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"Production of Bass and Bluegills in
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of the requirements for

M. S. degree in Zoology

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Date May 4, 1951.



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PRODUCTION OF BASS AND BLUEGILLS IN MICHIGAN PONDS

By

Howard David Tait

A THESIS

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INTRODUCTION

The practice of raising fish in ponds to provide food for man is very old, beginning in China centuries ago. It spread throughout the world and in many countries of Europe and Asia fish are now cultivated intensively in ponds and provide an important part of the food economy of those countries.

The beginning of the practice of cultivating fish in ponds in America is obscure, however it has been important since fish hatcheries began supplying fish for planting programs. Active interest in the development of farm ponds to augment natural fishing waters, and research on pond management have been of fairly recent origin, beginning about 1930 with investigations concerning the problems of producing black bass in hatcheries (Davis and Wiebe, 1930; Hogan, 1933; and Meehean, 1933).

Following these pioneering studies investigators have concentrated on several different approaches to the problems of pond management. Some investigators have been concerned with increasing the yield from ponds by artificial fertilization (Surber, 1943;

Bennett, 1946; Swingle and Smith, 1939). Others have analyzed the total production of ponds and the yield of fish to fishermen and applied the results of their efforts to the management of natural waters (Ricker, 1946; Moyle, 1949; Swingle, 1950). The relationships of predator and prey species have also received attention (Bennett, 1948; Swingle 1950) and the most recent investigations have been directed toward determining species combinations and ratios that will produce fish crops useful to man when stocked in newly developed ponds.

Establishing stocking recommendations for Michigan ponds is one of the objectives of this present report. Michigan has many lakes, and probably has little need for farm ponds to provide fishing, however, ponds have multiple uses such as stock watering, boating, swimming, and conserving ground water supplies in addition to recreational fishing. Ponds are also becoming important in Michigan for raising bait minnows for sale to fishermen.

Although much research has been done in other states concerning the production of fish in farm ponds, the differences in length of growing season,

and soil and water fertility in Michigan, make it necessary to establish stocking and management policies applicable to Michigan ponds. The experiments described in this report were designed to evaluate fish stocking combinations, and the role of fertilizer in the management of Michigan ponds.

ACKNOWLEDGMENTS

This work was made possible by a cooperative program between Michigan State College and the Institute for Fisheries Research of the Michigan Department of Conservation. Materials, equipment, and supervision were provided by the College and the Institute gave financial assistance and provided for the use of the hatchery facilities where these experiments were conducted.

The author wishes especially to thank Dr. Robert C. Ball for his guidance and assistance in conducting this investigation, and the Institute for Fisheries Research for making this work possible. The author would also like to express his appreciation to the men of the Wolf Lake State Fish Hatchery for their assistance and cooperation in the management and draining of the experimental ponds.

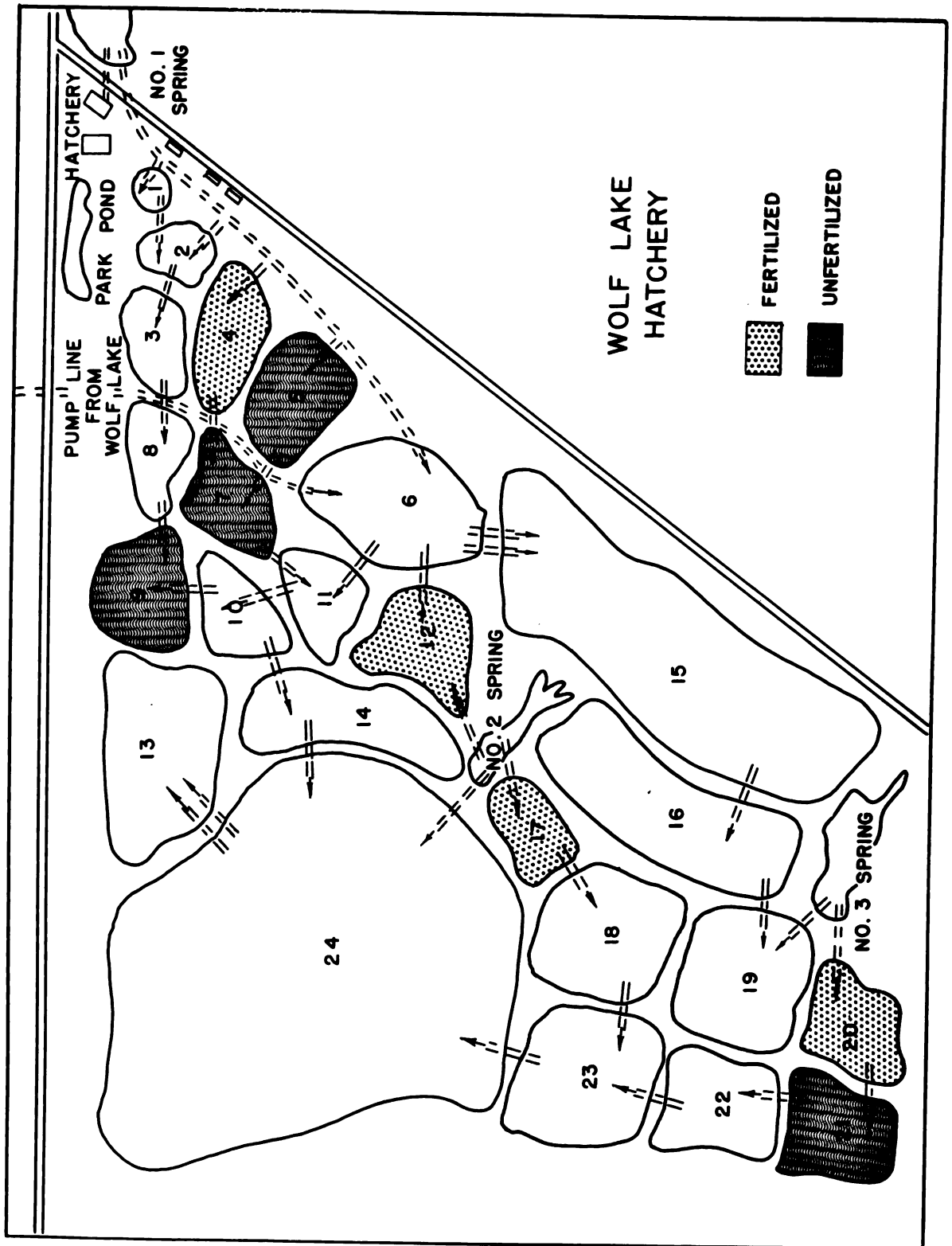
DESCRIPTION OF EXPERIMENTAL PONDS

The experiment described in this report was conducted at Wolf Lake State Fish Hatchery located ten miles west of Kalamazoo, Michigan. Detailed descriptions of the ponds have been given in an earlier publication, Patriarche and Ball (1949) and are only briefly reviewed here.

Three pairs of ponds were selected for this experiment on the basis of similarity of size, basin shape, and bottom type. One of each pair of ponds was fertilized with inorganic fertilizer, and the other served as a control, so that each experimental combination of bass and bluegills could be tested in a fertilized pond and in an unfertilized pond. Figure 1 shows the relative positions, and source water of the ponds at Wolf Lake Hatchery, with fertilized and unfertilized ponds designated.

The water supplying these hatchery ponds comes from three springs and is high in carbonate hardness. Methyl orange alkalinity tests of the springs showed 160 parts per million. Water levels were maintained in the ponds and no water was allowed to overflow

Figure 1. Diagram of Ponds at Wolf Lake State
Fish Hatchery



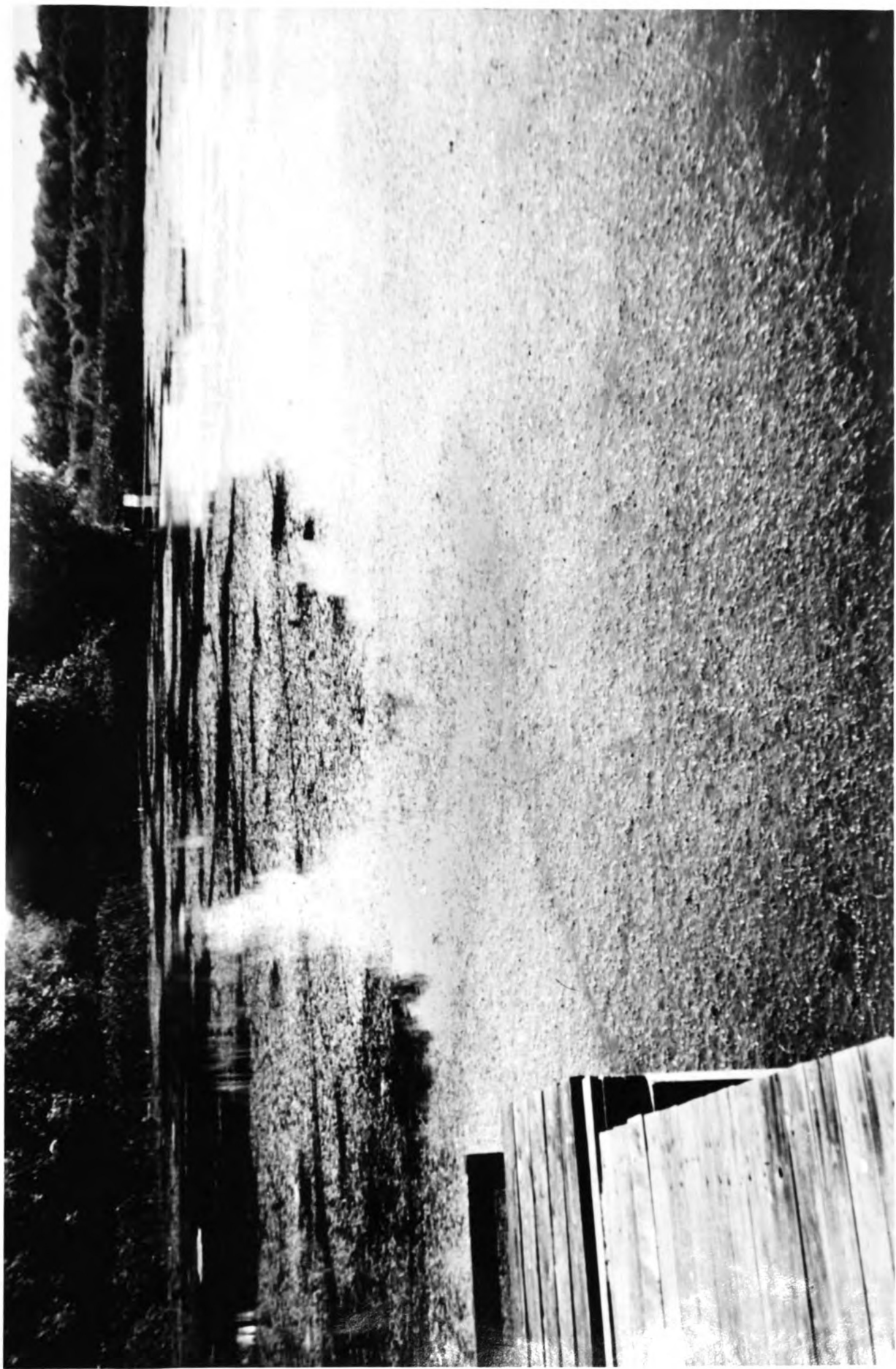
at the outlet. However, in all ponds there was some seepage through the bottom, and loss by evaporation.

