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RESULTS FROM DIFFERENT RATES OF STOCKING BLUEGILL FRY IN HATCHERY PONDS AND THE EFFECT OF INORGANIC FERTILIZER ON BLUEGILL PRODUCTION

by

Louis A. Krumholz

This report includes the findings of three years' experimentation on the rates of growth, survival, and production of bluegills from the "golden fry" stage when stocked at different intensities in ponds at the Wolf Lake Hatchery.

Five ponds were stocked at different intensities in June 1941 to determine the differences in growth rate in fish from heavily and lightly stocked ponds. Measurements of size and weight of these fish were recorded at intervals of five months, 11 months, and 17 months, from the date of stocking. During the summer of 1944 an attempt was made to determine the carrying capacity of each pond by having all of the ponds stocked at the same intensity. One of the ponds (Pond 8) was treated with commercial fertilizer in an effort to ascertain the effect of such treatment on the growth rate and production of hatchery-reared fish.

1941-1942 Experiment

A previous report[1] describes the five ponds and the methods used in

[1] The rate of growth and survival of bluegill fry as shown by stocking hatchery ponds at different intensities. Institute Report No. 763, November 31, 1942, by Louis A. Krumholz.

this investigation together with the results obtained during the first summer.

As mentioned in Report No. 763, all fish captured when the ponds were drained were sorted, counted, measured, and weighed at the end of the first summer. Fishes other than bluegills, when found, were destroyed and the bluegills were returned to their respective ponds in order to obtain survival and growth data during the subsequent winter and summer. The data obtained in handling these fish in October 1941 are given in Table 1. The results obtained from the use of inorganic fertilizer (10-6-4) are given under the discussion.

Table 1

Data obtained at the end of five months of bluegill experiments in five ponds at the Wolf Lake Hatchery, October 24-28, 1941

Pond number	Rate of stocking per acre	Number of bluegills recovered per acre	Percentage survival	Average total length in inches	Average weight in pounds per thousand	Pounds per acre of bluegills recovered	Pounds per acre of other fish recovered	Total production in pounds per acre
5	2,452	892	36.4	3.95	38.7	34.5	1.2	35.7
4	23,874	419	1.8	3.14	21.1	8.8	17.5	26.3
3	118,454	37,278	31.5	2.04	4.1	154.2	57.5	211.7
7	323,333	58,063	18.0	1.76	3.6	203.2	...	203.2
8	323,333	127,104	39.3	1.03	0.6	81.6	...	81.6

The water level in each of the ponds was lowered about a foot over winter in order to discourage muskrat digging in the levees. Pond 8 was not treated with fertilizer during the winter.

The ponds were drained April 28-30, 1942, by the hatchery personnel, Dr. Hazzard, and the writer, and all available fish were recovered. Individual length and weight measurements were made on representative samples of the bluegills and other fish taken from each pond, and all fish were counted and weighed. The fish other than bluegills, which were found in the representative samples, and the remainder of the population, were discarded and the bluegills were returned to their respective ponds.

Table 2 indicates the number of fry originally stocked and the data obtained from each of the five ponds at the end of eleven months (April 1942).

Table 2

Data obtained at the end of eleven months of bluegill experiments in five ponds at the Wolf Lake Hatchery, April 28-30, 1942

Pond number	Rate of stocking per acre	Number of bluegills recovered per acre	Percentage survival	Average total length in inches	Average weight in pounds per thousand	Pounds per acre of bluegills recovered	Pounds per acre of other fish recovered	Total production in pounds per acre
5	2,452	712	29.0	3.96	39.4	28.1	...	28.1
4	23,874	202	0.8	3.39	24.1	4.9	...	4.9
3	118,454	21,963	18.5	2.07	5.8	127.8	18.8	146.6
7	323,333	39,936	12.2	2.00	4.7	187.9	...	187.9
8	323,333	89,443	27.7	1.17	0.9	74.5	0.4	74.9

On May 28, 1942, Dr. W. C. Beckman and the writer made collections from each of the five ponds. Considerable difficulty was encountered in making collections of fish from Ponds 5 and 4 but adequate samples were obtained from each of the other three ponds. All fishes taken in these collections were measured and returned to the water. Fertilizer was placed in Pond 8.

Mr. W. F. Carbine and the writer made collections from each of the five ponds on June 29, 1942. The fish were measured and returned to their respective ponds. Bluegills were easily captured in Ponds 5 and 4 while on the spawning grounds, and as a result there was a predominance of males in each of the collections. Of the 48 fish taken from Pond 5, 46 were ripe males (running milt) and two were green females whereas all of the five fish captured in Pond 4 were ripe males. A total of 331 beds were counted in Pond 5. A few isolated nests and small colonies were observed at depths of one to two feet in most parts of the pond and a large colony of 263 beds was located in the southeast portion. One colony of 29 nests

was all that were observed in Pond 4. No spawning bluegills were seen in any of the other ponds, although green sunfish and pumpkinseeds had spawned in Pond 3 and there were many young of these two species embedded in the filamentous algae which clung to the seine. Pond 8 was treated with fertilizer.

On July 30, 1942, Dr. Hazzard and the writer found it impossible to capture any fish in Ponds 4 and 5, but did make collections from the other three ponds. Adult fish were observed in the deeper parts of Ponds 4 and 5 but the spawning area had been abandoned. Fertilizer was placed in Pond 8.

Due to the inability to secure collections in all ponds on July 30, attempts to make further monthly collections were abandoned. Mr. Henry Hatt, foreman at the Wolf Lake Hatchery, treated Pond 8 with fertilizer on September 1.

On October 19, 1942, Mr. R. D. Van Deusen of the Institute and the writer, aided by the personnel of the Wolf Lake Hatchery, drew down the water in Ponds 4 and 5. On the following day these fish were transferred to the hatchery building. Inasmuch as the bluegills in each of these ponds had spawned, the fish were sorted as to size and individual lengths, weights, and sex determinations were made on all the adult fish. Scale samples were taken from 350 of the adult bluegills from Pond 5. Young-of-the-year bluegills from each of these two ponds were counted and weighed and measurements of individual lengths were made of a representative sample from each pond.

The remaining three ponds were drained and the fish were sorted by species, counted and weighed. Samples of bluegills and other species were measured and weighed and the total fish production of each pond was calculated from these data. The data obtained at the termination of the experiment in October 1942 are given in Table 3. Those fish which were not destroyed in securing desired information were turned over to the Wolf Lake Hatchery for distribution.

