EFFECTS OF FOUR TREATMENTS ON THE FOOD HABITS
AND GROWTH OF CHANNEL CATFISH FRY, (*ICTALURUS PUNCTATUS*)

by 4589

DONALD L. BONNEAU

B. S., Fort Hays Kansas State College, 1968

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AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Division of Biology

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Manhattan, Kansas

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# INTRODUCTION

The production of channel catfish (_Ictalurus punctatus_) is an important and growing industry. Certain attributes make this species economically important. These are: the desirability to the sport fisherman (Tiemeier, 1957), the desirability as a table food (Tiemeier, 1957), ability to adapt to changing conditions (Doze, 1925) and the responses to supplemental feeding (Tiemeier, 1957, 1962; Tiemeier, Deyoe and Suppes, 1967; Tiemeier and Deyoe, 1968; Prather, 1960; Bryan and Allen, 1969; and McGuire, 1969).

Increased demand for channel catfish necessitated the development of artificial hatching techniques (Doze, 1925; Clapp, 1929). Millions of channel catfish fry could then be produced but food became a limiting factor (Clapp, 1929).

Many formulated feeds were manufactured and presented to channel catfish fry but such diets aided slightly in good growth and development of fry (Tiemeier and Deyoe, 1968). Until McGuire (1969), few studies had been conducted on qualitative or quantitative food habits of channel catfish fry. Swingle (1959) stated the most important problem in establishing a channel catfish industry was producing a large number of fingerlings cheaply. A better knowledge of nutrition could lead to better rearing techniques and more economical production of fingerlings.

Lagler (1956) stated initial food of most fish is plankton and benthic organisms. McGuire (1969) found Chironomidae larvae were the principal natural food item in stomachs of channel catfish 20 to 100 mm long. Darnell (1958) obtained similar results with channel catfish 76 to 119 mm long. Analyses of stomach contents of blue catfish (Ictalurus furcatus) 4 to 7 inches long showed that they fed primarily on benthic organisms, Diptera (Chironomidae) being numerically the most frequent food item (Minckley, 1962). Perry (1969) found channel catfish to 376 mm long relied primarily on amphipods, algae and small insects for food.

Bryan and Allen (1969) studied utilization of supplemental feed by channel catfish fry. Fry held in ponds were fed 5 to 6 times a day after leaving spawning cans. Feed was a floating commercial trout food, presented in finely ground form and dampened to allow it to sink near the fry. By periodic checks of the stomach contents, they found natural food made up only a small percentage of their diet.

McGuire (1969) examined the stomach contents of channel catfish fry by taking fish weekly. Stomach analyses showed fry did not accept supplemental feed until they were four weeks old and weighed approximately one gram. Continued sampling indicated natural food decreased in importance once fry began accepting supplemental feed.

The fact that channel catfish fry do feed on planktonic and benthic organisms and that these organisms can be replaced, at least to some degree, by supplemental feed provides the basis for this study. The purpose of my study was to determine effects of certain treatments on food habits and growth of fry. Better methods and techniques could increase rate of growth and would result in larger fingerlings at the end of the first growing season. Rapid growth would also shorten the more vulnerable period when fry are tiny. Channel catfish less than

50 millimeters long are more susceptible to parasites than are larger fish (Bryan and Allen, 1969).

Effects of fertilizers on fish production was discussed by Bennett (1962). Several studies have been carried out concerning the effects of inorganic fertilizer on aquatic production (McIntire and Bond, 1962; Swingle and Smith, 1942, 1947; and Ball, 1949). In general they agreed addition of fertilizer may increase primary production and all trophic level production up to the fish. Consequently inorganic fertilizer was considered in this study because of the possibility of increased fish production resulting from its application.

Supplemental feeding was used in this study because of the possibility of increasing fish production. The experiment was designed to determine when supplemental feed was first accepted by the fry and the relative importance of natural and supplemental feed in the diet. Also, a better understanding of the foraging tendencies of fry might be revealed by comparing the natural food consumed and that present in the environment.

The experimental design allowed comparisons of food habits and growth of fry held in four rearing ponds receiving four different treatments. The four ponds and four treatments were an expansion of the two ponds and two treatments used by McGuire (1969). The expansion gave a more intricate examination of treatment effects.

## MATERIALS AND METHODS

Rearing ponds were at the Tuttle Creek Fisheries Research Laboratory. The ponds and laboratory are located 0.5 mile south of Tuttle

Creek Reservoir, Pottawatomie County, Kansas. The experimental ponds are rectangular in shape, built from the same plan and constructed to be as similar as possible. The ponds have a surface area of .25 acre, but the polyethylene lining material restricted the water area to 0.1436 surface-acre. Ponds varied in depth from 0.75 m at the inlet end to 1.37 m at the outlet end. The polyethylene lining was used in the experimental ponds to control soil differences and seepage.

June 10, 1969, 400 grams of channel catfish fry were obtained from the Kansas Forestry, Fish and Game Commission hatchery near Pratt. The fry were hatched from the same spawn of 3 June and developed to the "swim-up" stage on 9 June. The afternoon of 10 June, 100 grams of fry were stocked in ponds 2, 4, 6 and 8. Ponds had been drained, and swept clean but not refilled until 10 June. Delay in refilling the pond was necessary to limit the development of a population of predaceous insects.

On 11 June, management procedures were initiated. Pond 2, the control pond, received no fertilizer and supplemental feed was not applied until late in the study (23 July). Ponds 6 and 8 received supplemental feed throughout the study. Fry in pond 4, like those in pond 2, did not receive supplemental feed until late in the study (5 August).

Supplemental feed was Z-13B. It was calculated to contain 35% protein, 2.9% fat, 6.5% fiber, 10.2% ash, 11.2% moisture and 956 Kcals./lb. of metabizable energy as determined from feed analysis tables for poultry. Supplemental feed was applied twice daily at 7:30 a.m. and 3:30 p.m. daylight saving time. Finely ground feed (fines) was given when fish were small. Crumbles were then fed until the termination of the experiment. Both fines and crumbles were applied by broadcasting from the windward edge of the pond. Prior to 19 August, fry were fed at 5% of the average estimated weight of 3,000 fry. From 19 August to the termination of the experiment feed was presented at 3% of the average weight of 3,000 fry. Quantity of feed given was revised on a weekly basis and an equal amount of feed was applied to all ponds being fed. This procedure eliminated variances that unequal applications could have caused, such as a fertilizing effect.

The inorganic fertilizer 18-46-0 (18% nitrogen and 46% triple super phosphate) was applied at 50 pounds per surface acre of water. Fertilizer was applied to ponds 4 and 8, on 11, 18, 25 and 10 July.

Plankton samples were first taken 13 June. Plankton, benthos and fry were taken once a week starting 17 June and repeated each Tuesday, up to and including 26 August. Chemical analyses of water in each pond were initiated 18 June and continued each Wednesday through 27 August. September 2 fingerlings were removed from the ponds by seining and draining. Fish were weighed and individual weights estimated by weighing 20 groups of 10 fish. The total number of fish was then estimated from data on weights.

Each Tuesday, 17 June through 26 August, 25 fish were seined and removed from each pond. Fish were sampled one hour after supplemental feeding and immediately placed in ice water to slow the rate of metabolic processes. Each group was then weighed to the nearest one-hundredth of a gram. This procedure overlooked the individual variance but the number and small size of the fry made this procedure necessary. Fry were then preserved in 10% formalin and labeled as to pond and date. In the laboratory, fry were measured for total length and stomachs dissected out with the aid of a dissecting microscope. The stomach contents of 25 fish from the same pond and for the same sampling date were combined and placed in 10% formalin. The small size and large number of stomachs made this procedure necessary.

Plankton tows and bottom samples were obtained each day fry were taken, except 2 September. These were taken prior to seining to avoid disturbances in the water caused by seining.

The plankton net was made of No. 20 (0.076 mm) mesh nylon bolting cloth and was 1.10 m long and had an inside hoop diameter of 0.33 m. A hose clamp held the lid of a pint mason jar to the cod end of the net. This allowed removal and preservation of each sample without transferring the contents. A 1.3 m rod attached to the net permitted sampling without interference by the sampler. Plankton samples were taken full length down the center of the pond at a medium depth. Each sample was preserved in 10% formalin.

The polyethylene lining of the pond prohibited using a dredge to obtain bottom samples. Benthos samples were obtained by pressing a plastic cylinder (area .00607 $m^2$) against the pond lining. A plastic tile was then slipped between the cylinder and pond lining. All benthos samples were taken at the deep end of the pond and each sample was preserved in 10% formalin.

Water analyses determined levels of dissolved oxygen, temperature, pH, free $CO_2$, and alkalinity ($CO_3$, $HCO_3$) of water from surface and bottom samples, and turbidity readings. The alkalinity measurements were terminated 30 July. The water sampling and chemical analyses were carried out as set forth by Swingle and Johnson (1953). The turbidity readings were taken at the deep end of the ponds using a Hellige platinum-wire turbidimeter and hydrogen ion concentrations were determined with a Hellige colorimeter. Water analyses commenced at 8:00 a.m. and required approximately 1 to 1 1/2 hours.

Partial counts of the stomach contents were made in a counting cell constructed of plexiglas. The cell was square with an area and grid of 36 $cm^2$. Each $cm^2$ was assigned a number and the squares to be counted were selected from a table of random numbers. The partial counts were 16.67% or 8.33% depending on the volume of the sample. A 10.5X to 45X variable power dissecting microscope aided in identification and enumeration of the contents. Keys in Pennak (1953), Ward and Whipple (1959) and Needham and Needham (1962) were used in identification. Identification of zooplankters was to genus, while that of other invertebrates was to class, subclass or family.

After the contents had been analyzed, they were placed in a 15 ml graduated centrifuge tube and centrifuged at 1200 revolutions per minute for 10 minutes. Centrifuging was used to obtain total volume and percent by volume of chironomids and plankton. The varying densities of the organisms allowed separation into distinguishable layers. The volume of chironomids also included other insect larva, adult insects, gastropods and ostracods.

Once the fry began accepting supplemental feed, the centrifuging procedure was discarded. The widely varying density of the supplemental feed particles rendered separation impossible. Stomach contents containing supplemental feed were placed under a dissecting microscope and the percentage by volume of plankton, chironomids and supplemental feed estimated. Total volume of stomach contents was obtained as in the centrifuging procedure described in the above paragraph.

Each plankton sample was transferred from the collecting jar to a bucket and diluted to 10 liters. A one milliliter sub-sample was taken from the concentrate using a Hensen-Stempel pipette. The sub-sample was transferred to a Sedgewick-Rafter counting chamber where the entire contents were identified and counted. Ten such sub-samples were analyzed and an average calculated. The average per one milliliter multiplied by a conversion factor (2.2294) gave the number of individuals per liter of pond water. The conversion factor was obtained by dividing the number of milliliters of concentrate (10,000) by the number of liters (4485.5) of pond water sampled.

Classification and counting of organisms obtained in plankton tows were made under a compound microscope using 30 and 100 power. Keys in Ward and Whipple (1959), Smith (1950) and Needham and Needham (1962) were used in identification of unknown organisms.

Benthic organisms were separated from inorganic matter with a No. 40 U. S. standard sieve. The organisms in the sample were identified and counted under a 10.5X to 45X variable power dissecting microscope and expressed as numbers of organism per $m^2$. The classification of organisms present in bottom and plankton samples were comparable to the extent of classification in the stomach samples. More precise identification would have been useless. Algae were classified according to major taxonomic division.

Water was added to ponds to replace that lost by evaporation and to increase dissolved oxygen concentrations. Formalin was also added to all four ponds on 19 August to control parasites.

A two-way analysis of variance was used to analyze the effects of treatments and time on measured variables. When the ratio of mean squares indicated significance in the pond source of variation (treatment effect) a Fisher's least significant difference was calculated. Statistical analysis was made on the transformed variable $y = (\text{count} + 1/2)^{1/2}$, (Fryer, 1968).