The surface area of these ponds ranged from 1.3 acres to 2.3 acres, and the basin of the ponds sloped gradually to a maximum depth of 6 feet at the drainage outlet. The bottom was a mixture of sand and marl with muck in the deepest parts of the ponds.

A filamentous algae mat began to develop on the surface of the fertilized ponds during the first summer of the experiment and on some ponds became more extensive each successive summer.

Submerged higher aquatic vegetation was very abundant in both fertilized and unfertilized ponds at the beginning of the experiment in 1947. Anacharis, Chara, Najas and two species of potamogeton were of major importance in all ponds at first, but as the experiment progressed Anacharis became dominant in the unfertilized ponds. Figure 2 illustrates the very abundant growth of this plant in the unfertilized ponds during late summer. The dominance of vegetation changed in fertilized ponds also, however these changes were associated with fertilization and are described in detail in another section of this report.

Figure 2. Dense Growth of Higher Aquatic Vegetation
in Unfertilized Pond



METHODS AND EQUIPMENT

Stocking Rates

The ponds were stocked with either adult or fingerling bluegills (Lepomis macrochirus) and yearling largemouth black bass (Micropterus salmoides). The bass were stocked on April 15, and the bluegills on May 20, 1947. Table 1 shows the numbers, stocking rates, and the average total length of each species when stocked.

TABLE I
Stocking Data

Pond (Acres)	Species	Total Number	Approx. Number Per Acre	Average Total Length in Inches
20 (1.8)	Bass	345	150	4.1
	Bluegill	41	18	6.5
21 (2.3)	Bass	330	150	4.0
	Bluegill	39	18	6.5
12 (1.8)	Bass	240	150	4.0
	Bluegill	86	50	6.5
7 (1.5)	Bass	225	150	4.0
	Bluegill	76	50	6.5
17 (1.3)	Bass	500	390	4.4
	Bluegill	3,300	2,540	2.7
9 (1.7)	Bass	850	500	4.4
	Bluegill	5,100	3,000	2.7

Fertilization

Commercial inorganic fertilizer was applied at the rate of 100 pounds per acre every three weeks from the middle of May until August 7th, which was approximately three weeks before the ponds were drained.

Several methods of applying fertilizer have been tried for ponds of this type including distribution from a boat, mechanical pumping, and broadcasting by hand (Figure 3). Broadcasting from shore or from a boat rowed around the pond seemed to be efficient methods for these small ponds, however better distribution of fertilizer was possible when the operator waded about the pond with a pail or tub of fertilizer than when the fertilizer was simply thrown from shore. Attempts to obtain a more even coverage by spraying a mixture of fertilizer and water over the pond with a centrifical pump were abandoned when it was found that the sand filler in the fertilizer clogged the pump mechanism.

The commercial fertilizer used in this experiment was of 6-10-4 and 10-6-4 (N-P₂O₅-K₂O) grade. The first figure of this analysis gives the percentage of total nitrogen; the second figure represents the percentage of available phosphoric acid (P₂O₅), and the last figure

represents the percentage of water-soluble potash.(K₂O). 10-6-4 fertilizer was applied during the summers of 1947 and 1948, but became unavailable in 1949. 6-10-4 was used in 1949 instead.

Chemical Methods

The temperature of the water at several stations in each pond was taken at regular intervals with two thermometers, a Taylor Maximum-Minimum, and a pocket thermometer. Figure 4 is a graph of the temperatures recorded during the summer of 1949 in pond 12. The water temperatures of the other experimental ponds did not vary significantly from pond 12.

The dissolved oxygen content, carbon dioxide, methyl orange alkalinity, and pH were also measured at frequent intervals in all ponds in an effort to detect differences among the ponds that could be attributed to fertilization.

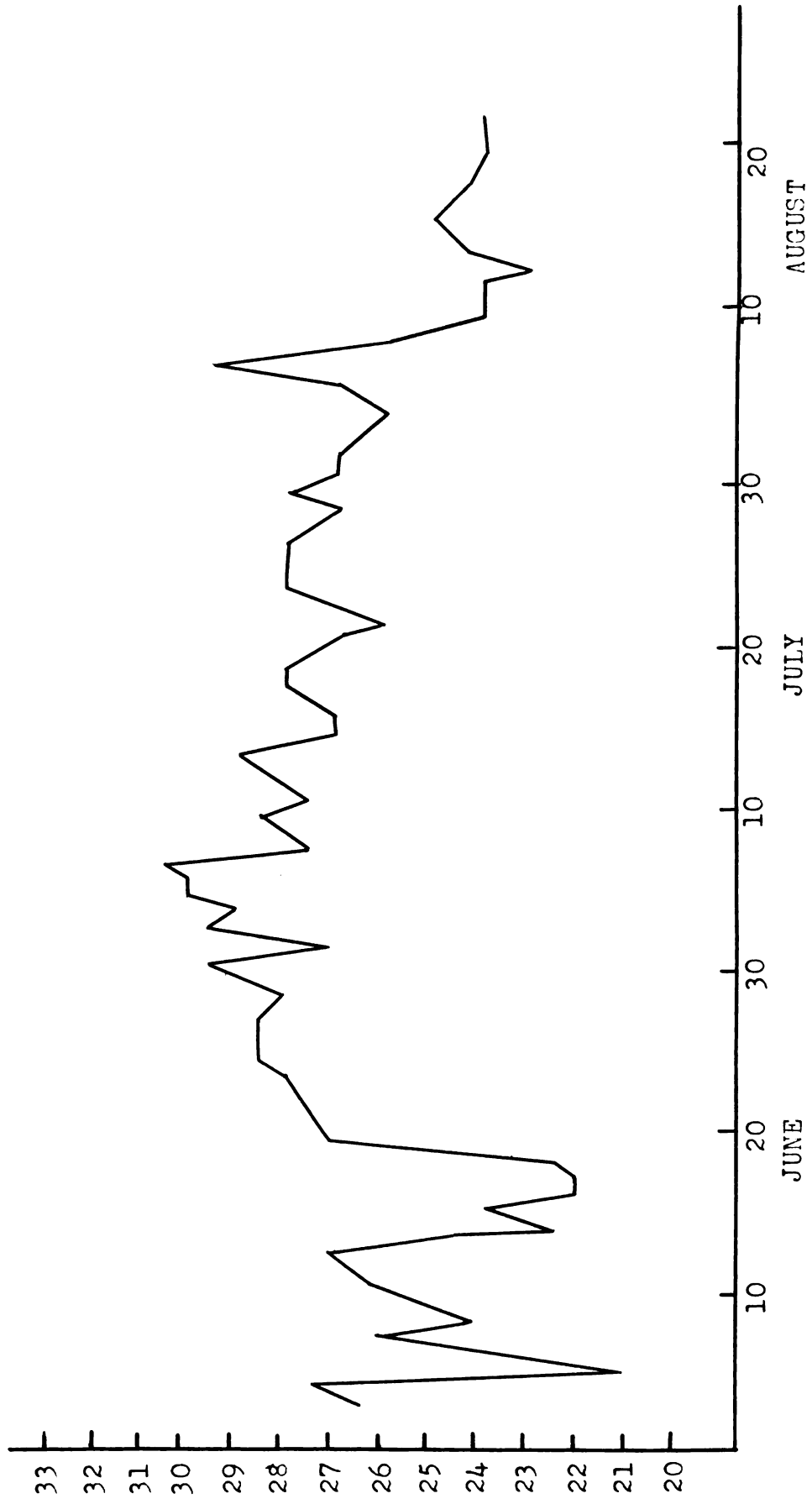
The amounts of free carbon dioxide in the waters of ponds 7, 9, 20, and 21 were high during the month of July, ranging from thirteen to thirty-eight parts per million. A series of measurements of dissolved oxygen content made at various depths showed that during periods of high carbon dioxide oxygen levels at three feet became very

Figure 3 Broadcasting Fertilizer by Hand



Figure 4 Water Temperatures of Pond 12 during the Summer
of 1949

DEGREES
CENTIGRADE



low or disappeared, but remained sufficiently high in the one foot surface stratum to support fish life. High carbon dioxide values and low pH values seemed to be correlated with periods of dark cloudy weather following hot, clear weather.

The chemical data however, did not indicate any particular difference between fertilized and unfertilized ponds.

Draining Operations

Water from these experimental ponds passes from the outlets into concrete seining boxes. The water level is lowered quite slowly during draining operations to allow the fish in the pond to move toward the outlet, particularly in ponds with heavy growths of aquatic plants. In these ponds the vegetation was piled and channeled to facilitate the movement of fish toward the outlet. Even so, some fish were stranded in the masses of vegetation that collapsed as the water receded. The numbers of these fish were estimated by taking several quadrat samples of the pond bottom.

The fish were netted in the seining box below each pond and transferred to tank trucks and then moved to holding tanks in the hatchery. There was often a considerable mortality of young fish caused by changing

them from the relatively warm pond water to the cold water in the holding tanks. The fish killed in this manner were weighed and their numbers estimated and recorded.

Procedure for Measuring Fish

The fish were separated into age groups of each species by their obvious size differences. It was not possible in all cases to separate the young-of-the-year from the yearling bluegills by size, and it was not expedient to age them by examination of the scales. Large samples of individual fish were measured and weighed. Random samples from each age group were counted and weighed, to determine the number of fish per pound, and the number of fish in each age group computed from the total weight.

After all data were taken in 1948 the fish, with the exception of those lost in handling, were returned to the ponds from which they came.

When the ponds were again drained in 1949 the experiments were terminated and the fish were either frozen for later use in processing studies (Ford & Ball, 1951, manuscript), or were used to stock new experimental ponds.

THE INTERRELATIONSHIPS OF LARGEMOUTH BLACK BASS AND BLUEGILLS IN PONDS

Largemouth black bass and bluegills are a desirable combination in farm fish ponds because both species are excellent food and provide sport in fishing for them. A combination of carnivore and forage fish such as the bass-bluegill combination is not only desirable, but is essential if a pond is going to provide an annual usable crop of fish.

