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RESULTS OF ATTEMPTS TO OPTIMIZE GROWTH AND SURVIVAL OF BLUEGILLS IN PONDS BY YEARLY POPULATION MANIPULATION[1]

By George B. Beyerle

Abstract

For 5 consecutive years bluegill populations in three ponds (1.0, 1.8, and 2.6 hectares) were manipulated to test the theory that optimum growth and survival would result if yearly survival of age-0 bluegills was restricted to less than 10,000 per hectare, and if 50% of all other age groups was harvested each fall when the ponds were drained. Age-0 bluegills were manipulated as planned, but the anticipated 50% yearly harvest of other age groups was reduced to 0-25% in an attempt to maintain total standing crops of approximately 100 kg per hectare. Analysis and projection of the data obtained lead to the postulation that, although the 50% yearly harvest of age-I and older bluegills did not permit the standing crop (expressed in weight) to expand as anticipated, a continuation of the planned harvest would have resulted in optimum sustained yield of bluegills 15.2 cm (6 inches) and larger.

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[1] Contribution from Dingell-Johnson Project F-35-R-3, Michigan

Introduction

In southern United States, bluegills (Lepomis macrochirus) grow rapidly to large size because of fertile waters and a long growing season. Much shorter growing seasons and less fertile waters, common in most northern states, cause bluegills to grow much more slowly. Bluegills that normally would be harvested at 2 years of age in southern waters may take 4 to 6 years to reach harvestable size in Michigan. However, fecundity and survival of bluegills remain high in northern states. Thus many lakes contain typically "stunted" bluegill populations, with the majority of fishes being between 3 and 6 inches in length. In fact, most of these fish die of natural causes without ever becoming large enough to be harvested by anglers.

In Michigan, attempts have been made to reduce numbers of stunted bluegills by various methods, including partial poisoning, complete poisoning and restocking, seining, poisoning of spawning beds, and encouragement of predatory fishes (Hooper et al. 1964; Beyerle and Williams 1967). However, no method or combination of methods has stimulated growth of bluegills for more than a few years, after which time the management technique must be repeated. The ideal method of population manipulation would seem to be one that could be applied easily and moderately over a number of years. This would tend to minimize the often drastic year-to-year fluctuations in size of consecutive year classes which typically occur when bluegill populations are grossly manipulated. To do this effectively, accurate data are required on the potential of bluegill populations to produce, survive, and grow under various degrees of harvest. Beyerle and Williams (1972) stocked three ponds at equal rates with spawning-size bluegills, and then harvested 60% and 90% respectively, of young-of-the-year bluegills produced in two of the ponds for 5 consecutive years. Fish older than young-of-the-year were not harvested. Very little stimulus to growth occurred, principally because, although numerically many fish were harvested, the harvest removed little of the total biomass.

In the present study it was proposed to reduce the standing crop of young-of-the-year bluegills to relatively low levels (2500, 5000, and 10,000 bluegills per hectare, respectively) in three ponds each fall for 5 consecutive years while also harvesting 50% of the standing crop of bluegills of each older age group in all ponds. The artificial harvest can logically be considered as representing a combination of harvest by predatory fishes (for bluegills less than 15.2 cm (6 inches) and anglers (for bluegills 15.2 cm and larger). Preliminary testing with models, utilizing data obtained from the previous study, indicated that the proposed levels of harvest should produce satisfactory bluegill growth in two of the ponds and marginal growth in the third pond. The plan was to modify the levels of harvest if after a year or two the anticipated results were not being realized.

Materials and methods

The models on which the population manipulations were based are presented in Tables 1 through 3 for ponds 1 through 3, respectively. In the models it was assumed that adult bluegills would be stocked in three ponds in spring 1970. It was predicted that the adults would produce a large 1970 year class and a very insignificant 1971 year class, a duplication of the sequence of events that occurred during the 2 years prior to artificial harvest at Belmont in the previous study (Beyerle and Williams 1972). By fall 1971, it was predicted that the standing crop of bluegills in each pond would have expanded to at least 200 kg per hectare. (In the previous study, average fall standing crops were 324, 226, and 249 kg per hectare, respectively.) The population would then be cropped as described previously to approximately 100 kg per hectare in each pond. Thus the only difference in the three population manipulations would be the number of age-0 bluegills restocked. In the previous study bluegills older than age 0 and not subjected to population manipulations had a mean yearly natural mortality of 56%. In the present study it was predicted that following the 50% cropping each fall, a compensatory survival of remaining bluegills would occur, reducing the yearly natural mortality to approximately 25%. Therefore, the total yearly mortality would consist of 50% artificial harvest, followed by 25% natural mortality of the remaining bluegills or a total yearly mortality of 62.5%. It was assumed the population in each pond would expand from 100 kg per hectare in fall 1971 to 200 kg per hectare by fall 1972, at which time the second artificial harvest would again reduce the total population to 100 kg per hectare. This process would continue to the end of the study.

Using Table 1 (Model 1) as an example, the procedure described in the following three paragraphs was used to estimate number of bluegills per hectare, mean length, and standing crop (kilograms per hectare) for each year class.

In fall 1971, survival of age-0 bluegills was predicted to be zero. Age-1 bluegills would be harvested down to 2500 fish per hectare. Their mean length (5.6 cm) was estimated from the previous study, and standing crop (6 kg per hectare) was determined from a length-weight table for bluegills from the Belmont Ponds. For adult bluegills stocked in 1970, it was predicted that survival to fall 1971 would be 254 fish per hectare, with 127 per hectare (50%) surviving artificial harvest. Mean length (18.3 cm) was estimated from the previous study and standing crop (11 kg per hectare) was calculated using the length-weight table.

