MICHIGAN DEPARTMENT OF NATURAL RESOURCES
Research and Development Report No. 273*

August 10, 1972

SURVIVAL, GROWTH, AND PRODUCTION BY BLUEGILLS SUBJECTED TO POPULATION REDUCTION IN PONDS [1]

By George B. Beyerle and John E. Williams

Abstract

Survival, growth, and production of bluegills, in populations subjected to yearly reduction were studied in three large, adjacent ponds at Belmont. In Pond 1 (control) the mean standing crop in fall during the 5-year study was 324 kg/ha; [2] in Pond 2 (60% yearly reduction of young-of-the-year bluegills) it was 226 kg/ha; and in Pond 3 (90% yearly reduction of young-of-the-year bluegills), 249 kg/ha. Mean yearly reduction in total standing crop was 4% (handling loss) in Pond 1, 33% in Pond 2, and 38% in Pond 3. Survival of young-of-the-year bluegills in Pond 1 was very low (mean of 0.5% per year), compared to survival of young in Pond 2 (mean of 8.1% per year) and Pond 3 (12.2% per year). No correlation occurred between calculated egg production and number of young bluegills surviving to fall. Growth of bluegills in all three ponds was very similar; it was also slow, averaging over 25 mm (1 inch) less than the statewide average for Michigan.

---

* Institute for Fisheries Research Report No. 1788.

[1] Contribution from Dingell-Johnson Project F-29-R, Michigan.

[2] Population data in this report are given in metric units, in anticipation of general adoption of this system by the scientific community. To convert number per hectare to number per acre, multiply by 0.405; for kilograms per hectare to pounds per acre, multiply by 0.893.

Mean total yearly production in ponds 2 and 3 was similar, and averaged 31% more than in Pond 1. Production by young-of-the-year bluegills in Pond 1 was only 27% of total production, compared with a mean of 58% for ponds 2 and 3. Pond 1 outdid the other ponds in production by year classes other than young-of-the-year. During the study, the number of catchable bluegills per hectare increased from 45 to 351 in Pond 1, decreased from 144 to 126 in Pond 2, and decreased from 169 to 10 in Pond 3.

Results of this study suggest that one way to produce larger and faster-growing bluegills in lakes where growth is slow is to keep the bluegill population substantially unbalanced by yearly removal of as much as 50% of the older bluegills, while cropping each new year class down to a level below 10,000 bluegills per hectare.

Introduction

The bluegill (Lepomis macrochirus) is the predominant fish in most lakes in southern Michigan. Because of a relatively short growing season and low productivity of many lakes, bluegills do not grow so rapidly in Michigan as they do in many southern states. In recent years such events as replacement of weedy, muddy shoreline with gravel at homesites, and increased fishing pressure on predatory fishes, have seemingly caused higher survival and even slower growth of bluegills. Today many southern Michigan lakes are characterized by predominant populations of slow-growing bluegills and depressed populations of predator fishes. Development of spawning marshes for northern pike has resulted in marked increases in pike populations in some lakes, but it has been shown that even large populations of northern pike (Esox lucius) will not control a predominant bluegill population (Beyerle, 1971). Various attempts have been made to reduce the number of bluegills in problem lakes by both seining and chemical treatment (Hooper et al., 1964), and by application of copper sulphate crystals to bluegill spawning nests (Beyerle and Williams, 1967). No management technique or combination of techniques has improved bluegill growth for more than a few years (Hooper et al., 1964). All techniques have usually been applied on a "one-shot" basis, and past results have shown that when a large percentage of a bluegill population is removed, it requires only a year or two for compensatory reproduction and survival to produce a population that is no better than the original. Thus, it seems clear that the number-one problem in management of slow-growing bluegills is understanding and coping with the tremendous reproductive and survival potential of the species. One way of obtaining such understanding is to establish populations under conditions where one can obtain information on production, survival, and growth following planned reductions in population.

The objectives of the present study were to determine the survival, growth, and production of bluegills in three ponds over a 5-year period, during which one population served as a control, and in two populations the young-of-the-year were cropped each year at 60% and 90%.

Materials and methods

The three ponds are located on state-owned property near Belmont in Kent County. Water is supplied by a creek which originates from springs located 1 mile from the ponds. The creek feeds Pond 1, which feeds Pond 2, which in turn feeds Pond 3. For the first 2 years of the study Pond 1 had to be drained into Pond 2, but during the last 3 years all ponds could be drained separately. Pond 1 is 1.8 hectares (4.4 acres) in area; has a maximum depth of 2.4 meters (7.9 feet), and an average depth of 1.2 meters (3.9 feet). Corresponding data for Pond 2 are 2.6 hectares (6.4 acres), 2.1 meters (6.9 feet), and 1.5 meters (4.9 feet); for Pond 3, 1.0 hectare (2.5 acres), 2.1 meters (6.9 feet), and 1.5 meters (4.9 feet).