Bluegills are prolific and produce far more young than the food supply of a pond will support, and unless bass or other predator species are present will soon overpopulate a pond. Carbine (1941) found in a study of bluegills in a small lake that a pair of spawning bluegills produces an average of 17,000 young per year. Only a few of these can survive in a pond if good growth is to result. Large numbers may exist in a pond, but because of the competition for food none of them grow to a useful size, although they may reach maturity and spawn, thus adding more young bluegills to an already overcrowded pond.

A pond will support only so many pounds of fish, depending on the fertility of the pond and the efficiency with which the species present utilize the food available. This poundage of fish or carrying capacity of the pond,

can be in the form of many small fish that will grow slowly and not reach a desirable size or, if the competition for food is reduced by eliminating a large proportion of the small fish, the remaining fish will grow rapidly and attain a larger size.

The results of several investigations lend support to this concept. Beckman (1941) has described the increased growth rate of fish following a reduction of the population. Experiments with stocking rates of bass and bluegills (Swingle, 1947; Surber, 1947) have shown that the size of bluegills varies inversely with the numbers stocked in a pond.

Largemouth black bass can make good growth with bluegills as forage, and seem to be a good predator fish to stock in ponds, however they may not effectively control the numbers of bluegills if there is an abundance of other foods such as crawfish, tadpoles, and insects present. In ponds filled with higher aquatic vegetation bass may not be able to crop off enough bluegills to meet their food requirements or to control the numbers of bluegills surviving to maturity.

EXPERIMENTAL STOCKING OF ADULT BLUEGILLS AND FINGERLING BLUEGILLS IN COMBINATION WITH LARGEMOUTH BLACK BASS

Several workers have tested various combinations of bass and bluegills to establish stocking recommendations that will give predictable results. Two views however, have been outlined as a result of these experiments. One, that stocking adult bluegills with bass is necessary, and the other that fingerling bluegills best produce the desired population balance.

Bennett, (1944) maintains that a dominant bass population should be built up by stocking bass first and delaying fishing for three or four years for this species.

Ball (1949) discusses the difficulties a pond owner would have in obtaining and identifying bluegill fry and recommends that adult bluegills be used.

Krumholz (1948) generalizing from the results of stocking adult bluegills and bass states that largemouth black bass, although predatory on other fishes by nature, were unable to keep bluegill populations in check.

Surber (1947) tested several ratios of fingerling bluegills to fingerling bass in hardwater ponds and found no significant difference in the production of edible-size fish, but he did note that the lower stocking rates

of his experiments (100 bass and 800 fingerling bluegills per acre) produced the largest fish.

Swingle (1947, 1949) recommends that fingerling bluegills be stocked to provide fishing in one year, and to establish a population balance that will be maintained from year to year. He has also shown that conditions suitable for good bluegill fishing (most of the weight of the population consisting of large bluegills) were not conducive to good bass growth which requires an abundance of small bluegills.

In Michigan, bass and bluegills do not grow nearly as rapidly as reported from Alabama, where four ounce bluegills and one pound bass have been produced in ponds within one year after stocking.

In these experiments in Michigan comparable weights were not reached until after the third growing season of the fish. That is, yearling bass stocked in June, 1947 weighed approximately one pound (fertilized ponds) when the ponds were drained in September, 1948. Only the bluegills originally stocked as adults weighed four ounces or more at any time during this experiment.

Spawning and survival of young of both species in Michigan is uncertain. Probably the greatest difference

of these Michigan waters when compared with the experimental ponds used in Alabama by Swingle is the cumulative effects of lower total heat income to the ponds. The relatively slower growth of bass and bluegills in Michigan may be accredited to the short growing season. Spawning activities are often delayed and the peak of spawning limited to four or five weeks in Michigan ponds by low water temperatures in the spring and summer. This means less food available to predator bass.

In Michigan, much of the fishing is selective for large fish. Fish populations that contain only medium size bluegills and bass are not attractive to fishermen. A pond population that produces a few large bass and bluegills is, in the opinion of many Michigan fishermen, more desirable however unbalanced it may be. Fishermen must be educated to the need for cropping small fish also if fish populations are to be utilized efficiently.

To determine whether fingerling or adult bluegills stocked in combination with fingerling bass would produce best results in Michigan, several ponds at Wolf Lake State Fish Hatchery were stocked with various combinations of bass and bluegills. The ponds were stocked in April and May of 1947 and drained in September of 1948. Data were obtained on the growth and numbers and weights of

fish present and the fish returned to the ponds. The ponds were drained again in September of 1949 to determine what changes had taken place.

Ponds Stocked with Fingerling Bluegills and
Fingerling Largemouth Bass

Pond 9

Pond 9 was stocked with 500 bass fingerlings and 3,000 bluegill fingerlings per acre. The average lengths, and total numbers of fish stocked are summarized in Table 1. This pond supported a very dense growth of aquatic vegetation, chiefly Anacharis, throughout the experiment.

When Pond 9 was drained in September, 1948, there were 460 bass present, which represented 53 per cent of the original number stocked. The bass had grown an average of only 2.6 inches and had not spawned.

Of the 5,100 bluegills originally stocked in 1947, 3,157 or 61.8 per cent had survived. These bluegills did not produce young during the first summer, 1947, with the exception of a few fry seen late in August. However, a great many young bluegills were produced in 1948. The bluegills originally stocked were, on the average, 6.0 inches long when the pond was drained.

When Pond 9 was drained in September 1949, the bass were reduced in number considerably. Only 221 of the 460 present at draining 1948 survived to draining 1949. It can be seen from Table 2 that these bass did not increase much in total length, but did increase considerably in weight. Bass spawned in this pond during 1947 as evidenced by 370 small bass present at draining.

Bluegill survival was poor (34 per cent) during the same period, and the remaining bluegills increased in length and weight only slightly.

This pond produced approximately 255 pounds of edible-size bluegills per acre during the period from June, 1947 to September, 1948. During the following year, however, mortality of bluegills was high and the crop was only 125 pounds per acre. The standing crop of bass in Pond 9 at draining each year was approximately 36 pounds per acre which was the poorest crop of bass of all ponds studied.

Pond 17

Pond 17 was stocked with fingerling bluegills and fingerling bass at approximately the same rate as in pond 9 and was fertilized with 10-6-4 fertilizer.

In July, 1947 many dead fish were observed in this pond, apparently killed by oxygen depletion resulting from

plant decay induced by fertilizer. No accurate estimate of the loss of fish was possible. However, the number of fish present at draining in 1948 reflects this summer-kill.

TABLE II

Growth of Largemouth Black Bass in Ponds Stocked with Adult Bluegills and in Ponds Stocked with Fingerling Bluegills

Pond	Average total length at draining		Weight in pounds per acre	
	1948	1949	1948	1949
Adult Bluegills				
20	11.9	13.1	137.2	131
21	10.6	10.5	88.2	67.5
12	12.1	12.8	91	83.2
7	10.8	11.2	65	63
Fingerling Bluegills				
17	8.0	8.3	43	39.2
9	7.0	8.4	36	36.2

Largemouth bass in Pond 17 made only slightly better growth than bass in Pond 9 even though Pond 17 was fertilized; and had a significant reduction of population due to a summer-kill in 1947.

Only 259 bass survived of the original 500 stocked. A few of these fish evidently became large enough to spawn for there were 133 bass fingerlings present when the pond was drained.

The summer-kill apparently reduced the original bluegills drastically, for only 713, or 21.7 per cent of the original number, were left when the pond was drained. All of these fish were of edible-size, but were not significantly larger than bluegills from Pond 9.

The original bluegills produced only a very few young during 1947, the first year in the pond, but produced many during the second summer (1948).

Examination of the fish when removed from the pond in September, 1949 revealed that the bass population had been further reduced in number, but the individual bass had increased slightly in length and weight so that the total weight of bass in the ponds was about the same as the previous year.

The survival of bass in pond 17 from September, 1948 to draining in September, 1949 was poor, for only

168 remained of 259 large bass that were present the previous September.

The bluegill population in the pond consisted of three size groups, indicating that spawning had been successful both in 1948 and in 1949. However, there was also a heavy mortality of bluegills of all sizes with the result that the total weight present at draining in 1949 was less than the weight in 1948.

It is apparent that bass and bluegills stocked at the rate of 500 bass and 3,000 bluegills per acre did not produce good results under the conditions of this experiment. The poor results may be attributed to several conditions.

- a. Too many fingerlings of both species were stocked. This is probably the chief contributing factor to the poor growth of both species.
- b. Food was unavailable to bass because of the very dense growths of aquatic plants in these ponds.
- c. The lack of small bluegills for bass forage during the summer of 1947 before the bluegill fingerlings matured and spawned.

The value of this combination was obscured by the high summer mortality that occurred in 1947. In general it was not a desirable combination, but in these two ponds stocked with fingerling bluegills, bluegills suitable for table use were available during the second summer. In

contrast, ponds stocked with bass and adult bluegills did not produce edible-size bluegills until the third summer of pond operation.

Ponds Stocked with Adult Bluegills and Fingerling
Largemouth Bass

Pond 7

Pond 7 was stocked with 150 largemouth bass fingerlings per acre and 50 adult bluegills per acre and was not fertilized. Heavy growths of aquatic plants were present in this pond throughout the experiment.

By 1948, 158 largemouth bass survived (.70 per cent) and grew from average 4.05 to 10.8 inches or an average gain of 6.3 inches, and all were of edible-size. These bass spawned during 1948 and 763 young survived to draining time.

Of the 76 adult bluegills stocked, 24 or (31 per cent) survived. They grew from a 6.5 inch average to 9.2 inches or an average gain of 2.7 inches. These bluegills spawned during 1947 and 1948. No attempt was made to separate yearlings and young-of-the-year bluegills as there was considerable overlap of the size ranges of the two groups.

There were three size groups present of both species, young-of-the-year, yearlings, and adults. The large bass were those originally stocked in the pond, but the original adult bluegills had disappeared, the largest bluegills present being those spawned during the summer of 1947.

Both species made good growth in the period between drainings of the pond, and provided a good crop of edible-size bass and bluegills. There were approximately 63 pounds of large bass and 100 pounds of edible-size bluegills per acre present when this pond was drained.

Pond 12

Pond 12 was stocked with 150 largemouth bass and 50 adult bluegills per acre, and fertilized with 6-10-4 fertilizer. (at the rate of 100 pounds per acre every three weeks) At the beginning of the experiment plants grew luxuriously in this pond, but were considerably reduced by the filamentous algae which resulted from fertilization.

This pond produced bass averaging slightly more than one pound each after being in the pond from June, 1947 to September, 1948, which was the best growth recorded for bass in this experiment.

