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A TURBIDITY-RELATED DELAY IN BLUEGILL (*LEPOMIS MACROCHIRUS*) REPRODUCTION AND SOME SIZE-DEPENDENT DIFFERENCES IN THE SPATIAL DISTRIBUTION OF BLUEGILL FRY

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ABSTRACT

The initiation of bluegill reproduction and the abundance and spatiotemporal distribution of bluegill fry were investigated in a central Illinois pond. High turbidity delayed successful reproduction, resulting in a short growing season. Small bluegill fry (14.0-20.0 mm total length) were generally most abundant at the 1-m depth at offshore locations, and large bluegill fry (20.5-26.5 mm) were generally most abundant at shoreline locations, supporting a littoral-limnetic-littoral migration pattern documented in published accounts. However, small bluegill fry were abundant at two shoreline locations, indicating that some bluegill fry either did not migrate to open water or returned to the shoreline at a smaller size than has been previously documented. A small mean length of age 0 bluegill in September followed the reduced growing season.

INTRODUCTION

In 1981 we initiated a study to compare the abundance and spatiotemporal distribution of the fry of bluegill and redear sunfish in a small pond in search of reasons for differences in recruitment success. Although redear sunfish failed to produce any fry, we were able to observe some effects of turbidity on bluegill reproduction as well as to describe aspects of the spatial distribution pattern of bluegill fry which differ from published accounts.

METHODS

Ringneck Pond, located in central Illinois, has a surface area of 0.6 ha, a maximum depth of 3.5 m, and a mean depth of 1.6 m. Aquatic macrophytes and filamentous algae have been absent since an application of herbicide in 1979, but some terrestrial vegetation was inundated for short intervals in 1981.

The pond was renovated in 1978 and young-of-the-year largemouth bass, bluegill, and redear sunfish were stocked in 1979. Both species of *Lepomis* suffered nearly total mortality following an excessive application of herbicide (simazine). Adult bluegill (n = 25) and redear sunfish (n = 25) were stocked in 1980; adult and juvenile bluegill (n = 95), redear sunfish (n = 43), and young-of-the-year bass (n = 50) were stocked in spring 1981.

Plexiglass fry traps (Bagenal and Braun 1978) were used to collect bluegill fry in 1981. Three habitats were sampled: shoreline (0.5-m depth, within 1 m of shore), nearshore (1.5-m depth, 4-6 m offshore), and midlake (3-m depth, approximately 30 m offshore). Traps were set at the surface at shoreline stations (I, VI, VII, X; Fig. 1), at the surface and 1-m depths at nearshore stations (II, V, VIII, IX), and at the surface, 1-, and 2-m depths at midlake stations (III, IV). Nearshore traps were moved between stations II and VIII and between stations V and IX at 2-day intervals because the number of traps was limited. Traps were fished 4 to 6 days per week, and contents were removed daily from 28 May through 11 September. The entire shoreline was inspected frequently for nesting activity throughout the sampling interval.

Every third 3-m section of shoreline was sampled with a 3- × 1.2-m seine (3.2-mm mesh) on 18 September 1981 to determine the abundance and size composition of young-of-the-year bluegill. Every third seine haul was retained for identification and measurement.

Samples from trap and seine collections were preserved in the field in 50% alcohol and returned to the laboratory for identification, enumeration and measurement. Using morphological and meristic characteristics suggested by Werner (1966), we determined that the bluegill was the only species of *Lepomis* present in trap and seine collections. In samples containing $\leqslant 30$ bluegill, all fry were measured to the nearest mm total length (TL). Thirty randomly selected fry were measured from samples containing >30 fry. Lengths were assigned to the remaining fry in proportion to the length composition of the subsample.

Daily rings in otoliths (Taubert and Coble 1977) were used to age all bluegill fry collected in traps between 26 July and 5 August (n = 48). An estimate of the interval from egg deposition to swimup (Childers 1967; Hall et al. 1970) was added to the "otolith age" to determine the date of spawning.

Daily trap catch data [transformed to $\log_{10}(\times + 1)$] were examined using Yate's weighted squares of means procedure (Steel and Torrie 1960). Treatment means were compared using the LSD test ($P<0.05$).

On each trapping day, surface turbidity was measured with a Hach Model 2100 Turbidimeter and water temperature was measured at the surface and at 1-m and 2-meter depths. A dissolved oxygen profile was determined weekly at station III using YSI Model 54 dissolved oxygen meter. Dissolved oxygen concentrations at the surface and 1-m depth were adequate for fish ($\geqslant 6$ ppm; Moore 1942) throughout the sampling interval but were generally too low (<2ppm) at the 2-m depth until early August.

