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FOOD HABITS, RATE OF GROWTH AND CANNIBALISM OF YOUNG "LARGEMOUTH" BLACK BASS (APLITES SALMOIDES) IN STATE-OPERATED REARING PONDS IN MICHIGAN DURING 1935.

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INTRODUCTION

Maximum production and maximum growth are the ultimate aims in the pond propagation of black bass. Important among the factors controling production and growth are food habits, rate of growth and cannibalism. Although previous investigations have contributed considerably to our knowledge of these factors, their interrelationships and their relationship to production, it is believed that further information along these lines will give the fish culturist a better understanding of the complicated processes involved in bass propagation and will aid him in increasing his output. The following studies have been undertaken as an attempt to obtain further data on the interrelationship between these basic factors in production, namely: rate of growth, food habits and cannibalism.

MATERIALS AND METHODS

The studies deal with the history of young "largemouth" black bass (Aplites salmoides) in state-operated rearing ponds in Michigan during 1935. The studies were based on the examinations of samples collected from the ponds at different times during the summer. The ponds examined are: two state-owned rearing ponds at Fenton (hereafter referred to as Fenton Ponds 1 and 2), the state-operated Corduroy Cord Pond at Grand Rapids and Pond AB at the Lydell Hatchery at Comstock Park.

The two Fenton ponds are of recent construction; Pond 1 was operated first in 1934 and Pond 2 in 1935. The large Corduroy Cord Pond is a relatively old, artificial pond, maintained by the Corduroy Cord Tire Co. as a fire protection. The Lydell Pond was remodeled during 1934. In the fall of 1934 all of the 4 ponds were drained, the fish removed and the ponds then allowed to fill with water. No fertilizer or artificial feeding was employed in any of the ponds during the period covered by the present study. Data on the area, depth, bottom composition, water supply and vegetation of each pond are given in the first part of Table 1.

The two Fenton ponds were stocked with bass fry seined from natural lakes in Oakland County: Pond 1 was stocked with 50,000 fry during the period of June 15 to 24, and Pond 2 was stocked with 160,000 fry during the period of June 24 to July 3. The bass fry in Corduroy Cord Pond were produced by natural reproduction in the pond. In November 1934, Mr. Claud Lydell stocked this pond with 302 adult "largemouth" bass and 6,957 adult golden shiners (Notemigonus crysoleucas). The 1935 hatch of bass fry appeared about the first of June. Definite data on the number of bass fry produced in this pond were not obtained; however, it was the opinion of the Lydell Hatchery personell that the number still far exceeded 200,000, even after 20,000 had been removed for stocking the Lydell Pond. This transferal of 20,000 bass fry from Corduroy Pond to Pond AB at the Lydell Hatchery was made on June 21.

Adult golden shiners were introduced accidentally into the Fenton ponds during the fall of 1934:—approximately 30 into Pond 1 and 400 into Pond 2. At the time of the first examination of the Fenton ponds on June 29, no shiner fry were encountered in Pond 1, but they were found in abundance in Pond 2. Similar observations were made by Mr. A. T. Stewart and members of his staff during the period of June 15 to 29. An enormous number of young shiners (estimated from sampling and observation to be several millions) was produced in Corduroy Pond. The Lydell

Pond had no shiners. Possible forage fishes, other than golden shiners, were so rare in all ponds as to be unworthy of mention.

Data on the number, date, time, etc. of samplings, taken throughout the season, of the bass and shiners in these ponds are given in Table 1. It is believed that each of these collections was a close approximation to a true random sample of the young fish in the pond at the time of collecting. Each of the two October samples from the Fenton ponds was taken by hand-net at random when the pond was drained and the entire pond population was confined in small holding pools; the cannibal bass were separated from the non-cannibal bass, on the basis of size, before the samples were taken. Thus these October samples from the Fenton ponds include separate random samples of these cannibal and non-cannibal groups, for example: the 34 non-cannibal bass of the sample (Pond 1) represent the total 9,250 individuals of that class which were taken from the pond, while the 64 cannibals of the sample represent the total 200 individuals of the cannibal class which were taken from the pond (see footnotes to Table 2). All other samples were collected by seines which had meshes sufficiently small (1/6 inch, 1/4 inch and 3/8 inch—bar measure) to capture the smaller fishes and were long enough (20 to 60 feet) to cover a sufficient area of both deep and shallow water to guarantee the capture of the larger individuals.

All fish in each sample were preserved in 10% formalin immediately after they were seined from the pond, and after 2 or 3 days were transfered to 70% alcohol for permanent preservation. Examinations of these samples were made during the period of December 9, 1935 to May 6, 1936. Since those samples which were collected first were likewise examined first, all of the samples had been in preservative approximately the same length of time. Since the method of preservation was identical for all collections, it is believed that any error in lengths and weights, resulting from the failure to correct for the effect of the preserving fluids, was uniform for all the samples. All lengths referred to in this paper are body or standard lengths; these were taken by placing each fish on the ruler and sighting to the nearest millimeter. In recording weights, the specimens were divided into three groups—non-cannibal bass, cannibal bass and golden shiners, and each group within each collection was weighed as a unit. The excess of preservative fluid was allowed to drain off before weighing and all weights were taken to the nearest gram.

The separation of the non-cannibal and cannibal groups among the bass was desirable due to the great difference both in food habits and in growth. This separation was made in part on the basis of direct evidence and in part on circumstantial evidence. Those bass which, during the food studies were found to contain other bass in their stomachs were used as the limits of the size range of the cannibal class; all other bass within this size range were also considered as cannibals except where the smaller cannibals were unusually small in relation to the entire bass population. It is believed that, in general, the data obtained during the food studies validate the separation of the two groups by this method. The records of cannibals are as follows:

Fenton Pond 1—July 5, of the 16 specimens in the cannibal class, 14 contained young bass; July 16, of 25 specimens, 7 contained bass; July 30, 9 specimens, no bass; Aug. 24, 18 specimens, 1 bass; Oct. 17, no food studies made. Fenton Pond 2—July 5, 26 specimens, 8 contained bass; July 16, 21 specimens, 6 bass; July 30, 7 specimens, 2 bass; Aug. 24, 2 specimens, 1 bass; Oct. 31, no food studies made. Corduroy Pond—July 27, 1 specimen, 1 bass. Summary—125 specimens recorded as cannibals, of which 40 specimens (32%) contained young bass in their stomachs at the time they were collected.

From these data it appears to be a logical assumption that, during the course of the summer, most if not all of the bass within the size range designated for the cannibal class were actually cannibalistic. The cannibal classes in the October samples from the Fenton ponds were defined on the basis of size distribution and the size range of cannibals in earlier collections. Scale examinations verified the fact that the large cannibals were young of 1935.

Food studies were made on all of the cannibal bass, and either on all or on a large sample of the non-cannibal bass in each collection, except the October collections from the Fenton ponds. For food studies on the bass, only the contents of the stomachs were analyzed; the contents of the intestines were not examined and are not represented in the data presented in this paper. The results of the examinations of stomach contents were recorded for individual fish as the number of each type of organism and as the estimated percentage of total volume represented by each type. Facilities were not available to measure the volumes of food organisms in individual fish; however, the total volume of each type of organism from all non-cannibal bass and from all cannibal bass in each collection was determined by water displacement, in a centrifuge tube with which readings to the nearest 0.02 cubic centimeters could be made. In the event of several types of organisms each of too small a volume to be accurately measured, their combined volume was measured and their respective volumes estimated. Identifications of the insect food organisms to family, genus or species were made chiefly by Mr. J. W. Leonard of the Institute for Fisheries Research.

RESULTS

This study is concerned with the history of the populations of each pond only during that time period included by the dates of sampling from each pond (Table 1). The amount of growth made by the bass in the two Fenton ponds prior to June 29 (date of the first sample) is not known. Those bass stocked in Pond 2 after June 29 (70,000 of the total 160,000 stock) were approximately the same average size as the bass already in the pond; therefore this introduction of bass into Pond 2 subsequent to the first sample was not an important cause for the difference in average size between the bass in the June 29 and July 5 samples. Data on production of bass in Corduroy Pond and on lengths and weights of bass in Lydell Pond at the end of the summer are not available.

The length frequencies of the bass and shiners in each collection are given in Figure 1. In the construction of Figure 1, the vertical dimensions of the graphs, in many instances, have been exaggerated at the extremes in order to show the presence of a relatively small number of specimens. The number of specimens range in standard length, average length and average weight of all bass and shiners in each collection are given in Table 2. The rates of growth of all non-cannibal and cannibal bass in the four ponds are presented in terms of average standard length in millimeters in Figure 2; for this figure the data have been plotted on a semi-logarithmic scale in order to show the percentage increase in length.

There was a considerable variation among the four bass populations in the amount of size dispersal which developed during the course of the summer. This size dispersal was much greater in the Fenton ponds than in the Corduroy and Lydell ponds. There was also a considerable variation in rate of growth. This was greatest in the Corduroy Pond and less in the Lydell Pond and Fenton ponds 1 and 2, in that order. The average rate of growth of the cannibal bass in the Fenton ponds was much greater than that of the non-cannibal population of any of the ponds.