At the beginning of this study Chara was the predominant aquatic plant in all three ponds. Potamogeton occurred in all ponds. Pond 1 contained a moderate growth of Elodea. The bottom fauna included moderate populations of midges, burrowing mayflies (Hexagenia), damselflies, dragonflies, crayfish and tadpoles. Prior to this study the ponds contained a variety of fish, including the pumpkinseed (Lepomis gibbosus), green sunfish (L. cyanellus), largemouth bass (Micropterus salmoides) mudminnow (Umbra limi), several minnows (Cyprinidae) and darters (Percidae). In addition, Pond 1 contained a moderate population of brook trout (Salvelinus fontinalis) which had gained entrance from the feeder stream.

The three ponds were drained and the feeder stream was treated with rotenone to remove existing fish populations in the spring of 1963. Bluegills were collected by seine from nearby lakes to restock the ponds in June 1963. The ponds were stocked with bluegills 7-18 cm (2.8-7.1 inches) in length, at a density of 112 kg/ha; a large handling mortality reduced the population to an estimated 56 kg/ha in each of the three ponds.

The general plan was to allow the bluegills to become established until the fall of 1964, and then to begin the 5-year study by making fall population estimates (Petersen method) and determining mean length from samples taken with electrofishing gear. In spring the ponds would be drained, all bluegills collected, and the standing crop and mean length determined for each year class. All bluegills collected from Pond 1, the control pond, would be returned; whereas 60% of the young-of-the-year from the previous year would be removed ("cropped") from Pond 2, and 90% of those in Pond 3 would be removed. Semi-annual determinations of survival, growth, and production would be made by comparing fall population data, with records obtained at draining in the spring.

The bluegills stocked in 1963 produced a large 1963 year class, but there was no noticeable production and/or survival of bluegills in the 1964 year class in any pond. Thus we removed fish of the 1963 year class from ponds 2 and 3 in the spring of 1965. We also removed 40% of the original stock of bluegills in ponds 2 and 3 to match the situation in Pond 1 where poachers had removed a substantial number of large bluegills during the previous winter. Although no reductions other than those stated above were planned, some incidental handling mortality occurred during the draining of each pond. In addition, during draining of ponds 1 and 2 in the spring of 1966, an old outlet from Pond 1 was reopened so that Pond 1 could be drained separately from Pond 2. During this process, fish from Pond 2 had to be held in hatchery ponds for an extended period; unfortunately there was a substantial mortality of 58% of original stock, 50% of the 1963 year class, and 98% (in place of the planned 60%) of the 1965 year class. Because of this high mortality, and because the spring pond drainings were extending into the normal spawning period for the bluegill, the plan of operation was changed in 1966 to pond draining in fall, followed by Petersen population estimates in spring.

By 1965 during the fall population estimate, the marking (caudal fin clip) of many small bluegills had become a tedious task. Consequently during the next population estimate in the spring of 1967, all small bluegills were marked (successfully) by immersion for

60 minutes in an oxygenated 1:25,000 solution of Bismark Brown Y (Latta, unpublished report). This marking procedure was continued during the remainder of the study.

Sometimes a population estimate was obviously incorrect when compared with preceding and succeeding estimates, or when compared to information obtained when the pond was drained. In such instances, the estimates were adjusted, separately by age groups, making appropriate allowances for time intervals, seasons, and known mortality rates.

Semi-yearly production for each year class of bluegills was calculated with a Fortran computer program (Hunt, 1966), using data obtained during population estimates and pond drainings. Production for young-of-the-year was calculated using fecundity data obtained by Latta (unpublished data) for bluegills from Sugarloaf Lake, Washtenaw County. Using available information, it was assumed that all female bluegills 127 mm (5 inches) and over in length were fecund, that 50% of all bluegills were female, that all eggs were spawned and hatched into fry, and (based on sample lot weights) that the average weight of fry was 0.002 gram.

From May through October in both 1966 and 1967, electrofishing gear was used to take monthly samples of bluegills, so periodicity of growth in length could be determined. In 1966, excessive growth of weeds in Pond 1 made summer electrofishing difficult. In June 1967, Pond 1 was treated with copper sulphate and Aquathol Plus (endothal plus silvex); this treatment eliminated most weeds in both Pond 1 and Pond 2 during 1967 and subsequent years.

Results

Standing crop

The standing crop of bluegills in each of the three ponds as determined at 6-month intervals throughout the study is shown in tables 1, 2, and 3, respectively. In Pond 1 (control pond) the standing crop varied from a spring low of 136 kg/ha to a fall high of 494 kg/ha. Mean standing crop (before population reductions) was 265 kg/ha in spring, and 324 kg/ha in fall. Following population reductions, the mean increase in standing crop during summer was 50 kg/ha, and the mean decrease over winter was 91 kg/ha. In Pond 2 (with a 60% reduction of young-of-the-year) standing crop varied from a spring low of 100 kg/ha to a fall high of 306 kg/ha. Mean standing crop in spring was 121 kg/ha, and in fall 226 kg/ha. Mean increase in standing crop during summer was 143 kg/ha, and mean decrease over winter was 67 kg/ha. Standing crop in Pond 3 (90% reduction of young-of-the-year) varied from a spring low of 9 kg/ha (in 1969, following an unusually high overwinter mortality) to a fall high of 458 kg/ha. Mean standing crop in spring was 140 kg/ha, and in fall it was 249 kg/ha. Mean increase in standing crop during the summer was 129 kg/ha, and mean decrease overwinter was 110 kg/ha.

