FISH POPULATIONS AND MANAGEMENT PROBLEMS IN MICHIGAN ARTIFICIAL PONDS OF VARIABLE DESIGN

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ABSTRACT

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By

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This study was conducted in the Saginaw Valley, Michigan to investigate: (1) present status of artificial ponds as recreational fisheries; (2) nature and frequency of management problems; and (3) relationships of certain aspects of pond design to fish populations.

Interviews were conducted with 60 pond owners. Thirty-three percent of the ponds were located on farms. Fishing and swimming were by far the leading purposes for building the ponds, as well as the most frequent uses. Sixty percent of the owners stated that they were generally satisfied with their ponds; however, only 8% felt they had no major management problems. Excessive algal growth, stunted fish, and trespass were the problems most frequently listed by owners. Twenty-seven percent of the owners had stocked their ponds with trout; of these, only 18% harvested any of the fish. Poor success with trout was probably due largely to shallow depth in many of these ponds. Other pond and owner characteristics and management problems are listed and discussed.

Fish populations were sampled in 25 ponds. Age and growth data, population and standing crop estimates, bluegill:largemouth bass ratios, and percentages and standing crops of catchable-size gamefish are given. Variability among ponds in regard to these fish

population parameters was pronounced. Standing crops ranged from 991 to 0.0 kg/hectare.

Results cast suspicion on the merits of the largemouth bass-bluegill combination in such ponds. Undesirable results included low standing crops and densities of catchable-size fish, poor growth of both largemouth bass and bluegills, and poor reproduction of bass in many ponds. Nine of 20 inventoried ponds previously stocked with this combination contained no catchable-size bluegills, and 9 contained no catchable-size largemouth bass. Growth of both largemouth bass and especially bluegills, as compared with state-wide averages, was slow in most ponds.

Linear step-wise multiple regression analyses of 11 fish population parameters on 6 pond variables (maximum depth, mean depth, surface area, age of the pond, soil type, and bottom type) explained 21% to 73% of the variability in the fish population variables. Mean depth appeared to influence fish populations more than did any other pond variable. Mean depth was positively correlated with total standing crop, standing crop of catchable-size gamefish, population density of bluegills, and population density of catchable-size largemouth bass. Relationships among other variables are delineated and discussed.

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INTRODUCTION

According to officials of the U.S. Soil Conservation Service (SCS), 20-30 thousand artificial ponds have been constructed in Michigan. The question arises whether many of these ponds have lived up to the expectations of their owners in regard to recreational fishing.

For many years, the wide application of common pond management guidelines to different locales has been practiced in the United States. Many of these guidelines have been developed from studies by Swingle (1950), Moss and Hester (1956), and other authors of the southeastern U.S. Ball (1952) stated that data originating in the South may not be applicable to artificial ponds in Michigan in regard to fish stocking, and Regier (1962a), Bennett (1971), and others have discussed many of the problems resulting from regional policies and standards.

Management standards followed by SCS in Michigan include advocation of the largemouth bass-bluegill combination, and various specifications for pond design. The unpredictability of the largemouth bass-bluegill combination in northern waters has been cited by several authors (Bennett, 1971; Krumholtz, 1952). No data from Michigan's privately-owned artificial ponds have been published in fisheries literature. The study by Ball (1952) was conducted in experimental ponds under controlled conditions.

Biologists and administrators from several agencies receive many requests for aid in solving management problems from pond owners in various areas of the State. One such area is the Saginaw Valley where this study was conducted to investigate: (1) present status of artificial ponds as recreational fisheries; (2) nature and frequency of management problems; and (3) relationship of certain aspects of pond design to fish populations.

DESCRIPTION OF STUDY AREA AND PONDS

The study area consisted of the Swan Creek and Bad River drainage basins of Saginaw County, Michigan. Saginaw County is located in the east-central portion of the Lower Peninsula of Michigan. The county is part of the Saginaw lowland, a smooth low-lying plain, underlain by unconsolidated clayey till of the Wisconsin glaciation (USDA, 1938). Soils are intricately mixed in small bodies and drainage is slow in most of the study area.

According to USDA (1938), the salient features of the climate are long cold winters, mild summers, and well distributed moderate precipitation. Average annual precipitation is 35.8 in. The average difference between winter and summer mean temperatures is about 45 F; the mean frost-free season is 157 days.

All ponds in the study area were constructed by excavation; all but two with a drag-line. Most of the ponds are less than 100 ft wide, owing to the 50-ft span of the drag-line equipment. SCS assisted in the development of many of these ponds; thus their influence on design was substantial. SCS specifications for pond depth, basin slope, site location, and fish stocking were followed in most cases.

Of the 25 ponds whose fish populations were sampled, 24 had been stocked with 100 largemouth bass (*Micropterus salmoides*) and 500 bluegill (*Lepomis macrochirus*) fingerlings per acre.[1] Owners obtained the fish from the U.S. Bureau of Fisheries and Wildlife. The owners introduced additional fish and fish species into a number of the ponds

[1]Hereafter, the abbreviations LMB and BG for largemouth bass and bluegills respectively, will be used.

in subsequent years and/or the fish entered accidently, as by overflow of nearby ditches or via trespassers. Ten of the 25 ponds were located on farms, the remainder in rural-suburban areas.[1] Owners and locations of ponds are listed in Appendix F.

Aquatic vegetation ranged from absent to very abundant with *Chara* sp. the dominant form. Table 1 lists physical characteristics of the 25 ponds in which fish populations were sampled.

[1] A farm was defined as a parcel of land containing more than one acre of cultivated cropland and/or grazing area for livestock within the last 10 years.

TABLE 1. Physical characteristics of the 25 ponds in which fish populations were inventoried.

Pond	Maximum Depth (m)	Mean Depth (m)	Area (Hectares)	Age (Years)	Percent Clay: Soil of Surrounding Area	Percent Clay: Soil of Pond Bed
1	2.3 (7.5)[a]	1.8 (5.7)	0.07	9	0	0
2	3.7 (12.0)	2.1 (6.7)	0.41	18	0	0
3	5.5 (18.0)	2.2 (7.3)	0.22	8	0	40
4	4.0 (13.0)	2.0 (6.4)	2.35	16	100	90
5	4.0 (13.0)	2.7 (8.9)	0.31	16	100	100
6	3.4 (11.0)	2.7 (6.9)	0.10	6	100	90
7	2.8 (9.0)	1.9 (6.1)	0.26	4	50	100
8	4.6 (15.0)	1.7 (5.6)	0.22	5	70	100
9	4.6 (15.0)	2.4 (7.7)	0.20	7	0	70
10	3.5 (11.5)	2.4 (7.9)	0.26	4	10	40
11	2.8 (9.0)	2.0 (6.4)	1.03	33	100	100
12	3.1 (10.0)	2.4 (7.9)	0.53	32	100	100
13	5.8 (19.0)	2.2 (7.1)	0.32	6	0	30
14	3.5 (11.5)	2.3 (7.5)	10.52	5	0	0
15	2.5 (8.0)	1.5 (5.0)	0.21	2	100	100
16	2.6 (8.5)	1.9 (6.2)	0.65	49	100	100
17	2.9 (9.5)	1.9 (6.2)	1.28	22	100	100
18	3.4 (11.0)	1.6 (5.3)	0.37	6	0	30
19	4.0 (13.0)	2.8 (9.0)	0.23	23	50	60
20	5.0 (16.0)	2.8 (8.9)	1.90	5	0	0
21	2.6 (8.5)	1.6 (5.2)	0.21	5	100	100
22	2.9 (9.5)	2.2 (7.2)	0.58	6	100	100
23	3.7 (12.0)	1.3 (4.1)	4.09	9	0	10
24	4.6 (15.0)	2.8 (8.9)	0.09	8	100	100
25	3.9 (12.5)	2.9 (9.3)	0.12	6	100	100

[a]Numbers in parentheses are feet.

METHODS

Interviewing

A table of random numbers was used to select 60 pond owners for canvassing by personal interview. The interviews were to gain information on: (1) history of pond construction and management; (2) owner expectations and satisfactions; (3) pond use; (4) management advice sought; (5) owner characteristics; and (6) pond problems perceived by owners. The following 18 questions were asked:

1. In what year was your pond constructed?
2. How many owners has the pond had?
3. Did you originally buy your land with the idea of creating a pond later?
4. Could you recall for me why you first wanted a pond?
5. Did it live up to your expectations?
6. Do you feel that you have any problems with your pond? If so, what are they?
7. Have you attempted to improve your pond since its construction? (For example by fertilization, weed control, additional digging, etc.)
8. Has upkeep or repair been necessary? If so, what kind?
9. If you were to create your pond again, what would you do differently?
10. Approximately how many fish were stocked in this pond? When? What kinds? What sizes?
11. Have you noticed any fish die-offs in your pond? If so, when? What kinds? How often?
12. What do you now use or value your pond for? List as many as you wish.
13. Which of these is the main use or benefit to you?

14. Do persons outside the family use the pond? Public? Invited guests? For what activities?

15. Is there any conflict of interest within the family about use or management of the pond?

16. What sources of advice or information have out sought in regard to your pond? If you were to seek information, what sources would you choose?

17. To what extent would you allow your pond to be studied? I will list alternatives.

    1. Depth measurements and surface area measurements.
    2. Samples of water.
    3. Netting with fish returned alive and unharmed.
    4. Entire fish population removed and subsequent restocking.

18. What is your age and occupation?

Fish Population Sampling

Based on information from pond owners and from my personal observations, ponds were divided into strata (for sampling purposes) according to depth, soil and bottom types, and age of the pond. A table of random numbers was used to select ponds by proportional allocation for fish population sampling.

Fish populations were sampled by either seining or rotenone poisoning. Sampling dates are listed in Table 2. A 100 x 8-ft bag seine with 3/8-inch mesh was used. Removal of some of the cork floats and addition of weights on the lead line allowed seining down to depths of about 14 ft. As most of the ponds were less than 100 ft wide, seining encompassed the entire area of the ponds in which population estimates were made. Six seine hauls were usually made over the entire pond area on each sampling day. Population extimates were made by the Petersen method, according to the formula $N=\frac{mc}{r}$ where N is the population present, m is the total number of marked fish at large,

TABLE 2. Dates of fish sampling in 25 ponds.

Pond	Date (1974)	Pond	Date (1974)
1	June 24-25	14	July 24-28
2	June 25-26	15	July 25-26
3	June 28-29	16	July 29-August 2
4	July 1	17	July 31-August 3
5	July 1-2	18	August 5-6
6	July 3-4	19	August 7-11
7	July 4-5	20	August 8
8	July 8-9	21	August 19
9	July 10-11	22	August 19-24
10	July 15-19	23	August 20
11	July 17-21	24	August 22-23
12	July 18-22	25	August 23
13	July 22-23		

c is the total sample taken, and r is the number of marked fish in c. Fish were marked by clipping the upper portion of the caudal fin, and recapture seining was done the following day. Population estimates were computed for 1-cm size intervals for LMB and BG; estimates of other species were subdivided into 5-cm size groups. Scale samples were taken from LMB and BG for determination of age and growth.

Rotenone was used in 7 ponds (with permission of the owners) where it was thought that seining would be inefficient or yield unreliable estimates. Pilot tests with the seine in ponds having submerged brush or substantial populations of fishes adept at avoiding capture (e.g. carp) indicated that poisoning was needed in such ponds. Prior to poisoning in the first 3 ponds, 100-200 fish of various species were marked and released so that recovery rates could be determined. In each case recovery of marked fish was complete, so this procedure was abandoned for the 4 subsequent ponds which were poisoned. Poisoning was confined to periods of extremely warm weather (mid-day air temperatures exceeded 90 F) to facilitate rapid recovery of fish. Extensive snorkel diving revealed few fish which sank to the bottom and failed to surface within 3 days.

