Survival of Adult, Florida and Northern Largemouth Bass Subjected to Cold Temperature Regimes

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Abstract: Adult Florida (*Micropterus salmoides floridanus*) and northern (*M. s. salmoides*) largemouth bass were subjected in the laboratory to low water temperature regimes similar to those occurring on Texas hatcheries. Northern largemouth bass survived all temperature regimes experienced. Florida largemouth bass suffered mortality that increased as temperature decline rate (1, 2, and 4 C/day) increased. They survived prolonged exposure (30 days) at 4 C well, but total mortality occurred at 3 and 2 C. Northern largemouth bass were more tolerant than Florida largemouth bass of rapid temperature decreases and low temperatures.

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Florida largemouth bass (FLMB) are being reared on several Texas state fish hatcheries for introduction into public reservoirs. However, concern was created during the severe winter of 1977–78 by heavy winter mortality of FLMB broodstock. Water temperatures at these hatcheries decreased rapidly on several occasions; surface temperatures reached 0 C, and this condition persisted for several days.

Other attempts to rear FLMB in ponds outside their native range have resulted in poor overwinter survival (Graham 1973, Stevenson 1973, Johnson 1975, Latta 1977). However, this mortality is difficult to explain because laboratory studies comparing the lower temperature tolerances of FLMB and northern largemouth bass (NLMB) are contradictory. Hart (1952) found the lower incipient lethal temperature for FLMB and NLMB acclimated at 20 C to be 5.2 and 5.5 C, respectively; Cichra et al. (1980) estimated the 96-hour median tolerance limit of the 2 fishes acclimated at 21 C was about 8.5 and 6.0 C, respectively. Johnson (1975) also noted FLMB were less tolerant of low water temperatures when both subspecies were acclimated to 15 C and subjected to a 1-C/day decline. Several authors (Brett 1956, Coutant et al. 1974, Coutant 1975) have hypothesized that a fast rate of temperature change can cause mortalities even at temperatures within the tolerable range of a species by outstripping the ability of fish to acclimate.

Critical water temperatures for largemouth bass survival have not been completely defined and little is known concerning the effects of rapid temperature change. This study was conducted to evaluate survival of adult FLMB and NLMB exposed to 1) temperature declines similar to those occurring on Texas hatcheries and 2) prolonged low temperatures.

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Methods

Two laboratory experiments were conducted to determine the temperature tolerances of adult FLMB and NLMB. Test fishes were collected by electrofishing and/or angling from reservoirs where only 1 subspecies was known to exist. These fishes were transported to Heart of the Hills Research Station, Kerr County, Texas and maintained in ponds.

Fishes were held in 700-liter tanks where water temperatures were thermostatically controlled with heaters and chillers during experimentation. Temperature regimes were maintained by electrically timed, gear-driven thermoregulators (modified from Abell et al. 1977). Due to the antagonistic behavior of test fish, tanks were partitioned to separate fish individually. Partitioning limited sample size to 8 fish (4 of each subspecies) per tank. Replicate tanks were used for each test, but due to tank availability replicates were sometimes run in different months (Table 1). One tank of fishes was maintained at acclimation as a control for each test.

Water temperatures were adjusted at a rate of 1 C/day from ambient to 10 C during the acclimation process. Fishes were maintained at acclimation for a minimum of 2 weeks before testing. Lighting was regulated with timers to provide a 12-hour photoperiod. Fishes were fed live flathead minnows (*Pimephales promelas*) and goldfish (*Carassius auratus*) during acclimation and testing.