Because of unanticipated handling mortality among the experimental fish, the original plans for population reduction (see "Procedures") were modified considerably; the actual reductions in per cent of total standing crops (by weight), resulting from the combination of experimental removal and unanticipated mortality, are shown in Table 4. While mean yearly reduction in the control pond (Pond 1) was only 4%, the 33% and 38% mean reductions in ponds 2 and 3, respectively, were much more significant. (To assure correct interpretation of the data in Table 4, take Pond 2 and April 1965 as an example. The young which were removed amounted to 35% by weight of the entire standing crop of bluegills of all ages, and the older fish which were removed amounted to 17%; the two values add to 52% total removal.)

Survival

The percentage survival of bluegills in the three ponds over 6-month periods throughout the study is shown in Table 5. Survival rate of original stock bluegills was highest in Pond 3 and lowest in Pond 1. Following production of the 1963 year class in Pond 1, original stock bluegills never made up more than 9% by weight of the total standing crop (Table 1). By winter of 1966 all original stock bluegills in Pond 1 had died. In Pond 2, following production of the 1965 year class, original stock bluegills never exceeded 15% of the total standing crop (Table 2). In Pond 3 following production of the 1965 year class, original stock bluegills never exceeded 25% of the total standing crop (Table 3). By spring of 1969 all original stock bluegills in both Pond 2 and Pond 3 had died.

The first year class of bluegills produced in Pond 1 (1963) survived in large numbers and dominated the population throughout the study (Tables 1 and 5). No bluegills of the 1964 year class were ever found in Pond 1. No bluegills of the 1965 or 1967 year classes survived beyond the spring of 1966 and 1968, respectively. A relatively small number from the 1966 year class survived the first winter, and some of these fish survived to the end of the study. A very large 1968 year class was produced in Pond 1, but an overwinter mortality in 1968 of over 97% decimated this population. Survival of the 1969 year class was unexpectedly low, considering the relatively small standing crop and the existing reproductive potential.

Much less variation in survival of bluegills occurred in ponds 2 and 3 (Tables 2, 3, and 5). In Pond 2 the 60% planned reduction of the 1963 year class in 1965, and the 50% unplanned reduction in 1966, resulted in a population less than one third the size of the 1963 year class in Pond 1. Thus a niche was provided for survival of subsequent year classes (1965 and 1966) in Pond 2. Other planned reductions in ponds 2 and 3 throughout the study conceivably permitted the relatively constant high survival of each new year class in both ponds. Further substantiation of this theory is the fact that no population reduction was made in ponds 2 and 3 in 1964, and no known survival of the 1964 year class occurred in either pond.

No positive correlation occurred in any pond between the calculated number of eggs produced each year and the subsequent number of young-of-the-year bluegills surviving to the fall (Table 6).

However, in ponds 2 and 3 there was a significant negative correlation between the number of eggs produced and the percentage survival of young-of-the-year.

Growth

Growth of bluegills in all three ponds is presented in Table 7, along with comparative figures on state-wide average growth of bluegills in Michigan (from Laarman, 1963). Bluegills of the original stock, after being put in the ponds, grew less than 2 mm (0.07 inch) per year in Pond 1; they grew 16 mm (0.6 inch) per year in Pond 2, and 17 mm (0.7 inch) per year in Pond 3. Growth of the important 1963 year class in each pond is shown in Figure 1. Growth in the three ponds was very similar, and also substantially below state average. Throughout the study, mean length in Pond 1 averaged 28 mm (1.1 inches) less than the Michigan average; in Pond 2, 38 mm (1.5 inches) less; and in Pond 3, 33 mm (1.3 inches) less. Growth of the small 1966 and 1968 year classes in Pond 1 was very close to average (Table 7). In both Pond 2 and Pond 3 growth of all year classes subsequent to 1963 was remarkably similar (33 to 41 mm, or 1.3 to 1.6 inches, less than average), except for the 1967 and 1968 year classes in Pond 3 which were somewhat faster growing (20 and 15 mm, or 0.8 and 0.6 inch, respectively, less than average). The 1967 year class was the smallest in Pond 3, and a severe over-winter mortality in 1968 undoubtedly was at least partially responsible for the faster growth of the 1968 year class.

Production

Production by each year class of bluegills was calculated for 6-month periods (October through March and April through September) throughout the study. In Pond 1 mean summer production for all year classes was 226 kg/ha, while mean winter production was 18 kg/ha (Table 8). In Pond 2 mean summer production was 318 kg/ha, and mean winter production was 11 kg/ha (Table 9). Mean summer production in Pond 3 was 310 kg/ha, and mean winter production was 1.8 kg/ha (Table 10). Mean total yearly production was 244 kg/ha in Pond 1, 330 kg/ha in Pond 2, and 312 kg/ha in Pond 3. Thus, mean total production in ponds 2 and 3 was similar, and averaged 31% more than in Pond 1. However, mean yearly production by young-of-the-year bluegills from 1965 through 1969 amounted to only 27% of the total production in Pond 1, compared with 52% in Pond 2 and 64% in Pond 3 (Table 11). Thus Pond 1 actually outdid the other ponds in mean yearly production by year classes other than young-of-the-year.

