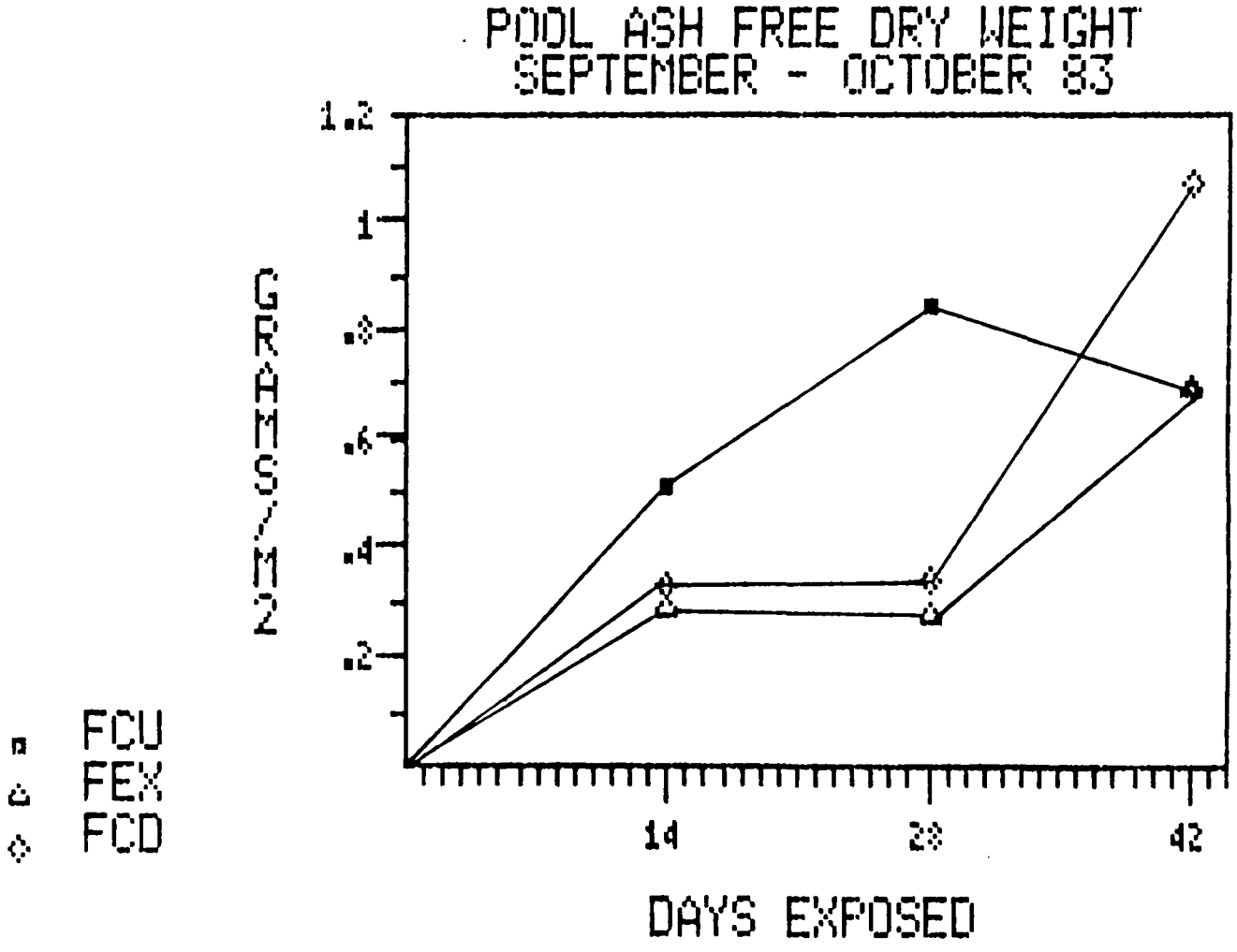

POOL ASH FREE DRY WEIGHT
SEPTEMBER - OCTOBER 83
GRAMS/M2
1.2
1
.8
.6
.4
.2
14
28
42
DAYS EXPOSED
FCU
FEX
FCD

FIGURE 4.13

While colonization patterns for chlorophyll a demonstrated a consistent, significantly higher rate of chlorophyll a accumulation for the upstream control site (FCU) compared to the experimental site (Figures 4.3, 4.4, 4.6, 4.7), this pattern of clear cut differences was not as apparent for biomass accumulation between sites (Figures 4.10-4.13). There was a tendency for FCU to have higher biomass accumulation rates especially during the summer (Figures 4.10, 4.11) but some crossover occurred for the 28 and 42 day samples in the Fall (Figures 4.12, 4.13). Even so, comparisons of means between sites for the 28 day exposure period for the entire growing season demonstrated that the biomass accumulation rate was significantly higher for the upstream control (FCU) compared to the corridor crossing or experimental site (FEX) while there was no significant difference between the downstream control (FCD) and the experimental site (FEX) (Table 4.6). On the basis of biomass accumulation differences between sites, we conclude that FCU should be eliminated as a potential control for the experimental site and that FCD is an acceptable control for FEX.

C. Phaeophytin a

Phaeophytin a is a degradation product of chlorophyll a. Analytical techniques for chlorophyll a must include determination of phaeophytin a for accuracy. The chlorophyll a to phaeophytin a ratio may also serve as an indicator of the physiological condition of the phytoplankton (American Public Health Assoc. 1980). We have calculated this ratio and find it to be highly variable, especially after 28 days (Figures 4.14-4.17). We question its value as an indicator of physiological condition of periphyton but will continue to report it as called for in the contract since we must determine it anyway as part of our chlorophyll a analyses.

TABLE 4.6: T-test Results From Comparisons of Pool and Riffle Mean Organic Matter Biomass (mg/m^2) for 28 Day Exposure Periods for Three Sites on the Ford River, May-October, 1983 ($\bar{x} \pm$ S.E.,N Indicated in Parentheses).

	FCU	FEX	Significance
Riffle	2030 ± 260(15)	957 ± 121(24)	*** p <0.001
Pool	1070 ± 87(16)	736 ± 94(24)	*** p <0.001
	FCD	FEX	
Riffle	1116 ± 142(22)	957 ± 121(23)	N.S. p > 0.2
Pool	757 ± 71(21)	736 ± 94(19)	N.S. p > 0.2

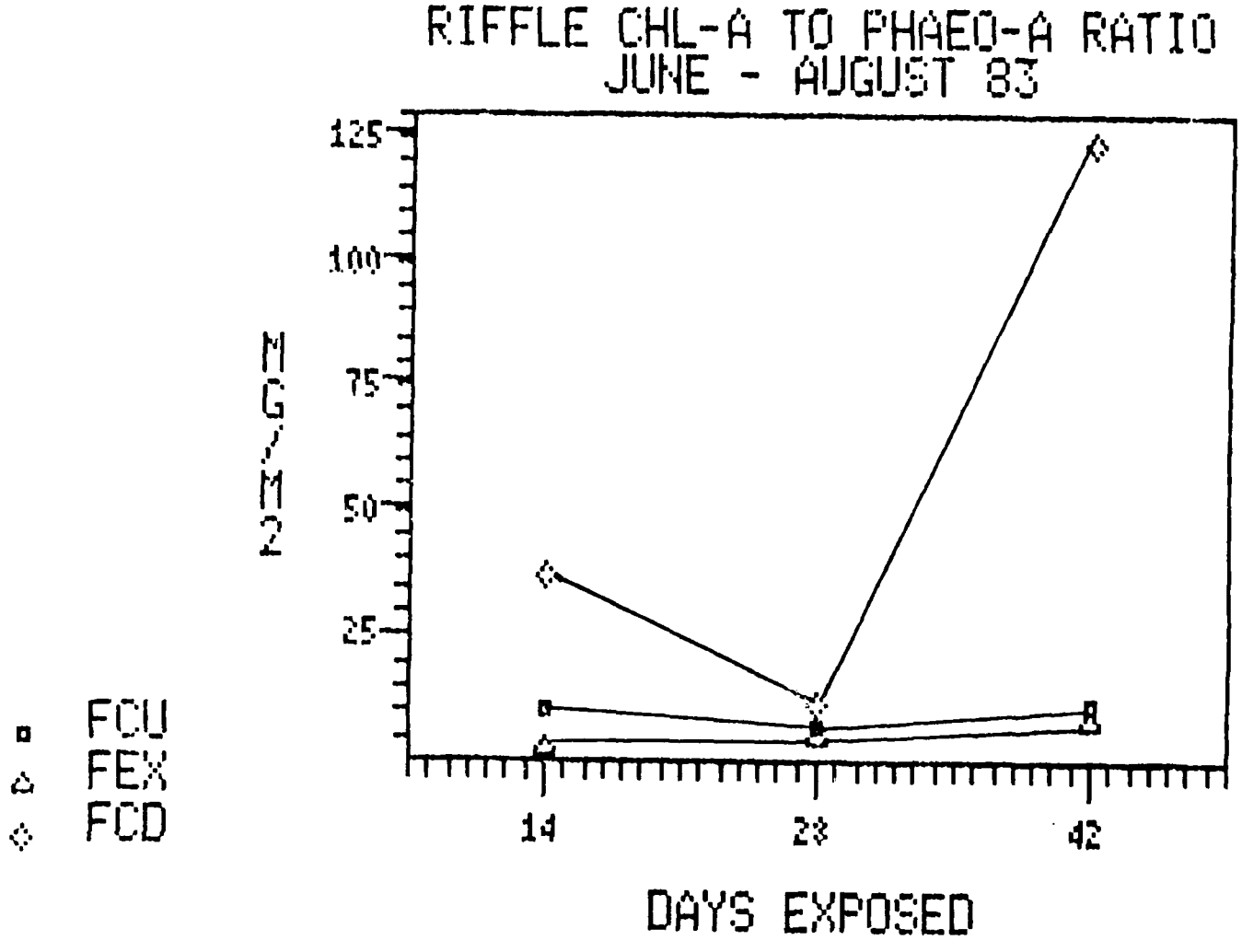

RIFFLE CHL-A TO PHAEO-A RATIO
JUNE - AUGUST 83
125
100
75
50
25
MG/M3
FCU
FEX
FCD
14
28
42
DAYS EXPOSED

FIGURE 4.14

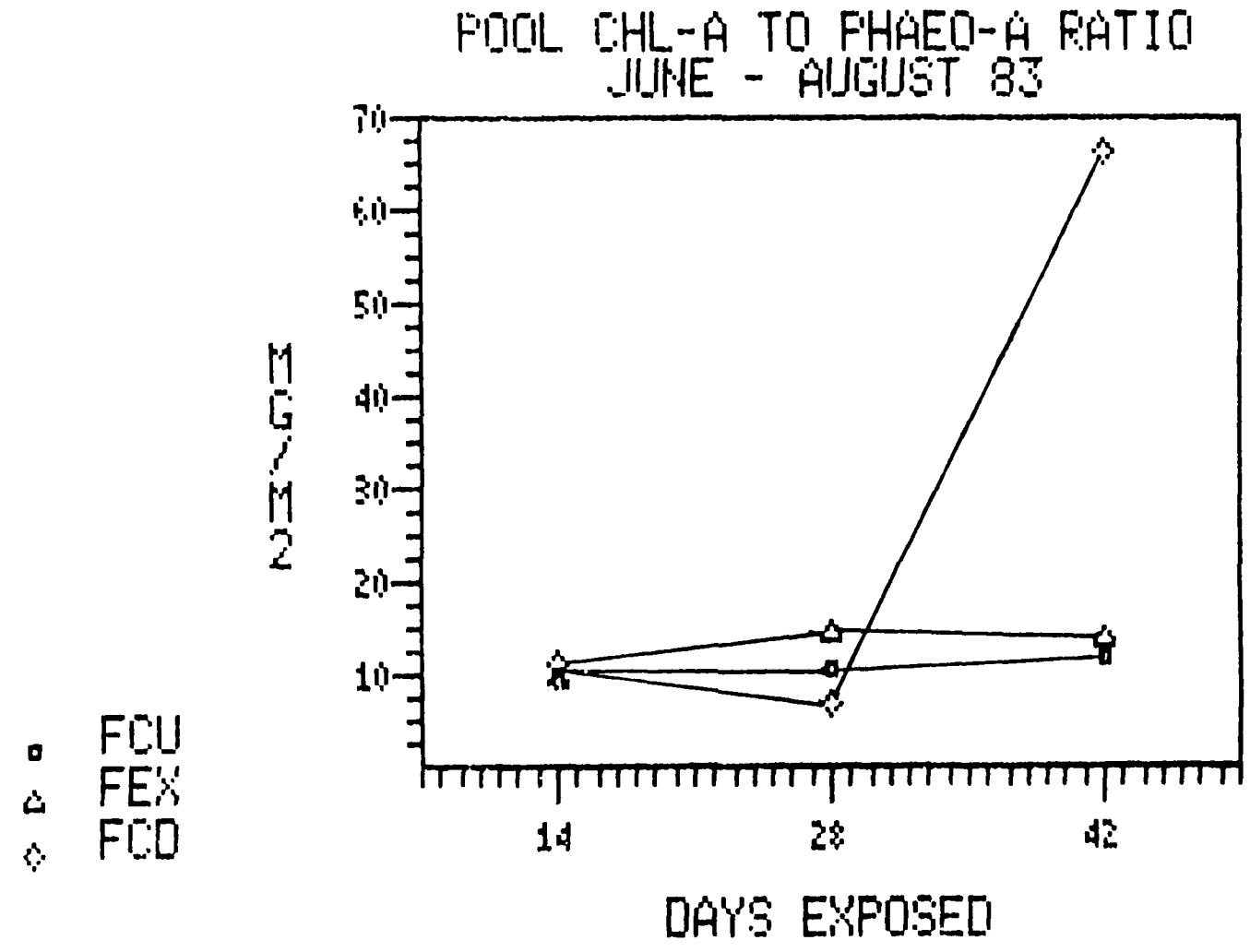

POOL CHL-A TO PHAEO-A RATIO
JUNE - AUGUST 83
70
60
50
40
30
20
10
MG/CM
FCU
FEX
FCD
14
28
42
DAYS EXPOSED

FIGURE 4.15

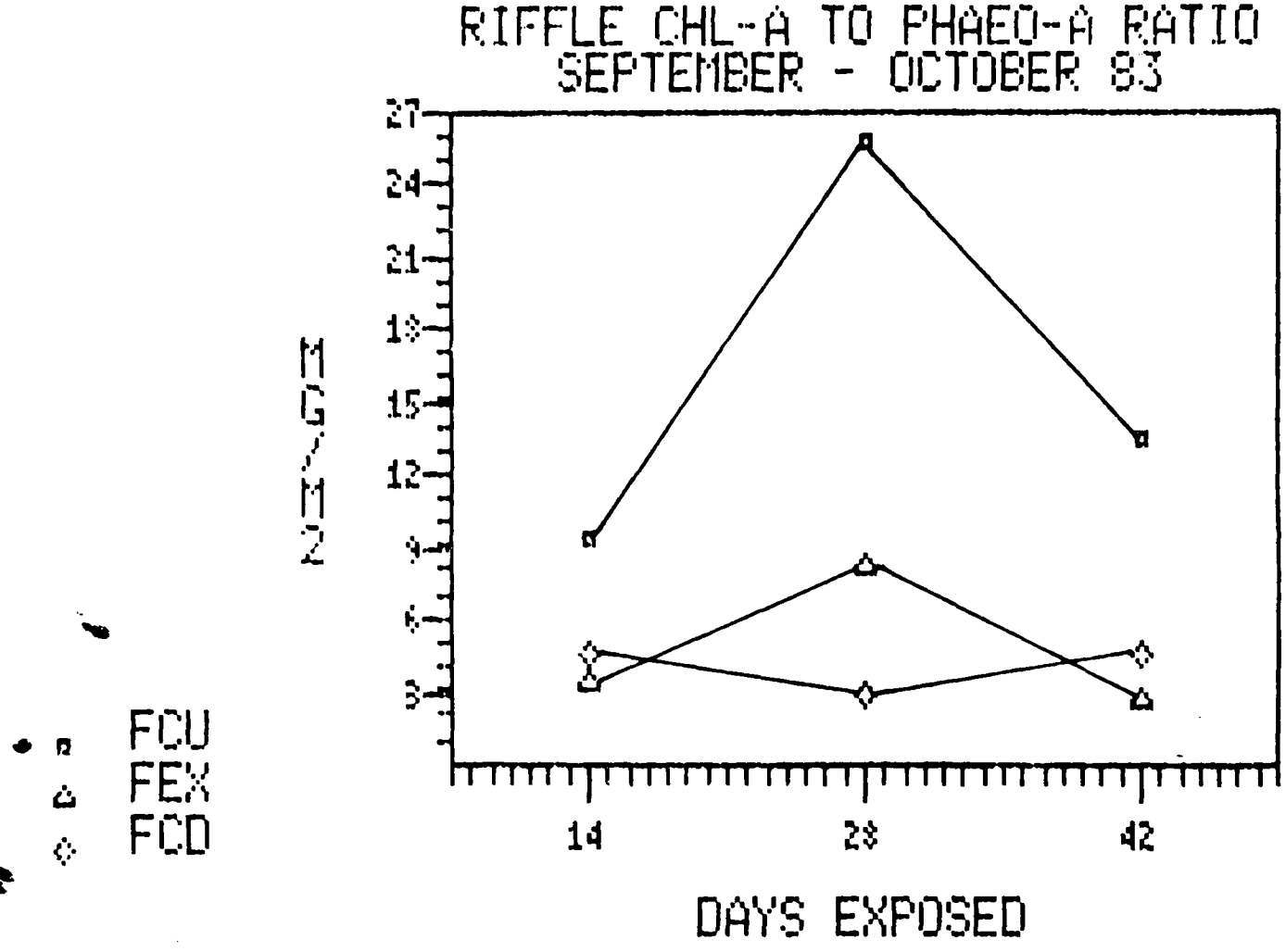

RIFFLE CHL-A TO PHAEO-A RATIO
SEPTEMBER - OCTOBER 83
MG/M
27
24
21
18
15
12
9
6
3
14
28
42
DAYS EXPOSED
FCU
FEX
FCD

FIGURE 4.16

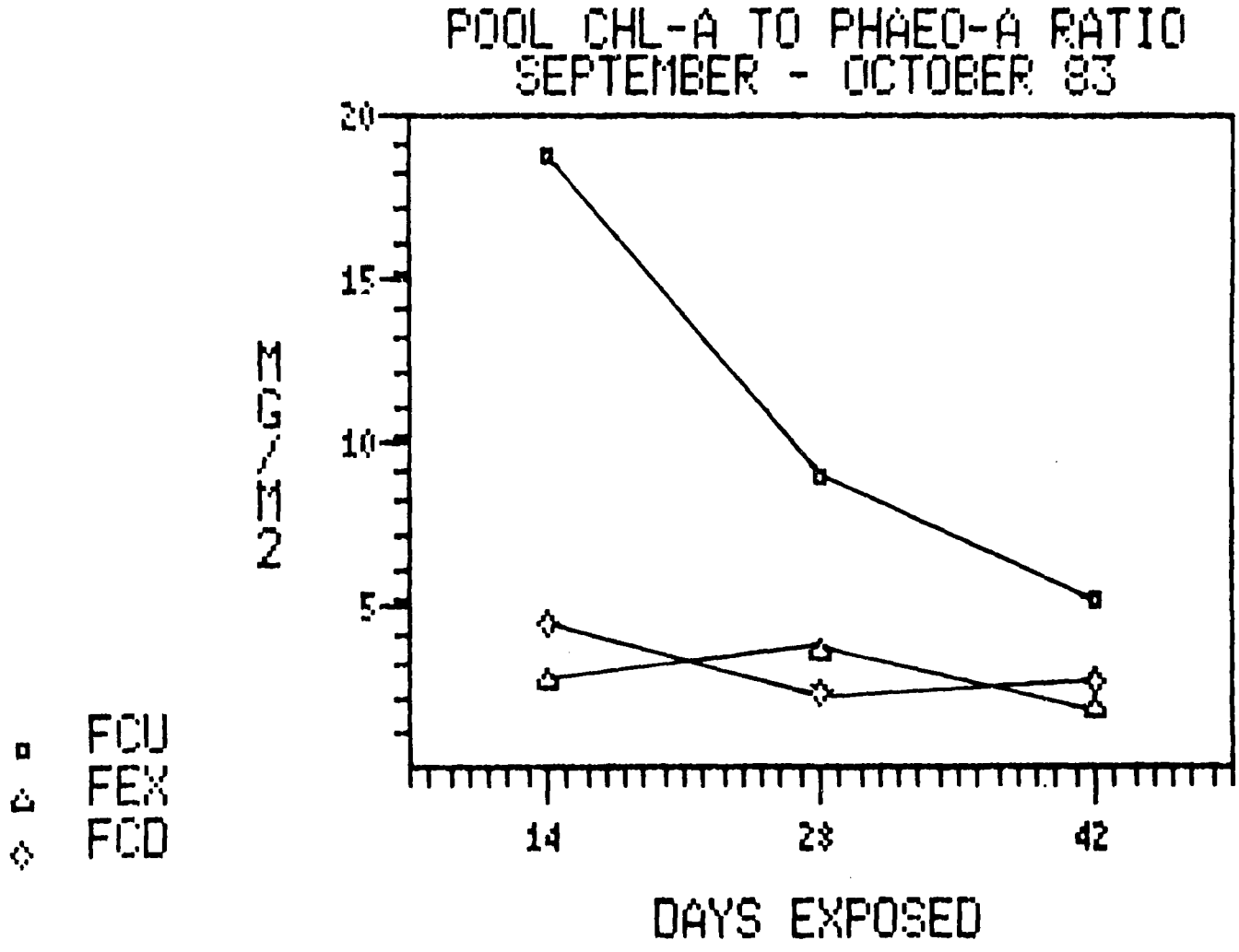

POOL CHL-A TO PHAEO-A RATIO
SEPTEMBER - OCTOBER 83
MG/CUM
20
15
10
5
14
28
42
DAYS EXPOSED
FCU
FEX
FCD

FIGURE 4.17

Inter-site T-test comparisons of the means of this ratio for 28 day exposure periods for the growing season suggest no significant differences ($p > 0.2$) between pool samples between FCU and FEX or between FEX and FCD. There was a significant difference ($p < 0.025$) between riffles for FCU and FEX and between riffles for FEX and FCD.

D. Species Composition - Dominance

A complete species list for the Ford River includes more than 300 taxa. Thus, it is very difficult to analyze differences between sites without using the more traditional community parameters such as diversity, evenness, species richness, etc. These parameters will be discussed below. We have also determined dominance for the more common species present. At present, we have completed these analyses from cell count data only for the Fall colonization period for Ford Site I for 1982. While this site was abandoned in 1983 after final ELF corridor selection proved it to be unsuitable, its position about two miles from FEX with no additional large tributaries between it and FEX suggest that data from this site may be useful in determining patterns of colonization for FEX (and hopefully FCD since chlorophyll a and biomass accumulation did not differ significantly between these two sites as discussed above).

From August to October, 1982, at Ford Site I, Cymbella and Amphora spp. showed an early dominance prior to day 4 in the pool and riffle areas (Figures 4.18, 4.19). Fragilaria and Synedra spp. accounted for 40-50% of the diatoms encountered in the riffle samples after day 4 and prior to a 17 day exposure period, yet remained less than 15% during the same period in the pool areas. Cocconeis spp. dominated the pool samples (>50%) by day 7 (Figure 4.18), while in the riffle area (Figure 4.19), these same species began to dominate (>22%) only after a 17 day exposure. From day 21 until day 42 the riffle and pool communities appeared to show nearly identical dominance patterns, with dominance increases by Cocconeis spp. and declining levels of Fragilaria and Synedra spp. as well as declining levels of Cymbella and Amphora spp. For the 42 day exposure period, little difference was observed between riffles and pools in major diatom species abundances.

The early colonizing species were not present in equal dominance in both riffle and pool habitats before day 21 yet thereafter showed similar abundances. Both pool and riffle habitats showed similar species dominances after a 21 day exposure period together with few shifts in major species abundances (Figures 4.18, 4.19).

From these data, we conclude that species dominance patterns are well established by day 21 and that a 28 day sampling regime will enable us to sample "mature" communities where species

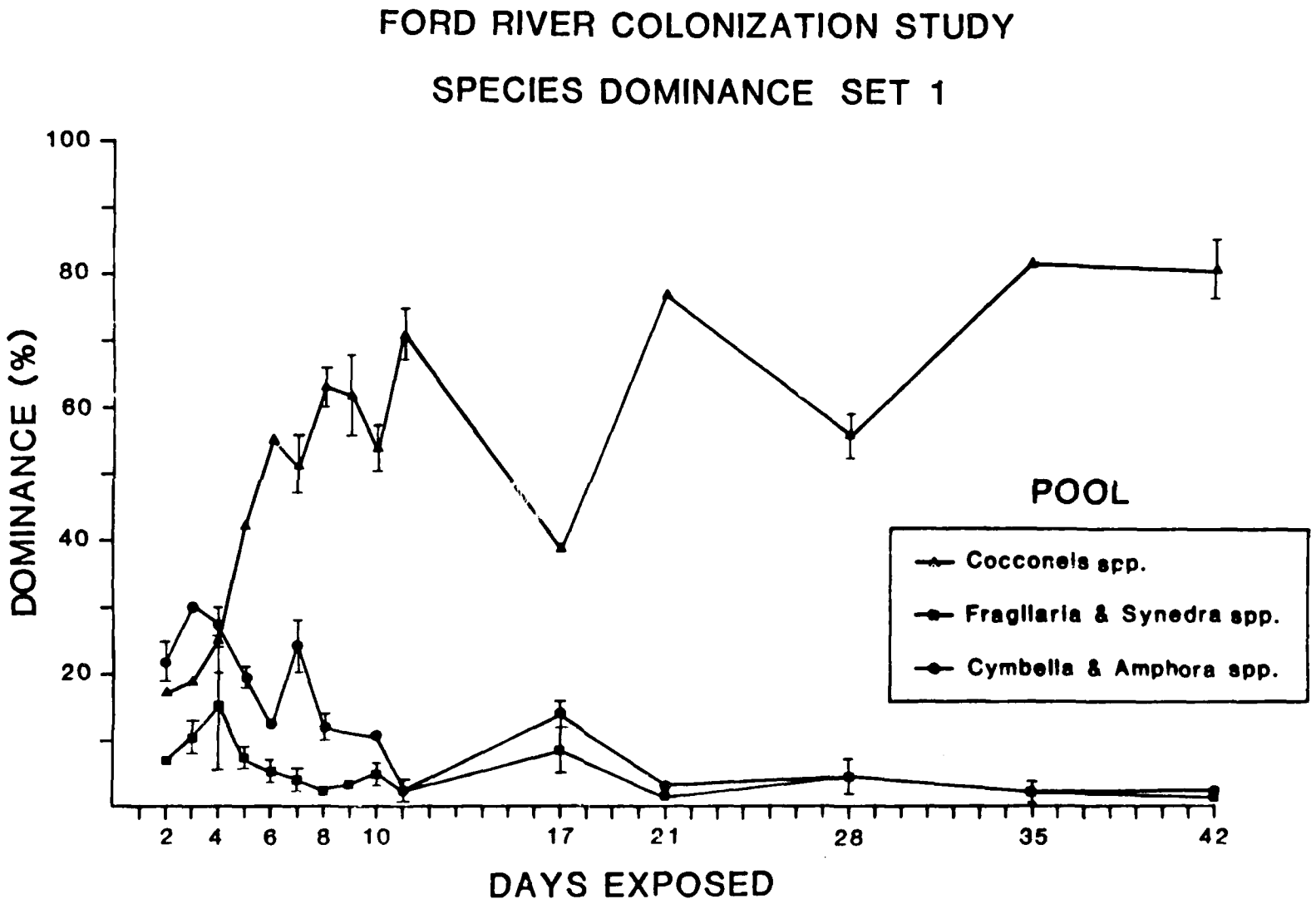

FORD RIVER COLONIZATION STUDY
SPECIES DOMINANCE SET 1
DOMINANCE (%)
100
80
60
40
20
2
4
6
8
10
17
21
28
35
42
DAYS EXPOSED
POOL
Cocconeis spp.
Fragilaria & Synedra spp.
Cymbella & Amphora spp.

FIGURE 4.18

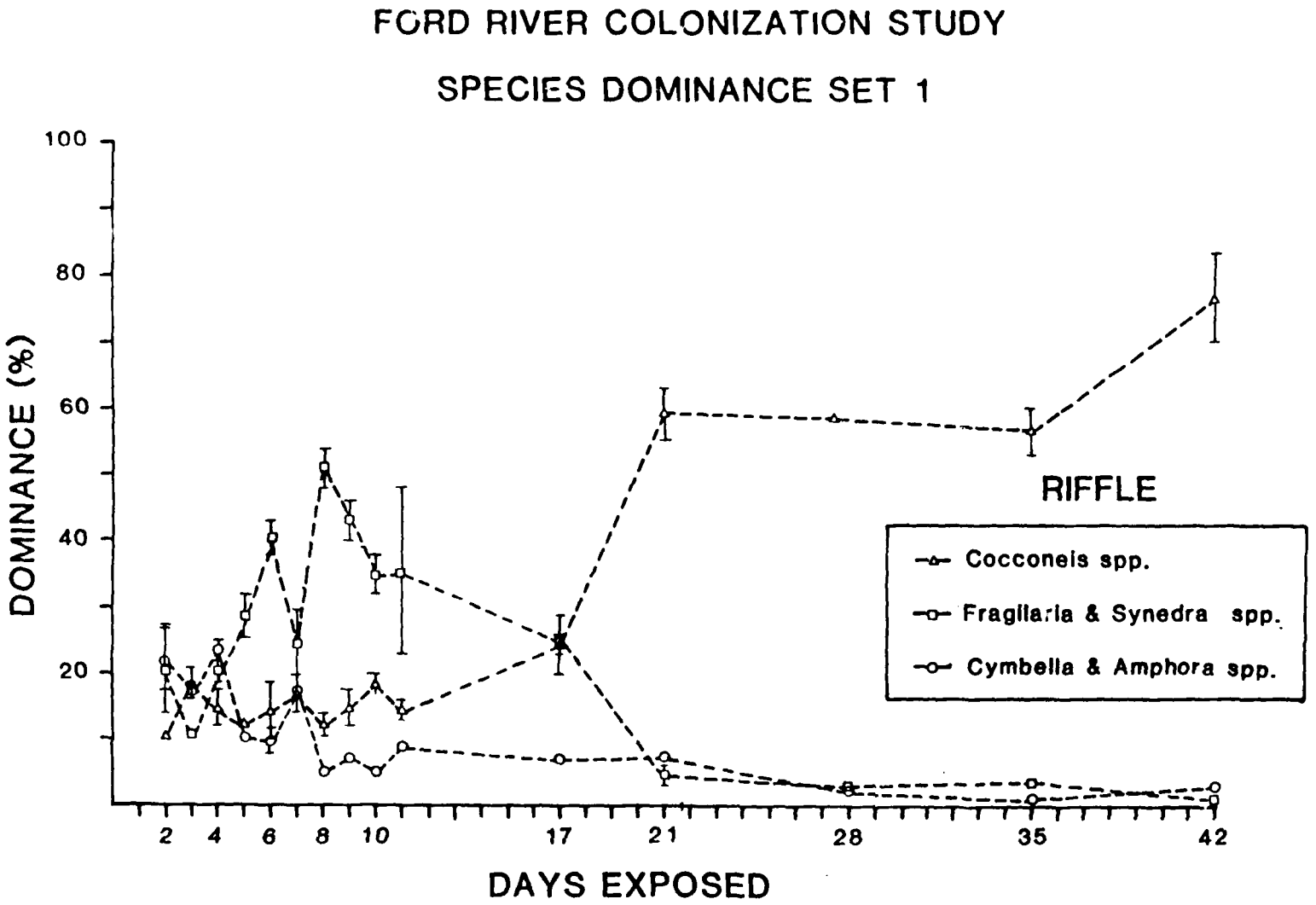

FORD RIVER COLONIZATION STUDY
SPECIES DOMINANCE SET 1
DOMINANCE (%)
100
80
60
40
20
2
4
6
8
10
17
21
28
35
42
DAYS EXPOSED
RIFFLE
Cocconeis spp.
Fragilaria & Synedra spp.
Cymbella & Amphora spp.

FIGURE 4.19

dominance is well established.

E. Species Composition - Evenness and Species Richness

The index of species evenness measures one aspect of species composition and distribution. A low evenness value indicates that only one or a few species dominate the sample even though many other rare species may be present. A high evenness value indicates shared dominance or at least near equal dominance by many of the species present. For example, one would expect higher evenness values early in colonization based on the dominance curves for Ford Site I (Figures 4.18, 4.19) but lower evenness values as Cocconeis spp. becomes more and more dominant after 21 days exposure.

For the three site comparison of the upstream control (FCU), experimental site (FEX) and downstream control (FCD) on the Ford River, the trend towards lower evenness as exposure time increases is apparent for all sites for the June 27-August 8, 1983 colonization period (Table 4.7, Figures 4.20, 4.21). This trend reflects the rapid fluctuations in species abundance that occur during early colonization followed by dominance by only a few species after day 21 (Figures 4.18, 4.19). Apparently, the same trend towards increased dominance with time described for Ford Site I from August to October, 1982, occurs for all seasons for all sites, with the possible exception of riffle samples at FCU (Table 4.7, Figure 4.21). In fact, evenness tends to be less for all sampling dates for FCU suggesting an earlier establishment of dominance at this site. This difference correlates well with the

TABLE 4-7: Diatom Species Evenness ($\bar{x} \pm$ S.E., n=2) for Pool and Riffle Samples From Three Sites on The Ford River

Date out of River	Days Exposure	FCU	FEX	FCD
			POOLS	
7/25/83	14	0.47 ± .02	0.74 ± .02	0.67 ± .03
7/25/83	28	0.39 ± .03	0.61 ± .01	0.60 ± .02
8/8/83	42	0.26 ± .05	0.52 ± .03	0.56 ± .04
			RIFFLES	
7/25/83	14	0.45 ± .01	0.85 ± .001	0.76 ± .01
7/25/83	28	0.39 ± .003	0.59 ± .005	0.64 ± .04
8/8/83	42	0.47 ± .01	0.52 ± .02	0.41 ± .02

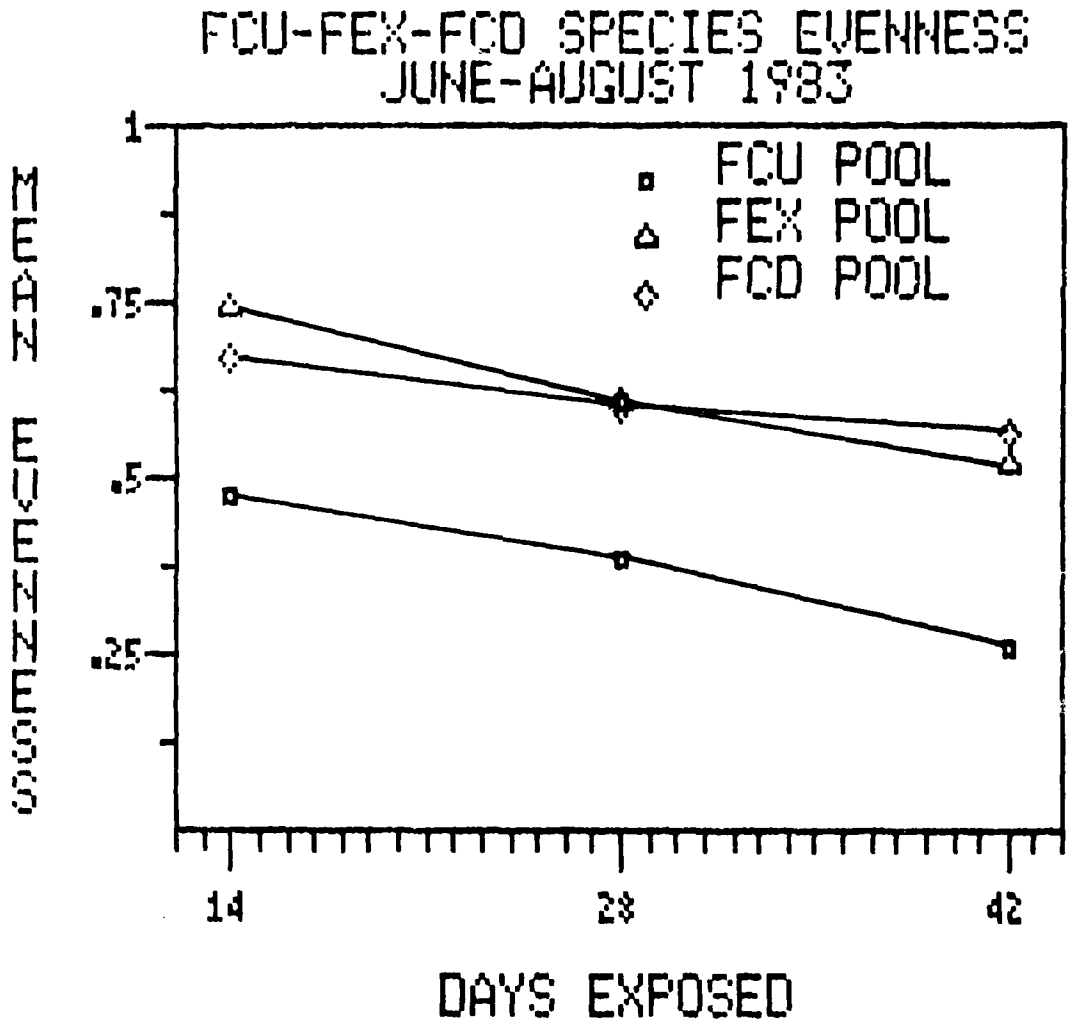

FCU-FEX-FCD SPECIES EVENNESS
JUNE-AUGUST 1983
1
.75
.5
.25
FCU POOL
FEX POOL
FCD POOL
14
28
42
DAYS EXPOSED

FIGURE 4.20

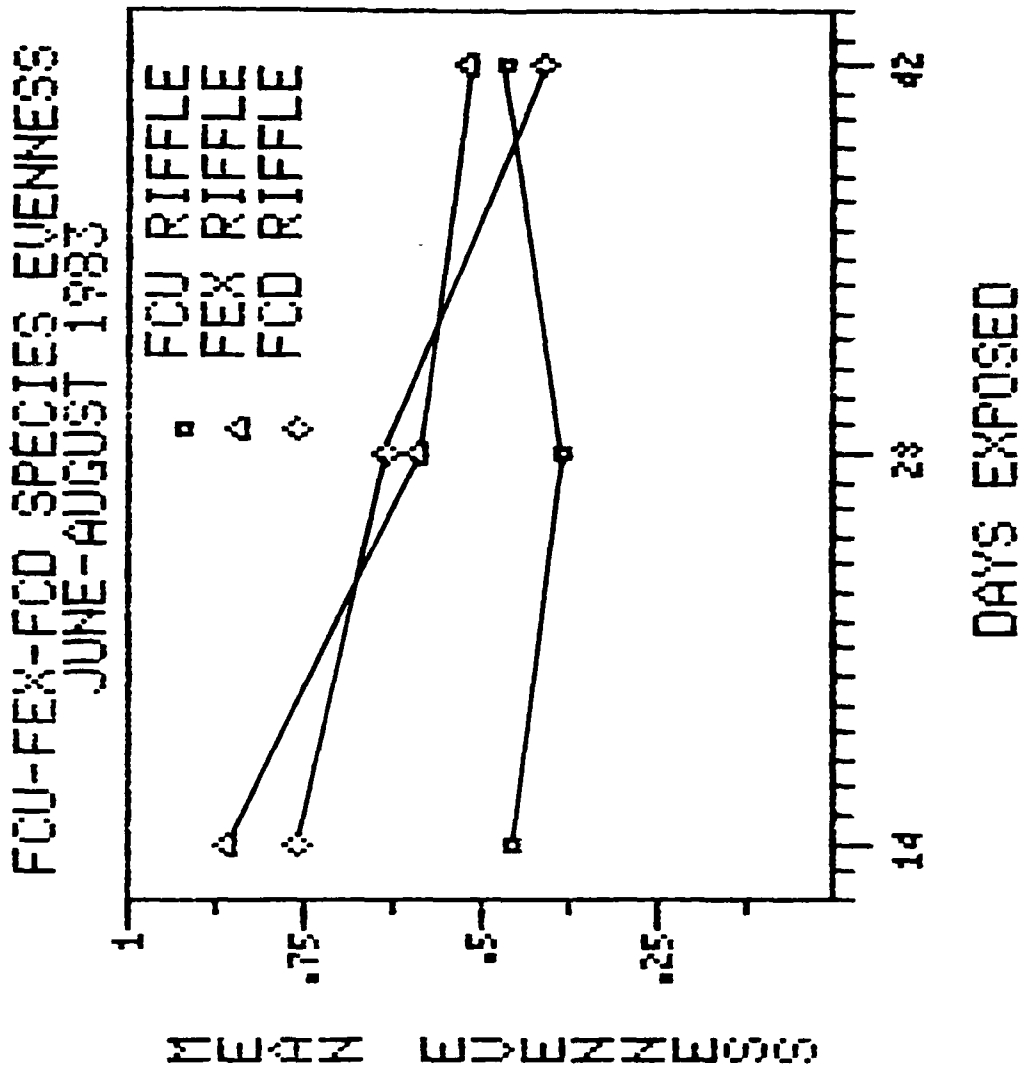

FCU-FEX-FCD SPECIES EVENNESS
JUNE-AUGUST 1983
FCU RIFFLE
FEX RIFFLE
FCD RIFFLE
1
.75
.5
.25
14
28
42
DAYS EXPOSED
SPECIES EVENNESS

FIGURE 4.21

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much greater rates of chlorophyll a and biomass accumulation for this site for the same period (Figure 4.3, 4.4, 4.10, 4.11).

A t-test comparison of the three sites (Table 4.8), show that evenness of both riffle and pool diatom samples from FCU are significantly different from FEX while there is no significant difference for FEX compared to FCD. This same trend was true for diversity which will be discussed in Section 4-G. Thus, based on the criterion of evenness, FCD is a reasonable control for FEX while FCU is not.

Species richness was also determined for the June 27-August 8, 1982 colonization period for all three sites (Table 4.9). Species richness was determined as the number of taxa encountered during counts of 300 diatom valves. There were generally fewer species present at FCU compared to FEX and FCD, particularly after 14 days exposure (Table 4.9). This trend suggested an early establishment of dominance at FCU compared to the other two sites and supported the evenness data which suggested the same trend.

Comparison of species richness between FCD and FEX show an early divergence for pools but a convergence in species richness between the two sites after 28 and 42 day exposures (Table 4.9). However, riffle data never converge with FCD riffle samples showing consistently lower species richness compared to FEX (Table 4.9). When plotted, the pattern of colonization for the two sites is parallel. We suggest that this difference reflects poor placement of FEX riffle slide racks in a shaded, backwater area and suspect that more attention to matching light and flow exposure of these slide racks will lead to convergence of species richness data. We are including more attention to exact matching of environmental parameters in our sampling design next year.

F. Diatom Density

Out most extensive study of colonization patterns for the Ford River to date was the August-October, 1982, study at Ford Site I already discussed in terms of diatom dominance (See Section 4-D). The density of diatoms in pools increased from a low of 1.12×10^7 cells/m^2 after a 4 day exposure in September to a maximum of 3.74×10^9 cells/m^2 after 56 days exposure in October (Figure 4.22). In the riffle habitat, density increased from a low of 3.93×10^6 cells/m^2 after 2 days exposure to 3.27×10^9 cells/m^2 after 49 days exposure in October (Figure 4.23).

TABLE 4.8: T-Test Results From Comparisons of Pool and Riffle Mean Species Diversity and Mean Species Evenness For Three Sites on the Ford River, June-August, 1983.
($\bar{x} \pm$ S.E., n=6)

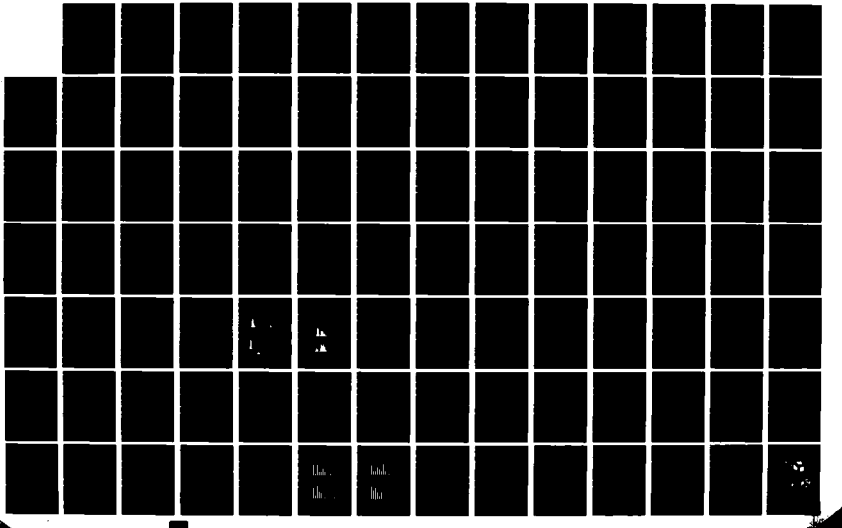
	SPECIES DIVERSITY			
	FCU	FEX	SIGNIFICANCE	
Riffle	1.76 ± .10	3.45 ± .48	* *	p<0.01
Pool	1.29 ± .16	2.96 ± .31	* * *	p<0.001
	FCD	FEX		
Riffle	2.71 ± .47	3.45 ± .48	N.S.	p>0.2
Pool	2.61 ± .12	2.96 ± .31	N.S.	p>0.2
	SPECIES EVENNESS			
	FCU	FEX	SIGNIFCANCE	
Riffle	0.44 ± .02	0.65 ± .07	* *	p<0.01
Pool	0.37 ± .04	0.62 ± .04	* *	p<0.01
	FCD	FEX		
Riffle	0.60 ± .07	0.65 ± .07	N.S.	p>0.5
Pool	0.61 ± .02	0.62 ± .04	N.S.	p>0.5

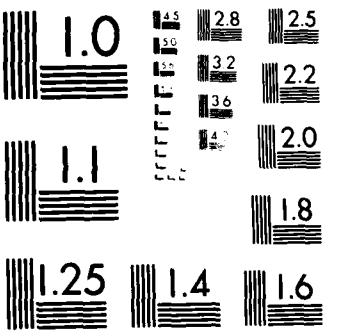
TABLE 4.9: Diatom Species Richness (Number Taxa Present in a Count of 300 Valves) and Total Number of Diatoms Enumerated in Pool and Riffle Samples for Three Sites on the Ford River.

Date out of River	Days Exposure	FCU	FEX	FCD
		POOLS		
7/25/83	14	10.7 - 645	35.1 - 658	18.3 - 606
7/25/83	28	10.2 - 615	16.5 - 655	21.4 - 645
8/8/83	42	8.5 - 708	18.5 - 797	17.1 - 596
		RIFFLES		
7/25/83	14	11 - 675	43.7 - 729	30.9 - 700
7/25/83	28	15.2 - 730	27.5 - 741	18.3 - 558
8/8/83	42	17.6 - 699	19.7 - 702	7.9 - 831

AD-A148 327 COMPILATION OF ANNUAL REPORTS OF THE NAVY ELF (EXTREMELY LOW FREQUENCY) C..(U) IIT RESEARCH INST CHICAGO IL R L FISCHER ET AL. JUL 84 4/6

UNCLASSIFIED IITRI-E06549-8-VOL-2 N00039-84-C-0070 F/G 6/6 NL





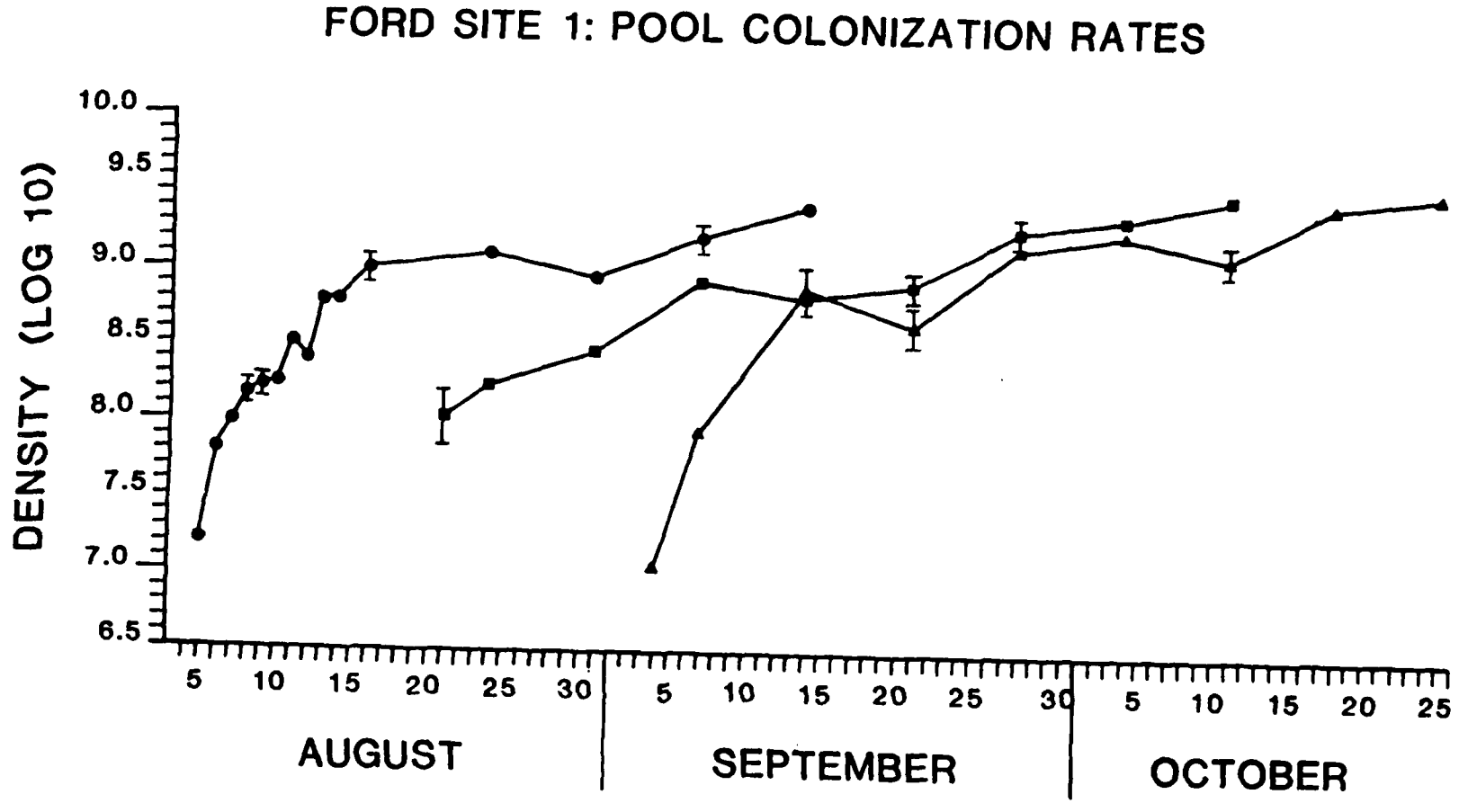

FORD SITE 1: POOL COLONIZATION RATES
DENSITY (LOG 10)
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
5 10 15 20 25 30
5 10 15 20 25 30
5 10 15 20 25
AUGUST
SEPTEMBER
OCTOBER

FIGURE 4.22

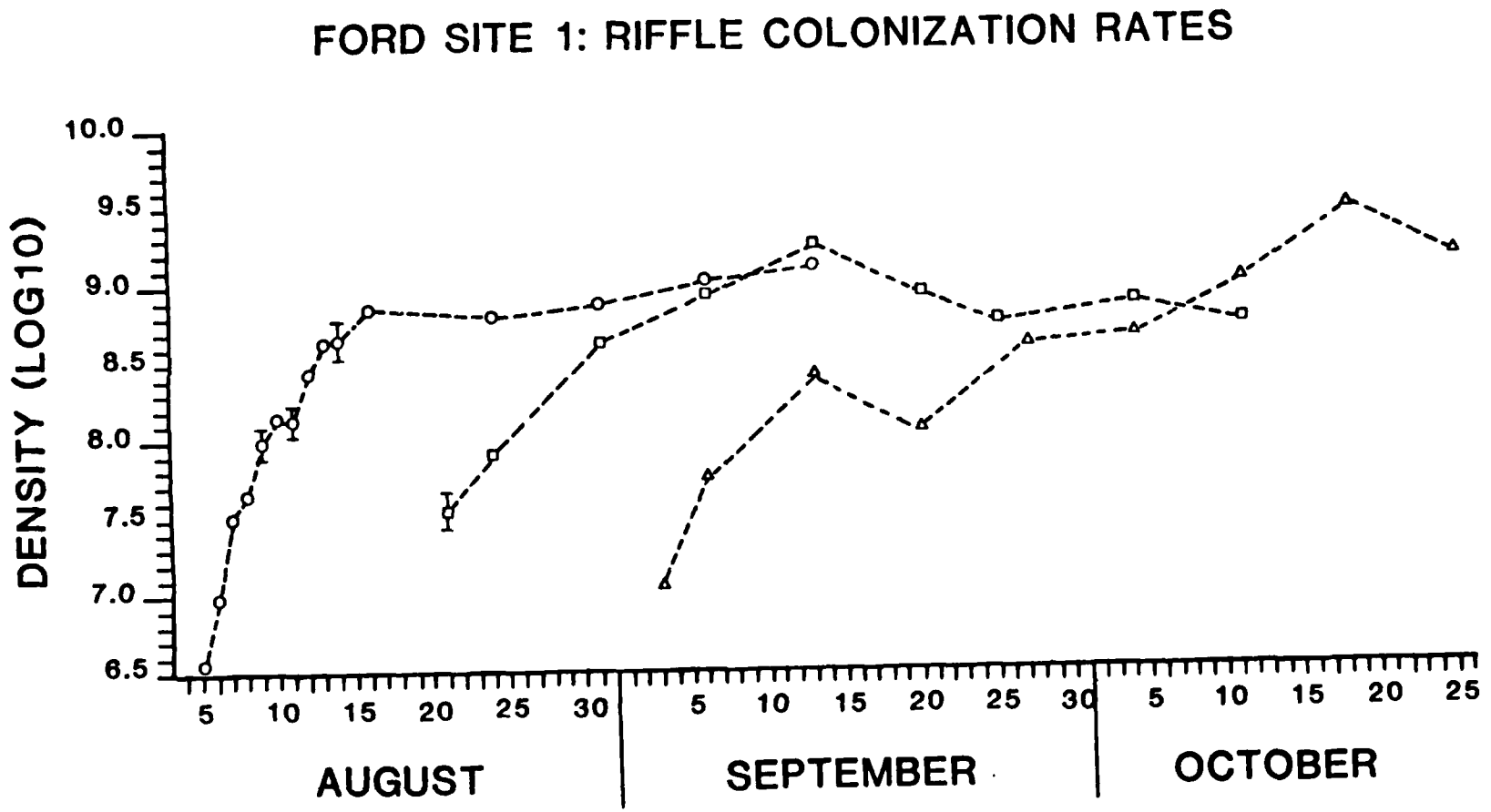

FORD SITE 1: RIFFLE COLONIZATION RATES
DENSITY (LOG10)
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
5
10
15
20
25
30
5
10
15
20
25
30
5
10
15
20
25
AUGUST
SEPTEMBER
OCTOBER

FIGURE 4.23

Each colonization curve for pool and riffle (Figures 4.22, 4.23) indicated a rapid accumulation or growth of cells which appeared to plateau by day 21 or day 28. This plateau affect suggested that perhaps major changes in diatom cell density are unlikely if routine sampling follows a 28 day monitoring cycle. Table 4.10 shows the mean densities for each sampling date and the corresponding exposure period for the complete study.

A t-test on the riffle and pool mean densities showed no significant difference between the mean number of diatoms/m^2 in the riffle and pool ($p>0.2$). A simple analysis of variance also showed no significant difference between pool and riffle cell densities ($p>0.25$).

Schwartz Creek, a 3rd order stream, was originally studied as a potential control site. In the Fall of 1982, three colonization studies were run in pool and riffle habitats to parallel the similar study discussed above for the Ford River. Densities recorded were lower than those recorded for the Ford River study, ranging from $1.05 \times 10^8 - 7.04 \times 10^8$ cells/m^2 in the pools to $3.44 \times 10^7 - 9.03 \times 10^8$ cells/m^2 in the riffles (Table 4.11).

Inter-site comparison studies of changes in cell densities for the upstream control (FCU), the experimental site near the ELF corridor (FEX), and the downstream control site (FCD) on the Ford River were conducted for the June 27-August 8 colonization period (Table 4.12, Figures 4.24, 4.25). Trends were similar to the August-October, 1982, data for Ford Site I (Figures 4.22, 4.23) in that rapid increases in density occurred during the first 14 days for all sites followed by a flattening or decline in the rate of cell density increases thereafter (Figure 4.24, 4.25). In fact, the shape of the curve is remarkably similar to the chlorophyll a accumumation curves for the same period (Figures 4.3, 4.4) as one might expect. A sample of cell density taken after 21-28 day exposure periods should certainly represent a time when cell densities are at or near their peak.

The cell densities at the upstream control were significantly greater than densities at the experimental site (FEX), while there was no significant difference in cell densities between FEX and the downstream control site (FCD) (Table 4.13). Thus, on the basis of cell density data, FCU is not a suitable control for FEX while FCD is. Cell densities at FEX ranged from a low of 3.28×10^8 to a maximum of 3.59×10^9 cells/m^2 compared to a low of 2.98×10^9 and a maximum of 8.93×10^9 cells/m^2 at FCU.

TABLE 4.10: Log of Diatom Densities for Pool and Riffle Samples From Three Overlapping Exposure Periods 8-5-82 to 9-14-82 (Set 1), 8-21-82 to 10-12-82 (Set 2) and 9-4-82 to 10-26-82 (Set 3) ($\bar{x} \pm$ S.E., n=2).

Date out	Days Exposure	POOL	RIFFLE
		Set 1	
8/5/82	2	7.7222 ± .0481	6.5998 ± .0102
8/6/82	3	7.8347 ± .0111	7.0995 ± .0072
8/7/82	4	8.0683 ± .0373	7.5111 ± .0574
8/8/82	5	8.1842 ± .0829	7.6593 ± .0385
8/9/82	6	8.2346 ± .0891	8.0346 ± .0963
8/10/82	7	8.2465 ± .0452	8.1634 ± .0125
8/11/82	8	8.5127 ± .0107	8.1325 ± .0833
8/12/82	9	8.4294 ± .0233	8.4253 ± .0110
8/13/82	10	8.8046 ± .0210	8.6404 ± .0395
8/14/82	11	8.8039 ± .0293	8.6637 ± .1334
8/16/82	17	9.0791 ± .0819	8.8704 ± .0004
8/24/82	21	9.1110 ± .0035	8.8072 ± .0636
8/31/82	28	8.9538 ± .0386	8.8925 ± .0290
9/7/82	35	9.2211 ± .0996	9.0191 ± .0105
9/14/82	42	9.4311 ± .0372	9.1169 ± .0128
		Set 2	
8/21/82	4	8.0322 ± .1834	7.5245 ± .1090
8/24/82	7	8.2594 ± .0292	7.9012 ± .0087
8/31/82	14	8.4810 ± .0055	8.6355 ± .0304
9/7/82	21	8.9426 ± .0557	8.9190 ± .0214
9/14/82	28	8.8211 ± .0089	9.2511 ± .0571
9/21/82	35	8.9269 ± .0867	8.9389 ± .0329
9/28/82	42	9.2929 ± .0858	8.7724 ± .0099
10/5/82	49	9.3911 ± .0154	8.8836 ± .0224
10/12/82	56	9.5293 ± .0402	8.7217 ± .0315
		Set 3	
9/4/82	4	7.0553 ± .0078	7.0790 ± .0292
9/7/82	7	7.9487 ± .0200	7.7443 ± .0078
9/14/82	14	8.8982 ± .1551	8.4151 ± .0170
9/21/82	21	8.6420 ± .1197	8.0960 ± .0215
9/28/82	28	9.1823 ± .0402	8.6047 ± .0733
10/5/82	35	9.2939 ± .0401	8.6976 ± .0519
10/12/82	42	9.1218 ± .0901	9.0234 ± .0164
10/19/82	49	9.4918 ± .0375	9.4976 ± .0167
10/26/82	56	9.5688 ± .0036	9.1885 ± .0269

TABLE 4.11: Diatom Densities for Pool and Riffle Samples Collected From Schwartz Creek From 8-24-82 to 10-6-82. ($\bar{x}$ numbers/m^2 + S.D., n=2) and Average Number of Taxa Identified for Each Sample.

Date out	Days Exposed	POOL	#Taxa	RIFFLE	#Taxa
		Set 1			
8/31/82	8	$1.7065 \pm .87 \times 10^8$	22	$1.3987 \pm .07 \times 10^8$	25.5
9/4/82	12	$1.4443 \pm .23 \times 10^8$	34	$1.7778 \pm .19 \times 10^8$	35.5
9/8/82	16	$3.4002 \pm .06 \times 10^8$	34	$4.9424 \pm .98 \times 10^8$	36.5
9/12/82	20	$3.3424 \pm .10 \times 10^8$	36	$4.1697 \pm$ — $\times 10^8$	39
		Set 2			
9/12/82	8	$1.9369 \pm .19 \times 10^8$	48	$4.2507 \pm .80 \times 10^8$	41.5
9/16/82	12	$3.0063 \pm .70 \times 19^8$	41	$7.0595 \pm .36 \times 10^8$	40
9/20/82	16	$1.7144 \pm .17 \times 10^8$	29.5	$3.9332 \pm .32 \times 10^8$	34.5
9/24/82	20	$7.0438 \pm .07 \times 10^8$	46	$4.3679 \pm .08 \times 10^8$	40
		Set 3			
9/24/82	8	$1.6609 \pm .35 \times 10^8$	19.5	$3.4351 \pm .44 \times 10^7$	23.5
9/28/82	12	$7.3379 \pm 2.40 \times 10^7$	42.5	$2.4404 \pm .12 \times 10^8$	33.5
10/2/82	16	$1.0524 \pm .10 \times 10^8$	39.5	$5.0610 \pm .03 \times 10^8$	36.5
10/6/82	20	$1.9310 \pm .72 \times 10^8$	40.5	$9.0324 \pm .82 \times 10^8$	30.5

TABLE 4-12: Diatom Cell Density ($\bar{x}$ $\log_{10}$ number/m^2 $\pm$ S.E., n=2) For Pool and Riffle Samples From Three Sites on the Ford River.

Date Out	Days Exposed	FCU	FEX	FCD
		POOLS		
7/25/83	14	9.5085 $\pm$ .0432	8.6642 $\pm$ .1159	9.3515 $\pm$ .0187
7/25/83	28	9.4912 $\pm$ .0237	9.3782 $\pm$ .0068	9.1375 $\pm$ .0582
8/8/83	42	9.6633 $\pm$ .1416	9.2252 $\pm$ .0394	9.5033 $\pm$ .0129
		RIFFLES		
7/25/83	14	9.5922 $\pm$ .0025	8.7031 $\pm$ .1431	9.1918 $\pm$ .0351
7/25/83	28	9.7105 $\pm$ .1350	9.0217 $\pm$ .0141	9.4044 $\pm$ .0313
8/8/83	42	9.7693 $\pm$ .2569	9.4774 $\pm$ .0978	9.4108 $\pm$ .1077

TABLE 4-13: T-tests of Mean $\log_{10}$ Diatom Cell Density For Three Sites on the Ford River. June-August, 1983 ($\bar{x} \pm$ S.E., n=6)

	FCU	FEX	SIGNIFICANCE
Riffle	9.6907 ± .0624	9.0674 ± .1456	* * p<.01
Pool	9.5543 ± .0441	9.0892 ± .1391	* * p<.01
	FCD	FEX	SIGNIFICANCE
Riffle	9.3357 ± .0503	9.0674 ± .1456	N.S. p>0.1
Pool	9.3308 ± .0681	9.0892 ± .1391	N.S. p>0.1

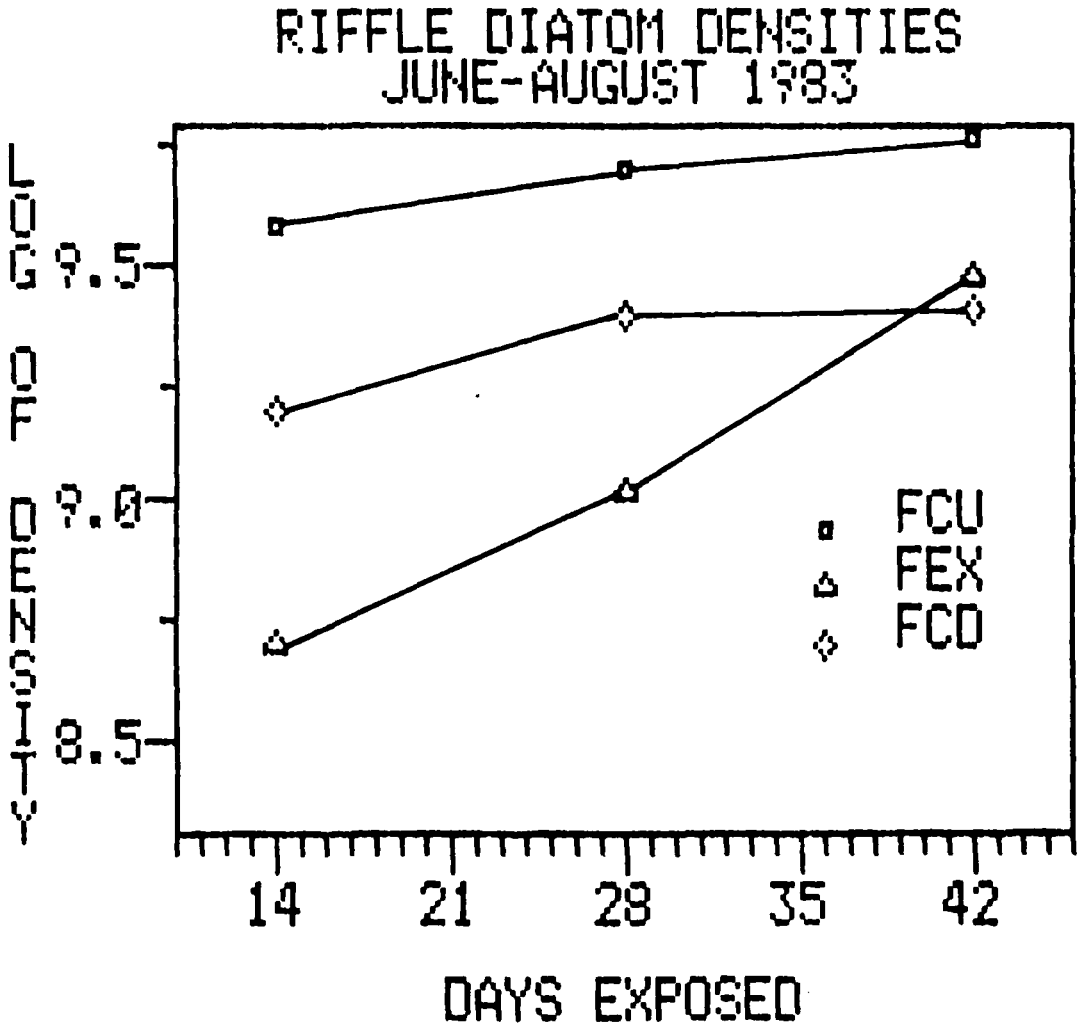

RIFFLE DIATOM DENSITIES
JUNE-AUGUST 1983
LOG OF DENSITY
9.5
9.0
8.5
14
21
28
35
42
DAYS EXPOSED
FCU
FEX
FCD

FIGURE 4.24

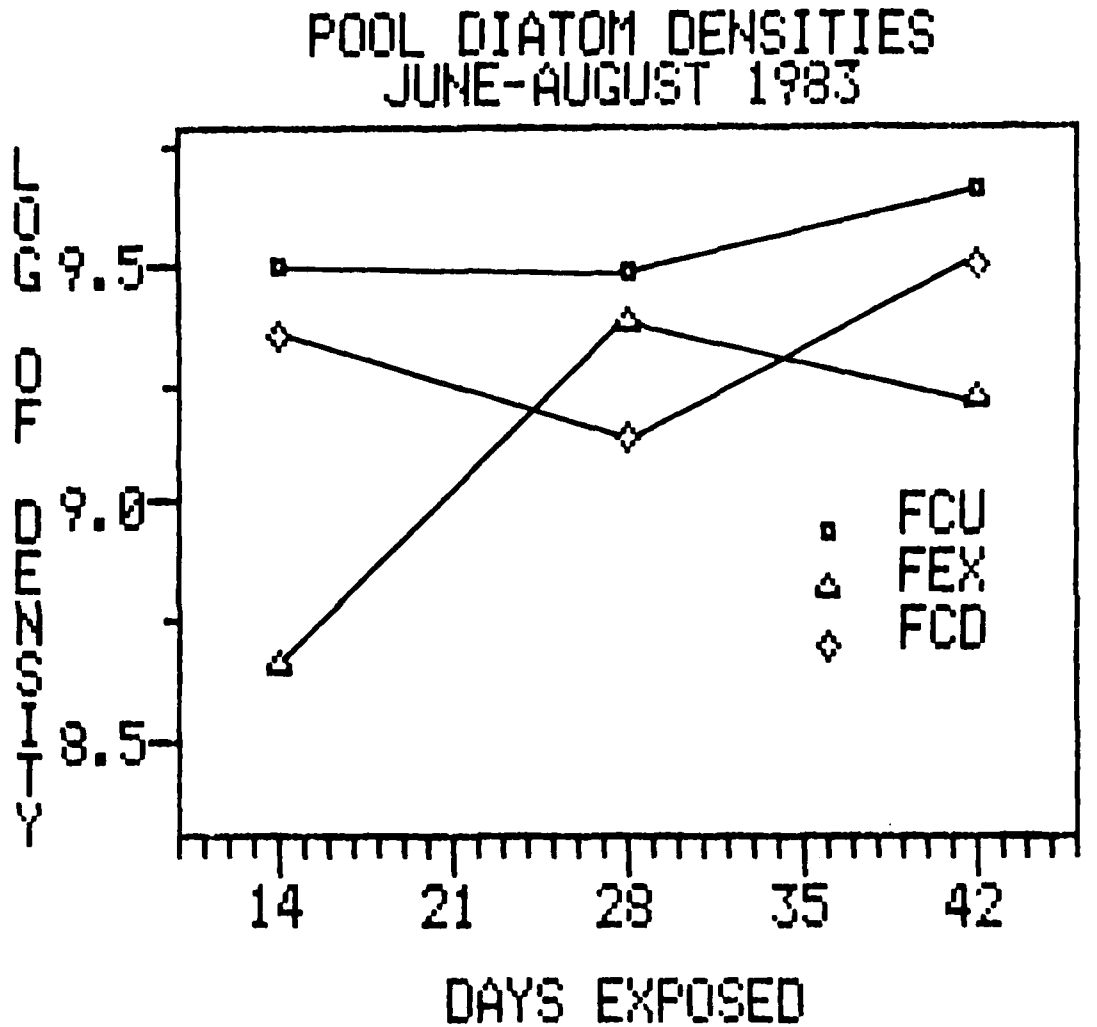

POOL DIATOM DENSITIES
JUNE-AUGUST 1983
LOG OF DENSITY
9.5
9.0
8.5
14
21
28
35
42
DAYS EXPOSED
FCU
FEX
FCD

FIGURE 4.25

G. Species Diversity

The August-September, 1982, study of colonization patterns for Ford Site I (Table 4.14, Figures 4.26, 4.27) showed that species diversity was at its maximum in the first few days of colonization. This early maximum reflected lack of dominance by any particular species early in succession (See Section 4-D) and paralleled trends in evenness (Table 4.14) and species richness (See Section 4-E). Decreases in diversity continued throughout the 42 day study for riffles (Figure 4.27) but tended to vacillate around a mean of 2.5 to 3.5 after day 11 for pools (Figure 4.26, Table 4.14) with perhaps a slight tendency towards decreasing diversity throughout the 42 day exposure period (Figure 4.26). In fact, t-test comparisons of pool and riffles for both diversity and evenness demonstrated that there was no significant difference between pool and riffles for either parameter (Table 4.15).