Table 3

Data obtained at the end of seventeen months of bluegill experiments in five ponds at the Wolf Lake Hatchery, October 19-24, 1942 *

Pond number	Rate of stocking per acre	Number of bluegills recovered per acre	Percentage survival	Average total length in inches	Average weight in pounds per thousand	Pounds per acre of bluegills recovered	Pounds per acre of other fish recovered	Total production, pounds per acre
5	2,452	487	19.9	5.98	145.2	76.3	2.4	78.7
4	23,874	181	0.8	5.70	134.9	47.9	1.2	49.1
3	118,454	4,594	3.9	3.93	32.1	145.9	218.3	364.2
7	323,333	25,171	7.8	3.18	17.1	431.1	...	431.1
8	323,333	60,500	18.7	2.32	6.6	398.5	1.1	399.6

* In addition there were 4,035 young-of-the-year bluegills per acre in Pond 5 which weighed 5.6 pounds, and 22,321 young-of-the-year bluegills per acre in Pond 4 which weighed 23.4 pounds.

Discussion

Growth rate

Bluegill fry stocked at the minimum rate per acre grew to a larger size than did similar fry which had been stocked at progressively higher rates per acre. The rate of stocking and the average total lengths of the bluegills from each of the five ponds at the end of five months, 11 months, and 17 months are given in Table 4.

Table 4

Actual rate of stocking per acre and average total lengths in inches of bluegills recovered from five hatchery ponds at intervals of five months, 11 months, and 17 months from the time of stocking

Pond number	Actual rate of stocking per acre	Average length in inches		
		5 months old	11 months old	17 months old
5	2,452	3.9	4.0	6.0
4	23,874	3.1	3.4	5.7
3	118,454	2.0	2.1	3.9
7	323,333	1.8	2.0	3.2
8	323,333	1.0	1.2	2.3

According to Beckman,[2] the average bluegill in Michigan lakes reaches legal size sometime during its fourth summer of life. The bluegills in Pond 7 grew at approximately the same rate as that of the average Michigan bluegill, as found by Beckman, whereas those in Ponds 5, 4, and 3 grew more rapidly and those in Pond 8 grew more slowly.

Pond 5 was stocked at the rate of approximately 2,500 golden fry per acre and these fish had attained an average total length of four inches at the end of their first summer of life (five months of age) and averaged six inches in length at the end of their second summer (17 months old). This growth was twice as fast as that for the average bluegill in Michigan lakes.

The size ranges and average lengths (indicated by peaks) of bluegills at the ages of five months (October 1941), 11 months (April 1942) and 17 months (October 1942) for each of the five ponds are shown in Figure 1. The rate of growth of the bluegills was greater during the first summer than during the subsequent winter and summer in all ponds with the exception of Pond 8. These different rates of growth are primarily dependent on two factors; 1) the intensity of stocking and 2) the rate of survival of the original planting. If the rate of survival is the same in all ponds, the growth of the fish is inversely proportional to the rate of stocking, i.e. the fish stocked at a lower rate will grow faster than the fish stocked at a higher rate. However, the survival rate of the bluegill fry, even though the ponds are stocked at different rates, has considerable effect on the rate of growth. For instance, the fish from Pond 4, although stocked ten times as heavily as Pond 5, grew nearly as fast as those in Pond 5 because of the high mortality early in the experiment with a consequent increase in the amount of food and space available for the survivors.

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[2] Growth rate of some Michigan game fishes. Institute Report No. 741, February 3, 1942, by William C. Beckman.

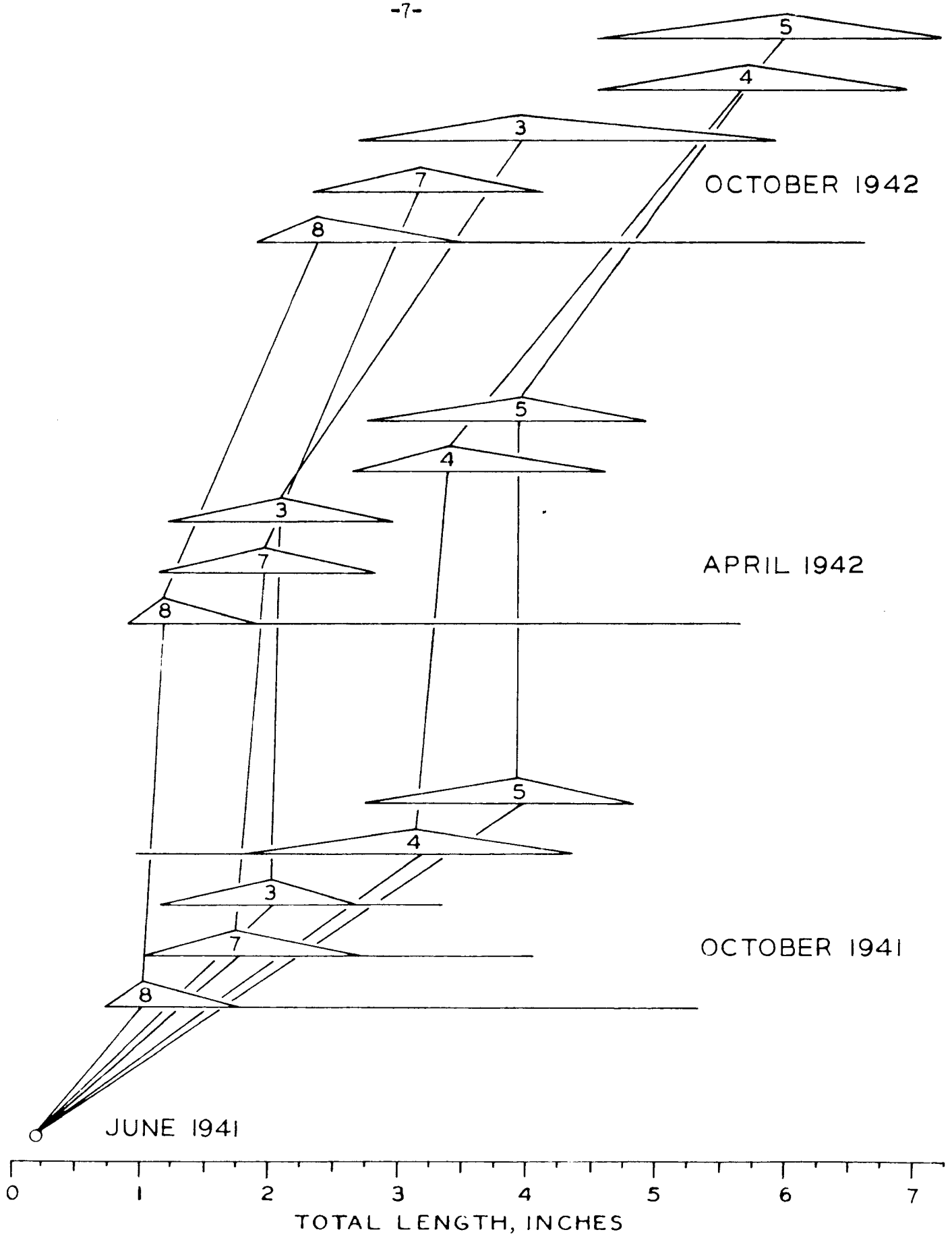

Figure 1. Size range and average length (peak of triangle) of bluegills at ages of five months (October 1941), 11 months (April 1942), and 17 months (October 1942) from five ponds at the Wolf Lake Hatchery.