Determination of Age and Growth

Scale samples from LMB and BG were processed for determination of age and growth. Scale impressions were made with a roller press on unheated plastic and examined with the aid of a projection apparatus. Back-calculations of previous years growth were made by a computer program modified from Hogman (1970). The values for the constants (intercepts) used in the calculations were taken from regressions incorporating data from all ponds. These "a" values were substituted into the equation:

$$Lx = \frac{SRx\ (Lc-a)}{SRc}$$

where Lx is the calculated length at annulus fomation, SRx is the scale radius (magnified) at that age, Lc is the total length at capture, and SRc is the scale radius (magnified) at capture. Regier (1962a) found errors induced by the use of average "a" values to be negligible and the scale method valid for BG from New York farm ponds.

Determination of Pond Dimensions

Measurements of surface area, maximum depth, and mean depth were made for each of the 25 ponds in which fish populations were sampled. Bottom type and soil type in the catchment basin were determined and quantified according to the percentage of the area covered by clay. Age of the pond was considered the number of years since the pond filled with water.

Statistical Analyses

Confidence limits for population estimates obtained by the Petersen method are based on the binomial distribution. Ricker (1937) states that when the r/c ratio is less than 0.05 the Poisson distribution is appropriate; values above 0.05 (as in estimates in this study) warrant use of the bionomial distribution. Standard errors of population estimates were computed by the formula of Robson and Regier (1958):

$$S.E.(N) = N\sqrt{\frac{(N-m)(N-c)}{mc(N-1)}}$$

One-way analyses of variances were computed according to Snedecor and Cochran (1967) for growth data for age-I-IV LMB and age-II-VI BG. Age-I BG were not considered due to the variability induced by different spawning times. Other age groups were excluded due to small numbers of fish and/or ponds involved.

Other results presented in this study were derived by linear step-wise multiple regression analyses of 11 fish population paremeters on 6 pond variables according to the method of Draper and Smith (1966). The 11 fish population parameters were: total standing crop (Y_1); standing crop of catchable-size gamefish (Y_2); percentage of the total standing crop as catchable-size gamefish (Y_3); the ratio of the number of BG to the number of LMB (Y_4); population densities of BG (Y_5) and LMB and (Y_6); population densities of catchable-size BG (Y_7) and catchable-size LMB (Y_8); total length of age-II and age-IV LMB at formation of last annulus (Y_9 and Y_{10}, respectively); and total length of age-II BG at formation of last annulus (Y_{11}). The 6 independent variables were maximum depth (X_1), mean depth (X_2), surface area (X_3), age of the pond (X_4), soil type (X_5), and bottom type (X_6). Arithmetic-to-arithmetic analyses of Y's on X's were fitted by computer at the Michigan State University Computer Center utilizing the MSU STAT System. In this algorithm, variables are deleted from the equation in accordance with a preset level of significance. In this study, two regressions--one with α=.05 and the other with α=.10 were calculated for each Y.

RESULTS

Interviews

Tables 3-5 summarize information obtained by interviewing owners concerning reasons for creating the ponds, uses, and management problems. In addition to these data, several other points were brought to focus by the interviews and personal observations.

History of pond construction and management. Eighty-five percent of ponds whose owners were interviewed were constructed within the last 20 years. The oldest pond was 76-years-old. This pond was dug by hand-shovel in 1898 while removing clay for use as brick-building material. The history of several ponds could not be traced due to frequent changes in ownership. Seventy-five percent of the ponds had had only one owner. Only 2 of these owners had originally bought their land with the idea of creating a pond later.

When questioned as to what they would do differently if recreating their ponds, 48% of the owners said they would make their pond deeper (increasing both mean and maximum depth). Twenty-five percent said they would make it larger. Two owners said they would create a sharper-sloping basin to discourage growth of rooted hydrophytes. One owner would choose a different site for the pond to try to avoid mid-summer drop in water level. Thirty-six percent of the owners said they would do nothing differently, and one owner said he would not create a pond at all owing to increased property tax after construction of the pond.

All owners said that they had tried to improve their pond since its construction. In some cases, these efforts centered around

TABLE 3. Percentages of pond owners who built their ponds for various purposes (n=45).

Purpose	Percentage
Fishing	69
Swimming	52
Other forms of recreation	27
Removal of fill material	23
Wildlife viewing	12
Irrigation	10
Esthetics	8
Livestock watering	7
Provide fish for stocking purposes	2
Water for concrete-making	2
For something to do	2

TABLE 4. Percentages of ponds used for various purposes according to the owners (n=60).

Use	Percentage of Ponds Used for This Purpose	Percentage of Ponds in Which This Use Was the Main Use
Fishing	76	32
Swimming	61	17
Esthetics	27	8
Ice skating	16	0
Wildlife viewing	13	10
None	10	10
Irrigation	10	8
Picnicking	6	6
Livestock watering	5	2
Water skiing	1	0
Snowmobiling	1	0
Water for concrete-making	1	1
To provide fish for stocking purposes	1	1
Remcval of fill material	1	1

TABLE 5. Frequency of occurrence of various problems in 60 artificial ponds as perceived by the owners.[a]

Problem	Frequency of Occurrence (%)
Excessive growth of algae	27
Stunted panfish	18
Trespassing	17
Excessive growth of aquatic weeds	13
Abundance of rough fish	10
Disappearance of stocked trout	8
Fish refuse to bite	5
Poor growth of LMB	5
Shallow depth	5
Winterkill	5
Disappearance of LMB	3
Failure of Agricultural Stabilization and Conservation Service to provide promised funds	3
Basin sedimentation	1
Pollution from coal mine drainage	1
Pollution from high iron content in soil	1
Loss of water in summer	1
Littering	1
Muck bottom	1
Muskrat damage along shoreline	1

[a]Eight percent of the owners felt that they had no major problems in regard to their ponds.

regular upkeep (mowing grass, picking up litter, etc.). Only 3 owners had enlarged the surface area of their pond since its construction.

Approximately 70% had added small numbers of fish taken from various waters by angling to their ponds. No owners regularly restocked their ponds, however. One owner attempted to reduce numbers of stunted bluegills by exploding dynamite in his pond. None of the 25 ponds in which fish populations were sampled received plantings of LMB or BG subsequent to initial stocking (at least to the owner's knowledge).

Twenty-five percent of the owners had attempted to control algae and/or rooted hydrophytes--4 with chemicals and 11 by dragging home-made devices (bed frames, logs wrapped with barbed wire, etc.) along the pond bottom. The latter method, according to the owners, was especially effective in controlling *Chara* sp. Dragging was less successful in controlling other forms of filamentous algae.

Only 2 owners stated that there was conflict of interest within the family about management of their ponds. In both of these cases, conflict centered around methods of controlling stunted populations of bluegills. While owners favored poisoning, other members of the family objected to this method.

Owner expectations and satisfactions. Despite the numerous management problems listed by owners in Table 5, 60% stated that they were generally satisfied with their ponds. Only 8%, however, felt that they had no major management problems.

Pond use. A variety of reasons were listed by owners as to why they built their ponds, with fishing (69%) and swimming (52%) the leading purposes by far (Table 3). Sixty-five percent listed more than one reason; 97% of ponds created for recreation were intended for more than one use.

According to many owners, large numbers of people make use of their ponds. Twenty-three percent said they grant permission for recreational use to anyone requesting it. An additional 63% said they allow invited guests, friend, and relatives. Fourteen percent restricted use to their immediate family. Several owners indicated reluctance to let others use their ponds, owing to fear of liability for injury or drowning. This apprehension was also evident in regard to trespassers.

As indicated in Table 4, fishing was listed as the main pond use by 32% of the owners. Ten percent of the owners, however, now have no use for their ponds. In the case of each of these owners, their ponds were created for purposes other than recreation, such as removal of fill material.

Management advice sought. Fifty-seven percent of interviewed owners had sought help from the Soil Conservation Service, 20% had contacted the Michigan Department of Natural Resources, but 37% had not sought advice from any source. One owner had received information regarding a fish-feeding program from Purina Company.

Owner characteristics. Thirty-three percent of the ponds whose owners were interviewed were located on farms; the remainder in rural-suburban areas. Only four owners were full-time farmers. Owners included factory laborers, morticians, doctors, businessmen, forestors, teachers, and many others. Ages of owners ranged from 29-81 years-old; 41% were more than 50 years-old.

Pond problems perceived by owners. Table 5 lists problems perceived by owners. Excessive algal growth, stunted fish, and trespass were the problems most frequently listed by owners.

Trespass was considered a major problem by 17% of the owners for several reasons. Trespassers were blamed for introducing undesirable fishes into ponds, overfishing of gamefish, littering, and vandalism. Neighborhood children were frequently cited for "stocking" ponds with rough fish obtained from nearby ditches and creeks.

Twenty-seven percent of the interviewed owners had stocked their ponds with trout; of these, only 18% harvested any of the fish.

A large percentage of owners overestimated the maximum depths of their ponds (Table 6). In 10 of the 25 ponds where depth was measured, the owners overestimated the maximum depth by 33% or more. The mean difference between actual and estimated maximum depth was 3.5 ft which was statistically significant (α=.001).

Only 2 owners refused permission to sample fish populations in their ponds. Ten gave permission for rotenone poisoning (with restocking).

Fish Populations

A total of 27 fish species were found in the 25 sampled ponds. Frequencies of occurrence are listed in Table 7. BG and LMB co-inhabited 20 ponds; 5 ponds contained these two species only. Despite intensive seining, no fish were captured in pond 21. According to the owner, a complete winterkill had apparently occurred during winter 1972-73. The pond had previously been stocked with LMB and BG.

Total standing crops and standing crops of catchable-size

TABLE 6. Variation among measured maximum pond depths and estimates of owners in 25 ponds.

Pond	Owner's Estimate of Max. Depth (ft)	Measured Max. Depth (ft)	Error of Owner's Estimate (ft)	Error of Owner's Estimate (%)
1	8	7.5	+0.5	+6.7
2	12	12.0	0.0	0.0
3	16	18.0	-2.0	-11.1
4	15	13.0	+2.0	+15.4
5	15	13.0	+2.0	+15.4
6	12	11.0	+1.0	+9.1
7	12	13.0	-1.0	-7.7
8	12	9.0	+3.0	+33.3
9	16	15.0	+1.0	+6.7
10	13	11.0	+2.0	+18.2
11	15	9.0	+6.0	+66.7
12	18	10.0	+8.0	+80.0
13	18	19.0	-1.0	-5.3
14	25	11.5	+13.5	+117.4
15	10	8.0	+2.0	+25.0
16	12	8.5	+3.5	+41.2
17	20	9.5	+10.5	+110.5
18	17	11.0	+6.0	+54.6
19	16	13.0	+3.0	+23.1
20	17	16.0	+1.0	+6.3
21	11	8.5	+2.5	+29.4
22	17	9.5	+7.5	+79.0
23	22	12.0	+10.0	+83.3
24	16	15.0	+1.0	-6.7
25	20	12.0	+7.5	+60.0

TABLE 7. Frequency of occurrence of fish species in 25 ponds.