The comparison of diversity changes during colonization for the upstream control FCU), the experimental site (FEX), and the downstream control (FCD) revealed that most diversity changes had probably already occurred by the time the first 14 day sample was taken for the June 27-August 8, 1983, study (Table 4.16, Figures 4.28, 4.29). Even so, diversity continued to drop throughout the 42 day exposure period for both the FEX and FCD sites, especially for the riffle habitats (Table 4.16, Figures 4.28, 4.29).

There were marked differences in diversity between the upstream control site (FCU) and both of the downstream sites (FEX, FCD) (Figure 4.28, 4.29) with lower diversity characteristic of FCU during at lest the first 28 days of colonization. The results of t-test comparisons (Table 4.8) showed that there were significant differences between mean species diversity for FCU and FEX sites for both pool ($p<0.001$) and riffle ($p<0.01$) habitats. Mean species diversity was not significantly different, however between FEX and FCD pool and riffle sites ($p>0.2$). On the basis of diversity as the criterion, FCU is not a reasonable control for FEX while FCD is.

H. Conclusions

On the basis of all criteria examined, we conclude the following:

(1) A 28 day sampling period represents a reasonable sampling regime for species composition, dominance, diversity, evenness, richness, and density to achieve our goal of sampling a "mature" community characteristic of rock substrates in the river.

TABLE 4.14: Species Diversity and Evenness for Set 1 Colonization Study Pool and Riffle Samples for Ford Site I ($\bar{x} \pm$ S.E., n=2).

Date Out	Days Exposed	DIVERSITY	EVENNESS
		POOL	
8/5/82	2	4.52 ± .05	.84 ± .01
8/6/82	3	4.12 ± .08	.79 ± .02
8/7/82	4	4.24 ± .09	.84 ± .02
8/8/82	5	3.72 ± .01	.75 ± .01
8/9/82	6	3.24 ± .13	.69 ± .01
8/10/82	7	3.23 ± .03	.68 ± .01
8/11/82	8	2.72 ± .03	.65 ± .01
8/12/82	9	2.70 ± .20	.64 ± .04
8/13/82	10	3.06 ± .06	.72 ± .02
8/14/82	11	2.46 ± .17	.65 ± .03
8/16/82	17	3.70 ± .04	.81 ± .01
8/24/82	21	2.55 ± .01	.63 ± .02
8/31/82	28	3.30 ± .09	.72 ± .01
9/7/82	35	2.29 ± .03	.64 ± .01
9/14/82	42	2.46 ± .14	.58 ± .03
		RIFFLE	
8/5/82	2	3.77 ± .50	.87 ± .01
8/6/82	3	3.81 ± .04	.82 ± .01
8/7/82	4	3.97 ± .08	.80 ± .02
8/8/82	5	4.34 ± .02	.89 ± .02
8/9/82	6	3.64 ± .01	.78 ± .01
8/10/82	7	3.97 ± .02	.85 ± .004
8/11/82	8	3.30 ± .21	.75 ± .02
8/12/82	9	3.20 ± .01	.76 ± .04
8/13/82	10	3.47 ± .01	.77 ± .01
8/14/82	11	3.10 ± .003	.76 ± .03
8/16/82	17	3.68 ± .09	.84 ± .02
8/24/82	21	3.12 ± .02	.72 ± .01
8/31/82	28	2.63 ± .04	.69 ± .01
9/7/82	35	2.47 ± .08	.68 ± .01
9/14/82	42	2.16 ± .16	.56 ± .05

TABLE 4.15: T-tests Results From Comparisons of Species Diversity Means and Species Evenness Means For Pool and Riffle Samples From Set 1, Colonization Study Ford Site I (August-September, 1982) (n=15)

INDEX	POOL	RIFFLE	d.f.	SIGNIFICANCE
Species Diversity	3.38 $\pm$ 0.16	3.22 $\pm$ 0.18	28	N.S., $p>0.5$
Species Evenness	0.77 $\pm$ 0.02	0.71 $\pm$ 0.02	28	N.S., $p>0.1$

TABLE 4.16: Diatom Species Diversity ($\bar{x} \pm$ S.E., n=2) for Pool and Riffle Samples From Three Sites on the Ford River.

Date Out	Days Exposed	FCU	FEX	FCD
		POOLS		
7/25/83	14	1.66 ± .05	3.94 ± .06	2.83 ± .04
7/25/83	28	1.33 ± .07	2.53 ± .12	2.73 ± .14
8/8/83	42	0.87 ± .24	2.40 ± .02	2.26 ± .004
		RIFFLES		
7/25/83	14	1.61 ± .14	4.92 ± .02	3.94 ± .07
7/25/83	28	1.63 ± .03	3.03 ± .06	2.80 ± .20
8/8/83	42	2.05 ± .06	2.40 ± .13	1.40 ± .04

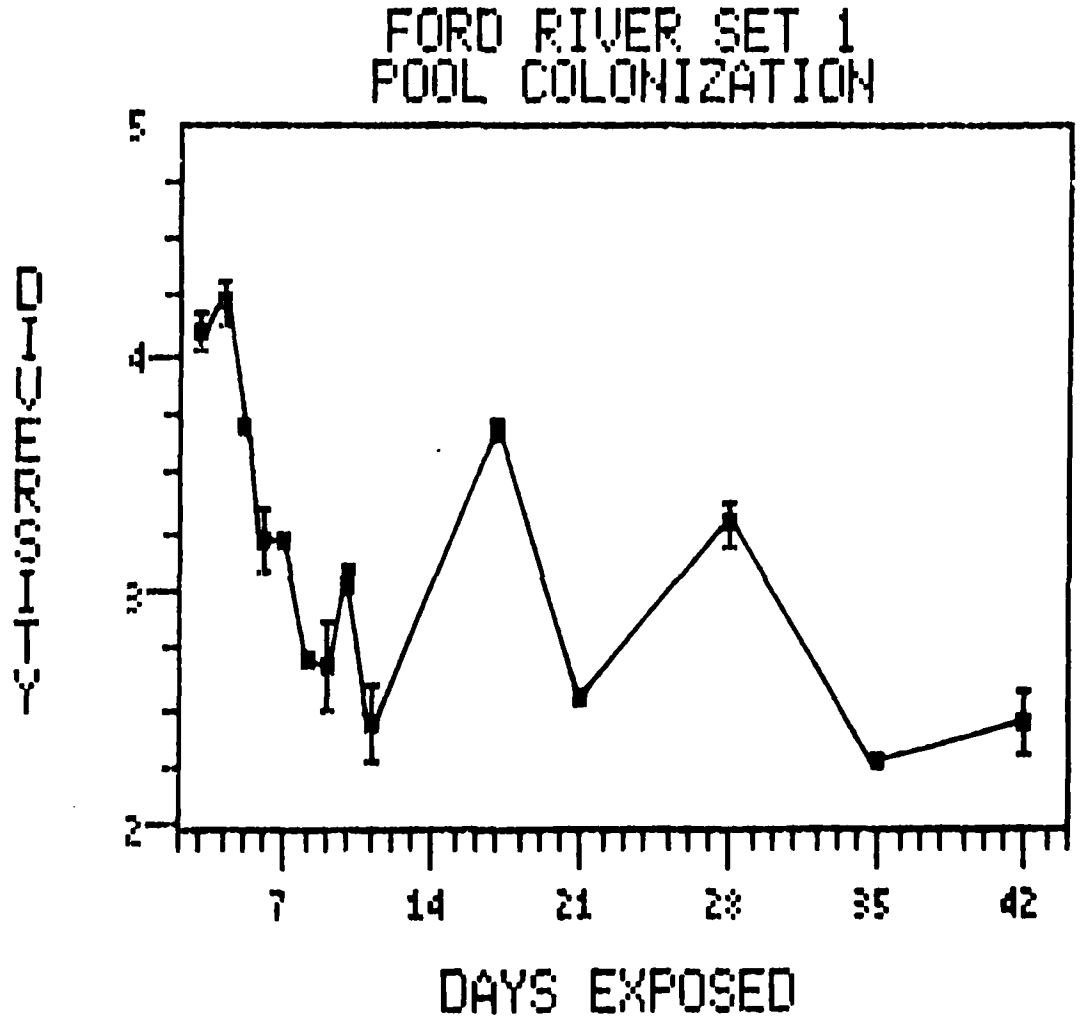

FORD RIVER SET 1
POOL COLONIZATION
DIVERSITY
5
4
3
2
7
14
21
28
35
42
DAYS EXPOSED

FIGURE 4.26

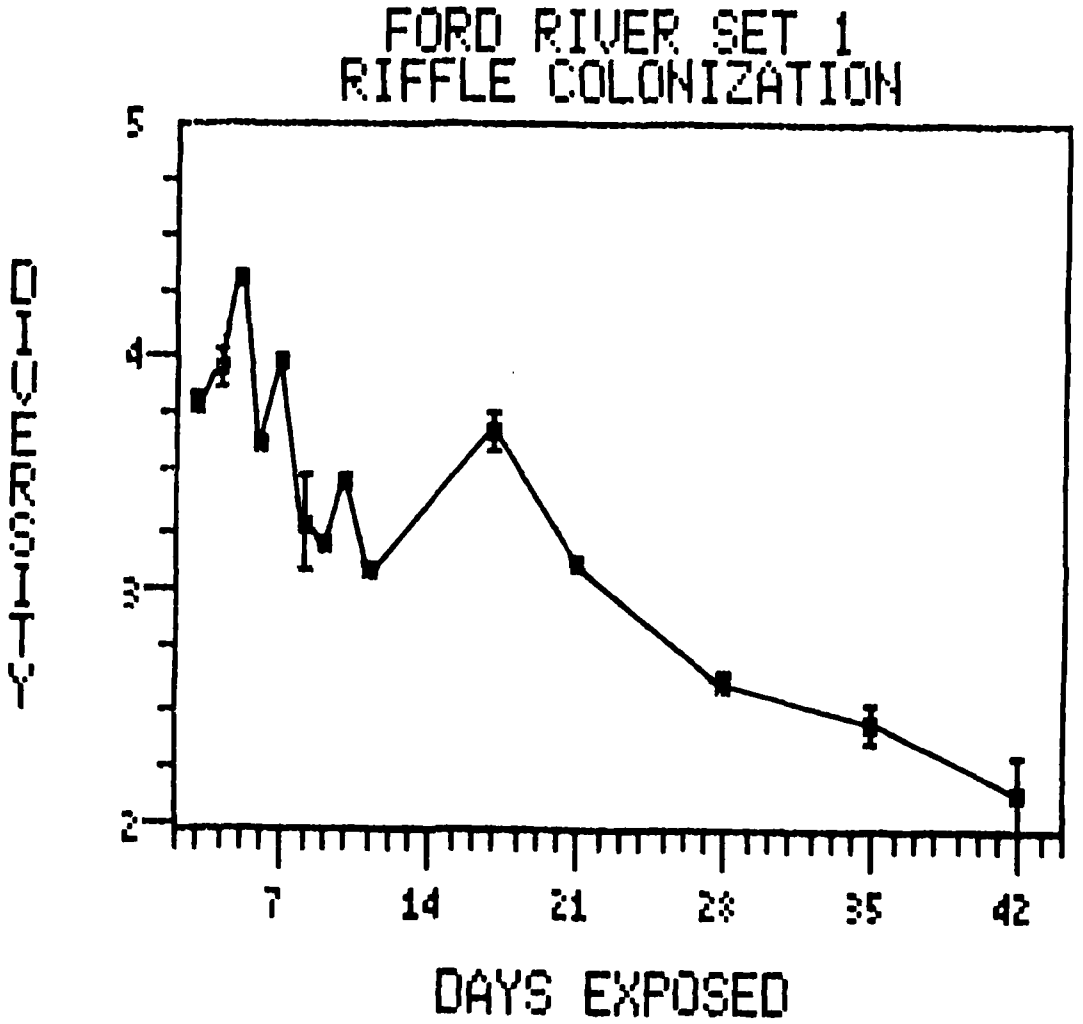

FORD RIVER SET 1
RIFFLE COLONIZATION
DIVERSITY
5
4
3
2
7
14
21
28
35
42
DAYS EXPOSED

FIGURE 4.27

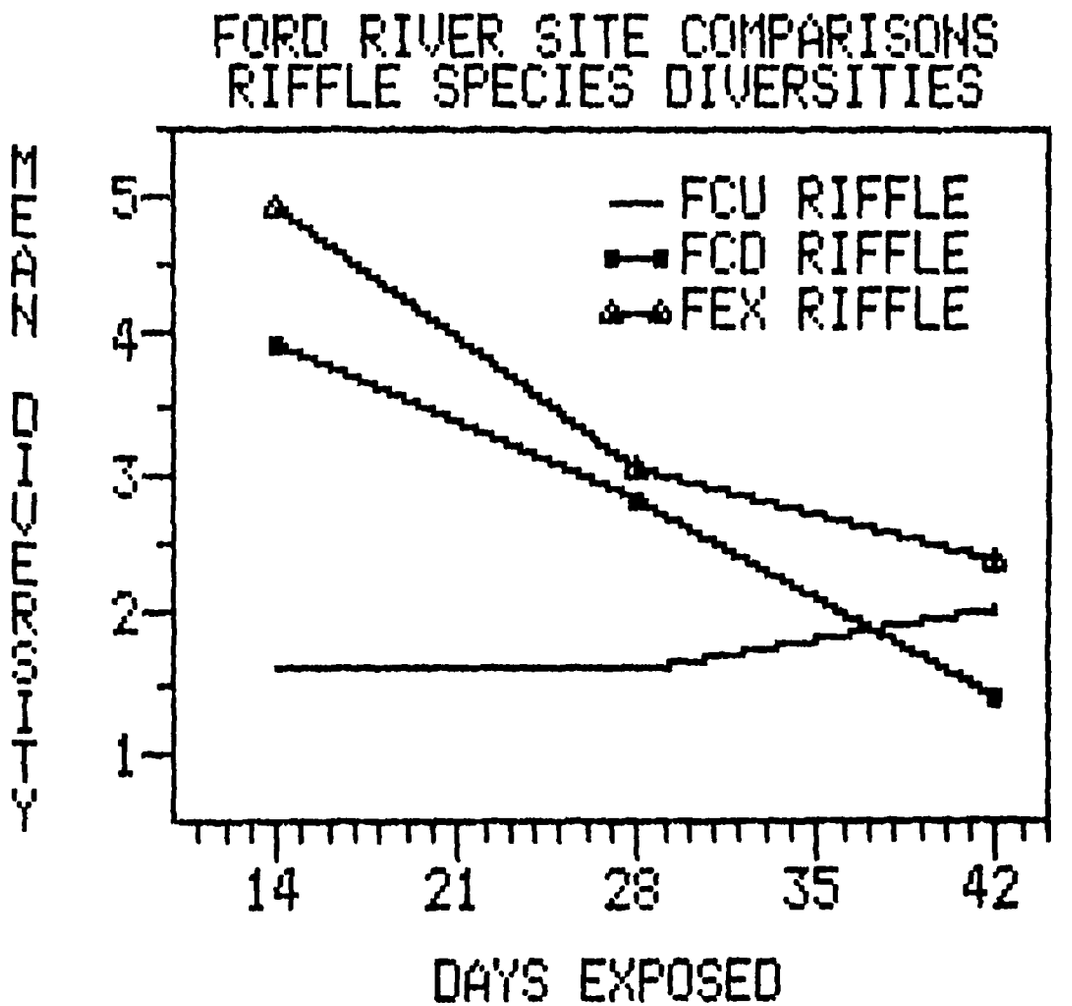

FORD RIVER SITE COMPARISONS
RIFFLE SPECIES DIVERSITIES
SHANNON-WIENER DIVERSITY
5
4
3
2
1
FCU RIFFLE
FCD RIFFLE
FEX RIFFLE
14
21
28
35
42
DAYS EXPOSED

FIGURE 4.28

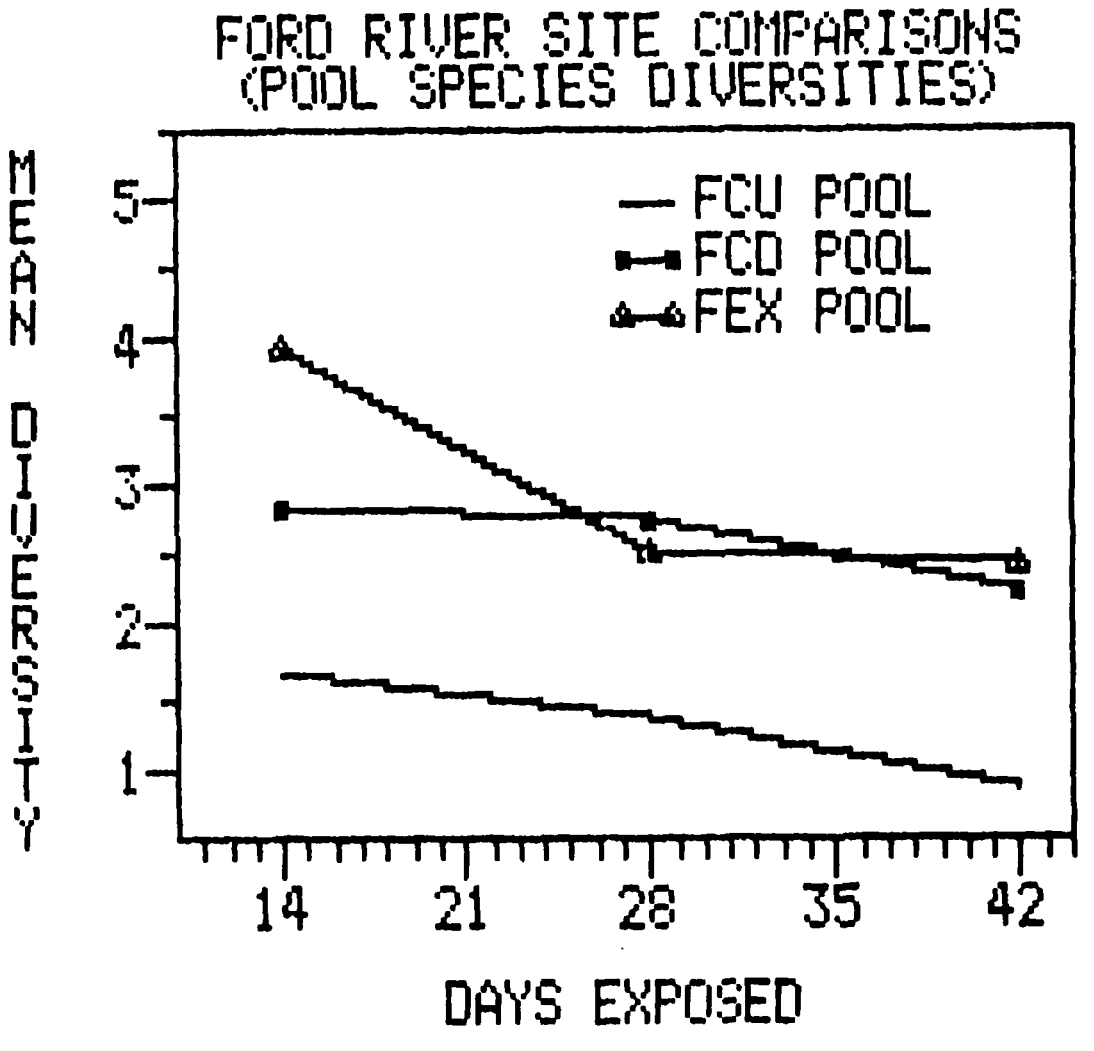

FORD RIVER SITE COMPARISONS
(POOL SPECIES DIVERSITIES)
MEAN DIVERSITY
5
4
3
2
1
FCU POOL
FCD POOL
FEX POOL
14
21
28
35
42
DAYS EXPOSED

FIGURE 4.29

(2) A 14 day sampling period during the active growing season should be used to determine productiviy parameters such as chlorophyll a and organic matter biomass accumulation rate. However, we will sample these same parameters on a 28 day sampling period as well as the 14 day period in order to correlate these parameters with the "mature" community parameters listed above.

(3) The downstream control site (FCD) is an excellent control for the experimental site (FEX) at the ELF corridor while the upstream control site (FCU) is unacceptable. The FCD-FEX comparison will be further enhanced in future studies by more careful matching of environmental parameters such as light exposure, water depth, and flow rates in the coming year.

Element 5 - Compare Periphyton Communities on Natural Substrates with those on Artificial Substrates

Synopsis - As a check on efficiency of sampling, natural substrates will be sampled and compared to communities on artificial substrates. This comparison will be done intensively during the first month of the study and at periodic intervals throughout the remainder of the study.

Changes from Original Synopsis - None.

Contributing Staff - T.M. Burton, Associate Professor (PI)
M.P. Oemke, Research Associate
M. O'Malley, Field Research Tech II

Objectives

To determine if the glass slides used as artificial substrates for periphyton collections accurately reflect the species composition of the surrounding periphyton from natural substrates.

Materials and Methods

Samples from natural substrates were taken at the Ford River upstream control site, the experimental site, the downstream control site and at Ford Site 1. Rock substrates were scraped with knife blades to remove the attached material which was then placed in either 6:3:1 (See Element 4, Materials and Methods) or 4% Glutaraldehyde. Natural substrate sampes also included scrapings from logs and wood debris, as well as aquatic plants. Additional samples were collected by squeezing masses of submerged plants over collection vials. Sediment samples were withdrawn with small pipettes. Diverse habitats were thus sampled at each potential river site. Samples which required cleaning followed the procedures given in the Methods section of Element 4.

Slides were made according to the nature of habitat i.e., rocks, wood scrapings, etc. or were made from composite samples containing periphyton material from all the substrates sampled at the site for each date.

Transects were examined across each slide at 1250 x magnification and algal species encountered were identified and counted. Between 250-500 valves were counted for each slide examined.

Results and Discussion

No samples examined from natural substrates contained species that were not found in either previous or subsequent samples from the glass slides. This agrees with previous work comparing communities on natural substrates to those on glass slides by Patrick et al (1954). It thus appears that samples of the periphyton community from glass slides accurately reflect the species composition of the natural periphyton. There were, however, differences between the qualitative natural substrate samples and the quantitative glass slide samples in regards to relative abundances of particular individual species. The natural substrates have a greater affinity for retaining the empty frustules of dead diatoms because of the nooks and crevices available and, thus, may give quite different species abundances when compared to the community developed on the smooth surfaces of the glass slides. The ability of natural substrates to retain empty frustules may also explain the higher species richness values obtained for natural substrate samples. As no effort was made in this study to remove empty frustules from consideration, it is possible that species richness values could have been elevated by including the empty frustules in the species abundances measured for the natural periphyton communities. The species richness values for natural substrates ($\sim$ 35 species/300 valves counted) were close to those obtained for glass slides exposed for 14 days periods or less (See Element 4).

It appears that glass slides adequately reflect the number of species present as well as the kinds of species, but may differ in relative species abundances. This difference may be more a function of substrate heterogeneity, related to the coarsness or texture of the natural substrate which results in increased retention of dead algal cells or filamentous forms, rather than a real difference in algal species composition.

In summary the glass slides appear to give a good overall picture of the periphyton community, particularly when compared against other slides at different sites (See Element 4), while natural substrates appear more variable particularly in determining the viable species relative abundance patterns.

Element 6 - Monitoring of Species Composition, Numbers, Diversity, biomass production, cell volume, and Chlorophyll a/ Phaeophytin a Production for Periphyton.

Synopsis - Routine monitoring of the parameters listed above will begin on August 1, 1982 for the streams to be studied. This monitoring will be moved to specific paired plots after they are selected. It will continue throughout the course of the study.

Changes from Original Synopsis - None

Contributing Staff - T.M. Burton, Associate Professor (PI)
M.P. Oemke, Research Associate
M. O'Malley, Field Research Tech II

Objectives

The objective of this study is to accumulate data on all parameters listed above as background data for assessing the effects of ELF radiation on the periphyton community.

Materials and Methods

The materials and methods for assessing periphyton community dynamics were discussed in Element 4 above. Based on data from Element 4, we selected a 28 day exposure period for species composition, numbers, diversity, and cell volume and 14 and 28 day , exposure periods for chlorophyll a, phaeophytin a and biomass production for routine monitoring of the periphyton community.

Results and Discussion

A. Chlorophyll a

The 14 day and 28 day exposure period chlorophyll a data demonstrated a high degree of seasonality (Figures 4.5, 6.1, 6.2). Chlorophyll a accumulation was slow during Spring for both FCD and FEX (Figures 4.5, 6.1), peaked by July 5 for all three sites, and usually declined for all sites thereafter to Fall values similar to Spring values. The exceptions to this trend included a somewhat later peak for pool samples at FCD (Figure 4.5) and a later peak and sustained high rate of chlorophyll a accumulation for riffles for FCU (Figure 6.2). All 14 and 28 day 1983 mean values with standard errors have already been presented for all three sites (Tables 4.1 and 4.2). Comparisons of 28 day mean values revealed

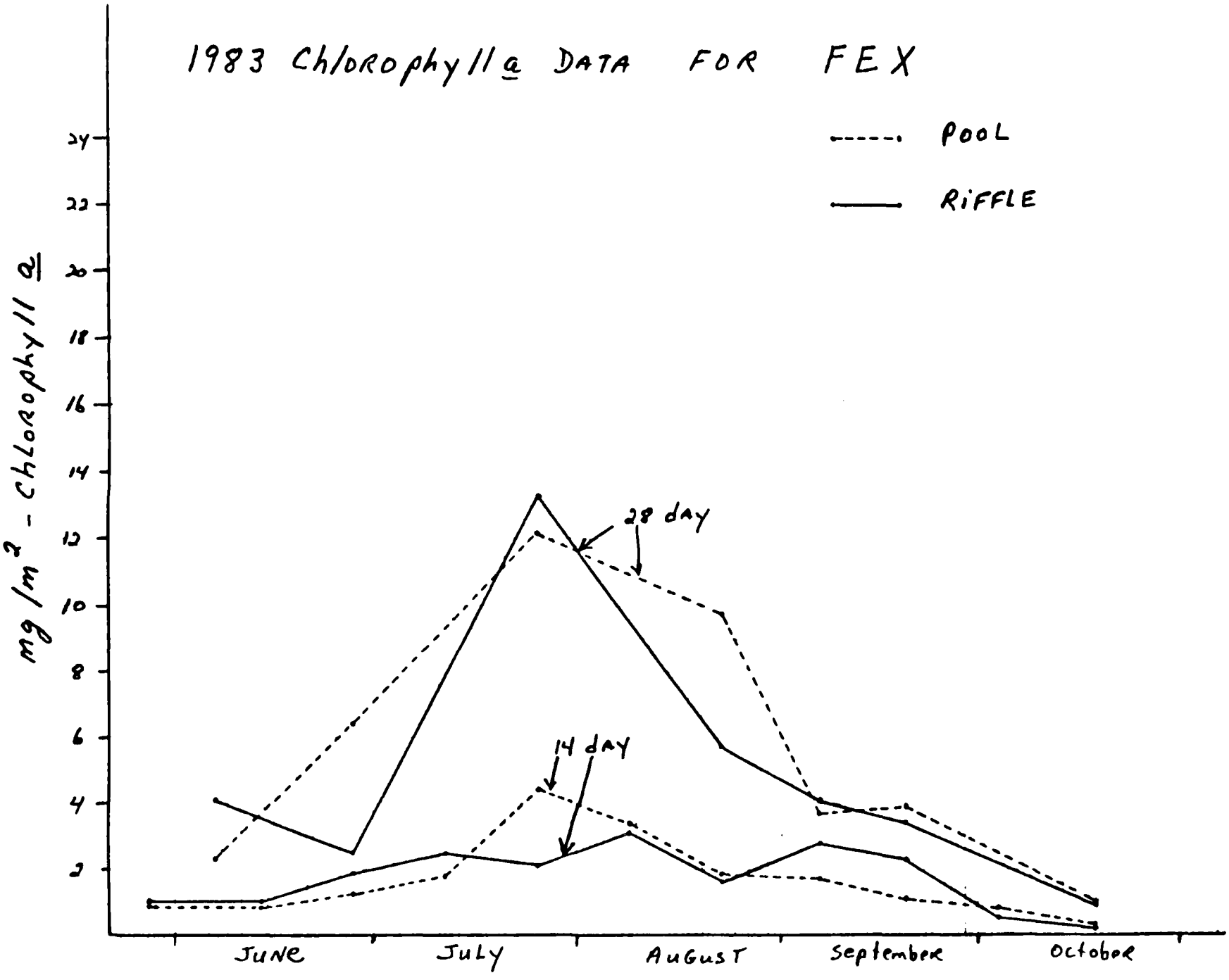

1983 Chlorophyll a DATA FOR FEX
POOL
RIFFLE
mg/m² - Chlorophyll a
24
22
20
18
16
14
12
10
8
6
4
2
28 day
14 day
JUNE
JULY
AUGUST
September
October

FIGURE 6.1

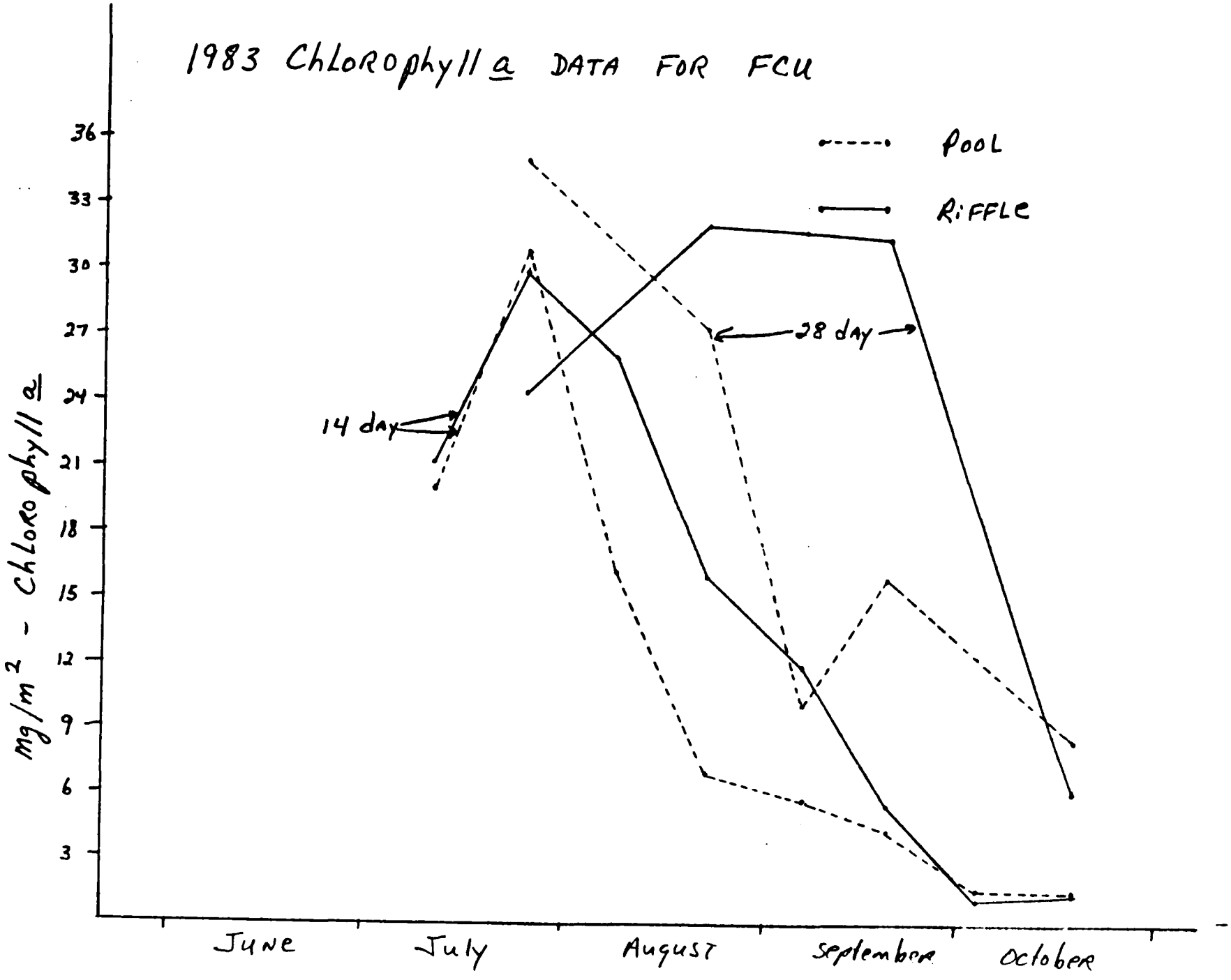

1983 Chlorophyll a DATA FOR FCU
Pool
Riffle
28 day
14 day
mg/m² - Chlorophyll a
36
33
30
27
24
21
18
15
12
9
6
3
June
July
August
September
October

FIGURE 6.2

no significant differences between FEX and FCD ($p>0.2$) but highly significant differences between FEX and FCU (See Discussion under Element 4.A and t-test results in Table 4.3).

B. Organic Matter Biomass Accumulation

Data for organic matter biomass accumulation for the 14 and 28 day routine monitoring periods were presented already in Tables 4.4 and 4.5. These data paralleled the chlorophyll a data in that peak values for most sites for most exposure periods occurred from late July to mid-August (Figures 6.3, 6.4, 6.5). Unlike chlorophyll a, organic matter biomass accumulation also had a Spring peak (Figures 6.4, 6.5). This Spring peak could have been related to rapid increases in bacterial and fungal populations as temperature increased in the Spring or could have been related to increased transport of organic matter by high Spring runoff. Settling of organic matter on the glass slides was unlikely due to vertical placement of substrates but could not totally be discounted. Increased transport of organic carbon in the Spring could certainly have been related to the Spring peak since increases in microbial biomass should be related to increased transport.

Comparisons of organic matter biomass between sites have already been presented (See Element 4.B) and revealed no significant differences between FEX and FCD but highly significant differences between FCU and FEX (See Table 4.6). These trends are illustrated in Figures 6.3, 6.4, and 6.5.

C. Phaeophytin a

Phaeophytin a data are not very useful in monitoring future effects of ELF radiation in our opinion. Nevertheless, these analyses were called for in the original RFP and are generated as part of chlorophyll a analyses. Phaeophytin a data for FCD and FEX are summarized in Tables 6.1 and 6.2.

D. Species Composition

A total of 304 diatom taxa were enumerated from pool and riffle samples from the Ford River from August 1982 to August 1983. Species identified came from thirty-two genera. The major dominant species recorded from all sites belonged primarily to either the genus Achnanthes or Cocconeis. Other genera like Gomphonema and Cymbella showed ocassional seasonal dominance as well.

Individual species reaching the greatest abundances were Achnanthes affinis Grun. var. affinis, Cocconeis placentula var. euglypta (Ehr.)Cl., Cocconeis placentula var. lineata (Ehr.)V.H. Other species showing seasonally high abundances included Gomphonema dichotomum Kutz. var. dichotomum, and Cymbella minuta

TABLE 6.1: Phaeophytin a Accumulation ($mg/m^2 \pm$ One Standard Error) on Glass Slides in Pools for Two Ford River Sites in 1983. n=4 unless otherwise indicated.

Date out of River	Days Exposure	FEX	FCD
6/6/83	7	0.006 ± 0.005 (N=2)	0.005 ± 0.003 (N=3)
6/13	7	0.113 ± 0.031 (N=5)	0.136 ± 0.028
6/20	7	0.147 ± 0.063	0.176 ± 0.034 (N=3)
6/27	7	0.270 ± 0115	0.053 ± 0.003 (N=3)
5/27/83	15	0.199 ± 0.013	0.524 ± 0.227 (N=3)
6/13	14	0.267 ± 0.028 (N=3)	0.152 ± 0.048 (N=3)
6/27	14	0.158 ± 0.036	0.409 ± 0.265
7/11	14	0.212 ± 0.047	0.207 ± 0.036 (N=2)
7/25	14	0.698 ± 0.251	1.365 ± 0.078
8/8	14	0.981 ± 0.163	0.319 ± 0.111
8/22	14	0.984 ± 0.534 (N=3)	0.525 ± 0.050
9/06	15	0.283 ± 0.024	0.670 ± 0.221
9/19	13	0.296 ± 0.085	0.172 ± 0.037 (N=3)
10/03	14	0.179 ± 0.081	0.192 ± 0.031
10/18	15	0.146 ± 0.031	0.173 ± 0.069 (N=3)
6/3/83	22	0.285 ± 0.031 (N=3)	0.277 ± 0.023 (N=3)
6/20	21	0.292 ± 0.060	0.200 ± 0.046
6/6/83	25	0.357 ± 0.050	0.592 ± 0.114
6/27	28	0.824 ± 0.242	0.[illegible]00 ± 0.077
7/25	28	0.872 ± 0.092	1.662 ± 0.283
8/22	28	1.282 ± 0.354	1.420 ± 0.829
9/06	29	0.470 ± 0.162	1.246 ± 0.105 (N=3)
9/19	28	0.897 ± 0.616	0.828 ± 0.172
10/18	29	0.341 ± 0.128	0.475 ± 0.224 (N=3)
8/8/83	42	1.224 ± 0.394	0.604 ± 0.287
10/18	42	1.560 ± 0.588	1.634 ± 0.132 (N=3)

TABLE 6.2: Phaeophytin a Accumulation (mg/m^2 ± One Standard Error) on Glass Slides in Pools for Two Ford River Sites in 1983. n=4 unless otherwise indicated.

Date out of River	Days Exposure	FEX	FCD
6/6/83	7	0.006 ± 0.003 (N=3)	0.014 ± 0.007 (N=3)
6/13	7	0.282 ± 0.092	0.098 ± 0.031
6/20	7	0.236 ± 0.089	0.205 ± 0.089
6/27	7	0.347 ± 0.171	0.709 ± 0.657
5/27/83	15	0.334 ± 0.142	0.724 ± 0.364
6/13	14	0.474 ± 0.117 (N=3)	0.236 ± 0.025 (N=3)
6/27	14	0.390 ± 0.141	0.230 ± 0.072 (N=5)
7/11	14	0.270 ± 0.089	0.491 ± 0.091
7/25	14	0.788 ± 0.137	1.372 ± 0.435
8/8	14	1.093 ± 0.349	0.473 ± 0.138
8/22	14	0.645 ± 0.104	0.635 ± 0.260
9/06	15	0.877 ± 0.089	0.982 ± 0.187
9/19	13	0.421 ± 0.094	0.477 ± 0.160 (N=3)
10/03	14	0.123 ± 0.029	0.160 ± 0.043
10/18	15	0.070 ± 0.005	0.113 ± 0.027
6/3/83	22	0.709 ± 0.269 (N=3)	0.276 ± 0.010 (N=3)
6/20	21	1.106 ± 0.241	0.229 ± 0.017
6/6/83	25	0.959 ± 0.407	0.365 ± 0.050 (N=6)
6/27	28	0.391 ± 0.073 (N=3)	0.642 ± 0.350
7/25	28	2.809 ± 0.115	1.797 ± 0.216
8/22	28	1.727 ± 0.273	1.832 ± 0.351
9/06	29	0.927 ± 0.062	3.241 ± 0.776
9/19	28	1.047 ± 0.172	1.279 ± 0.260
10/13	29	0.136 ± 0.022	1.185 ± 0.286
8/8/83	42	3.988 ± 1.070	0.257 ± 0.080
10/18	42	0.747 ± 0.217 (N=3)	1.357 ± 0.616 (N=3)

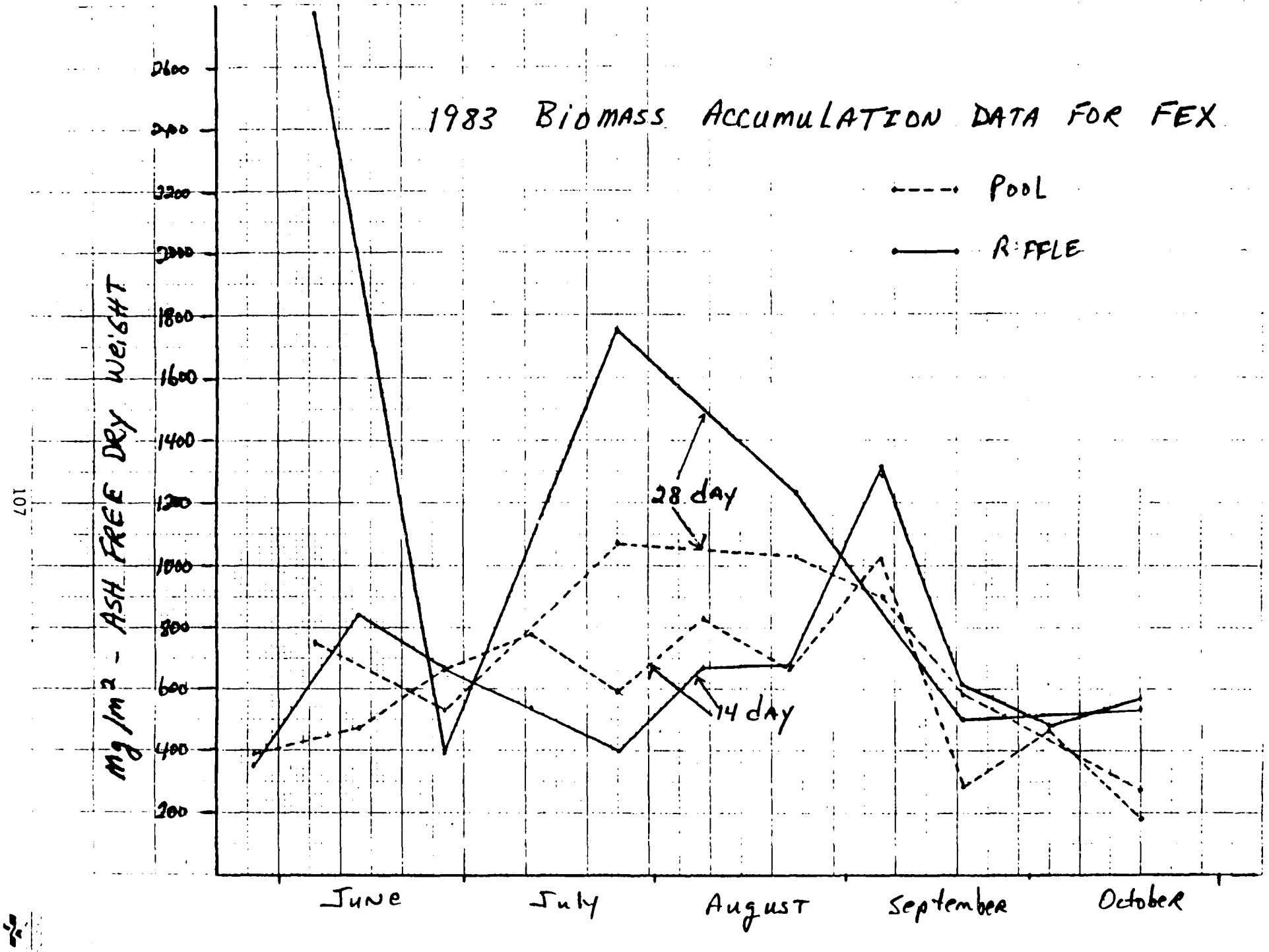

1983 Biomass Accumulation Data for FEX
Pool
Riffle
28 day
14 day
mg/m² - Ash Free Dry Weight
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
June
July
August
September
October

FIGURE 6.3

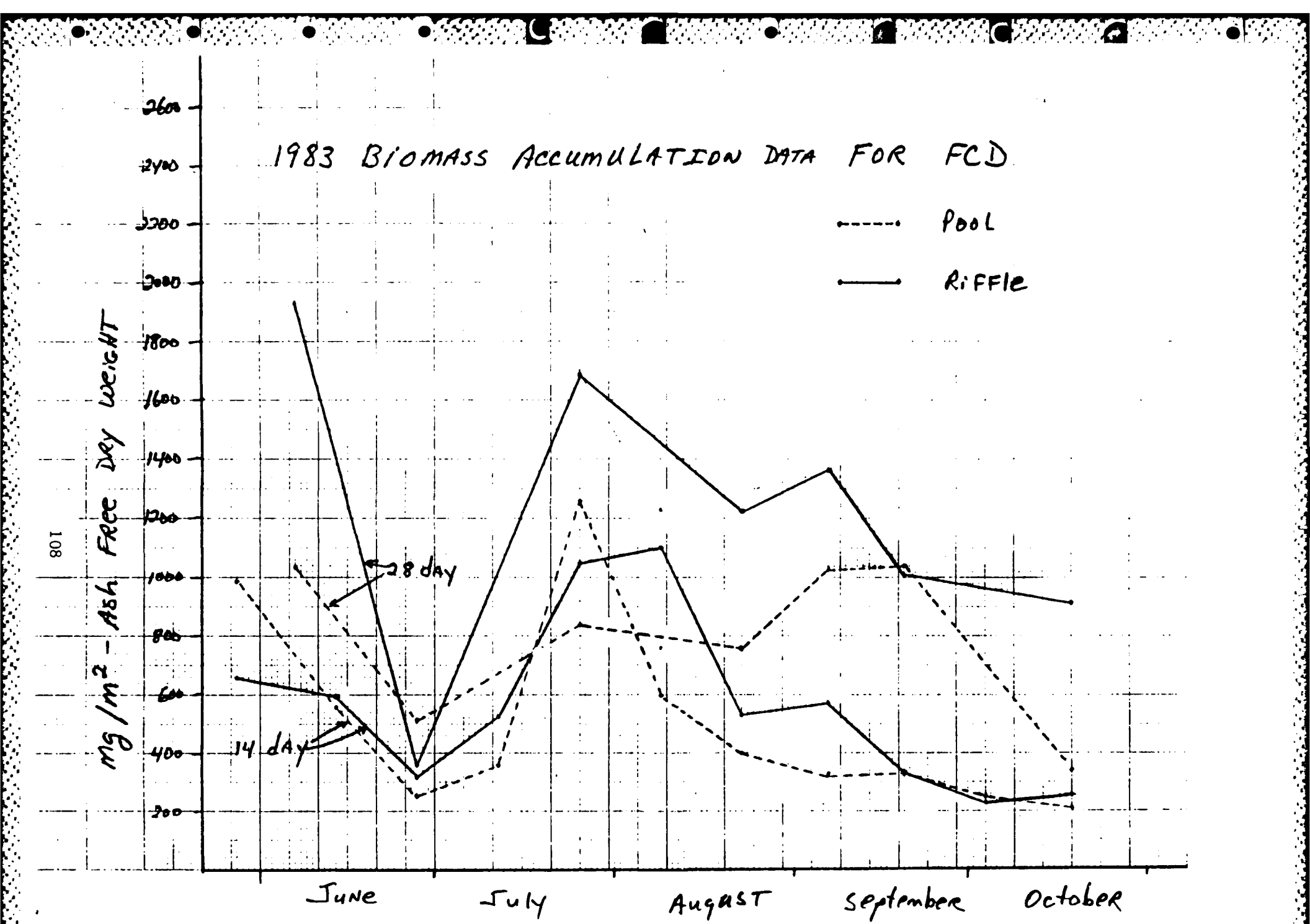

1983 BIOMASS ACCUMULATION DATA FOR FCD
POOL
RIFFLE
mg/m² - ASH FREE DRY WEIGHT
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
28 day
14 day
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER

FIGURE 6.4

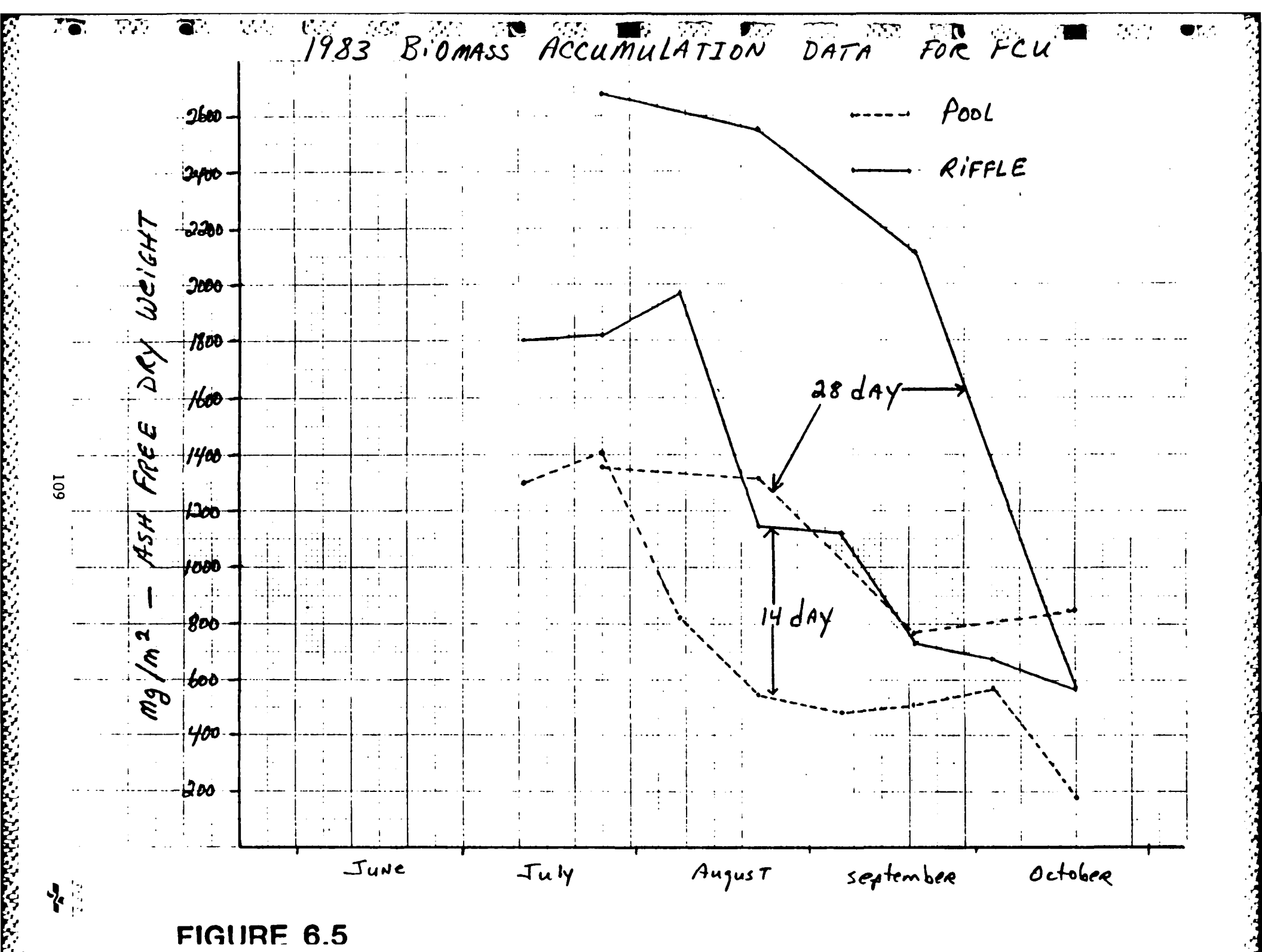

1983 BIOMASS ACCUMULATION DATA FOR FCU
POOL
RIFFLE
28 DAY
14 DAY
mg/m² - ASH FREE DRY WEIGHT
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER

FIGURE 6.5

var. silesiaca (Bleisch ex. Rabh.)Reim.

Other algal divisions besides the diatoms were also recorded in the samples but at cell densities greatly below those of the diatoms. It thus may be that future monitoring will concentrate more heavily on the diatoms because of their greater diversity and importance in the periphyton community for the Ford River. The second most common algal division, the Chlorophyta or green algae included species from the genera Spirogyra, Mougeotia, Stigeoclonium, and Coleochaete. A few species were also recorded from the division Cyanophyta, or blue-green algae, and included species from the genera, Lyngbya, Gloeocapsa, and Anacystis. Occasional species from the division Euglenophyta and the division Rhodophyta (Genus Batrachospermum) were also identified using keys from Prescott (1951).

E. Cell Volumes

Length and width measurements have been recorded for individuals from all diatom taxa encountered. Formulae to convert cell dimensions into their appropriate geometric solid have also been gathered, but no calculations have as yet been done.

F. Diversity

While a substantial amount of data have been analyzed to determine species diversity for several sites on the Ford River (See Element 4) data entry is not yet complete for the yearly study to permit monthly species diversity or species evenness values to be compared.

G. Cell Numbers, Cell Densities

Monthly cell density measurements for Ford Site I are complete for the entire year. The data for the three sites for 1983 (FCU, FEX, FCD) are still being analyzed. Measurements ranged from a maximum of 6.16×10^9 cells/m^2 in May to a minimum of 3.97×10^7 cells/m^2 in February for the pool samples for FSI. Riffle samples ranged from a high of 1.71×10^9 cells/m^2 in June to a low of 2.94×10^7 cells/m^2 in February. Both pool and riffle periphyton showed similar low cell densities from November-February and corresponding increases from April-August (Figure 6.6 and Table 6.3). Peak cell densities were recorded in both habitats in spring and continued at high densities throughout the summer period when warm water and high light intensities were present. A second, minor peak in density occurred in the early fall (September-October) for the pool habitat (Figure 6.6).

The density differences between pool and riffle periphyton appeared greatest during the fall and spring periods (Figure 6.6).

TABLE 6.3: Diatom Densities of Monthly Pool and Riffle Samples From Ford River, Site 1 Collected 8/31/82 to 9/14/83 ($\bar{x}$ $\log_{10}$ number/m^2 $\pm$ S.E., n=2)

Date out	POOL	RIFFLE
8/31/82	8.9691 ± .0614	8.8925 ± .0290
9/28	9.1826 ± .0399	8.6047 ± .0733
10/5	9.2939 ± .0401	8.6975 ± .0519
11/18	8.2653 ± .0299	6.8629 ± .1726
12/16	8.6023 ± .1321	8.0335 ± .0378
1/16	7.8456 ± .0329	7.9078 ± .0647
2/12	7.5967 ± .0448	7.4689 ± .0101
3/12	8.7745 ± .0834	———
4/15	9.5066 ± .0054	9.4809 ± .0726
5/27	9.7881 ± .0350	9.1888 ± .0898
6/27	9.7302 ± .0387	9.2312 ± .0854
7/25	9.5487 ± .0307*	9.3827 ± .0635*
7/25	———	9.6132 ± .0360
8/29	9.4604 ± .0139	9.6847 ± .0582
9/14	9.4311 ± .0372	9.1169 ± .0128

* 14 DAY EXPOSURE OF SLIDES

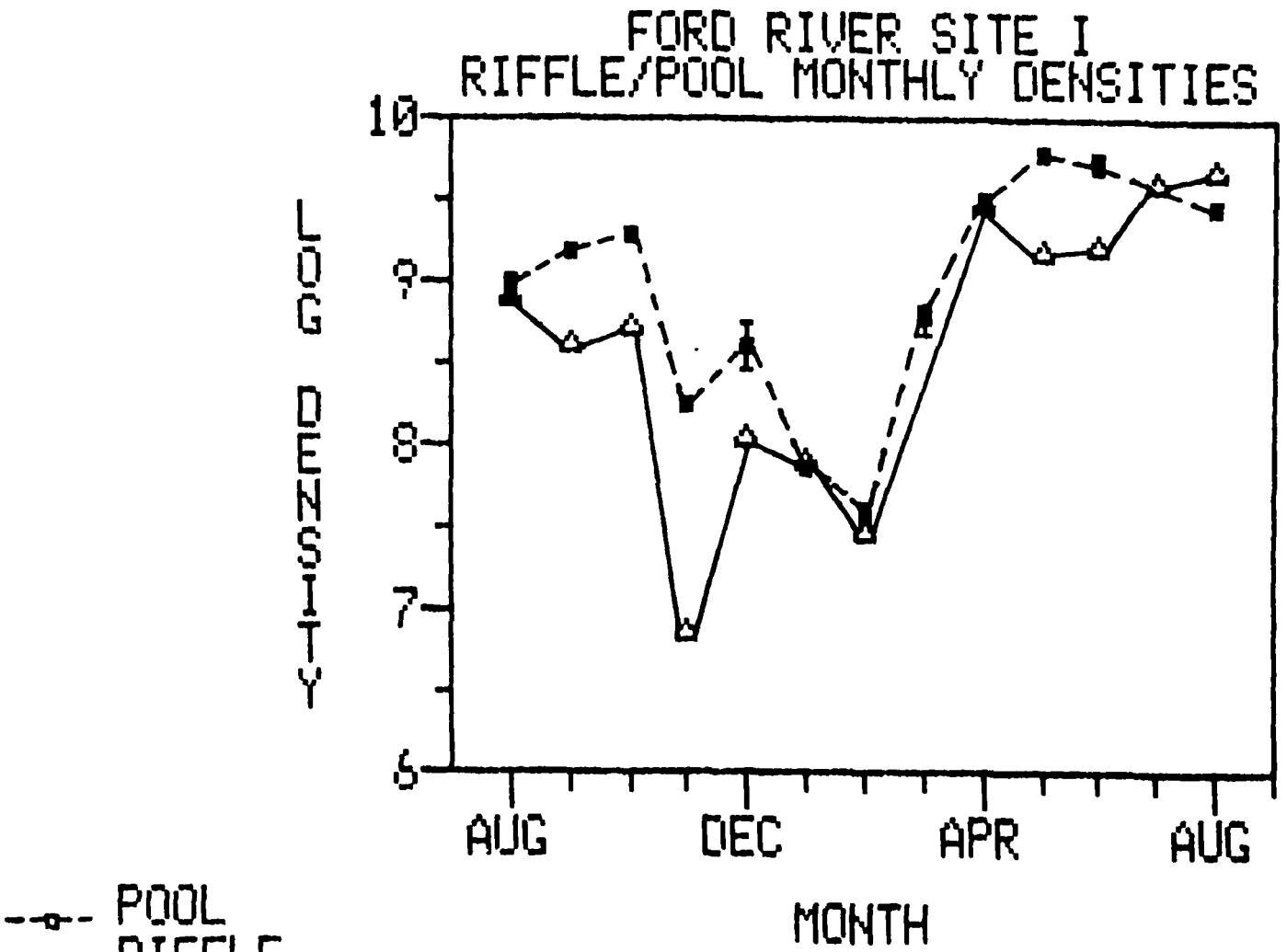

FORD RIVER SITE I
RIFFLE/POOL MONTHLY DENSITIES
LOG DENSITY
10
9
8
7
6
AUG
DEC
APR
AUG
MONTH
POOL
RIFFLE

FIGURE 6.6

These same periods coincided with increasing water levels from spring and fall rains. It is possible that riffle periphyton is affected more adversely during high water when increased current velocities may reduce the standing crop by increased sloughing of cells resulting in lower cell density levels compared to the more protected pool regions. Measured monthly pool and riffle cell densities (Table 6.3) were used to compare these two habitats on a seasonal basis, according to measured water temperatures (°C); Summer: warmer than 12.5°C, Fall: 3.5°-12.5°C, Winter: 0-3.5°, Spring: 3.5°-12.5°C (Table 6.4). T-tests indicated a significant difference in cell density for pool and riffle habitats (Table 6.5). These differences may be related, however, to the previously discussed differential effects of increased current velocities during the spring and fall periods on the shallower, riffle periphyton. Likewise winter comparisons may be influenced by the extent of ice cover, which in some cases extended to the bottom substrate in shallow riffle areas while leaving the deeper pool periphyton untouched. The effects of dislodged upstream ice particles may also reduce riffle periphyton levels more than pool levels.

Comparisons by season, using combined pool and riffle density measurements to provide a single mean density showed that winter periphyton densities were significantly lower than cell densities from Spring, Summer, or Fall (Table 6.5). Summer-Fall and Summer-Spring comparisons were not significantly different ($p>0.2$), but Spring-Fall densities were ($p<0.01$).

The Spring-Fall difference thus detected, may represent the deleterious effects of changing water flows on the periphyton rather than a true difference in production.

An overall t-test comparison, combining all monthly riffle and pool densities to provide a single yearly mean for the riffle and for the pool, showed no significant difference in cell density (Table 6.5, $p>0.1$). This indicates that perhaps pool and riffle habitats may not be distinctly different enough to justify separate sampling. Further comparisons in the next year will hopefully clarify this possibility.

TABLE 6.4: Diatom Densities by Season for Pool and Riffle at Ford RIver Site 1. ($\bar{x}$ $\log_{10}$ number/m^2 $\pm$ S.E.)

Season	POOLS	n	RIFFLES	n
Summer	9.3865 $\pm$ .1422	6	9.0882 $\pm$ .3009	8
Fall	9.2382 $\pm$ .0396	4	8.6511 $\pm$ .0454	4
Winter	8.2168 $\pm$ .1500	10	7.5683 $\pm$ .1767	8
Spring	9.6473 $\pm$ .0825	4	9.3348 $\pm$ .0966	4

TABLE 6.5: T-test Results of Diatom Densities From Monthly Samples Analyzed Seasonally From Pool and Riffle Habitats From Ford River, Site 1.

Comparison	d.f.	SIGNIFICANCE	
Riffle vs Pool - Summer	12	N.S.	p>.05
Riffle vs Pool - Spring	6	*	p<.05
Riffle vs Pool - Fall	6	*	p<.05
Riffle vs Pool - Winter	16	*	p<.05
Summer vs Fall (Combined Pool + Riffle)	20	N.S.	p>0.2
Summer vs Winter " "	30	***	p<0.001
Summer vs Spring " "	20	N.S.	p<0.2
Fall vs Winter " "	24	***	p<0.001
Fall vs Spring " "	14	**	p<0.01
Winter vs Spring " "	24	***	p<0.001
Yearly Riffle vs Yearly Pool	46	N.S.	p>0.1

Element 7 - Stream Invertebrate Collection and Identification

Original Synopsis - Collect and identify invertebrates present and prepare reference collection for species checklist and as aide to routine identification for each stream site.

Changes from Original Synopsis - None

Contributing Staff - J. Stout, Research Associate (PI)
R. Merritt, Associate Professor (PI)
W. Taft, Field Research Tech II
K. Webb, Graduate Research Assistant
D. Cornelius, Graduate Research Assist

Objectives

1) To collect and identify the aquatic invertebrates present at ELF study sites. 2) To establish a reference collection for related elements on this project.

Materials and Methods

Riffle and pool samples were collected from control and experimental sites on the Ford River (Dickinson Co.), Michigan. Both qualitative and quantitative samples came from: 1) substrate samples, 2) leaf pack samples, 3) drift samples, and 4) general collecting during 1982 and 1983. Most specimens were preserved in 80% alcohol and later identified. Specific groups, such as the Chironomidae, required mounting in a fixative before correct identifications could be made. Specimens of a few selected families of aquatic insects were sent off to specialists for species confirmation.

Results and Discussion

A list of the aquatic insects collected on the Ford River is given below. This list will be continually updated as new taxa are collected and identified.

FAMILY	GENUS AND SPECIES
Ephemeroptera	
Tricorythidae	*Tricorythodes* sp.
Caenidae	*Caenis* sp. *Brachycercus* sp.

FAMILY	GENUS AND SPECIES
Ephemerellidae	Ephemerella (Drunella) cornuta Morgan
	E. (Drunella) simplex McDunnough
	E. invaria (Walker)
	E. subvaria McDunnough
	E. (Serratella) deficiens McDunnough
	E. (Serratella) sordida McDunnough
	E. Bicolor Clemens
	E. needham McDunnough
Baetidae	Baetis flavistriga McDunnough
	B. vagans McDunnough
	Pseudocloeon sp. (possibly parvulum McDunnough)
Siphlonuridae	Isonychia sp.
Leptophlebiidae	Paraleptophlebia mollis (Eaton)
	Leptophlebia sp.
Heptageniidae	Epeorus vitreus (Walker)
	Rithrogena pellucida
	Stenonema vicarium (Walker)
	Heptagenia hebe McDunnough
	H. lucidipennis (Clemens)
Bastiscidae	Baetisca sp.
Ephemeridae	Ephemera sp.
Odonata	
Gomphidae	Ophiogomphus carolus Needham
	Gomphus (Stylurus) scudderi Selys
Aeschnidae	Boyeria vinosa Say
Cordulegasteridae	Cordulegaster maculatus Selys
Calopterygidae	Calopteryx sp.