The final measure of success of any program of bluegill population reduction must be the increase in production of catchable sized fish. The standing crop of bluegills over 152 mm (6 inches), in the three ponds each fall from 1964 through 1969, is given in Table 12. In 1964, before the first population reduction, the number of large bluegills in ponds 2 and 3 averaged almost 3.5 times that in Pond 1. In 1969, after 5 years of population reduction in ponds 2 and 3, Pond 1 had over five times as many large bluegills as did ponds 2 and 3.

During the 5-year study the number of large bluegills increased seven-fold (from 45 to 351) in Pond 1, decreased by 12% (from 144 to 126) in Pond 2; and decreased by 94% (from 169 to 10) in Pond 3.

Discussion

The results of the present 5-year study show why most attempts to stimulate bluegill growth by population reduction end in futility. Lake "rehabilitations" usually consist of removing 25 to 50% of the standing crop, either on a "one shot" basis, or periodically every few years. Often an attempt is made to selectively kill smaller bluegills by concentrating on shoreline areas. The present study was of the same general type, where in ponds 2 and 3, an average of 36% of the standing crop was removed each year for 5 consecutive years, and practically all of the reduction in most years involved young-of-the-year fish. The obvious result was that too much of the niche created by population reduction was merely filled by a higher survival of the next year class rather than by an increase in growth of individual fish. Removal of some 36% of the population year after year continued to stimulate better survival of the remaining young fish, to the extent that treated populations were even less desirable than an untreated population (as represented by Pond 1). Even though 60% to 90% of the young-of-the-year were removed each year, the mean number of bluegills which survived population reduction was still over 40,000 per hectare in Pond 2 and over 10,000 per hectare in Pond 3. Evidently yearly recruitment must be kept substantially below 10, 000 young bluegills per hectare, if more production is to be shifted from young-of-the-year to older fish.

Growth of bluegills in ponds 2 and 3 was no better than in Pond 1. This suggests that, in addition to the limitation on recruitment, a substantial percentage (perhaps 50%) of the standing crop of bluegills other than young-of-the-year must be removed each year to provide the potential necessary to stimulate faster growth. In summary, it seems that one way to produce larger, faster growing bluegills in lakes with chronically slow growing populations is to keep the population substantially unbalanced by yearly removal of as much as 50% of bluegills older than young-of-the-year, while cropping each new year class to a level below 10, 000 per hectare.

Acknowledgments

R. E. Fitch, Rhyner Scholma, R. N. Cobb, and H. E. St. Ours participated in the many hours of pond draining, population estimates, and various other tasks. J. R. Ryckman and R. N. Cobb provided computer programming assistance. W. C. Latta critically reviewed the manuscript.

Table 1. --Standing crop of bluegills in Pond 1 at 6-month intervals as determined by draining, or estimated by electrofishing (values underlined). Where date is repeated, first set of data represents fish collected by draining, second set represents fish restocked.

Month and year	Original stock	Year class 1963	1965	1966	1967	1968	1969	Total standing crop
Number of fish per hectare								
6/63	1, 933	-	-	-	-	-	-	-
10/64	232	60, 996*	-	-	-	-	-	-
4/65	111	44, 771	-	-	-	-	-	-
4/65	109	42, 803	-	-	-	-	-	-
10/65	49*	29, 139	-	-	-	-	-	-
4/66	22	27, 876	15	-	-	-	-	-
4/66	22	25, 508	5	-	-	-	-	-
10/66	10	19, 441	-	7, 667	-	-	-	-
10/66	10	19, 059	-	7, 511	-	-	-	-
4/67	-	8, 949	-	3, 707	-	-	-	-
10/67	-	6, 143	-	939	15	-	-	-
10/67	-	5, 911	-	914	-	-	-	-
4/68	-	4, 747	-	435	-	-	-	-
10/68	-	2, 423	-	299	-	168, 862	-	-
10/68	-	2, 418	-	299	-	146, 829	-	-
4/69	-	1, 709	-	222	-	4, 189	-	-
10/69	-	879	-	198	-	3, 567	3, 423	-
Kilograms per hectare								
6/63	56	-	-	-	-	-	-	56
10/64	35	384*	-	-	-	-	-	419
4/65	16	331	-	-	-	-	-	347
4/65	16	317	-	-	-	-	-	333
10/65	8*	431	-	-	-	-	-	439
4/66	3	429	tr	-	-	-	-	432
4/66	3	393	tr	-	-	-	-	396
10/66	1	480	-	13	-	-	-	494
10/66	1	471	-	13	-	-	-	485
4/67	-	221	-	6	-	-	-	227
10/67	-	212	-	9	tr	-	-	221
10/67	-	204	-	9	-	-	-	213
4/68	-	178	-	4	-	-	-	182
10/68	-	179	-	12	-	37	-	228
10/68	-	179	-	12	-	32	-	223
4/69	-	126	-	9	-	1	-	136
10/69	-	83	-	11	-	45	3	142

tr = trace

* Population estimates were obviously in error. Figures given here are estimates based on later data (see text under Procedures).

