# A COMPARISON OF ADULT AND IMMATURE SAMPLING TECHNIQUES UTILIZED IN AN ECOLOGICAL STUDY OF POND INSECTS


By

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AN ABSTRACT

Submitted to the School of Graduate Studies of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

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ABSTRACT

A comparison of sampling techniques for adult and immature insects was conducted at two locations in Michigan. The quantitative and qualitative distributions including seasonal variations of the insect population were used in the comparison of trapping techniques. Included in the study is a presentation of the biological and ecological data for the insects collected.

The adult midges of the family Tendipedidae contributed over 99 percent of the insects removed from the adult traps. The tribe Tendipedini was well represented in samples of both the adult and immature stages and proved to be the most useful taxonomic group for comparison of sampling techniques. Certain species of the tribe Tendipedini were consistently present in large numbers while other species were captured only occasionally during the investigation. A discussion of the number of generations present during the study is presented for those species with definite life-cycle trends. A study of the initial insect population as well as insect succession in a new pond is presented.

In the tribe Calopsectrini unequal numbers of males and females appeared in the months of May through August, but not in

September, and further, sex ratios differed among the months of May through August.

The tent and funnel traps were equally successful in making a quantitative estimation of all taxonomic groups sampled during the study with the exception of the heleid adults. Statistical analysis of the sampling data confirmed the assumption that the heleid adults were consistently more numerous in the tent trap samples. When the adult and immature insect populations in a pond were sampled to the same degree the emergence patterns of individual species and higher taxonomic groups could be predicted equally as well with the adult insect samples as with the bottom deposit samples.

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# INTRODUCTION

The aquatic insect fauna of ponds, lakes, and streams has received worldwide attention for many years. The aquatic insects, along with other components of the invertebrate fauna, have been studied not only by the taxonomists but also by biologists in general who have been interested in the part these organisms play in aquatic ecology.

Aquatic insects have been collected both quantitatively and qualitatively in the adult and immature stages. The types of trapping devices utilized in the sampling of aquatic insects have been extremely variable, each sampler being developed to meet the needs of a particular situation. In the United States there has been a general trend toward sampling the immature stages of aquatic insects. The immature forms are very useful in making quantitative volumetric and numerical estimations of the benthic fauna.

The taxonomic treatment of many of the immature forms of aquatic insects is not complete because of their variations and complexity. The recent interest in the study of pollution and its effect on the aquatic environment has led to a general need for more specific determination of the aquatic organisms. Since specific determinations can accurately be made on most of the adult aquatic insects, it appeared that adult trapping devices would be applicable for such work.

This study was undertaken to provide information concerning the effectiveness of adult insect trapping devices. Various types of adult sampling techniques were compared with the conventional bottom deposit samples. In making comparisons of the various sampling techniques the species composition, numerical distribution, and seasonal variations of the aquatic fauna were studied.

During the course of the investigation it became apparent that the data, which were primarily being taken for the purpose of evaluating the trapping techniques, would be even more valuable in a biological study of the aquatic insect fauna. The biological and ecological observations made during the study represent a substantial part of the data presented. It was intended that these data would serve both to determine the capabilities of the trapping techniques as well as to present the biological information.

Field work was begun at the Lake City Experiment Station in April, 1952, and continued until March of 1953. The Kellogg Forest Pond investigation was started in April of 1953 and completed the following November. Laboratory studies of the material collected in the field were carried on continuously from April, 1952, until June of 1954.

## HISTORICAL REVIEW

Aquatic invertebrates have been sampled quantitatively and qualitatively either by the use of various types of bottom deposit samplers or by different forms of floating traps designed to capture the emerging adults. Generally, ecological investigations of aquatic organisms have been undertaken to provide information concerning the productivity of a pond, lake, or stream.

Most of the sampling devices, built and described by researchers for sampling bottom organisms, have been built for the purpose of investigating the organisms inhabiting a lotic environment. Many of these bottom samplers have been modified for use in lake and pond studies. The bottom deposit samplers have included such devices as the hand-dip method used by Ludwig (1932), the square-foot trap described by Needham (1928), the dredges used by Peterson (1911) and Ekman (1911), and the collapsible one square foot sampler employed by Surber (1936) in his study of stream bottom fauna production.

The use of traps designed to sample the emergence of adult insects has been a more recent trend. Needham (1908), in his investigation of stream insects at Old Forge, New York, was the first to use the tent trap method for collecting adult insects. Ide (1940) and Sprules (1947) both used a modification of the tent trap described by Needham in their investigations of the insect fauna of Canadian streams.

Adamstone and Harkness (1923) were the first investigators to use the tent trap in the study of emerging insects from lakes. In Russian lakes, Grandilewskaja-Decksbach (1935) and Borutzky (1939) used metal funnel traps to study midge emergence. Brundin (1949) used a funnel trap made of metal netting in his investigation of the oligotrophic lakes of southern Sweden. Guyer (1952) used a modification of the funnel trap described by Brundin (1949) in the study of insects emerging from fertilized ponds in Michigan.

Various types of floating tent traps have been described for use on lakes and ponds. Miller (1941) used a floating tent trap to study the ecology of the family Tendipedidae in Costello Lake, Ontario. The tent trap technique was also employed by Scott and Opdyke (1941) in their investigation of emerging insects from Winona Lake, Indiana. Macan (1949) found a floating tent trap useful in his ecological study of Three Dubs Tarn.

There have been few studies in which both adult and larval samples have been taken from the same area at the same time.

Likewise there has been no effort to correlate adult and larval sample data. Usually adult emergence data have been used to supplement bottom sample analyses.

The accuracy of the various larval sampling devices has often been discussed as a part of a general study of bottom fauna. Leonard (1939) devoted a complete paper to the discussion of the accuracy of bottom sampling technique using the "Surber type" sampler.

The taxonomy and ecology of the European species of the family Tendipedidae has received concentrated study by many researchers. Thienemann and Kieffer (1916), Goetghebuer (1921), Edwards (1929), and Brundin (1949), as well as many other investigators, have made outstanding contributions to the tendipedid literature. Many of the European studies have involved the use of midge larvae as indicators of lake types.

In the United States the taxonomy of the family Tendipedidae has been considered by Malloch (1915), Johannsen (1937, 1937a), Hauber (1944, 1945), Townes (1945), and Johannsen and Townes (1952).

Life history and ecological investigations have been made by many American workers with some of the outstanding contributions in this field being made by Leathers (1922), Sadler (1934), Berg (1950), and Curry (1952). Both in Europe and America many of the taxonomic studies have been the result of a program undertaken to study a certain aspect of midge life history or ecology.

# EXPERIMENTAL STUDIES

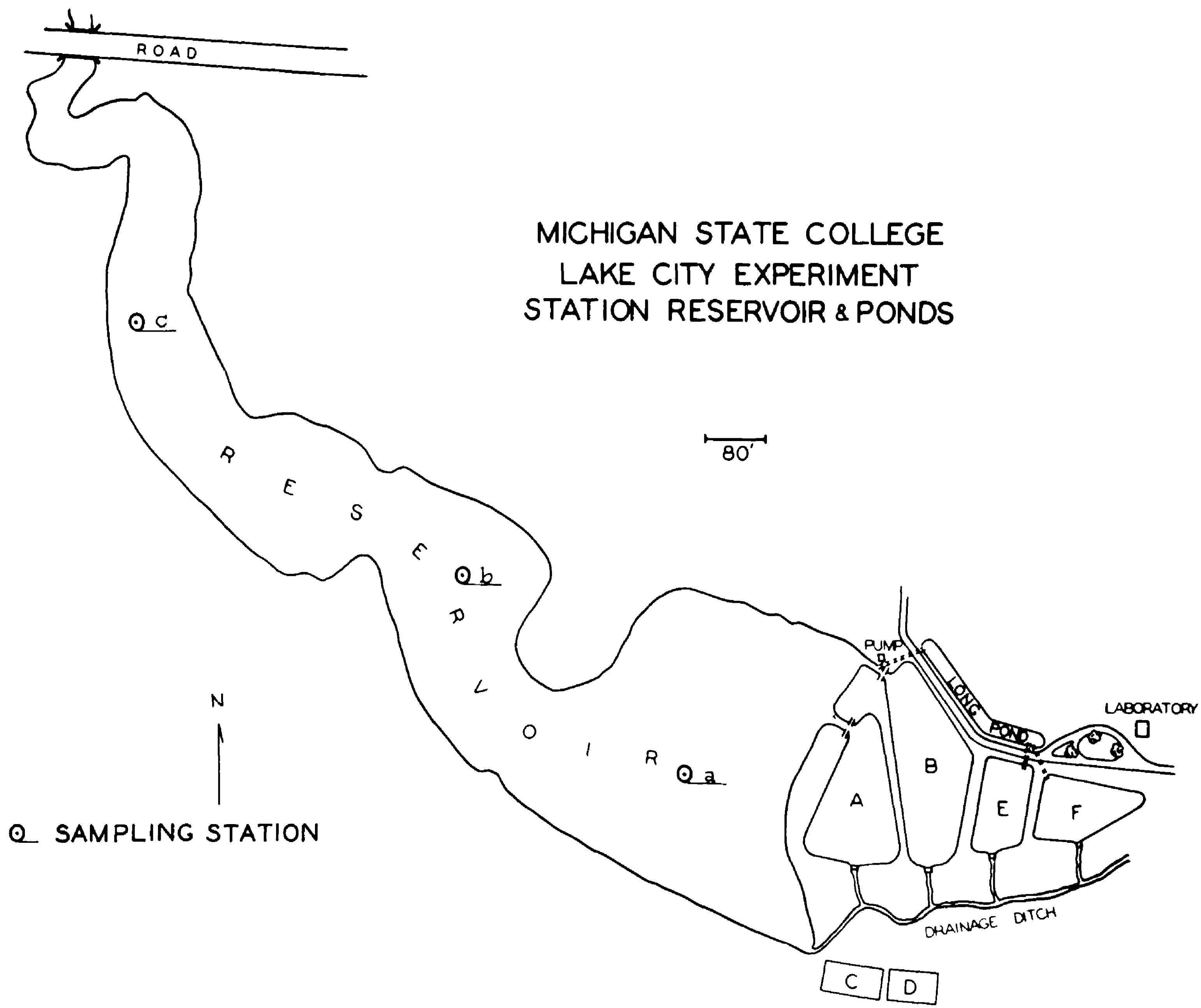
## Location and Description of Ponds

This investigation was conducted at two locations in the Lower Peninsula of Michigan. The 1952 studies were carried on at the Michigan State College Lake City Experiment Station in Missaukee County, T. 22 N., R. 7 W., Section 7. The 1953 studies were located at the W. K. Kellogg Forest in Kalamazoo County, T. 1 S., R. 9 W., Section 21.

At the Lake City Station six ponds and a reservoir area were included in the study (Figure 1). The Lake City ponds are of two general types. The first is represented by ponds "A," "B," "E," and "F" which are constructed with inlet and outlet structures making it possible to regulate the flow of water. During the study all ponds were maintained at maximum depth and no water was allowed to flow through the ponds. The maximum depth of ponds "A," "B," "E," and "F" was six feet, and the surface area varied from one-half acre in ponds "A" and "B" to two-tenths acre in ponds "E" and "F." The water supply for these ponds resulted from impoundment of a small stream forming a reservoir. Ponds

FIGURE 1

Map of the Lake City Ponds and Reservoir Area


MICHIGAN STATE COLLEGE
LAKE CITY EXPERIMENT
STATION RESERVOIR & PONDS
ROAD
RESERVOIR
a
b
c
80'
N
SAMPLING STATION
PUMP
LONG POND
LABORATORY
A
B
C
D
E
F
DRAINAGE DITCH

"C" and "D" are examples of the second type at the Lake City Station. These ponds are pits which remained after earth had been removed. Ponds "C" and "D" were not equipped with inlet and outlet structures and all of the water was the result of the seepage of subsurface water. The maximum depth of pond "C" was one and one-half feet, and of pond "D" was two and one-half feet.

The construction of the Lake City ponds was completed in 1945. Since their completion the ponds have been utilized for fertilization experiments (Tack and Morofsky, 1946; Schmidt, 1952) to improve fish production and for ecological insect investigations (Bray, 1949; Guyer, 1952). Ponds "B," "D," "E," and "F" have received varying amounts of commercial fertilizer, while ponds "A" and "C" were maintained as control ponds. The time of application and amount of 10-6-4 N-P-K fertilizer applied during 1952 are shown in Table I. All fertilizer was broadcast by hand over the pond surface.

The predominant species of fish in ponds "A," "B," "E," and "F" were the fathead minnows, Pimephales promelas promelas (Rafinesque), Northern redbelly dace, Chrosomus eos (Cope), and Northern black bullheads, Ameiurus melas melas (Rafinesque). During 1952 an unsuccessful attempt was made to stock ponds "A" and

TABLE I

FERTILIZER APPLICATIONS IN LAKE CITY PONDS, 1952

| Ponds | Pounds per Acre | | | |
|---|---|---|---|---|
| | May 19 | June 11 | July 2 | July 29 |
| A | 0 | 0 | 0 | 0 |
| B | 100 | 100 | 50 | 100 |
| C | 0 | 0 | 0 | 0 |
| D | 150 | 150 | 150 | 150 |
| E | 100 | 100 | 150 | 150 |
| F | 100 | 100 | 150 | 150 |

"B" with rainbow trout, Salmo gairdnerii (Gibbons). Ponds "C" and "D" contained no fish during the 1952 investigation.

The bottom deposits in the ponds consisted of an organic ooze varying in depth from two to six inches which was deposited over a firm clay base. This organic layer was distributed evenly over the bottom to within three feet of shore where it gave way to a sandy, scoured shoal area.

In all of the Lake City ponds higher aquatic plants were found only around the pond margins. Reed canary grass, Phalaris arundinacea (Linnaeus) was the predominant plant surrounding the ponds. Species of the genera Eleocharis, Scirpus, and Carex were intermingled with the reed canary grass. Duckweed, Lemna minor (Linnaeus), covered limited areas of pond "D." During the summer of 1952 a dense growth of Spirogyra sp. extended over the surface of pond "A." In pond "E" Chara sp. covered the bottom and formed a very dense mat. Pond "E" was the only pond with plant growth on the bottom.

During the period of this investigation a quantitative and qualitative study of the phytoplankton was also undertaken by the author. A total of fifty-four species of algae were identified from the six ponds. The algae identified belonged to five algal plant divisions with 55 percent of the species being members of the Division Chlorophyta (Prescott, 1951). In the Lake City ponds certain species appeared to increase numerically (bloom) at two periods during the investigation. This increase was more or less evident in all of the ponds. The "bloom" which developed appeared to do so irrespective of fertilization. Fertilization increased the total plankton production but it was not responsible for the seasonal variance. There was very little zooplankton production in the ponds.

The reservoir area at the Lake City Station consisted of a six and one-half acre impoundment built to provide a water supply for the previously described ponds. The maximum depth in the reservoir was ten feet. About one-half of the reservoir area was less than two feet deep and was heavily populated with vegetation. Dead trees and brush, which resulted from the flooding of a small cedar swamp, were present in much of the reservoir area.

The three sampling stations which were established in the reservoir were arranged so that three different aquatic habitats would be sampled. Station "a" was located in the center of the large, open water area. The depth at this station was 10 feet. The only vegetation present at station "a" was scattered plants of Chara sp. growing on the bottom. Station "b" was set up at the entrance of the large pond. At this station the maximum depth was three and one-half feet. An extensive bed of the floating-leaf pondweed, Potamogeton natans (Linnaeus), was the principal plant growth at station "b."

Station "c" was established in a protected cove where the water depth ranged from two to three feet. During the summer an extensive growth of bushy pondweed, Najas flexilis (Willdenow), completely filled the water at this station. At all three stations the bottom deposits consisted of a ten to twelve inch muck layer evenly distributed over clay subsoil. The northern redbelly dace, Chrosomus eos (Cope), was the predominant species of fish in the reservoir.

Kellogg Forest pond "1" was constructed during the summer of 1948. This pond was formed by removing a pulpy peat deposit which overlaid a firm bed of marl. Inlet and outlet structures were constructed to allow the movement of water through the pond from Augusta Creek. Each summer an extensive growth of Spirogyra sp. filled the pond rendering it almost useless for fish production. The decomposition of the Spirogyra as well as the settling out of debris from the running water rapidly filled the pond with a deep muck deposit. During the 1953 sampling season this muck layer was twelve to twenty-four inches in depth over the bottom of the pond. Above the organic deposit the water varied in depth from six to twenty-four inches. A steady flow of water was maintained through the pond during the investigation.

Pond "2" at the Kellogg Forest Station was built during the fall of 1952. The pond was formed by the impoundment of a small, spring-fed stream. In front of the dam a fibrous peat deposit was removed in order to deepen the pond. Pond "2" had a surface area of one and one-half acres. About one-half of the pond was less than twenty-four inches deep and resulted from the flooding of a swamp area. In this shallow section of the pond the bottom was characterized by a firm sod mat resulting from the dense vegetation present in the area previous to flooding. In the deeper area the bottom was free of vegetation. Starting in November of 1952 the pond was allowed to fill. On April 4, 1953, when this study was initiated, the pond had reached a maximum depth of five and one-half feet. Much of the water responsible for filling and maintaining the water level came from surface run-off.

The fish population in Kellogg Forest pond "2" consisted of one hundred Western shellcrackers, Lepomis microlophus (Gunther), averaging 4 inches in length. These fish were planted on the twenty-second of May, 1953.

During the first two weeks of August a dense mat of vegetation rapidly became dispersed over the surface of pond "2." This mat was composed primarily of duckweed, Lemna minor (Linnaeus), with scattered plants of Spirodela polyrhiza (Linnaeus). This mat of vegetation persisted on the surface of the water for the remainder of the sampling period.

Five sampling stations were established in pond "2." Station I was six feet out from the south margin of the pond where the water was four feet deep. The bottom type was of a coarse sand composition. Station II was eight feet from the north edge of the pond and the water was two feet deep. The bottom was composed of sand and clay with a thin layer of muck on top. Station III was in the deeper area of pond "2" where the water was six feet in depth. At station III the bottom deposit consisted of a deep fibrous peat layer. The first three stations were all located in the one-half of the pond where soil had been removed for the purpose of deepening the pond. Stations IV and V were placed in the western one-half of the pond where the water was shallow and the bottom was made up of the dense sod mat. During the summer of 1953 pond "2" declined twelve inches in depth due to the absence of sufficient rain to maintain the water level.

## Sampling of Adult Insects

Two general types of sampling devices were employed to obtain the adult insect samples. The first type was an inverted metal funnel structure used by the author (Guyer, 1952) to study the effects of fertilization on midge production in the Lake City ponds. This trap was a modification of one used by Brundin (1949) in his study of the fauna of Swedish mountain lakes. Two sizes of funnel traps were used; one which sampled a one square yard area, the other a one-half square yard area (Plate I, Figure A). The diameter of the larger opening of the funnel in the one square yard trap was 40.6 inches and it tapered to a 3.5 inch neck. The distance from the bottom of the funnel to the top of the trap was 20 inches including the neck which was two and one-half inches wide. The one-half square yard trap had a funnel opening of 28.8 inches and the distance from the bottom of the funnel to the top of the trap was 18 inches. All other measurements were the same for the two funnel traps.

At the top of the trap a three and one-half inch "Kerr-type" ring was soldered in place; to this ring was screwed a two quart fruit jar (Plate III, Figures A and B). A paper cup, with a hole cut in the bottom, was placed within the neck of the fruit jar and "Scotch tape'' was used to hold the paper cup in place. The traps were built of sheet metal with all joints soldered and around the bottom of the trap a heavy wire was built in to keep the trap rigid. A line was connected to the two quart jar and a buoy was fastened to the other end of the line.

The following procedure was followed in preparing and placing the funnel traps in the ponds. First, a paper cup with a one-half inch hole cut in the bottom was placed in the mouth of a Mason jar. At the margin of the pond the jar was screwed on the funnel and the trap was transported to the desired location in the pond. The trap was eased into the water and when air in the big funnel had been displaced by water it was lowered to the bottom of the pond.

Special precautions were taken to lower the trap in an upright position and to see that it rested evenly on the bottom with the jar in a vertical position. Whenever possible the trap was placed so that the jar was under water to prevent condensation on the inside of the jar. At the station where the funnel trap was suspended above the bottom the trap was handled in the manner described above except that the trap was suspended from a metal buoy. The distance between the bottom of the suspended funnel trap and the pond bottom varied from four to eighteen inches.

All adult traps were set in the water as nearly as possible to 1:00 P.M. on the sampling day and removed the following day at the same time. Special care was taken to keep the funnel submerged until the jar with the insects enclosed could be removed. The jar was raised just above the surface of the water, unscrewed from the funnel, and a lid slid over the opening. The jar was not turned upright until the lid was in position.

The Lake City ponds were superficially divided into quadrants and the traps were systematically moved from one quadrant to another each time the traps were placed in the pond. All depths were sampled since the traps were shifted back and forth from the shallow water to deep water areas in the pond. The Lake City reservoir stations, as well as the stations in the two Kellogg ponds, were decided upon and marked previous to the first sampling period. These were permanent stations and all samples were taken from the same area during the period of the investigation.

The second type of adult sampling device employed was a floating type tent trap, similar to the one used by Macan (1949) in his survey of a moorland fishpond (Plate II, Figure A). This trapping device was built in three parts. The tent itself consisted of a wooden frame which covered a one-half square yard area. The trap was 16 inches high. The sides were covered with cotton cloth and the top with a transparent plastic hardware cloth. The transparent plastic top allowed a maximum amount of light to pass through and it also made it possible to observe the activity of the insects inside.

The second part of the tent trap apparatus consisted of the platform on which the tent rested (Plate II, Figure B). This platform was constructed of a 44 inch square frame with four air-tight bottles used to float it. This platform was equipped with a rope and anchor which held it in place. The platform remained anchored at the station being sampled. By manipulating the tent trap in this manner it was possible to use the same tent at several locations on alternate days. Another advantage of the three-piece tent trap was that it made it possible to keep the trap inside when the sampling was not in progress.

