AN ANALYSIS OF THE BOTTOM FAUNA PRODUCTION IN FERTILIZED AND UNFERTILIZED PONDS AND ITS UTILIZATION BY YOUNG-OF-THE-YEAR-FISH

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

Mercer Harding Patriarche

1948

THESIS

This is to certify that the

thesis entitled

An Analysis Of The Bottom Fauna Production In Fertilized An Unfertilized Ponds And It's Utilization By Young-of-the-Year Fish.

presented by

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has been accepted towards fulfillment of the requirements for

M. S. degree in Zoology

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Major professor

Date April 14, 1948

M-795

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By

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A THESIS

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

MASTER OF SCIENCE

Department of Zoology

1948

6/9/49
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ACKNOWLEDGMENT

I would like to express my appreciation to Dr. Robert C. Ball of Michigan State College to whom I am especially indebted for his valuable advice, close supervision and helpful criticism throughout this investigation. I would also like to extend thanks to the Institute for Fisheries Research and its Director, Dr. Albert S. Hazzard, for making this work possible. Gratitude is due to Mr. Ralph Marks, Regional Fisheries Supervisor; Mr. Henry Hatt, District Fisheries Supervisor; and the personnel at the Wolf Lake State Fish Hatchery for their aid and assistance in carrying out the field work of this problem.

THESIS

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INTRODUCTION

The Michigan Department of Conservation, in cooperation with Michigan State College, made possible a series of experiments to determine the probable effects of fertilizer as applied to Michigan ponds and lakes, formulate management policies for ponds, and obtain figures on cost of application of the fertilizer. The experiment with which this report is concerned was a measure of the effect of fertilization on the fish-food organisms in pond waters and a consideration of the utilization of these organisms by the young-of-the-year fish.

Dredge sampling of bottom-dwelling fish-food organisms was carried out on four experimental ponds at the Wolf Lake State Fish Hatchery as a means of determining and comparing the productivity in terms of benthic fauna in fertilized and unfertilized ponds. Physical, chemical, and biological data ~~was~~ WERE collected on the ponds, two of which were fertilized and two left unfertilized. Stomach analyses were made of young-of-the-year bluegills to determine qualitatively and quantitatively how the available food in the ponds was being utilized by the fish.

The construction and management of farm fish ponds to conserve water resources and provide recreation has commanded the attention of workers in other states for several years. Missouri and Texas have developed an extensive farm pond program. Alabama, Louisiana, North Dakota, Oklahoma, and many other states have been active in similar projects. Michigan, with some 11,000 lakes within the state, has not had as great water conservation problems nor the need of establishing fishing waters as have some other states. In recent years popular interest in farm fish ponds as a means of better utilizing unproductive land as well as providing recreation for the owner has developed.

The practice of applying fertilizer to fish ponds to attain a greater production of fish has been tried and used successfully in India, China, Japan, and several European countries where pond fish culture has been carried on for centuries. Since 1930 several investigators in America have carried out work on fertilization and pond management with varying degrees of success (Davis and Wiebe, 1930; Hogan, 1933; Meehean, 1933; M. W. Smith, 1934; Swingle and Smith, 1939, 1941, 1942; Tack and Morofsky, 1946; Swingle, 1947).

The role that fertilizer plays in the production of fish is an indirect one in that it supplies the nutrients for the growth of phytoplankton, the primary food material upon which all fish are directly or indirectly dependent. Golden shiners, gizzard shad, and goldfish use phytoplankton directly in addition to other foods. Bluegills, small crappies, and young bass depend on the phytoplankton indirectly in that they feed on zooplankters and on insects which, in turn, rely on the phytoplankton, the bacteria that decompose it, and their own kind for food. Inasmuch as the larger carnivores prey on small fish they, too, are indirectly dependent on this fundamental phytoplankton.

In order to measure the productivity of a body of water, several workers have attempted to determine the relationship of average weight of bottom organisms per square foot and pounds of fish per mile of stream or acre of water (Richardson, 1921; Surber, 1937; Davis, 1938; Tarzwell, 1938; Howell, 1941; and Ball, 1948).

However no single index of productivity has been adopted for, as Welch (1935) pointed out, two considerations are involved in devising a single index of general biological productivity (1) the inherent capacity of a lake to support life (biotic potential) and (2) the actual productivity at a given time. Several indices including bottom fauna have been proposed but all have weaknesses. When a rich benthic fauna is present high productivity is common but not necessarily insured. It is believed, however, that the standing crop of bottom organisms will give a comparable measure of the productivity ofponds such as were under consideration in this investigation of pond fertilization.

DESCRIPTION OF THE PONDS

The field work was carried out during the summer of 1947 at the Wolf Lake State Fish Hatchery, the largest hatchery in the state, located ten miles west of Kalamazoo in Van Buren county, Michigan. Two pairs of ponds, selected on the basis of similarity in size, bottom type, and source of

water supply, were assigned to this problem. These were Ponds 7, 12, 20 and 21 and their location is shown on a map of the hatchery (Chart I).

Ponds 20 and 21 were paired, Pond 20 receiving the fertilizer treatments and Pond 21 being untreated. In like manner Ponds 7 and 12 were paired, Pond 12 being fertilized.

Pond 20 has a surface area of 2.3 acres, Pond 21 an area of 2.2 acres, and both ponds have a maximum depth of about 6.5 feet. Their bottom soil types are similar, varying from a mixture of sand and marl in the shallow areas to a black muck in the deepest part of the ponds. Water is supplied directly to Pond 20 from the Number 3 spring, one of three springs which, in addition to water pumped from Wolf Lake, supply the hatchery. Pond 21 is filled from the overflow of Pond 20.

Monthly chemical analyses of the water did not indicate any great difference between ponds in the total hardness of the water, the average for Pond 20 being 114 p.p.m. while that of Pond 21 was 95 p.p.m.. No free carbon dioxide was indicated for either pond.

There was an abundant growth of submerged higher aquatic plants but only four genera were represented in the flora. The dominant plant in Pond 20 was the water weed *Anacharis* sp. which flourished throughout the pond. *Chara* sp. was second in abundance but was confined to the shallow water. Two species of *Potamogeton* were also present - *P. crispus* and *P. Hillii*. Mats of filamentous algae covered

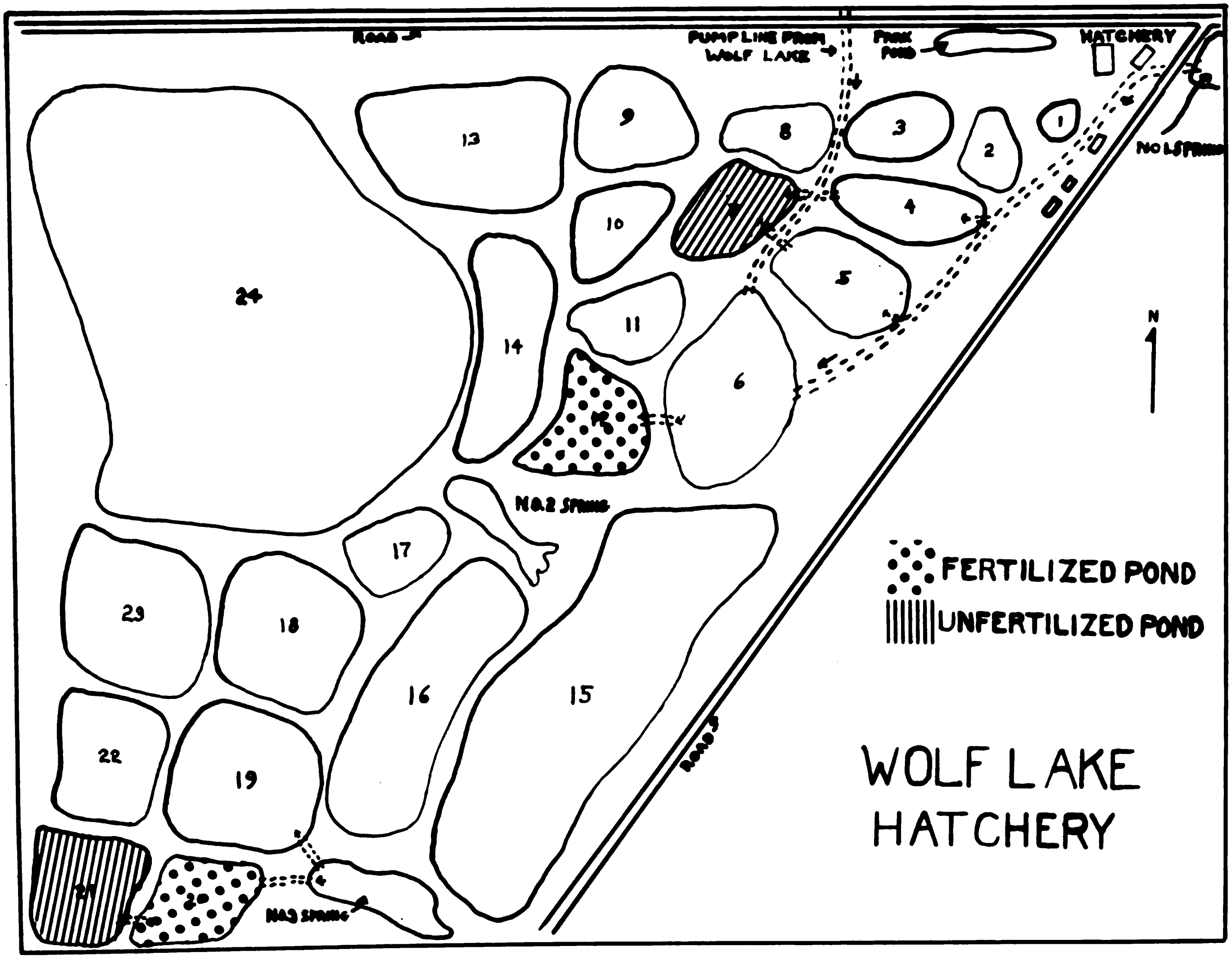


Chart I. - Diagram of Wolf Lake State Fish Hatchery showing the fertilized and unfertilized ponds used for this experiment.

approximately one-fourth of the surface area of the fertilized pond throughout most of the summer, especially above the thick submerged weed bed in the shallow end of the pond. Pond 21 also had a profuse growth of Chara sp. but the dominant plant in the pond was Najas sp. together with a scattering of Anacharis sp. and Potamogeton Hillii.

Ponds 7 and 12 are almost an acre smaller than the aforementioned ponds, having 1.5 and 1.6 acres respectively and a maximum depth of about seven feet. The bottom type of both ponds is a black organic muck, Pond 12 having, in addition, considerable organic detritus. The water supply for Pond 12 comes from the adjacent Pond 6 which receives water from both Wolf Lake and the Number 1 spring. Pond 7 is supplied indirectly from the same spring via the overflows of Ponds 4 and 5.

Chemical analyses of the water indicated an average total hardness of 117 p.p.m. for Pond 12 and 137 p.p.m. for Pond 7, no indication of free carbon dioxide for Pond 7 but one test at the end of August in Pond 12 showed 8 p.p.m. of free carbon dioxide in the water, presumably due to the decay of the filamentous algae.

These experimental ponds likewise supported luxuriant plant growths. The dominant plant in Pond 12 was Najas sp. with Chara sp. in the shoal areas together with Potamogeton Hillii. After fertilization was started an abundant growth of filamentous algae appeared in this pond and remained until the end of August. Pond 7 supported a floral population which included Ceratophyllum demersum, Anacharis sp., Potamogeton Hillii, and an excessive growth of Najas and Chara.