FAMILY	GENUS AND SPECIES
Plecoptera	
Capniidae	Paracapnis sp. Capnia sp.
Perlidae	Acroneuria lycorias (Newman) A. abnormis (Newman) Paragnetina sp.
Perlodidae	Isogeniodes sp. Isoperla transmarina (Newman)
Nemouridae	Paranemoura perfecta (Walker)
Pteronarcidae	Pteronarcys sp.
Taeniopterygidae	Taeniopteryx nivalis (Fitch)
Hemiptera	
Belostomatidae	Belostoma sp.
Corixidae	
Trichoptera	
Brachycentridae	Brachycentrus (possibly numerous)(Say))
Glossosomatidae	Glossosoma sp. (possibly nigrior Banks) Protoptila tenbrosa (Walker)
Limnephilidae	Anabolia sp. Hydatophylax sp. Pycnopsyche subfaciata (Say)
Hydropsychidae	Symphitopsyche bifida (Banks) S. sparna (Ross) Cheumatopsyche analis (Banks)(adult only) Potamyia sp.
Hydroptilidae	Leucotrichia pictipes (Banks)
Lepidostomatidae	Lepidostoma sp.
Leptoceridae	Oecetis avara (Banks) Ceraclea angustus (Banks)(adults only) Triaenodes tarda Milne (adults only)

FAMILY	GENUS AND SPECIES
Phryganeidae	Ptilostomis sp.
Polycentropodidae	Neureclipsis sp.
Psychomyiidae	Psychomyia flavida Hagen Lype diversa (Banks)
Rhyacophilidae	Rhyacophila sp.
Coleoptera	
Elmidae	Optioservus fastiditus O. trivittatus Macronychus glabratus Optioservus sp. Dubiraphia sp.
Dryopidae	Helichus lithophilus (Germar)
Gyrinidae	Gyrinus sp.
Dytiscidae	Laccophilus sp.
Megaloptera	
Corydalidae	Nigronia sp.
Diptera	
Blephariceridae	Blepharicera sp.
Tipulidae	Tipula abdominalis (Say) Hexatoma (Eriocera) sp. near spinosa (O.S.) Hexatoma sp. nr. cinerea Dicranota sp. Hesperoconopa sp.
Ceratopogoniidae	Probezzia sp.
Chironomidae	
Tanytarsini	Tanytarsus sp. Rheotanytarsus sp. Microspectra or Tanytarsus group Stempellina Bause
Tanypodinae	Ablabesmyia sp. Thienemannimyia group Labrundinia Fittkau

FAMILY	GENUS AND SPECIES
Orthocladini	Brillia spp. 1 + 2
	Parametriocnemus sp.
	Corynoneura sp.
	Eukiefferiella sp.
	Rheocricotopus sp.
	Cricotopus sp.
	Thienemanniella sp.
Chironomini	Polypedilum sp.
	Robackia Saether
	Microtendipes Kieffer
Athericidae	Atherix variegata
Simuliidae	Simulium corbis Twinn
	S. quebecense Twinn
	S. tuberosum (Lundstr.)
	S. venustum (Say)
	Prosimulium mixtum
	Ectemnia invenusta (Walker)
	Prosimulium mysticum

Element 8 - Effects of Exposure Period on Invertebrate Colonization of Artificial Substrates

Original Synopsis - Exposed artificial substrates in stream for different time periods (e.g., 3, 7, 10 days) to assess maximum colonization time. Analysis of benthic samples will be completed during winter months.

Changes from Original Synopsis - Exposed artificial substrates in the FEX site for 7, 14, 21 and 28 days to assess optimum colonization time.

Contributing Staff - J. Stout, Research Associate (PI)
R. Merritt, Associate Proffessor (PI)
W. Taft, Field Research Tech. II

Objectives

1) To determine the optimal exposure period for colonization of aquatic insects onto imbedded substrate samplers. 2) To quantify the variance among the samples. 3) To quantify the colonization pattern onto fresh substrates.

Materials and Methods

Plastic baskets 18 x 28 x 10 cm, lined with 60 μ mesh netting were filled with scrubbed sediments taken from the FEX site. Twelve samplers were buried in a riffle, flush with the stream bottom approximately 100 m downstream from the FEX monitoring station on 30 June 1983. Three replicates were taken after 7, 14, 21 and 28 days' exposure. Sediments were washed through a 60 μ mesh soil sieve; insects and detritus were preserved in 90% alcohol. Insects were later identified to family and measurements for each individual taken. Data analysis included means and standard error values among replicates for each family; structural community indices (richness, evenness and diversity); dominance values for the most common groups, and categorization of families into functional feeding groups. (Biomass estimates will be completed during the winter of 1984.)

Results and Discussion

No asymptote occurred for numbers of individuals over the 28-day exposure period (Table 8.1). The following functional feeding groups increased on an absolute scale over time: Hydropsychidae, Philopotamidae, Chironomidae (Collector-Filterers); Elmidae (Collector-Gatherers); Glossosomatidae (Scrapers); Tipulidae (Shredders); and Gomphidae, Perlidae and Athericidae (Predators). The only groups that peaked by Day 14 and then decreased were Hydroptilids (Collector-Gatherers) and Ceratopogonids (Predators).

TABLE 8.1

Mean Number of Individuals from Families of Aquatic Insects in Substrates over Time
(S.E. for 3 Replicates)

TROPHIC GROUP, FAMILY NAME	Day 7	Day 14	Day 21	Day 28
Collector-Filterers				
Siphlonuridae	3(0)	0	0	0
Brachycentridae	5(3.0)	4(1.0)	2(2.0)	12(2.1)
Hydropsychidae	4(0)	29.7(13.8)	46(5.7)	313.7(3.2)
Philopotomatidae	0	1(0)	1(0)	12.3(4.7)
Chironomidae	75.3(20.5)	148.7(41.8)	225(74.3)	316.7(37.9)
Simuliidae	1(0)	10.0(4.7)	2(0)	7.3(3.9)
Collector-Gatherers				
Baetidae	7.7(4.8)	79.0(8.0)	39.3(16.4)	58.7(11.3)
Ephemerellidae	5.5(2.9)	0	5.0(2.5)	5.3(1.3)
Heptageniidae	1.0(0)	10.3(4.5)	8.0(3.1)	8.3(3.2)
Tricorythodidae	1.0(0)	2.0(0)	0	1.0(0)
Hydroptilidae	1.0(0)	14.5(5.3)	9.0(0)	1.0(0)
Leptoceridae	2.0(0)	1.0(0)	0	0
Leuctridae	4.3(1.8)	2.0(0.8)	2.0(0.6)	1.0(0)
Elmidae	6.3(0.7)	37.7(5.5)	82.3(33.2)	147.7(46.6)
Scrapers				
Glossosomatidae	1.0(0)	22.3(12.4)	53.0(27.0)	77.3(14.5)
Shredders				
Tipulidae	0	2.0(0)	1.0(0)	1.3(0.3)
Predators				
Gomphidae	0	1.5(0.7)	6.0(2.6)	11.7(8.0)
Perlidae	4.0(2.4)	5.0(1.5)	13.7(2.9)	31.3(11.6)
Corydalidae	0	1.0(0)	0	4.0(0)
Ceratopogonidae	6.3(2.1)	18.7(3.4)	13.7(3.5)	5.0(1.2)
Athericidae	2.5(1.2)	7.7(2.3)	6.7(0.3)	11.7(1.7)
TOTAL MEAN NO. INDIVIDUALS	117.00(36.8)	392.7(62.4)	537.3(148.2)	1023(127.8)

The proportion of individuals within each functional feeding group remained rather constant over time (Table 8.1, Fig. 8.1), indicating that, although absolute numbers of individuals increased over time, the increase among groups was proportionately the same.

Figure 8.2 shows temporal changes in dominance values. Chironomid dominance patterns are close to a mirror image of the Hydropsychid dominance pattern. Chironomids dominated the samples at Day 7 and Hydropsychids comprised barely one percent of the individuals; by Day 28, each group contained 31% of the individuals. Either Chironomids were early opportunistic colonists onto the substrates and Hydropsychids slowly colonized substrates, or the seasonal variation in the benthic community was reflected in these samples. In order to separate the two possibilities, repeated colonization experiments would be necessary. Baetids peaked by Day 14; Elmids stabilized by Day 21. Once again, either colonization patterns per se were operating or seasonal stage and behavior fluctuations accounted for the results.

The structural community indices appear on Table 8.2. By Day 14, the means and standard errors for richness, diversity and evenness had stabilized, and by Day 28, the variances among the samples were low.

Although the variances for the structural community indices were low (Table 8.2), the variances for individuals from well represented families were rather high, indicating that the five replicates we used for benthic invertebrate studies (Element 9) gave more precise data for interpretation of differences among families over monthly intervals. Four or five, rather than three samples would be the best trade-off between the time necessary to process samples and the level of precision desired in the results.

Based on the above exposure period study, and on the results from Element 9 (See especially data from the July FEX samples, as those samplers were put in place at the same time), we will use at least a 30-day exposure period for monitoring changes in benthic community structure and biomass. We will also process at least four samples from each site for the chosen time periods.

FIGURE 8.1

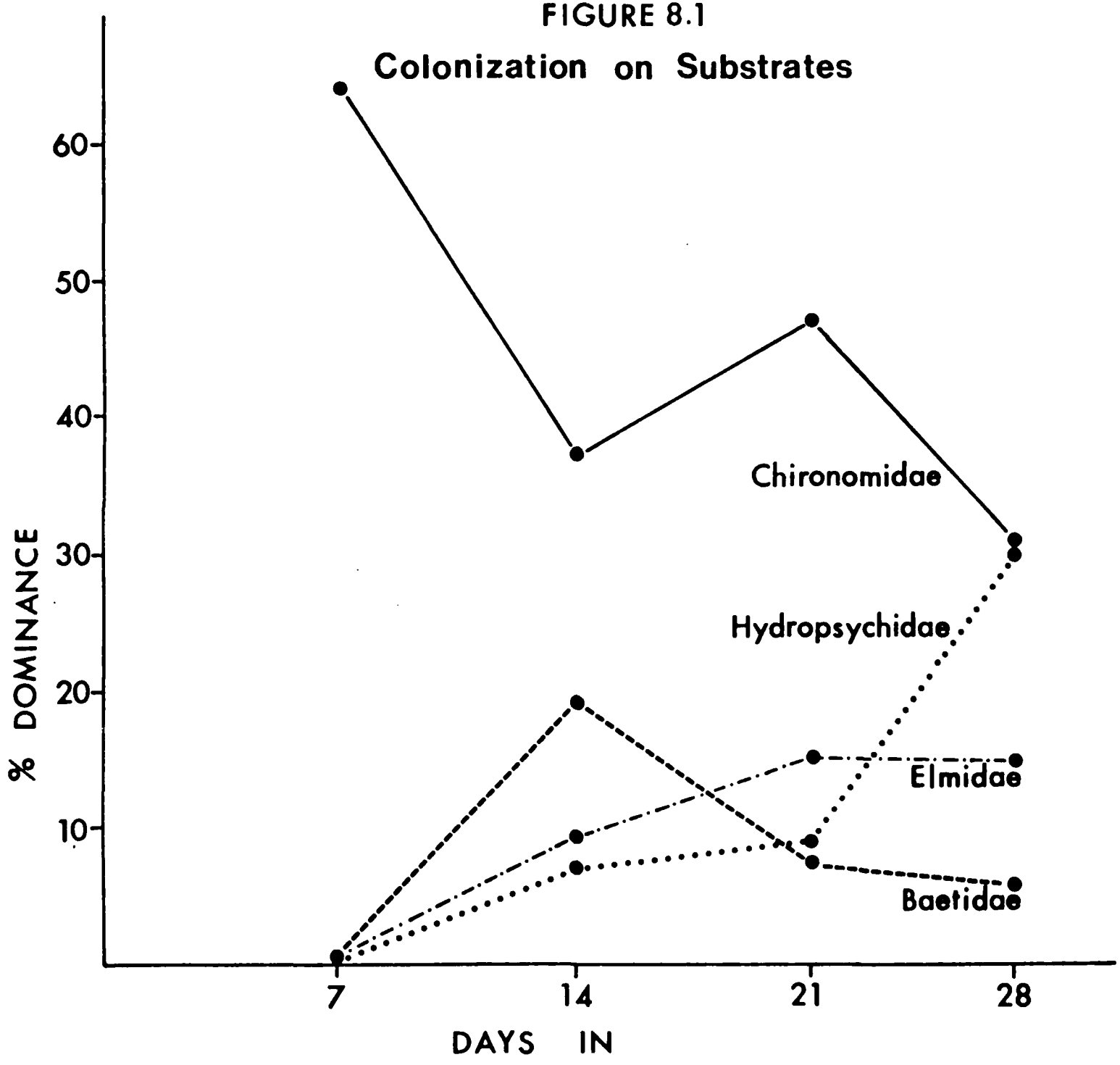
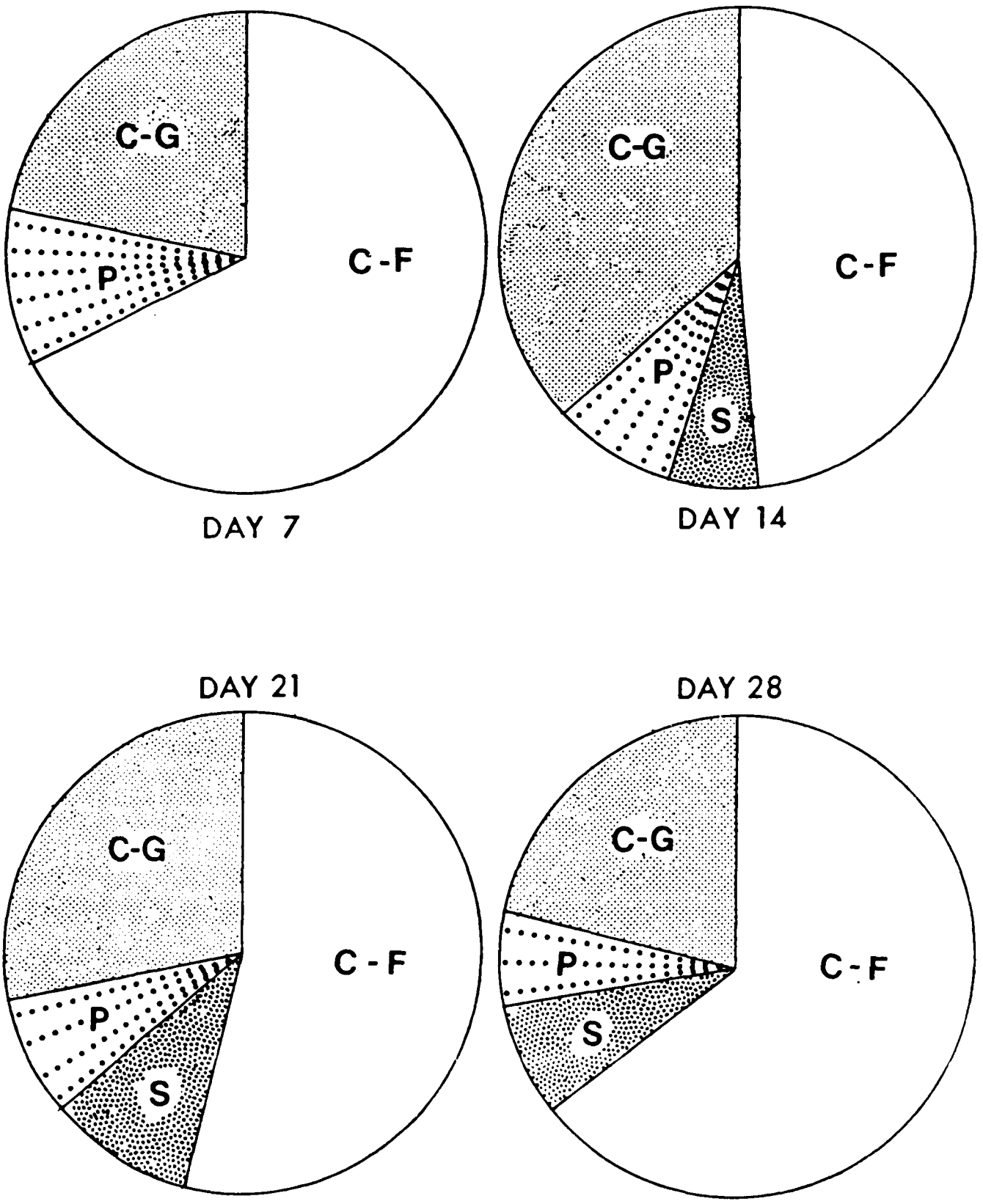

Colonization on Substrates
60
50
40
30
20
10
% DOMINANCE
Chironomidae
Hydropsychidae
Elmidae
Baetidae
7
14
21
28
DAYS IN

FIGURE 8.2
INVERTEBRATE TROPHIC RELATIONS



C-F = Collector-Filterers; S = Shredders; P = Predators; C-G = Collector-Gatherers

Table 8.2 Structural Community Indices for Insects Colonizing Benthic Substrates in the Experimental Site

Community Index	Day 7	Day 14	Day 21	Day 28
Richness				
mean	10.7	16.3	14.7	16.3
s.e.	2.3	0.7	0.7	1.3
Diversity				
mean	1.85	2.85	2.52	2.58
s.e.	0.29	0.08	0.23	0.08
Evenness				
mean	0.54	0.71	0.65	0.54
s.e.	0.04	0.03	0.06	0.02

Element 9 - Species Richness and Biomass of Stream Invertebrates from Artificial Substrates in Riffles and Pools

Synopsis - By means of artificial substrate samples and selected quantitative stream benthic samplers, we will determine the species richness and biomass per unit area at selected stream sites. Analysis of benthic samples will be conducted during the winter.

Changes from the Original Synopsis - Samplers will be used only in riffle areas. Diversity, richness, evenness and percent dominance will be done to family level first and to species level later. Biomass estimates will be completed prior to the field season 1984. Only samples from the 1983-designated sites on the Ford River will be processed (excluding samples taken in 1982 at the West Branch of the Escanaba and at Ford I).

Contributing Staff - J. Stout, Research Associate (PI)
R. Merritt, Associate Professor (PI)
W. Taft, Field Research Tech. II
Undergraduate Research Aide as needed

Objectives

1) To monitor changes in benthic insect fauna over time at control and experimental sites on the Ford River. 2) To compare the benthic insect community with the leafpack insect community. 3) To serve as a data base for Element 18 (fish food habits).

Materials and Methods

Plastic baskets 18 x 28 x 10 cm, lined with 60 mesh netting were filled with scrubbed sediments at each sampling site. In September of 1982, 40 samplers were imbedded in a riffle at Ford I and 35 were imbedded in a riffle at the West Branch of the Escanaba River. Five replicates were collected each month until April of 1983. In May of 1983, the FCD and at FEX sites were added; in June the FCU site was added.

From July to September, 5 replicates were taken at each of the three sites and replacements of 5 more samples were made each month. In October, 24 samplers were placed in substrates at FCD, 24 at FEX and 12 at FCU for 6 collections periods including 4 replicates each at FCD and FEX and 3 collection days including 4 replicates at the FCU site. Samples were taken in November and December of 1983; other months of collection will include February through May of 1984. Samples were processed and analyzed according to the methods described in Element 8.

Results and Discussion

The upstream control samples (FCU) contained significantly more insects in July of 1983 than did either of the other two sites. The differences between FEX and FCD were not significant (Table 9.1). Of the 15 families presented for FCU and FEX, only one family (Ceratopogonidae) showed no significant numerical difference. In contrast, FEX and FCD samples had similar numbers of individuals in five families. Three families at FCD were very under-represented at the FEX site. They included Hydropsychidae, Glossosomatidae and Gomphidae. These families were better represented at the FCU site. Polycentridae and Caenidae were more common at FEX than at either FCD or FCU. Based on total number of individuals in the samples and on numerical similarity among families, FEX and FCD were more similar to each other than was FCU to FEX. The site of choice as a control for the experimental site, *therefore, is FCD.*

Results differ for relative proportions of individuals, as compared with absolute numbers among families at the three sites. Table 9.2 presents percent dominance for major families in July and August. Additional samples (August at FCU and September through November) are being processed to assess changes over time at the three sites. Although absolute numbers of chironomids, numerically the most dominant family, were not significantly different between FEX and FCD, proportionately, FEX samples contained significantly more than did either of the other two sites. In August, both FEX and FCD sites had proportinately fewer chironomids than in July. However, their absolute abundances (Table 9.1) were higher, owing to the fact that numbers of individuals increased 2- to 3-fold in August, with a proportionately lower increase in chironomids for that month.

The families Hydropsychidae, Ephemerellidae, Elmidae and Leptophlebiidae also showed a significant increase in percent dominance in August. These changes are likely due to seasonal population fluctuations. After further processing of samples, we hope to give additional support to the thesis that the changes are seasonal rather than sample variance differences.

Table 9.1 Mean Numbers of Individuals for Major Insect Families in Substrates (s.e.)

FAMILY	SITES ON THE FORD FCU	FEX	FCD
JULY SAMPLES			
Chironomidae	2114 (254)	592 (144)	327 (67)
Hydropsychidae	434 (100)	0 (1)	87 (33)
Baetidae	189 (36)	22 (10)	29 (8)
Heptageniidae	159 (32)	51 (22)	15 (4)
Ephemerellidae	87 (17)	8 (2)	16 (4)
Glossosomatidae	72 (27)	0	52 (22)
Elmidae	61 (16)	17 (4)	15 (4)
Leptophlebiidae	39 (17)	10 (2)	16 (4)
Perlidae	39 (6)	8 (3)	22 (6)
Tricorythodidae	21 (4)	0	0
Siphlonuridae	14 (4)	2 (1)	2 (1)
Certapogonidae	6 (2)	6 (1)	0 (0)
Gomphidae	3 (1)	0 (1)	11 (4)
Polycenridae	0	20 (6)	6 (0)
Caenidae	0	15 (6)	4 (1)
Mean No. Individuals for all Families	3443 (445)	773 (184)	635 (118)
AUGUST SAMPLES			
Chironomidae		862.4 (125)	624 (61)
Hydropsychidae		79.4 (15)	266 (56)
Baetidae		18.4 (3)	74 (12)
Heptageniidae		85.6 (17)	29 (5)
Ephemerellidae		3.0 (0)	80 (21)
Glossosomatidae		18.4 (11)	17 (4)
Elmidae		71.4 (6)	62 (11)
Leptophlebiidae		87.8 (8)	460 (69)
Perlidae		14.2 (2)	72 (8)
Tricorythodidae		0	0
Siphlonuridae		0	0 (0)
Certogoponidae		10.2 (1)	5 (1)
Gomphidae		8.0 (2)	45 (7)
Polycentridae		0	0
Caenidae		2.5 (1)	0 (0
Mean No. Individuals for all Families		1351 (147)	1866 (284)

TABLE 9.2

Percent Dominance for Major Families of Insects in Substrates
(s.e. for 5 replicates)

FAMILY	SITES ON THE FORD		
	FCU	FEX	FCD
JULY SAMPLES			
Chironomidae	61.9(1.4)	77.8(2.8)	51.1(5.3)
Hydropsychidae	11.9(2.0)	0.02(.02)	11.9(2.8)
Baetidae	5.3(0.6)	2.6(1.0)	4.3(0.8)
Heptageniidae	4.5(0.6)	5.8(1.9)	2.3(0.7)
Ephemerellidae	2.5(0.3)	1.1(.03)	2.6(0.4)
Glossosomatidae	2.2(0.7)	0	11.0(6.0)
Elmidae	1.9(0.5)	2.3(0.2)	2.3(0.3)
Leptophlebiidae	1.2(0.3)	1.7(0.4)	2.8(0.9)
AUGUST SAMPLES			
Chironomidae		63.1(2.8)	34.4(1.0)
Hydropsychidae		6.0(1.1)	13.6(1.5)
Baetidae		1.4(0.1)	4.0(0.5)
Heptageniidae		6.0(0.8)	1.6(0.1)
Ephemerellidae		3.8(.01)	4.0(0.6)
Glossosomatidae		1.4(0.7)	11.0(6.0)
Elmidae		5.6(0.9)	3.7(1.0)
Leptophlebiidae		6.9(1.2)	20.9(3.3)

Similarities and differences for families between sites are given in Table 9.3. Numbers of families per site ranged from 25 to 30 familes; the number of families in common between sites ranged from 19 to 21; thus, there is high similiarity between sites for numbers of families. This is to be expected for samples taken over a nine mile distance in the single stream course. A comparison of families not in common between each set of two sites showed that FCD samples had more unique families than the other two sites. The difference is likely due to the higher number (30) of families found there than at the other two sites (25 and 26).

The structural community indices, richness, diversity and evenness for the sites in July and August are presented in Table 9.4. Richness (number of families) values were similar. (Note that the means in this table are lower than the overall number of families appearing in Table 9.3. Table 9.4 does not consider family names for all replicates together; but, rather, numbers of families in each replicate.) In July, diversity and evenness were significantly lower at FEX than at the other two sites. The low evenness can be attributed to two factors: High dominance of chironomids and low dominance values for all remaining families (Table 9.2). The differences in diversity and evenness between FEX and FCD in August were smaller, although FCD still had higher diversity and evenness values. In August, both percent dominance of chironomids decreased and percent dominance of all but one family (Baetidae) increased.

In summary, our data show more similarity in numbers of insects between FEX and FCD than between FEX and FCU. In August of 1983, in an effort to make the FEX and FCD sites more comparable for families represented, we moved the substrate sampling location at FEX upstream approximately 200 m to a site that appeared more similar to the FCD site. The new location contained more glossosomatids and hydropsychids in the natural substrates. Whether or not we achieved our goal will be determined when analyses are complete for the September through December samples.

Biomass data will be presented in the next annual report, as analysis had not been completed at this time.

TABLE 9.3

Overlap Values for Numbers of Families of Insects from Substrates
(Ford River, July,1983)

Pairwise Comparisons of Families in Common			
	S I T E S		
	FCU	FEX	FCD
FCU	25	19	22
FEX	-	26	21
FCD	-	-	30

Pairwise Comparisons of Unique Families			
SITES	No. Unique	% Unique	Total Unique
FEX	7	26.9	13
FCU	6	24.0	
FEX	5	19.2	14
FCD	9	30.0	
FCU	3	12.0	11
FCD	8	26.7	

TABLE 9.4. Structural Community Indices for Insects in Benthic Artificial Substrates in the Ford River (5 replicates)

	FORD RIVER SITES		
Community Index	FCU	FEX	FCD
July, 1983			
Richness			
mean	21.6	17.6	21.4
s.e.	1.0	1.6	0.8
Diversity			
mean	2.18	1.48	2.52
s.e.	0.04	0.15	0.14
Evenness			
mean	0.49	0.36	0.57
s.e.	0.01	0.03	0.03
August, 1983			
Richness			
mean		20.8	21.4
s.e.		0.5	1.0
Diversity			
mean		2.14	2.74
s.e.		0.11	0.02
Evenness			
mean		0.49	0.62
s.e.		0.03	0.01

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Element 10 - Movement Patterns of Selected Aquatic Invertebrates

Synopsis - By means of mark-recapture techniques, selected grazers and their predators will be collected, marked and released for later recapture (1, 2, 3, 7 days after release) to determine distances and directions traveled by the individuals. Various marking colors will be used according to day of marking. Analyses of data will occur during fall and winter.

Changes from Original Synopsis - None.

Contributing Staff - J. Stout, Research Associate (PI)
T. Burton, Associate Professor (PI)
R. Merritt, Associate Professor (PI)
D. Cornelius, Graduate Reseach Asst.
M. Ufford, Graduate Research Assistant

Objectives

1) Determine movement patterns of crayfish (Orconectes virilis) within and between sites. This includes both an analysis of movement patterns at each site as a function of site benthic characteristics and an analysis of long distance migration vs. local movements. 2) Determine microhabitat preference to be used as correlative data in movement studies of the crayfish at the sites. 3) Determine whether movement patterns of one of the dominant invertebrate predators, Ophiogomphus carolus, a larval odonate, exhibits non-random behavior in the stream. 4) To determine the life history of Ophiogomphus carolus in the Ford River, Dickinson County, Michigan, with emphasis on temporal features of cohort syncrony and emergence periods as a means of assessing reasons for observed movements.

Materials and Methods

A. Crayfish Movements

Much of this element was done in conjunction with the fish population and microhabitat preference (Element 15), since the same techniques and characterization of the benthos were used. Crayfish were captured by kick-seining at FEX, FCD and FCU fish population study sites. The crayfish were segregated by sample number and processed as described below. Additional data were gathered by hand capture at FCU and by accidental fyke net capture at FEX and FCD.

All crayfish were measured using total length from tip of rostrum to tip of the telson. Sex was determined by examining the first pair of pleopods for modification and sclerotization (males) and by looking for the annulus ventralis (females). Very young crayfish, generally less than 20 mm, could not be sexed during

August, but by September crayfish of all sizes captured had identifiable external sex characteristics.

All crayfish greater than 20 mm were marked by painting dots of enamel on the dorsal or lateral surfaces of the carapace. Crayfish at each site were marked with a unique color and pattern of dots so that their date and location of previous captures would be known.

B. Larval Odonate Studies

Two sites were chosen in June, 1983 for the study of Odonates. Both sites are considered riffle areas with a gravel substrate. The first site was located within the Ford Experimental Site (FEX) approximately 40 meters upstream from the ambient monitoring station. The site is 16 m long and 5 m wide, with a total area of 80 m^2. Due to substrate type and flow velocity considerations only 56 m^2 of this site were used in the study.

The second site was located within the upstream control site, (FCU), approximately 150 m above the periphyton sets. This site was 12 m long by 5 m wide, and divided into 60 m^2 plots. Individual square meter plots at both sites were marked in the corners by plastic flags embedded in the substrate. Each plot was numbered, from 1-56 and 1-60 for the experimental and upstream control sites respectively.

Samples to determine larval growth patterns and relative density were taken from square meter plots at both sites. The plots sampled for each sampling date were randomly determined by drawing numbers from a cup. Using a kickscreen consisting of two 1-inch dowels and a 1 m wide piece of window screen, the plots were kick sampled. Odonates were removed from the kickscreen and placed in a holding pan filled with stream water. The larvae were measured from the labrum to the tip of the abdomen using a 6-inch plastic ruler with mm divisions. After measurement the larvae were placed in a second holding pan until all individuals had been measured. The larvae were then returned to the plot before the next sample was taken. Samples were taken bi-weekly at each of the two sites during the summer of 1983. Samples will be taken in December 1983 and March 1984 at the experimental site.

Bi-weekly samples of Odonate larvae were collected from the upstream control site (FCU) and experimental site (FEX) from locations downstream of the experimental plots. The larvae were preserved in 90% ethanol and brought back to the lab. In the lab, food habits of the larvae will be determined from gut samples (Cummins 1973). This method of gut sampling involves micro-dissection of the gut in a depression slide, teasing out the gut contents, filtering the contents onto a millipore filter, and permanently mounting the filter on a slide for later examination.

Head capsules, sclerites, and other recognizable animal parts will be identified to determine prey frequencies and possible prey preference. Results of the gut samples will be compared with prey densities from benthic samplers (Element 9) using Ivlev's (1961) electivity index.

Emergence dates were determined by direct observation during the summer of 1983. For the emergence season of 1984, emergence traps will be used at the experimental and downstream control sites. The emergence traps will be placed on the stream bank overhanging the water surface. Emerging Odonates crawl from the stream and emerge on the stream bank or on streamside vegetation. Larval Odonates will enter the trap via the stream and emerge within the trap. The newly emerged dragonflies will fly to the top of the trap where they will be captured in a bread pan filled with formalin. The traps will be placed in the stream in mid-May and remain in the stream until mid-September.

Movement patterns of larval Odonates will be determined using mark-recapture techniques. The larvae will be marked using different colors of Testors paint (Stout 1982) coded by release site. The stream will be sectioned into 1 m^2 plots, demarked by flags at the corner of each plot. Initially, 40 m^2 plots in a 10 m by 4 m configuration will be used. The larval Odonates will be released in the center of the grid and recaptured by kick sampling individual plots after 1, 3 and 7 days. Movements will be statistically compared to movements expected on a random basis (Hart and Resh 1980).

Results and Discussion

A. Crayfish Movements

Based on successful Lincoln Index estimates of population size in 1982 at RAMSHACKLE (now abandoned as an ELF site), we began mark/recapture studies at FEX in June, 1983. The rocky riffle at the FEX ambient monitoring station (AMS) seemed ideal for studying the behavior of a crayfish population over time for the following reasons: 1) a sizable crayfish population was present, 2) there were no riffles with comparable substrate type for at least 1000 m up- or downstream; and 3) the riffle substrate is fairly heterogeneous, i.e., mostly cobble and larger rocks with some boulders, and some parts sandy. Within this riffle, we expected to follow growth rate and intermolt interval, local movements and microhabitat selection, and immigration and emigration for the entire riffle. However, recapture was unreliable-marked crayfish were not recpatured after one week. Since the intermolt interval is known to be longer than this and there was no evidence of excessive mortality or decline in the number of crayfish present, we concluded that the residence time of crayfish at this site was

short. Evidence that crayfish undertake long distance migrations in short time periods came when two female crayfish were captured in fyke nets set 440 m upstream from the riffle where they had been marked and released approximately 12 hours before.

One female was recaptured in a fyke net at FCD 600 m from where she had been released 4 days after marking. However, at the FCU site hand-captured marked crayfish remained within a 5 by 7 m rectangle that included the capture/release locations for at least 3 weeks. Crayfish captured by kick seining also were recaptured after 3 weeks near the location where they had been released. Hence, the technique used to capture the crayfish does not appear to influence subsequent recapture success. This evidence suggests that crayfish at FEX and FCD range widely and do not remain in a particular riffle for long periods of time. Crayfish at FCU neither leave the riffle nor do they appear to move very far within the riffle.

Once these movement patterns became apparent we ceased sampling at FEX-AMS riffle and began measuring and marking crayfish only within the fish population/microhabitat areas. (See Element 15 for description of sites). Habitat differences between the two downstream sites and FCU were hypothesized to be important in explaining different movement patterns and population sizes that we observed. O. virilis is an aggressive, non-burrowing species; the crayfish utilize interstitial spaces for resting between foraging bouts and for protection from predators (Bovbjerg, 1970). They also graze heavily on the diatoms and algae associated with the substrate. Therefore, more crayfish should be found in the habitats with larger average particle size (APS) and hence more interstitial spaces. Also, within a habitat, the crayfish should be distributed differentially in the microhabitats with larger APS. Figures 10.1-10.3 are length/frequency distributions for each site by date. There were always more crayfish at FCU than at the other two sites even after the young of the year were large enough to be sampled and occurred primarily at FEX and FCD.

Figures 10.4-10.6 show distribution of crayfish by micro-habitats for the three sites in August and September (crayfish were not separated by microhabitat in July). If APS was an important parameter for the observed distribution of crayfish among sites, we would expect that the distribution of animals among microhabitats would demonstrate the correlation as well. However, the distribution among microhabitats appears homogeneous except for the young of the year which were confined to microhabitats with greater than 80% rooted hydrophytes. A Pearson's r correlation was run for FCD, FEX and FCU for August (data not complete for September at the time of this report) and is summarized in Table 10.1; young of the year were excluded. There is low correlation between number of crayfish and APS at all microhabitats.

FIGURES 10.1, 10.2

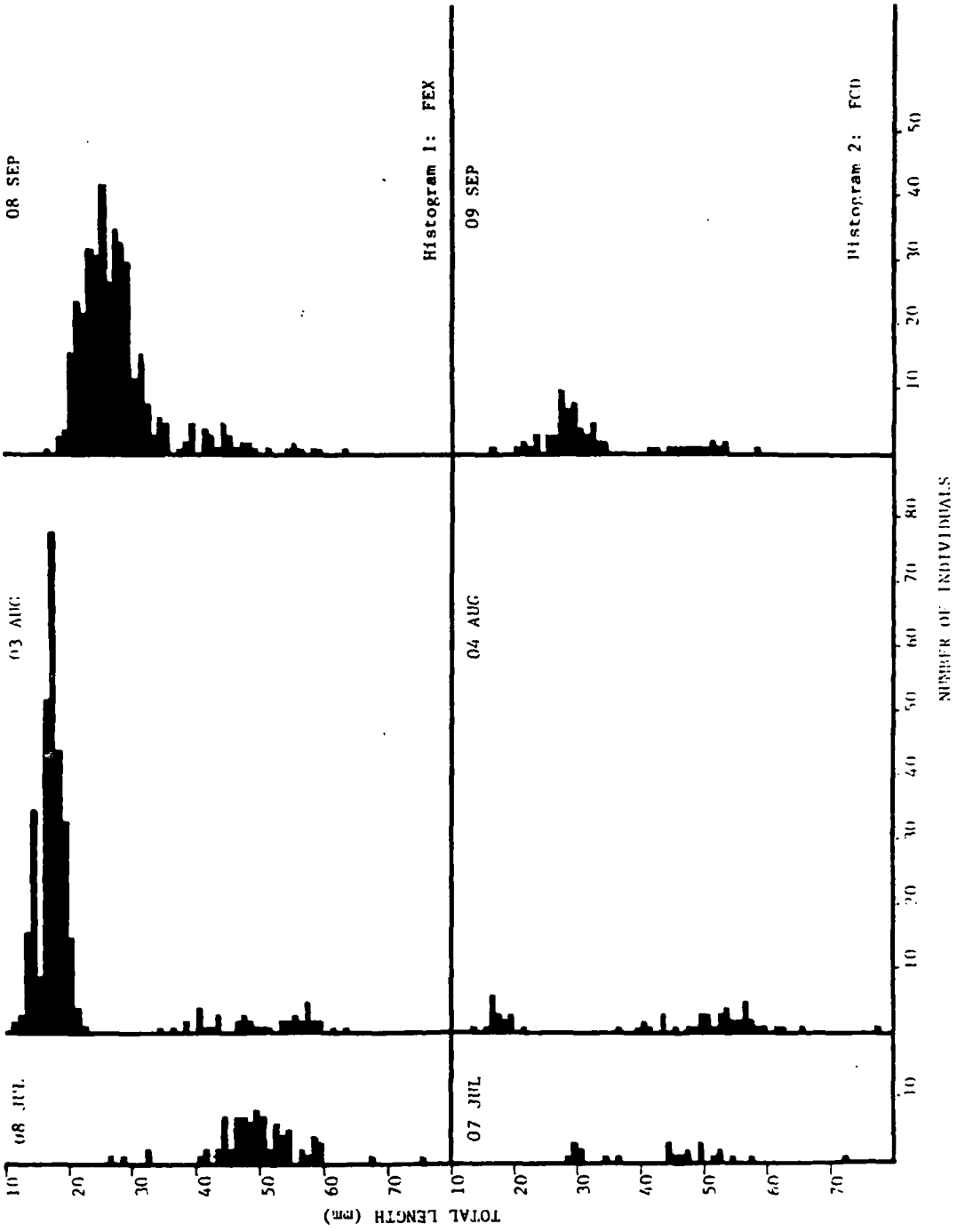


FIGURE 10.3

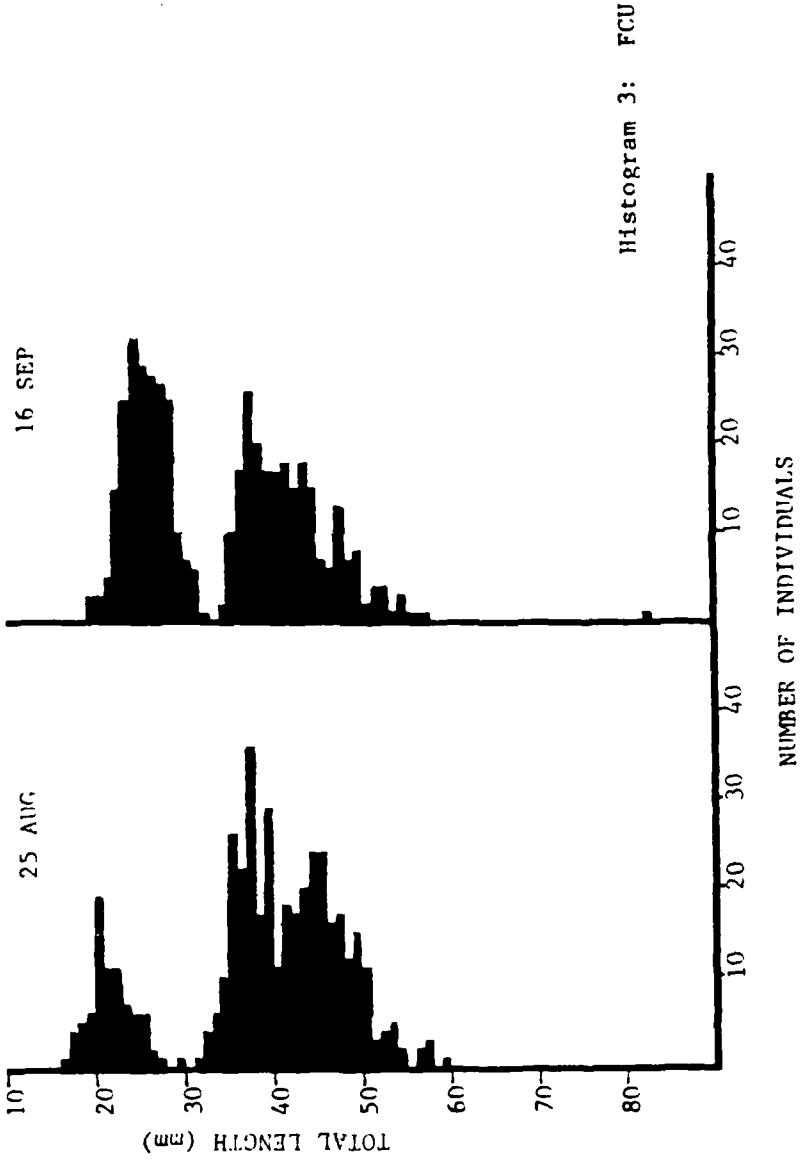

Histogram 3: FCU
16 SEP
25 AUG
NUMBER OF INDIVIDUALS
10
20
30
40
TOTAL LENGTH (mm)
10
20
30
40
50
60
70
80

TABLE 10.1

Pearson r values

		phi value*						
		-7	-6	-5	-4	-3	-2	-1
total number of crayfish	FEX	0	-.111	-.208	-.244	-.177	-.072	-.083
	FCD	0	.063	.264	-.013	.045	-.314	-.353
	FCU	.075	-.043	.023	.012	.102	-.136	-.106

*phi value	average particle size (mm)	
-7	64 - 256	cobble
-6	same	
-5	32 - 63	pebble
-4	16 - 31	"
-3	8 - 15	gravel
-2	4 - 7	"
-1	2 - 3	gravel

TABLE 10.2

Pearson r values

		bottom velocity
total number of crayfish	FEX	-.425
	FCD	-.244
	FCU	-.127

FIGURES 10.4, 10.5

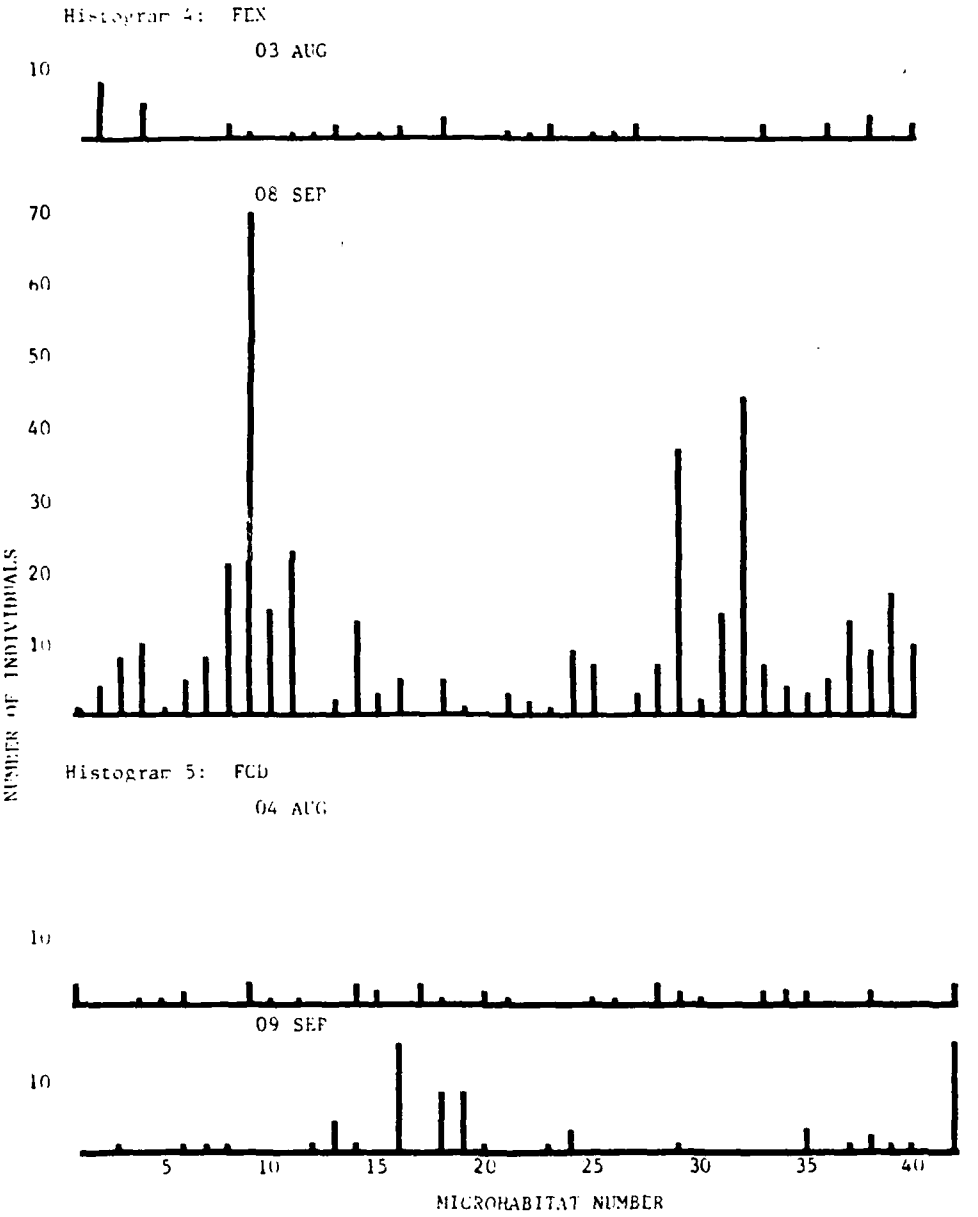
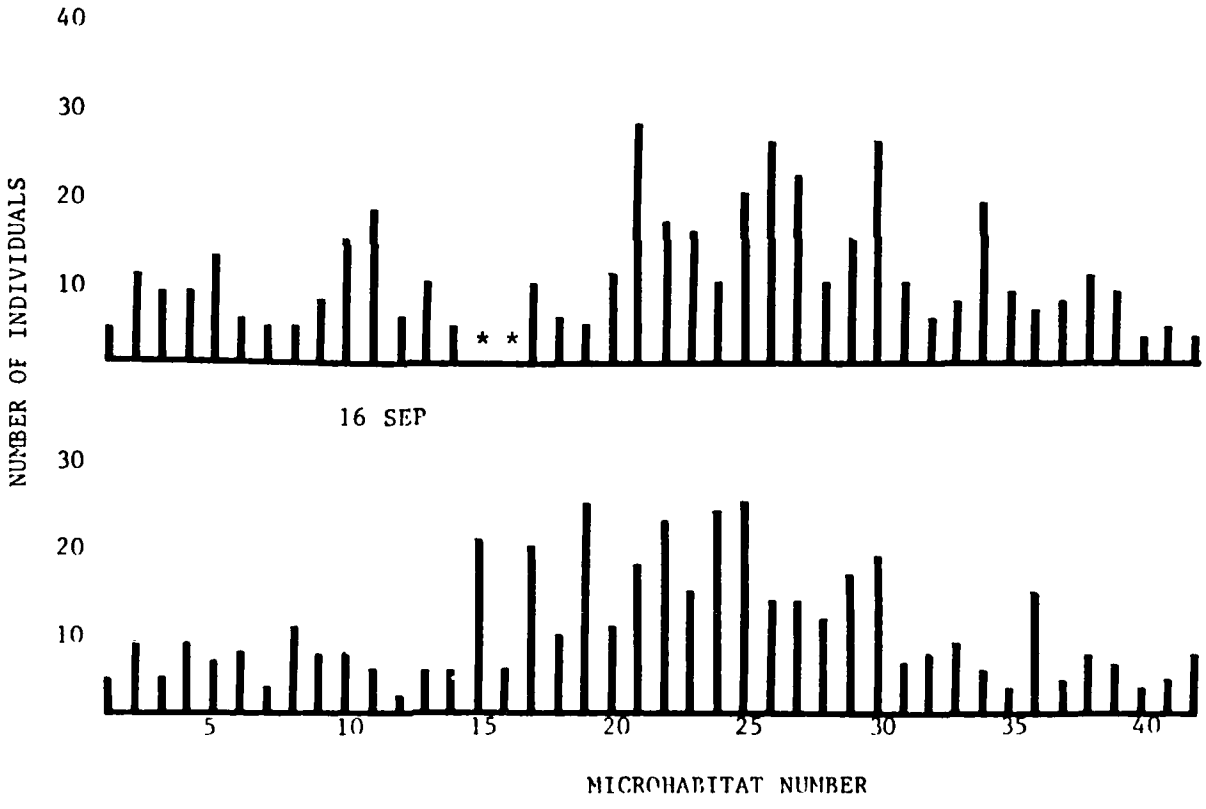


FIGURE 10.6

Histogram 6: FCU



* No Sample

Since APS reflects the maximum velocities along the channel bottom over time and not necessarily the present velocities, correlations were also run using bottom velocity measured at each microhabitat (Table 10.2). Once again, there was a low correlation between number of crayfish and bottom velocity. However, the velocities measured represent average velocities at zero depth for a larger area relative to the size of the crayfish, and may be quite different from the velocities actually encountered by crayfish within interstitial spaces. Furthermore, the interstitial velocities are not predictable based on APS.

O. virilis has been shown to be highly competitive in acquiring and retaining interstitial spaces (Bovbjerg, loc. cit.). Gut analyses have shown that a large proportion of the food consumed by these crayfish is periphyton associated with the substrate, but they do not appear to defend foraging territories or home ranges (Hazlett, 1974). These behaviors have been verified by observations on the crayfish in the Ford River. A possible explanation for the movement patterns observed, then, is that crayfish at FEX and FCD are resource limited with respect to interstitial spaces. Since suitable habitat appears to be widely separated, crayfish displaced from interstitial spaces may move long distances in order to find new habitat. Thus, the crayfish in the Ford River may be consistantly wide-ranging when habitat area is small and isolated, and may be more sedentary when it is continuous. The high recapture rate from 1982 RAMSHACKLE, which is a long riffle with continuous crayfish habitat similar to FCU, qualitatively supports this hypothesis.

Only larger females have been observed to migrate long distances. Crayfish making long distance migrations over the substrate where there is little protection from predators could be at risk. Larger individuals may make the journey more successfully than younger individuals. Whether females are more often excluded from habitats by the more aggressive males is unclear. When crayfish have been recaptured in the same area where they were marked there has been no difference between the sexes in recapture success, but this has not been analyzed using size class data.

In summary, crayfish at FEX and FCD exhibited both local and long distance movement patterns unlike those at FCU. Population size at FCU was larger than at either FEX or FCD even when the large cohort of young at FEX were included. There was not good correlation between number of crayfish and either APS or bottom velocity at microhabitats within sites. FCD is more comparable to FEX with respect to crayfish movement patterns and population density than FCU is to FEX.

When September's APS data become available, correlations will be run again using size class frequency of crayfish and APS, and bottom velocity. Population estimates using number of crayfish/ unit area will also be made when the average area of each kick seined sample is computed.

In order to determine why crayfish are so mobile at certain sites, we need to know which individuals are moving; weirs and minnow traps for capturing migrating crayfish were tested in September but difficulties with these methods remained unresolved at the close of the field season. This problem is the challenge for the 1984 season. Interstitial space velocities will be measured using dye dilution and electronic probe techniques, and observations with underwater gear will be used for determining local movements.

B. Larval Odonata Studies

It is suspected that Ophiogomphus carolus began emerging during late May and early June as researchers observed adults when they arrives at the site in late May/early June. No Ophiogomphus carolus adults were observed after August 19, 1983.

Sample size for the life history/relative density samples was estimated using Elliot's (1977) formula. Using this formula the minimum number of samples to estimate the mean density of the population at 90% confidence limits $\pm$ 40% of the mean was determined for both experimental and upstream control sites. The formula is as follows:

$$n = t^2/D^2 \ (1/\bar{x} + 1/K)$$

where:
- n = the number of replicates required
- t = the student's t distribution
- D = relative error in terms of % confidence interval
- x = mean number of organisms per sample

$$1/K = (s^2-\bar{x})/(\bar{x}^2 - s^2/n)$$

For the experimental site:

$n_o = 14$ where n_o = Number replicates taken to determine future sample size.

$s^2 = 79.8$
$\bar{x} = 23.6$
$t_{(.90,14-1)} = 1.8$
$D = .40$
$1/K = 0.10$

the number of replicates needed for the experimental site at 90% C.I. $\pm$ 40% was determined to be 2.8.

The number of replicates needed for the upstream control site were determined in the same manner. For the upstream control:

$n_o = 14$

$s^2 = 136.9$
$\bar{x} = 22.1$
$t_{(.90,14-1)} = 1.8$
$D = .40$
$1/K = 0.24$

The number of replicates required at 90% ± 40% for the upstream control site was determined to be 5.6.

A common sample number exceeding the minimum required for both sites was choosen. It was decided that 7 replicates would be taken from each site for each sampling date.

The density of Ophiogomphys carolus at the experimental site increased through mid-August and then declined in late-August and early September (Figure 10.7). This pattern could be due to recruitment during the early to mid summer period both from upstream and downstream areas and by reproduction. The upstream control site did not show this pattern (Figure 10.8). The population density was fairly stable through July, peaked in the beginning of August and rapidly declined by the end of August (Figure 10.8). The reasons for the decline to unacceptably low populations levels (for sampling purposes) was presumed to be a drastic reduction in flow, increased nutrient loading resulting in a bloom of aquatic macrophytes, and increased temperature. The most important factor influencing the decline of Odonates was felt to be siltation resulting from reduced flows. Areas that were observed to be silted yielded much lower densities of Odonates, however, these results were not quantified.

The independent-random samples from the two populations (upstream control and experimental site) were compared using a pooled estimate of the common σ^2. Individuals/square m over time for each site were compared as follows.

H_o: Density at experimental = density at upstream control
H_1: Density at experimental > density at upstream control

Experimental Site	Upstream Control
n=6 (dates combined)	n=5 (dates combined)
$s^2 = 114.3$	$s^2 = 67.4$
$(n-1)s^2 = 571.9$	$(n-1)s^2 = 571.5$
$\bar{x} = 36.9$	$\bar{x} = 21.6 = y$

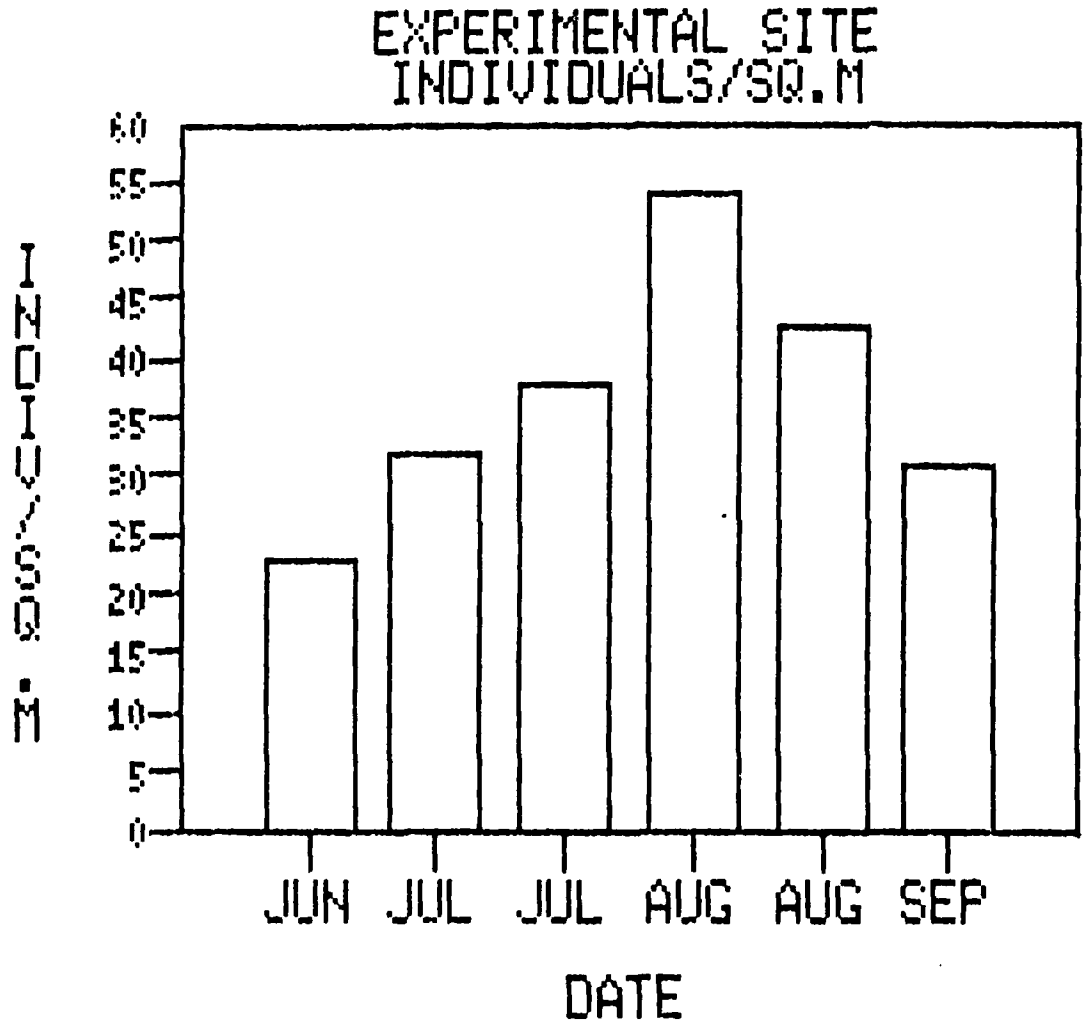

EXPERIMENTAL SITE
INDIVIDUALS/SQ.M
INDIV/SQ.M
60
55
50
45
40
35
30
25
20
15
10
5
0
JUN
JUL
JUL
AUG
AUG
SEP
DATE

FIGURE 10.7

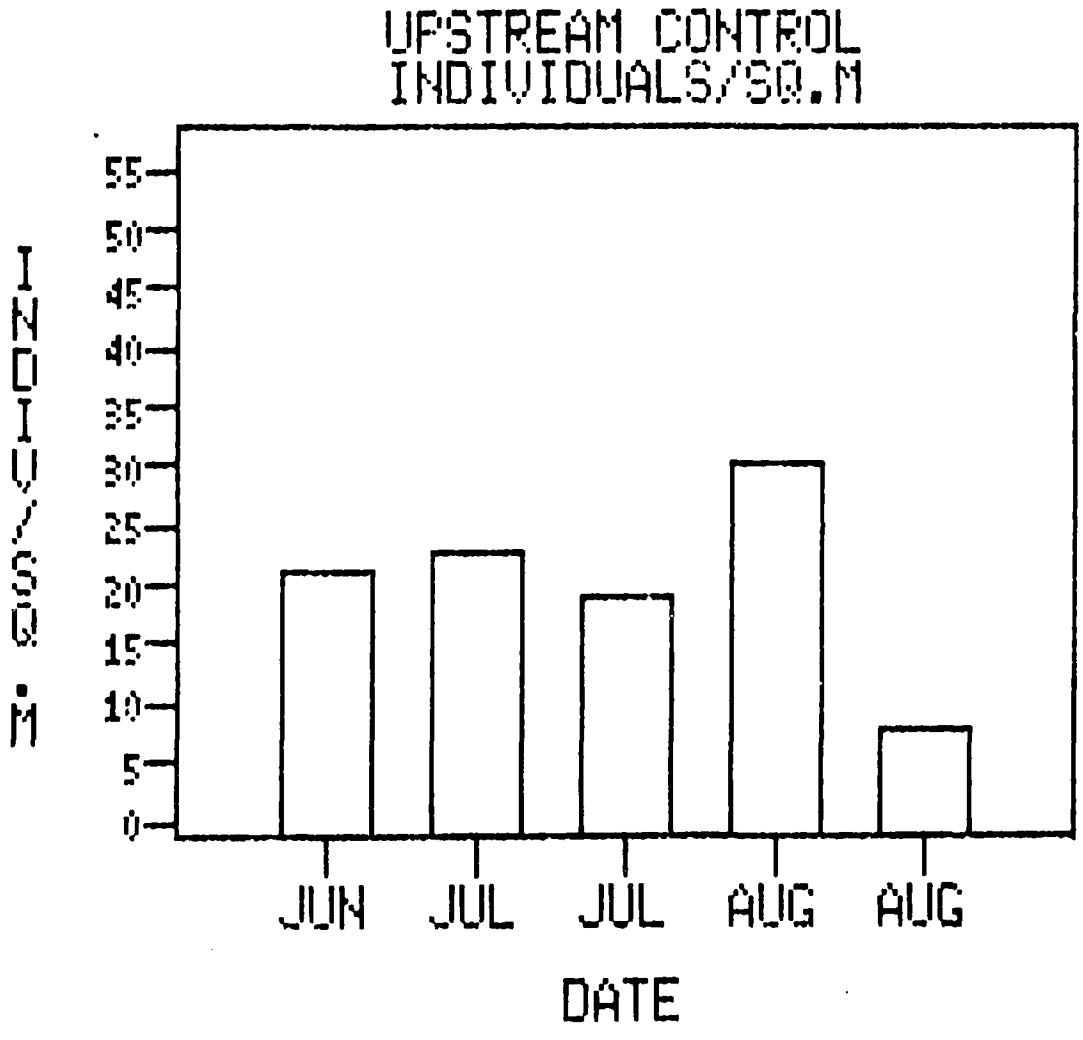

UPSTREAM CONTROL
INDIVIDUALS/SQ.M
INDIV/SQ.M
55
50
45
40
35
30
25
20
15
10
5
0
JUN
JUL
JUL
AUG
AUG
DATE

FIGURE 10.8

$$s^2_{pooled} = \frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1 + n_2 - 2} = 93.5$$

$$t = \frac{\bar{x} - y}{\sqrt{s^2_{pooled}\,(1/n_1 + 1/n_2)}} = 2.6$$

$$t = (.025,\ 9) = 2.3$$

Thus, H_o is rejected at $\alpha = .05$ level.

Thus, FCU is significantly different from the experimental site (FEX). For these reasons, the upstream control site has been dropped as a site for Odonate studies. Sampling will begin in the downstream control site to replace the site at the upstream control in March 1984.

Size frequency distributions were used to track larval development through time. A frequency distribution for the June, 1983 population of O. carolus at the experimental site (Figure 10.9) was compared with a combined distribution for two sampling dates in late August and early September (Figure 10.10). These data suggested that there were two distinct size groups that grew slowly through the summer. In June, there was a predominance of individuals in the 5 mm to 9 mm size classes and a second group between 14 mm and 16 mm. By late August early September these two size groups have grown to 8 mm - 12 mm and 16 mm - 18 mm respectively. This distribution with two distinct, slow growing size classes suggested a hemivoltine population. No pulses of individuals entered the small size classes during the summer season, suggesting a continuous recruitment over the summer. A similar pattern for size frequency distributions was also characteristic of the upstream control site (Figures 10.11 and 10.12). No sample was taken during September for the upstream control site because of extremely low population levels as previously stated.

Work on life histories for O. carolus is still very incomplete. Continued studies of larval growth and development will be carried out in the field and in the lab (using artificial streams) over the next year. These studies will be combined with gut analysis studies and movement studies to be conducted during the summer of 1984 to provide insight into the role of Odonates in the stream community.

At present, background life history and within riffle distribution data on larval Odonates has been collected as background data for the movement studies to be conducted in 1984.

