AN ABSTRACT OF THE THESIS OF

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Title:  THE ECOLOGY OF CHIRONOMIDAE ASSOCIATED WITH

STABILIZATION LAGOONS

Abstract approved: _____Redacted for privacy_____

Dr. R. L. Goulding

Chironomidae occurring in stabilization lagoons were studied

from 1964 to 1966 in Oregon.  Observations of other insects and

their impact on the lagoon environment are included.  Quantitative

data were obtained from two lagoons near Corvallis and qualitative

observations from preliminary work on two other lagoons are re-

ported.  The objectives of this investigation were to determine

(1) species composition and abundance of Chironomidae occurring in

lagoons; (2) the microdistribution of dominant larval species;

(3) rates of adult midge emergence from lagoons; (4) larval tolerance

to some physical and chemical stress factors occurring in lagoons,

and (5) future areas of research.

Ecological conditions in one lagoon were complicated by

changes in amount of sewage loading, and by the reversal of loading

sequence from primary to secondary cell.  A total of 11 species of

Chironomidae, including six species new to science, were recovered from two lagoons. Significant differences in larval abundance showed the following order of dominance: <u>Glyptotendipes barbipes</u> (Staeger) > <u>Chironomus riparius</u> Townes > <u>Anatopynia dyari</u> (Coquillett). The order of tolerance to physiochemical stress factors was <u>G</u>. <u>barbipes</u> > <u>A</u>. <u>dyari</u> > <u>C</u>. <u>riparius</u>. The established dominance order in lagoons was thought to be because larval <u>A</u>. <u>dyari</u> required more space for growth and development than did the tube dwelling species.

Statistical analysis of dredging results of one lagoon showed that total larval abundance was greater in winter, greater in the primary cell, and consistently greater in peripheral zones. Larval abundance of <u>G</u>. <u>barbipes</u> was greater in winter, greater in the primary cell, and greater in the peripheral zones. Larval abundance of <u>A</u>. <u>dyari</u> and <u>C</u>. <u>riparius</u> was greater in the summer, greater in the secondary cell, and greater in the peripheral zones.

The main factors affecting these differences are considered to be: sewage influent quality and quantity, depth of water, degree of peripheral slope, and duration and degree of dissolved oxygen stratification. Thus the microdistribution and abundance of chironmid larvae in stabilization lagoons can be explained in terms of the selective effect of the environment acting upon the limits of tolerance of the larvae.

The Ecology of Chironomidae Associated
With Stabilization Lagoons

by

Brian Thomas Sturgess

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# ACKNOWLEDGEMENTS

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# THE ECOLOGY OF CHIRONOMIDAE ASSOCIATED
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## INTRODUCTION

This thesis comprises a study of Chironomidae occurring in stabilization lagoons from 1964 to 1966 at Corvallis, Oregon. Observations of other insects and their impact on the lagoon environment are included.

The objectives of this investigation were to determine (1) species composition of Chironomidae occurring in lagoons; (2) the microdistribution and abundance of dominant larval species; (3) rates of adult midge emergence from lagoons; (4) larval tolerance to physical and chemical stress factors occurring in lagoons, and (5) future areas of research.

Patrick (1953) studied aquatic organisms as an aid in solving waste disposal problems. She discussed the important pollution effects of oxygen deficiency, toxicity, temperature changes, and physical properties of wastes. She concluded that laboratory toxicity tests and biological surveys aid in the planning of waste disposal.

Bottom faunas of New Zealand streams were studied to obtain biological criteria for evaluating the extent and severity of organic pollution (Hirsh, 1958). Evaluation was accomplished by classing fauna in characteristic species composition for each pollution level.

Evaluation can be conducted long after the critical pollution period

has passed, but the results are often less clear-cut and more subject

to judgment in interpretation than evaluations made shortly after the

critical period.

The effects of pollutants on a natural body of water are often

understood better when biotic factors are correlated with chemical

data. Benthic organisms reflect the history of an aquatic environ-

ment while chemical analysis is only valid for recent conditions

(Van Horn, 1950).

Some investigators (Butcher, 1946; Gaufin, 1958; Patrick,

1950) have concluded that pollution causes a reduction in species

diversity while tolerant species become abundant. Several authors

have sought to use various aquatic organisms as an index of pollu-

tion (Beck, 1955; Wurtz, 1955). These attempts suffered from the

difficulty of placing species in a rigid system of habitat classification

to assess the degree of pollution. As early as 1928, Richardson

stated that the number of bottom forms having dependable index

values was surprisingly small, and even these must be used with

caution. He concluded that of the 27 tolerant species only two were

generally common enough over wide ranges to warrant confidence

in their value as indicators when taken by themselves.

In an effort to quantify various comparisons of biological popu-

lations found in various aquatic environments, Burlington (1962)

calculated a prominence value obtained as the product of the density of a family and the square root of its frequency. These values made possible a comparison of samples of the basis of a single quantity which took into account both frequency and density. Methods were given for finding a coefficient of similarity, by which various sites were compared.

The quantitative values derived from these methods provided a concise description of the biological populations found in varying aquatic environments. The major differences in populations due to pollution could be correlated with chemical and physical data.

Most research findings concerning stabilization lagoons have been published by sanitary engineers, whose purpose has been to determine the feasibility of stabilization lagoons as sewage facilities in different climatic conditions. Loading criteria for stabilization lagoons, and effluent quality suitable for discharge in natural bodies of water have also been investigated.

The effects of organic enrichment in aquatic environments was discussed by Bartsch (1956). He showed the importance of photo-synthetic oxygenation, the interrelation of light penetration, algal density, and water depth in stabilization lagoons.

Several general descriptions of the use of waste stabilization lagoons and the mechanism of sewage treatment have been pub-lished (Bartsch et al 1957, Burgess et al 1962, Towne et al 1957,

and Wilson et al 1960). In this mechanism bacteria convert sewage
to a more stable product by using it as a source of energy required
by their metabolism, at the same time liberating nutrient elements
needed for the growth of phytoplankton.

Oxidation by aerobic bacteria utilizing dissolved oxygen is
complete. They produce carbon dioxide and water as end products
and yield a maximum of energy. Oxidation by anaerobic bacteria
is incomplete, as far as stabilization is concerned, and produces
less energy for these organisms. In addition to carbon dioxide and
water, anaerobic bacteria also produce incompletely oxidized prod-
ucts such as hydrogen sulfide, methane, alcohols, ketones and or-
ganic acids (Bollen, 1951). These products are susceptible to
eventual complete oxidation by the same or higher organisms in the
presence of oxygen.

A systematic survey of algae in stabilization lagoons was ac-
complished by Silva and Papenfuss (1953). They reported qualita-
tive findings and growth features of the varied algal flora of lagoons.
The role of phytoplankton in the stabilization lagoon mechanism
has been investigated by Oswald et al, (1951), who stressed the im-
portance of symbiotic relationships between phytoplankton and
bacteria in providing a mechanism for efficient stabilization of
sewage wastes. Their laboratory and pilot plant results suggest
the feasibility of harvesting phytoplankton as a means of reclaiming

materials from waste products.

The first comprehensive research on the role of insects in stabilization lagoons was published by Usinger and Kellen (1955). They concluded that, as a result of undulatory feeding and respiratory movements of chironomid larvae in their tubes, oxygenated water is drawn down into the mud-water interface, extending the zone of aerobic decomposition. The feeding activity of larvae upon algae and other organic material serves to reduce oxygen-demanding substances. Also, the emergence of adult Chironomidae removes organic material bound up in their bodies from the lagoon system.

Research on the ecology of insects associated with stabilization lagoons (Sturgess, 1964) has shown that larval Chironomidae are the most dominant feature of lagoons and are the only permanent insect residents. No insects were recovered from the central areas of an experimental lagoon. The main chemical and physical factors affecting insect populations in lagoons were, influent quality and quantity, wave action, bottom sediments, and season. Among the biological mechanisms affecting insect populations were algal photosynthesis, amount of peripheral vegetation, and insect predator-prey relationships.

Kimerle (1965) showed that it was possible to categorize lagoons into three types using algae, sewage load, and relative abundance of midge larvae. The primary factor influencing the

presence of predaceous species was amount of vegetation. He re-
covered 60 species of aquatic insects from 18 lagoons sampled, and
Chironomidae were present in each lagoon.

In a strategic chemical control approach to chironomid pest
problems from a metropolitan lagoon in Auckland, New Zealand, a
grid system was used for larval surveys (Spiller, 1965). Control
measures were used only in lagoon areas containing dense larval
chironomid populations. Timing of insecticide application and
evaluation of control measures were evaluated. Cost of chemical
control was reduced to less than one-tenth that of earlier years.
In most areas full control was achieved by a single aerial application
of malathion prior to the beginning of the summer (December) emer-
gence.

The first attempt to measure energy flow through a chironomid
population in an organically enriched environment was published by
Tubb and Dorris (1965). They determined the annual populations in
oil refinery effluent stabilization lagoons, established the rate of
energy removal by emerging adults, and studied the interaction be-
tween oil refinery effluent and populations of immature insects. The
lagoons lost about 62,500 kcal per year by emergence of adult midges,
indicating that the energy loss by emergence is significant. By re-
ducing the caloric content of the effluent, organic pollutional effects
were reduced. Energy transfer through respiration was large, but

it could not be measured in their study, because tendipedid larvae in lagoons live under anoxic conditions for long periods. They state that respiration values derived for other species were not applicable to such facultative animals.

Research on the distribution and biology of aquatic midges in Missouri lagoons was published by Fagan and Enns (1966). They compared the number of species and larval density to depth of the lagoon bottom, and concluded that larvae are able to overwinter in large numbers only in lagoons loaded with less than 30 pounds of biochemical oxidation demand per acre per day.

In general, chironomid populations are beneficial to sewage lagoon function in that they remove algae from the system, cause mixing at the soil-water interface, and reduce the calorific content of the effluent, thereby reducing the organic pollutional effect of wastes before it is discharged into natural bodies of water.

However, the benefits of chironomids in large stabilization lagoons can be offset by the mass emergence of midges that may create nuisance problems in nearby residential areas. Chironomidae in large stabilization lagoons adjacent to residential areas can be controlled by chemical means with relatively little increase in cost of lagoon maintenance and operation.

# MATERIALS AND METHODS

## Influent Quantity

Since the five-day biochemical oxygen demand (BOD) is the most widely accepted index of the amount of decomposable organic material present in sewage, this measure was used as the principal loading criterion in lagoons. Five-day BOD is defined as the quantity of dissolved oxygen needed in parts per million, during stabilization of decomposable organic matter by aerobic biochemical action while incubated for five days in the dark at $20^{\circ}C$ (American Public Health Association, 1955).

Calculated loading rates of BOD per acre per day in lagoons studied were based on the number of people using the facility. Average BOD production per person per day was estimated to be 0.17 pounds. It was then possible to calculate BOD load per acre per day in sewage produced by a known population using a lagoon of known size.

Water samples for analysis were collected in 500 ml BOD bottles. Two sampling bottles were placed in a plastic modification of the dissolved oxygen and BOD sampler developed by the American Public Health Association (1955). This sampler enabled water to be siphoned from the mud-water interface by displacing air from the BOD bottle volume several times. This prevented aerated water

from being sampled during the process.

Dissolved oxygen was determined by the azide modification of the Winkler method (American Public Health Association, 1955).

## Description of Lagoons

Four stabilization lagoons were observed during this investigation, including preliminary work at an experimental lagoon of two acres located near the Corvallis Sewage Treatment Plant (Sturgess, 1964). Observations were also made at a one-acre stabilization lagoon located near the Corvallis Airport.

University Park stabilization lagoon, located northwest of Corvallis, served a 100-unit apartment complex, and an average of 3.7 people occupied each apartment. Raw sewage influent was discharged into cell I until November 1964. As this cell had an area of 0.53 acre, the loading rate was 118 lbs of BOD per acre per day. Most of the BOD remained in cell I due to poor or non-existent circulation through the overflows to cells II and III (Figure 1). Consequently, a thick sludge blanket a foot or more deep was rapidly deposited on the bottom. Because cell I was clearly anaerobic, the flow through the lagoon was reversed by extending the influent pipe to cell III. Most of the oxygen-demanding substances were then treated in this larger cell of 0.9 acre. Thus, cell III became the primary cell with a load of approximately 70 pounds of BOD per acre

EARTH DIKE

CELL III

0.9 acre

Submerged
influent
pipe

Overflow

Effluent
pipe

CELL I

0.53 acre
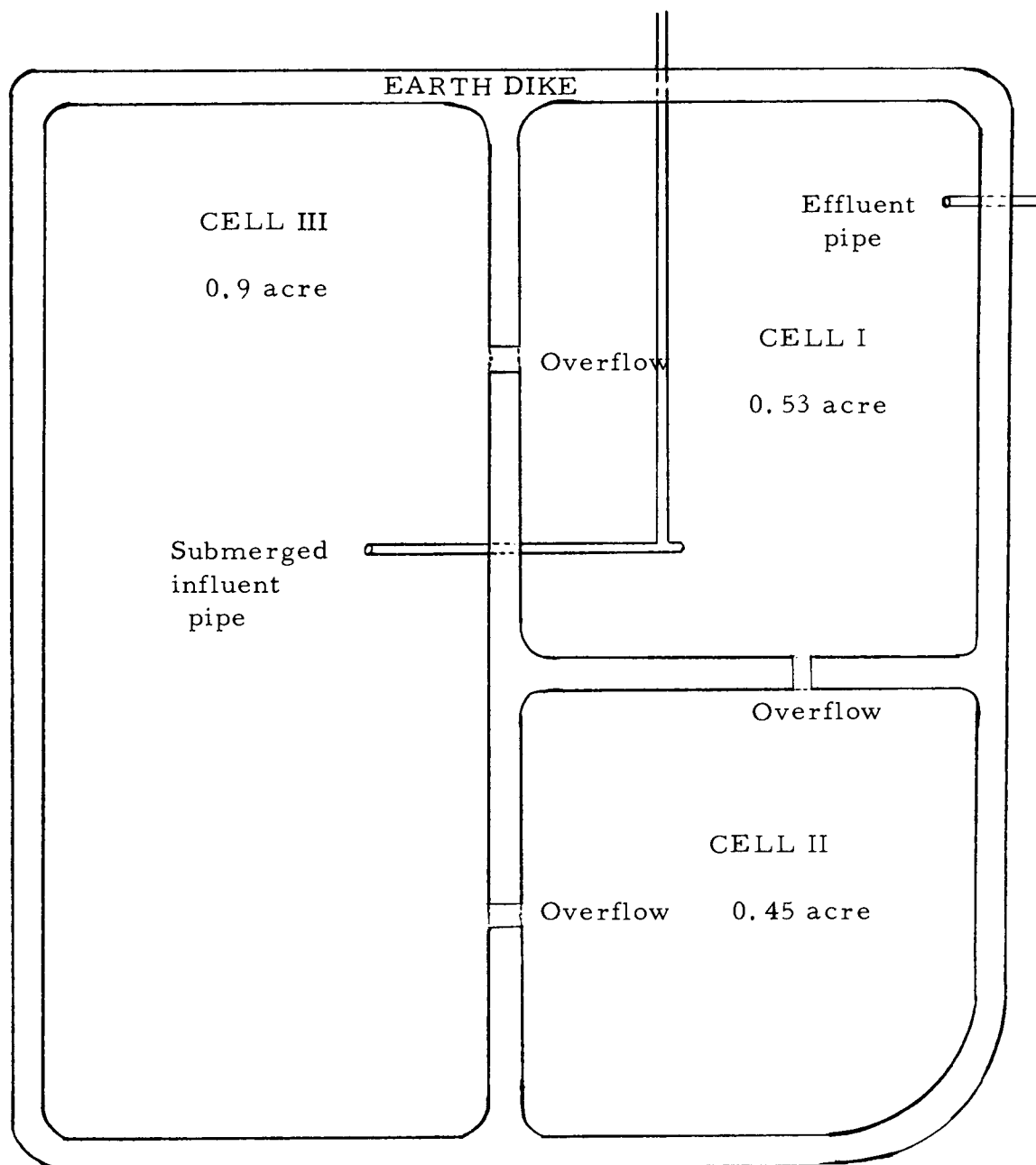
Overflow

Overflow

CELL II

0.45 acre

Figure 1. University Park stabilization lagoon plan.

per day for the remaining time of lagoon operation. Dikes enclosing

this facility were eight feet wide at the top and were overgrown with

weeds and tall grasses which extended down to the water. Small

willow trees about six feet high grew at the edge of the water and

occupied about one quarter of the shoreline. Water seeped into the

north end of cell III and kept the water level high, even after the

loading was discontinued in this lagoon in November 1965. The

peripheral zones of the cells sloped to a water depth of about three

feet. Central zones of the cells were four feet deep in winter and

3. 5 feet deep in the summer.

Village Green stabilization lagoon, northeast of Corvallis, had

been in service for about five years and was a single cell structure

of 0.9 acre enclosed in an earth dike eight feet wide at the top.