When Fenton Pond 2 was drained in October, it was found to contain, in addition to the young bass, 16 bass ranging in total length from 9 1/2 to 10 3/4 inches (see Figure 3). Examinations of scales from these larger individuals revealed that they were two summers old, or young of 1934. (These second-summer bass are not represented in any of the data presented elsewhere in this paper.) Whether they were introduced into the pond during late June as yearling fish along with the bass fry or whether they escaped from Pond 1 into Pond 2 during late fall in 1934 is not known. The scales indicated that these fish made a small amount of growth during 1934 (about the same as that made by the non-cannibal bass of Pond 2 during 1935, judging from the size of comparable growth areas of scales—Figure 4) but an enormous growth in Pond 2 during 1935. Only circumstantial evidence is available to explain the exceptional second-year growth of these 16 bass in Pond 2. The only food supply available in any quantity was an almost unlimited supply of bass and shiner fry, and the supposition is that the yearling bass fed on these fry.

A group photograph of approximately average-size bass from several of the different bass groups which have been discussed in this paper (the second-summer bass from Fenton Pond 2, the cannibal and non-cannibal young from Pond 2 and the non-cannibal young from Corduroy Pond) is presented in Figure 3. Photographs of scales taken from these same fish, and revealing their growth history, are shown in Figure 4.

Data on the numbers and lengths of non-cannibal bass from each collection which were examined for the present food studies are given in Table 3. A comparison of the data in Table 3 with that in Table 2 reveals that those bass which were studied were typical, in length range and average length, of their respective collections. A summary of the total number and total volume of each type of food organism taken from the non-cannibal bass of each collection is given in Table 4. The data on stomach contents of all bass studied are in Table 5 to show the variation in food habits according to size among each population of young bass at different times during the summer, and the variation in diet of each population throughout the summer. In the preparation of Table 5, the major food organisms were grouped into four classes according to size; several catagories of food organisms as listed in Table 4, such as "aquatic insects," "terrestrial insects," "animal remains" and "algae" were intentionally omitted in the preparation of Table 5. The non-cannibal bass in each sample were divided arbitrarily into two or three groups according to length; where cannibals were present, they constituted the third group. The importance of each food class to each bass group of each collection was determined according to (1) the actual number and the per cent of stomachs containing each food class, (2) the total and average number of organisms of each class, (3) the average estimated per cent of food by volume for each class and (4) an "importance factor" obtained by multiplying the "per cent of stomachs containing each food class" by the corresponding "average estimated per cent of food by volume for each class." This "importance factor" is thus a weighted average and is believed to be the most significant index to the relative importance of each food class, since it takes into account the frequency of occurrence of each and the relative importance of each to individual fish; it assumes, however, the total content of individual stomachs to be of equal importance regardless of the fact that the volume of such contents may vary greatly with individual fish.

The great bulk of the food organisms found consistently in the stomachs of the non-cannibal bass from the four ponds throughout the season were micro-crustaceans, mayfly numphs and chironomid larvae (Table 4). The larger aquatic insects (Odonata, Hemiptera, Coleoptera and Trichoptera) as a group were also important. The Amphipoda were of some importance only in Corduroy Pond. Terrestrial insects, arachnids, annelids, plant material and debris were generally of minor importance. The four food classes in sequence of importance to the four non-cannibal bass populations as a whole, from greatest to least, were: 2, 1, 3 and 4 (Table 5). The cannibal bass had fed mostly on food class 4 (crayfish, bass and shiners).

VARIATIONS IN FOOD HABITS

The data presented in Table 5 reveal certain tendencies in food habits. The "importance factors" show, for the Fenton ponds, little or no definite trend towards a change in the importance of each of the first three food classes with the advance of the season; however, in Corduroy Pond, a big decrease in the microcrustaceans was replaced chiefly by a big increase in the mayflies, chironomids and amphipods. Food class 4 was encountered to the least extent in the June samples, but the records of subsequent occurrence are too few to justify conclusions on the trend of importance of this food class during the remainder of the summer. Differences in food preference were consistent and prominent between the different size groups of bass of single collections. In almost every collection the smaller of the non-cannibal bass had fed more upon the micro-crustacea than had the larger ones. In general the two size groups of the non-cannibal bass of each collection had fed upon food class 2 (mayflies, chironomids and amphipods) in about equal amounts, and to a greater extent than had the bass of the cannibal group. Food class 3 (including the larger aquatic insects) was used more by the larger of the non-cannibal bass than by the smaller. Food class 4 was of importance only to the cannibal bass.

TABLE 2. THE NUMBER OF SPECIMENS, RANGE IN STANDARD LENGTH, AVERAGE LENGTH[1] AND AVERAGE WEIGHT OF ALL (EXCEPTIONS--SEE FOOTNOTES) NON-CANNIBAL AND CANNIBAL, YOUNG LARGE-MOUTHED BASS (LMB) AND OF YOUNG GOLDEN SHINERS (GS) IN THE RANDOM SAMPLES COLLECTED FROM THE FOUR BASS-REARING PONDS DURING 1935

	Locality	Fenton Pond No. 1						Corduroy Cord Pond						Lydell Pond
	Date	6/29	7/5	7/16	7/30	8/24	10/17	6/21		7/27		10/19		7/27
	Species	LMB	LMB	LMB	LMB	LMB	LMB	LMB	GS	LMB	GS	LMB	GS	LMB
Non-cannibal bass	No. specimens	159	381	232	127	93	34	375	..	67	..	143	..	71
	Range in	20-	24-	30-	37-	47-	50-	12-		39-		65-		30-
	length (mm.)	34	39	44	49	69	72	20	..	61		120	..	57
	Ave. length	28.1	30.4	36.1	43.2	57.4	61.5	16.7	..	47.2	..	80.4	..	39.3
	Ave. wt. grs.	0.57	0.7	1.1	1.9	4.2	5.2	0.11	..	2.8	..	12.2	..	1.5
Cannibal bass	No. specimens	..	16	25	9	18	64	..	..	1	..	..	..	..
	Range in		40-	45-	50-	70-	94-							
	length (mm.)	..	47	63	74	116	155	..	..	61	..	..	..	..
	Ave. length	..	42.7	50.1	55.6	88.4	121.7	..	..	61	..	..	..	..
	Ave. wt. grs.	..	2.2	3.1	4.4	17.0	41.6	..	..	7.5	..	..	..	..
Total	No. specimens	159	397	257	136	111	9450[2]	375	840[3]	68	208	143	411[3]	71[4]
	Ave. length (mm.)	28.1	30.9	37.4	44.0	62.4	62.8	16.7	12.2	47.4	38.9	80.4	50.0	39.3
	Ave. wt. grs.	0.57	0.7	1.3	2.1	6.3	6.0	0.11	0.02	2.9	0.91	12.2	1.7	1.5

	Locality	Fenton Pond No. 2										
	Date	6/29		7/5		7/16		7/30		8/24	10/31	
	Species	LMB	GS	LMB	GS	LMB	GS	LMB	GS	LMB	LMB	GS
Non-cannibal bass	No. specimens	423	..	365	..	504	..	390	..	137	164	..
	Range in	15-		19-		27-		33-		40-	41-	
	length (mm.)	30	..	40	..	50	..	61	..	68	66	..
	Ave. length	24.2	..	30.4	..	40.6	..	43.4	..	48.2	49.0	..
	Ave. wt. grs.	0.37	..	0.81	..	1.6	..	2.0	..	2.6	2.8	..
Cannibal bass	No. specimens	..	..	26	..	21	..	7	..	2	184	..
	Range in			38-		51-		74-		108-	71-	
	length (mm.)	..	..	41	..	61	..	88	..	119	171	..
	Ave. length	..	..	38.7	..	53.5	..	79.6	..	113.5	128.6	..
	Ave. wt. grs.	..	..	1.4	..	4.4	..	13.4	..	35.0	51.7	..
Total	No. specimens	423	281[3]	391[3]	282	525	68	397	45	139	32,375[2]	271
	Ave. length (mm.)	24.2	19.7	31.0	24.6	41.1	40.9	44.1	53.4	49.1	49.7	70.6
	Ave. wt. grs.	0.37	0.14	0.85	0.26	1.7	1.3	2.2	2.9	3.1	3.3	5.7

1 All average lengths are based on the frequencies of single millimeter classes, not on the 4-millimeter classes listed in Figure 1.

2 All collections were random samples of the pond populations except the October collections from the Fenton Ponds. At the time of draining in October, Fenton Pond No. 1 contained approximately 9,250 non-cannibal bass and 200 cannibals, and Fenton Pond No. 2 approximately 32,100 non-cannibal bass and 275 cannibals. Random samples (included in this table) of the non-cannibal and cannibal groups were taken separately for each group for each pond. The total average lengths and weights, however, are based on the entire populations of the two ponds.