In fall 1972, age-0 bluegills would be harvested to 2500 per hectare, with predicted mean length of 3.7 cm and standing crop of 4 kg per hectare. A predicted yearly natural mortality of 25% would have reduced original stock bluegills to 95 per hectare. A 50% artificial harvest would result in a survival of 48 per hectare. Based on previous experience, these bluegills would have grown to a mean length of 21.3 cm, resulting in a standing crop of 9 kg per hectare. For age-II bluegills, the 25% natural mortality plus 50% artificial harvest would result in survival of 938 fish per hectare. From past experience it was assumed that the total standing crop following artificial harvest would be 100 kg per hectare. Thus, age-II bluegills would have to expand to 87 (100-9-4) kg per hectare. From the length-weight table the mean length of age-II bluegills would be 16.9 cm.

The remainder of Table 1 was derived in similar fashion. The number of bluegills of each age group surviving natural mortality and artificial harvest was calculated. Then the mean length for each age group was estimated, based on past experience with bluegill growth at Belmont.

The estimated total weight of each age group was calculated from the length-weight table. Finally, mean lengths and total weights were adjusted until a reasonable compromise existed among the mean lengths for the various age groups and the combined total weights which had to total 100 kg per hectare.

The three ponds used for this study are located on state property at Belmont, Kent County. They are the same ponds that were used in the previous study of bluegill harvest (Beyerle and Williams 1972). Pond 1 (1.8 ha) is fed by a small stream which contains a population of brook trout (*Salvelinus fontinalis*). Pond 2 (2.6 ha) is fed by Pond 1, and Pond 3 (1.0 ha) by Pond 2. All three ponds are individually drainable. Average and maximum (in parentheses) depths are as follows: Pond 1, 1.2 m (2.4 m); Pond 2, 1.5 m (2.1 m); Pond 3, 1.5 m (2.1 m). *Chara* is the predominant aquatic vegetation in all three ponds. During the study the ponds were treated every other year with copper sulfate to control the *Chara* and facilitate draining and collecting fish.

The ponds were filled with water in early spring 1970. In May, adult bluegills (10 to 17 cm long) were stocked in each pond at a rate of 60 kg per hectare. As expected, the adults produced a large 1970 year class and an insignificant 1971 year class in all three ponds. In fall 1971, the ponds were drained and approximately 50% of the adult bluegills were harvested (127 adult bluegills per hectare were restocked in each pond). The insignificant 1971 year class was lumped with the large 1970 year class, as planned, and these combined year classes reduced to 2500 per hectare in Pond 1, 5000 per hectare in Pond 2, and 10,000 per hectare in Pond 3. Additional population manipulations were made in the fall of each year until 1975, when the study was ended, 1 year ahead of schedule.

Results

The actual population dynamics of bluegills in the three ponds from fall 1971 through fall 1975 are shown in Tables 4 through 6.

<u>Pond 1--low recruitment</u>

Obviously the bluegill population in Pond 1 (Table 4) never expanded as predicted in Table 1. In fact, despite reduced harvest rates in 1973, and no harvest at all of age-I and older bluegills in 1974, the total standing crop in 1975 was less than in 1971, when the first draining was made (Table 4). In fall 1972, original stock and 1970-year-class bluegills were each reduced by 50%, as planned. During the following year natural mortality of these bluegills was 46 and 51%, respectively, rather than the anticipated 25%. Thus the mean total mortality of all year classes from fall 1972 through fall 1973 was 74.2% (Table 7). In fall 1973, only the 1972 year class was cropped (25%). Natural mortality of the 1972 year class in the year following cropping was 71%, while the mean mortality of the two uncropped year classes was 58%. In 1974, no fall cropping was done, but mean natural mortality in the following year was a very high 84%. All years considered, the natural mortality of all year classes in Pond 1 averaged 68.6% per year, regardless of artificial cropping (Table 7).

In fall 1971, the mean length of the 1970 year class was 6.1 cm, or 3.8 cm (1.5 inches) less than Michigan state average for age-I bluegills (Table 4; Fig. 1). By fall 1972, mean length of the year class had reached 13.0 cm, exactly equivalent to state average, and by 1975 mean length was 22.6 cm, or 4.6 cm (1.8 inches) greater than state average. Although the final mean length attained by 1970 year-class bluegills was almost exactly as predicted, the year-to-year growth pattern was not as anticipated (Fig. 1). Growth of original stock bluegills was slightly greater than expected, but the 1973 and 1974 year classes were consistently below anticipated growth, despite the exceedingly high yearly natural mortalities that kept the population well below theoretical carrying capacity.

One measure of the quality of a fish population is the number of keeper-size (or catchable-size) individuals. For bluegills keeper-size is usually considered to be 15.2 cm (6 inches) and larger. For Pond 1 it was predicted that by fall 1975 the number of keeper-size bluegills would be 486 per hectare after cropping, or 972 per hectare before cropping. The actual number, with no cropping, was only 112 per hectare (Table 8).

Pond 2--medium recruitment

The actual population dynamics of bluegills in Pond 2 are given in Table 5. Following the artificial harvest in fall 1971, the natural mortality of original stock and 1970-year-class bluegills during 1972 was 9% and 42%, respectively--much lower than in Pond 1. Unfortunately, growth was less than expected, so that the population (in kilograms per hectare) did not expand as predicted. Nevertheless, both original stock and 1970-year-class bluegills were harvested at 50% in fall 1972, as planned. Natural mortality rates during 1973 were higher than expected: original stock, 83%; 1970 year class, 50%; 1972 year class, 28%. Thus by fall 1973 it was obvious that the rate of artificial harvest would have to be reduced in order to attain a standing crop approaching 100 kg per hectare. Consequently only 25% of age-I bluegills was harvested, and older fish were not cropped at all. The resulting standing total crop following harvest was 89 kg per hectare, reasonably close to the anticipated 100 kg per hectare. Natural mortality in 1974 averaged 63% per year class, equal to the predicted yearly total mortality (50% cropping mortality plus 25% natural mortality following cropping). Therefore in fall 1974 no harvest was made of any bluegills older than age 0, but the total standing crop was still only 85 kg per hectare, about the same as in 1973. Natural mortality in 1975 averaged only 40% per year class. If young-of-the-year fish had been cropped to 5000 fish per hectare in fall 1975, and all other year classes restocked without harvest, the total standing crop would have been 109 kg per hectare.