# DATA

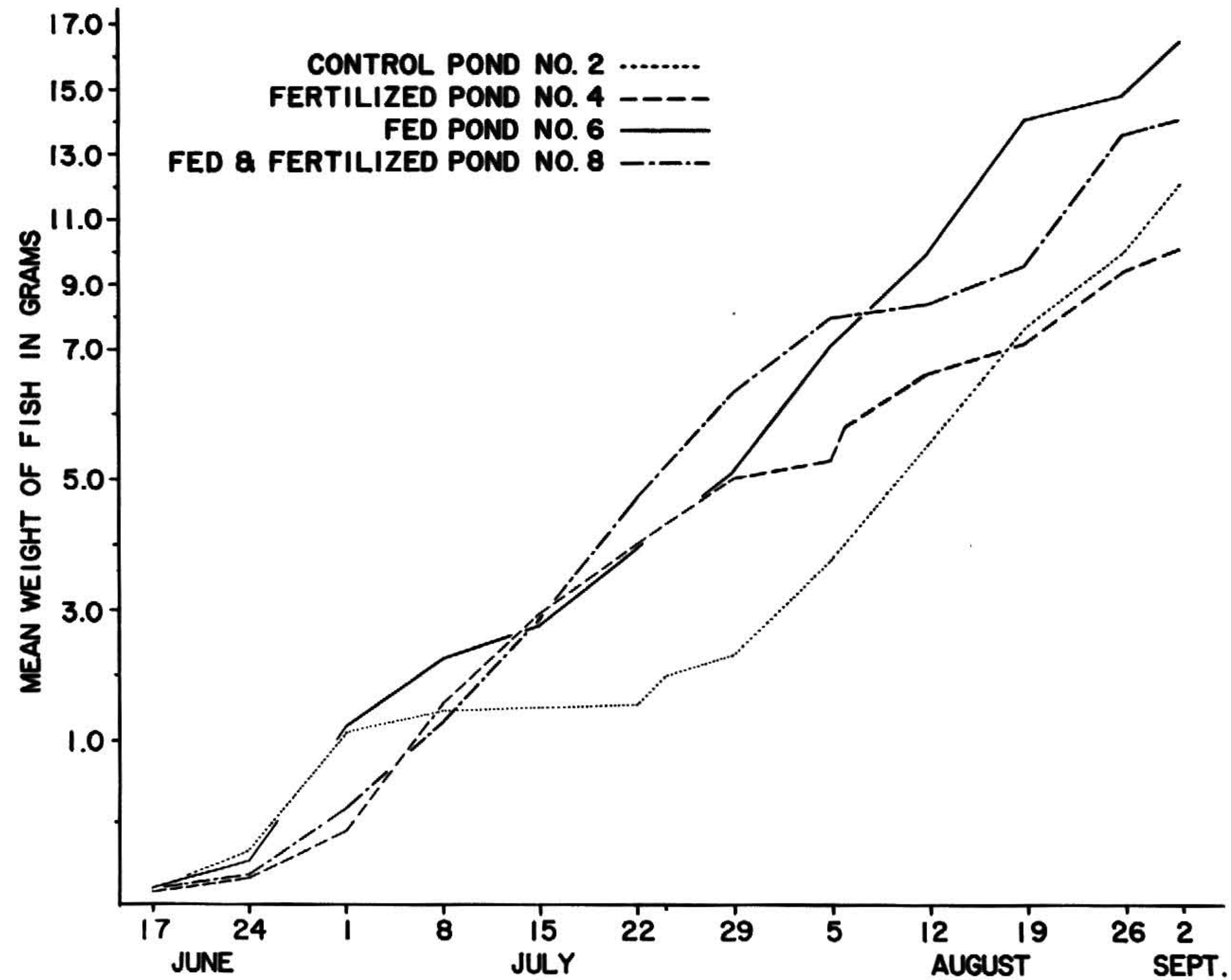


Figure 1. Mean weight of fry on sampling dates.

Table 1. Mean weight in grams of channel catfish fry stocked in four ponds. All weights based on samples of 25 fish.

| Sampling date | Mean weight in grams: Control Pond 2 | Fertilized Pond 4 | Fed Pond 6 | Fed & fertilized Pond 8 |
|---|---|---|---|---|
| 17 June | 0.09 | 0.08 | 0.10 | 0.09 |
| 24 June | 0.33 | 0.16 | 0.28 | 0.17 |
| 1 July | 1.16 | 0.45 | 1.18 | 0.58 |
| 8 July | 1.48 | 1.62 | 2.24 (1) | 1.29 (1) |
| 15 July | 1.52 | 2.90 | 2.78 | 2.84 |
| 22 July | 1.61 | 4.01 | 3.90 | 4.71 |
| 24 July | 2.02 (2) | - | - | - |
| 29 July | 2.37 | 5.02 | 5.20 | 6.36 |
| 5 August | 3.78 | 5.32 | 7.11 | 7.98 |
| 6 August | - | 5.83 (2) | - | - |
| 12 August | 5.61 | 6.67 | 9.98 | 8.40 |
| 19 August | 7.68 | 7.13 | 14.07 | 9.62 |
| 26 August | 9.91 | 9.44 | 14.76 | 13.53 |
| 2 September (3) | 11.88 | 10.08 | 16.68 | 13.78 |

(1) First evidence of supplemental feed in stomachs of fish from ponds 6 and 8.

(2) Supplemental feed was first presented on preceding days and was detected in stomachs of fry.

(3) Weight upon removal of fish was based on samples of 200 per pond.

Table 2. Two-way analysis of variance table for the mean weight of fry. Data were taken on control pond 2, fertilized pond 4, fed pond 6 and fed & fertilized pond 8.

| Source of variance | Degrees of freedom | Sums of squares | Mean square | F Statistic |
|---|---|---|---|---|
| Ponds | 3 | 38.108 | 12.703 | 7.637* |
| Time | 10 | 628.860 | 62.886 | 37.809* |
| Error | 30 | 49.898 | 1.663 | |
| Total | 43 | 716.866 | | |

* Indicates significance at .05 level.

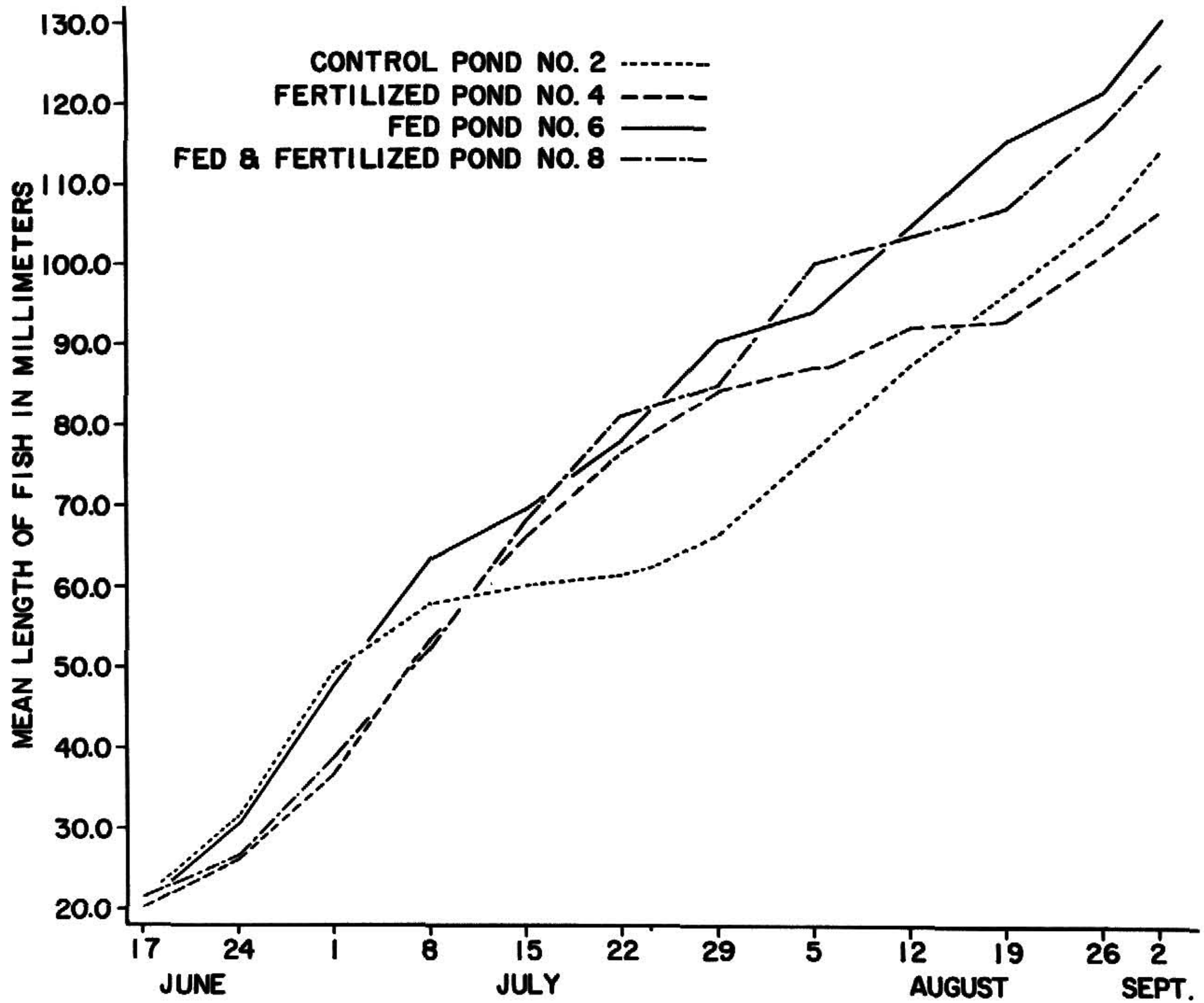


Figure 2. Mean length of fry on sampling dates.

Table 3. Mean length in millimeters of channel catfish fry stocked in four ponds. All lengths based on samples of 25 fish.

| Sampling date | Mean length in millimeters | | | |
|---|---|---|---|---|
| | Control Pond 2 | Fertilized Pond 4 | Fed Pond 6 | Fed & fertilized Pond 8 |
| 17 June | 21.19 | 20.89 | 20.94 | 21.36 |
| 24 June | 31.76 | 26.45 | 31.10 | 26.92 |
| 1 July | 49.45 | 36.71 | 48.59 | 38.85 |
| 8 July | 58.00 | 53.36 | 63.86 (1) | 53.19 (1) |
| 15 July | 60.37 | 66.79 | 69.92 | 68.08 |
| 22 July | 61.49 | 76.88 | 78.17 | 81.64 |
| 24 July | 62.78 (2) | - | - | - |
| 29 July | 66.36 | 84.44 | 90.90 | 85.26 |
| 5 August | 77.00 | 87.42 | 94.20 | 100.24 |
| 6 August | - | 87.49 (2) | - | - |
| 12 August | 87.46 | 92.91 | 104.95 | 103.68 |
| 19 August | 96.50 | 93.20 | 115.73 | 107.14 |
| 26 August | 105.92 | 101.48 | 121.71 | 117.32 |
| 2 September | 114.00 | 106.52 | 130.68 | 124.92 |

(1) First evidence of supplemental feed in stomachs of fish from ponds 6 and 8.

(2) Supplemental feed was first presented on preceding day and was detected in stomach contents of fry.

Table 4. Two-way analysis of variance table for mean length of fry. Data were taken on control pond 2, fertilized pond 4, fed pond 6 and fed & fertilized pond 8.

| Source of variance | Degrees of freedom | Sums of squares | Mean square | F Statistic |
|---|---|---|---|---|
| Ponds | 3 | 221.316 | 73.772 | 301.154* |
| Time | 10 | 8996.824 | 899.682 | 3672.721* |
| Ponds x Time | 30 | 277.651 | 9.255 | 37.781* |
| Error | 1056 | 258.681 | .245 | |
| Total | 1099 | 9754.473 | | |

* Indicates significance at the .05 level.