The presence of higher aquatic plants in any large quantity in small ponds is undesirable for several reasons. In the first place they may seriously deplete the dissolved oxygen content of the pond water at night or over a period of several cloudy days thereby causing suffocation of the fish. This is especially true in fertilized ponds where a phytoplankton bloom may have developed which will further tax the oxygen supply. Secondly, a luxuriant growth will provide too many places for the young fish to hide thereby reducing the chances of the bass, or any other predator, of controlling their excess numbers. Consequently the pond becomes overcrowded and stunting results. And, finally, the plants have a nuisance value in that they interfere with harvesting of the fish.

Swingle and Smith (1941, 1942) have employed fertilizer successfully to control submerged aquatic plants. The fertilizer induces a plankton bloom which shades the plants thus reducing their photosynthetic activity and as a result the plants die. Observations on the fertilized Pond 12 at Wolf Lake showed that at the end of the summer the submerged plants had almost completely disappeared and in Pond 20 there was little evidence of the pond weeds (Potamogeton) but Anacharis seemed unaffected. There was no apparent reduction in the higher aquatic flora in the unfertilized ponds nor ~~was~~ WERE there any extensive filamentous algal mats in these ponds. Apparently the mats of filamentous algae in the fertilized ponds were instrumental in eliminating the pond weeds with the exception of the Anacharis and Chara.

A Secchi disk was used to measure the turbidity of the pond waters every week but the water remained clear until the last week in August when readings of 58 inches were obtained in the fertilized Pond 20 and 50 inches in Pond 18, the other fertilized pond. These plankton blooms were observed after the filamentous algae disappeared. Slight blooms were recorded in all ponds for July 7 and August 12 but they were not heavy enough for a turbidity reading.

It is more desirable to develop a heavy plankton bloom than filamentous algae since excessive growths of ~~this~~ these latter forms of algae are generally considered obnoxious inasmuch as it interferes with fishing and other harvesting operations. Swingle (1947) concluded that filamentous algae could be prevented by applying inorganic fertilizer only after the water has warmed up in the spring. At this time the plant nutrients are dispersed throughout the pond from top to bottom rather than settling immediately and are available to the plankton algae instead of the filamentous forms.

METHODS AND EQUIPMENT

Stocking

The ponds were stocked with a combination of adult bluegills (Lepomis macrochirus) and yearling largemouth bass (Micropterus salmoides) at the rate of 12 bluegills

and 150 bass per acre for Ponds 20 and 21, and 40 bluegills to 150 bass per acre in Ponds 7 and 12. The bluegills that were used in stocking the ponds were in poor condition. To offset an anticipated mortality extra bluegills were put in the ponds, the increase being in proportion to the stocking rate just described.

The following table (Table 1) shows the numbers and planting dates for the four ponds:

Table 1

POND	SPECIES	NUMBER	PLANTING DATE
7	Bluegill	76	5/20/47
	Largemouth bass	240	4/15/47
12	Bluegill	86	5/20/47
	Largemouth bass	240	4/15/47
20	Bluegill	41	5/20/47
	Largemouth bass	345	4/15/47
21	Bluegill	39	5/20/47
	Largemouth bass	330	5/1 /47

Fertilization

A 10-6-4 commercial inorganic fertilizer containing 10 per cent Nitrogen, 6 per cent available Phosphoric Acid, and 4 per cent Potash was applied to Ponds 12 and 20 at the rate of 100 pounds to the acre every three weeks between April 2 and August 6.

At the outset two methods of fertilization were tried.

One method was to broadcast it from along the shore and the other was to spread the fertilizer over the pond surface from the back of a boat as it was rowed around the pond. The latter method proved to be the most effective and was used throughout this work.

Bottom Sampling

A total of 255 bottom samples were collected by random sampling from the four ponds between the last week in June and the middle of September. Seven samples were collected each week in Ponds 20 and 21 and 6 per week in Ponds 7 and 12. As time did not permit adequate sampling of the entire pond a section judged typical of the pond was selected and the dredge samples were collected in this area, every effort being made to insure randomness in the sampling.

A Peterson dredge, which covers an area of .826 square feet, was used for the sampling. After a bottom sample was obtained, the dredged material was put into a tub and any plant material brought up was removed, washed in a 30-mesh sieve, and placed in a quart jar containing a little water. The remaining material was thoroughly stirred in water in the tub and poured through the sieve. The organisms and residue remaining were washed several times, put in another quart jar, and all samples taken to the laboratory. If they could not be picked over within a short time the samples were kept in a refrigerator until such time that they could be sorted out and preserved in 80 per cent alcohol.

Fish Collections

Bluegill fry were first observed in the ponds on July 8. Beginning the first week in August, at least 25 were collected weekly from each pond by seining and taken to the laboratory where they were measured and the stomachs removed and preserved in 10 per cent formalin for future analysis. A total of 503 fish were collected and their stomachs preserved.

Seining was done from a boat. One end of a fifty-foot, fine-mesh seine was weighted and, after selecting an area over a weed bed, the weighted brail was tossed into the water from the rear end of the boat and the net passed into the water while an assistant described a small circle with the boat and returned to the starting point. The seine was then hauled into the boat and 25 or 30 fingerlings were transferred to a pail and taken to the laboratory. In the fertilized ponds, one cast was all that was required to collect the desired number of fish whereas in the control ponds often several tries were needed.

Laboratory Procedure

Bottom samples - The method employed in separating the organisms from the bottom sample debris was to place a portion of the sample in a white pan, add a little water, and remove them as they were detected moving around. However, the plant samples required a different technique. A "salting out" process was used to facilitate separating the clinging organisms from the plants and, by doing this, greater assurance was felt that all of the minute invertebrates (as well as the larger ones) were obtained.

This method consisted of preparing a saturated salt solution in a pan, immersing a few of the plants, and stirring them around in the solution. After letting it stand a few minutes, the organisms were removed as they floated on the surface and preserved in 80 per cent alcohol with the others.

The quantitative analysis can be made by either comparing the dry weights or the volumes of the organisms with numerical counts. Because many invertebrate organisms in bodies of water differ considerably in size, it has been found desirable by many investigators of bottom fauna production to consider their data both volumetrically and numerically (Tester, 1932; Lyman, 1942; Ball, 1948). Unless both methods of evaluation are considered, a false concept of the invertebrate population may be obtained. As, for example, in the samples from Pond 12 it was found that leeches made up only 3 per cent of the bottom fauna population numerically but more than 53 per cent volumetrically.

The volumetric method was employed, along with numerical counts, in this analysis because it is relatively faster than the dry weight method, requires simple equipment, and is sufficiently accurate for this work. As determined by Ball (1948), the conversion factor for changing the preserved volume of organisms in cubic centimeters to an equivalent live weight in grams is 0.98. For purpose of this problem one cubic centimeter of preserved volume is considered as one gram live weight.

In making volumetric determinations, the organisms were first placed in a graduated centrifuge tube and the alcohol allowed to drain off the sample by putting the tube in a rack which was inclined at about a 45 degree angle. To measure the volume of the invertebrates more alcohol was then added to the tube from a burette until the entire sample was displaced in the liquid. By using a burette which had been calibrated with the centrifuge tube, the difference in readings between the two scales was noted and recorded as the total volume of the sample. The invertebrates were then sorted into taxonomic groups, counted, and their group volumes measured.

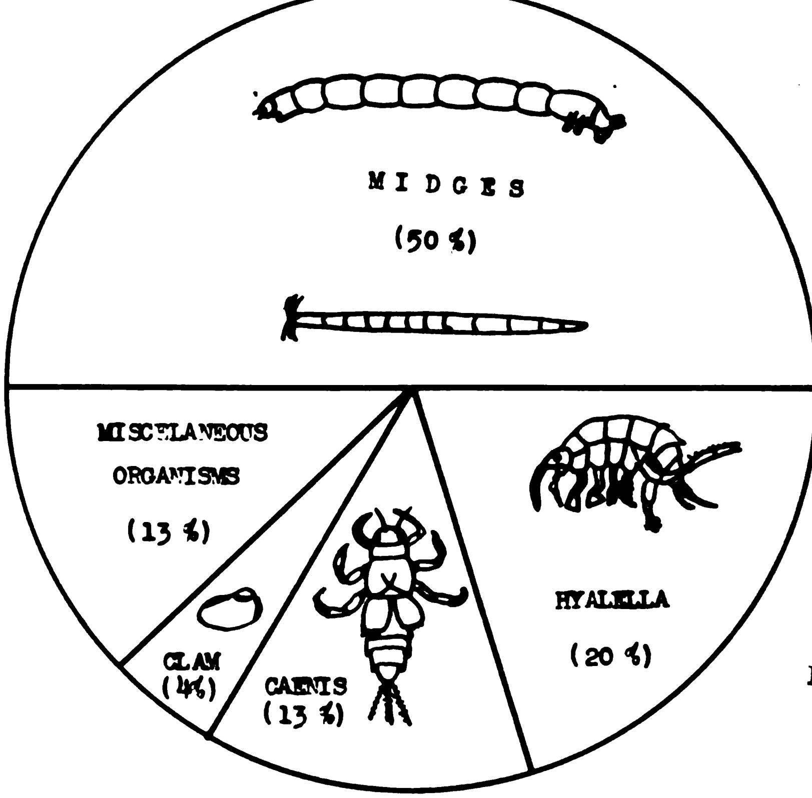
Food analysis - The stomach analyses were made under a binocular microscope. Numerical tabulations were made of the contents and the food organisms identified. Observations were recorded on the presence of any other material in the stomachs. Volumetric determinations were not made because the limitations of the equipment would not permit an accurate measurement of the minute organisms. This omission is not considered serious because, in a food study of fish of this size (1.3-2.6 inches), numerical data will provide a significant index to the food habits of the small fish.

BOTTOM FAUNA

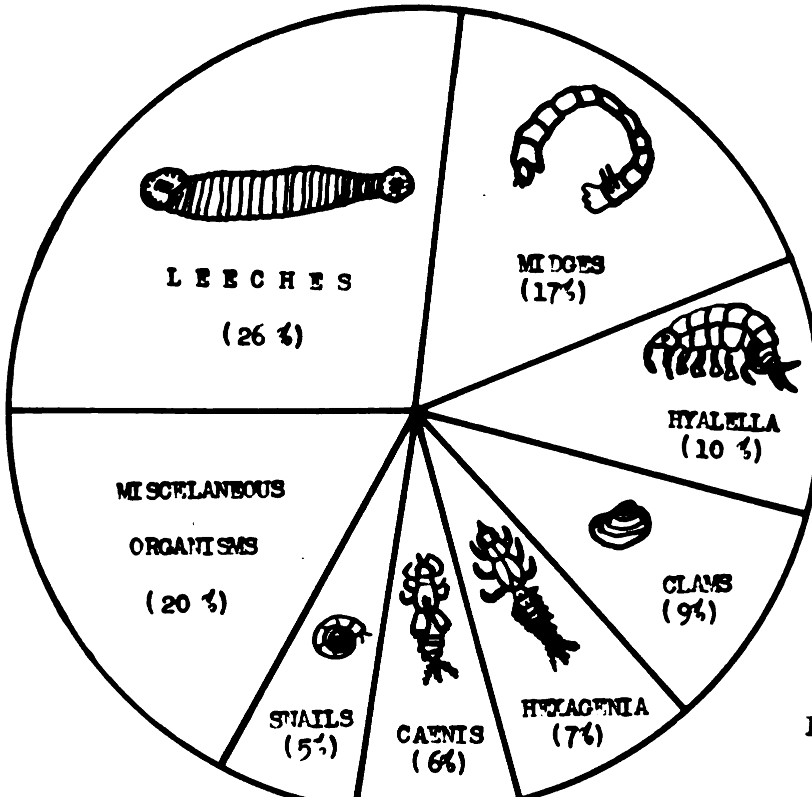
Charts II, III, IV, and V show the composition of the bottom fauna populations of the dredge samples taken from the four ponds, both numerically and volumetrically. From these it can be seen that the midges were, numerically, the dominant organism in three of the four ponds. The Chironomidae were the most abundant, followed by the Ceratopogonidae and the Chaoborinae. The latter appeared in the bottom samples from Ponds 12 and 21 about the middle of August and became abundant in Pond 21 in September but none were taken from the fertilized Pond 20 and only one from Pond 7.