Growth of original stock and 1970-year-class bluegills (Table 5 and Fig. 1) was less than anticipated in 1971 and 1972. However, during 1973, growth of these fish accelerated and by fall mean lengths of both fish groups approximated the predicted mean lengths. In 1974 and 1975, growth of these fish continued as anticipated. Growth of all other year classes in Pond 2 was relatively slow. By fall 1975, mean lengths of age-I, age-II, and age-III bluegills were 1.6, 1.1, and 2.1 cm, respectively, less than predicted.

In fall 1975 the standing crop of keeper bluegills in Pond 2 was 507 fish per hectare, with no cropping (Table 8). The anticipated number of keeper bluegills was 848 per hectare before cropping (Table 2).

Pond 3--high recruitment

The actual population dynamics of bluegills in Belmont Pond 3 are shown in Table 6. Following the planned harvest in fall 1971, natural mortality during 1972 of original stock and 1970-year-class bluegills was 80% and 53%, respectively. Despite the high natural mortalities, both groups of bluegills were harvested 50% in fall 1972, as planned, In 1973, natural mortality was 38% for both original stock and 1970 year class, and 41% for the 1972 year class. In fall 1973, it was decided to decrease the harvest to 25% for the original stock and the 1972 year class, and to not harvest the 1970 year class. As a result, the total standing crop after harvest was increased to 102 kg per hectare. Mean natural mortality in 1974 was 55%, again necessitating a reduced harvest of 25% for age-I and older fish in fall 1974 in order to maintain a total standing crop of 87 kg per hectare. During 1975, mean natural mortality of age-I and older bluegills (not including original stock fish) was 43%. If the population of age-I and older bluegills had again been harvested at 25% in fall 1975, the total standing crop would have been 110 kg per hectare. Thus, during the last 3 years of the study, standing crops were maintained at a level closely approximating the predicted 100 kg per hectare by a harvest of 25% instead of 50%.

Growth of 1970-year-class bluegills in Pond 3 was practically identical to predicted growth through 1973 (Fig. 1; Table 6). During 1974 and 1975 growth increased so that by the fall of 1975, mean length of the 1970 year class was 4.4 cm more than predicted. Growth of all other year classes in Pond 3 was remarkably close to predicted growth.

By fall 1975, the standing crop of keeper bluegills was 223 per hectare before cropping (Table 8). The predicted number of keeper-size bluegills was 234 per hectare before cropping.

Discussion

Differential water temperature was one obvious variable that made Pond 1 a relatively unfavorable environment for bluegills. In spring and summer 1973, water temperatures were taken periodically at the outlets from each pond. Surface and bottom temperatures at the outlet structures were averaged to obtain mean pond temperatures. Bennett (1962) states that, "growth of warm-water fishes is very slow at temperatures below 55°F." In 1973, water temperatures in Pond 2 and Pond 3 probably reached 55 F the second week in May, but 55 F was not reached in Pond 1 until the first week in June (Fig. 2). Temperatures of 70 F occurred in Pond 2 and Pond 3 by the second week in June, but not until the first week in August in Pond 1.

In the previous study (Beyerle and Williams 1972), the bluegill population in Pond 1 was dominated by the 1963 year class which (without yearly cropping) by fall 1966 produced a standing crop of 480 kg per hectare. However, during the following 3 years, as this same year class was being reduced by natural mortality to 83 kg per hectare, there was very little survival of other year classes. In fact, age-0 bluegills were practically nonexistent in the fall of two of the three years, despite the presence of an adequate population of adult bluegills. In the present study stustantial numbers of age-0 bluegills were present in Pond 1 in the fall of each year (Table 9). Unfortunately Pond 1 happened to be chosen for harvest of age-0 bluegills down to only 2500 fish per hectare. Thus in Pond 1 a planned low restocking rate for age-0 bluegills plus extremely low water temperatures during the spring and summer, were factors which combined to severely limit expansion of the bluegill population.

In Pond 2 the plan was to reduce age-0 bluegills to 5000 per hectare each fall, while at the same time harvesting all other year classes by 50%. During the first 2 years of the study relatively slow growth and high natural mortality resulted in the population not expanding as anticipated. By completely eliminating the 50% yearly harvest during the final 2 years, a standing crop was attained that equalled the predicted crop. However, growth of all but the 1970 year class bluegills was less than anticipated. If the study had been extended, continued reduction of age-0 bluegills to 5000 per hectare, plus no harvest of older fish would probably have maintained the total standing crop at approximately 100 kg per hectare. However, growth of all bluegills would have been relatively slow and the quality of the population (number of keeper-size bluegills) would have diminished somewhat.

In Pond 3 it was planned to reduce age-0 bluegills to 10,000 per hectare each fall, and harvest all other year classes by 50%. However, as in Pond 2, it was necessary to reduce the harvest rate of fish older than age 0 in fall 1973 in order to maintain a total standing crop of approximately 100 kg per hectare. In 1974 and 1975, a reduced harvest rate of 25% for bluegills older than age 0 was necessary to maintain the standing crop. Continuation of the study, using the harvest rates established in 1974, would theoretically have maintained the standing crop and growth rates. Increasing the harvest rate to 50% would have reduced the fall standing crop significantly, while moderately increasing the growth rate. Eliminating all harvest of fish older than age 0 would almost duplicate the management strategy applied to Pond 3 in previous years (Beyerle and Williams 1972), which resulted in a typical "stunted" population.