RESULTS

As a result of high spring runoff from an adjacent plowed field, turbidity was high in Ringneck Pond when trapping began in late May (Fig. 2). Turbidity declined in early June, remained relatively constant through mid-June, and then declined rapidly to <10 NTU by mid-July. Slow settling of introduced soil particles, rather than new runoff or wind-induced wave action, was responsible for the extended interval of high turbidity.

The high turbidity in May and June has a marked effect on the water temperature profile. Surface water absorbed most of the solar radiation and warmed rapidly, resulting in a stable temperature gradient which insulated subsurface water. Midday water temperatures at the surface and at 1 meter down differed by as much as 12 C (4 June) and rarely by less than 6 C until turbidity declined in early July. Thereafter, water temperature at the 1-m depth increased rapidly and differed from the surface temperature by no more than 2.5 C from 19 July through the end of the summer.

Nesting activity was first observed on 8 July, when five bluegill nests were discovered along the dam (Fig. 1), and continued sporadically through mid-August. Bluegill nesting activity was concentrated along the dam throughout the summer and peaked in late July when 24 males were observed guarding nests.

Bluegill fry (n = 4,554) were collected in traps from 25 July through the end of the sampling interval (11 September). Consistent with our observations of nesting activity, otolith-derived ages of bluegill fry collected between 26 July and 5 August indicated that successful spawning began during the first week of July. Thus, the first successful spawn occurred at least a month later than the typical date of first spawning for bluegill in central Illinois (Childers 1967) and 1.5 months later than the initiation of spawning in Ringneck Pond in 1980 (unpublished data).

Analysis of the spatial distribution of bluegill fry was limited to fish 14-26.5 mm in length because smaller fry were not sampled in proportion to their abundance and too few larger fry were collected. Two length categories were considered: 14-20 mm and 20.5-26.5 mm.

Fry were not uniformly distributed throughout the pond ($P<0.05$; Table 1), and small and large fry were distributed differently ($P<0.05$). Both size groups were significantly more abundant at the north end of the pond at trap locations VII_0 $VIII_1$ (subscripts indicate the depth of the trap in meters) than at all other trap locations. The lowest densities of both size groups occurred at nearshore and midlake surface locations (II_0, III_0, IV_0, V_0, $VIII_0$, IX_0). Densities at the 1-m depth were always greater than at the surface at the same location. However, for large fry, the difference was significant only at station VIII.

Small and large fry differed most in their use of shoreline habitat. Shoreline traps accounted for 61% and 41% of the catch of large fry and small fry respectively, indicating that large fry were more closely associated with the shoreline than were small fry. Also, small fry were significantly more abundant at the 1-m depth than at the 2-m depth, while large fry were equally abundant at both depths.

Catch rates of bluegill fry in the September seining collection were highest at the north end of the pond, which was consistent with the distribution of fry collected in traps. The length distribution of bluegill collected by seining ($\bar{X} = 21$ mm) was similar to that of bluegill collected in traps in the last week of sampling ($\bar{X} = 19$ mm). However, some fry collected in seine samples were larger (>40 mm) than any collected in traps.

DISCUSSION

Bluegill generally begin spawning when water temperature reaches 20-27 C (Childers 1967). In contrast, successful bluegill reproduction did not begin in Ringneck Pond until turbidity declined in early July, even though surface temperatures had reached 27 C by 3 June (Fig. 2). High turbidity could interfere with bluegill reproduction directly, by a mechanism such as impairment of visual spawning cues, or indirectly, by reducing the rate of warming of subsurface water. A direct effect was indicated in Ringneck Pond, because successful reproduction began during an interval when turbidity was declining rapidly and water temperature at the 1-m depth was relatively constant. Because turbidity levels equal to or greater than those recorded in Ringneck Pond are common in nature (Buck 1956, Gardner 1981), high turbidity may often disrupt the normal temporal distribution of spawning activity. Buck (1956) associated high turbidity with reduced production of bluegill fry in Oklahoma ponds but did not document a direct relatinship between the initiation of reproduction and turbidity.

Werner (1967) concluded that bluegill fry in Crane Lake, Indiana, migrated to the limnetic zone soon after leaving the nest and returned to the littoral zone when they attained a size of 20-25 mm. Others have found small bluegill fry in the limnetic zone, but the size at which these fry returned to the littoral zone varied: 12 mm (Storck et al. 1978), 15 mm (Keast 1980), and 15-20 mm (Beard 1982). The high density of small bluegill fry at Ringneck Pond shoreline stations VI_0 and VII_0 indicates that a fraction of the population of fry either did not participate in the offshore migration or returned to the shoreline at a very small size. The substantial use of shoreline habitat by small bluegill fry may have reflected the poor definition of limnetic and littoral habitats resulting from the small size of the pond and the absence of aquatic vegetation. Regardless, substantial movement of bluegill fry was indicated, since they became dispersed throughout most of the pond even though spawning was concentrated along the dam at the south end.