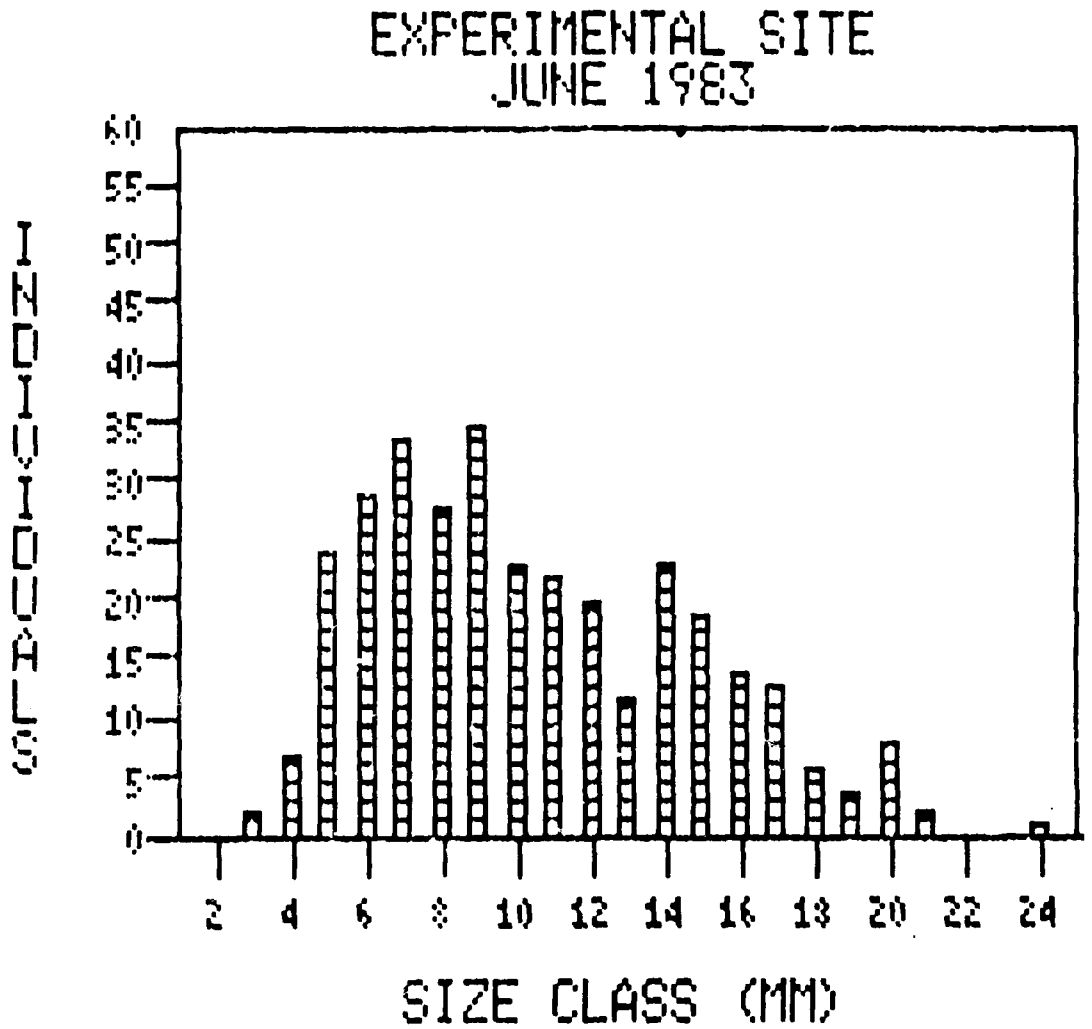

EXPERIMENTAL SITE
JUNE 1983
INDIVIDUALS
0
5
10
15
20
25
30
35
40
45
50
55
60
2
4
6
8
10
12
14
16
18
20
22
24
SIZE CLASS (MM)

FIGURE 10.9

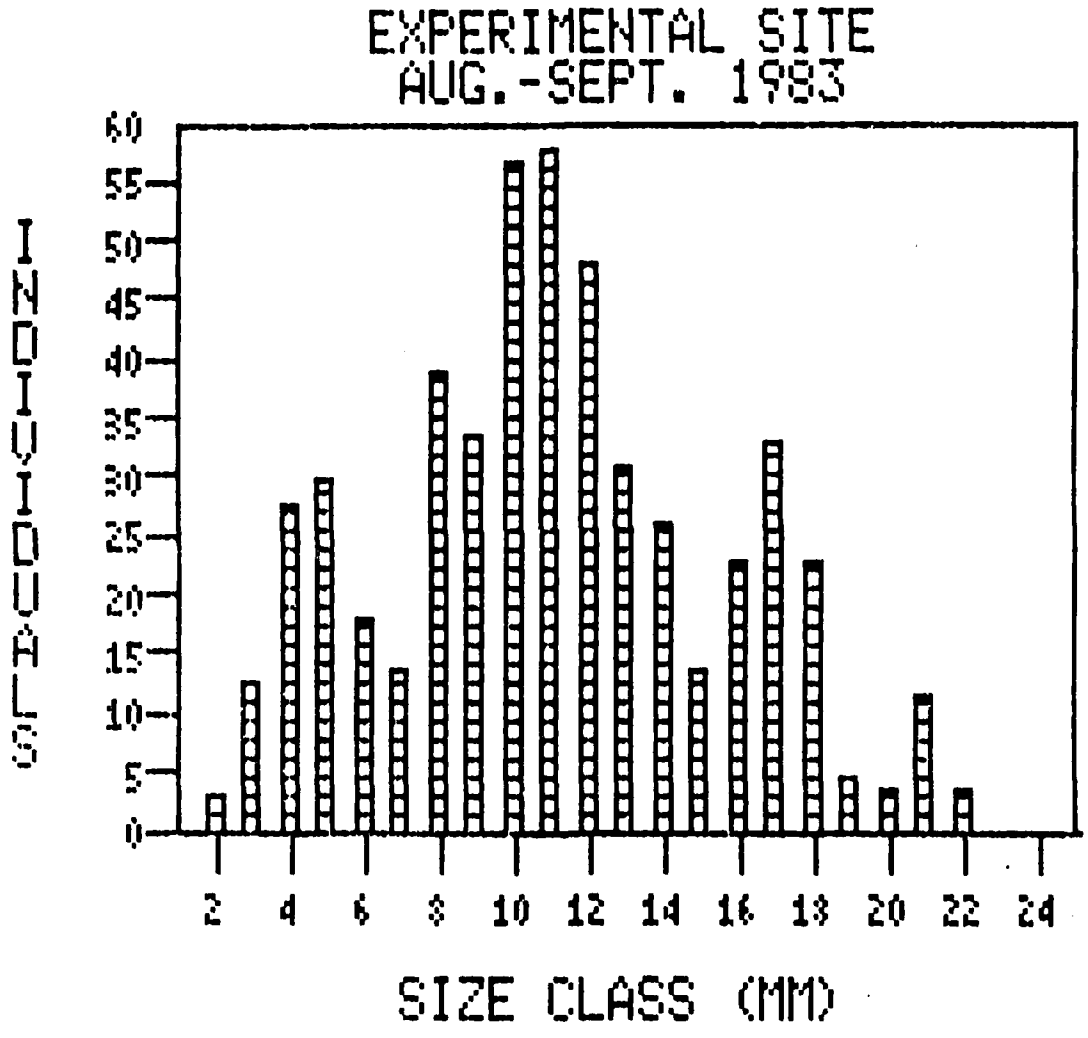

EXPERIMENTAL SITE
AUG.-SEPT. 1983
FREQUENCY
0
5
10
15
20
25
30
35
40
45
50
55
60
2
4
6
8
10
12
14
16
18
20
22
24
SIZE CLASS (MM)

FIGURE 10.10

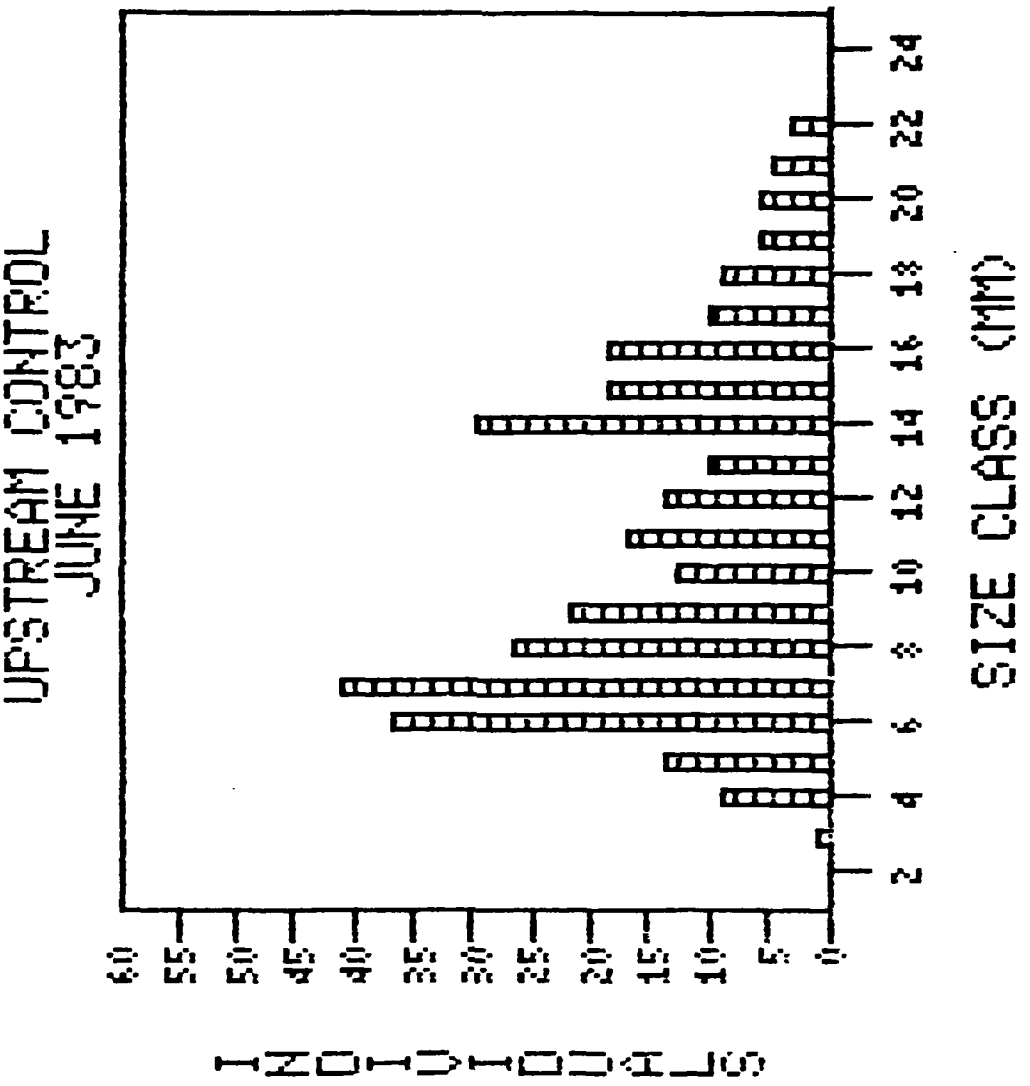

UPSTREAM CONTROL
JUNE 1983
NUMBER OF SNAILS
0
5
10
15
20
25
30
35
40
45
50
55
60
2
4
6
8
10
12
14
16
18
20
22
24
SIZE CLASS (MM)

FIGURE 10.11

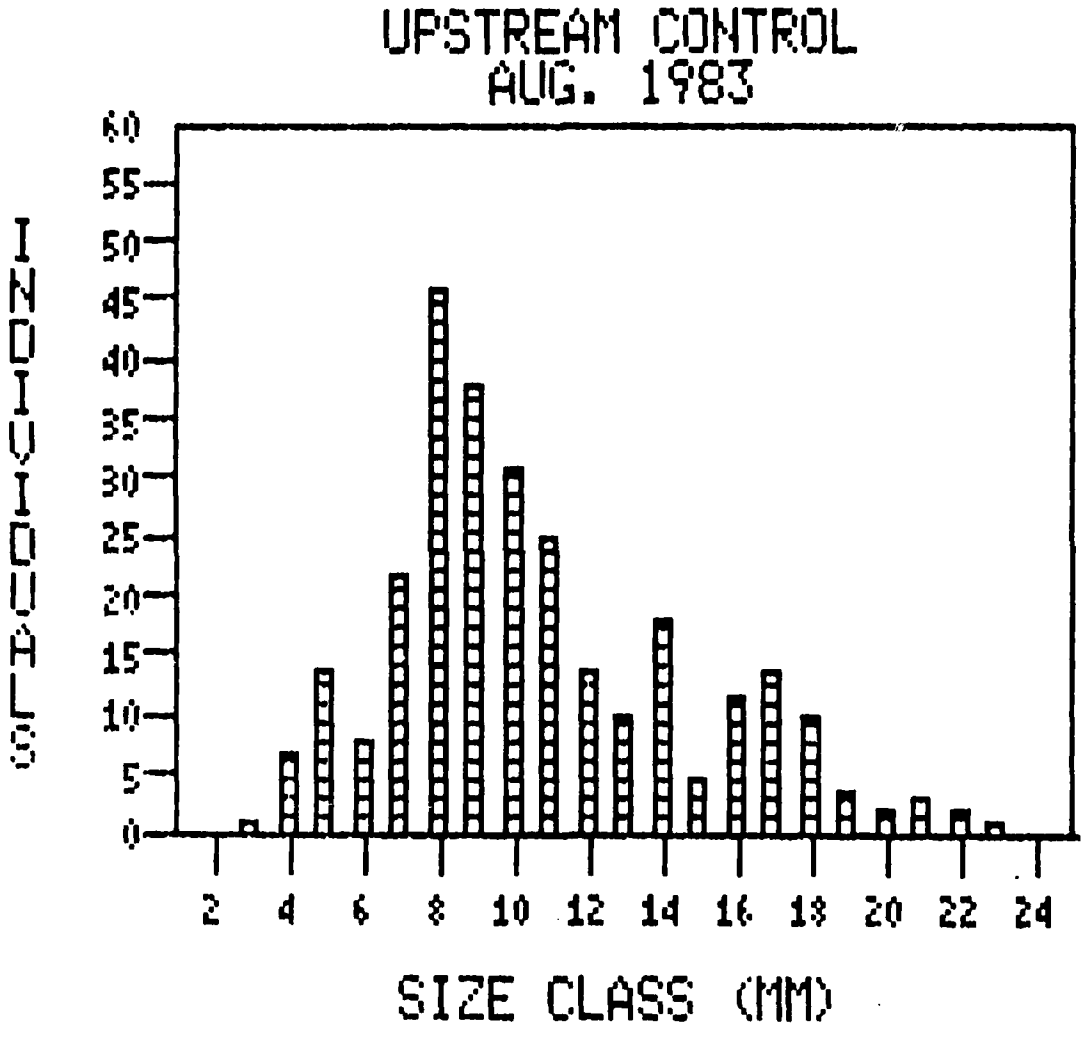

UPSTREAM CONTROL
AUG. 1983
INDIVIDUALS
0
5
10
15
20
25
30
35
40
45
50
55
60
2
4
6
8
10
12
14
16
18
20
22
24
SIZE CLASS (MM)

FIGURE 10.12

Element 11 - Colonization Patterns and Processing by Invertebrates on Autumnal Freshly Fallen Leaves

Original Synopsis - Examine the species diversity, species richness, abundance and biomass of stream macroinvertebrates on natural leaf litter accumulations in the stream. This task will also involve the collection and storage of leaves for leaf litter experiments in Fall of 1983.

Changes from Original Synopsis - Compare freshly picked leaves with Autumnal dried leaves with respect to leaf loss, insect diversity, richness, evenness and biomass. Identify and measure individuals to family level for most samples, with species identifications being done for one sample period in October and one sample period in January. Select two streams, one at the projected experimental area (Ford I) and one at a potential control stream (Schwartz).

Contributing Staff - J. Stout, Research Associate (PI)
T. Burton, Associate Professor (PI)
R. Merritt, Associate Professor (PI)
K. Webb, Graduate Research Assistant
D. Cornelius, Graduate Research Assistant
W. Taft, Field Research Tech. II

Objectives

1) To study dynamics of allochthonous input processing in the ELF experimental stream (Ford) and a (potential) control stream (Schwartz). 2) To determine colonization patterns of aquatic insects onto natural fresh and natural autumn leaves. 3) To determine loss rates of leaves over time. 4) To see if aquatic insects preferentially process either fresh or dried autumn leaves.

Materials and Methods

Two sites, Ford I (approximately 1.3 mi upstream from FEX), and Schwartz Creek (R28W, T44N, Sect. 10) were selected in the summer of 1982. The first site receives as its primary leaf inputs, Speckled Tag Alder (Alnus rugosa) and Balm of Gilead (Populus gileadensis); whereas, the second site receives primarily White Cedar needles.

Freshly picked Speckled Tag Adler leaves were gathered and measured for leaf area on a Licor Model LI-3000 leaf area meter. Ten leaves per leafpack were then strapped onto bricks. The bricks were placed in a riffle section of each stream on August 27, 1982. Parachutes were used for daily collection of autumn-fallen Speckled Tag Alder. Leaves were oven-dried at 60°C for 48 hr, weighed out into 3 gm leafpacks and strapped onto bricks. Bricks were placed adjacent to fresh leafpacks on September 22, 1982. Five replicates for each treatment at each site were picked up after 3, 9, and 27 days, and thereafter, at monthly intervals from September of 1982 through June of 1983.

At days of collection fresh leaves were measured for leaf area, dried 48 hr and weighed; autumn leaves were dried for 48 hr and weighed. Insects from the leafpacks were washed into sieves and then preserved in 90% alcohol. At the laboratory, insects were generally identified to family level and individuals were measured for later biomass estimates. Two exceptions were made for identification to family level: October 1982 and January 1983, insects were identified to species level.

Analysis included changes in leaf area and dry weight of leaves, counts of individuals among families (or species), determination of means and standard errors within replicates for the structural community indices diversity, richness and evenness (Shannon-Weiner), one-way ANOVA tests for differences over time for the above variables and Tukey's Multiple Range test for grouping exposure times when ANOVA tests showed over-all differences. In addition, percent dominance of common groups were determined, and canonical distribution graphs were made to better visualize the relationships among the community indices.

Results and Discussion

A. Autumnal, dried leaves.

Leaf loss was slightly faster in the Ford than in Schwartz Creek. By approximately Day 65, 50% of the leaf dry weight was lost in the Ford and by approximately Day 115, 50% of leaf area was lost in Schwartz Creek (Fig. 11.1). Diversity values were significantly different between the two sites. The types of insects coming onto dried leaves in the Ford were more diverse than insects in Schwartz leafpack samples. This was especially true in the fall and winter months (Fig. 11.1). Except for Day 57, there were significantly more families in leaves in the Ford than in Schwartz Creek dry leaves (Fig. 11.2). Evenness was also higher in the Ford during the initial colonization phase (through Day 57). Later, the high variance found in Schwartz samples resulted in a statistical overlap between the two sites for evenness (Fig. 11.2).

Within the Ford samples, one-way ANOVA tests and Tukey's H.S.D. tests were done to test several hypotheses ($\bar{q}$) regarding changes in leaf mass, diversity, richness and evenness over time.

FIGURE 11.1

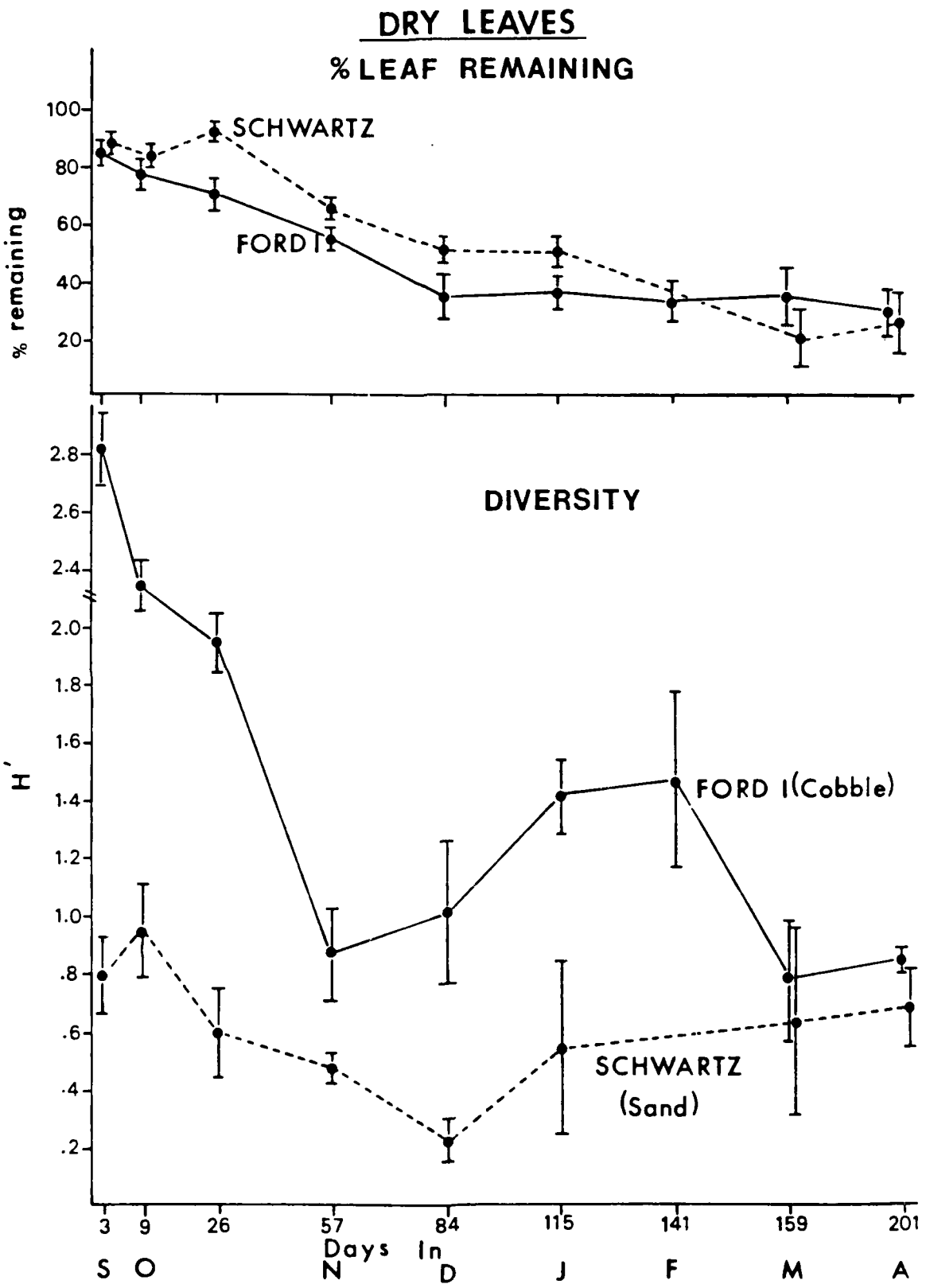

DRY LEAVES
% LEAF REMAINING
% remaining
100
80
60
40
20
SCHWARTZ
FORD I
DIVERSITY
H'
2.8
2.6
2.4
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
FORD I(Cobble)
SCHWARTZ
(Sand)
3
9
26
57
84
115
141
159
201
Days In
S
O
N
D
J
F
M
A

FIGURE 11.2

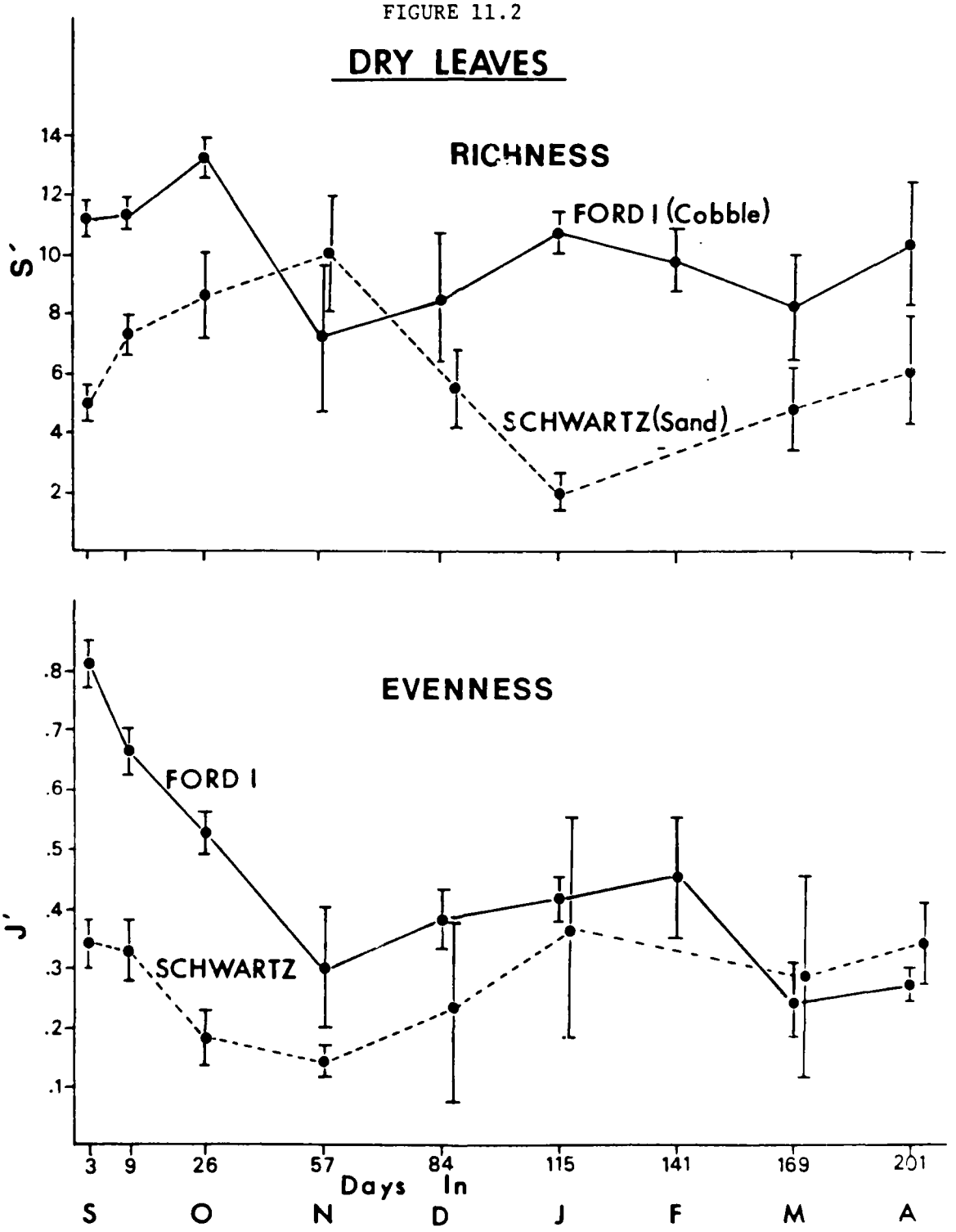

DRY LEAVES
RICHNESS
S'
14
12
10
8
6
4
2
FORD I (Cobble)
SCHWARTZ(Sand)
EVENNESS
J'
.8
.7
.6
.5
.4
.3
.2
.1
FORD I
SCHWARTZ
3
9
26
57
84
115
141
169
201
Days In
S
O
N
D
J
F
M
A

Table 11.1 gives a synopsis of the results. Where the ANOVA tests showed significant differences among days for any given variable, Tukey's tests were done. Only in the case of richness was there no significant difference among treatments (days = treatments). By Tukey's test, leaves lost weight at a significantly higher rate in the fall versus the winter and in the fall versus the winter and spring combined. Diversity showed the same pattern. Evenness was significantly higher during the first nine days of conditioning as compared with the next 48 days, and the evenness index was significantly higher in the fall (to Day 57) as compared with winter and spring combined. For all parameters, neither the winter nor spring sampling periods showed significant differences among days. It was, therefore, the fall period (57 days) which showed the greatest changes for the variables tested. The fall time when leaves had been in the streams for the shortest period showed the most active processing and most active colonization period for leaves and aquatic insects.

B. Freshly picked leaves

Fresh leaves do fall in streams during the summer and autumn months; however, most aquatic researchers have not looked at the processing rates and invertebrate colonization patterns on fresh leaves. We chose to do so, and to compare fresh leaf inputs with dry autumn leaves -- the leaves that most temperate zone researchers use.

The rate of leaf area loss was similar in the Ford and Schwartz. In both cases 50% of the leaf area was gone by Day 83. Although diversity for aquatic insects was lower for fresh leaves in Schwartz Creek as compared with the Ford, the difference was not as pronounced as for dried autumn leaves because invertebrates on the fresh leaves were more diverse than invertebrates on the autumn leaves in Schwartz (Fresh; $\bar{x}$ = 1.536, s.e. = 0.406. Dry; $\bar{x}$ = 0.605, s.e. = 0.127, see also Fig. 11.3). The same pattern held for richness; i.e., the Ford samples had higher richness than the Schwartz, but the difference was not as great as for insects coming onto dried Tag Alder (Fig. 11.4). There was no difference for evenness between the Ford and Schwartz samples during the early colonization phase; there also was low variance among replicates for the Schwartz samples throughout the study, resulting in a lack of statistical overlap for evenness for the two streams later in the study (Fig. 11.4).

TABLE 11.1

Tests for Differences Across Time for Dried Leaf Study in the Ford

VARIABLE	ONE-WAY ANOVA d.f	MSS	F ratio	F prob.	TUKEY'S H.S.D. TEST
Percent Leaf Remaining	8 34	2608.534 187.731	13.895	.0000	$\bar{q}_1$=146.177, $MSD_{.01}$=110.896 (> 99%) $\bar{q}_3$=807.29, $MSD_{.01}$=420.212 (> 99%)
Diversity (H')	8 34	2.740 0.177	15.472	.0000	$\bar{q}_1$=3.125, $MSD_{.05}$=2.8935 (> 95%) $\bar{q}_3$=18.601, $MSD_{.01}$=12.9066 (> 99%)
Richness (S)	8 34	17.880 11.404	1.568	.1713	--------
Evenness (J')	8 34	0.194 0.016	11.776	.0000	$\bar{q}_3$=4.698, $MSD_{.01}$=3.9394 (> 99%) $\bar{q}_4$=0.667, $MSD_{.01}$=0.5883 (> 99%)

Hypotheses:

q_1 = September through November samples differ from December through January samples (Fall versus Winter)

q_2 = December through January samples differ from February through April samples (Winter versus Spring)

q_3 = September through November samples differ from December through April samples (Fall versus Winter and Spring)

q_4 = Day 3 differs from Day 9 (Initial conditioning period)

q_5 = October samples differ from November samples (Colonization period after conditioning)

q_6 = January samples differ from March samples (Mid-winter versus early Spring)

q_7 = March samples differ from April samples (Within Spring season comparison)

q_8 = December samples differ from January samples (Within Winter season comparison)

FIGURE 11.3

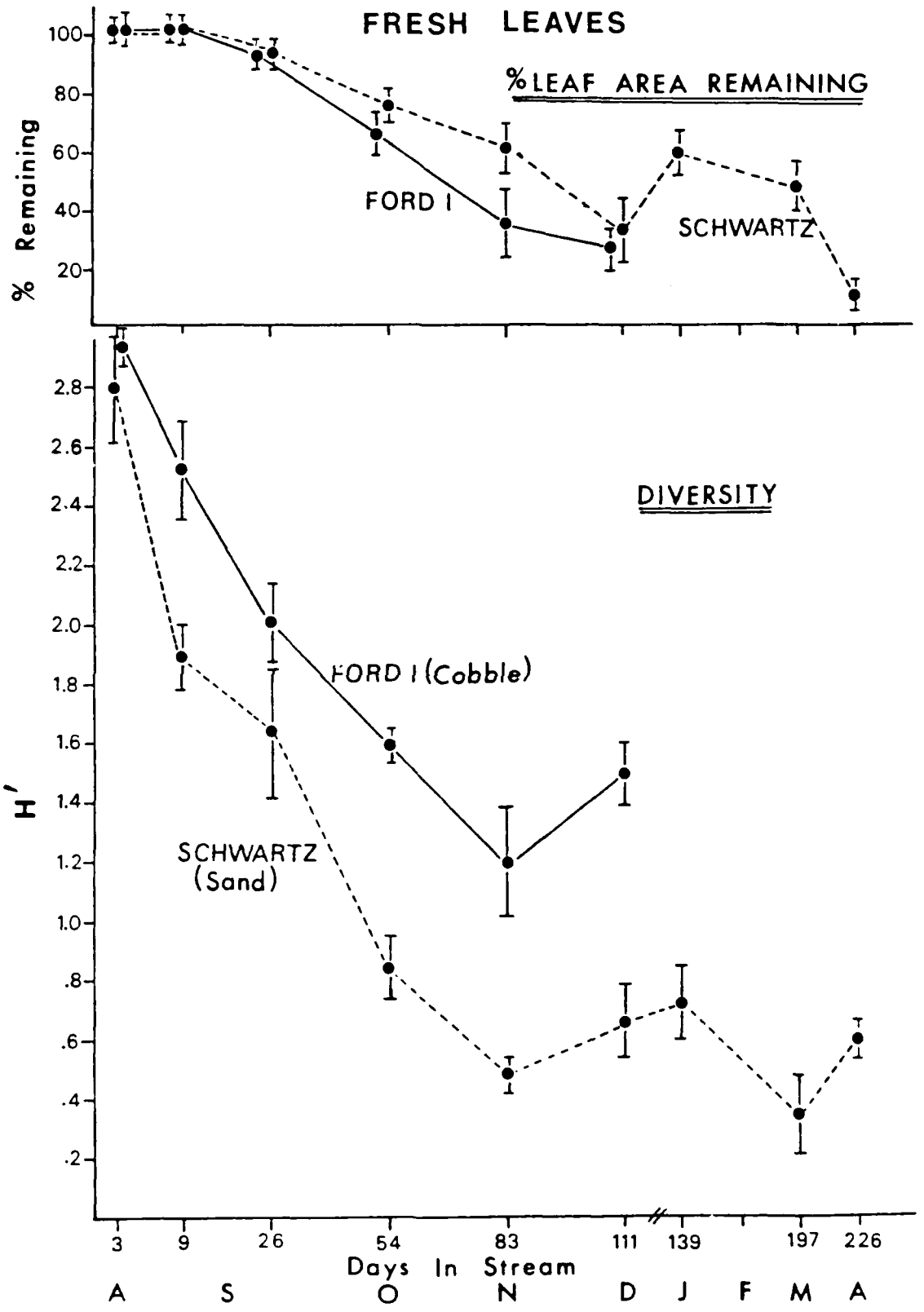

FRESH LEAVES
%LEAF AREA REMAINING
% Remaining
100
80
60
40
20
FORD I
SCHWARTZ
DIVERSITY
H'
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
FORD I (Cobble)
SCHWARTZ
(Sand)
3
9
26
54
83
111
139
197
226
Days In Stream
A
S
O
N
D
J
F
M
A

FIGURE 11.4

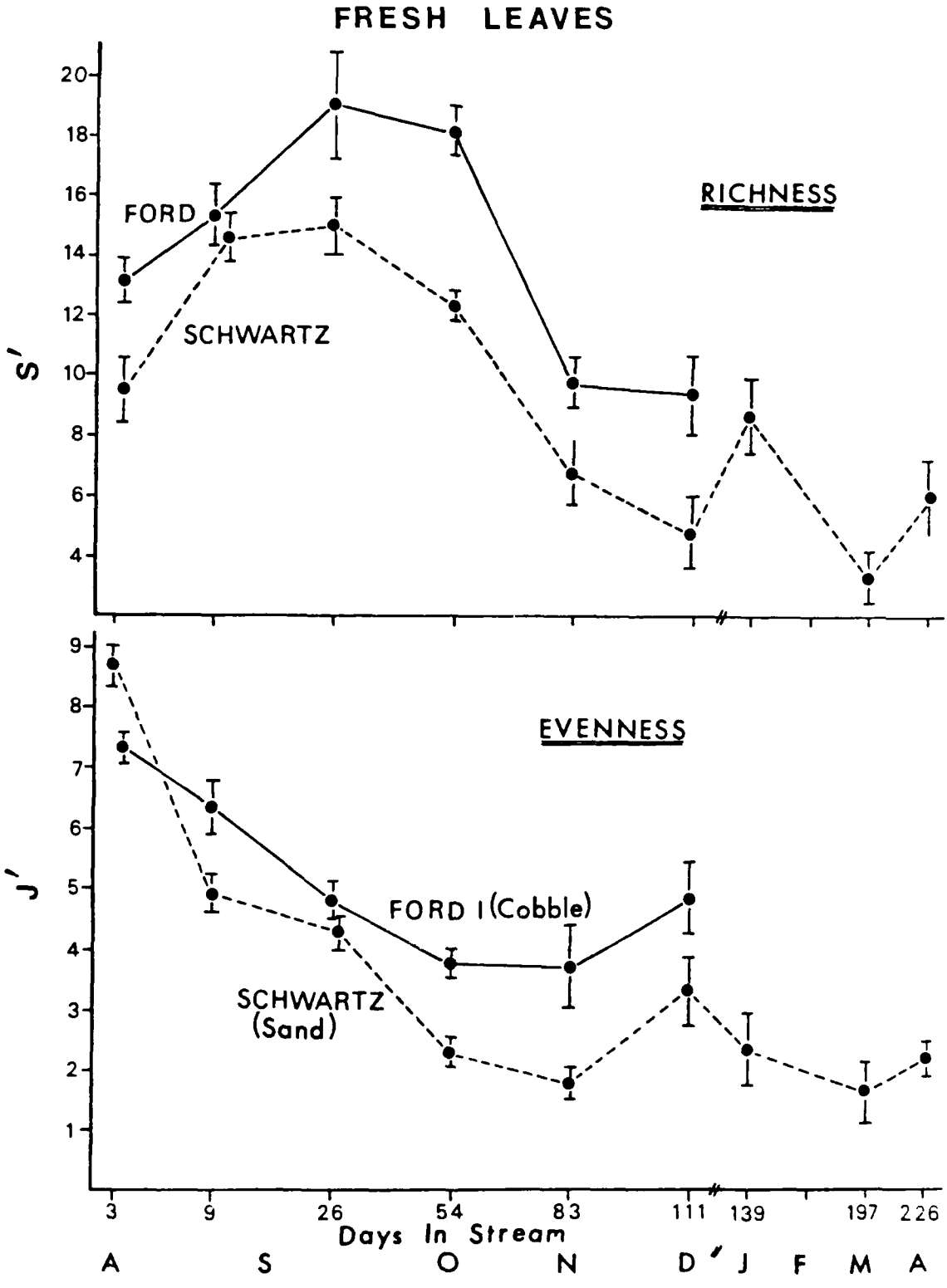

FRESH LEAVES
RICHNESS
FORD
SCHWARTZ
S'
20
18
16
14
12
10
8
6
4
EVENNESS
J'
9
8
7
6
5
4
3
2
1
FORD I (Cobble)
SCHWARTZ
(Sand)
3
9
26
54
83
111
139
197
226
Days In Stream
A
S
O
N
D
J
F
M
A

FIGURE 11.5

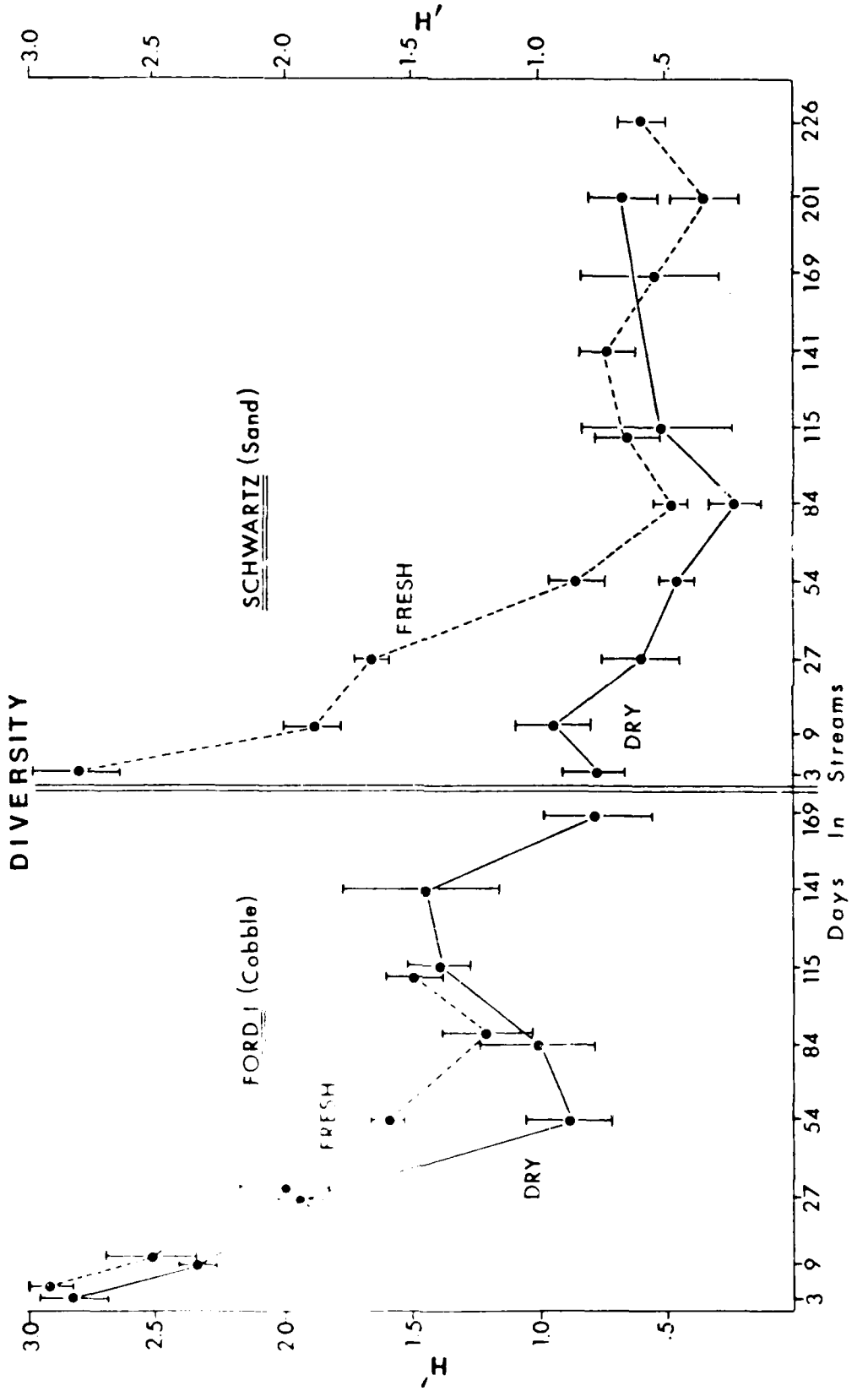

DIVERSITY
H'
3.0
2.5
2.0
1.5
1.0
.5
SCHWARTZ (Sand)
FRESH
DRY
FORD I (Cobble)
FRESH
DRY
3
9
27
54
84
115
141
169
201
226
Days In Streams

TABLE 11.2

Mean Number of Individuals per Leafpack on Dry and Fresh Leaves
(5 replicates)

SITE	DAYS IN	DRY LEAVES	FRESH LEAVES	DAYS IN
FORD				
	3	49.0	138.0	3
	9	160.0	317.4	9
	26	227.2	657.2	26
	57	158.0	783.5	54
	84	122.8	213.5	83
	115	152.2	135.4	111
SCHWARTZ				
	3	37.6	35.4	3
	9	180.4	146.0	9
	27	306.6	308.8	26
	58	395.0	396.3	52
	85	257.4	183.4	81
	116	7.8	85.2	108

FIGURE 11.6

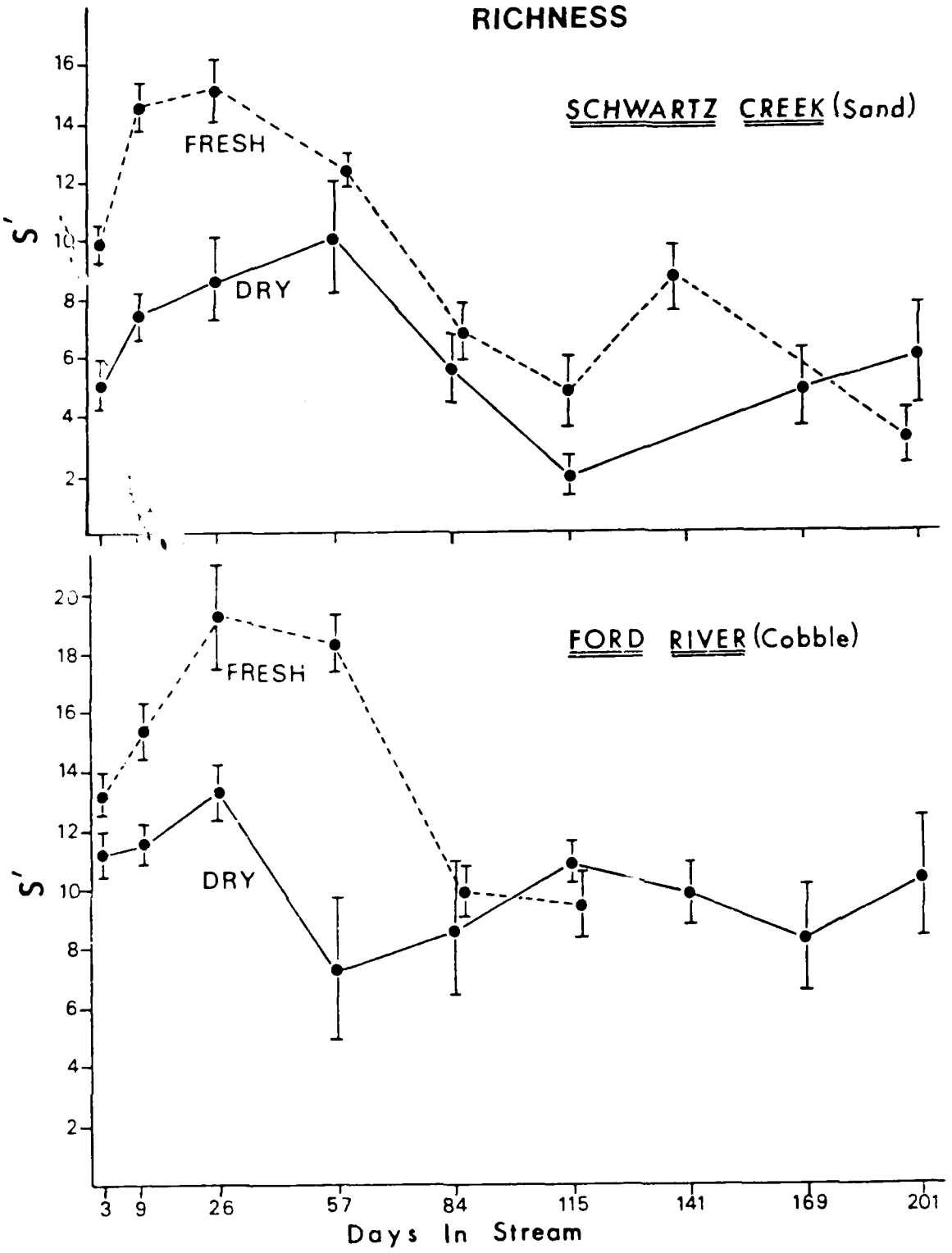

RICHNESS
SCHWARTZ CREEK (Sand)
FRESH
DRY
S'
16
14
12
10
8
6
4
2
FORD RIVER (Cobble)
FRESH
DRY
S'
20
18
16
14
12
10
8
6
4
2
3
9
26
57
84
115
141
169
201
Days In Stream

FIGURE 11.7

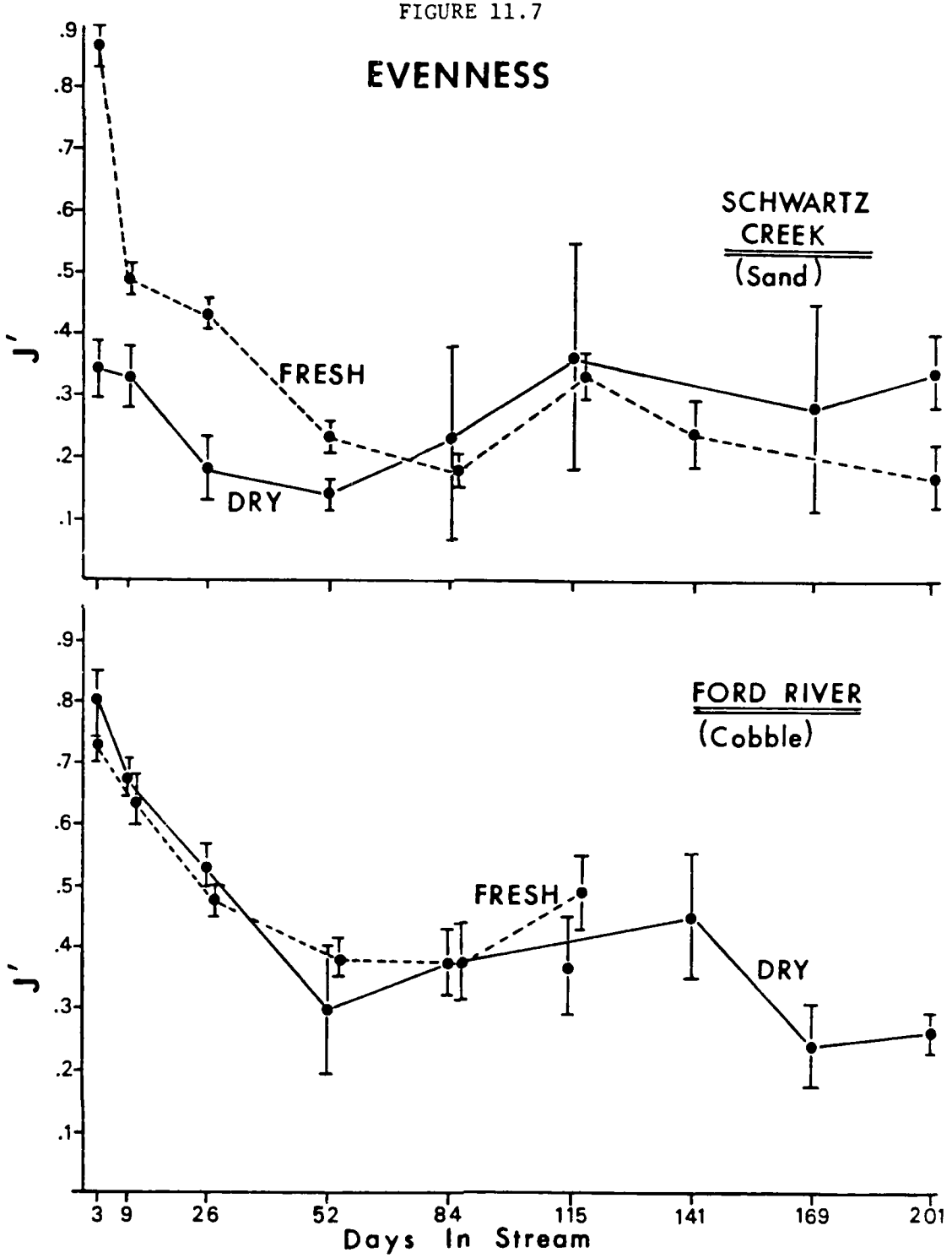

EVENNESS
SCHWARTZ CREEK
(Sand)
FRESH
DRY
FORD RIVER
(Cobble)
FRESH
DRY
J'
.9
.8
.7
.6
.5
.4
.3
.2
.1
3 9 26 52 84 115 141 169 201
Days In Stream

TABLE 11.3

STRUCTURAL COMMUNITY PARAMETER
DIFFERENCES FOR TWO STREAM TYPES
IN MICHIGAN

SITE	SPECIES DIVERSITY		SPECIES RICHNESS		SPECIES EVENNESS	
	Fresh Leaves	Dry Leaves	Fresh Leaves	Dry Leaves	Fresh Leaves	Dry Leaves
FORD RIVER	0	0	+	-	0	0
SCHWARTZ CREEK	+	-	+	-	+	-

where 0 = no difference

\+ = higher

\- = lower

TABLE 11.4

STRUCTUAL COMMUNITY PARAMETER DIFFERENCES FOR AQUATIC INSECTS ON FRESH VERSUS DRY AUTUMN LEAVES IN TWO MICHIGAN STREAMS

LEAF CONDITION	SPECIES DIVERSITY		SPECIES RICHNESS		SPECIES EVENNESS	
	Ford	Schwartz	Ford	Schwartz	Ford	Schwartz
FRESH	+	-	+	-	0	0
DRY AUTUMNAL	++	--	Mixed	Mixed	+	-

where 0 = no difference

\+ = higher

\- = lower

FIGURE 11.8

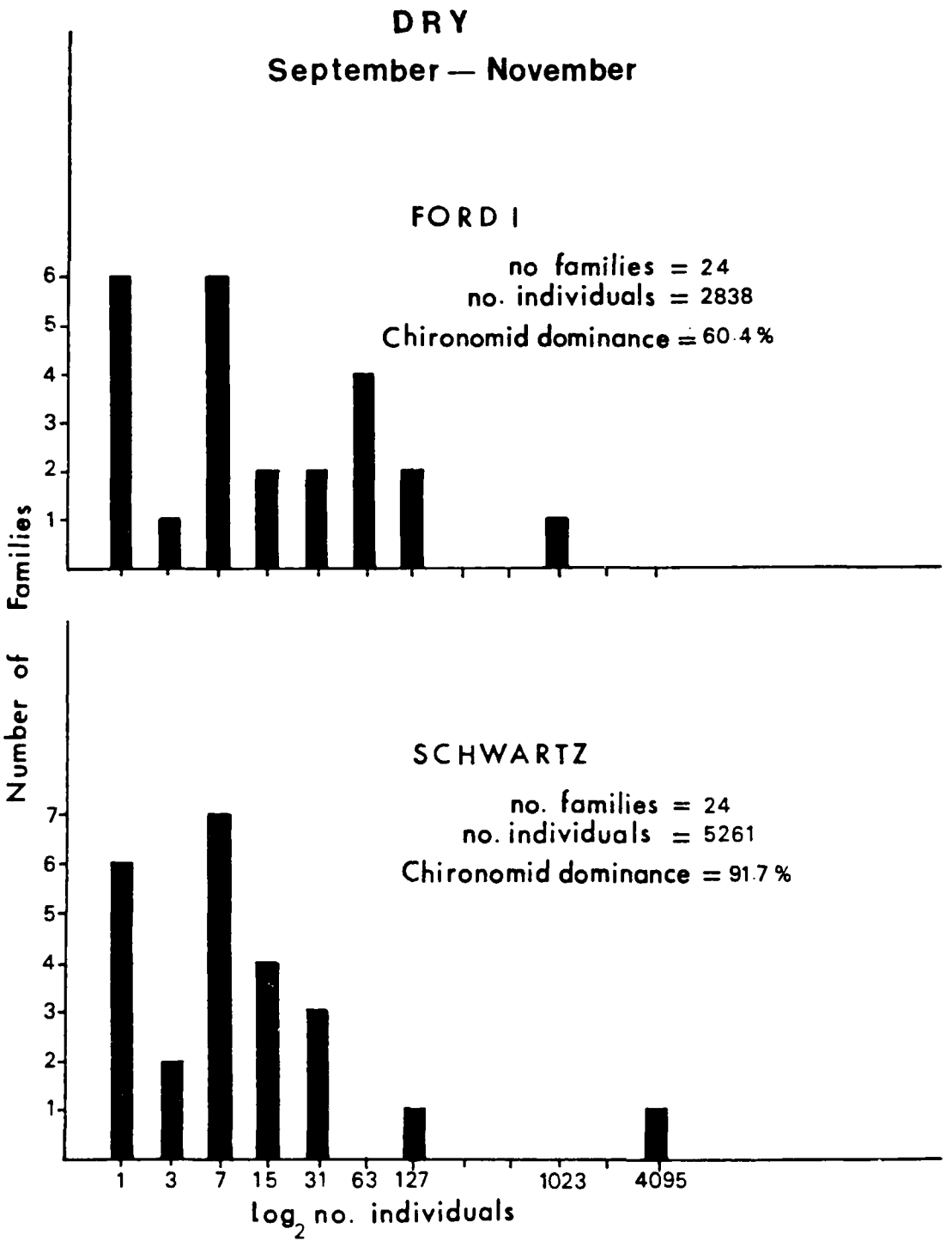
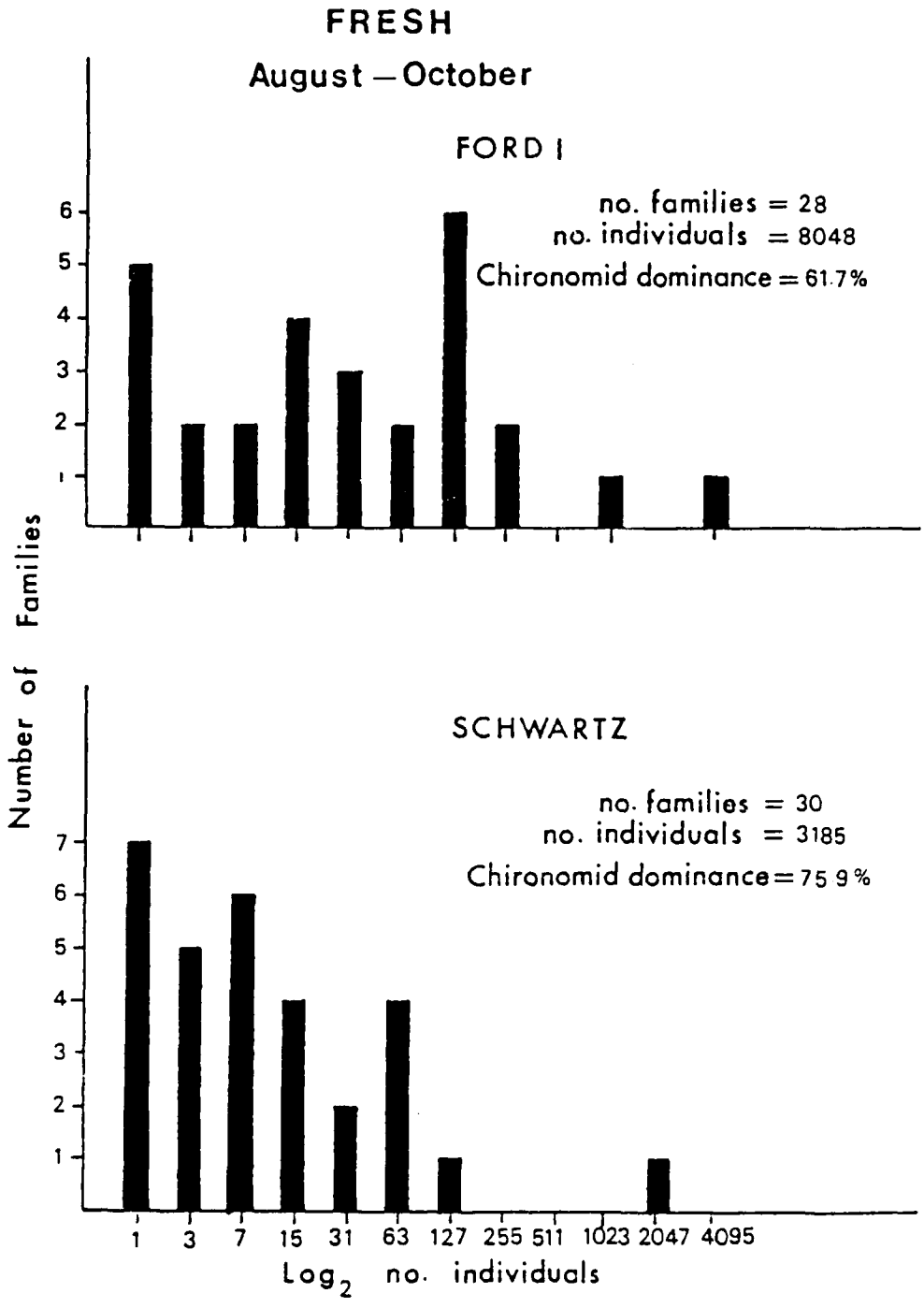

DRY
September — November
FORD I
no families = 24
no. individuals = 2838
Chironomid dominance = 60.4 %
SCHWARTZ
no. families = 24
no. individuals = 5261
Chironomid dominance = 91.7 %
Number of Families
1
2
3
4
5
6
7
1
3
7
15
31
63
127
1023
4095
log2 no. individuals

FIGURE 11.9


FRESH
August – October
FORD I
no. families = 28
no. individuals = 8048
Chironomid dominance = 61.7%
SCHWARTZ
no. families = 30
no. individuals = 3185
Chironomid dominance = 75.9%
Number of Families
1 2 3 4 5 6
1 2 3 4 5 6 7
1 3 7 15 31 63 127 255 511 1023 2047 4095
Log2 no. individuals

C. Comparison between fresh and autumn dried leaves at the two sites.

Fresh leaves were put into the streams 26 to 27 days before the autumn leaves were added. Although comparison between fresh and autumn leaves are down below, the 26-day hiatus has to be considered. Thus, comparison between the two treatments are more tenuous than comparisons between sites for the same leaf treatment.

Diversity values between insects on fresh versus autumn dried leaves did not differ significantly in the Ford River. Diversity values for insects on fresh leaves in the Schwartz Creek were significantly higher than values for insects on autumn-dried leaves through the major colonization period (through 84 days' incubation. See Fig. 11.5). These results were counter-intuitive, owing to the fact that there was a nearly 3-fold increase in numbers of individuals on fresh as compared on dried leaves in the Ford River, and there was no increase in numbers of individuals on fresh over dry leaves in Schwartz Creek (Table 11.2). However, when one looks at the two indices that comprise diversity; namely, richness and evenness (Figs. 11.6, 11.7), it becomes evident that an increase in richness alone was not sufficient to compensate for lack of change in the evenness-component for the Ford fresh leaf samples. Thus, diversity indices for the two leaf types in the Ford were not significantly different. Conversely, both richness and evenness components increased for the fresh leaf samples as compared with the autumn leaf samples in Schwartz Creek. This accounts for the significant difference in the diversity index for the two leaf types. Thus, in the Ford, the additional numbers of individuals included new families but the proportion of individuals found in each family remained the same as for dried leaves. Fresh leaves in the Schwartz "attracted" more families, and the proportion of individuals in each family was more equitable on fresh leaves (fewer rare families and/or lowered dominance by common families).

Another way of showing the relationship among the indices is by way of a canonical distribution presentation. Graphs 11.8 and 11.9 show that in the Ford River there was an elevation in number of families for fresh leaves and they also show no change in dominance by the major family, Chironomidae; this, in spite of a 3-fold increase in numbers of individuals on fresh leaves. Fresh leaves in Schwartz Creek contained six more families, but more importantly, the domination of the community by chironomids decreased from 91.7% for autumn-dried leaves to 75.9% for the fresh leaves. This occurred, in spite of the fact that the actual numbers of individuals coming onto the fresh leaves was lower than for autumn-dried leaves.

Summary Table 11.3 shows that the Ford River samples did not

differ (O values) for fresh versus dry leaves for the structural community indices, with the exception of richness. However, for the Schwartz Creek samples, all indices were higher in the fresh samples as compared with dry leaf samples. Summary Table 11.4 shows that when one compares results between streams, the major impact fresh leaves had was on the evenness component of diversity. Only in that case did the Schwartz Creek results approximate those of the Ford River.

Elliott Tramer (1969) suggests that in labile communities, the evenness component accounts for changes in diversity; whereas, in more stable communities, the change in richness component accounts for the majority of change in diversity. If this theory is appropriate to our data, the Schwartz Creek contains a more "labile" potential leafpack inhabiting insect community. Possibly, the fresh leaves represent a more unique "resource" there than do the dry leaves, and the resource is preferentially utilized by insects -- insects that would otherwise remain in wood debris or would otherwise drift downstream to sites where deciduous leaf inputs are more common.

We do not know why the fresh leaves appear to be a more "attractive" resource than autumn leaves (resulting in both an elevated numerical rsponse and an elevated richness and evenness index). We suggest research that has been done for dried leaves be done for fresh leaves; e.g., microbial colonization patterns, chemical changes in leaves over time, and structural characterization of leaves.

We have not had sufficient time to identify all insects to species. Table 11.4 shows the relationship between number of species and number of families for samples from October 1982 and from January 1983. Most species are in unique families and so we tentatively suggest that family designation, in this study, is not too far removed from species designation. The only group for which this may not be true are the Chironomids. They will be broken down to at least generic level in the near future.

TABLE 11.5

Comparisons Between Numbers of Species and Numbers of Families of Insects in Fresh and Dry Leaves (S. E.)

SITE	DAYS IN	DRY LEAVES $\bar{X}$ NO. SPECIES	DRY LEAVES $\bar{X}$ NO. FAMILIES	DRY AUTUMN LEAVES $\bar{X}$ NO. SPECIES	DRY AUTUMN LEAVES $\bar{X}$ NO. FAMILIES	DAYS IN
FORD	26	16.2 (0.97)	13.2 (0.66)	22.5 (2.25)	19.2 (1.75	26
	115	12.4 (0.75)	10.8 (0.58	13.8 (0.43)	12.0 (0.58)	26
SCHWARTZ	27	9.4 (2.23)	8.6 (1.50)		15.0 (1.08)	26
	116	2.0 (0.45)	2.0 (0.45)		8.7 (1.20)	108

Element 12 - Drift Patterns of Aquatic Invertebrates

Original Synopsis - Determine behavioral drift patterns of major macro-invertebrates utilizing drift nets. These studies will be run for selected time periods and at selected intervals. Identification of major fauna will be done during the winter.

Changes from Original Synopsis - Owing to the necessity of reducing the budget, we elected to delete studies on *insect drift* (*See Supplement to Aquatic Ecosystems Task Group Proposals, June 28, 1982*).

Contributing Staff - J. Stout, Research Associate (PI)
T. Burton, Associate Professor (PI)
R. Merritt, Associate Professor (PI)
K. Webb, Graduate Research Assistant
W. Taft, Field Research Tech II

(We did, however, run 24-hr drift studies on the West Branch of the Escanaba and at the Ford River in 1982. Priorities for other elements meant that we did not process the samples. They remain in our shelves. We also ran three 24-hr drift studies at Two-Mile Creek and at the Ford River in May of 1983. Those samples await processing.)

Element 13 - Leaf Litter Processing Experiments Using Natural Leaf Packs and Cages

Original Synopsis - Lab constructed leaf litter packs will be placed in streams during the fall and litter breakdown rates will be assessed on a bimonthly (fall and spring) and monthly (winter) basis. Once major shredder organisms are identified, caged leaf packs containing selected macro-invertebrates will be placed out and leaf degradation rates will be followed.

Changes from Original Synopsis - Due to significant overlap with Element 11, we restricted this Element to caged leaf pack studies with those major shredder species identified in Element 11. After conditioning, insects were added. Samples were collected during conditioning and after addition of insects.

Contributing Staff - R. Merritt, Associate Professor (PI)
T. Burton, Associate Professor (PI)
J. Stout, Research Associate (PI)
W. Taft, Field Research Tech II
K. Webb, Graduate Research Assistant
D. Cornelius, Graduate Res. Asst.
Undergraduate Research Aide as needed

Objectives

1) To determine and quantify the role of a major shredder, Tipula abdominalis, in leaf litter degradation in the FEX and FCU sites on the Ford River; and 2) to determine the role of other biological (microbes, other insect species) and abiotic (mechanical fragmentation) processes in stream litter processing.

Materials and Methods

Three gram leaf packs of Balm-of-Gilead (Populus gileadensis) were used for this experiment. This is a common riparian species along the Ford River. We originally were going to use Tag Alder (Alnus rugosa) leaves; however, the unusually warm fall delayed abscission and we therefore had to choose another leaf species which could be collected in catch nets in significant quantities earlier in the season. The caged leaf experiment was conducted in the Ford Experimental Site and Downstream Control Site.

The role of a particular group of insects, such as shredders, in leaf litter processing can be demonstrated through the use of in-stream cages which enclose leaf packs and shredders (Fig. 13.1). The cages are constructed from plastic freezer containers from which most of the sides and bottoms have been removed and the open areas covered with Nitex® netting. The netting is attached to the inside of the cage with hot glue. The mesh size chosen depends on the size of organisms to be kept in the cages or selectively admitted in stream systems, and the concentration of suspended particulates in transport. Based on collections of aquatic organisms in the Ford River, Tipula abdominalis appears to be the major detritivore of leaf litter in the system.

The procedural details of this experiment are presented in flow chart Fig. 13.2, and a further elaboration of this technique can be found in Merritt et al. (1979). The number of replicates and collection dates are given in Table 13.1.

Results and Discussion

Data are currently being collected for this experiment and are not yet subject to analysis.

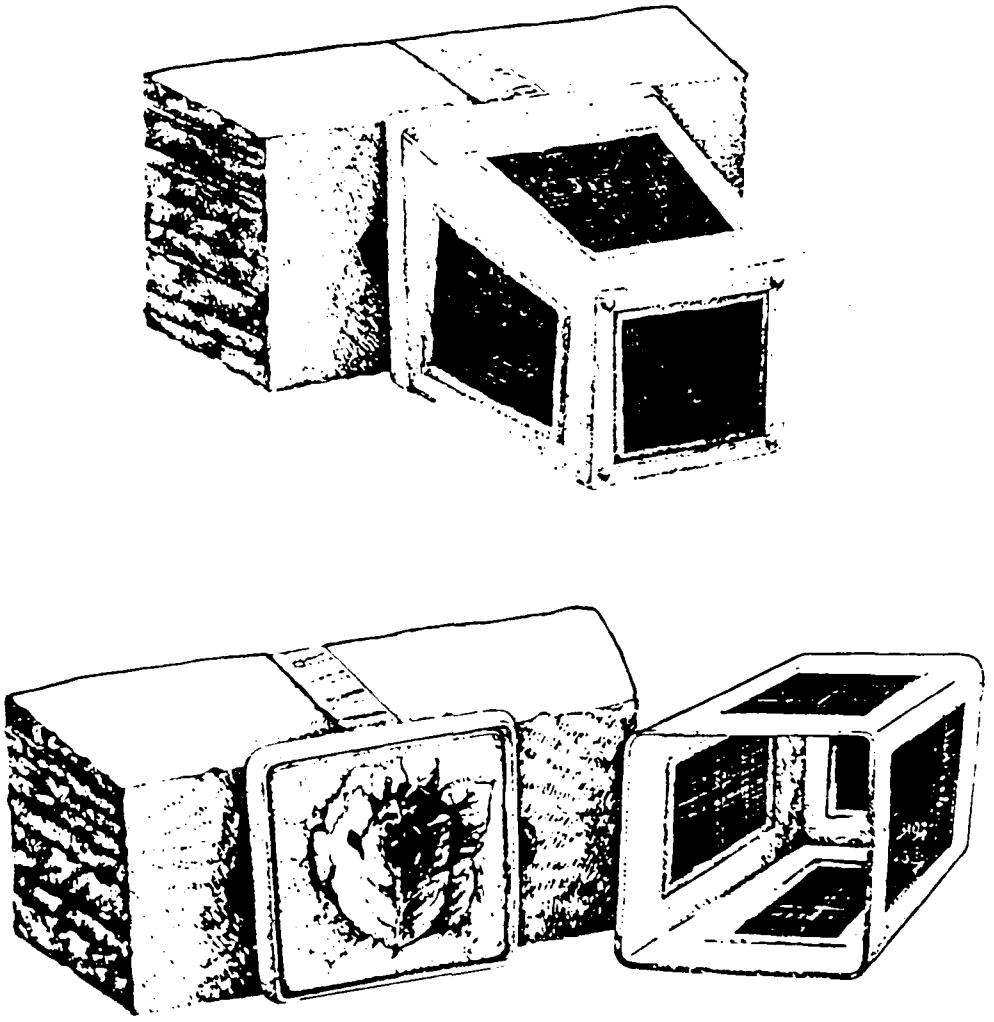


Fig. 13.1 Leaf pack system utilizing plastic containers or "cages" with different mesh sizes to exclude or enclose selected organisms. Lower drawing shows open cage with leaf pack attached to cage cover and brick. Upper drawing shows closed cage.