Adult bluegills spawned in 1947 and 1948 established a bluegill population of three size groups. Small,

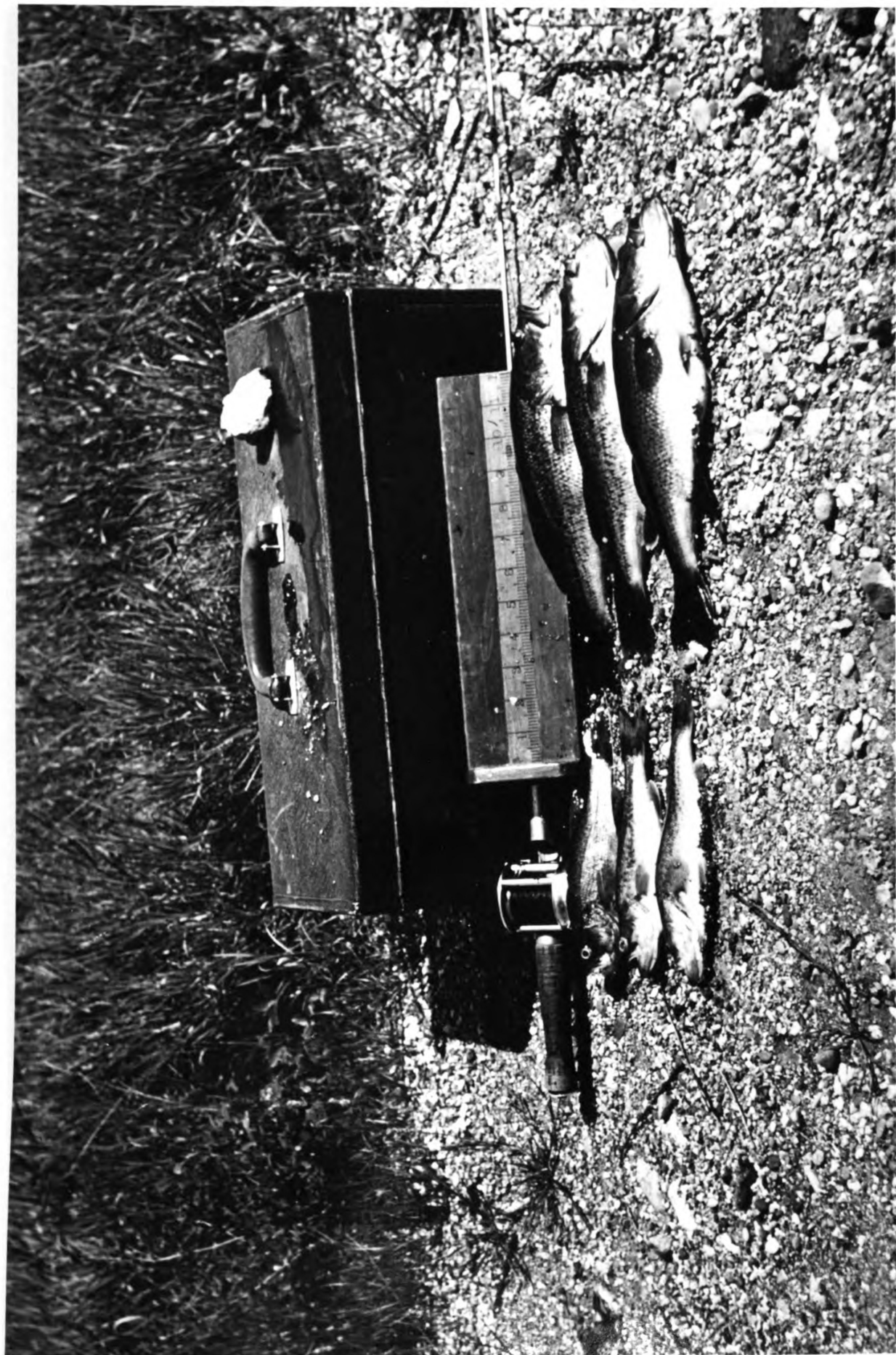
intermediate, and large bluegills were present when the pond was drained in 1948, indicating at that time that spawning and survival of young bluegills was adequate to maintain the population, but draining of the pond in September, 1949 did not support this conclusion.

Small, intermediate, and large bass were present when the pond was drained in 1949, and all size groups had made good growth, however, the bluegill population consisted entirely of large bluegills. This is presumed to be a result of bass predation on young bluegills as there was very little vegetation present in this pond.

This combination of fingerling bass and adult bluegills stocked at the rate of 150 bass and 50 bluegills per acre is apparently more satisfactory than stocking fingerlings of both species if large bass are desired, but not if edible-size bluegills are wanted the first year. The significant difference in the size of bass from these ponds in 1948, is illustrated by Figure 5 which shows individual fish representing the average from pond 17 and the average from Pond 12.

Figure 5 Samples from Pond 17 (left) and Pond 12 (right)
Representing the Average Size of Largemouth Bass
at Draining, 1949

light
Bas



Ponds 20 and 21

Ponds 20 and 21 were stocked originally with approximately 150 largemouth bass and 18 adult bluegills per acre, but during the summer of 1947 a few of each species escaped from pond 20 into pond 21 through a defective screen.

Pond 21 was not fertilized except that some water from pond 20, which was fertilized, was released into pond 21 to maintain the water level. Pond 21 had a very dense growth of aquatic plants, chiefly Najas and Chara, during the experiment.

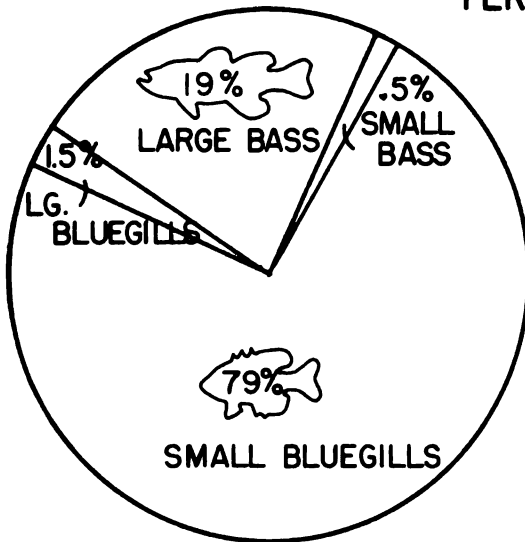
Pond 20 also had an abundant growth of higher aquatic plants, and in addition a thick filamentous algae mat covered progressively more of the pond each summer of the experiment.

Pond 20 produced the greatest poundage of fish of this experiment, yielding approximately 720 pounds per acre when the pond was drained in 1948. Bass had made good growth in this pond and produced young in 1948. The bulk of the population consisted of small bluegills ranging in size from 1.5 to 4.1 inches.

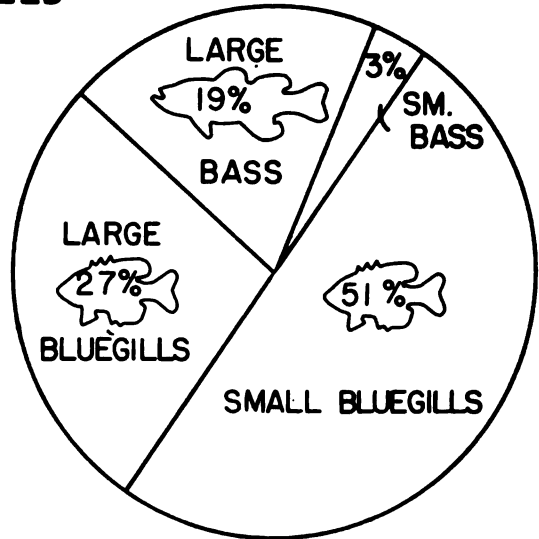
The population in pond 21 was similar to that in pond 20 in that both species had reproduced and the percentage by weight composition was about the same (Figure 6).

Figure 6 Composition of Fish Populations in Successive
Years in Fertilized and Unfertilized Ponds
Stocked with Fingerling Largemouth Bass and
Adult Bluegills.

POND 20
FERTILIZED



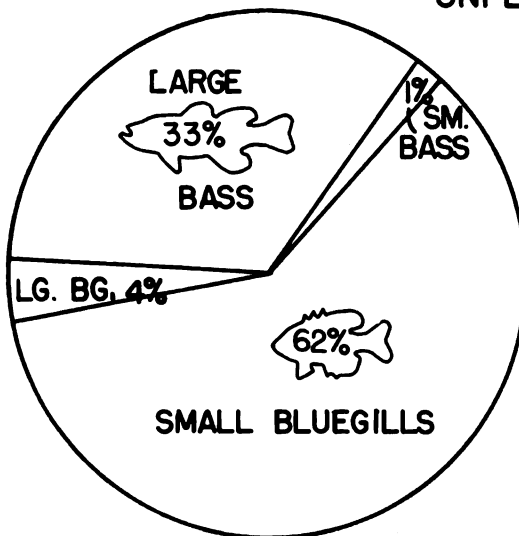
1948



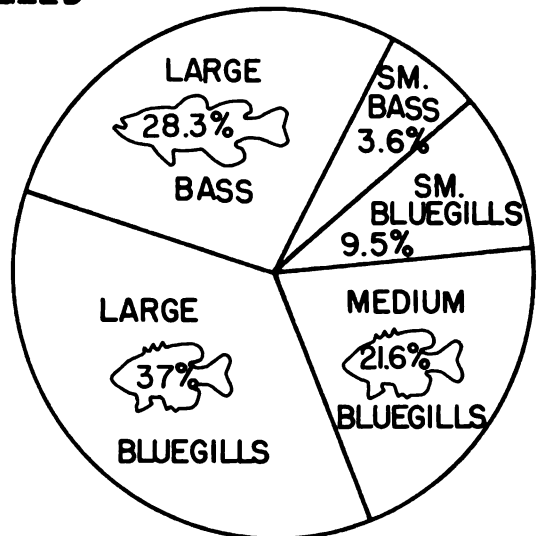
1949

PERCENT BY WEIGHT

POND 21
UNFERTILIZED



1948



1949

However, the bass in pond 21 had not grown as rapidly, and the total weight of fish was considerably less than in pond 20.

Again in 1949, Pond 20 (fertilized) produced the greatest weight in pounds per acre of all ponds studied, and comparatively the production in Pond 21 (unfertilized) was poor. The composition of the populations in pond 20 and pond 21 were similar with respect to percentage by weight, but the bass in pond 21 were in very poor condition, having lost weight during the period between pond drainings.