The third part of the tent trap assembly consisted of a 39 square inch piece of masonite board which slid into a grooved area on the underside of the trap (Plate I, Figure B). With this board in position it was possible to transport the tent from the field to the laboratory where the insects were removed with an aspirator.

## Sampling of Bottom Deposits

All of the quantitative bottom deposit samples were taken with an Ekman dredge. The Ekman sampler collected a sample from a 36 square inch surface area. Bottom deposit samples were taken as near as possible at weekly intervals at the Lake City ponds and biweekly periods at the Kellogg Forest ponds.

The sample was taken by carefully wading to the area to be sampled and lowering the open dredge to the pond bottom. After the dredge was closed it was raised slowly until its top was just under the surface of the water. The sorting screen was placed beneath the dredge while it was still submerged and both were lifted from the water. The entire contents of the dredge, as well as any materials released into the sorting screen, were emptied into a pail which was taken to a central sorting area. All material that would wash through an 18 mesh screen was sifted out. At the Lake City station the organisms were removed from the residue while they were still alive. A small quantity of material containing the live animals was transferred to a white enamel pan where they were easily seen and removed.

The bottom deposit samples taken from the Kellogg Forest ponds were taken with the Ekman dredge following the same procedure as that above for the Lake City samples. The residue containing the insects which remained after the Kellogg Forest samples had been washed was transferred to a one or two quart Mason jar. To preserve the material for future study, formalin was added to the jar containing the sample.

In the laboratory a modification of the flotation method described by Welch (1948) and used by Lyman (1952) in his investigation of the bottom fauna of the Watts Bar Reservoir was employed for separating the organisms from the debris. The preserved field residue was placed in an 18-mesh screen and thoroughly rewashed. After the excess water had drained off, the sample was subdivided into portions convenient for handling. Each subsample was placed in a white enamel pan and flooded with a saturated solution of sodium chloride. Each sample was stirred vigorously and as the organisms floated to the surface they were transferred into Carls Solution. This procedure of stirring followed by the removal of the organisms was carried out five times for each subsample. A series of samples was run to determine the effectiveness of the flotation method. It was found that after five times of alternately stirring and removing the floating organisms, 96 percent of the organisms could be removed. The absence of aquatic vegetation, as well as the predominance of sand and fine muck in the Kellogg Forest samples, made the salt-flotation method especially applicable. At station III, where the predominant bottom deposit was pulpy peat, it was necessary to allow the sample to stand eight to ten minutes after each stirring so that the pulpy peat would settle to the bottom. All immature organisms were preserved in Carls Solution for future study. The transfer of the organisms from formalin to sodium chloride and then into Carls Solution did not cause injury to those structures used for taxonomic determinations.

## Laboratory Methods

Immediately after the Mason jar containing the adult specimens was removed from the funnel section of the trap, it was taken directly to the laboratory. The lid was removed from the sampling jar and a one quart cyanide killing bottle was placed in the mouth of the jar. As soon as possible after the insects were killed they were removed from the jar and placed on a white sheet of paper. It was necessary to remove the insects immediately to prevent them from becoming trapped in the water which often condensed on the sides of the jar. It was found that by classifying and pinning the specimens within 24 hours after they were taken from the ponds they were easier to work with and the characteristics used for making determinations were more pronounced.

All adult specimens of the family Tendipedidae were classified by the author. Verifications of the determinations of the family Tendipedidae were made by Dr. W. W. Wirth of the U. S. National Museum. All other Diptera were determined by Dr. Wirth. The adult and immature Ephemeroptera were determined by Dr. Lewis Berner of the University of Florida. The adult Trichoptera were determined by Dr. Herbert Ross of the Illinois Natural History Survey. All of the immature insects, with the exception of the mayfly nymphs, were determined by the author.

Taxonomic keys are not available for many of the species of the tribe Tendipedini identified in the adult study. Nevertheless it was often possible to associate adult and larval cycles at a station and in that way make species determinations of larval specimens. At the Lake City station the number of species present was greater and cyclic variations were not as pronounced as those collected from the Kellogg Forest ponds. For this reason the larval classification of the immature midges from the Lake City ponds was restricted to tribe determination. A metric rule, graduated in millimeters, was used to measure the length of all immature specimens taken from the Kellogg Forest ponds. Following the numerical recording of the immature organisms, quantitative volumetric measurements were made for each taxonomic group. A modification of the procedure used by Ball (1948) in his investigation of available fish food was followed in making the volumetric determination. It was found that volumetric measurements of single specimens of the smaller invertebrates, as well as of groups such as the tribe Calopsectrini, were not accurate. For this reason volumetric measurements were restricted to the taxonomic groups containing larger and more numerous specimens. Immediately following the subdivision of a sample into various taxonomic categories, volumetric measurements were made. First, the group of organisms to be measured was spread out on absorbent paper just long enough to allow the liquid to drain from the specimens. Care was exercised to prevent the specimens from losing moisture by evaporation. The organisms were then transferred to a graduated centrifuge tube which had previously been calibrated against a burette having the same graduation values. The centrifuge tube and its contents were then placed under a burette, and enough liquid to cover the sample was allowed to run out. The difference between the reading on the burette and the reading on the centrifuge tube was the volume of the immature insects. Each taxonomic group was preserved in separate vials after the quantitative measurements were made.

## PRESENTATION AND ANALYSIS OF DATA

### Numerical Distribution of Taxonomic Groups

#### Adult Insects

A total of 626 adult insect samples were taken from the Lake City reservoir and ponds and the Kellogg Forest ponds during 1952 and 1953. Of these 626 samples, 514 were collected during 1952 at the Lake City station and the remaining 112 from the Kellogg Forest tract during 1953. Table III gives a breakdown of the number of samples taken with the different types of adult samplers. From these 626 adult samples there were 10,409 insects removed and classified. This would represent an average of 20.11 insects emerging from one square yard during each sampling period. Considering the Lake City and Kellogg Forest ponds separately the average would be 22.16 and 11.1 insects per square yard, respectively. The Lake City ponds and reservoir area produced 88 percent of the adult insects. The 10,409 adult insects belonged to the following four orders: Diptera, Ephemeroptera, Trichoptera, and Coleoptera (Table II). The order Diptera, with a total of 10,327 insects, made up 99.3 percent of the total number of insects sampled. Specimens belonging to ten families

TABLE II

LIST OF INSECTS REMOVED FROM THE ADULT TRAPS

Order Diptera

Family Tendipedidae

Subfamily Pelopiinae

1. Procladius culiciformis (Linnaeus)
2. Procladius bellus (Loew)
3. Procladius riparius (Malloch)

4. Pentaneura, Probably monilis (Linnaeus)
5. Pentaneura guttipennis (Van derWulp)
6. Pentaneura group E of Johannsen and Townes 1952
7. Pentaneura sp.

8. Pelopia stellata (Coquillett)

9. Anatopynia dyari (Coquillett)

10. Clinotanypus nervosus (Meigen)

Subfamily Hydrobaeninae

1. Cricotopus trifasciatus (Panzer)
2. Cricotopus sp.

3. Hydrobaenus (? Chaetocladius) sp.
4. Hydrobaenus sp.

5. Corynoneura spp.

Subfamily Tendipedinae

Tribe Calopsectrini

TABLE II (Continued)

Subfamily Tendipedinae (continued)

Tribe Tendipedini

1. Pseudochironomus banksi Townes

2. Lauterborniella varipennis (Coquillett)

3. Microtendipes pedellus pedellus (DeGeer)

4. Polypedilum sordens (Wulp)
5. Polypedilum simulans Townes
6. Polypedilum nubeculosum (Meigen)

7. Tanytarsus nigricans (Johannsen)
8. Tanytarsus protextus Townes
9. Tanytarsus annulicrus Townes

10. Stenochironomus hilaris (Walker)

11. Cryptochironomus digitatus (Malloch)
12. Cryptochironomus fulvus (Johannsen)
13. Cryptochironomus psittacinus (Meigen)

14. Tendipes modestus (Say)
15. Tendipes nervosus (Staeger)
16. Tendipes dux (Johannsen)
17. Tendipes brunneipennis (Johannsen)
18. Tendipes decorus (Johannsen)
19. Tendipes tuxis (Curran)
20. Tendipes atrella Townes
21. Tendipes staegeri (Lundbeck)
22. Tendipes plumosus (Linnaeus)
23. Tendipes tentans (Fabricius)

24. Glyptotendipes brachialis (Coquillett)
25. Glyptotendipes paripes (Edwards)
26. Glyptotendipes lobiferus (Say)

TABLE II (Continued)

Subfamily Tendipedinae (continued)

Tribe Tendipedini (continued)

27. Harnischia abortiva (Malloch)
28. Harnischia tenuicaudata (Malloch)
29. Harnischia pseudotener (Goethghebuer)
30. Harnischia viridulus (Linnaeus)

Family Heleidae

1. Jenkinshelea albaria (Coquillett)

2. Culicoides biguttatus (Coquillett)
3. Culicoides crepuscularis Malloch
4. Culicoides spinosus Root and Hoffman

5. Forcipomyia bipunctata (Linnaeus)

6. Dasyhelea grisea (Coquillett)

7. Bezzia glabra (Coquillett)
8. Bezzia sp. probably opaca (Loew)

9. Atrichopogon sp.

10. Johannsenomyia n. sp.

Family Culicidae

1. Chaoborus punctipennis (Say)
2. Chaoborus flavicans (Meigen)

Family Tipulidae

1. Polymeda caloptera (Say)
2. Shannonomyia lenta (O. S.)

TABLE II (Continued)

Order Diptera (continued)

Family Liriopidae

1. Liriope rufocinctus (O. S.)

Family Psychodidae

1. Telmatoscopus furcatus (Kinc.)

Family Itonididae

1. Contarinia sp.

Family Musidoridae

1. Musidora furcata (Fallen)

Family Ephydridae

1. Hydrellia cruralis Coquillett
2. Hydrellia proctori Cresson?
3. Hydrellia sp. near griseola (Fallen)
4. Lemnaphila scotlandae Cresson

Family Stratiomyidae

1. Hedriodiscus vertebratus (Say)

Order Coleoptera

Family Chrysomelidae

1. Neohaemonia nigricornis (Kby.)

TABLE II (Continued)

Order Ephemeroptera

Family Baetidae

1. Callibaetis fluctuans (Walsh)
2. Callibaetis hageni
3. Callibaetis sp.
4. Cloeon mendax (Walsh)
5. Cloeon sp.

Family Caenidae

1. Caenis simulans McDunnough
2. Caenis sp.

Family Ephemeridae

1. Hexagenia sp.

TABLE III

NUMBER OF SAMPLES TAKEN WITH THE ADULT SAMPLING DEVICES

| Pond or Station | Type of Sampling Device | | | |
|---|---|---|---|---|
| | 1 sq. yd. Funnel | $\frac{1}{2}$ sq. yd. Funnel | $\frac{1}{2}$ sq. yd. Funnel (suspended) | $\frac{1}{2}$ sq. yd. Tent |
| Lake City Ponds | | | | |
| Pond "A" . . . . . . | 40 | | | |
| Pond "B" . . . . . . | 77 | 40 | 40 | 40 |
| Pond "C" . . . . . . | 40 | | | |
| Pond "D" . . . . . . | 77 | | | |
| Pond "E" . . . . . . | 40 | | | |
| Pond "F" . . . . . . | 40 | | | |
| Lake City Reservoir | | | | |
| Station "a" . . . . . | | 20 | | 20 |
| Station "b" . . . . . | | 20 | | |
| Station "c" . . . . . | | 20 | | |
| Kellogg Forest Ponds | | | | |
| Pond 1 . . . . . . . . | 16 | | | |
| Pond 2, Station I . | 16 | | | |
| Pond 2, Station II . | 16 | | | |
| Pond 2, Station III. | 16 | | | 16 |
| Pond 2, Station IV. | | 16 | | |
| Pond 2, Station V . | | 16 | | |
| Total . . . . . . . . . . . . | 378 | 132 | 40 | 76 |

of Diptera were identified from the adult samples. Table IV gives the numerical distribution of the various taxonomic groups identified.

The numerical distribution as well as the various taxonomic groups sampled at the Lake City ponds during 1952 compare very closely with those present in the 1953 Kellogg Forest pond samples. The order Trichoptera was the only group which was not represented in the 1952 Kellogg Forest pond samples. In an earlier study of the same Lake City ponds a similar distribution of taxonomic groups was observed (Guyer, 1952).

The family Tendipedidae was represented by 8,527 insects, or 82 percent of the total production (Figure 2). The insects belonging to the family Tendipedidae were distributed among the subfamilies Pelopiinae, Tendipedinae, and Hydrobaeninae.

At the Lake City station the tribe Calopsectrini was the most productive group, contributing 40.9 percent of the adult insects. At the Kellogg Forest ponds 59 percent of the adults sampled were members of the tribe Tendipedini, making this the most productive taxonomic group. The subfamilies Pelopiinae and Hydrobaeninae were responsible for 10.8 percent of the total adult production.

The Dipterous families Culicidae, Heleidae, Itonididae, Tipulidae, Liriopidae, Psychodidae, Musidoridae, Ephydridae, and Stratiomyidae were also represented in the adult samples.

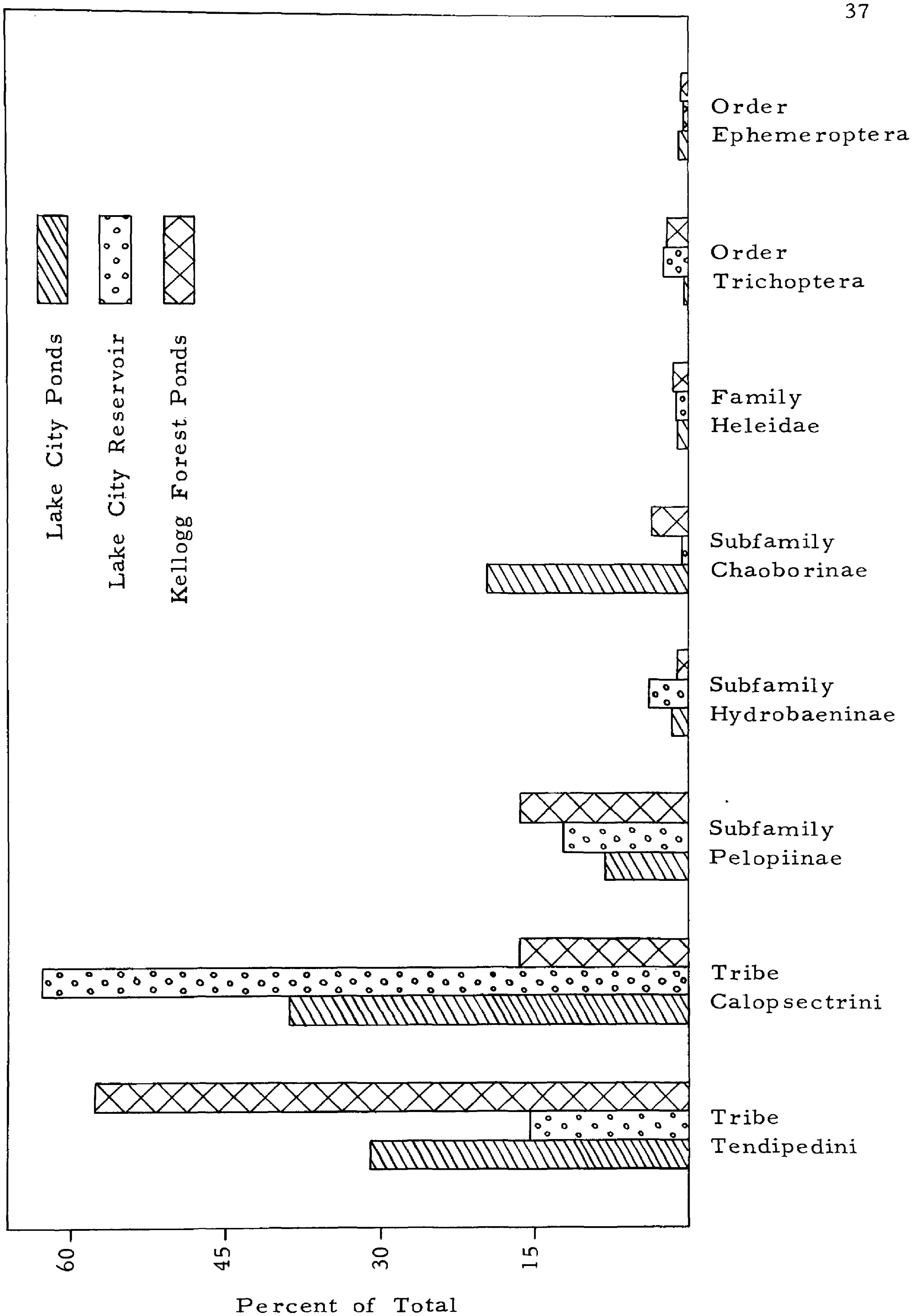
TABLE IV

NUMERICAL DISTRIBUTION OF ADULT INSECTS

| Pond and Station | Tribe Tendipedini | Tribe Calopsectrini | Subfamily Pelopiinae | Subfamily Chaoborinae | Subfamily Hydrobaeninae | Family Heleidae | Order Trichoptera | Order Ephemeroptera | Miscellaneous Insects |
|---|---|---|---|---|---|---|---|---|---|
| Lake City Ponds | | | | | | | | | |
| "A" . . . . . | 161 | 268 | 84 | 1 | 13 | 4 | 1 | 0 | 2 |
| "B" (1 yd.). | 249 | 623 | 73 | 7 | 2 | 8 | 0 | 2 | 2 |
| "B" ($\frac{1}{2}$ yd.). | 55 | 124 | 14 | 1 | 3 | 1 | 0 | 0 | 0 |
| "B" ($\frac{1}{2}$ yd., suspended) . | 70 | 198 | 20 | 3 | 2 | 1 | 2 | 2 | 0 |
| "B" (tent). . | 70 | 286 | 64 | 6 | 12 | 53 | 4 | 0 | 0 |
| "C" . . . . . | 184 | 10 | 9 | 39 | 0 | 1 | 0 | 0 | 0 |
| "D" . . . . . | 1362 | 166 | 82 | 1572 | 3 | 0 | 0 | 2 | 1 |
| "E" . . . . . | 268 | 562 | 159 | 0 | 56 | 15 | 3 | 12 | 0 |
| "F" . . . . . | 159 | 1014 | 155 | 0 | 38 | 4 | 2 | 9 | 1 |
| Reservoir | | | | | | | | | |
| "a" . . . . . | 40 | 83 | 9 | 1 | 0 | 1 | 2 | 1 | 0 |
| "a" (tent) . . | 59 | 331 | 74 | 2 | 15 | 6 | 4 | 2 | 0 |
| "b" . . . . . | 13 | 48 | 8 | 1 | 2 | 1 | 1 | 1 | 0 |
| "c" . . . . . | 12 | 41 | 9 | 1 | 13 | 1 | 1 | 1 | 1 |
| Kellogg Forest | | | | | | | | | |
| Pond 1 . . . | 4 | 0 | 134 | 0 | 0 | 7 | 0 | 0 | 0 |
| Pd. 2, st. I . | 154 | 18 | 10 | 17 | 0 | 0 | 0 | 2 | 0 |
| Pd. 2, st. II . | 206 | 167 | 37 | 2 | 0 | 3 | 0 | 3 | 0 |
| Pd. 2, st. III | 21 | 2 | 0 | 3 | 2 | 1 | 0 | 2 | 0 |
| Pd. 2, st. III (tent) . . . . . | 94 | 1 | 12 | 21 | 1 | 0 | 0 | 5 | 0 |
| Pd. 2, st. IV | 82 | 10 | 9 | 0 | 7 | 3 | 0 | 10 | 5 |
| Pd. 2, st. V . | 171 | 7 | 3 | 1 | 0 | 2 | 0 | 2 | 4 |
| Total . . . . . . . | 3434 | 3959 | 965 | 1678 | 169 | 112 | 20 | 56 | 16 |

FIGURE 2

PERCENTAGE DISTRIBUTION OF ADULT TAXONOMIC GROUPS



The three families of Ephemeroptera identified from the samples were Baetidae, Caenidae, and Ephemeridae. Only twenty Trichoptera specimens were collected. A single specimen of the order Coleoptera was taken from the traps and this belonged to the family Chrysomelidae. In the following section the taxonomic groups mentioned above will be subdivided and the important species discussed ecologically and in respect to numbers. Although some of the groups were represented by only a small number of specimens and in some cases single insects, all of the groups represented will be presented. Many of the species taken have not been reported from adult trapping devices of the type used in this study. The fact that they will successfully emerge and develop in such a situation appears to be sufficient reason to include all insects in this discussion.

Tribe Tendipedini. The tribe Tendipedini, according to Townes (1945), includes 201 described species of midges from the Nearactic region. Numerous papers have been devoted to the taxonomic and ecological discussion of the adults of this group. It is the larvae of the tribe Tendipedini that have received extensive consideration by research workers for the part they play in the food chain of various fish as well as their connection with industrial polution.

In this investigation 3,434 adult midges of the tribe Tendipedini were collected. This represented 33.0 percent of all insects sampled. The Lake City ponds produced 78.1 percent of the midges taken. The four stations in the Lake City reservoir produced only 124 insects belonging to the tribe Tendipedini, which was only 3 percent of the total production of the tribe. The Kellogg Forest ponds provided the remaining 19.0 percent of the Tendipedini production.