The predominately shoreline distribution of large bluegill fry in Ringneck Pond was consistent with the observations of Werner (1967) and Beard (1982). However, since vegetative cover was absent in Ringneck Pond, littoral vegetation is not a requisite for shoreline residence by large bluegill fry.

Our results are in agreement with Werner's (1966) finding that bluegill fry occupying open water are relatively rare near the surface. However, bluegill fry <12 mm (essentially absent from Werner's and our collections) may exhibit a different vertical distribution. Storck et al. (1978), using towed nets, found higher densities of 5-11 mm bluegill fry at the surface than at the 2-m depth in the limnetic zone of a large Illinois reservoir.

The mean length of age 0 bluegill in Ringneck Pond in September (21 mm) was much less than the 40-70 mm range reported by Carlander (1977) for other midwestern waters. Small length at the end of the growing season has been associated with low overwinter survival of age 0 largemouth bass (Aggus and Elliott 1975; Shelton et al. 1979) and smallmouth bass, *Micropterus dolomieui* (Oliver and Holeton 1979). Furthermore, Beard (1982) found that for bluegill, the date of first fry dispersal from the nest was one of the two most important variables affecting yearclass strength. Thus, by reducing the mean size attained by young-of-the-year, the turbidity-caused spawning delay in Ringneck Pond may have had a detrimental impact on the future strength of the 1981 bluegill yearclass.

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Table 1. Geometric means of numbers of small and large bluegill fry collected daily in Ringneck Pond. Means within a size group without a letter in common are significantly different ($P<0.05$). Subscript indicates depth of trap in meters.

Small Fry		Large Fry	
Station	Mean density	Station	Mean density
VII_0	9.35a	VII_0	1.42a
VIII_1	8.00a	VIII_1	1.15a
IV_1	4.09b	VI_0	0.60b
III_1	2.66c	X_0	0.47bc
V_1	2.53cd	I_0	0.43bcd
VI_0	2.35cd	IX_1	0.42bcde
II_1	2.28cd	II_1	0.28bcdef
IX_1	1.95cde	III_1	0.22bcdef
IV_2	1.77de	IV_2	0.19cdef
I_0	1.48ef	IV_1	0.17cdef
X_0	1.29f	V_1	0.13cdef
III_2	1.23f	III_2	0.11def
II_0	1.19f	V_0	0.08ef
VIII_0	1.05fgh	VIII_0	0.08ef
IV_0	0.99fgh	IV_0	0.06ef
III_0	0.82gh	II_0	0.04ef
IX_0	0.72h	IX_0	0.04ef
V_0	0.59h	III_0	0.02f

