Letter to the Editor

Feeding and Growth Responses of Bluegill Fish (*Lepomis macrochirus*) at Various pH Levels

Z. Brogowski[1]*, H. Siewert[2], D. Keplinger[2]

[1]Agriculture Univeristy, Department of Soil Environment Science, ul Nowoursynowska 159, 02-776 Warszawa, Poland,
[2]Department of Natural Resources, Ball State University, Muncie, Indiana, 47306 USA

Received: April 19, 2004
Accepted: December 10, 2004

Abstract

Mortality, length and weight changes of bluegill fish (*Lepomis macrochirus*) were investigated at pH 1eve1s of 5.5, 6.5 and 7.5. A sulfurici/nitric (7:3) solution was used to simulate the effects of acid rain on bluegills. Fish at pH 5.5 had a significantly higher mortality and smaller 1ength and weight changes than those of 6.5 and 7.5. No significant difference in length and weight was observed in fish raised at pH 6.5 and 7.5. These results indicate that bluegill in waters of pH 5.5 have a reduced chance to survive and will not grow as well as those at pH 6.5 and 7.5.

Keywords: fish, *Lepomis macrochirus*, pH, acidification

Introduction

During the last two decades acid precipitation has been recognized as an acute problem for fish survival. Numerous studies on acid stress behavior, growth and survival of fish in acidic environments have been conducted [1-11]. All investigators agree that high acidity in lakes will cause a decrease in fish populations.

Palmer et al. found that certain fish species react differently to low pH levels. For example, bluegill were less sensitive to low pH levels than fathead minnows *Pimephales promelas* [14]. Hill found that bass consumed more food at low pH levels than in neutral water [4]. Generally, the growth of fish paralleled food intake. However, it was found that fish increased their food intake at low pH 1evels but did not gain any weight [8].

Most studies of food intake and growth of fish in acidified water were determined in the laboratory. Some investigators have used HCl [14] or H_2SO_4 [4, 12, 13] to acidify the water, which does not simulate natural acid precipitation. Sulfuric acid contributes 65 to 70% of the acidity of rain and nitric acid adds another 25 to 30% [16]. The survival and growth of mosquito larva raised in sulfuric acid water acidified with sulfuric acid were not affected as much as those exposed to a sulfuric/nitric acid solution at the same pH [11]. Fish may respond similarly when exposed to simulated rain rather than sulfuric acid only.

The effects of sulfuric/nitric acidification of water on bluegill growth are not known. Consequently, this study was designed to determine mortality and growth of bluegills in water acidified with a mixture of sulfuric/nitric acid.

The objectives of this study were to:

1. Determine bluegill survival at pH levels of 5.5, 6.5, and 7.5.
2. Determine the influence of pH on b1uegill length and weight gains.

Materials and Methods

Twelve 40-liter-aquaria were filled with 50% dechlorinated tap water and 50% distilled water. Central Indi-

*Corresponding author; e-mail: knosg@sggw.waw.pl

ana tap water contains between 400 and 750 ppm $CaCO_3$. This provides a high buffering capacity which requires large amounts of acid to maintain the desired pH level. To avoid large fluctuations of pH, the tap water was dilluted. This method was successfully tried by Palmer et al. [4]. Four aquaria were designated for each pH level. In each set of aquaria the water was adjusted to a pH of 5.5, 6.5, and 7.5. The pH was controlled by continuously adding a dilluted mixture of 70% sulfuric and 30% nitric acid solution with a Beckman Model 746 Solution Metering Pump. The pH was monitored with an Orion pH meter. Levels of soluble aluminum, copper, lead, zinc and iron were determined with a Perkin Elmer Model 2280 atomic absorption spectrophotometer. Sulfate and nitrate were analyzed with a Dionex chromatographic unit.

Bluegill were obtained from a farm pond and eight fish (52±6mg and 15±5mm) were placed in each aquaria for two weeks and acclimated to a pH of 7.5. Four aquaria remained at this concentration. The water of the other aquaria was gradually lowered to pH 6.5 over a 48 hour period. This is probably biologically relevant in such experiments. Again, four aquaria were kept at this acid level whi1e the water in the remaining tanks was adjusted to pH 5.5. Dried fish food consisting of 24% protein, 4% fat and 6% crude fiber was given to the fish twice a day. We weighed the fish in each aquarium and determined the daily food ration as 4% body weight. Bluegills consume 3-5% of their body weight daily [8].