There were thirty species belonging to ten genera of Tendipedini represented in the adult samples (Table V). Ten of these thirty species were members of the genus Tendipes which were responsible for 68.1 percent of the total Tendipedini production. There were 606 specimens of Tendipes brunneipennis identified, which were 17.6 percent of the 3,434 Tendipedini removed from the traps. This indicated that T. brunneipennis was the most productive species of the tribe Tendipedini. All of the T. brunneipennis specimens were taken from the Lake City ponds and reservoir. The following ten species, Lauterborniella varipennis, Polypedilum nubeculosum, Tanytarsus protextus, Tanytarsus anulicrus, Stenochironomus hilaris, Cryptochironomus psittacinus, Glyptotendipes brachialis, Harnischia abortiva, Harnischia tenuicaudata, Harnischia pseudotener, of the tribe Tendipedini contributed less than five specimens each and were

TABLE V

DISTRIBUTION OF THE SPECIES OF THE TRIBE TENDIPEDINI

| Species | No. of Insects | Pct. of Total |
|---|---|---|
| Pseudochironomus banksi Townes | 67 | 1.9 |
| Lauterborniella varipennis (Coquillett) | 3 | * |
| Microtendipes pedellus pedellus (DeGeer) | 267 | 7.8 |
| Polypedilum sordens (Wulp) | 11 | 0.3 |
| Polypedilum simulans Townes | 82 | 2.4 |
| Polypedilum nubeculosum (Meigen) | 1 | |
| Tanytarsus nigricans (Johannsen) | 112 | 3.4 |
| Tanytarsus protextus Townes | 1 | |
| Tanytarsus annulicrus Townes | 1 | |
| Stenochironomus hilaris (Walker) | 3 | |
| Cryptochironomus digitatus (Malloch) | 40 | 1.2 |
| Cryptochironomus fulvus (Johannsen) | 55 | 1.6 |
| Cryptochironomus psittacinus (Meigen) | 1 | |
| Tendipes modestus (Say) | 25 | 0.7 |
| Tendipes nervosus (Staeger) | 249 | 7.3 |
| Tendipes dux (Johannsen) | 131 | 3.8 |
| Tendipes brunneipennis (Johannsen) | 606 | 17.6 |
| Tendipes decorus (Johannsen) | 227 | 6.6 |
| Tendipes tuxis (Curran) | 394 | 11.5 |
| Tendipes atrella Townes | 235 | 6.8 |
| Tendipes staegeri (Lundbeck) | 410 | 11.9 |
| Tendipes plumosus (Linnaeus) | 63 | 1.8 |
| Tendipes tentans (Fabricius) | 5 | 0.1 |
| Glyptotendipes brachialis (Coquillett) | 2 | |
| Glyptotendipes paripes (Edwards) | 339 | 9.9 |
| Glyptotendipes lobiferus (Say) | 23 | 0.7 |
| Harnischia abortiva (Malloch) | 2 | |
| Harnischia tenuicaudata (Malloch) | 1 | |
| Harnischia pseudotener (Goethghebuer) | 1 | |
| Harnischia viridulus (Linnaeus) | 77 | 2.2 |

* Species with five or less specimens contributed less than 0.5 percent of the total Tendipedini production.

TABLE V (Continued)

| Ponds or Stations Present | | |
|---|---|---|
| Lake City Ponds | Lake City Reservoir | Kellogg Forest Ponds |
| A, E, F | | |
| A, B | a | |
| B, C, D, E, F | a, b, c | |
| B, E | a, c | |
| C, D, F, | | II, III |
| F | | |
| B, D, E, F | a | |
| A | | |
| | | II |
| | a | |
| B, C, D | | |
| B, C, D | | |
| B | | |
| B, E, F | a | I, II |
| A, B, D, E, F | a, b, c | II |
| | | I, II, III, IV, V |
| A, B, C, D, E, F | a | |
| B, C, D | c | I, II, III, IV |
| B, D, E, | b, c | I, II, III |
| B | b | I, II, III, IV, V |
| B, C, D | a, b | Pond 1 |
| B | a | |
| | | IV, V |
| D | | |
| B, D | b, c | I, II, III, IV, V |
| B, D, F | a | |
| D | | |
| E | | |
| B | | |
| B, C, D, E, F | a, b, c | Pond 1 |

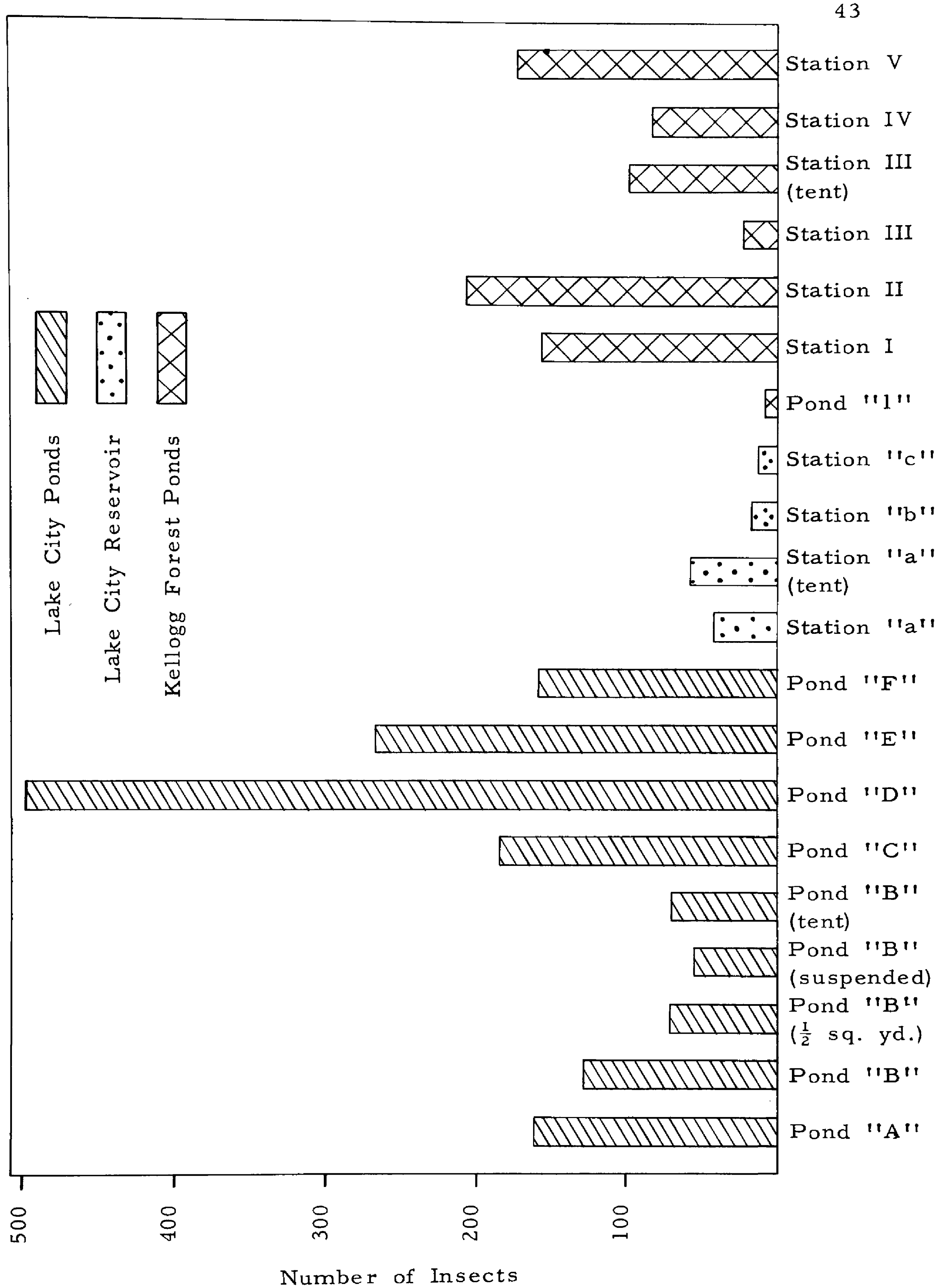
responsible collectively for 0.5 percent of the total Tendipedini production.

The Lake City ponds were represented by twenty-seven species of Tendipedini. The three species not taken from the Lake City ponds were T. anulicrus, S. hilaris, and Tendipes tentans. There were sixteen species of Tendipedini identified from the reservoir area. The 732 Tendipedini specimens from the Kellogg Forest ponds were members of thirteen species. It was interesting to note that Kellogg Forest pond "1" was represented by only two species of the tribe Tendipedini and by a total of four specimens.

Figure 3 shows the numerical distribution of the Tendipedini specimens in the various ponds and stations. The number of Tendipedini represented on the graph for ponds "B" and "D" are based on the same number of samples as the other Lake City ponds. The shallow, fertilized pond "D" produced 52.8 percent of the Tendipedini specimens taken from the Lake City ponds. An earlier study by Guyer (1952) of these ponds indicated that fertilization of the shallow ponds greatly increased the Tendipedini production. Station "a" in the Lake City reservoir was four times as productive of Tendipedini adults as stations "b" and "c." In Kellogg Forest pond "2" the greatest production of Tendipedini adults occurred at the shallow

FIGURE 3

NUMERICAL DISTRIBUTION OF THE TRIBE TENDIPEDINI



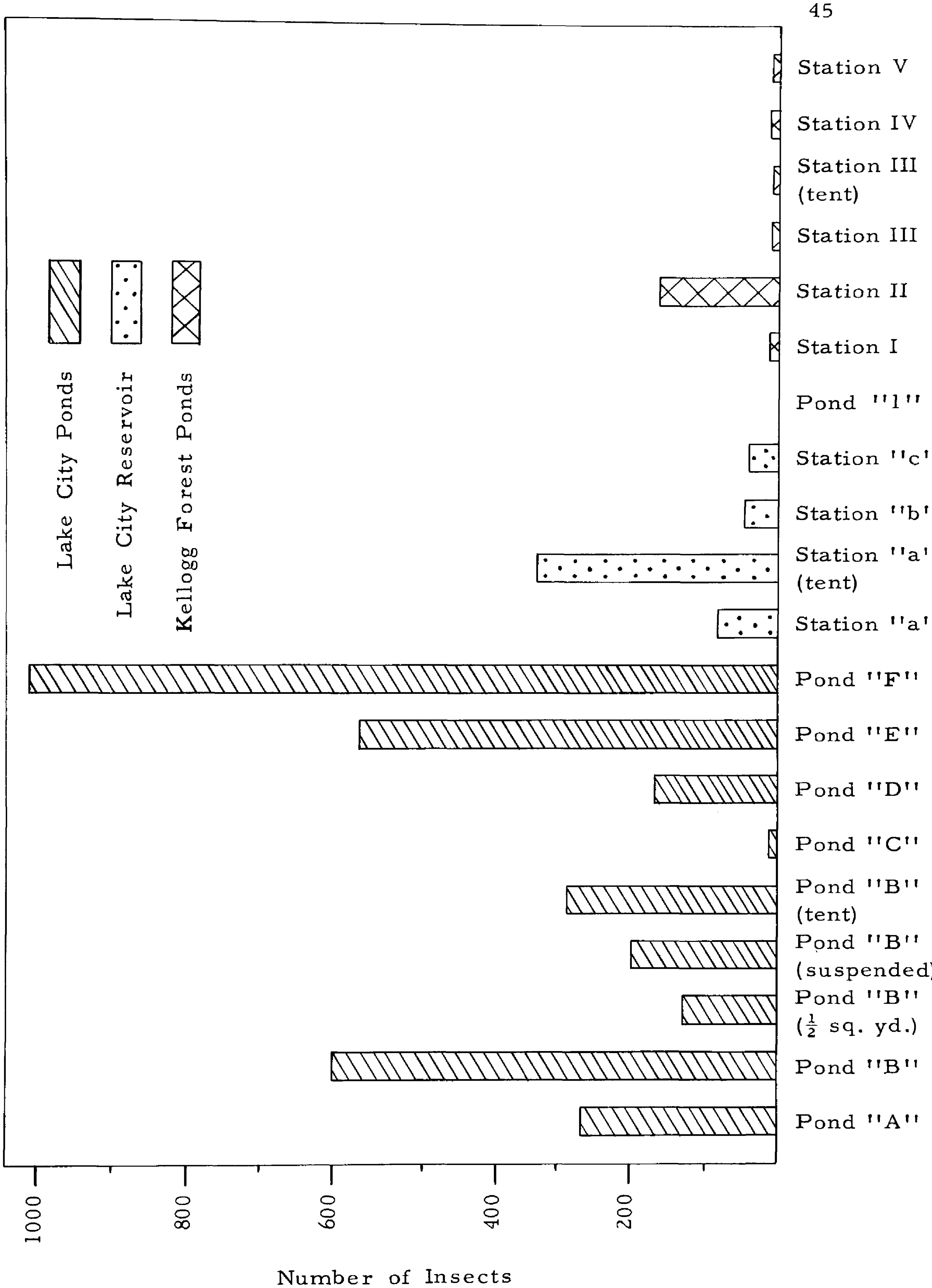
stations. From these data it appears that in the Lake City reservoir and Kellogg Forest pond "2" ecological conditions such as bottom composition, vegetation, and location are more important in the regulation of the Tendipedini production than the depth of the water.

Tribe Calopsectrini. The tribe Calopsectrini was the most productive of all adult insect groups. There were 3,959 adult insects identified belonging to the tribe Calopsectrini, which was 38.1 percent of the total adult production. The Lake City ponds and reservoir produced 94.8 percent of the Calopsectrini. The tribe Calopsectrini was not subdivided into further taxonomic divisions. The reason for identifying these insects to tribe only was that the taxonomic treatment of the adult Calopsectrini is not complete. Edwards (1929) made a preliminary classification of the group and Johannsen and Townes (1952) proposed a key to the northeastern species. An attempt was made to identify the Calopsectrini in this study using the above references. Many of the species collected did not fit the keys and taxonomic discussions given for the group. Also, specimens sent to the United States National Museum were returned identified to tribe only.

The Calopsectrini were represented in all of the ponds and collecting areas. Figure 4 shows the numerical distribution of the tribe Calopsectrini at the various sampling stations. It was apparent

FIGURE 4

NUMERICAL DISTRIBUTION OF THE TRIBE CALOPSECTRINI



from the data taken from the fertilization work at the Lake City ponds that the tribe Calopsectrini did not respond directly to fertility as did the tribe Tendipedini. The Calopsectrini production appeared to be regulated to a certain degree by the depth of water. It was the deeper ponds and those stations that were in the deeper areas of the reservoir that were the greatest producers of the Calopsectrini.

The most interesting phenomenon connected with the tribe Calopsectrini was the significant predominance of female specimens. Of the 3,959 insects taken from adult traps, 2,962, or 74.8 percent, were female specimens. This same predominance of females was observed during the fertilization studies conducted at the Lake City ponds during 1951. During the fertilization study 80 percent of the Calopsectrini were females. The Calopsectrini specimens collected immediately following the disappearance of the ice cover in the spring had the same predominance of female insects. The uneven ratio of females to males continued until September. There were 141 Calopsectrini specimens collected after September 1 during the two-year study. Of these 141 insects, 71 were females and 70 were males. Although the fall production of the tribe Calopsectrini was not large, there was an indication of a 50:50 sex ratio. Only further research perhaps will determine whether this is the result of a parthenogenetic summer generation or some other phenomenon. Hauber (1944), in his paper on the life histories of this group and ecology of Iowa midges, made no mention of this uneven sex ratio. When this group is better understood taxonomically perhaps the reason for this uneven sex ratio will be apparent. A statistical presentation of this uneven sex ratio will be considered in a following section.

Subfamily Pelopiinae. The 965 insects belonging to the subfamily Pelopiinae represented 9.3 percent of the total adult insect emergence. There were ten species represented in the production of the subfamily Pelopiinae. The following four species, *Procladius culiciformis*, *Procladius bellus*, *Pentaneura monilis*, and *Pelopia stellata*, were responsible for 97.6 percent of the total Pelopiinae production.

Table VI gives the percentage distribution of the species of Pelopiinae as well as the ponds from which the species were represented. All of the species with the exception of *Anatopynia dyari* were sampled at least once from the Lake City ponds. The Lake City reservoir and Kellogg Forest ponds both contributed five species of Pelopiinae. *P. bellus* was the most widely distributed species of the tribe Pelopiinae. This species was identified from all of the ponds as well as from all stations with the exception of station IV in Kellogg Forest pond "2." Of the 145 insects removed from the adult trap

TABLE VI

DISTRIBUTION OF THE SUBFAMILY PELOPIINAE

| Species | No. of Insects | Pct. of Total |
|---|---|---|
| Procladius culiciformis (Linnaeus) | 306 | 31.7 |
| Procladius bellus (Loew) | 216 | 23.8 |
| Procladius riparius (Malloch) | 2 | 0.2 |
| Pentaneura monilis (Linnaeus) | 282 | 31.1 |
| Pentaneura guttipennis (Van derWulp) | 3 | 0.3 |
| Pentaneura group E of Johannsen and Townes 1952 | 7 | 0.8 |
| Pentaneura sp. | 4 | 0.3 |
| Pelopia stellata (Coquillett) | 137 | 15.1 |
| Anatopynia dyari (Coquillett) | 7 | 0.8 |
| Clinotanypus nervosus (Meigen) | 1 | |

TABLE VI (Continued)

| Ponds or Stations Present | | |
|---|---|---|
| Lake City Ponds | Lake City Reservoir | Kellogg Forest Ponds |
| A, B, C, D, E, F | a, b, c | Pond 1 |
| A, B, C, D, E, F | a, b, c | Pond 1, I, II, III, IV |
| F | a, b | |
| A, B, E, F | a, b | II, IV, V |
| E, F | | |
| F | | |
| A, E | | |
| B, C, D | a, b, c | |
| | | III, IV |
| B | | |

in Kellogg Forest pond "1," 92.4 percent were members of the subfamily Pelopiinae.

There were three species identified from the collections made from Kellogg Forest pond "1" but 76.1 percent of the Pelopiinae were P. stellata specimens. If an attempt were made to classify the ponds as to the type of fauna present, Kellogg Forest pond "1" would be considered a Pelopiinae type pond.

Subfamily Hydrobaeninae. The subfamily Hydrobaeninae, which was the third subfamily of the family Tendipedidae represented in the adult samples contributed 169 adult insects. The insects identified as members of the subfamily Hydrobaeninae represented 1.6 percent of the total adult production. The Lake City ponds contributed 76 percent of the specimens belonging to the subfamily Hydrobaeninae.

There were three genera identified belonging to the subfamily Hydrobaeninae. From these three genera it was possible to identify only one species, Cricotopus trifasciatus. One-third of the Hydrobaeninae specimens were taken from Lake City pond "E." Of the Hydrobaeninae specimens removed from the pond "E" adult trap, 98 percent were a single unidentified species of the genus Hydrobaenus. This unidentified species, which was so predominant in pond "E," was the most numerous species of the subfamily Hydrobaeninae.

C. trifasciatus was taken from Lake City ponds "B" and "E" as well as station IV in Kellogg Forest pond "2." It is interesting to note that the larvae of this insect have been reported by Johannsen (1937) and Willem (1910) as mining in the floating leaves of the pond lily. Thienemann (1933) and Berg (1950) associated the larvae of this species with Potamogeton natans, P. amplifolius, and P. nodosus. None of the higher aquatic plants associated with this insect by other investigators were present at the sampling areas where C. trifasciatus was taken in this study. The only vegetation that might be associated with C. trifasciatus in this study was the Chara sp. and Spirogyra sp. present in pond "E" and the dense sod mat at station IV. Miller (1941) reported C. trifasciatus adults emerging into adult tent traps set over deep as well as shallow water. It appears that the biology of C. trifasciatus is exceedingly variable and the insect may have adapted itself to various ecological situations.

The shallow ponds "C" and "D" produced only three Hydrobaeninae specimens. The specimens of the subfamily Hydrobaeninae appeared to prefer the deeper ponds as well as those that contained some type of higher aquatic vegetation. Where a dense phytoplankton growth was present the subfamily Hydrobaeninae was poorly represented.

*Family Culicidae*. The family Culicidae was restricted to a single genus and two species which were members of the subfamily Chaoborinae. A total of 1,678 Culicidae specimens were captured in the adult traps. The Culicidae production represented 16.1 percent of the total adults removed from the traps. The Lake City ponds produced 97 percent of the culicid adults and Lake City pond "D" provided 93 percent of the culicids.

The two species of culicids identified were *Chaoborus punctipennis* and *Chaoborus flavicans*. There were 1,560 *C. punctipennis* specimens identified, which was 93 percent of the insects identified belonging to the family Culicidae. Of the 118 *C. flavicans* specimens identified, 64 percent were taken from Lake City pond "D." A single specimen was identified from Lake City pond "B." The remaining 42 *C. flavicans* adults were taken from the traps in Kellogg Forest pond "2." Lake City pond "D," producing 1,497 *C. punctipennis* specimens, was also the most productive station for this species.

It was interesting to note that in the Lake City ponds the culicid production was composed of 96 percent *C. punctipennis* specimens, while at the Kellogg Forest ponds, *C. flavicans* contributed 93 percent of culicid specimens. The shallow ponds were much more productive of culicid specimens than the deeper ponds. *C. punctipennis* appeared to prefer an environment with high fertility and concentrated plankton production.

Family Heleidae. There were seven genera represented by the 112 adult specimens belonging to the family Heleidae. The family Heleidae contributed 1.1 percent of the total adult specimens. Ten species were identified from the family Heleidae, one of which was a new species. The Lake City ponds produced 86 percent of the adult heleid specimens, with the tent trap in pond "B" contributing 46 percent.

Table VII gives the number of specimens contributed by each species and the ponds where each species was collected. A single species, *Jenkinshelea albaria*, produced 72 percent of all heleid specimens captured. The ecological requirements of the family Heleidae could not be ascertained. It was apparent that the deeper ponds were preferred over the shallow ones and that fertilization and plankton production had little effect on heleid abundance.

