NESTING SUCCESS OF THE BLUEGILL, *LEPOMIS MACROCHIRUS* RAFINESQUE, IN A SMALL OHIO FARM POND[1, 2]

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ABSTRACT

Some of the factors influencing the reproductive success of the bluegill sunfish, *Lepomis macrochirus* Rafinesque, in an Ohio farm poind were investigated during three summers from 1965 to 1967. The availability of nesting substrate was the major variable affecting spawning success in the pond. Fine gravel and sand substrates produced the most fry. Those of mud and debris produced less fry. Chemical control of algal mats in 1965 and 1967, by providing open areas of preferred substrate, increased nesting success and thus indirectly contributed to overpopulation of bluegills in the pond.

INTRODUCTION

Farm ponds have become a permanent feature of the American landscape. Many ponds are stocked with largemouth bass, *Micropterus salmoides* (Lacepede), and bluegill, *Lepomis macrochirus* Rafinesque. Dissatisfaction with this combination in northern United States is well documented by Bennett (1952) in Illinois, Ball (1952) in Michigan, Krumholz (1950) in Indiana, and Regier (1963) in New York. Regier (1963) stated that most pond owners do very little of the management necessary for the success of the bass-bluegill combination. One major problem in management of this combination is the overpopulation of bluegills, caused by their excellent reproductive success in farm ponds. Some of the factors determining nesting success and fry production in freshwater fish populations are:

1. weather conditions,
2. type of substrate available,
3. characteristics of the spawning population, and
4. abundance of nesting sites (Kramer & Smith, 1962).

Observations were made on the effect of these factors on the total numerical production of young during three nesting seasons. This provided base-line data on bluegills in Ohio fish ponds of use in improving management techniques.

Our study was done at Lehman's Pond, a spring-fed 0.53-hectare pond having a maximum depth of 14.6 meters and an average depth of 10 meters. This pond is located in Scioto Township, Pickaway County, Ohio, one mile northeast of the intersection of State Routes 104 and 762. The pond has steep sloping shorelines, except for a shallow beach in the southwest corner, and the water remains clear most of the year because of limited surface drainage. It was overpopulated with bluegills and had a moderate population of largemouth bass at the time of this study.

METHODS AND MATERIALS

Fish for marking were captured in the spring of 1965 with a $10.6 \times 1.25 \times 0.01$-m bag seine. They were divided into two size groups, based on the size at maturity

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of males and females. Because of dense aquatic vegetation, sampling was by angling during the fall of 1965 and the springs of 1966 and 1967. This method proved selective for larger, more mature fish. Adult population was estimated by the Peterson method in 1965 and by the Schnabel method in 1966. No estimates were made in 1967. Both the Petersen and the Schnabel methods are described in Lagler (1956).

Measurements of the fish were of total length in millimeters and of weight in grams. Scale samples were obtained from a large random sample of fish, and ages were determined by the scale method, using a Rayoscope microprojector.

The number of active nests during each spawning interval was determined by counting guarding males from both shore and boat. During 1965 and 1966, fry were collected by siphoning them from nests into plastic tubing for transfer into a four-liter jar. After fry were collected, the nest itself was removed and placed into another jar containing a 10 percent solution of formalin. Fry were sorted and counted immediately. Seven nests were collected in 1965, five in 1966, and 22 in 1967.

Fry were collected from nests on different substrates during each of three spawning periods during 1967. Five substrate categories were used: sand and fine gravel; medium gravel; large gravel; mixed mud, gravel, and sand; and mud and detritus. The fry were placed in jars, which were labelled as to the depth of nest, type of substrate, and date collected. The jars were numbered and the numbers recorded on a map of the pond. The fry were then taken to the laboratory and counted.