When full (Figure 2), the soil-water interface, representing the

peripheral zone, sloped toward the center of the lagoon for eight

feet. The lagoon was loaded at an estimated rate of 21 pounds of

BOD per acre per day. The influent consisted of raw sewage from

a suburban housing development of 31 houses with approximately 115

occupants. During the dry summer months the water level fell, ex-

posing the peripheral slope for approximately six feet, and the cen-

tral zone maintained a depth of 1-1.5 feet. The water became deeper

and covered the peripheral slope during the fall and winter. Excess

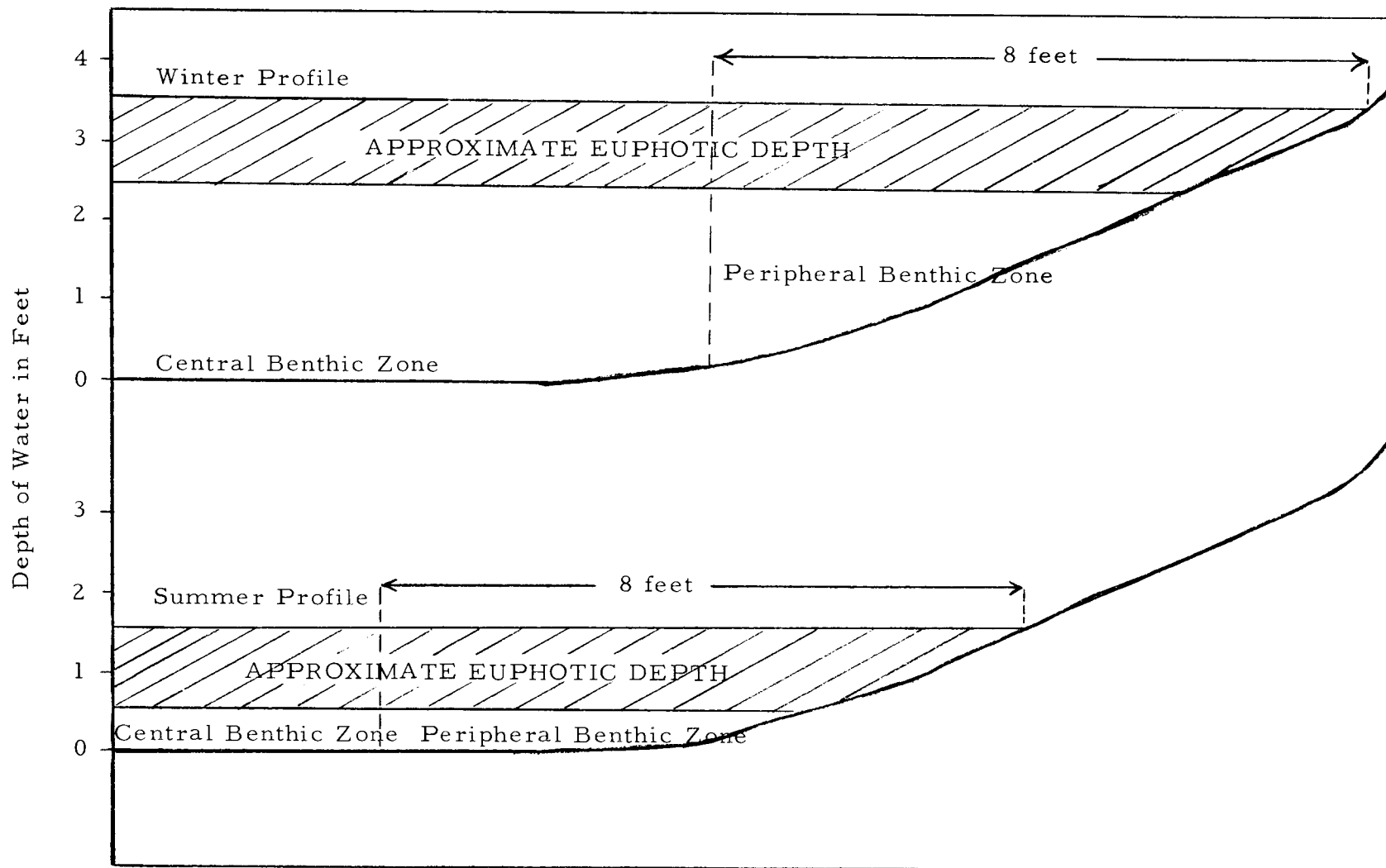water was discharged through an effluent pipe and water depth

Figure 2. Schematic diagram of seasonal profiles of Village Green stabilization lagoon 1966, showing approximate water depths.

remained at 3. 5 feet in the central zone during winter and spring.

Winter larval sampling was done at the end of March 1966, six

months after the lagoon became full.  Summer sampling was done in

July after the shoreline had receded.

### Larval Surveys by Dredging

Larval Chironomidae are the most abundant insect species oc-

curring in waste water stabilization lagoons.  Preliminary work indi-

cated that most larvae occurred around the periphery of each lagoon

within four feet of the shoreline and to depths of one to two feet.

Two transects were laid out in each cell and samples were

taken with a six-inch Eckman dredge in order to survey the bottom

fauna.  Peripheral zones were sampled by taking dredge hauls at

two-foot intervals along the sloping bottom out to a distance of eight

feet from the shoreline.  In the central zone dredge hauls were

taken at 16-foot intervals along the transects.  Bottom material

from dredge hauls was reduced in volume in the field to about one

liter by screening through a large sieve of 32 meshes to the inch.

These samples were then sieved in the laboratory through a graded

series of 9, 16, and 32-mesh screens.  Test screenings showed that

26 percent of larvae less than two mm in length passed through a

32-mesh screen and were retained in a 60-mesh screen.  Thus, the

32-mesh screen was selected as the smallest mesh for practical use.

Larger debris was removed by coarse screens and the larvae were then back washed from the 32-mesh screen into large white enamel pans for identification and counting. Larvae five mm or more were identified macroscopically, based on characters described in this thesis.

Where larvae were numerous, dredge samples were sub-sampled once or twice in the laboratory by means of a sample split-ter that separated samples into two equal amounts. Barlett's test of homogeneity of variance on the dredging data (appendix) showed that the variance is correlated with the mean. It was found that a log transformation of the dredging data was best suited for the analysis of variance (Healy and Taylor, 1962).

## Tolerance to Chemical and Physical Factors

Laboratory tests were made on fourth-instar larvae to deter-mine their tolerance to chemical and physical factors occurring in stabilization lagoons. All specimens used in these tests were col-lected in the field. Tolerance to concentrations of organic material was evaluated with solutions prepared from a formula for synthetic sewage developed by Weinberger (1949). A solution of 522 ppm concentration had the following properties: BOD, 210 ppm; pH, 8.2; total nitrogen, 25.3 ppm. A stock suspension of 100,000 ppm was prepared in a Waring Blender, Model DL-202, and dilutions were

made by adding the necessary portions of stock to 100 ml of tap water for test concentrations. Ten larvae were placed in wide-mouthed, one-pint jars containing each dilution and held at room temperature ($75^\circ$ - $80^\circ$F) for five days. Five replicates were used for each dose and the calculated percent mortality was averaged and converted into probits. Dose was converted into logs and a provisional probit line was drawn on graph paper. Probit analysis was done by fitting the log dose probability (LDP) line by the least squares method (Finney, 1947). Procedures for using weighting coefficients and calculating the dose at which 50 percent of the test species die ($LD_{50}$), and its fiducial limits are given by Finney (1947).

For the tolerance to cold tests, ten larvae per jar were placed in 25 wide-mouthed, one-pint jars containing 300 ml of tap water and 30 ml of fine sand. Jars were held at $10^\circ$C for 24 hours prior to being placed in a constant temperature cabinet at $0^\circ$C for the tolerance tests. Five replicates were removed at daily intervals and held at $10^\circ$C for 24 hours. Mortality was converted to probits, and days (dose) converted to logarithms. This experiment was analyzed by the approximate method of Finney (1947), in which the LDP line is merely drawn by eye through the provisional probits. The procedure for obtaining the $LD_{50}$ and its fiducial limits were patterned after a model given by Andrewartha (1965, p. 233).

For the anaerobic tests, a medium was prepared with 20 ppm

solution of nutrient broth in water inoculated with 20 ppm of a sludge

suspension containing methane-forming bacteria indigenous to sew-

age. Dissolved oxygen determinations were made by means of the

unmodified Winkler method (American Public Health Association,

1955). When the medium was stoppered in 500 ml BOD bottles at

room temperature, it became anaerobic in 24 hours. After the

bottles were stoppered for 24 hours, ten larvae per series were

placed in 25 BOD bottles and held at $10^{o}C$. Five replicates were

removed at daily intervals and mortality was noted. The $LD_{50}$ and

its standard error were estimated by the approximate method of

probit analysis.

## Emergence Traps

Adult chironomid emergence data were obtained from eight

floating pyramidal tent traps. Two traps, sampling emergence

from water at a constant depth six feet from the shore line, were

used for each cell of the two lagoons studied. In an attempt to avoid

any loss in efficiency due to trap effect, and to reduce the effect of

any uneven microdistribution in the larval habitat, traps were

moved periodically along the shore.

Emergence traps sampled an area 2.5 feet square and were

constructed on one-inch wood frame in the shape of a pyramid.

The frame was covered with black muslin sail cloth, and two-inch

diameter plastic tubing was attached to the sides for flotation (Figure 3). Emerging insects were collected in a wide-mouthed glass jar fitted with a retention cone of clear plastic. This assembly was inverted and screwed to the apex of the pyramid. During the summer, jars with a 15 mm hole drilled through the base were used to improve air circulation. Traps were secured by nine-foot long poles staked with steel pins at the shore. Emergence samples of 24-hour duration were taken at least once a week and data obtained were adjusted in terms of numbers per square yard per week.

Although it is well known that emergence traps made of dark materials may cause insects to be attracted or repelled in some degree (Scott and Opdyke, 1941 and others), the present design was considered to be the best all-season compromise. Traps could be quickly serviced during inclement weather by changing the collecting jar and repositioning the trap. Collection of adults by aspirator was not required.

Many alternate trap designs were evaluated in preliminary work but all had disadvantages. To reduce trap effect, a submerged funnel trap of clear plastic was tried. Within two days, however, a thick algal growth destroyed the transparency, many chironomid larvae took up residence and built tubes on the outside of the funnel; and the trap also admitted aquatic predators, such as the Pacific coast newt (Triturus torosus) which feeds upon any pupae present in

Figure 3. Method of aspirating insect catch from a transparent floating trap.

the trap receiving jar at the top of the funnel. Some trap designs were subject to considerable damage by the chewing and boring activities of rc¹ ⋅s. Morgan, Waddel and Hall (1963), after comparing submerged funnel traps and floating box traps, concluded that funnel traps are much less efficient.

Trap effect will probably be present regardless of construction materials, but differences in trap efficiency resulting from differences in light intensity and temperature were evaluated by constructing a duplicate trap covered with clear plastic material. The clear trap was placed next to a standard dark trap for insect catch comparison. Traps were relocated after each 24-hour catch. Insect catches from the clear trap were collected by removing the trap from the water and placing it on a white board fitted with a cloth saturated with ethyl acetate. After this gas had dissipated, the dead Chironomidae were aspirated from the board for counting (Figure 3). No Chironomidae escaped during this procedure and adults that had become swamped could easily be counted at the surface of the water before the trap was disturbed. It was assumed that total catch recovered from the transparent trap was 100 percent efficient, and this total was compared to the receiving jar catch recovered from a dark trap. Data collected in this manner was then used to calculate the dark trap efficiency for each species.

# INSECTS OCCURRING IN STABILIZATION LAGOONS

Peripheral areas of stabilization lagoons are well suited to the growth and reproduction of some insect species. Poorly maintained lagoons with emergent aquatic plants and a profusion of shrubs and shoreline vegetation provide an excellent habitat for large numbers of insects. Kimerle (1965) recovered 60 aquatic species from lagoons in Missouri. Sturgess (1964) recovered 25 species of aquatic insects from an experimental lagoon at Corvallis, Oregon. Mosquitoes in large numbers are found only in lagoons containing moderate to large amounts of aquatic vegetation (Myklebust and Harmston, 1962). Conversely, well maintained lagoons with a minimum of shoreline vegetation are less conducive to insect production.

## Species of Chironomidae in Stabilization Lagoons

Species of Chironomidae associated with two stabilization lagoons near Corvallis are listed in Table 1. Of these species G. barbipes, C. riparius and A. dyari were most dominant. G. barbipes was found more frequently and in larger numbers than any other species.

Studies of the biology of some Chironomidae by previous workers are probably in a confused state because of inadequate

Table 1. Chironomidae recovered from University Park and Village
Green stabilization lagoons.


Glyptotendipes (Phytotendipes) barbipes (Staeger), Townes

Chironomus (s. r.) riparius Meigen, Townes

Chironomus plumosus L.

Micropsectra n. sp. 2 Sublette and Sublette, in manuscript

Tanytarsus n. sp. 11 Sublette and Sublette, in manuscript


Anatopynia dyari (Coquillett)

Procladius freemani Sublette

Corynoneura (s. s) n. sp.

Acricotopus n. sp.

Cricotopus n. sp.

Limnophyes n. sp.


Taxonomic determinations were made by Dr. J. E. Sublette, Eastern
New Mexico University.

knowledge of the systematics of this Family. The life stages of the three dominant species in this study consist of egg, four larval instars, pupa, and adult. The general seasonal cycles in stabilization lagoons are exceedingly difficult to follow because of overlapping generations, and the variability of maturation times and emergence of adults from eggs of a single generation.

The eggs of G. barbipes are enveloped in cylinder-shaped mass of clear gelatinous substance 30-40 mm in length. They may be attached to emergent vegetation but are usually found free-floating or settled at the bottom of the lagoon. At times egg masses deposited for a period of a week or more adhere together, resulting in large jelly-like agglomerates of egg masses up to a liter or more in volume, drifting at the edge of the lagoon. Each egg mass contains from 1500-2000 light brown eggs organized in a series of horseshoe-shaped spirals. Two days after oviposition the gelatinous material becomes less firm and the egg spirals become loosely organized in the egg mass (Figure 4). Eggs hatch in two or three days in the laboratory depending on the temperature. A total of 149 adults were reared from a single egg mass held at 70-75$^\circ$F, and maximum emergence occurred at 48.5 $\pm$ 5.5 days after hatching. Percent hatch is unknown, but 10 separate egg masses were reared to emergence and the average survival was 160 adults for each egg mass. Assuming that there were 1600 eggs in each egg mass, this
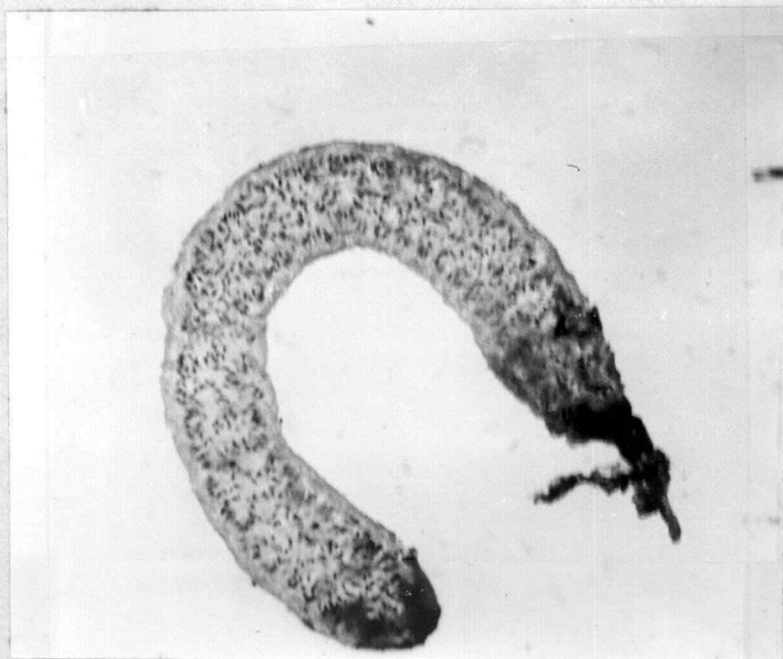
Figure 4. Egg mass of G. barbipes.



Figure 6. Larval tubes of G. barbipes and larvae
feeding on detritus.

represents a mortality of 96 percent from eggs to adults under laboratory conditions. Most mortality occurred in the first-instar larvae.

The larva of G. barbipes is relatively large in the fourth-instar, varying in length from 14-20 mm, depending on environmental conditions in the larval habitat and the time of year. For instance, after adult emergence ceases in October, each instar takes more time to develop but under favorable environmental conditions grows larger than normal. The fourth larval instar, attaining a larger size (16-20 mm), grows darker in color during the winter. This larvae is characterized macroscopically in the field by its wide, heavily sclerotized head capsule, a short stout pair of abdominal gills (Figure 5), and dark red color.

The larvae dwell in tubes and are frequently found extended their entire length from the tube to graze on settled algae and detritus (Figure 6). They are sometimes found in the upper strata of water swimming with characteristic lashing movements that are common to most "blood worms." The larvae can be induced to swim under laboratory conditions by starvation or by creating an anaerobic environment. A few larvae held in low oxygen conditions in the laboratory left their tubes in the substrate and built tubes near the air-water interface. Those that remained in their tubes in the bottom substrate all died within a week.
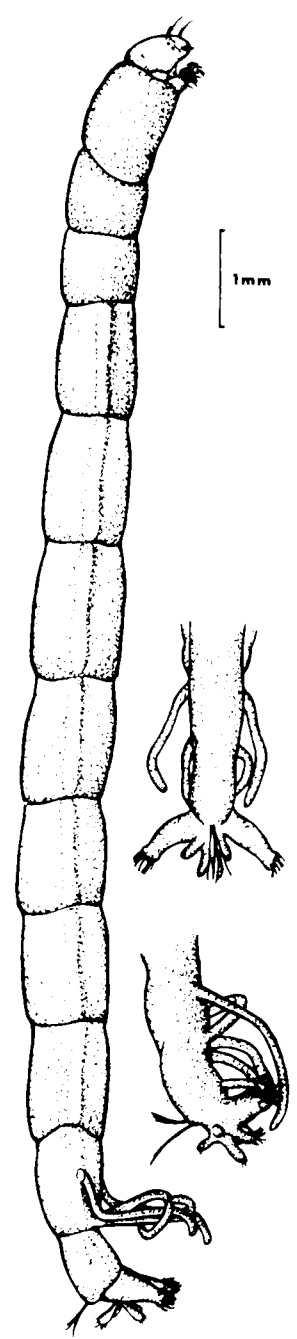
Figure 5

Fourth-instar larvae of the dominant Chironomidae

occurring in stabilization lagoons.  Drawing by

Thelwyn Koontz.

