DIFFERENTIAL RESISTANCE OF NORTHERN AND FLORIDA LARGEMOUTH BASS TO COLD SHOCK

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Abstract: Texas stocks of northern and Florida largemouth bass *(Micropterus salmoides salmoides* and *M. s. floridanus)* were compared for resistance to cold shock. The 45 advanced fingerlings of each subspecies had nearly identical rearing histories and were acclimated to a common temperature near 21 C. Laboratory tests were conducted at constant temperatures ranging from 5.3 to 13.5 C. Over all tests, more than twice as many Florida bass as northern bass died during the 7 days of observation. We estimated that the 96-h median tolerance limit was about 6 C for northern bass and about 8.5 C for the Florida bass. These findings are consistent with the hypothesis that Florida bass stocked outside their original range may suffer higher overwinter mortality, owing to lesser cold tolerance, than native northern bass.

Proc. Ann. Conf. S.E. Assoc. Fish & Wildl. Agencies 34:19-24

Bailey and Hubbs (1949) confirmed that the largemouth bass is comprised of two distinct but closely related subspecies, the northern largemouth bass and the Florida largemouth bass. Florida largemouth bass obtain larger maximum size (Chew 1975), live longer (Bottroff 1967), are more difficult to catch (Stevenson 1973), and spawn earlier in life (Clugston 1964, 1966) than the northern subspecies. These characteristics have aroused much interest in the use of the Florida largemouth bass in fisheries management (Chew 1975, Inman 1974).

The northern largemouth bass is endemic to southeastern Canada, northeastern Mexico, and the eastern half of the United States, except for New England and the peninsula of Florida (Trautman 1957). The Florida largemouth bass is endemic to the peninsula of Florida and occurs northward to the St. Johns River in the east and to, but not including, the Suwannee River system in the west (McLane 1948). In areas further north, natural intergrades occur between the northern and Florida subspecies (Bailey and Hubbs 1949).

Since 1959, Florida largemouth bass have been introduced throughout the more temperate United States, including California (Sasaki 1961, Smith 1971), Alabama (Addison and Spencer 1972), Arkansas (Buchanan 1973), Ohio (Stevenson 1973), Missouri (Graham 1973), Oklahoma (Rieger and Summerfelt 1976), and Texas (Noble et al. 1975). Some of these introductions have been unsuccessful, possibly related to apparent inadequate cold tolerance of the Florida subspecies. Stevenson (1973) reported high overwinter mortality of Florida largemouth bass in Ohio ponds. Florida largemouth bass survival was lower than that of the northern subspecies in Missouri ponds (Graham 1973) and in Boomer Lake, Oklahoma (Rieger and Summerfelt 1976). During 1977/78, Texas experienced one of the coldest winters on record. Mortality claimed at least one-third the estimated number of adult Florida largemouth bass in the water-supply reservoir at Texas A&M University's Aquaculture Research Center, but there was no apparent die-off of native bass in nearby ponds.

Despite these observations, there still exists the possibility that differential winter mortality of the two subspecies is related not to differences in cold tolerance *per se*, but rather to a difference in thermal acclimation state attributable to differing patterns of distribution during winter. In Boomer Lake, Oklahoma, young-of-the-year Florida largemouth bass were never found in water cooler than 9.5° C if warmer water was available. The northern subspecies showed no such avoidance of lower temperatures (Rieger and Summerfelt 1976). In Trinidad Lake, Texas, northern largemouth bass were distributed uniformly in the lake throughout the year, but Florida largemouth bass tended to concentrate during winter in parts of the lake warmed by effluent from a power plant (Hall 1977).

Both subspecies of largemouth bass are cultured at San Marcos, Texas, by the U.S. Fish and Wildlife Service in raceways supplied with ground-water from springs; raceway temperatures are $21 \pm 1°$ C throughout the year. The proximate motive for the present study was our concern that these 21 ° C-acclimated fish—especially those of the Florida subspecies—might die of thermal shock when stocked into relatively cold Texas ponds and reservoirs during late fall and early spring. Our specific objective was to determine and compare cold-shock resistances of the two subspecies of largemouth bass reared under nearly identical conditions and acclimated to a temperature near 21° C. To accomplish this objective, we measured survival times of San Marcos fish transferred to various constant temperatures between 5.3 and 13.5° C.