The number of fry in each sample nest was estimated volumetrically in 1967 because of the large number of individuals. After removing foreign material and placing the fry in a 10 percent formalin solution to assure the same specific bouyancy, each sample was divided into five subsamples of 1 to 3 ml, and the fry counted. Total count of fry per subsample divided by the number of ml in the subsample gave the mean number of fry per ml of subsample. All mean numbers of fry per ml of subsample were then added together and divided by five to estimate the mean number of fry per ml in the sample nest. Total volume in ml of fry in each sample nest multiplied by the mean number of fry per ml gave the total number of fry in each nest. Variation between subsamples was less than five percent of the mean of the five subsamples.

In October of each year, young-of-the-year bluegills were seined by pulling a $3.0 \times 0.01 \times 1.25$-m seine in an arc covering approximately 9 m^2 per haul. Approximately 20 hauls were made each of the 3 years throughout the circumference of the pond.

Daily water temperatures were taken at approximately 4:30 p.m. each day during the summer, at depths of 25 and 125 cm, with an electric thermometer. Daily high and low air temperatures were obtained from the U.S. Weather Bureau at Port Columbus, Ohio, and, although this office is about 15 miles away, it provided a general idea of variations in daily temperatures.

SIZE OF THE BREEDING POPULATION DURING 1965 AND 1966

The number of bluegills over 130 mm in size were estimated to be 440 in the spring of 1965. Minimum spawning size of males approximated 130 mm. Recruitment of small fish to the adult population increased the number of bluegills over 130 mm long to an estimated 803 in the fall of 1965. In the spring of 1966, this number decreased to an estimated 408 fish (Table 1). Most fish over 130 mm were 4 years old or older (Table 2). Very few six-year-old bluegills were collected in Lehman's pond, indicating a high mortality rate for five-year-old fish. The high mortality estimates agree with Gerking's (1962) study of an overcrowded population in Wyland Lake, Indiana.

The number of 90–129-mm fish remained quite constant. There were an

TABLE 1

Population estimates of bluegills in Lehmann's pond

Type of estimate	Season and Year	Length intervals (mm)	Total sample size	Number previously narked	Number recaptured	Population estimate	95% Confidence limits
Petersen—seining	Spring 1965	50–89	601	214	19	6,441	3,572–10,717
		90–129	85	92	5	1,303	868–2,606
		130+	21	40	1	440	160–840
Petersen—angling	Fall 1965	90–129	54	206	7	1,416	809–2,832
		130+	46	188	11	803	491–1,473
Schnabel—angling	Spring 1966	90–129	562	507	110	1,447	1,180–1,766
		130+	229	177	47	408	327–595

estimated 1,303 fish of this size group in the spring of 1965, 1,416 in the fall, and 1,447 in the spring of 1966 (Table 1). The slight increase in the population of this size group from 1965 to 1966 was due to increased recruitment from the estimated 6,441 two-year-old fish present in 1965. No estimate was made of immature two-year-old fish in 1966.

Males ranged in length from 112 to 180 mm and in age from 3 to 6 years during the period of the study. Though all were sexually mature, none less than 125 mm long successfully maintained a nest. The average length of spawning males was 142 mm in 1965 and 153 mm in 1966.

TABLE 2

Length-frequency distribution by age groups of all fish seined in Lehmann's pond 29 April and 1 May 1965

Total length in mm	Age-group II	III	IV	V	VI	Total number of fish
60–64	10					10
65–69	8					8
70–74	10					10
75–79	3					3
80–84	2	1				3
85–89	1					1
90–94		2				2
95–99		2				2
100–104		2				2
105–109		2	2			4
110–114		1	7			8
115–119			7			7
120–124			2			2
125–129			1	1		2
129–134			1	3		4
135–139			1	1		2
140–144				8		8
145–149						
150–154					1	1
Total	34	10	21	13	1	79

Females ranged in total length from 85 to 204 mm and in age from two to seven years. They spawned 1 to 2 years earlier than did males in this crowded population.

