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OBSERVATIONS ON THE SPAWNING HABITS OF CENTRARCHID FISHES IN DEEP LAKE, OAKLAND COUNTY, MICHIGAN

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Introduction

A definite need for more detailed information concerning the spawning habits of our most important game fishes has been recognized. Intelligent fish management requires accurate knowledge of the number of eggs, fry and adults that result from natural reproduction and the losses which occur in each stage of development so that the final returns to the angler may be determined.

The reproductive habits of centrarchids have been studied by various workers, but the knowledge of many important phases of their early life histories is incomplete. Previous investigations have failed to answer many questions of which the following are examples: (1) Does more than one female spawn in each nest? (2) Are eggs of a single female deposited at one spawning, or in two or more successive spawnings? (3) How many eggs are produced by females of various sizes and ages? (4) What is the percentage of fertilization of eggs in nature? (5) How many and what percentage of the eggs result in fry? (6) What is the size and age at maturity of males and females? (7) What are the effects of temperature, sunlight and wave action on spawning activities?

Observations are presented in this paper on the spawning habits, and the number of fry produced per nest by the bluegill (Lepomis macrochirus), the common sunfish (Lepomis gibbosus), the rock bass (Ambloplites rupestris), and the largemouth bass (Huro salmoides).

The investigation was initiated by Dr. R. W. Eschmeyer, formerly a member of the Institute staff, who turned over the problem and data already collected to the author.

The investigation was conducted on Deep Lake, owned by Messrs. James Inglis and Ben E. Young. The lake is located in Oakland County, Rose Township, Michigan, between the villages of Clyde and Rose Center. Deep Lake has an area of 14.9 acres, a maximum length of 1230 feet in a W. N. W.--E. S. E. direction, and a maximum width of 660 feet. The lake is approximately oval in shape and consists of two basins, a western with a maximum depth of 61 feet, and an eastern with a maximum depth of 51 feet. The intervening area averages approximately 45 feet in depth. The drop-off from shore toward the center is so sharp that the amount of shoal area is extremely limited. The lake has neither inlet nor outlet and most of the common types of bottom may be found, singly or in combinations. The northern, southern and eastern shoal areas, varying from 10 to 62 feet in width, are composed chiefly of sand, with patches of gravel, rocks, roots and vegetation interspersed. The bottom of the western shoal area, varying from 13 to 70 feet in width, is composed principally of fibrous peat, with some underlying sand and gravel.

The following fishes inhabit Deep Lake: the bluegill (Lepomis macrochirus), common sunfish (Lepomis gibbosus), rock bass (Ambloplites rupestris), largemouth bass (Huro salmoides), green sunfish (Lepomis cyanellus), yellow perch (Perca flavescens), yellow bullhead (Ameiurus natalis), and the mud pickerel (Esox vermiculatus). No other fishes, not even small cyprinids or darters, were present.

Methods

Field observations were made from a rowboat. The nests and the majority of the fish were easily distinguished in the shallower waters during periods of calm weather; windy weather hampered the work because of the attendant wave action. The majority of the observations were made during early morning and late afternoon when the water was more uniformly calm than during the middle of the day. Polaroid glasses (specially designed sun glasses) were effective in eliminating the surface reflection on the water during the daytime. Many observations were made at night by the use of an automobile spot-light and a storage battery. There was less wind action at night and the majority of the fish were not frightened as readily as during the day.

The species to which the nest belonged could usually be identified positively only when the guarding male was present. The characteristics of the nest are not specifically associated with the species occupying it. For example, some nests of the largemouth bass, rock bass and common sunfish were almost identical as to size, shape and depth of water. Spawning beds were marked with colored glass marbles. Some fish objected strenuously to the introduction of "foreign objects" into their nests. Rock bass, at times, carried the marbles from one to several feet from the nest. Some bluegills and sunfish buried the marbles while fanning the nest.

Certain individuals of those species studied constructed well defined nests, while others occupied nests that were poorly defined. Fish of one species sometimes appropriated nests built by individuals of another species. Whether this intrusion took place only after the original owner had finished spawning was not determined. It appears, however, that the nests were pre-empted only when the original owner had finished spawning and the fry

and adults had left. For example, rock bass used sunfish and largemouth bass nests. Largemouth bass used rock bass nests. Common sunfish appropriated the nests of bluegills and vice versa. Individual nests of the bluegill and common sunfish were sometimes used several times during one season, perhaps either by the same male and female, by the same male and different females, or by different males and females, to produce successive broods of fry.