Table 5. Total volume and percent by volume of plankton, chironomids and supplemental feed in stomachs of fry sampled from control Pond No. 2, fertilized Pond No. 4, fed Pond No. 6 and fed & fertilized Pond No. 8.

| Date | Ponds Nos. | | | | Ponds Nos. | | | | Ponds Nos. | | | | Ponds Nos. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 4 | 6 | 8 | 2 | 4 | 6 | 8 | 2 | 4 | 6 | 8 | 2 | 4 | 6 | 8 |
| | Volume (ml.) of food in stomachs | | | | Percent plankton | | | | Percent chironomid [1] | | | | Percent feed | | | |
| 17 June | .20 | .10 | .13 | .11 | 100 | 40 | 54 | 64 | 0 | 60 | 46 | 36 | 0 | 0 | 0 | 0 |
| 24 June | .44 | .31 | .36 | .35 | 4 | 3 | 3 | 3 | 96 | 97 | 97 | 97 | 0 | 0 | 0 | 0 |
| 1 July | .48 | .95 | 1.05 | .84 | 17 | 5 | 5 | 5 | 83 | 95 | 95 | 95 | 0 | 0 | 0 | 0 |
| 8 July | .36 | 2.12 | 4.60 | 1.30 | 6 | 1 | 1 | 2 | 94 | 99 | 2 | 48 | 0 | 0 | 97 | 50 |
| 15 July | .30 | 1.70 | 2.80 | 2.80 | 40 | 41 | 2 | 4 | 60 | 59 | 3 | 14 | 0 | 0 | 95 | 82 |
| 22 July | .40 | .80 | 4.00 | 4.00 | 75 | 25 | 2 | 1 | 25 | 75 | 3 | 2 | 0 | 0 | 95 | 97 |
| 24 July | 3.90 | - | - | - [2] | 5 | - | - | - | 3 | - | - | - | 92 | - | - | - |
| 29 July | 4.00 | 1.10 | 8.30 | 6.20 | 2 | 93 | 1 | 1 | 3 | 7 | 2 | 3 | 95 | 0 | 97 | 96 |
| 5 August | 8.40 | 1.30 | 12.40 | 8.70 | 2 | 77 | 1 | 1 | 3 | 23 | 2 | 1 | 95 | 0 | 97 | 98 |
| 6 August | - | 9.60 | - | - | - | 3 | - | - | - | 2 | - | - | - | 95 | - | - |
| 12 August | 6.80 | 2.50 | 13.60 | 9.70 | 1 | 2 | 1 | 0 | 2 | 5 | 1 | 95 | 97 | 93 | 98 | 5 |
| 19 August | 12.20 | 3.60 | 21.70 | 5.20 | 1 | 1 | 1 | 1 | 1 | 98 | 1 | 2 | 98 | 1 | 98 | 97 |
| 26 August | 12.90 | 9.20 | 14.60 | 12.60 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 1 | 98 | 98 | 98 | 98 |

(1) Percent chironomids includes other insects, gastropods and ostracods.

(2) - Indicates no samples were taken.

Table 6. Two-way analysis of variance table for volumes of stomach contents in fish sampled from control pond 2, fertilized pond 4, fed pond 6, and fed & fertilized pond 8.

| Source of variance | Degrees of freedom | Sums of squares | Mean square | F Statistic |
|---|---|---|---|---|
| Ponds | 3 | 165.976 | 55.325 | 6.970* |
| Time | 10 | 759.073 | 75.907 | 9.562* |
| Error | 30 | 238.144 | 7.938 | |
| Total | 43 | 1163.193 | | |

* Indicates significance at the .05 level.

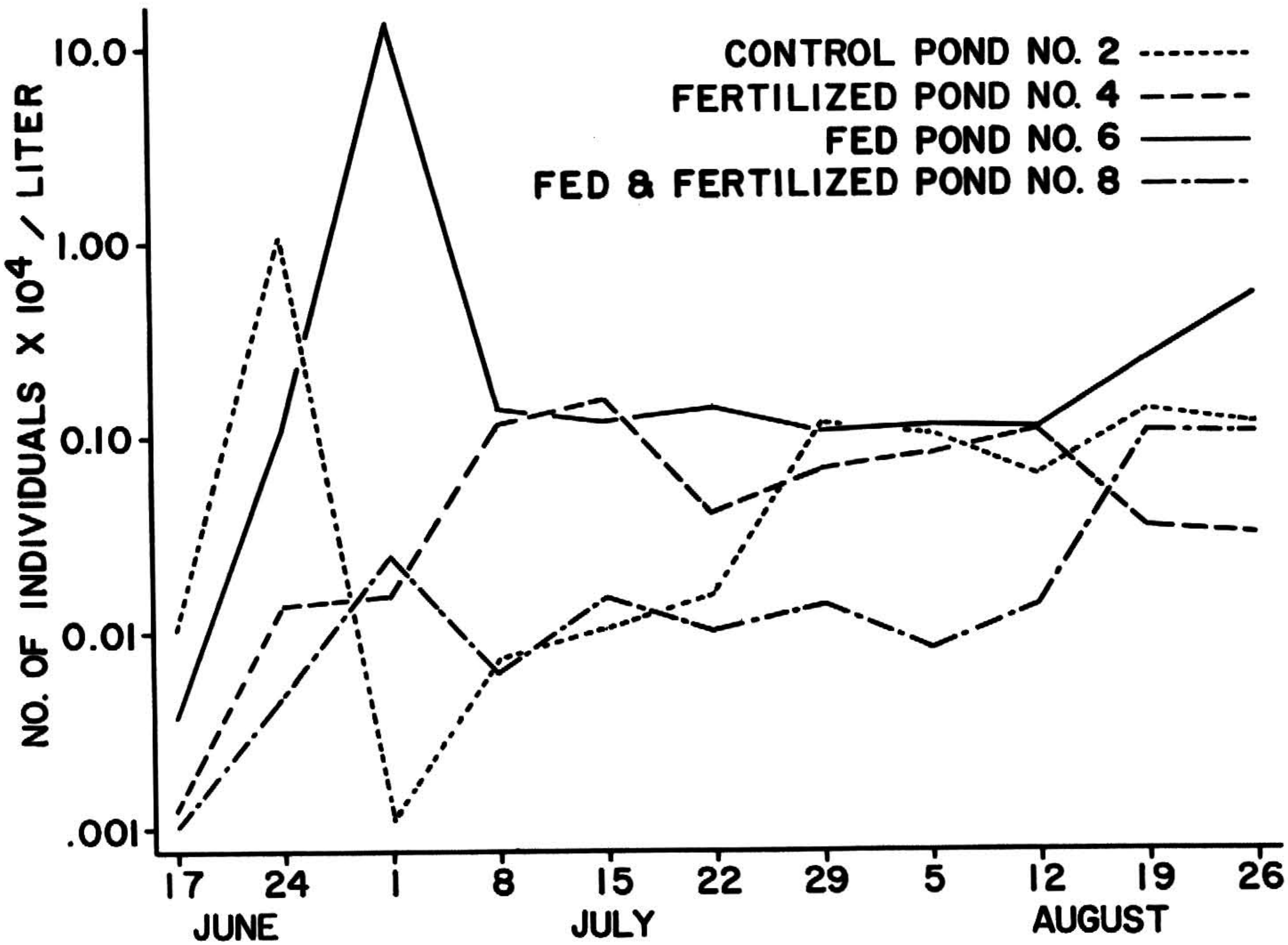


Figure 3. Number of algae per liter of pond water on sampling dates.

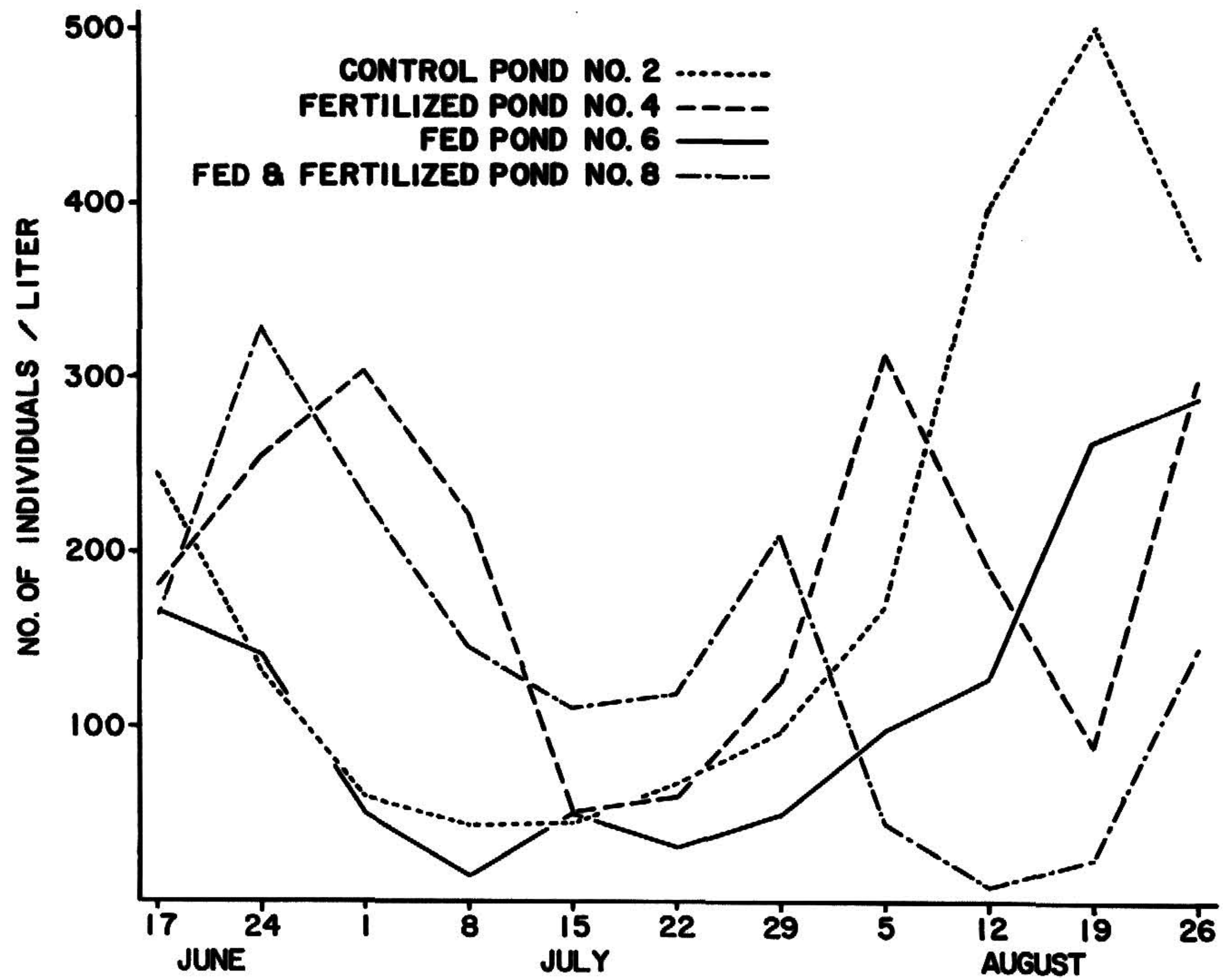


Figure 4. Number of Crustacea per liter of pond water on sampling dates.

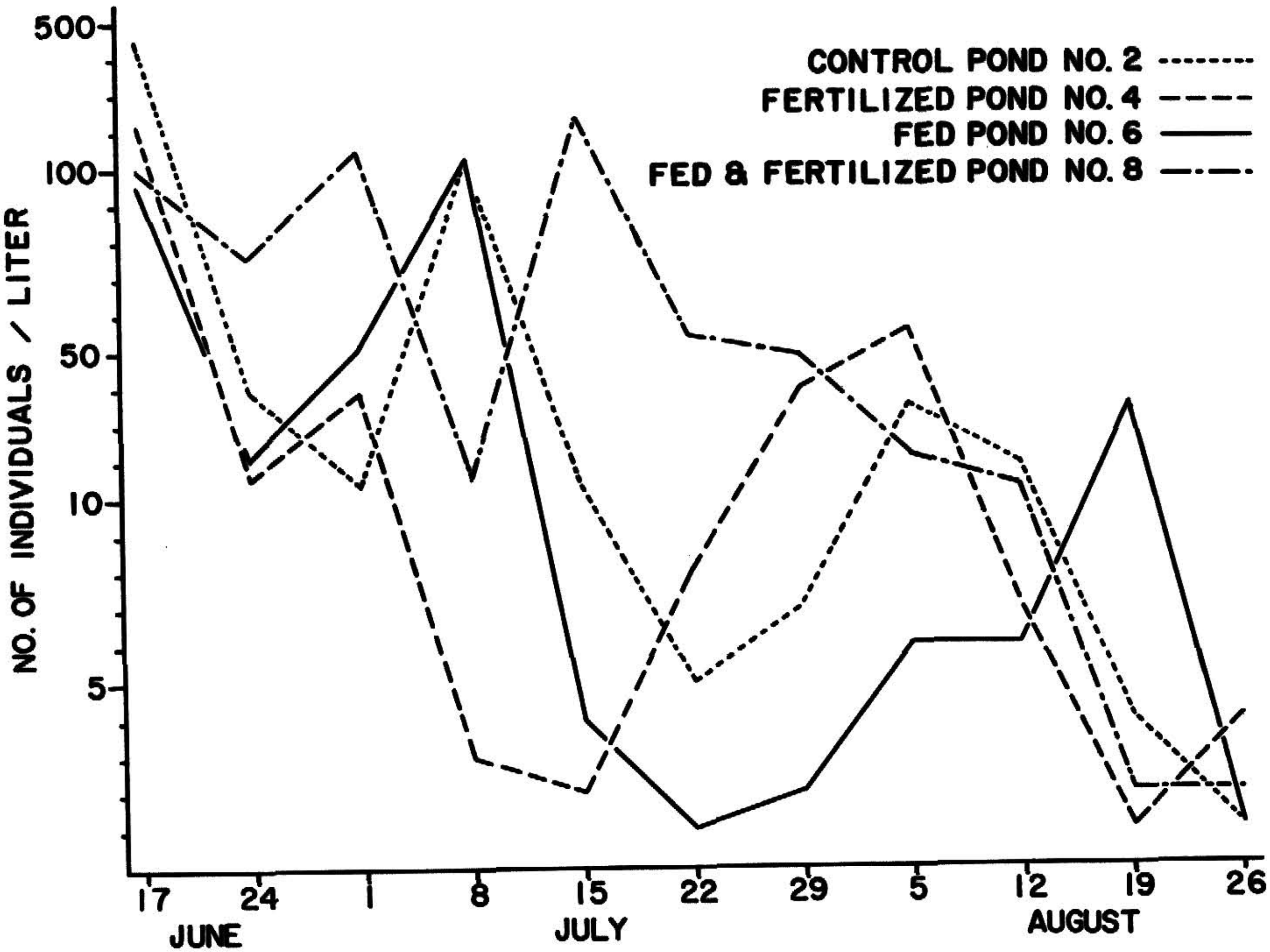


Figure 5. Number of Rotifera per liter of pond water on sampling dates.