The combination of 150 fingerling largemouth bass and 18 adult bluegills tested in two ponds produced a satisfactory population composition and maximum yield in the fertilized pond, and a population of emaciated fish in the unfertilized pond. This combination then, was not satisfactory in an unfertilized pond that was filled with higher aquatic plants. Eighteen adult bluegills per acre were sufficient to establish a bluegill population in these ponds.

FISH POPULATION BALANCE IN EXPERIMENTAL PONDS

Several criteria have been developed by H. S. Swingle (1950) for judging fish population balance. These criteria were developed after examining the results of many experiments with pond fishes and therefore were considered as a means of evaluating the populations of the experimental ponds with which this present report is concerned.

Swingle described a balanced fish population as one that yields, year after year, crops of harvestable fish that are satisfactory in amount when the basic fertilities of the bodies of water containing these populations are considered. Ability of the species within the population to reproduce, and control of the numbers of fish by carnivorous species are also necessary in a balanced population. The interrelationships between the various groups of fish in a balanced population are discussed at some length in Swingle's excellent paper. In the following section the relationships or criteria of pond balance proposed by Swingle are reviewed and applied to the data concerning the populations of fish in these experimental ponds in Michigan to further evaluate the various combinations of bass and bluegills tested.

The F/C Ratio

This is the ratio of the total weight of all forage fishes to the total weight of all carnivorous fishes in a population.

Bass are the carnivorous component and bluegills the forage component in a bass-bluegill combination such as was stocked in these Michigan ponds. Swingle found the desirable range for F/C values to be between 3.0 and 6.0 with values below 2.0 indicating overcrowding of bass and values above 10.0 indicating a large population of medium and small bluegills.

The F/C values and other relationships for the populations from Wolf Lake ponds are summarized in Table 3. Judged by F/C ratios alone most of the ponds were crowded with bass, with the exception of ponds 9 and 20. Figures 6, 7 and 8 also show the composition of the populations from these ponds by percentage of total weight. F/C ratios are well worth considering, for when carnivorous species are overcrowded predation on forage species is excessive and not enough small forage fish escape to replace adults as they are removed. The low F/C ratio of pond 12 during 1948 and 1949 indicates that this pond was overcrowded with bass. No small bluegills were among

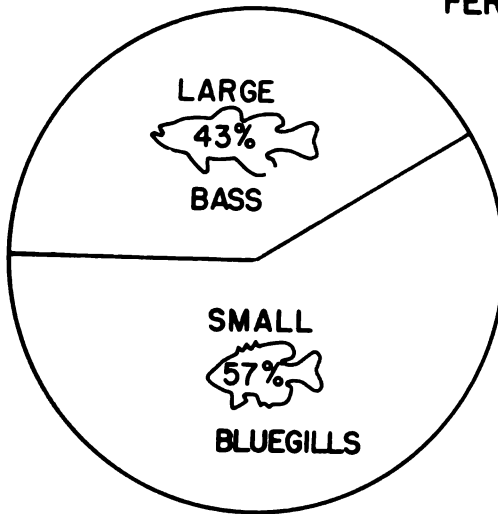
TABLE III

Relationships Between Species and Between Groups in
Fish Populations in Experimental Ponds in Michigan

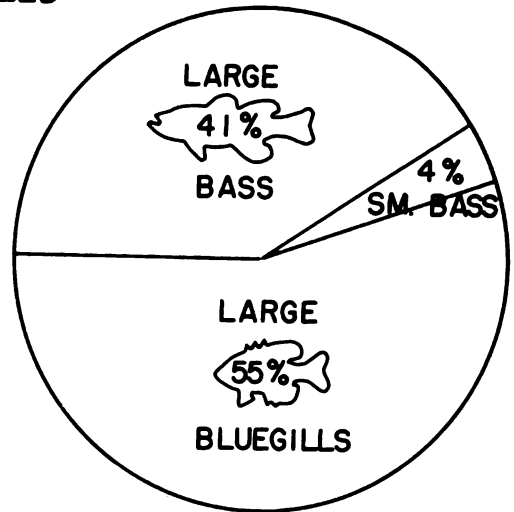
Pond	Year	F/C	Y/C	At	E Values		A	I	S
		Ratio	Ratio	Value	Bass	Bluegill	Bluegill	Values	
20	1948	4.0	4.0	20.3	19.8	80.2	1.6		98.4
	1949	3.5	2.2	46.2	22.6	77.4	34.5	65.5	
21	1948	2.0	1.7	36.6	34.8	65.1	5.3		94.7
	1949	2.0	.3	62.5	32.0	67.9	54.3	31.7	14.0
12	1948	1.5	1.3	43.0	43.0	57.3	.5		99.5
	1949	1.5	...	96.2	44.7	55.3	100.0		
7	1948	3.0	2.8	28.7	25.6	74.4	4.2		95.8
	1949	1.3	.1	77.1	45.7	54.3	80.1	13.5	6.4
17	1948	3.0	1.3	68.3	22.6	77.4	59.5		40.5
	1949	2.0	1.0	66.8	32.2	67.8	25.5	26.9	47.6
9	1948	9.0	2.4	67.2	9.6	90.3	74.4		25.6
	1949	4.0	.5	85.6	20.4	79.6	80.0	8.3	11.7

Figure 7 Composition of Fish Populations in Successive
Years in Fertilized and Unfertilized Ponds Stocked
With Fingerling Largemouth Bass and Adult
Bluegills

POND 12
FERTILIZED



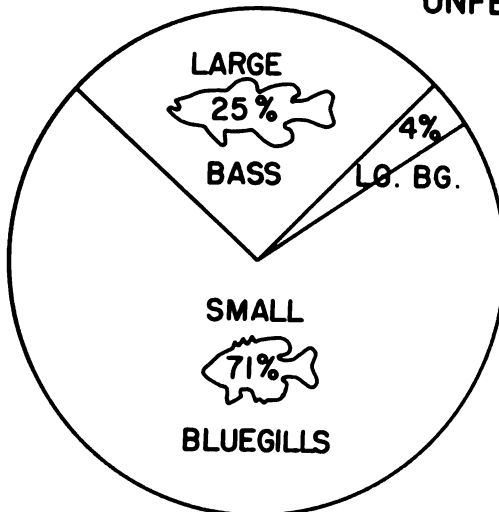
1948



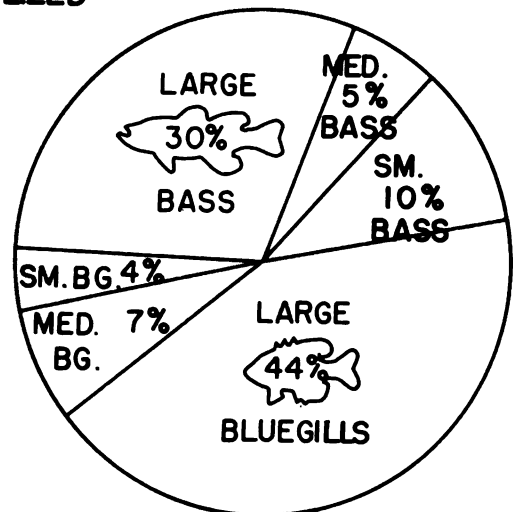
1949

PERCENT BY WEIGHT

POND 7
UNFERTILIZED



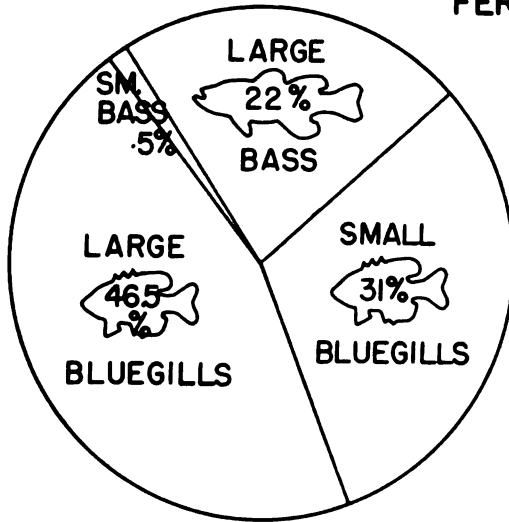
1948



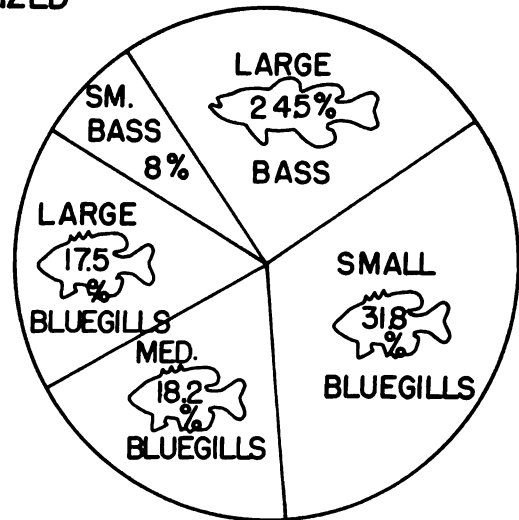
1949

Figure 8 Composition of Fish Populations in Successive
Years in Fertilized and Unfertilized Ponds Stocked
with Fingerling Largemouth Bass and Fingerling
Bluegills

POND 17
FERTILIZED



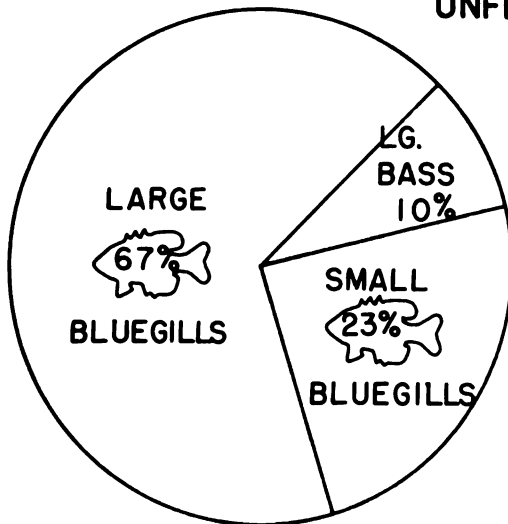
1948



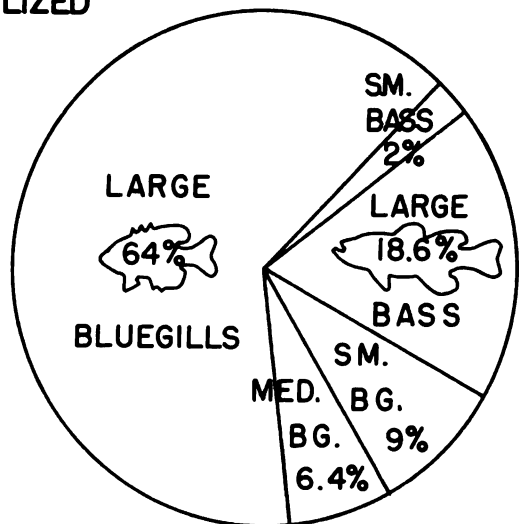
1949

PERCENT BY WEIGHT

POND 9
UNFERTILIZED



1948



1949

the fish present at draining in 1949 and it is assumed that this was due to the overcrowding of bass.