In the first experiment (4 tests), fishes were exposed to temperature declines similar to those occurring on Texas state fish hatcheries. Morning surface water temperature data from these hatcheries revealed a 1-2 C/day decrease was typical during winter months, and a 4 C/day decrease was the

Table 1. Cumulative Percentage Mortalities (Replicates Combined) of Adult Florida (FLMB) and Northern (NLMB) Largemouth Bass Acclimated at 10.0 C and Subjected to Different Temperature Declines, then Held at 4.0 C for 30 Days (SE Given with Lengths and Weights)

Subspecies	Size TL (mm)	Size Wt (g)	N	Test Month(s) (yr)	Pre-acclimation[a] Temperature(s) (C)	Temperature Decline Date	Cumulative Percentage Mortality, Days 7	14	21	30
NLMB	348 ± 25	646 ± 116	8	Apr,Dec			0	0	0	0
FLMB	323 ± 21	510 ± 94	8	('79)	17.9,14.9	1 C/day	0	0	0	13(25)[c]
NLMB	335 ± 18	556 ± 101	8	Apr,Dec			0	0	0	0
FLMB	313 ± 17	500 ± 98	8	('79)	17.9,14.9	2 C/day	0	0	0	38(23,30)[c,d]
NLMB	346 ± 25	662 ± 117	8	Apr,Dec			0	0	0	0
FLMB	343 ± 14	609 ± 88	8	('79)	17.9,14.9	4 C/day	0	0	25(19)[c]	38(24)[d]
NLMB	377 ± 11	780 ± 85	8	Feb			0	0	0	0
FLMB	365 ± 13	713 ± 68	8	('80)	13.6	Lewisville[b]	0	0	13(16)[c]	50(25)[d]

[a] Mean water temperatures for a 1-month period before testing.
[b] Fish subjected to a temperature decline simulating that occurring in a pond at the Lewisville State Fish Hatchery on 29 December 1978. This included a temperature decrease of 2 C/day down to 1.5 C (held constant for 12 hours), then warmed to 4.0 C (2 C/day).
[c] Day first fish died.
[d] Day last fish died.

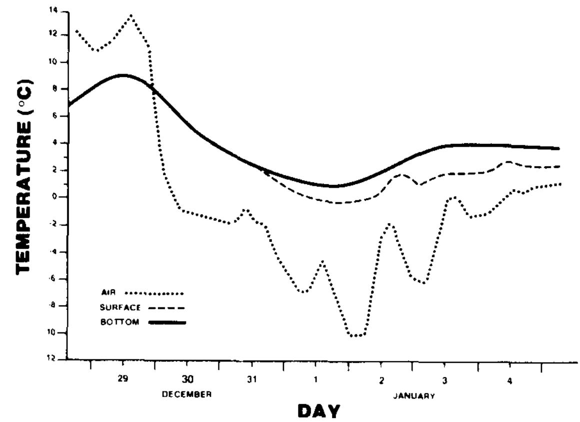

Figure 1. Surface and bottom water temperatures from a pond on Lewisville State Fish Hatchery, 29 December 1978 through 4 January 1979. Air temperature data were recorded at the Dallas-Fort Worth Regional Airport.

most severe. In the first 3 tests of the experiment, both subspecies were subjected to temperature declines of 1, 2 and 4 C/day from 10 to 4 C. Fishes were held at 4 C for 30 days and survival determined. The 4-C holding temperature was chosen because pond bottom water temperatures were not known and it was assumed that they did not decline below this level. The fourth test used a temperature decline based on bottom water temperature data from the Lewisville State Fish Hatchery, Denton County, Texas, where FLMB mortalities occur. A thermograph was placed in a pond during the 1978–79 winter to continuously record surface and bottom pond water temperatures. On 29 December 1978, a cold front caused water temperatures to decline rapidly (Fig. 1) and adult FLMB died several days later. The bottom water decline rate was simulated in the laboratory by lowering water temperatures from 10.0 C to 1.5 C (2 C/day), holding for 12 hours, then warming to 4.0 C (2 C/day). FLMB and NLMB were observed for the subsequent 30 days and mortalities recorded.

In the second experiment (3 tests), both subspecies were subjected to constant low temperatures of 3, 2 and 1 C for 30 days to determine approximate ultimate lower lethal temperatures as defined by Fry et al. (1946). Water temperatures were decreased from acclimation 1 C/day to the test temperature, and fish mortalities observed. Mortalities for the 1 C/day temperature decline to 4 C observed in experiment 1 were incorporated into the statistical analysis of this experiment.