3 Only part of the entire sample is represented here. The June 21 collection from Corduroy Pond contained 1616 shiners; the October 19 collection from Corduroy Pond contained 1230 shiners; the June 29 collection from Fenton Pond No. 2 contained 621 shiners, and the July 5 collection from Fenton Pond No. 2 contained 741 bass. The specimens from these four collections which are listed in this table were taken at random from these total collections and are representative in size for the particular species and date.

4 The average size of the bass in this pond on June 21 was the same as that of the Corduroy Pond from which they were obtained on this date.

RELATION OF VOLUME OF FOOD CONTAINED TO RATE OF GROWTH

The data reveal that differences in average rate of growth between the bass populations are correlated with differences in the average volume of food contained in the stomachs. In enumerating the following comparative data, it is recognized that comparisons are significant only where the bass populations are of approximately the same average size or where smaller bass contain more food than the larger ones of another pond. The following comparison of non-cannibal populations are to be made:

1. June 29 bass of Pond 2 (ave. length 24.2 mm.) with June 29 bass of Pond 1 (ave. length 28.1 mm.).
2. July 5 bass of Pond 2 (30.4 mm.) with July 5 and July 16 bass of Pond 1 (30.4 and 36.1 mm.).
3. July 16 bass of Pond 2 (40.6 mm.) with July 30 bass of Pond 1 (43.2 mm.).

Whereas the bass in Pond 2 were smaller than the bass in Pond 1 on June 29, the average rate of growth of the Pond 2 fish during the period of June 29 to July 16 was much greater than the average rate of growth of the Pond 1 fish during the period of June 29 to July 30 (see Figure 2). The more rapidly growing fish in Pond 2 contained more food on the average. The average volumes of the stomach contents for each of the bass samples, just cited, are:

1. June 29 bass of Pond 2, 0.016 c.c.; June 29 bass of Pond 1, 0.006 c.c.
2. July 5 bass of Pond 2, 0.031 c.c.; July 5 and July 16 bass of Pond 1, 0.006 c.c. and 0.008 c.c. respectively.
3. July 16 bass of Pond 2, 0.014 c.c.; July 30 bass of Pond 1, 0.010 c.c.

This greater rate of growth of non-cannibal bass in Pond 2 during the early part of the summer was made in spite of a probably greater concentration per acre. During essentially the same time period, Pond 1 was stocked with 15,600 fry per acre and yielded 2,950 per acre while Pond 2 received 25,000 per acre and yielded 5,060 per acre. During the latter part of the summer (July 30 to August 24 for Pond 1 fish, July 16 to August 24 for Pond 2 fish), however, the relative rates of growth of the bass populations in the two Fenton ponds was just the reverse of those during the first part of the summer—the Pond 1 fish grew more rapidly and made a much greater total growth. Here again the more rapidly growing fish contained the greater average volume of food (the August 24 fish of Pond 1 contained 0.031 c.c., the July 30 and August 24 fish of Pond 2 contained 0.021 and 0.012 c.c.), but this fact is of doubtful significance because the Pond 1 fish were also the larger.

The much greater rate of growth of bass in Corduroy Pond over the two Fenton ponds was definitely correlated with the amount of food eaten. The July 27 bass from Corduroy contained an average of 0.079 c.c. or approximately 2 1/2 to 7 times the amount contained by the bass in the August collections from the Fenton ponds (the bass in the latter were the larger. The amount contained by the October bass from Corduroy was also comparatively very great (ave., 0.109 c.c.), but its significance is open to question due to lack of comparative material. According to the estimates by members of the Lydell Hatchery staff, the Corduroy Pond contained in excess of 13,000 young bass per acre at the beginning of the summer, or at least nearly the equivalent of the initial stocking of Fenton Pond 1. The data suggest that the greater total increase in length, during the summer, of the bass in Fenton Pond 1 over that of the bass in Pond 2 was, at least in part, due to the fact that there were fewer fish per acre in Pond 1, but that the big difference in rate of growth between the Corduroy and Fenton Pond 1 bass was due chiefly to differences in amount of food consumed. General observations at the time of sampling indicated that Corduroy Pond was, by far, the richest of the three ponds in abundance of food organisms, especially the mayflies.

RELATION OF FOOD HABITS TO SIZE DISPERSAL AND THE BEGINNING OF CANNIBALISM

The data obtained during the present food studies suggest that food is a factor of prime importance in the increase of size dispersal. It has been indicated that the larger of the non-cannibal bass fed upon food class 3 (the larger aquatic insects) more than did the smaller ones, and conversely, the smaller ones fed on food class 1 (microcrustacea) more than did the larger ones. Further, it was observed during the food studies that the actual volume of the contents of individual stomachs was much greater when the food was mostly insects than when it was mostly micro-crustaceans. This fact is suggested by a comparison of the "importance factors" (Table 5) with the data on measured volume of food organisms (Table 4); the aquatic insects are ranked as more important by the measured volumes than by the "importance factors" which do not take into account the variation in volume of the contents of individual stomachs. The fact that, over a considerable portion of the summer, the larger of the non-cannibal bass actually fed upon food class 3 (the aquatic insects) more than did the smaller of the non-cannibal group is indicated by the data, for example: among the bass of Fenton Pond 1 (comparing fish of the same size) the "importance factor" of food class 3 for the larger of the non-cannibals of June 29 was 32, while that for the smaller of the non-cannibals on July 16 was 3, the two groups being of the same size range, approximately, on their respective dates--all similar comparisons for the Fenton ponds reveal the same circumstance. The food organisms of food class 3 of most importance to the bass in the Fenton ponds during the early part of the summer were the Corixidae and Coleoptera, and during the early summer the supply of corixids was nearly exhausted. During the latter part of the summer the larger insects of food class 3, such as the Odonata, replaced the corixids. It is believed that the unequal extent of utilization of the larger aquatic insects was responsible for the initiation of the rapid increase in size dispersal among the Fenton bass during the summer. During early summer the larger bass, by virtue of their size advantage, fed more upon the corixids than did the smaller bass, and nearly eliminated these insects before the smaller bass reached a sufficient size to use this food source to an equal advantage. The resultant size dispersal was sufficient to allow cannibalism to begin. This explanation of the beginning of cannibalism receives confirmation from a comparison of the conditions in the Fenton ponds with those of Corduroy Pond. In Corduroy, the larger aquatic insects were of less importance; the entire population was more uniform in food habits at any one time; there was much less size dispersal among the bass, and the occurrence of cannibalism was less frequent in Corduroy Pond (0.47% among all specimens collected) than in Fenton ponds 1 and 2 (2.1% and 0.8% respectively at the time the ponds were drained in October; 7.5% and 3.9% in the summer collections).

RELATION OF CANNIBALISM AND VOLUME OF FOOD CONTAINED TO SIZE DISPERSAL

Once cannibalism was started by virtue of a certain size advantage of predator over prey, the cannibals continued to grow much more rapidly than the non-cannibals, resulting in a continual increase in size dispersal throughout the summer. This continual increase in size dispersal may have been a necessary condition for the continuation of cannibalism as well as the result of it. The cannibals were always the larger bass of a population, and they were feeding on only the smaller bass in the pond. The average difference in length between predator and prey in the Fenton ponds increased continually, from 16.9 mm. on July 5 to 21.2 mm. on July 16 to 46.5 mm. on July 30 to 56.5 mm. on August 24 (Table 6). The data indicate that cannibalism was dependent upon size dispersal and that (comparing the Corduroy population with those of the Fenton ponds, see Figure 1) the amount of cannibalism was proportional to the extent of the size dispersal.

The much greater rate of growth of the cannibal bass over the non-cannibal bass was unquestionably due to the fact that they consumed a much greater amount of food which was probably also more nourishing in quality. The total content of the stomachs of the 557 non-cannibal bass from the Fenton ponds listed in

Table 5 was 8.70 c.c., an average of 0.016 c.c. per stomach. The total content of the stomachs of the 124 cannibal bass from the Fenton ponds listed in Table 5 was 21.91 c.c., an average of 0.17 c.c. per stomach or 10 times that for the average non-cannibal bass; 17.09 c.c. or 78% of this amount consisted of food class 4 (bass, shiners and crayfish), and the remainder was mostly the larger aquatic insects. Also, the cannibal bass contained more food than did non-cannibal of the same size, or larger, taken at a later date. Of the Fenton Pond 1 collections, the 16 cannibals of July 5 contained an average of 0.201 c.c. while the 43 non-cannibals of July 30 contained an average of 0.010 c.c.; the 25 cannibals of July 16 and the 9 cannibals of July 30 contained 0.143 and 0.084 c.c. respectively, while the 42 non-cannibals of August 24 contained 0.031 c.c. Of the Fenton Pond 2 collections, the 26 cannibals of July 5 contained an average of 0.057 c.c., while the 65 non-cannibals of July 16 contained 0.014 c.c. The 21 cannibals of July 16 from Pond 2 contained an average of 0.285 c.c., whereas the 42 non-cannibals of August 24 from Pond 1 contained an average of 0.031 c.c. The bass population of Corduroy Pond was about intermediate between the cannibals and the non-cannibals of the Fenton ponds in average rate of growth (Figure 2) and in average volume of stomach contents. The data obtained point to the conclusion that for all bass, cannibal or non-cannibal, the rate of growth was approximately in proportion to the amount of food contained in the stomachs.