Only the larger two-year-old females spawned. Thus, sexual maturity was related to size rather than to age in both males and females. Morgan (1951) gave 115 mm as the size of sexually mature female bluegills in Ohio. Some of the Lehman's Pond fish were ripe at 90 mm.

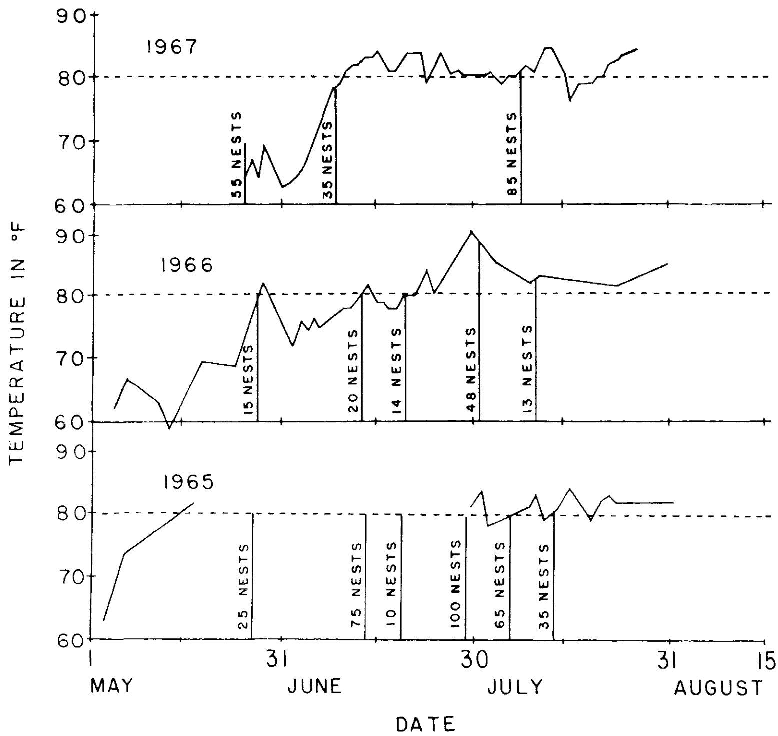
Nest construction followed closely the descriptions of Breder (1936), Breder and Rosen (1966), and Miller (1963). The male scooped out a saucer-shaped depression in the bottom, in shallow water. Most nests were about 600 mm in diameter and 150 mm deep. Nests were built in groups of three to 100, but spawning did not necessarily take place immediately after construction. Males spawned for two consecutive days. The number of females per spawning male varied, but it was commonly four or five.

EFFECTS OF PHYSICAL FACTORS ON NESTING SUCCESS

Temperature

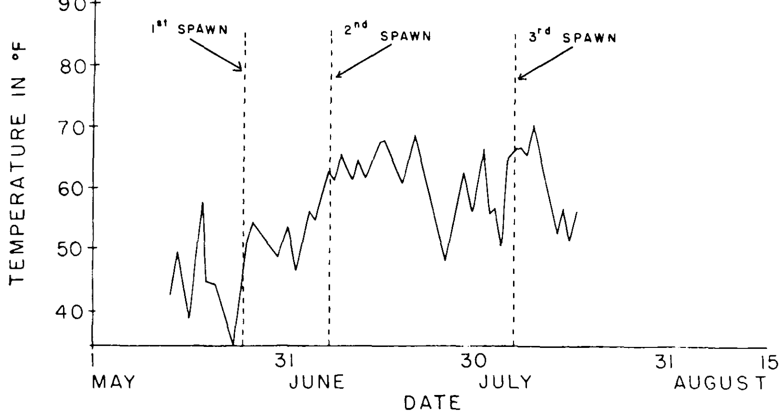
Shallow-water temperature turned out to be a good index to correlate temperature and spawning. In all cases the water temperature was rising when spawning began. Usually the shallow-water temperature was near 80.0°F. In general, bluegill spawning in this pond usually occured while the temperature was increasing and was at or near 80°F (Fig. 1). An exception were the observations on May 15, 1967. With water at a temperature of 63° F, bluegills built