Photographs were made, principally at night, of representative types of spawning beds of the various species. Special technique and apparatus for the photography (Figure 1) were developed for the Institute by Mr. F. W. Ouradnik, who was largely responsible for the excellent results obtained.

Newly hatched fry are golden in color, occupy the center of the nest, and exhibit little or no movement. The majority of the fry were collected while in the golden stage by means of a length of heavy glass tubing (boiler-gauge glass) one-half inch, inside diameter. The collection of fry from the nests was a tedious task that required from one to four and one-half hours per nest. To be certain that all fry were obtained, each nest was visited at least twice after the initial collection of fry had been made, either several hours later or during the following day.

Several difficulties were encountered during the process of collection of fry. Individuals of other species, chiefly small sunfish and bluegills continuously attempted to rush in and eat the fry. (Many partially collected nests had to be discarded when the collector was unable to keep these smaller fish away.) This difficulty was minimized when the guarding male remained on or near the nest. But, sometimes the guarding male left the nest and occasionally in so doing would scatter the newly-hatched fry, either intentionally or accidentally. Nests so disturbed could seldom be used for counts. The fry, together with any sand, gravel and water taken

Figure 1. Method used in taking photographs of spawning beds. Courtesy of Jack Van Coevering.

with them were placed in a five-gallon pail. Sometimes, more than twenty gallons of this material were taken from a single nest. The water in the sample was strained through a plankton net to prevent the loss of any fry. The majority of the fry remained on or above the sand when the sample settled, and were collected in the plankton net by repeated washings with water. The balance of the fry and the sand containing them were preserved separately in a 10 per cent formalin solution.

The number of fry per nest was determined by actual count. Volumetric and weighing methods of estimating the number of fry were not used because of the error introduced by the varying amounts of sand and debris invariably included with the fry. The calcium chloride floatation method (a modification of the method of Beak, 1937) was found efficacious in removing the fry from the sand and gravel. The calcium chloride method cannot be used if samples contain inert organic material. The sand and gravel was not examined in the majority of samples after washing with calcium chloride.

The sand from a number of samples was carefully examined with a large magnifying glass to determine the number of fry that remained after the addition of calcium chloride and the removal of the floating fry. From a critical study of a sample that contained more than 500 cc. of sand (the amount taken from one nest), the following information was obtained: (1) number of fry removed by repeated washings with water, 9,781; (2) number of fry removed after the addition of calcium chloride, 2,282; and (3) number picked out of the sand, 28. Therefore the total number of fry in the nest was the sum of these three values, or 12,091. The washing with water and the calcium chloride treatment, therefore, resulted in the recovery of 99.8 per cent of the fry from that nest. The percentages recovered from two additional samples were 99.8 and 99.7 per cent.

Spawning Observations

The details of nest construction and the spawning act of certain centrarchids have been studied by many previous investigators, notably by Reighard (1906), Jordan and Evermann (1903), Evermann and Clark (1920), Adams and Hankinson (1928), Breder (1936), and will not be discussed in this paper.

The present investigation was conducted from May 28 to August 15, 1938. Pertinent observations made on the spawning activities of each of the species studied are as follows:

Largemouth bass--The species was already spawning on May 28 when the first observations were made, and June 18 was the latest date developing eggs were found in the nests (Table 1). A total of thirty-three nests were counted in the lake (which probably does not represent the total number in the lake because spawning was in progress when the investigation was started). The nests occurred singly, the majority were poorly defined, and were located in from 1 to 3.5 feet of water. The bottom of the nest was composed principally of sand, gravel, and roots, either singly or in combinations. The spawning adults in Deep Lake were small, averaging approximately 11 inches in total length. The total number of fry per nest varied from 751 to 11,457, and the average total number in the five nests counted was 4,375 (Table 2).