During this one and the earlier study of bluegill population manipulations at Belmont, in ponds 2 and 3 the mean yearly natural mortality did not vary by more than 10% (from 46 to 56%) regardless of the magnitude of fall cropping. Apparently natural mortality can be considered constant. Also, the parameters for growth of bluegills at Belmont are reasonably well defined for most harvest rates. Thus, enough data are available from past population manipulations to predict with some confidence the results of other, hypothetical, manipulations. Essentially, the procedure used to determine survival and growth in the hypothetical manipulations which follow was the same as was used to construct the preliminary models for this study (see Materials and Methods). However, natural mortality was assumed to be the same (46-47%) as observed in the actual population manipulations, and no compensatory survival was calculated. Growth (mean length) was predicted based on results of actual manipulations. Previously collected length-frequency data from the Belmont Ponds were used to plot a graph comparing mean length of year classes with percent of bluegills 15.2 cm

(6 inches) and over in length. Thus, for any given mean length and total standing crop the number of keeper-size bluegills could be estimated.

In tables 10 and 11 are comparisons of various actual and hypothetical population manipulations in ponds 2 and 3, respectively. The tables show production and harvest of keeper bluegills that would occur in the third, fourth, and fifth year following initiation of the manipulations. Mean populations of keeper bluegills and projected harvest at various cropping rates are also shown in Figure 3. At a yearly fall harvest rate of 25%, 81 keeper-size bluegills per hectare would be cropped from Pond 2 and 53 bluegills per hectare from Pond 3. In both ponds the maximum number of fish cropped (176 per hectare in Pond 2 and 155 per hectare in Pond 3) would occur with a 50% harvest rate. At a 75% rate, the total yield of keeper bluegills would not increase, but would remain about the same (171 per hectare) in Pond 2 and decrease slightly (138 per hectare) in Pond 3. Also, the data suggest that a population subjected to 75% cropping could not sustain itself for more than a few years, while cropping rates of 50% should result in sustained yields for as long as the management strategy was applied. Thus, the optimum yearly fall harvest rate seems to be approximately 50%.

As suggested previously, annual fall cropping logically represents the sum of mortality due to predation (for bluegills under 15.2 cm) and mortality due to angling (for bluegills 15.2 cm and larger). Therefore, for slow-growing bluegill populations with characteristics similar to those described here, optimum yearly production and harvest of keeper-size bluegills should occur when age-0 bluegills are cropped each fall to approximately 5000 fish per hectare and the combination of angling plus predation mortality of older bluegills is equivalent to a yearly fall artificial harvest of 50%.

Summary

This study tested the theory that optimum growth and survival of bluegill populations which tend to grow slowly could be attained by each fall restricting survival of age-0 fish to less than 10,000 per hectare, and

harvesting 50% of all other age groups. During the study the yearly fall harvest rate for age-I and older bluegills was reduced to 25% or completely eliminated because of the much higher than expected natural mortality, which prevented the anticipated expansion of the standing crop. However, from the data obtained it can be calculated that if the 50% fall harvest (following the 46-47% yearly natural mortality) had been continued, the standing crops would have continued to be less than anticipated, but optimum sustained production and harvest of keeper bluegills would have occurred. Thus, in a slow-growing bluegill population with yearly natural mortality of approximately 50%, optimum sustained production and harvest of keeper bluegills will occur when the yearly survival of age-0 bluegills is restricted to approximately 5000 per hectare and when the yearly mortality of older bluegills is equivalent to a fall artificial harvest of 50%.

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Table 1.--Predicted population dynamics of bluegills in Belmont Ponds with artificial harvest in fall. Assumptions: 50% yearly artificial harvest of age-I and older fish; age-0 fish reduced to 2500 per hectare each fall; 25% yearly natural mortality of all fish; total standing crop is reduced to 100 kg/ha each fall and increases to 200 kg/ha by the following fall.

Age group	Number of blue-gill per hectare	Mean length (cm)	Standing crop (kg/ha)	Number of blue-gill per hectare	Mean length (cm)	Standing crop (kg/ha)	Number of blue-gill per hectare	Mean length (cm)	Standing crop (kg/ha)
	1971			1972			1973		
0	0	...	..	2500	3.7	4	2500	3.7	4
I	2500	5.6	6	0	...	..	938	12.7	36
II	....	...	..	938	16.9	87	0	...	..
III	....	...	..	....	...	..	352	20.1	56
IV	....	...	..	....	...	..	....	...	..
V	....	...	..	....	...	..	....	...	..
VI	....	...	..	....	...	..	....	...	..
Original stock	127	18.3	11	48	21.3	9	18	22.3	4
Total standing crop after harvest (kg/ha)			17			100			100
	1974			1975			1976		
0	2500	3.7	4	2500	3.7	4	2500	3.7	4
I	938	11.7	27	938	11.3	25	938	11.3	25
II	352	18.1	40	352	17.1	34	352	16.6	31
III	0	...	..	132	20.8	24	132	20.6	23
IV	132	21.5	27	0	...	..	50	22.7	12
V	....	...	..	50	22.7	12	0	...	..
VI	....	...	..	....	...	..	19	23.2	5
Original stock	7	23.6	2	3	24.4	1	0	...	..
Total standing crop after harvest (kg/ha)			100			100			100

Table 2.--Predicted population dynamics of bluegills in Belmont Ponds with artificial harvest in fall. Assumptions: 50% yearly artificial harvest of age-I and older fish; age-0 fish reduced to 5000 per hectare each fall; 25% yearly natural mortality of all fish; total standing crop is reduced to 100 kg/ha each fall and increases to 200 kg/ha by the following fall.