In addition to the midge population there were other organisms whose distribution and numbers varied considerably among the ponds. Oligochaetes were numerous in Ponds 20 and 21, represented in Pond 7, but were quantitatively not significant in Pond 12. The scud, *Hyalella knickerbockerii*, was fairly abundant in Ponds 20 and 7 and present in Ponds 21 and 12 whereas the small mayfly, *Caenis* sp., was found in larger numbers in Ponds 21 and 12 than in Ponds 20 and 7. Leeches (Hirudinea) constituted a low percentage numerically in all of the bottom samples but swelled the volumetric percentages considerably in the samples from Ponds 7, 12, and 21.

Very few dragonflies (Anisoptera) were taken in the samples but they represented from two to five per cent of the total sample volume of each pond. The large burrowing mayfly, *Hexagenia* sp., was numerous in the bottom

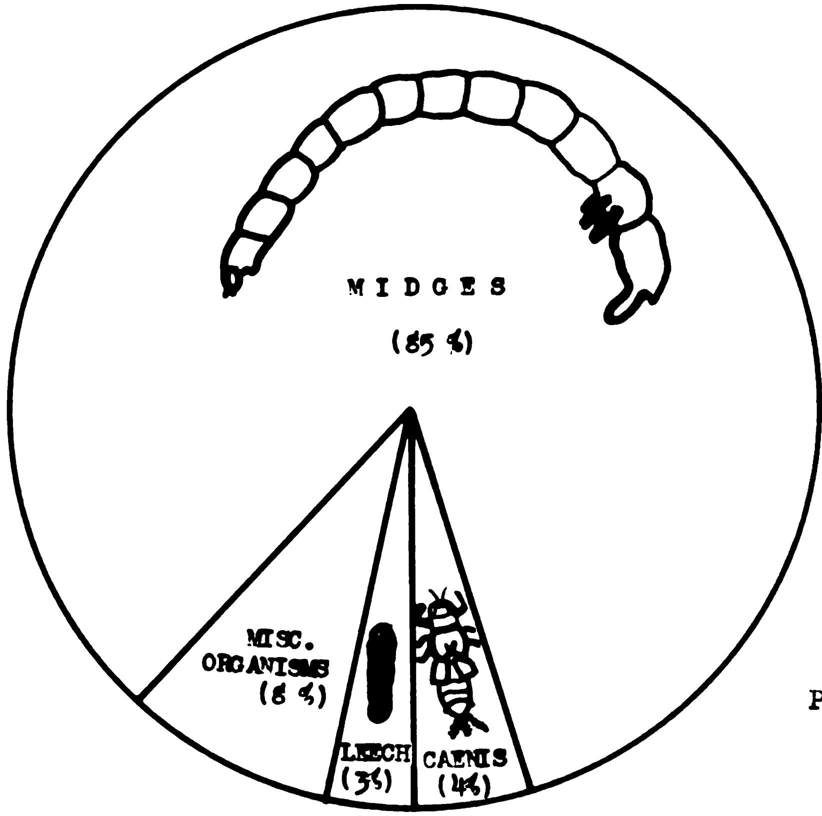


Per cent by number

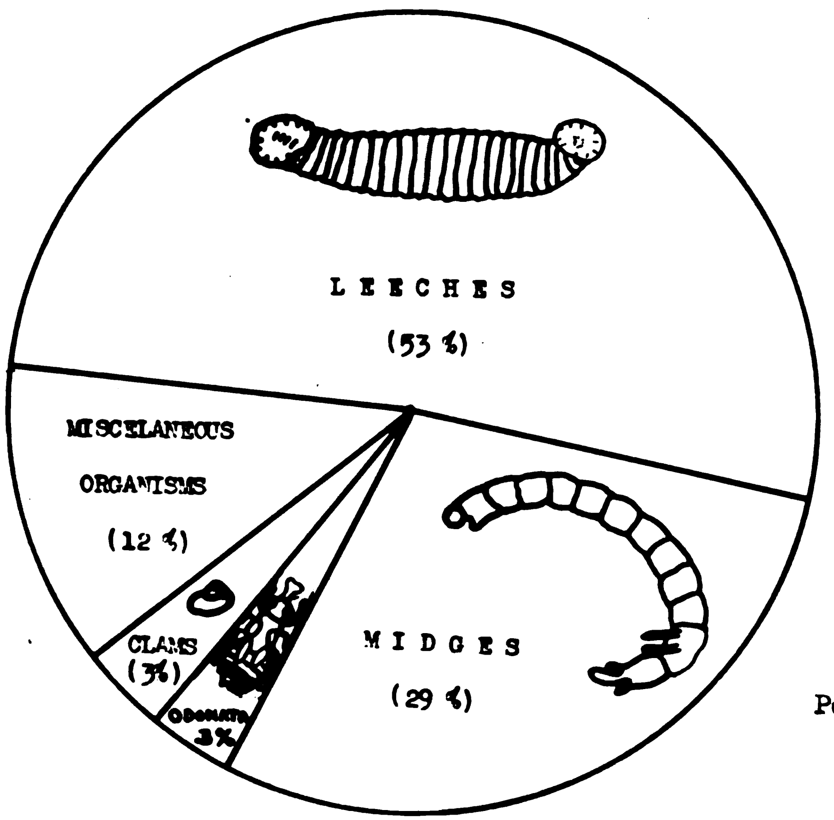


Per cent by volume

Chart II. - Composition of bottom fauna in dredge samples from unfertilized Pond 7.

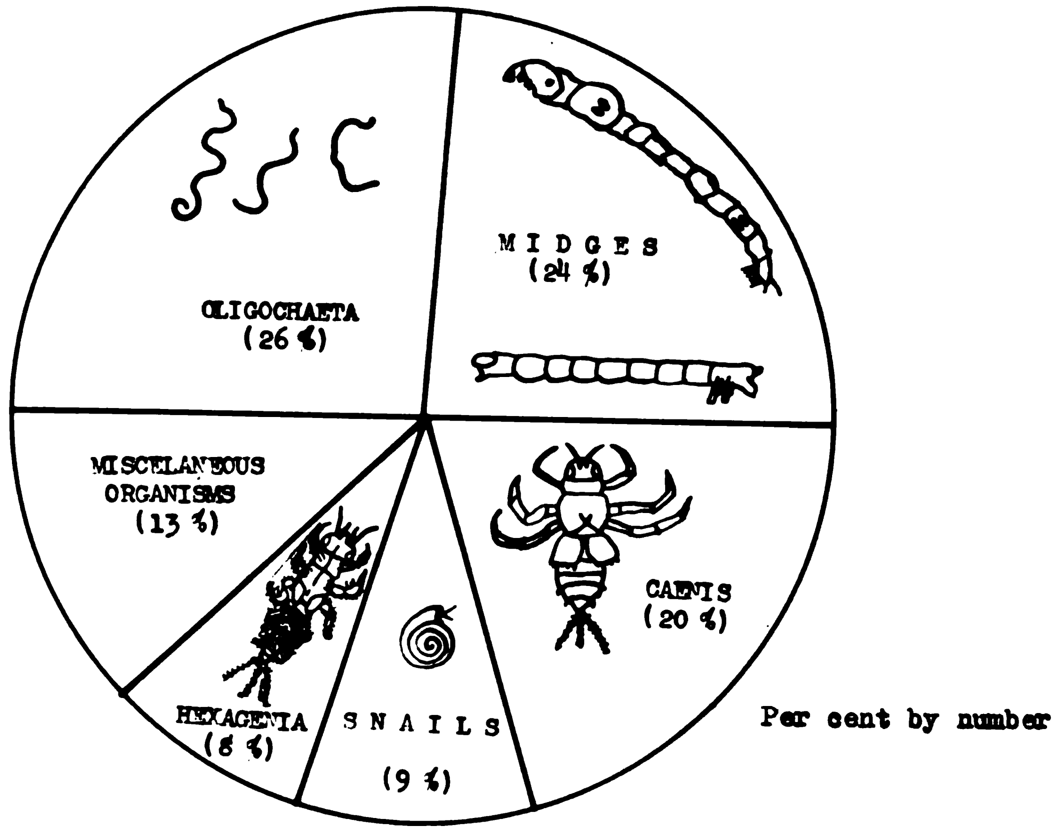


Per cent by number



Per cent by volume

Chart III. - Composition of bottom fauna in dredge samples from fertilized Pond 12.



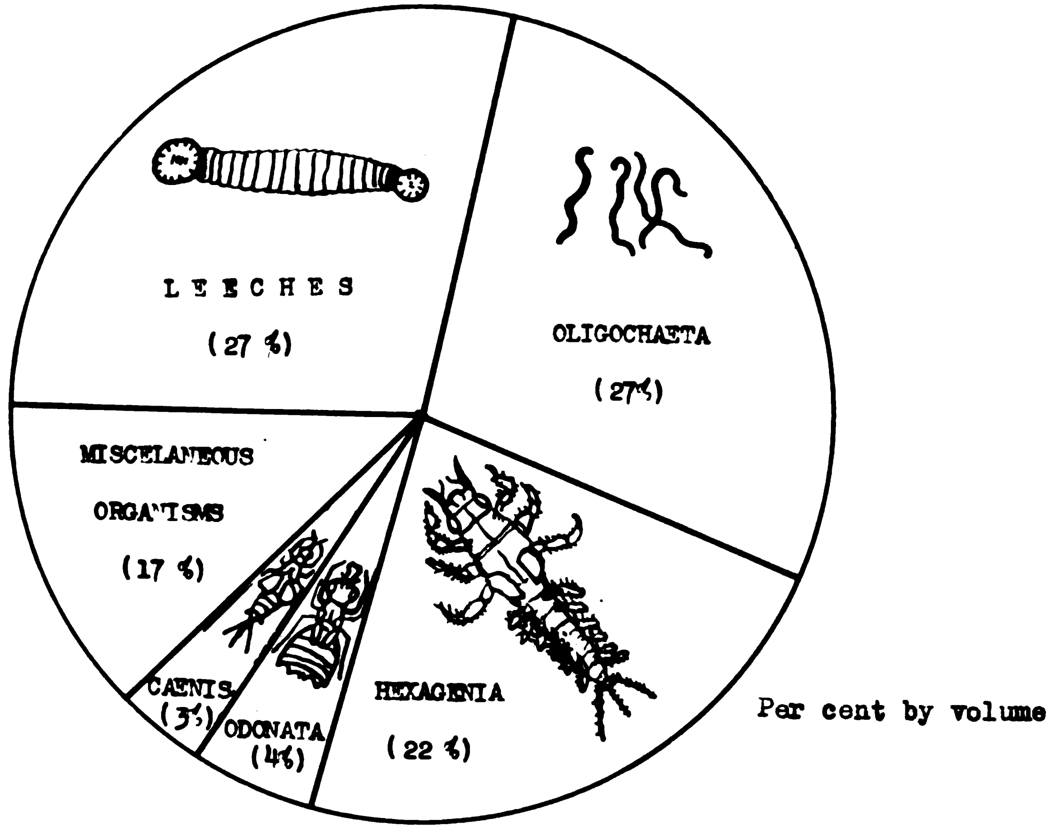


Chart V. - Composition of bottom fauna in dredge samples from unfertilized Pond 21.

fauna of Pond 21 and present in Pond 7 but none were found in Pond 12 and only two individuals were taken from Pond 20.