Table 7. Most frequent natural food items in stomachs of channel catfish fry sampled from control Pond No. 2.

| | June | | July | | | | | | August | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | 17 | 24 | 1 | 8 | 15 | 22 | 24 | 29 | 5 | 12 | 19 | 26 |
| Organisms | | | | | | | | | | | | |
| Chironomidae larvae | 0 | 228 | 375 | 54 | 378 | 486 | 216 | 180 | 1116 | 108 | 156 | 108 |
| Chironomidae pupae | 0 | 30 | 24 | 0 | 0 | 0 | 0 | 0 | 36 | 0 | 0 | 12 |
| *Culicoides* larvae | 12 | 0 | 6 | 12 | 36 | 0 | 6 | 6 | 18 | 12 | 0 | 0 |
| *Chaoborus* larvae | 0 | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 12 |
| *Bosmina* | 36 | 0 | 0 | 0 | 102 | 0 | 156 | 102 | 432 | 132 | 228 | 30 |
| *Alona* | 0 | 0 | 0 | 0 | 492 | 792 | 426 | 48 | 126 | 120 | 24 | 24 |
| *Daphnia* | 96 | 6 | 54 | 0 | 30 | 6 | 0 | 0 | 6 | 12 | 24 | 0 |
| *Ceriodaphnia* | 0 | 0 | 6 | 6 | 24 | 12 | 246 | 30 | 0 | 0 | 0 | 24 |
| *Diaphanosoma* | 6 | 0 | 0 | 0 | 42 | 0 | 0 | 6 | 0 | 0 | 0 | 0 |
| *Cyclops* | 0 | 0 | 0 | 54 | 216 | 204 | 84 | 18 | 6 | 72 | 48 | 12 |
| *Diaptomus* | 0 | 0 | 0 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 |
| Ostracoda | 0 | 0 | 0 | 846 | 120 | 702 | 0 | 0 | 0 | 0 | 36 | 0 |
| Gastropoda | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 2 | 2 | 0 |

Table 8. Most frequent natural food items in stomachs of channel catfish fry sampled from fertilized Pond No. 4.

| | June | | July | | | | | August | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | 17 | 24 | 1 | 8 | 15 | 22 | 29 | 5 | 6 | 12 | 19 | 26 |
| Organisms | | | | | | | | | | | | |
| Chironomidae larvae | 60 | 96 | 54 | 492 | 30 | 432 | 120 | 726 | 396 | 204 | 1812 | 72 |
| Chironomidae pupae | 6 | 18 | 138 | 60 | 0 | 0 | 0 | 12 | 12 | 0 | 0 | 0 |
| *Culicoides* larvae | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 36 | 12 |
| *Chaoborus* larvae | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 12 | 0 |
| Dytiscidae | 0 | 12 | 12 | 6 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Corixidae | 0 | 0 | 0 | 0 | 45 | 3 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Bosmina* | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 1824 | 840 | 0 | 0 | 24 |
| *Alona* | 0 | 0 | 0 | 0 | 0 | 36 | 570 | 4410 | 2940 | 60 | 0 | 48 |
| *Daphnia* | 6 | 0 | 30 | 6 | 0 | 0 | 6 | 0 | 0 | 0 | 24 | 0 |
| *Ceriodaphnia* | 0 | 0 | 6 | 0 | 3978 | 216 | 72 | 30 | 144 | 12 | 0 | 12 |
| *Diaphanosoma* | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Cyclops* | 0 | 0 | 0 | 0 | 42 | 204 | 3780 | 1302 | 250 | 0 | 0 | 12 |
| *Diaptomus* | 0 | 0 | 0 | 0 | 18 | 0 | 12 | 0 | 0 | 0 | 0 | 0 |
| Ostracoda | 0 | 6 | 0 | 0 | 0 | 18 | 0 | 24 | 0 | 12 | 0 | 0 |
| Gastropoda | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 8 | 0 |

Table 9. Most frequent natural food items in stomachs of channel catfish fry sampled from fed Pond No. 6.

| | June | | July | | | | | August | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | 17 | 24 | 1 | 8 | 15 | 22 | 29 | 5 | 12 | 19 | 26 |
| Organisms | | | | | | | | | | | |
| Chironomidae larvae | 42 | 72 | 240 | 66 | 84 | 186 | 144 | 396 | 96 | 132 | 36 |
| Chironomidae pupae | 0 | 36 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Culicoides* larvae | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 0 | 0 |
| *Chaoborus* larvae | 0 | 0 | 0 | 12 | 0 | 0 | 1 | 0 | 0 | 0 | 24 |
| *Bosmina* | 18 | 0 | 0 | 0 | 12 | 114 | 342 | 930 | 936 | 1872 | 3780 |
| *Alona* | 0 | 0 | 0 | 0 | 102 | 600 | 1578 | 282 | 252 | 0 | 240 |
| *Daphnia* | 6 | 6 | 42 | 6 | 0 | 0 | 0 | 0 | 36 | 12 | 12 |
| *Ceriodaphnia* | 0 | 0 | 0 | 6 | 42 | 72 | 84 | 174 | 132 | 72 | 96 |
| *Diaphanosoma* | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 6 | 12 | 24 | 12 |
| *Cyclops* | 0 | 0 | 0 | 12 | 42 | 168 | 234 | 144 | 60 | 12 | 120 |
| *Diaptomus* | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 24 | 0 | 0 | 0 |
| Ostracoda | 0 | 0 | 0 | 24 | 12 | 0 | 0 | 0 | 12 | 0 | 0 |
| Gastropoda | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |

Table 10. Most frequent natural food items in stomachs of channel catfish fry sampled from fed & fertilized Pond No. 8.

| | June | | July | | | | | August | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | 17 | 24 | 1 | 8 | 15 | 22 | 29 | 5 | 12 | 19 | 26 |
| Organisms | | | | | | | | | | | |
| Chironomidae larvae | 24 | 66 | 174 | 342 | 330 | 870 | 246 | 78 | 9540 | 240 | 252 |
| Chironomidae pupae | 0 | 36 | 60 | 12 | 6 | 0 | 0 | 6 | 1920 | 0 | 0 |
| *Culicoides* larvae | 12 | 0 | 0 | 6 | 24 | 0 | 18 | 12 | 36 | 0 | 12 |
| *Chaoborus* larvae | 0 | 0 | 6 | 0 | 2 | 0 | 0 | 0 | 168 | 24 | 24 |
| Dytiscidae | 0 | 0 | 66 | 6 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| Haliplidae | 0 | 0 | 0 | 0 | 24 | 1 | 2 | 0 | 4 | 0 | 0 |
| *Bosmina* | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 0 | 24 | 12 |
| *Alona* | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 0 | 0 | 60 | 288 |
| *Daphnia* | 30 | 0 | 6 | 30 | 0 | 6 | 6 | 12 | 12 | 0 | 12 |
| *Ceriodaphnia* | 0 | 0 | 0 | 0 | 1080 | 1008 | 54 | 348 | 12 | 24 | 24 |
| *Diaphanosoma* | 0 | 0 | 0 | 0 | 0 | 18 | 12 | 6 | 0 | 12 | 0 |
| *Cyclops* | 18 | 0 | 0 | 0 | 18 | 168 | 138 | 36 | 24 | 0 | 0 |
| *Diaptomus* | 0 | 0 | 0 | 0 | 0 | 18 | 30 | 0 | 0 | 0 | 0 |
| Ostracoda | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 0 | 0 |
| Gastropoda | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 2 | 1 |

Table 11. Two-way analysis of variance table for the $(\text{number} + 1/2)^{1/2}$ of Chironomidae in stomachs of fish sampled from control pond 2, fertilized pond 4, fed pond 6, and fed & fertilized pond 8.

| Source of variance | Degrees of freedom | Sums of squares | Mean square | F Statistic |
|---|---|---|---|---|
| Ponds | 3 | 888.138 | 296.046 | 1.174 |
| Time | 10 | 2607.254 | 260.725 | 1.034 |
| Error | 30 | 7561.723 | 252.057 | |
| Total | 43 | 11057.117 | | |

Table 12. Two-way analysis of variance table for the $(\text{number} + 1/2)^{1/2}$ of zooplankters in the stomachs of five sampled from control pond 2, fertilized pond 4, fed pond 6 and fed & fertilized pond 8.

| Source of variance | Degrees of freedom | Sums of squares | Mean square | F Statistic |
|---|---|---|---|---|
| Pond | 3 | 1365.979 | 455.326 | 1.597 |
| Time | 10 | 8225.359 | 822.536 | 2.885* |
| Error | 30 | 8553.809 | 285.127 | |
| Total | 43 | 18145.148 | | |

* Indicates significance at the .05 level.

Table 13. Analyses of plankton samples taken from control Pond No. 2. Numbers given in individuals per liter

| | June | | | July | | | | | August | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dates | 13 | 17 | 24 | 1 | 8 | 15 | 22 | 29 | 5 | 12 | 19 | 26 |
| Organisms | | | | | | | | | | | | |
| Crustacea | | | | | | | | | | | | |
| Cladocera | | | | | | | | | | | | |
| Daphnia | 3 | 42 | 29 | 35 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Bosmina | 16 | 48 | 0 | 0 | 1 | 5 | 3 | 22 | 101 | 342 | 455 | 320 |
| Ceriodaphnia | 0 | 0 | 1 | 1 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| Alona | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Total | 19 | 90 | 30 | 36 | 1 | 7 | 5 | 22 | 101 | 343 | 456 | 320 |
| Copepoda | | | | | | | | | | | | |
| Cyclops | 35 | 56 | 4 | 10 | 14 | 16 | 19 | 32 | 31 | 23 | 10 | 6 |
| Diaptomus | 4 | 15 | 1 | 1 | 7 | 10 | 7 | 5 | 3 | 1 | 2 | 0 |
| Total | 39 | 71 | 5 | 11 | 21 | 26 | 26 | 37 | 34 | 24 | 12 | 6 |
| Nauplius larvae | 56 | 84 | 97 | 13 | 23 | 13 | 36 | 37 | 34 | 29 | 38 | 43 |
| Insecta | | | | | | | | | | | | |
| Chaoborus | 0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Grand Total | 114 | 245 | 133 | 60 | 45 | 46 | 67 | 96 | 169 | 396 | 506 | 369 |
| Rotifera | 676 | 450 | 38 | 13 | 115 | 13 | 5 | 7 | 35 | 19 | 4 | 1 |
| Algae | | | | | | | | | | | | |
| Chlorophyta | 0 | 0 | 70 | 4 | 15 | 4 | 2 | 8 | 47 | 18 | 111 | 383 |
| Cyanophyta | 0 | 0 | 0 | 0 | 0 | 0 | 52 | 1634 | 1134 | 791 | 1977 | 1041 |
| Chrysophyta | 0 | 115 | 12859 | 10 | 73 | 104 | 218 | 10 | 2 | 4 | 70 | 231 |
| Total | 0 | 115 | 12929 | 14 | 88 | 108 | 272 | 1652 | 1183 | 813 | 2158 | 1655 |

Table 14. Analyses of plankton samples taken from fertilized Pond No. 4. Numbers given in individuals per liter.