Species	Number of ponds
Bluegill (*Lepomis macrochirus*)	22
Largemouth bass (*Micropterus salmoides*)	19
Pumpkinseed sunfish (*Lepomis gibbosus*)	10
Yellow perch (*Perca flavescens*)	9
White crappie (*Pomoxis annularis*)	8
Black bullhead (*Ictalurus melas*)	7
Carp (*Cyprinus carpio*)	7
Green sunfish (*Lepomis cyanellus*)	7
Northern pike (*Esox lucious*)	6
Rock bass (*Ambloplites rupestris*)	5
Brown bullhead (*Ictalurus nebulosus*)	4
Channel catfish (*Ictalurus punctatus*)	4
White sucker (*Catostomus commersoni*)	3
Golden shiner (*Notemigonus crysoleucas*)	3
Central mudminnow (*Umbra limi*)	3
Spottail shiner (*Notropis hudsonius*)	3
Fathead minnow (*Pimephales promelas*)	3
Gizzard shad (*Dorosoma cepedianum*)	1
Blue catfish (*Ictalurus furcatus*)	1
White bass (*Morone chrysops*)	1
Johnny darter (*Etheostoma nigrum*)	1
Bluntnose minnow (*Pimphales notatus*)	1
Goldfish (*Carassius auratus*)	1
Riverchub (*Hybopsis micropogon*)	1
Redear sunfish (*Lepomis microlophus*)	1

gamefish for individual ponds are shown in Tables 8 and 9.[1] Population densities for LMB and BG and numbers of BG/LMB are listed in Table 10. Population and biomass estimates for LMB and BG by size class are presented in Appendices A and B. Appendix C shows biomass estimates for other species.

In addition to pond 21, no BG were found in ponds 16 and 19. No LMB were found in ponds 16, 19, 22, and 24. Six of the 17 ponds in which BG were found contained no catchable-size BG; 4 of the 17 ponds in which LMB were present contained no catchable-size bass (Table 9). BG:LMB ratios varied widely ranging from 1.1 to 632 (Table 10).

Populations of other species were found in 19 of the 25 ponds. Carp were the dominant species in terms of biomass in each of the 5 ponds where they were found (ponds 11, 12, 17, 19, and 22). All carp were large, weighing 3-10 pounds.

Age and Growth

Tables 11 and 12 summarize age and growth data for LMB and BG respectively, from sampled ponds. Data for these species from individual ponds are presented in Appendices D and E.

Analyses of variances of growth for both LMB and BG indicated highly significant differences between ponds for each age group considered.

[1]Catchable-size gamefish were defined as follows: LMB and smallmouth bass $\geq$ 250 mm; BG, other sunfish, and yellow perch $\geq$ 150 mm; northern pike $\geq$ 500 mm; white crappie $\geq$ 175 mm; channel catfish $\geq$ 225 mm.

TABLE 8. Standing crops (kg/hectare) of fishes in 20 ponds.[a]

Pond	Total	Species		
		BG	LMB	Other
1	198.8	172.0 (87)	26.9 (13)	0.0
2	137.9	108.3 (79)	29.5 (21)	0.0
3	519.8	480.9 (93)	37.2 (6.7)	1.7 (0.3)
5	994.3	882.1 (89)	112.2 (11)	0.0
6	116.9	84.1 (72)	32.8 (28)	0.0
7	81.4	60.4 (74)	21.3 (26)	0.0
8	31.4	12.5 (40)	13.8 (44)	5.0 (16)
9	304.3	275.4 (90)	14.6 (5)	114.2 (5)
10	233.0	209.4 (89.9)	23.3 (9.9)	0.5 (0.2)
11	329.0	34.7 (11)	16.9 (5)	277.4 (84)
12	266.2	109.8 (41)	25.6 (10)	130.9 (49)
13	445.6	430.4 (97)	12.3 (2.7)	2.9 (0.3)
15	103.4	4.5 (4)	9.3 (9.5)	89.6 (86.5)
16	408.8	0.0	0.0	408.8 (100)
17	356.9	113.4 (32)	8.7 (2)	234.8 (66)
18	89.1	27.0 (30)	42.7 (48)	19.4 (22)
19	229.6	0.0	0.0	229.6 (100)
21	0.0	0.0	0.0	0.0
22	629.5	1.2 (0.3)	0.0	628.3 (99.7)
24	579.3	240.1 (41)	0.0	339.1 (59)

[a]Numbers in parentheses are percentages of the total standing crop.

TABLE 9. Standing crop (kg/hectare) of catchable-size gamefish in 20 ponds.[a]

Pond	Total	Species BG	Species LMB	Species Other	Percentage of the Total Standing Crop as Catchable-size Gamefish
1	86.4	65.4	20.6	0.0	43
2	12.0	0.0	12.6	0.0	0.9
3	227.6	206.9	19.0	1.7	44
5	170.5	80.8	89.7	0.0	17
6	83.6	83.6	0.0	0.0	80
7	54.0	54.0	0.0	0.0	66
8	16.0	12.0	0.0	4.0	51
9	54.7	34.1	7.0	13.6	18
10	26.7	9.2	17.4	0.0	11
11	20.0	0.0	14.5	5.5	6
12	32.6	0.0	22.6	10.0	12
13	4.5	0.0	4.5	0.0	1
15	5.1	0.0	0.0	5.1	5
16	0.0	0.0	0.0	0.0	0.0
17	18.4	1.0	7.5	9.8	5
18	19.3	0.0	19.3	0.0	22
19	20.5	0.0	0.0	20.5	9
22	35.8	0.8	0.0	35.0	6
24	359.9	20.7	0.0	339.1	62
21	0.0	0.0	0.0	0.0	0.0
Mean	64.6				25.7
Stand. Dev.	93.1				24.7

[a]Catchable-size gamefish were defined as follows: LMB and smallmouth bass $\geq$ 250 mm; BG, other sunfish and yellow perch $\geq$ 150 mm; northern pike $\geq$ 500 mm; white crappie $\geq$ 175 mm; channel catfish $\geq$ 225 mm.

TABLE 10. Population densities of largemouth bass and bluegills in 20 ponds previously stocked with these species.

Pond	Number/Hectare		Number of Catchable-size[a] Fish/Hectare		Number of BG/LMB
	BG	LMB	BG	LMB	
1	4740	219	1043	28	21.6
2	6235	247	0	42	25.3
3	17883	583	2504	41	30.7
5	43149	526	1294	89	82.0
6	851	208	825	0	4.1
7	649	151	539	0	4.3
8	174	100	124	0	1.7
9	24859	131	497	20	189.3
10	19394	239	155	26	81.0
11	2643	99	0	17	26.6
12	10038	86	0	38	117.3
13	34109	191	0	0	178.9
15	332	56	0	0	5.9
16	0	0	0	0	
17	12806	20	26	12	631.9
18	1590	1478	0	15	1.1
19	0	0	0	0	
21	0	0	0	0	
22	1	0	0	0	
24	61112	0	244	0	

[a]Catchable-size BG were defined as $\geq$ 150 mm; catchable-size LMB as $\geq$ 250 mm.

TABLE 11. Averages of mean total lengths and weights at capture and mean back-calculated total lengths at annulus formation for largemouth bass in sampled ponds.

No. of Ponds	Age	Av. T.L. at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated T.L. (mm) at Annulus Formation 1	2	3	4	5	6
13	I	102	16	120	68					
16	II	158	58	248	60	123				
14	III	206	120	87	58	120	162			
12	IV	275	297	73	57	130	189	247		
7	V	336	573	23	64	128	200	257	305	
5	VI	340	669	28	64	115	169	270	311	

TABLE 12. Averages of mean total lengths and weights at capture and mean back-calculated total lengths at annulus formation for bluegills in sampled ponds.

No. of Ponds	Age	Av. T.L. at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated T.L. (mm) at Annulus Formation 1	2	3	4	5	6	7
13	I	66	7	172	41						
18	II	92	17	346	35	73					
17	III	110	23	449	34	66	94				
18	IV	131	46	261	36	72	104	126			
15	V	142	56	106	30	60	94	114	130		
15	VI	148	67	154	29	56	84	104	121	137	
13	VII	156	66	44	28	52	83	103	119	145	148

Relationships Among Pond Characteristics and Fish Population Parameters

Table 13 summarizes results of multiple regression analyses of 11 dependent variables on mean pond depth, maximum pond depth, pond surface area, pond age, bottom type, and soil type in the catchment basin. The portion of variability of Y explained by the independent variables before and after deletion of non-significant factors is expressed as R_T^2 and R^2 (or r^2), respectively. Significant simple correlation coefficients between variables are listed in Tables 14 and 15.

Total standing crop. The coefficient of multiple determination for total standing crop was 0.7246, indicating that the 6 independent variables accounted for 72% of the variability in standing crop. Mean depth, age, and surface area accounted for 70%; average depth alone explained 56% (Table 13). The resultant predictive equation is:

$$Y = -1090.1 + 197.4X_2 + 242.68X_3 - 11.82X_4$$

where: X_2 = mean depth of pond in feet, X_3 = surface area in acres, and X_4 = age of pond in years. The regression coefficients indicate total standing crop increases with greater mean depth and area, and decreases with increased pond age.

Standing crop of catchable-size gamefish. A sigificant positive correlation between standing crop of catchable-size gamefish and mean depth was found (Table 14). The 6 independent variables explained 56% of variability in standing crop of catchable-size gamefish; mean pond depth accounted for 41%.

Percentage of total standing crop as catchable-size gamefish. The independent variables accounted for 40% of the variability in this parameter. Area was the most important factor, accounting for 29%.

TABLE 13. Coefficients of multiple determinations (R^2) and coefficients of determination (r^2) of independent variables (X) affecting various dependent variables.

Dependent Variable	R_T^2	X (α=.05)	(r^2)	X (α=.10)	R^2
Total standing crop	0.725	mean depth	0.562	mean depth age area	0.701
Standing crop of catchable-size gamefish	0.563	mean depth	0.407	--[a]	
% of total standing crop as catchable-size gamefish	0.397	area	0.294	--	
BG:LMB ratio	0.639	age	0.477	--	
Population density of BG	0.733	mean depth	0.648	mean depth max. depth	0.706
Population density of LMB	0.317	soil type	0.233	--	
Population density of catchable-size BG	0.286	All variables were deleted		max. depth	0.190
Population density of catchable-size LMB	0.419	mean depth	0.237	--	
Length of age-II LMB at formation of last annulus	0.304	All variables were deleted		All variables were deleted	
Length of age-IV LMB at formation of last annulus	0.210	All variables were deleted		All variables were deleted	
Length of age-II BG at formation of last annulus	0.384	mean depth	0.246	--	

[a]The same variable remained in the equation at α=.10.

TABLE 14. Significant correlation coefficients (r) between independent and dependent variables.

Fish Population (Dependent) Variable	Pond (Independent) Variables				
	Maximum Depth	Mean Depth	Area	Age	% Clay in Soil
Total standing crop		0.7499**			
Standing crop of catchable-size gamefish	0.4812*	0.6383**			
% of total standing crop as catchable-size gamefish			-0.5420*	-0.4523*	
BG:LMB ratio			0.6874**	0.6904*	
Population density of BG	0.6550*	0.8051**			
Population density of LMB					-0.4825*
Population density of catchable-size LMB		0.4867*			
Length of age-II BG at formation of last annulus		-0.4960*			

*Significant at α=.05.

**Significant at α=.01.

TABLE 15. Significant correlation coefficients (r) between selected variables.

Fish Population Variable	Y_1	Y_2	Y_7
Y_1-Total standing crop			
Y_2-Standing crop of catchable-size gamefish	.53790*		
Y_3-% of total standing crop as catchable-size gamefish		.51405*	
Y_5-Population density of BG	.66224*	.73132*	
Y_7-Population density of catchable-size BG		.57939*	
Y_8-Population density of catchable-size LMB	.51910*		.50201*

*Significant at α=.05.

**Significant at α=.01.

Smaller surface area was associated with a greater percentage of the total standing crop as catchable-size gamefish (Table 14).