Other organisms represented in the bottom samples in small numbers were damselfly nymphs (Zygoptera), Coleoptera larvae, immature forms of the mayfly, Baetis sp., caddisfly larvae (Trichoptera), a few small molluscs (Gastropoda and Pelecypoda) and the water mite (Hydracarina). Two or three Lepidoptera larvae and several Diptera larvae, other than midges, were also taken.

While crayfish and tadpoles were present in all of the ponds, and a few were brought up in the samples, they have been excluded from consideration because it was felt that the method of sampling used would not adequately sample their numbers. The comparatively large volume of those few taken would unduly influence the total volume of the fish food organisms thereby producing a volumetric total not truly indicative of the pond population.

From the bottom sampling it appears as though each pond had a bottom fauna composition more or less peculiar to itself, thereby emphasizing the fact that no two bodies of water are exactly alike. Swingle (1947) reported a similar variation in the production of plankton algae in 27 small ponds at the Alabama Experiment Station. Even though the ponds had a common water supply and were, morphologically, almost alike the composition of the phytoplankton varied from pond to pond.

Tables 2, 3, 4, and 5 have been prepared summarizing

Table 2. - A summary of the dredge-sample data of the unfertilized Pond 7 and a tabulation of the bottom fauna in the samples.

Collection Date		July		August		September		Totals
No. of Samples			30		18		6	54
Total Sample Area (sq. ft.)			24.78		14.87		4.96	44.60
Total No. Organisms			1515		611		84	2210
No. Organisms/sq.ft.			61.14		41.09		16.93	49.46
Total Vol. Organisms (cc.)			15.4		5.3		1.3	22.0
Vol. Organisms/sq.ft.			.62		.36		.26	.49
Chironomidae	A	773	51.02	248	40.57	48	57.14	48.32
	B	2.9	17.68	1.1	16.42	.1	7.69	16.80
Ceratopogonidae	A	30	1.98	10	1.64	1	1.19	1.85
	B	---	trace	---	trace	---	trace	trace
Chaoborinae	A	---	-----	---	-----	1	1.19	.05
	B	---	-----	---	-----	---	trace	trace
Caenis	A	245	16.17	52	8.51	---	-----	13.42
	B	1.1	6.71	.3	4.48	---	-----	5.74
Baetis	A	5	.33	---	-----	---	-----	.23
	B	---	trace	---	-----	---	-----	trace
Hexagenia	A	6	.40	11	1.80	---	-----	.77
	B	.8	4.88	1.0	14.93	---	-----	7.38
Anisoptera	A	5	.33	---	-----	---	-----	.23
	B	.8	4.88	---	-----	---	-----	3.28
Zygoptera	A	13	.86	21	3.44	---	-----	1.54
	B	.2	1.22	.1	1.49	---	-----	1.23
Trichoptera	A	3	.20	9	1.47	3	3.57	.68
	B	---	trace	.1	1.49	---	trace	.41
Coleoptera	A	41	2.71	10	1.64	6	7.14	2.58
	B	.3	1.83	---	trace	---	trace	1.23
Lepidoptera	A	---	-----	---	-----	---	-----	-----
	B	---	-----	---	-----	---	-----	-----
Other Diptera	A	4	.26	5	.82	---	-----	.41
	B	---	trace	---	trace	---	-----	trace
Hyalella	A	261	17.23	182	29.78	7	8.33	20.34
	B	1.4	8.54	1.0	14.93	---	trace	9.84
Hirudinea	A	22	1.45	6	.98	3	3.57	1.40
	B	4.9	29.88	.2	2.99	1.2	92.31	25.82
Hydracarina	A	---	-----	---	-----	4	4.76	.18
	B	---	-----	---	-----	---	trace	trace
Oligochaeta	A	32	2.11	5	.65	2	2.39	1.72
	B	.7	4.27	.3	4.48	---	trace	4.10
Gastropoda	A	25	1.65	25	4.09	3	3.57	2.40
	B	.5	3.05	.7	10.45	---	trace	4.92
Pelecypoda	A	49	3.23	27	4.42	6	7.14	3.71
	B	1.8	10.97	.5	7.46	---	trace	9.43

A - Number of organisms and per cent of all organisms by number.

B - Volume of organisms in cubic centimeters and per cent of all organisms by volume.

Table 3. - A summary of the dredge-sample data of the fertilized Pond 12 and a tabulation of the bottom fauna in the samples.

Collection Date		July		August		September		Totals
No. of Samples			30		18		6	54
Total Sample Area (Sq. Ft.)			24.78		14.87		4.96	44.60
Total No. Organisms			2512		956		176	3644
No. Organisms/sq. ft.			101.37		64.29		35.48	81.70
Total Vol. Organisms (cc.)			32.1		19.9		1.6	53.6
Vol. Organisms/sq.ft.			1.30		1.34		.32	1.20
Chironomidae	A	2203	87.68	791	82.74	117	66.47	85.24
	B	11.3	35.20	5.5	22.84	.7	43.75	29.41
Ceratopogonidae	A	4	.16	10	1.05	---	-----	.38
	B	----	trace	---	trace	---	-----	trace
Chaoborinae	A	----	-----	---	-----	14	7.95	.38
	B	----	-----	---	-----	---	trace	trace
Caenis	A	113	4.50	40	4.18	---	-----	4.19
	B	.6	1.76	.2	.86	---	-----	1.56
Baetis	A	7	.28	---	-----	---	-----	.19
	B	----	trace	---	-----	---	-----	trace
Hexagenia	A	----	-----	---	-----	---	-----	-----
	B	----	-----	---	-----	---	-----	-----
Anisoptera	A	13	.52	2	.21	10	5.68	.68
	B	1.4	4.12	---	trace	.2	12.50	2.98
Zygoptera	A	18	.72	3	.31	7	3.98	.77
	B	.3	.88	---	trace	---	trace	.51
Trichoptera	A	2	.08	7	.73	1	.57	.27
	B	----	trace	.1	.43	---	trace	.17
Coleoptera	A	22	.88	10	1.05	2	1.14	.93
	B	.3	.88	---	trace	---	trace	.51
Lepidoptera	A	1	.04	---	-----	---	-----	.03
	B	----	trace	---	-----	---	-----	trace
Other Diptera	A	2	.08	8	.84	---	-----	.17
	B	----	trace	.1	.45	---	-----	.17
Hyalella	A	47	1.87	25	2.62	1	.57	2.00
	B	.1	.29	.1	.43	---	trace	.34
Hirudinea	A	56	2.23	36	3.77	---	-----	2.52
	B	17.4	51.18	13.8	69.48	---	-----	58.04
Hydracarina	A	3	.04	4	.41	1	.57	.14
	B	----	trace	----	trace	---	-----	trace
Oligochaeta	A	7	.28	1	.10	---	-----	.22
	B	----	trace	---	trace	---	-----	trace
Gastropoda	A	2	.08	11	1.15	12	6.82	.69
	B	.1	.29	---	trace	.1	6.25	.34
Pelecypoda	A	11	.44	8	.84	11	6.25	.82
	B	.6	1.76	.3	1.29	.6	37.50	2.55

A - Number of organisms and per cent of all organisms by number.

B - Volume of organisms in cubic centimeters and per cent of all organisms by volume.

Table 4. - A summary of the dredge-sample data of the fertilized Pond 20 and a tabulation of the bottom fauna in the samples.

Collection Date	June	July	August	September	Totals
No. of Samples	4	35	28	7	74
Total Sample Area (Sq. ft.)	3.30	28.91	23.13	5.78	61.12
Total No. Organisms	232	3451	1845	352	5880
No. Organisms /sq. ft.	70.3	119.37	79.77	60.90	96.20
Total Vol. Organisms (cc.)	3.1	36.5	18.8	4.3	62.7
Vol. Organisms/sq. ft.	.94	1.26	.81	.81	1.03

		June		July		August		September		Totals
Chironomidae	A	136	58.62	2139	61.82	568	30.79	79	22.44	49.67
	B	.8	25.81	19.1	51.19	6.6	30.27	1.6	20.00	40.01
Ceratopogonidae	A	3	1.30	45	1.30	139	7.53	43	12.21	3.91
	B	tr.*	tr.	.1	.27	.4	1.93	.1	1.25	.85
Chaoborinae	A	----	-----	---	-----	---	-----	---	-----	------
	B	----	-----	---	-----	---	-----	---	-----	------
Caenis	A	5	2.16	162	4.68	59	3.20	2	.57	3.88
	B	tr.	tr.	.7	1.88	.2	.92	tr.	tr.	1.28
Baetis	A	----	-----	17	.49	3	.16	1	.28	.36
	B	----	-----	.3	.80	tr.	tr.	tr.	tr.	.71
Hexagenia	A	1	.43	1	.03	---	-----	---	-----	.03
	B	.1	3.23	.3	.80	---	-----	---	-----	.57
Zygoptera	A	----	-----	10	.29	42	2.28	27	7.67	1.34
	B	----	-----	tr.	tr.	.2	.92	.1	1.25	.43
Anisoptera	A	3	1.30	17	.49	1	.05	8	2.27	.49
	B	1.4	45.16	1.8	4.82	tr.	tr.	.3	3.75	4.98
Trichoptera	A	----	-----	1	.03	13	.70	----	-----	.24
	B	----	-----	tr.	tr.	.1	.46	----	-----	.14
Coleoptera	A	9	3.88	44	1.27	36	1.95	3	.85	1.56
	B	.3	9.68	.7	1.88	.2	.92	tr.	tr.	1.57
Corixidae	A	----	-----	---	-----	---	-----	---	-----	------
	B	----	-----	---	-----	---	-----	---	-----	------
Lepidoptera	A	----	-----	---	-----	---	-----	4	1.14	.07
	B	----	-----	---	-----	---	-----	.1	1.25	.14
Other Diptera	A	----	-----	7	.20	10	.49	5	1.42	.36
	B	----	-----	.20	1.07	tr.	tr.	.3	3.75	1.00
Hyalella	A	19	8.19	430	12.43	309	16.75	50	14.20	13.74
	B	.2	6.45	3.5	9.38	1.9	8.72	.1	1.25	8.12
Hirudinea	A	---	-----	23	.66	34	1.84	11	3.12	1.16
	B	---	-----	1.6	4.23	1.1	5.04	.5	6.25	4.56
Hydracarina	A	---	-----	9	.09	20	.98	4	.85	.41
	B	---	-----	tr.	tr.	tr.	tr.	tr.	tr.	tr.
Oligochaeta	A	56	24.14	469	13.55	545	29.54	97	27.55	19.84
	B	.3	9.68	6.0	16.08	6.7	30.73	.8	10.00	19.65
Nematoda	A	---	-----	4	.12	---	-----	---	-----	.07
	B	---	-----	.1	.27	---	-----	---	-----	.14
Gastropoda	A	---	-----	73	2.11	66	3.58	18	5.11	2.67
	B	---	-----	1.7	4.56	1.4	6.42	.4	5.00	4.98
Pelecypoda	A	---	-----	---	-----	---	-----	---	-----	------
	B	---	-----	---	-----	---	-----	---	-----	------

A - Number of organisms and per cent of all organisms by number.
B - Volume of organisms in cubic centimeters and per cent of all organisms by volume.
* - trace

Table 5. - A summary of the dredge-sample data of the unfertilized Pond 21 and a tabulation of the bottom fauna in the samples.