Also, Ponds 7 and 8 were stocked at the same rate but a larger percentage of the fish in Pond 8 survived and as a result grew slower than the bluegills in Pond 7. Survival rates in all ponds will be discussed in another part of this paper.

The bluegills grew very little over winter in all ponds under consideration, the greatest average increase in length (0.3 inch) being recorded in Pond 4 and the smallest average increase in Ponds 5 and 3 (0.1 inch). During the second summer the average increase in length of the bluegills from each pond was in the same order as in 1941 with the exception of Pond 4. The increases during the second summer were: 2.0 inches in Pond 5; 2.3 inches in Pond 4; 1.8 inches in Pond 3; 1.2 inches in Pond 7; and 1.1 inches in Pond 8.

Increase in weight is as much an index of growth as increase in length. At the time the bluegill fry were planted in June 1941 the weight per thousand fry was less than 0.01 pound. Because this weight of the fry was negligible, any figure in the increase in weight from the time of planting has been figured from zero. The average weights per thousand bluegills from each pond at the end of each period are given in Table 5.

Table 5

Actual rate of stocking per acre and average weight per thousand bluegills recovered from five hatchery ponds at intervals of five months, 11 months, and 17 months from the time of stocking

Pond number	Actual rate of stocking per acre	Average weight (in pounds) per thousand bluegills		
		5 months old	11 months old	17 months old
5	2,452	38.7	39.4	145.2
4	23,874	21.1	24.1	134.9
3	118,454	4.1	5.8	32.1
7	323,333	3.6	4.7	17.1
8	323,333	0.6	0.9	6.6

Comparison of the data in Tables 4 and 5 shows that the increase in weight was considerably greater in the second summer whereas the increase in length was greater in the first summer. This is in accordance with the general rule that fishes increase in weight according to the cube of the length.

According to studies on several species of sunfishes (Centrarchidae), the males grow more rapidly in length than do the females (Tester, 1932; Hubbs and Hubbs, 1933; Hubbs and Cooper, 1935; Bailey and Lagler, 1938; Bennett, 1938; Eschmeyer, 1940; Hile, 1941).[3] These studies have shown

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[3] Bailey, Reeve M., and Karl F. Lagler. 1938. An analysis of hybridization in a population of stunted sunfishes in New York. Pap. Mich. Acad. Sci., Arts, and Letters, Vol. XXIII, 1937, pp. 577-606.

Bennett, George W. 1938. Growth of the small-mouthed black bass, Micropterus dolomieu Lacépède, in Wisconsin waters. Copeia, No. 4, pp. 157-170.

Eschmeyer, R. W. 1940. Growth of fishes in Norris Lake, Tennessee. Tenn. Acad. Sci., Vol. XV, pp. 329-341.

Hile, Ralph. 1941. Age and growth of the rock bass, Ambloplites rupestris (Rafinesque), in Nebish Lake, Wisconsin. Trans. Wis. Acad. Sci., Arts, and Letters, Vol. 33, pp. 189-337.

Hubbs, Carl L., and Laura C. Hubbs. 1933. The increased growth, predominant maleness, and apparent infertility of hybrid sunfishes. Pap. Mich. Acad. Sci., Arts, and Letters, Vol. XVII, 1932, pp. 613-641.

Hubbs, Carl L., and Gerald P. Cooper. 1935. Age and growth of the long-eared and the green sunfishes in Michigan. Pap. Mich. Acad. Sci., Arts, and Letters, Vol. XX, 1934, pp. 669-696.

Tester, Albert L. 1932. Rate of growth of the small-mouthed black bass (Micropterus dolomieu) in some Ontario waters. Pub. Ont. Fish. Res. Lab., Vol. 47, pp. 205-221.

that growth in length is about the same in both sexes during the first year of life for bluegills, green sunfish, and longear sunfish and that the males usually grow faster than the females after they are a year old (second summer of life). In the rock bass and smallmouth bass the males grow at about the same rate as the females until the third summer when the males begin to grow more rapidly.

At the termination of the experiment at the Wolf Lake Hatchery in October 1942, all adult bluegills from Pond 5 were measured, weighed, and sexed. Of these 618 fish, 365 (59 per cent) were males and 253 (41 per cent) were females. The size range of the males was from 115 to 184 millimeters with an average of 155.7 (6.13 inches) whereas the females ranged in size from 130 to 173 millimeters with an average of 146.5 (5.77 inches). Thus there was a difference of 9.2 millimeters (0.36 inch) between the average total lengths of the male and female bluegills at the age of 17 months in Pond 5.

Similarly in Pond 4, where all the fish were sexed, measured, and weighed, the average length of the males was greater than that of the females. Conversely to Pond 5, there were fewer males (78 fish) than females (103 fish). The males ranged in length from 115 to 187 millimeters with an average of 152.5 (6.00 inches) and the lengths of females ranged from 120 to 170 millimeters and averaged 138.8 (5.46 inches). The difference between the average total lengths of the males and females in Pond 4 was 13.7 millimeters (0.54 inch) at the end of 17 months.

In each case the size range of the males was considerably greater than that of the females and the size ranges of the males and females in each of the ponds corresponded closely with those from the other pond.