The Y/C Ratio

The Y/C ratio as defined by Swingle equals the Y value, or the total weight in ponds of all those individuals in the "F" group that are small enough to be eaten by the average-sized adult in the "C" species in a population. In this present experiment bluegills that were two to three inches long and numbered one hundred or more per pound were considered to be small enough to be eaten by the bass. This is quite arbitrary, because the maximum size bluegill that could be swallowed by the largest bass in these ponds was not determined.

Swingle found that Y/C ratios in balanced ponds ranged from 0.02 to 4.8 and that between 0.02 to 0.5 all populations were so severely overcrowded with "C" species that they probably should be considered "temporarily balanced" because the bass were unable to gain weight and in fact lost weight, while insufficient numbers of bluegills were surviving to utilize available food. This situation existed in pond 21 of this experiment which had a Y/C ratio of .3 at draining in 1949 and in which the bass lost weight. However, each year there were many

small bluegills present when this pond was drained indicating that some other factor was operating to prevent good growth of the bass. In this pond heavy growths of aquatic vegetation were probably a contributing factor to the poor condition of the bass.

The condition of the population of Pond 20 as indicated by Y/C ratios of 4.0 in 1948 and 2.2 at draining 1949 should be considered to be balanced. The Y/C ratios of other pond populations fell below the desirable range of 1.0-3.0 recommended by Swingle. By his standards these ponds would be considered to be overcrowded with bass. In all ponds studied the Y/C ratios were considerably less at draining in 1949 than at draining the previous year.

The A_t Value

The A_t value (total availability value) is defined as the percentage of the total weight of a fish population composed of harvestable size fish.

In this experiment 8.3 inches for bass and 5.0 inches for bluegills were considered to be minimal sizes in considering harvestable fish. The A_t values for these ponds therefore, are not strictly comparable with the A_t values

given by Swingle who used minimum sizes of .4 pounds for bass and .1 pounds for bluegills. This change of standards for minimum harvestable size for Michigan experimental ponds was made so as to include some fish that did not quite reach the minimum of .1 or .4 pound and yet seemed worth cleaning for table use.

All ponds originally stocked with adult bluegills had A_t values in the inefficient or unbalanced range when the populations were examined in 1948. As would be expected since no cropping of large fish was done, the A_t values increased in 1949.

In ponds 9 and 17, originally stocked with fingerling bluegills, high A_t values in 1948 reflect the large crop of harvestable bluegills that were present.

The A_t value 96.2 of pond 12 in 1949 is an indication of the overcrowding of this pond with bass.

The E Values

The E value of a species or group is the percentage of weight of the entire population composed of that species or group.

Swingle found that the average E values in twenty-six balanced populations containing only bluegills and

largemouth bass were 22.8 for bass and 77.2 for bluegills. E values for these experimental ponds in Michigan are also listed in Table III. Pond 20, E values were very close to the optimum listed above, while E values for bass from Ponds 7, 12, and 21 were higher than the proposed desirable range for balanced populations. E values seemed to be fairly stable from year to year for these ponds.

A, I, and S Values

In his study of the relationships between various groups within a species Swingle defined A, I, and S values as the percentage of the total weight of a species consisting of large, intermediate, and small fish respectively. Large fish are those of harvestable or edible-size, and intermediate are those which escape predation by bass and are available to replace large fish as they are removed. Small fish are those fish small enough to be eaten by the large bass and are usually young-of-the-year.

The most desirable part of the range of A values for bluegills in balanced populations as recommended by Swingle was from 60 to 80, and the minimum value was 35.5. It can be seen from Table III that A values for bluegills in these Michigan ponds ranged from .5 to 100 per cent.

A values for these ponds changed considerably from 1948 to 1949. Ponds 21, 7, and 9, all unfertilized, were the only ponds which had A values within the desired part of the range from 60 to 80.

In both balanced and unbalanced ponds Swingle found that the intermediate group of bluegills normally made up less than 7 per cent of the total weight. No intermediate size bluegills were present in any of the Michigan ponds at draining in 1948. In the ponds originally stocked with adult bluegills the spawn of 1947 and 1948 were not yet large enough to be considered as intermediate. In the ponds originally stocked with fingerling bluegills, fingerlings had grown beyond the intermediate stage and were all considered as large. I values were high for most ponds at draining in 1949 indicating that too many bluegills were surviving bass predation.

S values for bluegills were given by Swingle as being most desirable between 15 and 40 with values in excess of 60 unsatisfactory and values less than 10. indicating that the ponds were overcrowded with bass.

The Michigan ponds originally stocked with adult bluegills had excessively high S values for bluegills when the ponds were drained in 1948 and very low values when the ponds were drained in 1949. In the ponds stocked

with fingerling bluegills the S values for bluegills did not change much from 1948 to 1949 and were approximately within the desired range of 15 to 40 each year.

THE EFFECTS OF VEGETATION ON THE SURVIVAL
OF YOUNG-OF-THE-YEAR BLUEGILLS

Fertilization affects the dynamics of a bass-bluegill population by increasing the fish-food organisms, and by altering the habitat of the fish. Patriarche and Ball (1949) and others, have shown that the application of fertilizer in proper amounts will increase the standing crop of fish food organisms. Swingle (1949) found in experiments in southern ponds that fertilization alters the habitat of pond fishes by killing higher aquatic vegetation, and that this reduces the cover for young bluegills. As a result, the largemouth bass are able to reduce the population of young fish to the extent that most of the weight of bluegills is in the form of large fish.

The populations of fish from the experimental ponds at Wolf Lake Hatchery were examined to compare the abundance of young-of-the-year bluegills in ponds having several different densities of vegetation. Under the conditions of this experiment no particular survival trends were noted. The data from these ponds are somewhat contradictory and are presented (Table IV) to show the survival of young bluegills under variable conditions of vegetative cover.

TABLE IV

Number of Young-of-the-Year Bluegills
per Acre at Draining in Successive
Years

Pond	1948		1949	
	Density of Vegetation	Number of Bluegills	Density of Vegetation	Number of Bluegills
20	Moderate	91,591	Moderate	0
21	Heavy	29,408	Heavy	2,826
7	Heavy	28,788	Heavy	1,584
12	Moderate	5,609	Scarce	0
9	Very Heavy	12,410	Heavy	7,470
17	Heavy	33,380	Heavy	2,335

In pond 12, which had a considerable reduction of aquatic plants following fertilization, there was an excellent survival of young bluegills one year and none the next year. Pond 20, with a partial plant density reduction after fertilization produced large numbers of small bluegills in 1948 but not in 1949. Similarly, in pond 21, which remained almost filled with aquatic vegetation during the same period, a large percentage of the total weight of fish was in small bluegills only one

year. It can be seen from the above table that ponds with similar densities of vegetation showed considerable variation in the number of young bluegills present at draining.

In all ponds, both fertilized and unfertilized, there was a much smaller proportion of young-of-the-year bluegills present at draining in 1949 than in 1948. The near absence of young bluegills in some ponds may have been due to poor spawning conditions during 1949. Occasionally in Michigan bluegills fail to spawn in lakes and ponds, possibly due to low water temperatures. During 1950, for example, cool temperatures prevailed throughout most of the summer, and production of young bluegills was reported to be poor in many sections of the state.

Tadpoles and crayfish were very abundant in these ponds during the summer of 1948, but not in 1949. These organisms are bass food and undoubtedly served as a buffer to effective control of small bluegills by bass.

CROPPING OF FISH IN EXPERIMENTAL PONDS

There was no cropping of fish from these ponds during the experiment except for the loss of small bluegills which occurred each year when the ponds were drained.

Table V shows the weight of fish at draining in 1948, the fish lost in handling, and the weight of fish at draining in the fall of 1949.

TABLE V

Weight of Fish at Draining in Successive Years

Pond	Total Weight of Fish at Draining 1948 (Pounds)	Weight of Fish Lost At Draining (Pounds)	Weight of Fish Restocked in Pond (Pounds)	Total Weight of Fish at Draining 1949 (Pounds)
20	1298	520	778	1209
21	611.5	179.5	432	546.5
12	385.5	88.7	296.8	366.8
7	382.5	58.6	323.9	315

By draining time 1949 the total weight of fish in each pond was nearly equal to the weight present before the mortality occurred in 1948. Therefore, the weight present in each pond in 1948 can be presumed to be the carrying capacity of that pond. Krumholz (1948) has

suggested that the term carrying capacity should signify the upper limit of the weight of a species or combination of species that can be supported by a body of water over an extended period of time.

INCREASING POND PRODUCTIVITY BY THE USE OF FERTILIZER

It has been shown repeatedly that the application of fertilizers will increase the numbers and weight of fish that a pond will produce. The extensive research of Swingle (1947) in Alabama, Surber (1943) in Virginia, and many others has shown that an increased production of fish resulted when nutrients were added to ponds. The method of fertilizing and the results obtained vary with the locality under observation. Similarly, the mechanism by which added nutrients increase productivity has been interpreted differently by each of several authors. Not all localities are infertile to the extent that fertilization is needed. Bennett (1943) found that many small artificial lakes in Illinois were naturally fertile, and concluded that increasing production in those lakes by fertilization was not justified.

This variability in results of fertilization in various localities prompted the testing of fertilization as a means of increasing production in Michigan Ponds.

Comparison of The Yield of Fish From Fertilized and Unfertilized Ponds

Ball (1949) compared fertilized and unfertilized ponds in Michigan and reported significant differences

in the abundance of fish-food organisms, and some evidence of greater production of fish, attributable to the addition of fertilizer.