Table 2.--Standing crop of bluegills in Pond 2 at 6-month intervals as determined by draining, or estimated by electrofishing (values underlined). Where date is repeated, first set of data represents fish collected by draining, second set represents fish restocked

Month and year	Original stock	Year class 1963	1965	1966	1967	1968	1969	Total standing crop
Number of fish per hectare								
6/63	1,933	-	-	-	-	-	-	-
10/64	749*	68,984*	-	-	-	-	-	-
4/65	358	55,118	-	-	-	-	-	-
4/65	215	21,857	-	-	-	-	-	-
10/65	183	18,614	212,455	-	-	-	-	-
4/66	114	15,504	65,292	-	-	-	-	-
4/66	47	7,835	1,511	-	-	-	-	-
10/66	30	5,241	331	188,100	-	-	-	-
10/66	30	5,236	331	75,241	-	-	-	-
4/67	28*	4,011	153	47,990	-	-	-	-
10/67	25	3,384	104	9,119	227,196	-	-	-
10/67	25	3,349	104	9,001	83,153	-	-	-
4/68	10*	1,166	64*	7,040	53,052*	-	-	-
10/68	0.7	924	40	4,164	33,140	76,333	-	-
10/68	0.7	904	37	4,083	26,266	30,425	-	-
4/69	-	598	-	3,193	9,863	8,200*	-	-
10/69	-	457	-	2,576	8,719	4,360	168,852	-
Kilograms per hectare								
6/63	56	-	-	-	-	-	-	56
10/64	88*	74*	-	-	-	-	-	162
4/65	42	58	-	-	-	-	-	100
4/65	25	23	-	-	-	-	-	48
10/65	28	108	47	-	-	-	-	183
4/66	20	99	14	-	-	-	-	133
4/66	8	50	0.3	-	-	-	-	58
10/66	6	107	2	47	-	-	-	162
10/66	6	107	2	19	-	-	-	134
4/67	6*	91	1	25	-	-	-	123
10/67	6	129	2	45	100	-	-	282
10/67	6	127	2	44	37	-	-	216
4/68	2*	48	1*	38	29*	-	-	118
10/68	0.2	53	1	64	146	42	-	306
10/68	0.2	51	1	62	116	17	-	247
4/69	-	34	-	49	43	5*	-	131
10/69	-	29	-	56	93	22	62	262

*Population estimates were obviously in error. Figures given here are estimates based on later data (see text under Procedures).

Table 3.--Standing crop of bluegills in Pond 3 at 6-month intervals as determined by draining, or estimated by electrofishing (values underlined). Where date is repeated, first set of data represents fish collected by draining, second set represents fish restocked.

Month and year	Original stock	Year class 1963	1965	1966	1967	1968	1969	Total standing crop
Number of fish per hectare								
6/63	1,933	-	-	-	-	-	-	-
10/64	1,146*	190,000*	-	-	-	-	-	-
4/65	548	125,076	-	-	-	-	-	-
4/65	262	6,014	-	-	-	-	-	-
10/65	223*	5,100*	420,000*	-	-	-	-	-
4/66	158	3,984	256,260	-	-	-	-	-
4/66	156	3,974	25,626	-	-	-	-	-
10/66	94	3,653	18,379	89,822	-	-	-	-
10/66	94	3,619	18,095	8,982	-	-	-	-
4/67	52	2,159	15,250*	5,669	-	-	-	-
10/67	42	1,823	12,911	5,046	16,798	-	-	-
10/67	40	1,764	12,394	4,844	1,680	-	-	-
4/68	16*	319	9,950*	1,354	1,230*	-	-	-
10/68	3	143	6,368	1,339	697	104,508	-	-
10/68	2	143	6,360	1,336	697	10,451	-	-
4/69	-	22*	35	220*	20*	4,400*	-	-
10/69	-	7	10	54	-	1,694	81,270	-
Kilograms per hectare								
6/63	56	-	-	-	-	-	-	56
10/64	101*	357*	-	-	-	-	-	458
4/65	48	235	-	-	-	-	-	283
4/65	31	12	-	-	-	-	-	43
10/65	32*	80*	126*	-	-	-	-	238
4/66	23	58	77	-	-	-	-	158
4/66	22	58	8	-	-	-	-	88
10/66	17	84	72	51	-	-	-	224
10/66	17	83	71	5	-	-	-	176
4/67	9	57	59*	4	-	-	-	129
10/67	8	60	119	23	30	-	-	240
10/67	7	58	114	22	3	-	-	204
4/68	3*	10	96*	7	3*	-	-	119
10/68	0.7	13	129	20	6	61	-	230
10/68	0.4	13	129	20	6	6	-	174
4/69	-	2*	0.7	3*	0.2*	3*	-	9
10/69	-	0.6	0.8	2	-	36	63	102

* Population estimates were obviously in error. Figures given here are estimates based on later data (see text under Procedures).