| | June | | | July | | | | | August | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dates | 13 | 17 | 24 | 1 | 8 | 15 | 22 | 29 | 5 | 12 | 19 | 26 |
| Organisms | | | | | | | | | | | | |
| Crustacea | | | | | | | | | | | | |
| Cladocera | | | | | | | | | | | | |
| *Daphnia* | 4 | 6 | 0 | 28 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| *Bosmina* | 6 | 23 | 2 | 0 | 0 | 0 | 1 | 29 | 229 | 161 | 68 | 110 |
| *Ceriodaphnia* | 0 | 0 | 1 | 35 | 25 | 14 | 4 | 2 | 1 | 0 | 0 | 0 |
| *Diaphanosoma* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 4 | 7 |
| *Alona* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Total | 10 | 29 | 3 | 63 | 27 | 14 | 5 | 31 | 232 | 166 | 72 | 121 |
| Copepoda | | | | | | | | | | | | |
| *Cyclops* | 30 | 62 | 169 | 187 | 24 | 21 | 40 | 18 | 9 | 8 | 10 | 87 |
| *Diaptomus* | 5 | 6 | 3 | 4 | 1 | 1 | 3 | 4 | 4 | 1 | 0 | 1 |
| Total | 35 | 68 | 172 | 191 | 25 | 23 | 43 | 22 | 13 | 9 | 10 | 88 |
| Nauplius larvae | 65 | 84 | 83 | 49 | 170 | 13 | 11 | 71 | 67 | 16 | 7 | 89 |
| Grand Total | 110 | 181 | 255 | 303 | 222 | 49 | 59 | 124 | 312 | 191 | 89 | 298 |
| Rotifera | 228 | 221 | 16 | 37 | 3 | 2 | 8 | 39 | 56 | 7 | 1 | 4 |
| Algae | | | | | | | | | | | | |
| Chlorophyta | 2 | 9 | 229 | 267 | 1496 | 2663 | 643 | 731 | 802 | 614 | 105 | 323 |
| Cyanophyta | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 83 | 62 | 583 | 478 | 114 |
| Chrysophyta | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 28 | 41 | 8 | 0 | 105 |
| Total | 2 | 19 | 229 | 267 | 1496 | 2663 | 653 | 842 | 905 | 1205 | 583 | 542 |

Table 15. Analyses of plankton samples taken from fed Pond No. 6. Numbers given in individuals per liter.

| | June | | | July | | | | | August | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dates | 13 | 17 | 24 | 1 | 8 | 15 | 22 | 29 | 5 | 12 | 19 | 26 |
| Organisms | | | | | | | | | | | | |
| Crustacea | | | | | | | | | | | | |
| Cladocera | | | | | | | | | | | | |
| Daphnia | 4 | 17 | 62 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bosmina | 18 | 31 | 2 | 0 | 0 | 2 | 3 | 9 | 26 | 52 | 208 | 214 |
| Ceriodaphnia | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 |
| Diaphanosoma | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 7 | 2 | 1 |
| Total | 22 | 48 | 64 | 11 | 0 | 4 | 3 | 10 | 29 | 59 | 210 | 215 |
| Copepoda | | | | | | | | | | | | |
| Cyclops | 39 | 59 | 8 | 6 | 3 | 7 | 10 | 6 | 27 | 23 | 14 | 20 |
| Diaptomus | 2 | 5 | 3 | 4 | 4 | 10 | 4 | 6 | 6 | 2 | 1 | 1 |
| Total | 41 | 64 | 11 | 10 | 7 | 17 | 14 | 12 | 33 | 25 | 15 | 21 |
| Nauplius larvae | 83 | 54 | 66 | 29 | 8 | 30 | 14 | 26 | 36 | 43 | 38 | 51 |
| Grand Total | 146 | 166 | 141 | 50 | 15 | 51 | 31 | 48 | 98 | 127 | 263 | 287 |
| Rotifera | 265 | 96 | 21 | 52 | 123 | 4 | 1 | 2 | 6 | 6 | 35 | 1 |
| Algae | | | | | | | | | | | | |
| Chlorophyta | 0 | 1 | 24 | 117 | 15 | 36 | 15 | 78 | 69 | 97 | 70 | 122 |
| Cyanophyta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 260 | 1238 | 936 | 3194 | 3109 |
| Chrysophyta | 24 | 62 | 2101 | 218232 | 2372 | 1697 | 2341 | 895 | 118 | 201 | 1288 | 4254 |
| Total | 24 | 63 | 2125 | 218349 | 2387 | 1733 | 2356 | 1233 | 1425 | 1234 | 4552 | 7485 |

Table 16. Analyses of plankton samples taken from fed & fertilized Pond No. 8. Numbers given in individuals per liter.

| | June | | | July | | | | | August | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dates | 13 | 17 | 24 | 1 | 8 | 15 | 22 | 29 | 5 | 12 | 19 | 26 |
| Organisms | | | | | | | | | | | | |
| Crustacea | | | | | | | | | | | | |
| Cladocera | | | | | | | | | | | | |
| *Daphnia* | 10 | 10 | 11 | 107 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| *Bosmina* | 9 | 22 | 3 | 1 | 1 | 11 | 12 | 106 | 17 | 3 | 7 | 3 |
| *Ceriodaphnia* | 0 | 0 | 0 | 6 | 10 | 29 | 4 | 11 | 0 | 0 | 0 | 0 |
| *Diaphanosoma* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 1 | 3 | 12 |
| *Alona* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| Total | 19 | 33 | 14 | 114 | 13 | 40 | 16 | 117 | 27 | 5 | 10 | 18 |
| Copepoda | | | | | | | | | | | | |
| *Cyclops* | 42 | 46 | 101 | 7 | 42 | 41 | 60 | 10 | 1 | 1 | 4 | 43 |
| *Diaptomus* | 9 | 11 | 2 | 2 | 3 | 3 | 3 | 4 | 0 | 1 | 0 | 0 |
| Total | 51 | 57 | 103 | 9 | 45 | 44 | 63 | 14 | 1 | 2 | 4 | 43 |
| Nauplius larvae | 9 | 74 | 210 | 108 | 87 | 27 | 38 | 78 | 17 | 1 | 10 | 84 |
| Grand Total | 79 | 164 | 327 | 231 | 145 | 111 | 117 | 209 | 45 | 8 | 24 | 145 |
| Rotifera | 435 | 104 | 76 | 140 | 15 | 236 | 54 | 48 | 22 | 13 | 2 | 2 |
| Algae | | | | | | | | | | | | |
| Chlorophyta | 0 | 11 | 63 | 356 | 81 | 253 | 83 | 89 | 46 | 104 | 29 | 161 |
| Cyanophyta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 42 | 52 | 1186 | 988 |
| Chrysophyta | 270 | 0 | 10 | 94 | 0 | 10 | 23 | 122 | 5 | 59 | 79 | 47 |
| Total | 270 | 11 | 73 | 450 | 81 | 263 | 106 | 221 | 93 | 215 | 1294 | 1196 |

Table 17. Two-way analysis of variance table for the $(\text{number} + 1/2)^{1/2}$ of algae per liter of water in control pond 2, fertilized pond 4, fed pond 6 and fed & fertilized pond 8.

| Source of variance | Degrees of freedom | Sums of squares | Mean square | F Statistic |
|---|---|---|---|---|
| Ponds | 3 | 29975.746 | 9991.914 | 2.155 |
| Time | 10 | 38719.141 | 3871.914 | 0.835 |
| Error | 30 | 139098.125 | 4636.602 | |
| Total | 43 | 207793.062 | | |

Table 18. Two-way analysis of variance table for the $(\text{number} + 1/2)^{1/2}$ of Crustacea per liter of water in control pond 2, fertilized pond 4, fed pond 6 and fed & fertilized pond 8.

| Source of variance | Degrees of freedom | Sums of squares | Mean square | F Statistic |
|---|---|---|---|---|
| Ponds | 3 | 91.048 | 30.349 | 1.754 |
| Time | 10 | 278.073 | 27.807 | 1.607 |
| Error | 30 | 519.080 | 17.303 | |
| Total | 43 | 888.201 | | |

Table 19. Number of chironomid larvae per square meter of pond bottom calculated for control pond 2, fertilized pond 4, fed pond 6 and fed & fertilized pond 8.

| Date | Ponds Nos. | | | |
|---|---|---|---|---|
| | 2 | 4 | 6 | 8 |
| 17 June | 0 | 827 | 1,984 | 661 |
| 24 June | 17,026 | 19,505 | 16,659 | 8,100 |
| 1 July | 6,777 | 9,257 | 19,671 | 2,149 |
| 8 July | 1,653 | 9,918 | 2,149 | 7,934 |
| 15 July | 826 | 1,157 | 661 | 2,975 |
| 22 July | 1,653 | 1,818 | 1,984 | 3,471 |
| 29 July | 826 | 826 | 2,480 | 826 |
| 5 August | 661 | 4,298 | 1,984 | 2,314 |
| 12 August | 7,769 | 0 | 331 | 6,116 |
| 19 August | 331 | 15,373 | 826 | 2,645 |
| 26 August | 0 | 661 | 331 | 0 |

Table 20. Number of chironomid pupae per square meter of pond bottom calculated for control Pond 2, fertilized pond 4, fed pond 6, and fed & fertilized pond 8.

| Date | Ponds Nos. | | | |
|---|---|---|---|---|
| | 2 | 4 | 6 | 8 |
| 17 June | 165 | 331 | 0 | 0 |
| 24 June | 661 | 331 | 992 | 496 |
| 1 July | 0 | 661 | 496 | 0 |
| 8 July | 0 | 66.1 | 0 | 826 |
| 15 July | 0 | 0 | 0 | 165 |
| 22 July | 0 | 0 | 0 | 0 |
| 29 July | 0 | 0 | 0 | 0 |
| 5 August | 0 | 0 | 0 | 0 |
| 12 August | 0 | 0 | 0 | 0 |
| 19 August | 0 | 0 | 0 | 0 |
| 26 August | 165 | 0 | 0 | 0 |

Table 21. Two-way analysis of variance table for the $(\text{number} + 1/2)^{1/2}$ of chironomids found per square meter of pond bottom in control pond 2, fertilized pond 4, fed pond 6 and fed & fertilized pond 8.

| Source of variance | Degrees of freedom | Sums of squares | Mean square | F Statistic |
|---|---|---|---|---|
| Ponds | 3 | 1623.043 | 541.014 | 0.712 |
| Time | 10 | 39482.125 | 3948.212 | 5.193* |
| Error | 30 | 22807.125 | 760.237 | |
| Total | 43 | 63912.297 | | |

* Indicates significance at .05 level.

Table 22. Number of gastropods per square meter of pond bottom calculated for control pond 2, fertilized pond 4, fed pond 6 and fed & fertilized pond 8.

| Date | Ponds Nos. | | | |
|---|---|---|---|---|
| | 2 | 4 | 6 | 8 |
| 17 June | 1,157 | 2,480 | 331 | 0 |
| 24 June | 661 | 661 | 1,653 | 331 |
| 1 July | 3,677 | 0 0 | 0 | 331 |
| 8 July | 1,984 | 1,488 | 3,130 | 0 |
| 15 July | 2,149 | 165 | 165 | 165 |
| 22 July | 4,463 | 0 | 2,314 | 2,314 |
| 29 July | 496 | 331 | 1,818 | 165 |
| 5 August | 165 | 661 | 1,818 | 165 |
| 12 August | 5,455 | 992 | 1,818 | 1,322 |
| 19 August | 9,092 | 1,157 | 3,306 | 661 |
| 26 August | 2,975 | 8,430 | 6,281 | 826 |

Table 23. Number of ostracods per square meter of pond bottom calculated for control pond 2, fertilized pond 4, fed pond 6 and fed & fertilized pond 8.

| Date | Ponds Nos. | | | |
|---|---|---|---|---|
| | 2 | 4 | 6 | 8 |
| 17 June | 1,653 | 3,967 | 8,100 | 0 |
| 24 June | 0 | 1,157 | 1,488 | 331 |
| 1 July | 992 | 0 | 331 | 1,322 |
| 8 July | 7,273 | 8,100 | 8,430 | 1,653 |
| 15 July | 3,802 | 1,818 | 826 | 1,488 |
| 22 July | 27,605 | 6,116 | 4,132 | 4,463 |
| 29 July | 0 | 3,967 | 3,471 | 3,802 |
| 5 August | 165 | 0 | 661 | 6,116 |
| 12 August | 496 | 0 | 496 | 11,075 |
| 19 August | 0 | 496 | 0 | 2,975 |
| 26 August | 0 | 826 | 0 | 1,818 |

Table 24. Dissolved oxygen in ppm near the surface and at 3.5 feet in control pond 2, fertilized pond 4, fed pond 6 and fed & fertilized pond 8.