The presence of the 16 second-summer bass in Pond 2 offers further evidence of the inherent capacity of the "largemouth" bass for rapid growth if sufficient food is available. The apparently reliable circumstantial evidence points to the conclusion that the enormous amount of growth during their second summer was the result of an almost unlimited food supply; their very slow growth during the first year was probably due to a limited food supply.

RELATION OF AVERAGE GROWTH OF THE POPULATION TO AMOUNT OF CANNIBALISM

Those factors which were found to be condusive to cannibalism—unequal utilization of certain types of food, and the resultant increase in size dispersal— were of less importance, and consequently the frequency of cannibalism was less, among the more rapidly growing population of bass in Corduroy than among the more slowly growing populations of the Fenton ponds. Thus it appears that the rate of growth of the bass populations was another factor of importance in the development of cannibalism.

GOLDEN SHINERS AS FORAGE IN BASS PONDS

The present study has furnished some information on the problems involved in the use of golden shiners as a forage in bass rearing ponds. In Fenton Pond 1, young shiners, according to the collections and counts made at the time the pond was drained, outnumbered the bass 2 to 1 at the beginning of the summer, but by the end of the season the proportion was about 1 to 1. Young shiners in Corduroy outnumbered the young bass more than 5 to 1 and, on a per acre basis, were several times as abundant as the shiners in the Fenton pond. The rate of growth of the shiners was more rapid in Pond 1 than in Corduroy (just the opposite of that of the bass in the two ponds, see Figure 1), and was correlated with density of population. Shiners were found in bass stomachs in two instances for the Fenton pond (July 16 and 30) and in 10 instances for Corduroy Pond (June 21 to October 19); it does not follow, however, that the Corduroy bass ate more shiners because the shiners in this pond were smaller, for they were also at least 5 times as abundant. In the Fenton pond the bass involved were of the cannibal class; the differences in length between bass and shiner were 13 to 38 mm., respectively. For Corduroy the bass were also among the largest of the population and the shiners were among the smallest; the average differences in length between the bass and the shiners which they ate were 9 mm. for June 21, 21 mm. for July 27 and 63 mm. for October 19—a continual increase in the difference in length between predator and prey.

The data reveal that size of the fish-prey was the most important factor in determining whether the larger bass fed on the smaller bass or on the shiners. From Fenton Pond 1 there were 17 recorded instances of cannibalism and 2 instances of predation on shiners; from Corduroy there were 10 instances of predation on shiners and 1 instance of cannibalism. In the former pond the smallest of the shiners were larger than the smallest of the bass; in the latter pond the reverse was true. It should be indicated also that a greater difference in size frequency between the populations of bass and forage minnows than existed among the fishes in Corduroy Pond is necessary for an extensive use of the shiners as food by the bass.

Table 1. Descriptive data on the four bass-rearing ponds involved in the present study, and notes on the collecting of samples.

	Fenton Pond No. 1					Fenton Pond No. 2					Corduroy Pond			Lydell Pond
Area (acres)	3.2					6.4					15			1
Max. depth (ft.)	6					8					9			8
Ave. depth (ft.)	3					3					4			4
Bottom	Sand					Sand					Peat & mud			Sand
Water supply	Spring Creek					Fenton Pond No. 1					Warm Creek			Warm Creek
Vegetation	Scant to abundant (mostly algae)					Abundant (mostly algae)					Extremely abundant (submergent types)			Scant
Date (1935)	June 29	July 5	July 16	July 30	Aug. 24	June 29	July 5	July 16	July 30	Aug. 24	June 21	July 27	Oct. 19	July 27
Time of sampling	3 to 4 P.M.	9:30 to 10 A.M.	5 to 6 P.M.	3:30 to 4 P.M.	4 to 6:30 P.M.	4 to 5 P.M.	10 to 12 A.M.	6 to 6:30 P.M.	4 to 5 P.M.	5 to 6 P.M.	10 to 12 A.M.	8:30 to 10 A.M.	9 to 12 A.M.	11 to 11:30 A.M.
Water temp. C.	29	29	28	27	25	30	30	28	27	25	..	29	14	29
Air temp. C.	27	29	26	28	17	27	30	27	28	17	..	27	19	28

TABLE 3. NUMBER OF SPECIMENS, RANGE IN STANDARD LENGTH AND AVERAGE LENGTH OF NON-CANNIBAL, YOUNG "LARGEMOUTH" BASS FROM EACH COLLECTION EXAMINED FOR THE PRESENT STUDY ON FOOD HABITS

Locality	Fenton Pond No. 1					Fenton Pond No. 2					Corduroy Pond			Lydell Pond
Date	June 29	July 5	July 16	July 30	Aug. 24	June 29	July 5	July 16	July 30	Aug. 24	June 21	July 27	Oct. 19	July 27
No. specimens	41	47	49	43	42	118	53	65	55	44	50	67	143	71
Range in length (mm.)	22-33	26-37	30-41	38-49	48-69	16-30	19-40	31-50	35-57	41-68	13-20	39-61	65-120	30-57
Ave. length	28.4	31.2	35.7	43.4	58.3	24.4	31.9	39.9	44.5	49.8	17.3	47.2	80.4	39.3

TABLE 4. SUMMARY DATA FROM THE STUDIES OF STOMACH CONTENTS OF THE NON-CANNIBAL, YOUNG "LARGEMOUTH" BASS COLLECTED DURING 1935 FROM FOUR BASS-REARING PONDS IN MICHIGAN, INCLUDING THE TOTAL NUMBER AND TOTAL VOLUME (IN CUBIC CENTIMETERS) OF EACH TYPE OF FOOD ORGANISM FOR EACH COLLECTION STUDIED. DATA ON THE BASS EXAMINED ARE GIVEN IN TABLE 3.

	Fenton Pond No. 1									
	June 29		July 5		July 16		July 30		Aug. 24	
Food Organisms	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.
Cladocera	293	0.008	1032	0.015	803	0.025	8530	0.17	1332	0.10
Copepoda	114	0.01	1183	0.025	214	0.012	145	0.003	79	0.01
Ostracoda	14	tr.	71	tr.	32	0.003	5	tr.	8	tr.
Decapoda	...	...	1	tr.	...	...	...	...	...	...
Ephemeroptera, nymphs (Baetis and Caenis)	18	0.025	9	0.004	357	0.070	18	0.017	603	0.84
Zygoptera, nymphs and adults										
Coenagriidae	...	...	1	tr.	2	0.003	1	0.001	4	0.14
Anisoptera, nymphs										
Gomphidae (Gomphus)	...	...	...	...	1	0.002	1	0.005	...	...
Libellulidae	...	...	...	...	1	0.002	1	0.004	...	...
Homoptera	...	...	...	...	2	0.001	...	...	...	...
Hemiptera										
Corixidae	40	0.13	3	tr.	...	...	...	...	...	...
Other Hemiptera	...	...	...	...	3	0.002	...	...	...	...
Coleoptera, larvae										
Gyrinidae (Dineutes)	...	...	3	0.015	...	...	...	...	2	0.03
Hydrophilidae (Berosus)	...	...	6	0.024	7	0.04	14	0.10	4	0.05
Dytiscidae	13	0.005	6	0.025	...	...	...	...	...	...
Chironomidae, larvae	146	0.05	517	0.178	552	0.19	203	0.11	239	0.15
Diptera, adults	...	...	...	...	8	0.006	...	...	...	...
Hymenoptera	...	...	...	...	2	0.001	...	...	...	...
Aquatic insects (other)	2	0.002	5	0.004	8	0.013	...	...	1	tr.
Arachnida	...	...	...	...	2	tr.	...	...	...	...
Algae	...	...	...	...	...	...	...	...	?	tr.
Total volume	...	0.23	...	0.29	...	0.37	...	0.41	...	1.32