Order Ephemeroptera. There were fifty-six mayfly specimens captured in the adult traps, which represented only 0.5 percent of the total adult production. Four genera of mayflies were identified belonging to the families Baetidae, Caenidae, and Ephemeridae. It was

TABLE VII

DISTRIBUTION OF THE SPECIES OF THE FAMILY HELEIDAE

| Species | No. of Insects | Pct. of Total |
|---|---|---|
| Jenkinshelea albaria (Coquillett) . . . . . . . . . . . | 81 | 72.0 |
| Culicoides biguttatus (Coquillett) . . . . . . . . . . | 1 | 0.8 |
| Culicoides crepuscularis (Malloch) . . . . . . . . . | 1 | 0.8 |
| Culicoides spinosus Root and Hoffman . . . . . . | 2 | 2.0 |
| Forcipomyia bipunctata (Linnaeus) . . . . . . . . . | 1 | 0.8 |
| Atrichopogon sp. . . . . . . . . . . . . . . . . . . . . . | 1 | 0.8 |
| Dasyhelea grisea (Coquillett) . . . . . . . . . . . . . | 4 | 3.7 |
| Johannsenomyia n. sp. . . . . . . . . . . . . . . . . . | 6 | 5.5 |
| Bezzia glabra (Coquillett) . . . . . . . . . . . . . . . . | 8 | 7.3 |
| Bezzia sp. probably opaca (Loew) . . . . . . . . . | 7 | 6.3 |

TABLE VII (Continued)

| Ponds or Stations Present | | |
|---|---|---|
| Lake City Ponds | Lake City Reservoir | Kellogg Forest Ponds |
| A, B, E, F | a | |
| C | | |
| | | III |
| B | | |
| | | IV |
| | | IV |
| | | IV |
| | a | |
| A, E, F | | |
| F | | II |

possible to identify four species of mayflies from the adult collection. There were seventeen adult specimens which were subimagos and these insects could be classified to genus only.

Table VIII gives the numerical and percentage distribution as well as the ponds represented by the various species. The only species of mayfly identified from the Kellogg Forest ponds was *Callibaetis fluctuans*. There were also twelve subimago specimens taken from Kellogg Forest pond "2" which were members of the genus *Callibaetis*.

At the Lake City ponds three species of mayflies were identified. Subimago specimens were also plentiful at the Lake City ponds, where four genera were represented. Lake City ponds "E" and "F" were the best producers of mayfly specimens. The ecological conditions present in the ponds which were the most productive of mayfly specimens compared closely with those described by Burk (1953) and Needham (1935) for the species identified in this study. They associated these species with permanent ponds which were productive but not filled with vegetation. There were no mayflies collected from the shallow ponds "C" and "D." It appeared that the conditions in these ponds were comparable with those described as ideal for the growth of *Caenis simulans* but this species was not taken from these ponds.

TABLE VIII

DISTRIBUTION OF THE SPECIES OF THE ORDER EPHEMEROPTERA

| Species | No. of Insects | Pct. of Total |
|---|---|---|
| Callibaetis fluctuans (Walsh) | 5 | 8.9 |
| Callibaetis hageni | 5 | 8.9 |
| Callibaetis sp. | 18 | 32.2 |
| Cloeon mendax (Walsh) | 3 | 5.4 |
| Cloeon sp. | 10 | 17.9 |
| Caenis simulans McDunnough | 10 | 17.9 |
| Caenis sp. | 4 | 7.1 |
| Hexagenia sp. | 1 | 1.7 |

TABLE VIII (Continued)

| Ponds or Stations Present | | |
|---|---|---|
| Lake City Ponds | Lake City Reservoir | Kellogg Forest Ponds |
| | | II, IV |
| D | a, b, c | |
| | a | II, III, IV, V |
| F | | |
| B, F | | |
| E, F | | |
| E, F | | |
| E | | |

*Miscellaneous insects.* There were sixteen miscellaneous insects which were captured by the adult traps. Seven families of Diptera and one family of Coleoptera were represented by these insects. One note of caution should be injected here. It is possible that since only a small number of diversified specimens were collected, some may have entered the trap when it was being set in the pond. Every precaution was taken to prevent this, and it was thought that the specimens were representative of the pond indicated.

Table IX gives the number of miscellaneous insects collected and the ponds and stations from which each species was taken. The Kellogg Forest pond stations IV and V were responsible for nine of the sixteen miscellaneous insects. The shallow water and decaying sod mat, which existed at these two stations, appeared to provide the conditions necessary for the growth of certain members of the families Psychodidae, Stratiomyidae, Musidoridae, and Ephydridae.

Doctor Willis Wirth reported that two of the species of the family Ephydridae, *Hydrellia proctori* and *Lemnaphila scotlandae*, are very rare. The remaining seven miscellaneous insects were distributed among five ponds with only one specimen of each species being identified from any one pond. It appeared that these insects were extremely rare visitors in the ponds represented by them.

TABLE IX

DISTRIBUTION OF THE MISCELLANEOUS INSECTS

| Species | No. of Insects | Pct. of Total |
|---|---|---|
| Tipulidae | | |
| Polymeda caloptera (Say) . . . . . . . . . . . . . . | 1 | 6.2 |
| Shannonomyia lenta (O. S.) . . . . . . . . . . . . | 1 | 6.2 |
| Liriopidae | | |
| Liriope rufocinctus (O. S.) . . . . . . . . . . . . | 1 | 6.2 |
| Psychodidae | | |
| Telmatoscopus furcatus (Kinc.) . . . . . . . . . | 2 | 12.5 |
| Itonididae | | |
| Contarinia sp. . . . . . . . . . . . . . . . . . . . . . | 1 | 6.2 |
| Musidoridae | | |
| Musidora furcata . . . . . . . . . . . . . . . . . . . | 3 | 12.5 |
| Ephydridae | | |
| Hydrellia cruralis Coquillett . . . . . . . . . . . | 1 | 6.2 |
| Hydrellia proctori Cresson? . . . . . . . . . . . | 1 | 6.2 |
| Hydrellia sp. near griseola (Fallen) . . . . . . | 1 | 6.2 |
| Lemnaphila scotlandae Cresson . . . . . . . . | 2 | 12.5 |
| Stratiomyidae | | |
| Hedriodiscus vertebratus (Say) . . . . . . . . . . | 1 | 6.2 |
| Chrysomelidae | | |
| Neohaemonia nigricornis (Kby.) . . . . . . . . . | 1 | 6.2 |

TABLE IX (Continued)

| Ponds or Stations Present | | |
|---|---|---|
| Lake City Ponds | Lake City Reservoir | Kellogg Forest Ponds |
| D | | |
| F | | |
| | | |
| | | |
| A | | |
| | | |
| | | |
| | | IV |
| | | |
| | | |
| B | | V |
| | | |
| | | |
| B | | |
| | | |
| | | |
| | | IV |
| | | IV |
| | | IV |
| | | V |
| | | |
| | | |
| | | V |
| | | |
| | | |
| A | | |

## Immature Insects

An Ekman dredge bottom sampler was used to take 338 bottom deposit samples from the Lake City ponds and reservoir and the Kellogg Forest ponds during 1952 and 1953. During 1952 there were 161 bottom deposit samples taken from the Lake City ponds and 57 samples from the reservoir. The remaining 120 bottom samples were taken from the two Kellogg Forest ponds during 1953.

In order that the bottom deposit samples from the Lake City ponds would be randomized as much as possible each pond was divided into quadrants. Samples were taken from the quadrants according to a randomized schedule decided on previous to the beginning of the study. This procedure of taking the bottom deposit sample from randomized quadrants was the same method that was followed in sampling the adult insects from the Lake City ponds. In the Lake City reservoir and the Kellogg Forest ponds definite stations were established and both the adult and immature samples were taken at the designated stations. There were no bottom deposit samples taken at stations IV and V in Kellogg Forest pond "2" because of the dense sod mat.

Each time bottom deposit samples were taken from the Kellogg Forest ponds, two samples were taken at each station. The reason for taking two samples at each station was to study the distribution of the organisms over the bottom of the ponds. These data will be discussed in a following section.

The 338 Ekman samples produced 14,343 immature insects which were more than 5 millimeters in length (Table X). This represented a production of forty-two organisms per one-fourth square foot sample. The Kellogg Forest ponds were the most productive sampling areas for immature insects. There were 9,350 immature insects removed from the two Kellogg Forest ponds, which represented 66 percent of the total immature production.

The Lake City ponds contributed 4,088 immature insects, or 28 percent of the total production. The additional 905 immature insects were removed from the Lake City reservoir bottom deposits.

There were five orders of insects represented in the bottom deposit samples. These five orders were Diptera, Ephemeroptera, Odonata, Coleoptera, and Hemiptera. The orders Coleoptera and Hemiptera were represented by so few specimens that they will not be discussed numerically. The following four families of Coleoptera were identified from the bottom deposit samples: Dytiscidae, Gyrinidae, Haliplidae, and Elmidae. The only place where any of the members of the families of the order Coleoptera became numerous

TABLE X

NUMERICAL DISTRIBUTION OF THE IMMATURE INSECTS*

| Pond and Station | Tribe Tendipedini | Subfamily Pelopiinae | Subfamily Chaoborinae | Family Heleidae | Order Ephemeroptera | Suborder Anisoptera | Suborder Zygoptera |
|---|---|---|---|---|---|---|---|
| Lake City Ponds | | | | | | | |
| A . . . . . . . . . . . . . . . . | 144 | 28 | 4 | 13 | 15 | 9 | 0 |
| B . . . . . . . . . . . . . . . . | 149 | 49 | 8 | 25 | 3 | 2 | 0 |
| C . . . . . . . . . . . . . . . . | 590 | 0 | 17 | 4 | 0 | 5 | 0 |
| D . . . . . . . . . . . . . . . . | 1146 | 4 | 1124 | 9 | 13 | 4 | 0 |
| E . . . . . . . . . . . . . . . . | 67 | 81 | 0 | 7 | 193 | 47 | 5 |
| F . . . . . . . . . . . . . . . . | 36 | 58 | 2 | 27 | 145 | 54 | 1 |
| Lake City Reservoir | | | | | | | |
| a . . . . . . . . . . . . . . . . | 62 | 24 | 4 | 53 | 11 | 2 | 0 |
| b . . . . . . . . . . . . . . . . | 403 | 25 | 0 | 12 | 4 | 4 | 2 |
| c . . . . . . . . . . . . . . . . | 210 | 42 | 0 | 1 | 34 | 9 | 3 |
| Kellogg Forest Ponds | | | | | | | |
| Pond 1 . . . . . . . . . . . | 100 | 169 | 0 | 93 | 0 | 0 | 0 |
| Pond 2, st. I . . . . . . . | 2585 | 97 | 6 | 8 | 53 | 13 | 6 |
| Pond 2, st. II . . . . . . . | 3183 | 72 | 10 | 32 | 159 | 25 | 40 |
| Pond 2, st. III . . . . . . | 2193 | 425 | 24 | 45 | 10 | 1 | 1 |
| Total . . . . . . . . . . . . . . . | 10,868 | 1074 | 329 | 1199 | 640 | 175 | 58 |

* This table includes all larvae over 5 millimeters in length.

was in Kellogg Forest pond "2," where the family Gyrinidae was represented in many of the bottom deposit samples by the genus Dineutus. The family Dytiscidae was represented by two genera, Laccophilus and Coptotomus, in Kellogg Forest pond "2."

Water boatman (family Corixidae) specimens were removed from the bottom deposits of all the ponds. The only ponds where a concentrated water boatman population existed were Lake City ponds "E" and "F." Members of the family Notonectidae were also present in many of the ponds, but only two specimens were recovered in the bottom deposit samples.

There were five immature specimens belonging to the family Ephydridae and two members of the family Tipulidae identified from the bottom deposit samples taken from Kellogg Forest pond "2."

The class Crustacea was represented in the bottom deposits by a single species, Hyalella azteca (Saussure). H. azteca was occasionally identified from many of the bottom deposit samples and in Lake City ponds "E" and "F" it was often present in sizeable numbers. The bottom deposit samples from Lake City ponds "C" and "D" produced large numbers of aquatic earthworms (Phylum Annelida). The order Diptera produced 94 percent of the 14,343 immature insects. The family Tendipedidae contributed 83 percent of the immature insects. The immature insects of the family Tendipedidae were members of the subfamilies Tendipedinae and Pelopiinae. The immature forms of the subfamily Hydrobaeninae and the tribe Calopsectrini were not included in the numerical consideration of immature forms. The reason for not considering the subfamily Hydrobaeninae and the tribe Calopsectrini was that all the immature specimens collected belonging to these two taxonomic groups were 5 millimeters or less in length. It was decided that the screens used in handling the immature insects would only accurately sample insects above 5 millimeters in length.

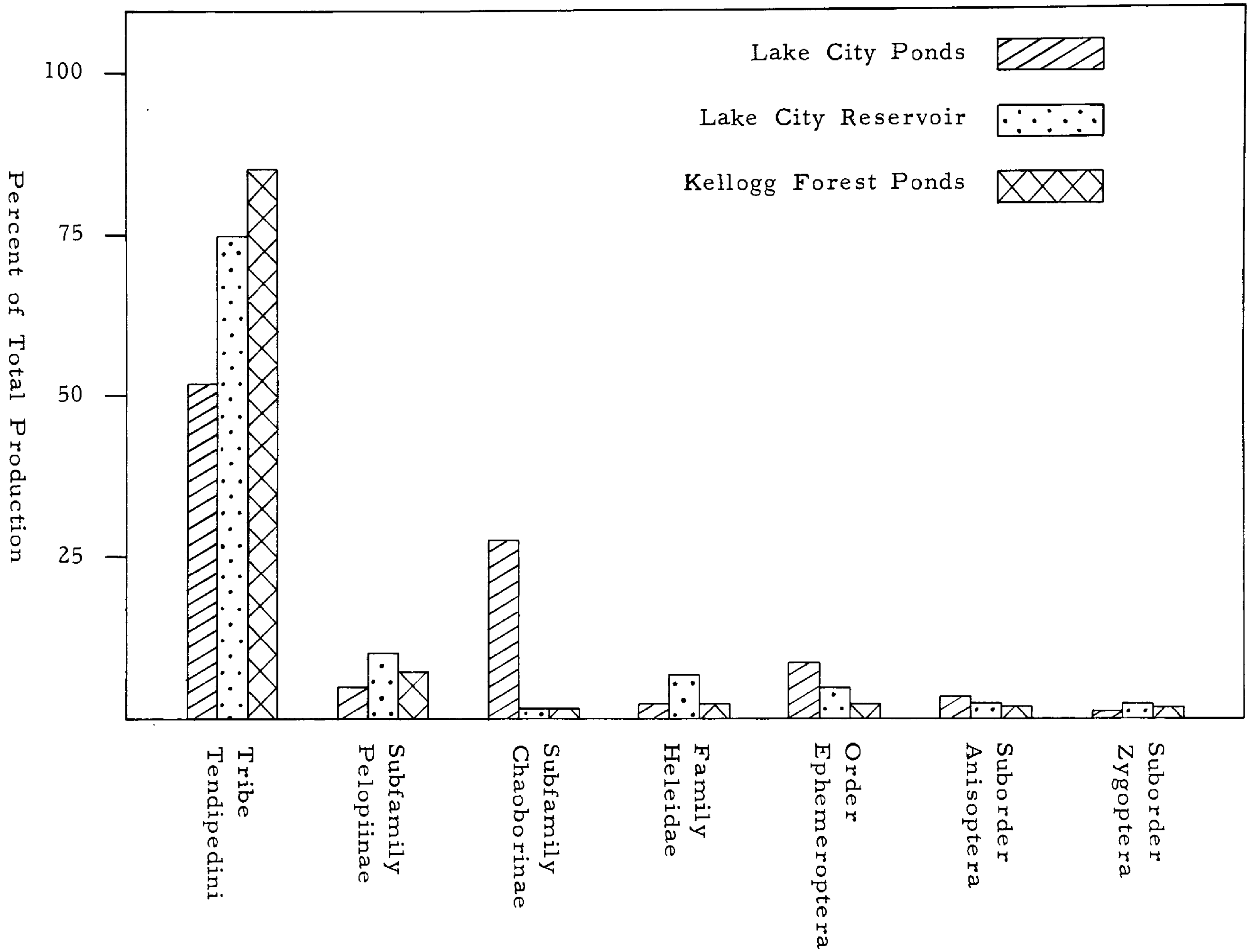
The family Culicidae contributed 8 percent of the immature specimens and all of these larvae were members of the subfamily Chaoborinae. The remaining immature Diptera specimens were members of the family Heleidae. Four percent of the immature specimens were contributed by the order Ephemeroptera. The remaining 2 percent of the immature insects were Odonata specimens.

The highest concentration of immature insects was present in the bottom deposits of Kellogg Forest pond "2." This pond averaged one hundred immature insects per one-fourth square foot sample. The lowest density of immature insects was present in Kellogg Forest pond "1" where the bottom samples averaged only twelve immature insects per one-fourth square foot sample. The Lake City ponds had an average production of twenty-five immature insects per sample. The reservoir stations were only slightly less productive with an average of sixteen insects per sample.

Figure 5 gives the percentage distribution of various taxonomic groups of immature insects in the Lake City ponds and reservoir as well as the Kellogg Forest ponds. Only those taxonomic groups which appeared to be reliably sampled both as adult and immature forms are included in Figure 5. Several general trends appear when the adult and immature data are handled in this manner. In the Lake City ponds where the interval between adult samples was three days and the interval between bottom deposit samples was one week, there was a close correlation between the percentage distribution of adult and immature insects. At the Lake City reservoir stations where adult as well as the bottom deposit samples were taken at weekly intervals there was not as close a correlation between the distribution of adult and immature forms. At the Kellogg Forest ponds, where the sampling interval was two weeks for both adults and immature forms, there was even less agreement between the percentage distribution of adults and larvae.

FIGURE 5

PERCENTAGE DISTRIBUTION OF THE IMMATURE TAXONOMIC GROUPS



In certain taxonomic groups the percentage distribution of adults was consistently higher than for the immature forms, and in other groups just the opposite condition occurred. This condition was especially evident in the order Ephemeroptera, where the immature samples always contained a higher percentage of mayflies than the adult samples. It was apparent from observations made of the mayflies emerging into the adult traps that the mayflies did not emerge from their nymphal skin and pass through the subimago stage as readily in the traps as under natural conditions.

The phantom-midges of the subfamily Chaoborinae were consistently more numerous in the adult samples than in the immature samples. The larval forms of the subfamily Chaoborinae appeared to be distributed in isolated colonies in the bottom deposits. Often several samples would be taken from various locations in a pond and only one would contain phantom-midges. When the adults emerged from a pond they appeared to be more evenly distributed over large areas of the pond and thus a more representative adult sample would result.

In the subfamily Pelopiinae the percentage distribution of adults was always greater than the larvae. One explanation for this is the fact that Procladius bellus, a very numerous species in the adult samples, is a small species and no doubt many of the immature larvae pass through the sorting screens.

Figure 6 gives the percentage distribution of the adults and immature forms in the various ponds and stations. These percentages do not include the entire adult and larval collection. The percentages are computed from the same numbers of adult samples at each pond or station as well as equal numbers of bottom deposit samples at each pond or station. The extra adult samples which were taken at certain stations are omitted from the percentage computation in Figure 6.

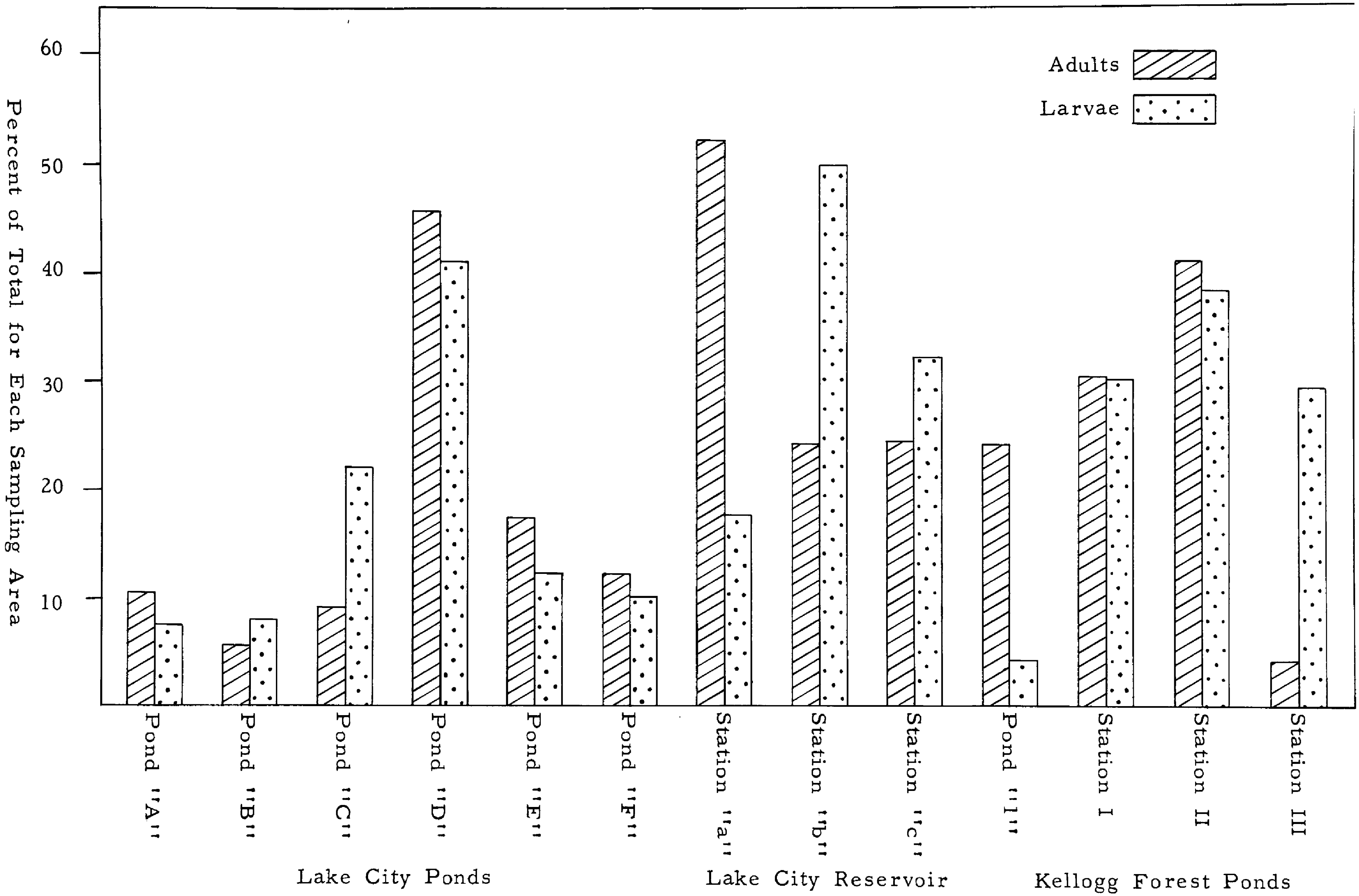
The same condition that was evident in the taxonomic group distribution occurred in the percentage distribution of adult and immature forms. When the sampling interval was the shortest, as in the Lake City ponds, the adult and immature distribution was very closely correlated.