Rock bass--Spawning was underway when the first observations were made on May 28, and July 13 was the latest date that eggs or fry were found on nests. Fifty-eight nests were counted in Deep Lake, (which does not represent the total number in the lake because spawning was in progress when this investigation was started) The nests occurred singly, invariably near some object such as a waterlogged stump, rock, or clump of weeds, and the

TABLE 1. SPAWNING HABITS OF DEEP LAKE FISH, 1938

Species	Duration of spawning season	Bottom types used for nests	Character of nests	Depth of water (in feet) in which nests are found	Nests of other species used	Action of guarding male when approached by collector
Largemouth Bass	[1] Before May 28 to June 18. (Fry were last seen on this date.)	Gravel (coarse and fine) Sand Roots	Inconspicuous Single nests	1-3.5	Rock bass Apparently never use same nest twice during one season	Stayed near nest. Did not always drive other fish away
Rock Bass	Pre-spawning period [1] May 28 Spawning period May 28-July 13 Post-spawning period July 14-20	Roots Gravel (coarse and fine) Sand (with roots)	Inconspicuous Single nests Usually nest next to object	1-3	Largemouth bass Common sunfish Apparently never use same nest twice during one season	Stayed on nest Drove other fish away
Common Sunfish	Pre-spawning period [2] Before May 28 Spawning period May 31-July 18 Post-spawning period July 19-Aug. 1	Gravel (coarse and fine) Sand Roots Muck All combinations of above with sticks, leaves and/or shells	Majority conspicuous May nest in colonies. Some may nest in bluegill colony	1-5	Bluegill Rock bass May use own nests several times during season	Majority stayed on or near nest
Bluegill	Pre-spawning period May 31-June 18 Spawning period June 19-Aug. 1 Post-spawning period Aug. 2-Aug. 8	Gravel (coarse and fine) Sand Muck All combinations of above found with marl, roots, sticks, leaves and/or sticks	Well defined nests Usually in a colony of 3 or more Occasionally nest singly	1-5 Mode about 2½ feet	Common sunfish Rock bass May use own nests several times during season	Majority retreated into deeper waters

[1] Spawning had started when first observations were made

[2] Some nests were built when first observations were made

TABLE 2. FRY COUNTS, DEPTH OF WATER AND THE TYPE OF BOTTOM MATERIALS USED IN EACH NEST, DEEP LAKE, 1938

Species	Nest	Date of Collection	Number of fry	Depth of water	Type of bottom materials used in nest
Bluegill (17 nests)	A[1]	July 5	4,670	2 feet	Sand and gravel
	B	July 8	22,333	2 "	Sand, gravel underlying 2 inches of muck
	C	July 8	8,124	2 "	" " " " " " "
	D	July 8	38,703	2 "	" " " " " " "
	E	July 8	23,169	2 "	Sand and gravel
	F	July 9	9,162	3.5 "	Muck, sand, shells, sticks
	G	July 9	16,974	2.5 "	Sand and fine gravel
	H	July 9	21,974	2.5 "	Sand and gravel
	I	July 10	8,345	2.5 "	Gravel and sand
	J	July 10	10,351	2.5 "	" " "
	K	July 12	8,559	3.5 "	Sand and gravel
	L	July 13	7,161	3 "	" " "
	M	July 14	39,903	3 "	" " "
	N	July 16	12,091	3.5 "	Gravel and sand
	P	July 17	61,815	3 "	Sand
	Q	July 21	4,819	2.5 "	Sand and gravel
	R	July 21	6,389	2.5 "	Sand and gravel
Rock Bass (9 nests)	1	June 2	575	...	Roots and sand
	2	June 3	352	...	" " "
	3	June 3	1,056	...	Gravel
	4	June 13	1,407	...	Sand
	5	June 17	1,756	...	Weeds, roots, sand and gravel
	A	June 29	774	2 feet	Sand and gravel
	B	July 2	344	2 "	" " "
	C	July 10	401	1.5 "	Roots over sand
	D	July 11	499	1.5 "	Roots over sand
Largemouth Bass (5 nests)	1	May 29	[2]11,457	...	Sand, fine gravel and roots
	2	May 30	[2]1,967	...	...
	3	June 1	751	...	Roots and sand
	4	June 3	4,189	...	Roots
	5	June 3	3,511	...	Roots, small amount of gravel
Common sunfish (2 nests)	A	June 29	1,509	2 feet	Sand and gravel
	B	July 13	14,639	3 feet	" " "

[1] Letters refer to those collected by W. F. Carbine. Arabic numerals refer to collections made by R. W. Eschmeyer.

[2] These were advanced fry, guarded by male, and had just left the nest. Collected with a fine-meshed dip net.

majority were poorly defined. The nests were located in from 1 to 3.5 feet of water. The bottoms of the nests were composed principally of sand, gravel and roots, either singly or in combinations (Figures 2 and 3). The number of fry per nest varied from 344 to 1,756, or an average of 796 for each of the nine nests counted.