Collection Date		June		July		August		September		Totals
No. of Samples		4		35		28		7		74
Total Sample Area (Sq. ft.)		3.30		28.91		23.13		5.78		61.12
Total No. Organisms		105		1033		924		298		2365
No. Organisms/sq.ft.		31.82		35.73		39.95		51.55		38.69
Total Vol. Organisms (cc.)		3.1		40.2		15.7		1.7		60.6
Vol. Organisms/sq.ft.		.94		1.39		.68		.29		.99
Chironomidae	A	3	2.86	44	4.26	100	10.82	18	6.04	6.96
	B	---	trace	.2	.49	.4	1.98	.1	4.76	1.06
Ceratopogonidae	A	1	.95	40	3.87	44	4.76	4	1.34	3.76
	B	---	trace	---	trace	---	trace	---	trace	.15
Chaoborinae	A	---	-----	---	-----	83	8.98	230	77.17	13.21
	B	---	-----	---	-----	.2	.99	.6	28.57	1.21
Caenis	A	3	2.86	299	28.94	159	17.20	1	.34	19.50
	B	---	trace	1.4	3.41	.5	2.48	---	trace	2.87
Baetis	A	---	-----	5	.48	2	.22	---	-----	.30
	B	---	-----	---	trace	---	trace	---	-----	trace
Hexagenia	A	20	19.05	123	11.91	34	3.68	1	.34	7.51
	B	1.1	35.48	9.4	22.93	4.1	20.30	---	trace	22.02
Anisoptera	A	1	.95	7	.68	2	.22	5	1.68	.72
	B	---	trace	2.2	5.36	.3	1.49	.2	9.52	4.07
Zygoptera	A	---	-----	8	.77	27	2.92	3	1.01	1.60
	B	---	-----	---	trace	.1	.50	---	trace	.15
Trichoptera	A	2	1.90	10	.97	14	1.51	---	-----	1.10
	B	.1	3.23	.3	.73	.1	.50	---	-----	.75
Coleoptera	A	---	-----	19	1.84	5	.54	---	-----	1.01
	B	---	-----	.3	.73	---	trace	---	-----	.45
Corixidae	A	---	-----	3	.29	---	-----	---	-----	.13
	B	---	-----	.3	.73	---	-----	---	-----	trace
Lepidoptera	A	---	-----	1	.10	---	-----	---	-----	trace
	B	---	-----	---	trace	---	-----	---	-----	.04
Other Diptera	A	---	-----	40	3.89	5	.54	---	-----	1.90
	B	---	-----	1.2	2.93	---	trace	---	-----	1.81
Hyalella	A	1	.95	72	6.97	22	2.38	---	-----	4.00
	B	---	trace	.2	.49	---	trace	---	-----	.45
Hirudinea	A	---	-----	24	2.32	14	1.51	4	1.34	1.77
	B	---	-----	13.7	33.41	4.3	21.29	---	trace	27.14
Hydracarina	A	---	-----	8	.77	17	1.83	5	1.68	1.27
	B	---	-----	---	trace	---	trace	---	trace	trace
Oligochaeta	A	64	60.95	276	26.72	259	28.02	8	2.68	25.62
	B	1.8	58.06	10.5	25.61	4.8	23.76	.6	28.57	26.69
Nematoda	A	---	-----	----	-----	---	-----	---	-----	-----
	B	---	-----	----	-----	---	-----	---	-----	-----
Gastropoda	A	10	9.52	49	4.74	131	14.17	18	6.04	8.78
	B	.1	3.23	.5	1.22	.9	4.46	.2	9.52	2.56
Pelecypoda	A	---	-----	1	.10	1	.11	---	-----	.08
	B	---	-----	---	trace	---	trace	---	-----	trace

A - Number of organisms and per cent of all organisms by number.
B - Volume of organisms in cubic centimeters and per cent of all organisms by volume.

the sampling data by months for each pond. A monthly summary of the bottom fauna taken in the samples is included showing the numbers, per cent of all organisms by number, volume, and per cent of all organisms by volume.

The total bottom fauna production for each pond, as calculated from the dredge sampling of the standing crop of organisms, is presented in Table 6. The computations show that the fertilized Pond 20 produced 16 per cent more invertebrate organisms than did the unfertilized Pond 21 and the fertilized Pond 12 produced 136 per cent more invertebrates than the unfertilized Pond 7.

However, in order to present a more accurate picture of the potential fish food production of these ponds, the figures were revised, omitting the leeches and oligochaetes as they were seldom taken as food. This is believed justified not only from the results of the stomach analyses presented here but also from results reported in the literature (Bennett, Thompson, and Parr, 1940; Leonard, 1940; Howell, 1941; Ball, 1948). This revision, shown in the second column of Table 6 shows that the fertilized Pond 20 produced 91 per cent more food organisms of a size used by small fish than did Pond 21, and Pond 12, also fertilized, produced 50 per cent more food organisms found in the diet of small bluegills than did Pond 7. In each instance the ponds that were treated with fertilizer had a greater standing crop of benthic organisms than did the untreated ponds.

Table 6.- Comparison in pounds per acre of total bottom fauna with the production of organisms found in the diet of bluegills in fertilized and unfertilized ponds.

	Pounds per acre	
Pond	Total bottom fauna	Food organisms**
Pond 20*	92	71
Pond 21	79	37
Pond 12*	92	48
Pond 7	39	32

* Fertilized pond.

** Oligochaetes and leeches omitted.

STATISTICAL ANALYSIS

In a quantitative analysis of this sort a statistical approach is highly desirable although not always essential. As Lyman (1943) pointed out "Biological research from the quantitative angle does not in all situations lend itself to statistical analysis.... Indications and trends are often as useful as absolute values." However, an attempt was made to offer mathematical support of the results obtained in this experiment by analyzing the variance of the data.

Leeches and oligochaetes were omitted from the data in order that the tests could be made on the population of the organisms generally found in the diet of the bluegill. The null hypothesis to be tested was that the data from each pair of experimental ponds are random samples from a common population. If the test is significant the variance in the data is not due to the sampling but rather that the populations in the fertilized and unfertilized ponds are different.

Fisher's 'F' test of significance (Snedecor, 1947) was applied to the weekly sample data of Ponds 20 and 21. The 'F' ratio of the volumetric data was 5.52 with 1 and 20 degrees of freedom which is significant at the 5 per cent level. The test of the numerical data showed a ratio of 11.55 with 1 and 20 degrees of freedom which is highly significant at the 1 per cent level. The first test indicated that there was less than one chance in 20 that the samples were drawn from the distribution specified in the hypothesis while the results of the second test showed that there was less than one chance in 100 that the samples were drawn from the distribution stated in the hypothesis. Evidently the population of organisms in the fertilized and unfertilized ponds was different. Since fertilization was the factor tested in these experiments, the significantly greater invertebrate population of the fertilized Pond 20 over that of the unfertilized Pond 21 can be attributed to the application of fertilizer.

The 'F' ratios obtained from testing the data of Ponds 7 and 12 were 1.38 for the volumetric data and 2.99 for the numerical data, both with 1 and 16 degrees of freedom. Neither tests were significant so that the null hypothesis was not disproved. The individual variations among the data within each pond were too great for the small number of samples taken. More samples would be required for a statistically positive test.

Although the results were not mathematically supported, indications of a greater production of bottom fauna in the fertilized Pond 12 than in the unfertilized Pond 7 can be demonstrated. In addition to the computations already presented in Table 6, Charts VI, VII, VIII, and IX have been prepared to show the results and fluctuations in the weekly bottom sample data. Charts VIII and IX show a considerable difference in the production of food organisms in

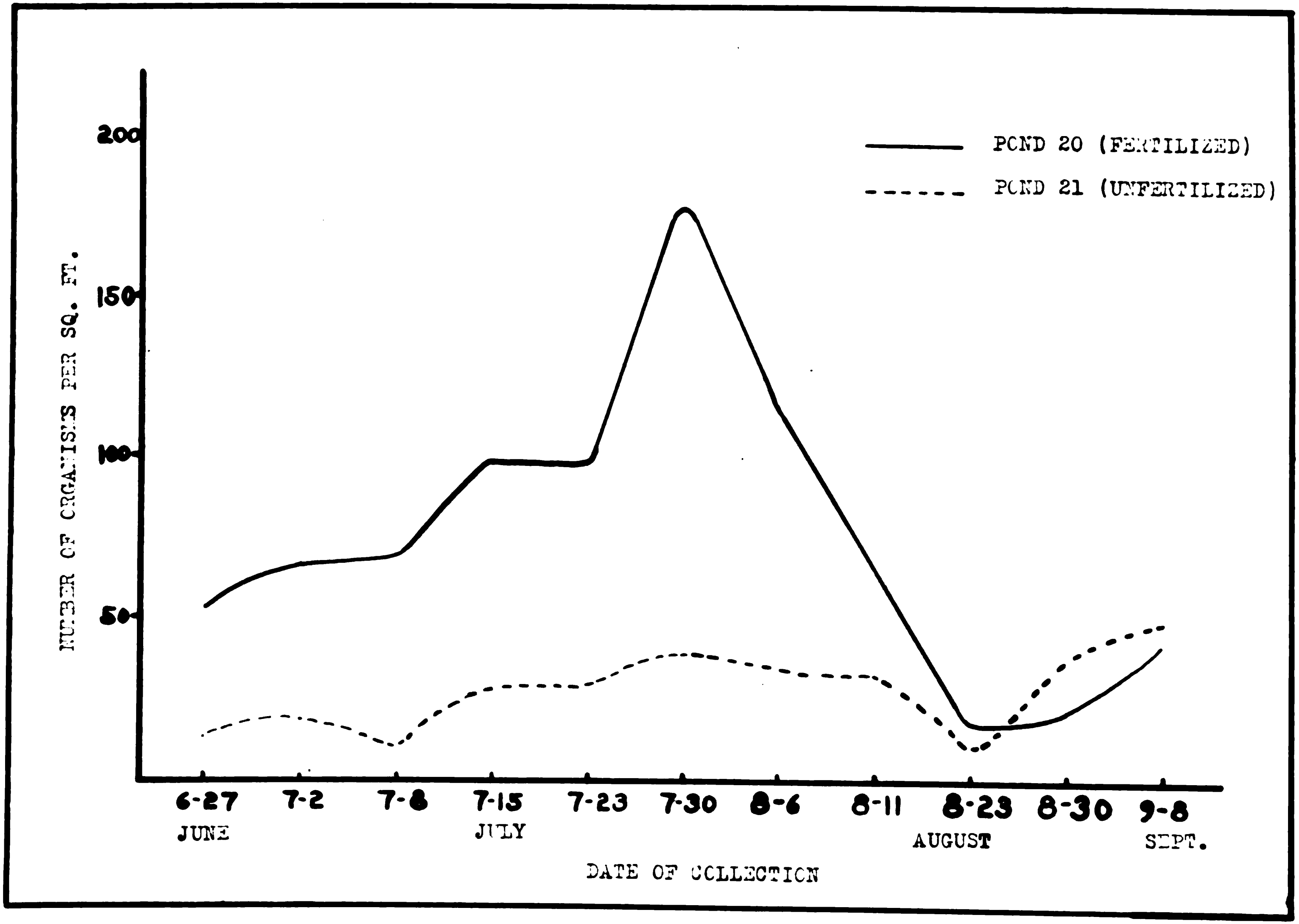


Chart VII. – The number of organisms per square foot collected weekly in dredge samples from Pond 20 and Pond 21, oligochaetes and leeches omitted.