Anatopynia dyari

1mm
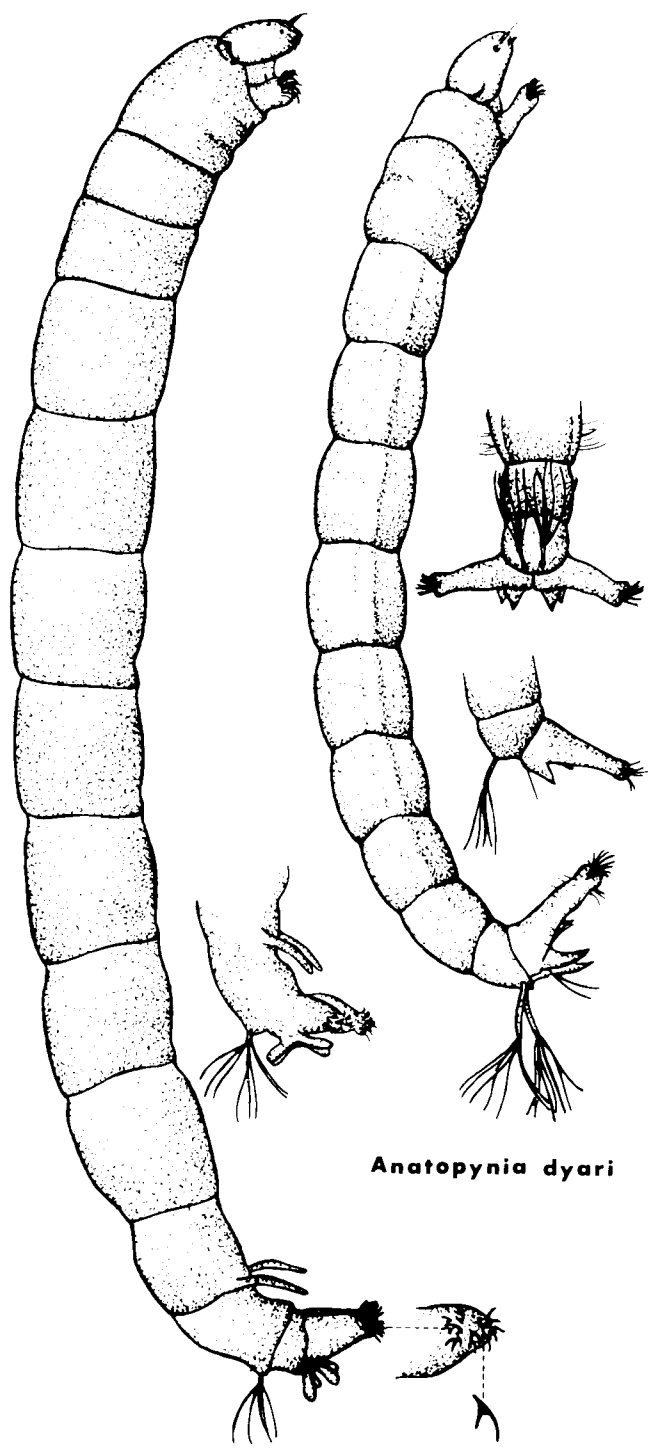
Glyptoptendipes barbipes

Chironomus riparius

Pupation occurs within the larval tubes prior to swimming to the surface to emerge. Most pupae cease swimming movement when they reach the surface. Of 30 emergences observed, a split appears in the pronotum within 5-30 seconds. The adult emerges from the pupal exuvia about 10-30 seconds later and stands on the surface of the water. Then after a lapse of approximately 5-15 seconds, the adult takes flight and alights in the tall grass at the edge of the lagoon.

In the early morning large numbers of pupae were occasionally found swimming or drifting at one end of the lagoons. They were never observed to emerge and presumably this portion of the population was moribund. About 50-100 of these pupae were collected and observed in the laboratory, and no emergence took place. No parasites were observed on the pupae, and none was seen to leave any pupa, but no dissections were made to determine the cause of mortality.

The egg masses of C. riparius are also enclosed in a sausage-shaped, gelatinous substance (Figure 7) and contained about 750 eggs. They can be distinguished from egg masses of G. barbipes by their smaller size, 10-15 mm, and by the dark brown to black color of the eggs. These egg masses are found in the water attached to vegetation or on the bottom of the lagoons. The eggs remain in the horseshoe-shaped spiral until hatched. In the laboratory 70-75°F

the eggs hatch in 2-3 days. A total of 238 adults were reared from a single egg mass held at 70-75$^{\circ}$F, and maximum emergence occurred at 31.5 $\pm$ 4.4 days after hatching. Percent hatch is unknown, but 10 separate egg masses were reared to emergence and the average survival was 235 adults for each egg mass. Assuming that there were 750 eggs in each egg mass, this represents a mortality of 69 percent from eggs to adults under laboratory conditions. Most mortality occurred in the first-instar larva.

C. riparius larvae are also tube dwellers and occupy the same microhabitat as G. barbipes, but C. riparius larvae are easily distinguished macroscopically in the field by their smaller size (10-15 mm), bright red color, weak sclerotization, small head capsule, and four filamentous abdominal gills on segment 11 (Figure 5). When disturbed, this species curls up in a characteristic flat coil. C. riparius larvae also graze on settled algae and detritus in the vicinity of their tubes and will vacate their tubes and swim readily if deprived of dissolved oxygen.

The eggs of A. dyari are enveloped in a lenticular mass of clear gelatinous substance. Each egg mass is usually attached to recumbent reeds or grasses below the surface of the water, but none was found submerged more than 5 cm below the surface (Figure 8). The eggs are dark brown in color and number about 400 for each egg mass. Development time from eggs to the emergence of adults
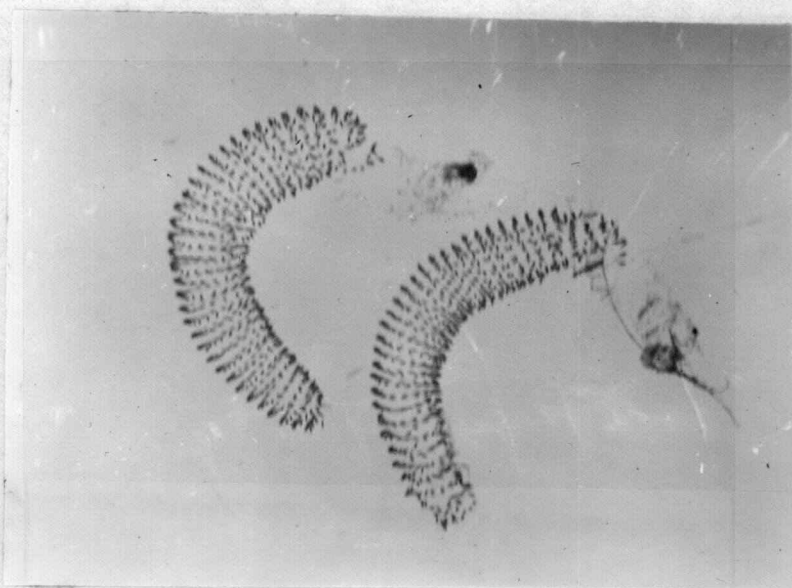
Figure 7. Egg masses of C. riparius
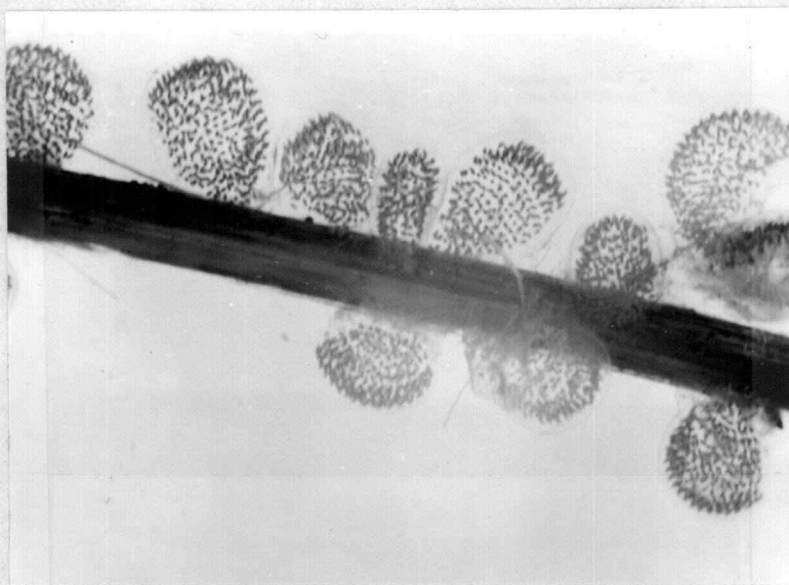


Figure 8. Egg masses of A. dyari attached
to a submerged grass stem.

is approximately 30 days at 70-75°F. The larvae of A. dyari do not

construct tubes but move along the substrate in undulatory move-

ments with the aid of their relatively long prolegs (Figure 5).

Though most of them are green in color, a few members of each

population are as red as the larvae of tube-dwelling species. Last-

instar larvae are 9-11 mm long and are characterized macroscopi-

cally by pointed anal gills and absence of abdominal gills on the

eleventh segment.

The only other large species listed from these stabilization

lagoons is C. plumosus, whose larvae are 18-25 mm long. They

were rare and did not exert a significant impact on the ecology of

stabilization lagoons.

The larvae of P. freemani are relatively small, about five

millimeters long in the last instar. They are tube makers, red in

color, and are difficult to distinguish macroscopically from the

early instars of G. barbipes. The tubes of P. freemani are easily

recognizable. They protrude from the substrate, are thin-walled

and somewhat coiled (Figure 9). The less conspicuous openings of

the large buried tubes in Figure 9 are tubes of G. barbipes. The

larvae of P. freemani were encountered in Village Green lagoon

only and were restricted in their microdistribution to a narrow band

about three feet wide around the periphery of the entire lagoon at a

depth of about a foot. These bands were quite densely populated in
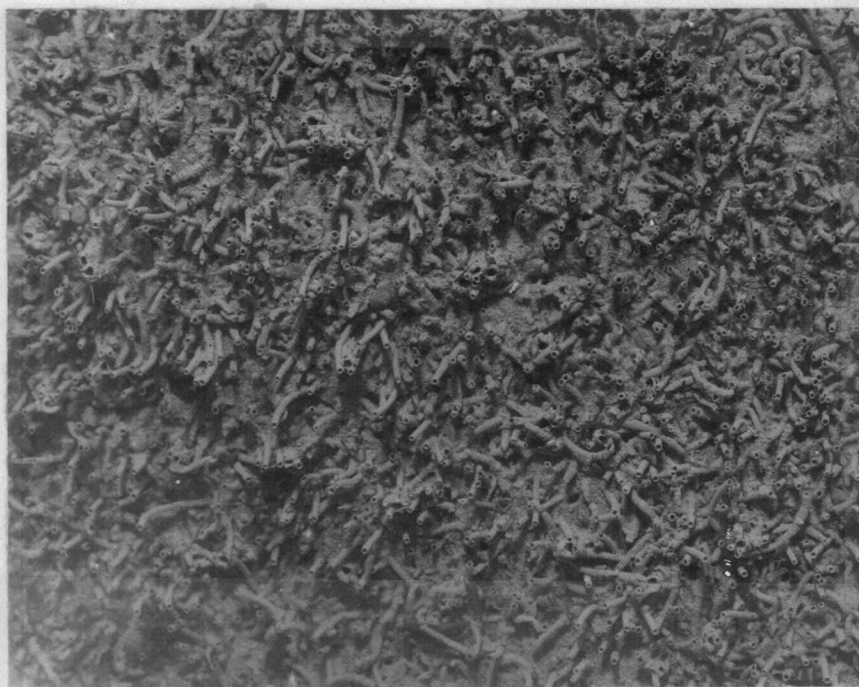
Figure 9. Occupied tubes of P. freemani showing the characteristic density in Village Green lagoon. May 1966.

May, with about 200 to 400 larvae per dredge haul, but most had emerged by June and these larvae were not found again.

The other species of Chironomidae in Table I are all less than five millimeters long in the last larval instar and were found very infrequently. Six of these species are new to science and are being described by Dr. J. E. Sublette, Eastern New Mexico University. The larvae of these species were usually found in small tubes attached to floating vegetation in well oxygenated water. They can also be collected by scraping them from the wooden sides of floating emergence traps or other solid objects submerged in water. These species were incidental and had very little impact upon the lagoon ecology.

## Other Insect Species in Stabilization Lagoons

Although most insect activity occurs at the periphery of the lagoons, larval Chaoboridae, Chaoborus nyblaei (Zett) and Chaoborus flavicans (Meigen), were sometimes very abundant in the center of lagoons. These larvae are transparent and difficult to detect in dredge samples screened in the laboratory. Their crescent-shaped "hydrostatic" organs, however, are visible against a white background, and counts of 50 larvae per dredge haul were sometimes obtained. As these were collected in dredge samples, they apparently occur in water near the sludge-water interface, at

least during daylight hours. Stahl (1966) showed that C. flavicans
and Chaoborus puntipennis (Say) became benthic during the daytime
and underwent vertical migration at night.

Most of the species of Corixidae recovered from an experi-
mental lagoon and listed by Sturgess (1964) were found in the lagoons
during the present investigation. Although no accurate sampling
method was worked out, population densities of corixids were esti-
mated at 20-30 per square foot in the peripheral areas of the cells.
Lagoons with large numbers of Corixidae were turbid with a muddy
suspension. Observations in the laboratory showed that water in
aquaria containing a mud substrate with both Chironomidae and
Corixidae were also turbid. Water in aquaria containing a mud sub-
strate and Chironomidae only were always clear. The suspension
of mud and detritus found in aquaria containing Corixidae was due to
their feeding and swimming behavior. The scooping movements of
the palae (modified tarsi) over the rostrum during feeding stirred
up mud and detritus and much of it remained in suspension. The
frequent movements to the surface to renew their oxygen supply also
increased turbidity by mixing the suspension in to the upper water
layers.

## ABUNDANCE AND SPECIES COMPOSITION
## OF LARVAL CHIRONOMIDAE

Village Green lagoon was lightly loaded with an estimated 21 pounds of BOD per acre per day. Insect population densities were relatively stable, with a strong seasonal variation, but no high winter mortalities occurred. Abundance and species composition of larval Chironomidae found in this lagoon presumably resulted from the relatively stable chemical and physical factors.

University Park lagoon consisted of three cells of unequal size and received unequal BOD loading rates on different occasions. Primary loading was switched from cell I at 118 pounds per acre per day to cell III at 70 pounds of BOD per acre per day in order to make the lagoon system function properly as an aerobic facility. This change appears to have strongly affected species composition and abundance within these cells. The sludge blanket of cells I and III supported permanent populations reaching a maximum density of 921 larvae per dredge haul (Figure 10), and these cells provided data suitable for analysis of variance.

The population numbers in cell II were low in winter and zero in summer. This was probably due to the absence of a sludge blanket to sustain the larvae, as this cell was not properly loaded at any time during the normal lagoon operation. Other factors producing the marginal environment for some chironomid larvae in cell II
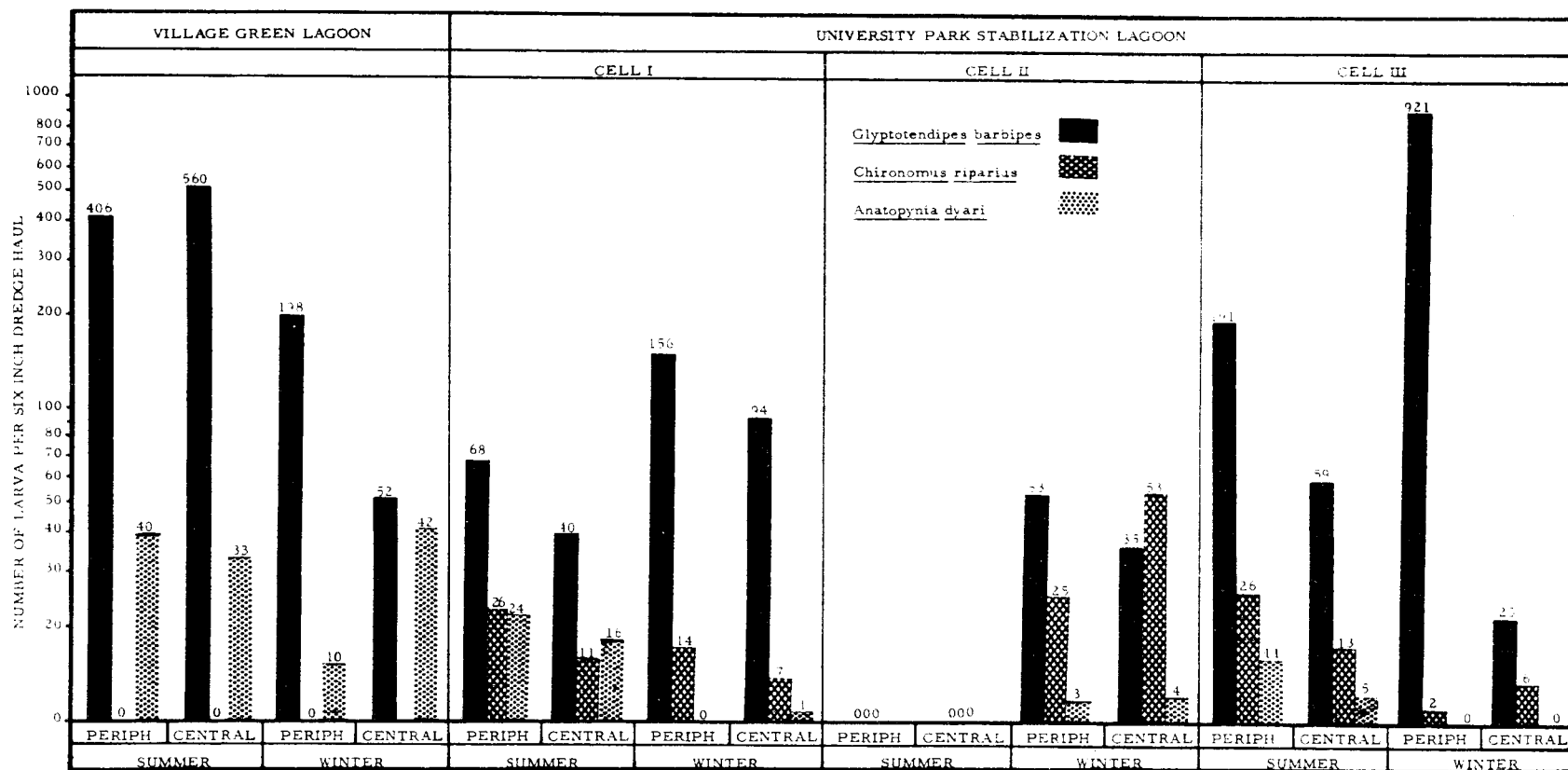
**FIGURE 10. RELATIVE SEASONAL ABUNDANCE OF LARVAL CHIRONOMID SPECIES FOR EACH ZONE**

were complicated and will be examined more fully in the discussion.