Table 4.--Percentages of total standing crop of bluegills (by weight) removed from the three ponds at time of draining, computed separately for young-of-the-year and for older fish. (For total percentage, add the two.) Young removed in 1965 were of the 1963 year class.

Date	Pond 1		Pond 2		Pond 3	
	Young	Older	Young	Older	Young	Older
4/65	4	0	35	17	79	6
4/66	0	8	11	45	44	0
10/66	0	2	17	0	20	1
10/67	0	4	22	1	11	4
10/68	2	0	8	11	24	0
Mean	1	3	19	14	36	2

Table 5.--Percentage survival of each year class of bluegills in the three ponds from one season to the next. S = summer (April through September). W = winter (October through March). T = survival from pond draining to pond draining, tr = less than 0.01.

	Year and season		Original stock	Year class[1]					
				1963	1965	1966	1967	1968	1969
Pond 1	1964	W	48	73	-	-	-	-	-
	1965	S	45	68	tr	-	-	-	-
		W	45	96	26	-	-	-	-
		T	20	65	tr	-	-	-	-
	1966	S	45	76	0	0.7	-	-	-
		T	45	76	0	0.7	-	-	-
		W	0	47	-	49	-	-	-
	1967	S	-	69	-	25	tr	-	-
		T	-	32	-	12	tr	-	-
		W	-	80	-	48	0	-	-
	1968	S	-	51	-	69	-	2	-
		T	-	41	-	33	-	2	-
		W	-	71	-	74	-	3	-
	1969	S	-	51	-	89	-	85	0.02
		T	-	36	-	66	-	2	0.02
Pond 2	1964	W	48	80	-	-	-	-	-
	1965	S	85	85	7	-	-	-	-
		W	62	83	31	-	-	-	-
		T	53	71	2	-	-	-	-
	1966	S	64	67	22	22	-	-	-
		T	64	67	22	22	-	-	-
		W	94	77	46	64	-	-	-
	1967	S	89	84	68	19	5	-	-
		T	83	65	31	12	5	-	-
		W	40	35	61	78	64	-	-
	1968	S	8	79	63	59	62	2	-
		T	3	28	38	46	40	2	-
		W	0	66	51	78	38	27	-
	1969	S	-	76	0	81	88	53	5
		T	-	50	0	63	33	14	5
Pond 3	1964	W	48	66	-	-	-	-	-
	1965	S	85	85	12	-	-	-	-
		W	71	78	61	-	-	-	-
		T	60	66	7	-	-	-	-
	1966	S	60	92	72	2	-	-	-
		T	60	92	72	2	-	-	-
		W	55	60	84	63	-	-	-
	1967	S	81	84	85	89	0.5	-	-
		T	45	50	71	56	0.5	-	-
		W	40	18	80	28	73	-	-
	1968	S	19	45	64	99	57	11	-
		T	8	8	51	28	42	11	-
		W	0	15	1	16	3	42	-
	1969	S	-	32	29	25	0	38	36
		T	-	5	2	4	0	16	36

[1] There was no survival of a 1964 year class to the first winter (of 1964).

Table 6. --Relationship between calculated egg production and survival of young-of-the-year bluegills to fall. Figures which are underlined are estimates based on later population data.

Year	Calculated production of eggs per hectare	Number of young-of-year per hectare in fall	Per cent survival
Pond 1			
1965	1,812,000	57	<0.01
1966	1,179,000	7,667	0.7
1967	3,938,000	15	<0.01
1968	10,746,000	168,862	1.6
1969	14,852,000	3,423	0.02
Mean	-	-	0.46
Pond 2			
1965	2,893,000	212,455	7.3
1966	869,000	188,100	21.6
1967	4,305,000	227,196	5.3
1968	4,454,000	76,333	1.7
1969	3,639,000	168,852	4.6
Mean	-	-	8.10
Pond 3			
1965	3,520,000	420,000	11.9
1966	4,804,000	89,822	1.9
1967	3,576,000	16,798	0.5
1968	924,000	104,508	11.3
1969	228,000	81,270	35.6
Mean	-	-	12.24

Table 7.--Mean length in millimeters[1] of bluegills in the three ponds at the time of draining

Month and year	Age group 0	I	II	III	IV	V	VI	Original stock
Michigan state-wide averages[2]								
May	-	76	97	127	150	-	-	-
October	-	99	130	147	165	180	193	-
Pond 1								
4/65	-	-	78	-	-	-	-	198
4/66	-	-	-	98	-	-	-	201
10/66	50	-	-	113	-	-	-	202
10/67	-	86	-	-	125	-	-	-
10/68	27	-	132	-	-	159	-	-
10/69	41	91	-	146	-	-	171	-
Pond 2								
4/65	-	-	43	-	-	-	-	184
4/66	-	27	-	76	-	-	-	207
10/66	28	73	-	109	-	-	-	220
10/67	33	70	104	-	131	-	-	228
10/68	35	67	99	-	-	148	-	248
10/69	31	70	89	110	-	-	170	-
Pond 3								
4/65	-	-	52	-	-	-	-	168
4/66	-	29	-	98	-	-	-	197
10/66	36	65	-	113	-	-	-	208
10/67	51	68	85	-	126	-	-	216
10/68	36	85	99	109	-	168	-	236
10/69	39	110	-	-	-	-	-	-

[1] For length in inches, divide by 25.4

[2] Modified from Laarman, 1963.