The numbers of males and females in each millimeter length group (data from Ponds 4 and 5 are combined), and the minimum, average, and maximum weights for the individuals in each group are given in Table 6. Although

Table 6

Length-weight data from adult bluegills (17 months old) taken from Ponds 4 and 5, Wolf Lake Hatchery, October 1942, indicating the number of specimens in each millimeter length group, and the minimum, average, and maximum weights for each group. The solid line in the body of the table shows the minimum legal length of six inches

Total length, millimeters	Males				Females			
	Number of specimens	Weight, grams			Number of specimens	Weight, grams		
		Minimum	Average	Maximum		Minimum	Average	Maximum
115	2	27	28.0	29				
116								
117								
118	1	30	30.0	30				
119								
120					2	30	31.5	33
121	1	28	28.0	28				
122								
123					1	36	36.0	36
124	2	31	34.5	38				
125	1	31	31.0	31	6	29	32.2	34
126					2	32	33.0	34
127	3	27	36.0	43	1	41	41.0	41
128	4	30	34.5	37	9	31	38.0	42
129					2	41	41.0	41
130					2	35	38.0	41
131	1	39	39.0	39	1	34	34.0	34
132	3	43	44.3	46	6	36	39.3	48
133	4	38	39.8	43	4	37	40.8	45
134					9	38	40.4	44
135					10	38	43.4	50
136	1	47	47.0	47	7	40	44.1	50
137	1	45	45.0	45	6	41	44.5	49
138	4	43	50.5	54	13	43	45.5	51
139					11	41	48.7	53
140					20	39	50.3	64
141	1	51	51.0	51	10	47	51.1	57
142					8	47	53.3	60
143	3	40	51.3	58	37	44	52.3	64
144	3	50	56.7	67	23	49	53.2	58
145	7	51	59.4	66	17	48	56.0	61
146	9	51	57.0	61	14	49	55.4	60
147	21	53	59.2	71	20	47	56.0	66
148	13	56	61.4	68	18	53	59.0	67
149	7	59	60.9	63	9	52	60.4	83
150	21	57	63.9	78	12	53	59.3	65
151	19	60	67.2	76	5	60	62.8	66
152	12	58	65.7	75	11	52	63.5	68
153	29	58	67.3	74	13	59	64.8	70
154	19	64	69.4	76	7	63	66.4	71
155	29	66	71.6	88	5	63	69.8	75
156	16	56	71.5	81	6	55	64.5	73
157	28	67	73.3	83	8	66	72.4	87
158	27	69	78.4	91	6	67	75.8	85
159	24	69	78.7	88				
160	24	73	81.0	95	1	73	73.0	73
161	20	70	78.9	95	3	73	81.3	93
162	7	76	82.2	94	1	81	81.0	81
163	9	73	81.2	88				
164	9	76	84.9	98	2	65	75.0	85
165	9	78	89.4	104				
166	6	80	94.0	117	3	96	99.0	102
167	6	82	89.7	94	1	88	88.0	88
168	7	87	97.1	102	1	85	85.0	85
169	2	86	94.0	102				
170	5	92	104.2	125	2	110	111.0	112
171	2	101	104.0	107				
172	1	109	109.0	109				
173	6	100	115.3	124	1	93	93.0	93
174	1	100	100.0	100				
175	2	108	109.0	110				
176	2	96	111.5	127				
177	2	110	112.5	115				
178	2	78	100.5	123				
179								
180	1	127	127.0	127				
181								
182	1	131	131.0	131				
183	1	133	133.0	133				
184	1	138	138.0	138				
185								
186								
187	1	147	147.0	147				

the average differences in condition (length-weight relationship) between the males and females were not great, they were sufficient to indicate that the males were relatively heavier than the females at the end of their second summer of life (Figure 2).

Survival

Bluegill fry stocked in ponds at a low rate per acre might generally be expected to show a greater survival rate than would fry stocked at a higher rate. However, in stocking bluegill fry in hatchery ponds, it is common practice to place the fry on trays that are set below the surface and covered with a screen which serves to keep out predators and yet allow the fry to rise off the tray. Bluegill fry at the "golden" stage are extremely delicate creatures and excessive or improper handling, rapid changes in temperature, or any one of many other phenomena may cause a high rate of mortality. Hatchery men are aware that considerable mortality may occur before the fry leave the tray or shortly after they are free-swimming.

It is inevitable that some individuals will die or be killed during the removal of many thousands of fish from hatchery ponds. Mortality occurred in the populations of some of the ponds each time they were drained and the desired information secured. Table 7 shows the rates of survival of bluegills from the original stock and during each period of the experiment, and the loss incurred in handling the fish. No mortality due to handling was recorded in October 1942 because the entire populations of Ponds 4 and 5 were killed to obtain desired information and the fish from the remaining ponds were turned over to the hatchery for distribution.

In some cases it may be that the survival of the bluegill stock was hampered by the presence of other species as in Pond 4 where there were 3,543 Iowa darters per acre when the pond was drained at the end of the