	Fenton Pond No. 2									
	June 29		July 5		July 16		July 30		Aug. 24	
	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.
Annelida										
Oligochaeta	...	...	...	...	2	0.11	...	...	...	...
Hirudinia	...	...	1	0.01	...	...	1	0.22	...	...
Cladocera	1288	0.06	6034	0.77	3206	0.10	3048	0.12	564	0.06
Copepoda	1690	0.13	553	0.06	3386	0.15	3009	0.16	183	0.02
Ostracoda	2	tr.	...	...	29	tr.	45	tr.	8	tr.
Amphipoda	1	tr.	...	...	...	...	...	...	...	...
Ephemeroptera, nymphs (Baetis and Caenis)	226	1.33	24	0.08	469	0.10	164	0.13	125	0.12
Zygoptera, nymphs and adults										
Coenagriidae	...	...	...	...	29	0.07	35	0.33	14	0.224
Anisoptera, nymphs										
Libellulidae	...	...	...	...	1	0.04	...	...	2	0.004
Homoptera	1	tr.	...	...	...	...	...	...	1	tr.
Hemiptera										
Corixidae	260	0.23	105	0.26	3	0.10	...	...	...	...
Gerridae	...	...	...	...	2	0.02	...	...	1	tr.
Coleoptera, larvae										
Hydrophilidae	...	...	...	...	...	...	1	0.002	1	0.002
Dytiscidae	18	0.02	19	0.05	10	0.01	5	0.008	2	0.004
Coleoptera, adults	...	...	...	...	5	0.04	1	tr.	1	tr.
Trichoptera, larvae										
Hydroptilidae	...	...	...	...	...	...	...	...	5	0.004
Limnephilidae	...	...	...	...	...	...	...	...	2	0.002
Chironomidae, larvae	175	0.13	174	0.39	374	0.13	219	0.17	62	0.07
Diptera, adults	...	...	...	...	6	tr.	1	tr.	1	tr.
Hymenoptera	...	...	...	...	...	...	...	...	3	tr.
Aquatic insects (other)	1	tr.	9	0.01	[illegible]	0.01	1	0.02	1	tr.
Terrestrial insects (other)	...	...	...	...	...	...	...	...	1	tr.
Arachnida	1	tr.	...	...	1	tr.	...	...	...	...
Animal remains	...	...	?	tr.	...	...	...	...	1	tr.
Algae	?	tr.	...	...	?	tr.	?	tr.	?	tr.
Undigestible debris	...	...	?	tr.	...	...	...	...	...	...
Total volume	...	1.9	...	1.63	...	0.88	...	1.16	...	0.51

TABLE 4 (CONCLUDED)

	Corduroy Pond						Lydell Pond	
	June 21		July 27		Oct. 19		July 27	
	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.
Annelida								
Oligochaeta	...	...	...	...	...	...	1	0.01
Hirudinia	...	...	2	0.203	1	0.01	2	0.10
Cladocera	408	0.06	2525	0.96	3512	2.4	1245	0.32
Copepoda	222	0.018	365	0.10	256	0.08	855	0.11
Ostracoda	...	...	36	0.002	2	tr.	75	0.01
Amphipoda	1	0.001	24	0.05	120	0.48	...	...
Decapoda	...	...	...	...	3	1.68	...	...
Ephemeroptera, nymphs (Baetis and Caenis)	8	0.005	725	3.12	4760	5.6	185	0.20
Zygoptera, nymphs and adults								
Coenagriidae	...	...	3	0.007	21	0.54	9	0.07
Anisoptera, nymphs								
Gomphidae (Gomphus)	...	...	3	0.007	...	...	...	...
Aeshnidae (Anax junius)	...	...	4	0.008	5	0.04	...	...
Libellulidae (Libellula)	...	...	...	...	71	0.54	...	...
Hemiptera								
Corixidae	1	0.001	12	0.018	5	0.10	...	...
Notonectidae (Notonecta)	...	...	...	...	3	0.05	...	...
Belostomatidae	...	...	...	...	...	...	1	0.007
Gerridae	...	...	...	...	...	...	3	0.003
Coleoptera, larvae								
Dytiscidae	2	0.001	15	0.03	...	...	6	0.015
Haliplidae	...	...	...	...	...	...	5	0.015
Coleoptera, adults	...	...	...	...	1	0.02	1	0.01
Trichoptera, larvae								
Hydroptilidae	...	...	...	...	...	...	7	0.013
Limnephilidae	...	...	...	...	...	...	6	0.012
Leptoceridae	...	...	...	...	...	...	2	0.005
Other Trichoptera larvae	...	...	...	...	1	0.02	...	...
Chironomidae, larvae	42	0.01	278	0.41	40	0.08	85	0.09
Diptera, adults	...	...	...	...	...	...	1	0.01
Aquatic insects (other)	...	...	25	0.044	?	0.08	?	0.22
Terrestrial insects (other)	...	...	...	...	...	...	10	0.03
Arachnida	...	...	...	...	1	0.10	...	...
Notemigonus	2	0.005	1	0.3	7	2.98	...	...
Animal remains	?	0.018	?	0.034	...	...	?	0.03
Algae	...	...	...	...	?	0.30	...	...
Plant remains	?	0.001	?	0.007	...	...	...	...
Undigestible debris	...	...	...	...	?	0.01	?	0.01
Total volume	...	0.12	...	5.3	...	15.65	...	1.3

TABLE 5. SUMMARY OF STOMACH CONTENTS OF 14 COLLECTIONS OF "LARGEMOUTH" BASS TAKEN FROM FOUR STATE BASS-REARING PONDS AT DIFFERENT TIMES THROUGHOUT THE SUMMER OF 1935, ARRANGED ACCORDING TO SIZE GROUPINGS[1] OF BOTH BASS AND FOOD ORGANISMS. THE FOUR FOOD CLASSES INCLUDE THE FOLLOWING TYPES OF ORGANISMS:

FOOD CLASS 1 CLADOCERA, COPEPODA AND OSTRACODA
" " 2 EPHEMEROPTERA, DIPTERA LARVAE AND AMPHIPODA
" " 3 ODONATA, HEMIPTERA, COLEOPTERA, TRICHOPTERA, HOMOPTERA, DIPTERA ADULTS, HYMENOPTERA, ARACHNIDA AND ANNELIDA
" " 4 DECAPODA, NOTEMIGONUS AND APLITES

Food class	No. stomachs containing food class	No. stomachs by %	Total no. food organisms	No. organisms per stomach	Ave. % of food by volume (estimated)[2]	"Importance factor"
			FENTON POND NO. 1, JUNE 29			
			13 bass, 22-27 mm.			
1	11	85	360	33	25	21
2	10	77	76	7.6	69	53
3	5	38	14	2.8	18	7
			28 bass, 28-33 mm.			
1	8	29	61	7.6	9	3
2	16	57	88	5.5	52	30
3	11	39	39	3.6	81	32
			FENTON POND NO. 1, JULY 5			
			20 bass, 26-30 mm.			
1	18	90	1621	90	39	35
2	18	90	234	13	56	50
3	4	20	5	1.3	20	4
			27 bass, 31-37 mm.			
1	24	89	665	28	23	20
2	27	100	292	11	60	60
3	11	41	14	1.3	38	16
4	1	4	1	1.0	5	0.2
			16 cannibal bass, 40-47 mm.			
2	3	19	14	4.7	83	16
3	1	6	1	1.0	50	3
4	13	81	14	1.1	100	81
			FENTON POND NO. 1, JULY 16			
			23 bass, 30-35 mm.			
1	20	87	815	41	18	16
2	22	96	491	22	77	74
3	3	13	3	1.0	25	3
			26 bass, 36-41 mm.			
1	21	81	234	11	16	13
2	25	96	418	17	70	67
3	8	31	25	3.1	45	14
			25 cannibal bass, 45-63 mm.			
1	2	8	11	5.5	4	0.3
2	9	36	137	15	84	30
3	6	24	10	1.7	72	17
4	9	36	9	1.0	100	36
			FENTON POND NO. 1, JULY 30			
			23 bass, 38-43 mm.			
1	20	87	5923	296	73	64
2	13	57	55	4.2	24	14
3	4	17	5	1.3	56	10
			20 bass, 44-49 mm.			
1	16	80	2757	172	50	40
2	14	70	166	12	56	39
3	4	20	12	3.0	55	11
			9 cannibal bass, 50-74 mm.			
1	6	67	419	70	30	20
2	7	78	300	43	74	58
3	1	11	4	4.0	100	11

[1] The relative numbers of bass in the different size groups in most instances do not represent the components of random samples of pond populations for relatively large numbers of the cannibal class were selected for this food study. However, all bass not indicated as cannibals represent random samples of the non-cannibal populations.

[2] The average % by volume is based on only those specimens which contained the particular food class.