Table 8. --Production of bluegills in kilograms per hectare over consecutive 6-month periods in Pond 1

Winter= October through March; Summer = April through September

Period	Original stock	Year class 1963	1965	1966	1967	1968	1969	Total
Winter 1964	0.0*	58	-	-	-	-	-	58
Summer 1965	1.4	259	10	-	-	-	-	271
Winter 1965	-0.4	17	0*	-	-	-	-	17
Summer 1966	<0.1	206	0	54	-	-	-	260
Winter 1966	0.0	0*	-	0*	-	-	-	0
Summer 1967	-	72	-	14	23	-	-	109
Winter 1967	-	16	-	-0.2	0	-	-	16
Summer 1968	-	121	-	12	-	138	-	271
Winter 1968	-	0*	-	0*	-	0*	-	0
Summer 1969	-	25	-	3.4	-	92	100	221

* Estimated as 0 because no measurement of mean length was made during spring population estimate; therefore same length as during fall draining was assumed.

Table 9. --Production of bluegills in kilograms per hectare over consecutive 6-month periods in Pond 2

Winter = October through March; Summer = April through September

Period	Original stock	Year class						Total
		1963	1965	1966	1967	1968	1969	
Winter 1964	0 *	-1	-	-	-	-	-	-1
Summer 1965	6.7	112	123	-	-	-	-	242
Winter 1965	3.4	10	0*	-	-	-	-	14
Summer 1966	1.5	92	3.7	118	-	-	-	215
Winter 1966	0.5	10	0.1	16	-	-	-	26
Summer 1967	0.2	57	1.5	78	294	-	-	430
Winter 1967	0 *	6	0*	4	7	-	-	17
Summer 1968	0.4	17	0.8	53	183	143	-	397
Winter 1968	0	0*	0*	0*	0*	0*	-	0
Summer 1969	-	18	0	18	61	29	182	308

* Estimated as 0 because no measurement of mean length was made during spring population estimate; therefore same length as during fall draining was assumed.

Table 10.--Production of bluegills in kilograms per hectare over consecutive 6-month periods in Pond 3

Winter = October through March; Summer = April through September

Period	Original stock	Year class						Total
		1963	1965	1966	1967	1968	1969	
Winter 1964	0 *	0*	-	-	-	-	-	0
Summer 1965	5.8	94	337	-	-	-	-	437
Winter 1965	0.9	-5	0*	-	-	-	-	-4
Summer 1966	3.7	33	103	172	-	-	-	312
Winter 1966	-0.6	10	-0.7	1.5	-	-	-	10
Summer 1967	1.5	13	76	24	127	-	-	242
Winter 1967	0 *	-2	4	0.8	0.4	-	-	3
Summer 1968	0.6	12	84	15	7	178	-	296
Winter 1968	0	0*	0*	0*	0*	0*	-	0
Summer 1969	-	-0.1	1.1	2.4	0	70	188	261

* Estimated as 0 because no measurement of mean length was made during spring population estimate; therefore same length as during fall draining was assumed.

Table 11.--Production of bluegills as kilograms per hectare in three Belmont Ponds, in relation to the extent of annual reduction of the standing crop. All figures are averages for several years.

Measures	Pond 1	Pond 2	Pond 3
Standing crop before reduction	344	197	227
Reduction in standing crop (%)	4	33	38
Annual production:			
By all year classes	244	330	312
By young-of-year only	65	172	200
% by young-of-year	27	52	64
By older year classes	179	158	112
% by older year classes	73	48	36

Table 12.--Number of bluegills 6 inches and over, per hectare in the three Belmont Ponds each fall throughout the study. (O. S. = Original stock)

Date	Pond 1		Pond 2		Pond 3	
	Year class	Number	Year class	Number	Year class	Number
10/64	O. S.	45	O. S.	144	O. S.	169
10/65	O. S.	9	O. S.	46	O. S.	64
	1963	17				
	Total	26				
10/66	O. S.	4	O. S.	12	O. S.	38
	1963	29	1963	8	1963	59
	Total	33	Total	20	Total	97
10/67	O. S.	0	O. S.	10	O. S.	17
	1963	149	1963	109	1963	74
	Total	149	Total	119	Total	91
10/68	O. S.	0	O. S.	0	O. S.	1
	1963	625	1963	132	1963	41
	Total	625	Total	132	Total	42
10/69	1963	316	1963	126	1963	3
	1965	0	1965	0	1965	4
	1966	20	1966	0	1966	3
	1967	15	1967	0	1967	0
	Total	351	Total	126	Total	10