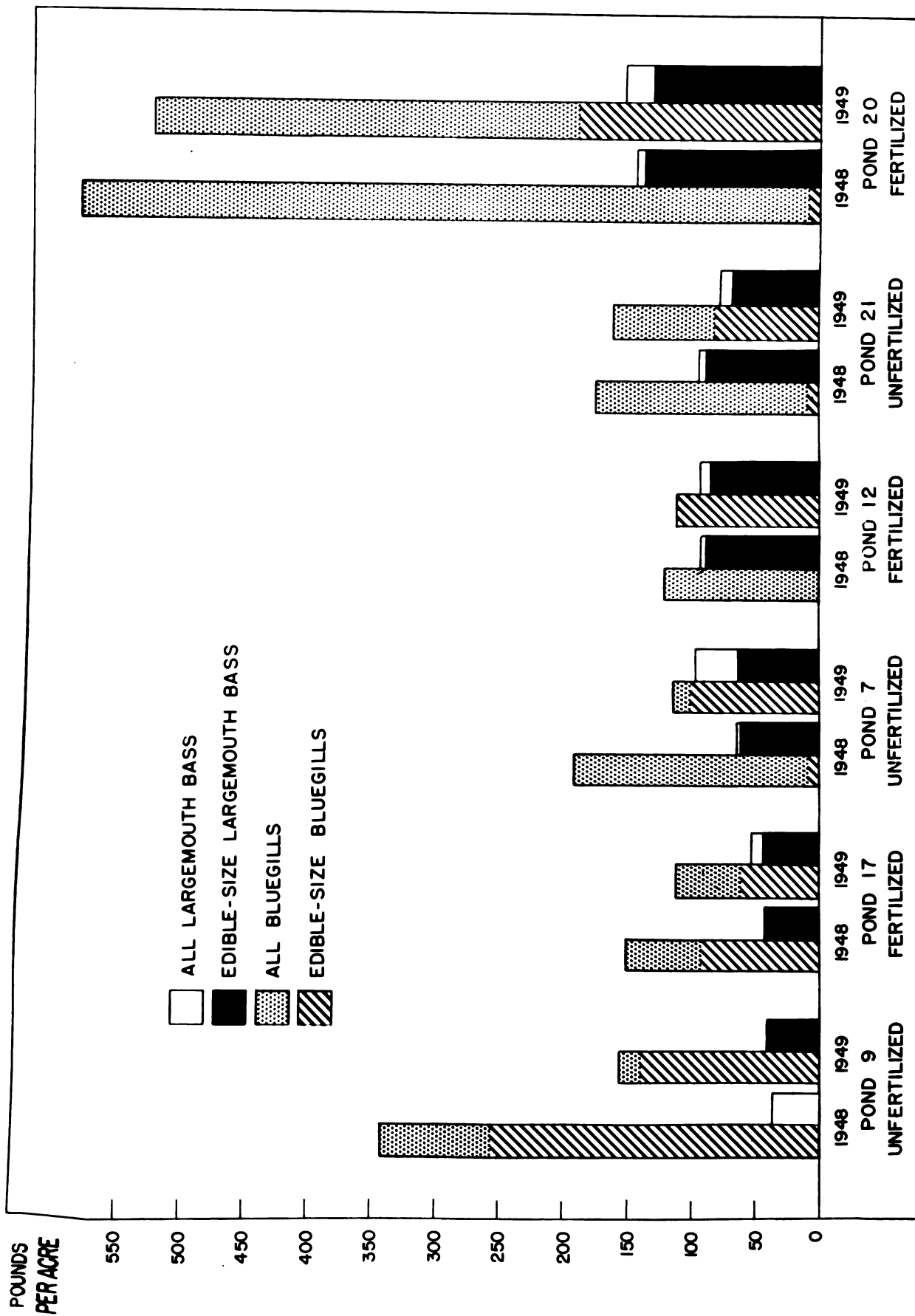
In this present experiment the evaluation of the addition of fertilizer in producing more fish in Michigan ponds is continued. Each combination of bass and bluegills previously described was tested in a pond fertilized with commercial inorganic fertilizer and also in a pond that received no fertilizer.

A summary of the total weight in pounds per acre of each species and the weight of edible-size fish for each pond is given in Figure 9. The total weight in pounds per acre for all fish in the ponds each year at draining were as follows:

Year	20 (Fert.)	21	12 (Fert.)	7	17 (Fert.)	9
1948	721	266	214	256	193	379
1949	669	237	203	209	194	196

The total yield for fertilized ponds ranged from 193 to 721 pounds per acre and for unfertilized ponds from 196 to 379 pounds per acre. When each pair of ponds is considered separately there appears to be no significant

Figure 9 Standing Crop of Bass and Bluegills in
Experimental Ponds at Draining in Successive
Years



difference demonstrated between the yields of fertilized and unfertilized ponds with the exception of Ponds 20 and 21. The figures listed for ponds 9 and 17 are not comparable because of the heavy kill of fish in pond 17 during the summer of 1947.

Cost of Fertilizer in Relation to Increased
Yield of Edible-Size Fish

In considering the cost of an increased yield of edible fish it is assumed that the fish will be cropped effectively by the pond owner. There is little value in an increased poundage of fish if it is not utilized. During this experiment the total amount of fertilizer used, and the weight of fish produced in the ponds was recorded in an attempt to assign a cost to any increased yield due to fertilization.

The total amount of fertilizer applied to each pond and the yields of fish when the ponds were drained were as follows:

Pond	Total Pounds of Fertilizer Applied in Three Years	Yield of Edible- Size Fish in Pounds per Acre	Cost of Increased Yield per Pound of Fish
20	3,640	310.2	\$1.78
21	0	148.4	
12	2,920	195.9	\$2.14
7	0	161.9	

The total weights of edible-size fish in the ponds were determined three years after the fish were stocked. Bluegills 5.0 inches total length, and largemouth black bass 7.3 inches were considered to be the smallest of those fish present to be worth cleaning. The greater weight of edible-size fish in the fertilized pond compared with the unfertilized pond was considered as an increased yield due to fertilizer. The data presented included only the total cost of fertilizer at \$50 per ton with no consideration of the cost of applying the fertilizer. The labor cost figured at one dollar per hour was approximately \$21 per acre for the three years. The cost per pound of edible-size fish was based on the standing crop of fish at the end of the third year and does not take into account the possible residual effects of the fertilizer, or is it representative of a fish population from which an annual increment was harvested. The cost of producing these fish in terms of fertilizer applied would have been less if that cost had been computed for the standing crop at the end of the second year when the ponds apparently reached carrying capacity.

In September 1948, the second year of this experiment, the ponds were drained and data obtained on the fish

populations present. Surber (1943) suggested that nutrient materials were tied up in higher aquatic vegetation and that plant decay released nutrients into the water, which stimulated the development of certain kinds of algae, such as Spirogyra, Ocellularia, and the water-bloom types. In this experiment some types of higher aquatic vegetation and the filamentous algae in the fertilized ponds were in an advanced state of decay when the ponds were drained. With the loss of fertilized water and subsequent refilling of the ponds with spring water some of the nutrient materials were probably lost.

Fertilizer may have a residual effect for several years following fertilization. However, no attempt was made in this experiment to evaluate any later effects of the fertilizer. Swingle (1947) found that relatively good growths of phytoplankton were maintained after fertilization was discontinued, but fish production did not remain at a high level.

These data indicate that under the conditions of this experiment the costs of producing an increased poundage of fish by fertilizer are prohibitive.

The Effects of Fertilizer on Higher Aquatic Vegetation

Swingle (1947) found in experiments in southern ponds that fertilization killed higher aquatic vegetation by producing filamentous algae which covered the plants and shaded them. Plankton blooms resulted from the nutrients released by the decaying higher aquatic plants. Surber (1943) suggested that water blooms could not be produced merely by fertilization, but were associated with plant decay.

Without exception in these experiments conducted in Michigan plankton blooms have not been produced or higher aquatic vegetation eliminated by fertilization in ponds that supported dense growths of higher aquatic vegetation. Several different rates of application of inorganic fertilizer were tried in these experiments, and the earliest date of application was also varied, but in all cases filamentous algae grew when higher aquatic vegetation was present.

The effects of the filamentous algae on the vegetation were not the same in all ponds, and did not affect all species of higher aquatic vegetation the same. The broad-leaved potamogetons which grew abundantly before fertilization were readily killed by the filamentous algal

mat, but remained erect in the ponds until late in August. Anacharis and Chara were not killed by filamentous algae, but seemed to flourish in spite of it. In pond 17, which was fertilized with 100 pounds of 10-6-4 fertilizer every three weeks, filamentous algae covered most of the surface by the middle of June and clung to the leaves and stems of Anacharis throughout the summer, but did not kill it.

Pond 12, which was fertilized at the same rate, developed a more extensive algal mat each succeeding year, but enough higher aquatic vegetation remained throughout the summer to interfere with fishing. An algal mat, such as shown in Figure 10 was formed early each summer and completely covered the pond by August. Wind tended to break up the solid mat and push it into the corner of the pond.

Plankton blooms were produced and maintained by fertilizer in ponds that had no vegetation at the inception of the experiment. In these ponds, once higher aquatic vegetation gained a foothold, plankton blooms could not be produced by the addition of fertilizer.

Ponds 4 and 5 were treated with Bentonite to control bottom seepage, and were completely void of higher aquatic vegetation at the beginning of this experiment. Pond 4

Figure 10 Filamentous Algae Mat on the Surface of
A Fertilized Pond



was fertilized with 100 pounds of 6-10-4 per acre every three weeks during the summer. Heavy plankton blooms were produced in this pond until the third summer of operation, when Chara became well established, but could not be produced thereafter. Pond 5, which served as a control and received no fertilizer, did not have a plankton bloom at any time. Chara became established in this pond also during the third summer.

These data and observations on other ponds support the view of Hasler and Jones (1949) that dense growths of large aquatic plants have an inhibiting effect upon phytoplankton.