| Date | Ponds Nos. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2 | | 4 | | 6 | | 8 | |
| | Depth | | | | | | | |
| | 0' | 3.5' | 0' | 3.5' | 0' | 3.5' | 0' | 3.5' |
| 18 June | 7.6 | 7.4 | 9.0 | 8.6 | 8.9 | 8.0 | 11.0 | 11.1 |
| 25 June | 6.8 | 6.4 | 5.8 | 5.8 | 6.6 | 6.2 | 6 2 | 6.1 |
| 2 July | 8.3 | 7.7 | 4.2 | 3.8 | 7.7 | 8.4 | 6.0 | 5.0 |
| 9 July | 6.6 | 6.6 | 6.4 | 5.9 | 6.8 | 6.4 | 7.1 | 7.1 |
| 16 July | 6.8 | 6.5 | 10.8 | 10.5 | 6.4 | 5.9 | 8.0 | 7.8 |
| 23 July | 7.2 | 7.1 | 6.6 | 6.4 | 6.4 | 6.3 | 6.8 | 6.6 |
| 30 July | 10.4 | 11.5 | 6.3 | 6.0 | 8.8 | 8.6 | 10.6 | 10.4 |
| 6 August | 7.6 | 6.6 | 6.9 | 5.9 | 5.7 | 5.5 | 10.6 | 10.3 |
| 13 August | 6.2 | 5.4 | 8.5 | 7.4 | 6.4 | 4.6 | 7.3 | 6.9 |
| 20 August | 2.8 | 1.4 | 6.8 | 6.2 | 3.2 | 2.6 | 10.0 | 9.0 |
| 27 August | 3.6 | 3.5 | 7.2 | 6.5 | 5.5 | 5.0 | 8.5 | 7.5 |

Table 25. Hydrogen ion (pH) measurements obtained near the surface and at 3.5 feet in control pond 2, fertilized pond 4, fed pond 6 and fed & fertilized pond 8.

| Date | Ponds Nos. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2 | | 4 | | 6 | | 8 | |
| | Depth | | | | | | | |
| | 0' | 3.5' | 0' | 3.5' | 0' | 3.5' | 0' | 3.5' |
| 18 June | 8.4 | 8.4 | 9.4 | 9.4 | 8.4 | 8.3 | 9.3 | 9.3 |
| 25 June | 8.0 | 8.2 | 9.4 | 8.2 | 8.0 | 8.0 | 9.4 | 9.4 |
| 2 July | 8.4 | 8.4 | 9.0 | 9.0 | 8.4 | 8.4 | 8.9 | 8.9 |
| 9 July | 8.4 | 8.3 | 8.9 | 8.9 | 8.2 | 8.2 | 9.4 | 9.4 |
| 16 July | 8.5 | 8.5 | 9.2 | 9.2 | 8.4 | 8.2 | 9.0 | 9.0 |
| 23 July | 8.7 | 8.6 | 9.1 | 9.1 | 8.2 | 8.2 | 8.9 | 8.9 |
| 30 July | 9.4 | 9.4 | 8.9 | 8.9 | 8.3 | 8.4 | 9.2 | 9.2 |
| 6 August | 9.2 | 9.2 | 8.9 | 9.0 | 9.2 | 9.2 | 9.6 | 9.6 |
| 13 August | 8.9 | 8.9 | 9.4 | 9.4 | 8.5 | 8.5 | 9.1 | 9.1 |
| 20 August | 8.2 | 8.2 | 9.0 | 9.0 | 8.2 | 8.0 | 9.0 | 9.2 |
| 27 August | 8.0 | 8.0 | 8.8 | 8.8 | 8.0 | 8.0 | 9.0 | 9.0 |

Table 26. Two-way analysis of variance table for pH readings near the surface in control pond 2, fertilized pond 4, fed pond 6 and fed & fertilized pond 8.

| Source of variance | Degrees of freedom | Sums of squares | Mean square | F Statistic |
|---|---|---|---|---|
| Ponds | 3 | 5.315 | 1.772 | 21.630* |
| Time | 10 | 1.752 | 0.175 | 2.139 |
| Error | 30 | 2.457 | 0.082 | |
| Total | 43 | 9.525 | | |

* Indicates significance at the .05 level.

Table 27. Platinum wire turbidity readings (ppm) taken in control pond 2, fertilized pond 4, fed pond 6 and fed & fertilized pond 8.

| Date | Ponds Nos. | | | |
|---|---|---|---|---|
| | 2 | 4 | 6 | 8 |
| 18 June | 28 | 45 | 28 | 45 |
| 25 June | 18 | 45 | 17 | 40 |
| 2 July | 22 | 25 | 19 | 12 |
| 9 July | 30 | 53 | 34 | 38 |
| 16 July | 47 | 32 | 55 | 25 |
| 23 July | 40 | 35 | 80 | 22 |
| 30 July | 51 | 32 | 85 | 22 |
| 6 August | 75 | 33 | 95 | 45 |
| 13 August | 70 | 60 | 65 | 60 |
| 20 August | 90 | 95 | 80 | 80 |
| 27 August | 70 | 50 | 65 | 65 |

Table 28. Two-way analysis of variance table for turbidity readings taken in control pond 2, fertilized pond 4, fed pond 6 and fed & fertilized pond 8.

| Source of variance | Degrees of freedom | Sums of squares | Mean square | F Statistic |
|---|---|---|---|---|
| Ponds | 3 | 1378.976 | 459.658 | 1.828 |
| Time | 10 | 14212.492 | 1421.249 | 5.653* |
| Error | 30 | 7542.781 | 251.426 | |
| Total | 43 | 23134.250 | | |

* Indicates significance at the .05 level.

Table 29. Carbonate alkalinity (mg/l) and bicarbonate alkalinity (mg/l) obtained near the surface and at 3.5 feet in control Pond No. 2, fertilized Pond No. 4, fed Pond No. 6 and fed & fertilized Pond No. 8.

| Ponds Nos. | 2 | | 4 | | 6 | | 8 | |
|---|---|---|---|---|---|---|---|---|
| Depth | 0' | 3.5' | 0' | 3.5' | 0' | 3.5' | 0' | 3.5' |
| Date | | | | | | | | |
| | | | | Carbonate alkalinity | | | | |
| 18 June | 5 | 5 | 39 | 31 | 4 | 4 | 42 | 44 |
| 25 June | 0 | 0 | 45 | 0 | 0 | 0 | 30 | 49 |
| 2 July | 9 | 9 | 24 | 27 | 12 | 15 | 18 | 18 |
| 9 July | 12 | 6 | 21 | 24 | 0 | 0 | 30 | 36 |
| 16 July | 12 | 12 | 44 | 43 | 12 | 8 | 21 | 24 |
| 23 July | 12 | 10 | 22 | 25 | 3 | 4 | 15 | 15 |
| 30 July | 30 | 27 | 18 | 18 | 6 | 6 | 30 | 30 |
| | | | | Bicarbonate alkalinity | | | | |
| 18 June | 117 | - | 119 | - | 125 | - | 110 | - |
| 25 June | 113 | 112 | 38 | 92 | 93 | 113 | 24 | 32 |
| 2 July | 153 | 136 | 88 | 113 | 92 | 101 | 73 | 88 |
| 9 July | 67 | 110 | 70 | 61 | 131 | 116 | 37 | 21 |
| 16 July | 92 | 110 | 24 | 40 | 92 | 130 | 73 | 58 |
| 23 July | 85 | 78 | 60 | 59 | 85 | 103 | 72 | 58 |
| 30 July | 30 | 37 | 70 | 58 | 101 | 107 | 40 | 38 |

Table 30. Temperature ($^{o}F$) obtained near the surface and at 3.5 feet in control pond 2, fertilized pond 4, fed pond 6 and fed & fertilized pond 8.

| Date | Ponds Nos. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2 | | 4 | | 6 | | 8 | |
| | Depth | | | | | | | |
| | 0' | 3.5' | 0' | 3.5' | 0' | 3.5' | 0' | 3.5' |
| 18 June | 66 | 66 | 66 | 66 | 69 | 67 | 70 | 68 |
| 25 June | 75 | 76 | 75 | 76 | 75 | 76 | 76 | 76 |
| 2 July | 77 | 77 | 77 | 77 | 78 | 77 | 78 | 77 |
| 9 July | 81 | 81 | 81 | 81 | 81 | 81 | 81 | 81 |
| 16 July | 84 | 84 | 84 | 84 | 84 | 84 | 84 | 84 |
| 23 July | 81 | 82 | 82 | 82 | 81 | 81 | 82 | 82 |
| 30 July | 79 | 79 | 81 | 81 | 78 | 78 | 81 | 81 |
| 6 August | 81 | 81 | 83 | 83 | 80 | 80 | 83 | 83 |
| 13 August | 76 | 75 | 76 | 76 | 75 | 75 | 76 | 76 |
| 20 August | 80 | 80 | 79 | 80 | 79 | 80 | 79 | 80 |
| 27 August | 74 | 74 | 74 | 75 | 74 | 74 | 75 | 75 |

Table 31. Production of channel catfish fry in control pond 2, fertilized pond 4, fed pond 6 and fed and fertilized pond 8.

| Pond No. | Lbs. fish | Mean wt. (gms) | No. fish | Lbs./acre | Fish/acre | No. harvested/lb. fry stocked |
|---|---|---|---|---|---|---|
| 2 (1) | 62.7 | 11.88 | 2,396 | 436.63 | 16,685 | 10,878 |
| 4 (1) | 37.1 | 10.08 | 1,675 | 258.36 | 11,664 | 7,605 |
| 6 (2) | 77.8 | 16.68 | 2,116 | 541.78 | 14,735 | 9,607 |
| 8 (2) | 45.1 | 13.78 | 1,489 | 314.07 | 10,369 | 6,760 |

(1) 312 fish removed during summer but data not included in (lbs. fish), (mean wt.) or (lbs./acre).

(2) 286 fish removed during summer but data not included in (lbs. fish), (mean wt.) or (lbs./acre).

Table 32. Fisher's least significant difference (Fryer, 1968) among means of four ponds for all sampling dates. Means not connected were significantly different.

| | | | | | |
|---|---|---|---|---|---|
| Pond No. | 6 | 8 | 4 | 2 | $LSD_{.05}$ |
| Mean wt. of fry in gms | 5.59 | 5.05 | 3.89 | 3.23 | 1.12 |
| Pond No. | 6 | 8 | 4 | 2 | |
| Mean length of fry in mm | 7.58 | 7.36 | 6.68 | 6.51 | 0.42 |
| Pond No. | 6 | 8 | 2 | 4 | |
| Mean stomach content volume in ml | 7.59 | 4.71 | 4.22 | 2.15 | 2.45 |
| Pond No. | 8 | 4 | 2 | 6 | |
| Mean pH | 9.16 | 9.09 | 8.55 | 8.34 | 0.24 |

# RESULTS

Growth of fry was slightly greater in control pond 2 and fed pond 6 for the first two weeks of the experiment (Fig. 1 and Table 1). Samples taken 8 July indicated fry in control pond 2 had experienced a drastic decrease in weight gain compared to the other ponds. The period of slow growth continued until 22 July. Fry sampled on 24 July from pond 2 showed a marked increase in weight after initiation of a supplemental feeding program on 23 July. The feeding program was identical to that of the two continually fed ponds (fed pond 6 and fed & enriched pond 8). Rate of growth in pond 2 was similar to that of fry in fed pond 6 from 24 July until the termination of the experiment.

Fry in enriched pond 4 exhibited rate of growth similar to fry in fed pond 6 from 15 July to 29 July. Sampling 5 August indicated fry in pond 4 had experienced a decrease in weight gain similar to that experienced by fry in pond 2 on 6 July. In response to the decrease in growth rate, a supplemental feeding program identical to that of the other three ponds was commenced 5 August. Fry sampled 6 August revealed an abrupt increase in weight due to feed consumed. During August, growth of fry in the two enriched ponds was generally less and more variable than that obtained by fry in the non-enriched ponds.

Fry in fed pond 6 had the most consistent weight gain of the four ponds sampled (Fig. 1). It also contained the largest fingerlings from 12 August until termination of the experiment. A two-way analysis of variance calculated for weight of fry indicated a significant difference among ponds and among sampling dates (Table 2).

Curves for growth in length and weight were similar for the four ponds sampled (Figs. 1 and 2), but curves for growth in length exhibited less drastic fluctuation than those for weight. Analysis of variance of total length indicated significant differences for Ponds, Time and Ponds x Time interaction sources of variation (Table 4).