Replicate tests were combined for analyses. Mortality data for each subspecies were grouped at weekly intervals, and effects of temperature decline rates and constant low temperatures on mortality were analyzed with 3-way tests of independence (*G*-tests).

Results

No mortalities occurred in control tanks during testing. In the first experiment, NLMB survived all temperature regimes experienced for the 30-day exposure at 4 C (Table 1). FLMB mortalities appeared to increase over time as the rate of temperature decline increased from 1 to 4 C/day, but a statistical difference ($P < 0.05$) was not found with this study's sample size ($G = 3.49$, df = 2). FLMB subjected to the "Lewisville" decline regime reacted similarly to those exposed to the 4 C/day regime. In all tests, FLMB mortalities were delayed at least 14 days or more after temperatures stabilized at 4 C.

NLMB survived exposure to all constant low temperatures tested in the second experiment (Table 2). FLMB were less tolerant of low water temperatures than NLMB. They survived well at 4.0 C, but all fish held at 3 and 2 C for 30 days died. FLMB appeared to exhibit slower mortality over time at 2 C than 3 C, but a significant difference ($P < 0.05$) could not be detected ($G = 1.93$, df = 1). Forty percent of the FLMB exposed to 1 C died; however, this test was terminated after 7 days due to equipment failure. These results suggest that the ultimate lower lethal temperature for adult FLMB is between 3 and 4 C, while NLMB can survive temperatures of 2 C or below for extended periods.

Discussion

The determination that FLMB are less tolerant of cold water temperatures than NLMB is consistent with recent laboratory studies (Johnson 1975, Nieman 1978, Cichra et al. 1980). However, mortalities of both subspecies in the present study differed from those found in a similar study. Johnson (1975) exposed FLMB and NLMB to a 1 C/day decrease, and all FLMB and 14% of the NLMB died within 3 days after exposure to 4 C which is considerably different from present findings (Table 1). Seasonal differences may have caused this discrepancy, as Johnson's tests were conducted in the fall and present tests during winter and spring months. Seasonal differences in lethal temperature responses have been noted by Hart (1952) and Fry (1967).

FLMB mortalities in Lewisville ponds also occurred a few days after the severe temperature decline described in Fig. 1. These fish could have been numbed by the rapid temperature change and unable to detect 4-C

Table 2. Mean Exposure Temperatures and Cumulative Percentage Mortalities (Replicates Combined) of Adult Florida (FLMB) and Northern (NLMB) Largemouth Bass Acclimated at 10.0 C and Subjected to a 1 C/day Temperature Decrease to Various Exposure Temperatures Where They Were Held for 30 Days (SE Given with Lengths, Weights and Mean Exposure Temperatures

Subspecies	Size		N	Test Month(s) (yr)	Pre-acclimation Temperature(s)[a] (C)	Mean Exposure Temperature (C)	Cumulative Percentage Mortality Days			
	TL (mm)	Wt (g)					7	14	21	30
NLMB	348 ± 25	646 ± 116	8	Apr,Dec			0	0	0	0
FLMB	323 ± 21	510 ± 94	8	('79)	17.9,14.9	4.0 ± 0.0[b]	0	0	0	13(25)[d]
NLMB	376 ± 20	806 ± 129	7	Dec			0	0	0	0
FLMB	372 ± 14	749 ± 88	8	('79)	14.9	2.9 ± 0.1	0	13(11)[d]	50	100(23)[e]
NLMB	400 ± 14	932 ± 91	7	Feb			0	0	0	0
FLMB	404 ± 6	985 ± 34	8	('80)	13.6	2.0 ± 0.1	0	0	63(17)[d]	100(30)[e]
NLMB	363 ± 13	682 ± 36	8	Dec			0[c]			
FLMB	352 ± 13	624 ± 79	5	('78)	17.4	0.8 ± 0.0	40(1)[d](3)[e]			

[a] Mean water temperatures for a 1-month period before testing.
[b] Data taken from Table 1.
[c] Test terminated after 7 days due to equipment failure.
[d] Day first fish died.
[e] Day last fish died.

water, and therefore, subjected themselves to colder surface water temperatures which hastened death. This type phenomenon, termed "low thermal responsiveness," was described by Beitinger and Magnuson (1976).