Common sunfish--The first spawning occurred on May 31 and continued until July 18, which was the latest date when eggs or fry were found in the nests. A total of 188 nests were counted in the lake. The nests occurred singly, in groups of two or three, and occasionally nests were found within a bluegill colony. The majority of the nests were clearly defined. All the common types of bottom were used either singly or in combination (Figure 4). Counts of the fry collected from two nests totalled 1,509 and 14,639 respectively.

Bluegill--The first spawning took place on June 18 and continued until August 1, which was the last day that eggs were found in the nests. A total of 369 nests were counted in the lake. The majority of the nests were in colonies of from 3 to 54, although a few nests occurred singly (Figure 5). The nests located on sand and (or) gravel bottom were approximately circular in outline and all were about the same diameter, from 18 to 24 inches, whereas the nests on muck bottom were considerably larger and were not always circular in outline. All of the common bottom types were used either singly or in combinations. The total number of fry per nest varied from 4,670 to 61,815; the average total number for the seventeen nests counted was 17,914.

Observations of the spawning activities of the four species studied are contrasted in Table 1. The pre-spawning period refers to that time when the nests were under construction, or were already built, but no eggs had been deposited. The spawning period includes the interval from the first

Figure 2. Rock bass on nest composed of gravel with some roots, in water 23 inches in depth. Photograph taken on June 9, 1938 in Deep Lake, Michigan, by F. W. Ouradnik.

Figure 3. Rock bass nest in weed bed with bottom composed of roots, and sand. Diameter of nest 9 inches, depth of water 26 inches. Photograph taken on June 15, 1938 at Deep Lake, Michigan, by F. W. Ouradnik.

Figure 4. Common sunfish on nest. Bottom composed of fine gravel and sand. Diameter of nest 20 inches, depth of water 2.5 feet. Photograph taken July 15, 1938 at Deep Lake, Michigan, by F. W. Ouradnik.

Figure 5. Portion of a colony of twenty-one bluegill nests located on sand and gravel bottom, with fish occupying six nests. Depth of water varied from 1.5 to 4 feet. Picture taken on June 24, 1938, at Deep Lake, Michigan, by F. W. Ouradnik.

spawning observed until the time the fry were last seen on the nests. That period when there were no eggs or fry on the nests, although the male fish was still hovering over the nest, is referred to as the post-spawning period. The spawning season for the fishes studied was prolonged for at least two reasons. The eggs of a single female do not mature at the same time, and the eggs may be deposited in "batches" at intervals. The eggs of all females do not ripen simultaneously, and therefore some spawn early and some late. These facts partially explain the cycles of spawning, that is, the occurrence of periods when spawning was intensive and intervening periods of reduced activity. Three cycles were noted for the rock bass. The theory that water temperatures alone regulate spawning activities does not satisfactorily explain the extended spawning season of some centrarchids.

The narrow shoal may account for the variety of bottom materials used for nest construction in Deep Lake. But if the fish had preferred any particular type of bottom for nests, there would have been sufficient area of either sandy shoal or mucky shoal to accommodate all of the nests enumerated. Because the largemouth bass and rock bass nests are single and are usually some distance apart the number of nests might exceed the area available of a particular type of bottom. Since common sunfish and bluegill nests are usually more or less closely grouped (colonial), all nests of these species in Deep Lake could have been located on a single type of bottom. It appears that spawners of the species mentioned may not thoroughly investigate all types of bottom, but tend to use whatever type is most available, at least in Deep Lake.

The depth of water in which the nests are situated is shallower in Deep Lake (1 to 5 feet) than has been found in many other waters (as deep as 15 feet). The degree of slope of the bottom may be the factor limiting

the depth of water in which the fish nest. Presumably nests could be fanned out more readily over a rather flat or gently sloping bottom than on one having a steep slope.

Number of Fry per Nest

There was considerable variation in the number of fry counted from individual nests (Table 2). Because of the small number of largemouth bass and common sunfish nests from which fry were secured, the results are probably not as representative as the fry counts from the bluegill and rock bass nests.