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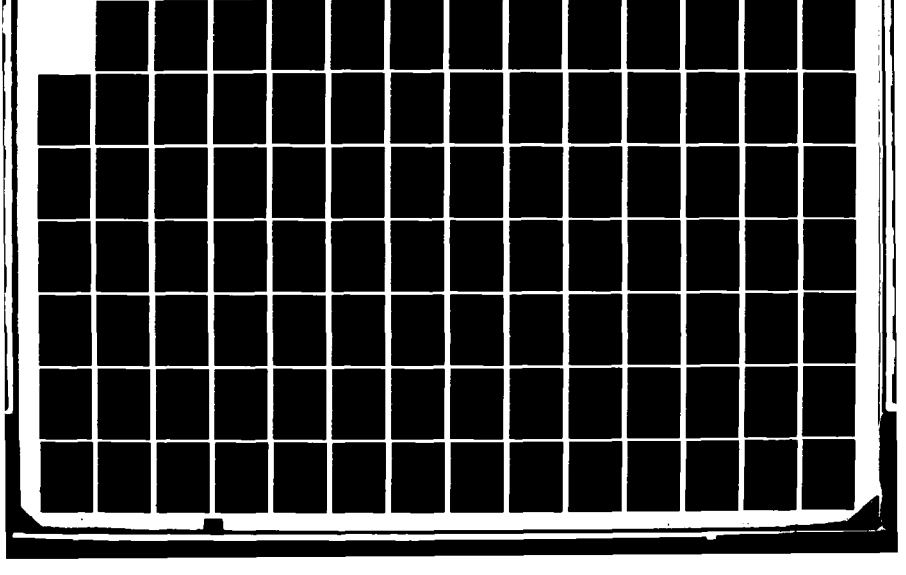


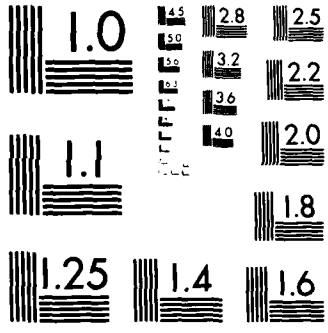


Fig. 13.2. Experimental Procedure for Caged Leaf Pack Experiment.

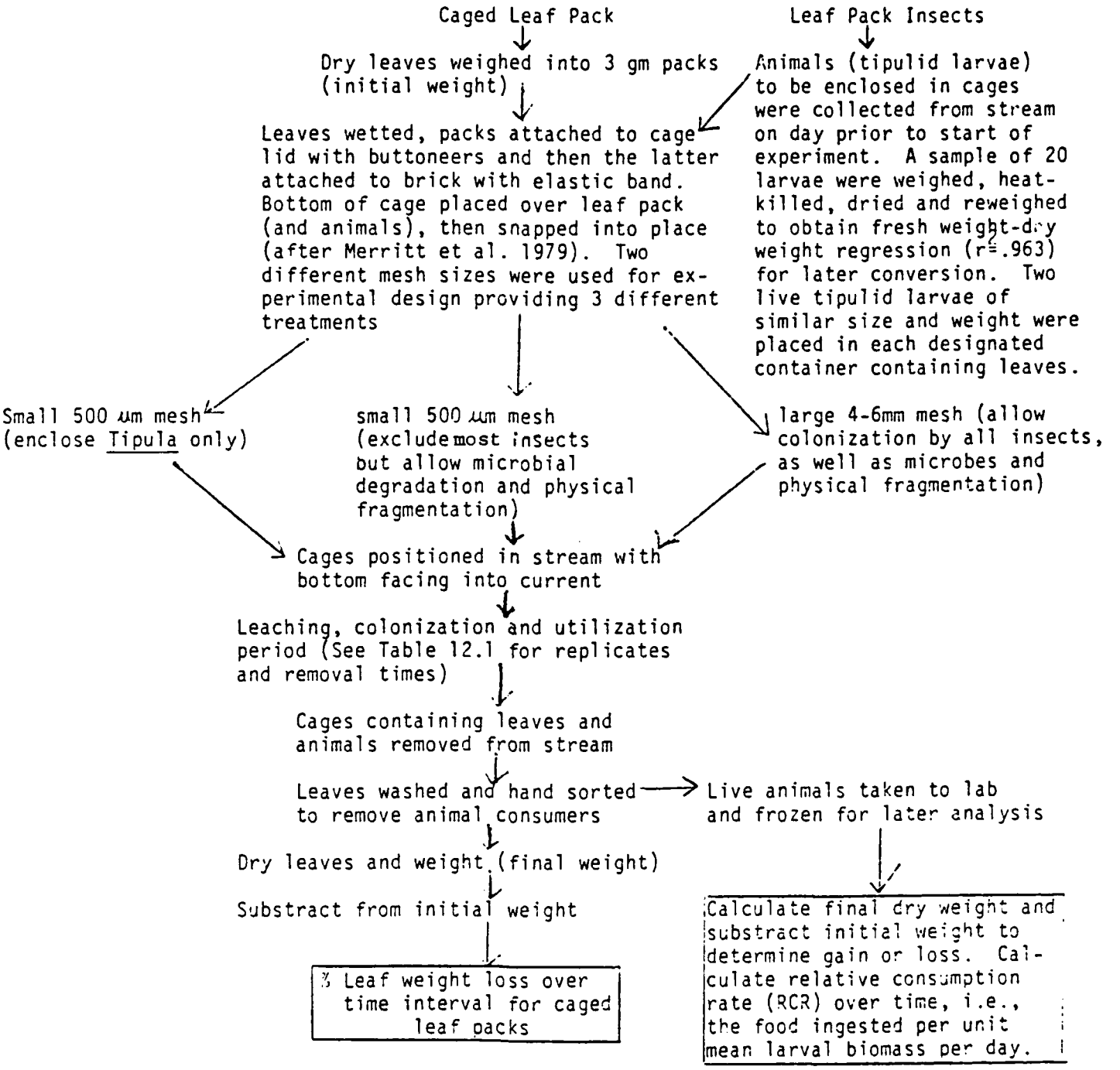


Table 13.1. Replicates and Collection Dates for Gaged Leaf Pack Experiment.

TOTAL CAGES	CALENDAR DATE JULIAN DAYS (LEAF) JULIAN DAYS (INSECT)	25 SEPT. 1	2 OCT. 7 0	13 OCT. 20 7	19 OCT. 26 14	26 OCT. 33 31	14 NOV. 50 61	15 DEC. 81 92	15 JAN. 112 123	15 FEB. 143 123	15 MARCH 174 154
22	Treatment Tipula only (small mesh)	PUT IN LEAVES ONLY		ADD INSECTS	4	3	3	3	3	3	3
28	w/o Tipula (small mesh)	PUT IN LEAVES	3	3	4	3	3	3	3	3	3
26	Colonization by all insects (large mesh)	PUT IN LEAVES		4	4	3	3	3	3	3	3

24 x 3 reps = 72 x 2 sites (downstream control and experimental) = 144 + 8 extra reps. = 152 cages

Cages	Large Mesh	Small Mesh	
Site A (experiment)	26	28 (+22 w/Tipula) = 76	
Site B (control)	26	28 (+22 w/Tipula) = 76	
	52 Large	56 (+44 w/Tipula)	Grand Total of 152 Cages

Element 14 - Feeding Activity of Grazer Populations

Original Synopsis - Major grazing macroinvertebrates will be identified and feeding strategies and resource partitioning among different species will be followed.

Changes from Original Synopsis - A detailed study of the feeding and production of one major grazer will be carried out.

Contributing Staff - R. Merritt, Associate Professor (PI)
T. Burton, Associate Professor (PI)
M. Oemke, Research Associate
K. Webb, Graduate Research Assistant

Objectives

To compare the nymphal feeding habitats and production of natural populations of S. vicarium in the Ford River to those held in replicate shaded and unshaded enclosures. Shading reduces the quantity and quality of periphyton, while the unshaded enclosures serve as a control for miscellaneous enclosure effects (e.g. reduced current, reduced mobility).

Materials and Methods

Enclosure Experiment. Enclosures consisted of plastic storage containers (16 x 16 x 10 cm) with all four sides cut out and replaced with nylon window screening (1.25 mm mesh; screened openings 10 x 7 cm). Unshaded enclosures had clear plexiglass tops, whereas shaded enclosures were painted entirely black to minimize light transmittance. Four glass microscope slides (75 x 25 x 1 mm) were glued vertically inside each enclosure for estimation of periphyton biomass and chlorophyll-a. Each enclosure was tied to a cement patio block (40 x 20 x 4 cm). A total of 36 enclosures were used for the experiment--6 shaded and 6 unshaded for each three sampling dates.

All enclosures were placed in a riffle at FEX on July 11, 1983. Each enclosure was filled approximately half-way with gravel and pebbles taken from the stream bank which matched the stream substrate as closely as possible. Substrate material was taken from the stream bank to avoid introducing periphyton into the shaded enclosures. Ground, stream-conditioned leaves were mixed with the substrate material to provide an alternate food source. Enclosures were placed in the stream in a randomized array so that all periphyton slides were parallel to the current, and with staggered rows so that no enclosure was directly downstream of

another. The array was situated so that current and lighting were as even as possible. S. vicarium nymphs were not added to the enclosures for the first 7 days of the experiment to allow periphyton colonization to occur in the unshaded enclosures.

Throughout the experiment, all enclosures were rotated 180° every 24 hours. This prevented the clogging of the upstream screens with debris and so minimized current reduction inside the enclosures.

S. vicarium nymphs were stocked in the enclosures on July 8, 1983 for the first series, July 19 for the second series, and July 20 for the third series (Days 7-9 respectively). Nymphs were collected at the study site with a kick net. Each enclosure received 12 nymphs which were measured on 1 mm gridded paper. Nymphs less than 2.5 mm in length were not used since they would be able to escape through the enclosure screens.

The first series of enclosures were pulled from the stream on August 8, 1983, the second series on August 29, and the third series on September 14 (Days 21, 41, and 56 for insects, and Day 28, 49, and 65 for periphyton slides). The periphyton slides were removed from each enclosure and were handled as in Element 4, 2 for biomass analysis and 2 for chlorophyll-a analysis. The technique used to remove the insects from the enclosures was similar to that used for artificial substrates (see Element 9). Care was taken to ensure that no insects on the outside of the enclosures were included in the samples. The insects in each sample were anesthesized in carbonated water to prevent them from regurgitating when formaldehyde was added to the sample.

Periphyton Colonization. On August 16 a second experiment was initiated to obtain periphyton data that would be directly comparable to data collected for Element 4. Periphyton samplers used for Element 4 were tied inside one empty shaded enclosure and one unshaded enclosure, and a third was placed in the stream adjacent to these two enclosures. These enclosures were not rotated daily as described above, but the upstream screens were cleaned daily. Four slides, 2 for biomass and 2 for chlorophyll-a were removed from each sampler on Days 14 and 28 (August 30 and September 13, respectively) and were handled as in Element 4.

Biomass and chlorophyll-a analyses were carried out as described in Element 4. The slide surface areas for slides glued inside the enclosures were adjusted for the area covered by glue.

Length/Weight Relationship. Eighty-four S. vicarium nymphs were collected by the study site for length/weight regression analysis. Nymphs were measured to the nearest .02 mm using an ocular micrometer, then dried for 48 h at 50°C. Dried nymphs

were weighed to the nearest .01 ug using a Cahn electrobalance. The length/weight relationship will be used in the production estimates described below.

Production Estimates. S. vicarium nymphs recovered from the enclosures will be remeasured to the nearest .25 mm using the same 1 mm gridded paper used at the beginning of the experiment. Production of S. vicarium will be estimated using the instantaneous growth method (Waters 1977).

S. vicarium nymphs collected in artificial substrates for Element 9 will also be measured to obtain a production estimate for naturally-occurring populations. Estimates will be derived for FEX and at least one other site for which a full year's samples are available. The instantaneous growth method will be used for samples taken during July through September 1983 for direct comparability to the results of the enclosure experiment. Annual production will be estimated using the Hynes-Coleman (1968) method as modified by Hamilton (1969) and Benke (1979), with the variance estimate of Kreuger and Martin (1980).

Feeding Habits. Slide-mounted gut contents of all S. vicarium nymphs used in the enclosure experiment and the production estimates will be prepared and analysed using a standard method outlined by Cummins (1973). Since it may be necessary to lump the contents of several guts to obtain countable slides, lumping will be done within 1 mm size classes (and of course treatment and sample date) so that age-specific differences in feeding may be determined. Ten random fields of each slide (at 400x) will be photographed, and the total surface area in each field of diatoms, filamentous algae, detritus, and mineral fragments determined with a digitizer.

Results and Discussion

To date, only the enclosure periphyton and the length/weight relationship for S. vicarium have been completed. The production and feeding habits of S. vicarium are currently being analyzed.

Enclosure Periphyton. Differences in biomass (AFDW/m^2), chlorophyll-a, and chlorophyll/pheophytin ratios were insignificant between enclosures within the same treatment and sample date (multivariate ANOVA; P = .243, .607, .592, respectively). Therefore, Autotrophic Indices (AI) were calculated as mean AFDW/m^2 divided by mean chlorophyll-a/m^2 within each treatment and sample date. The results are presented in Table 14.1.

Without exception, the AI's for the unshaded enclosures fell within the normal range of 50 to 200 for healthy periphyton communities (APHA 1980). The AI's for the shaded enclosures

Table 14.1. Estimates of biomass, chlorophyll-a, chlorophyll/pheophytin ratio, and Autotrophic Index (AI) in unshaded (Light) and shaded (Dark) enclosures. Biomass, chlorophyll-a, and chlorophyll/pheophytin ratio all ± 95% CI. AI = mean AFDW/mean chlorophyll-a.

Day		AFDW mg/m^2	Chl-a mg/m^2	Chl-a/Pheo	Mean AI
28	Light	1510.98 ± 131.85	10.87205 ± 0.95750	6.25 ± 1.29	139
	Dark	1079.06 ± 137.24	3.05409 ± 0.87330	1.22 ± 0.38	353
49	Light	1871.11 ± 151.34	14.97767 ± 1.58768	8.31 ± 3.58	125
	Dark	1079.25 ± 167.88	3.21866 ± 0.95364	1.61 ± 0.49	355
65	Light	2106.38 ± 143.16	11.92813 ± 0.65325	19.53 ± 12.95	177
	Dark	1068.26 ± 107.49	1.87297 ± 0.41047	4.07 ± 0.95	570

exceeded 300, indicating that heterotrophic conditions existed inside these enclosures. Furthermore, the shaded enclosures had proportionally more pheophytin-a than the unshaded enclosures which is indicative of senescent periphyton communities.

Periphyton Colonization. The results of the second periphyton colonization experiment are presented in Figs. 14.1-4. In general, colonization was much more rapid on the fully exposed slides ("Stream") than on either set of the enclosure slides, as would be expected. However, by Day 28 there was little difference in biomass between any of the treatments. More significantly, there was little difference in either the chlorophyll/pheophytin ratio or AI between the Stream slides and the Light enclosure slides. This indicated that the unshaded enclosures reasonably simulated natural conditions with respect to the periphyton community.

Length/Weight Relationship. The dry weight (mg) to length (mm) relationship for S. vicarium was found to be:

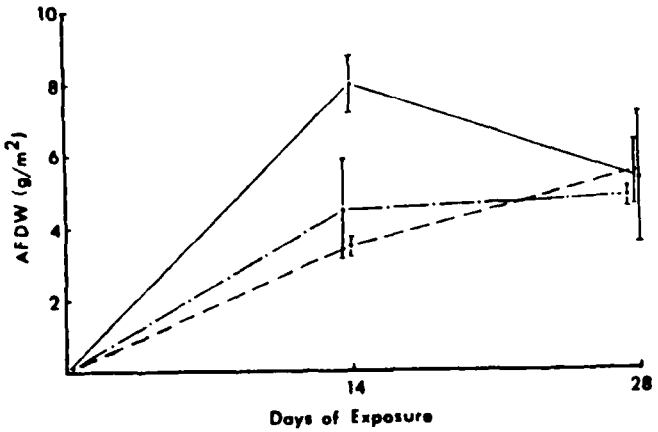
$$\text{Weight} = .0233 \times \text{Length}^{2.2345} \qquad r^2 = .847$$

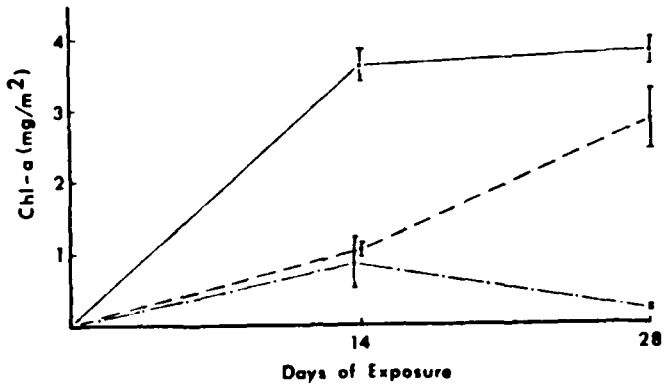
These values are similar to those found by Smock (1980) for Stenonema annexum.

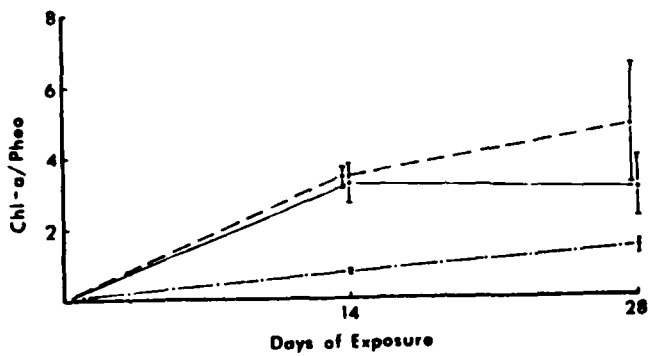
Summary

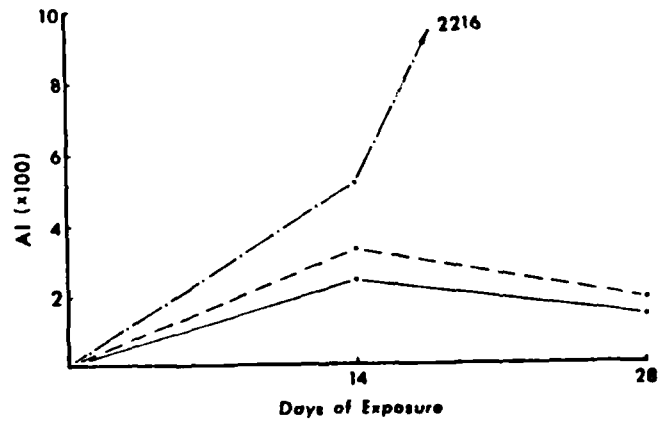
This element concentrates on assessing the importance of periphyton in the feeding and growth of the mayfly Stenonema vicarium (Walker) (Heptageniidae), a common grazer, during the summer in the Ford River. Published information indicates that S. vicarium is specialized on periphyton grazing. If this is true, one would expect production S. vicarium to be low where periphyton production is also low, since S. vicarium may not be able to feed effectively on other food resources (e.g., detritus). The overall hypothesis is that production of S. vicarium, and grazers in general, is positively correlated with periphyton production. The results of this study could be used to assess the indirect effects of ELF electromagnetic radiation on grazers via the periphyton community.

Figs. 14.1-14.4. Colonization of periphyton on glass slides inside shaded (—·—) and unshaded (— — —) enclosures, and slides with full exposure (———). Vertical bars indicate range of two measurements. AI calculated as mean AFDW (mg/m^2)/mean chlorophyll-a (mg/m^2).









Element 15 - Fish Species Composition Relative Abundance and Habitat Relationships

Original synopsis - The fish communities in the Ford River under or adjacent to the ELF system (experimental) and a control site will be sampled using nets and visual underwater observation to determine species composition of the fish fauna, relative abundance, and habitat preference.

Changes from Original Synopsis - None

Contributing staff - William W. Taylor, Assistant Professor (PI)
Gary E. Whelan, Field Research Technician II
David Gesl, Graduate Research Assistant

Objective

To determine and compare the fish species composition relative abundance and habitat preferences at the Ford River experimental site (FEX), upstream control site (FCU) and downstream control site (FCD).

Materials and Methods

A. Fyke netting

Fyke netting was employed to examine the mobile component of the fish community. This was accomplished by dividing each site into randomly selected stations that were suitable for netting (FEX 3 stations, FCD 3 stations and FCU 2 stations). These eight stations were then randomized, within the block, in respect to sampling dates. Each block of eight stations was randomized separately. Two nets were fished (one facing upstream and the other downstream) during each netting period throughout the field season. The data analysis is in progress, thus only preliminary data from 7/20/83 to 9/20/83 night sets will be presented in this report.

B. Kick sampling

Kick sampling was employed to examine the more sedentary non-mobile component of the fish community. This was accomplished by selecting a representative riffle station at each site which was sampled monthly. Monthly sampling was used to minimize habitat destruction and abandonment by fish of these riffles. These riffle stations were mapped and gridded into 5 m segments. The stations were randomly kicked on each transect twice and in between each transect twice. The actual sampling technique is further described in the habitat section of element 15. The seine used was 10 feet long by 6 feet in depth with 1/8" mesh. The mean area kicked was 2.76 m^2.

C. Habitat Relations

The microhabitat requirements of longnose dace and mottled sculpin were examined in this section by per area kick sampling using a 10' x 6' seine with 1/8" mesh. This sampling was done by first setting the lead line on the bottom, then two people begin kicking the substrate (rolling over substrate) simultaneously at the same distance in front of the net as the net enclosed. When the kickers reached the back of the net is lifted with the catch. The area kicked was calculated to be 2.76 m^2.

Monthly samples were taken at each site in a representative riffle which had been mapped into 5 m transects (11 transects for FEX and FCD, and 12 transects for FCU). Two samples were taken on each transect and between each transect for a total of 40 for FCD and FEX (110.4 m^2 or 20.4% of the site area) and 44 for FCU (121.4 m^2 or 37.9% of the site area). All fish captured were enumerated and measured for total length. The concurrent physical measurements made with each sample were: 1) bottom and midwater velocity using a Swoffer current meter; 2) depth; 3) percent vegetation using visual estimation; and 4) particle size composition as measured using a ruler for 50 cm. The particle size data was converted to phi particle size categories using a modified Wentworth scale (Table 2.1) and then to percentages for analysis. The data presented here is a preliminary correlation analysis of all physical parameters measured with numbers caught of longnose dace and mottled sculpine. This winter the data will be further analyzed by correlation analysis and principal component analysis for inclusion into a regression model predicting habitat use by each species and size class.

Results and Discussion

A. Fish Composition

Twenty species representing two families and five orders were collected from ELF sites (Table 15.1). FCU had 15 species, FEX had 16 species and FCD had 17 species. The major changes in taxa collected appeared to be caused by the addition and replacement of species with downstream distance. From FCU to FEX, the northern redbelly dace (Phoxinus eos) dropped out and the pearl dace (Semotilus margarita) and brook stickleback (Culaea inconstans) were added, with the brook stickleback only collected at FEX. From FEX to FCD, two lake run species were added, the alewife (Alosa psuedoharengus) and sea lamprey (Petromyzon marinus), along with the rock bass (Amploplites rupestris). The changes in the fish community may be attributable to the effect of Lake Michigan, and habitat differences discussed in element 2 and the habitat section of element 15. In summary, the fish species collected at the three sites were similar.

B. Relative Abundance

1. Fyke netting -- Combined data from both mesh sizes shows that the fish community of the Ford River was dominated numerically by Cyprinids, in particular common shiners (Notropis cornutus) and creek chubs (Semotilus atromaculatus) (Table 15.2). Individual species dominance varied with the sampling site. Creek chubs were the most abundant numerically at FCU and FEX, and were superceded by common shiners at FCD. Blacknose dace

TABLE 15.1. Fish species collected at each ELF site from May 1983 to November 1983.

Scientific Name	Common Name	Collection Sites FCU	FEX	FCD
Clupeiformes				
Clupidae				
Alosa pseudoharengus (Wilson)	Alewife			X
Cypriniformes				
Catostomidae				
Catustomus commersoni (Lacepede)	White sucker	X	X	X
Cyprinidae				
Hybognathus hankinsoni Hubs	Brassy minnow	X	X	X
Notropis cornutus (Mitchill)	Common shiner	X	X	X
Phoxinus eos (Cope)	Northern redbelly dace	X	X	X
Phoxinus erythrogaster (Rafinegue)	Southern redbelly dace	X	X	
Rhinichthys atratulus (Hermann)	Blacknose dace	X	X	X
Rhinichthys cataractae (Valenciennes)	Longnose dace	X	X	X
Semotilus atromaculatus (Mitchill)	Creek chub	X	X	X
Semotilus margarita (Cope)	Pearl dace		X	X
Gadiformes				
Gadidae				
Lota lota (Linnaeus)	Burbot	X	X	X
Gasterosteiformes				
Gasterosteidae				
Culaea inconstans (Kirtland)	Brook stickleback		X	
Perciformes				
Centrarchidae				
Ambloplites rupestris (Rafinesque)	Rock bass			X
Cottidae				
Cottus bairdi Girared	Mottled sculpin	X	X	X

Scientific Name	Common Name	Collection Sites		
		FCU	FEX	FCD
Percidae				
Etheostoma flabellare Raginesque	Fantail darter	X	X	X
Etheostoma nigrum Rafinesque	Johnny darter	X	X	X
Percina maculata (Girard)	Blacksided darter	X	X	X
Petromyzontiformes				
Petromyzontidae				
Petromyzon marinus Linnaeus	Sea lamprey			X
Salmoniformes				
Esocidae				
Esox lucius (Linnaeus)	Northern pike	X	X	X
Salmonidae				
Salvelinus fontinalus (Mitchill)	Brook trout	X	X	X

TABLE 15.2 Percent catch by family of fish from the Ford River, MI using combined data from 1/2" and 1/4" fyke nets and encompassing from 07/20/83 - 09/20/83. Data was standardized to a 15 hour net night.

Family	Site		
	FCU	FEX	FCD
Cyprinidae	53.10	73.61	47.44
Gadidae	18.00	13.60	11.30
Catostomidae	13.80	8.58	21.70
Salmonidae	11.90	1.60	14.80
Esocidae	2.05	1.55	0.56
Cottidae	1.15	0.45	1.37
Centrarchidae	0	0	0.53

(Rhinichthys atratulus) and longnose dace (Rhinichthys cataractae) were important at FCU and FEX, and were reduced in numerical importance at FCD (Table 5.13). Pearl dace, brassy minnows (Hybognathus margarita), southern redbelly dace (Phoxinus erythrogaster) and northern redbelly dace were all incidential catches representing less than 2.5% of the catch. In summary, the cyprinid community was similar at FCU and FEX and changed in composition at FCD.

Three other families (Salmonidae, Catostomidae and Gadidae) each represented by a single species made up the majority of the rest of the catch (Table 15.2). The Salmonidae represented by the brook trout (Salvelinus fontinalis) showed percent catches of greater than 10% at FCU and FCD, with FEX exhibiting only 1.4%. The Catostomidae represented by white suckers (Catostomus commersoni) showed a similar trend to the brook trout. The Gadidae represented by the burbot (Lota lota) showed consistent catches although slightly declining from FCU to FCD.

Five other species were caught in low numbers mottled sculpins (Cottus bairdi), blacksided darters (Percina maculata), johnny darters (Etheostoma nigrum), northern pike (Esoc lucius) and rock bass. It is important to emphasize here that this technique best sampled the mobile fish segment of the fish community, thus fish species with low percent catches may not be suspectible to the net because of their low mobility.

An analysis of each catch per unit effort (CPUE) showed that the sites did differ by the number of fish caught per species (Table 15.4). The data for this analysis was standardized to a 15 hour net night to correct for differences in the time fished for each net. No significant differences were seen in numbers caught per unit effort within species in the 1/2" mesh using a Kruskal-Wallis test (=0.05) although large differences in mean catch was noted for white suckers and brook trout. The only significant difference detected in the 1/4" mesh catch was for the blacknose dace (Kruskal-Wallis test, =0.05) which was caused by the low catch of blacknose dace at FCD. Again as in the 1/2" catches, the 1/4" show large differences in mean catches in this case primarily for creek chubs, longnose dace, and white suckers. These data, although indicating that the mean number of each species appeared to differ between sites, exhibited no statistical differences in abundance between sites. This conclusion should be qualified by: 1) the small sample size use for this analysis, and 2) the high variance at each site in the catch. More research is needed before any firm conclusions can be drawn regarding site similarities in terms of species abundance.

2. Kick netting -- Kick netting results displayed a different fish composition than did fyke netting. This is primarily a function of this technique sampling a different component of the fish community; sedentary versus mobile. The preliminary results presented here should be viewed with caution because of the small size (N=2) which makes statistical analysis of this data impossible at this time.

These preliminary percent catch data did show different fish community structures at the ELF sites with the data standardized to 40 kicks (Table 15.5). Data from FCU exhibited a fish community dominated by longnose dace and blacknose dace. Creek chubs were at their higherst percent catch, and mottled sculpins at their lowest percent catch of the three sites. This was in contrast to FEX and FCD which showed the dominant species as mottled

TABLE 15.3. Percent catch by number, of fish species from the Ford River, MI using 1) combined data from 1/2" and 1/4" fyke nets, 2) 1/2" fyke net data, and 3) 1/4" fyke net data for the dates 7/20/83 to 9/20/83. Data was standardized to a 15 hour net night.

Species	Combined			1/2"			1/4"		
	FCU	FEX	FCD	FCU	FEX	FCD	FCU	FEX	FCD
Common shiner	10.7	23.35	35.5	2.3	22.6	43.3	19.1	24.1	27.7
Creek chub	30.0	27.0	4.65	26.7	35.7	8.0	33.4	38.3	1.3
Blacknose dace	7.8	4.5	1.35	0	1.2	0	15.6	9.0	0.8
Longnose dace	3.6	6.5	0.75	2.3	4.4	0	4.9	8.6	1.5
Brook trout	11.7	1.6	14.00	22.7	2.0	26.5	1.1	1.2	1.5
White sucker	13.5	8.5	20.60	22.7	13.5	9.4	4.2	3.5	31.8
Burbot	17.95	13.35	10.75	20.9	19.0	8.8	15.0	7.7	12.7
Mottled sculpin	1.15	0.45	1.3	2.3	0	1.2	0.4	0.9	0.4
Blacksided darter	1.65	1.15	0.4	0	0.4	0	3.3	1.9	0.8
Brassy minnow	0	1.45	2.5	0	0	0	0	2.9	5.0
Johnny darter	0.4	0.4	0.55	0	0	0	0.8	0.8	1.1
Northern pike	0	0.6	2.2	0	1.2	2.1	0.8	0	2.3
Rock bass	0	0	0.5	0	0	0.6	0	0	0.4
Southern redbelly dace	0	0.15	0	0	0	0	0	0.3	0
Northern redbelly dace	0.7	0	0	0	0	0	1.4	0	0
Pearl dace	0	0.001	0.20	0	0	0	0	0.002	0.4

TABLE 15.4. Mean catch per unit effort (CPUE) + 1 SD of fish species in the Ford River, MI using 1/2" and 1/4" mesh Fyke nets for dates 7/20/83 to 9/20/83. Data was standardized to a 15 hour net night. Asterisk indicates significant differences in mean catch (Kruskal-Wallis test, α=0.5).

Species	1/2" mesh			1/4" mesh		
	FCU N=2	FEX N=6	FCD N=5	FCU N=3	FEX N=6	FCD N=3
Creek chub	4.7	9.4±3.5	2.7±2.6	31.2±28.1	42.6±36.3	6.7±2.2
Common shiner	0.4	6.0±6.1	14.3±8.6	17.9±15.8	26.9±23.3	13.6±20.1
Longnose dace	0.4	1.1±2.0	0	4.6±4.4	9.6±10.0	0.8±1.3
Blacknose dace	0	0.3±0.8	0	14.7±12.5*	10.0±6.6*	0.4±0.5
Burbot	3.6	5.0±3.0	2.9±1.4	14.0±19.2	8.5±8.1	6.2±4.5
Brook trout	5.3	0.5±0.6	7.0±12.3	1.0±1.0	1.3±1.7	0.8±1.3
White sucker	4.0	3.6±3.9	3.1±2.5	4.0±5.2	4.0±5.7	15.7±33.5
Mottled sculpin	0.4	0.0	0.4±0.5	0.3±0.6	1.0±0.6	0.2±0.4
Johnny-darter	0	0	0	0.7±1.2	0.9 1.5	0.6±0.9
Blacksided darter	0	0.2±0.4	0	3.0±2.6	2.1±1.9	0.4±0.5
Brassy minnow	0	0	0.2±0.4	0	3.3±5.0	2.5±2.0
Pearl dace	0	0	0	0	0.2±0.4	0.2±0.4
Northern pike	0	0.4±0.6	0.8±0.8	0.7±0.6	0	1.1±1.2
Northern redbelly dace	0	0	0	1.3±1.1	0	0
Southern redbelly dace	0	0	0	0	0.3±0.5	0
Rock bass	0	0	0.2±0.4	0	0	0.2±0.4

TABLE 15.5. Percent catch by number of fish from the Ford River, MI using Kick netting (mean area kicked = 2.76 m^2) for August and September 1983. All data was standardized to 40 kicks (110.4 m^2 sampled).

Species	Site FCU	FEX	FCD
Mottled sculpin	12.2	34.7	32.3
Longnose dace	30.6	15.7	40.1
Blacknose dace	29.7	18.8	4.1
Blacksided darter	4.0	15.0	16.5
Creek chub	12.7	2.7	2.1
Johnny darter	1.8	3.5	1.0
Brook trout	0.2	2.3	0
Burbot	2.6	0	3.0
Common shiner	0.8	0.2	0
Fantail darter	0	6.0	0
Brassy minnow	5.4	0	0
Brook stickleback	0	1.0	0
White sucker	0	0	0.4

sculpin. Overall FCD and FEX percent catches of mottled sculpin, blacksided darter, and creek chub were similar. The primary differences between these sites was the higher percent catch of the longnose dace at FCD and the higher percent catches of blacknose dace, fantail darters and brook trout at FEX. FCU percent catches were dissimilar to the other sites for all species except burbot. The percent catch data indicates that FEX and FCD were more similar than FCU and FEX. The differences in the percent catches between sites maybe attributable to microhabitat and macrohabitat differences which will be addressed in element 15.

Although percent catch was similar between FCD and FEX, numbers caught at FEX of mottled sculpin, blacksided darters, fantail darters (Etheostoma flabellare), brook trout, creek chubs, brook stickleback and johnny darters was higher than at FCD (Table 15.6). FCD on the other hand, had higher catches of burbot and longnose dace. These data were much closer in numbers caught than seen in a comparison between FCU and FEX. FCU had higher catches of blacknose dace, longnose dace, creek chubs, brassy minnows and burbot than FEX. FEX had higher catches of mottled sculpins, blacksided darters, fantail darters, brook trout and brook stickleback. These preliminary results indicate that FEX and FCD were the most similar pairing of sites in respect to percent catch and numbers caught by kick netting. The differences between sites may again be attributed to habitat differences (which will be further examined in element 15) and to the small preliminary data base.

In conclusion, these preliminary results indicate that the three sites are very similar in respect to species composition and fyke net percent catch. Some differences were seen in numbers caught in the fyke nets but no significant differences were detected. FCD and FEX appeared to be the most similar using both kick net catch percentages and in numbers caught. These trends will be further analyzed and examined with the use of the mainframe computer and as the data is base expanded.

3. Future plans -- This element will be incorporated into three work elements (migration, habitat and population elements) in the 1983/84 work plan. Further data analysis will include: 1) examining the net catches by total weight, mean weight, mean size and age; 2) increasing the data base to all observations of the 1983 field season; and 3) analyzing site differences using similarity and diversity indices. Future statistical analysis will include: 1) the use of Kruskal-Wallis tests to determine significance of the means; and 2) the use of an multivariable regression model to relate abiotic and biotic factors to catch data. These analyses will be reported on in upcoming monthly reports.

C. Habitat relationships

Mottled sculpin and longnose dace numbers showed significant correlations with physical parameters at all sites (Table 15.7). FCD and FEX showed more significant relationships than FCU indicating a more uniform distribution of mottled sculpins and longnose dace at FCU. The hypothesis of a more uniform distribution of fish at FCU may be supported by the relatively stable cobble-boulder complex that is seen at FCU which is in contrast to the smaller cobble-sand complex at the other sites (Table 2.2) thus habitat maybe more limiting at FEX and FCD. The only significant correlation found at FCU was between midwater velocity and longnose dace numbers. The correlation

TABLE 15.6. Mean number of fish by species captured at each site in 40 Kick netting samples (110.4 m^2) for August and September 1983 (N=2).

Species	FCU		FEX		FCD	
	$\bar{x}$	Range	$\bar{x}$	Range	$\bar{x}$	Range
Mottled sculpin	26.1	21.9-30.4	49.2	39-59.5	29.1	22-36.2
Longnose dace	65.7	61.9-69.6	24.0	12.0-36.1	35.0	30.0-40.0
Blacknose dace	64.9	56.5-73.3	31.8	11.0-52.7	3.4	2.8-4.0
Creek chub	28.2	16.5-40.0	4.4	2-6.8	1.9	1.0-2.8
Johnny darter	3.6	3.5-3.8	5.4	3.0-7.8	0.9	0-1.9
Blacksided darter	8.5	5.7-11.3	18.8	15.6-22.0	13.7	10.5-17.0
Burbot	5.5	5.2-5.8	0	---------	2.4	1.9-3.0
Brook trout	0.5	0-1	2.9	2.9-3.0	0	---------
Common shiner	1.8	0.9-2.8	0.5	0-1.0	0	---------
Brassy minnow	12.2	6.9-17.1	0	---------	0	---------
Fantail darter	0	---------	9.8	5.0-14.7	0	---------
White sucker	0	---------	0	---------	0.4	0-0.9
Brook stickleback	0	---------	1.0	0-2.0	0	---------

TABLE 15.7. Site correlation matrix for Longnose dace (LND) and Mottled sculpin (MS) numbers with selected physical parameters. Correlation values designated with an astrick were found to be significant at α=0.05.

Physical Parameter	Site					
	FCU		FEX		FCD	
	MS#	LND#	MS#	LND#	MS#	LND#
Depth	-0.025	-0.131	-0.145	-0.081	-0.024	-0.314*
Bottom Velocity	-0.09	-0.0007	-0.40	-0.351*	-0.22	-0.048
Midwater Velocity	0.145	0.347*	-0.325*	-0.413*	-0.17	-0.252
% Vegetation	------	-------	0.538*	0.36*	0.434*	-0.021
Rock Substrate Size Class						
Phi-7	-0.02	0.233	-------	-------	-------	--------
Phi-6	-0.022	-0.207	0.063	0.363*	0.049	-0.291
Phi-5	0.233	-0.196	0.037	-0.103	0.285	-0.37*
Phi-4	0.231	0.03	0.324*	-0.225	-0.147	-0.019
Phi-3	-0.127	-0.034	-0.296	-0.358*	-0.108	0.048
Phi-2	-0.03	-0.195	-0.428*	-0.246	-0.166	0.193
Phi-1	-0.161	0.204	-0.156	-0.153	-0.136	0.333
Vegetation Mat Size Class						
Phi-7	------	------	------	------	-0.083	-0.108
Phi-6	------	------	------	------	0.128	0.044
Phi-5	------	------	0.722*	0.219*	0.328*	-0.153
Phi-4	------	------	0.101*	0.095	0.51*	-0.152
Phi-3	------	------	0.156*	0.314*	------	------
Phi-2	------	------	-0.524*	0.385	------	------
Phi-1	------	------	-0.07	0.089	------	------
Wood Substrate Size Class						
Phi-4	-0.136	0.041	------	------	-0.083	0.587*
Phi-3	0.061	-0.163	------	------	-0.083	0.17
Phi-2	-0.113	-0.04	------	------	------	------
Phi-1	------	------	------	------	------	------

matrix (Table 15.7) indicates that percent vegetation and rock substrates of the phi sizes -4 and -5 were important to mottled sculpin numbers at FCD. Bottom velocity, mid-water velocity, percent vegetation, rock substrate of phi sizes -5 and -2, and vegetation mats of phi sizes -5 and -2 were important to mottled sculpin numbers at FEX. Significant relationships between longnose dace numbers and bottom velocity, midwater velocity, percent vegetation, rock substrates of phi sizes -6 and -3, and vegetation mats of phi sizes -3 and -2 were found at FEX. Longnose dace numbers and depth, rock substrates of phi sizes -5 and -1, and vegetation mats of phi size -4 were significantly related at FCD. These data indicate the physical parameters that were important to the distribution of mottled sculpins were similar at FEX and FCD. Longnose dace distribution was influenced by different physical factors at FEX and FCD. These trends maybe attributable to either differences in available habitat or to differences in habitat utilized by different size classes. These relationships will be further investigated this winter. It is important to note that these relationships will have to be examined using a multivariate regression function that includes cross product terms because of the high amount of correlation between many of the physical factors. In summary, it appears that mottled sculpin and longnose dace numbers are related to some physical habitat factors and that these relationships are best seen at the sites where habitat may be limiting (FEX and FCD).

Element 16 - Assessment of Equipment Efficiency for Capture of Selected Fish Species

Original synopsis - Fish capture efficiency using nets will be evaluated by comparing net capture with visual underwater observation for the study sites. In addition, capture efficiency will be compared to electrofishing capture efficiency for adjacent streams not included in the study (introduction of additional electromagnetic radiation in the study areas will be avoided).

Changes from Original Synopsis - High water events during electrofishing - kick sampling efficiency tests forced postponement of this until this coming field season.

Contributing staff - William W. Taylor, Assistant Professor (PI)
Gary E. Whelan, Field Research Technician II
David Gesl, Graduate Research Assistant

Objectives

1) To determine the best techniques to sample fish for the ELF project. 2) To examine and compare where possible the relative effectiveness of the techniques.

Materials and Methods

Six gear types were used in this element: 1) 1/2" fyke nets, 2) 1/4" fyke nets, 3) kick sampling, 4) modified box sampler, 5) seines, and 6) visual observation. The sampling regimes for the first three techniques have already been discussed in element 15. The sampling regimes for the other three techniques are described below.

The modified box sampler (meter square sampler) that was used had a steel frame (1 m X 1 m X 1/2 m) and 1/8" mesh seine sides with a 1 m bag of 1/8" mesh netting. This sampler was tested at FCD in June and at FEX in July. Twenty samples were taken randomly at each site by herding the fish into the catch bag. The sampler bag was then lifted out of the water and the catch was enumerated and measured for total length. Since this sampler was designed as both a population sampler (on a per area basis) and a microhabitat sampler, concurrent physical measurements of depth, current velocity and substrate were made for each sample.

Regular seining with a 6' X 30' straight seine (1/4" mesh) and a 6' X 30' bag seine (1/4" mesh) was tested at FEX in June and July. The seine hauls were approximately 50 feet long in both the upstream and downstream directions. These were repeated over all sections of a representative riffle. All fish were identified, counted and measured for total length after

each haul.

Visual observation using snorkeling was tested at FEX and FCD in July and August. Transects through each site were snorkeled in daytime, and all fish were identified and enumerated. Snorkeling was also used in examining seining, kick seining and box sampler effectiveness.

Results and Discussion

A. Fyke Netting

This technique had the highest total catches of mobile fish as seen in element 15. Night sets were only used after June because it became apparent day sets were avoided by fish. The catches for 1/4" mesh were higher than for 1/2" mesh because of the different selectivity of different mesh sizes (Table 15.3). To examine the different selectivity of these two nets the length frequency of the catches from 7/20/83 to 9/20/83 at FEX was compared for three representative fish: 1) common shiners, a thin but deep bodied fish; 2) burbot, a long slender fish; and 3) creek chubs, an intermediate fish (Figures 16.1-16.3). The 1/4" mesh common shiner catches showed that the thin deep bodied fish began to be caught at 40 mm and were fully recruited to the gear at 65 mm (Figure 16.1). The 1/2" catches of common shiners began at 90 mm and were fully recruited to the gear at 95 mm (Figure 16.1). The 1/4" mesh catches of creek chubs showed that catches began at 30 mm with full recruitment at 40 mm (Figure 16.2). The differnces in size between the creek chub and common shiner 1/4" catches can be explained by the faster growth of the YOY common shiners which were much larger than the YOY creek chubs. The 1/2" mesh catches of creek chubs showed catches starting at 90 mm and full recruitment at 115 mm. Both of these species demonstrated that the exclusive use of 1/2" would miss a year class by beginning to fish at 90 mm. These trends are also seen in burbot catches with the 1/4" nets beginning to fish at 80 mm with full recruitment to the gear at 90 mm and the 1/2" nets starting to fish at 135 mm with full recruitment to the gear at 145 mm (Figure 16.3). The difference in catchability due to shape is readily apparent when one compares the later recruitment of the slender burbot to the recritment of the other fish. In conclusion, 1/2" mesh nets did not catch the smaller size classes of fish that the 1/4" catch and that recruitment size was dependent on shape.

Another pattern seen in the fyke netting results was that the larger creek chubs and burbot were caught more often in the 1/2 mesh than the 1/4" mesh. This maybe attributable to an avoidance of the smaller mesh sizes by the larger fish although more data is needed to determine this trend.

In summary two points can be made regarding fyke net catches: 1) To fully assess the mobile component of a fishery one should use a combination of 1/2" and 1/4" nets at night; and 2) When examining the catch of the target fish one must be aware of the different sizes of recruitment to the gear and must target the gear to the objectives.

B. Kick sampling

Figure 16.1. Night fyke net catches of common shiners at FEX from 7/20/83 to 9/20/83 for 1/4" and 1/2" mesh sizes. Catch bars represent 5 mm size groups.

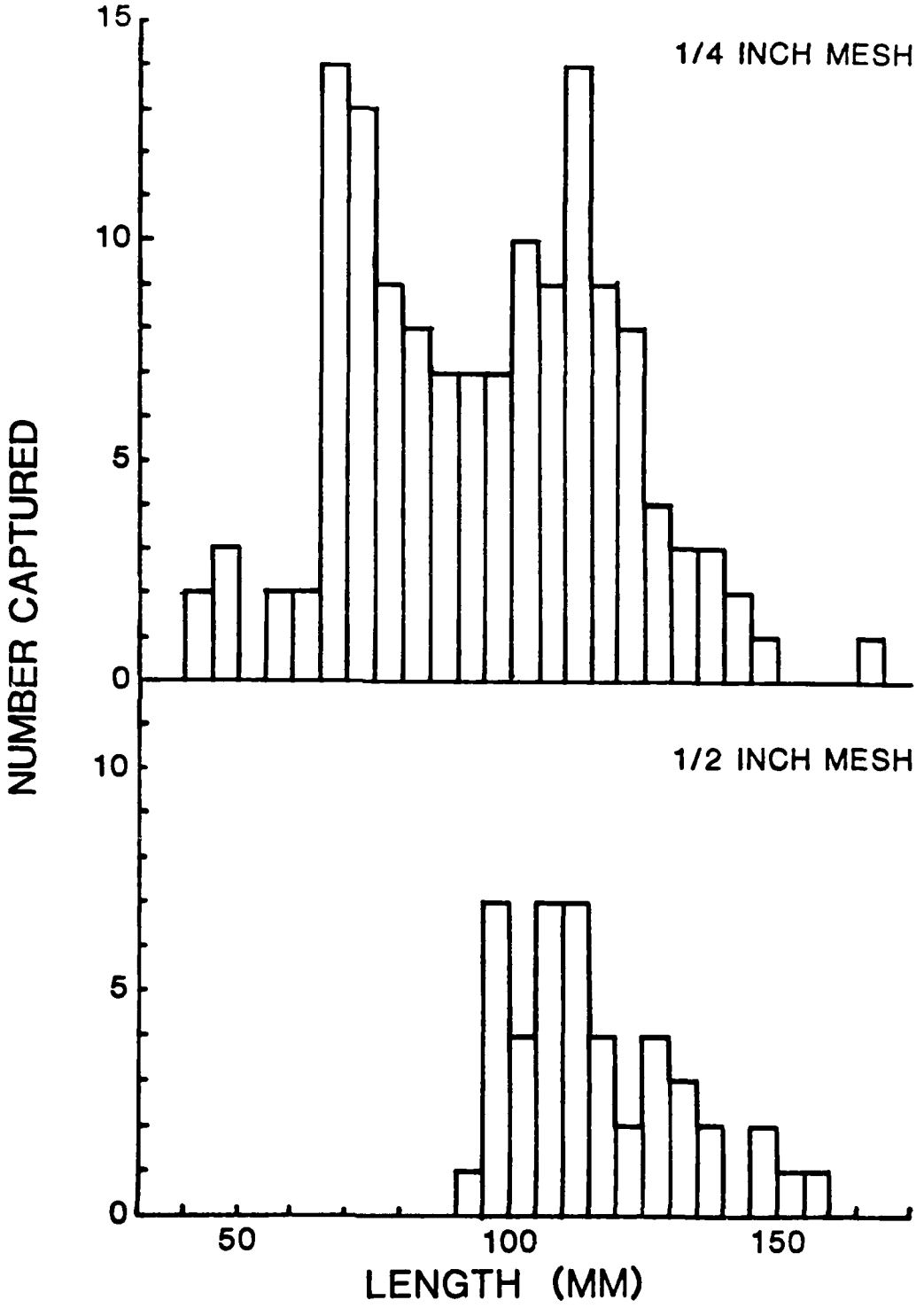


Figure 16.2 Night fyke net catches of creek chubs at FEX from 7/20/83 to 9/20/83 for ¼" and ½" mesh sizes. Catch bars represent 5 mm groups.

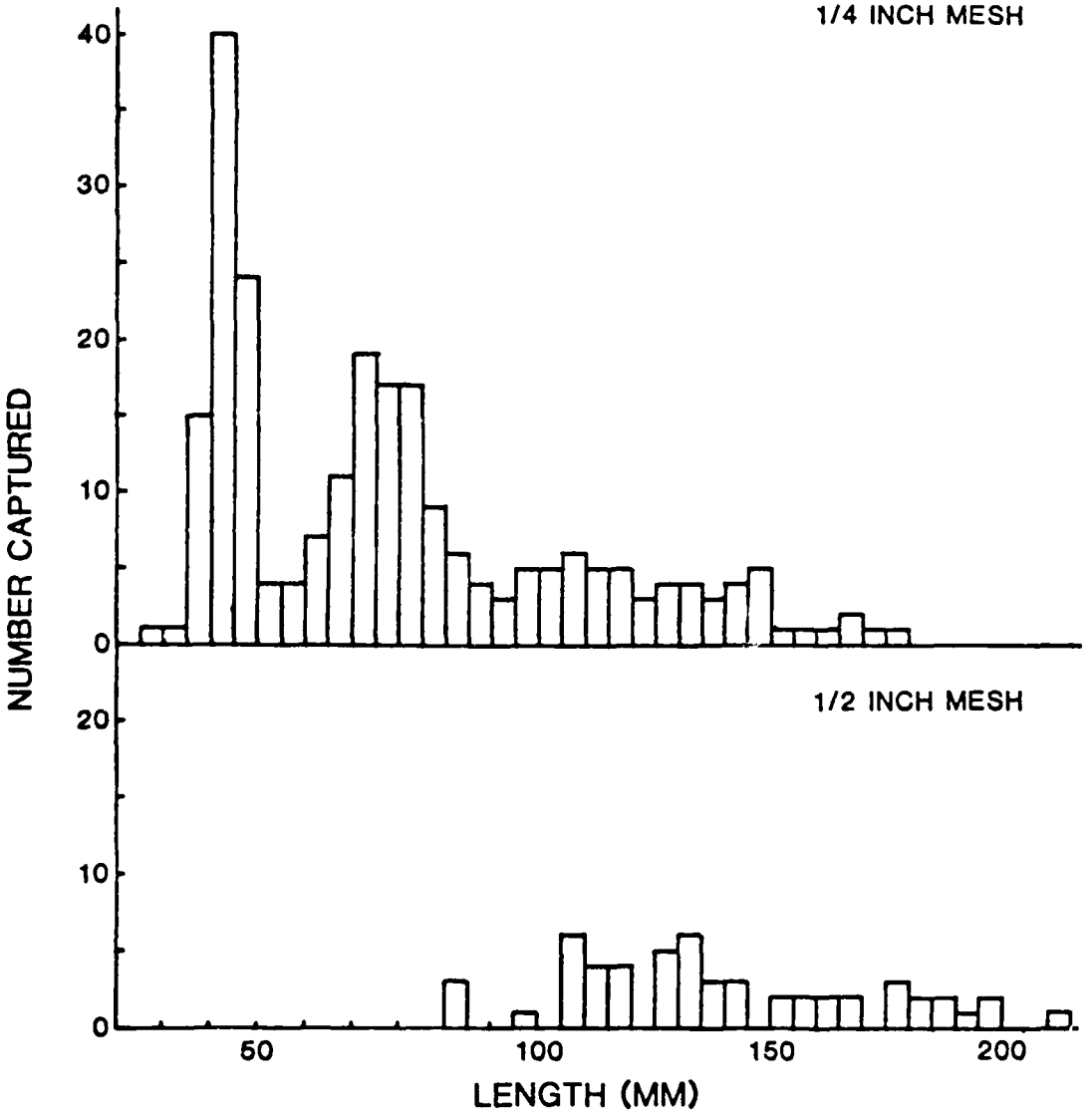
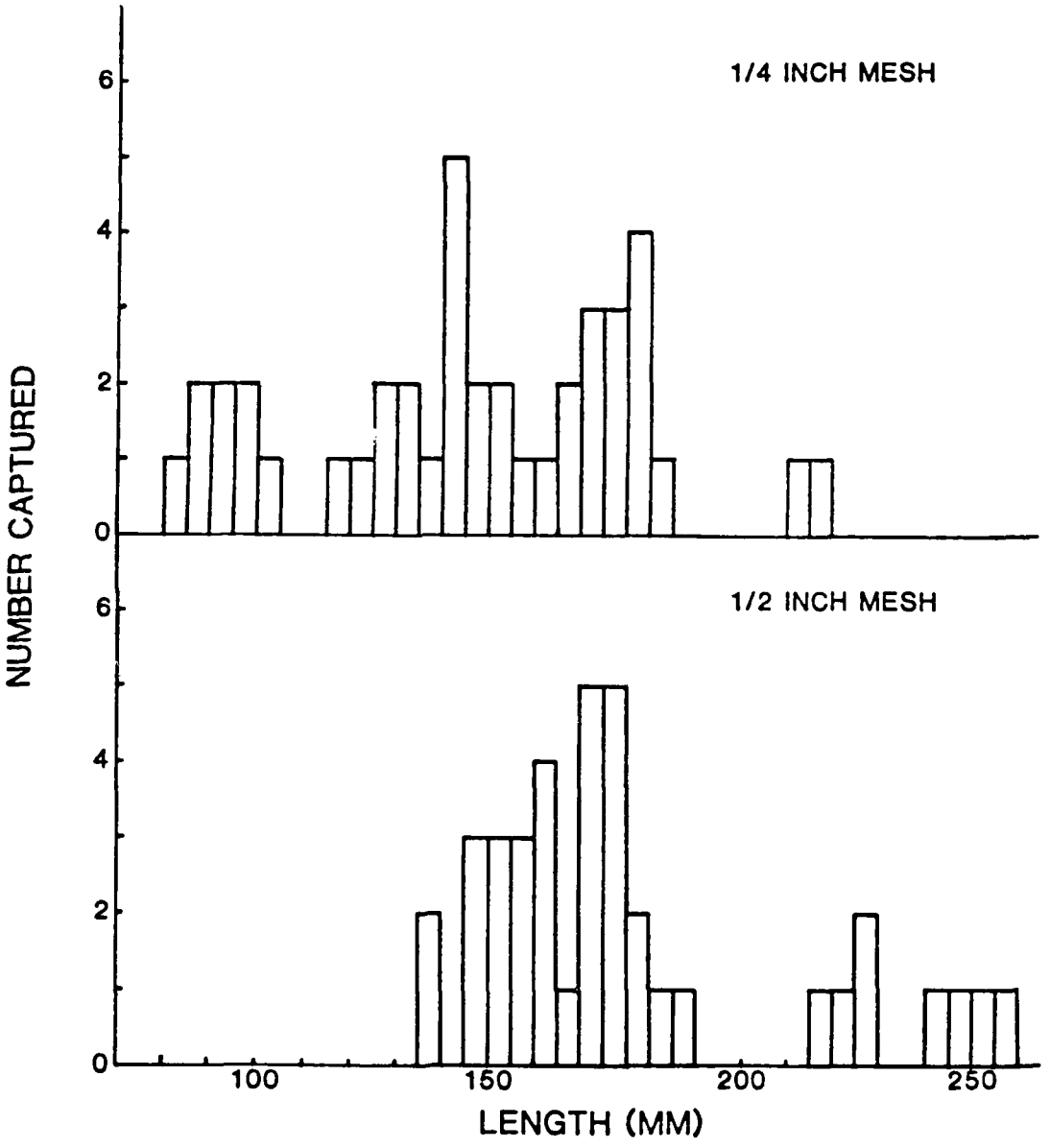


Figure 16.3 Night fyke net catches of burdot at FEX from 7/20/83 to 9/20/83 for ¼" and ½" mesh sizes. Catch bars represent 5 mm size groups.



Kick netting appeared to be a effective method of assessing non-mobile benthic fish from the numbers of fish caught (Table 15.6). Diver observation of this technique indicated that few fish escaped under or around the net. The 1/8" mesh began to catch mottled sculpins at 20 mm and fully recruited them to the gear at 30 mm (Figures 16.4-6). Longnose dace were first caught at 30 mm and were fully recruited at 35 mm (Figures 16.7-9). Fish shape was again important to recruitment with sculpins, a thick bodied fish, caught at smaller sizes than the slender longnose dace.

This technique does have two assumptions or sampling considerations associated with it which are: 1) That the researchers do not disturb the relative position of the fish which is critial to microhabitat use (in our study visual observation showed little change in position); and 2) The technique catches all fish in the enclosed area (which will be verified with electroshocking this coming field season on the Escanaba River). In summary, these data and observations indicate that this technique works well with benthic fish and can be used to assess their population dynamics and microhabitat use.

C. Modified box sampler

The design used this season did catch some fish but also had fish avoidance problems. Diver observation of this technique showed that it took too much time to herd fish into the bag which allowed the fish to find small gaps in the lead line in the absence of some type of disturbance. With these problems in mind, gear modifications will be made this winter and will be tested in the coming summer. The advantage of this gear type is its ease of operation and calibration of the catch to actual population numbers.

D. Seining

Seining was a complete failure in the Ford River. This river had too much debris and too fast of current for seining to be successful. In twelve hauls, no fish were captured and diver observation indicated that the lead line would either hang up or ride too high off the bottom, either of which allowed escapement. Thus effectiveness of this technique was low and will not be used in the coming field season.

E. Visual observation

Visual observation showed some potential as a sampling technique in the Ford River. Fish could be observed and counted but only at close range because of the high amount of suspended material in the current. The major problems of this technique were: 1) The lack of fish in daytime dives; 2) The use of large debris dams by fish in daytime which could not be penetrated for fish identification and enumeration; 3) The fast current which made diving by debris dams dangerous; and 4) The problems of rapid underwater identification because of visibility problems from the high suspended load. This technique will be retested using night dives and spotlights in order to examine its suitability to assess population dynamics and microhabitat use of selected fish species.

In summary, night fyke netting combining both 1/4" and 1/2" meshs worked well for catching mobile fish populations and kick sampling worked well for

Figure 16. 4 Monthly kick sampling catches of mottled sculpins at FCU in 1983. Catch bars represent 5 mm size groups.

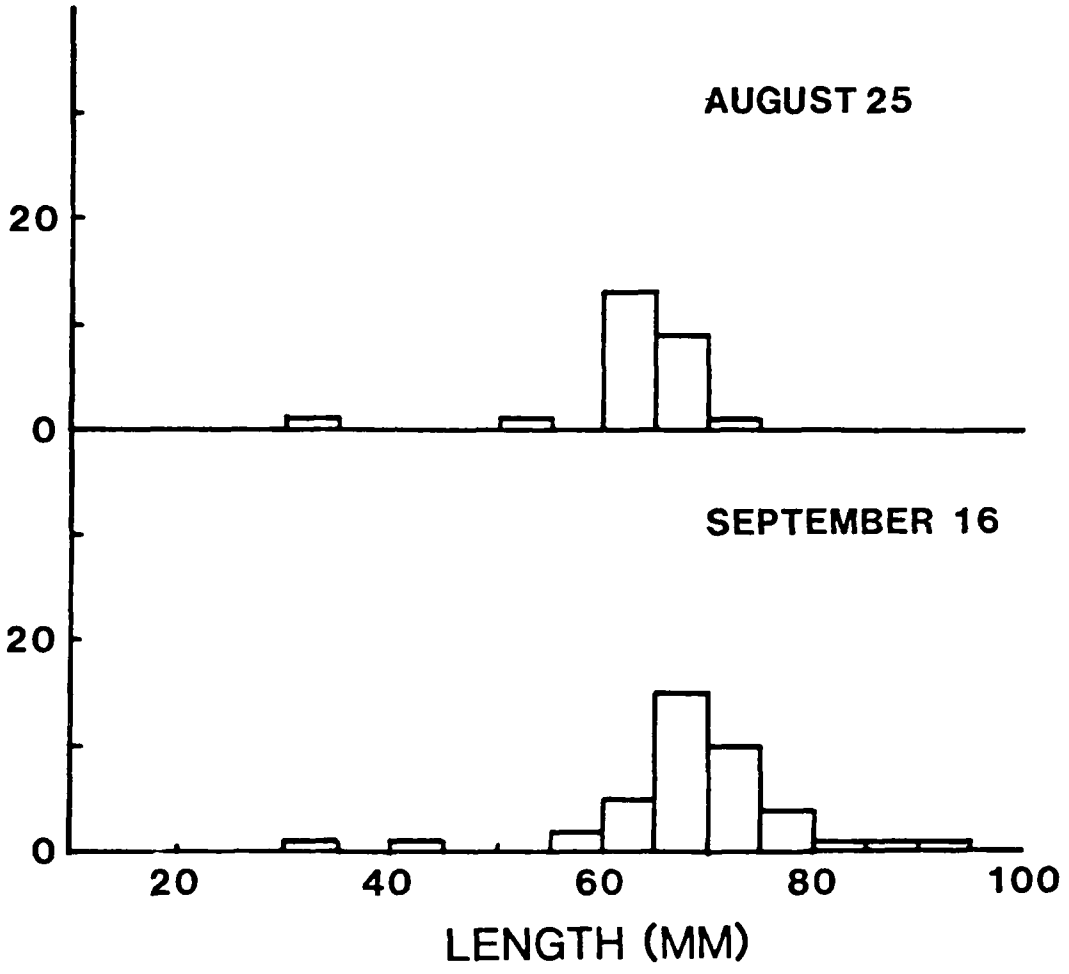


Figure 16.5 Monthly kick sampling catches of mottled sculpins at FEX in 1983. Catch bars represent 5 mm size groups.

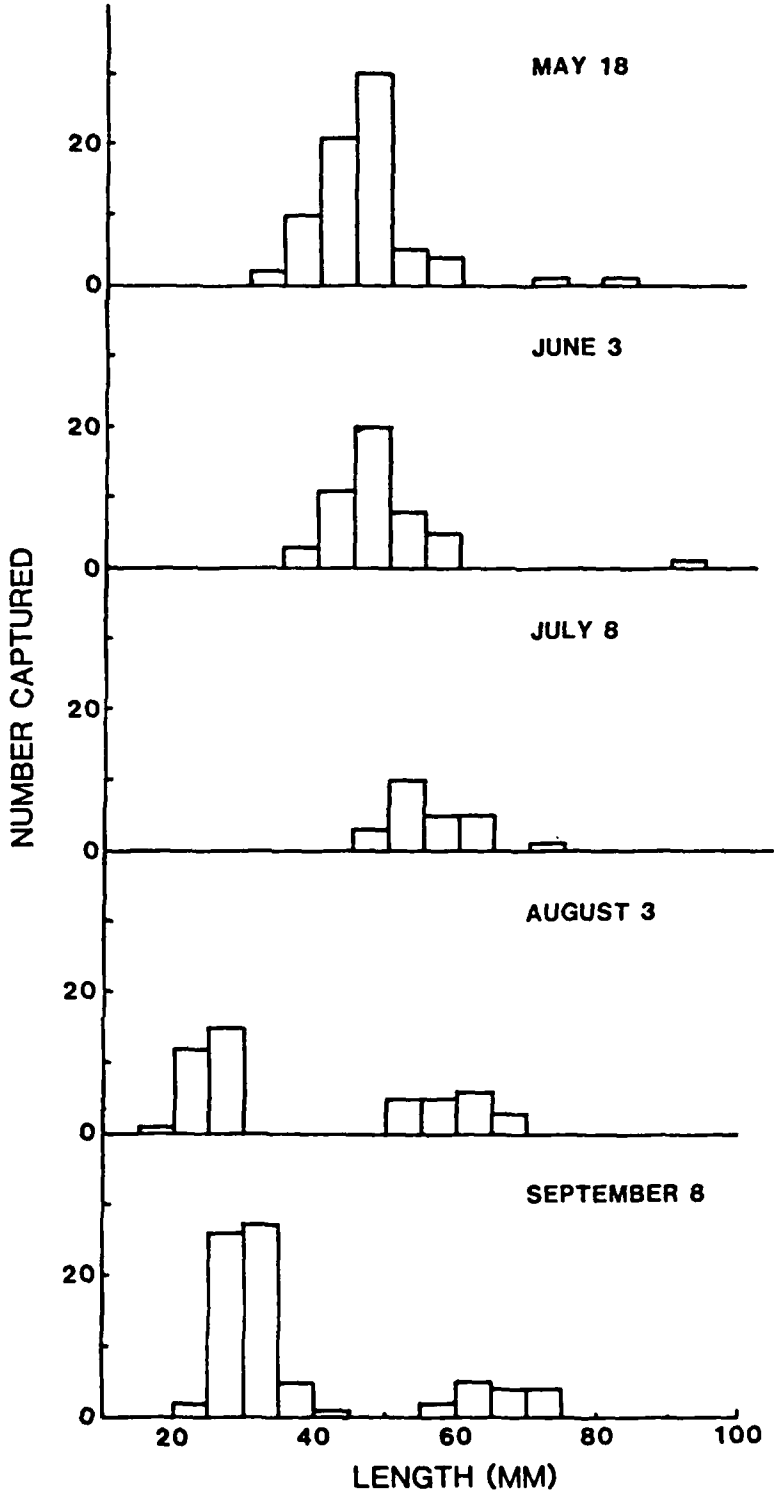


Figure 16.6 Monthly kick sampling catches of mottled sculpins at FCD in 1983. Catch bars represent 5 mm size groups.