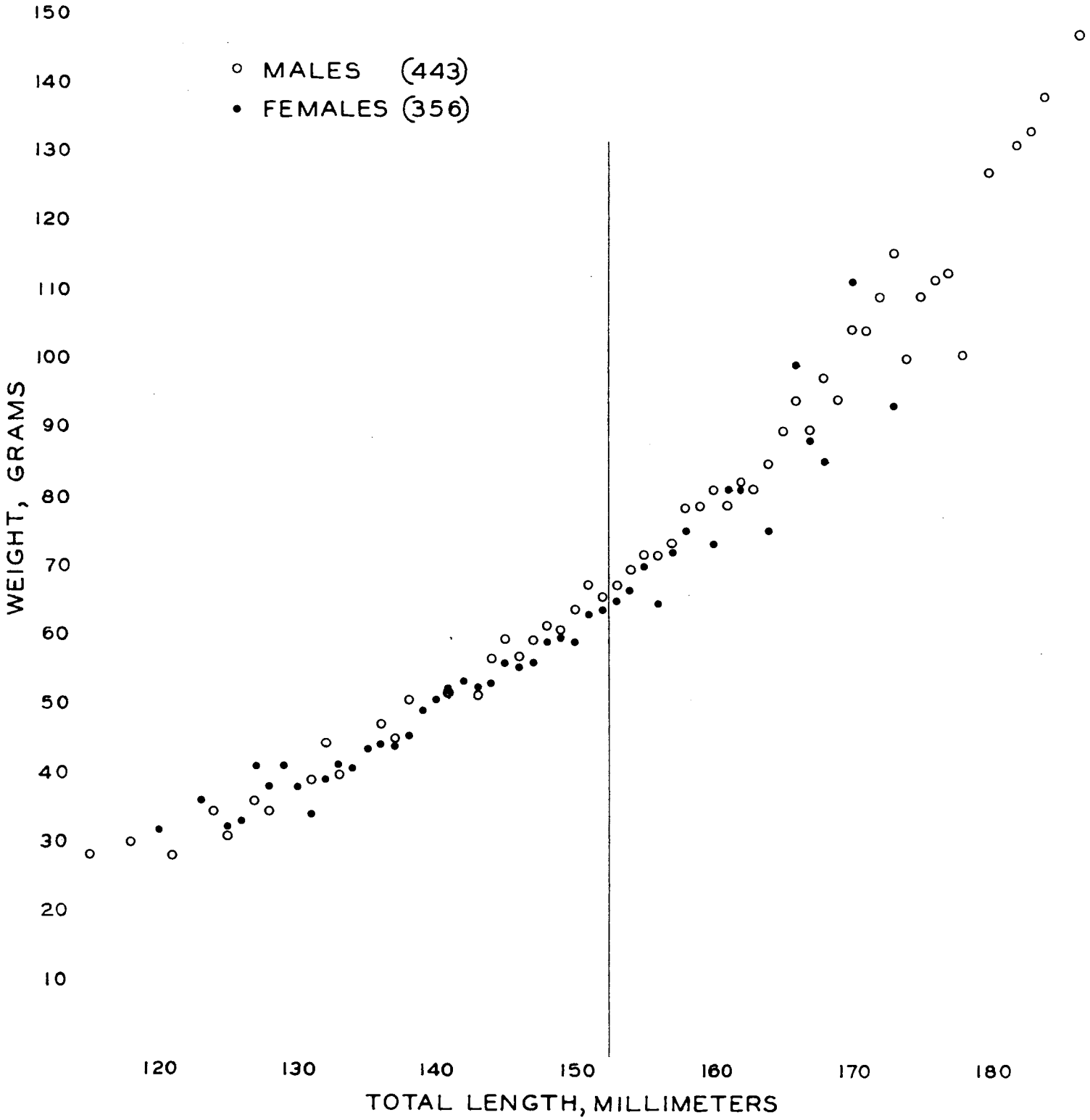

Figure 2. Relationship between average lengths and weights of male and female bluegills at the end of their second summer of life (17 months old), Wolf Lake Hatchery, Ponds 4 and 5, October 1942. The vertical line through the graph indicates the legal length of six inches.

Table 7

Data showing rates of survival from original stock and during each period of the investigation from five ponds at the Wolf Lake Hatchery during 1941 and 1942

		October 1941				April 1942					October 1942		
Pond number	Actual rate of stocking per acre	Bluegills recovered per acre	Percentage survival of original stock	Percentage lost in handling	Bluegills returned to pond per acre	Bluegills recovered per acre	Percentage survival over winter	Percentage survival of original stock	Percentage lost in handling	Bluegills returned to pond per acre	Bluegills recovered per acre	Percentage survival during second summer	Percentage survival of original stock
5	2,452	892	36.4	...	892	712	79.8	29.0	...	712	487	68.4	19.9
4	23,874	419	1.7	12.7	366	202	55.2	0.8	1.0	200	181	90.5	0.8
3	118,454	37,278	31.5	0.4	37,129	22,222	59.9	18.8	0.9	22,024	4,594	20.9	3.9
7	323,333	58,063	18.0	0.9	57,515	39,936	69.4	12.4	1.4	39,838	25,171	63.2	7.8
8	323,333	127,104	39.3	10.4	113,891	89,443	78.5	27.7	6.5	83,649	60,500	72.3	18.1

first summer (October 1941). Another similar instance occurred in Pond 3 where the green sunfish increased from an estimated 409 fish, which were returned to the pond along with the bluegills in April 1942, to an estimated total of 48,486 individuals in October of the same year. These green sunfish apparently offered severe competition to the bluegills.

The data in Table 7 indicate that the survival was poorest in each pond except in Pond 3 during the first summer. The survival during the subsequent winter and summer was higher than during the first summer in all cases with the single exception of Pond 3 during the summer of 1942. This poor rate of survival in Pond 3, as mentioned above, was probably due to the presence of large numbers of green sunfish. The mortality in the remaining ponds was probably due to other natural causes.

Effect of fertilization

As has been previously mentioned, Pond 8 was treated with commercial fertilizer once a month for four months during each of the two summers included in this experiment. One hundred pounds of Swift and Company's (N-P-K) 10-6-4 commercial fertilizer and 25 pounds of soil lime were used in each application. Pond 7 which is similar to Pond 8 in bottom type was used as the control in this experiment and both ponds were stocked at the same rate.

There appear to be three interdependent effects of the fertilization: 1) a markedly increased production of plankton organisms early in the summer, 2) a dearth of submerged aquatic vegetation during the period of fertilization, and 3) an increased survival rate of bluegill fingerlings with a consequent slowing down of the growth rate. Early each summer there were large clouds of Daphnia present in Pond 8. This abundance of plankton in the pond eased the competition for food among the small fish and enhanced the possibilities of the fry surviving to the fingerling stage. However, as the fish increased in size, the food and space necessary

for normal growth were insufficient in Pond 8 and those fish which grew rapidly in the early part of the summer were able to prey upon the smaller fish as indicated by stomach examinations of the adult bluegills from Pond 5 which will be discussed later. Other workers (Smith and Swingle, 1942[4]) have shown that fertilization may retard or even prevent the growth of certain submerged aquatic plants. In Pond 8 there were no submerged aquatic plants present during either summer of the experiment and only a light growth of filamentous algae was present.

Effect of other fish

Once the bluegills have risen from the trays, adult fishes of other species, which entered the pond through the water supply, may prey upon them and thereby cut down the rate of survival. Also, if extraneous fishes are hatched in large numbers at the same time the bluegills leave the trays, they enter into competition for food and space and in some instances might crowd out the bluegills.

The numbers of other fish and the combined weights recovered from each of the ponds each time they were drained were as follows:

October 1941:

Pond 5 - 1 brook trout, 27 muddlers, 17 Iowa darters - 1.25 pounds per acre.

Pond 4 - 3,543 Iowa darters, 1 sucker - 17.5 pounds per acre.

Pond 3 - 3,184 green sunfish, 947 pumpkinseeds, 172 suckers, 30 Iowa darters, 12 golden shiners, 4 sand shiners, 1 smallmouth black bass - 57.5 pounds per acre.

Pond 7 - 12 Iowa darters - trace.

Pond 8 - no other kinds taken.

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[4] Smith, E. V., and H. S. Swingle. The use of fertilizer for controlling several submerged aquatic plants in ponds. Trans. Am. Fish. Soc. 71: 94-101. (1941), 1942.

April 1942:

Pond 5 - no other kinds taken.

Pond 4 - no other kinds taken.

Pond 3 - 2,044 green sunfish, 418 pumpkinseeds - 22.0 pounds per acre.

Pond 7 - no other kinds taken.

Pond 8 - 6 green sunfish, 3 pumpkinseeds - 0.4 pounds per acre.