Age group	Number of blue-gill per hectare	Mean length (cm)	Standing crop (kg/ha)	Number of blue-gill per hectare	Mean length (cm)	Standing crop (kg/ha)	Number of blue-gill per hectare	Mean length (cm)	Standing crop (kg/ha)
	1971			1972			1973		
0	0	...	..	5000	3.7	7	5000	3.7	7
I	5000	5.6	13	0	...	..	1875	10.7	35
II	....	...	..	1875	13.5	84	0	...	..
III	....	...	..	....	...	..	703	16.0	54
IV	....	...	..	....	...	..	....	...	..
V	....	...	..	....	...	..	....	...	..
VI	....	...	..	....	...	..	....	...	..
Original stock	127	18.3	11	48	21.3	9	18	22.3	4
Total standing crop after harvest (kg/ha)			24			100			100
	1974			1975			1976		
0	5000	3.7	7	5000	3.7	7	5000	3.7	7
I	1875	9.4	26	1875	9.1	24	1875	9.1	24
II	703	14.4	39	703	13.7	33	703	13.4	30
III	0	...	..	264	16.7	23	264	16.4	22
IV	264	17.4	26	0	...	..	99	18.6	12
V	....	...	..	99	18.6	12	0	...	..
VI	....	...	..	....	...	..	37	19.2	5
Original stock	7	23.6	2	3	24.4	1	0	...	..
Total standing crop after harvest (kg/ha)			100			100			100

Table 3.--Predicted population dynamics of bluegills in Belmont Ponds with artificial harvest in fall. Assumptions: 50% yearly artificial harvest of age-I and older fish; age-0 fish reduced to 10,000 per hectare each fall; 25% yearly natural mortality of all fish; total standing crop is reduced to 100 kg/ha each fall and increases to 200 kg/ha by the following fall.

Age group	Number of blue-gill per hectare	Mean length (cm)	Stand-ing crop (kg/ha)	Number of blue-gill per hectare	Mean length (cm)	Stand-ing crop (kg/ha)	Number of blue-gill per hectare	Mean length (cm)	Stand-ing crop (kg/ha)
	1971			1972			1973		
0	0	...	..	10,000	3.7	14	10,000	3.7	14
I	10,000	5.6	26	0	...	..	3,750	8.5	32
II	....	...	..	3,750	10.7	77	0	...	..
III	....	...	..	....	...	..	1,406	12.6	50
IV	....	...	..	....	...	..	....	...	..
V	....	...	..	....	...	..	....	...	..
VI	....	...	..	....	...	..	....	...	..
Original stock	127	18.3	11	48	21.3	9	18	22.4	4
Total standing crop after harvest (kg/ha)			37			100			100
	1974			1975			1976		
0	10,000	3.7	14	10,000	3.7	14	10,000	3.7	14
I	3,750	7.5	24	3,750	7.2	22	3.750	7.2	22
II	1,406	11.3	36	1,406	10.8	31	1,406	10.5	28
III	0	...	..	527	13.1	21	527	12.9	20
IV	527	13.6	24	0	...	..	198	14.4	11
V	....	...	..	198	14.4	11	0	...	..
VI	....	...	..	....	...	..	74	15.3	5
Original stock	7	23.6	2	3	24.4	1	0	...	..
Total standing crop after harvest (kg/ha)			100			100			100

Table 4.--Actual population dynamics of bluegills in Belmont Pond 1, after artificial or no harvest in fall.

Age group	Number of blue-gill per hectare	Mean length (cm)	Standing crop (kg/ha)	Number of blue-gill per hectare	Mean length (cm)	Standing crop (kg/ha)	Number of blue-gill per hectare	Mean length (cm)	Standing crop (kg/ha)
	1971			1972			1973		
0	0	...	..	2500	3.6	2	2500	4.1	2
I	2500	6.1	8	0	...	...	406[a]	10.7	8
II	....	...	..	506	13.0	21	0	...	..
III	....	...	..	....	...	..	250[b]	17.3	27
IV	....	...	..	....	...	..	....	...	..
V	....	...	..	....	...	..	....	...	..
Original stock	127	19.3	18	24	22.4	6	12[b]	24.1	4
Total standing crop after harvest (kg/ha)			26			29			41

Age group	Number of blue-gill per hectare	Mean length (cm)	Standing crop (kg/ha)	Number of blue-gill per hectare	Mean length (cm)	Standing crop (kg/ha)
	1974			1975		
0	2500	3.0	1	2500	2.7	1
I	916[b]	10.7	20	547[b]	8.9	6
II	116[b]	14.5	10	124[b]	15.4	9
III	0	...	..	32[b]	19.3	4
IV	64[b]	20.6	12	0	...	..
V	....	...	..	3[b]	22.6	1
Original stock	6[b]	25.1	2	1[b]	25.7	<1
Total standing crop after harvest (kg/ha)			45			21

[a] Only 25% artificial harvest.

[b] No artificial harvest.

Table 5.--Actual population dynamics of bluegills in Belmont Pond 2, after artificial or no harvest in fall.

Age group	Number of blue-gill per hectare	Mean length (cm)	Standing crop (kg/ha)	Number of blue-gill per hectare	Mean length (cm)	Standing crop (kg/ha)	Number of blue-gill per hectare	Mean length (cm)	Standing crop (kg/ha)
	1971			1972			1973		
0	0	...	..	5000	3.0	2	5000	2.9	1
I	5000	5.7	14	0	...	..	2699[a]	8.4	24
II	....	...	..	1452	10.8	27	0	...	..
III	....	...	..	....	...	..	727[b]	16.2	61
IV	....	...	..	....	...	..	....	...	..
V	....	...	..	....	...	..	....	...	..
Original stock	127	15.0	9	58	17.3	5	10[b]	22.9	3
Total standing crop after harvest (kg/ha)			23			34			89

Age group	Number of blue-gill per hectare	Mean length (cm)	Standing crop (kg/ha)	Number of blue-gill per hectare	Mean length (cm)	Standing crop (kg/ha)
	1974			1975		
0	5000	2.5	1	5000	2.7	1
I	736[b]	7.6	5	1706[b]	7.5	10
II	1870[b]	12.0	51	555[b]	12.6	19
III	0	...	..	905[b]	14.6	47
IV	278[b]	16.9	27	0	...	..
V	....	...	..	192[b]	20.3	31
Original stock	2[b]	23.3	1	2[b]	24.0	1
Total standing crop after harvest (kg/ha)			85			109

[a] Only 25% artificial harvest.

[b] No artificial harvest.

Table 6.--Actual population dynamics of bluegills in Belmont Pond 3, after artificial or no harvest in fall.