FIG 1
RELATIONSHIP OF SURFACE WATER TEMPERATURE TO SPAWNING ACTIVITY AT LEHMANN'S POND



and successfully spawned in 55 nests. This contradicted our earlier experiences in 1965 and 1966 that spawning did not take place until temperatures were at or near 80° F. However, this low temperature is well within the range for bluegill spawning, as Clark and Keenleyside (1967) reported nesting at 63° F in Ontario ponds. They also reported that numbers of occupied nests increased with rising surface temperatures. Our data also agree with Kramer and Smith's (1962) study of largemouth bass in Lake George and adjoining sloughs, Anoka County, Minnesota, where a drop in mean daily water temperature, followed by a rise, stimulated repeated spawning. While the variation in daily water temperature in Lehman's Pond was slight, fish usually spawned during a hot spell that followed a series of cool nights which had lowered the shallow-water temperature (fig. 2). Initial spawning activities began within 72 hours of each other in the three successive years of study (fig. 1).

FIG 2
RELATIONSHIP OF 1967 DAILY LOW AIR TEMPERATURES TO SPAWNING ACTIVITY



Wave Action

Kramer and Smith (1962) recorded wave action as one of the major factors in setting year-class strength in largemouth bass. They studied both the open lake and sloughs connected with it. Since farm ponds are somewhat protected, wave action seldom destroyed any bluegill nests. In Lehmann's Pond, only those nests found at depths of less than 150 mm were affected. Only three of 310 nests were totally destroyed in 1965, and none of 110 nests in 1966 or of the 176 nests in 1967 were destroyed by wind-generated waves.

EFFECTS OF BIOLOGICAL FACTORS ON NESTING SUCCESS

Effects of Aquatic Vegetation on Substrate Availability

Rooted aquatic plants were very abundant in the pond during all three years. Species collected and identified from the deeper parts of the pond included *Potamogeton pectinatus*, *P. nodosus*, and *Zannichellia palustris*. *Potamogeton pectinatus* was by far the most abundant deep-water plant, at times covering most of the bottom of the pond. Those plants found in the shallow water around the edges of the pond included *Carex brevior*, *C. cephalophora*, *C. granularis*, *C. vulpinoides*, *C. stipata*, *Eleocharis calva*, *Scirpus atrovirens*, *Juncus* sp., *Sagittaria* sp., *Typha* sp. Shoreline plants were not abundant.

Algal mats of *Spirogyra* sp. covered almost all shallow areas of the pond in 1966. Algal mats were not present in 1965 because the pond was treated with copper sulfate on June 21, 1965. Algae did not reappear in the pond until the end of August, 1965, so that little or no floating algae were present in the pond during the entire spawning season. During the 1967 season, the pond was treated for algae with 12 liters of Diquat on May 10 and 1 p.p.m. of copper sulfate on June 14. These proved very effective in reducing algal growth.

The role of aquatic vegetation in the survival of young bluegills has been adequately discussed by Bennett (1962) and by Swingle and Smith (1942). However, the role of aquatic vegetation in decreasing reproduction is less well known. Moorman (1956) noted a decrease in reproduction of bluegills caused by floating algae, but gave no reason. In Lehmann's Pond, about 25 percent of the pond is suitable for spawning, of which about half is provided by a sandy shallow beach in the southwest corner of the pond. The increase in aquatic vegetation in 1966 resulted in the use of substrates such as large gravel, which were avoided, for the most part, by the fish in 1965 and 1967. Most of the spawning area available in 1966 was large to medium gravel, whereas sand and fine gravel, which were preferred in 1965 and 1967, were not available in 1966. About the same number of fry were collected on fine-gravel substrates in 1965, on medium-gravel substrates in 1966, and on fine- to medium-gravel substrates in 1967, which proved to be an exceptional year (Table 3). In 1967 additional collections of fry were made from both gravel and sand nests throughout the spawning season. Fry collected from 22 different substrates showed good correlation between substrate and total fry per nest (Table 3). The finer and cleaner nest substrates, sand and small gravel, produced more fry per nest, so the change in predominant nesting substrate from sand to coarse gravel and mud would also contribute to decreased total fry production in 1966, in comparison with 1965 or 1967.