Dredging data are graphed from a table of means in Figure 10,

which illustrates results obtained by analysis of variance for both

lagoons.

## Dredging Results from Village Green Stabilization Lagoon

Results of the analysis of variance are shown in Table 2, and

the following is a discussion of the significant effects.

There was a significant (P < 0.001) main effect for seasons

which indicates a greater abundance of larvae during the summer.

The mean number of larvae per dredge haul in summer was 3.4

times that of the winter season.

Main effect for transects was non-significant, indicating no

difference between the two replicate transects. For this reason

dredging data of both transects were averaged to obtain the mean

population densities plotted in Figure 10.

Two species were treated in this analysis and the main effect

for species was significant (P < 0.001). Larvae of G. barbipes were

9.5 times more abundant than larvae of A. dyari.

First order interaction between species x seasons was signifi-

cant (P < 0.01), indicating the effect of species was not independent

of seasons. Larvae of G. barbipes were 6.5 times more abundant

in the summer than in winter. Similarly, larvae of A. dyari were

Table 2. Analysis of variance on the number of larval Chironomidae per dredge haul at Village Green stabilization lagoon, 1966.

| Source | d.f. | S.S. | E.V. | F |
|--------|------|------|------|---|
| Total | 127 | 67.399 | | |
| Seasons | 1 | 8.637 | 8.637 | 81.66*** |
| Zones | 1 | .280 | .280 | 2.65ns |
| Transects | 1 | .073 | .073 | .69ns |
| Species | 1 | 35.333 | 35.333 | 334.05*** |
| Species x Seasons | 1 | .842 | .842 | 7.96** |
| Species x Zones | 1 | 3.047 | 3.047 | 28.81*** |
| Species x Transects | 1 | .000 | .000 | .00ns |
| Seasons x Zones | 1 | .001 | .001 | .01ns |
| Seasons x Transects | 1 | 1.636 | 1.636 | 15.47*** |
| Zones x Transects | 1 | .119 | .119 | 1.13ns |
| Species x Seasons x Zones | 1 | 4.895 | 4.895 | 46.28*** |
| Species x Seasons x Transects | 1 | .078 | .078 | .73ns |
| Species x Zones x Transects | 1 | .051 | .051 | .48ns |
| Seasons x Zones x Transects | 1 | .455 | .455 | 4.30* |
| Species x Seasons x Zones x Transects | 1 | .051 | .051 | .48ns |
| Residual | 112 | 11.901 | .10626 | |

*Significant at the 95% confidence level  ***Significant at the 99.9% confidence level
**Significant at the 99% confidence level

1.4 times as abundant in the summer season than in winter.

Species x zones interaction was significant (P < 0.001), indicating that species abundance was not independent of zones. In the peripheral zone, G. barbipes was 13 times more abundant than A. dyari. In the central zone, G. barbipes was 8.1 times more abundant than A. dyari. Larval abundance of A. dyari was 1.5 times greater in the central zone than in the peripheral zone.

Seasons x transects showed a strong interaction, indicating that abundance of larvae in the two transects was not independent of seasons. Inspection of the dredging data in the appendix shows that in the summer 1.6 times more larvae were recovered from transect B than transect A. This trend was reversed for the two replicate transects in the winter season and larvae were 1.2 times more abundant in transect A.

Species x seasons x zones interaction was significant (P < 0.001). Larvae of G. barbipes were 1.4 times more abundant in the central zone than in the peripheral zone in the summer, and conversely, 3.8 times more abundant in the peripheral zone than in the central zone during winter. The situation with respect to A. dyari was reversed; larvae of this species were 1.2 times more abundant in the peripheral zone during the summer and, conversely, 4.2 times more abundant in the central zone than in the peripheral zone during winter.

The only other significant (P < 0.05) interaction was between seasons x zones x transects, indicating that the effects of zones x transects are not independent of seasons. In the summer larvae were 1.2 times more abundant in the central zone than in the peripheral zone of transect A and 1.4 times more abundant in the central zone than in the peripheral zone of transect B. The situation in winter was reversed; larvae were now 1.7 times more abundant in the peripheral zone than in the central zone of transect A, and 2.0 times as abundant in the peripheral zones than in the central zone of transect A.

In summary, the analysis of variance of Village Green lagoon dredging data indicate the following: Total larval abundance was greater in the summer, greater for G. barbipes than for A. dyari, and greater for G. barbipes in both zones. Total larval abundance was greater from transect B than A in summer, and greater from transect A than B in winter. Larval abundance of G. barbipes was greater in the central zone during summer, and greater in the peripheral zone in winter. Conversely, larval abundance of A. dyari was greater in the peripheral zone during summer, and greater in the central zone during winter.

## Dredging Results from University Park Stabilization Lagoons

Of the dredge samples obtained from three cells of University

Park lagoon, only cells I and III provided data suitable for analysis of variance (Table 3).

Three species were treated in this analysis of variance and the main effect for species was significant ($P < 0.001$), indicating that there was a significant difference between species population densities. Figure 10 shows that for cells I and III the order of species dominance was G. barbipes > C. riparius > A. dyari.

The main effect for seasons was significant ($P < 0.001$), indicating a seasonal difference in population densities. The effect for seasons was very pronounced due to the large overwintering populations of G. barbipes. The mean abundance of all larval Chironomidae was 2.5 times greater in the winter season.

The main effect for cells showed a significant difference ($P < 0.01$), indicating that the population densities are different for each cell. The average larval density for cell III was 2.7 times greater than that of cell I.

Main effects for zones were significant ($P < 0.001$), indicating that zones influence larval abundance. This was in contrast to the main effect for zones of the Village Green analysis. Larval concentrations in University Park were consistently higher in the peripheral zones, and were 2.5 times greater than those of the central zones.

The first order interaction species x seasons was significant ($P < 0.001$), indicating that species abundance was not independent

Table 3. Analysis of variance on the number of larval Chironomidae per dredge haul at University Park stabilization lagoon, 1966.

| Source | d.f. | S.S. | E.V. | F |
|---|---|---|---|---|
| Total | 383 | 277.9820 | | |
| Species | 2 | 149.129 | 92.763 | 875.94*** |
| Seasons | 1 | 8.458 | 8.458 | 79.87*** |
| Cells | 1 | 0.818 | 0.819 | 7.73** |
| Zones | 1 | 12.575 | 12.575 | 118.75*** |
| Species x Seasons | 2 | 30.759 | 15.379 | 145.23*** |
| Species x Cells | 2 | 2.136 | 1.068 | 6.72** |
| Species x Zones | 2 | 11.195 | 5.597 | 52.86*** |
| Seasons x Cells | 1 | 3.317 | 3.317 | 31.32*** |
| Seasons x Zones | 1 | 0.032 | 0.032 | .31ns |
| Cells x Zones | 1 | 0.017 | 0.017 | .17ns |
| Species x Seasons x Cells | 2 | 5.824 | 2.912 | 27.50*** |
| Species x Seasons x Zones | 2 | 8.718 | 4.359 | 41.16*** |
| Species x Cells x Zones | 2 | 4.610 | 2.305 | 21.77*** |
| Seasons x Cells x Zones | 1 | 0.016 | 0.016 | 0.00ns |
| Species x Seasons x Cells x Zones | 2 | 2.177 | 1.089 | 10.28*** |
| Residual | 360 | 38.159 | 0.106 | |

**Significant at the 99% confidence level
***Significant at the 99.9% confidence level

of season. The larvae of G. barbipes were 3.3 times more abundant in the winter. In contrast, the larval abundance of C. riparius was 2.6 times greater in the summer. Larvae of A. dyari were sparse or absent during the winter, but an average of 14 larvae per dredge haul was found in these cells during the summer season.

Species x cells showed a significant (P < 0.01) interaction, indicating that species abundance was not independent of cells. The larval abundance of G. barbipes in cell III was 3.2 times greater than in cell I. In contrast, the larval abundance of C. riparius in cell I was 1.2 times that of cell III. The larval abundance of A. dyari was 2.6 times greater in cell I than in cell III.

Species x zones was significant (P < 0.001), indicating that species abundance was not independent of zones. Larval G. barbipes were 6.1 times more abundant in the peripheral zones than in the central zones. Larval abundance of C. riparius in the peripheral zones was 2.5 times that of the central zones. Larval A. dyari were only slightly (1.1 times) more abundant in the peripheral zones than in the central zones.

Seasons x cells showed a significant (P < 0.001) interaction, indicating that the effect of cells is not independent of seasons. The seasonal effect in cells I and III is evident in Figure 10, which shows large overwintering populations. Larval density was 1.5 times greater during the winter than in summer in cell I, and 3.0 times

greater during the winter in cell III than in the summer.

Second order interactions showed significant (P < 0.001) differences between species x seasons x cells. The average larval $\underline{G}$. $\underline{barbipes}$ density in cell III during winter was 3.8 times that of cell I. In summer the density of this species in cell III was 2.3 times that of cell I. Conversely, the average larval density for $\underline{C}$. $\underline{riparius}$ in cell I during the winter was 2.6 times greater than cell III, and in the summer the average larval density of this species was almost equal for each cell. Populations of $\underline{A}$. $\underline{dyari}$ were sparse or absent in both cells in the winter but were 2.5 times more abundant in cell I during the summer.

Species x seasons x zones showed a significant (P < 0.001) difference. The larval abundance of $\underline{G}$. $\underline{barbipes}$ in the winter was 9.2 times greater in the peripheral zones, and 2.6 times greater in the peripheral zones during the summer. Larval abundance of $\underline{C}$. $\underline{riparius}$ in the winter was 2.3 times greater in the peripheral zones, and 1.5 times as great in the summer. Larvae of $\underline{A}$. $\underline{dyari}$ were sparse or absent in both zones during winter but were 1.7 times more abundant in the peripheral zones during summer.

Species x cells x zones interaction is significant (P < 0.001). Larvae of $\underline{G}$. $\underline{barbipes}$ in cell I were 1.7 times more abundant in the peripheral zones than in the central zones. In cell III this species is 13.5 times more abundant in the peripheral zones than in the

central zones. Larvae of C. riparius in cell I were 1.7 times more abundant in the peripheral zones than in the central zones. In cell III these larvae relative to the central zones were 1.5 times more abundant in the peripheral zones. Larvae of A. dyari in cell I relative to the central zones were 1.4 times as abundant in the peripheral zones. In cell III the larvae of this species relative to the central zones were 2.2 times more abundant in the peripheral zones.

The third order interaction species x seasons x cells x zones was significant (P < 0.001), indicating that all these sources of interaction are not independent of each other, and consequently all have an effect on species abundance in the lagoon environment. Larval abundance of G. barbipes was greater in the winter, greater in cell III, and greater in the peripheral zones. Larval abundance of C. riparius was greater in the summer, greater in cell I, and greater in the peripheral zones. Larval abundance of A. dyari was greater in the summer, greater in cell I, and greater in the peripheral zones.

# EMERGENCE OF ADULT CHIRONOMIDAE

Emergence rates for each cell were estimated in order to compare the relative adult midge production for each lagoon habitat. There were no reports of nuisance conditions from nearby residential areas that can be attributed to midge emergence from stabilization lagoons. From data obtained by larval surveys in the lagoons, it seems improbable that any chironomid other than G. barbipes would occur in numbers sufficient to cause nuisance conditions.

When chironomid catches from the receiving jar of a dark emergence trap used in this study were compared to the total catch recovered from a transparent trap, the following results were found for dark trap efficiency for each species: G. barbipes, 34 percent, C. riparius 48 percent, and A. dyari 58 percent. Weekly catches were then adjusted to show the estimated relative abundance in Figures 11, 12 and 13.

These results are not in agreement with those obtained by Kimerle and Anderson (1967). Efficiencies of their dark traps were: G. barbipes 10 percent, C. riparius and A. dyari 37 percent. Differences in dark trap efficiency were probably due to differences in construction materials and design. Kimerle and Anderson used traps made of impervious black plastic material. I used black muslin cloth that transmitted some light, and the use of wide-mouthe d

jars at the apex of the pyramid also increased the amount of light entering these dark traps.

## Emergence of G. Barbipes

The emergence of adult G. barbipes populations was characterized by their sudden appearance in large numbers; sustained emergence activity throughout the summer; and sudden cessation of emergence in the fall.

Seasonal emergence patterns of G. barbipes in 1966 are illustrated in Figure 11. Village Green lagoon data show a characteristic emergence pattern which culminates during May at 1700 midges per square yard per week. Emergence continues throughout the summer season at the rate of about 300 per square yard per day. In late summer emergence rates increase to 500 per square yard per day in September before ceasing in October.

Emergence patterns of G. barbipes from the cells of University Park lagoon were in contrast to the characteristic seasonal pattern and are not representative of lagoons under continuous BOD loading. Cell III, for example, showed a typical emergence pattern in the spring with a maximum rate of 1500 per square yard per week in May. This activity was sustained for two weeks before rapidly declining in June and finally ending in the first week of July.

Cell II was characterized by low numbers of emerging
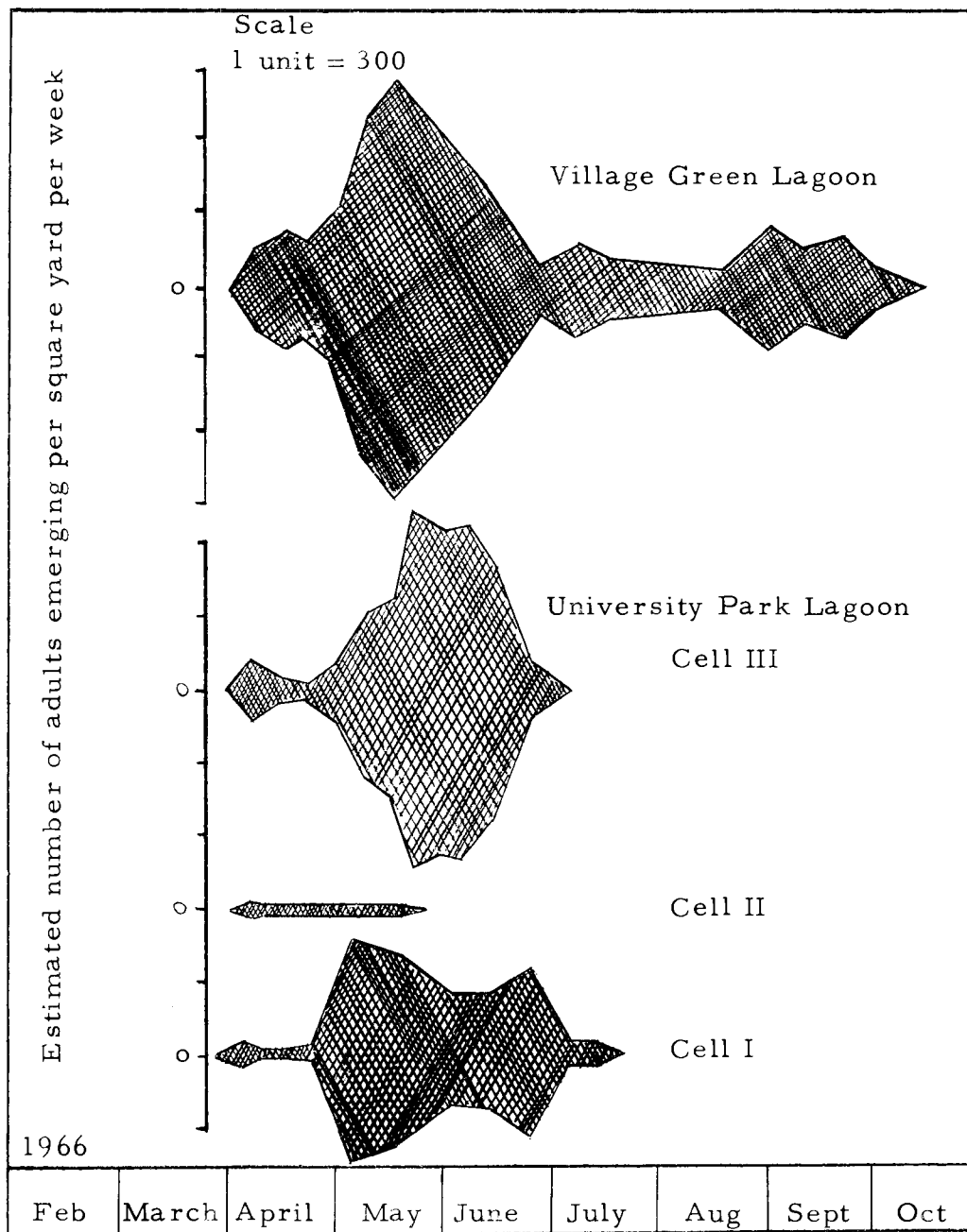
Figure 11. Relative abundance of G. barbipes estimated from dark trap catches. Village Green and University Park lagoons.

G. barbipes, probably due to the combined effects of poor nutrition for larval development of this species, and the thick mat of duckweek growing at the surface throughout the season. There was no pronounced maximum emergence rate in this cell and emergence ended in May.

Emergence of G. barbipes from cell I is similar to that of cell III with maximum activity in May but with marked reduction in emergence ending in July. Several considerations must be taken into account in explaining the differences in patterns of emergence from these two lagoons. Village Green lagoons shows an example of G. barbipes emergence from a lagoon environment under continuous low-level organic loading. This loading makes nutrients available to the larval population and emergence continues until October. In contrast, the loading of University Park lagoon was shut down in November 1965. Consequently, the sludge blanket served directly as a food reservoir for larval development, and an indirect food source supplying dissolved nutrients that sustained growths of single-celled algae, which in turn served as food for chironomid larvae.