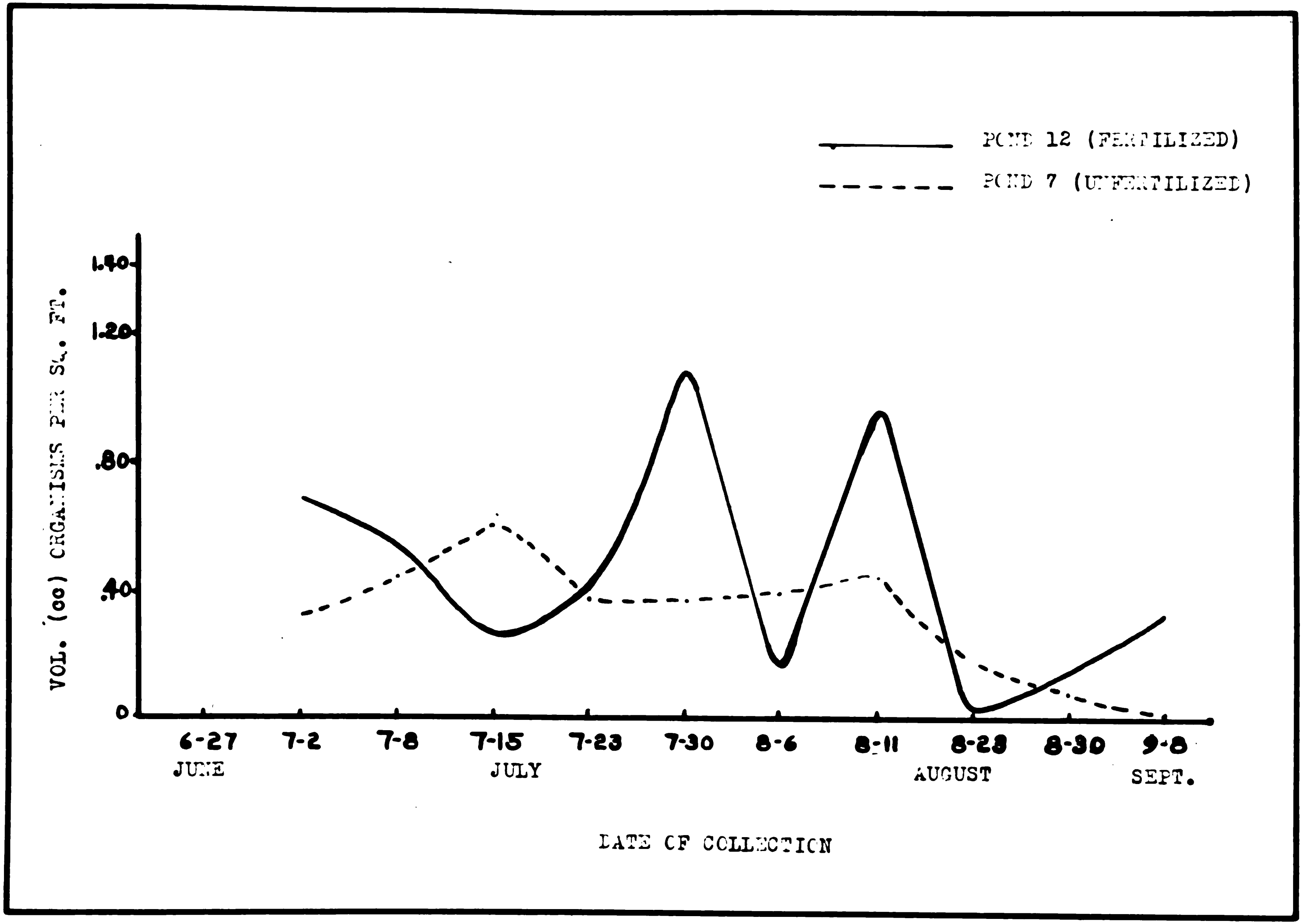


Chart VIII. – The volume of organisms per square foot collected weekly in dredge samples from Pond 7 and Pond 12, oligochaetes and leeches omitted.

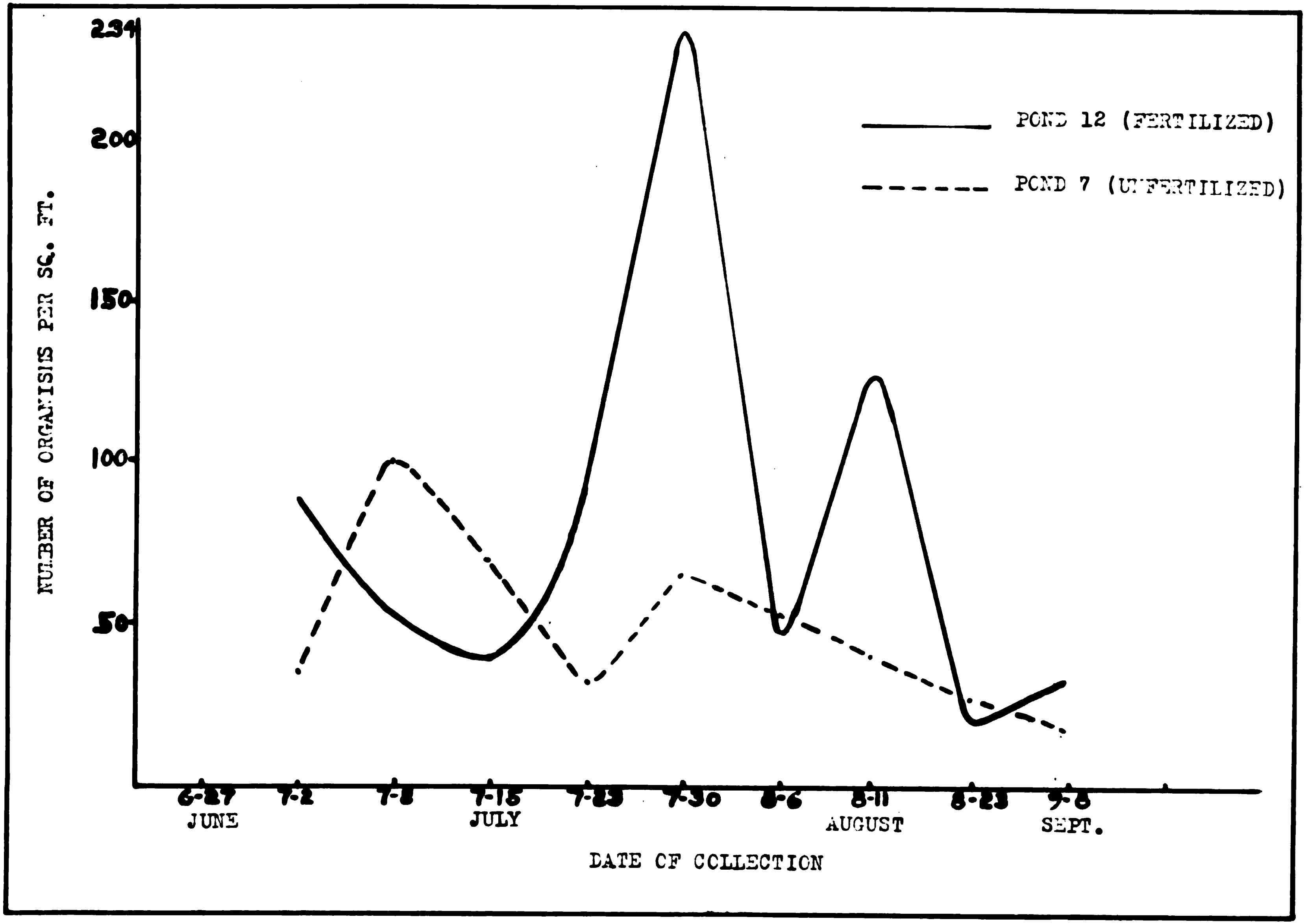


Chart IX. - The number of organisms per square foot collected weekly in dredge samples from Pond 7 and Pond 12, oligochaetes and leeches omitted.

the fertilized Pond 12 over that of the unfertilized Pond 7.

Ball (1948) has shown from his work on Third Sister Lake, Michigan, over a three-year period that there is an annual cycle in the bottom fauna production. The organisms reach a peak in abundance in January after which their numbers decline until a low point is reached somewhere around the end of June or the first week in July. At this time the population again starts to rise toward the winter peak. From the charts it appears as though there was an interruption in the normal upswing of production in the experimental ponds at Wolf Lake. This can be accounted for by at least two factors. One was the effects of predation by the young bluegills which had reached an active foraging size at this time. The other was an emergence of the numerically dominant midges. The predatory activities of the fish presumably kept the bottom fauna population in check the rest of the summer.

STOMACH ANALYSIS

The measurements of the bluegills taken for this food study ranged between 1.3 and 2.6 inches (total length). Most of the stomachs contained at least some undigested or partially digested material, there being only 19 of the 503 examined that were empty. Chart X presents the principal organisms taken as food by the young-of-the-year bluegills, showing each organism as the per cent of the total number of organisms taken and the percentage of stomachs contain-