BG:LMB ratio. The independent variables accounted for 64% of variability in number of BG to number of LMB. Age of pond was the most important factor, accounting for 48%. A highly significant positive correlation existed between pond age and the BG:LMB ratio (Table 14).

Population density of BG. The independent variables accounted for 73% of variability in the population density of BG. Mean pond depth explained 65%. The resultant prediction equation is:

$$Y = -68.77 + 12.1X_2$$

where Y = thousands of BG/hectare. Both mean depth and maximum depth were positively correlated with BG population density.

Population density of LMB. The independent variables explained 32% of variability in population density of LBM. Soil type was the most important factor, accounting for 23% of variability.

Population density of catchable-size LMB. The independent variables accounted for 42% of variabliity in population density of catchable-size LMB. Mean depth was most important and explained 24%. Mean pond depth was positively correlated with this dependent variable (Table 14).

Population density of catchable-size BG. Maximum depth was the most important measured factor affecting population density of catchable-size BG, but accounted for only 19% of variability. Increasing maximum depth was associated with increase in numbers of catchable-size BG.

Growth. Linear multiple regression analyses of lengths of 2-year-old and 4-year-old LMB on the independent variables produced empty equations; all variables were deleted. Mean depth was the most important factor regarding length of 2-year-old BG, but accounted for only 25% of the variability. The correlation coefficient was negative.

Relationships among fish population variables. Simple correlations among 7 of the dependent variables are shown in Table 15. Significant positive correlations occurred between total standing crop and the following variables; standing crop of catchable-size gamefish, population density of BG, and population density of catchable-size LMB. Significant positive correlations were found between standing crop of catchable-size gamefish and 3 variables; population density of BG, percentage of the standing crop as catchable-size gamefish, and population density of catchable-size BG. A significant positive correlation was also found between population densities of catchable-size BG and catchable-size LMB.

DISCUSSION

Interviews of Pond Owners

The results of the interviews must be interpreted in light of several points. It must be emphasized that Table 5 represents only what the owners perceive as problems and may not indicate the actual frequency of various problems. For example, only 5% of owners listed fish kills as a problem; however, when questioned directly, 27% stated they had observed major winter and/or summer fish die-offs. Similarly, only 23% mentioned stunted panfish and poor growth of LMB; however, the data shown in Appendices D and E suggest these problems probably occurred with much greater frequency.

That many ponds were created and used for more than one purpose has undoubtedly contributed to management problems in many cases. Perhaps the most common problem occurs when a pond is constructed for both fishing and swimming. In that case, the shallow, gently-sloping areas desirable for swimming encourage growth of aquatic plants and provide abundant spawning area for sunfish, thus compounding stunting problems (Bennett, 1971). In this study, excessive growth of algae and stunted panfish were the problems most frequently perceived by owners. Another potential source of management problems may be that many owners overestimate the maximum depth of their ponds (Table 6). Conversations with owners indicated that most excavators measured depth of the pond basin during construction from ground level rather than from the expected level of the water table. Thus, owners contracting for a given depth often were left with a pond several feet shallower.

Since many owners were apparently unaware of this, stocking of trout in unsuitably shallow waters occurred in a number of cases. Trout in these ponds failed to survive, probably owing to intolerable temperature and/or low dissolve oxygen levels.

That only 33% of the ponds whose owners were interviewed were located on farms suggests that the term "farm ponds" traditionally used by many as a synonym for artificial ponds, is hardly applicable within the study area. This point may be of significance to extension personnel, natural resource agency administrators, and biologists who often stereotype Michigan's artificial ponds as "farm ponds" with associated characteristics and problems. Management publications geared to farmers may not be ideally suited to many pond owners.

Fish Populations

While other fishes were present in many of the ponds, BG and LMB made up most of the biomass and numbers in 16 ponds. Thus, the data from these ponds provide some opportunity to assess success of the LMB-BG combination. The effect of interspecific competition and predation on results of this study cannot be accurately determined. Nevertheless, the results cast suspicion on the merits of the LMB-BG combination. Undesirable results included low standing crops and densities of catchable-size fish, and poor growth of both LMB and BG.

Growth of both LMB and BG as compared to state-wide averages (Laarman, 1963) was slow in most ponds (Figure 1). Growth of BG in many ponds was very poor (Appendix E). Considerably better growth was found in ponds 7, 14, and 20, of which all were less than 5 years old. It must be emphasized that data in Tables 11 and 12 represent

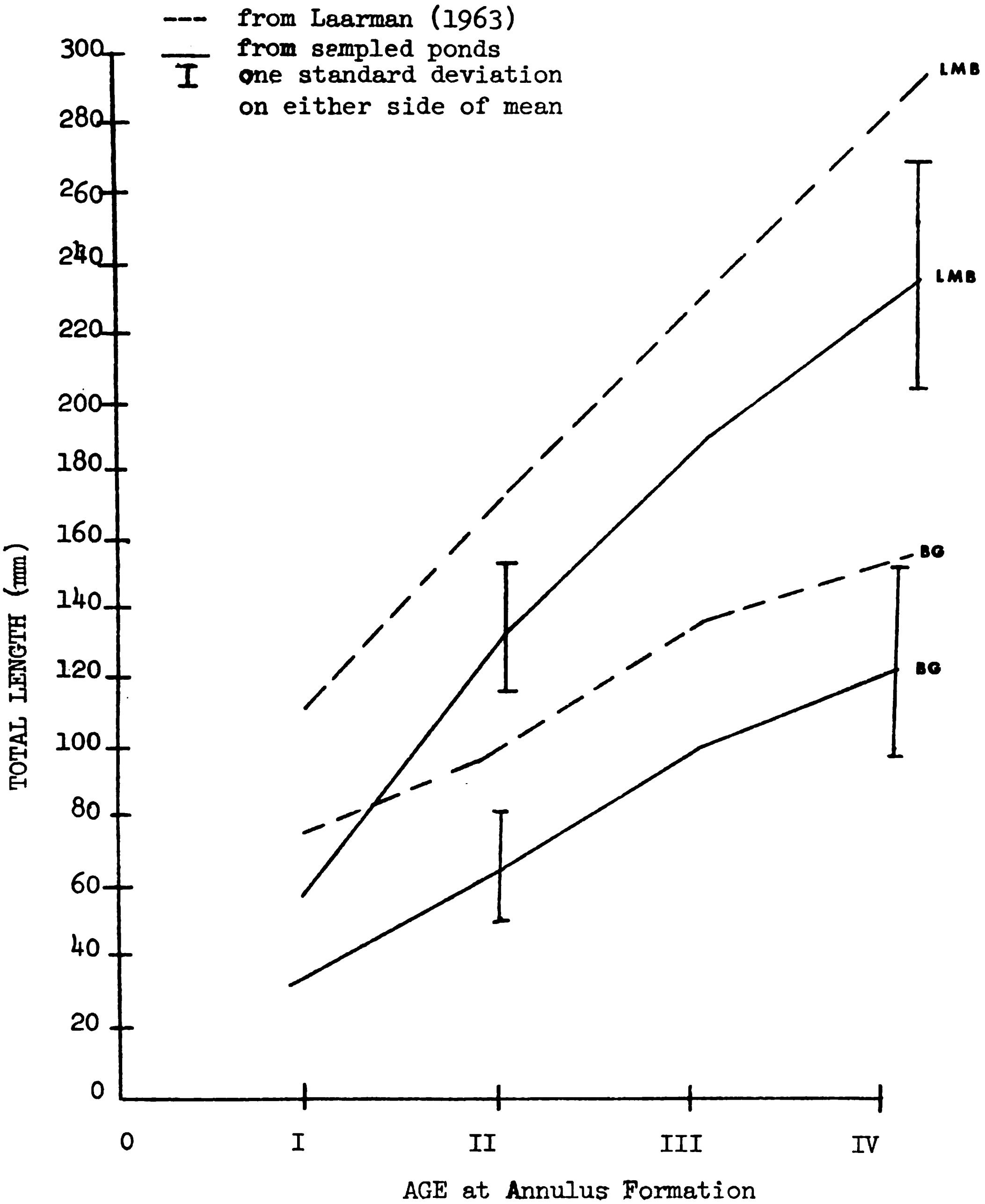

FIGURE 1. Comparison of growth rates of 4-year-old largemouth bass and bluegills from sampled ponds with state-wide averages from Laarman (1963).

averages (equally weighted) of mean back-calculated lengths at annulus formation. Thus, what appears to be an example of Lee's phenomena (Table 12) is probably largely the result of differences in age structure and growth rates between BG populations.

Several authors from midwestern and northern U.S. areas have documented the poor results often obtained with this species combination. Krumholtz (1950) cited both the prolificness of BG and the inadequacy of LMB as a predator of BG for poor results obtained with this combination in Indiana ponds. Bennett (1974:10) states:

> The largemouth bass is less affected by the fishing activities of man than most other species of fishes. However, bass are highly vulnerable to predation in embryo and fry stages when living with stunted populations of other centrarchids.

Bennett (1952:249) also acknowledged the inefficiency of the LMB as a predator of BG in midwestern ponds:

> As is suggested in the discussion of stocking, bluegills are more effective in controlling bass than are bass in controlling bluegills.

Werner and Hall (1974) found that prey-size selectivity by BG varies with prey abundance. The assumption that BG will feed low on the food chain may not hold for stunted populations. Rawson and Ruttan (1952) in Saskatchewan and Saia (1952) in New York also provided evidence that the LMB-BG combination is poorly suited for ponds in northern climates.

Data from several ponds in this study exemplify some of the classical problems associated with the LMB-BG combination such as slow growth of BG due to overcrowding, poor reproduction of LMB, and the unpredictability of results obtained with this combination. Pond 6, for example, had low density of BG, with over 80% larger than 150 mm.

LMB in this pond, however, grew very slowly; the mean total length at capture of 6-year-old LMB was 207 mm. No other year class of bass was evident in the pond. Similarly, in ponds 1, 2, 8, 9, 11, 12, 13, and 17, LMB reproduction was poor. LMB disappeared from pond 24, while BG continued to multiply. The unpredictability of the LMB-BG combination is reflected in the wide variability between ponds in regard to the fish population parameters examined in this study (Tables 8-10).

Conversations with owners indicated that most ponds in this study had provided good fishing during the first 2-5 years after stocking. Subsequently, the situation had steadily worsened. In this study, a significant positive correlation between age of pond and ratio of BG to LMB was found.

Results of linear stepwise multiple regression analyses must be interpreted in light of the limitations of my methods. Range and distribution of the data points upon which analyses are based, discourage both broad interpolation and extrapolation of results. While multiple regression analyses, as used in this study, are useful in identifying associations among variables, no cause-effect relationship can be directly inferred (Snedecor and Cochran, 1967). It is encouraging, however, that pond design features explained a high proportion of the variability in several fish population parameters.

Results indicate mean pond depth is an important factor influencing several population parameters. Greater mean depth is associated with larger total standing crop, standing crop of catchable-size gamefish, population density of BG, and standing crop of catchable-size LMB. Several authors have recognized the importance of mean depth to fish productivity and survival. Ryder et al (1974) defined the morphoedaphic index as the total dissolved solids divided by mean depth of a body of water and associated this variable with fish productivity. Rawson and Ruttan (1952) found depth to be of critical importance to fish populations in Saskatchewan ponds; winterkill was common in shallow ponds.

Relationships between mean depth, water temperatures and dissolved oxygen are well documented in limnological literature. The importance of temperature and dissolved oxygen to survival and growth rates of fishes have been established (Stewart et al, 1967). No significant correlations between growth of LMB and depth were observed in this study. A significant correlation between growth of age-II BG and mean depth was observed, but mean depth accounted for only 25% of variability. This suggests that depth may be associated more closely with mortality and recruitment rates than with growth in these ponds.