A surface layer of duckweed started growing in cell II in the summer of 1965, and by April 1966 had completely covered the cell. This layer prevented light penetration and precluded oxygen production by algae. Consequently, anaerobiosis occurred at times at the

soil-water interface presumably resulting in low larval chironomid populations.

## Emergence of C. riparius

Emergence patterns for C. riparius populations were in contrast to those of G. barbipes in that small numbers emerged throughout the entire winter except when ice completely covered the lagoon. The pupae presumably remained in the larval tubes during ice cover.

Emergence of C. riparius from Village Green lagoon was very sparse and irregular with a few adults emerging in May-June. Since their presence in this lagoon was incidental emergence rate was not plotted on a graph. Figure 12 shows that emergence activity of C. riparius for cell III of University Park reached a maximum rate in June at 850 per square yard per week and ended in July. Cell II shows a year-round production of adult C. riparius except for the period of ice cover in December. Emergence numbers rapidly built up in the spring and culminated in March at 1,250 per square yard per week. Emergence of adults then rapidly declined in April and ended in June. Cell I shows a continous low level production of adults throughout the winter except during ice cover, but there were no discernible maximum production rates and emergence ended in July.

III

Scale

1 unit = 200

II

Estimated numbers of adults emerging per square
yard per week

I

1965

1966

| Sept | Oct | Nov | Dec | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct |
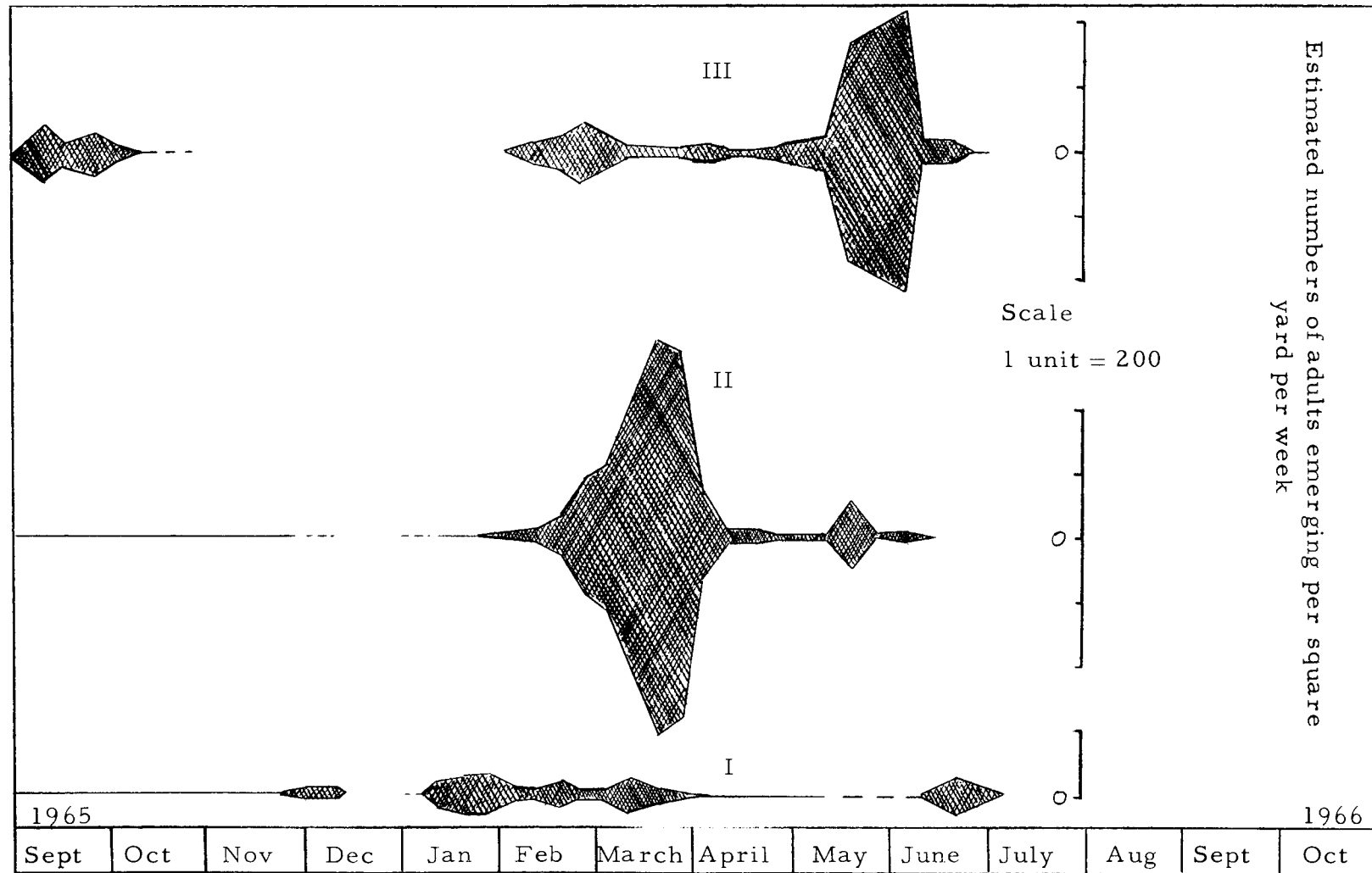
Figure 12. Relative abundance of C. riparius estimated from dark trap catches University Park
lagoon.

## Emergence of <u>A</u>. <u>Dyari</u>

A few <u>A</u>. <u>dyari</u> emerged from Village Green lagoon in May-June, but since their numbers were low they were not plotted on a graph. Cell III of University Park (Figure 13) shows emergence beginning early in March with increasing activity in May and a strong maximum production rate in June at 920 emergences per square yard per week. Emergence ceased in July 1966, but preliminary observations made in 1965 indicated that emergence activity was likely to continue to November or December (Figure 13). Cell II shows intermittent production in the fall of 1965. Emergence in 1966 started in March and reached a maximum rate in April at 180 per square yard per week and ended in June. Cell I also showed intermittent production in the fall of 1965 ending in December. Emergence in 1966 started in March and showed ill-defined maximum emergence rates in April at 100 per square yard per week and continued until July.
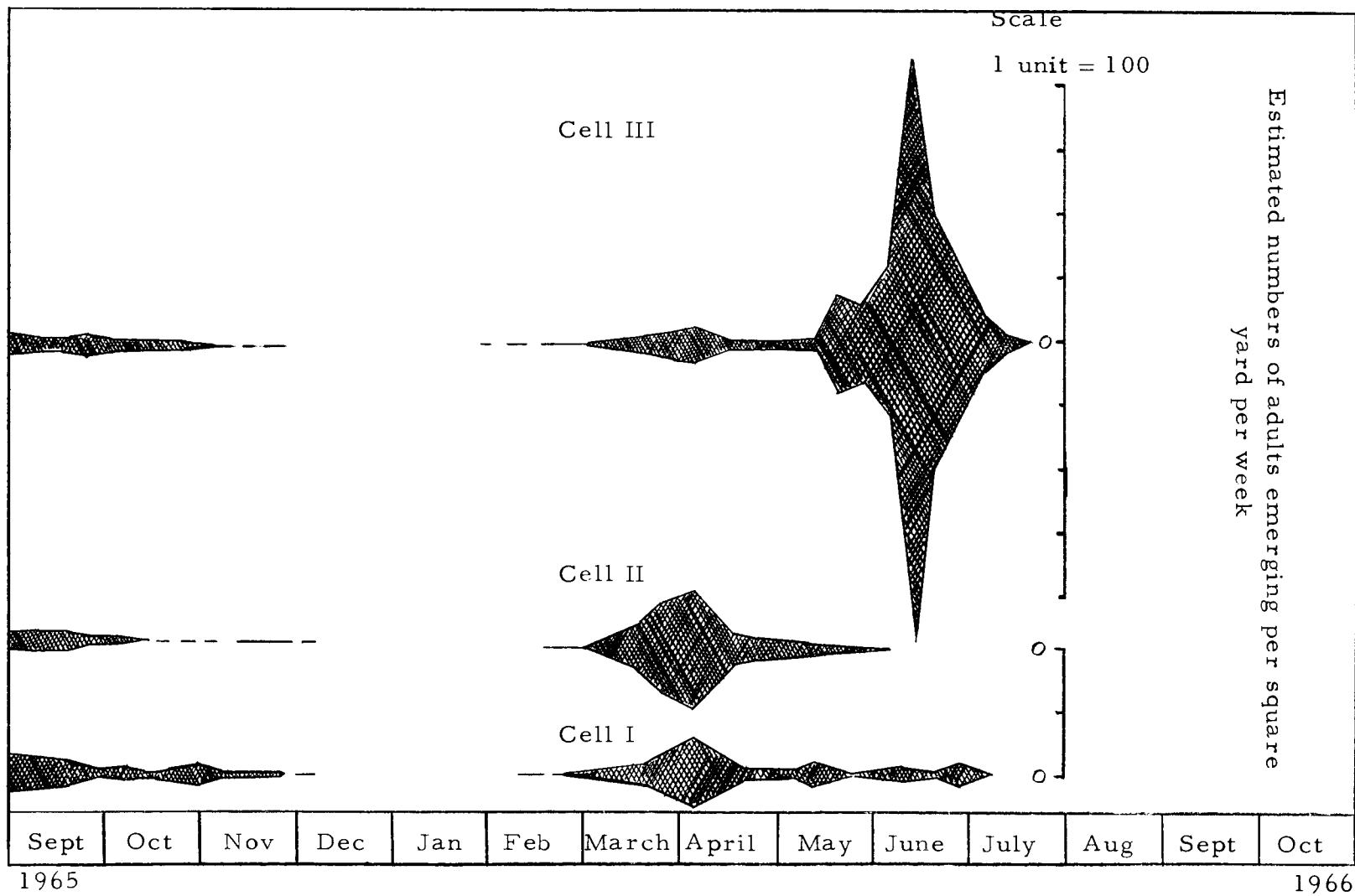
Figure 13. Relative abundance of $\underline{A}$. $\underline{dyari}$ estimated from dark trap catches. University Park lagoon.

# TOLERANCE OF LARVAE TO CHEMICAL AND
# PHYSICAL STRESS FACTORS OCCURRING IN
# STABILIZATION LAGOONS

Quantitative estimates of tolerances of the dominant species to

the most important chemical and physical factors in their micro-

environment were obtained in order to attempt an explanation of the

species composition and microdistribution of larval Chironomidae in

stabilization lagoons.

G. barbipes and A. dyari are hardy species and no mortality

occurred in controls. However, C. riparius is not as hardy and 10

percent mortality occurred in controls. Consequently, Abbott's

formula (Busvine, 1938) was used as a correction factor in these

tests for C. riparius only. Chironomidae respond to treatment in

many ways and are quite variable. However, observations during a

large number of preliminary tests have shown any one of the follow-

ing mortality criteria to be irreversible: discoloration, unnatural

posture, tremors, incoordination or rigor, and inability to swim

when touched with a probe.

## Tolerance to Synthetic Sewage

Sewage loading is an important factor affecting the abundance

and microdistribution of larval Chironomidae in stabilization

lagoons (Sturgess, 1964). Larvae require organic material for food,

but an excess of suspended solids and dissolved organic materials

is detrimental to their development (Fagan and Enns, 1966).

The log dose probability (LDP) lines for response of two

species to concentrations of synthetic sewage are drawn in Figure

14. Calculated $LD_{50}$ for C. riparius is 4,240 ppm. This is the

dose required to kill 50 percent of these larvae during a five-day

exposure to this concentration at room temperature. The standard

error of this $LD_{50}$ for C. riparius 120 ppm. The $LD_{50}$ and the

standard error for G. barbipes is 18,110 $\pm$ 104 ppm.

The response of A. dyari larvae to concentrations of synthetic

sewage is also plotted in Figure 14, but a Chi-square test on these

data showed that they had a significant (P < 0.05) departure from

linearity. Thus, a straight line does not adequately represent the

relationship between log concentration of synthetic sewage and probit

mortality. The $LD_{50}$ and its fiducial limits cannot be calculated

from these data. There may be interactions present due to the

chemical composition of the synthetic sewage, but when the homo-

geneous results for the two previous species are considered, it is

more likely that the variability in response is inherent in the popula-

tion selected for the test. Fourth-instar larvae of A. dyari were in

short supply when these tests were made, and those selected from

the wild population were probably not homogeneous in age or physio-

logy. The number of replicates could not be increased and variability
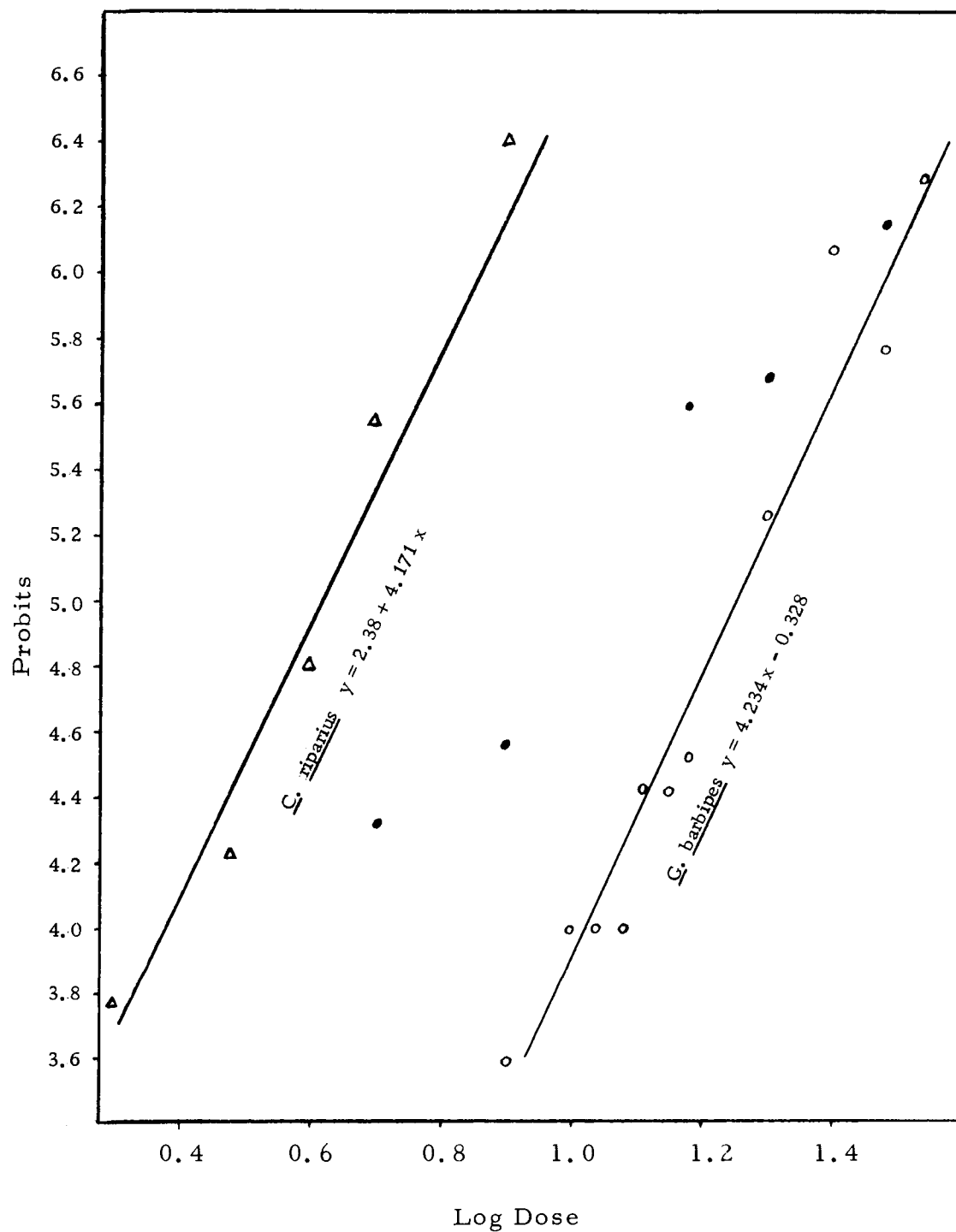
Figure. 14. Probit analysis of two species of Chironomidae against synthetic sewage. Data for A. dyari plotted (solid dots) but no LDP line drawn. Abscissae are log concentrations of synthetic sewage (dose).

in response was quite large. However, this test indicates that the

order of tolerance for two species to synthetic sewage is as follows:

G. barbipes > C. riparius.

## Tolerance to Cold

Low temperatures may have adverse effects on the develop-

ment of larval Chironomidae and may account for their particular

microdistribution in stabilization lagoons. When the ambient air is

colder than the water, a definite temperature gradient exists in

stabilization lagoons (Bartsch and Allum, 1957; Marais, 1966).

Temperature is usually warmer at the mud-water interface than in

water above this layer. Under these conditions, temperature of the

mud-water interface increases slightly with depth and distance from

the shore.