October 1942

Pond 5 - 1,083 Iowa darters, 10 muddlers - 2.4 pounds per acre.

Pond 4 - 640 Iowa darters, 7 muddlers - 1.25 pounds per acre.

Pond 3 - 48,486 green sunfish, 596 pumpkinseeds, 1,421 golden shiners, 78 Iowa darters, 36 Great Lakes shiners - 218.3 pounds per acre.

Pond 7 - no other kinds taken.

Pond 8 - 83 green sunfish, 7 pumpkinseeds - 1.1 pounds per acre.

In Pond 4 there were 3,453 Iowa darters per acre taken from the pond in October 1941 and the survival rate of the bluegills was very low (1.7 per cent). Either the bluegills died while on the trays or were killed afterwards. It is difficult to determine just when this mortality took place inasmuch as there was no biologist at the hatchery to make regular observations throughout the season.

In Pond 3 there were several extraneous species present during the first summer. This pond receives its water supply from Pond 2 where trout were being reared at the time. To avoid the accumulation of waste material from the food given the trout in Pond 2, "scavenger fish" (sturgeon, carp, and suckers) as well as other species of fish were held in the pond. The extraneous species in Pond 3 probably entered through the screen from Pond 2. Each time Pond 3 was drained during this experiment most of these undesirable fish were removed. Apparently some of the pumpkinseeds and green sunfish escaped notice at those times and were

returned to the pond along with the bluegills. In October 1941 there was an estimated total of 3,184 green sunfish in Pond 3. Of these, 362 were known to have been destroyed leaving a total of 2,822 individuals in the pond. In April 1942, 2,044 green sunfish were present, a survival of 74.2 per cent over winter. This rate of survival was considerably higher than that for the bluegills from Pond 3 (59.9 per cent) over the same period. Of these 2,044 green sunfish, 1,635 were destroyed leaving 409 (19.1 pounds per acre) of these undesirable fish in the pond with the bluegills. On June 29, 1942, green sunfish were seen making nests and spawning and an examination of some of the fish showed that the males were running milt and some of the females were spent. When Pond 3 was drained in October 1942, there was an estimated total of 48,486 green sunfish (187.2 pounds per acre), a hundred-fold increase in numbers and nearly a ten-fold increase in weight. These green sunfish, together with the other extraneous species apparently had some deleterious effects on the bluegill population inasmuch as the number of bluegills fell from 31,686 individuals (154.2 pounds per acre) in October 1941 to 3,905 fish (145.9 pounds per acre) a year later. The ability of the green sunfish to successfully reproduce in large numbers and to actually overtake the bluegills in a pond where it was outnumbered more than fifty to one coupled with the fact that the green sunfish is apparently more able than the bluegill to survive the winter in hatchery ponds, indicate that every effort should be made to rid bluegill hatcheries of this highly undesirable species.

In many of the hatchery ponds in Michigan there is an abundance of crayfish and polliwogs every year. It is well known that both of these invertebrates are considerable nuisances to hatcherymen when ponds are being drained. Whether crayfish and polliwogs offer serious competition to pondfish in hatcheries has not been determined. Mr. Carbine and the writer observed crayfish working over the bluegill beds in Pond 5 on

June 29, 1942.

The production of crayfish and polliwogs in the five ponds was not recorded but it is known that several five-gallon pailfuls were taken out of each pond when they were drained in October 1941 and 1942. Relatively few were taken in April 1942. There was well over a washtubful of crayfish alone taken from Pond 3 when it was drained in October 1941.

So far as is known there is no practicable means of keeping these animals out of hatchery ponds.

Production of fish

The index by which the production of a body of water is measured is the number of pounds of fish produced per acre of water surface. There are many factors which may influence the productive capacity of a pond, such as the type of bottom, vegetation, available food supply, chemical composition of the water, etc. As mentioned in Institute Report No. 763, Ponds 4 and 5 had sand bottoms with very little vegetation and could not be expected to be as productive as Ponds 7 and 8 which had muck bottoms that ordinarily supported a heavy growth of aquatic plants. Pond 3, which had a sand and muck bottom and a fairly good plant growth, might be expected to be somewhere in between the other types in productivity. The figures on total production of fish at the end of 17 months support this theory.

The production, in pounds per acre, of bluegills and other fish together with the total production of each pond is given in Table 8. Figure 3 shows the production of bluegills and other species in pounds per acre for each of the five ponds each time they were drained. From these data it is evident that none of the ponds had reached their carrying capacity by the end of the first summer. In all ponds there was a decrease in total production of fish over the winter months, even in those ponds where no undesirable fish had been found and removed. This decrease in production took place even though the average lengths and weights of the bluegills in all ponds had increased during the same period. This decrease in

Table 8

Pounds per acre of bluegills, other fish, and total production in five ponds at Wolf Lake Hatchery at intervals of 5 months, 11 months, and 17 months from time of stocking with golden fry

Pond number	October 1941 (5 months)			April 1942 (11 months)			October 1942 (17 months)		
	Bluegills	Other kinds	Total	Bluegills	Other kinds	Total	Bluegills	Other kinds	Total
5	34.5	1.2	35.7	28.1	...	28.1	76.3	2.4	78.7
4	8.8	17.5	26.3	4.9	...	4.9	47.9	1.2	49.1
3	154.2	57.5	211.7	127.8	18.8	146.6	145.9	218.3	364.2
7	203.2	...	203.2	187.9	...	187.9	431.1	...	431.1
8	81.6	...	81.6	74.5	0.4	74.9	398.5	1.1	399.6