It is somewhat surprising that carp apparently were not reproducing in the ponds in which they were found. In each case, the carp had entered the pond via overflow from nearby ditches. Mraz and Cooper (1957) reported poor reproduction of carp in Wisconsin lakes but noted high natural reproduction rates in experimental ponds.

Management Implications

Results of this study emphasize the importance of pond design, particularly mean depth, in regard to fish populations. Increasing mean depth may be a practical way for future pond builders to maintain more-desirable fish populations. At any rate, mean depth should be a major consideration in pond design.

Several basic patterns of competition and predation and growth-production strategies described by various authors seemed to hold for these ponds. Problems associated with the LMB-BG combination seemed obvious in many of these Michigan ponds. Alternative species combinations, such as the LMB-golden shiner combination, have been more successful in other northern states (Regier, 1963). Ball (1952) found that this combination produced superior results in experimental ponds in Michigan. As Krumholtz (1950) states:

> In Indiana, and probably elsewhere as well, the correct solution to initial stocking policies for small ponds lies in the selection of the proper kind or kinds of fish.

It seems that proper selection of the kind or kinds of fish is also an important key to successful management in this part of Michigan. It has often been said that the LMB-BG combination simply requires management by pond owners. According to USDA (1965:10):

> These species reproduce regularly and fishing is usually good unless mismanagement or an accidental fish kill upsets the population. Unfortunately, many fish ponds become overpopulated with intermediate-size sunfish. Some people, therefore, feel that good fishing year after year is not possible with the bass-bluegill or redear combination. The fact is that thousands of ponds with this combination have been successfully fished for many years with regular and proper management. Overpopulation results from muddy water, faulty management, incorrect stocking, or unusual mishaps such as too much floodwater or a fish kill by insecticides.

But Hackney (1974) stated that often 75-90% of a stunted population must be removed to achieve balance. This would obviously require considerable effort, as well as technique. A species combination requiring such intensive management seems ill-suited for a recreational resource.

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APPENDICES

APPENDIX A:

Estimates of numbers and biomass of largemouth bass by size class in 15 inventoried ponds (Tables A1-A15).

Key to TABLES A1-A15.

m = number of marked fish

r = number of recaptured fish

u = number of unmarked fish

P = population estimate

LP = lower 95% confidence limit for population estimate

UP = upper 95% confidence limit for population estimate

B = biomass estimate

LB = lower 95% confidence limit for biomass estimate

UB = upper 95% confidence limit for biomass estimate

TABLE A1. Estimates of numbers and biomass of largemouth bass in pond 1.[a]

Size Class (mm)	Numbers						Biomass (gm)		
	m	r	u	P	LP	UP	B	LB	UB
60-69	1	1	1	2			14		
70-79	3	2	2	6			53		
80-89	1	1	0	1			19		
90-99	1	1	0	1			17		
110-119	1	1	0	1			22		
150-159	1	1	0	1			55		
170-179	1	1	0	1			70		
190-199	1	1	0	1			110		
340-349	1	1	0	1			518		
400-409	1	1	0	1			1816		
Totals	12	11	3	16	15	18	2694	2525	3031

[a]Estimates by Petersen method.

TABLE A2. Estimates of numbers and biomass of largemouth bass in pond 2.[a]

Size Class (mm)	Numbers						Biomass (gm)		
	m	r	u	P	LP	UP	B	LB	UB
80-89	1	1	2	3			33		
130-139	3	1	3	12	6	29	312	156	754
150-159	2	1	4	10	6	23	450	270	1035
160-169	3	1	3	12	6	29	780	390	1885
170-189	2	1	4	10	6	23	750	450	1725
190-209	4	2	6	16	10	30	1760	1100	3300
210-229	3	1	3	12	6	29	1608	804	3886
230-249	4	2	6	16	10	30	2800	1750	5250
270-279	1	1	2	3			750		
300-309	1	1	2	3			1254		
330-339	1	1	2	3			1470		
Totals	25	13	37	100	67	133	11967	8020	15920

[a]Estimates by Petersen method.

TABLE A3. Estimates of numbers and biomass of largemouth bass in pond 3.[a]

Size Class (mm)	Numbers						Biomass (gm)		
	m	r	u	P	LP	UP	B	LB	UB
90-99	2	1	2	6	4	13	62	41	134
100-109	6	4	3	10	9	13	159	143	206
110-119	12	11	16	29	28	32	493	476	544
120-129	15	13	7	23	22	25	554	530	602
130-139	7	5	6	15	13	20	530	459	706
140-149	8	5	4	14	12	19	529	453	718
150-159	3	2	2	6	5	10	274	228	456
160-169	3	2	2	6	5	10	301	250	501
170-179	3	2	0	3			204		
180-189	2	1	0	2			166		
200-209	3	1	0	3			300		
210-219	1	1	1	2			232		
230-239	1	1	1	2			272		
310-319	1	1	1	3			740		
320-329	2	1	0	2			836		
340-349	1	1	1	2			912		
350-359	3	2	0	3			1740		
Totals	74	56	42	130	119	141	8306	7603	9008

[a]Estimates by Petersen method.

TABLE A4. Estimates of numbers and biomass of largemouth bass in pond 5.[a]

Size Class (mm)	Numbers						Biomass (gm)		
	m	r	u	P	LP	UP	B	LB	UB
80-89	4	1	4	20	8	51	160	64	408
90-99	3	1	3	12	6	30	120	60	300
100-109	2	1	2	6	4	13	72	48	156
140-149	4	2	4	12	8	20	432	288	720
150-159	5	2	4	15	9	28	690	414	1288
170-179	8	2	11	52	19	111	3754	1371	8013
180-189	2	1	2	6	4	13	498	332	1079
200-209	3	1	3	12	6	30	1206	603	3015
320-329	2	1	2	6	4	13	3348	2232	7254
340-349	3	1	2	9	5	21	5256	2920	12264
400-409	2	1	2	6	4	13	4860	3240	10530
440-459	2	1	2	6	4	13	14160	9440	30680
Totals	40	15	41	162	81	356	34556	21012	75707

[a]Estimates by Petersen method.

TABLE A5. Estimates of numbers and biomass of largemouth bass in pond 6.[a]

Size Class (mm)	Numbers						Biomass (gm)		
	m	r	u	P	LP	UP	B	LB	UB
180-189	2	1	2	6	4	13	366	244	793
190-199	4	2	1	6	5	10	564	470	940
200-209	10	7	4	15	14	18	1475	1376	1769
210-219	3	2	1	4	4	5	440	440	510
220-229	3	2	1	4	4	5	468	468	585
Totals	22	14	9	35	31	51	3313	2998	4597

TABLE A6. Estimates of numbers and biomass of largemouth bass in pond 7.[a]

Size Class (mm)	Numbers						Biomass (gm)		
	m	r	u	P	LP	UP	B	LB	UB
220-229	6	2	2	12	8	22	1612	1074	2820
230-239	14	5	4	25	18	35	3555	2559	4977
240-249	2	1	0	2			338		
Totals	22	8	6	39	28	56	5505	3971	8135

[a]Estimates by Petersen method.

TABLE A7. Estimates of numbers and biomass of largemouth bass in pond 8.[a]

Size Class (mm)	Numbers						Biomass (gm)		
	m	r	u	P	LP	UP	B	LB	UB
210-219	2	2	1	3			366		
220-229	9	6	0	9			1175		
230-239	6	5	0	6			852		
240-249	4	4	0	4			627		
Totals	21	16	1	22	22	23	3020	3020	3157

[a]Estimates by Petersen method.

TABLE A8. Estimates of numbers and biomass of largemouth bass in pond 9.[a]

Size Class (mm)	Numbers						Biomass (gm)		
	m	r	u	P	LP	UP	B	LB	UB
80-89	1	1	0	1			9		
90-99	1	1	0	1			11		
100-109	1	1	1	2			28		
110-119	1	1	0	1			17		
170-179	1	1	2	3			166		
180-189	1	1	1	2			120		
190-199	2	2	3	5			407		
200-209	1	1	3	4			380		
210-219	2	1	0	2			212		
230-239	1	1	0	1			144		
290-299	1	1	0	1			284		
300-309	1	1	1	2			686		
360-369	1	1	0	1			427		
Totals	15	14	11	26	26	28	2892	2892	3114

[a]Estimates by Petersen method.

TABLE A9. Estimates of numbers and biomass of largemouth bass in pond 10.[a]

Size Class (mm)	P	B (gm)
100-109	10	123
110-119	8	150
120-129	14	345
130-139	13	373
140-149	2	80
150-159	6	268
160-169	1	56
170-179	1	58
270-279	1	230
320-329	3	1286
340-349	2	1100
470-479	1	1898
Totals	62	5967

[a]Inventoried by rotenone poisoning.

TABLE A10. Estimates of numbers and biomass of largemouth bass in pond 11.[a]

Size Class (mm)	P	B (gm)
90-99	26	296
100-109	21	263
110-119	4	62
120-129	12	301
130-139	1	34
140-149	1	34
150-159	3	121
160-169	1	53
170-179	8	480
180-189	2	151
190-199	1	68
200-209	3	328
210-219	1	138
220-229	1	140
260-269	1	249
350-359	2	1156
360-369	2	1347
370-379	1	692
380-389	3	2530
390-399	2	1841
400-409	3	3017
430-439	2	2622
440-449	1	1447
Totals	62	5967

[a]Inventoried by rotenone poisoning.

TABLE A11. Estimates of numbers and biomass of largemouth bass in pond 12.[a]

Size Class (mm)	P	B (gm)
100-109	4	64
120-129	1	26
140-149	2	64
150-159	2	86
160-169	2	114
170-179	2	118
180-189	1	69
190-199	1	88
200-209	5	638
210-219	2	266
230-239	1	148
240-249	2	418
260-269	1	232
270-279	2	540
280-289	1	296
290-299	1	330
300-309	5	2075
330-339	1	537
340-349	1	565
350-359	1	567
360-369	3	2536
400-409	2	1970
410-419	1	2260
Totals	45	13443

[a]Inventoried by rotenone poisoning.

TABLE A12. Estimates of numbers and biomass of largemouth bass in pond 13.[a]

Size Class (mm)	Numbers m	r	u	P	LP	UP	Biomass (gm) B	LB	UB
90-99	2	1	1	4	3	9	36		
100-109	9	4	3	21	12	36	287		
110-119	5	2	4	15	9	29	252		
120-129	3	2	3	7	6	12	158		
130-139	2	1	1	4	3	9	96		
190-199	1	1	1	2			160		
210-219	1	1	1	2			248		
220-229	1	1	1	2			276		
300-309	2	1	0	2			700		
400-409	1	1	1	2			1726		
Totals	27	15	16	61	43	88	3939		

TABLE A13. Estimates of numbers and biomass of largemouth bass in pond 15.[a]

Size Class (mm)	Numbers m	r	u	P	LP	UP	Biomass (gm) B	LB	UB
200-209	3	2	0	3			381		
210-219	4	2	0	4			627		
220-229	1	1	0	1			194		
230-239	3	3	1	4			794		
Totals	11	8	1	12	12	13	1996	1996	2162

[a]Estimates by Petersen method.

TABLE A14. Estimates of numbers and biomass of largemouth bass in pond 17.

Size Class (mm)	P	B (gm)
110-119	1	16
140-149	1	30
160-169	2	112
230-239	3	493
240-249	4	799
250-259	1	194
260-269	1	256
270-279	1	270
290-299	1	326
360-369	3	1938
370-379	6	4432
390-399	1	922
480-489	1	1341
Totals	26	11113

[a]Inventoried by rotenone poisoning.