Age group	Number of blue-gill per hectare	Mean length (cm)	Stand-ing crop (kg/ha)	Number of blue-gill per hectare	Mean length (cm)	Stand-ing crop (kg/ha)	Number of blue-gill per hectare	Mean length (cm)	Stand-ing crop (kg/ha)
	1971			1972			1973		
0	0	...	..	23,000[a]	3.3	14	10,000	3.6	7
I	10,000	5.6	20	0	...	..	10,218[b]	7.4	46
II	....	...	..	2,360	10.5	44	0	...	..
III	....	...	..	....	...	..	1,319[c]	13.1	47
IV	....	...	..	....	...	..	....	...	..
V	....	...	..	....	...	..	....	...	..
Original stock	127	17.5	11	13	19.6	2	6[b]	23.1	2
Total standing crop after harvest (kg/ha)			31			60			102

Age group	Number of blue-gill per hectare	Mean length (cm)	Stand-ing crop (kg/ha)	Number of blue-gill per hectare	Mean length (cm)	Stand-ing crop (kg/ha)
	1974			1975		
0	10,000	2.4	2	10,000	2.6	2
I	3,350[b]	7.5	19	4,216[b]	7.3	20
II	2,620[b]	10.5	46	2,237[b]	10.8	41
III	0	...	..	796[b]	13.5	31
IV	331[b]	14.9	19	0	...	..
V	....	...	..	106[b]	18.8	15
Original stock	2[b]	23.4	1	2[b]	24.9	1
Total standing crop after harvest (kg/ha)			87			110

[a] 13,000 excess bluegills per hectare stocked because of inaccurate scales.

[b] Only 25% artificial harvest.

[c] 9% handling mortality.

Table 7.--Mean yearly mortality of bluegills (in percent) in the Belmont Ponds, 1971-75; number of observations in parentheses.

	Pond number (density of recruits per hectare, in parentheses)					
	No. 1 (2,500)		No. 2 (5,000)		No. 3 (10,000)	
	Mortality		Mortality		Mortality	
	Natural	Total	Natural	Total	Natural	Total
Original stock 1972 only	62.2 (1)	....	9.4 (1)	....	80.3 (1)	....
Recruits[a]	69.5 (4)	....	55.0 (4)	....	48.2 (4)	....
Age II through age V, plus original stock following artificial harvest at percentages shown[b]						
0%	75.3 (6)	75.3 (6)	45.8 (6)	45.8 (6)	66.6 (1)	66.6 (1)
25%	71.0 (1)	78.2 (1)	25.0 (1)	43.8 (1)	37.8 (6)	52.9 (6)
50%	48.5 (2)	74.2 (2)	66.5 (2)	83.2 (2)	38.0 (2)	69.0 (2)
Mean yearly mortality all age groups	68.6 (14)	75.4 (9)	47.3 (14)	53.9 (9)	45.9 (14)	58.0 (9)

[a] Mortality for age I--1973-75, and age II--1972.

[b] Age II in 1972 and original stock in 1972 not included.

Table 8.--Actual versus predicted number per hectare of 6-inch and larger bluegills present after cropping in the Belmont Ponds, 1971-75.

Pond number and date	Actual	Predicted	Percent difference
Pond No. 1			
1971	127	123	+3
1972	106	803	-87
1973	236	447	-47
1974	162	497	-67
1975	112	486	-77
Pond No. 2			
1971	43	123	-65
1972	48	328	-85
1973	546	502	+9
1974	280	424	-34
1975	507	424	+20
Pond No. 3			
1971	98	123	-20
1972	13	48	-73
1973	158	123	+28
1974	146	105	+39
1975	167	117	+43

Table 9.--Standing crops (in fish per hectare) of young-of-the-year bluegills before artificial cropping in the Belmont Ponds, fall 1972-1975.

Date	Pond 1	Pond 2	Pond 3
Fall 1972	25,074	200,969	52,809
Fall 1973	62,444	84,988	108,920
Fall 1974	116,624	259,657	249,755
Fall 1975	375,003	232,015	309,545
Mean per year	144,786	194,407	180,257

Table 10.--Actual or predicted production (H plus R)[a] and harvest, in fish per hectare, of keeper-size bluegills in Pond 2 during the third, fourth, and fifth year following initiation of an annual fall harvest which cropped age-0 bluegills to 5000 per hectare and cropped all other age groups at rates shown below.

Year	Percent annual fall harvest of bluegills older than age 0							
	0[b]		25		50		75	
	H	R	H	R	H	R	H	R
3	0	546	60	179	210	210	210	70
4	0	280	67	202	152	152	204	68
5	0	507	115	347	167	167	99	33
Mean per year	0	444	81	243	176	176	171	57

[a] H = keeper-size bluegills harvested; R = keeper-size bluegills remaining in population.

[b] The mean yearly natural mortality of 47% observed with no annual harvest (Beyerle and Williams 1972) was assumed to be the same for all harvest rates.

Table 11.--Actual or predicted production (H plus R)[a] and harvest, in fish per hectare, of keeper-size bluegills in Pond 3 during the third, fourth, and fifth year following initiation of an annual fall harvest which cropped age-0 bluegills to 10,000 per hectare, and cropped all other age groups at rates shown below.

Year	Percent annual fall harvest of bluegills older than age 0							
	0[b]		25[c]		50		75	
	H	R	H	R	H	R	H	R
3	0	130	53	158	161	161	258	86
4	0	175	49	146	140	140	78	26
5	0	128	56	167	164	164	78	26
Mean per year	0	144	53	157	155	155	138	46

[a] H = keeper-size bluegills harvested; R = keeper-size bluegills remaining in population.

[b] Mean yearly natural mortality was 52%.

[c] Mean yearly natural mortality was 46% with 25% annual artificial harvest and assumed the same with 50% and 75% harvest rates.