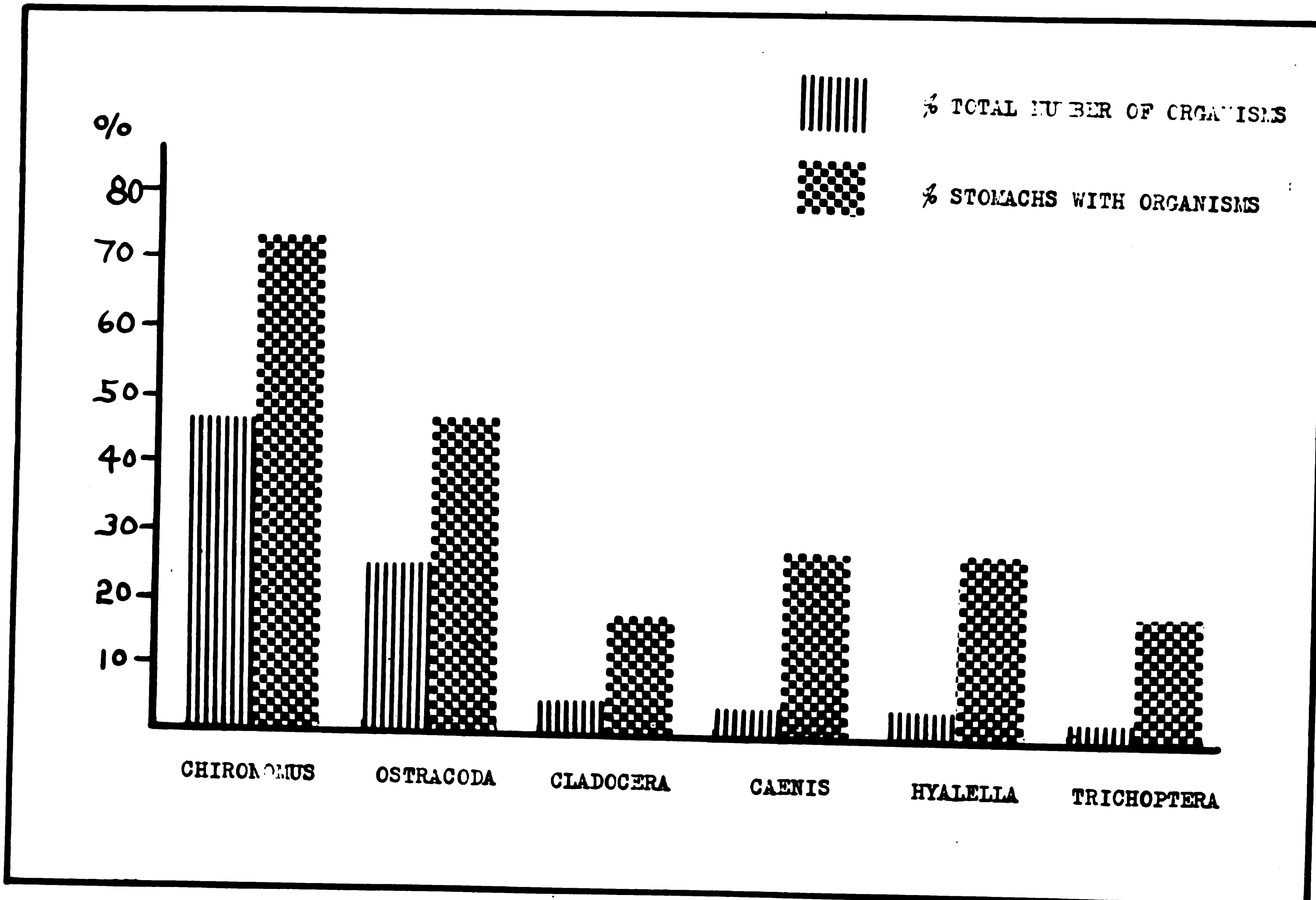


Chart X. - The principal organisms taken as food by 503 young-of-the-year bluegills (percentage of total number of organisms), and the percentage of stomachs containing the organisms.

ing the organism.

Midge larvae and pupae were found to be the principal item in the omnivorous diet of these fish. Chironomidae and Ceratopogonidae constituted 48 per cent of the total number of organisms, the former occuring in 73 per cent of all stomachs containing food. Midges are apparently one of the staple items of food for these young fish. This is further borne out by the fact that at the time of capture 85 per cent of the bluegills were feeding on these insects in the fertilized ponds while about 60 per cent of the fish in the unfertilized ponds were feeding on them.

Next, in numerical importance, were the Ostracoda which made up 25 per cent of the total number and were taken by 47 per cent of the fish. The scud, *Hyalella knickerbockeri*, and mayfly, *Caenis* sp., were each taken by 29 per cent of the bluegills, both forming roughly 5 per cent of the total number of organisms. Water fleas (Cladocera) comprised 6 per cent of the total number but were taken by only 18 per cent of the fish. Twenty per cent of the stomachs contained caddisfly larvae (Trichoptera). Other invertebrates found in the stomachs were copepods, damselfly nymphs (Zygoptera), snails, mayfly nymphs of the genus *Baetis*, water mites (Hydracarina), beetle larvae (Coleoptera), water boatmen (Corixidae), and one leech.

Tables 7 and 8 are summaries of all the material taken by the 503 bluegills examined, each organism being tabulated as per cent of the total number of organisms along with

Table 7.-The food of 230 young-of-the-year bluegills which were taken from Pond 7 and Pond 12. Average total length-1.86" (Range 1.3-2.5 inches).

	POND 12 (fertilized)		POND 7 (unfertilized)	
	Per cent of all organisms	Per cent of stomachs containing organisms	Per cent of all organisms	Per cent of stomachs containing organisms
MOLLUSCA				
Snails	1.71	15.13	1.44	9.00
MALACOSTRACA				
Hyalella	2.35	26.05	7.38	30.63
ENTOMOSTRACA				
Cladocera	8.46	30.25	8.26	27.93
Ostracoda	36.28	58.82	9.54	29.73
Copepoda	4.02	29.41	1.52	9.91
AQUATIC INSECTS				
Midges:				
Chironomidae	35.61	84.87	51.24	62.16
Ceratopogonidae	4.35	33.62	2.24	14.41
Ephemerida:				
Caenis	1.79	26.05	8.82	40.54
Baetis	.19	2.52	.24	2.70
Odonata:				
Anisoptera	.11	2.52	.16	1.80
Zygoptera	2.98	15.97	1.68	14.41
Trichoptera	.82	13.44	5.05	25.23
Coleoptera	.34	4.20	.24	1.80
Hemiptera	4.02	29.41	.88	4.50
Other Diptera	.11	2.52	-----	-----
TERRESTRIAL INSECTS	.04	.84	.08	.90
ARACHNIDA	.11	1.68	.16	1.80
HYDRACARINA	.78	11.76	.48	4.50
LEECH	-----	-----	.08	.90
OLIGOCHAETA	.04	.84	-----	-----
NEMATODE	.07	1.68	.16	1.80
ORGANIC DEBRIS	-----	3.36	-----	6.31
INORGANIC DEBRIS	-----	21.00	-----	15.32
VEGETATION	-----	1.68	-----	8.11
ALGAE	-----	9.24	-----	3.60

Table 8.-The food of 273 young-of-the-year bluegills which were taken from Pond 20 and Pond 21. Average total length-1.91" (Range 1.3-2.6 inches).

	POND 20 (fertilized)		POND 21 (unfertilized)	
	Per cent of all organisms	Per cent of stomachs containing organisms	Per cent of all organisms	Per cent of stomachs containing organisms
MOLLUSCA				
Snails	.18	2.21	1.16	5.84
Clams	.12	1.47	.06	.73
MALACOSTRACA				
Hyalella	9.89	46.32	1.90	13.87
ENTOMOSTRACA				
Ostracoda	26.30	48.52	15.01	49.63
Cladocera	.78	5.15	4.72	13.14
Copepoda	1.69	5.88	.25	2.19
AQUATIC INSECTS				
Midges:				
Chironomidae	48.13	86.02	52.20	59.85
Ceratopogonidae	4.71	25.00	.98	9.49
Ephemerida:				
Caenis	1.33	9.56	12.81	42.33
Baetis	.60	5.15	1.23	7.30
Hexagenia	.06	.74	.12	1.46
Odonata				
Anisoptera	.18	2.21	.06	.73
Zygoptera	.54	5.88	2.39	13.14
Trichoptera	2.29	19.85	4.84	20.44
Coleoptera	.30	3.68	.31	3.65
Hemiptera	.36	3.68	.12	1.46
Other Diptera	.84	9.56	.43	2.92
ARACHNIDA	.18	2.21	.98	8.03
HYDRACARINA	1.51	11.03	.43	4.38
ORGANIC DEBRIS	-----	24.26	-----	9.49
INORGANIC DEBRIS	-----	2.94	-----	7.30
VEGETATION	-----	12.50	-----	13.14
ALGAE	-----	6.62	-----	2.19

the per cent of stomachs containing the item. The heading "Vegetation" refers to the leaf and floral parts of higher aquatic plants presumably taken in along with some organism as they were always a minor item in the 46 stomachs in which they were found. This seams to be also true for the fragments of filamentous algae and Chara sp. which were found in 27 stomachs. Animal matter which was unidentified has been classed as organic debris. Leonard (1940) pointed out that the proportion of various organisms represented in the debris is about in direct ratio to their abundance among recognizable organisms and need not be considered in calculating the percentage composition of the stomach contents.

The percentage of occurence of the organisms in the stomachs of the bluegills may be interpreted as the percentage of fish feeding on the organism at the time of capture. Twenty per cent or more of the fish were taking individuals from at least one of the following groups: Entomostraca, scuds, midges, mayflies, and caddisflies. Therefore it is important to note that these organisms thrive and multiply rapidly in fertilized ponds to a greater extent than in unfertilized ponds.

One criterion of measurement in fish food studies is the 'forage ratio' suggested by Hess and Swartz (1940). This factor is a ratio of the percentage of occurence of an organism in the population to its percentage of occurence in the stomach of the fish. If the ratio of a group of organisms varies significantly from one, it should be due to either a difference in availability or a difference in preference.

Allen (1942), offering the term 'availability factor' for the forage ratio, states that in order to obtain a true estimate of the actual quantity of fish food any fauna represents, one must consider differences in availability to the fish. Therefore the forage ratios have been computed for four principal organisms that were found both in the bottom samples and in the stomachs and are presented in Table 9. These ratios would seem to indicate that the organisms were available to the fish but that only in Pond 21 was any preference indicated and that was for the midges. Leonard (1941) suggested that the forage ratio be used as a measure of availability only. In view of this criticism, the midge ratio for the unfertilized Pond 21 would indicate instead that they were not readily available to the fish.

DISCUSSION

Considerable work has been done in measuring the standing crop of bottom fauna of streams and lakes (Adamstone and Harkness, 1923; Surber, 1930; Pate, 1931; Needham, 1934; Tarzwell, 1938; Cooper, 1941; and Ball, 1948) but very little has been done on ponds. Meehean (1936), reporting on bass production in Louisiana ponds, stated that with the application of fertilizer the bottom fauna in the ponds reached a production of 105 pounds per acre. H. H. Howell (1942) demonstrated in Alabama ponds that the addition of fertilizer more than trebled the average dry weight of the bottom organisms. Ball (1948) converted Howell's results to a pounds per acre basis to show that the fertil-

Table 9.-Forage ratios of four organisms found in the diet of bluegills and the per cent composition by number of the organisms in the bottom samples and bluegill stomachs.

	Midges	Mayflies	Scuds	Damselflies
<u>POND 20</u>				
Per cent in samples	54	4	14	1
Per cent in stomachs	48	2	10	.5
Forage ratio	.9	.5	.7	.5
<u>POND 21</u>				
Per cent in samples	11	28	4	2
Per cent in stomachs	52	14	2	2
Forage ratio	4.7	.5	.5	1
<u>POND 12</u>				
Per cent in samples	85	4	2	1
Per cent in stomachs	39	2	2	3
Forage ratio	0.45	.5	1	3
<u>POND 7</u>				
Per cent in samples	50	13	20	2
Per cent in stomachs	53	9	7	2
Forage ratio	1.1	.7	.35	1

ized ponds produced approximately an average standing invertebrate crop of 98 pounds per acre and 28.8 pounds per acre in the unfertilized ponds.

Howell's results compare favorably with those obtained in this experiment in which it was also shown that the bottom fauna production of the fertilized ponds was greater than that of the unfertilized ponds. Table 6 showed that both the fertilized Pond 20 and Pond 12 had a standing crop of bottom fauna of 92 pounds per acre whereas the unfertilized Ponds 21 and 7 had respectively 29 and 39 pounds per acre of benthic organisms.