The results of probit analysis for three species of larvae

are shown in Figure 15. Estimated $LD_{50}$ for C. riparius is 3.0 $\pm$

0.1 days at $0^{\circ}C$. The results for A. dyari were sufficiently linear

in this test, and the estimated $LD_{50}$ is 5.4 $\pm$ 0.1 days. The larvae

of G. barbipes showed the greatest tolerance for exposure to cold,

and the $LD_{50}$ for this species was 15.9 $\pm$ 0.1 days. Taking the

antilog of dose 1.5 in Figure 15 gives 31 days. This indicates that

at 31 days exposure to $0^{\circ}C$ about 10 percent of G. barbipes will

survive.
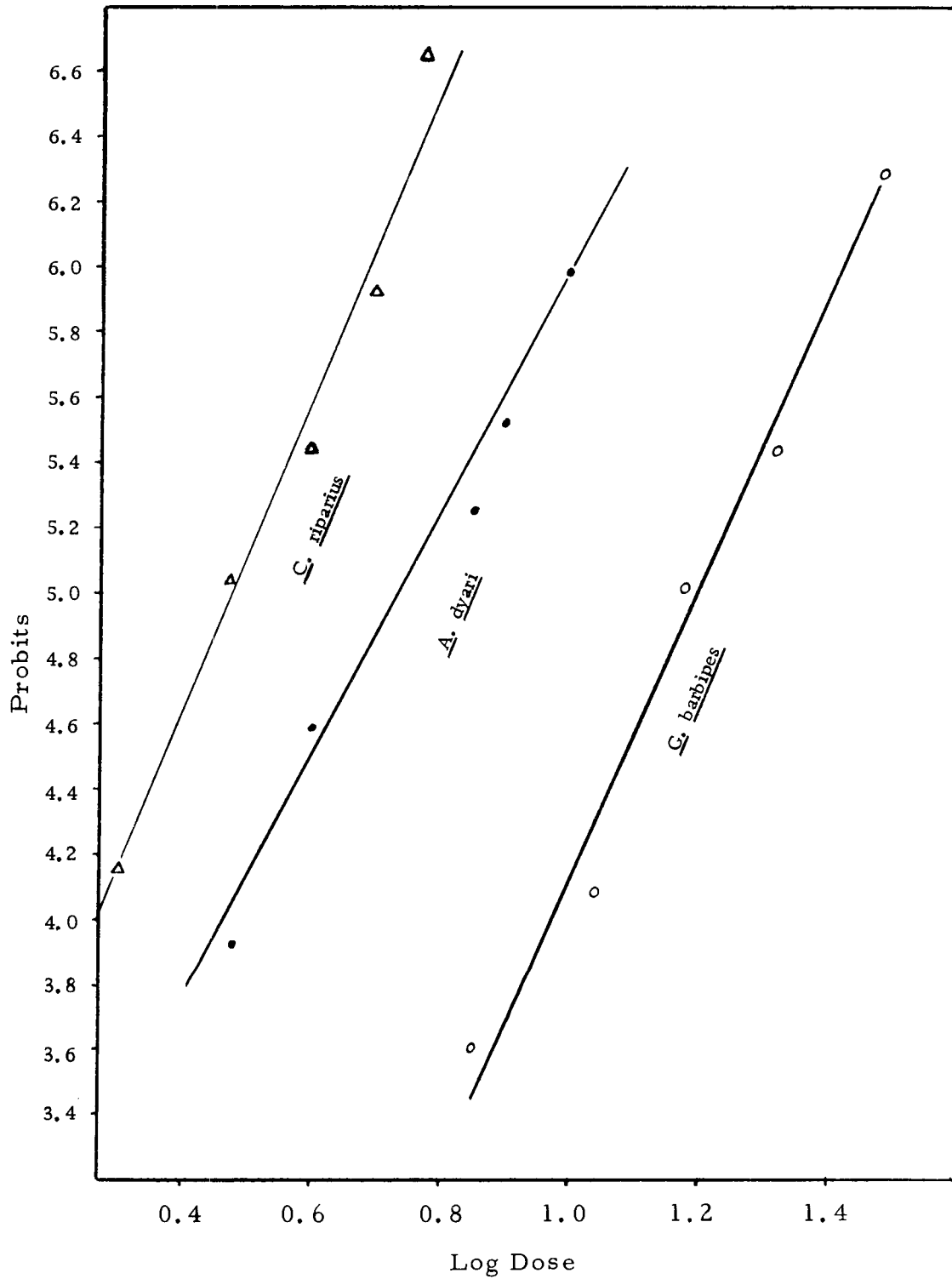
Figure 15.  Probit analysis for three species of Chironomidae to cold.  Abscissae are log of days at $0^{\circ}C$ (dose).

Tolerance to Anaerobiosis

Oxygen lack for extended periods of time has a detrimental effect on larval Chironomidae. The dominant larvae of stabilization lagoons are, however, adapted to some degree to oxygen deficiencies. Samples of water taken near the micro-environment of larval Chironomidae indicate that dissolved oxygen decreases with depth and distance from the shore (Brundin, 1950; Marais, 1966; Mundie, 1956). Extended periods of anaerobiosis are believed to be responsible for catastrophic reductions of benthic macrofauna of lagoons loaded in excess of 30 pounds of BOD per acre per day (Fagan and Enns, 1966).

The following tests were designed to evaluate the effect of experimental anaerobiosis on the three dominant species of chironomid larvae. To reduce the effect of mortality due to other factors such as methane production, and other excretion products of anaerobic bacteria, a minimum amount of organic material was used in the culture medium.

The results of probit analysis for three species of larvae to anaerobiosis are shown in Figure 16. Estimated $LD_{50}$ for C. riparius is $1.8 \pm 0.1$ days. The results of A. dyari show an estimated $LD_{50}$ of $2.3 \pm 0.1$ days. The results for G. barbipes indicate that this species is the most tolerant to anaerobiosis, and
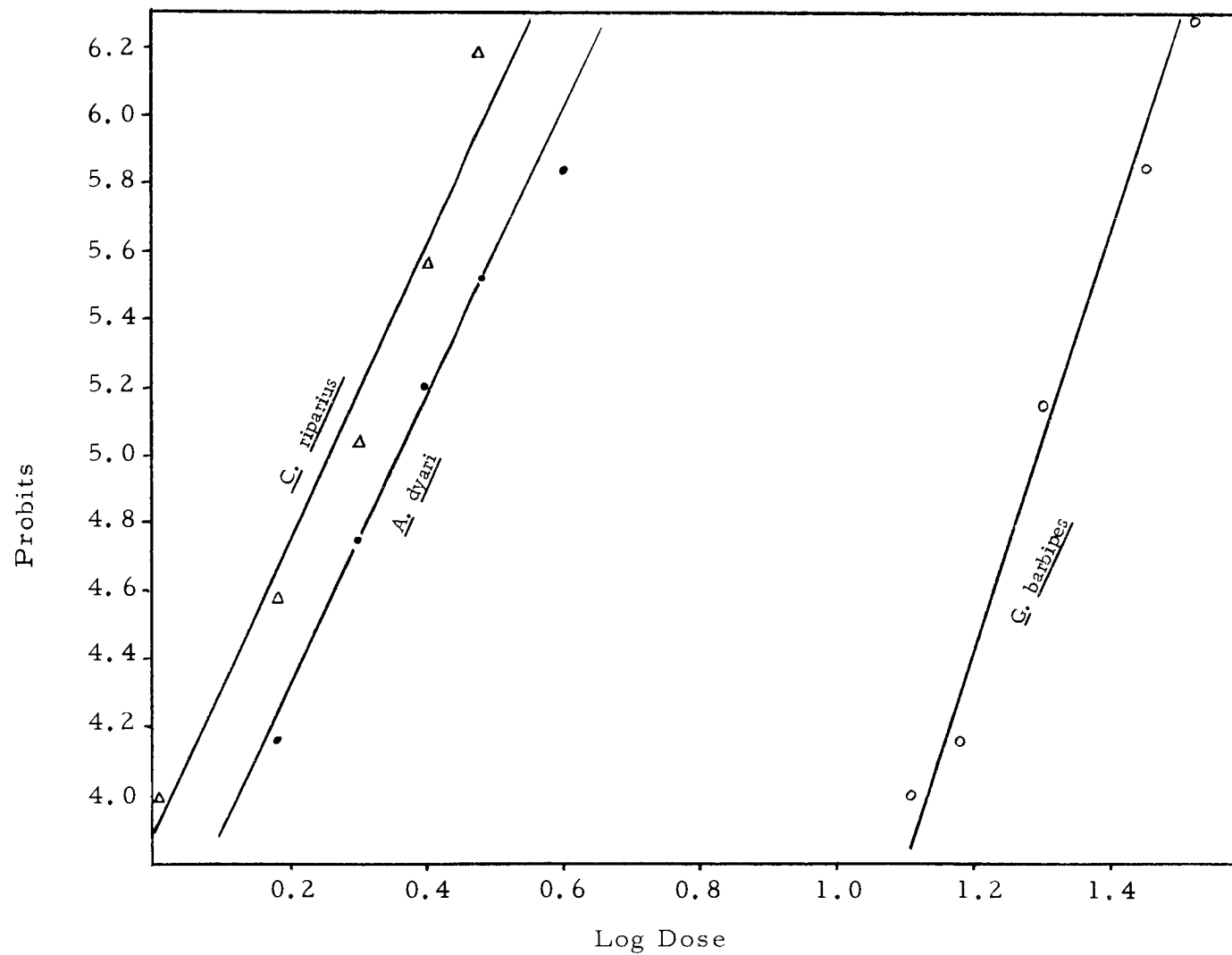
Figure 16. Probit analysis for three species of Chironomidae to anaerobiosis. Abscissae are log of days of anaerobiosis at $10^{\circ}$C (dose).

the estimated $LD_{50}$ is 19.5 $\pm$ 0.1 days. Inspection of the LDP line

for G. barbipes shows that 10 percent of this population will survive

experimental anaerobiosis for 33 days when held at $10^{\circ}C$.

Table 4.  Tolerance of fourth-instar larvae to chemical and physical
factors occurring in stabilization lagoons.

| Species | Factors | | |
|---|---|---|---|
| | Synth. Sewage (ppm) | Cold (Days) | Anaerobiosis (Days) |
| G. barbipes | 18,110 $\pm$ 104* | 15.9 $\pm$ 0.1 | 19.5 $\pm$ 0.1 |
| A. dyari | -- | 5.4 $\pm$ 0.1 | 2.3 $\pm$ 0.1 |
| C. riparius | 4,240 $\pm$ 120 | 3.0 $\pm$ 0.1 | 1.8 $\pm$ 0.1 |

*$LD_{50}$ $\pm$ standard error

The results of these experiments are summarized in Table 4,

which shows the following order of tolerance to these factors:  G.

barbipes > A. dyari > C. riparius.

Dissolved Oxygen Content in Stabilization Lagoons

Dissolved oxygen determinations are quite variable in stabiliza-

tion lagoons and no two determinations give identical results unless

taken simultaneously from identical sites.  Dissolved oxygen deter-

minations of water samples taken eight feet from the shore on a

sunny day with no wave action at the surface of the lagoon were 25.0

ppm at six-inch depth and 1.5 ppm at 2.5 foot depth near the

mud-water interface. A day later under approximately the same

conditions with the exception of strong wave action, the dissolved

oxygen readings at the same location were 11.1 ppm at six-inch

depth, and 8.5 ppm at 2.5 foot depth near the mud-water interface.

Many factors affect the dissolved oxygen content in lagoons

and these will be examined more fully in the discussion.

DISCUSSION

One of the principal factors affecting the microdistribution and
abundance of chironomid larvae in stabilization lagoons is influent
quality and quantity. Sustained BOD loadings in excess of 50 pounds
per acre per day are detrimental to larval chironomid populations
(Fagan and Enns, 1966; Sturgess, 1964). Low BOD loading rates
of less than 10 pounds per acre per day provide aquatic environ-
ments conducive to wide species diversity and attendant reduction
in chironomid production. The diversity of insect predators be-
comes more widespread with an increase in community complexity,
and an increase in the number of predators curtails large population
increases of prey species, such as some Chironomidae (Patrick,
1953). The usual BOD loading rate for aerobic stabilization lagoons
in a maritime climate is from 20 to 30 pounds per acre per day
(Wilson, McDermott and Livingston, 1960). Village Green lagoon
was continuously loaded at 21 pounds of BOD per acre per day.

### Microdistribution of Larvae in Village Green Lagoon

In the summer season, larval abundance in Village Green was
significantly greater than in the winter. This was due to the reduc-
tion in water depth during the summer, resulting in a reduction in
degree of slope of the peripheral zone (Figure 2), and less

pronounced stratification of dissolved oxygen. In general, stratification of dissolved oxygen occurred only on windless days when no water mixing was evident.

Research on the performance of stabilization lagoons (Marais, 1966) at Lusaka, Zambia, has shown that when there is no wind, dissolved oxygen stratification develops abruptly and a thermocline forms. Temperature above the thermocline increases to a maximum and then decreases daily, while below the thermocline the temperature rapidly falls to a value approximately that of the soil and thereafter remains practically constant.

Under windy conditions water mixing above the thermocline overcomes the stratification forces and progressively mixes the water displacing the thermocline downwards until the whole lagoon is in a state of mixing. Marais concludes that anaerobic conditions are much more likely to occur in summer than in winter because of the intense stratification.

Observations made at Village Green lagoon indicate that dissolved oxygen stratification and anaerobiosis at the sludge-water interface are more likely to occur in winter due to the increased depth of water. Conversely, no pronounced stratification occurred in the summer due to the reduction of water depth.

Reduction in water depth to 1.0 - 1.5 feet (Figure 2) in the central zone created a more comparable environment for larval

Chironomidae in both peripheral and central zones, and total larval

abundance from each zone was not significantly different. Larvae

in both zones occupied a well oxygenated environment, and due to

lowering of the euphotic layer, phytoplankton was probably at suf-

ficient density near the sludge-water interface of the central zone to

provide ample food for the larvae. Also, sufficient sunlight pene-

trated the reduced water depth to support growths of algae among

larval tubes at the bottom and contributed to the food supply.

These summer conditions made possible the rapid growth and

development of larvae throughout both zones of the lagoon.

Winter ecological conditions between peripheral and central

zones were not comparable. This was due to an increase in water

depth to 3.5 feet in the central zone which resulted in a more pro-

nounced dissolved oxygen stratification with frequent nocturnal

anaerobic conditions at the sludge-water interface. Consequently,

larvae were more concentrated in the peripheral zone where pre-

sumably, dissolved oxygen and algal food from the euphotic layer

was more readily available to them.

Larval abundance of G. barbipes was significantly greater than

A. dyari, and was probably due to the greater degree of tolerance

of G. barbipes to physiochemical factors occurring in lagoons. Also,

larval tubes of G. barbipes were packed together and required rela-

tively little space. In contrast, larvae of A. dyari are ambulatory

and require more foraging space per larva than do tube dwelling species.

The low population density of larval C. riparius in Village Green lagoon was probably the result of sustained sewage loading.

Larval abundance of both G. barbipes and A. dyari was significantly greater during the summer due to the more favorable ecological conditions throughout the lagoon during this season. In summer the peripheral slope was exposed to desiccation during the reduction in water depth, and no organic material accumulated on the dry portion of the slope. When the lagoon filled in winter, this portion of the slope became submerged and the resulting soil-water interface probably lacked nutrients, or was otherwise in poor condition to support large numbers of overwintering larvae.

Larval abundance of A. dyari was significantly greater in the central zone during winter. This species does not swim readily, and because of their ambulatory method of locomotion it is possible they do not migrate up the peripheral slope as readily as G. barbipes. Also, the seasonally desiccated portion of the slope may not meet the food requirements of larval A. dyari in winter.

Significant seasons x transects interaction showed that larval abundance was greater at one end of the lagoon in the summer, and that the situation was reversed in the winter. These results could have been due to a normal shift in population densities at the bottom

of the lagoon, but it was more likely a result of biased sampling.

This could have come about by locating the transect lines at unequal

distances from the influent pipe at each season. The influent pipe

discharges sewage into the center of the lagoon and larval density

probably varies with distance from this pipe. Any beneficial effects

of increased nutrients, or detrimental effects due to shock BOD

loadings (Sturgess, 1964) upon larval abundance, would be ampli-

fied in the immediate vicinity of the influent.

## Microdistribution of Larvae in University Park Lagoon

Ecological conditions in University Park lagoon were compli-

cated by changes in amount of sewage loading, and by the reversal

of loading sequence from the primary cell to the secondary cell.

Changes in cell usage had a strong effect on insect abundance and

microdistribution. However, cell III represented the most usual

lagoon environment for tolerant species. Cell I was the primary

cell in 1964 and due to poor water circulation throughout the lagoon,

the loading rate was 120 pounds of BOD per acre per day. This ex-

cessive loading resulted in the rapid deposition rate of sludge, and

consequent anaerobic conditions. No larval Chironomidae were

found in this cell during 1964, and in November the primary loading

of this lagoon was switched to the larger cell III at the rate of 70

pounds of BOD per acre per day. Subsequently, the sludge blanket

in cell I underwent aerobic decomposition and compaction, and by January 1965 all three dominant species of larval Chironomidae were overwintering in this cell.

Loading had been suspended at University Park lagoon by the time this larval survey was made, but this lagoon was more representative in that the water depth was relatively constant throughout the summer.

Larval abundance was significantly different between species, and the following order of dominance prevailed:  G. barbipes > C. riparius > A. dyari.  The order of larval tolerance to some physiochemical factors was G. barbipes > A. dyari > C. riparius, indicating that other factors were involved in establishing the dominance order in this lagoon.  Larvae of G. barbipes and C. riparius are tube dwelling species and were found packed in a layer about one inch thick in the substrate and occupied very little space.  In contrast, larvae of A. dyari did not build tubes but were ambulatory and constantly moved about the surface of the substrate.  This species became pugnacious when crowded in a laboratory habitat and their evasive behavior under these conditions resulted in rapid dispersal to unoccupied areas.  Their need for more space for growth and development compared to the need of the tube dwelling species may have resulted in the established order of dominance in cells I and III.

Larval abundance was significantly greater in the winter

season, in contrast to the results for seasons obtained from Village

Green lagoon. The greater larval abundance in University Park

lagoon during winter was due to the development of large overwinter-

ing populations in the more stable environment of a permanently

submerged peripheral slope.

The significantly greater larval abundance in cell III was

presumably due to greater availability of nutrients in this cell, but

other features complicating the ecology will be discussed along with

the historical facts of the lagoon operation and other environmental

considerations.

Significant difference for zones was in contrast to the results

from Village Green lagoon. Relatively constant water depths of

3.5-4.0 feet in the central zone of University Park lagoon usually

maintained dissolved oxygen stratification. Also, incompletely

oxidized metabolic products from anerobic bacteria such as

hydrogen sulfide, methane, alcohols, ketones and organic acids

(Bollen, 1951) were probably deleterious to larval Chironomidae.

These metabolic products are susceptible to eventual complete

oxidation by bacteria in the presence of oxygen in the upper water

layers, or in shallow water of the peripheral zones. The swimming

behavior of some chironomids during periods of anaerobiosis may

cause them to migrate to the peripheral zones where ecological

conditions were more favorable for their survival.