Nests were constructed on all types of solid substrates available in the pond. Breder (1936) stated that, if a solid base is unavailable, nesting will be attempted, but no spawning will occur. Sand was the predominant substrate used in 1965, with 174 nests on this base, compared with 33 nests on gravel, 94 nests on clay and mud with some gravel, and 2 nests on leaf litter. In 1966, when floating algae covered much of the pond's sandy portion, only 12 nests were on sand, with 63 on gravel, 36 on clay mixed with gravel, and none on leaf litter.

Effect of Density of Spawning Population

Density of adult bluegills did not affect total numerical production of fry. This agrees with Regier (1963), who also found that the density of bluegill populations did not markedly affect the reproductive success of bass or bluegills. Though the population of adult bluegills was nearly the same in both years (Table 1), three times as many nests were built in 1965 as in 1966 (Fig. 2). In addition, the number of fry per nest was lower in 1966 than in 1965 or 1967.

RELATIVE FRY PRODUCTION DURING THE YEAR

The number of fry produced in Lehmann's Pond declined from an estimated 2.8 million in 1965 to 0.5 million in 1966, and rose to 7.1 million in 1967. The estimate was made by multiplying the number of nests by the average number of fry collected from nests found on different substrates. The estimate is limited in that the number of nests involved was small (33 nests) and, except for 1967, nests were not collected for all types of substrates at all times of the year. Data from the nest samples are presented in Table 5. Carbine (1939) found an average of 17,914 bluegill fry per nest in his study of Deep Lake in Michigan. This figure compares very closely with production in nests on sand substrates in Lehmann's Pond (19,263) during 1965, but was much higher than fry per nest on gravel and clay substrates (3,415) in 1965 and 1966. Spawning success proved to be exceptionally good in 1967, as the overall average number of fry per nest was 44,522—about twice that of the next best year, 1965.

TABLE 3

Number of frey collected from nests in Lehmann's Pond

Date	Substrate	Average number fry/ml	Total volume in ml in sample	Total
5/24/67	Sand & fine gravel	447	165	73,755
6/07/67	Sand & fine gravel	506	120	60,720
7/07/67	Sand & fine gravel	459	123	56,457
7/07/67	Sand & fine gravel	557	110	65,169
				X̄64,025
5/24/67	Medium gravel	439	163	71,557
5/24/67	Medium gravel	513	65	33,345
5/24/67	Medium gravel	450	135	60,750
7/07/67	Medium gravel	471	112	52,752
7/07/67	Medium gravel	609	110	66,990
				X̄63,848
6/07/67	Large gravel	449	64	28,736
6/07/67	Large gravel	607	24	14,568
6/07/67	Large gravel	628	17	10,676
6/07/67	Large gravel	459	58	26,622
				X̄20,150
5/24/67	Mixed mud, gravel & detritus	578	150	86,700
5/24/67	Mixed mud, gravel & detritus	473	75	35,475
6/07/67	Mixed mud, gravel & detritus	438	47	20,586
7/07/67	Mixed mud, gravel & detritus	465	92	42,780
7/07/67	Mixed mud, gravel & detritus	447	17	7,599
				X̄48,285
5/24/67	Mud & detritus	458	38	17,404
5/24/67	Mud & detritus	608	35	21,280
6/07/67	Mud & detritus	443	38	17,034
7/07/67	Mud & detritus	490	49	24,010
				X̄19,932
5/22/65	Sand			36,383
7/02/65	Sand			17,412
7/02/65	Sand			16,680
7/03/65	Sand			6,576
				X̄19,263
7/02/65	Mud & gravel			4,537
7/08/65	Mud & gravel			3,106
7/10/65	Mud & gravel			3,147
				X̄= 3,597
6/20/66	Gravel			5,655
6/20/66	Gravel			3,438
6/20/66	Gravel			2,652
6/20/66	Gravel			1,372
6/20/66	Gravel			242+
				X̄= 3,279

*Data for 1965 and 1966 are direct counts.