The results of these investigations indicate that the application of fertilizer in proper amounts will increase the standing crop of bottom organisms. Other evidence presented in this paper showed that fertilization had little effect on the total hardness of the pond waters nor was it possible to produce a plankton bloom until late in the summer in ponds with submerged beds of higher aquatic plants. Instead of a plankton bloom a heavy growth of filamentous algae was produced which resulted in eliminating most of the submerged higher aquatic plants although it had little effect on <u>Anacharis</u> sp.

It was also demonstrated that fertilization favors the production of organisms used as food by young-of-the-year bluegills. Fisher's 'F' test of analysis of variance was applied to the sample data of the standing crop of these fish-food organisms to show that the variance in the

data was not a sampling variation but rather one of population differences between the fertilized and unfertilized ponds. Both significant and highly significant results were obtained on the data from Ponds 20 and 21.

The results of the food analysis of the young-of-the-year bluegills compare favorably with previous studies. Pearse (1918), Leonard (1939), Bennett, Thompson and Parr (1940), and Howell (1941) all agree that entomostracans and midges form the chief articles of diet of the young bluegill. Chironomids, Ostracoda, and small mayfly nymphs were the principal items in the diet of the small bluegills in these experimental ponds. Leonard sums up the food of all sizes of bluegills from his work on Ford Lake, Michigan in this manner: "Members of the group of smallest fish (15-26 mm.) fed almost exclusively on plankton, small mayfly nymphs, and chironomids. Plankton, Chironomids, and aphids bulked about the same in the group of middle-sized fish (33-50mm.) but the Odonata were almost as abundant. The largest specimens (105-130 mm.) fed on anisoptera dragonfly nymphs almost to the exclusion of other groups."

Howell (1941) and Ball (1948) observed that the phantom midge Chaoborus was not taken by the bluegill and this was true in Pond 21 where these midges were becoming increasingly abundant at the end of the summer but were not found in a single stomach.

Howell, Swingle, and Smith (1941) reached the conclusion that bluegills resorted to plant foods only when the supply of invertebrates was reduced, apparently preferring the animal food. This was corroborated by the work of Ball (1948). The young bluegills in these experimental ponds at Wolf Lake fed almost exclusively on animal foods, vegetation being only incidental items of food in a few stomachs. Evidently in all of the ponds the young bluegills had an abundance of invertebrate food organisms upon which to feed.

The weekly data on the stomach contents revealed a definite change in the diet of these young fish about the time they had reached a length of almost two inches. At that time their principal food changed rather markedly from entomostracans, scuds and small mayfly nymphs to a diet in which midges were most important.

The application of fertilizer to small Michigan ponds is desirable in that it will indirectly increase the food supply of the fish. Inasmuch as it is generally accepted that food is a limiting factor in fish production, this increase of bottom fauna by fertilization and its utilization by the fish should result in an increased production of fish.

Swingle and Smith (1939) demonstrated, from their work in Alabama, that by applying inorganic fertilizer in proper amounts to a pond they could increase the production of bluegill bream (<u>Lepomis macrochirus</u>) from 130 pounds per acre to between 300 and 500 pounds per acre. That these results can be equalled in Michigan has not been demonstrated. Local conditions such as fertility of the soil, length of the growing season, and characteristics peculiar to the individual pond have to be taken into consideration.

In Illinois, Bennett (1946) reported that from a survey of 22 small, unfertilized bodies of water it was found that they supported fish populations varying from 71 pounds per acre in a new pond on a sterile site to 1145 pounds per acre in an old oxbow lake.

It was shown in this investigation that the ponds used for this experiment, although physically quite similar, proved to be biologically quite different as shown by the composition of the flora and bottom fauna.

SUMMARY

1. The standing crop of bottom fauna of two fertilized and two unfertilized ponds was measured and compared. The two fertilized ponds showed 16 and 136 per cent greater production of organisms respectively than the corresponding unfertilized ponds.

2. A similar comparison between the two pairs of ponds showed that the fertilized ponds produced, respectively, 91 and 50 per cent more of those food organisms important in the diet of the bluegill than did the unfertilized ponds.

3. Fisher's "F" test of analysis of variance, applied to the data, demonstrated a significant difference in the production of bottom fauna of one of the fertilized ponds over the production of its untreated control pond.

4. The application of fertilizer produced a heavy growth of filamentous algae throughout most of the summer. This resulted in eliminating most of the submerged higher aquatic plants in Pond 12 and *Potamogeton crispus* in Pond 20 but did not seem to affect *Anacharis* sp.

5. Stomach analyses were made on 503 young-of-the-year bluegills. There was a marked change in their diet from entomostracans to midges when they reached a length of about two inches. There was no evidence that the fish were eating vegetation indicating that a sufficient animal food supply was available in all of the ponds.

6. The application of fertilizer to small ponds in Michigan is desirable in that it will indirectly increase the food supply of the fish, which is one of the limiting factors in fish production.

7. The evidence presented from this investigation shows that fertilization favors the production of organisms used as food by young-of-the-year bluegills.

8. Although physically quite similar the ponds proved to be biologically quite different as shown by the composition of the flora and bottom fauna.

9. In ponds with submerged beds of higher aquatic plants it was impossible to obtain a plankton bloom until late in the summer even though the amount of fertilization was varied considerably.

10. Fertilization had little effect on the total hardness of the pond waters.

LITERATURE CITED

Adamstone, F. B. and W. J. K. Harkness

1923 The bottom organisms of Lake Nipigon. Univ. Toronto Studies. Biol. 22. Pub. Ont. Fish. Lab. 15.

Allen, K. Radway

1942 Comparison of bottom faunas as sources of available fish food. Trans. Am. Fish. Soc., 1941 Vol. 71, pp. 275-283.

Ball, Robert C.

1948 Relationship of lake productivity to total fish production and to fish feeding habits. Tech. Bull. 206, Michigan State College Agr. Exp. Sta.

Bennett, George W.

1946 Fertilizers in fish pond management. Mimeo. leaflet of Ill. Nat. Hist. Surv. 2 pp.

Bennett, Geo. W., David H. Thompson, and Sam A. Parr

1940 A second year of fisheries investigations at Fork Lake, 1939. Ill. Nat. Hist. Surv. Biol. Notes No. 14, 24 pp.

Cooper, Gerald P.

1941 A biological survey of lakes and ponds of the Androscoggin and Kennebec River drainage systems in Maine. Fish. Surv. Rept. No. 4, Maine Dept. Inland Fish. and Game. 238 pp.

Davis, H. S.

1938 Instructions for conducting stream and lake surveys. Fisheries Circular No. 26, pp. 1-55, U. S. Bureau of Fisheries.

Davis, H. S. and A. H. Wiebe

1930 Experiments in the culture of the black bass and other pond fish. Rept. U. S. Comm. of Fisheries, 1930, Appendix IX, pp. 177-203.

Hess, A. D. and Albert Swartz

1940 The forage ratio and its use in determining the food grade of streams. Trans. Fifth N. A. Wildlife Conf., pp. 162-164.

Hogan, Joe

1933 Experiments with commercial fertilizers in rearing largemouth black bass fingerlings. Trans. Am. Fish. Soc., Vol. 63, pp. 110-119.

Howell, Henry H.

1942 Bottom organisms in fertilized and unfertilized fish ponds in Alabama. Trans. Am. Fish. Soc., 1941 Vol. 71, pp. 165-179.

Howell, H. H., H. S. Swingle and E. V. Smith

1941 Bass and bream food in Alabama waters. Alabama Cons. Vol. 1, No. 4, p. 3.

Leonard, J. W.

1940 Further observations on the feeding habits of the Montana grayling and bluegill in Ford Lake, Mich. Trans. Am. Fish. Soc., 1939 Vol. 69, pp. 244-256.

Leonard, J. W.

1941 Some observations on the winter feeding habits of brook trout fingerlings in relation to natural food organisms present. Trans. Am. Fish. Soc., 1941 Vol. 71, pp. 219-227.

Lyman, F. Earle

1943 A pre-impoundment bottom-fauna study of Watts Bar reservoir area (Tennessee). Trans. Am. Fish. Soc. 1942 Vol. 72, pp. 52-62.

Lyman, F. Earle and Jack S. Dendy

1943 A pre-impoundment bottom-fauna study of Cherokee Reservoir Area (Tennessee). Trans. Am. Fish. Soc. 1942 Vol. 73, pp. 194-208.

Meehean, O. Lloyd

1933 The role of fertilizers in pondfish culture. Trans. Am. Fish. Soc., 1932 Vol. 63, pp. 103-109.

1936 Some factors controlling largemouth bass production. U. S. Bur. Fish., Prog. Fish-Cult., No. 16, pp. 1-6.

Needham, P. R.

1934 Quantitative studies of stream bottom foods. Trans. Am. Fish. Soc., 1933. Vol. 64, pp. 238-247.

Pate, V. S. L.

1931 "Studies on the fish food supply in selected areas". A biol. surv. of the Oswegatchie and Black river systems. Suppl. 21st. Ann. Rept.,

1930. State of N. Y. Cons. Dept., pp. 133-149.

Pearse, A. S.

1918 The food of the shore fishes of certain Wisconsin lakes. U. S. Bur. Fish. Bull., Vol. 35, pp. 247-292.

Richardson, R. E.

1921 The small bottom and shore fauna of the middle and lower Illinois River and its connecting lakes. Bull. Ill. Nat. Hist. Surv., Vol. 13, pp. 362-522.

Smith, E. V. and H. S. Swingle

1939 The relationship between plankton production and fish production in ponds. Trans. Am. Fish. Soc., 1938 Vol. 68, pp. 309-315.

1941 The use of fertilizer for controlling several submerged aquatic plants in ponds. Trans. Am. Fish. Soc., 1940 Vol. 71, pp. 94-101.

Smith, M. W.

1934 Physical and biological conditions in heavily fertilized water. Journ. Biol. Bd. Canada, Vol. 1, pp. 67-93.

1934 The dissolved oxygen content of fertilized waters. Trans. Am. Fish. Soc., 1933 Vol. 64, pp. 408-415.

Snedecor, George W.

1947 Statistical Methods. Iowa State College Press, Ames, Iowa. 485 pp.

Surber, E. W.

1931 A quantitative method of studying the food of small fishes. Trans. Am. Fish. Soc., 1930 Vol. 60, pp. 158-163.

1937 Rainbow trout and bottom fauna production in one mile of stream. Trans. Am. Fish. Soc., Vol. 66, 1936. pp. 193-202.

Swingle, H. S.

1947 Experiments on pond fertilization. Ala. Exp. Sta., Ala. Poly. Inst. Bull. No. 254. 23 pp.

Swingle, H. S. and E. V. Smith

1942 Management of farm fish ponds. Ag. Exp. Sta., Ala. Poly. Inst. Bull. No. 254. 23 pp.

Tack, P. I. and W. F. Morofsky

1946 A preliminary report on farm pond management in Michigan. Mich. Ag. Exp. Sta. Qt'ly Bull., Vol. 28, No. 4, May.

Tarzwell, Clarence M.

1938 Factors influencing fish food and fish production in southwestern streams. Trans. Am. Fish Soc., 1937 Vol. 67, pp. 246-255.

Tester, A. L.

1932 Food of the small-mouthed black bass (<u>Micropterus dolomieu</u>) in some Ontario waters. Univ. Toronto Studies No. 36. Pub. Ont. Fish. Res. Lab. No. 46, pp. 171-203.

Welch, Paul S.

1935 Limnology. McGraw-Hill Book Co., New York, N. Y. 471 pp.