The fish were exposed to 12 hours of light and 12 hours of darkness at 24±1°C. For proper dissolved oxygen (DO) concentrations, and to remove suspended particles from the water, charcoal filter pumps were used to recirculated the water at a rate of 416 liters per hour. The (DO) level was monitored by the modified Winkler method.

Total length and weight for each bluegill was determined at the beginning and at the end of the 30-day study.

A one-way Analysis of Variance (p=0.05) analyzes differences in length and weight of fish as a function of the selected pH levels.

Results and Discussion

Morta1ity of bluegills was highest (32%) for fish at the pH 5.5 treatment (Table 1). This was twice as high as the loss of fish in the aquaria of pH 6.5.

Significant decreases in length and weight between 5.5 and 6.5 were observed over 30 days (Table 2). The 1ength of fish in pH 5.5 was 49.6% less than that of fish in pH 6.5 and 7.5. A similar trend was observed for weight changes. Bluegill weight gain was 61.6% lower at pH 5.5 as compared to those in pH 6.5 and 7.5. No significant difference in data existed between pH 6.5 and 7.5.

Dissolved oxygen (DO) ranged from 7-8ppm throughout the experiment. This was equiva1ent to an 80-85% saturation, which was sufficient for survival [3]. Rounselfell and Everhart indicated that b1uegills grew best at temperatures between 15°C and 27°C [12]. The temperature of water in this experiment was well within the optimal growth range. Since the water in the aquaria contained only small amounts of metals (undetectable 1eve1s of aluminum, 0.53 µg/l copper, 0.06 µg/l iron, 1.51 µg/l 1ead and 0.08 µg/l zinc), they were not contributing factors in mortality. The United States Environmental Protection Agency considers the following maximum metal concentrations to be toxic to fish: 0.66 µg/l copper, 1000 µg/l iron, 2.38 µg/l lead, 53.80 µg/l zinc [12, 16]. Sulfate concentrations increased during the study period in all aquaria because of the addition of sulfuric acid to keep pH constant (Table 3). Although the largest amount of acid was added to the water at pH 5.5, the final sulfate level did not exceed that of water at pH 6.5. The reason for the similar final reading of pH 6.5 and 7.5 is not understood. However, we assume that the 158.14 ppm may represent the upper limit of sulfate in solution, while the excess amount was removed by charcoal filters. A 3.5-fold increase in sulfate concentration was observed at pH 7.5.

Table 1. Mortality of bluegills at pH levels 5.5, 6.5 and 7.5 over 30 days. (n=32).

pH	No. lived	No. died	% Mortality*
5.5	22	10	32a
6.5	27	5	16b
7.5	26	6	19b

*Percent mortality followed by dissimilar letters are significantly different at the 0.05 probability level.

Table 2. Mean* length and weight changes of bluegills at pH levels 5.5, 6.5 and 7.5 over 30 days.

pH	Length (mm)	Weight (mg)	No. of fish
5.5	1.82a	96a	22
6.5	1.67b	262b	27
7.5	1.57b	235b	26

*Means followed by dissimilar letters are significantly different at the 0.05 probability level.

Table 3. Mean* sulfate and nitrate concentrations in water of pH 5.5, 6.5 and 7.5 at the beginning and end of the 30-day experiment.

pH	SO_4 (ppm)		NO_3(ppm)	
	initial	final	initial	final
5.5	82.8	158.1a	38.8	91.4a
6.5	53.5	158.4a	31.0	ND**b
7.5	39.6	139.6b	20.6	ND**b

Means followed by dissimilar letters are significantly different at the 0.05 probability level. ND**=not detectable

Table 4. Mean* conductance, DS and hardness in water of 5.5, 6.5 and 7.5 at the beginning and end of the 30-day experiment.

pH	Conductance		DS (ppm)		Hardness (ppm)	
	initial	final	initial	final	initial	final
5.5	395	550a	310	485a	204	285a
6.5	395	532b	310	467b	204	268b
7.5	395	503c	310	425c	204	268b

*Means followed by dissimilar 1etters are significantly different at the 0.05 probability level.

The final nitrate concentrations showed a similar increase over time, but only at pH 5.5 (Table 3). In the aquaria with water of 6.5 and 7.5 no nitrate was observed. Algae growing in all the aquaria except at pH 5.5, presumably utilized the nitrate.