TABLE 5 (CONTINUED)

Food class	No. stomachs containing food class	No. stomachs by %	Total no. food organisms	No. organisms per stomach	Ave. % of food by volume (estimated)[2]	"Importance factor"
FENTON POND NO. 1, AUGUST 24						
22 bass, 48-58 mm.						
1	16	73	1215	76	21	15
2	18	82	339	19	79	65
3	2	9	2	1.0	24	2
20 bass, 59-69 mm.						
1	15	75	204	14	12	9
2	18	90	503	28	76	68
3	6	30	8	1.3	41	12
18 cannibal bass, 70-116 mm.						
1	8	44	111	14	4	2
2	14	78	574	41	60	47
3	11	61	37	3.4	54	33
4	3	17	3	1.0	86	15
FENTON POND NO. 2, JUNE 29						
48 bass, 16-23 mm.						
1	47	98	2314	49	34	33
2	42	87	167	4.0	56	49
3	36	75	127	3.5	24	18
70 bass, 24-30 mm.						
1	57	81	666	12	12	10
2	68	97	235	3.5	79	77
3	51	73	153	3.0	19	14
FENTON POND NO. 2, JULY 5						
22 bass, 19-30 mm.						
1	22	100	3159	144	48	48
2	17	77	84	4.9	52	40
3	11	50	49	4.5	23	12
31 bass, 31-40 mm.						
1	30	97	3428	114	55	53
2	16	52	114	7.1	45	23
3	20	65	76	3.8	31	20
26 cannibal bass, 38-41 mm.						
1	5	19	127	25	8	2
2	12	46	47	3.9	36	17
3	15	58	65	4.3	63	37
4	9	35	9	1.0	98	34
FENTON POND NO. 2, JULY 16						
31 bass, 31-39 mm.						
1	27	87	3756	139	50	44
2	25	81	301	12	51	41
3	9	29	23	2.6	20	6
34 bass, 40-50 mm.						
1	22	65	2865	130	39	25
2	25	74	542	22	42	31
3	15	44	36	2.4	66	29
21 cannibal bass, 51-61 mm.						
1	4	19	28	7.0	2	0.4
2	12	57	187	16	70	40
3	10	48	16	1.6	54	26
4	7	33	7	1.0	92	30
FENTON POND NO. 2, JULY 30						
29 bass, 35-44 mm.						
1	29	100	4668	161	63	63
2	23	79	269	12	39	31
3	9	31	28	3.1	20	6
26 bass, 45-57 mm.						
1	15	58	1434	96	54	31
2	17	65	114	6.7	53	34
3	5	19	16	3.2	79	15
7 cannibal bass, 74-88 mm.						
2	1	14	2	2.0	60	8
3	2	29	6	3.0	28	8
4	3	43	3	1.0	95	41

TABLE 5 (CONCLUDED)

Food class	No. stomachs containing food class	No. stomachs by %	Total no. food organisms	No. organisms per stomach	Ave. % of food by volume (estimated)[a]	"Importance factor"
			FENTON POND NO. 2, AUGUST 24			
			28 bass, 41-52 mm.			
1	24	86	659	27	37	32
2	22	79	161	6.9	54	43
3	8	29	11	1.4	49	14
			16 bass, 53-68 mm.			
1	8	50	96	12	38	19
2	11	69	36	3.3	23	16
3	10	63	23	2.3	75	47
			2 cannibal bass, 108-119 mm.			
3	1	50	2	2.0	25	13
4	1	50	1	1.0	75	38
			CORDUROY POND, JUNE 21			
			12 bass, 13-16 mm.			
1	12	100	148	12	75	75
2	4	33	11	2.8	15	5
3	1	8	1	1.0	20	2
			38 bass, 17-30 mm.			
1	35	92	482	14	73	67
2	15	39	40	2.7	30	12
3	2	5	2	1.0	10	0.5
4	2	5	2	1.0	95	5
			CORDUROY POND, JULY 27			
			41 bass, 39-48 mm.			
1	39	95	2341	60	22	21
2	41	100	616	15	72	72
3	11	27	18	1.6	16	4
			26 bass, 49-61 mm.			
1	25	96	585	23	14	13
2	25	96	411	16	77	74
3	8	31	21	2.6	24	7
4	1	4	1	1.0	60	2
			1 cannibal bass, 61 mm.			
4	1	100	1	1.0	100	100
			CORDUROY POND, OCTOBER 19			
			50 bass, 65-76 mm.			
1	47	94	1769	38	24	23
2	49	98	1855	38	67	66
3	18	36	36	2.0	25	9
			82 bass, 77-92 mm.			
1	74	90	1787	24	27	24
2	80	98	2839	35	66	65
3	24	29	64	2.7	28	8
4	2	2	2	1.0	74	1
			11 bass, 96-120 mm.			
1	3	27	214	71	27	7
2	7	64	226	32	33	21
3	2	18	9	4.5	52	9
4	6	55	8	1.3	96	53
			LYDELL POND, JULY 27			
			26 bass, 30-37 mm.			
1	26	100	1462	56	54	54
2	21	81	102	4.9	37	30
3	5	19	12	2.4	50	10
			38 bass, 38-45 mm.			
1	34	89	713	21	33	29
2	26	68	173	6.7	51	35
3	12	32	27	2.3	35	11
			7 bass, 48-57 mm.			
3	3	43	5	1.7	52	22

TABLE 6. RANGE IN STANDARD LENGTH (MM.) OF CANNIBAL BASS AND OF YOUNG BASS FOUND IN THEIR STOMACHS, AND AVERAGE DIFFERENCE IN LENGTH BETWEEN PREDATOR AND PREY, FOR ALL ACTUAL RECORDS OF CANNIBALISM ENCOUNTERED IN THE PRESENT STUDY

Locality	Fenton Pond No. 1			Fenton Pond No. 2				Corduroy Pond
Date	July 5	July 16	Aug. 24	July 5	July 16	July 30	Aug. 24	July 27
Length: cannibals	40-47	45-63	70-116	38-41	51-61	74-88	108-119	61
No.: cannibals	16	25	18	26	21	7	2	1
Length: bass eaten	24-30	31-38	49	22-24	30-36	35-36	45	39
No.: bass eaten	14	7	1	8	6	2	1	1
Ave. difference in length: predator and prey	17.1	20.9	50	16.6	21.5	46.5	63	22

Fig. 1. Length frequency distributions of young non-cannibal and cannibal "largemouth" bass and of young golden shiners in all collections from the four rearing ponds.

Fig. 2. Average growth in length of non-cannibal and cannibal bass based on all collections from the four rearing ponds. Data are from Table 2 and are plotted on semi-logarithmic paper to show per cent of increase.

Fig. 3. Group photograph of "largemouth" bass to illustrate variation in rate of growth. A scale from each fish is pictured in Figure 4.

A– Maturing male taken from Fenton Pond 2 on October 29, 1935 at the end of its second growing season. Standard length 227 mm., total length 268 mm., weight 332 grs. This fish was presumably a cannibal during its second summer, see scale in Figure 4.

B– Immature female cannibal taken from Pond 2 on October 31, 1935 at the end of its first growing season. Standard length 145 mm., total length 181 mm., weight 72 grs.

C– Immature female non-cannibal taken from Corduroy Pond on October 19, 1935 at the end of its first growing season. Standard length 77 mm., total length 96 mm., weight 10.3 grs.

D– Non-cannibal taken from Pond 2 on October 31, 1935 at the end of its first growing season. Standard length 52 mm., total length 64 mm., weight 2.4 grs.

Fig. 4. Scales from the bass shown in Figure 3 revealing their age and growth history. All scales are reproduced at the same magnification and they are arranged in this figure in the order corresponding to that of the fish they represent. Data on the fish are given in Figure 3.

A.- Fish two summers old (one annulus, I); cannibal during its second summer.

B.- Cannibal young-of-the-year from Fenton Pond 2.

C.- Non-cannibal young-of-the-year from Corduroy Pond.

D.- Non-cannibal young-of-the-year from Fenton Pond 2.

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INSTITUTE FOR FISHERIES RESEARCH
DIVISION OF FISHERIES
MICHIGAN DEPARTMENT OF CONSERVATION
COOPERATING WITH THE
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September 11, 1936

APPENDIX TO REPORT 382

This appendix was not included in the report itself (the report is to be published by the American Fisheries Society) because it includes certain criticisms of the present methods of operating our bass rearing ponds.

Of the four ponds in question, the complete history of the populations of young bass (initial stocking, food and growth studies, and production per acre at the end of the summer) was obtained for only the two Fenton ponds. For Corduroy Pond, the initial stocking of young bass was not known because they were produced by adult bass in the pond; and the production was not determined because the pond was not drained. Data on the stocking and the production in the Lydell Pond were available but the number of samples obtained for the present study were too few. Therefore the following discussion of the methods of operating the bass rearing ponds refers specifically only to these two Fenton ponds, although it might be found to apply to several other bass rearing ponds in this state if a careful study of these other ponds were made.

Data on the number of young bass stocked in the Fenton ponds at the beginning of the summer and on the number produced when the ponds were drained in the fall, and the percentage of survival in each pond, are (the figures on total number stocked in, and taken from each pond, and the figures on pond areas were furnished by Mr. A.T. Stewart):

	Stocking		Production		% sur-	Area
	Total number	No. per acre	Total No.	No. per acre	vival	acres
Fenton Pond 1	50,000	15,600	9,450	2,950	18.9	3.2
Fenton Pond 2	160,000	25,000	32,375	5,060	20.2	6.4

The productions per acre obtained in these two ponds were comparatively good, considering the fact that no artificial feeding was done. However, the percentage of survival of the young bass in the two ponds was very low--approximately 20%; and their growth was also quite poor, compared to the growth of the bass in Corduroy Pond, which is believed by the writer to be quite typical of natural waters in southern Michigan. These bass were in the Fenton ponds for approximately $4\frac{1}{2}$ months during which period approximately 80% of them perished for one reason or another[1]. All available evidence points to the conclusion that the cannibals accounted for a big portion of this loss.