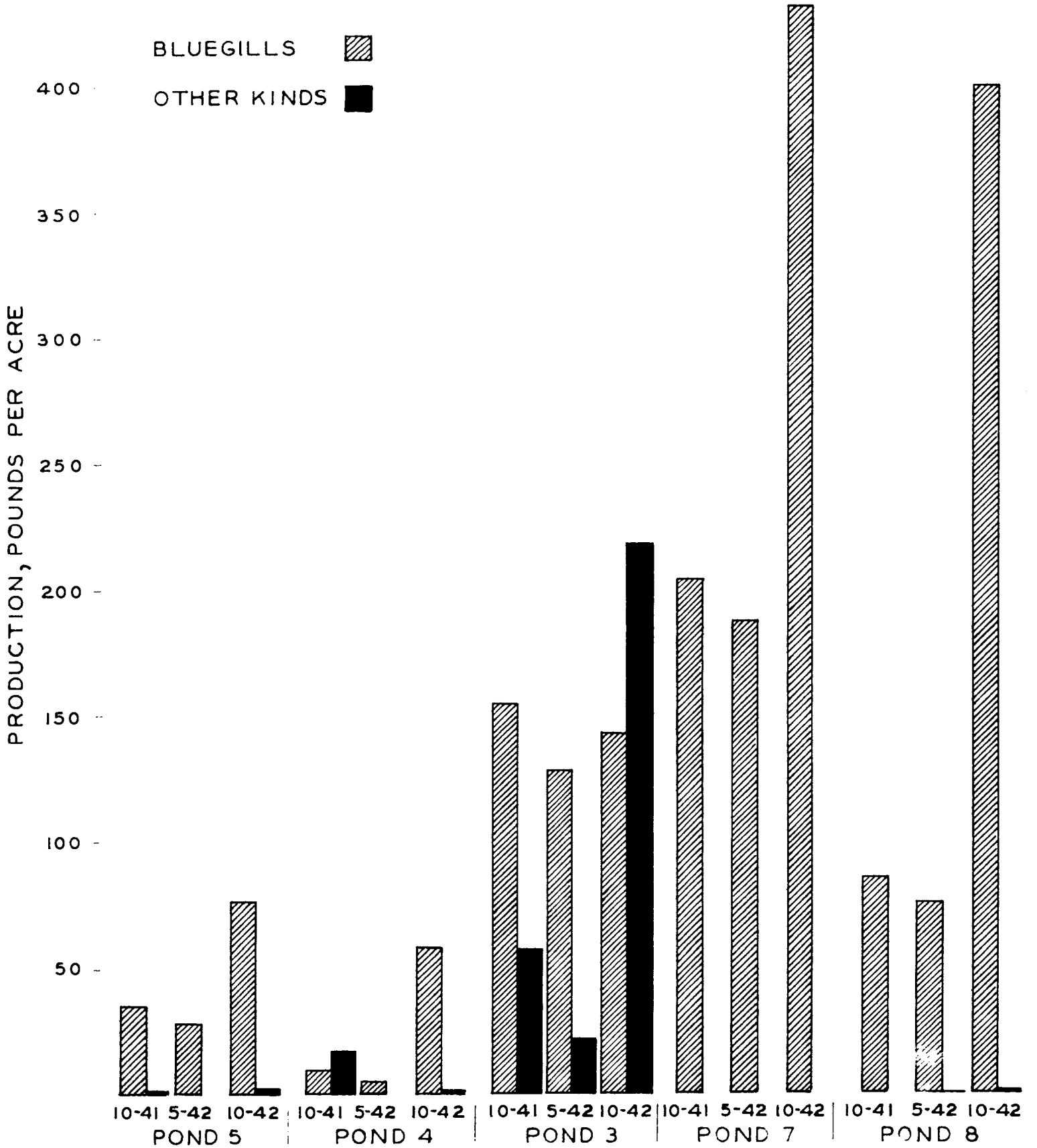

Figure 3. Production in pounds per acre of bluegills (diagonal lines) and other kinds of fish (solid blue) in each of five ponds at the Wolf Lake Hatchery at intervals of five months, 11 months, and 17 months from the time of stocking.

production per acre in spite of the average growth in the fish indicates that there may be an actual lowering in the carrying capacity of ponds over winter. However, the lowering of the water levels about one foot in all ponds over winter might have been partly responsible.

During the six-month period from April to October 1942, the total production of each pond was more than doubled. It is unfortunate that the experiment was not continued for another year or two so that information could have been secured on the time required for such ponds to reach their ultimate carrying capacities and whether or not there were reductions in the production of fish during subsequent winters.

Spawning of bluegills

In natural waters in Michigan most bluegills will spawn for the first time in their third summer of life but in some instances, where growth is better than average, they will begin to reproduce when only a year old (second summer). The bluegills in Ponds 5 and 4 spawned during their second summer whereas none of the bluegills in the other three ponds reproduced at that time. As previously mentioned, a total of 331 nests was found in Pond 5 and 29 nests were observed in Pond 4. Accordingly it would be expected that Pond 5 might have contained more young-of-the-year fish than Pond 4. However, when the ponds were drained in October 1942, only 5,125 young bluegills were found in Pond 5 whereas 22,321 young were taken from Pond 4. Stomach examinations of adult bluegills from Pond 5 revealed that 27 out of 60 contained small bluegills. No small bluegills were found in the stomachs of 30 adult bluegills from Pond 4. This cannibalism which is not as frequently noticed among bluegills as among other hatchery-reared fish (especially the black basses and yellow pikeperch), obviously reduced the population of young bluegills in Pond 5 to a large extent.

1944 Experiment

During the summer of 1944 an attempt was made to obtain accurate information on the carrying capacity and relative productivity of the individual ponds used during the experiments performed in 1941 and 1942.

On June 16, Mr. W. F. Carbine and the writer stocked each of the five ponds at the relatively low rate of 10,000 golden fry per acre. These fry had been collected by Messrs. Henry Hatt and Willard Hall of the Wolf Lake Hatchery from Muskrat Lake, Van Buren County. Preliminary counts of the number of fry per cubic centimeter were made to assure that the fry would be stocked at the desired rate. These counts indicated that there were approximately 1,000 fry per cubic centimeter, and this figure was used in stocking the ponds. In addition, four samples, which ranged in size from 1.5 to 4.9 cubic centimeters were preserved and taken to the laboratory to be counted. The results of these counts and the percentage of error based on the figure of 1,000 fry per cubic centimeter are given in Table 9.

Table 9

Numbers of fry in four preserved samples and percentage of error based on the figure of 1,000 fry per cubic centimeter

Sample number	Volume of sample	Actual number of fry in sample	Number of fry per cubic centimeter	Percentage of error
1	2.1 cc.	2,258	1,075	7.5
2	2.2 cc.	2,406	1,094	9.4
3	1.5 cc.	1,507	1,005	0.5
4	4.9 cc.	5,253	1,072	7.2
Total or average	10.7 cc.	11,424	1,068	6.8

The ponds were to be stocked at the rate of 10,000 fry per acre, but because of the difficulty in making precise measurements without injuring the fish, the volume of fry necessary for stocking each pond at the desired rate was not exact in any case. The results of the stocking together with the area of each pond are given in Table 10.