+Part of the fry from this nest had already left prior to collection and are not included in the mean.

DISCUSSION AND CONCLUSIONS

Successful nesting of bluegills in Lehmann's Pond appears to be dependent on several factors. These are (1) an adequate number of spawning fish, (2) the availability of suitable substrate, and (3) water temperature above the minimum required for spawning and subsequent hatching of the fry. The availability of nesting substrate is the major variable affecting spawning success in Lehmann's, and in most Ohio ponds. The minimum water temperature suitable for spawning is a requirement met in most Ohio ponds. In addition, most Ohio ponds have adequate numbers, usually an overpopulation, of spawning fish.

Spawning appears to be controlled by the availability of suitable substrate, its composition, and the total area occupied by the various types of substrate. Nests on sandy and fine-gravel substrates produce the largest number of fry. Detritus and mud substrates produce the fewest fry per nest. In general, the structually best defined nests are those built on the firmest substrates.

In general, vegetation control is considered a desirable fish pond management technique. Excessive vegetation interferes with fish production and harvest, reduces the effectiveness of predators by providing hiding places for small fish, often provides an unpleasant taste and smell in the water, interferes with swimming, boating and other recreational use of the pond (Stockdale, 1967). However, chemical control of aquatic vegetation contributes to over-successful nesting of bluegills, as shown by our study. This leads to the maintenance of a more dense population, through over-recruitment in an overcrowded situation, an undesirable side effect from the use of a commonly accepted technique. Thus, in the construction of new farm ponds planned for fishing, the quality and quantity of the substrate should be taken into account. By limiting the amount of exposed sand and gravel, it may be possible to reduce the nesting success of bluegills, reducing the likelihood of over-recruitment. These undesirable side effects of chemical vegetation-control point out the necessity of treating each pond on the basis of an individual ecological analysis, rather than as a general case, as is done so often.

Contributing equally to the problem of over-recruitment through successful nesting is, of course, the underharvest of bluegills by anglers, probably Ohio's number one problem in farm-pond management. Underharvest can probably be controlled to a greater extent than can reproduction. Good bluegill-bass-pond management requires an adequate balance between fish reproduction and harvest. It demands the production of fewer fry for bigger fish or at least the assurance that the supply of fry does not exceed the number required to replace those harvested, and yet requires that enough fry be available to furnish adequate forage for the bass. These multiple objectives make the problem extremely complicated; perhaps the solution is to provide either new combinations of species for pond management or the production of a domesticated bluegill with good growth and low fecundity.

The farm pond can become a significant recreational resource in the state of Ohio. Except for Lake Erie, Ohio has a great shortage of inland fishing waters. There are no significant inland lakes, less than 12,000 miles of useable streams, and only 130,000 acres of reservoirs. Yet the state has nearly 800,000 licensed fishermen, about 8 percent of the population. It is estimated that, by 1976, state-owned public recreation areas will supply only about 0.0075 acres of inland public water per person (Diamond, 1962).

Present water supplies cannot possibly meet all the future recreational demands. Leased farm ponds can help bear the brunt of this increasing demand for fishing. Farmers need to be encouraged to build more ponds for fishing and to learn how to manage these ponds effectively. Management goals require understanding of the results of basic research on the population dynamics of the pond fishes. Because these bodies of water can be more easily managed than can natural ones, the continuation of such research will be of great value in this practical application.

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