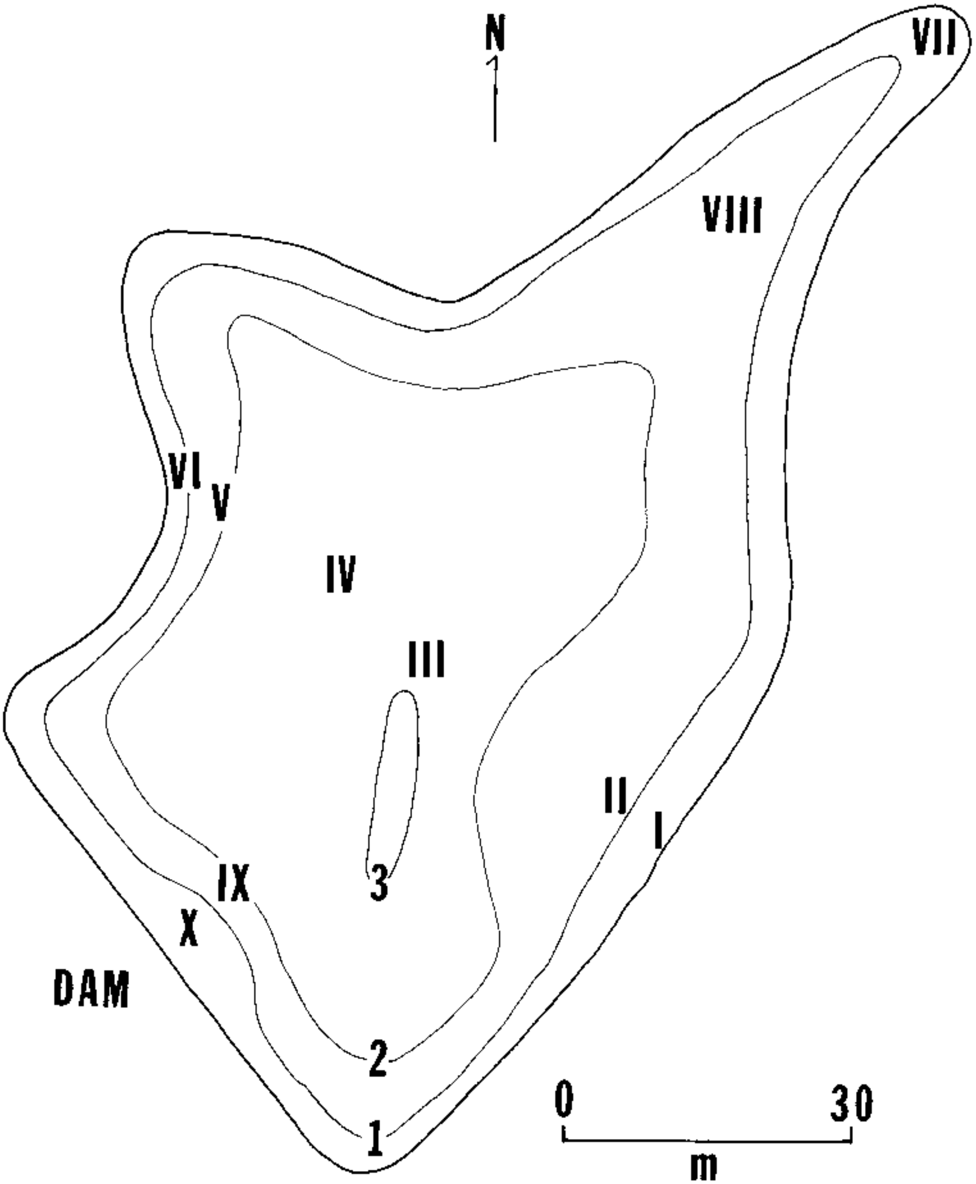

Fig. 1. Ringneck Pond, showing trap locations.

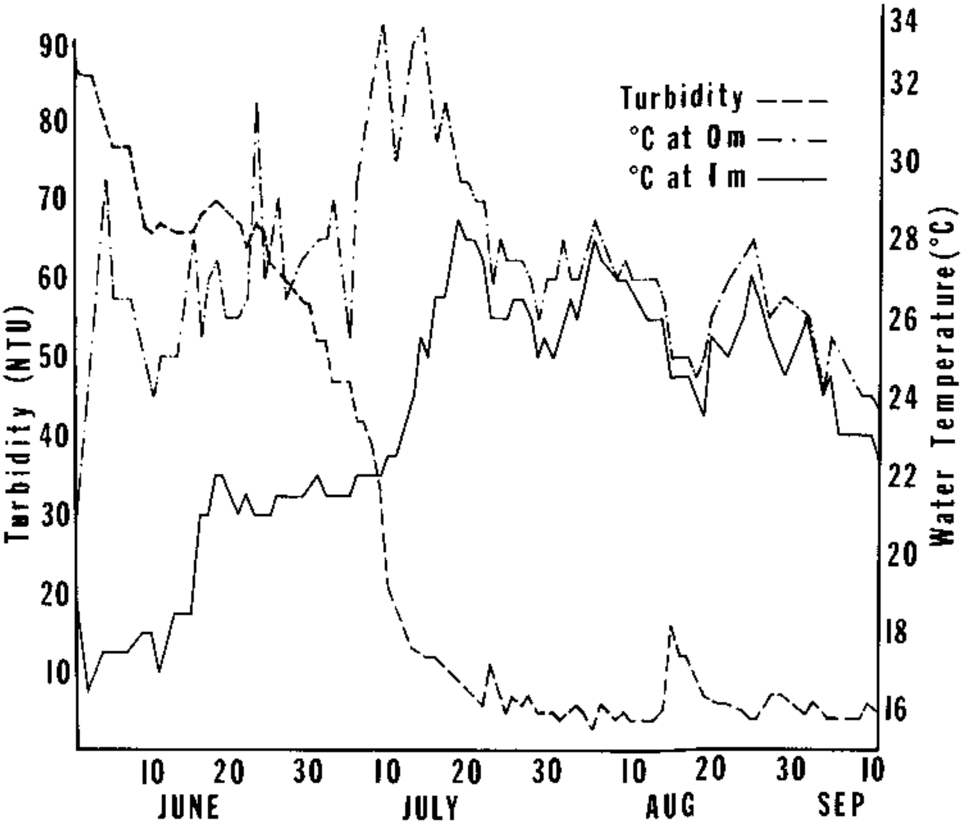

Fig. 2. Surface turbidity and water temperature at the surface and at 1-m depths in Ringneck Pond in 1981.