Prolonged exposure to low temperatures appeared to be more critical to FLMB survival than rate of temperature change. Mortalities occurred more quickly when FLMB were exposed to constant low water temperatures (Table 2) than when the temperature decline was rapid (Table 1). In the decline rate experiment, fish exposed to temperatures below 4 C ("Lewisville" test) died quicker than others regardless of decline rate. Griffith (1978) also has observed for threadfin shad (*Dorosoma pentenense*) minimum exposure temperatures to be more critical than decline rate.

Temperatures $\leq$ 4 C seldom occur for prolonged periods in most southern reservoirs, but rapid declines and prolonged exposure to $\leq$ 4 C are common in ponds of this region. When these lower temperature conditions persist, substantial FLMB mortalities can be expected.

Literature Cited

Abell, P. R., L. B. Richardson, and D. T. Burton. 1977. Electronic controller for producing cyclic temperatures in aquatic studies. Prog. Fish-Cult. 39:140–141.

Beitinger, T. L., and J. J. Magnuson. 1976. Low thermal responsiveness in the bluegill, *Lepomis macrochirus*. J. Fish Res. Board Can. 33:293–295.

Brett, J. R. 1956. Some principles in the thermal requirements of fish. Q. Rev. Biol. 31:75–87.

Cichra, C. E., W. H. Neill, and R. L. Noble. 1980. Differential resistance of northern and Florida largemouth bass to cold shock. Proc. Annu. Conf. Southeast. Assoc. Fish & Wildl. Agencies 34:19–24.

Coutant, C. C. 1975. Responses of bass to natural and artificial temperature regimes. Pages 272–285 *in* H. E. Clepper and R. H. Stroud, eds. Black bass biology and management. Sport Fishing Inst., Wash., D.C.

———, H. M. Ducharme, Jr., and J. R. Fisher. 1974. Effects of cold shock on vulnerability of juvenile channel catfish (*Ictalurus punctatus*) and largemouth bass (*Micropterus salmoides*) to predation. J. Fish Res. Board Can. 31:351–354.

Fry, F. E. J. 1967. Responses of vertebrate poikilotherms to temperature. Pages 375–409 *in* A. H. Rose, ed. Thermobiology. Academic Press.

———, J. S. Hart, and K. F. Walker. 1946. Lethal temperature relations for a sample of young speckled trout, *Salvelinus fontinalis*. Univ. Toronto Stud., Biol. Ser. 54, Publ. Ontario Fisheries Res. Lab. 66:9–35.

Graham, L. K. 1973. The introduction of Florida largemouth bass in Missouri ponds. Missouri Dept. Conserv. Proj. F-1-R-22, Study No. 1-14, Job No. 2. 6pp.

Griffith, J. S. 1978. Effects of low temperature on the survival and behavior of threadfin shad, *Dorosoma petenense*. Trans. Am. Fish. Soc. 107:63–70.

Hart, J. S. 1952. Geographic variations of some physiological and morphological characters in certain freshwater fish. Publ. Ont. Fish Res. Lab. LXXII: 79pp.

Johnson, D. L. 1975. A comparison of Florida and northern largemouth bass in Missouri. Ph.D. Diss., Univ. Mo. at Columbia. 111pp.

Latta, W. C. 1977. Survival and growth of Florida largemouth bass in ponds and lakes in Michigan. Mich. Dept. Nat. Res. Proj. F-35-R-3, Study No. 27. 14pp.

Nieman, D. A. 1978. Some aspects of the ecology of Florida and northern largemouth bass in a thermally enriched reservoir. M.S. Thesis. Okla. State Univ., Stillwater. 97pp.

Stevenson, F. 1973. A preliminary evaluation of a Florida strain of largemouth bass, *Micropterus salmoides floridanus*, in Ohio ponds. Ohio Dept. Nat. Res. Proj. F-29-R-13, Job No. VI-C, Final Rep. 7pp.