Significant species x seasons difference was due to the pres-ence of large populations of larval G. barbipes in the winter. This species usually ceased emerging in October and overwintering larval instars grew larger and darker in color, and survivors began emerging in April. In contrast, larvae of C. riparius and A. dyari were more abundant in the summer. This is partly because some emergence of C. riparius and A. dyari occurred all year round and resulted in lower population densities for these species in the winter. Also, evidence from laboratory rearing has indicated that the larval development rate of G. barbipes was approximately 0.60 times that of C. riparius and A. dyari, consequently, the latter species are able to increase their population numbers at a faster rate under favorable conditions during spring.

Significant species x cells difference was due to the larger amount of organic material stored in the deeper more recently deposited sludge blanket of cell III. Thus G. barbipes, being the most tolerant species, is more abundant in III. Chironomid larvae in cell I were living in an old sludge blanket that had been under-going compaction and decomposition for one year. Consequently the oxygen demand of the partly decomposed sludge was less than that of cell III, which underwent primary loading during the final year of lagoon operation.

Larval abundance of C. riparius and A. dyari in cell III was less than in cell I presumably because these larvae have less tolerance to physiochemical factors occurring in cell III. They were more abundant in cell I because of the reduced amount of organic material present. They were most abundant in cell II, which had no sludge blanket. Consequently, G. barbipes, adapted to an environment of high organic content, were least abundant in cell II. Species abundance was consistently greater in peripheral zones due to the more favorable physiochemical conditions found there.

Cell II remained unchanged as far as BOD loading was concerned, and supported small overwintering populations of larval Chironomidae and an aquatic insect community structure similar to that encountered in farm ponds. There was no sludge at the mud-water interface of cell II, but by the end of 1965 it was covered with decaying duckweed that had settled from a surface mat of this growth. There were no benthic chironomid larvae in cell II during the summer of 1966.

Ecological conditions disadvantageous for the larval development of G. barbipes in cell II were more favorable for the production of large numbers of C. riparius. In general, the emergence patterns show that where there is a high population of G. barbipes, the production of C. riparius is low to non-existent. Conversely, if the environment is characterized by a low BOD content, and a

correspondingly high dissolved oxygen level, a low population density

of G. barbipes is usually observed, and a potential for the rapid

build-up of C. riparius exists. This is evident in Figure 10, which

shows that larger overwintering populations of C. riparius rather

than G. barbipes occur in the central zone of cell II in 1965. Since

C. riparius is less tolerant to anaerobiosis and to concentrations of

synthetic sewage than are the other two dominant species of

Chironomidae, C. riparius appears to be better adapted to the rela-

tively clean water of cell II, which was not loaded while the lagoon

was functioning as a sewage facility.

Evidence from laboratory rearing had indicated that the larval

development rate of C. riparius was 1.6 times that of G. barbipes

enabling C. riparius to utilize rapidly any suitable environment, and

would account for the maximum emergence rate of 1250 adults per

square yard per week in cell II. Cell III of University Park lagoon

was similar in species composition and abundance to that of Village

Green lagoon. The low numbers or absence of C. riparius in these

environments was probably due to the high BOD content of the sludge

blanket, or to sustained BOD loading. Interspecific competition may

also exert an adverse effect on these species.

## Environmental Considerations

Normally, G. barbipes was the dominant species in all lagoons

studied and its well-defined emergence pattern indicates that its

pupation and emergence are contingent upon well-defined ecological

factors. It is well known that certain ecological stimuli trigger vital

development processes in insects (Beck, 1963; Wigglesworth, 1953),

and it is probable that photoperiod controls pupation and emergence

of G. barbipes, whose normal emergence activity is characterized

by a sudden appearance at the beginning of April and the abrupt

termination of emergence in the middle of October. Dredge samples

in July 1966 showed that fully grown fourth-instar larvae of G.

barbipes were present in cells I and III of University Park, but

emergence had prematurely ended in these cells for the season. It

is possible that lack of nutrients prevented sustained emergence.

Starved laboratory populations of larval G. barbipes produced fewer

adults, smaller in size and lighter in weight than properly nourished

controls, but emergence of the starved population was only slightly

retarded.

Light penetration in stabilization lagoons is much less than in

most bodies of water (Bartsch and Allum, 1957). Dense planktonic

algal populations are responsible for the rapid light extinction ob-

served. Those larvae with behavior patterns enabling them to

choose a substrate receiving adequate daylight are possibly favored

over larvae choosing a substrate receiving little or no light. If

pupation and emergence of G. barbipes are contingent upon light

intensity or photoperiod, it is likely that selection pressure would result in populations that built tubes in those areas receiving some sunlight. The upper layer of water, about a foot thick at the surface, would represent the so-called euphotic depth of lakes where light can penetrate and most photosynthetic production of oxygen occurs. In lagoons with sustained phytoplankton densities it is possible that the water below the euphotic depth would be in total darkness. Consequently, larvae dependent upon light as an ecological stimulus for emergence would be found in greater numbers in the peripheral zones of lagoons.

Algal density and light penetration in lagoons are complicated by frequent outbreaks of Entomostraca, principally Daphnia sp. and Cyclops sp. These small Crustacea rapidly graze upon the phytoplankton and reduce them to low densities. At such times the lagoon becomes more transparent and light penetration is increased. Sometimes the appearance of Entomostraca outbreaks is cyclic, presumably occurring after each algal bloom, but this periodic mechanism is little understood.

It is well known that dissolved oxygen decreases with depth of water in stabilization lagoons (Towne, Bartsch and Davis, 1957; Marais, 1966). Observations made during the present study showed that on calm days dissolved oxygen decreased with depth and distance from the shore. On windy days, thorough mixing of water layers by

wave action occurred and no pronounced stratification was found,

and dissolved oxygen content was only slightly lower at the sludge-

water interface. Dissolved oxygen concentrations at the sludge-water

interface were observed to vary from 0 to 25 ppm at one foot depth,

and followed a daily photosynthetic cycle of afternoon highs and noc-

turnal lows (Sturgess, 1964). At times when the water was calm on

warm sunny days, oxygen bubbles could be seen escaping from the

water surface, indicating a high degree of supersaturation. How-

ever, on calm warm nights anaerobic conditions occurred at the

sludge-water interface.

In addition to the respiration requirements of the phytoplankton

at night, the sludge blanket exerted an oxygen demand on the over-

lying water layers, and the greater the depth of water over the sludge

blanket, the less likely that dissolved oxygen obtained by surface

reaeration would be available to larvae in their microhabitat.

Chironomid larvae can leave their tubes in the substrate and swim

readily. It is possible that during extended periods of anaerobiosis

in their microenvironment, they simply swam in the upper layers of

oxygenated water and replenished their oxygen supply.

The relation of oxygen microstratification at the mud surface

and its effect on the ecology of the profundal bottom fauna of lakes

have been studied by Brundin (1950), who sampled water from the

actual microhabitat and concluded that the distribution of bottom

fauna was due to the degree of tolerance to the lack of oxygen. A stabilization lagoon could be considered to be a compressed lake system with extremes in dissolved oxygen content, but these conditions are dependent on the periodic photosynthetic oxygen production and on the degree of mixing by wave action, which can change within the hour, while most lake systems are more static and change only during the seasonal turnover.

These observations indicate that chironomid populations are more abundant on the peripheral slope of stabilization lagoons because of the greater availability of dissolved oxygen there. The large mortality rates that are known to occur among overwintering populations of Chironomidae are probably due to anaerobic conditions resulting from high BOD loading rates. Laboratory observations in 1966 have shown that the last larval instars are less tolerant to anaerobiosis than are the earlier instars. Field observations also indicate that the later instar larvae are more susceptible to winter die off.

The effect of predation by larval Chaoboridae is not known, but when present these larvae are more abundant in the central zones near the sludge-water interface, and they presumably rise to upper layers of oxygenated water during periods of anaerobiosis at the bottom. Chaoborid larvae prey on chironomid larvae, but copepods are the preferred food (Deonier, 1943; Main, 1953).

It is possible that, when present, chaoborid larvae prey upon the exposed A. dyari larvae in lagoons. This would explain the absence of larval A. dyari in cells I and III of University Park lagoon during the winter. Chaoborid larvae were absent in Village Green lagoon, and the large population density of 42 larval A. dyari per dredge haul in the central zone during winter can be explained in part by the absence of these predators.

Usinger and Kellen (1955), used india ink to demonstrate the pumping action of tube dwelling larvae as they irrigate their tubes by undulatory pumping action. The ability of different species of tube dwelling larvae to pump down water from higher oxygenated water layers is no doubt varied. Brundin (1950) has shown that due to the greater muscular power of larger chironomid species, they are able to pump down water from higher water layers above the mud. He lists five species of chironomid larvae representing a series with decreasing body size. This order directly corresponds to the proven ability of the larvae to survive unfavorable respiratory conditions in profundal zone.

Owing to their larger size and greater muscular power, larvae of G. barbipes must be more effective in pumping water down than are the smaller C. riparius larvae. Also, the capillary force must be much greater in the thinner tubes of C. riparius, and may place them at a further disadvantage in near anaerobic conditions.

Thus the microdistribution and abundance of chironomid larvae in stabilization lagoons can be attributed to the selective effect of the environment acting upon the limits of tolerance of the larvae. We need to know more about predator-prey relationships in lagoons, particularly the degree of predation by chaoborids in the central zones of the lagoons. The impact of predation by corixids upon early-instar larvae of chironomids, and the ecological consequences of increased turbidity due to the feeding activity of corixid populations should be investigated. Regarding the microdistribution of species within a single cell of any lagoon, much more knowledge is needed of the developmental stage of the species at which mortality is highest, their precise nutritional needs, and the effect of competitive exclusion, before these factors can be elucidated.

SUMMARY

The microdistribution and abundance of Chironomidae, and the impact of other insect species on the lagoon environment were investigated from 1964 to 1966 at Corvallis, Oregon.

Quantitative studies were made at University Park lagoon, which consisted of three cells with a total surface area of two acres, and at a single celled lagoon of approximately one acre located at Village Green near Corvallis.

A total of 11 species of Chironomidae, including six species new to science, were recovered from the lagoons. Of these G. barbipes, C. riparius, and A. dyari were the most abundant.

Other insects having an important impact on lagoon ecology included species of Chaoboridae and Corixidae. It is possible that both these groups are important predators of early-instar chironomid larvae.

Analysis of variance of dredging results of Village Green lagoon indicate the following significant differences: Total larval abundance was greater in the summer, greater for G. barbipes than for A. dyari, and greater for G. barbipes in both peripheral and central zones. Total larval abundance was greater from transect B than A in summer, and greater from transect A than B in winter. Larval abundance of G. barbipes was greater in the central zone

during summer, and greater in the peripheral zone in winter. Conversely, larval abundance of A. dyari was greater in the peripheral zone during summer, and greater in the central zone during winter.

Analysis of variance of dredging results of University Park lagoon indicate the following significant differences: Larval abundance for each species showed that the order of species dominance was G. barbipes > C. riparius > A. dyari, total larval abundance was greater in winter, greater in cell III, and consistently greater in the peripheral zones. Larval abundance of G. barbipes was greater in the winter, greater in cell III, and greater in the peripheral zones. Larval abundance of A. dyari and C. riparius was greater in the summer, greater in cell I, and greater in the peripheral zones.

Emergence of adult G. barbipes populations was characterized by their sudden appearance in large numbers, sustained emergence activity throughout the summer, and their sudden cessation of emergence in the fall. Low emergence of this species from cell II was presumably due to poor nutrition and thick growths of duckweed.

Emergence patterns for C. riparius and A. dyari populations were in contrast to those of G. barbipes in that small numbers emerged throughout the winter. Emergence of C. riparius from cell II reached a maximum of 1,250 midges per square yard per week in March and was due to the absence of BOD loading in this cell.

Tests of fourth-instar larvae to some physiochemical factors occurring in lagoons show the following order of tolerance: $G.$ barbipes > $A.$ dyari > $C.$ riparius. Calculated $LD_{50}$ for concentrations of synthetic sewage against $G.$ barbipes and $C.$ riparius was 18,110 and 4.240 ppm respectively.

Estimated $LD_{50}$ for time held at $0^{\circ}C$ cold against $G.$ barbipes, $A.$ dyari and $C.$ riparius was 15.9, 5.4 and 3.0 days respectively.

Estimated $LD_{50}$ for time held under anaerobiosis against $G.$ barbipes, $A.$ dyari, and $C.$ riparius was 19.5, 2.3 and 1.8 days respectively.

Significantly greater larval abundance in the summer at Village Green lagoon was due to the reduction in water depth, resulting in a less pronounced dissolved oxygen stratification. The reduced water depth also resulted in a flatter peripheral slope and presumably increased the algal food supply from the lowered euphotic water layer.

Larval abundance of $G.$ barbipes was significantly greater than $A.$ dyari due to the greater degree of tolerance of $G.$ barbipes to physiochemical factors occurring in lagoons.

In Village Green lagoon larval abundance of $A.$ dyari was significantly greater in the central zone during winter due to the poor ecological condition of the seasonally desiccated portion of the slope.

The dominance order in University Park lagoon for species was G. barbipes > C. riparius > A. dyari. The order of tolerance to some physiochemical factors was G. barbipes > A. dyari > C. riparius. The established dominance order in the lagoon was due to the fact that larval A. dyari required more space for growth and development than the tube dwelling species.

The significantly greater larval abundance in cell III was due to the greater availability of nutrients in this cell.

Significant difference for zones at University Park lagoon was in contrast to the results from Village Green lagoon. This was due to dissolved oxygen stratification which was maintained by the relatively constant water depths of 3.5-4.0 feet in the central zones of University Park lagoon.

Corixidae and larval Chaoboridae probably prey upon the early-instar larvae of chironomids, but this is not known.

Because of their larger size and greater muscular power, larvae of G. barbipes must be more effective in pumping water down from the higher oxygenated water layers than are the smaller C. riparius larvae.

Thus the microdistribution and abundance of chironomid larvae in stabilization lagoons can be attributed to the selective effect of the environment acting upon the limits of tolerance of the larvae.

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APPENDIX

| | CELL I | | | | CELL II | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Summer | | Winter | | Summer | | Winter | |
| | Peripheral | Central | Peripheral | Central | Peripheral | Central | Peripheral | Central |
| | 40 | 22 | 688 | 208 | 150 | 94 | 912 | 22 |
| | 80 | 16 | 1072 | 104 | 264 | 17 | 1104 | 16 |
| | 16 | 24 | 256 | 120 | 316 | 26 | 688 | 24 |
| | 32 | 8 | 600 | 90 | 60 | 37 | 444 | 8 |
| | 16 | 14 | 164 | 86 | 102 | 64 | 308 | 14 |
| | 24 | 18 | 640 | 46 | 240 | 77 | 620 | 18 |
| | 108 | 14 | 848 | 38 | 126 | 50 | 1304 | 14 |
| | 140 | 16 | 624 | 112 | 148 | 92 | 1224 | 16 |
| | 67 | 5 | 960 | 112 | 149 | 49 | 1020 | 5 |
| | 18 | 6 | 2848 | 248 | 240 | 44 | 1440 | 6 |
| | 4 | 26 | 860 | 60 | 166 | 110 | 720 | 26 |
| | 10 | 5 | 240 | 52 | 170 | 69 | 460 | 5 |
| | 68 | 92 | 160 | 68 | 162 | 39 | 420 | 92 |
| | 58 | 170 | 272 | 28 | 300 | 45 | 1320 | 170 |
| | 272 | 113 | 960 | 52 | 318 | 51 | 1500 | 113 |
| | 136 | 96 | 912 | 80 | 156 | 76 | 1252 | 96 |
| $\bar{X}$ | 68 | 40 | 156 | 94 | 191 | 59 | 921 | 23 |
| $\Sigma X$ | 1,089 | 645 | 12,104 | 1,504 | 3,067 | 940 | 14,736 | 362 |
| $\Sigma X^2$ | 146,773 | 62,463 | 15,275,872 | 194,944 | 679,397 | 65,280 | 15,979,200 | 12,170 |
| $(x)^2$ | 72,652 | 36,461 | 6,119,196 | 53,568 | 91,491 | 10,055 | 2,407,344 | 3,979 |
| $\sigma^2$ | 4,843 | 2,430 | 407,946 | 3,571 | 6,099 | 670 | 160,489 | 265 |

LARVAL C. RIPARIUS PER DREDGE HAUL FROM TWO TRANSECTS IN
EACH CELL OF UNIVERSITY PARK STABILIZATION LAGOON

| | CELL III | | | | CELL I | | | |
| | Summer | | Winter | | Summer | | Winter | |
| | Peripheral | Central | Peripheral | Central | Peripheral | Central | Peripheral | Central |
|---|---|---|---|---|---|---|---|---|
| | 12 | 20 | 0 | 12 | 16 | 12 | 16 | 0 |
| | 50 | 8 | 0 | 12 | 44 | 8 | 16 | 4 |
| | 48 | 9 | 0 | 6 | 8 | 4 | 8 | 12 |
| | 18 | 5 | 32 | 3 | 8 | 4 | 16 | 12 |
| | 16 | 13 | 4 | 4 | 16 | 6 | 8 | 12 |
| | 44 | 16 | 0 | 2 | 8 | 4 | 16 | 12 |
| | 8 | 7 | 0 | 2 | 12 | 8 | 16 | 4 |
| | 64 | 20 | 0 | 2 | 24 | 4 | 16 | 0 |
| | 7 | 13 | 0 | 12 | 36 | 2 | 16 | 4 |
| | 26 | 5 | 0 | 8 | 22 | 3 | 16 | 12 |
| | 14 | 16 | 0 | 3 | 4 | 12 | 8 | 12 |
| | 16 | 12 | 0 | 4 | 4 | 4 | 16 | 16 |
| | 18 | 13 | 0 | 10 | 28 | 18 | 16 | 10 |
| | 20 | 16 | 0 | 2 | 15 | 18 | 16 | 8 |
| | 32 | 20 | 0 | 4 | 68 | 44 | 8 | 2 |
| | 18 | 12 | 0 | 8 | 98 | 35 | 16 | 0 |
| $\bar{X}$ | 26 | 13 | 2 | 6 | 26 | 11 | 14 | 7 |
| $\Sigma X$ | 411 | 205 | 36 | 94 | 411 | 186 | 224 | 116 |
| $\Sigma X^2$ | 14,873 | 3,007 | 1,040 | 778 | 20,409 | 4,354 | 3,328 | 1,320 |
| $(x^2)$ | 4,315 | 380 | 959 | 226 | 9,851 | 2,191 | 192 | 479 |
| $\sigma^2$ | 287 | 25 | 64 | 15 | 656 | 176 | 13 | 32 |