TABLE A15. Estimates of numbers and biomass of largemouth bass in pond 18.[a]

Size Class (mm)	Numbers						Biomass (gm)		
	m	r	u	P	LP	UP	B	LB	UB
70-79	76	14	12	142	94	190	994	658	1130
80-89	145	46	37	261	220	302	1827	1540	2114
90-99	8	4	4	16	12	24	160	120	240
100-109	3	1	2	9	5	21	99	55	231
110-119	6	3	3	12	9	19	192	144	304
120-129	9	3	4	21	13	36	483	299	828
130-139	8	5	4	14	12	19	364	312	494
160-169	10	5	3	16	13	22	794	645	1091
180-189	12	5	3	19	15	27	1292	1020	1936
190-199	14	6	6	28	20	40	2422	1730	3460
380-389	3	1	1	4	3	8	2836	2127	5672
460-469	1	1	0	1			1791		
500-509	1	1	0	1			2462		
Totals	295	95	79	544	418	710	15706	12903	21853

[a]Estimates by Petersen method.

APPENDIX B:

Estimates of numbers and biomass of bluegills by size class in 17 inventoried ponds (Tables B1-B17).

Key to TABLES B1-B17.

m = number of marked fish

r = number of recaptured fish

u = number of unmarked fish

P = population estimate

LP = lower 95% confidence limit for population estimate

UP = upper 95% confidence limit for population estimate

B = biomass estimate

LB = lower 95% confidence limit for biomass estimate

UB = upper 95% confidence limit for biomass estimate

TABLE B1. Estimates of numbers and biomass of bluegills in pond 1.[a]

Size Class (mm)	Numbers						Biomass (kg)		
	m	r	u	P	LP	UP	B	LB	UB
40-49	1	1	0	1			0.01		
50-59	6	5	1	7	7	8	0.04	0.04	0.05
60-69	9	8	1	10	10	11	0.07	0.07	0.08
70-79	4	3	0	4			0.03		
80-89	8	8	1	9	9	10	0.14	0.14	0.15
90-99	28	22	2	30	30	31	0.38	0.38	0.40
100-109	18	16	2	20	20	21	0.45	0.45	0.47
110-119	63	58	4	67	67	68	1.71	1.71	1.73
120-129	56	53	3	59	59	60	2.04	2.04	2.08
130-131	33	30	2	35	35	36	1.55	1.55	1.59
140-149	26	24	2	28	28	29	1.36	1.36	1.41
150-159	56	55	3	59	59	60	3.60	3.60	3.66
160-169	12	9	3	16	15	17	1.10	1.04	1.17
170-179	1	1	0	1			0.07		
Totals	322	293	24	346	346	354	12.55	12.55	12.84

[a]Estimates by Petersen method.

TABLE B2. Estimates of numbers and biomass of bluegills in pond 2.[a]

Size Class (mm)	Numbers						Biomass (kg.)		
	m	r	u	P	LP	UP	B	LB	UB
70-79	9	3	11	42	20	76	0.42	0.20	0.76
80-89	61	15	45	244	151	337	2.78	1.72	3.84
90-99	125	33	169	765	561	969	9.87	7.24	12.49
100-109	113	30	148	670	483	857	9.58	6.91	12.26
110-119	95	21	79	452	301	603	9.31	6.20	12.42
120-129	26	10	42	135	76	194	3.29	1.85	4.73
130-139	29	12	56	164	100	228	5.20	3.17	7.23
140-149	14	5	24	81	29	133	3.43	1.23	5.63
Totals	472	129	561	2525	1721	3397	43.88	28.52	59.36

[a]Estimates by Petersen method.

TABLE B3. Estimates of numbers and biomass of bluegills in pond 3.[a]

Size Class (mm)	Numbers						Biomass (kg)		
	m	r	u	P	LP	UP	B	LB	UB
60-69	10	4	10	35	20	58	0.21	0.12	0.35
70-79	133	50	167	577	467	687	4.39	3.55	5.22
80-89	276	98	276	1053	909	1197	10.86	9.37	12.33
90-99	75	27	81	302	223	381	5.29	3.90	6.67
100-109	96	38	110	373	264	452	7.83	5.54	9.49
110-119	124	45	128	476	380	562	11.33	9.41	14.01
120-129	113	42	108	403	321	485	11.81	9.04	14.21
130-139	45	17	48	172	122	222	7.09	5.03	9.15
140-149	17	7	14	51	31	75	2.30	1.40	3.38
150-159	67	24	49	203	141	261	11.53	8.01	14.82
160-169	41	15	36	139	99	179	10.19	7.26	13.12
170-179	10	4	9	32	19	53	2.62	1.16	4.35
180-189	34	14	28	102	69	135	10.51	7.12	13.91
190-199	11	5	12	37	23	51	5.33	3.31	7.34
200-209	8	3	8	29	16	47	4.93	2.72	7.99
250-259	2	1	1	4	3	9	1.04	0.84	2.52
Totals	1062	394	1085	3988	3107	4854	107.23	77.76	136.21

[a]Estimates by Petersen method.

TABLE B4. Estimates of numbers and biomass of bluegills in pond 5.[a]

Size Class (mm)	Numbers						Biomass (kg)		
	m	r	u	P	LP	UP	B	LB	UB
60-69	89	9	38	464	206	722	3.75	1.67	5.84
70-79	166	17	72	869	517	1221	8.26	4.91	11.60
80-89	204	25	107	1077	721	1433	14.76	9.88	19.63
90-99	541	68	487	4415	3496	5334	73.29	58.04	88.54
100-109	301	37	310	2822	2017	3627	56.72	40.54	72.90
110-119	290	30	199	2213	1514	2912	50.24	34.37	66.10
120-129	129	15	78	799	452	1146	26.45	14.96	37.93
140-149	51	8	34	267	85	427	13.35	4.25	21.35
150-159	49	7	31	266	201	431	17.02	12.86	27.58
160-169	12	2	9	66	21	145	5.21	1.66	11.46
170-179	8	2	6	32	14	55	2.66	1.16	4.57
Totals	1840	220	1371	13290	9244	17453	271.70	184.30	367.51

[a]Estimates by Petersen method.

TABLE B5. Estimates of numbers and biomass of bluegills in pond 6.[a]

Size Class (mm)	Numbers						Biomass (gm)		
	m	r	u	P	LP	UP	B	LB	UB
50-59	1	1	0	1			6		
90-99	1	1	0	1			20		
110-119	1	1	0	1			21		
150-159	3	2	1	4	4	5	284	284	355
160-169	15	12	1	16	16	17	1211	1211	1286
170-179	27	24	1	28	28	29	2629	2629	2722
180-189	18	16	1	19	19	20	2113	2113	2194
190-199	11	9	0	11			1405		
200-209	5	5	0	5			802		
Totals	82	71	4	86	86	90	8491	8491	8811

[a]Estimates by Petersen method.

TABLE B6. Estimates of numbers and biomass of bluegills in pond 7.[a]

Size Class (mm)	Numbers						Biomass (kg)		
	m	r	u	P	LP	UP	B	LB	UB
130-139	3	1	1	6	4	13	0.28	0.19	0.60
140-149	11	2	2	22	13	42	1.37	0.81	2.60
150-159	24	7	13	68	37	102	4.77	2.59	7.14
160-169	7	2	2	14	9	26	1.38	0.88	2.55
170-179	6	2	2	12	8	22	1.31	0.87	2.40
180-189	8	2	3	20	11	39	2.50	1.37	4.84
190-199	10	4	5	22	15	38	3.45	2.35	5.93
200-209	2	1	1	4	3	9	0.60	0.45	1.35
Totals	71	21	29	168	100	291	15.64	9.52	27.41

[a]Estimates by Petersen method.

TABLE B7. Estimates of numbers and biomass of bluegills in pond 8.[a]

Size Class (mm)	Numbers m	r	u	P	B (gm)
50-59	4	3	0	4	22
60-69	6	5	0	6	43
140-149	1	1	0	1	61
150-159	3	3	0	3	263
160-169	7	6	0	7	579
170-179	13	11	0	13	1284
180-189	4	4	0	4	491
Totals	38	33	0	38	2743

[a]Estimates by Petersen method.

TABLE B8. Estimates of numbers and biomass of bluegills in pond 9.[a]

Size Class (mm)	Numbers						Biomass (kg)		
	m	r	u	P	LP	UP	B	LB	UB
30-39	16	3	12	80	28	153	0.08	0.03	0.16
40-49	75	11	67	531	266	796	1.06	0.53	1.59
50-59	101	16	98	719	418	1020	2.44	1.42	3.47
60-69	130	19	149	1149	713	1585	5.52	3.42	7.61
70-79	59	8	48	413	165	661	2.89	1.16	4.63
80-89	38	6	26	202	65	339	1.90	0.61	3.19
90-99	73	12	71	504	231	764	6.40	2.93	9.70
100-109	71	10	60	497	229	765	8.68	4.00	13.35
110-119	43	7	41	294	120	468	5.97	2.44	9.50
120-129	40	6	32	253	81	425	6.71	2.15	11.26
130-139	21	4	16	105	37	189	3.21	1.13	5.78
140-149	11	2	10	66	21	136	2.92	0.93	6.02
150-159	10	2	11	65	21	139	3.56	1.15	7.60
160-169	8	2	5	28	13	57	1.78	0.83	3.62
170-179	4	1	3	16	7	38	1.42	0.62	3.38
Totals	700	109	658	4922	2415	7535	54.54	23.34	90.86

[a]Estimates by Petersen method.

TABLE B9. Estimates of numbers and biomass of bluegills in pond 10.[a]

Size Class (mm)	P	B (kg)
30-39	65	0.07
40-49	390	0.70
50-59	654	2.22
60-69	134	0.73
70-79	387	2.83
80-89	1504	14.14
90-99	456	5.15
100-109	199	3.24
110-119	581	11.56
120-129	341	9.72
130-139	240	8.40
140-149	36	1.82
150-159	24	1.16
160-169	3	0.22
170-179	4	0.32
180-189	6	0.57
190-199	1	0.12
Totals	5023	54.23

[a]Inventoried by rotenone poisoning.

TABLE B10. Estimates of numbers and biomass of bluegills in pond 11.[a]

Size Class (mm)	P	B (kg)
60-69	109	0.38
70-79	272	2.38
80-89	489	4.55
90-99	1060	13.67
100-109	598	9.93
110-119	163	3.47
120-129	54	1.35
Totals	2717	35.73

[a]Inventoried by rotenone poisoning.

TABLE B11. Estimates of numbers and biomass of bluegills in pond 12.[a]

Size Class (mm)	P	B (kg)
40-49	531	1.70
50-59	724	3.19
60-69	735	2.82
70-79	212	1.27
80-89	847	7.54
90-99	639	6.90
100-109	635	9.34
110-119	744	15.92
130-139	106	3.82
140-149	107	4.25
Totals	5280	57.75

[a]Inventoried by rotenone poisoning.

TABLE B12. Estimates of numbers and biomass of bluegills in pond 13.[a]

Size Class (mm)	Numbers						Biomass (kg)		
	m	r	u	P	LP	UP	B	LB	UB
40-49	69	9	48	437	193	681	0.88	0.39	1.36
50-59	188	26	155	1308	877	1739	3.41	2.28	4.52
60-69	170	24	145	1197	786	1608	4.41	2.91	5.92
70-79	379	52	361	3010	2300	3720	18.38	14.04	22.69
80-89	183	27	166	1308	871	1745	11.80	7.86	15.71
90-99	217	37	262	1753	1272	2234	19.80	14.37	25.23
100-109	107	16	94	735	429	1041	10.28	6.01	14.55
110-119	119	19	121	876	732	1020	20.32	16.98	23.66
120-129	89	12	67	585	302	868	17.40	8.98	25.78
130-139	45	7	43	321	119	523	11.75	4.36	19.14
140-149	64	7	38	411	147	675	19.30	6.90	31.69
Totals	1630	236	1500	10915	8028	15854	137.72	85.08	190.25

[a]Estimates by Petersen method.