In Deep Lake the number of bluegill fry per nest varied from 4,670 to 61,815 with an average of 17,914 in the seventeen nests counted. Coggeshall (1924) found that the number of bluegill fry per nest varied from 11,257 to 224,000, and that the average total number for the four selected nests was 86,631. The variation in the number of fry per nest for the bluegill probably indicates that more than one female spawned in some individual nests. Coggeshall (1924) counted 11,257 eggs in the ovary of a 14 centimeter bluegill. Ulrey, Risk and Scott (1938) counted the number of eggs in eighteen bluegill ovaries. Seven 2-year old fish, averaging 13 centimeters in length contained an average of 3,820 eggs; nine 3-year olds, averaging 14.8 centimeters, contained an average of 9,264 eggs; and two 4-year olds, averaging 18.7 centimeters contained an average of 19,169 eggs. The ovaries of a number of bluegills from Deep Lake have been preserved and counts of the eggs will be published later.

The smaller number of fry in rock bass nests suggests that probably only one female had used each nest. Definite conclusions must await actual counts of eggs in rock bass ovaries. Likewise no conclusions concerning

single or multiple occupancy of largemouth bass and common sunfish nests are warranted by the data that have been accumulated so far.

A summarization of the data of Table 2 may be used for an estimation of fry production in Deep Lake (Table 3). The number of nests of each of the four species observed must be considered a minimum. Some nests probably were overlooked because of interruptions in the observations caused by unfavorable weather or inability to make daily trips to the lake. Removal ~~of~~ by the fish of the colored marbles used to identify the nests of each species may have resulted in failure to record a certain number.

No estimation of the number of adult males and females present in Deep Lake can be made. The total number of nests counted does not indicate the number of spawning males and females because of possible multiple occupancy of nests, or the utilization of more than one nest by a single female during successive spawnings in a single season or the possible failure of certain fish to spawn even though sexually mature.

Coggeshall (1924) ~~employing~~ employed his average counts of eggs per ovary and the calculated total number of fry produced in Winona Lake to estimate the number of spawning females present. He determined that the number of females was 18,467, and assuming a 50-50 sex ratio, that the total adult population of bluegills was about 36,000. But only 2,400 nests were found in Winona Lake the same year. Coggeshall concluded that more than one male constructs and guards a nest or that a large proportion of the adult males were non-functional. The latter was to him the more plausible explanation. The weight method used by Coggeshall for determining the number of fry per nest is open to some criticism as mentioned earlier in this paper. The estimated minimum number of fry produced in Deep Lake (Table 3) was calculated by multiplying the average number per nest by the total number of nests observed. The number of fry produced per acre was obtained by dividing the total number of fry produced by the area of the lake

TABLE 3. NUMBER OF NESTS IN LAKE,
NUMBER OF NESTS EXAMINED, NUMBER OF FRY PER NEST
AND THE ESTIMATED NUMBER OF FRY PRODUCED IN DEEP LAKE, 1938

Species	Number of nests in lake	Number of nests examined	Number of fry per nest			Estimated number of fry produced in lake	Estimated production per acre
			Minimum	Average	Maximum		
Largemouth Bass	[1] 33	4	751	4,977	11,457	164,000	11,000
Rock Bass	[1] 58	9	344	796	1,756	46,000	3,000
Common Sunfish	188	2	1,509	8,074	14,639	1,518,000	101,900
Bluegill	369	17	4,670	17,914	61,815	6,610,000	443,600
Totals	648	32				8,339,000	559,600

[1] This does not represent a complete count because spawning was underway when first observations were made.

(14.9 acres). Figures were rounded off to the nearest hundred. It is admitted that the data on rock bass, common sunfish, and largemouth bass are inadeuqate and would probably be subjected to some revision if the fry produced in a larger number of nests had actually been enumerated. The estimated total fry production of these three species are presented merely for comparison with the bluegill data.

Summary

1. Observations were made of the spawning habits and the number of fry produced by four centrarchid fishes (the bluegill, common sunfish, largemouth bass and rock bass) in Deep Lake, Oakland County, Michigan.

2. A total of 648 nests of the species studied, were counted.

3. Fry were collected from thirty-two nests of the four species, by means of a glass tube. Fry were removed from the sand that was collected with the fry, by the calcium chloride floatation method. The flaatation method was found to be approximately 99.8 per cent efficient in removing fry from the bottom sand. Counts of the fry were made by actual enumeration.

4. The average number of fry per nest for bluegills was 17,914; for the common sunfish 8,074; for the rock bass 796; and for the largemouth bass 4,977.

5. The minimum production of fry in Deep Lake was estimated to be 6,610,000 for the bluegill; 1,518,000 for the common sunfish; 46,000 for the rock bass; and 164,000 for the largemouth bass.

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