The specific conductance and dissolved solids (DS) were higher in water with a high acidity (Table 4). This may have been due to the addition of acids. Hardness levels, caused mainly by calcium carbonate, were also highest at pH 5.5. The higher hardness may have been caused by calcium leaching from the bones of the bluegill. Beamish theorized that the occurrence of spinal deformities of fish in acidic waters was the result of demineralization of bones [1]. This condition is referred to as acidemia. In this process, calcium carbonate is withdrawn from the bones and enters the blood stream, where it acts as a buffer. In bluegills, calcium is stored in the bones as well as in the blood. When the buffering capacity of the ambient water is exhausted, hydrogen ions may enter the bluegill's body fluid. The calcium carbonate stored in the body may then be utilized to buffer the acidic fluids. Under prolonged exposure to an acidic environment, the buffering capacity of the blood might be exhausted, thus depleting the ca1cium carbonate reserves of the bone. This may not only contribute to the increase of hardness in the water, but may also effect the mortality of the fish.

Since the above parameters indicate no adverse conditions, the high mortality and significantly lower gains in length and weight of fish at pH 5.5 were apparently related to high hydrogen ion concentrations. Lowering pH from 7.5 to 6.5 had little effect of mortality and growth of fish. A significant difference appears when the pH level is reduced to pH 5.5.

References

1. BAKER et al. Acid lakes and streams in the United States; the role of acid deposition. Science **252**, 1151, **1991**
2. BEAMISH. R. J. Growth and survival of white suckers in an acidified lake. J. Fish. Res. Board Can. **31**, 49, **1972**
3. FROMM. P. O. A review of some physiological and toxicological responses of freshwater fish to acid stress. Env. Biol. Fish **5**, 79, **1980**
4. HILL J., FOLEY R. E., BLAZER V. S., WERNER R. G. and GAIRMON J. E. Effects of acidic water on young-of-the-year smallmouth bass (*Microoterus dolomeiui*). Env. Biology of Fishes **21** (3), 223, **1988**
5. MURAD and BOYD. Production of sunfish (*Leopomis spp.*) and channel catfish (*Iictalurus punctatus*) in acidified ponds. Aquaculture **94** (4), 381, **1991**
6. STALLSMITH et al. The effect of acid episodes on lepomis sunfish recruitement and growth in two ponds in Massachusetts, USA Freshwater Biology **36**, 731, **1996**
7. JARRETT at al. Seasonal variation in pH and alkalinity and recruitment of sunfish populations. Freshwater Biology **30**, 409, **1993**
8. COCHRAN A. and ADELMAN I. R. Seasonal aspect of daily rotation and diet of Largemounth bass. Micropterus salmonides, with an evoluation of gastric evacuation rates. Envir. Biology Fish **3**, 265, **1982**
9. KLEEREKOPER K. Effects of sublethal concentrations of pollutants on the behavior of fish. J. Fish. Res. Board Can. **33**, 2036, **1976**
10. LEIVESTAD, H. Physiologial effects of acid stress on fish. In: R. E. Johnson (ed.) Acid rain fisheries. Proc. Int. Symp. Acid Precip. and Fish Impacts in N. E. N. Amer., Amer. Fish. Soc., Bethesda. pp. 157- 164, **1982**
11. MACFARLANE R. B. and LINGSTON R. J. Effects of acidified water on the locomotor behavior of the gulf killifish. Fundulus grandis a time series approach. Arch. Environ. Contam. Toxicol. **12**, 163, **1983**
12. ROUNSELFELL G. A. and EVERHART W. H. Fishery science, its methods and applications. New York.. John Wi1ey and Sons, pp. 444. 13. U. S. Environmental Protection Agency. 1976. Quality criteria for water. Washington, D. C. 20460 pp. 256, **1953**.
13. NOBLE T. H. Effects of nitric and sulfuric -nitric acid solutions on mortality and development of Aedes triseriatus mosquito larvae and pupae. M. S. Thesis, Ball State University. pp. 34, **1986**
14. ORSATTI S. D. and COLGAN P. W. Effects of sulfuric acid exposure on the behavior of largemouth bass, Micropterus salmoides. Env. Biol. Fish. **19**, 119, **1987**
15. PALMER R. E., KLAUDA R. J. and LEWIS T. E. Comparative sensitivity of bluegill, channel catfish and fathead minnows to pH and aluminum. Env. Tox. and Chem. **7**, 505, **1988**
16. U. S. Environmental Protection Agency. Acid rain. Publication No. 60019-73-036. Government Printing Office. Washington, D. C. p. 36, **1980**