TABLE B13. Estimates of numbers and biomass of bluegills in pond 15.[a]

Size Class (mm)	Numbers						Biomass (gm)		
	m	r	u	P	LP	UP	B	LB	UB
60-69	3	2	1	4	4	5	31	31	38
70-79	12	9	4	17	16	21	153	144	189
80-89	16	13	4	20	20	24	226	226	288
90-99	20	15	4	25	24	28	458	439	512
100-109	4	3	1	5	5	6	104	104	125
Totals	50	42	14	71	69	84	972	944	1152

TABLE B14. Estimates of numbers and biomass of bluegills in pond 17.[b]

Size Class (mm)	P	B (kg)
70-79	1129	6.76
80-89	11273	93.57
90-99	3226	34.20
100-109	771	9.64
150-159	31	1.33
Totals	16430	145.52

[a]Estimates by Petersen method.

[b]Inventoried by rotenone poisoning.

TABLE B15. Estimates of numbers and biomass of bluegills in pond 18.[a]

Size Class (mm)	Numbers						Biomass (kg)		
	m	r	u	P	LP	UP	B	LB	UB
60-69	3	1	1	6	4	13	.04	0.02	0.08
70-79	7	2	2	14	9	26	.09	0.06	0.17
80-89	13	3	9	52	22	97	0.47	0.20	0.87
90-99	12	3	9	48	21	92	0.51	0.22	0.98
100-109	46	11	25	150	84	216	2.55	1.43	3.67
110-119	94	20	42	291	198	384	5.62	3.82	7.40
120-129	8	2	3	20	11	39	0.54	0.30	1.05
130-139	2	1	1	4	3	9	0.13	0.10	0.30
Totals	185	43	92	585	352	876	9.95	6.15	14.53

[a]Estimates by Petersen method.

TABLE B16. Estimates of numbers and biomass of bluegills in pond 22.[a]

Size Class (mm)	P	B (gm)
110-119	1	37
120-129	2	72
130-139	2	95
140-149	1	53
150-159	2	125
160-169	2	161
170-179	2	166
Totals	12	709

[a]Inventoried by rotenone poisoning.

TABLE B17. Estimates of numbers and biomass of bluegills in pond 24.[a]

Size Class (mm)	Numbers						Biomass (kg)		
	m	r	u	P	LP	UP	B	LB	UB
40-49	878	459	479	1794	1714	1874	2.87	2.74	2.99
50-59	804	428	471	1688	1606	1770	2.21	2.10	2.30
70-79	227	117	137	479	436	522	2.40	2.18	2.61
80-89	200	108	106	396	361	431	2.77	2.53	3.01
90-99	395	202	216	817	762	872	3.18	2.96	3.38
100-109	56	31	29	108	91	125	1.91	1.61	2.21
110-119	79	38	34	149	126	172	2.30	1.94	2.65
120-129	11	7	5	18	16	23	0.62	0.55	0.79
140-149	15	9	8	28	23	34	1.29	1.06	1.60
150-159	5	3	3	10	8	15	0.51	0.41	0.76
160-169	4	2	2	8	6	14	0.70	0.53	1.23
200-209	3	2	2	6	5	10	0.64	0.53	1.06
Totals	2671	1406	1458	5439	5154	5862	21.37	19.14	24.59

[a]Estimates by Petersen method.

APPENDIX C:

Biomass estimates of fishes (excluding bluegills and largemouth bass) in 14 inventoried ponds (Tables C1-C14).

TABLE C1. Biomass estimates of fishes (excluding bluegills and largemouth bass) in Pond 3.[a]

Species	Biomass estimate (gm)
Pumpkinseed	379 (1)[b]

TABLE C2. Biomass estimates of fishes (excluding bluegills and largemouth bass) in Pond 8.[a]

Species	Biomass estimate (gm)
Pumpkinseed	459
Rock bass	230
Yellow perch	617
Total	1306

TABLE C3. Biomass estimates of fishes (excluding bluegills and largemouth bass) in Pond 9.[a]

Species	Biomass estimate (gm)
White crappie	2690
Pumpkinseed sunfish	120
Central mudminnow	7 (1)[b]
Total	2820

[a]Estimates by Petersen method.

[b]Numbers in parentheses are numbers of individuals.

TABLE C4. Biomass estimates of fishes (excluding bluegills and largemouth bass) in pond 10.[a]

Species	Biomass (kg)
Green sunfish	0.14

TABLE C5. Biomass estimates of fishes (excluding bluegills and largemouth bass) in pond 11.[a]

Species	Biomass (kg)
Carp	208.39
White sucker	2.72
Northern pike	1.34
Black bullhead	6.14
Brown bullhead	0.88
Green sunfish	1.75
Golden shiner	5.13
White crappie	0.52
Rock bass	55.50
Channel catfish	0.48
Total	285.13

[a]Inventoried by rotenone poisoning.

TABLE C6. Biomass estimates of fishes (excluding bluegills and largemouth bass) in pond 12.[a]

Species	Biomass (kg)
Carp	58.34
White crappie	3.40
Yellow perch	0.05
Northern pike	5.53 (1)[b]
Pumpkinseed sunfish	0.12
Black bullhead	1.41
Total	68.85

TABLE C7. Biomass estimates of fishes (excluding bluegills and largemouth bass) in pond 13.[c]

Species	Biomass (kg)
Yellow perch	0.92
Green sunfish	0.03
Total	0.95

[a]Inventoried by rotenone poisoning.

[b]Numbers in parentheses are numbers of individuals.

[c]Estimates by Petersen method.

TABLE C8. Biomass estimates of fishes (excluding bluegills and largemouth bass) in pond 15.[a]

Species	Biomass (kg)
Rock bass	1.20
River chub	0.48
Channel catfish	0.76
Redear sunfish	16.73
Total	19.17

TABLE C9. Biomass estimates of fishes (excluding bluegills and largemouth bass) in pond 16.[b]

Species	Biomass (kg)
Black bullhead	189.96
Miscellaneous minnows	73.87
Goldfish	0.41 (1)[c]
White crappie	0.27 (2)
Total	264.52

[a]Estimates by Petersen method.

[b]Inventoried by rotenone poisoning.

[c]Numbers in parentheses are numbers of individuals.

TABLE C10. Biomass estimates of fishes (excluding bluegills and largemouth bass) in pond 17.[a]

Species	Biomass (kg)
Carp	232.22
Yellow perch	1.01
Channel catfish	2.95
Northern pike	6.30
White sucker	2.90
Golden shiners	0.85
Pumpkinseed sunfish	2.80
Black bullheads	1.13
White crappie	50.62
Central mudminnow	0.20
White bass	0.22
Total	301.22

TABLE C11. Biomass estimates of fishes (excluding bluegills and largemouth bass) in pond 18.[b]

Species	Biomass (kg)
Yellow perch	7.13

[a]Inventoried by rotenone poisoning.

[b]Estimates by Petersen method.

TABLE C12. Biomass estimates of fishes (excluding bluegills and largemouth bass) in pond 19.[a]

Species	Biomass (kg)
Smallmouth bass	2.04 (1)[b]
Carp	22.02
Black bullhead	11.44
Rock bass	0.35 (2)
Green sunfish	6.30
Miscellaneous minnows	3.36
Yellow perch	10.10
Northern pike	2.84 (1)
White sucker	0.10 (1)
Total	58.55

[a]Inventoried by rotenone poisoning.

[b]Numbers in parentheses are numbers of individuals.

TABLE C13. Biomass estimates of fishes (excluding bluegills and largemouth bass) in pond 22.[a]

Species	Biomass (kg)
Carp	265.68
White crappie	9.30
Blue catfish	11.12
Black bullhead	0.07
Green sunfish	0.12
Pumpkinseed sunfish	0.03
Gizzard shad	78.00
Total	364.32

TABLE C14. Biomass estimates of fishes (excluding bluegills and largemouth bass) in pond 24.[b]

Species	Biomass (kg)
Channel catfish	6.60 (19)[c]
Smallmouth bass	5.13 (6)
White crappie	18.46 (136)
Total	30.19

[a]Inventoried by rotenone poisoning.

[b]Estimates by Petersen method.

[c]Numbers in parentheses are numbers of individuals.

APPENDIX D:

Average total lengths and weights at capture and back-calculated total lengths at annulus formation for largemouth bass in sampled ponds (Tables D1-D19).

TABLE D1. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for largemouth bass in pond 1.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation				
				1	2	3	4	5
I	79	11	9	55				
II	150	49	3	53	140			
III	194	110	1	51	119	171		
V	372	751	2	73	167	237	281	341
Grand Mean	140	124		57	146	215	281	341

TABLE D2. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for largemouth bass in pond 2.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation				
				1	2	3	4	5
II	169	60	10	70	150			
III	210	107	4	72	138	191		
IV	243	174	5	69	137	170	227	
V	319	454	2	74	132	200	255	299
Grand Mean	209	134		70	143	183	235	299

TABLE D3. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for largemouth bass in pond 3.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation 1	2	3	4
I	94	10	3	69			
II	129	28	72	62	114		
III	185	83	7	63	105	157	
IV	334	456	4	55	208	267	314
Grand Mean	142	52		62	118	197	314

TABLE D4. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for largemouth bass in pond 4.

Age	Ave. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation 1	2	3
I	90	10	4	60		
II	119	19	16	51	102	
III	203	96	1	40	87	183
Grand Mean	117	21		52	101	183

TABLE D5. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for largemouth bass in pond 5.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation								
				1	2	3	4	5	6	7	8	9
II	99	14	7	46	83							
III	165	55	8	71	107	141						
IV	178	69	5	59	91	125	157					
V	244	256	3	62	97	132	176	228				
VI	329	558	1	73	117	153	212	251	291			
VIII	402	810	1	56	88	137	208	262	302	337	375	
IX	456	2281	1	52	71	101	144	176	222	281	376	424
Grand Mean	186	204		60	95	134	170	229	291	309	376	424

TABLE D6. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for largemouth bass in pond 6.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation					
				1	2	3	4	5	6
VI	207	100	16	61	86	139	158	175	191

TABLE D7. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for largemouth bass in pond 7.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation			
				1	2	3	4
III	233	142	20	44	107	176	
IV	233	141	6	42	105	166	206
Grand Mean	233	142		44	106	174	206

TABLE D8. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for largemouth bass in pond 8.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation			
				1	2	3	4
IV	229	138	21	45	101	160	206

TABLE D9. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for largemouth bass in pond 9.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation			
				1	2	3	4
I	97	44	4	64			
II	195	83	17	70	156		
III	290	284	1	47	163	255	
IV	303	343	2	74	161	223	275
Grand Mean	192	107		68	156	233	275

TABLE D10. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for largemouth bass in pond 10.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation						
				1	2	3	4	5	6	7
I	106	12	9	76						
II	125	25	26	63	104					
III	148	41	14	57	94	127				
IV	307	362	3	48	147	229	288			
V	343	550	2	61	102	229	278	321		
VII	477	1898	1	51	120	221	300	348	408	447
Grand Mean	152	98		63	104	157	286	330	408	447