According to Mr. Stewart the bass stocked in the Fenton ponds were obtained mostly from Lake Oakland (or Liggett Lake) in Oakland County. The Michigan Lake and Stream Directory lists the "largemouth" as an important game fish of this lake; and the Institute files indicate that this lake produces large bass. From this it is assumed that Lake Oakland is at least fairly good natural water for the "largemouth" bass.

Unfortunately we have no information on the rate of mortality at different ages of bass populations in natural waters. However, it is the opinion of most fisheries workers that the mortality during the first year is relatively high. It might be as high as 80%; it might be somewhat less, or it might possibly be as high as 90%. It does not seem possible that the mortality of bass in natural waters could be more than 90% for the first $4\frac{1}{2}$ months of existence, and less than 10% for the remaining 10 or more years before the particular population has been exterminated. Allowing generously in favor of this propagation enterprise, its efficiency from the standpoint of survival was certainly not more than 10% better than that of the natural waters from which the young bass were taken.

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[1] The total number of bass taken for all of the sample collections used in this study was very small compared with the initial stocking of the ponds: 1,094 specimens or 2.19% for Pond 1; 2,389 specimens or 1.49% for Pond, 2. Further, as the summer progressed and the populations of the two ponds probably decreased, relatively fewer bass were taken from the ponds for the samples.

No collections of young bass were made during the summer from Lake Oakland from which the stock for the Fenton ponds was obtained. Therefore it is impossible to compare the growths of the bass in the Fenton ponds with their expected growth had they been left in Lake Oakland. However, to evaluate their growth in the rearing ponds, the writer has compared the size range of the Fenton bass at the time of draining with the size ranges of numerous August and September collections of young bass from natural waters in Michigan (these collections are in the Fish Division of the Museum of Zoology; the collections were selected at random). Here again all allowances in the comparison were made in favor of the Fenton bass, for all of the collections from natural waters were made earlier in the growing season. The conclusions from this comparison are that the growth of the Fenton bass was only slightly if any better than the growth of young bass in natural waters.

It is concluded that, from the standpoints of both survival and growth (the two ultimate goals in the method of bass rearing employed for the Fenton ponds), there was probably very little, if anything, gained by the use of the two Fenton ponds during 1935. Under normal conditions, these bass which were seined from Lake Oakland would probably have fared nearly or just as well had they been left in Lake Oakland.

The data on food habits and growth together with the data on production and survival point to the one conclusion that both Fenton ponds during 1935 were greatly overstocked for the amount of food available. (Probably most of the men experienced in fish culture would have arrived at the same conclusion without undertaking the laborious task of studying numerous samples.) The shortage of food resulted in a comparatively slow growth of the big bulk of the bass population which in turn was a factor in the cause of cannibalism; the cannibals, in turn, accounted for a large portion, if not most, of the 80% mortality among the whole populations.

In order to increase the efficiency of the operation of the Fenton ponds and thereby justify the continuation of their operation, either the stocking should be reduced, or more food should be made available, or both. If there were more food available for each fish, it would be expected that the whole population would grow more rapidly with less variation between individual fish; there would be fewer cannibals, and there would be a greater percentage of survival. Artificial fertilization would probably add considerably to the food supply. Such large ponds as those at Fenton are not well suited to "hand-feeding" (according to information obtained through conversation with Mr. Stewart and Mr. Lydell); thus this method is not recommended. The use of forage minnows in the bass ponds is promising but there is still much to be learned about the best methods of using this type of food supply. The enormous population of young golden shiners in Corduroy Pond was of no practical value to the bass because the shiners were too large. A suggested method for future use of the golden shiner in bass rearing ponds is as follows: hold the adult shiners in cold spring or trout water from about the middle of May until the end of June and thereby delay their spawning season (this was done successfully at the ponds of the U. S. Beach estate at Highland, Michigan in 1935); then stock the bass ponds very heavily with adult shiners (about 500 per acre) so that a very large hatch of young shiners is produced. It would require a large population of young shiners to feed the bass; and an increase in the shiner population would tend to slow up their rate of growth, by competition within the species, but would not tend to retard the growth of the bass through the factors related to population density--conclusions based on a comparison of Corduroy Pond and Fenton Pond 2.

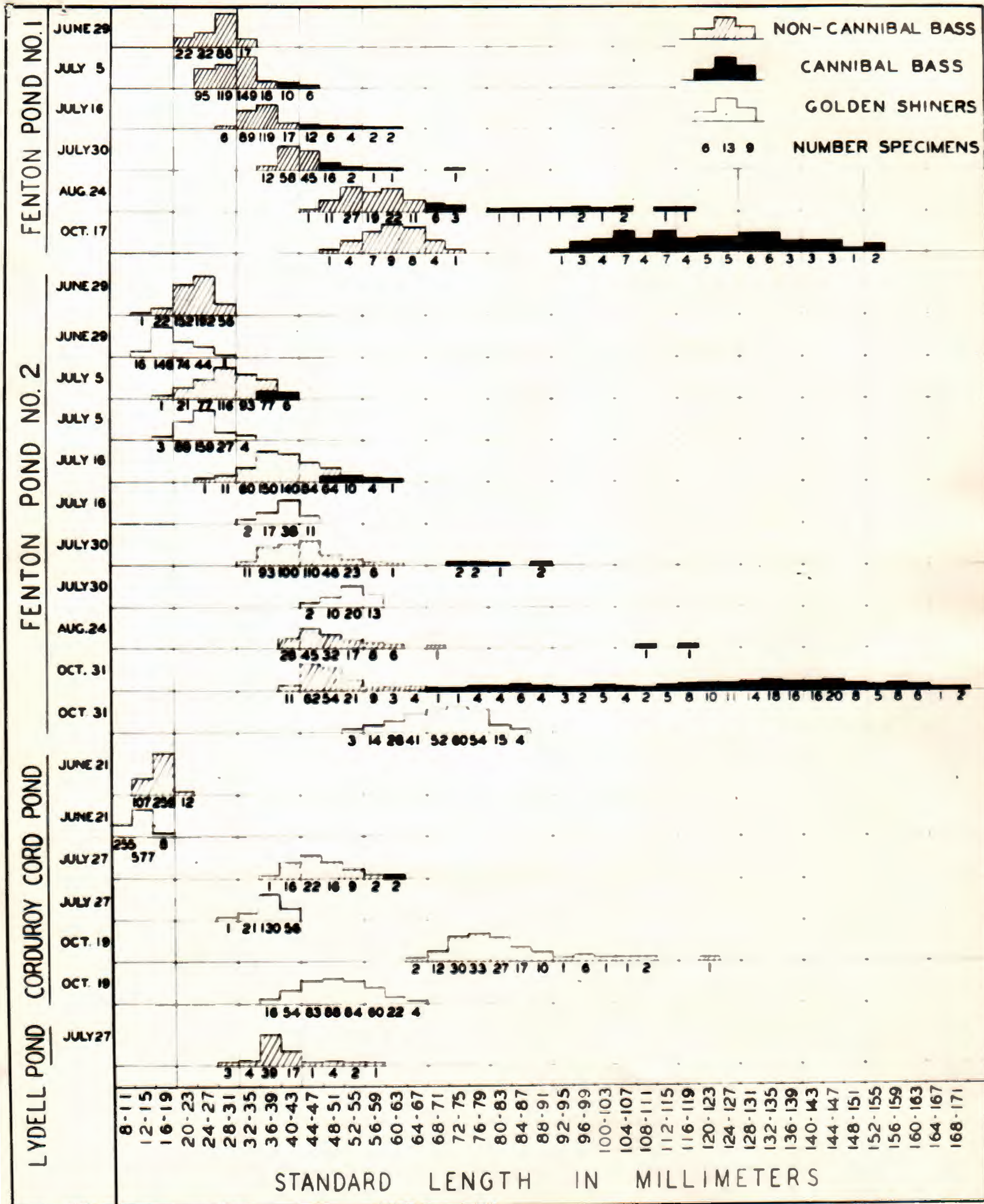
The writer believes that it would be desirable, in the management of the Fenton ponds, to both reduce the amount of stocking, and to attempt to increase the food supply by fertilization and by the use of golden shiners according to the method mentioned above.

Whatever methods employed in the future in operating these ponds should be carefully evaluated if there is to be any improvement in the work. The results of each year's work at these ponds should be compared in order to determine what concentrations of stocking give the best results--percentage of survival and growth, within certain limits of production, should be considered of most importance in making this evaluation.