## Seasonal Distribution of Taxonomic Groups

The seasonal distribution of the adult and immature forms of the various taxonomic groups was studied both qualitatively and quantitatively. The principal reason for studying the variation in seasonal populations was to compare the fluctuations which existed in the insect

FIGURE 6

PERCENTAGE DISTRIBUTION OF ADULT AND IMMATURE INSECTS OF THE TRIBE TENDIPEDINI



population using both adult and larval trapping devices. It was also possible to utilize the seasonal distribution data to determine the length of life cycle as well as the number of generations per year for some of the more numerous species.

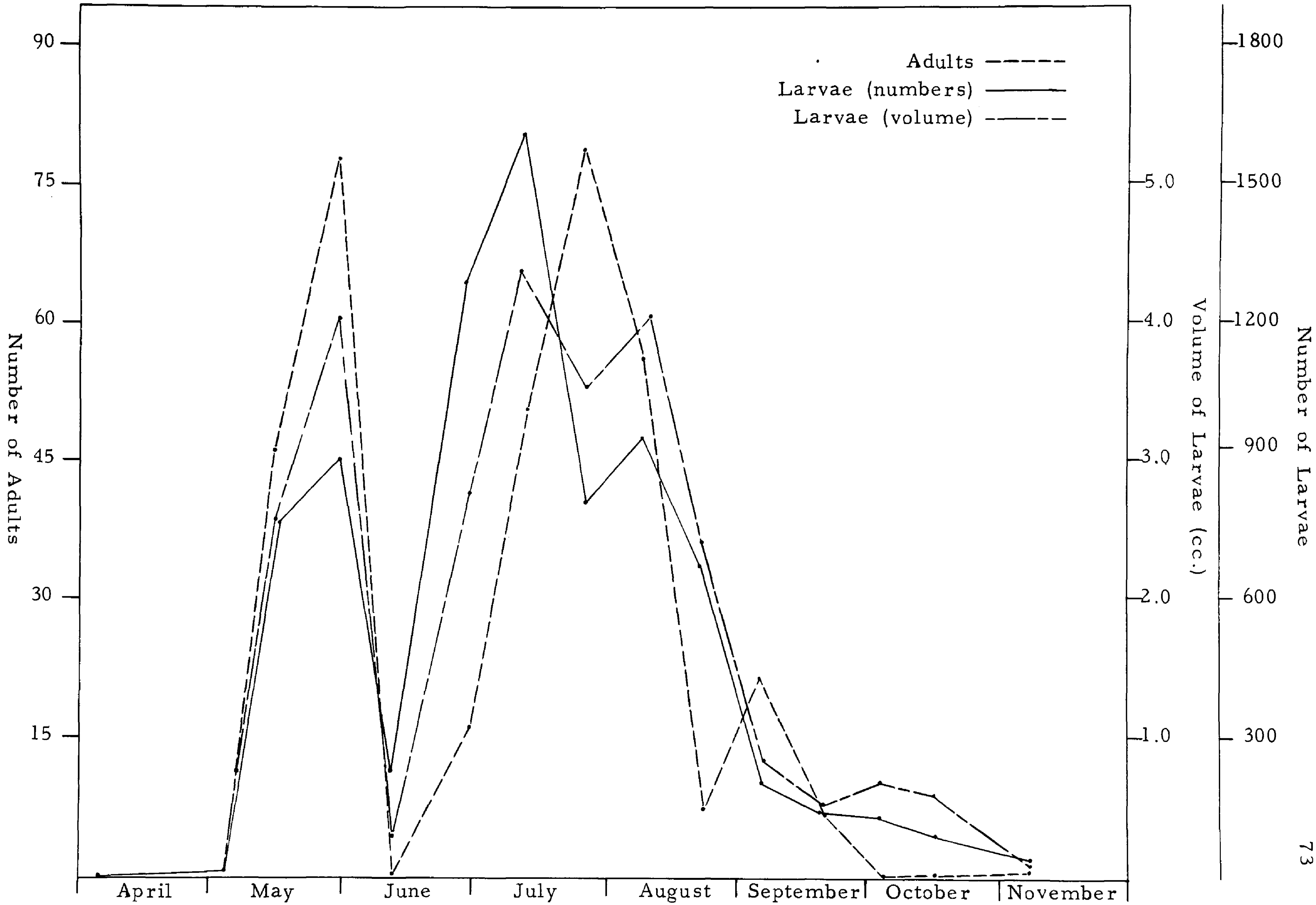
Tribe Tendipedini, Kellogg Forest Pond "2"

The Tendipedini population which existed at stations I, II, and III in Kellogg Forest pond "2" exhibited pronounced periods of maximum and minimum abundance. No bottom deposit samples were taken from stations IV and V, so only the Tendipedini production from the three stations in Kellogg Forest pond "2" could be used. The distinct peaks and depressions which were present in a graph of the seasonal distribution of the Tendipedini population in Kellogg Forest pond "2" made this group an extremely valuable one for studying the adult and immature sampling devices.

Figure 7 shows that there were two periods of maximum production of the tribe Tendipedini in Kellogg Forest pond "2." The same graph also shows two periods when very few adults were emerging as well as a minimum of larval production. The first peak in the Tendipedini collection occurred in the May 31 adult and larval samples. Three species of Tendipedini, Tendipes decorus, T. atrella,

FIGURE 7

SEASONAL DISTRIBUTION OF THE TRIBE TENDIPEDINI IN KELLOGG FOREST POND "2"



and *T. tuxis*, were responsible for this peak emergence. The numerical and volumetric larval values as well as the adult production reached a peak concurrently during this initial increase in production. This peak production was followed by a sudden decline in both adult and larval abundance in the June 14 sample. A general increase was evident in the June 28 samples and a second peak in adult emergence occurred on July 26. A second generation of *Tendipes decorus* and *T. tuxis* as well as a concentrated emergence of *Glyptotendipes paripes*, *Tendipes dux*, and *Polypedilum simulans* were responsible for the second emergence peak. There was very limited emergence in the August 23 sample, followed by a slight increase on September 6. *G. paripes* and *T. dux* were the principal species responsible for the September emergence. Similar peaks and depressions were evident in the numerical and volumetric curves. There was no adult emergence in the October and November samples and the larval production continued to decline until a minimum was reached on November 7. In each instance, the maximum and minimum points in the immature curves were evident two weeks previous to the corresponding point in the adult curve.

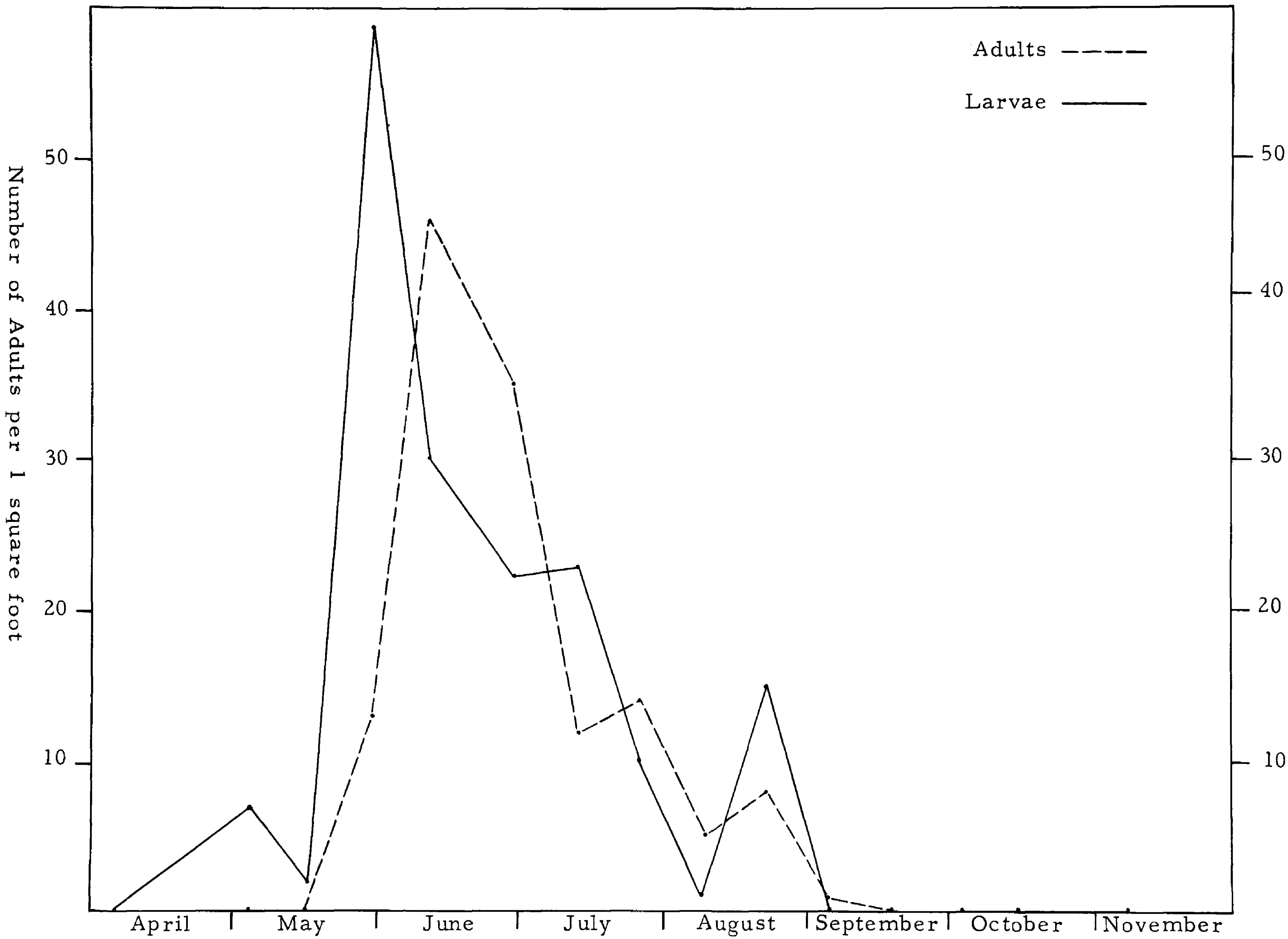
## Subfamily Pelopiinae, Kellogg Forest Pond "1"

Three species of the subfamily Pelopiinae were responsible for 92 percent of the total insect production in the Kellogg Forest pond "1." During the last week of May and the first week of June, larval and adult forms were present in maximum numbers in the samples (Figure 8).

The first adults were taken from the May 30 funnel sample. The peak adult production was present in the June 14 sample, when forty-seven adult insects were identified. The three species of the subfamily Pelopiinae which were responsible for this peak emergence were *Pelopia stellata*, *Procladius bellus*, and *Procladius culiciformis*. *P. stellata* occurred in the greatest numbers and was present over the longest period of time. The Pelopiinae production continued to decline with minor variations until September 6. There were no adults captured after September 6. Figure 8 shows that the curve representing the larval production in Kellogg Forest pond "1" corresponds very closely to the curve for the adult emergence. The peak larval production occurred two weeks before the high point in adult emergence was reached. This situation, where the trends in the curve representing larval production appeared two weeks before

FIGURE 8

NUMERICAL DISTRIBUTION OF THE SUBFAMILY PELOPIINAE
IN KELLOGG FOREST POND "1"



a similar condition was evident in the adult emergence, was also present in the Tendipedini production of pond "2" (Figure 7).

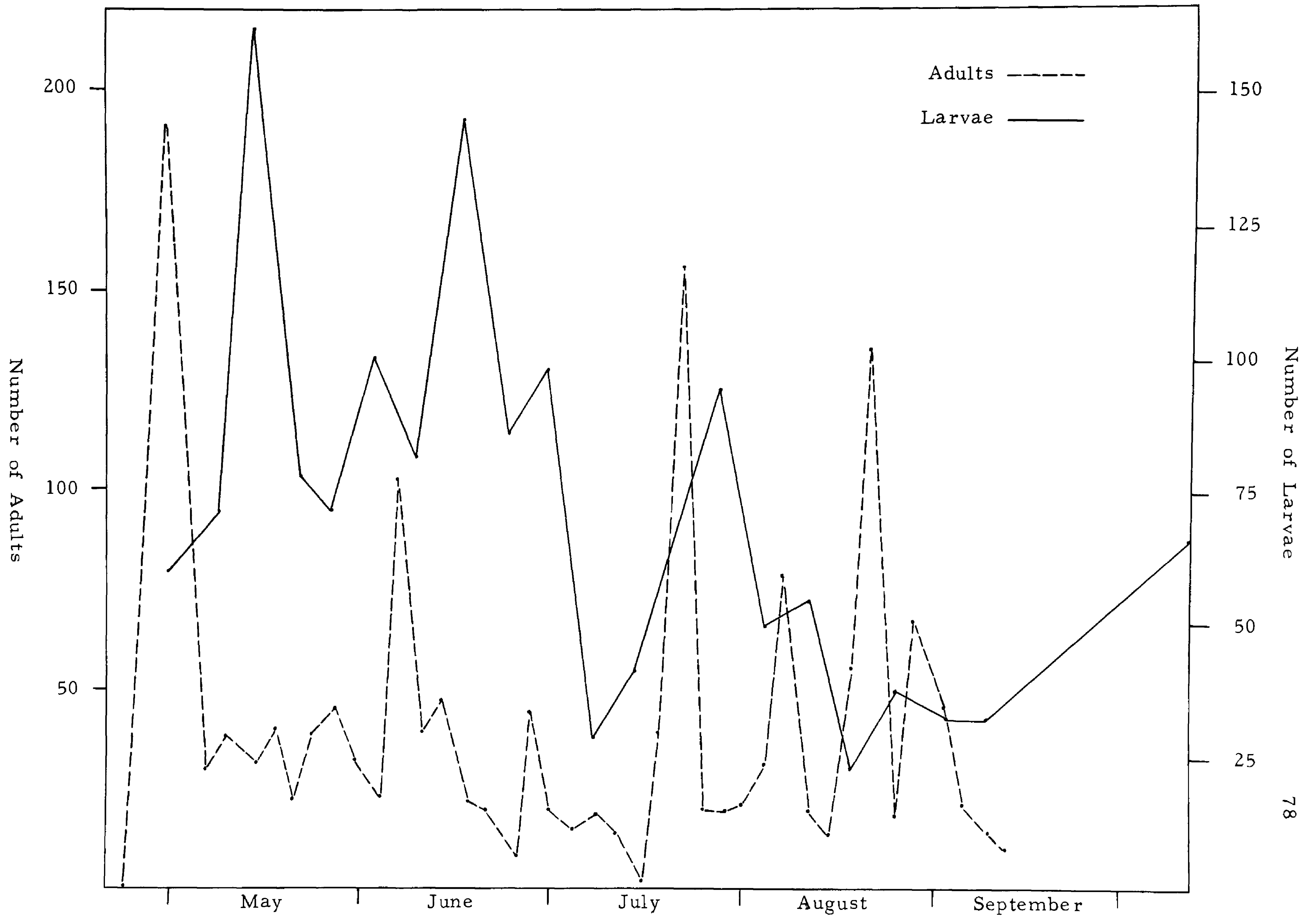
It is possible that the absence of adult and immature insects in the samples taken after September 6, 1953, was the result of the decomposition of the large Spirogyra deposits.

## Tribe Tendipedini, Lake City Ponds

The adult and larval emergence curves representing the total production of the tribe Tendipedini in the Lake City ponds are extremely variable (Figure 9). The close correlation which existed between the adult and larval production of the tribe Tendipedini in the Kellogg Forest ponds was not reflected in the data at the Lake City ponds. It must be pointed out that the samples were not taken at definite stations, but rather, each time a new sample was taken a different area of the pond was sampled. A great amount of variation in the species of midges present at different locations in the pond as well as in the quantity of midges produced was noted. This may partially explain the sharp peaks and depressions which are evident in Figure 9. These may be the result of sampling an area of a pond where a certain species of midge was emerging in large numbers and taking the following sample at an area of limited emergence.

FIGURE 9

SEASONAL DISTRIBUTION OF THE TRIBE TENDIPEDINI IN THE LAKE CITY PONDS



There was no adult emergence in the first adult samples taken from the Lake City ponds on April 23. The following adult sample taken on April 30 was the most productive Tendipedini sample. This peak emergence occurred only seven days after the ice cover had melted from the pond. A single species, Microtendipes pedellus var. pedellus, was responsible for this initial emergence. A second peak in adult tendipedid emergence occurred on June 6 with the emergence of Tendipes brunneipennis in ponds "A" and "D." A second emergence of T. brunneipennis took place in pond "D" on July 22, which is responsible for the high point in the adult emergence curve for that date. The emergence peak which was evident in the August 22 adult samples was the result of the emergence of ten species of Tendipedini of which Tendipes staegeri, Tanytarsus nigricans, Polypedilum simulans, and Glyptotendipes paripes were the principal contributors.

Figure 9 shows that there is very little relationship between the curve representing adult emergence and the curve of larval production. Many of the larvae of the species of the tribe Tendipedini which were present in the adult samples were so small, even during their last instar, that they passed through the sorting screen. These smaller species often were responsible for emergence peaks in the adult curve without any indication of their presence in the larval samples. The larvae of the tribe Tendipedini were more numerous in the samples taken during May and June followed by a period of low larval production during August and September. This same condition of early spring production followed by a low point in July and August has been observed by several investigators (Ball, 1938; Bray, 1949; and Curry, 1952).

In Lake City pond "A" the maximum production of the larvae of the tribe Tendipedini occurred on May 14, and three weeks later was followed by the peak adult emergence (Figure 10). Two of the larger species of the tribe, *Pseudochironomus banksi* and *Tendipes brunneipennis*, were the species responsible for this concentrated emergence in pond "A." There were no adult or larval specimens captured from pond "A" after July 9.

### Tribe Calopsectrini, Lake City Ponds

The seasonal distribution of the tribe Calopsectrini is restricted to a discussion of adult insects only. Because of their small size, the Calopsectrini larvae were not accurately sampled with the equipment and techniques employed in this investigation. Figure 11 shows that there was an early high point in the emergence

FIGURE 10

SEASONAL DISTRIBUTION OF THE TRIBE TENDIPEDINI IN LAKE CITY POND "A"