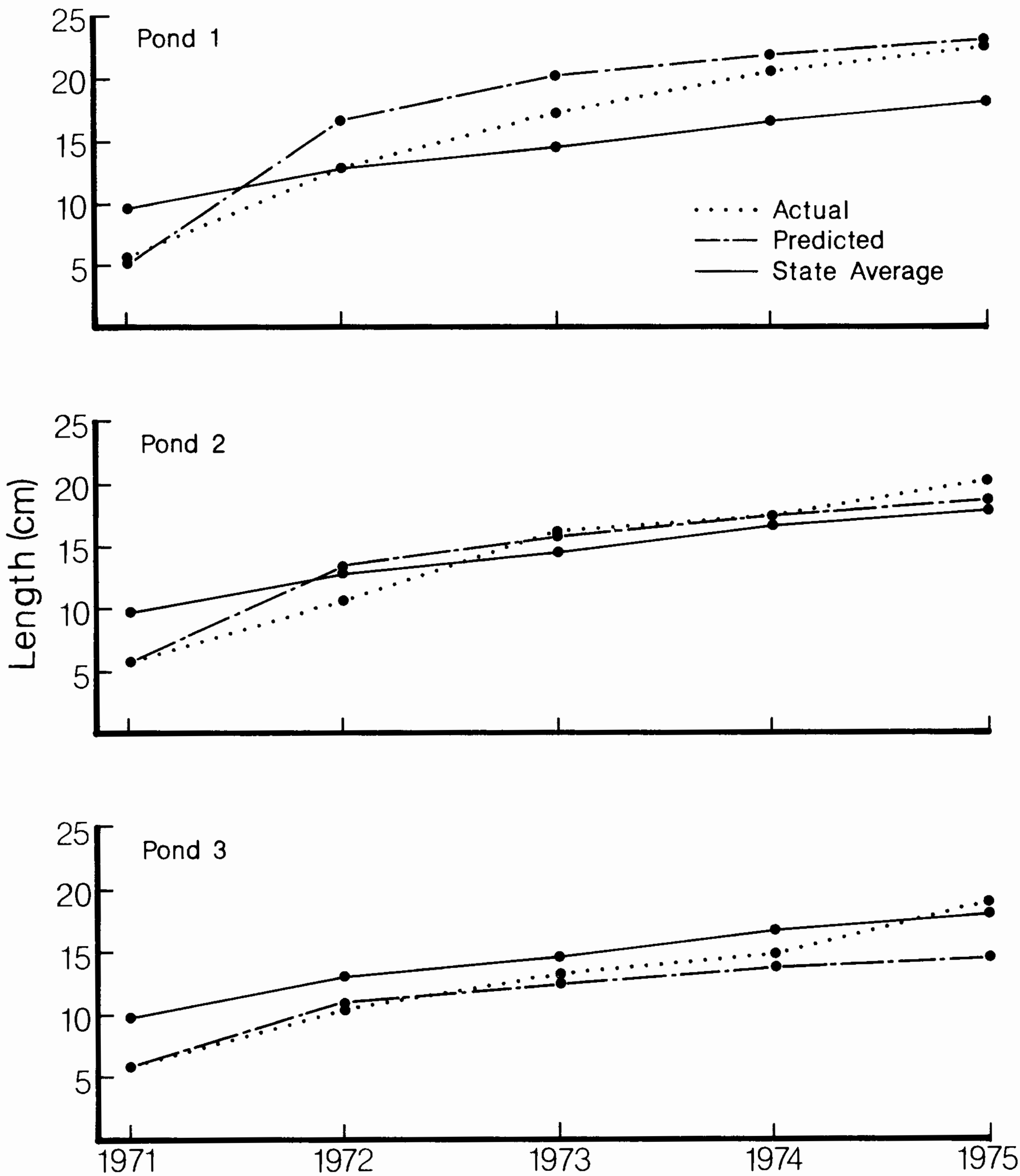

Figure 1.--Mean length of 1970 year-class bluegills in the Belmont Ponds from fall 1971 through fall 1975.