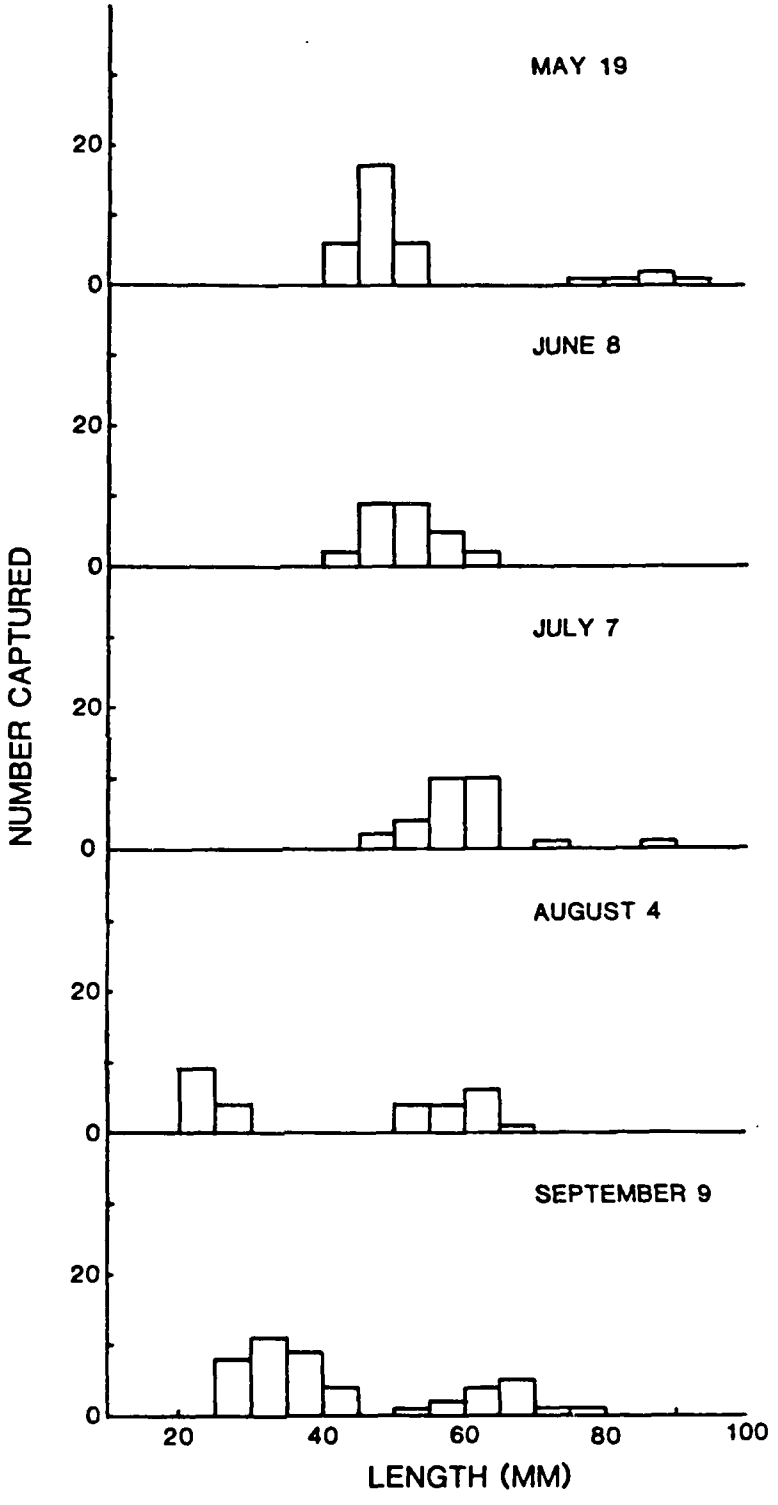


Figure 16.7 Monthly kick sampling catches of longnose dace at FCU in 1983. Catch bars represent 5 mm size groups.

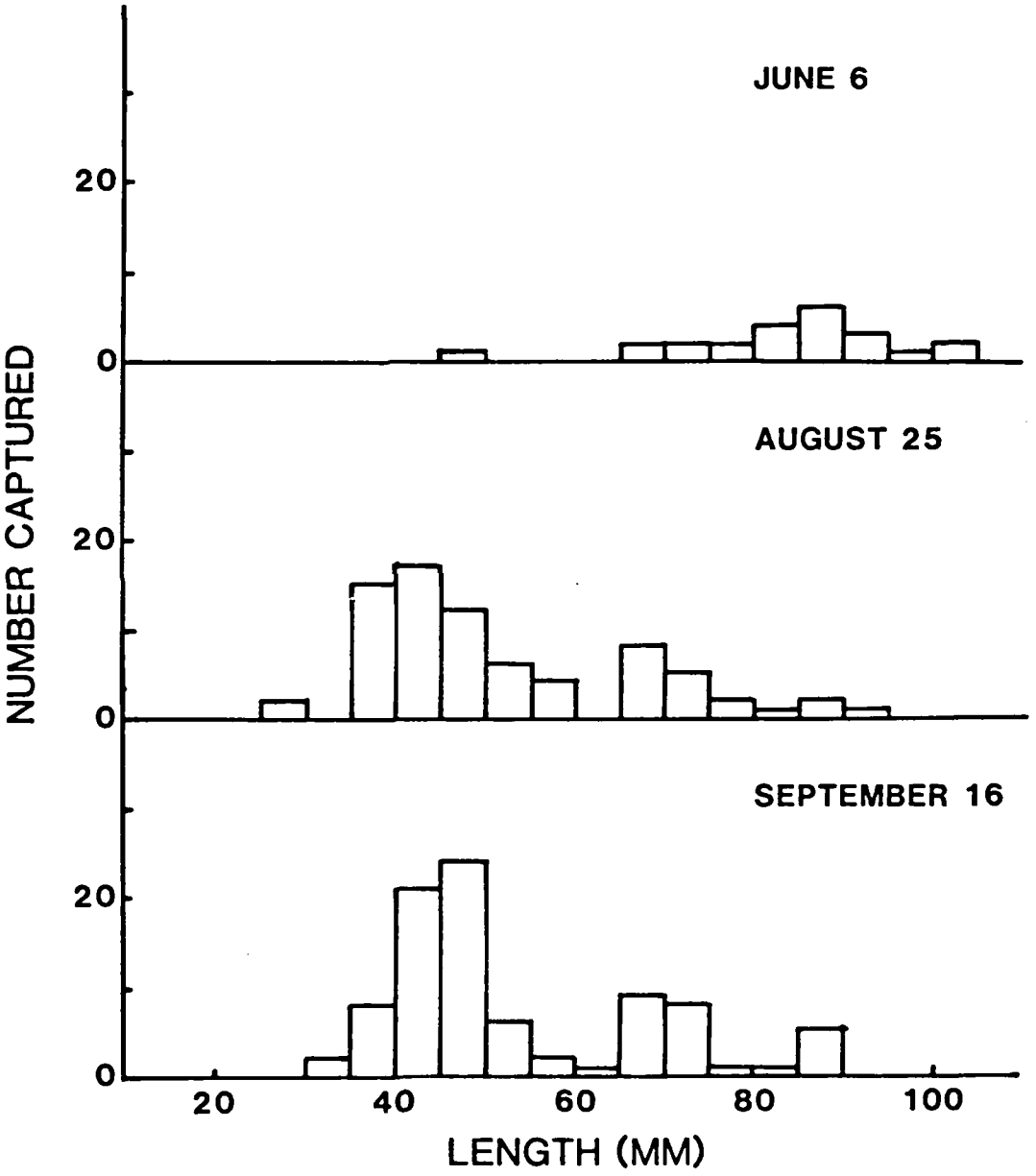


Figure 16.8 Monthly kick sampling catches of longnose dace at FEX in 1983. Catch bars represent 5 mm size groups.

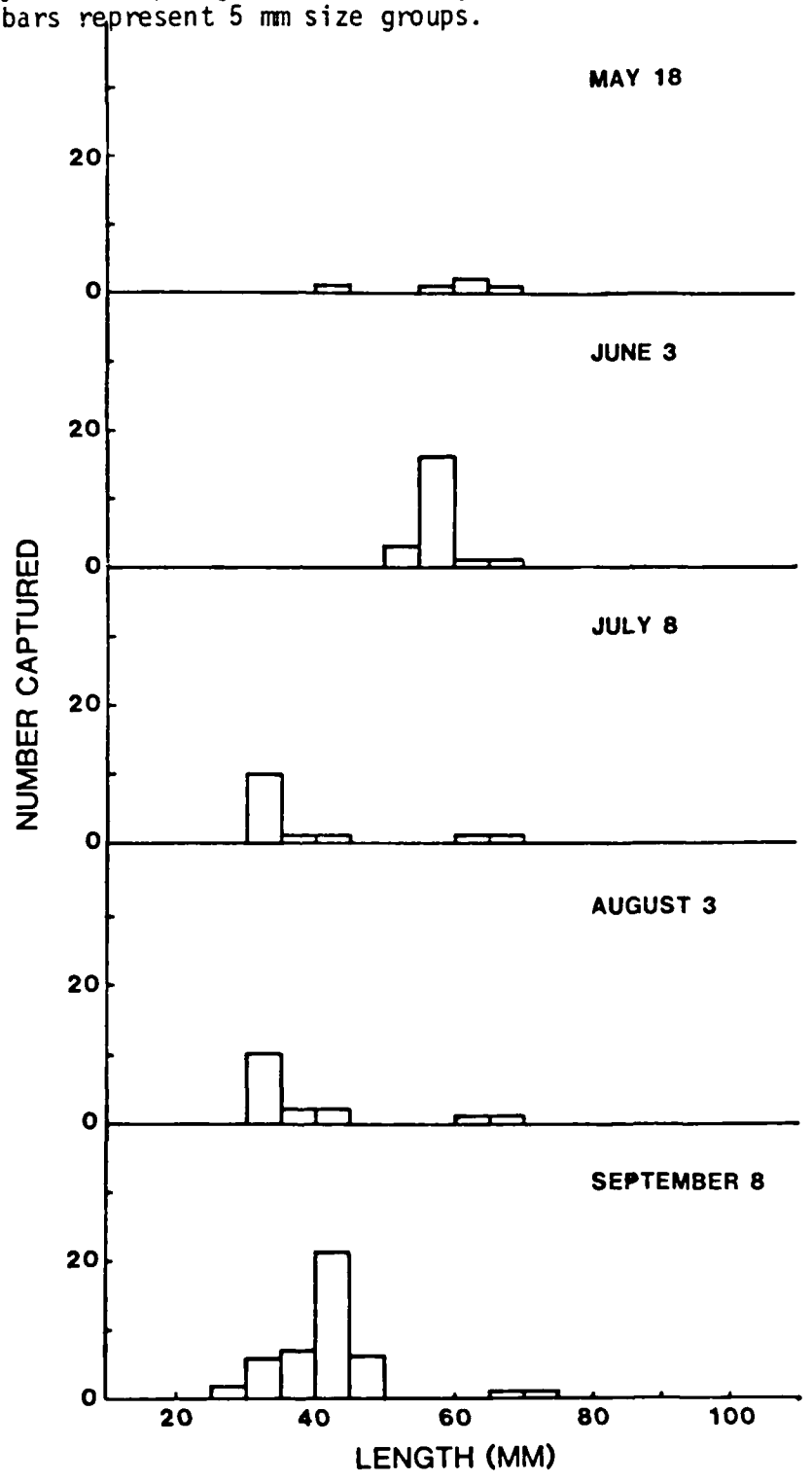
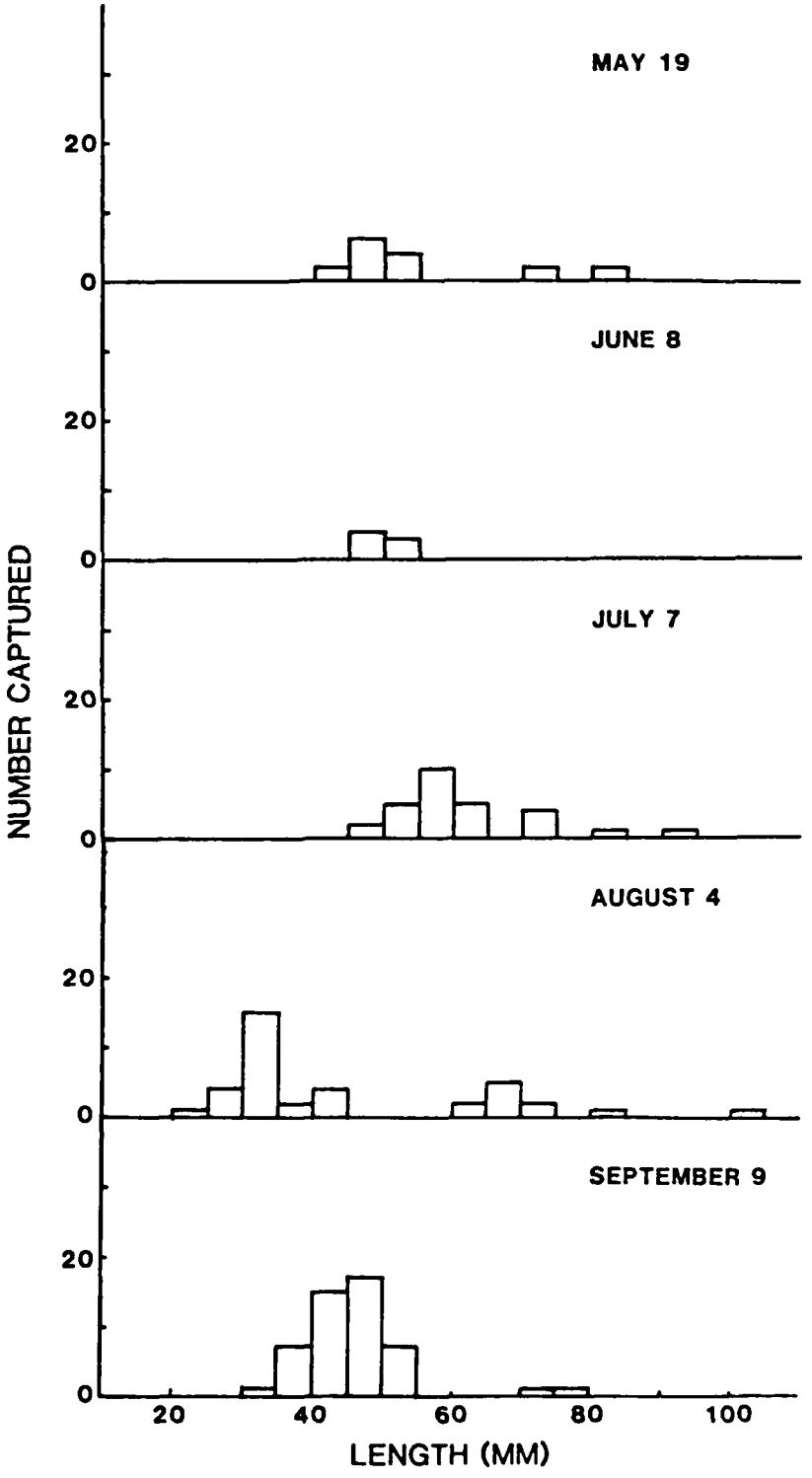


Figure 16.9 Monthly kick sampling catches of longnose dace at FCD in 1983. Catch bars represent 5 mm size groups.



catching benthic fish. Both methods are selective in their catch and must be geared to the target fish and study objectives. Fyke netting is appropriate to examine fish movement, age and growth, fecundity and parasites of mobile fish. If examining population dynamics, food habits, microhabitat use, fecundity and parasites of non-mobile benthic fish in the objective then kick seining is an appropriate technique. The box sampler has the potential to work well for benthic fish and will be retested in a modified form next field season. Visual observation will be retested at night next year for sampling suitability since daytime sampling was ineffective. Regular seining was found to be ineffective and will not be used in the coming field season. Additional visual observation of all techniques and electroshocking efficiency tests of kick sampling will be done in the coming field season and will be discussed in future reports.

Element 17 - Age-Length-Weight Relationships, Growth, Fecundity, Survival and Distribution of Selected Fish Species

Original synopsis - The basic vital statistics of selected species (sculpin, Cottus bairdi and brook trout, Salvelinus fontinalis) will be determined from specimens captured with nets and by visual observation in the control and experimental sites.

Changes from Original Synopsis - Brook trout have been dropped from most of this section because of the inability to catch sufficient numbers of them. Longnose dace have been selected to replace them. Distribution was moved from this element to element 16.

Contributing Staff - William W. Taylor, Assistant Professor (PI)
Gary E. Whelan, Field Research Technician II
David Gesl, Graduate Research Assistant

Objectives

1) To determine and compare the age and growth, and length-weight relationships of mottled sculpin, longnose dace, and brook trout from ELF sites.
2) To determine and compare the survival and fecundity of mottled sculpins and longnose dace from ELF sites.

Materials and Methods

A. Age and growth

Fish were collected using the sampling methods and schemes in element 15 (for length frequency analysis), and in elements 15 and 21 (for bony part analysis). Mottled sculpin and longnose dace were measured for total length and a length-age key was developed for each site. Mottled sculpin, longnose dace and brook trout collected in elements 15 and 21 were measured for total length, weighed and had either scales, fin rays or otoliths removed. Scales were ultrasonically cleaned, wet mounted and analyzed on a compound microscope. Otoliths were cleaned in glycerine, mounted on slides, ground on emery cloth, and analyzed on a compound microscope. Fin rays were mounted in epoxy, sectioned using a Dremel saw, mounted on a slide and then analyzed on a compound microscope. Data analysis will examine mean length at age using both actual length frequency data and backcalculated length. These means will then be tested between sites using either ANOVA or Kruskal-Wallis tests depending on sample size and normality. Only length frequency data will be presented here as the rest of the analyses are in progress and will be completed by the end of the winter.

B. Length-weight relationships

Fish were collected using the techniques and sampling scheme in elements 15 and 21. All mottled sculpins, longnose dace and brook trout were measured

for total length and weighed. Regression equations of the data were computed using log 10 transformed data to linearize the relationship. The regression lines were then tested for significant differences between sites using Bartlett's test and analysis of covariance techniques as outlined in Snedecor and Cochran (1979).

C. Fecundity

Fish were sampled according to the methods and sampling scheme in element 21. Gonads were removed from each fish and weighed. Egg counts, mean egg diameter and mean egg weight were determined for all females. Egg diameter was measured on a calibrated whipple grid on a compound microscope. Eggs were weighed on a Brainweight B300 analytical scale. Data analysis will include statistical testing of mean gonad weight, mean egg weight, mean egg size, mean egg numbers and mean GSI (GSI=(gonad wet wt./total wet wt.-gonad wet wt.) using either ANOVA or Kruskal-Wallis tests depending upon sample size and normality. Regression analysis of length and weight relationships with gonad weight and egg numbers will also be computed and tested for significant differences by site using analysis of covariance techniques. These analyses are currently in progress and will be completed by the end of this winter.

D. Survival

Fish were collected using the techniques and sampling scheme reported in the habitat section of element 15. Length frequency analysis was used to calculate survivorship using stable age distribution techniques (S=Nt/Nt+1) at each site by month for an age class and by year between age classes. Data analysis will statistically examine mean survivorship between sites using either ANOVA or Kruskal-Wallis techniques depending on sample size and normality of the data. Future analysis will shift to cohort analysis as year classes are followed through successive years.

Results and Discussion

A. Age and growth

Three distinct year classes of mottled sculpins occurred at all three sites (Figures 16.4-6). The age 0+ fish began to appear in the catch in August at approximately 23.5 mm an grew to approximately 32 mm by September (Table 17.1). No significant differences were found in mean size between FEX and FCD with too small of a sample size to test at FCU (TTest, α=0.05). The age 1+ fish began the sampling year at approximately 45 mm and grew to approximately 65 mm by September (Table 17.1). No significant differences were found by month in mean age 1+ fish size between FEX and FCD (ANOVA-DNMRT,α=0.05). FCU age 1+ fish were significantly larger than fish at FCD and FEX in August, and were significantly larger than FCD age 1+ fish in September (ANOVA-DNMRT, α=0.05) although FCD fish showed the fastest mean change in size (5.50 mm) in that period (August- September). Age 2+ fish were larger than 80 mm throughout the sampling year (Table 17.1). An insufficient number of age 2 fish were caught for statistical testing of this data. In summary, based on these preliminary results, sites FCD and FEX were very similar in the mean size of mottled sculpin while FCU mottled sculpins were

TABLE 17.1. Monthly mean total length (mm) ± 1 SD of mottled sculpin by age class (as determined by length frequency analysis) for FCU, FEX and FCD in 1983.

Month	Age Class	Site FCU	FEX	FCD
May	0	----------	----------	----------
	1	----------	44.63±5.17	47.00±3.27
	2	----------	82.00±4.24	83.80±6.30
June	0	----------	----------	----------
	1	----------	47.17±4.92	50.78±5.72
	2	----------	88	----------
July	0	----------	----------	----------
	1	----------	55.09±5.56	58.30±5.96
	2	----------	----------	86
August	0	30	24.22±2.50	23.20±2.04
	1	64.69±3.79	60.06±5.71	58.66±4.66
	2	----------	----------	----------
September	0	39.00±7.07	31.00±3.69	33.03±4.47
	1	68.72±4.95	64.91±5.59	64.17±6.99
	2	94	97	----------

larger. Data analyses this winter will include: 1) An aging study using bony parts to confirm the mottled sculpin length frequency; 2) An analysis of backcalculated growth; and 3) An analysis of growth rates between sites. These data analyses will be completed by spring and will be discussed in a future report.

Three distinct year classes of longnose dace were observed using length-age analysis (Figures 16.5-7). The age 0+ fish appeared August at approximately 35 mm and grew to approximately 45 mm by September (Table 17.2). FCU age 0+ fish in August and were significantly larger than FEX in September (ANOVA-DNMRT, α=0.05). The age 1+ fish began the sampling season at approximately 50 mm with the age 1+ fish at FEX significantly larger in mean size than FCD fish (TTest, α=0.05) and ended the sampling season at approximately 70 mm with no other significant differences found in mean size (TTest, α=0.05). The sample size of age 1+ fish was too small in August and September for statistical testing. Age 2+ fish began the sampling year at approximately 70 mm and grew to approximately 85 mm by September (Table 17.2) with no statistical testing possible because of the small sample size. In summary, based on these preliminary data, FCD and FEX appeared to be more similar in age group mean size by month than FCU and FEX. Further analyses on longnose dace this winter will include: 1) Further scale analysis to confirm the length-age key; 2) Backcalculated growth analysis; and 3) An analysis of growth rates between sites. Both analyses will be tested for significant differences between sites using either ANOVA or Kruskal-Wallis tests and will be discussed in future reports.

Brook trout age and growth analysis is in progress and will be included in a future report.

B. Length-weight relationships

Mottled sculpin length-weight regression analysis (on log10 transformed data) results are presented in Table 17.3. All regression lines were significant (FTest, α=0.05). Analysis of covariance test lresults showed that the three regression lines were significantly different because of heterogenity in variance (Barlett's test, α=0.05), thus could not be pooled. Further analysis of covariance between sites showed that FCU was significantly different in variance when compared to FCD and FEX (FTest, α=0.05). No significant differences in variance were found between FCD and FEX (FTest, α=0.05). FCD and FEX sites were significantly differ in the slope of the regression lines (FTest, α=0.05). These data indicate that the ELF sites were not similar in terms of fish growth.

Longnose dace length-weight regression analysis (on log10 transformed data) results are presented in Table 17.3. These regression lines' were significant (FTest, α=0.05). These relationships were not significantly different in slope variance but were significantly different in the y intercept when examined using analysis of covariance (FTest, α=0.05). These results further indicate that these lines were parallel indicating that the rates of fish growth were the same between sites. It is unclear, at this time, whether these slight differences in the y intercept value are biologically important.

TABLE 17.2. Monthly mean total length (mm) ± 1 SD of longnose dace by age class (as determined by length frequency analysis) for FCU, FEX, and FCD in 1983.

Month	Age Class	Site FCU	FEX	FCD
May	0	----------	----------	----------
	1	----------	55.33±9.54	47.92±3.00
	2	----------	----------	77.30±3.55
	3	----------	----------	----------
June	0	----------	----------	----------
	1	46	----------	48.14±2.48
	2	70.50±3.41	----------	----------
	3	90.12±6.20	----------	----------
July	0	----------	----------	----------
	1	----------	56.79±3.15	56.06±4.13
	2	----------	----------	74.25±4.03
	3	----------	----------	91
August	0	42.54±5.71	33.10±3.35	33.29±4.83
	1	67.93±4.98	64.50±3.53	68.00±3.46
	2	86.00±3.74	----------	82
	3	----------	----------	----------
September	0	45.00±4.85	39.57±5.08	44.38±4.46
	1	69.64±3.53	70.00±5.65	74.50±6.36
	2	85.67±2.80	----------	----------
	3	----------	----------	----------

TABLE 17.3. Length-weight regression lines on logic transformed data for longnose dace, mottled sculpin and brook trout for FCU, FEX, and FCD in 1983.

Species	Site	N	Regression Formula	R^2
Longnose dace	FCU	157	Log wt = -4.70+2.83 Log Ln	0.94
	FEX	219	Log wt = -4.78+2.88 Log Ln	0.96
	FCD	142	Log wt = -5.05+3.04 Log Ln	0.97
Mottled sculpin	FCU	115	Log wt = -4.84+3.00 Log Ln	0.96
	FEX	189	Log wt = -5.10+3.12 Log Ln	0.95
	FCD	184	Log wt = -4.79+2.95 Log Ln	0.96
Brook trout	FCU	14	Log wt = -5.24+3.10 Log Ln	0.99
	FEX	90	Log wt = -5.48+3.21 Log Ln	0.99
	FCD	83	Log wt = -5.05+3.03 Log Ln	0.99

Brook trout regression analysis (on log 10 transformed data) results are presented in Table 17.2. All regression lines were found to be significant (FTest, α=0.05). Analysis of covariance on these relationships showed that the three regression lines have significantly different slopes (FTest, α =0.05), indicating that the sites have different rates of fish growth.

In summary, all regressions between length and weight were significant. Longnose dace demonstrated the least difference between sites. Growth of mottled sculpins and brook trout were very different based on site location. Thus, in terms of fish growth the ELF sites were not replicates of each other.

C. Fecundity

Fecundity analysis is in progress and data analysis will not be completed until spring. Results will be discussed in a later report.

D. Survival

Mottled sculpin survivorship was estimated by both a yearly estimate (i.e. age 1+ to age 2+) and a monthly estimate for each year class. Annual mortality estimates for age 0+ to age 1+ was calculated only at FEX and FCD because of insufficient numbers of age 0 fish at FCU. Mottled sculpin age 0+ to age 1+ survivorship was calculated to be 44.4% at FCD and 22.9% at FEX using September data (Table 17.4). September data was used because the age 0+ year class was fully recruited to our gear at this time. The lack of age 0+ fish at FCU might be a function of by the habitat differences at this site which maybe suitable for age 0+ fish. Further analysis of microhabitat preferences and bony part aging analysis (to determine the validity of the length-age key) should allow us to better understand this relationship.

Estimates of age 1+ to age 2+ survivorship of mottled sculpins ranged from 3% to 21.4% (Table 17.4). FCD consistantly showed the highest survivorship although the sample size was small and statistically untestable. Survivorship at FCU and FEX was found to be similar (Table 17.4) and was not testable because of the small sample size. This analysis had some problems because of the disappearence and reappearance of year classes in the catch. This maybe attributable to the changing water levels through the summer which in turn changed some of the micro and macrohabitat, and may have caused a movement of the age 2+ fish out of the sites. Further data analysis of micro and macrohabitat preference by size class should clarify this relationship. Future data analysis will consist of testing the mean survivorship by site of mottled sculpins using either ANOVA or Kruskal-Wallis tests depending on the sample size and normality of the data.

Monthly survivorship estimates for mottled sculpins are only available for age 1+ sculpins because the age 0+ sculpins were not fully recruited to the gear and the small age 2+ sample size (Table 17.5). No significant differences were found between FCD and FEX for mean monthly survivorship using arcsin transformed data (TTest, α=0.05). The mean monthly age 1+ survivorship at FCD was found to be 80.1% (range 52.2-95.2%) and 66.4% at FEX (range 50.8-83.8%). There was a larger decline in monthly catches of age 1+ fish at FEX than at FCD although this was not significantly greater (Mann-Whitney U Test, α=0.05). Insufficient sample size at FCU did not allow for

TABLE 17.4. Yearly survival rates (%) of longnose dace (LND) and mottled sculpin (MS) for FCU, FEX and FCD in 1983 using montly estimates (Survival = $\frac{Nt}{Nt+1}$).

Date	Site											
	FCU				FEX				FCD			
	LND		MS		LND		MS		LND		MS	
	0^+-1^+	1^+-2^+	0^+-1^+	1^+-2^+	0^+-1^+	1^+-2^+	0^+-1^+	1^+-2^+	0^+-1^+	1^+-2^+	0^+-1^+	1^+-2^+
May	----	----	----	----	----	----	----	3.0	----	50.0	----	17.2
June	----	----	----	----	----	----	----	2.1	----	----	----	----
July	----	----	----	----	----	----	----	----	22.2	----	----	21.4
August	36.3	25.0	----	----	20.0	----	69.6	----	38.1	12.5	----	----
September	30.9	35.3	----	2.8	5.7	----	22.9	9.1	5.1	----	44.4	----

TABLE 17.5. Monthly survival rates (%) of longnose dace (LND) and mottled sculpin (MS) for FCU, FEX and FCD in 1983 by age class.

Interval	Site																	
	FCU						FEX						FCD					
	LND			MS			LND			MS			LND			MS		
	0^+	1^+	2^+	0^+	1^+	2^+	0^+	1^+	2^+	0^+	1^+	2^+	0^+	1^+	2^+	0^+	1^+	2^+
May-June	----	----	----	----	----	----	----	----	----	----	64.1	45.0	----	58.3	----	----	93.1	----
June-July	----	----	----	----	----	----	----	----	----	----	50.8	----	----	----	----	----	----	----
July-August	----	----	----	----	----	----	----	10.4	----	----	83.8	----	----	44.4	25.0	----	52.2	----
August-September	----	97.0	----	----	----	----	----	97.8	----	----	67.0	----	----	23.8	----	----	95.2	----

the statistical testing of this data. Again the small sample size presented here hindered the statistical analysis of this data. This should be overcome in this coming field season.

In summary, the preliminary data indicates that FCD had higher survivorship both monthly and yearly for mottled sculpins. This conclusion should be qualified by the small sample size used for these estimates. Problems encountered with these estimates such as migration effects and microhabitat changes will be further investigated in the upcoming field season. The use of cohort analysis will also help to clarify these problems.

Longnose dace survivorship was examined using the same methods as for mottled sculpins. Annual estimates of survivorship of age 0+ to age 1+ fish ranged from 5.1% to 38.1% with FCU having the highest of survivorship for age 1+ to age 2+ ranged from 12.5% to 50% with usuable data from FCD and FCU. FCU had the most consistent and lower survivorship estimates, in contrast to the other sites which had highly variable rates. This again maybe attributable to: 1) the high amount of mobility of longnose dace; 2) changes in microhabitat use; and 3) the small sample size of age 2 fish at FCD and FEX. No statistical analysis of this data will be done because of the small sample size. The larger sample size expected this year along with the use of cohort analysis should decrease the variation and allow for the use of mean comparison techniques such as ANOVA or Kruskal-Wallis tests depending upon normality of the data.

Monthly survivorship of individual year classes was highly variable (Table 17.5). The estimates of survival of year 1+ fish range from 10.4 to 97.8% (both of which are from FEX). FCD had consistent and lower survival estimates ($\bar{x}$=42.1) than the other sites although this was statistically untestable because of the small sample size. This variance is attributed to the same reasons as given for the yearly estimates.

In summary, no clear trends were found between sites in longnose dace survivorship although it appears that FCD and FEX were more similar than any pairing with FCU. This section will be sampled in more detail in the coming field season and combined with microhabitat modeling and movement data should provide more reliable survivorship estimates. Further data analysis will consist of the comparison of yearly and monthly mean survivorship by either ANOVA or Kruskal-Wallis tests depending on the sample size and normality of the data.

Element 18 - Dirunal Food Habits and Consumption Rates of Selected Fish Species

Original synopsis - Food habits of selected fish species (sculpin and brook trout) and consumption rates will be determined in the control and experimental sites for the study stream.

Changes from Original Synopsis - Brook trout were dropped from this element because of the inability to catch sufficient sample sizes. Longnose dace were selected to replace them. Food consumption techniques were only tested at FCU on longnose dace because of the inability to catch sufficient numbers of mottled sculpins at the time intervals necessary at FCU, and inability to catch sufficient numbers of either species at FEX.

Contributing staff - William W. Taylor, Assistant Professor (PI)
Gary E. Whelan, Field Research Technician II
David Gesl, Graduate Research Assistant

Objectives

1) To determine and compare the food habits of mottled sculpin and longnose dace at all sites. 2) To determine the daily amount of food consumed by mottled sculpins and longnose dace at all sites.

Materials and Methods

A. Food Habits

The fish used in this section were collected using the techniques and sampling scheme in element 21. After being processed for parasites, the gut contents were removed and examined under a binoccular microscope with a calibrated whipple grind. Individual food items were identified to the lowest possible taxa, total volume estimated, total length and head capsule width measured, weighed and then dried for 24 hours at 70C for dry weight. Data analysis included comparing mean numbers of each taxa, mean weight, mean total length, either ANOVA or Kruskal-Wallis tests (depending on normality) for each fish species and size class. Chi-square analysis was used to examine for differences in the total diet by site. These analyses are in progress and will be discussed in a later report. Preliminary analysis of non-ELF survey sites in the Ford and Escanaba Rivers will be reported here to establish a taxanomic basis of the food habits of mottled sculpins and longnose dace.

B. Consumption

Daily food consumption was estimated using the technique of Nakashima and Leggett (1978). This technique consists of sampling 10 fish every 3 hours for 2-24 hour periods. The fish were killed then preserved in 10% formalin for lab analysis. The gut contents are then removed and examined as in the food habits section. The peaks in gut content wet weight are then summed

over time and are presented as the daily amount consumed. These amounts will be compared by site using either ANOVA or Kruskal-Wallis tests depending normality. This year because of sampling problems the technique was only tested at FCU with longnose dace. These analyses are in progress and will be discussed in a future report.

Results and Discussion

Analysis by taxa order (by numbers) of food consumed by mottled sculpins and longnose dace indicates that mottled sculpin concentrated on Ephemeroptera and longnose dace concentrated on Diptera (Table 18.1). Ephemeroptera constituted 63.5% by number of the food items consumed by mottled sculpins (N=31) and appeared in 66.7% of the gut of Trichoptera (15.3% by number and appeared in 29.2% of the stomachs). Plecoptera and Diptera made up only 9.4% of the diet. Mottled sculpin masticated their food thus making for identification problems as seen by the 11.8% of the diet made up of unidentifiable animal material. Longnose dace showed a different emphasis in their food preference with Diptera consisting of 68.4% by number and appearing in 42.6% of the stomachs. Although Trichoptera and Ephemeroptera made up only 11.8% and 15.1% of the diet by number, they did occur in more stomachs than Diptera (53.7% and 44.4% respectively). Plecoptera and unidentified animal matter made up only 4.7% of the diet by number of longnose dace. The percentage of empty guts was similar for both fish (longnose dace=23.9% and mottled sculpin= 26.0%).

In summary, these data indicate that mottled sculpin and longnose dace appeared to eat different food items although this should be qualified by the small sample size used in this analysis. Problems were seen in mottled sculpin food taxa identification which should be overcome by increases in sample size. Between site comparisons, and size class analysis of the whole data set will be completed by spring and will be discussed in a future report.

TABLE 18.1. Diet composition by insect order for mottled sculpin and longnose dace for non-ELF survey sites.

Longnose dace (N=71)

Order	n	% occurrence	$\bar{x} \pm 1$ SD	% of total
Diptera	23	42.6	9.42±17.67	68.4
Ephemeroptera	22	44.4	2.09±1.97	15.1
Trichoptera	29	53.7	1.62±0.98	11.8
Plecoptera	4	7.4	0.20±0.51	1.5
Unidentified Animal Material	11	20.4	0.44±1.53	3.2
Empty	17	23.9		

Mottled Sculpin (N=31)

Order	n	% occurrence	$\bar{x} \pm 1$ SD	% of total
Ephemeroptera	16	66.7	2.16±2.29	63.5
Trichoptera	7	29.2	0.52±0.46	15.3
Plecoptera	4	16.64	0.16±0.05	4.7
Diptera	3	12.5	0.16±0.34	4.7
Unidentified Animal Material	10	40.0	0.4±0.25	11.8
Empty	8	26.0		

Element 19 - Mark-Recapture Studies of Sculpin

Original synopsis - The sculpin, Cottus bairdi, will be collected from the control and experimental sites of the Ford River with nets, marked and released. This mark-recapture procedure will continue until reasonable population estimates are established and will be repeated seasonally.

Changes from Original Synopsis - Per unit area kick sampling was added as population estimator when mark-recapture assumptions were violated.

Contributing staff - William W. Taylor, Assistant Professor (PI)
Gary E. Whelan, Field Research Technician II
David Gesl, Graduate Research Assistant

Objective

To determine and compare population estimates of Cottus bairdi at all sites.

Materials and Methods

Each site was sampled using a 6' X 10' seine with 1/8" mesh following the sampling scheme outlined in element 15. Mark-recapture estimates were made according to the methods and assumptions in Ricker (1975). Single mark-recapture estimates were made using the adjusted Petersen method (Chapman 1951) which uses the equation: $N=(M+1)(C+1)/(R+1)$. Multiple mark-recapture estimates were made using the Chapman adjustment of Schnabel's method (Chapman 1952, 1954) which uses the equation: $N= (CtMt)/R+1$. Population estimates were also directly estimated using per unit area kick sampling (2.76 m^2/kick) as described in element 15 (habitat relationship section).

Results and Discussion

Population results for two of the three sites showed that the mark-recapture estimates were much higher than the per unit area estimates (Table 19.1). The mark-recapture estimate was highest at FEX although August and September estimates reflect no recaptures of marked fish. Lower stable estimates were found at FCD. No estimates are available at FCU because no recaptures of marked fish occurred. These results do not appear to reflect actual catches by the per unit area samples and indicate that violations of the assumptions of the mark-recapture model occurred thus no statistical analysis of this data will be done.

The mark-recapture model is an indirect estimator of population numbers which relies on six assumptions to operate: 1) The marked fish suffer the

TABLE 19.1. Monthly population estimates of mottled sculpin for FCU, FEX and FCD in 1983 using mark-recapture and per unit area kick sampling. Method abbreviations are P = Peterson single mark-recapture and SC = Schnabel-Chapman multiple mark-recapture. Asterick values are months of no recaptures of marked fish. Sites are FCU = 320.45 m^2, FEX = 540.9 m^2 and FCD = 540.7 m^2.

Site	Month	Mark-Recapture			Per Unit Area Kick Sampling	
		Method	#	#/m^2	#	#/m^2
FCU	August	P	----*	----	60.84	0.19
	September	SC	----*	----	85.85	0.27
FEX	May		----	----	269.84	0.49
	June	P	544	1.00	188.23	0.35
	July	SC	546	1.01	89.23	0.16
	August	SC	739.9*	1.37	186.20	0.34
	September	SC	964*	1.78	238.31	0.44
FCD	May		----	----	133.33	0.25
	June	P	459	0.85	105.88	0.20
	July	SC	284	0.53	90.19	0.17
	August	SC	266	0.49	107.80	0.20
	September	SC	273	0.51	172.80	0.32

same mortality as unmarked fish; 2) The marked fish are as vulnerable to fishing as are the unmarked fish; 3) The marked fish do not lose their marks; 4) The marked fish are randomly mixed in the population; 5) All marks are recognized and reported on recovery; and 6) Recruitment is negligible during the recapture period (Ricker 1975). The technique as used this sampling season appeared to violate two of these assumptions: 1) The system must be a closed system with no immigration or recruitment; and 2) Marked individuals are randomly distributed in the population. River systems are inheritately open systems which do not directly violate the model assumptions unless the target fish are mobile. We did find one marked fish which traveled approximately 200 m from the site thus some movement of marked fish did occur. This movement was not great as shown by recapture rates of marked individuals of between 12.5-15.0% at FEX and 7.4-33.3% at FCD but may have been enough to bias our estimate. Additional violations of that assumption occurred from the recruitment of a new year class. Since we only marked fish over 35 mm (below this size was impractical) our estimates are only valid for fish over 35 mm. The recruitment of the year over 35 mm occurred by September thus biasing that result and was most easily seen in the FEX results. The FCD results did not reflect the impact of recruitment thus seem biased. The other assumption violation occurred when it appeared that the catch of our marked larger individuals was clumped not random which also biased the results. This bias may be the key to the continued use and integration of mark-recapture techniques in our program. The clumping of marked individual may be caused by the microhabitat preferences of these fish. This coupled with the overall assumption in calculating densities at the sites of a random distribution of fish (which also appears false) leads us to combining mark-recapture techniques with microhabitat modeling to give us population estimates of size classes by habitat type. This should help overcome one of the assumption violations and make the mark-recapture estimate a valuable tool in our program. The other assumption can be overcome by using only 1+ fish in our model leaving the young of the year estiamtes for the other technique or using formulas which correct for recruitment. This approach will be tested in the coming field season.

The per unit area estimate is a direct sampling technique which randomly sampled all habitats. This estimator does not have the model assumptions that the mark-recapture estimator has and appeared to be more reasonable in reflecting actual population densities (Table 19.1). Per unit area estimates of mottled sculpin population numbers showed FEX had a significantly higher mean site population of sculpins ($\bar{x}$=194.36, range 89.23-269.84) than FCD (Mann-Whitney U test, α=0.05). The mean FCD sculpin population was found to be 121.9 individuals with a range from 90.13 to 172.8. FCU had the lowest mean population ($\bar{x}$=73.34) which ranged from 60.84-85.85 although statistically not tested because of the small sample size.

In summary, per unit area estimates appeared to be least biased and showed that FEX had the largest population of mottled sculpins. Mark-recapture estimates were biased by assumption violations and were not statistically tested. A combination approach using mark-recapture and microhabitat modeling will be tested this field season after additional data analysis of the microhabitat preferences of mottled sculpin. Per unit area estimates will continue to be used and compared to other techniques.

Element - 20 Studies of Patters of Development From Egg to Adult for Selected Fish Species

Original synopsis - The development of brook trout and sculpin will be determined by visual observation and specimen collection and study for the control and experimental sites.

Changes from Original Synopsis - This element was dropped because of budget cutbacks thus only a descriptive analysis will be presented here.

Contributing Staff - William W. Taylor, Assistant Professor (PI)
Gary Whelan, Field Research Technician II
David Gesl, Graduate Research Assistant

Objective

To determine and quantify any unusual development pattern evident at any of the sites.

Materials and Methods

Fish were visually examined for deformities using fish from elements 15, 16, and 21. All observed deformities were enumerated and reported in monthly reports.

Results and Discussion

No unusual development patterns or deformities were seen in any of the fish examined. This visual observation for growth deformities will not be continued in the coming sampling season.

Element 21 - Parasite Loads of Selected Fish Species

Original synopsis - The internal and external parasites of selected fish species were determined by collection of fish and laboratory examination of the kinds and numbers of parasites for both the control and experimental sites.

Changes from Original Synopsis - Selected fish species are the mottled sculpin, Cottus bairdi (Family: Cottidae) and longnose dace, Rhinichthys cataractae (Family: Cyprinidae). These species have also been collected from the Ford (non-ELF sites) and Escanaba rivers and their tributaries.

Contributing Staff - P. Muzzall, Associate Professor (Cooperating Investigator)

Objectives

1) To establish a taxonomic base of parasitic species that infect mottled sculpins and longnose dace. 2) To calculate the infection rates (prevalence and mean number) of parasites of these two fish species. 3) To establish a base of statistical tests which will analyze the data and determine if relationships exist between parasite infection rates and fish sex, length, age, and weight.

Materials and Methods

Fishes were collected from the Ford and Escanaba rivers and their tributaries from August 1982 through December 1982, and monthly from May 1983 through November 1983 by kick sampling with a 1/8" mesh minnow seine, and fyke netting. At the collecting site, fishes were killed in 10% formalin; a slit was then made from the vent anteriad to the isthmus area of the fish to preserve the viscera. After this, fishes were preserved in 10% formalin, individually packaged by Kapak heat sealable pouches and sent to MSU.

At necropsy, a fish specimen accession number was formulated and the weight, total length, and sex of each fish were recorded and scales or otoliths were taken for age determination. Fishes were examined for external parasites before the abdominal cavity was opened. The eyes, brain, gills, liver, gall bladder, kidney, urinary bladder, gonads, and the digestive tracts were placed in petri dishes and examined with a dissecting microscope.

Trematodes and cestodes recovered were processed by several techniques and stained with Mayer's Alum Carmine, Grenacher's Alcoholic Borax-Carmine, and Lynch's Precipitated Method using Grenacher's Alcoholic Borax-Carmine (Meyer and Penner, 1958). Nematodes were cleared in glycerin and examined in temporary mounts. Parasites were identified to genus according to Hoffman (1967), Schell (1970), Schmidt (1970), and Yamaguti (1963, 1971). Species were determined, wherever possible by reference to the original description within a genus. I thank Dr. Charles R. Peebles, Department of Natural

Science, MSU, for his help in identifying some of the parasites. Prevalence is the percentage of fish infected in a given sample, and mean number is the number of worms per host in a given sample. Data presented here will include all fish from 1982 and May 1983. All other analyses are in progress and will be discussed in future reports.

Results and Discussion

Sixty-six mottled sculpins, Cottus bairdi, and 90 longnose dace, Rhinichthys cataractae, were collected from the Ford and Escanaba rivers and their tributaries and examined for parasites. Fifty-seven (86%) mottled sculpins and 86 (96%) longnose parasitic species found are systematically arranged showing prevalence, mean number, and site of infection in Tables 21.1 and 21.2. Ten parasitic species infected sculpins, four of which were not found infecting dace; nine parasitic species infected dace, three of which were not found infecting sculpins. All parasitic species reported constitute new distribution records.

Four species of external parasites and six species of endohelminths infected sculpins. Of these, Rhabdochona cotti had the highese prevalence, followed by strigeid metacercariae (Superfamily: Strigeoidea) which had the highest mean number. Four species of external parasites and five species of endohelminths occurred in dace. Posthodiplostomum m. minimum had the highest prevalence and mean number followed by Rhabdochona canadensis. Of the endohelminths found, only R. cotti and R. canadensis mature in mottled sculpins and longnose dace, respectively; the other species obtain maturity in fish-eating birds and mammals (Hoffman, 1967).

The parasitic species from mottled sculpins and longnose dace from the FCU, FCD, and FEX sites are representative of the parasitic fauna of these two species of the area because seven parasitic species found in sculpins, and seven from dace, from the ELF sites also occurred in these fish collected from non-ELF sites. The parasitic species found in sculpins and dace from the FUC, FCD, and FEX sites occurred on and in these hosts as listed in Tables 21.1 and 21.2; Proteocephalus sp. was found in the intestine of one sculpin from the FCD site.

The parasites of mottled sculpins collected from the FCU, FCD, and FEX sites are reported in Table 21.3. Metacercariae (Superfamily: Strigeoidea) had the highest prevalence and mean number of all the endohelminths found in sculpins from each site. The number of metaceracriae significantly decreased as sculpins increased in length and weight (Spearmans Correlation Coefficient, $p = -0.191$, $p < 0.05$; $p = -0.196$, $p < 0.05$, respectively) and may be explained by a change in the sculpins' behavior and/or habitat. Sculpins from the FCU site had significantly more R. cotti than did sculpins from the FCD or FEX sites (Kruskal Wallis Test, $T = 7.74$, $p < 0.01$). Epistylis sp. was the most prevalent external parasite on sculpins as well as on dace at each site.

The parasites from longnose dace collected from the ELF sites are listed in Table 21.4. Posthodiplostomum m. minimum had the highese prevalence and mean number (except for Haplonema sp. FCU site) of all the endohelminth species found at each site. The number of P. m. minimum metacercariae

TABLE 21.1. Prevalence and mean number of parasites found in 66 mottled sculpins from the Ford and Escanaba Rivers and their tributaries collected from August 1982 through December 1982.

Parasite	No. inf. (%)	Mean no. ± 1 SD	Site of infection
Trematoda			
Monogenea			
Gyrodactylus bairdi	3 (4.6)	3.5 ± 2.2	gills
Digenea			
Diplostomum sp.*	21 (31.8)	3.5 ± 2.2	eye orbit, gonads, kidney, liver
Metacercariae (Superfamily: Strigeoidea)*	2 (3.0)	2.5 ± 2.1	muscle, mesenteries, eye orbit, gonads, heart, kidney, liver, urinary bladder
Cestoda			
Proteocephalus sp.+	1 (1.5)	1.0	intestine
Nematoda			
Contracaecum sp.+	1 (1.5)	1.0	stomach, intestine
Rhabdochona cotti	37 (56.1)	2.6 ± 1.6	stomach, intestine, rectum
Protozoa			
Epistylis sp.	9 (13.6)		gills
Myxobolus sp.	9 (13.6)		area between branchiostegal rays, gills
Trichodina sp.	3 (4.6)		gills

*Larval stages; +immature parasites; no postscript indicates adult parasites.

TABLE 21.2. Prevalence and mean number of parasites found in 90 longnose dace from the Ford and Escanaba Rivers and their tributaries collected from August 1982 through December 1982.

Parasite	No. inf. (%)	Mean no. ± 1 SD	Site infection
Trematoda			
Monogenea			
Gyrodactylus sp.	3 (3.3)		gills
Digenea			
Neascus sp.*	28 (31.1)	2.5 ± 3.0	integument, caudal fin, pectoral fin, pelvic fin, area between brachiostegal rays, muscles under integument and next to spinal cord, operculum
Posthodiplostomum m. minimum	80 (88.9)	14.7 ± 15.5	gonads, mesenteries
Cestoda			
Ligula sp.*	4 (4.4)	1.0	hemocoel
Nematoda			
Contracaecum sp.+	2 (2.2)	2.0 ± 1.4	intestine
Rhabdochona canadensis	35 (38.9)	2.8 ± 2.6	stomach, intestine
Protozoa			
Epistylis sp.	3 (3.3)		gills
Myxobolus sp.	7 (7.8)		gills
Trichodina sp.	6 (6.7)		gills

*Larval stages; +immature parasites; no postscript indicates adult parasites.

TABLE 21.3. Parasites of mottled sculpins from the FCU, FCD, and FEX sites in May 1983.

Parasite	No. inf. (%)	Mean no. ± 1 SD
FCU, 8 sculpins examined		
Trematoda		
Digenea		
Diplostomum sp.*	1 (13)	1
Metacercariae (Superfamily: Strigeoidea)*	8 (100)	6.3 ± 2.9
Nematoda		
Rhabdochona cotti	5 (63)	4.6 ± 2.3
Protozoa		
Epistylis sp.	7 (88)	
FCD, 20 sculpins examined		
Trematoda		
Digenea		
Diplostomum sp.*	1 (5)	1
Metacercariae (Superfamily: Strigeoidea)*	20 (100)	11.3 ± 7.2
Cestoda		
Proteocephalus sp.+	1 (5)	1
Nematoda		
Rhabdochona cotti	5 (25)	1
Protozoa		
Epistylis sp.	18 (90)	
Myxobolus sp.	9 (45)	

TABLE 21.3 Continued.

FEX, 20 sculpins examined		
Trematoda		
Digenea		
Diplostomum sp.*	7 (35)	2.6 ± 1.8
Metacercariae (Superfamily: Strigeoidea)*	20 (100)	13.3 ± 7.8
Nematoda		
Contracaecum sp.+	1 (5)	1
Rhabdochona cotti	10 (50)	2.2 ± 1.0
Protozoa		
Epistylis sp.	17 (85)	
Myxobolus sp.	8 (40)	

*Larval stages; +immature parasites; no postscript indicates adult parasites.

TABLE 21.4. Parasites of longnose dace from the FCU, FCD, and FEX sites in May 1983.

Parasite	No. inf. (%)	Mean no. ± 1 SD
FCU, 18 dace examined		
Trematoda		
Monogenea		
Gyrodactylus sp.	1 (6)	
Digenea		
Neascus sp.*	7 (39)	2.6 ± 1.9
*Posthodiplostomum m. minimum**	17 (94)	22.1 ± 25.4
Nematoda		
Haplonema sp.+	1 (6)	2
Rhabdochona canadensis	3 (17)	1
Protozoa		
Epistylis sp.	8 (44)	
Trichodina sp.	1 (6)	
FCD, 20 dace examined		
Trematoda		
Digenea		
Neascus sp.*	7 (35)	1.3 ± 0.5
*Posthodiplostomum m. minimum**	9 (45)	1.9 ± 0.8
Cestoda		
Ligula sp.*	1 (5)	2

TABLE 21.4 Continued.

Nematoda		
Haplonema sp.+	4 (20)	2.5 ± 1.7
Protozoa		
Epistylis sp.	17 (85)	
FEX, 20 dace examined		
Trematoda		
Digenea		
Neascus sp.*	10 (50)	3.2 ± 5.3
*Posthodiplostomum m. minimum**	12 (60)	18.4 ± 30.4
Cestoda		
Ligula sp.*	4 (20)	1.3 ± 0.5
Proteocephalus sp.+	2 (10)	1.0
Nematoda		
Haplonema sp.+	2 (10)	2.0 ± 1.41
Rhabdochona canadensis	2 (10)	2.0 ± 1.41
Protozoa		
Epistylis sp.	8 (40)	
Trichodina sp.	2 (10)	

*Larval stages; +immature parasites; no postscript indicates adult parasites.

significantly increased as the length and weight of dace increased at the FCU and FCD sites (FCU - Spearmans Correlation Coefficient, $p = 0.89$, $p < 0.001$, $p = 0.89$, $p < 0.001$; FCD, $p = 0.75$, $p < 0.05$, $p = 0.86$, $p < 0.001$, respectively). Although not statistically significant, a positive relationship also existed at the FEX site between the number of P. m. minimum and dace length and weight. Male and female dace from the FCU site and FEX site had significantly more P. m. minimum metacercariae than did male and female hosts from the FCD site (Kruskal Wallis Test, $T = 7.59$, $p < 0.01$, male; $T = 7.79$, $p < 0.01$, female). Also, the number of Neascus sp. metacercariae significantly increased as the length of dace increased when the data for all three sites were combined (Spearmans $p = 0.387$, $p < 0.05$). The increase in the number of P. m. minimum and Neascus sp. metacercariae with an increase in dace length may depend on a longer exposure time to parasitism, since body length is generally determined by age, and/or changes in the behavior of the fish.

In summary, the parasitic faunas of mottled sculpins and longnose dace between sites were comparable taxonomically and generally in species numbers. The number of species found infecting sculpins from the FCU, FCD and FEX sites were four, six, and six respectively. Parasitic species from longnose dace numbered five at the FCD site, seven at the FCU site, and eight at the FEX site. Strigeoid metacercariae and P. m. minimum metacercariae were most prevalent endohelminths found in sculpins and dace, respectively, at each site. The endohelminth faunas of sculpins and dace at each site were characterized by being composed of larval parasites which mature in fish-eating birds and mammals; only R. cotti and R. canadensis mature in sculpins and dace, respectively (Hoffman 1967). Of the external parasites found on both sculpins and dace at each site, Epistylus sp. was the most common.

Future Research

Fifteen mottled sculpins and 15 longnose dace will be collected and examined monthly at the FCU, FCD and FEX sites from April through December. The prevalence, mean number, seasonal occurrence, and species diversity of the parasites infecting these fish species, as well as the condition coefficient for each fish necropsied will be calculated and then analyzed between months by the Kruskal Wallis Test. Correlation analyses between prevalence, mean number, and species diversity of the parasites and the sex, length, weight, and condition coefficient of each fish necropsied will be performed to establish relationships if they exist. Also, the role of abiotic environmental factors and their influence on parasite populations will be addressed and integrated into the objectives discussed above.

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ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM:

WETLAND STUDIES

ANNUAL REPORT, 1983

SUBCONTRACT NUMBER: E06516-82-C-60015

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ABSTRACT

This report summarizes results of a pilot study designed to examine potential effects of ELF generated electromagnetic fields on wetlands. An intensive site selection process resulted in selection of forested peatlands as representative study sites. A series of eleven matched sites were chosen to reflect four different levels along an ELF electromagnetic gradient. Detailed information about the vegetation, water quality parameters, and electromagnetic fields was gathered for each site. Preliminary data on plant tissue nutrient content and weight loss of cellulose decomposition strips were obtained. Studies of leaf diffusion resistance are in the developmental phase. Procedures to reduce variation in the data set are under consideration. Initial estimates of sample size for foliar nutrient analysis are considered adequate; however, sample size estimates for the decomposition work must wait on the results of our second sample collection. The work plan for FY 1984 and FY 1985 has been modified to reflect information gathered during the pilot phase of the study.

SUMMARY

In this report, we describe the progress of a pilot study investigating potential effects of the ELF Communication System on wetlands near the Clam Lake Test Facility. Peatlands are common in the Clam Lake Area and were chosen for study. The peatland type we selected is relatively open, dominated by black spruce and tamarack with an understory of ericaceous shrubs (leatherleaf and labrador tea), sedges and sphagnum mosses on an organic substrate. These study sites share a specific vegetation, adapted to extreme physical and chemical conditions, characterized by low pH, low water cation concentration, and low conductivity. A series of matched sites were located along the electromagnetic field gradient generated by the ELF antennae system. The primary factors used in selecting these sites were:

1. similarity of species,
2. structural similarity of the vegetation,
3. density of the vegetation,
4. environmental parameters, and,
5. magnitude of ELF generated electro-magnetic fields (specifications supplied by IITRI).

Fifteen sites were chosen initially and eleven of these were used in the pilot study. Several sites now seem inappropriate for use and suitable replacements will be needed before sampling begins in 1984.

We chose first to study the responses of three different wetland plant species to ELF generated electromagnetic fields. Black Spruce (Picea mariana) is representative of the overstory, leatherleaf (Chamaedaphne calyculata) a shrub, and (Smilacina trifolia) an herb, are representative of the understory. They are found in abundance on all the study sites and some ecological information is available for each of them.

The detailed study plan is provided in Appendix A. We have directed our work toward potential ELF effects at the individual and the community levels. Our current studies were designed to examine the competitive ability of the three wetland species by investigating physiological functions that provide an indication of the overall status of the plant. Studies of water-use efficiency, leaf nutrient content, and the rate of decomposition were initiated during 1983, utilizing a sample size adequate for statistical analysis. Decomposition rates will permit assessment of the functional operation of the decomposer community.

Our initial results indicate, as anticipated, that there is large within-site-variation for the parameters we have chosen. The concentration of cations found in black spruce needles compares favorably to that in other studies. Variation in weight loss by standardized cellulose sheets indicates that a short sampling interval, such as a month, is inappropriate for this work element. The studies of water-use efficiency are in the developmental phase and will be implemented early in the 1984 field season.

The results from this pilot study have provided us with information needed to evaluate and modify the study plan and to reduce within site variation. If the variables that we are studying change, those changes may eventually cause effects evident at the ecosystem level.

INTRODUCTION

Wetlands are familiar features of the region surrounding the Wisconsin ELF Test Facility. However, wetlands have not been previously considered in ELF related research. This year (1983) we have initiated preliminary studies that examine the possible effects of ELF fields or selected biological processes within wetland plant communities.

ELF fields may perturb the transport processes in biological membranes of microorganisms and plants (U. S. Navy 1977). For instance, the transfer of water and mineral nutrients from the soil medium into the plant takes place through the membranes of root cells. Any perturbation of the transport mechanisms may lead to altered water and/or ion balances within the plants. Such effects may be expected to occur in the vicinity of an ELF antenna. As electromagnetic fields are efficiently transported through water and soil, the greatest effect might be expected in wet soil at the membrane level (NRC 1977).

The ultimate goal of our research is to examine the possible effects of ELF fields on important attributes of wetland community structure and function. Our preliminary studies involve measurements of: foliar nutrient content (related to transport across root membranes), and substrate decomposition (as an integrator of microbial activity). Perturbations of these functions have important consequences for individual organisms and ecosystem level processes.

The major objectives of the 1983 field season were to:

1. Screen and choose appropriate wetlands,
2. Obtain and test field equipment needed for sampling,

3. Describe the wetlands and select plots within each wetland,
4. Field test the sampling protocol,
5. Initiate field sampling, and
6. Carry out laboratory and data analyses on samples collected.

This work was intended to provide a framework on which to develop future studies. The first year of data was also designed to provide the basis for future sampling efforts. A detailed work plan is to be found in Appendix A.

Research Plan

The study will employ analysis of variance (ANOVA) techniques to identify any significant effects of ELF electromagnetic fields on measures of water stress, foliar nutrient content, and decomposition. ANOVA is a technique by which the variance between treatments can be compared to variance within each treatment and the significance of differences can be tested rigorously. Replicating the treatments can be used to separate and explain random variation resulting from site differences because the sites cannot be exact duplicates. It also permits examination of differences in species' response. Because the pattern of energy attenuation from the ground terminal differs from that of the antenna, independent analyses are anticipated for the two sources. Measurement will be made at several sites along gradients of field strength. 'True' pre-operational controls are not possible as the system is already functioning. One set of treatment sites will be chosen in which only background levels of electromagnetic fields are present. These will be referred to as "control" sites. Treatment sites will be selected along gradients of field strength away from either the ground or antenna. Within each site permanent plots will be established. The basic sampling scheme is outlined in Appendix A.

Analysis of variance and covariance will be used to determine the significance of the variance found among treatments for the response parameters. The hypothesis to be tested will be: the variance of the mean of the dependent variable observed between treatments is not significantly larger than that observed within each treatment group. Analysis of covariance will be used to account for differences between treatments (sites) that are independent of the experimental design, such as ambient factors and site characteristics,

such as pH, conductivity, or tree dbh. (See Appendix A for a complete description of statistical techniques and experimental design to be used).

SITE SELECTION

Introduction:

Wetland screening in 1983 was conducted to choose wetlands with similar vegetation communities and environmental characteristics along a gradient of field strength (see Appendix A). Because the test facility is already in operation, true control sites are not possible. However, we anticipate that effects, when observed, will be evident at different levels along the gradient of field strength, i.e., in wetlands at different distances away from the antenna and ground cable.

Site selection was considered the most important work element this year. Considerable time was required in the process of identifying similar wetlands with common species for analysis of diffusion resistance, leaf nutrient content, and decomposition. The choice of study sites was made only after extensive reconnaissance and analysis of vegetation patterns and composition.

Wetland Screening

Wetlands in the ELF test facility area were initially identified from black and white infra-red (1982) and black and white panchromatic (1979) aerial photographs of the Chequamegon National Forest with a scale of 1" = 12,000'. Low level aerial photographs from GTE supplemented this data base. Potential wetlands were initially identified as flowing or perched in nature. If the wetlands were perched they were further characterized as open, short stature tree cover, or tall tree cover. This information was transferred to topographic maps of the area.

The area we examined covered over 100 sq. miles. More than 200 potential sites were identified in the region. An initial field check confirmed our

interpretation of the aerial photography. Subsequent aerial and field surveys were made to sort through this list of potential sites. Our initial site selection criteria included:

1. Commonness of the vegetation type in the ELF area,
2. Distribution of potential sites within the framework of our experimental design,
3. Similarity of environmental variables (such as pH, temperature, water quality, water table depth, and redox potential),
4. Similarity of the plant communities between sites,
5. Constraints of the ELF (76HZ) and electrical transmission line (60HZ) field strength criteria adopted by IITRI, and,
6. Accessability of the site.

Fifty wetlands were chosen and prioritized using the selection procedure. We visited 45 of these sites and evaluated them using the same selection procedure. Initial pH and conductivity readings were taken and the vegetation of each site was examined.

We assessed this initial data and decided to revisit 24 of the 45 sites. These sites were dominated by an overstory of black spruce, and had an understory of ericaceous shrubs and sedges. All had low pH, low conductivity, an organic substrate, and were presumably perched to some degree. At nineteen of these twenty-four sites additional water chemistry data and detailed vegetation surveys were obtained (see Vegetation Analysis section for details). A quantitative vegetation analysis program ORDIFLEX(see Vegetation Analysis section) was used to analyze the data from these nineteen sites. The results of this analysis are presented in Fig. 1.

This vegetation analysis confirmed our field impressions. Separation of the plots along the X-axis represents a shift in dominance in the understory from shrub to sedge moving left to right. Interpretation of the plot separation along the Y-axis is more complicated. It appears to represent a decrease in the importance of shrub species and in several cases the appearance of rare species. Separation along the Y-axis also appeared to be correlated with a moisture gradient. The sites at the upper end of the Y-axis were dry when compared to the rest of the sites. Following this analysis, fifteen sites were chosen. The sites we discarded least resembled the ones we retained and scored low in our site selection criteria.

These fifteen sites were evaluated by IITRI personnel. ELF and 60 Hz fields were measured in potential study plots, one per site, each 60 meters long and 4 meters wide, and parallel to the closest antenna arm. These plots were located in each site in an area with representative vegetation for that site. They were removed sufficiently from the margin or edge so the plot was not influenced by runoff from the adjacent uplands. Enk (1983) presents a summary and evaluation of this data. The sites meet the criteria for electro magnetic exposure established by IITRI at the onset of this study (Appendix F). Detailed measurements of the tree, shrub, and herb layers as well as water quality data were collected at each site (see Vegetational Description section). Eleven study sites were finally chosen for our preliminary summer 1983 studies (see Figure 2).

Environmental Parameters

All proposed research--foliar diffusion resistance, cation concentration, and decomposition rate--can be affected by the local environment. For example, the oxygen content of soil, soil-water temperature and pH, and measures of ion content, such as specific conductance and concentration of cations (Ca^{+2}, Mg^{+2}, K^{+1}), may greatly affect the conductive functions of plant roots, translocation of water and materials through plants, and transpiration. Likewise, microbial activity is affected by soil-water temperature, pH, ion content, and redox potential (Eh). Micro organisms that are active in wetland substrates are dependent upon oxygen content and the availability of electron acceptors for the oxidation of substrate. Redox potential is a reliable and general measure of the "reducing conditions" of substrate (Wetzel 1975). To determine the effect of microhabitat and separate this from the effects of different ELF field strengths, i.e., distance from the sources of ELF radiation, several environmental parameters were measured concurrently. By choosing sites with similar plant communities, we anticipate that environmental conditions will be similar (although not identical).

Correlation analysis, regressing decomposition rate, cation concentration, leaf diffusion against one or more of the environmental parameters taken concurrently, will indicate whether significant trends when observed are associated with proximity to the ELF source or with sample site environmental differences.

Four water quality parameters were measured routinely during the later stages of the site selection process and during routine sampling. Temperature, pH, and conductivity were measured in situ. Cations were measured in the laboratory.

A slotted shallow well (15" deep) closed at the bottom was inserted into a hole formed using a polyethylene corer. Each well was placed in the upper peat horizon. After the well filled with water, it was pumped dry and allowed to fill again. Temperature, pH, and conductivity probes were placed in the well and allowed to equilibrate. Measurements were taken in three wells in each plot, at both endpoints and the center. Water was collected in polyethylene bottles and stored on ice. Later the same day, these samples were filtered and acidified and then transported to the laboratory for cation analysis.

The conductivity data was standardized to 25^{o}C, and the conductivity contributed by hydrogen ions substracted in order to estimate the effect of varying acidity (Sjors 1950). However, this calculation gave several negative values (see Sjors 1962) and we decided to report conductivity values standardized to 25^{o}C. Acidity was measured with a combined reference electrode. The water collected was used to determine the concentration of Ca^{+2}, Mg^{+2}, and K^{+} with an atomic absorption spectrophotometer (see Appendix D for a summary of these results). The results and their significance are discussed in the vegetation analysis section.

Vegetation Analysis

Vegetation analysis was performed at several levels based on the degree of selectivity needed for identifying potential field sites. Initial qualitative assessment of wetlands in the area resulted in determination of general classes of wetland vegetation. Once the wetland type was chosen, finer degrees of discrimination were needed.

Relevés provide a reasonably quantitative assessment of vegetation within community types. We used the relevé method of Braun-Blanquet (see Mueller-Dombois and Ellenberg 1974 and Shimwell 1971 for a detailed explanation). The scaled cover-abundance procedure devised by Braun-Blanquet requires little time per stand, provides a quantitative estimate of species abundance and is a good compromise between species presence-absence data and very detailed measurements. To use this method, the investigator initially compiles a complete species list for the stand. A cover-abundance value is then estimated for each species using the following scale:

5 cover greater than 75%

4 cover between 50 and 75%

3 cover between 25 and 50%

2 cover between 5 and 25%

\+ few individuals with low cover

r solitary/rare species

The stands were ordinated using the relevé data. The ordination programs in ORDIFLEX provide a quantitative technique that expresses the similarity and affinity of samples based on species abundance data. Ordinations can also be

used to search for patterns in the data and interpret these patterns based on correlations with environmental gradients.