Fry were first sampled 17 June when they were two weeks old, 20 millimeters long and weighed approximately 0.10 gram. Percentages by volume of plankton found in the stomachs varied from 100 percent in fry sampled from control pond 2 to approximately 50 percent in the other three ponds (Table 5); the remaining volume consisted primarily of Chironomidae larvae. Fry in pond 2 fed primarily on chironomids from 24 June to 8 July. On that date ostracods became the principal food item and were taken in large numbers until the acceptance of supplemental feed. On the 15 and 22 July sampling dates, stomach contents contained 40 and 75 percent plankton, respectively. Supplemental feed was first presented to fry in control pond 2 on 23 July and the following day supplemental feed comprised 92 percent of the stomach contents.

The fry in enriched pond 4 fed primarily on midge larvae until 15 July. Foraging began to shift to zooplankters on that date and stomach contents sampled 29 July and 5 August contained 93 and 77 percent zooplankton, respectively. Supplemental feed was first presented to fry in pond 4 on 5 August and 6 August it made up 95 percent of the stomach contents.

Fry in fed pond 6 and fed & enriched pond 8 feed primarily on Chironomidae larvae for the first three sampling dates (Table 5). Supplemental feed was first detected in stomachs of fry sampled from the two continually fed ponds 8 July. The fry were five weeks old and had attained a weight of 2.24 grams in pond 6 and 1.29 grams in pond 8. The percentage of supplemental feed found in the stomachs was 97 percent in pond 6 and 50 in pond 8 (Table 5).

Once the fry accepted supplemental feed, a marked decrease in volumetric importance of natural food items was noted. After its initial acceptance, supplemental feed comprised 80 to 98 percent of the total stomach contents. On only two sampling dates did the percent by volume of supplemental feed decrease. Stomach contents of fish sampled from fed & enriched pond 8 the 12 August consisted volumetrically of 5 percent supplemental feed and 95 percent midge larvae and pupae. Stomach contents of fry sampled from enriched pond 4 on 19 August consisted volumetrically of one percent supplemental feed and 98 percent midge larvae.

A two-way analysis of variance indicated ponds (treatments) had a significant effect on the total volume of stomach contents and volume of stomach contents varied significantly over the sampling period (Table 6).

Numerically Daphnia and Bosmina were the dominant zooplankters consumed during the first three weeks of the experiment. Three weeks prior to initiation of a supplemental feeding program in pond 2, a sharp increase in numerical importance of Alona, Cyclops and ostracods occurred (Table 7). After acceptance of supplemental feed ostracods were rarely consumed and *Cyclops* and *Alona* decreased in importance. *Bosmina* showed a substantial increase in dietary importance on 5 August.

Fry in enriched pond 4 showed a heavy reliance on chironomid larvae and pupae the first four weeks of the study (Table 8). Foraging on zooplankton increased the four weeks prior to initiation of a supplemental feeding program. The plankton species utilized in large numbers were *Ceriodaphnia*, later *Cyclops*, *Alona* and *Bosmina*. After the acceptance of supplemental feed, natural prey species decreased in importance.

Fry in fed pond 6 fed primarily on midge larvae and pupae and *Daphnia* prior to the acceptance of supplemental feed. Once the fry accepted supplemental feed (8 July) planktonic Crustacea became numerically important. Important forage species after acceptance of supplemental feed were *Bosmina*, *Alona*, *Ceriodaphnia* and *Cyclops* (Table 9).

Fry in fed & enriched pond 8 fed primarily on chironomid larvae and pupae before acceptance of supplemental feed (8 July). Zooplankters, especially *Ceriodaphnia* and *Cyclops*, became more important as the populations increased.

Later in the study gastropods were consumed more frequently by fry in all four ponds and larval Dytiscidae, Haliplidae, *Culicoides* and *Chaoborus* had sporadic dietary importance throughout the study. Algae, nauplius larvae and rotifers were absent from stomach samples.

A two-way analysis of variance was used to analyze differences in the number of chironomids and zooplankters consumed by fish. The ratio of mean squares for the number of chironomids showed no significant difference among ponds or for the period studied (Table 11).

Analysis of variance indicated the numbers of zooplankters were the same in the four ponds sampled but varied over the sampling period (Table 12).

The algae population attained two peaks in control pond 2 (Fig. 3). The first peak consisted primarily of Melosira. The phytoplankton population markedly decreased by 1 July and a second peak was attained 29 July (Table 13). Anabeana was the primary contributor to the second bloom. Chlorophyta also became more abundant late in the study (Table 13). The algae population in enriched pond 4 exhibited two major peaks as did the population in pond 2 (Fig. 3). The peaks occurred 2 to 3 weeks after those of the control pond but no drastic population decrease was noted. Chlorophyta was abundant at the first peak and contributed heavily to the second. Cyanophyta became dominant the final two weeks of the experiment (Table 14). Some Chrysophyta were present in pond 4 throughout the study. Fed pond 6 maintained a larger population of algae than the other three ponds. The population again showed two distinct peaks (Fig. 3). The first peak was due primarily to an increase in the Chrysophyta population and the second to blooms of Chrysophyta and Cyanophyta (Table 15). Substantial numbers of Melosira maintained throughout the study were responsible for the more dense algae population. Pond 6 contained a few Chlorophyta throughout the study.

The algae population in fed & enriched pond 8 was more variable than that in other three ponds (Fig. 3). The first two peaks consisted of Chlorophyta and the last more substantial peak to a bloom in the Cyanophyta populations (Table 16).

Pediastrum was the most abundant genus of green algae in the four ponds and Anabaena was the largest contributor to blue-green algae populations. The yellow-green algae consisted largely of Melosira. Scenedesmus and Synedra were present in smaller numbers.

Zooplankton populations in the four ponds displayed a similar trend (Fig. 4). Initially each of the four ponds contained a relatively dense population. The initial populations consisted of Daphnia, Bosmina, Cyclops and Nauplius larvae. The low population densities resulted from a decrease or absence of the above organisms. The second increase in zooplankton populations in ponds 2, 4 and 6 was primarily the result of an increased number of Bosmina. The increased numbers in pond 8 consisted of higher populations of Cyclops and nauplius larvae. Ceriodaphnia and Diaptomus were also present in substantial numbers.

The rotifer populations varied drastically over the entire summer (Fig. 5). Populations suffered an initial drop after the first sampling date, but pond 2, 4 and 6 experienced a population increase early in July and a second increase in August. Pond 8 maintained the highest Rotifera population throughout the study, but a reduction in the rotifer population of all ponds occurred the last of August. Keratella, Brachionus and Hexarthra were the more abundant rotifers present.

The benthos samples contained 1/4 to 1/2 inch sedimentation. Silt, sand and detritus were consistently obtained in the bottom samples. Populations of chironomid larvae attained their greatest peaks on 24 June (ponds 2, 4 and 8) and 1 July (pond 6). After the initial rise and tapering off period a second rise was noted (Table 19). The second rise occurred 12 August in ponds 2 and 8, and 29 July and 12 August in ponds 6 and 4. Benthos samples indicated Chironomidae pupae were most abundant during the first four weeks (Table 20). An analysis of variance was calculated for the number of chironomids per square meter of pond bottom in four ponds on 11 sampling dates (Table 21). The ratio of mean squares indicated no significant differences among ponds but did indicate a significant alteration in midge numbers for the period studied.

The number of gastropods and ostracods per square meter of pond bottom varied considerably among ponds and sampling dates (Tables 22, 23). Control pond 2 supported the largest population of ostracods for a given sampling date (22 July). Ponds 2, 4 and 6 contained substantial populations of ostracods on 17 June, but numbers tapered off until 8 July when another population rise was noted. The second population decrease occurred the last week of July. The population of ostracods sampled in pond 8 did not show the fluctuation seen in the other three ponds. The population began increasing from the beginning of the experiment and a peak was attained 12 August. The number decreased the succeeding two sampling dates.

Dissolved oxygen concentrations were generally greater at the surface than at the bottom (Table 24). The highest dissolved oxygen concentration (11.5 mg/l) occurred in control pond 2 on 30 July. The two lowest dissolved oxygen concentrations were 1.4 and 2.6 milligrams per liter in control pond 2 and fed pond 6, respectively. Both minimum dissolved oxygen measurements were obtained from bottom samples taken 20 August.

Hydrogen ion (pH) measurements were similar for top and bottom samples taken within the same pond and on the same sampling dates (Table 25). The highest pH reading was 9.6 obtained 6 August in fed and enriched pond 8. The lowest pH reading was 8.0 and it occurred in both control pond 2 and fed pond 6 on several sampling dates. Analysis of variance calculated for pH measurements taken near the surface in each of the four ponds on 11 sampling dates (Table 26) indicated a significant difference among ponds but no significant difference for the time sourse of variation.

Platinum wire turbidity readings were taken (Table 27). Ponds did not vary significantly in turbidity (Table 28). The F ratio calculated for the time source of variation indicated turbidity did vary significantly over the sampling period.

Carbonate alkalinity was higher in the fertilized ponds than in the non-enriched ponds (Table 29), and bicarbonate alkalinity was generally higher in the non-enriched ponds. Hydroxide alkalinity was not present on any sampling date. Free carbon dioxide was detected in control pond 2 on 25 June, 20 and 27 August and in ponds 4 and 6 on 25 June.

Temperature measurements ranged from a low of $66^{\circ}$ to a high of $84^{\circ}$ F (Table 30).

Non-enriched ponds 2 and 6 produced more pounds of fish, fish per acre and pounds of fish per acre than did enriched ponds 4 and 8 (Table 31). Fed pond 4 produced the largest fingerlings and control pond 2 produced the most fingerlings. The feed conversion rates (pounds of feed per pound of gain) calculated for ponds 2, 4, 6, and 8 were .93, 1.25, .98 and 1.69, respectively.

LSD's were calculated to determine how the ponds varied in their effects on the mean length, mean weight, mean stomach content volume and mean pH; the means were the average of samples taken on 11 sampling dates (Table 32).

A LSD test indicated no significant difference for mean weights and lengths of fry sampled from fed pond 6 and fed & enriched pond 8. The LSD test did indicate mean weights and lengths of fry sampled from the two continually fed ponds (ponds 6 and 8) were significantly greater than those of fry sampled from ponds 2 and 4. Neither the mean weights nor mean length of fry sampled from control pond 2 and enriched pond 4 were significantly different when compared by the LSD procedure.

A LSD comparing the mean volume of stomach contents of fry taken from each pond indicated fed pond 6 had a significantly greater total volume of stomach contents when compared with the other three ponds. The LSD test also showed volume of stomach contents of fish sampled from fed & enriched pond 8 was not significantly different when compared to fertilized pond 4. Control pond 2 and enriched pond 4 did not produce significantly different stomach volumes when compared using the LSD procedure.

The mean pH of each of the four ponds were compared by the LSD procedure (Table 32). The test indicated the pH readings taken in the two ponds receiving fertilizer were statistically the same and were significantly higher than those taken in the two non-enriched ponds.

Over the sampling period a few dead fish were removed from each of the four ponds. Gross mortality was detected only on 13 July;

approximately 140 fish were found dead in fertilized pond 4. Sampling at 6:00 a.m. the following day, 14 July, indicated the presence of 8.7 ppm dissolved oxygen in the affected pond.

An infestation was detected on 19 August in the enriched ponds. The dorsal fins of the fish became red and the candal fins became red and frayed. The fish were immediately treated with formalin and by the next sampling date no symptoms were noted.

## DISCUSSION

The study by McGuire (1969) indicated a possible advantage in production by applying an inorganic fertilizer to ponds used for rearing channel catfish fry. This study was designed to test further the effects of supplementally feeding fry and fertilizing pond water on the growth and food habits of channel catfish fry. The original two treatments utilized by McGuire (one fed pond and one enriched pond) were expanded to four treatments, a control pond, one fed pond, one enriched pond and one fed and enriched pond. The study of McGuire (1969) will be designated as the 1969 study.

Sampling methods and techniques used in this study assumed random distribution and sampling of measured variables. Plankton samples were taken full length of the pond at a medium depth to reduce possible errors in population estimation that patchy distribution of organisms might have produced. Epifaunal cladoceran populations were not adequately sampled by the above technique, thus true estimates of population densities of *Alona* were not obtained.

Fish sampling commenced one hour after supplemental feeding. This procedure was necessary to determine when supplemental feed was first ingested by the fry. Opportune timing of fish sampling may have biased results of stomach content analyses in favor of supplemental feed, especially volumetrically. Digestive mutilation of zooplankters and other soft bodied organisms indicated volumetric reduction of natural organisms had taken place.