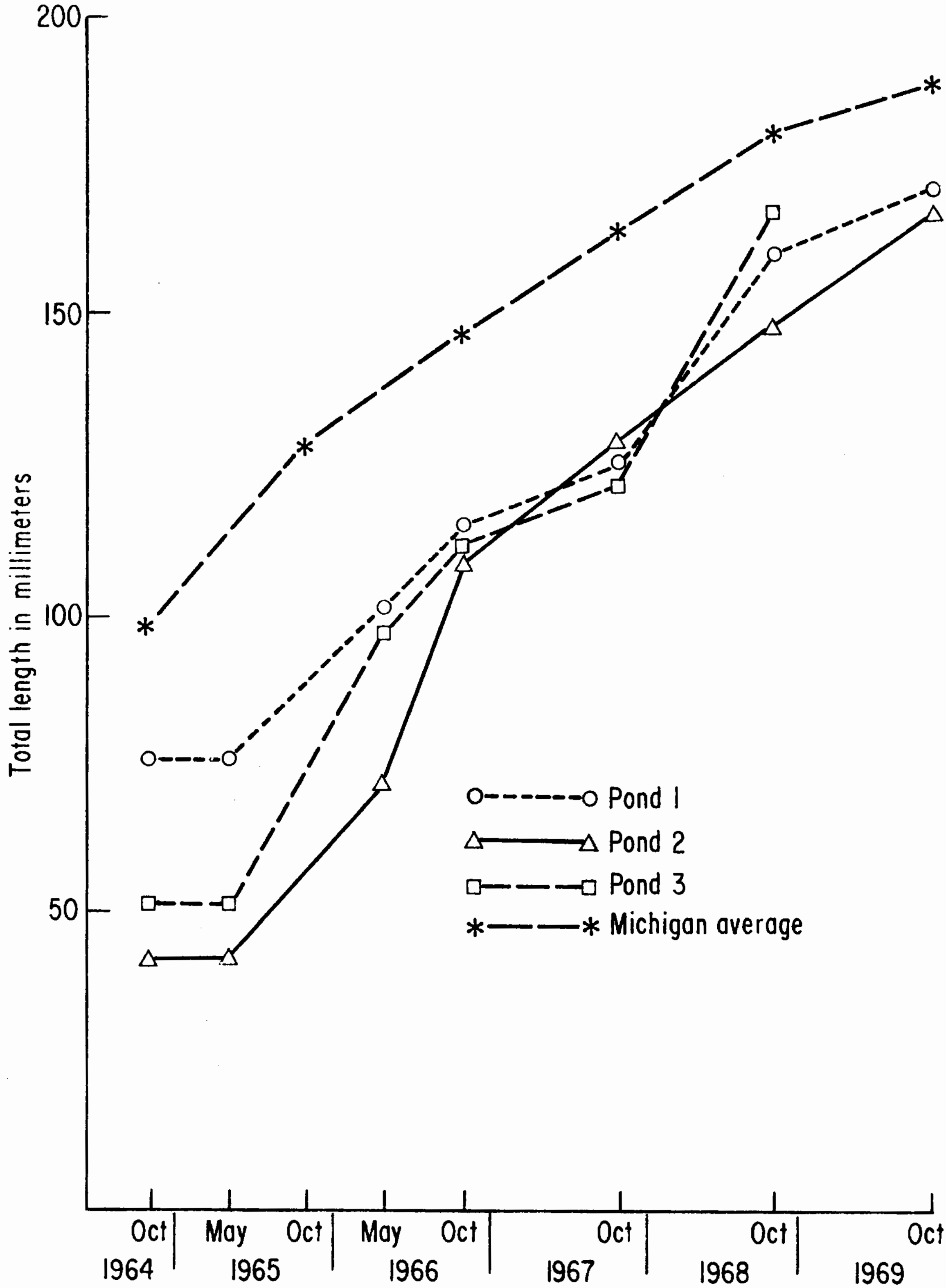

Figure 1.--Growth of bluegills of the 1963 year class in the three ponds, compared to the state-wide average for Michigan.

Literature cited

Beyerle, G. B. 1971. A study of two northern pike-bluegill populations. Trans. Amer. Fish. Soc., 100(1): 69-73.

Beyerle, G. B., and J. E. Williams. 1967. Attempted control of bluegill reproduction in lakes by the application of copper sulfate crystals to spawning nests. Prog. Fish-Cult., 29(3): 150-155.

Hooper, F. F. et al. 1964. Status of lake and stream rehabilitation in the United States and Canada with recommendations for Michigan waters. Inst. Fish. Research Rep. No. 1688, 56 p.

Hunt, R. L. 1966. Production and angler harvest of wild brook trout in Lawrence Creek, Wisconsin. Wisc. Conserv. Dep., Tech. Bull. 35, 52 p.

Laarman, P. W. 1963. Average growth rates of fishes in Michigan. Inst. Fish. Research Rep. No. 1675, 9 p.

INSTITUTE FOR FISHERIES RESEARCH

George B. Beyerle and John E. Williams

Report approved by G. P. Cooper

Typed by M. S. McClure