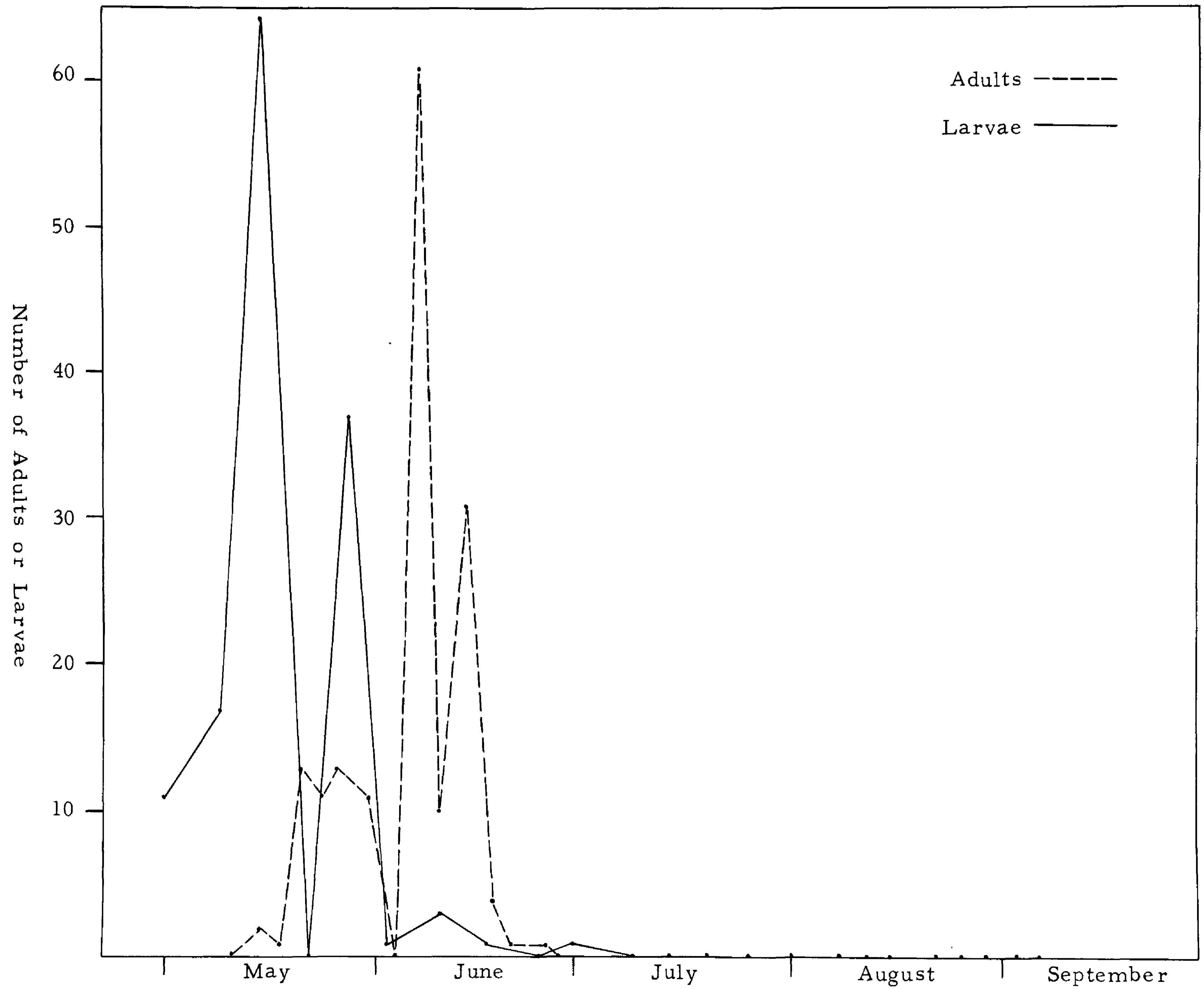
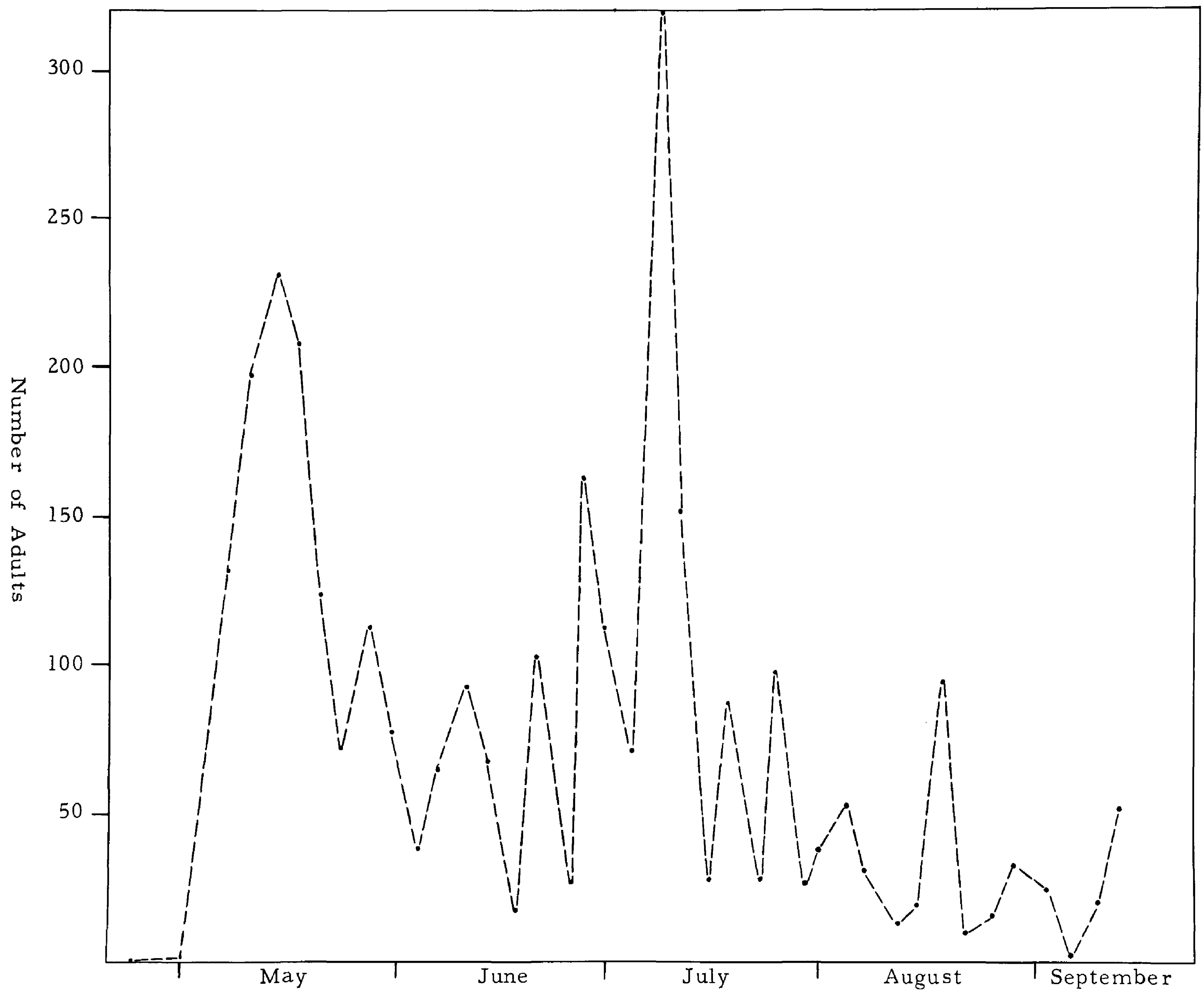


FIGURE 11

SEASONAL DISTRIBUTION OF THE ADULTS OF THE TRIBE CALOPSECTRINI IN THE LAKE CITY PONDS



of Calopsectrini on May 14. The maximum emergence of the Calopsectrini occurred in the July 8 samples, when 324 specimens were removed from the adult traps.

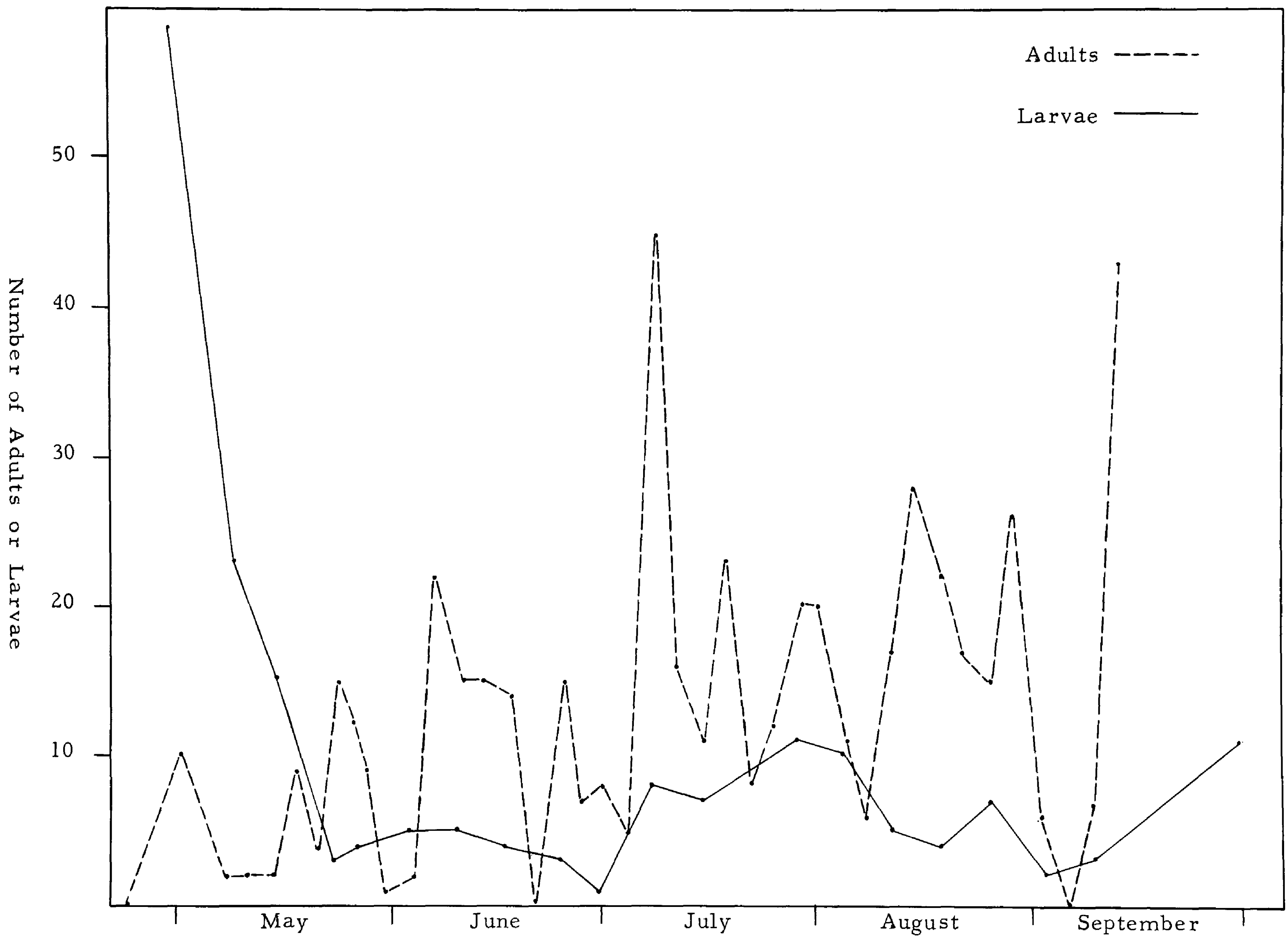
Since members of the tribe Calopsectrini were not identified to species it was impossible to determine whether the peaks in the emergence curve were composed of a single species or a species complex. Observations made during the sorting of the adult specimens indicated that many of the samples were composed of several different species.

### Subfamily Pelopiinae, Lake City Ponds

Figure 12 shows that the adult emergence of the subfamily Pelopiinae in the Lake City ponds was extremely variable. The lack of continuity in the adult emergence curve is caused by the rotation of the sampling areas from one location to another as previously described. There was a general trend of higher adult production during July and August. Pentaneura sp. (probably monilis) was the most numerous species present in the adult samples. This species was not characterized by a short emergence period but, rather, spread over a three-month period.

FIGURE 12

SEASONAL DISTRIBUTION OF THE SUBFAMILY PELOPIINAE IN THE LAKE CITY PONDS



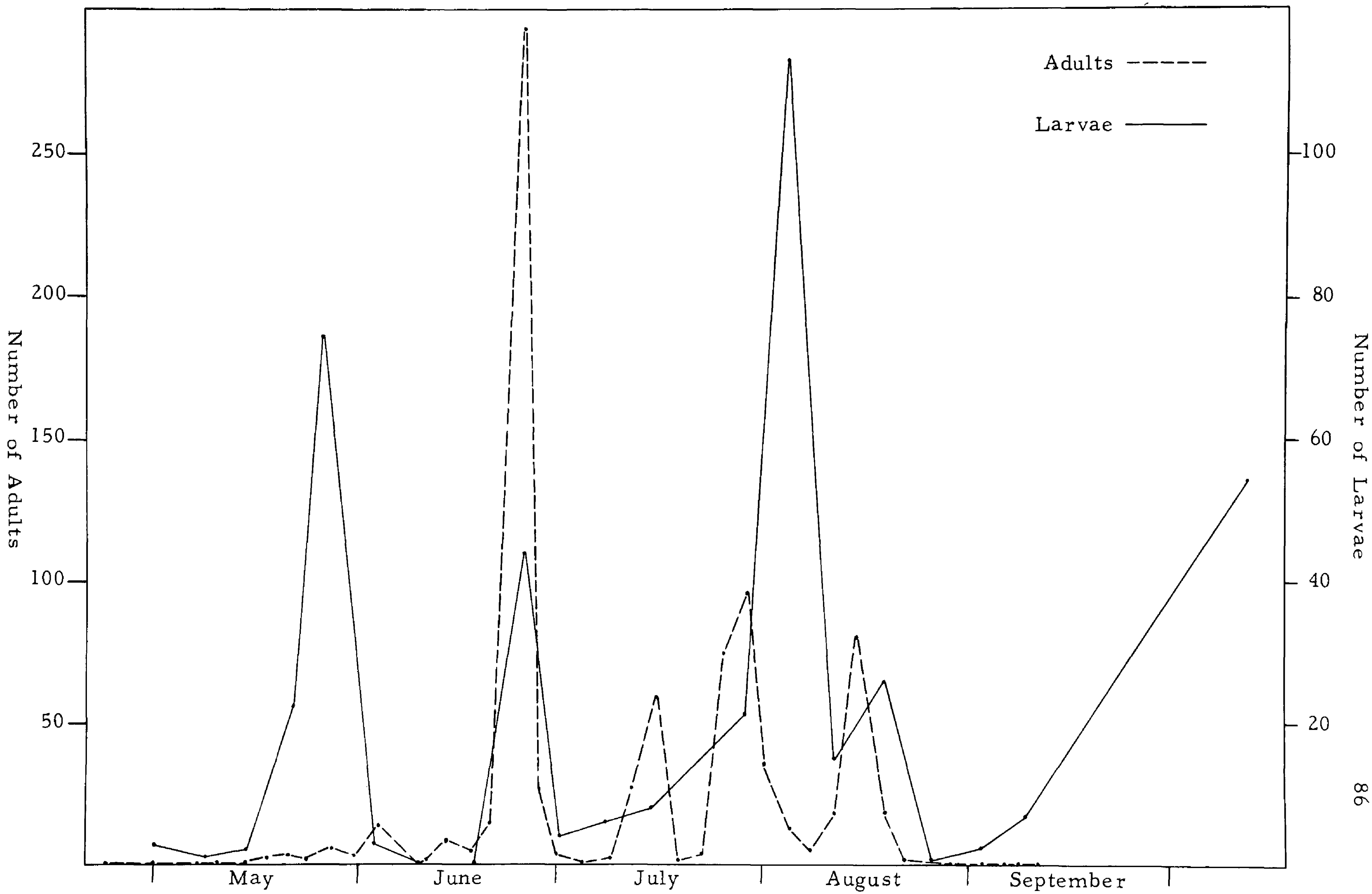
The curve representing the Pelopiinae larval production is characterized by a very high larval population in the ponds immediately following the spring ice break-up (Figure 12). There was no indication in the adult curve when the insects represented by the high larval population of May 2 emerged. There was a general increase in the number of organisms in the larval samples during July and the first week of August. The increase in Pelopiinae larvae during July and August corresponds to the increase in adult emergence during this period. Procladius bellus, one of the important species present in the adult samples, was a small species and the larvae of this species were not recovered. The absence of P. bellus specimens in the larval samples accounts for some of the lack of continuity between the adult and larval samples.

Subfamily Chaoborinae, Lake City Ponds

Pond "D" produced 96 percent of the specimens recovered of the Chaoborinae and these insects were unevenly distributed in the pond. At only two intervals during the sampling period were specimens of the subfamily Chaoborinae numerous in the adult samples (Figure 13). The first emergence peak occurred on June 25 and a second high point was reached on August 20. This second

FIGURE 13

SEASONAL DISTRIBUTION OF THE SUBFAMILY CHAOBORINAE IN THE LAKE CITY PONDS



peak is not evident in the adult emergence curve of Figure 13, but the high larval production on August 6 indicates that a large population of insects was present. Adult samples taken in connection with another part of the investigation indicated this emergence did take place on August 20. Previous to the June 25 emergence and following the August 6 high point there were very few Chaoborinae specimens collected in the adult traps. The curve representing the larval production of the subfamily Chaoborinae corresponds closely to the adult emergence curve except for the high point on May 26. The results from the adult and larval sampling data indicated that members of the subfamily Chaoborinae were present in the ponds as isolated aggregations. For this reason certain sections of the adult and larval curves are not adequately recorded for the area where the Chaoborinae were located.

## Seasonal Distribution of Individual Species

Many of the species of midges identified during this investigation displayed definite emergence periods. The number of generations present during the sampling period and the length of the emergence period varied with the different species. In this discussion only those species with a definite emergence pattern will be considered.

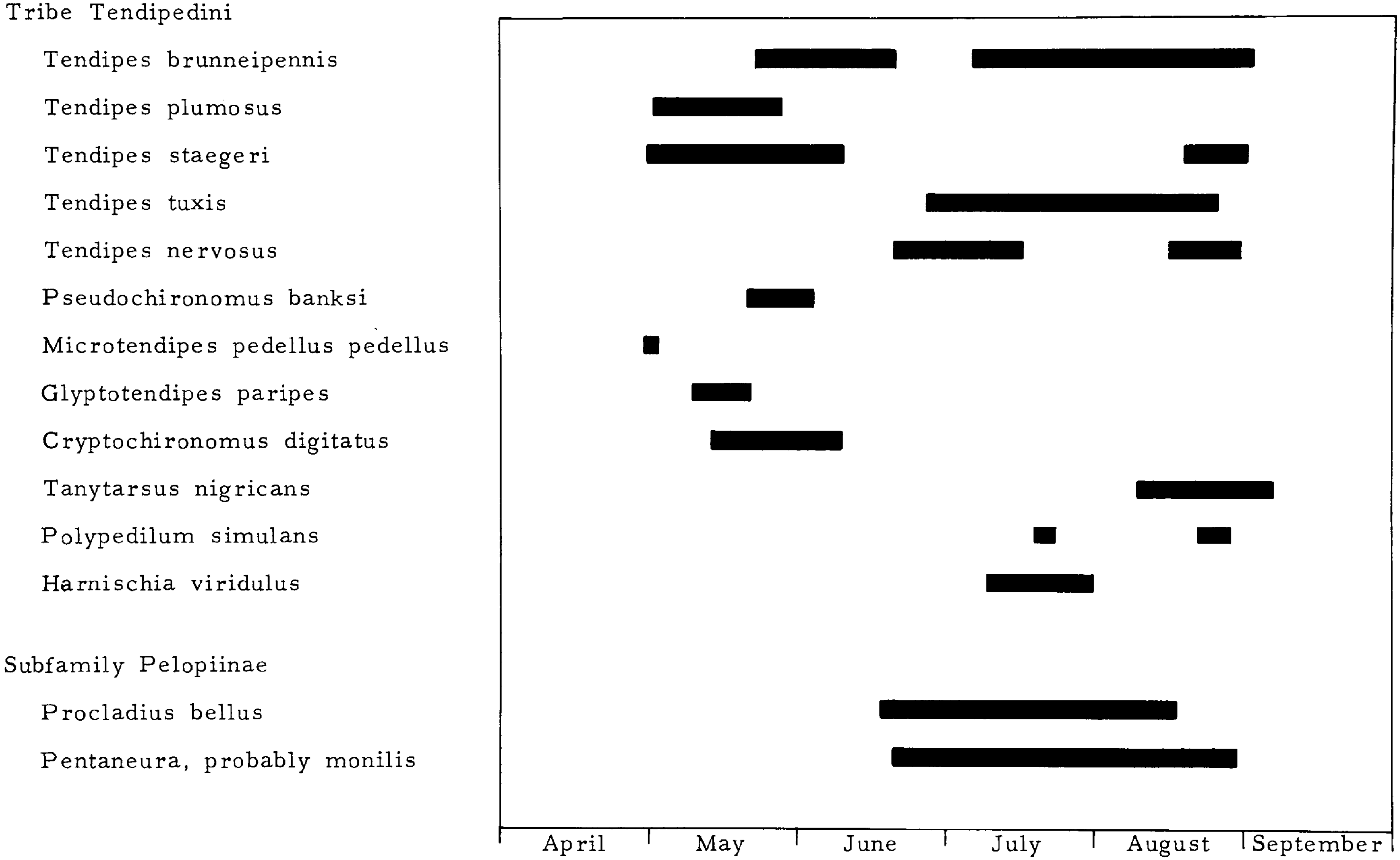
Species which are not included in this discussion of seasonal distribution were not recovered in numbers sufficient to determine a definite emergence pattern.

The distribution data of the species from the Lake City ponds are based on adult samples only. Both adult and larval sample data from the Kellogg Forest ponds were employed to arrive at the seasonal distribution of the various species. Since Kellogg Forest pond "2" was a new pond, without any insects present when the ice cover melted, the emergence data relating to the various species might very well undergo considerable variation in future seasons as the pond matures.

In the Lake City ponds there were twelve species of the tribe Tendipedini which appeared to have definite emergence patterns (Figure 14). Two generations were produced during the sampling period by *Tendipes brunneipennis*, *T. staegeri*, *T. nervosus*, and *Polypedilum simulans*. The remaining eight species had a single generation. Figure 14 gives the relative length of the emergence period as well as the time of year it occurred. The determination of the length of the emergence period was based on the time lapse of the greatest emergence of a species. In many instances individual specimens were

FIGURE 14

PERIODS OF ADULT INSECT EMERGENCE IN THE LAKE CITY PONDS



taken from the traps during the entire sampling period with greatest emergence taking place as shown in Figure 14.

When a species was present in more than one pond, the corresponding emergence period for that species was very similar in all of the ponds. There was some indication that the midges in ponds "C" and "D" completed their life cycle more rapidly than the same species in the other ponds. This was especially true of _T. brunneipennis_, where, as in pond "D," this species appeared to complete three generations during the sampling period and only two in the other ponds. Perhaps the presence of a more concentrated food supply as well as a higher mean temperature during the sampling season was responsible for this phenomenon.

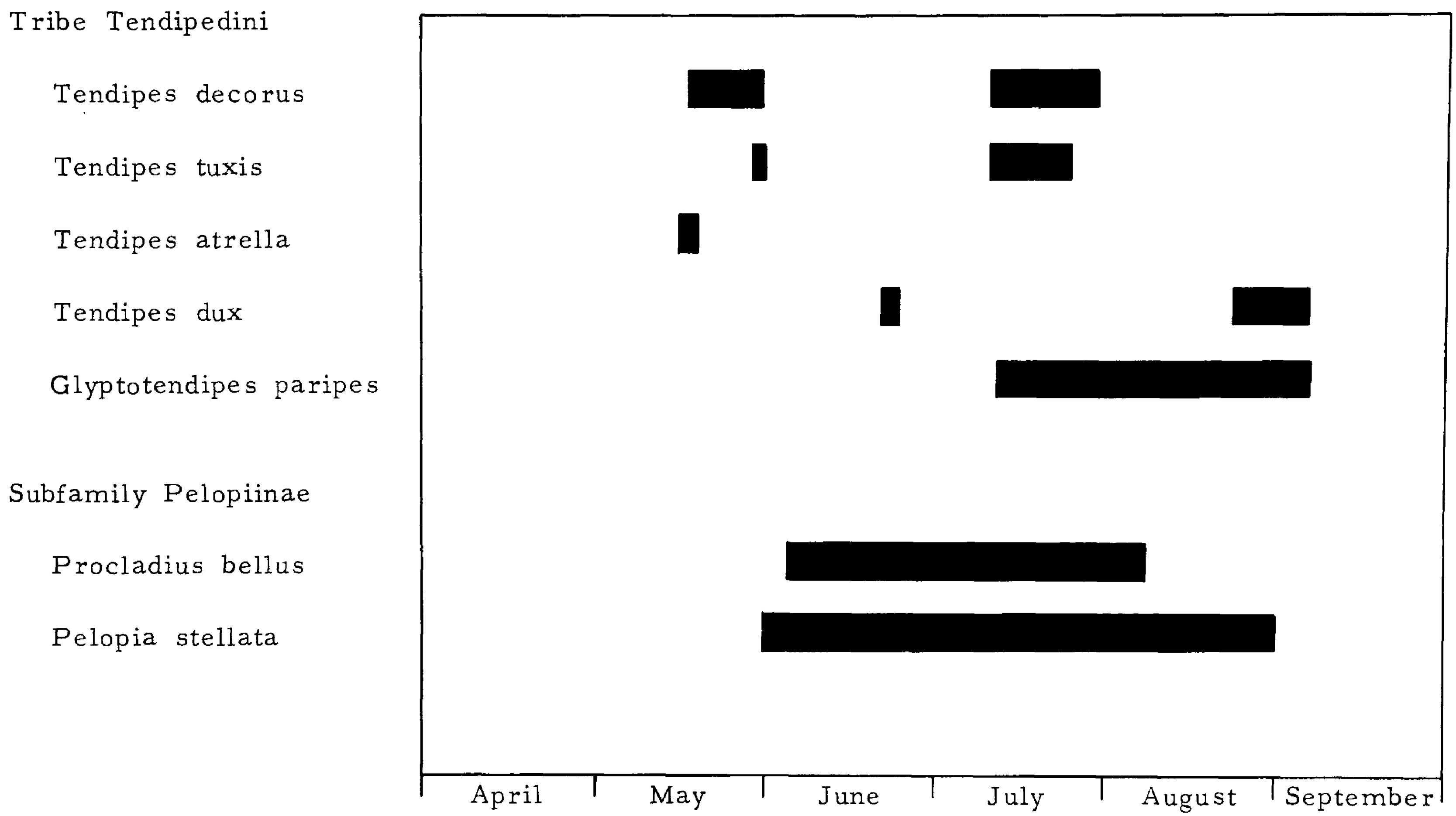
There was considerable variation in the length of the emergence period for the various species. The species with the shortest emergence period was _Microtendipes pedellus_ var. _pedellus_. This species was one of the first to emerge after the ice left the pond and was represented in the samples until July 1. There was some indication that a very small second generation emerged during the first week of July. The two emergence periods of _P. simulans_ were of very short duration with the maximum production limited to one or two samples.