ORDIFLEX is a program CEP-25B in the Cornell Ecology Program Series developed by H. Gauch Jr. Complete documentation is available from: Department Ecology and Systematics, Cornell University, Ithaca, New York 14853. A more detailed vegetation analysis was performed after the number of potential sites were reduced to a manageable number. We collected data on three distinct strata: tree, shrub, and herb. These are the life-forms that we anticipate using for our physiological comparisons. Tree density, dbh, and basal area was assessed in 3 10 x 10 m. plots parallel to the long axis of each study plot and including a portion of the plot. Shrub and herbaceous plant cover was measured in eleven 1 x 1 meter quadrants within each study plot and oriented along the plots' long axis. After study, three of the 15 sites were omitted from further consideration because of access problems and extreme environmental characteristics. These sites were considered either too dry or too wet relative to the other sites.

Fig. 3 and Appendix B, C1, C2 and D3 include the data from 12 sites we considered using in our analysis in 1983. Site 9 was eliminated at the outset because of its extremely low tree density. All of the remaining sites are dominated by spruce (Appendix C2) and most of the spruce trees on the site are similar in size, between 0.5-3 inches dbh (Appendix C1). Although tree density differs among the sites, the sites appear similar enough to meet our criteria and purposes. The ordination results and Appendix B support this decision. The antennae sites (2, 7, 11, 20, 21, 22, 40 and 41) appear to be similar. (Fig. 3 and Appendix B). Site 19, chosen as a control site, differs somewhat from the antenna sites. (Fig. 3 and Appendix D3). The ground

terminal sites: 10T and $10T_2$ appear distinct from the main group of antenna sites (Fig. 2 and Appendix D3). This does not pose a problem because the ground sites represent a treatment different from the antenna sites. We decided to retain stand 19 in the experimental design because it resembled sites 10T and $10T_2$ and could serve as the ground control. However, this means that in 1984 we will need to find another control site to maintain a balanced design for the antenna sites.

In our original design we anticipated using 4 treatments for the ground terminal sites: high, medium, low and background. Analysis of ELF generated electro-magnetic fields suggested that ground fields were higher than initial IITRI estimates. The field strengths found meant that only 2 of these 4 conditions (high and medium) could be found within the ground wetland. Data from the northern ground field also indicated that we would not find a wetland at any of the other three grounds that would be large enough to include plots for our 4 treatments. We decided that one of the control sites from the antenna gradient would also serve as a control for the ground gradient. However, we will still lose one ground treatment level from our original design. Appendix D presents the location of our study sites, with vegetative and chemical characteristics of each site.

Late in the fall we discovered that most of the upland surrounding Site 19 (a control site) had been clear-cut. We believe that this logging represents a major perturbation and that Site 19 will have to be replaced. We plan to determine what, if any, other logging or similar disturbances are planned by the Forest Service near our study sites.

All the study sites have an organic relatively undecomposed peat substrate, low pH, low conductivity, and low cation water concentration. They

resemble bog or poor fen types described elsewhere in the mid-west (Glasser et. al. 1981, Schwintzer 1981). The bog waters have a low concentration of ions (i.e. conductivity), are low in calcium (1.0-3.3 mg l^{-}) and magnesium (0.2-0.9 mgl^{-1}), and exhibit low pH values (generally below 4.2). The chemical properties of the bog waters give rise to a unique vegetation community that is relatively consistent between sites.

Decomposition

The rate of breakdown of organic material is an index of microbial activity. In wetlands, decomposition and organic matter accumulation are important forcing functions. Because wetlands are often water-saturated, decomposition is usually incomplete, and organic material tends to accumulate. Decomposition in such habitats results from fungal and/or bacterial activity. Since decomposition in wetlands takes place in water saturated substrates and near the soil surface, the process may be susceptible to perturbation by ELF fields. Any change in the rate of decomposition may alter the rate of peat accumulation, the physical properties of the substrate (e.g. water movement resulting from changes in bulk density), species composition and the biogeochemical cycling of mineral nutrients. Such changes could, in time, alter the nature of the wetland. Although such changes typically take place over a period of years, we can measure decomposition over a short time as an index of longer trends. Any differences in decomposition rate demonstrated by our experimental design would be an indication of changes in the microbial community.

Pure cellulose has been used as a standard material (Lahde 1969, 1974, Ulehlova 1978, Hundt and Unger 1968, Golley 1960, and Ratliff 1976, 1980). Cellulose in sheet form is a well-defined medium representing the chief organic constituent of most plants and is an important component of the organic

matter of wetlands. It also provides a nearly constant surface: bulk ratio and uniform contact with the surrounding medium. As such, it is a uniform material, and decomposition can be compared between sites that differ in exposure to ELF fields while avoiding site and species differences, e.g. litter quality and nutrient composition, that could complicate results if natural materials were used.

We examined decomposition of standard cellulose during our first field season. One gram cellulose squares inserted in nylon mesh bags were placed in the wetland substrate. Over the course of the growing season, bags were selected at random and harvested. Weight loss was determined for each sample interval. Detailed procedures for weighing were as follows: Cellulose squares were cut from cellulose pulp sheets and weighed under constant conditions. One of every 30 to 40 squares was selected. After being weighed, all such squares from one sheet (roughly ten percent) were air dried (in a 70°C oven), placed in a dessicator, and reweighed. The mean dry weight correction factor was multiplied by the individual weights of each square from that sheet to arrive at an initial dry weight. After harvesting, nylon mesh bags collected from the field were gently washed with double distilled water to remove foreign particulates (peat fibers). They were then oven-dried to a constant weight in a 70°C oven, placed in a dessicator and weighed. The difference between the corrected initial weight and the final weight was designated as weight loss for the sample interval. These data were then converted to percentages.

Decomposition bags were placed in groups of five at intervals along the long axis of the permanent plots and within the plot. Each bag was inserted to a depth of 15-20 cm by slicing narrow slots in the peat substrate, with

minimum disturbance to the site. All samples were placed in hollows to minimize environmental variation. In 1983, two complete samples were collected. Samples were placed in August and collected after one and two months incubation. One hundred bags in 20 groups of five were collected at random, each sampling interval. Soil moisture content, as well as other environmental parameters were determined each time that sample bags were collected.

The results from samples left in the field for only one month show some variability among sample means (Table 1). Bog 21 samples appear to have gained weight. We examined the data for bog 21 and found that of the 100 samples, 23 gained weight. The magnitude of the weight gain may result from errors in weighing or in sample processing. When these 23 values are eliminated, the resulting mean is comparable to data from the other sites.

This data set shows a high C.V. (coefficient of variation). Values range from 49-126%. The C.V. for bog 21 is greatly reduced when samples showing gains rather than losses are eliminated. In general, the C.V. is reduced for all sites when similar samples (with weight gain) are removed. However, the C.V. is still high at between 50 and 80%. The large variability within sites means that any statistical test will require a large sample (N probably greater than 150). We will attempt to explain this variability before deciding on an appropriate sample size to use.

Fox and Van Cleve also used cellulose strips to study decomposition in black spruce ecosystems and obtained C.V.'s ranging from 42 to 70%; however, their sample size was small (n=10). Their results were based on samples left in place for an entire year. We suspect that our sample variability will be significantly reduced when samples are left for longer periods. In October we placed an additional 200 samples per bog (Total = 2200 samples).

These will be left to over winter and the longer incubation period should provide a better estimate of the appropriate sampling interval. Additional blocking of samples (a statistical technique) within the individual bogs included in the experimental design may also help to increase our precision.

Stomatal Resistance

Change in the water budget of an individual plant will alter stomatal resistance, since the plant regulates stomatal opening to adjust transpiration to the requirements of a new water balance. Control over stomatal function also affects photosynthesis, respiratory gas exchange, and, to a certain extent, leaf temperature (Turner & Kramer 1980). Thus, measurements of stomatal resistance can provide an indication of the overall physiological status of a plant.

Methods

We expect to determine if ELF fields alter the stomatal resistance of characteristic species of northern wetland habitats. We have selected species characteristic of the herbaceous, (Smilacina trifolia or Carex oligosperma), shrub (Chamaedaphne calyculata), and tree layer (Picea mariana) in our sites (as described in the experimental design). Small (1972) measured the water relations of some typical northern wetland plants. He used techniques similar to those we propose and plant species that we may consider. Because stomatal resistance may vary over the course of a day (Chabot and Bunce 1978) it will be necessary to determine the appropriate time period during the day for our measurements. The use of LI-COR 1600 steady state porometer will permit collection of large amounts of data in a relatively short time. The LI-COR 1600 provides a determination of transpiration along with concurrent measurements of relative humidity, leaf temperature, and photosynthetically active radiation. Because sampling will be restricted to a several-hour portion of a day, these attributes of the instrument are particularly important.

The goals of our first year study were to work out problems associated with measurements of stomatal resistance and initiate a sampling scheme.

Progress

During the summer we met with individuals from the Botany Department of Duke University who are familiar with the LI-1600 porometer. Technical problems associated with use of the instrument to measure transpiration in Smilacina trifolia, Carex oligosperma, Chamaedophne calyculata and Picea mariana were discussed and several problems were noted that we must resolve before we can use the instrument with confidence.

A major problem is the conversion of transpiration output from a conifer to loss on an area basis. This is not so difficult for the broad leaf species, but conifer needles present a special problem. No one method is preferred to obtain needle surface area but Drew and Runneng (1975) suggest several possibilities.

Based on the advice of the Duke researchers we developed a sampling protocol for our test species. However, time, weather and plant senescence forced us to delay a test of the procedure. Tests are now planned for the early summer using species available to us in the Milwaukee area that resemble our test species. Preliminary data, including determination of sample size, variation over time, and variance among individuals will be assessed initially in bogs near Milwaukee before sampling is attempted in the ELF Test Facility Area.

Foliar Nutrient Analysis

Mineral nutrition is an important ecological consideration. Altered nutrient absorption may result in effects on plants ranging from deficiency to toxicity. Thus, variation in plant nutrient levels can be of great importance in plant competition.

The nutrient concentration of leaves may 1) be affected by ELF fields disturbing the transport of nutrients across root membranes or 2) reflect a related stress caused by ELF fields. Water stress can limit plant growth and result in changes in concentrations of foliar nutrients (van den Driessche 1974). Such changes in plant nutrient concentration may alter plant growth and influence competitive ability.

In our preliminary study we planned to measure the foliar nutrient concentration of representatives of the herb, shrub, and tree layer. These measurements will be an indication of the overall health of the species in a particular site and will indirectly test whether ELF fields alter nutrient uptake.

Methods

Tissue samples will be analyzed for three cations: calcium, magnesium, and potassium. Cations are assimilated by the plant through the formation of electrostatic or coordinate bonds. These bonds account for most of the potassium and some of the calcium and magnesium absorbed by plant cells. Calcium, magnesium and potassium are essential elements and perform important functions in plant growth. Foliar analysis is a recognized technique used to examine potential plant stress (van den Driessche 1974). The extraction

of minerals and subsequent measurement by atomic absorption spectrometry is a simple, reliable and repeatable procedure. Only a small amount of tissue (less than 0.5 grams) is needed for analysis of the three elements and its removal will not alter the sample plots in any major way so as to preclude subsequent sampling. Use of National Bureau of Standards standardized plant material will ensure quality control. NBS standards (pine and tomato) were included with each batch of samples as a control on our technique. Our analysis of Pine for K^+ and Ca^{++} and Mg^{++} for tomato leaves matches the certified values closely. Samples will be taken from individual plants using a protocol established to minimize variation. Only current year foliar tissue will be used and sampling will be from similar individuals and similar positions within individuals. Leather leaf and Smilicina have growth forms that are consistent. Leather leaf is a low shrub, and Smilicina a small herb. We need only be concerned with sampling healthy individuals. Black spruce is a more structurally complex plant. We sampled current year foliage from the lower one-third of trees which were 3-5 meters tall.

Progress

Two sets of samples were collected for each of the test species; one in August and the second in late September. We obtained 20 samples from four species in each of the 11 study sites generating 880 samples per sampling date. One tree, one shrub, and two herb species were used. We also collected information on the dbh (diameter breast height) and height of each individual tree to determine whether a correlation existed between those parameters and tree foliar nutrient content.

Techniques and procedures for use of the atomic absorption spectrophotometer were developed with samples prepared using a modified Kjeldahl digestion.

Our biggest difficulty has been the initial acid digestion of the plant material. This essential step is time consuming and is the bottle-neck in development of sample analysis. We are considering procedures to increase our efficiency.

All plant samples have been prepared for AA Analysis. However, only spruce needles, samples of leather leaf (Chamaedaphne calyculata), and exploratory samples of Smilacina trifolia have been analyzed completely.

The mean nutrient concentrations of new (current year) spruce needles from the eleven study sites (Table 2) resemble those determined in other studies of current year foliage nutrient concentrations in black spruce (Watt & Heinselman 1965, Roberge et. al. 1965, Wikum and Ondrus 1983).

When each element is considered separately the coefficient of variation among the different populations is similar (Appendix E). The coefficients of variation are high (15-20%) but comparable to nutrient analyses of other multiple populations (e.g. see Boyd 1978), and in fact are lower than most. The C.V. for Ca is higher than those for K or Mg; this may result from experimental error or from greater inherent variation within individuals. We checked the C.V.'s for our NBS standards and found slightly higher values for Ca than either K or Mg (5% vs. 1%). We are reviewing our techniques and will attempt to reduce the variation for this element. It may be appropriate to express our results on an ash free-dry weight basis to reduce variation from differences in ash weight. The coefficient of variation may also be reduced by modifying our sampling scheme. We designed our sampling protocol to minimize variation but are reevaluating it this winter.

The variation inherent in our samples is important when considering whether our sample size is adequate to detect a significant difference between means.

We initially estimated an N of 20 for our site samples. With the preliminary data presented here we are evaluating this estimate. Sokal and Rohlf (1981, p. 263) present a method for determining the sample size to establish existence of a difference between means and determine that the difference is significant at a level of X, (percent of the mean) and with a probability P that it will be found. Their formula follows:

$$N \geq 2 \left(\frac{\text{True std. deviation}}{X}\right) 2 \left(t_{\alpha v} + t_2 (1\text{-}P)_v\right.$$

where v = degrees of freedom of the sample standard deviation

$t_{\alpha v}$ and $t_2 (1\text{-}P)_v$ = values from a two tailed t-table with v degrees of freedom and corresponding to probabilities of X and 2 (1-P).

It is evident from this equation that if you wish to detect a small difference between means, a large sample number per site is essential. For instance, the sample size (N) required to be 80% certain of detecting a 5, 15 or 20% difference in means for the element K^+ at the 5% level, would be 146, 16 or 9 respectively. The equation is very sensitive to changes in the ratjo $\left(\frac{\text{True std. dev.}}{X}\right)$ but relatively insensitive to changes in X or P.

A difference of 15-20% for the % concentration of the mineral elements seems reasonably small. It would be difficult for us to suggest that differences smaller than the 15-20% range would be biologically significant. There have been few studies suggesting critical foliar nutrient concentrations for natural populations; however, Swan (1970) provides standards for the evaluation of foliar nutrient levels in black spruce.

Based on the variation present in our data, the biological significance of differences in nutrient concentration and using the Sohal and Rohlf formula, we feel reasonably confident that our sample size of 20 is appropriate.

Inspection of the preliminary cation data from spruce, leather leaf, and Smilacina support this. However, we also plan to investigate several other approaches in 1984. We will collect a large sample (N>100) of one species from one site that has shown a large amount of variation. As an alternative and perhaps more efficient approach we also intend to subdivide several permanent plots into blocks from which both foliar samples and environmental data (as described previously) may be collected. Analysis of covariance and regression techniques may indicate some environmental variation within our plots that may account for the variation in cation values. Several analyses of spruce cation concentration versus different environment variables gave us poor correlations (Appendix G). However, blocking and increasing the number of sampling points for the environmental data may provide better results.

The data (Table 2) do indicate some large differences between some sample means for various elements. In the light of these differences, we are examining the environmental data and other site attributes to determine, if possible, the basis for this variation.

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Technical Proposal Addendum for
FY 1984 and FY 1985.

The direction and emphasis of the overall study remains unchanged, as does the basic question, "In what ways, if any, do ELF-generated fields influence ecosystem function in wetlands?" To examine this question, we have chosen a wetland type, typical of the Clam Lake area, the open spruce-tamarack bog forest with a sphagnum-ericaceous shrub-sedge ground layer. We will continue to pursue those membrane-related processes, related to ecosystem function including: foliar cation concentration, decomposition, and leaf diffusive resistance. In our experimental design, we are using representative species of the major vegetation strata: a tree, a shrub, and an herb, as well as integrating the microbial community in the substrate. Although membrane effects should not differ in general nature, some plants may be more susceptible than others. As indicated in the technical proposal, we plan to expand these studies to include another group of plants, the sphagnum mosses, and another process, that of nitrogen fixation.

In 1983, the pilot study was initiated to test methods, select sites, and obtain preliminary data with which to evaluate our original study plan. What we have learned about variation within communities and about the processes being studied, permits us to make the productive alterations in the technical proposal discussed below.

a) We need to reexamine our cation analysis techniques and attempt to reduce the higher variation associated with Ca^{+2} compared to the other cations.

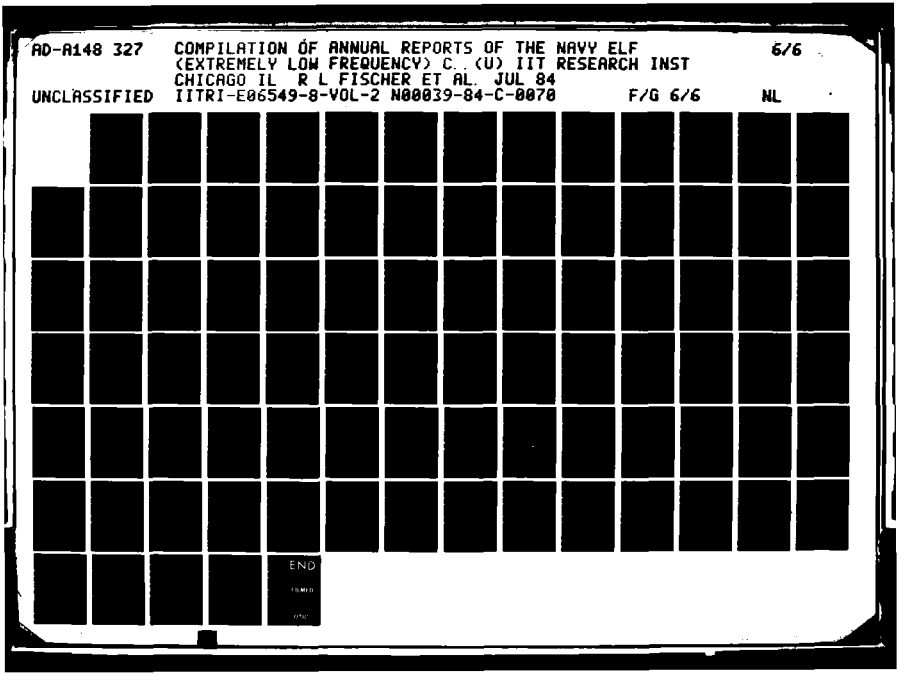
b) Initially, we had planned to collect decomposition samples after one to three months incubation in the bogs. Our preliminary results suggest that a longer incubation time is needed, hence, we may collect samples less frequently.

c) The large variation we encountered and the large number of samples that must be analyzed to provide statistically and biologically reasonable data, indicates the need to maintain emphasis on the studies of cation uptake, decomposition and leaf diffusion resistance.

The original 1983-1986 proposal was planned to build on work initiated in 1983. We will continue, as planned, those work elements, including studies of cellulose decomposition, cation analysis of foliar tissue, and diffusive resistance of bog species. A full set of field data for these parameters will be obtained in 1984 and 1985 as proposed.

d) We will begin exploratory work on nitrogen fixation in 1984. Our preliminary studies will develop and test techniques needed to determine the feasibility of this work element. As a result of time constraints, we have decided to delay field planting of nitrogen-fixing shrubs until 1985. That phase of the nitrogen fixation work will proceed, dependent on our success with plant material in the greenhouse and on the acquisition of preliminary data from field exploration.

e) If the techniques of clone development, re-establishment of N-fixing shrub clones, and in situ measurements prove successful--we will begin work with the shrub species to integrate other parameters, such as cation concentration, diffusive resistance and decomposition. However, data on the other species, mentioned earlier will provide critical information that should stand alone as potential evidence on the effects of ELF radiation. We do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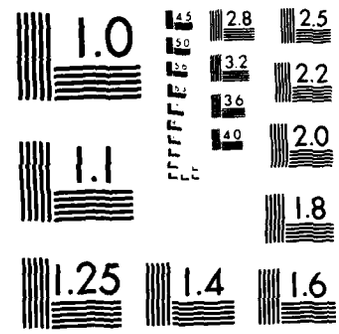

not plan to work solely with the N-fixing shrub, since we are not certain about the success of clone development techniques.

f) We also propose initiating the planned studies of decomposition of natural leaf material, cation analysis of mosses and, if warranted, possibly other studies of water stress in plants.

g) It will be necessary to replace one control site disturbed by logging in the adjacent upland. We intend to coordinate with the Chequamegon National Forest and GTE to avoid similar problems that would necessitate other site location changes.

h) Depth to the water table appears to be a critical environmental parameter affecting many of our measurements. We had planned to measure water table effects indirectly by measuring the redox potential of the soil. We have had poor results in our initial measures of redox potential but we have acquired new instrumentation and will continue our attempts. We also plan to install wells in our plots and develop a technique which will measure depth to the water table based on information provided by Dr. H. Hemond of the Massachusetts Institute of Technology.

i) We are becoming increasingly concerned about human disturbance in our plots. We have tried to minimize damage to the peat by restricting traffic in our sample plots. This summer we will reevaluate the disturbance and, if necessary, install boardwalks in the sites to reduce trampling.

Results from the 1984 field season will be evaluated and the work plan alterations that appear necessary, will be proposed to the project officer before the 1985 field season.

Peatland communities are composed of unique assemblages of plants adapted to specific sets of environmental parameters. Their development and patterns of vegetation appear strongly related to dynamics of water movement and water chemistry. However, developmental patterns also involve changes in vegetation. Vegetation, water chemistry, and hydrology of a site all interact to determine the type of peatland present.

It would appear that changes in nutrient cycling, water movement, or vegetation would also alter ecosystem function and structure. The assessment of changes in nutrient uptake, decomposition, nitrogen fixation, or diffusive resistance help to predict potential ecosystem level effects. Because peatland patterns change along a gradient from ombrotrophic to minerotrophic, alterations in the parameters we measure can be evaluated in this context.

Summary

Our 1984-1986 technical proposal continued work initiated in 1983 and included modifications in the studies of leaf diffusion resistance, decomposition, and foliar analysis. Further modifications are contingent on the assessment of parameter and site variability found in our pilot study.

An additional work element--studies in biological nitrogen fixation---was added in the 1984-1986 continuation proposal. However, the nitrogen fixation study has been modified. Several aspects of the nitrogen study will be delayed until 1985, dependent on the success of preliminary work.

Peatlands are strongly influenced by nutrient availability. Nutrient gradients are reflected in gradients of peatland type ranging from ombrotrophic (nutrient poor) to minerotrophic (nutrient rich). We can assess the parameters under study by relating them to these natural gradients of nutrient cycling. Changes in various parameters may initiate a sequence of events that would lead to other changes in water chemistry, water movement, and vegetation, which in turn will result in alteration of ecosystem properties.

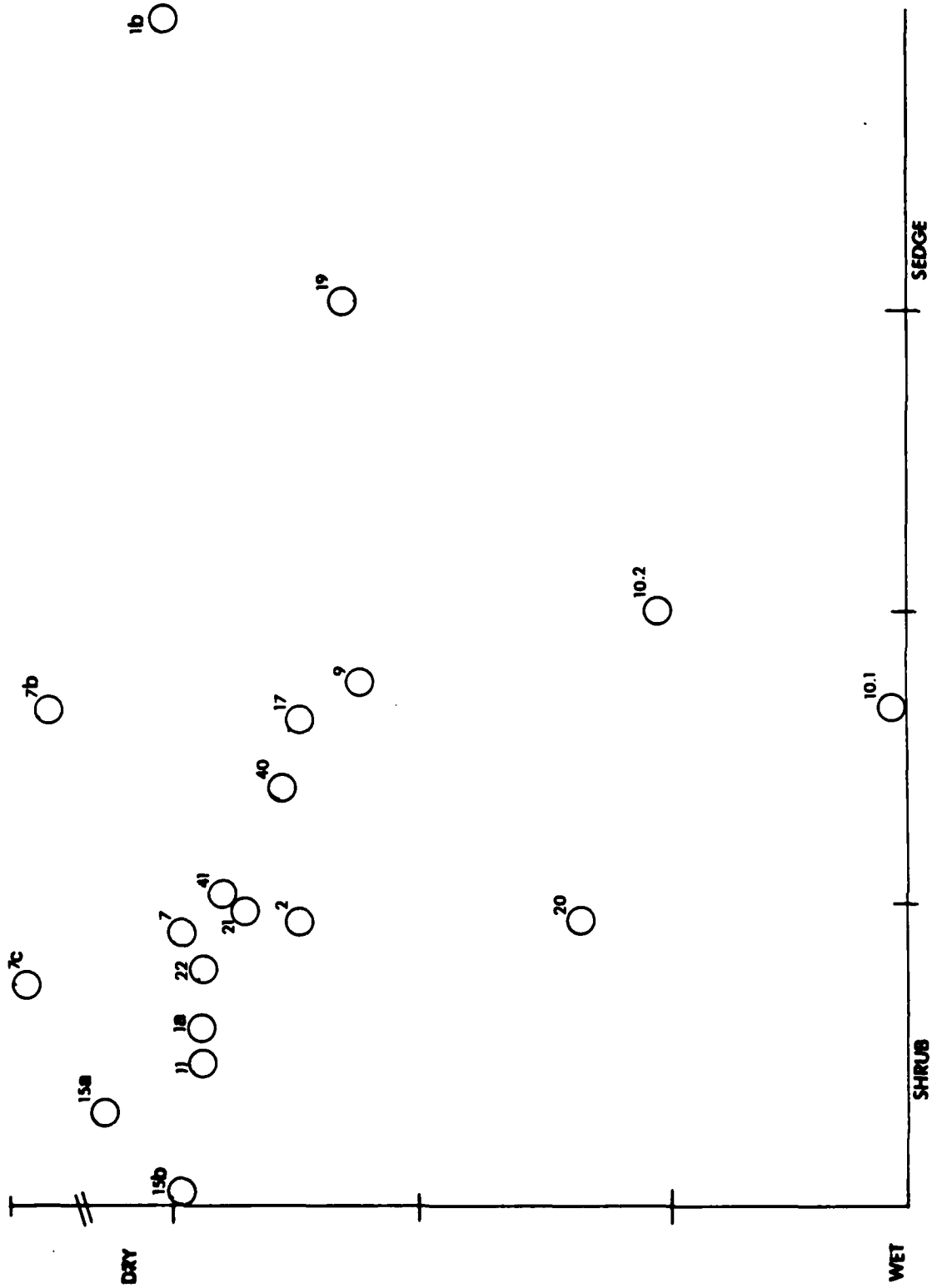

Fig. 1 Polar Ordination for Clam Lake Bogs

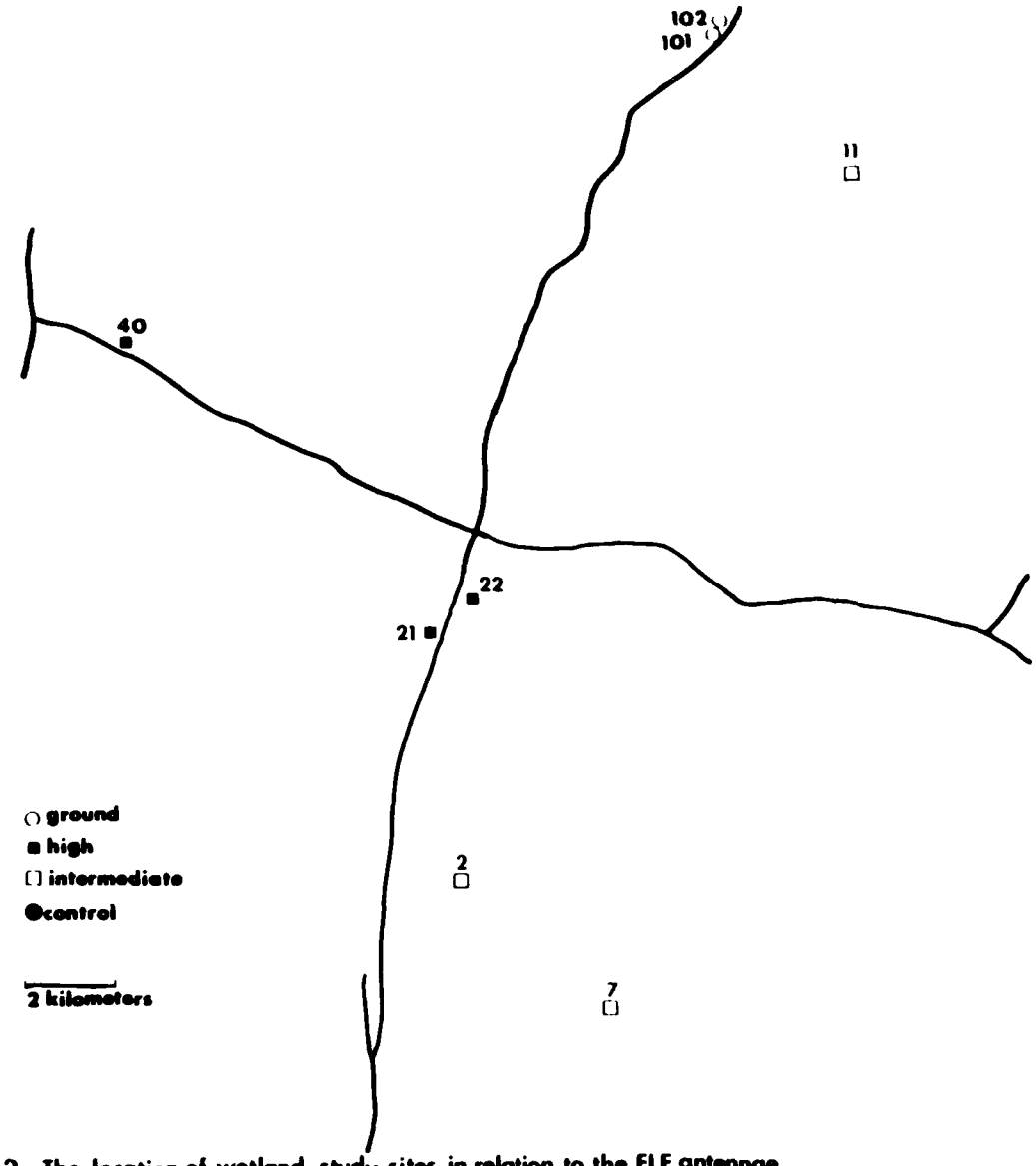

Fig 2 The location of wetland study sites in relation to the ELF antennae

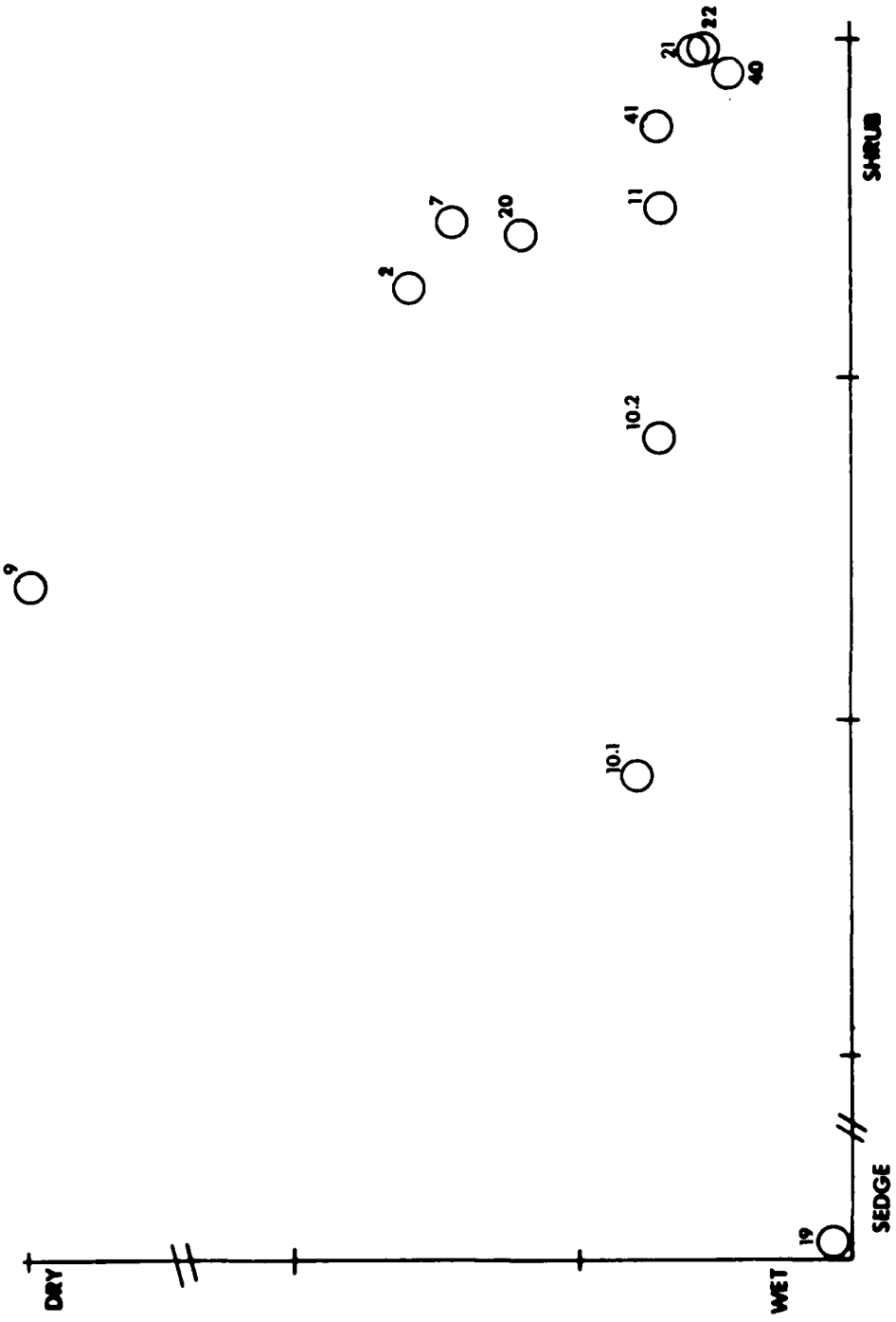

Fig 3 Reciprocal Averaging Ordination for Clam Lake Bogs

Table 1. Mean Proportion of Weight loss (± 1 standard error) for cellulose squares inserted in peat substrates in bogs of the Clam Lake area after 1 month incubation. Samples were placed in August and retrieved in September.

BOG ID	N	% Loss	C.V.[3]	
2	100	0.011 (.0013)	113.	
7	100	0.011 (.0010)	90.5	*
11	100	0.038 (.0019)	49.0	
19	100	0.038 (.0019)	49.0	
20	100	0.008 (.0004)	50.0	
21	100	(0.009)[2](.0036)	400	*
22	100	0.015 (.0018)	120	*
40	95	0.023 (.0012)	50	
41	95	0.023 (.0013)	54	
10.1	100	0.019 (.0018)	95	*
10.2	60+[1]	0.014 (.0024)	126	*

[1]Samples were lost from this bog.
[2]The mean change was a gain in weight.
[3]C.V. = (standard deviation/mean) (100)

*Indicates presence of samples which gained weight.

Table[2]. Mean (± 1 Standard Error) Nutrient Content (Percent dry weight) of Current Year Black Spruce Foliage for Bogs in the Clam Lake Area

BOG ID	N	K+	Ca+	Mg+
2	20	.46 (.013)	.45 (.026)	.11 (.004)
7	20	.55 (.021)	.38).021)	.10 (.003)
11	20	.38 (.013)	.45 (.029)	.10 (.003)
19	20	.56 (.018)	.31 (.033)	.09 (.004)
20	20	.51 (.019)	.36 (.014)	.10 (.003)
21	20	.61 (.015)	.38 (.020)	.20 (.007)
22	20	.59 (.030)	.42 (.021)	.19 (.007)
40	20	.53 (.017)	.41 (.025)	.10 (.004)
41	20	.67 (.017)	.39 (.024)	.09 (.003)
10.1	20	.51 (.017)	.42 (.022)	.10 (.004)
10.2	20	.53 (.025)	.37 (.018)	.10 (.003)

APPENDIX A.

Effects of ELF Fields on Selected Wetland Functions: A Pilot Project for ELF Communications Program Environmental Protection Plan

Technical Proposal

Part I

Scientific Approach

INTRODUCTION

Wetland types in the upper midwest are sensitive ecosystems. They also represent ecosystems not considered by previous ELF research despite their wide distribution in the Clam Lake area and the fact that ELF fields are transmitted most effectively through water (NRC 1977). These waterlogged habitats are sites where ELF effects are likely to occur.

The topography of the region around the Wisconsin Test Facility near Clam Lake is characterized by low rolling hills, small rivers and creeks , interspersed with small lakes. The Clam Lake area is a complex region of glacial end moraine, ground moraine and outwash deposits (Thwaites 1956, Hole 1976). Drainage is complex and relief over most of the region is low. The slow drainage and the unsorted nature of most of the covering glacial drift has resulted in extensive wetland formation.

Northern wetlands are characterized by the life form of the canopy and the dominant plant species. Most occur on uniform peat substrates. A variety of wetland types occur in the Clam Lake area. The main wetland types of northern Wisconsin and their characteristic species are listed in Table 1 and include: Northern conifer swamp, shrub wetlands, northern sedge meadow, open bog, and emergent marshes. These northern wetlands are relatively uniform in species composition (Stearns et al. 1982). Given the nature of the topography and the drainage pattern, we expect to find several communities of each of the wetland types mentioned

in Table 1.

Because of the prevalance of wetlands and lack of any detailed ELF research on this particular ecosystem type, we propose a pilot study of limited duration and extent. These initial studies are designed to look at attributes of community structure and function that may be affected by ELF radiation. Although ELF effects seem to operate at the cellular level, cellular phenomena can be manifested at the organismal and ecosystem level.

A variety of field and laboratory tests have attempted to demonstrate environmental effects resulting from electromagnetic radiation emanating from the ELF antennae and ground installations.In general, this work has been unable to show demonstrable effects.

However, since other studies have indicated that plant membranes may be affected by electromagnetic radiation, we propose to examine possible alteration of plant competitive ability through measurement of leaf diffusion resistance (a parameter readily measured and directly related to membrane transport of water) and foliar nutrient content (foliar nutrient content is likewise related to transport across root membranes). Since decomposition by microorganisms depends in large measure on secretion and adsorption through membranes, differences in decomposition rates may well be indicative of other equally or more subtle effects.

The work we propose in this pilot study will allow us to examine possible ELF effects statistically. At the same time our work will provide a framework on which to evaluate

the need for further wetland studies in Wisconsin or Michigan. The Clam Lake area provides a variety of wetland types in which suitable sites dominated by herbaceous, shrubby, and arboreal species can be found for this study.

METHODS

Parameters for consideration

Stomatal Resistance and Nutrient Content

ELF fields may perturb the transport processes in biological membranes of vascular plants (U.S. Navy 1977). Transfer of water and mineral nutrients from the soil medium into the plant takes place through the root cell membrane. Any perturbation of the transport mechanism might lead to altered water and/or ion uptake by the plant.ELF fields are transmitted most effectively through water and soil, and, in wetlands, the greatest effect is expected at the soil-root level (NRC 1977).

STOMATAL RESISTANCE

It follows that a change in the water budget of an individual plant would cause changes in stomatal resistance; the regulation of stomatal opening enables the plant to adjust transpiration to the requirements of the new water balance.

Control over stomatal function also affects photosynthesis,respiratory gas exchange, and to a certain extent leaf temperature.Thus measurements of stomatal resistance provides an indication of the overall status of a plant.

Wetlands are characterized by the presence of abundant water and waterlogged soils. Wetland plants have adapted to life in these saturated conditions. The presence of abundant water eliminates it as a limiting factor in photosynthesis. As a consequence, many emergent wetland plants have high water use rates. Any factor that inhibits water movement through a plant may be expected to create a stress. The consequences of such a stress might be the death of the plant or the lowering of its° competitive ability that, in turn, might result in replacement with a species more efficient in water use and better able to tolerate such stresses.

We propose to determine if ELF fields alter the stomatal resistance of characteristic species of northern wetland habitats. We would select species characteristic of the herbaceous, shrub, and tree layer in our sites (as described in the experimental design). Because stomatal resistance may vary over the course of a day (Chabot and Bunce 1978) measurements will be needed to determine the appropriate time period during the day for our measurements. Once this has been determined and the representative species chosen the measurements can be routinely done. The use of a LI-COR 1600 steady state porometer will allow for the collection of large amounts of data in a relatively short time period. The LI-COR 1600 also provides a readout of transpiration along with concurrent measurements of relative humidity, leaf temperature, and photosynthetically active radiation. If sampling is restricted to a several-

hour portion of a day, this attribute of the machine will be particuliarly important.

FOLIAR NUTRIENT ANALYSIS

The nutrient concentration of leaves maybe affected by 1) ELF fields perturbing the transport of nutrients across root membranes or 2) reflect a related stress caused by ELF radiation. Moisture stress can limit plant growth and result in changing concentrations of foliar nutrients (van den Driessche 1974). These changes in plant nutrient content can lead to altered growth and changes in competitive ability.

We propose to measure the foliar nutrient concentration of herbaceous, shrub, and tree new leaves. This will be an indication of the overall health of the species in a particuliar site and will test whether ELF fields alter nutrient uptake. Nutrition is an important ecological factor. The response of individual plant species to altered nutrient availability may range from deficiency to toxicity.Thus, variation in nutrient availability can be of great importance in plant competition.

We will analyze each tissue sample for three cations: calcium, magnesium, and potassium. Cations are assimilated by the plant through the formation of electrostatic or coordinate bonds. These bonds account for most of the potassium and some of the calcium and magnesium absorbed by plant cells. These cations are essential elements and perform important functions in plant growth. Foliar analysis is a recognized technique (van den Driessche 1974).

The extraction of minerals and subsequent measurement by atomic absorption spectrometry is a simple, reliable, and repeatable procedure. Only a small amount of tissue (less than 0.05 grams) is needed for analysis of the four elements and will not alter the sample plots in any major way so as to preclude their subsequent use. The use of National Bureau of Standards standardized plant material will ensure quality control. Also, the lab we will be working in is an EPA approved facility. Samples will be taken from individuals via a protocol established which will minimize variation. Only current year foliar tissue will be used and sampling will be from similar individuals and similar positions within individuals (where appropriate).

We have chosen a sample size based on our best estimates and past experience. An initial set of samples will be taken during our site selection trip which will show us what variability will be encountered and if necessary sample size will be altered.

DECOMPOSITION OF CELLULOSE

The breakdown of organic material is an index of microbial activity. In wetlands, decomposition and organic matter accumulation are important forcing functions. Because wetlands are often water saturated, decomposition is incomplete and organic material tends to accumulate.Most decomposition in such habitats results from microbial activity. Any change in the rate of decomposition may alter the rate of peat accumulation, the physical properties of the substrate (such as water movement due to changes in bulk

density), species composition, and the biogeochemical cycling of mineral nutrients. These changes might in time alter the nature of the wetland. Although such changes typically take place over a period of years, we can measure decomposition over a short period of time as an index of longer trends. Any differences in decomposition rate demonstrated by our experimental design would be an indication of changes in the microbial community.

We propose to examine the breakdown of a standardized organic material during the course of the growing season. Pure cellulose has often been used as a standard material (Lahde 1974, Ulehlova 1978, Hundt and Unger 1968, Golley 1960, and Fatliff 1980). Cellulose is a well- defined medium representing the chief organic constituent of most plants and is an important component of the organic matter of wetlands. It also provides a nearly constant surface:bulk ratio and uniform contact with the surrounding medium. As such it is a uniform material and decomposition can be compared between sites that differ in exposure to ELF radiation. Cellulose sheets will be placed in nylon mesh bags. Over the course of the growing season, bags will be selected at random and harvested.

Environmental Parameters

Leaf diffusion resistance, foliar nutrient concentration, and decomposition of cellulose are affected by the local environment. To determine the effect of microhabitat and separate this from the effects of distance

from the source of ELF radiation, several environmental parameters associated with sample sites will be measured concurrently with determination of diffusion resistance and decomposition rate. The moisture content of soil, soil-water temperature and pH, and measures of ion content, such as specific conductance and the concentrations of cations (Ca^{++}, Mg^{++}, K^{+}), may greatly affect the conductive functions of plant roots, translocation of water and materials through plants, and transpiration. Likewise, microbial activity is affected by soil-water temperature, pH, ion content, and redox potential (Eh). The types of organisms that are active in wetland substrates are dependent upon oxygen content and the availability of election acceptors for oxidation of substrates. Redox potential (Eh) is a reliable and general measure of the "reducing condition" of substrate (Wetzel 1975 and others).

By choosing similar plant communities, we anticipate that environmental conditions will be similar (although not identical). Correlation analysis, regressing decomposition rate or leaf diffusion resistance against one or more of the environmental parameters taken concurrently, will indicate whether significant trends seen are associated with proximity to the ELF source (electric and magnetic field strength) or with sample site environmental differences.

SITE SELECTION

The study will employ analysis of variance techniques to identify any significant effects of ELF on measures of "

ecosystem health": diffusion resistance of plant leaves, foliar nutrient analysis, and decomposition of cellulose. ANCVA is a simple statistical technique by which the variance between treatments can be compared to variance within each treatment and the significance of differences can be tested rigorously.

As the attenuation pattern of energy from the groundwire differs from that of the antenna, independent investigations are proposed for the two sources. Measurements will be made along gradients of field strength to better analyze any effect of intensity. Understanding that true controls in this study are not possible, as the system is already functioning, "treatment" sites will be chosen far enough away from the ground sites and the antenna so that only background levels are present. These will be referred to as "control" sites for purposes of the study.

Measures of plant species abundance will be used a) in choosing appropriate wetlands as study sites and b) as a first measure to examine differences (if any) between study areas. The plant species associations of wetlands may be used as indicators of general chemical and physical conditions. Wetlands with similar vegetation associations may be expected to posses similarities in other attributes, such as hydrologic regime and nature of the substrate. Although it is unlikely that any wetlands will be found to possess identical plant assemblages, we anticipate that wetlands in the Clam Lake area will differ only slightly.

The releve method of Braun-Blanquet (Mueller-Dombois and Ellenberg 1974) is a relatively rapid method of obtaining a measure of species cover and abundance. "Cover" is a useful measure of a species' role at a site as it is a descriptor of "space occupied". Lists of species and their relative abundances will result from this analysis; this information will be used to measure the similarity between the sites. Contingency tables and indices of similarity, such as Sorensens Index, will be used with releve data to point to differences between sites. This information will indicate common species for other analyses and indicate whether more rigorous measures of diversity and abundance may be warranted in future studies. Environmental parameters (pH,Eh,etc.) will also be measured at this time to insure site similarity.

It is anticipated that considerable time will be spent in identifying similar wetlands and common species for the analysis of diffusion resistance, leaf nutrient analysis, and decomposition. Measurements of electric field strength in likely areas of study will be made by JJT;this will enable us to identify sites of relatively high, medium, low, and background radiation. The choice of study sites will be made following extensive reconnaissance and vegetation pattern analysis.

BASIC RESEARCH PLAN

"Treatment" and "control" sites will be chosen along a

gradient of field strength away from the source (ground area or antenna area). Within each site, permanent plots to sample herbaceous vegetation and marked individuals of shrubs and trees will be identified. The following measurements will be made in each plot: diffusion porometer measurements, collection of leaf tissue for nutrient analysis, and placement and sequential removal of decomposition units. The following environmental measurements will be made: soil temperature,pH,Eh, a water sample taken for specific conductance and later analysis for cations, and a soil sample for moisture content.

Table 2 outlines the number of plots, individuals and samples expected for the ground area and antenna area investigations.

Four sample periods will be chosen during the growing season for all measurements. Plots of a dominant herbaceous species in a wetland with the ground wire will be sampled four times; for wetlands around the antenna, diffusion resistance measurements and sample collection for nutrient analysis will be made on each life form (herb,shrub,tree). Decomposition samples will be collected four times.Environmental samples will be taken during each of the sample periods.

One-way analysis of variance (Sokal and Rohlf 1969, Johnston 1978) will be used to determine the significance of the variance of means observed between treatments. The hypothesis to be tested will be: the variance of the mean of the dependent variable observed between treatments is not

significantly larger than that observed within each treatment group. The nominal independent variable for each ANCVA will be treatment type (high, medium, low, "control"). Separate analyses will compare this to each dependent variable: a) diffusion resistance b) decomposition rate and c) nutrient analysis. Separate analyses will be performed for the data obtained on the ground area and antenna region and for each life form on each sample date. The effect of plot (wetland site) will be determined in two ways: 1) using two-way ANCVA (independent variable: a) treatment, b) plot; dependent variables: a) diffusion resistance, b) decomposition c) nutrient content) and 2) using regression analysis to detect correlation between either dependent variable and any of the environmental parameters (temperature, pH, Eh, soil moisture, specific conductance, concentration of cations). The sample size (Table 2) should be large enough to provide conclusive results even if effects are subtle. Analysis of variance and regression routines are available in SPSS and MINITAB available through the UNIVAC 1100 at the University of Wisconsin-Milwaukee.

Table 1. Northern Wetland Types and Typical Vegetation (Stearns et al. 1982)

Northern Conifer Swamp		
Canopy	Black spruce	Picea mariana
	Tamarack	Larix laricina
	Balsam fir	Abies balsamea
	White cedar	Thuja occidentalis
Understory	Labrador tea	Ledum groenlandicum
	Bog rosemary	Andromeda glaucophylla
	Leatherleaf	Chamaedaphne calyculata
	Blueberry	Vaccinium myrtilloides
Ground layer	Sedges	Carex spp.
	Cotton grass	Eriophorum spp.
	Cranberry	Vaccinium macrocarpon
	Mosses	Sphagnum spp., Polytrichium spp.
Shrub Wetland	Tag alder	Alnus rugosa
	Sweet gale	Myrica gale
	Meadow sweet	Spiraea spp.
	Bluejoint grass	Calamagrostis canadensis
Emergent Marsh	Cattail	Typha spp.
	Bulrush	Scirpus spp.
	Rush	Juncus spp., Eleocharis spp.
	Arrowhead	Sagittaria spp.
	Burreed	Sparganium eurycarpum
	Wild Rice	Zizania aquatica
Northern Sedge Meadow		
	Sedges	Carex stricta, C. aquatilis, C. lacustris, and others
	Bulrush	Scirpus spp.
	Willow	Salix spp.
Open Bog		
Shrub layer	Leatherleaf	Chamaedaphne calyculata
	Bog rosemary	Andromeda glaucophylla
	Bog laurel	Kalmia polifolia
	Labrador tea	Ledum groenlandicum
	Blueberry	Vaccinium angustifolium
Ground layer	Sedges	Carex spp., Dulichium spp.
	Cotton grass	Eriophorum spp.
	Beaked rush	Rhynchospora spp.
	Mosses	Sphagnum spp.

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Appendix B. The mean percent cover for 12 bogs in the Chequamegon National Forest. (Based on 11 1 meter x 1 meter quadrats per bog.)

Species \ Bog number	2	7	9	11	19	20	21	22	40	41	10.1	10.2
Chamaedaphne calyculata	12.05	10.91	17.95	25.0	11.14	4.55	4.44	4.55	2.73	11.14	14.09	9.32
Ledum groenlandicum	13.41	34.55	5.00	11.82	0	6.82	28.06	18.18	49.09	38.18	6.14	12.27
Andromeda glaucophylla	9	9	0.68	0.23	1.82	1.59	0	0	0.45	0.91	2.95	3.86
Kalmia polifolia	2.50	1.59	3.18	5.23	6.59	8.64	1.39	2.27	2.73	2.27	2.73	2.27
Picea mariana	12.73	5.68	3.86	35.68	2.27	7.73	4.72	9.55	8.64	10.00	0	9.32
Smilacina trifolia	11.82	7.50	0	15.45	0	21.82	16.94	8.18	16.59	12.27	7.73	8.54
Carex paupercula	0.45	0.23	0	0	0	1.14	1.39	9.55	0	0	0	0
Carex pauciflora	0.23	0	0	0	0	2.27	0	0	0	0.45	0	0
Carex trisperma	3.41	1.14	0	0.91	0.91	0	3.33	5.45	0	2.95	0	0
Eriophorum virginicum	1.82	0.68	1.36	1.36	0	1.36	0.56	1.14	1.82	2.50	1.59	1.36
Vaccinium angustifolium	0	0	0.68	1.14	0	0	1.39	0.23	2.95	0	0	0
Vaccinium myrtilloides	0.45	1.14	0.45	2.05	0	0.45	1.11	0	0	2.27	1.82	0
Vaccinium oxycoccus	0.91	2.05	3.18	2.05	2.05	2.95	1.67	1.82	3.86	2.50	2.27	2.50
Larix laricina	0.23	0	2.27	0	1.82	0.45	0	0.23	0	0.23	3.41	0
Carex oligosperma	2.05	3.41	0.23	0	35.45	0	0	0	1.59	0.91	9.09	5.68
Eriophorum spissum	5.00	0.91	16.59	0.45	2.73	1.82	0	0	0.23	0	0	0

Appendix B (cont'd.)

Species \ Bog number	2	7	9	11	19	20	21	22	40	41	10.1	10.2
Eriophorum angustifolium	0	0	0	0.91	0	0	0	0	1.82	2.29	0	0
Betula pumila var glandulifera	0	0	0	0	0	0	0	0	0	0	2.27	0
Scheuchzeria palustris	0	0	0	0	0	0	0	0	0	0	1.14	0.23
Iris versicolor	0	0	0	0	0	0	0	0	0	0	0.23	0
Carex stricta	0	0	0	0	0	0.23	0	0	0	0	1.82	0.23
Gaultheria hispidula	0	0	0	0	0	0	0.11	0	1.14	0	0	0
Drosera rotundifolia	0	0	0	0	0	0	0	0	0	0	0	0
Betula lutea	0	0	0	0	0	0	0	0	0	0.23	0	0

Appendix C1. Spruce tree DBH size distribution (inches) for bogs of the Clam Lake Area. An individual was tallied as a tree if it were taller than 1.37 meters.

SIZE CLASS	.1-.4	.5-.9	1-1.4	1.5-1.9	2.0-2.4	2.5-2.9	3-3.4	3.5-3.9	4-4.4	4.5-4.9	5-5.4	5.5-5.9
BOG ID												
2	0	10	18	11	9	11	2	1	0	0	0	0
7	0	17	25	11	10	11	9	2	1	3	1	0
10.1	0	10	17	4	3	3	3	1	0	0	0	0
10.2	0	19	20	11	9	5	1	0	0	0	0	0
11	0	11	18	7	11	1	2	0	0	0	0	0
19	0	10	11	7	9	5	4	1	3	0	0	1
20	0	24	25	7	10	3	2	0	0	0	0	0
21	0	24	35	45	43	26	10	5	0	0	0	0
22	0	3	22	7	17	5	8	2	2	0	0	0
40	1	9	5	4	3	4	6	8	13	3	1	0
41	6	21	17	17	24	19	12	0	2	0	1	0

Appendix C2. Tree density (#/ha) for Spruce (*Picea mariana*) and Tamarack (*Larix laricina*) mean values based on 3 10 x 10 m plots in bogs of the Clam Lake area.

BOG ID	TOTAL	SPRUCE	TAMARACK
2	719	689	33
7	1108	999	109
11	576	556	23
19	1308	566	742
20	1022	775	243
21	2121	2087	33
22	932	789	143
40	842	632	209
41	1355	1322	33
10.1	909	456	456
10.2	1065	709	356

Appendix D1. Water quality data (pH temperature, conductivity and cation concentration) for bogs in the Clam Lake Area

	pH	T (^{o}C)	K_{25}* Scm^{-1}	K+ mgl^{-1}	Ca++ mgl^{-1}	Mg++ mgl^{-1}
2	4.04	18	35.2	1.29	2.23	0.56
7	3.83	16.2	46.2	1.52	2.08	0.39
11	3.88	16.9	40.4	1.46	1.53	0.33
19	3.84	17.7	42.2	1.28	1.62	0.35
20	3.98	15.4	36.2	1.25	1.44	0.35
21	4.10	17.2	34.1	0.98	1.80	0.67
22	4.13	17.0	34.6	0.71	2.77	0.94
40	3.98	15.9	38.9	1.91	1.96	0.62
41	3.84	16.4	38.8	0.81	1.01	0.25
10T1	4.22	17.4	38	1.78	3.32	1.07
10T2	4.01	17.7	40.3	2.03	2.60	0.85

*K_{25} = conductivity (S cm^{-1}) corrected to a standard temperature of $25^{o}C$.

Appendix D2. Site Locations and Description

Site Name	Type	County	Location
2	Intermediate	Ashland	T41N R4W, SW1/4 Sec 19
7	Intermediate	Ashland	T41n R4W, SW1/4 Sec 33
11	Intermediate	Ashland	T43N R4W, SE1/4 Sec 36
19	Control	Sawyer	T40N R3W, NW1/4 Sec 15
20	Control	Sawyer	T40N R3W, NE1/4 Sec 10
21	Antennae	Sawyer	T41N R5W, SE1/4 Sec 01
22	Antennae	Ashland	T42N R4W, SW1/4 Sec 31
40	Antennae	Sawyer	T42N R5W, NW1/4 Sec 17
41	Control	Sawyer	T40N R3W, SE1/4 Sec 2
10T1	Ground	Ashland	T43N R4W, SE1/4 Sec 22
10T2	Ground	Ashland	T43N R4W, SE1/4 Sec 22

Appendix D3. Sorensen's* index of similarity calculated for each pairwise comparison between bog study sites. Data used are mean species cover in eleven 1 x 1 m quadrants within each 60 x 4 m study plot.

	BOG ID										
	2	7	11	19	20	21	22	40	41	10.1	10.2
2	--	--	--	--	--	--	--	--	--	--	--
7	92	--	--	--	--	--	--	--	--	--	--
11	74	80	--	--	--	--	--	--	--	--	--
19	69	67	64	--	--	--	--	--	--	--	--
20	88	80	77	64	--	--	--	--	--	--	--
21	77	83	80	48	64	--	--	--	--	--	--
22	80	78	75	50	75	87	--	--	--	--	--
40	67	72	85	64	69	72	67	--	--	--	--
41	86	74	79	67	79	67	69	71	--	--	--
10.1	64	62	59	62	74	54	56	59	69	--	--
10.2	64	70	67	60	75	61	64	75	69	80	--

*Sorensen's index is calculated from the formula $\frac{2C}{B_a+B_b}$

where B_a and B_b are species totals for each bog and C is the number of species common to the two bogs.

Appendix E. The variability* within samples for mean nutrient concentration (percent dry weight) of current year black spruce foliage for bogs in the Clam Lake area.

Bog ID	N	K^+	Ca^+	Mg^+
2	20	13.04	25.77	15.45
7	20	17.27	25.00	17.00
11	20	15.53	28.67	15.00
19	20	14.47	48.06	18.89
20	20	16.47	17.50	15.00
21	20	10.82	23.42	16.50
22	20	22.37	21.90	16.32
40	20	16.03	27.32	19.00
41	20	11.49	27.69	15.55
10.1	20	14.90	23.81	22.00
10.2	20	21.32	22.16	15.00

*Variability calculated as the coefficient of variation (C.V.) where

C.V. = (standard deviation/mean) (100)

APPENDIX F.

TABLE 2

ELECTROMAGNETIC FIELD INTENSITIES AND FLUX DENSITIES (1) **

SITE NO.	MEAS PT	TRANSVERSE ELECTRIC FIELD (IN THE AIR) INTENSITY (V/m)		LONGITUDINAL ELECTRIC FIELD (IN THE EARTH) INTENSITY (V/m)		MAGNETIC FLUX DENSITY (Gauss)	
		76 Hz	60 Hz	76 Hz	60 Hz	76 Hz	60 Hz
BA1	1	0.12	<0.001	0.082	0.000023	0.022	<0.000001
BA1	2	0.18	"	0.087	0.000020	0.024	0.000005
BA2	1	0.19	"	0.15	0.000081	0.0080	0.000002
BA2	2	0.15	"	0.093	0.000044	0.0076	<0.000001
BA2	3	0.12	"	0.049	0.000028	0.0081	0.000002
BA3	1	0.21	"	0.24	0.000065	0.0[illegible]2	0.000001
BA3	2	0.25	"	0.25	0.000072	0.021	"
BA3	3	0.29	"	0.26	0.000070	0.023	"
BG1	1	0.62	"	0.45	0.00036	0.0024	0.000002
BG1	2	0.51	"	0.51	0.00041	"	"
BG1	3	0.47	"	0.43	0.00035	0.0023	"
BG2	1	0.31	"	0.29	0.00030	0.00067	<0.000001
BG2	2	0.33	"	0.32	0.00035	0.00072	"
BG2	3	0.27	"	0.24	0.00028	0.00070	"
BC1	1	<0.001	"	0.0018	0.000036	0.000025	"
BC1	2	"	"	0.0020	0.000086	"	"
BC2	1	"	"	0.0012	0.000026	0.000024	"
BC2	2	"	"	0.0013	0.000034	0.000023	"
BC3	1	"	"	0.0027	0.000075	0.000025	"
BC3	2	"	"	"	0.000077	"	"
BC3	3	"	"	0.0029	0.000081	"	"
BM1	1	0.039	"	0.031	0.000091	0.00022	"
BM1	2	0.034	"	0.032	0.000094	"	"
BM1	3	0.024	"	0.028	0.000077	"	"
BM2	1	0.063	"	0.054	0.000064	0.00055	"
BM2	2	0.076	"	0.060	0.000071	0.00056	"
BM2	3	0.085	"	0.080	0.000094	"	"
BM3	1	0.030	"	0.023	0.000095	0.00012	"
BM3	2	0.033	"	0.032	0.00012	"	"
BM3	3	0.029	"	0.025	0.000086	0.00011	"
BM4	1	<0.001	"	0.010	0.000004	0.00016	"
BM4	2	0.006	"	0.0056	0.000001	0.00015	"
BM4	3	0.007	"	0.0041	0.000017	0.00018	"
BM5	1	<0.001	"	0.038	0.000063	0.00025	"
BM5	2	"	"	"	0.000065	0.00026	"
BM5	3	"	"	0.034	0.000054	"	"
BM6	1	"	"	0.065	0.000068	0.00088	"
BM6	2	"	"	0.070	0.000041	0.00093	"
BM6	3	"	"	0.052	0.000037	0.00088	"
BM7	1	A	A	0.040	0.000045	0.00018	"
BM7	2	"	"	0.027	0.000043	0.00019	"
BM7	3	"	"	0.029	0.000039	0.00020	"

1) Values shown are magnitudes determined as the square root of the sum of the squares of the orthogonal field components measured. Data for 76 Hz represent worst case values determined by summation of the magnitudes of the fields produced by the E-W and N-S antennas extrapolated to full operating current (300 Amps).

A) Data not taken

** from Enk (1983)

APPENDIX G. The relationship between August foliar cation concentration and August water quality parameters for bog sites in the Clam Lake area (correlation coefficients).

	WATER QUALITY			
	Conductivity	Potassium	Calcium	Magnesium
Leaf Cations				
Potassium	.003	.030	.070	.033
Magnesium	.015	.116	.049	.077
Calcium	.059	.538	.010	.016

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Subcontract Number: E06516-82-C-50015

ELF Communications System Ecological Monitoring Program: Field Studies of Effects of ELF on Migrating Birds

Annual Report, 1983

Principal Investigator: Ronald P. Larkin

Releasing Authority:
Head, Section of Wildlife Research
Illinois Natural History Survey

Table of Contents

GLOSSARY AND ACRONYMS

A/D Converter: Analog-to-Digital converter. Generates a number whose value corresponds to an analog voltage present on an input line.

A-scope: A fundamental radar display presenting the strength of radar echo vertically and the range horizontally, along the radar beam.

Air Speed: The rate at which a target travels with respect to the air.

Amplitude: In this report, radar echo amplitude is used virtually synonymously with intensity and reflectivity. It is the amount of energy reflected back to the radar from a given target and is a function of the size of the target, the orientation of the target if it is not spherical, and especially of the range of the target.

ASCII: American Standard Code for Information Exchange. A representation of alphanumeric characters as numbers.

Aspect: The direction a radar target is facing relative to the radar. Aspect is commonly measured by examining the amplitude of radar echo returned from a target as the target is rotated around through 360°.

Azimuth: Compass bearing measured from 0 to 360° relative to true north.

Beamwidth: The angle subtended by a radar beam. Specifically, the azimuthal beamwidth is the number of degrees over which the radiated radar energy is at least half that in the center of the beam, where the energy is maximal.

D/A Converter: Digital-to-Analog converter. An output device which generates a voltage corresponding to the value of a number.

Directory: A list of the FILES or RECORDS on a device, along with information as to their length and where they reside on the device.

Disk: A platterlike magnetic mass storage device. The platter, or sometimes the reading head, spins rapidly and the data are arranged in concentric strips around the platter. Any part of the data is accessible in a fraction of a second.

Echo: A wave signal reflected off a target and picked up by an appropriate receiving device.

Elevation: The vertical angle of the radar beam, with the horizon as 0° and the zenith as 90°.

ELF: Extremely Low Frequency.

File: A unit of data storage which is composed of many records or other subunits and which is represented in a directory by a name or other unique code.

Format: An arrangement of data by convention. Formatting data often includes inserting identifying information, scaling or changing radix, arranging into standard-size blocks, etc.

GPG: A 3-cm tracking radar unit operated by the Illinois State Natural History Survey for the purpose of studying flying animals. This unit, an AN/GPG-1, has been modified from a military radar designed to track aircraft in fire-control work.

Ground Clutter: Targets on or near the ground generating unwanted radar echoes. These include topographic features, trees, buildings, ocean waves, automobiles, and other moving or stationary targets.

Ground Speed: The rate at which a target travels with respect to the ground. The vector addition of wind speed and a target's air speed equals the ground speed.

Heading: Angle of travel with respect to the air. It is assumed that the heading is the direction an animal's body is pointed. The heading is one component of velocity relative to the air; air speed is the other component.

IF: Intermediate Frequency.

IITRI: Illinois Institute of Technology Research Institute.

K-value: Integer ranging from 0-9 which indicates the range of disturbance in the earth's ambient magnetic field within a specified time period (3 hours).

Line Printer: An output device which (usually) impacts one entire line of alphanumeric characters at a time on a moving sheet of paper.

Memory: Usually refers to ferrite CORE, SEMICONDUCTER, or sometimes DISK where data and programs are stored for ready access.

Migration Traffic Rate: Rate of migrants passing a point or over a line. Usually expressed in migrants per linear unit of front per unit time.

Minicomputer: A computer which is small in size and cost. It is bigger than a MICROCOMPUTER and substantially bigger than a MICROPROCESSOR, but smaller than a MAINFRAME.

Mist Net: A fine string, large mesh net, rectangular in shape and supported by poles, used to live trap birds for tagging, banding, etc.

Modem: MOdulator-DEModulator. A device used in communications to perform parallel-to-serial conversion and to send data along a phone line or similar channel.

Off-Line: Method of operation in which data are gathered at one time and place and fed into the computer at a later time and different place, usually at the computer's convenience.

On-Line: Method of operation in which the user and/or data-generating or display mechanism communicates directly and often interactively with the computer. On-line has nothing to do with the New York expression "standing on line".

Operating System: A set of compatible programs or routines, often written by the manufacturer of the computer, which governs the running of the computer and may perform such functions as communicating with peripheral devices, allocating portions of core or semiconductor memory to different programs, scheduling jobs, and maintaining organized files on mass storage devices.