LARVAL <u>A. DYARI</u> PER DREDGE HAUL FROM TWO TRANSECTS IN EACH
CELL OF UNIVERSITY PARK STABILIZATION LAGOON

| | CELL I | | | | CELL III | | | |
| | Summer | | Winter | | Summer | | Winter | |
| | Peripheral | Central | Peripheral | Central | Peripheral | Central | Peripheral | Central |
|---|---|---|---|---|---|---|---|---|
| | 8 | 2 | 0 | 0 | 4 | 1 | 0 | 4 |
| | 30 | 4 | 0 | 0 | 6 | 1 | 0 | 0 |
| | 10 | 16 | 0 | 0 | 10 | 2 | 0 | 0 |
| | 4 | 2 | 0 | 0 | 6 | 1 | 0 | 0 |
| | 8 | 4 | 0 | 0 | 28 | 9 | 0 | 0 |
| | 26 | 4 | 0 | 0 | 18 | 6 | 0 | 0 |
| | 30 | 18 | 0 | 4 | 12 | 1 | 0 | 0 |
| | 40 | 4 | 0 | 16 | 14 | 4 | 0 | 0 |
| | 30 | 5 | 0 | 0 | 8 | 3 | 0 | 0 |
| | 10 | 2 | 0 | 0 | 12 | 8 | 0 | 0 |
| | 10 | 13 | 0 | 0 | 14 | 12 | 0 | 0 |
| | 8 | 19 | 0 | 0 | 12 | 11 | 0 | 0 |
| | 48 | 32 | 0 | 0 | 6 | 6 | 0 | 0 |
| | 27 | 62 | 0 | 0 | 8 | 6 | 0 | 0 |
| | 52 | 31 | 0 | 0 | 4 | 7 | 0 | 0 |
| | 42 | 34 | 0 | 0 | 10 | 6 | 0 | 0 |
| $\bar{X}$ | 24 | 16 | 0 | 1 | 11 | 5 | 0 | 0 |
| $\Sigma X$ | 383 | 252 | | 20 | 172 | 84 | | |
| $\Sigma X^2$ | 12,985 | 8,196 | | 272 | 2,400 | 636 | | |
| $(x^2)$ | 3,817 | 4,227 | | 247 | 551 | 195 | | |
| $\sigma^2$ | 254 | 281 | | 16 | 37 | 13 | | |

## LARVAE PER DREDGE HAUL FROM TWO TRANSECTS OF VILLAGE GREEN STABILIZATION LAGOON

| | | TRANSECT A | | | TRANSECT B | | | |
| | | Winter | | Summer | | Winter | | Summer | |
| | Peripheral | Central | Peripheral | Central | Peripheral | Central | Peripheral | Central |
|---|---|---|---|---|---|---|---|---|
| | 72 | 56 | 180 | 328 | 128 | 12 | 204 | 396 |
| | 288 | 88 | 404 | 496 | 220 | 40 | 652 | 832 |
| *G. barbipes* | 248 | 68 | 180 | 612 | 260 | 32 | 548 | 896 |
| | 248 | 48 | 608 | 492 | 200 | 36 | 532 | 824 |
| | 260 | 88 | 300 | 388 | 152 | 68 | 404 | 1140 |
| | 160 | 52 | 404 | 356 | 176 | 40 | 528 | 520 |
| | 196 | 80 | 364 | 248 | 268 | 64 | 408 | 444 |
| | 184 | 36 | 236 | 392 | 120 | 32 | 540 | 576 |
| | 1656 | 516 | 2676 | 3312 | 1524 | 324 | 3816 | 5628 |
| X̄ | 207 | 64.5 | 334.5 | 414 | 190.5 | 40.5 | 477 | 703.5 |
| | 0 | 40 | 0 | 24 | 0 | 32 | 20 | 28 |
| | 0 | 120 | 36 | 16 | 4 | 20 | 116 | 48 |
| *A. dyari* | 24 | 52 | 45 | 12 | 8 | 28 | 76 | 44 |
| | 32 | 76 | 84 | 28 | 28 | 16 | 24 | 36 |
| | 16 | 12 | 24 | 16 | 16 | 16 | 56 | 80 |
| | 20 | 60 | 20 | 24 | 0 | 16 | 12 | 28 |
| | 0 | 100 | 24 | 12 | 8 | 16 | 40 | 36 |
| | 0 | 52 | 20 | 20 | 4 | 8 | 36 | 76 |
| | 92 | 512 | 253 | 152 | 68 | 152 | 380 | 376 |
| X̄ | 11.5 | 64 | 31.6 | 19 | 8.5 | 19 | 47.5 | 47 |
| Total Ave. | 218.5 | 128.5 | 366.1 | 433 | 198.5 | 59.5 | 524.5 | 750.5 |

WEEKLY EMERGENCE OF ADULTS RECOVERED
FROM TWO DARK TRAPS
CELL I - UNIVERSITY PARK LAGOON

| 1965 | Trap | G. barbipes A | B | C. riparius A | B | A. dyari A | B |
|---|---|---|---|---|---|---|---|
| 9-07 | | 0 | 0 | 0 | 0 | 6 | 3 |
| 9-14 | | 0 | 0 | 0 | 0 | 9 | 5 |
| 9-21 | | 0 | 0 | 1 | 3 | 8 | 0 |
| 9-28 | | 0 | 0 | 1 | 2 | 8 | 0 |
| 10-05 | | 0 | 0 | 2 | 2 | 4 | - |
| 10-12 | | 0 | 0 | 1 | 2 | 12 | 8 |
| 10-19 | | 0 | 0 | 1 | 3 | 6 | 3 |
| 10-26 | | 0 | 0 | 3 | - | 1 | 2 |
| 11-01 | | 0 | 0 | 1 | 3 | 2 | 2 |
| 11-09 | | 0 | 0 | 2 | 1 | 0 | 0 |
| 11-16 | | 0 | 0 | 1 | 2 | 1 | 0 |
| 11-23 | | 0 | 0 | 4 | 5 | 0 | 2 |
| 11-30 | | 0 | 0 | 16 | 9 | 1 | 0 |
| 12-07 | | 0 | 0 | 21 | 16 | 0 | 0 |
| 12-14 | | 0 | 0 | 16 | 18 | 0 | 0 |
| 12-21 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 12-28 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 1-04 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 1-11 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 1-18 | | 0 | 0 | 10 | 51 | 0 | 0 |
| 1-25 | | 0 | 0 | 47 | 43 | 0 | 0 |
| 2-01 | | 0 | 0 | 45 | 49 | 0 | 0 |
| 2-08 | | 0 | 0 | 22 | 29 | 0 | 0 |
| 2-16 | | 0 | 0 | 32 | 15 | 0 | 0 |
| 2-23 | | 0 | 0 | 39 | 30 | 0 | 0 |
| 3-02 | | 0 | 0 | 15 | 20 | 0 | 0 |
| 3-09 | | 0 | 0 | 8 | 4 | 6 | 3 |
| 3-16 | | 0 | 0 | 73 | 0 | 15 | 6 |
| 3-23 | | 0 | 0 | 0 | 0 | 6 | 12 |
| 3-30 | | 3 | 2 | 5 | 3 | 35 | 16 |
| 4-06 | | 20 | 25 | 2 | 3 | 28 | 49 |
| 4-13 | | 19 | 9 | 1 | 1 | 22 | 20 |
| 4-20 | | 7 | 8 | 0 | 1 | 14 | 18 |
| 4-27 | | 2 | 1 | 0 | 0 | 1 | 2 |
| 5-04 | | 12 | 7 | 0 | 0 | 10 | 9 |
| 5-11 | | 175 | 300 | 0 | 0 | 14 | 7 |
| 5-18 | | 105 | 220 | 0 | 1 | 0 | 0 |
| 5-25 | | 84 | 45 | 0 | 3 | 0 | 0 |
| 6-01 | | 28 | 30 | 0 | 0 | 7 | 10 |
| 6-08 | | 70 | 50 | 0 | 0 | 14 | - |
| 6-15 | | 42 | 80 | 0 | 0 | 6 | 8 |
| 6-22 | | 101 | 225 | 83 | 0 | 16 | 14 |
| 6-29 | | 210 | 205 | 0 | 0 | 14 | 14 |
| 7-06 | | 25 | 30 | 20 | 4 | 3 | 0 |
| 7-13 | | 38 | 20 | 1 | 0 | 0 | 0 |
| 7-20 | | 18 | 10 | 3 | 0 | 0 | 0 |
| 7-27 | | 9 | 0 | 0 | 0 | 0 | 0 |

## WEEKLY EMERGENCE OF ADULTS RECOVERED
## FROM TWO DARK TRAPS
## CELL II - UNIVERSITY PARK LAGOON

| 1965 | Trap | G. barbipes | | C. riparius | | A. dyari | |
|------|------|-----|-----|-----|-----|-----|-----|
| | | A | B | A | B | A | B |
| 9-07 | | 40 | 47 | 5 | 4 | 11 | 22 |
| 9-14 | | 37 | 31 | 6 | 7 | 3 | 1 |
| 9-21 | | 6 | 5 | 2 | 3 | 2 | 4 |
| 9-28 | | 9 | 4 | 2 | 1 | 8 | 9 |
| 10-05 | | 0 | 0 | 1 | 0 | 12 | 8 |
| 10-12 | | 0 | 0 | 0 | 0 | 7 | 9 |
| 10-19 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 10-26 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 11-01 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 11-09 | | 0 | 0 | 8 | 6 | 0 | 0 |
| 11-16 | | 0 | 0 | 5 | 1 | 0 | 0 |
| 11-23 | | 0 | 0 | 5 | 4 | 2 | 3 |
| 11-30 | | 0 | 0 | 3 | 1 | 3 | 4 |
| 12-07 | | 0 | 0 | 3 | 0 | 0 | 0 |
| 12-14 | | 0 | 0 | 3 | 0 | 0 | 0 |
| 12-21 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 12-28 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 1-04 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 1-11 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 1-18 | | 0 | 0 | 6 | 9 | 0 | 0 |
| 1-25 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 2-01 | | 0 | 0 | 0 | 18 | 0 | 0 |
| 2-08 | | 0 | 0 | 20 | 25 | 0 | 0 |
| 2-16 | | 0 | 0 | - | - | 0 | 0 |
| 2-23 | | 0 | 0 | 43 | 58 | 0 | 0 |
| 3-02 | | 0 | 0 | 126 | 150 | 0 | 0 |
| 3-09 | | 0 | 0 | 195 | 181 | 5 | 2 |
| 3-16 | | 0 | 0 | 232 | 240 | 16 | 25 |
| 3-23 | | 0 | 0 | 546 | 332 | 28 | 42 |
| 3-30 | | 0 | 0 | 406 | 427 | 49 | 70 |
| 4-06 | | 1 | 0 | 98 | 84 | 48 | 97 |
| 4-13 | | 9 | 14 | 2 | 8 | 47 | 8 |
| 4-20 | | 2 | 11 | 3 | 25 | 16 | 28 |
| 4-27 | | 12 | 1 | 10 | 6 | 10 | 18 |
| 5-04 | | 6 | 8 | 6 | 2 | 8 | 8 |
| 5-11 | | 8 | 9 | 3 | 1 | 4 | 6 |
| 5-18 | | 7 | 10 | 84 | 80 | 7 | 5 |
| 5-25 | | 4 | 2 | 2 | 13 | 0 | 5 |
| 6-01 | | 0 | 0 | 2 | 1 | 0 | 0 |
| 6-08 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 6-15 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 6-22 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 6-29 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 7-06 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 7-13 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 7-20 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 7-27 | | 0 | 0 | 0 | 0 | 0 | 0 |

## WEEKLY EMERGENCE OF ADULTS RECOVERED
## FROM TWO DARK TRAPS
## CELL III - UNIVERSITY PARK LAGOON

| 1965 | Trap | G. barbipes | | C. riparius | | A. dyari | |
|---|---|---|---|---|---|---|---|
| | | A | B | A | B | A | B |
| 9-07 | | 30 | 11 | 15 | 10 | 5 | 11 |
| 9-14 | | 10 | 7 | 50 | 22 | 6 | 8 |
| 9-21 | | 8 | 5 | 40 | 30 | 6 | 9 |
| 9-28 | | 6 | 2 | 37 | 15 | 11 | 8 |
| 10-05 | | 0 | 1 | 5 | 6 | 6 | 5 |
| 10-12 | | 1 | 0 | 3 | 2 | 5 | 4 |
| 10-19 | | 0 | 0 | 0 | 0 | 4 | 3 |
| 10-26 | | 0 | 0 | 0 | 0 | 1 | 0 |
| 11-01 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 11-09 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 11-16 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 11-23 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 11-30 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 12-07 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 12-14 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 12-21 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 12-28 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 1-04 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 1-11 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 1-18 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 1-25 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 2-01 | | 0 | 0 | 0 | 4 | 0 | 0 |
| 2-08 | | 0 | 0 | 21 | 15 | 0 | 0 |
| 2-16 | | 0 | 0 | 60 | 35 | 0 | 0 |
| 2-23 | | 0 | 0 | 63 | 60 | 0 | 0 |
| 3-02 | | 0 | 0 | 21 | 51 | 0 | 0 |
| 3-09 | | 0 | 0 | 5 | 4 | 1 | 2 |
| 3-16 | | 0 | 0 | 5 | 6 | 4 | 6 |
| 3-23 | | 0 | 0 | 3 | 7 | 4 | 15 |
| 3-30 | | 0 | 0 | 6 | 3 | 2 | 28 |
| 4-06 | | 0 | 1 | 7 | 2 | 10 | 30 |
| 4-13 | | 19 | 98 | 3 | 2 | 7 | 2 |
| 4-20 | | 11 | 46 | 2 | 3 | 0 | 2 |
| 4-27 | | 2 | 10 | 8 | 2 | 0 | 2 |
| 5-04 | | 61 | 54 | 23 | 10 | 6 | 1 |
| 5-11 | | 154 | 161 | 14 | 42 | 0 | 14 |
| 5-18 | | 182 | 168 | 140 | 336 | 56 | 77 |
| 5-25 | | 420 | 230 | 56 | 56 | 54 | 35 |
| 6-01 | | 245 | 280 | 259 | 280 | 119 | 77 |
| 6-08 | | 378 | 257 | 399 | 226 | 728 | 50 |
| 6-15 | | 199 | 250 | 15 | 30 | 156 | 200 |
| 6-22 | | 98 | 100 | 35 | 20 | 98 | 125 |
| 6-29 | | 35 | 15 | 0 | 0 | 35 | 40 |
| 7-06 | | 2 | 1 | 0 | 2 | 6 | 14 |
| 7-13 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 7-20 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 7-27 | | 0 | 0 | 0 | 0 | 0 | 0 |

## WEEKLY EMERGENCE OF ADULTS RECOVERED
## FROM TWO DARK TRAPS
## VILLAGE GREEN LAGOON

| 1966 | Trap | G. barbipes | | C. riparius | | A. dyari | |
|------|------|-------------|---|-------------|---|----------|---|
|      |      | A | B | A | B | A | B |
| 3-28  |  | 0   | 0   | 0  | 0  | 0  | 0  |
| 4-06  |  | 2   | 3   | 0  | 0  | 0  | 0  |
| 4-13  |  | 98  | 74  | 0  | 0  | 0  | 0  |
| 4-20  |  | 78  | 90  | 0  | 0  | 0  | 0  |
| 4-27  |  | 236 | 242 | 1  | 0  | 0  | 7  |
| 5-04  |  | 432 | 391 | 0  | 1  | 7  | 0  |
| 5-11  |  | 236 | 242 | 0  | 0  | 11 | 14 |
| 5-18  |  | 180 | 162 | 11 | 14 | 0  | 0  |
| 5-25  |  | 135 | 280 | 11 | 7  | 14 | 7  |
| 6-01  |  | 160 | 175 | 7  | 7  | 0  | 0  |
| 6-08  |  | 60  | 90  | 7  | 14 | 7  | 14 |
| 6-15  |  | 102 | 98  | 7  | 0  | 14 | 7  |
| 6-22  |  | 103 | 94  | 0  | 0  | 0  | 0  |
| 6-29  |  | 40  | 68  | 0  | 0  | 0  | 0  |
| 7-06  |  | 89  | 75  | 0  | 0  | 0  | 0  |
| 7-13  |  | 90  | 84  | 0  | 0  | 0  | 0  |
| 7-20  |  | 56  | 42  | 0  | 0  | 0  | 0  |
| 7-28  |  | 49  | 56  | 0  | 0  | 0  | 0  |
| 7-30  |  | 70  | 92  | 0  | 0  | 0  | 0  |
| 7-07  |  | 63  | 72  | 0  | 0  | 0  | 0  |
| 7-19  |  | 62  | 50  | 0  | 0  | 0  | 0  |
| 7-19  |  | 42  | 53  | 0  | 0  | 0  | 0  |
| 7-23  |  | 77  | 93  | 0  | 0  | 0  | 0  |
| 9-03  |  | 154 | 99  | 0  | 0  | 0  | 0  |
| 9-05  |  | 70  | 86  | 0  | 0  | 0  | 0  |
| 9-15  |  | 78  | 79  | 0  | 0  | 0  | 0  |
| 9-30  |  | 21  | 28  | 0  | 0  | 0  | 0  |
| 10-13 |  | 10  | 8   | 0  | 0  | 0  | 0  |
| 10-20 |  | 0   | 0   | 0  | 0  | 0  | 0  |