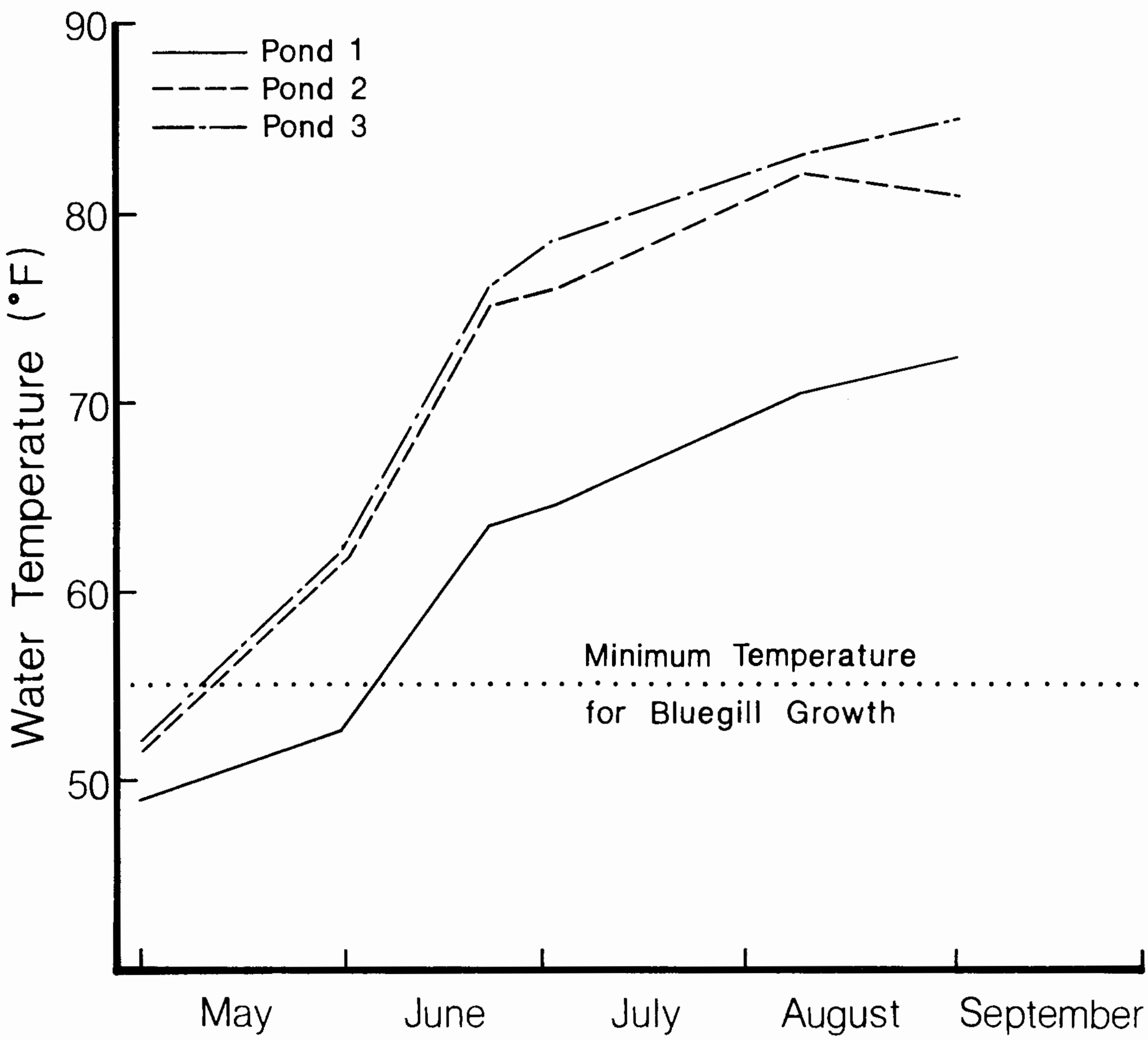

Figure 2.--Mean water temperatures in the three Belmont Ponds during 1973.

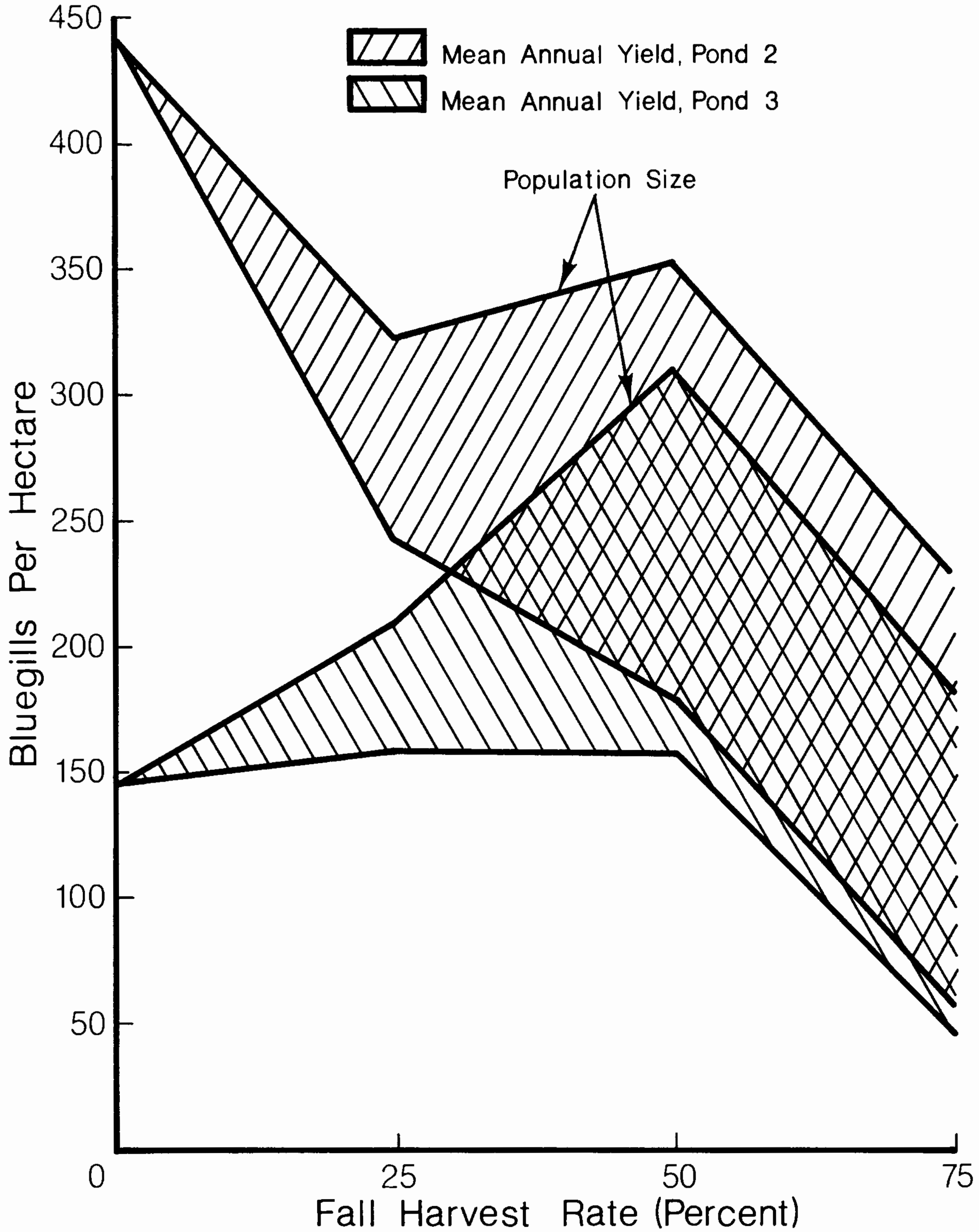

Figure 3. --Mean population size and annual yield of 15.2 cm and larger bluegills for various yearly harvest rates in Belmont Ponds 2 and 3.

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