Peripheral Equipment: Devices which connect with the CPU. Usually synonymous with I/O devices.

Pulse Length: The length of a brief pulse of radar energy, measured in time (microseconds) or in distance (meters).

Pulse Width: Same as pulse length.

Range: Straight-line distance from the radar to the target. By "range" is usually meant "slant range", not distance over the ground.

Real Time: Responses to a situation are in real time if they occur fast enough to influence the events to which they are responsive.

Shear: In the most common meteorological usage, shear refers to variation in wind velocity with altitude above the ground.

Shorebird: Charadriiform birds; they commonly frequent the seashore and other open habitats and are small-to moderate-sized birds with longish legs and narrow bills. They characteristically fly in densely-packed flocks and include plovers, sandpipers, and similar birds.

Target: Something that generates a radar echo.

Terminal: A peripheral device which is physically separated from its computer. It is a teletype, keyboard-and-display, card reader, or possibly a collection of data acquisition devices which may be connected directly to the computer or via phone lines. Terminals are often serial devices which transmit and receive ASCII code.

Track: (1) A record of an animal's path.
(2) The direction of travel relative to the ground.

UP: Upper Peninsula of Michigan.

VSU: Video Sampling Unit. Equivalent to a sweep-sampling circuit, it takes one sample of the radar IF after each radar pulse. The time delay (range) of the sample is programmable.

Waterfowl: Collective referring to ducks, geese, and swans (members of the order Anseriformes).

Wave Length: The distance between crests of the wave-like electromagnetic energy emitted by microwave radars. Radar wave lengths range from millimeters to a few tens of centimeters. Wave length is inversely proportional to frequency.

Winchester Disk: A non-removable mass storage device for computers.

Wingbeat Signature: The time series of echo amplitude fluctuations of an animal target being tracked by radar.

ABSTRACT

Progress on the project to study the effects of the ELF antenna system on migrating birds is reported for the 1983 period. The selected radar site, constrained by topography and power requirements, provides an excellent vantage for comparisons of avian migration before-and-after ELF installation and close to vs distant from the antenna. Data collected during 13 nights in fall, 1983 include 751 individual tracks (mostly birds), 38 counts of target density, and 26 records of wingbeat signatures. Possible reactions of birds to a nearby broadcasting tower were also noted. Few waterfowl were recorded during the census period (24 - 30 October). Radio tracking results were limited by low capture rates of birds in Wisconsin. Software utilities have been developed or modified specifically for the collection, handling, and analysis of data from the Upper Peninsula.

SUMMARY

Field studies of possible effects of ELF upon birds migrating near an ELF antenna system or living near it and then departing in the fall were conducted by the Illinois Natural History Survey, a division of the Department of Energy and Natural Resources. Part of the study, censusing waterfowl, was performed at nearby lakes in daytime. However, because the majority of birds migrate at night, it is necessary to use special techniques to monitor possible effects upon bird migration. Techniques employed were tracking and counting birds with the use of a portable radar unit and following individual birds tagged with miniature radio transmitters.

Field work was supported for a 5.5 month period during which time no construction on the Michigan ELF system had yet taken place. The waterfowl census, performed in Michigan in late October when waterfowl on the Great Lakes are still abundant, nevertheless encountered only small numbers of migrant ducks, geese, and swans. The proposed Michigan site is near but not directly within major waterfowl migration routes.

Monitoring with miniature radio transmitters was not successful, partly due to a paucity of birds in the Wisconsin area that could be captured in order to attach the miniature transmitters and partly due to administrative problems. This technique is important because it allows birds to be followed beyond the range at which radar can effectively operate and therefore permits one to distinguish long-term effects from those that may be only temporary.

Radar is recognized as a useful technique for recording the altitude, speed of flight, and numbers of passing migrants. Previous studies in Wisconsin have found varying degrees of effect of ELF radiation upon migrating birds. Monitoring with radar was carried out using a trailer-mounted tracking

radar sited about 500 m from a segment of the ELF antenna right-of-way. Over 700 radar tracks were recorded. Unusually warm weather during early fall, 1983, was associated with lower-than-expected numbers of passing migrants visible on the radar displays, rendering generalizations concerning the normal migration patterns in the Upper Peninsula premature. This first field season indicated that curving paths of migrating birds may be more common in the Upper Peninsula in fall than suspected and that insects as well as birds are commonly found flying above the ELF right-of-way.

SCIENTIFIC BACKGROUND

The NAS Committee (1977) reviewed the evidence for effects of Extremely Low Frequency radiation (ELF) effects on migrating birds and recommended "further research on the basic biology of bird navigation and orientation designed to verify recent highly suggestive experiments and to address the questions noted [in the review]". Several other reviews of this literature have appeared since (Keeton, 1979a, 1979b; Able, 1980; Moore, 1980; Walcott, 1982). The major conclusions of the NAS report are not significantly altered by developments since its publication in 1977. Magnetic sensitivity is well-established in birds which regularly migrate or make homing flights. Laboratory conditioning experiments are rarely successful in revealing this sensitivity, with the exception of Bookman's (1977, 1978) paradigm. Birds seem to use several orientation cues rather than relying on any single cue such as magnetism, although in some birds the magnetic "compass" appears to serve as the cue which is used to align nonmagnetic orientation systems (Wiltschko and Wiltschko, 1978 and papers cited therein). Magnetic cues have a small yet detectable influence on pigeon homing even under sunny skies, when visual mechanisms predominate (reviewed in Keeton, 1979b; Visalberghi and Alleva, 1979). Much remains to be learned about the interaction of different sensory channels in avian orientation. The remainder of this section will address issues on which new findings have emerged since the NAS report.

Low-level magnetic fields appear to affect normal avian orientation. Experiments and observations by Southern (1975), Larkin and Sutherland (1977) and Williams and Williams (1978) agreed that operation of the Wisconsin Test Facility sometimes affected the direction taken by birds, strongly suggesting that the birds therefore could sense the electromagnetic fields produced by the

transmitter. In a previous report, Keeton et al. (1974) had found that normally-occurring slight fluctuations in the earth's magnetic field (K-values) affect the departure bearings taken by homing pigeons. Therefore, it was suggested that birds could sense weak magnetic fields, on the order of one or a few percent of the earth's field, and that both AC and DC fields affected avian orientation. Although other reports found little or no effect of fluctuations in K-values on migratory direction (Able, 1974; Richardson, 1974, 1976) or speed (Larkin and Thompson, 1980), evidence for effects of low-level magnetic fields has continued to accumulate. Schreiber and Rossi (1978) reported that speed of homing was negatively correlated with solar activity (and therefore with magnetic disturbance). Moore (1977) found that free-flying passerine migrants responded to increased K-values, increasing the variability of flight directions. T. S. Larkin and Keeton (1976) found that magnets masked the effect of K-values on pigeon homing, supporting the direct effect of magnetic disturbance as opposed to an indirect effect via some other hidden variable.

Experiments by Walcott and colleagues (Walcott, 1978, 1980, 1982) demonstrate that naturally-occurring magnetic anomalies in the earth's crust affect the paths taken by homing pigeons; these experiments have been corroborated and the nature of the influence of anomalies investigated by investigations in Europe (Frei, 1982; Kiepenheuer, 1982). Thus, small temporal and spatial changes in the DC field of the earth appear to play a part in normal orientation of at least some birds; it is not known whether effects of AC fields at the Wisconsin site are mediated by the same physiological mechanisms responsible for DC sensitivity.

Structures with magnetic activity are present in birds, honeybees, and other animals; the structures are obviously candidates for "the magnetic

receptor". Cells containing small, seemingly well-organized magnetic structures have been reported in the abdomens of bees (Gould et al. 1978), in the heads and necks of pigeons (Walcott, et al., 1979; Presti and Pettigrew, 1980; Walcott and Walcott, 1982), in the heads of Pacific dolphins (Zoeger et al., 1981), and in the skulls of small rodents (Mather, 1982), and humans (Baker, 1982). The location of the magnetic material is variable or imprecisely determined; its function has not been demonstrated. Semm (1982) reports single-cell evoked responses to magnetic stimuli in pigeon pineal organ. No sensitivity levels nor behavioral thresholds have been demonstrated thus far in any tissue or animal. Nevertheless, the outlook is promising for discovering a physiological substrate for magnetic sensitivity (at least to DC fields).

The impact of ELF upon migrating birds is still an open question. A review article by Grissett (1980) minimizes the potential impact of ELF upon migrating birds, implying that the recommendations of the NAS Committee (1977, p. 242) regarding further work on this subject had been completely followed. The article relies on the final project report of the continuation of Williams and Williams' (1978) study using the low-power Ornithar radar. It overlooks the limitations of the Ornithar. The unit often cannot distinguish XY turns from altitude changes (Cohen and Williams, 1980). The majority of migrants cannot be detected by the unit because they pass above its maximum range of 1000 feet (300 m). Many or most of the responses to antenna state found by Larkin and Sutherland (1977) could not have been observed with the Ornithar. The Williams' (1978) simulation of migration based on a fixed-compass model with ELF perturbations lacks empirical support; we do not know the mechanism of goal-directed orientation of migrating birds over land.

GENERAL EXPERIMENTAL DESIGN

Field procedures and data analysis have been designed to assess several potential impacts of the ELF antenna system on migrating birds (Table 1). Altered density (numbers) of migrants passing over a functioning ELF antenna would automatically signal potentially serious impact, because of the implied interference with the success of the migratory journey. If effects are found, follow-up investigations would have to ascertain whether individual birds suffered negative effects, or whether effects would be temporary, the birds merely detouring around the system. Studies of pigeons near magnetic anomalies and wearing permanent magnets demonstrate the adaptability of the magnetic orientation system of birds (Keeton et al., 1974; Walcott, 1978, 1982). The techniques used in this investigation provide measures of density of migration.

Disorientation of birds in ELF fields, previously reported by Southern (1975) and by Larkin and Sutherland (1977), and the effects of growing up in an altered magnetic field (Wiltschko, et al., 1983; Bingman, 1983; Alerstam and Hoegstedt et al., 1983) might be temporary or long-term. In assessment of ELF impacts, discrimination between temporary and long-term alterations in course is essential. Short-range techniques such as the cellometer and low-power radars cannot make this discrimination. The tracking radar technique proposed in the present study allows a single bird to be followed for 3 km or more, with favorable siting. This range permits the investigator to discriminate temporary course changes from longer-lasting ones within the antenna array. The radio tracking technique allows recording of the direction of a bird out to a range of about 150 km; this technique will allow a bird to be released from within the Michigan antenna array and followed as it leaves the array toward

Table 1. Variables Important in the Radar Tracking Task.

Variables that might show effects of ELF (dependent variables)

- Target density
- Altitude distribution
- Straightness and levelness of tracks
- Orientation of tracks
- Speed of flight

Variables determining or influencing possible ELF effects

- Target identity (including size and wingbeat signature)
- Geographic location of tracks (including 2- and 3-dimensional distance from antenna)
- Before/after installation of antenna
- Wind speed and direction
- Time of night
- Ambient magnetic environment (including magnetic topography, K-values, and ELF radiation not due to Project ELF)

surrounding habitat. If the birds are reoriented or disoriented by the ELF fields, it will be possible to ascertain whether they resume a normal flight direction as they leave the fields. No other available method permits this kind of discrimination between temporary and chronic effects.

The tracking radar permits unambiguous determination of flight altitude independent of the path taken by the target over the ground. In tracking mode, the radar allows changes in altitude to be recorded; such changes were among effects found in the earlier ELF impact work. In VSU mode (Appendix 2), automatic distributions of birds' flight altitude are generated; distributions within and without the ELF fields can be compared statistically.

The VSU and radio tracking techniques allow the departure times of, respectively, the overall migrant population and individual birds to be measured within seconds or minutes. The VSU, when used at 15 degrees elevation, can detect birds as low as 50 m.

Originally, five techniques were to be used to investigate possible effects of ELF upon migrating birds. The original design evolved, partly at the suggestion of IITRI, partly because of experience in the first field season, into a structure consisting of four tasks:

(1) Radar Tracking
(2) Radio Tracking
(3) Waterfowl Survey
(4) Ambient Monitoring

CHRONOLOGY

Research originally scheduled over a 14-month period was conducted in 5 months because of funding delays (Appendix 1). One field season instead of two was spent on the radio tracking task (see below). Other tasks were completed. No measurement of AC or DC electromagnetic fields was made in 1983 at the study sites.

ACCOMPLISHMENTS IN STUDY TASKS

Radar Tracking

The NAS committee (1977, p. 53) recommended "a baseline study using radar tracking of bird navigational patterns among migrating species in the vicinity of the proposed installation, to be continued when the ELF (antenna) is in operation". The committee discounted the possibility that the radar technique itself influenced flying birds (p. 239). Direct effects of the ELF on the tracking radar were not observed in the earlier study (Larkin and Sutherland, 1977); because the birds' reactions occurred in Cartesian coordinates and the radar operates in polar coordinates, such direct effects on the radar were ruled out completely.

Initial radar site selection took place in late July 1983 in the Upper Peninsula of Michigan. However, information obtained at that time regarding land ownership was incorrect. The search for an alternate site and the installation of power delayed work approximately one week after arrival in mid-August.

Site selection was constrained by a suite of requirements: proximity to the ELF antenna right-of-way; vantage over the ELF right-of-way and over other land distant from the ELF right-of-way; accessibility by road; location on land unlikely to be disturbed during the study; freedom from nearby human activity such as a heavily-travelled road, town, and so on; and availability of power. A location in the Upper Peninsula was found that met these requirements, and the radar was sited there. Towers provide some obstruction, but other aspects of the site are nearly optimal.

The site is located in typical upland habitat used for commercial wood production. Rolling terrain with no prominent topographic features surrounds

the radar site and nearby antenna right-of-way. Vegetation is almost entirely monotypic stands of Jack Pine from 0 to 30 years of age in different land holdings. Aside from a 5 ha lake about 1 km away, only small streams flow through the land in the purview of the tracking radar.

Field data were collected from 26 August to 09 September 1983 (actually until 0730 on 10 September, Table 2). Weather during this period was atypical and, generally, unfavorable for large scale migrations. Winds toward the south, the most favorable for fall migration, occurred on only one night. Some nights with favorable wind also had continuous rain. Recorded densities of migrants ranged from 2-60 birds per minute passing through the lowest 1725 m of the atmosphere in the beam of the radar. Actual Migration Traffic Rates, computed from the VSU data, are being calculated based upon the observed target size distributions and other parameters.

Problems occurred with the azimuth data collection circuits and with the target selector. These two problems occurred following a storm which also left us without electrical power for the early part of one evening sess'on; we were gathering data a very short time after power was restored.

A total of 2 megabytes of data were collected. This included 26 records of wingbeat signatures, 38 counts of target densities totalling several thousand birds, and 751 individual tracks, the majority of which are birds.

Data analysis is ahead of schedule. Running of the first three programs of the data reduction process has been completed (Appendix 3). Other support software that has been developed or modified includes:

1. utility for transferring data files from the field computer to the lab computer;
2. translation of wingbeat frequencies from binary to ASCII formats;
3. display of wingbeat frequencies (Figs. 1 and 2);

Table 2. Overall summary of radar data collected in the Upper Peninsula in 1983.

Date 1983	Number of tracks			Wind direction toward	% cloud cover	Targets per minute
	Insects	Birds	Balloons			
26 Aug	26	7	1	N	30-80	--
27	12	47	2	airs	0-10	3-15
28	17	34	1	none or airs	0	2-5
29	25	26	1	airs	0-70	4-18
30	21	19	2	S	0	13-60
31	35	62	3	airs	0-10	3-6
1 Sept	4	4	0	N to NE	0	3
3	19	27	1	S	90-100	8
4	10	43	2	N or airs	85-100	16
5	6	9	0	N	100 (fog)	20-30
6	11	52	0	E	0	11-30
8	4	*	0	E	5-20	--
9	28	87	3	variable	0-100	3-14

4. plotting of radar ground clutter;

5. summary of target size and variability;

6. display of target standard deviations;

7. on-line program that collects ground clutter information and produces real-time plots for more efficient data gathering in the future;

8. off-line graphical track editing program.

Planned research in Wisconsin could not be conducted because of Navy commitments to use the WTF for Navy operations. Therefore, IITRI and the investigators decided to change plans and mount an effort in the field in Michigan instead of WTF. Protocols designed for WTF will not be used and replication of Larkin and Sutherland (1977) will not be feasible.

Based on initial field work, we can now revise the scientific protocols for the radar part of the bird migration study. We are located south of an east-west leg of the antenna system right-of-way. Because of the geographical situation, birds cannot approach the radar (except from about 100°) without flying over part of the surveyed ELF antenna right-of-way. Thus, our central location provides before-and-after comparison but does not allow tracking of birds at a great distance from the ELF antenna.

For the before-and-after comparison, we are gathering data on departure times (measuring the onset of nocturnal migration), on straightness and constancy of altitude of long bird tracks, and on the numbers of targets passing over the area per unit time. In support of these data, we are gathering data to assess the variability in number, altitude, and orientation of bird targets over the site.

If one assumes that increasing distance from a transmitting ELF acts to diminish its potential effects, then this relationship may be exploited to advantage. We now have a radar site that allows us to obtain tracks of birds

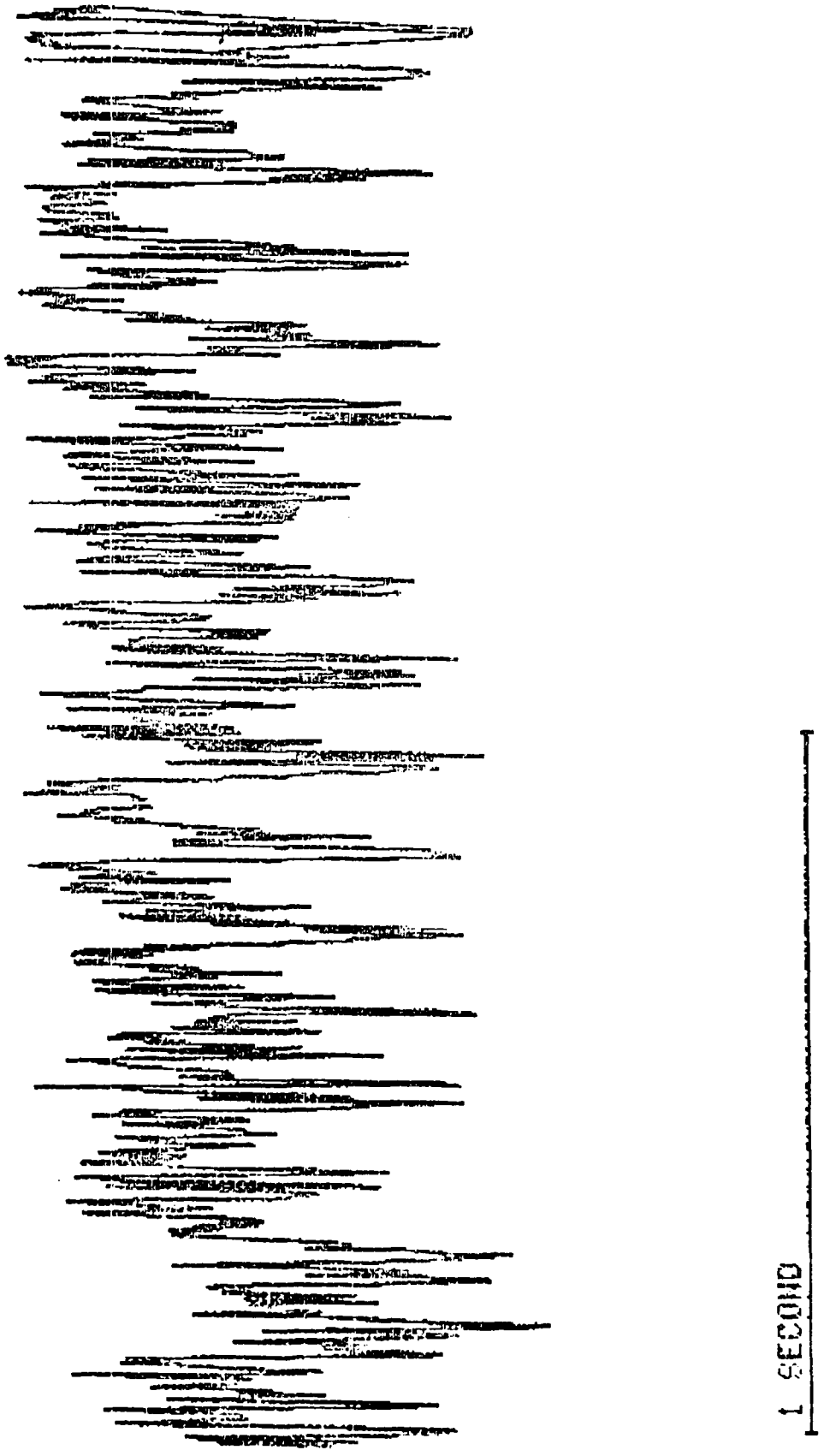

Figure 1. Echo time series (wingbeat signature record) of a "birdlike" target.

Figure 2. Echo time series (wingbeat signature record) of a "non-birdlike" (insect) target. Flocks of several or more birds might also generate a time series as steady as this record. Vertical scale is the same as Figure 1.

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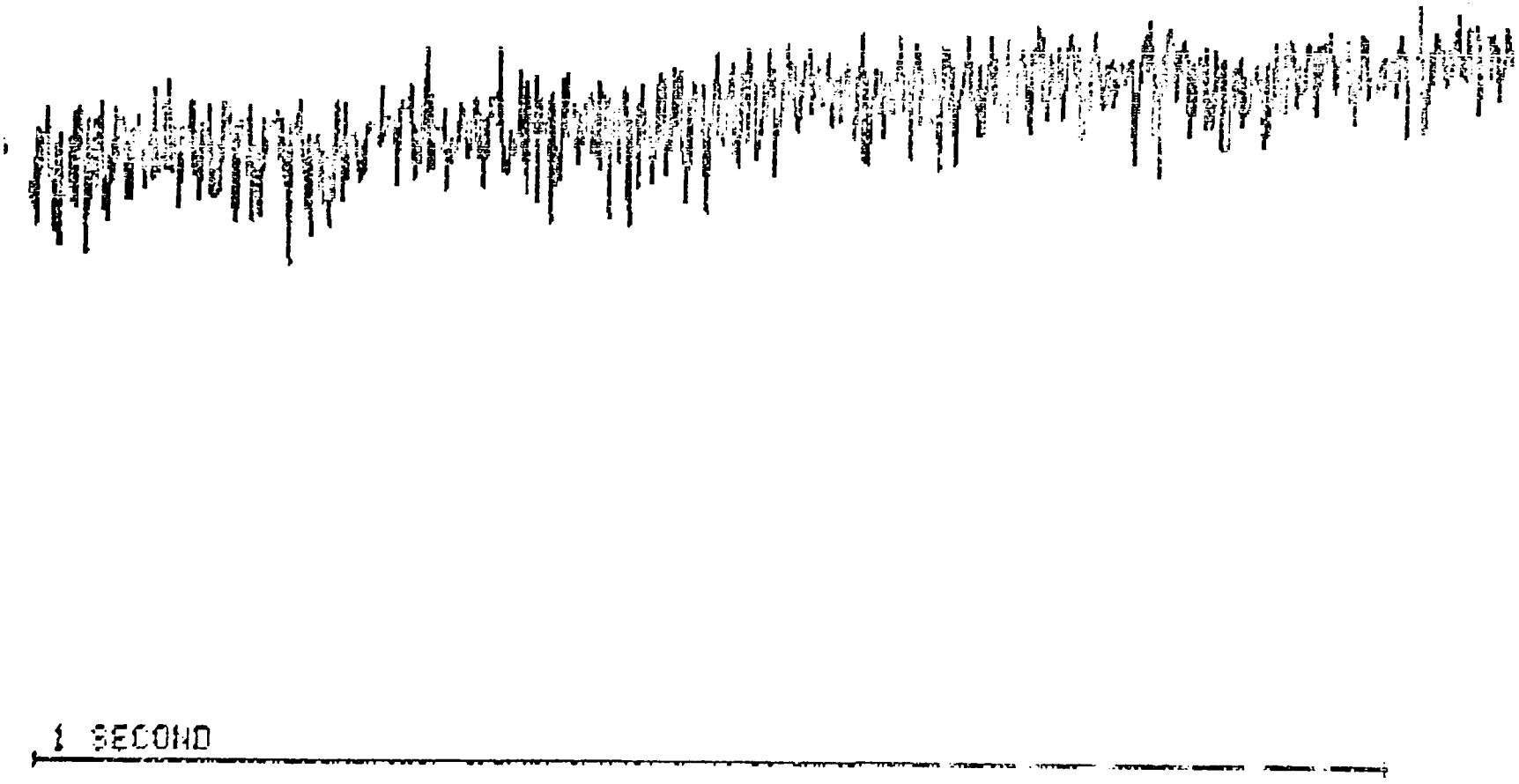


high over the antenna right-of-way (up to about 2 km AGL) as well as very low over it (below 200 m). Also, we can track birds at a distance from the antenna right-of-way laterally, as well as tracking birds directly above it. We have been concentrating on obtaining very long records of the paths of individual migrants (up to about 4 minutes in duration) that allow comparison of the straightness and levelness of targets in different spatial proximity to the antenna. Many such tracks cross the antenna and allow us to look for spatial effects within different parts of the journey of a single bird.

We suppose that typical post-cold front fall migration will produce rather tighter clumping in the directions assumed by the animals than we have thus far observed (Richardson, 1982). If and when we can predict the probable path of a bird during more typical migration, it should be possible to set up rigid protocols (for instance, of the ABABAB variety) to track birds passing along specific routes. Thus far we have been forced by the weather to remain opportunistic. The results will be less amenable to simple statistical analysis, but will nevertheless provide quantified and statistically testable data (see below). In no case will the data be subject to bias, because the radar unit operates automatically once a track is initiated.

Presence of the Aurora Borealis means that it will be imperative to obtain records of K-values and use them in analyzing the data.

Possible effects of two nearby broadcast towers are being investigated to permit estimation of their importance as confounding factors. This is being done while taking long tracks, as discussed above. Occasionally we track a bird whose path takes it directly toward or near one of the towers. Analysis will permit us to name a distance, angular or linear, constituting a threshold for avoidance of or attraction toward the towers. Birds whose paths exceed

this distance from the towers can then be said to be unaffected by them and thus not subject to confounding. This work needs to be conducted on moonlit, dark, and cloudy, as well as clear nights because these variables are known to be important to birds reacting to lights. Age and other factors may also influence effects of towers (Dunn and Nol, 1980).

Following nights with fog or low cloud and heavy or moderately heavy migration, we shall look for tower-killed migrants below the guy wires to the towers. This will provide an unexpected opportunity to learn something about the species composition of migration exactly at the time and place of the study.

Radio Tracking

The University of Wisconsin had considerable difficulty in finalizing a subcontract. This delayed signing of the subcontract until after useful radio tracking work could be initiated in the fall of 1983.

In an effort to bring this task back on schedule, we developed and submitted to IITRI a plan to take on this task at the Illinois Natural History Survey. The report from the University of Wisconsin (Appendix 4) summarizes their work up until this time. Because no further work on radiotracking will be conducted under this subcontract, detailed review of our previous plans to perform further radio tracking is inappropriate.

Waterfowl Survey

The Illinois Natural History Survey assumed this task from the University of Wisconsin. An experienced field investigator was dispatched to the ELF site on 24 October, immediately after telephone approval. As evident from the field

report (Appendix 5) few waterfowl are present on the lakes in the UP as late as late October. Contacts with biologists from Michigan Department of Natural Resources and Seney National Wildlife Refuge and also local birding enthusiasts indicate:

(1) peak numbers of waterfowl are present from 1-10 October;

(2) few waterfowl are located on the small lakes as late as 24 October;

(3) some mallards, black ducks, and mergansers nest in the small lakes while most others nest in the larger lakes such as Seney NWR.

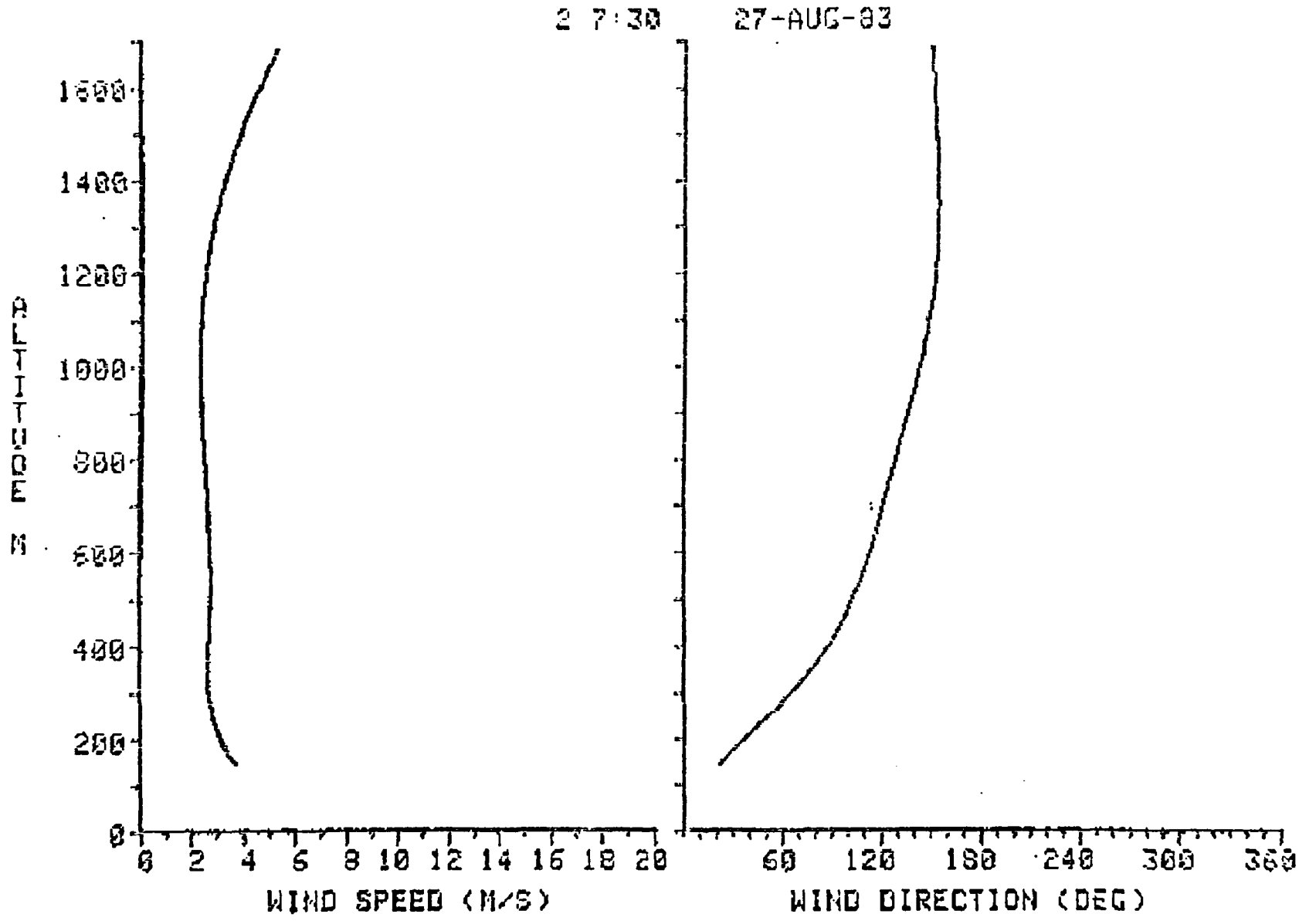
This Task also will not be performed under our Subcontract next year.

Ambient Monitoring

This Task consists of monitoring local weather conditions apt to have an effect upon bird migration in the region and in obtaining data files from other sources in order to look for correlations.

We measure local winds using the technique of tracking radar targets suspended from helium-filled balloons. As the balloons ascend, they are passively transported by the wind in the XY plane, giving an accurate picture of the wind at all altitudes of interest. These wind data are taken at the location of the radar studies and balloons are released at intervals during a data-gathering session, so that winds can be accurately estimated for the time, geographical location, and altitude of each bird track recorded. Off-line programs fit polynomial equations to the X and Y coordinates of the wind vector as a function of altitude, generating wind profiles such as shown in Figure 3. The method of polynomial fitting is being reworked mathematically in order to improve the performance of the algorithm at low and high altitudes.

Figure 3. Vertical wind profile taken with a radar-tracked helium-filled balloon.



Supplementary to the balloon-tracking method of gathering data about the wind was proposed a stationary wind-vane and anemometer to record winds in the surface boundary layer at the radar site. Such a local wind-measuring station has proven most useful to us in previous studies for signalling changes in the wind and therefore providing a timely indication that another balloon-borne radar target should be launched. Funding in 1983 was not received early enough to complete construction of a wind-measuring instrument in time for the 1983 field season in the Upper Peninsula; however, the device has now been constructed and will be field-tested in Illinois in time for the 1984 data collection period.

Because only one night in 1983 had favorable conditions for migration, correlations of migration parameters with K-values, cloud ceilings, and synoptic weather conditions is premature at this point. These aspects of the radar study will be performed in 1984.

PLANNED STATISTICAL ANALYSIS AND SELECTION OF CONTROL GROUPS

This section is written under the assumption that the ELF array will be absent or nonoperative during a Before period, and operating continuously in one mode during an After period, rather than under the control of the experimenters.

We received definitive information about the exact geographical siting of the ELF antenna only in January 1984 and thus have not been able to determine the location of our radar targets relative to the eventual antenna system. Thus, the present section outlines plans for dealing with our data rather than techniques employed in 1983. However, the methods, and in many cases the computer programs, for performing these analyses have been used in previous

publications (e.g., Larkin and Sutherland, 1977; Larkin and Thompson, 1980). It is premature to state the individual statistical test to be used in each analysis; we favor nonparametric statistics when possible (Siegel, 1956) and shall follow Batschelet (1981) for analysis of circular distributions.

Counts of the numbers of migrants flying over the antenna system before and after installation can reveal gross differences. Such counts in fall will be affected by synoptic weather variables (Richardson, 1978), local weather and cloud conditions, productivity in the breeding areas, and the geographical situation in the Upper Peninsula, all factors not under our control. In addition, the unexpected presence of substantial numbers of insect targets in the Upper Peninsula in fall 1983 suggests that overall target counts will have to be corrected for non-bird targets. Before-vs-After comparisons of numbers of migrants flying over the antenna system should be made in at least two ways: (1) matching individual nights or portions of nights in the Before and the After period, and (2) comparing the nights with maximum recorded bird densities in the Before period with those in the After period. Separate analyses should be conducted for all birds passing over the radar and for only those birds in the lowest altitude strata.

Altitude distributions of migrants passing over the antenna might reveal either avoidance of the antenna system in a vertical direction (landing or rising upon encountering the edge of the antenna system) or disorientation to the extent that the numbers of low-altitude migrants (close to the antenna) would be changed. For this analysis, histograms of altitude for individual VSU runs will be converted to frequency distributions and compared for the Before and the After periods.

Disorientation of birds in ELF fields was found by Larkin and Sutherland (1977) and presence of nonlinear or curving radar tracks can be expected to be the most sensitive indication of possible effects of the Michigan ELF system. We have here the advantage of an analysis procedure that has been tried and proven (in a within-night comparative design). Therefore, emphasis in the present monitoring program should be placed upon improving the techniques of the earlier study and in adapting them to a Before-vs-After design. "Non linearities" will be used to designate radar tracks or portions of radar tracks that depart from a straight line in the XY plane. (Including the Z axis is easily accomplished and will not be discussed here for reasons of clarity.)

We can expect about four classes of nonlinearities:

(a) Switches from one radar target to another nearby one. Such "mistakes" on the part of the radar's automatic tracking apparatus are more frequent on nights with many targets present than on nights with only a few. They can usually, but not always, be detected by the radar operator and entered on the handwritten field notes. Most undetected switches can be detected from the stored radar tracks and the graphic editing program allows the data to be split into two separate files during editing of the data.

(b) Artifacts of the data collection circuits. These take the form of either abrupt or gradual changes in one polar coordinate. Because the birds' flight takes place in Cartesian coordinates, polar coordinate artifacts introduce nonlinearities. These are often rectified by recalibrating the radar in the field. Equipment to avoid such artifacts is not available for the monitoring program.

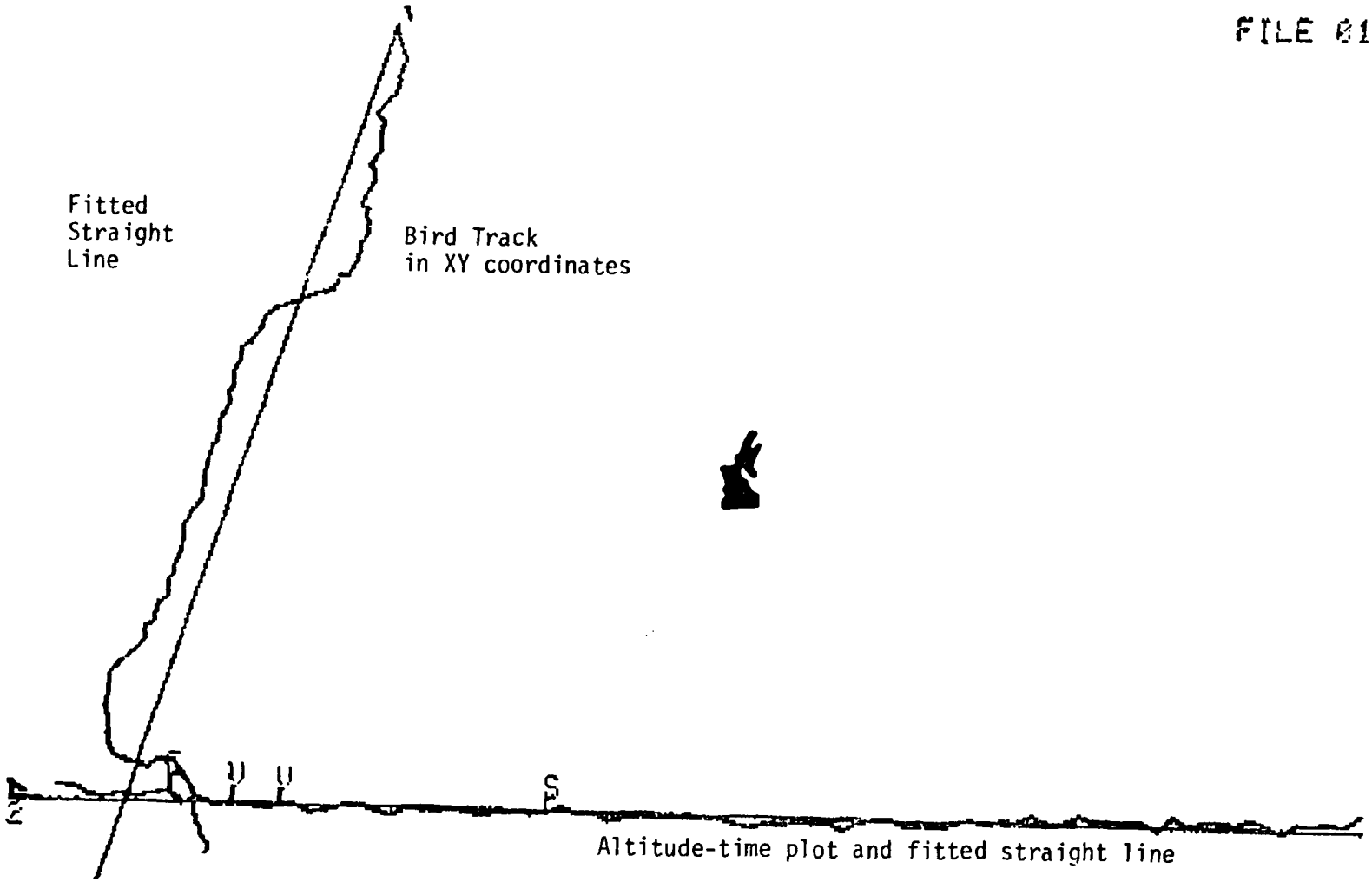
The artifacts often occur at specific ranges or azimuths and thus often can be spotted during the editing procedure.

(c) Continuous curves. Radar tracks are sometimes collected in which the bird changes direction during most or all of the time it is being tracked, either in a series of sharp turns or in one long gradual one (e.g., Fig. 5).

(d) Abrupt curves. A straight track in XY coordinates can suddenly change direction or speed, then can either maintain the new orientation or resume the former flight path. These nonlinearities were encountered in the earlier study at the WTF.

Graphic editing of the radar tracks is performed off-line by an editor without regard to external conditions. In addition, the display does not indicate the altitude of the radar track, so that the editor does not see if a bird is 200 m or 2 km above the antenna array (Fig. 4). During editing, artifacts and switches are first removed from a track. Then straight lines are fitted to the XYZ radar tracks from the beginning of the track up to the place, if any, where a nonlinearity occurs (the onset). If no linear portion is evident at the beginning of a track, no line fitting is done. Thus, the position in four coordinates (X,Y,Z, time) of onset of each abrupt nonlinearity is located for each track in the stored data. If doubts are voiced about the objectivity of the editing procedure, we intend to re-edit selected nights of radar tracking data with the coordinates rotated about the radar by a different random angle for each radar track, thus making it impossible for the editor to tell the direction of the track or the position of the track relative to the ELF array.

Figure 4. Nonlinear bird track of the kind characteristic of many nights of migration activity in the Upper Peninsula.



Analysis for disorientation of radar tracks will take several forms. Directions of migration (headings and air speeds) can be compared directly between the Before and After conditions using standard statistical tests on the fitted straight segments of tracks (Larkin and Thompson, 1980). Continuous nonlinearities can be analyzed by fitting straight lines to the entire radar tracks and comparing distributions of the Standard Error of the linear fits. Abrupt nonlinearities, identified by their onset as described above, can be analyzed using their position relative to the antenna leg (north vs south or before vs after the the bird passes over the antenna leg), their geographical position on a map of the study area, and their occurrence in tracks or different altitudes, directions, etc. Individual tracks in the After period will be matched with control tracks in the Before period in altitude, air speed, and wind conditions.

In the case of abrupt nonlinearities, it will be possible to conduct an analysis comparing tracks within a single night. This comparison will be analogous to studies inside-vs-outside the antenna system being conducted in other aspects of the Ecological Monitoring Program. The procedure will be as follows: Onset of nonlinearities will be identified as described above. Then a control track for each track with a nonlinearity will be selected using, first, a criterion of similarity in altitude, then the closest track in time to the nonlinear track that is as long in duration as the linear portion of the nonlinear track before the onset of the nonlinearity. The XYZ distance from the nearest antenna segment and other parameters can then be compared statistically in order to test the hypothesis that birds flying near an energized ELF antenna are most likely to be disoriented. Of course, the same analysis can be performed on the data from the Before period in order to check

the matching procedure. This analysis assumes that ELF effects diminish with distance (up to approximately the 2-3 km range of the radar unit).

The sensitivity of the tests for nonlinearities will be checked by investigating birds encountering one of the broadcast towers. Such birds are expected to change course upon encountering a large, illuminated steel structure in their path, and we therefore expect to be able to detect a geographical region of increased nonlinearities centered on the broadcast towers. This effect will be weather-dependent, as discussed above.

The above analyses for nonlinearities require that birds be tracked at varying distances from the ELF antenna system during each night's data collection and that the tracks be long in duration. These requirements were largely met in the 1983 season.

Acknowledgments: The preparation of this report benefitted from the comments and criticisms of P. Bartels, A. Lednor, W. J. Richardson, and R. Szafoni.

CONCLUSIONS

We have made the following qualitative observations regarding bird migration over the proposed ELF antenna right-of-way:

- Bird movements are light or nonexistent in daytime, as is common at inland locations, and increase dramatically at dusk.
- Most birds fly straight and level, although the proportion of targets that climb, drop, or turn has been greater than in other work with this radar unit (Fig. 4). This generalization, if sustained in analysis of the results, could be due to the unusual weather conditions, to local or general magnetic effects (Aurora Borealis has

been seen during the study), or to other factors. Some targets have flown such convoluted paths that we suspect they are not migrating birds, but rather gulls, bats, or other kinds of targets.

- Again, probably due to unfavorable weather, directions of travel have been quite variable, both within a night and between nights.
- Low-flying birds, important for assessment of possible ELF effects, have been common enough. When possible, we have concentrated efforts on these birds close over the antenna right-of-way.
- Movements have been studied both on cloudy and on clear nights. Visibility of sunset and of celestial objects is known to be important to migrating birds.
- We have not yet seen a lull or gap in southward migration due to the area of Lake Superior to our north. If present, such a gap should appear in the bird counts obtained by the Video Sampling Unit. We expect to produce better evidence on this point when and if cold fronts penetrate the area.
- Insect-like targets are common in this area (Fig. 5). Their numbers have exceeded those of bird targets on some nights. They appear at a wide range of altitudes and provide problems for the measurement of densities of bird targets. It seems that ELF effects on these numerous and mobile animals might be appreciable, especially if they should become disoriented and alight near an ELF antenna.

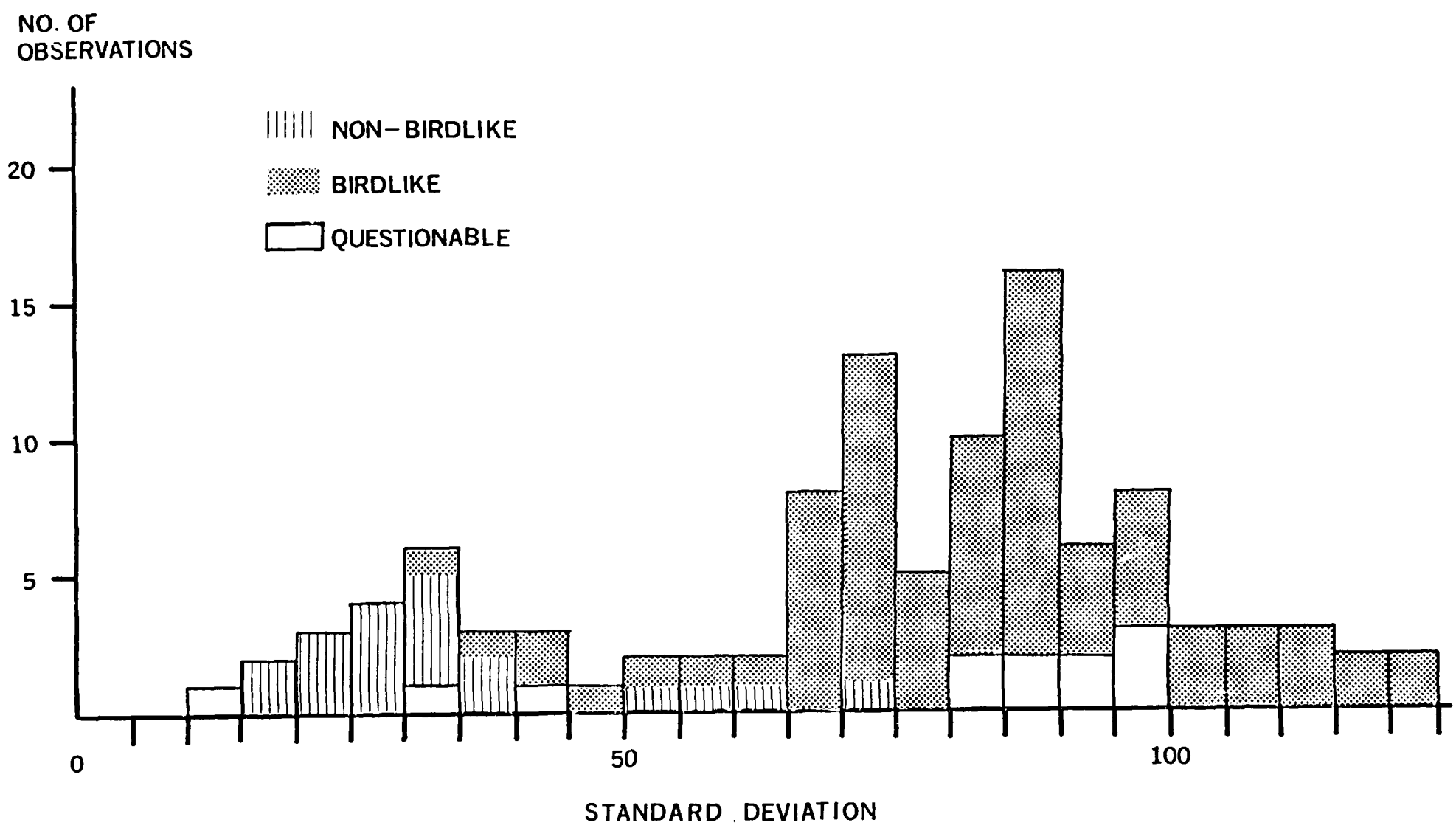


Figure 5. Histogram of standard deviations of echoes of tracked radar targets over Marquette County, Michigan on 9 September 1983. The targets are separated into those targets that appeared to be birds to the radar operator observing the A-scope (shaded), those that were steady without apparent wingbeats (striped), and a few targets that were ambiguous or for which no judgement was recorded. Standard deviations are given in arbitrary units that approximate millivolts of receiver video. The lowest values of standard deviation indicate the approximate noise level of the receiver at moderate ranges.

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Appendix 1

Chronology of First Year: Migrating Birds

April, 1982	-Original proposal submitted
September, 1982 April, 1983	-Revised proposals submitted
February, 1983	-2 months' start-up funding approved
May, 1983	-Radio tracking field study conducted in Wisconsin
June, 1983	-Subcontract issued -Field work shifted to Michigan at the suggestion of IITRI
July, 1983	-Reconnaisance trip to Michigan
August-September, 1983	-Radar tracking field study conducted in Michigan
September, 1983	-University of Wisconsin withdrew from project
October, 1983	-Waterfowl survey conducted in Michigan
November, 1983	-One-month no-cost extension issued for the subcontract -Instructions issued concerning content of Annual Report

Appendix 2

General Description of the Illinois Natural History Survey Tracking Radar Unit

The unit is a surplus AN/GPG-1 military tracker that has been modified for use in the study of flying animals. It is portable in that it is mounted on a newly-built trailer with a combined gross weight of about 2,500 kg. Tracking is of the classical nutating-scan type (specifications are given in Table A3). The effective range for passerine bird targets is from just over 100 m minimum to 2000-3000 m maximum. Individual insects (Cabbage Looper Moths) have been tracked at a range of 1,100 m. Mounted on the trailer with the radar is a weatherproof cabin containing a dedicated minicomputer and other instruments used in calibration and data collection.

When used in tracking mode, the radar operator selects an individual target by observing the A-scope display while manually scanning the antenna in azimuth or elevation. The operator then manually marks the range of the target selected and operates a switch to start the radar autotracking. While autotracking, the radar follows the target being tracked without human intervention; if a larger target crosses near to the target being tracked, the radar may switch to tracking this new target. The target is followed in the three coordinates of azimuth, elevation, and range until the radar switches to a stronger target, the echo from the target being tracked becomes too weak, or the human operator intervenes. A spotlight coaxial with the radar antenna can illuminate the target being tracked and binoculars can then be used to identify nocturnal targets when they are at close enough range.

During tracking, the minicomputer automatically samples the antenna position and range of the target being tracked, converts these values into Cartesian coordinates with the radar at the origin, and stores the information

at a programmable rate on disk. Each radar track is stored as one file, including identifier information and records of events that may have occurred during the progress of the track. One 1-4 sec epoch of target amplitude data can be displayed on-line and stored in a separate signature file. Special modes of operation are available for tracking balloon targets (to obtain wind information) and for calibrating the antenna position circuits.

In addition to long-distance tracking of individual birds, the radar apparatus can also operate in a stationary beam mode in conjunction with a Video Sampling Unit (VSU). The VSU is presently a one-of-a-kind instrument developed by the investigator. Its operation is described in two publications (Larkin and Eisenberg, 1978; Larkin, 1982). It allows objective monitoring of the density and altitude and time distributions of migrating birds, providing data which are uniquely quantitative and free from bias, for the determination of ELF effects. Wingbeat signatures during tracking are monitored by techniques under development.

When used in stationary-beam mode, only the VSU is used to collect data from the radar. The radar antenna is pointed in a certain direction (often vertically) and a computer pattern-recognition program is run to recognize and store records of individual targets passing through the radar beam. Rate of passage is dependent upon altitude, echo amplitude, and speed relative to the ground of each target; the pattern-recognition program takes these variables into account in setting thresholds for the recording of migratory activity. The resulting data (see Fig. A6) can be used in calculating Migration Traffic Rates, altitude distributions, and time profiles of migration during a period of observation.

Table A3. Specifications, Illinois Natural History Survey Tracking Radar.

Type: AN/GPG-1 (AN/MPQ-29) nutating-scan tracker, trailer-mounted

Modes of use: autotracking, stationary-beam (search mode disabled)

Transmitting system
- Frequency: nominal 8850 MHZ (X-band)
- Peak power: 40 kW
- Pulse repetition frequency: nominal 3500 Hz. (variable)
- Source of RF power: Magnetron type 2J51
- Pulse duration: nominal 0.25 microsecond (75 m)

RF and receiving systems
- Antenna: Paraboloid, 76 cm diameter
- Feed: Cutler type
- Beam: 3 degree, conical
- Nutation: nominal 30 Hz, 3 degree conical
- Receiver: Superheterodyne, using 2K25 Klystron as local oscillator
- Intermediate frequency: 30 MHz

Coverage
- Azimuth: 360 degrees
- Elevation: -11.25 to +85 degrees, nominal
- Range: minimum 100 m (ideal clutter conditions), maximum 20 km

Data outputs
- For target acquisition: A-scope and J-scope
- Antenna position and range: digitized by minicomputer (10 bits)
- Target size and signature: digital output from Video Sampling Unit (10 bits)
- Event recording: via event logic and pushbuttons (12 channels)
- Ancillary data: Wind speed and direction, date, time
- Data storage: 8-inch floppy diskettes (file-structured ASCII)
- Tracking data: XYZ position sampled at 0.5-10 Hz, 1 m precision
- Wingbeat signature data: 1-2 second epochs sampled at nominal 350 Hz
- Target density data: target passage through beam recorded within a range window of 225-1725 m
- Real-time computer displays: X-Y, altitude-time, echo amplitude-time, range histogram

Power and physical
- Frequency: 60 Hz
- Power: 4 to 7 kW
- Mass, including trailer and instruments: about 3,000 kg
- Trailer: 579 cm long X 244 cm wide X ca 270 cm high

Ancillary equipment
- Target selector for acquiring targets visually (tripod-mounted)
- Wind vane and anemometer for canopy-level wind measurement (pole-mounted)
- Tracking telescope for observing target (trailer-mounted)

Figure A6. Example of data from a brief period of stationary-beam bird counting using the Video Sampling Unit. The radar was aimed vertically (85 degrees) and dots represent individual birds flying through the radar beam. These data are used to provide Migration Traffic Rates and distributions of altitudes of targets.

Appendix 3

Illinois State Natural History Survey Tracking Radar: Data Reduction Programs

Kind of Data	Data Collection	Editing, Artifact Removal, Formatting	Processing: s/n ratios, coordinate conversion, scaling	Summarization: descriptive statistics and display
Tracks of birds Straightness Levelness Orientation Speed of flight	R	REDIT	$V_{\bar{a}}$ transformation WIND8* linear fitting*	CATCH8 RLIST UPPLOT
Migration density Stationary-beam counts	V	V1		SPECKS, VLIST, DDD
Ground clutter records	N	NOISV1		PLOTN
Echo characteristics	R			
Target size		REDIT	RANGE*	CATCH8, VSSUM
Target S. D.		REDIT		VSSUM, SDPLOT
Wing Beat Signatures		VSTOVA	FFT**	PLOTV

*Program is being modified and/or improved
**Program not yet written

TO: IIT Research Institute and Cooperators

FROM: Stanley A. Temple, Project Leader and Scott M. Melvin, Research Specialist, Department of Wildlife Ecology, University of Wisconsin, Madison, WI 5370[illegible]

RE: Progress Report, Research on effects of ELF on bird migration, 17 February-8 June 1983

This report summarizes research conducted by Stanley A. Temple and Scott M. Melvin, Department of Wildlife Ecology, University of Wisconsin-Madison, on the effects of ELF on migrating birds at the Clam Lake ELF Test Facility in the Chequamegon National Forest, Wisconsin.

Preparations for Research, Spring Migration 1983

The period 17 February-14 May was spent planning for spring migration research, and procuring and preparing equipment and supplies for field work. Little preparation could be accomplished prior to late April because of delays and uncertainty in funding. Activities during this period include:

(1) ordering radio-tracking receivers, transmitters, and antennas;

(2) purchasing and reviewing topographic maps of potential study areas near Clam Lake, Wisconsin;

(3) outfitting a tracking vehicle;

(4) obtaining mist netting and banding equipment and miscellaneous field supplies;

(5) obtaining required federal banding permits.

Research, Spring Migration 1983

During 15 May-6 June we conducted field work in the Chequamegon National Forest near the south leg of the ELF antenna (Fig. 1).

Objectives were to: (1) capture and radio-mark migrant thrushes, and monitor their flight paths and subsequent departure bearings over the ELF antennas, (2) evaluate the suitability of our capture, radio-marking, and tracking techniques for studies of effects of ELF on bird migration, and (3) use mist net captures as an index to the volume of migrating birds passing over the ELF antennas.

Birds were captured by a 2-person crew using 5, 6-m and 5, 12-m mist nets, arranged in a roughly east-west line. The forest vegetation at the netting site appeared representative of the surrounding region. Netting effort (Table 1) was calculated in mist net hours; 1 mist net hour equivalent to 1, 6-m net in place for 1 hour.

We captured a total of 15 birds during 603 mist net hours (Tables 1, 2), including 3 hermit thrushes (Catharus guttatus) and 1 veery (Catharus fuscescens). We did not radio-mark the hermit thrushes, believing them to be resident birds that had been present on the study area when we arrived. The veery was thought to be a migrant, and we radio-marked (Raim 1978) and released it on 22 May. It appeared to adjust quickly to its back-mounted radio package, and flew immediately when released. We maintained radio contact with the veery for 9 days and 8 nights. It remained within a localized area of less than .15 mi^2 through at least 30 May. Winds were unfavorable for migration (from the northwest, north, and east) on the nights of 22 May through 30 May. The night of 30 May was completely overcast with rain and winds from the north and east. We did not monitor the radio-marked veery after 2200, assuming that the probability of it migrating under those conditions was low. However, we were unable to re-establish

radio contact with the bird the next morning, 31 May, or on subsequent days. We do not know if the veery actually migrated out of the area or simply made a local movement beyond the range of our searching capabilities, if the radio package fell off, if the radio antenna broke, thereby significantly reducing the range of reception, or if the radio ceased transmitting.

We believe that the large expanse of relatively homogeneous habitat suitable for migrant thrushes that exists in the Chequamegon National Forest was a major factor contributing to our inability to capture larger numbers of migrating thrushes. There are essentially no geographic leading lines or fragmented "islands" of forest habitat to concentrate migrants in the Clam Lake area; thus the probability of encountering large numbers of migrants at a single netting site is low.

During 7-8 June, S. Melvin traveled to the Upper Peninsula of Michigan, to purchase topographic maps and to reconnoiter potential study areas near the site of the proposed ELF antenna. Initial impressions suggested that access to study areas and mobility in radio-tracking migrants would be more difficult in Michigan than at the Clam Lake study site in Wisconsin.

Research Plans, Fall Migration 1983

We intend to shift our mist-netting and radio-tracking studies of migrant birds to the Michigan ELF site during the period of approximately 20 August-15 September 1983, providing a subcontract is issued to the University of Wisconsin-Madison that makes research funds available prior to that period. This will allow us to begin collecting a "control"

set of pre-construction data at the Michigan site, which can be compared to post-construction migration data collected after the Michigan ELF facility has become operational.

We hope to increase our trapping effort by using ground traps in addition to mist nets to capture migrants. We are also exploring the possibility of using migrant thrushes captured at established banding stations along the shore of Lake Michigan, in the Green Bay area, for radio-tracking studies at the Michigan ELF study site.

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Raim, A. 1978. A radio transmitter attachment for small passerine birds. Bird-banding 49(4):326-332.

Fig. 1. Location of mist netting site (⊛) and ELF transmitter (⊗) in the Chequamegon National Forest south of Clam Lake Wisconsin.

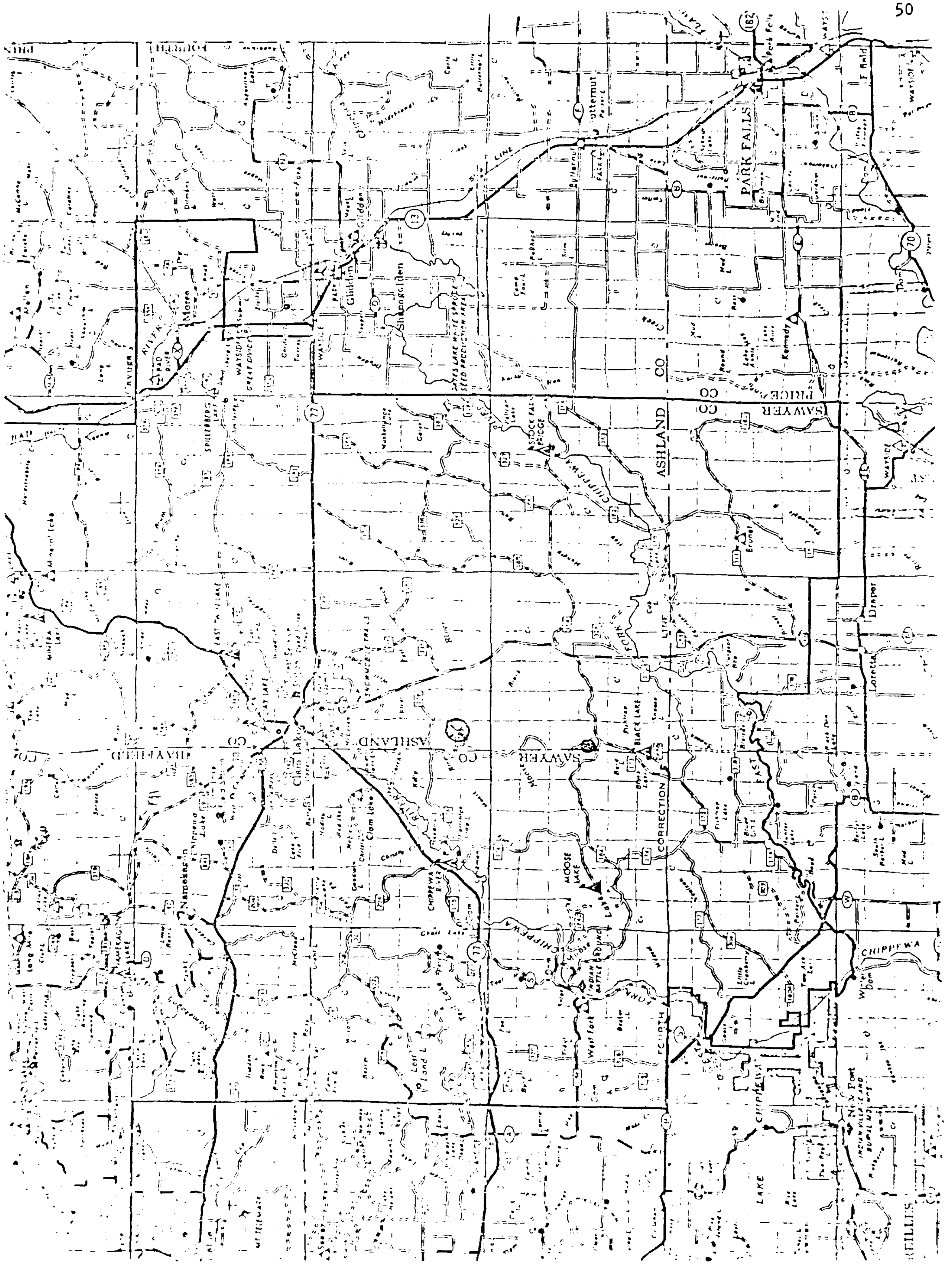
PARK FALLS
Butternut
Glidden
Shanagolden
Morse
WAYSIDE
ASHLAND CO
SAWYER CO
PRICE CO
BAYFIELD CO
Clam Lake
Clam Lake
CORRECTION LINE
FOURTH
EAST FORK
CHIPPEWA
CHIPPEWA RIVER
MOOSE LAKE
BLACK LAKE
Kennedy
Brunet
Draper
Loretta
New Port
Namekagon
Lost Land L
West Fork
LAKE

Table 1. Mist netting effort and success during ELF migration studies in the Chequamegon National Forest, Wisconsin, 18 May-2 June 1983.

Date	Mist net hours	No. of individuals captured
18 May	7.0	0
21 May	57.0	4
22 May	35.0	1
23 May	49.5	1
24 May	33.0	0
25 May	67.5	1
26 May	67.0	2
27 May	60.0	2
28 May	32.0	1
31 May	75.0	3
1 June	60.0	0
2 June	60.0	0
TOTAL	603.0	15

Table 2. Summary of birds captured during ELF migration studies in Chequamegon National Forest, Wisconsin, 18 May-2 June 1983.

Date	Common name	Sex[1]/Age[2]
21 May	Ovenbird	UK/AHY
	Magnolia Warbler	M/AHY
	Nashville Warbler	M/AHY
	Nashville Warbler	M/AHY
22 May	Veery	M/AHY
23 May	Nashville Warbler	M/AHY
25 May	Hermit Thrush	UK/UK
26 May	Ovenbird	UK/AHY
	Ovenbird	UK/AHY
27 May	Yellow-bellied Flycatcher	UK/AHY
	Ovenbird	UK/AHY
28 May	Black-billed Cuckoo	UK/AHY
31 May	Hermit Thrush	UK/AHY
	Hermit Thrush	UK/AHY
	Sharp-shinned Hawk	UK/SY

[1]UK--Unknown, M--Male.

[2]AHY--After Hatching Year, UK--Unknown, SY--Second Year.

Appendix 5. Results of the waterfowl survey conducted during October 1983 at the proposed ELF antenna site (D = kilometers from center of the lake to nearest ELF line).

LAKES CENSUSED

Lake	Township	Sec.	D*	# counted
Unnamed lake south of Martell's Lake	T 45 N, R 29 W	27	0.21	0
Unnamed lake east of Pike Lake	T 45 N, R 26 W	21	0.21	0
Sunsun Lake	T 46 N, R 29 W	35	0.37	0
Skinnes Lake	T 46 N, R 29 W	25	0.54	0
Chain of Lakes	T 45 N, R 29 W	28	0.54	0
Martell's Lake	T 45 N, R 29 W	22	0.70	0
Birch Lake	T 46 N, R 29 W	11	0.76	0
Unnamed lake NW of Martell's lake	T 46 N, R 29 W	22	0.81	1 (male mallard) 1 (female ring-necked duck)
Unnamed lake east of Pike Lake	T 46 N, R 26 W	21	0.92	0
Charley's Lake	T 46 N, R 26 W	25	0.97	0 **
Big Perch Lake	T 46 N, R 28 W	34	1.18	0
Unnamed lake east of Pike lake	T 45 N, R 26 W	28	1.18	0
Twin Lakes	T 46 N, R 29 W	35	1.40	0
Long Lake	T 46 N, R 29 W	35	1.50	1 (female ring-necked duck ?)
Crooked Lake	T 45 N, R 26 W	30	1.50	0
Portersville Lake	T 45 N, R 29 W	28	1.72	1 (species Unknown)
Pike Lake	T 45 N, R 26 W	29	1.72	0 **
Fidney Lake	T 45 N, R 27 W	33	1.77	0
Tanglefoot Lake	T 46 N, R 28 W	20	2.21	0 **
Little Perch Lake	T 45 N, R 28 W	3	2.37	0 **
Unnamed lake southeast of Helen Lake	T 45 N, R 29 W	10	3.06	0
Beaver Lake	T 46 N, R 29 W	21	3.70	0
Perch Lake	T 46 N, R 29 W	8	5.20	0
Milwaukee Lake	T 46 N, R 29 W	8	5.52	0
Silver Lake	T 44 N, R 30 W	14	10.47	0 **

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