Table 10

Records of the number of fry actually stocked in five ponds at the Wolf Lake Hatchery and percentage of error based on the figure of 10,000 fry per acre, June 16, 1944

Pond number	Area in acres	Volume of fry stocked (cubic centimeters)	Theoretical number of fry to be stocked	Actual number of fry stocked	Actual number of fry stocked per acre	Percentage of error in stocking
5	1.27	10.7	12,700	11,428	8,998	-10.2
4	1.00	10.2	10,000	10,894	10,894	+ 8.9
3	0.85	8.4	8,500	8,971	10,554	+ 5.5
7	1.59	16.2	15,900	17,302	10,882	+ 8.8
8	0.90	9.0	9,000	9,621	10,690	+ 6.9
Total or average	5.61	54.5	56,100	58,216	10,404	+ 4.0

The figures on the actual rate of stocking as shown in Table 10 were calculated from the number of fry per cubic centimeter as shown in Table 9. Since the original estimate was somewhat high, all ponds except Pond 5 were stocked at a rate from 5 to 9 per cent higher than the theoretical figure of 10,000 fry per acre. The relatively low rate of stocking in Pond 5 was due to misinformation on the actual acreage.

Pond 8 was treated with fertilizer on June 12 and July 22, 1944 at the same rate as in 1941 and 1942. Other than this, the ponds were not disturbed and no collections were made until the ponds were drained in the fall. On October 26-28, 1944, Dr. Hazzard, Dr. William H. Burt of the University of Michigan, and the writer, counted and weighed the fish recovered from each of the five ponds by the hatchery crew.

Individual lengths and weights were taken from representative samples of bluegills from each pond. The data thus obtained are given in Table 11.

Table 11

Summary of data obtained on growth, survival, and production of bluegills stocked at the same rate per acre in five ponds at the Wolf Lake Hatchery

Pond number	Actual rate of stocking per acre	Number of bluegills recovered per acre	Average total length in inches	Average total weight per thousand in pounds	Percentage survival	Production of bluegills, pounds per acre
5	8,998	6	3.17	...	0.06	0.10
4	10,894	0	...	...	0.00	0.00
3	10,554	9	3.33	...	0.08	0.19
7	10,882	3,304	3.60	25.52	29.41	84.04
8	10,690	1,257	3.86	31.28	11.76	39.31

Carrying capacity

As previously mentioned, production of fish in a pond is measured in pounds per acre. In a newly-stocked pond the production will increase over a period of time until the maximum is reached and the pounds of fish produced per acre will level off. The point at which the production levels off is called the carrying capacity. The 1944 experiment was an attempt to determine the carrying capacities of each of the five ponds used in 1941 and 1942.

When the five ponds were drained in October 1944, only two of the ponds contained enough fish to furnish adequate data upon which to base reliable estimates for the relative productivity of the ponds. For some reason, probably one of those discussed under "Survival" in the first part of this report, the fry did not survive and the other three ponds contained only very few fish. Mr. Henry Hatt, foreman at the Wolf Lake Hatchery, said that he had not seen any fish in Pond 4 and had seen but very few fish in Ponds 3 and 5 during the entire summer. Also, Mr. Jay Marks,

superintendent at the Wolf Lake Hatchery, and Mr. Hatt stated that this was the first time they had ever seen ponds which had been stocked with bluegill fry and which had failed to produce a crop. The ponds had been stocked under the supervision of Mr. Hatt in June 1944, and the usual hatchery methods were employed, with the exception that the ponds were stocked at a much lower rate.

Pond 5, which was stocked with only 2,452 fry per acre in June 1941, yielded the highest survival of any of the unfertilized ponds that year, whereas, when stocked at more than three times the 1941 rate in 1944, the survival was practically nil. A summary of the information obtained from the 1944 experiment has been given in Table 11. Had the survival of fish in each of the ponds been adequate, the information on the relative productivity of each pond would have materially assisted in the interpretation of the data obtained in 1941 and 1942. Nevertheless, it is of interest to note that the production of bluegills in pounds per acre was in the same order for all unfertilized ponds at the end of the first summer in each experiment.

Summary and Conclusions

1. Bluegill fry stocked at a low rate per acre in hatchery ponds produce much larger fish in the same period of time than do fry stocked at higher rates. When stocked at a rate of approximately 2,500 individuals per acre, the fish reached a size during their first summer of life (4 inches) as large as that of the average bluegill from Michigan lakes during its second or third summer. The rate of growth of the individual fish is inversely proportional to the rate of stocking per acre. Male bluegills grow faster than females during the second summer of life.

2. Rates of survival of bluegill fry as shown by these experiments are so diverse that only general conclusions may be drawn. The mortality in hatchery ponds was generally greater during the first summer than during the subsequent winter and summer. Survival of fry is dependent on many phenomena, such as, rapid changes in temperature, wave action over the trays, predation by other animals, and others.

3. Fertilizer, when applied at monthly intervals from June to September, caused an increase of plankton organisms, retarded the growth of submerged aquatic plants and apparently caused an increase in the survival of the fry by furnishing an abundance of food early in life. In 1944, however, when there were only two applications of fertilizer, the production and the rate of survival in Pond 8 which was fertilized were not as high as in Pond 7 which was not treated with fertilizer. The growth of the bluegills in Pond 8 was only slightly greater than in Pond 7 during 1944, when both ponds were stocked at the same intensity, and the production in pounds per acre was at about the same ratio for the two ponds in 1944 as it was at the end of the summer of 1941. This information suggests that the use of 10-6-4 inorganic fertilizer is of little value in rearing bluegills in Michigan.

4. Fishes of other species, especially green sunfish, which were present in bluegill rearing ponds, offered severe competition to the bluegills and thereby decreased the rate of survival and production.

5. The type of bottom soil and the amount of submerged aquatic vegetation apparently are factors in the productivity of hatchery ponds. Ponds with muck bottoms and good growth of submerged aquatic plants are usually more productive than are ponds with sand bottoms and little or no vegetation. The production of bluegills in pounds per acre in hatchery

ponds is considerably greater during the second summer than the first. Treatment of hatchery ponds with fertilizer did not materially increase the production. There is an indication that there may be a decrease in the carrying capacity of hatchery ponds during the winter months. For this reason and also because growth over winter is negligible, it is not profitable to hold bluegills over for spring planting.

6. Bluegills can be raised in hatchery ponds to sizes at which they will spawn at the beginning of their second summer of life. Large numbers of adult bluegills which spawn in hatchery ponds tend to be more cannibalistic than do smaller numbers of spawning bluegills.

Recommendations

It is recommended that the experiment attempted during the summer of 1944 be repeated at the earliest opportunity when adequate personnel is available to make continuous, close observations. The study should be continued long enough to furnish information on the length of time necessary for hatchery ponds to reach maximum production. Growth, survival, and production data should be carefully gathered in October and April of each year following the original stocking until the carrying capacity of each pond is reached. Continuous observations are required in order to find out what happens and when it occurs.

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