It is desirable to produce a phytoplankton bloom rather than filamentous algae for several reasons. In the first place, the decay of filamentous algae and those plants affected by the algal mat may exhaust the dissolved oxygen in the pond and result in a summer kill of fish. Secondly, the algal mat interferes with fishing and rowing on the pond. Also, in this experiment it was much easier to drain and recover fish from ponds in which heavy plankton blooms were maintained. Figure 11 shows this type of pond at the completion of draining operations. This pond was drained rapidly with little loss of fish by stranding. In ponds that supported dense growths of plants, draining

Figure 11 Draining Operations of a Fertilized Pond



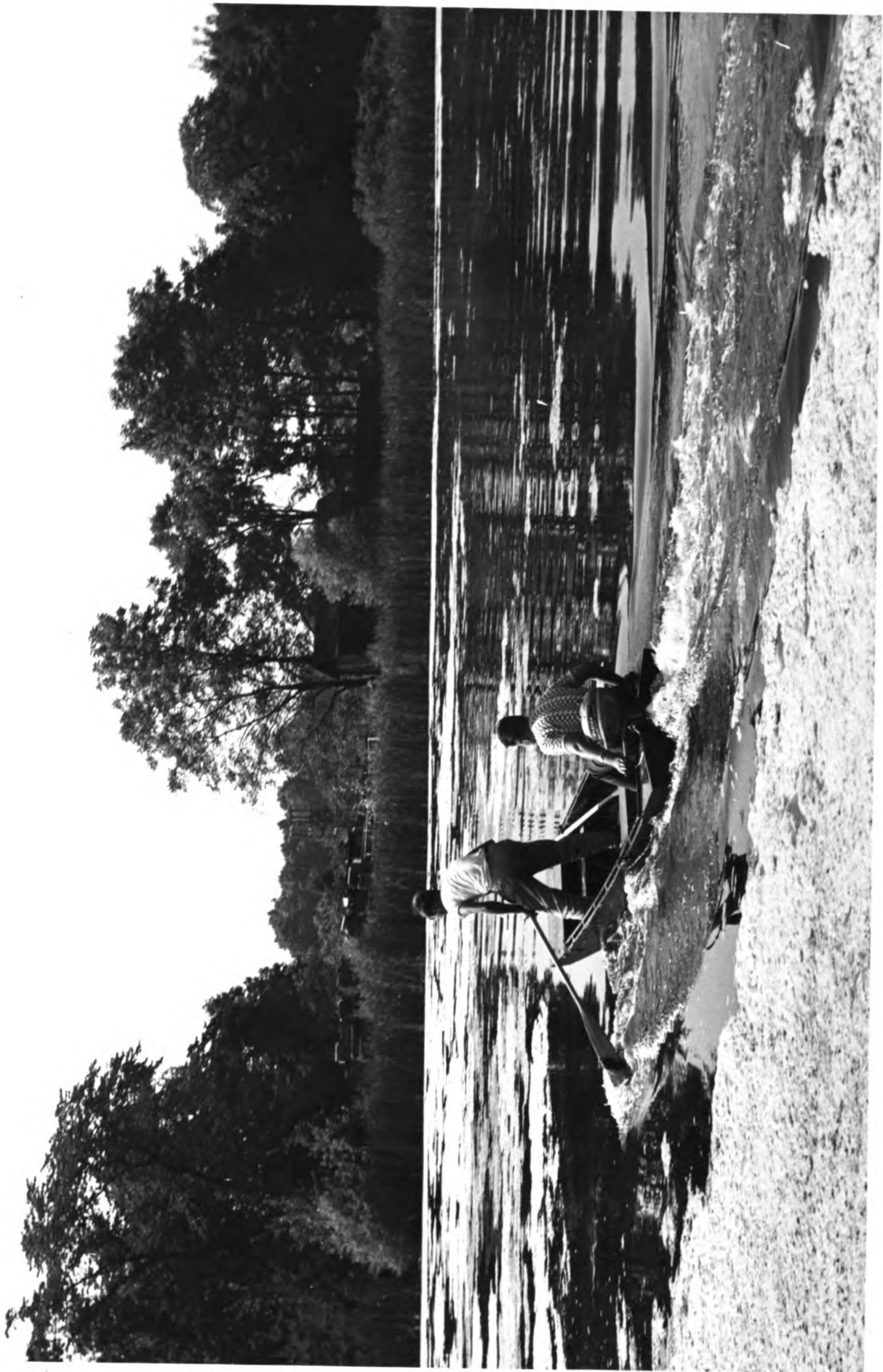
operations were more involved. The vegetation, chiefly Anacharis, had to be piled and channeled to allow stranded fish to work down to the outlet. These ponds, one of which is shown in Figure 12, had to be drawn down very slowly to avoid stranding fish.

The surface mat of filamentous algae that grew in the fertilized ponds seriously hampered attempts to harvest fish by hook and line and with fyke nets. An attempt was made to break up this surface mat with outboard motors to provide open areas from which the fish could be harvested. Approximately one half of a two acre pond, almost completely covered with filamentous algae, was thoroughly agitated with outboard motors and oars the last week in September. Both the algae and some of the higher aquatic plants present in the pond were in an advanced state of decay and sank to the bottom when agitated with the motor. Figure 13 illustrates the method used to break up the surface mat. The test area was cleared sufficiently to allow fishing, while the surface mat on the other half of the pond remained intact.

Figure 12 Draining Operations of an Unfertilized Pond



Figure 13 Experimental Control of Filamentous Algae to
Allow Harvest of Fish Crop



DISCUSSION

Weather, temperature, and soil in Michigan seemed to be enough different to warrant testing the methods of pond management developed by investigators in other states. This study evolved chiefly into attempts to apply methods used in Alabama by H. S. Swingle to Michigan ponds, and is concerned specifically with an evaluation of the role of fertilizer in the management of Michigan ponds and the results of stocking several different combinations of largemouth black bass and bluegills in fertilized and unfertilized ponds.

These experiments, conducted at Wolf Lake Hatchery, indicate that for Michigan ponds fertilization is probably neither necessary nor economically justified.

While there was a significantly greater yield of edible-size fish from some fertilized ponds the cost of that greater yield seems to be prohibitive. Further, the total yields from unfertilized ponds, which ranged from 196 to 379 pounds per acre, indicate that Michigan ponds may be fertile enough to provide substantial yields of fish without fertilization. It should be noted however, that one fertilized pond produced a total weight of 721 pounds per acre. There was sufficient variability

among ponds tested to preclude comparison of yields from fertilized and unfertilized ponds.

The investigations of Bennett (1946) showed similar conditions in Illinois. He found that several small bodies of water produced poor fishing in spite of a relatively high fertility of these waters, and concluded that there was little value in increasing yields by fertilization. Bennett specified however, that ponds in infertile areas might benefit from a fertilization program if combined with a limited fish population.

Hansen and Bennett have also compared the yield to the sport-fisherman from fertilized and unfertilized ponds and found that fertilization could not be justified as a paying farming operation when the fish were harvested with hook and line.

In some infertile areas of Michigan fertilization may be justified economically to increase yields of fish, but only when these fish will be harvested adequately. Larger fish can be produced by adding fertilizer, and perhaps the extra cost of fertilizer could be placed in the same category as tackle, bait, boats, and motors, none of which can be justified economically in terms of return of fish to the fisherman.

In these experiments it has not been possible to eliminate higher aquatic vegetation by the use of fertilizer. Higher aquatic vegetation not only protects small bluegills from bass predation, but also seems to support large populations of tadpoles and crawfish and other invertebrates that are food for bass. It was noted in these experiments that ponds free of higher aquatic plants supported very few, if any, crawfish or tadpoles while ponds with higher aquatics produced several hundred pounds of these organisms. The extent to which the presence of tadpoles, crawfish, and other invertebrates modify bass predation on bluegills is unknown, but if the higher aquatic vegetation with which they seem to be associated can not be eliminated from Michigan ponds the vegetation and its effect on pond fish populations must be considered in a pond management program.

There are other disadvantages of fertilization that make it seem undesirable for Michigan. As has been noted in a section of this report the filamentous algae that usually accompanied fertilization formed a mat over most of the surface of the ponds. This filamentous algae mat was extremely objectionable in that it produced a bad odor

and was unsightly. The algae mat also eliminated any use of the ponds for rowing, swimming, or fishing. There is some indication that fertilization was responsible for a heavy summer-kill of fish in one pond. Apparently the oxygen of the pond was exhausted when the heavy growths of filamentous algae and plants began to die off. Winter-kill is also a possible consequence of fertilization. Ball (1950) has described the winter-kill that occurred in natural lakes in Michigan as a direct result of fertilization.

In Michigan bluegills do not often become as large as those described from southern ponds. The shorter growing season in Michigan results in a smaller production of those invertebrates upon which the bluegills depend and may account for the relatively slower growth of this species. However, it has been possible to produce in experimental ponds populations of bass and bluegills containing from 100 to 200 twelve to fourteen inch bass. These were much more desirable for fishing and eating than the average bluegills produced. These populations are apparently unbalanced in that the values of the forage/carnivore ratio, and other criteria for pond balance are not within the range of values suggested by

Swingle, but nevertheless may be useful populations for Michigan ponds. Production of large predator bass for hook and line fishing rather than emphasis on balanced populations of bass and bluegills may be more satisfactory since bluegills seldom reach large size in Michigan.

SUMMARY

1. Several combinations of largemouth black bass and bluegills were stocked in fertilized and unfertilized ponds at Wolf Lake State Fish Hatchery and the standing crops of fish resulting from each combination examined on successive years.
2. Ponds stocked with fingerling bluegills in combination with fingerling largemouth bass produced a crop of edible-size bluegills one year sooner than ponds stocked with adult bluegills and fingerling bass.
3. Largemouth bass grew much faster in ponds stocked with adult bluegills than in ponds stocked with fingerling bluegills.
4. The transfer of the fish from the warm water of the ponds to cold water in holding tanks resulted in a heavy mortality of young fish but did not kill many adult fish.
5. Part of the total weight of fish in each pond at draining in 1948 was lost in handling, but the total weights of fish at draining in 1949 were approximately equal to the total weights in 1948.

6. The fact that the total weight of fish in any particular pond was approximately the same each year in spite of the mortality at draining indicates that these ponds had approached their carrying capacity in 1948, or the second summer of pond operation.
7. The growth of bass and bluegills in these experimental ponds was not nearly as rapid as that reported by Swingle from Alabama where four ounce bluegills and one pound bass were produced in one year. Comparable weights were not produced under the conditions of this experiment in Michigan until after the third growing season of the fish.
8. Stocking at the rate of 500 bass fingerlings and 3,000 bluegill fingerlings per acre produced a population of slow growing bass and small bluegills. This stocking rate apparently is excessive for both species.
9. A combination of 150 fingerling bass and 18 adult bluegills per acre produced a satisfactory population in a fertilized pond, but not in an unfertilized pond.

10. The fish populations of six experimental ponds were examined and judged to be balanced or unbalanced using the criteria described by H. S. Swingle (1950). Most ponds were judged by these standards to be overcrowded with bass.
11. The abundance of young-of-the-year bluegills in different densities of higher aquatic vegetation was compared to evaluate the effect of vegetation on the survival of young bluegills subject to bass predation. No particular trends were detected in the limited data available. Some indication of good and poor years for bluegill spawning was noted.
12. The total weight of fish in fertilized ponds at draining ranged from 193 to 721 pounds per acre, and in unfertilized ponds from 196 to 379 pounds per acre.
13. Records of the amount of fertilizer applied and the difference in weight of edible-size fish between fertilized and unfertilized ponds were considered in an attempt to assign a cost to the fish produced by fertilizer. On the basis of this experiment

fertilization does not seem to be justified economically.

14. Plankton blooms could not be produced or higher aquatic vegetation eliminated by fertilization in ponds that already supported dense growths of higher aquatics. Filamentous algae grew profusely in these ponds.
15. Filamentous algae seemed to be differential in killing higher aquatics. Anacharis and Chara were not killed by these algae.
16. Outboard motors were effective in breaking up a filamentous algae mat so that fish harvesting was possible.
17. Fertilization does not seem to be necessary or desirable for most Michigan ponds.

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