TABLE D11. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for largemouth bass in pond 11.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation					
				1	2	3	4	5	6
I	104	13	30	75					
II	156	45	11	68	121				
III	205	113	6	68	98	161			
IV	353	585	1	86	142	196	312		
V	378	781	6	69	137	222	288	340	
VI	421	1187	5	64	95	177	271	338	388
Grand Mean	183	216		72	116	188	283	339	388

TABLE D12. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for largemouth bass in pond 12.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation					
				1	2	3	4	5	6
I	105	16	4	63					
II	165	53	8	51	134				
III	217	144	9	52	99	180			
IV	259	236	2	50	97	140	223		
V	335	583	7	56	141	208	269	308	
VI	374	810	3	55	138	205	244	300	340
Grand Mean	233	266		54	120	189	255	306	340

TABLE D13. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for largemouth bass in pond 13.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation			
				1	2	3	4
I	113	17	22	79			
II	213	114	3	65	162		
IV	353	606	2	71	158	233	328
Grand Mean	142	72		77	158	233	328

TABLE D14. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for largemouth bass in pond 14.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation			
				1	2	3	4
I	141	33	6	79			
II	169	55	24	52	115		
III	250	181	6	60	179	221	
IV	255	206	1	43	150	199	222
Grand Mean	180	76		58	128	218	222

TABLE D15. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for largemouth bass in pond 15.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation	
				1	2
II	220	171	10	49	119

TABLE D16. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for largemouth bass in pond 17.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation							
				1	2	3	4	5	6	7	8
I	112	16	1	62							
II	201	116	6	55	140						
III	255	220	7	64	141	200					
IV	247	244	1	53	70	144	209				
V	362]	636	1	52	117	154	210	295			
VI	368	689	3	66	140	170	227	287	331		
VII	373	740	4	60	99	142	187	242	309	350	
VIII	409	996	4	54	90	132	183	241	295	347	384
Grand Mean	294	439		59	123	165	198	257	310	349	384

TABLE D17. **Average total lengths and weights at capture and back-calculated total lengths at annulus formation for largemouth bass in pond 18.**

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation		
				1	2	3
I	89	9	15	61		
II	155	48	9	68	121	
III	182	66	1	48	140	163
Grand Mean	116	25		63	123	163

TABLE D18. **Average total lengths and weights at capture and back-calculated total lengths at annulus formation for largemouth bass in pond 20.**

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation	
				1	2
I	103	11	4	65	
II	133	25	24	70	116
Grand Mean	129	23		69	116

TABLE D19. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for largemouth bass in pond 23.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation		
				1	2	3
I	98	10	9	71		
II	123	19	2	72	103	
III	142	32	2	73	101	118
Grand Mean	108	14		71	102	118

APPENDIX E:

Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in sampled ponds (Tables E1-E22).

TABLE E1. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 1.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation						
				1	2	3	4	5	6	7
II	82	9	1	41	72					
III	86	9	96	34	64	77				
IV	93	10	2	32	64	75	87			
VII	156	43	1	31	53	76	91	110	126	146
Grand Mean	87	9		34	64	76	88	110	126	146

TABLE E2. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 2.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation							
				1	2	3	4	5	6	7	8
III	93	12	36	33	58	85					
IV	106	17	29	28	54	78	97				
V	110	18	11	28	53	71	87	102			
VI	113	21	5	27	51	71	85	97	106		
VII	136	34	8	25	50	73	90	105	118	129	
VIII	134	32	1	23	43	59	75	97	109	120	127
Grand Mean	105	17		30	55	79	92	101	113	127	127

TABLE E3. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 3.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation							
				1	2	3	4	5	6	7	8
II	81	10	50	33	65						
III	113	25	45	28	59	97					
IV	159	72	10	27	58	106	147				
V	161	70	9	29	56	104	136	152			
VII	184	110	1	35	71	140	162	168	173	179	
VIII	205	260	1	28	63	128	143	162	178	191	199
Grand Mean	108	29		30	62	101	143	155	175	185	199

TABLE E4. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 4.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation						
				1	2	3	4	5	6	7
I	60	7	2	47						
II	88	10	6	36	72					
III	105	14	32	39	72	95				
IV	114	18	23	36	70	93	106			
V	121	24	7	37	71	92	105	115		
VI	139	46	4	39	65	86	100	116	130	
VII	142	49	1	26	49	84	100	120	131	138
Grand Mean	109	18		38	71	93	105	116	130	138

TABLE E5. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 5.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation 1	2	3	4	5	6	7	8
II	73	9	7	29	60						
III	99	18	47	34	61	86					
IV	114	25	11	31	58	81	101				
V	114	22	8	29	53	72	88	103			
VI	128	35	2	27	48	66	84	99	115		
VII	138	41	4	27	49	71	87	103	111	127	
VIII	160	79	2	28	54	66	80	99	117	132	146
Grand Mean	104	22		32	59	82	92	102	114	129	146

TABLE E6. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 6.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation					
				1	2	3	4	5	6
I	82	15	3	56					
II	111	21	1	25	73				
IV	165	74	9	33	87	132	151		
V	174	92	21	31	83	118	144	161	
VI	182	110	60	36	88	122	145	164	178
Grand Mean	175	99		39	87	122	145	163	178

TABLE E7. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 7.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation	
				1	2
II	155	75	42	50	129

TABLE E8. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 8.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation			
				1	2	3	4
I	61	6	10	37			
IV	170	94	28	31	85	131	154
Grand Mean	141	71	38	33	85	131	154

TABLE E9. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 9.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation						
				1	2	3	4	5	6	7
II	67	6	22	34	59					
III	100	15	37	30	57	88				
IV	114	22	22	33	61	87	103			
V	131	31	6	31	60	95	110	122		
VI	146	49	6	29	55	85	107	125	136	
VII	165	72	3	33	60	89	111	129	142	153
Grand Mean	102	19		32	58	88	105	124	138	153

TABLE E10. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 10.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation								
				1	2	3	4	5	6	7	8	9
I	52	3	19	36								
II	84	10	30	36	71							
III	115	23	33	31	72	100						
IV	138	43	1	40	82	103	129					
VI	162	60	4	27	55	87	103	121	143			
VII	172	79	7	26	53	82	107	124	144	175		
VIII	180	92	4	24	49	76	108	135	148	163	172	
IX	187	108	2	23	43	71	97	125	149	162	171	180
Grand Mean	104	25		33	68	93	106	126	147	169	171	180

TABLE E11. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 11.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation				
				1	2	3	4	5
I	76	8	11	46				
II	95	14	31	36	75			
III	99	15	6	36	70	89		
IV	110	20	2	33	76	88	100	
V	122	25	1	25	48	87	100	111
Grand Mean	92	13		38	74	88	100	111

TABLE E12. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 12.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation						
				1	2	3	4	5	6	7
I	51	4	11	40						
II	65	5	10	38	58					
III	88	9	10	39	61	78				
IV	102	15	10	36	60	78	93			
V	110	20	6	32	54	70	86	100		
VI	110	19	1	26	37	57	66	86	98	
VII	137	38	2	26	47	68	79	103	120	133
Grand Mean	83	11		37	58	75	88	99	113	133

TABLE E13. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 13.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation 1	2	3	4	5	6
I	52	2	12	36					
II	72	6	27	28	56				
III	92	12	11	33	54	75			
IV	103	18	9	33	51	65	85		
V	116	26	10	30	49	67	82	100	
VI	134	37	6	30	48	65	82	98	120
Grand Mean	86	13		31	53	69	83	100	120

TABLE E14. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 14.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation 1	2	3
I	56	6	41	31		
II	127	36	30	28	84	
III	147	56	29	30	96	131
Grand Mean	103	29		30	90	131

TABLE E15. **Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 15.**

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation	
				1	2
I	87	14	29	40	
II	87	15	21	42	77
Grand Mean	87	14		41	77

TABLE E16. **Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 17.**

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation						
				1	2	3	4	5	6	7
II	82	9	1	41	72					
III	86	9	96	34	64	77				
IV	93	10	2	32	64	75	87			
VII	156	43	1	31	53	76	91	110	126	146
Grand Mean	87	9		34	64	76	88	110	126	146

TABLE E17. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 18.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation						
				1	2	3	4	5	6	7
I	87	9	8	48						
VI	113	19	34	25	45	62	79	94	105	
VII	111	18	7	26	43	57	73	86	96	104
Grand Mean	108	17		29	45	61	78	93	103	104

TABLE E18. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 20.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated total length (mm) at Annulus Formation					
				1	2	3	4	5	6
II	72	8	31	31	54				
III	118	30	39	30	65	96			
IV	167	76	3	29	68	116	144		
V	190	105	1	24	70	124	149	173	
VI	326	222	1	28	78	129	166	192	222
Grand Mean	104	26		30	61	99	149	182	222

TABLE E19. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 22.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation 1	2	3	4
II	129	42	6	38	99		
III	155	53	4	38	72	120	
IV	169	80	3	38	77	110	141
Grand Mean	146	54		38	86	116	141

TABLE E20. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 23.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation 1	2	3	4	5	6	7
I	79	8	19	43						
III	112	18	3	41	70	99				
IV	120	23	3	41	69	92	109			
V	125	25	6	35	59	80	99	116		
VI	122	24	13	29	49	67	85	100	113	
VII	127	30	5	25	42	63	78	91	104	117
Grand Mean	105	18		36	54	75	89	102	110	117

TABLE E21. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 24.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation						
				1	2	3	4	5	6	7
I	53	6	4	36						
II	84	9	3	37	66					
III	105	17	10	38	73	94				
IV	126	34	2	42	71	97	116			
V	159	78	2	39	72	106	133	150		
VI	134	39	2	30	61	87	104	116	126	
VII	205	134	1	29	58	83	118	141	170	189
Grand Mean	106	27		37	69	94	118	134	141	189

TABLE E22. Average total lengths and weights at capture and back-calculated total lengths at annulus formation for bluegills in pond 25.

Age	Av. Total Length at Capture (mm)	Av. Wt. (gm)	No. of Fish	Av. Back-calculated Total Length (mm) at Annulus Formation					
				1	2	3	4	5	6
I	59	6	3	37					
II	90	17	19	31	62				
III	127	41	8	32	65	100			
IV	158	99	14	37	78	114	133		
V	167	125	14	32	62	111	131	147	
VI	162	112	1	27	55	75	101	128	145
Grand Mean	129	66	59	33	66	108	131	146	145

APPENDIX F:

Owners and locations of the 25 ponds in which fish populations were sampled.

TABLE F1. Owners and locations of the 25 ponds in which fish populations were sampled.

Pond	Owner	Location of Pond		
		Township	Range	Section
1	Matt Borsenik	10N	2E	21
2	Matt Borsenik	10N	2E	21
3	Jerry Fraser	10N	3E	17
4	Frank W. Martin	11N	3E	31
5	Ernest Kendall	10N	2E	1
6	Donald Zorn	11N	2E	12
7	Norman Guziak	10N	2E	24
8	Dale Durham	11N	2E	21
9	Norman Hahn	11N	3E	17
10	Harold Asmus	11N	3E	19
11	Larry Clark	12N	3E	36
12	Eugene Robinson	12N	3E	36
13	Alex Teselsky	10N	2E	12
14	Fred Hare	11N	3E	4
15	Roy Colpean	11N	2E	31
16	Michael Steeves	12N	4E	31
17	Wyman Day	11N	4E	6
18	Ervin Levan	10N	2E	12
19	Jack Bullard	11N	1E	16
20	Jack Riser	11N	3E	5
21	Vincent Liebrock	10N	2E	12
22	Vincent Liebrock	10N	2E	12
23	Bennett Claspbell	12N	2E	13
24	Amos Snider	11N	4E	5
25	Robert Hall	11N	2E	36