Two species of the subfamily Pelopiinae displayed definite emergence patterns (Figure 14). Both *Procladius bellus* and *Pentaneura sp.* (probably *monilis*) had a single generation a year. The emergence of both of these species was evenly distributed over a two and one-half month period.

Emergence patterns were determined for five species of the tribe Tendepedini in Kellogg Forest pond "2" (Figure 15). Three of the five species produced two generations during the sampling period and the other two species only a single generation. *Tendipes decorus*, *T. tuxis*, and *T. dux* were the species with two distinct periods of adult emergence. It was interesting to observe that *T. decorus* and *T. tuxis*, two species which are very closely related taxonomically, had almost identical life cycles. It required approximately 60 days for these two species to complete their life cycle. *T. dux*, which was active later in the sampling period, required 70 days to pass from the egg to adult stage. There was a general trend for those species having two generations to have a relatively short initial period of emergence followed by a longer second adult emergence interval. The species present in Kellogg Forest pond "2" in general had a shorter emergence period than the same species in the Lake City ponds.

FIGURE 15

PERIODS OF ADULT INSECT EMERGENCE IN THE KELLOGG FOREST PONDS



The only species of the subfamily Pelopiinae present in Kellogg Forest pond "2" in sufficient numbers to determine an emergence pattern was P. bellus. P. bellus had a single generation with adults present in the traps from June 5 until August 1. In Kellogg Forest pond "1" the emergence period for P. bellus and Pelopia stellata was determined. The emergence of P. bellus occurred from May 31 until July 26, with the maximum number of adults present in the June 28 sample. P. stellata, which was the most numerous species in pond "1," was present in samples from May 31 until August 23, with peak emergence on June 14.

It is possible that some of the species considered in this life cycle discussion may have completed another generation after the sampling was discontinued in the fall. A continuous decline in emerging adults during the last five sampling periods indicated that very little emergence took place after September 30. The possibility also exists that with certain species, another generation or at least partial generation occurred during the investigation. This is especially true in the Lake City ponds, where the life cycle data were based on adult insect emergence only. In order to eliminate this difficulty as much as possible only those species which were numerous and exhibited clear-cut emergence trends were included. In the Kellogg

Forest ponds, where both adult and larval data were consulted in order to arrive at the emergence pattern, the life cycles should be especially accurate.

## Insect Succession in Kellogg Forest Pond "2"

Since Kellogg Forest pond "2" was a new pond and did not contain an insect population when the ice cover melted in April, 1953, it provided an ideal area for the study of aquatic insect succession. The original outline for this investigation did not include a study of insect succession; however, the absence of this type of information in the literature led to the inclusion of a discussion of insect succession here.

There were no adult or immature insects present in any of the samples taken on April 4, 1953, from Kellogg Forest pond "2." The first evidence of immature insects was found in the bottom deposit samples taken on May 2. Specimens of the genus *Tendipes* were identified from bottom deposit samples taken at stations I, II, and III. There were also two immature specimens of the genus *Glyptotendipes* removed from the bottom samples taken at station III. All of the immature insects sampled on May 2 were five or more millimeters in length. The maximum number of larval specimens in any one sample was eleven _Tendipes_ larvae in the station II sample. The adult midges were very active depositing eggs during the evening and night of May 1 and 2. There were fourteen midge egg masses clinging to a single square yard adult trap which had been in the water only 24 hours. The first evidence of predaceous insects was present on May 2, when many small dytiscid larvae as well as corixid and notonectid adults were observed.

The initial emergence of adult insects occurred at the five pond "2" stations in the May 17 samples. Adult specimens of the tribes Tendipedini and Calopsectrini as well as the subfamily Hydrobaeninae were captured in the May 17 samples. _Tendipes decorus_, _T. atrella_, and _T. tuxis_ were the species of the tribe Tendipedini which were present in the May 17 samples. At station II it appeared that _T. decorus_ and _T. atrella_ were approaching their peak emergence of first generation adults. The Calopsectrini adults were captured at stations IV and V. _Cricotopus trifasciatus_ adults removed from the station IV traps were the only Hydrobaeininae specimens taken in the early sample. There was a large increase in the number of immature insects in the May 17 samples. On

May 17 at stations I and II there was a mean population of 170 *Tendipes* larvae per 36 square inches of bottom area sampled. These larvae averaged 9.5 millimeters in length. It is interesting to note that these larvae had increased less than 5 millimeters in length to the 9.5 average during a two-week interval. There were three additional genera of the tribe Tendipedini identified from the May 17 larval samples. All of these Tendipedini larvae were five or less millimeters in length. Immature specimens of the subfamilies Pelopiinae and Chaoborinae were also identified from the bottom deposit samples taken at station II on May 17. There was a concentrated population of small gyrinid larvae of the genus *Dineutus* along the entire shore of the pond on May 17. These gyrinid larvae had a mean length of 10 millimeters.

The peak emergence of the first generation *T. decorus*, *T. atrella*, and *T. tuxis* specimens was evident at stations I, II, and III on May 31. The first emergence of *Chaoborus flavicans* specimens also occurred on May 31. The mean length of the *Tendipes* larvae had increased from 9.5 millimeters on May 17 to 12 millimeters on May 31. These mean larval lengths are based on the *Tendipes* complex which was present in the pond not on single *Tendipes* species. The generation of midges which was at peak emergence in the May 31 sample had completed their entire development since the melting of the ice cover on April 3. It was not ascertained when the eggs from which the larvae of this generation developed were deposited but it appeared that egg laying occurred during the last two weeks of April. If this were the case T. decorus, T. tuxis, T. atrella, and C. flavicans effectuated a complete life cycle between April 15 and May 31. A large population of G. paripes larvae, all five or less millimeters in length, first appeared in the May 31 samples.

The Dineutus sp. specimens which were concentrated in shallow water on May 17 had dispersed and moved to deeper water on May 31. Several Dineutus sp. specimens were captured in the May 31 bottom deposit samples and they had a mean length of 11 millimeters. The first immature mayfly specimens were also taken in the May 31 samples. These nymphs had a mean length of 3 millimeters. In the shallow water along the shore of the pond where small whirligig beetle larvae were numerous on May 17, now a dense population of small water boatman specimens was evident.

There was a very definite decline in both adult and immature production in the June 14 samples. This limited production was due to the large emergence which occurred on May 31. The Dineutus sp. larvae recovered from the June 14 samples had a mean length of 13 millimeters.

The adult samples taken on June 28 also showed a very small emergence of adult insects. The larvae hatching from eggs laid by the three species of *Tendipes* which had their peak emergence on May 31 were starting to appear in the June 28 bottom deposit samples. Larval specimens of *Glyptotendipes paripes* and *Polypedilum simulans* had increased very rapidly both numerically and in size. The *G. paripes* larvae which were five or less millimeters in length on May 31 had increased to a mean length of 7 millimeters on June 28.

The second generation of adults of *T. decorus* and *T. tuxis* were at their peak emergence in the July 12 samples at stations I, III, and IV. It required six weeks for these two species to complete their second generation. *G. paripes* and *P. simulans* were the first captured in the July 12 samples. At stations IV and V the maximum emergence of *T. dux* adults occurred on July 12. The subfamily Pelopiinae was first represented in the pond "2" adult samples by emergence of *Procladius bellus* adults on July 12.

The first appearance of Odonata specimens in the bottom deposit samples was in the July 12 samples when *Plathemis lydia* (Drury) and *Ischnura vertricilis* (Say) were identified.

The peak emergence of G. paripes and P. bellus was present on July 26 at all stations. At stations I, II, and III, T. dux reached its maximum adult emergence in the July 26 samples. The first emergence of mayfly adults was also evident in the samples taken on July 26. G. paripes, P. simulans, T. dux, and P. bellus adults were still numerous in the August 9 samples but the peak emergence for these species had occurred previously.

The adult samples taken on August 23 as well as those taken during September, October, and November showed a continuous decline in the number of adults captured. There was an indication that a second generation of Chaoborus flavicans emerged at station III during September. At station V a second generation of both T. dux and T. tuxis appeared to emerge between the September 6 and 20 sampling periods.

Following the August 23 sampling of immature insects there was a general trend toward fewer midge larvae in the samples and a corresponding increase in the number and size of predaceous insects. The only species of midge which persisted in the bottom deposit samples until the sampling was discontinued in November was G. paripes. In the October and November immature samples the Odonata were the principal constituents of the bottom deposits. The Dineutus sp.

increased in size until they reached a mean length of 20 millimeters on August 9. The Dineutus sp. larvae continued to decline numerically in each sample and there were no larvae sampled after August 9.

## Statistical Analysis

A statistical examination of the data from the four most important taxonomic groups has been made by analysis of variance. The purpose of this statistical consideration was to determine whether any significant statistical differences in catch existed among the different traps. The total emergence in numbers of adult insects from a one-half square yard area during each month was used for these determinations. Because of the recorded zero emergence during certain months as well as an apparent correlation of the mean values with the variance, a logarithmic transformation was used. The actual transformation used was the logarithm of (X + 1) as recommended by Bartlett (1947) and used successfully by Ball and Hayne (1952) and Curry (1952).

An analysis of variance was arranged to test the differences among stations and among months for the tribes Tendipedini and Calopsectrini, the subfamily Pelopiinae and the family Heleidae.

Differences among traps were further considered with regard to the various types of adult traps. The analysis of variance data for these groups appear in Tables XI, XII, XIII, and XIV.

The analysis of variance shows that no significant difference existed among the four types of traps when used to sample adult specimens of the tribes Tendipedini and Calopsectrini and the subfamily Pelopiinae in Lake City pond "B." The F test shows differences among the traps used to sample the adult specimens of the family Heleidae to be significant at the 5 percent level. Further analysis of these differences between the traps used to sample heleid specimens shows that a highly significant difference existed when the tent trap was compared with the three funnel traps. No significant difference existed among the three funnel traps used to sample heleid adults. The low numbers of heleids captured by the funnel traps dictates caution in interpretation of these results.

The F test shows differences among monthly values of the tribes Tendipedini and Calopsectrini to be highly significant. This results from the marked seasonal fluctuations in adult emergence for these two taxonomic groups. The analysis of the difference among months for the subfamily Pelopiinae and the family Heleidae indicates that no significant difference existed. This corresponds with

TABLE XI

ANALYSIS OF VARIANCE DATA FOR THE TRIBE TENDIPEDINI FROM LAKE CITY POND "B"

| Month | Type of Trap | | | |
|---|---|---|---|---|
| | 1 Yard Funnel | ½ Yard Funnel (suspended) | ½ Yard Funnel on Bottom | ½ Yard Tent |
| April . . . . . . . . . . . . . . . . | 0.886 + | 1.097 | 0.699 | 0.845 |
| May . . . . . . . . . . . . . . . . . | 0.462 | 0.415 | 0.591 | 0.531 |
| June . . . . . . . . . . . . . . . . . | 0.415 | 0.342 | 0.415 | 0.431 |
| July . . . . . . . . . . . . . . . . . | 0.146 | 0.000 | 0.230 | 0.204 |
| August . . . . . . . . . . . . . . | 0.415 | 0.204 | 0.255 | 0.279 |
| September . . . . . . . . . . . . | 0.342 | 0.301 | 0.623 | 0.568 |

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Square | "F" Ratio |
|---|---|---|---|---|
| Total . . . . . . . . . . . . . . . . | 23 | 1.480 | | |
| Traps . . . . . . . . . . . . . . . | 3 | 0.026 | 0.008 | 0.533 |
| Months . . . . . . . . . . . . . . | 5 | 1.232 | 0.246 | 16.4** |
| Discrepance . . . . . . . . . . | 15 | 0.228 | 0.015 | |

+ Based on a ½ square yard area.

TABLE XII

ANALYSIS OF VARIANCE DATA FOR THE TRIBE CALOPSECTRINI FROM LAKE CITY POND "B"

| Month | Type of Trap | | | |
|---|---|---|---|---|
| | 1 Yard Funnel | ½ Yard Funnel (suspended) | ½ Yard Funnel on Bottom | ½ Yard Tent |
| May[+] | 0.690[++] | 0.748 | 0.740 | 1.250 |
| June | 1.181 | 0.745 | 0.708 | 1.049 |
| July | 1.146 | 0.755 | 1.176 | 0.939 |
| August | 0.000 | 0.041 | 0.000 | 0.322 |
| September | 0.176 | 0.114 | 0.301 | 0.041 |

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Square | "F" Ratio |
|---|---|---|---|---|
| Total | 19 | 3.651 | | |
| Traps | 3 | 0.151 | 0.050 | 1.724 |
| Months | 4 | 3.149 | 0.787 | 27.13** |
| Discrepance | 12 | 0.351 | 0.029 | |

[+] April sample contained no specimens.

[++] Based on a ½ square yard area.

TABLE XIII

ANALYSIS OF VARIANCE DATA FOR THE SUBFAMILY PELOPIINAE FROM LAKE CITY POND "B"

| Month | Type of Trap | | | |
|---|---|---|---|---|
| | 1 Yard Funnel | ½ Yard Funnel (suspended) | ½ Yard Funnel on Bottom | ½ Yard Tent |
| April . . . . . . . . . . . . . . . . | 0.439+ | 0.000 | 0.397 | 0.000 |
| May . . . . . . . . . . . . . . . . . | 0.097 | 0.053 | 0.053 | 0.209 |
| June . . . . . . . . . . . . . . . . . | 0.053 | 0.137 | 0.209 | 0.301 |
| July . . . . . . . . . . . . . . . . | 0.176 | 0.250 | 0.193 | 0.524 |
| August . . . . . . . . . . . . . . . | 0.053 | 0.097 | 0.250 | 0.556 |
| September . . . . . . . . . . . . | 0.000 | 0.000 | 0.000 | 0.512 |

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Square | "F" Ratio |
|---|---|---|---|---|
| Total . . . . . . . . . . . . . . . | 23 | 0.751 | | |
| Traps . . . . . . . . . . . . . . . | 3 | 0.212 | 0.070 | 2.26 |
| Months . . . . . . . . . . . . . . | 5 | 0.074 | 0.014 | 0.45 |
| Discrepance . . . . . . . . . . | 15 | 0.465 | 0.031 | |

+ Based on a ½ square yard area.

TABLE XIV

ANALYSIS OF VARIANCE DATA FOR THE FAMILY HELEIDAE FROM LAKE CITY POND "B"

| Month | Type of Trap | | | |
|---|---|---|---|---|
| | 1 Yard Funnel | ½ Yard Funnel (suspended) | ½ Yard Funnel on Bottom | ½ Yard Tent |
| May . . . . . . . . . . . . . . . . . | 0.000 | 0.000 | 0.000 | 0.097 |
| June . . . . . . . . . . . . . . . . . | 0.097 | 0.053 | 0.053 | 0.589 |
| July . . . . . . . . . . . . . . . . . | 0.086 | 0.000 | 0.000 | 0.577 |
| August . . . . . . . . . . . . . . . | 0.000 | 0.000 | 0.000 | 0.053 |

| Source of Variation | Degrees of Freedom | Sum of Squares | Mean Square | "F" Ratio |
|---|---|---|---|---|
| Total . . . . . . . . . . . . . . | 15 | 0.553 | | |
| Traps . . . . . . . . . . . . . . | 3 | 0.281 | 0.093 | 5.16* |
| Tent vs. rest . . . . . | (1) | (0.277) | (0.277) | (15.22**) |
| Within rest . . . . . . . . | (2) | (0.004) | (0.002) | (0.111) |
| Months . . . . . . . . . . . . . | 3 | 0.108 | 0.036 | 2.00 |
| Discrepance . . . . . . . . . . | 9 | 0.164 | 0.018 | |

the fact that the emergence of adult insects of these two taxonomic groups followed a rather uniform pattern during the investigation.

At station "a" in the Lake City reservoir and station III in Kellogg Forest pond "2," the emergence from only two types of adult traps were compared by a "t" test of paired comparisons (Tables XV and XVI). The test is based on differences in the numbers of adult insects emerging into the two adult traps during each sampling period when captures were made. Use was made of the same logarithmic transformation described with the analysis of variance data.

There was no significant statistical difference between the funnel and tent trap used in sampling the emerging adults of the tribe Tendipedini at the Lake City reservoir, station "a." The "t" value of 1.65 with 17 degrees of freedom indicates that we could expect such a value between 10 and 20 percent of the time by chance of sampling alone.

The "t" value for the funnel tent trap comparison of the emerging adults at Kellogg Forest pond "2," station III, indicates that a highly significant statistical difference occurred. The "t" value which resulted, when the Tendipedini emergence in the funnel and tent traps was compared, was 4.08 with 7 degrees of freedom.

TABLE XV

"t" TEST DATA FOR THE TRIBE TENDIPEDINI FROM LAKE CITY RESERVOIR, STATION "a"

| Date | | Funnel Trap | Tent Trap | Tent-Funnel (X) | $X = (X) - \bar{X}$ |
|---|---|---|---|---|---|
| May | 1 . . . . . . . . . . . . . . . | 0.903 | 0.778 | -0.125 | 0.328 |
| | 8 . . . . . . . . . . . . . . . | 0.477 | 0.954 | +0.477 | 0.274 |
| | 16 . . . . . . . . . . . . . . . | 0.845 | 0.699 | -0.146 | 0.349 |
| | 21 . . . . . . . . . . . . . . . | 0.477 | 0.845 | +0.368 | 0.165 |
| | 29 . . . . . . . . . . . . . . . | 0.000 | 0.602 | +0.602 | 0.399 |
| June | 5 . . . . . . . . . . . . . . . | 0.000 | 0.903 | +0.903 | 0.700 |
| | 12 . . . . . . . . . . . . . . . | 0.699 | 0.602 | -0.097 | 0.300 |
| | 19 . . . . . . . . . . . . . . . | 0.301 | 0.903 | +0.602 | 0.399 |
| | 26 . . . . . . . . . . . . . . . | 0.000 | 0.954 | +0.954 | 0.751 |
| July | 3 . . . . . . . . . . . . . . . | 0.602 | 0.477 | -0.125 | 0.328 |
| | 10 . . . . . . . . . . . . . . . | 0.000 | 0.301 | +0.301 | 0.098 |
| | 17 . . . . . . . . . . . . . . . | 0.000 | 0.845 | +0.845 | 0.642 |
| | 24 . . . . . . . . . . . . . . . | 0.903 | 0.477 | -0.425 | 0.628 |
| | 31 . . . . . . . . . . . . . . . | 0.602 | 0.000 | -0.602 | 0.805 |
| Aug. | 14 . . . . . . . . . . . . . . . | 0.301 | 0.602 | +0.301 | 0.098 |
| | 28 . . . . . . . . . . . . . . . | 0.602 | 0.000 | -0.602 | 0.805 |
| Sept. | 4 . . . . . . . . . . . . . . . | 0.000 | 0.301 | +0.301 | 0.098 |
| | 11 . . . . . . . . . . . . . . . | 0.477 | 0.602 | +0.125 | 0.078 |

$\bar{X} = 0.203.$

$s^2 = 0.276.$

$SX^2 = 0.015.$

$SX = 0.123.$

$t = 1.65$ with 17 degrees of freedom.

Probability $< 0.20$.

TABLE XVI

"t" TEST DATA FOR THE TRIBE TENDIPEDINI FROM KELLOGG FOREST POND "2," STATION III

| Date | | Funnel Trap | Tent Trap | Tent-Funnel (X) | $x = (X) - \bar{X}$ |
|---|---|---|---|---|---|
| May | 3 | 0.176 | 0.000 | -0.176 | 0.789 |
| | 17 | 0.176 | 0.477 | +0.301 | 0.312 |
| | 31 | 0.000 | 1.255 | +1.255 | 0.642 |
| June | 28 | 0.000 | 0.699 | +0.699 | 0.086 |
| July | 12 | 0.398 | 1.279 | +0.881 | 0.268 |
| | 26 | 0.544 | 1.342 | +0.789 | 0.176 |
| Aug. | 9 | 0.788 | 1.380 | +0.602 | 0.011 |
| | 23 | 0.398 | 0.954 | +0.556 | 0.057 |

$\bar{X} = 0.613.$

$s^2 = 0.178.$

$SX^2 = 0.022.$

$SX = 0.15.$

$t = 4.08^{**}$ with 7 degrees of freedom.