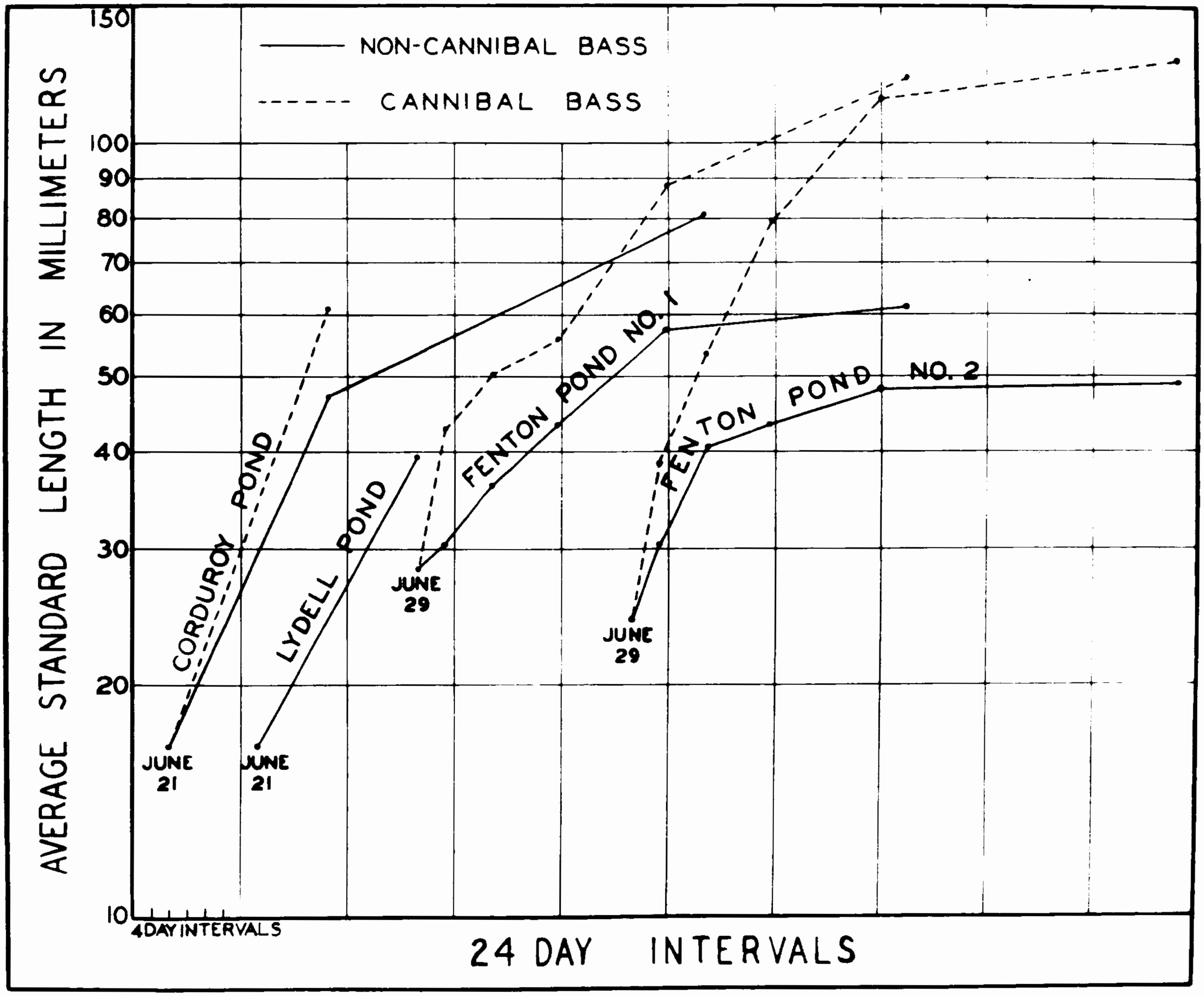
Further, our Conservation Department is obligated to itself and to the sportsmen who fish the lakes in Oakland County to determine the rate of growth and percentage of survival of young "largemouth" bass in these natural waters, and to demonstrate that there is an appreciable gain by taking these bass from the natural waters and holding them in the Fenton ponds.

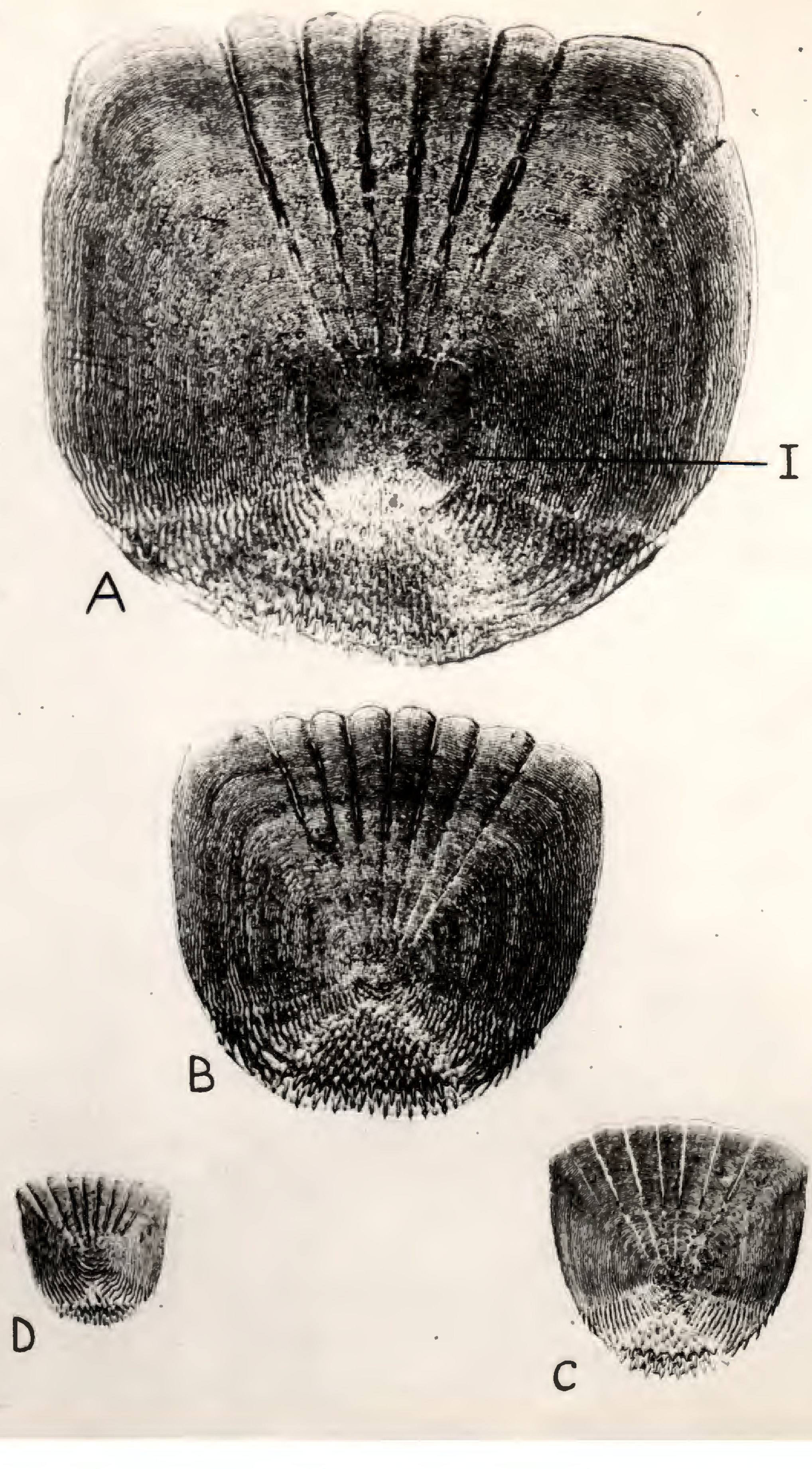
INSTITUTE FOR FISHERIES RESEARCH

By: Gerald P. Cooper



FENTON POND NO. 1
JUNE 29
JULY 5
JULY 16
JULY 30
AUG. 24
OCT. 17
FENTON POND NO. 2
JUNE 29
JUNE 29
JULY 5
JULY 5
JULY 16
JULY 16
JULY 30
JULY 30
AUG. 24
OCT. 31
OCT. 31
CORDUROY CORD POND
JUNE 21
JUNE 21
JULY 27
JULY 27
OCT. 19
OCT. 19
LYDELL POND
JULY 27
NON-CANNIBAL BASS
CANNIBAL BASS
GOLDEN SHINERS
6 13 9
NUMBER SPECIMENS
8-11
12-15
16-19
20-23
24-27
28-31
32-35
36-39
40-43
44-47
48-51
52-55
56-59
60-63
64-67
68-71
72-75
76-79
80-83
84-87
88-91
92-95
96-99
100-103
104-107
108-111
112-115
116-119
120-123
124-127
128-131
132-135
136-139
140-143
144-147
148-151
152-155
156-159
160-163
164-167
168-171
STANDARD LENGTH IN MILLIMETERS


NON-CANNIBAL BASS
CANNIBAL BASS
AVERAGE STANDARD LENGTH IN MILLIMETERS
150
100
90
80
70
60
50
40
30
20
10
CORDUROY POND
LYDELL POND
FENTON POND NO. 1
FENTON POND NO. 2
JUNE 21
JUNE 21
JUNE 29
JUNE 29
4 DAY INTERVALS
24 DAY INTERVALS


A
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