Applying an inorganic fertilizer to ponds did not differ significantly the mean number of algae (Table 17), zooplankters (Table 18) or chironomids (Table 21) produced, however volumetric or graviometric measures of production might have been different. Ball (1949) found chironomid larvae were larger in enriched ponds than non-enriched ponds, but another study (FAO, Fish Culture Bulletin, p. 5, 1969) indicated the dry weight of amphipods and midge larvae did not differ significantly in a control and two ponds given an inorganic fertilizer. Clark (1952), Saila (1952), Ewing (1964) and Bennett (1962) recognized the variability and unpredictability of results involving addition of fertilizer to water.

Neither mean weights nor mean lengths of fry in fed pond 6 and fed & enriched pond 8 were significantly different (Table 32). Such results would be expected if, in fact, there was no significant change in trophic level production resulting from treatments. Indications that production in all four ponds was equal were stated in the above paragraph.

The major taxonomic divisions of algae represented in the phytoplankton community varied depending on whether or not the pond had been enriched (Tables 13, 14, 15 and 16). This study indicated

Chrysophyta (diatoms) occurred primarily in non-enriched ponds while the 1969 study showed a bloom of Chrysophyta in an enriched pond and no such population increase in a non-enriched pond. McIntire and Bond (1962) found Chrysophyta (diatoms) were the primary phytoplankters in ponds not enriched with phosphorus, and that diatoms were much less abundant in phosphorus enriched ponds. Ewing (1964) concluded that phytoplankton communities varied considerably both in population size and in pattern of fluctuation among ponds treated similarly. These findings exemplify the variability found in an aquatic ecosystem.

Fry relied heavily on chironomidae larvae and pupae and cladocerans during the first three weeks of the study. The principal Cladocera consumed were Daphnia and Bosmina. Copepods contributed little to the diet of fry less than 4 weeks old, even though populations of copepods reached substantial numbers (Table 13, 14, 15 and 16).

The mean growth (length and weight) of fry in ponds 2 and 4 was significantly less than growth of fry in ponds 6 and 8 (Table 32). The most probable explanation for the smaller size of fish in ponds 2 and 4 was the delay in initiation of supplemental feeding programs. Fry in the two continually fed ponds had accepted supplemental feed before a drastic decrease in the chironomid populations was noted and supplemental feed constituted a large proportion of the stomach contents. Fry in ponds 2 and 4 reacted to a decrease in the midge population by changing their diet to a more available food source. Fry in pond 2 utilized ostracods in large numbers (Table 7); this period coincided with a peak in the Ostracoda population (Table 23). A drastic decrease in the Ostracoda population noticed 29 July may have resulted from heavy predation by fry. The period of heavy foraging on ostracods also coincided with a low in the zooplankton population (Fig. 4). Alona, Bosmina and Cyclops were the primary forage species after the drop in the Ostracoda population. Channel catfish in control pond 2 went from a three week period of slow growth to a period of good growth when supplementally fed (Fig. 1). Similar results were obtained in the 1969 study and by Tiemeier and Elder (1960) using larger fish. Fry in enriched pond 4 maintained an acceptable growth rate longer than fry in control pond 2. Better growth of fry in pond 4 might be attributed to a slightly more sustained chironomid population and a more plentiful and varied Cladocera population (Table 14 and 19). The Ceriodaphnia population reached substantial numbers on 1 July in pond 4 and on 15 July they contributed to approximately 40 percent of the stomach contents. The Ceriodaphnia population decreased by 22 July and foraging switched to Bosmina, Alona and Cyclops. July 8 ostracods were more abundant in ponds 4 and 6 than in pond 2, but on that date more were consumed by fry in pond 2. Ostracods were consumed only in small numbers by fry in ponds 4, 6 and 8 even though a large population was attained 12 August in pond 8.

Ceriodaphnia was more abundant in enriched ponds than in non-enriched ponds and they were consumed in large numbers by fry in fed and enriched pond 8 after the acceptance of supplemental feed (Table 10). Either dietary preference or availability seemed to favor Ceriodaphnia as a natural food item after a decrease in the Chironomidae populations. The 1969 study reported Ceriodaphnia and ostracods as only appearing in small numbers, with Bosmina, Daphnia, Alona and Cyclops as dominant contributors to the zooplankton portion of the diet.

After the initial acceptance of supplemental feed, natural food items became less important but zooplankters and chironomids were consumed in larger numbers as their availability increased. Consumption of Bosmina in ponds 2, 4 and 6 increased as the populations of Bosmina increased in these ponds (Tables 7, 8, 9, 13, 14 and 15). The utilization of Ceriodaphnia by fish in pond 8 has already been noted. Foraging on Alona increased in pond 2 after the acceptance of supplemental feed, but because of inadequate sampling it can only be assumed that the population was increasing.

Increased consumption of midge larvae in pond 4 on 19 August and midge larvae and pupae in pond 8 on 12 August provided additional evidence that foraging by channel catfish was affected by availability of the food item. On the above sampling dates extremely large numbers of midge larvae (many fourth instar) and pupae were consumed by fry (Tables 8 and 10) and chironomids made up at least 95 percent of the stomach contents (Table 5). The period of pupation and preparation for emergence is a short but highly vulnerable time for midge larvae and pupae. The fourth instar larvae may be limnetic (Hilsenhoff, 1967) and thus more vulnerable to predation. Pupation occurs within a day at water temperature attained in July and August (Hilsenhoff, 1967), thus pupation and emergence of large numbers of midge could account for the tremendously increased predation of larvae and pupae on only silitary sampling dates. Weekly sampling could also account for missing short duration emergence activities in the other two ponds.

Fish increased utilization of gastropods toward the end of the experiment. This would indicate a minimum size of fry might be involved because the gastropod populations were substantial throughout the study (Table 22).

Fry in fed pond 6 had significantly more food in their stomachs than fry in the other three ponds (Table 32). On 19 August the stomachs of fry from pond 8 had 25 percent as much food as fry sampled from pond 6 (Table 5). On the same date parasites were noted on fry in pond 8, and may have reduced feeding and growth of fry. Satisfactory treatment of the disease increased food consumption and growth the following week (Fig. 1 and Table 5).

The immediate acceptance of supplemental feed 8 July in pond 6 and 8, 24 July in pond 2 and 6 August in pond 4 indicated no extensive learning process was necessary for the utilization of supplemental feed. Undoubtedly the availability of natural food organisms does determine the amount of supplemental feed consumed. On 8 July, pond 6 had a substantially lower chironomid population than pond 8 and fry in pond 8 consumed about one fourth the volume of supplemental feed as was consumed by fry in pond 6 (Table 5). On the following sampling date the chironomid population in pond 8 dropped (Table 19) and the fry reacted by utilizing larger volumes of supplemental feed. Other cases of increased consumption with increased availability have been stated earlier with reference to ostracods, Bosmina, Ceriodaphnia and Chironomidae. Young channel catfish, 76 to 119 mm long, first fed primarily on midge larvae, but later were observed to be omnivorous and ate food that was abundant in direct proportion to its availability

(Darnell 1958). A study by Bryan and Allen (1969) implied size was not a limiting factor in acceptance of supplemental feed by fry. Availability of natural food organisms appears to be the determining factor.

The higher carbonate alkalinity (Table 29) and consequently significantly higher pH (Table 25) in the enriched ponds may have resulted from a chemical reaction between the natural water hardness (Ca ions) and the added phosphate. In alkaline water, containing high levels of calcium, phosphorus may precipitate as tricalcium phosphate, also more soluble di- and monocalcium phosphates are formed (Neess, 1949). Thus, it is possible less calcium carbonate was precipitated in the phosphate enriched ponds than in the non-enriched ponds. McIntire and Bond (1962) also reported an increase in pH with application of inorganic fertilizer.

More fish and pounds of fish were obtained from the non-enriched ponds in both the 1969 and 1970 studies. Large fingerlings were obtained by stocking 100 grams of fry. This is supported by Tiemeier Deyoe and Suppes (1967). They found stocking 150 grams of fry in .1436 acre ponds resulted in large fingerlings than did 170 or 340 gram stocking rates. The mean weight of fingerlings obtained by stocking 150 grams in the 1967 study was 11.4 grams as compared to 16.68 grams in this study. The earlier study also indicated more fish and pounds of fish were obtained by stocking 340 grams rather than the reduced stocking rates.

Data collected in 1969 and 1970 indicated a high degree of variability in comprehensive food habit and growth studies of tiny fry. Results are affected by many variables and as stated earlier many of these variables are uncontrolable and/or unpredictable. Also, the polyethylene lining of the ponds may have varied results from those which might have been obtained in a less artificial environment (Shell, 1966). The plastic lining may also have effected the availability of chironomid larvae. Chironomid larvae (2nd and 3rd instar) may be limnetic especially over a hard bottom (Hilsenhoff, 1967).

In general, growth of fry in the continually fed ponds of the 1969 and 1970 studies was more consistent than that displayed by fry sampled from other treatments. The critical factor apparently was availability of supplemental feed when natural food organisms became dietarily inadequate for maintenance of good growth.

## CONCLUSIONS

1. The effect of inorganic enrichment of ponds on food habit and growth of young-of-the-year channel catfish was variable and unpredictable.

2. Addition of fertilizer resulted in higher carbonate alkalinity and thus a higher pH.

3. Enrichment with an inorganic fertilizer (18-46-0) seemed to alter species composition of the phytoplankton community. Chrysophyta (diatoms) were abundant in non-enriched ponds and rare in nitrogen and phosphorus enriched ponds. Chlorophyta were more abundant in enriched ponds than non-enriched ponds.

4. Young-of-the-year channel catfish consumed many natural food organisms in direct proportion to their availability.

5. With the exception of supplemental feed, young channel catfish 20 to 130 mm long appeared to be carnivorous. Insect larvae and pupae (primarily Chironomidae), cladocerans (Bosmina, Alona, Daphnia, Cyclops and Ceriodaphnia) and ostracods contributed to the bulk of the natural diet of fish.

6. More sustained growth of fish in enriched pond as compared to the control may have been due to a less rapid decrease in the chironomid population and a larger cladoceran population (primarily Ceriodaphnia).

7. Ostracods and copepods may not be preferred or be less available food items when compared to other forage species consumed by channel catfish fry. Both groups of organisms attained their greatest importance in the diet during periods of slow growth of fish.

8. Fry in continually fed ponds accepted supplemental feed when natural food items became limiting to growth.

9. Immediate acceptance of supplemental feed by fry indicated an extensive learning process was not necessary.

10. Supplemental feed in the diet of channel catfish decreased the importance of natural food items, but many were consumed in direct proportion to their availability.

11. After acceptance, supplemental feed was the primary factor contributing to the consistent and good weight gain of fry.

12. Large fingerlings (16.68 grams) were produced in less than three months by supplementally feeding fry stocked at a rate of 700 grams per surface-acre.

13. The critical factor in good growth of channel catfish fry seems to be the availability of supplemental feed when natural food items became limiting to the diet.

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# VITA

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Four plastic-lined rearing ponds were stocked with 100 grams of week-old fry to study effects of four treatments on the food habits and growth of young-of-the-year channel catfish (*Ictalurus punctatus*). The treatments consisted of a control pond, a pond enriched with an inorganic fertilizer, a fed pond and a fed & enriched pond. Weekly sampling of fish, benthos, plankton and water was used to analyze treatment effects.

Enrichment with an inorganic fertilizer (18-46-0) had no significant effects on the mean number of algae, zooplankton or Chironomidae when compared to non-enriched ponds. No significant difference was noted in the mean growth (weight and length) of fry when the fed pond and fed & enriched ponds were compared. Production and percentage survival of fish was not improved in the enriched ponds.

Feeding habits of young-of-the-year channel catfish varied with the availability of the food items. Early in the study fry feed largely on midge larvae. A decrease in Chironomidae populations in all four ponds resulted in a more omnivorous diet in channel catfish studied. Fish switched to more available food sources such as Ostracoda and zooplankton. Zooplankters consumed in large numbers were *Ceriodaphnia*, *Bosmina*, *Alona* and *Cyclops*. Fry in the continually fed ponds reacted to a decrease in the Chironomidae population by consuming large volumes of supplemental feed. Stomach analyses indicated that after acceptance of supplemental feed many natural food items were consumed in direct proportion to their availability.

Fry in the two continually fed ponds accepted supplemental feed at an age of approximately five weeks. After initial acceptance, supplemental feed comprised the majority of food consumed and was responsible for the consistent growth rate of fish. The benefit of supplemental feed became especially apparent as the size of the fry and demand for food increased. In the absence of supplemental feed availability of adequate natural food limited growth of fish.