Probability $< 0.01$.

We might expect such a high "t" value to occur naturally less than 0.1 percent of the time in such a population. Kellogg Forest, station III, was the only location where a significant statistical difference existed when the funnel and tent traps were used to capture emerging adults of the tribe Tendipedini.

In comparing the sex ratio observed among captured Calopsectrini adults with the hypothetical even sex ratio, highly significant departures were recorded for each of the months except September, when the ratio was almost exactly even (Table XVII). Since heterogeneity of sex ratio from month to month was demonstrated (see below) any comparison based upon grouped data seems meaningless biologically.

Testing for homogeneity of sex ratio from month to month indicated a highly significant degree of heterogeneity (chi-square of 113.8, 4 degrees of freedom). Since the sex ratio during September was even as opposed to an excess of females in each of the other months, the September data were removed, and a test of homogeneity made for the other four months. This test indicated that a highly significant degree of heterogeneity remained (chi-square of 70.6, 3 degrees of freedom).

TABLE XVII

CHI-SQUARE DATA FOR THE TRIBE CALOPSECTRINI

| Month | Fe-males | Ex-pected | Chi-square | Males | Ex-pected | Chi-square |
|---|---|---|---|---|---|---|
| | | | Test for 50:50 Ratio | | | |
| May ........ | 971 | 581 | 261.8 | 190 | 581 | 261.8 |
| June ........ | 392 | 290 | 35.9 | 187 | 290 | 35.9 |
| July ........ | 727 | 488 | 117.0 | 249 | 488 | 117.0 |
| August ...... | 431 | 261 | 110.7 | 90 | 261 | 110.7 |
| September .... | 44 | 46 | 0.0 | 47 | 46 | 0.0 |
| | | | Test for Homogeneity | | | |
| May ........ | 971 | 894 | 6.6 | 190 | 266 | 21.7 |
| June ........ | 392 | 446 | 6.5 | 187 | 133 | 21.9 |
| July ........ | 727 | 752 | 0.8 | 249 | 224 | 2.8 |
| August ...... | 431 | 406 | 2.1 | 90 | 119 | 7.1 |
| September .... | 44 | 67 | 7.9 | 47 | 21 | 36.4 |
| Totals ..... | 2565 | 2565 | | 763 | 763 | |
| (total Chi-square = 113.8** 4 degrees of freedom) | | | | | | |
| | | | Test for Homogeneity (Minus September) | | | |
| May ........ | 971 | 904 | 4.9 | 190 | 257 | 17.5 |
| June ........ | 392 | 451 | 7.7 | 187 | 128 | 27.2 |
| July ........ | 727 | 760 | 1.4 | 249 | 216 | 5.0 |
| August ...... | 431 | 406 | 1.5 | 90 | 115 | 5.4 |
| Totals ..... | 2521 | 2521 | | 716 | 716 | |
| (total Chi-square = 70.6** 3 degrees of freedom) | | | | | | |

It may be concluded, therefore, that the sex ratios, at least as revealed by these captured insects, departed from equal numbers of males and females in the months of May through August, but not in September, and further, sex ratios differed among the months May through August.

# DISCUSSION

Early observations indicated that the numerical distribution and seasonal variation of the various insect groups provided ideal criteria for the comparison of different insect trapping devices. The biological observations not only provided the necessary analytical data needed for comparison of the trapping devices but also contributed to the knowledge of pond biota.

The family Tendipedidae was the most numerous insect group represented in the samples as well as the most useful group for comparison of the various trapping techniques. The species of the tribe Tendipedini were especially valuable in the study of emergence patterns and in providing statistical data. This tribe was represented by thirty different species but it was apparent that many of these species could be grouped together in a consideration of their activities in the ponds. At all of the sampling areas there were certain species which numerically dominated the benthic communities and other species which were only occasionally identified from the samples. An excellent example of this phenomenon was present in Lake City pond "C" where *Tendipes staegeri* was the predominant species and *T. brunneipennis*, *Cryptochironomus fulvus*, *C. digitatus*, and

*Harnischia viridulus* were only occasionally present in the samples. The predominant species in a pond were, almost without exception, species of the genus *Tendipes*. This indicated that the ecological conditions associated with the ponds where this group was predominant were ideal for the development of the egg and larval stages.

Several of the species of midges identified in this study, such as *Tendipes plumosus* and *T. tentans*, have been considered as indicators of pollution. The stations where these species were recovered in this study were characterized by deposits of high organic matter but polluted conditions were not present. The conditions outlined by Gaufin and Tazwell (1952) might very well apply to these species. They considered the criteria for determining pollution not to be reflected by the absence or presence of a certain species but rather by the composite biota of the area.

The length of life cycle as well as the number of generations per year showed great variation among the species of the tribe Tendipedini. It was evident that each species had a definite life cycle pattern and that this pattern remained consistent for the species at different geographical locations. This is illustrated by a species such as *Glyptotendipes paripes*, which was numerous in both the Lake City and Kellogg Forest ponds. This was a species which developed slowly and completed only a single generation a year at both locations. Tendipes brunneipennis was a species which completed the transition from the egg to adult in a very short period of time. These data indicate that the presence, as well as the activity, of the species of the tribe Tendipedini was dependent upon a complex association of ecological factors such as water depth, water temperature, available food supply, type of bottom deposit, and the surrounding terrestrial environment.

The data indicated that the emergence patterns of individual species as well as for the tribe Tendipedini as a whole could be predicted equally well by the use of either the immature adult samples. This was possible only when the immature forms were sampled to the same degree as were the adults. When the population is composed of small species the screens and techniques used in sampling the immature groups must be adjusted accordingly. In the Lake City ponds where the tribe Tendipedini was composed of both large and small species it was impossible to get a comparable picture of the emergence pattern from the two different sampling techniques. In the Kellogg Forest ponds where the population was composed primarily of large tendipedid species the adult and larval curves approximated each other very closely.

There appeared to be no significant statistical difference in the sampling of the emerging adults of the tribe Tendipedini with the funnel and tent trap when used in this pond insect investigation. This information denotes that when the pupae of this group are ready to move to the surface they will do so equally well by moving up the sides of the funnel and emerging into the jar as they do by migrating directly to the surface and emerging into the tent trap. The semi-darkness in the funnel trap had no apparent effect on the number of midges emerging into the jar. Perhaps the reason for this is that adult midges are primarily nocturnal in their activities and are thus not adversely affected by the subdued light in the funnel traps.

There were more adult Calopsectrini specimens identified from the samples than any other group. The tribe Calopsectrini was poorly represented in the immature samples. The reason for the poor representation of immature forms of this group was due to the sampling technique followed. It is surprising to note that this group of midges, which was extremely numerous in all of the sampling areas studied during this investigation, has not been reported by biologists who have studied similar habitats. It is reasonable to assume that the larvae of this group may very well play an important part in pond ecology.

The most interesting phenomenon connected with the tribe Calopsectrini was the deviation from the 50:50 male-female sex ratio. It was determined that there was a highly significant difference between the male-female sex ratio encountered in this group and an expected 50:50 ratio. It was also determined that this sex ratio did not remain constant from month to month. There was an indication that the sex ratio for those adults captured during September did conform to the 50:50 ratio. No satisfactory explanation was found for this very interesting phenomenon.

Where both the funnel and tent trap were employed to sample emerging Calopsectrini adults there was no significant difference in number of specimens captured by the two types of traps. It appeared that because of their small size the adult trapping devices were ideally suited for sampling of the adults of the tribe Calopsectrini. It seems reasonable to assume that, with a modification of some of our sampling techniques as well as a concentrated study of this group, a valuable contribution might very well result.

All of the species of the subfamily Pelopiinae identified in this study have been reported as being predacious feeders in the larval stage. Since this is the case we might expect to find the larvae of this group dispersed among the larvae of the subfamily

Tendipedinae which would serve as food for the Pelopiinae larvae. This was exactly the condition which occurred in all of the ponds with the exception of Kellogg Forest pond "1." In this pond the insect population was almost completely restricted to Pelopiinae specimens. The reason for the predominance of Pelopiinae specimens in Kellogg Forest pond "1" was not ascertained. It was quite possible that the Pelopiinae dominance was in some way correlated with the dense Spirogyra sp. deposits which filled the pond during the summer months.

The emergence period of adult Pelopiinae specimens was generally much longer than for other groups of midges. The emergence of Pelopiinae adults was sampled equally well with the use of either the funnel or tent trap. The family Heleidae was the only taxonomic group sampled in which there appeared to be a significant difference in the number of adults captured by the funnel and tent trap. The data indicated that the heleid adults emerged more readily into the tent traps than into the funnel traps. This apparent difference in the number of adults captured by the two types of traps was based on a relatively small heleid emergence and no plausible explanation was discovered.

Neither the funnel nor tent traps were completely successful in quantitatively sampling emerging Ephemeroptera adults. Usually when an emergence of mayfly adults occurred in the traps only a relatively small number would complete the subimago stage and emerge as true adults. Since it is impossible to make species determinations on the subimago stage, a true picture of the mayfly emergence could not be ascertained. There were always sufficient true mayfly adults for making a qualitative study of the group.

The adult trapping devices utilized in this investigation successfully sampled, for qualitative purposes, all of the aquatic insects which emerge from their pupal skin at the surface of the water. The traps were equally as successful in quantitatively sampling the aquatic insect fauna with the exception of the mayflies and heleids. Perhaps the most significant attribute of the adult sampling technique for studying the aquatic fauna is the ease in classification of adult forms.

## SUMMARY AND CONCLUSIONS

1. A comparison of sampling techniques for adult and immature insects was conducted at two locations in Michigan.

2. Adult and bottom deposit samples were taken from eight ponds and a reservoir area over a two-year period.

3. The quantitative and qualitative distributions including seasonal variations of the insect population were used in the comparison of trapping techniques.

4. There were four orders of insects identified from the adult samples with the order Diptera responsible for 99.3 percent of the emerging insects.

5. The tribe Calopsectrini was the most numerous group in the adult samples, but because of their small size, few larvae were removed from the bottom deposit samples.

6. The tribe Tendipedini was well represented in samples of both adult and immature stages and proved to be the most useful taxonomic group for comparison of sampling techniques.

7. Certain species of the tribe Tendipedini such as *Tendipes staegeri*, *T. decorus*, *T. plumosus*, *T. brunneipennis*, *T. atrella*, and *Glyptotendipes paripes* were consistently present in large numbers

when they were represented in a pond. There were other species of the tribe Tendipedini which were captured only occasionally during the investigation.

8. All of the species studied appeared to be governed by a complex set of ecological conditions such as depth of water, fertility, and bottom deposit composition.

9. There was considerable variation among the species in the length of emergence period and the number of generations produced during the sampling interval.

10. In Kellogg Forest pond "2," Tendipes decorus, T. tuxis, and T. atrella effectuated a complete life cycle between April 3 and May 31, and a second emergence of these same species occurred six weeks later.

11. Kellogg Forest pond "2" was a new pond and the initial insect population was composed entirely of midges. These midges were extremely numerous in the early samples, but as predacious insects moved into the pond the midge population steadily declined. A complete study of insect succession in Kellogg Forest pond "2" was conducted between April 4, 1953, when the ice cover melted, and November 7, 1953.

12. The adult midges of the tribe Calopsectrini were represented in the samples by 80 percent female specimens. In the tribe Calopsectrini unequal numbers of males and females appeared in the months of May through August, but not in September. It was further concluded that the sex ratio differed among the months May through August.

13. The tent and funnel traps were equally successful in making a quantitative and qualitative estimation of all taxonomic groups sampled during the study with the exception of the heleid adults. There was no significant difference in the number of insects captured when suspended funnels were compared with funnels placed on the pond bottom.

14. A highly significant difference existed when the tent trap was compared with the funnel traps for sampling heleid adults. The species of the family Heleidae were consistently more numerous in the tent trap samples.

15. The adult trapping devices were adequate for making qualitative examination of the Ephemeroptera population. The reason that the adult traps failed to produce accurate quantitative results was that only part of the subimago specimens would emerge as true adults and these subimagos could not be identified to species.

16. When the adult and immature insect populations in a pond were sampled to the same degree the emergence patterns of individual species and higher taxonomic groups could be predicted equally as well with the adult insect samples as with the conventional bottom deposit samples.

## LITERATURE CITED


Adamstone, F. B., and W. J. K. Harkness
1925 The bottom organisms of lake Nipigon. Univ. Toronto Studies, Biol. Ser. 22:1-24.

Ball, R. C.
1948 Relationship between available fish food, feeding habits of fish and total fish production in a Michigan lake. Mich. State College Agr. Exp. Sta. Tech. Bull. No. 206, pp. 1-59.

Ball, R. C., and Don W. Hayne
1952 Effects of the removal of the fish population on the fish-food organisms of a lake. Ecology 33 (1):41-48.

Bartlett, M. S.
1947 The use of transformation. Biometrics 3:39-52.

Berg, C. O.
1950 Biology of certain Chrionomidae reared from Potamogeton. Ecological Monographs 20:83-101.

Borutzky, E. W.
1939 Dynamics of the Biomass of Chironomus plumosus in the Profundal of Lake Beloie. Arb. Limnol. Stat. Kossino 22: 156-195.

Bray, D. F.
1949 An investigation of the number and volume of aquatic insects in relation to the use of fertilizer. "Unpublished M. S. thesis," Michigan State College, pp. 1-79.

Brundin, Lars
1949 Chironomiden und andere bodentiere der südschwedischen Urgebirgsseen. Inst. of Freshwater Research, Drottningholm. Report No. 30, 1-914.

Burk, B. D.
1953 The mayflies, or Ephemeroptera of Illinois. Bull. Ill. Nat. Hist. Surv. 26:1-216.

Curry, L. L.
1952 An ecological study of the family Tendipedidae of two fresh-water lakes in Isabella County. "Unpublished Ph.D. thesis," Michigan State College. pp. 1-193.

Edwards, F. W.
1929 British non-biting midges. Trans. Ent. Soc. London 77: 279-430.

Ekman, S.
1911 Neue Apparate zur qualitativen und quantitativen Erforschung der Bodenfauna der Seen. Int. Rev. Hydrobiol. 7:146-204.

Gaufin, A. R., and C. M. Tazwell
1952 Aquatic Invertebrates as indicators of stream pollution. Public Health Report 67:57-64.

Goetghebuer, M.
1921 Chironomides de Belgiques. Mém. Mus. Hist. Nat. Belgique 31:1-208.

Grandilewskaja-Decksbach, M.
1935 Materialien zur Chironomidenbiologie verschiedener Becken. Zur Frage über die Schwankungen der Anzahl und der Biomasse der Chironomidenlarven. Arb. Limnol. Stat. Kossino 19:145-182.

Guyer, G. E.
1952 A quantitative and qualitative investigation of the midges of the family Tendipedidae in fertilized and unfertilized ponds. "Unpublished M. S. thesis," Mich. State College, pp. 1-63.

Hauber, U. A.
1944 Life histories and ecology of Iowa midges. I. The genus Tanytarsus. Proc. Iowa Acad. Sci., 51:451-461.

1945 Tanypodinae of Iowa. I. The genus Pentaneura. Amer. Midland Naturalist 34:496-503.

Ide, F. P.
1940 Quantitative determination of the insect fauna of rapid water. Univ. Toronto Studies, Biol. Ser. 47:1-20.

Johannsen, O. A.
1905 Aquatic nematocerous Diptera, II Chironomidae, N. Y. State Mus. Bull. 86:76-331.

1937 Aquatic Diptera, Part IV. Chironomidae: Subfamily Chironominae. Mem. Cornell Univ. Agr. Exp. Sta. 210:1-52.

1937a Aquatic Diptera, Part III. Chironomidae: Subfamilies Tanypodinae, Diamesinae and Orthocladiinae. Mem. Cornell Univ. Agr. Exp. Sta. 205:1-84.

Johannsen, O. A., H. K. Townes, F. R. Shaw, and E. G. Fisher
1952 Guide to the insects of Connecticut, Part VI. The Diptera or true flies. Fifth Fascicle: Midges and gnats. Bull. No. 80. State Geol. and Nat. Hist. Surv., pp. 1-255.

Leathers, A. L.
1922 Ecological study of aquatic midges and some related insects with special reference to feeding habits. Bull. U. S. Bur. Fish. 38:1-61.

Leonard, J. W.
1939 Comments on the adequacy of accepted stream bottom sampling technique. Trans. Amer. Wild. Conf. 4:289-295.

Ludwig, W. B.
1932 The bottom invertebrates of the Hocking River. Ohio Biol. Surv., 5:665-688.

Lyman, F. E.
1942 A pre-empoundment bottom-fauna study of Watts Bar Reservoir area (Tennessee). Trans. Am. Fish. Soc. 72:52-62.

Macan, T. T.
1949 Survey of a moorland fishpond. Journal of Animal Ecology 18:160-186.

Malloch, J. R.
1915 The Chironomidae or midges, of Illinois. Bull. Ill. Nat. Hist. Lab. 10:275-543; 11:306-319.

Miller, R. B.
1941 A contribution to the ecology of the Chironomidae of Costello Lake, Algonquin Park, Ontario. Univ. Toronto Studies, Biol. Ser. 49:1-63.

Needham, J. G.
1908 Report of the entomological field station conducted at Old Forge, N. Y., in the summer of 1905. N. Y. State Mus. Bull. No. 124, pp. 167-168.

Needham, P. R.
1928 Quantitative studies of the fish food supply in selected areas. A biological survey of the Erie-Niagara system. N. Y. State Conser. Dept., Suppl. to 18th Ann. Rpt., pp. 220-232.

Needham, J. G., J. R. Traver, and Yin-Chi Hsu
1935 The biology of Mayflies. Comstock Publishing Company, Ithaca, New York.

Peterson, C. G. J.
1911 Valuation of the sea. I. Rpt. Dan. Biol. Sta. 20:1-76.

Prescott, G. W.
1951 Algae of the western great lakes area. Cranbrook Institute of Science Bull. No. 30, pp. 1-946.

Sadler, W. O.
1935 Biology of the midge Chironomus tentans Fabr., and methods for its propagation. Mem. Cornell Univ. Agr. Exp. Sta. 173:1-25.

Schmid, J. S.
1952 Some ecological observations on experimental farm ponds. "Unpublished M. S. thesis," Michigan State College. pp. 1-49.

Scott, W., and D. F. Opdyke
1941 The emergence of insects from Winona Lake. Invest. Indiana Lakes and Streams, 2:4-14.

Sprules, W. M.
1947 An ecological investigation of stream insects in Algonquin Park, Ontario. Univ. Toronto Studies, Biol. Ser. 56:1-81.

Surber, E. W.
1936 Rainbow trout and bottom fauna production in one mile of stream. Trans. Amer. Fish. Soc., 66:193-202.

Tack, P. I., and W. F. Morofsky
1946 A preliminary report on farm pond management in Michigan. Mich. Agr. Exp. Sta. Quar. Bull. 28:294-304.

Thienemann, A.
1933 Chironomiden-Metamorphosen. III Zur Metamorphose der Orthocladiariae. Deut. Ent. Zeitschr. (1933):1-39.

Thienemann, A., and J. J. Kieffer
1916 Schwedische Chironomiden. Mit Beschreibungen neurer Arten. Arch. Hydrobiol. Planktonkde. Suppl. 2:483-554.

Townes, H. K.
1945 The Nearctic species of Tendipedinae. Amer. Midland Naturalist 34:1-206.

Welch, P. S.
1935 Limnology. McGraw-Hill Book Company, New York, First Edition, pp. 170 and 299.

Willem, V.
1910 Une nouvelle larvae, mineuse, de Chironomidae. Bull. L'Acad. Roy. Belg. (cl. D. Sci.):697-704.

## KEY TO PLATES

### Plate I

Figure

A. The tent and funnel traps used in the study of emerging adult insects.

B. The three sections of the tent trap

### Plate II

A. Tent trap in place at sampling station.

B. Platform on which tent trap rests.

### Plate III

A. Complete funnel trap with two quart jar in place.

B. Enlarged view of jar with inverted paper cup in position.

PLATE I

Figure A

Figure B

PLATE II

Figure A

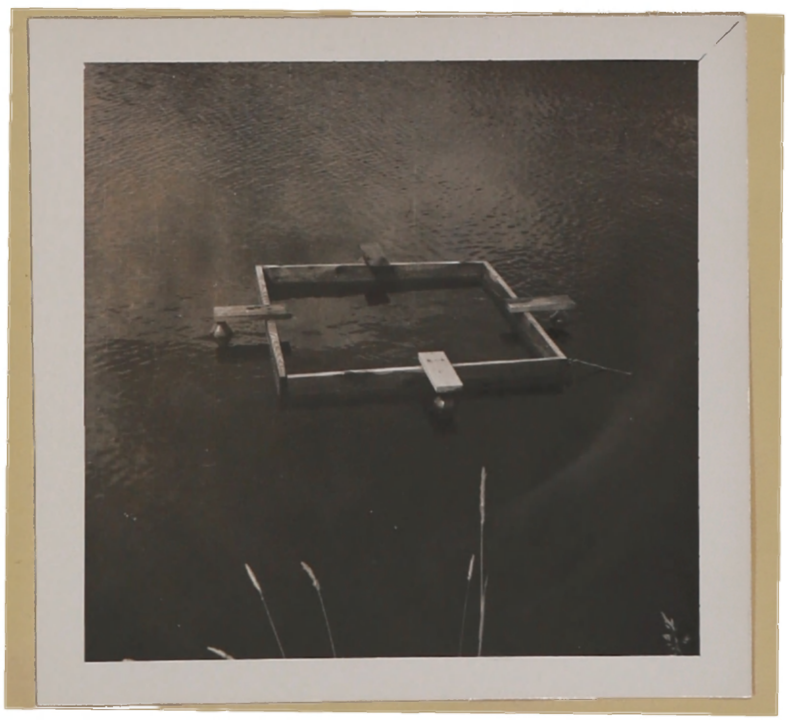


Figure B

PLATE III

Figure A

Figure B