We thank personnel of the U.S. Fish and Wildlife Service, Fish Cultural Development Center at San Marcos, Texas, for kindly donating the fish used in this study. We are also grateful for the help of W. Clell Guest of the Texas Parks and Wildlife Department; Clell provided useful information and constructive comments on the manuscript. This study was conducted as a part of Texas Agricultural Experiment Station projects H-6295 and S-6206.

METHODS

Fish

Yearling Florida and northern largemouth bass, 45 of each subspecies, were obtained from captive stocks of the U.S. Fish and Wildlife Service at San Marcos, Texas. Fish of the 2 subspecies had been reared on "Oregon-Moist" pellets in adjacent spring-fed raceways that flow year-round at 21 ± 1 ° C. Florida bass had a mean weight of 51.5 g (range 21.5 - 103.1 g) and mean total length of 162 mm (range 126 - 196 mm). Northern bass averaged 66.4 g (range 38.8 - 96.6 g) and 174 mm (range 150 - 198 mm).

All fish were removed from raceways on 29 March 1978, transported in aerated tanks to the Texas A&M University campus, and held for 3 days within raceway-temperature limits. The 2 subspecies were kept in separate 190-liter holding tanks. The water was well aerated; one-third was replaced daily with dechlorinated tap water. The fish were not fed. No mortalities occurred during transport or holding.

Apparatus

White polyethylene pails, each 20 liters in volume, served as baths for cold-resistance tests. Each pail contained 17.5 liters of water. One-third of the water was replaced daily with dechlorinated tap water of the same temperature. An airstone in each pail maintained dissolved oxygen near air-saturation and prevented temperature stratification. Pails were covered individually with tan polyethylene film, punched randomly with several 6 mm diameter holes. Covering the pails reduced evaporative loss of water, helped maintain constant low water temperatures, and prevented escape of jumping fish.

Test temperatures were achieved by partial immersion of the 15 pails (in 3 rows of 5 each) to various levels in a rectangular cooling tank. Wooden blocks of varying thickness were placed under the pails to support them at the levels necessary to obtain the desired test temperatures. Lowest temperatures were achieved by setting the pails directly on the bottom of the tank in 22.5 cm of water. Highest test temperatures were achieved by setting the pails only 1 to 3 cm into the tank.

Water in the 91 x 167 cm cooling tank was kept at 4.6 $\pm$ 0.1° C by a 1/3 H.P. Neslab recirculating cooler. Aeration enhanced the circulation required for maintenance of uniform temperature. The tank walls were insulated with expanded polystyrene of 19 mm thickness. Two additional layers of this material were placed between the pails at the surface of the water in the tank. A sheet of polyethylene film was added over the insulation to reduce evaporative water loss from the tank.

Procedure

Six fish, 3 of each subspecies, were netted from the holding tanks and placed immediately into a pail at one of the test-temperatures. This process was repeated until all 15 pails contained fish. The fish were observed over the next 7 days. Observations were made continually for the first 2 days when most deaths occurred, then less frequently (abou' every 2 to 6 hours) for the remainder of the experiment. Estimated time of death for each fish was recorded. Criteria for death included body stiffness, light skin color, blanched gills, and lack of opercular movement. Dead fish were removed, weighed, measured, and assigned to subspecies on the basis of lateral-line-scale count.

Because temperature fluctuated somewhat in each pail, a mean temperature of exposure was calculated for each fish by dividing the total number of degree-minutes that the fish endured (calculated from the transfer time, estimated time of death, and temperature records for the individual pails) by the number of minutes elapsed before death.

Temperatures were measured with a digital electronic thermometer, accurate to $\pm$0.1° C. The experiment was conducted under constant light from overhead fluorescent lamps. The fish were not fed during the experiment.

RESULTS

Mean bath temperatures ranged from 5.3 to 13.5° C (Fig. 1). Temperature variation within any pail was small, with the highest standard deviation for any one pail during the 7-day experiment being 0.32° C. Temperature variation was greatest for the warmest baths, which were most exposed to fluctuating room temperatures. Temperature within any pail was uniform from surface to bottom.

As soon as the fish were put into the baths, they became frantic, darting about for several seconds; then, they lapsed into torpor. Almost all fish underwent a loss of equilibrium; but, after 2 to 4 hours, most regained their normal, upright attitude. Upon introduction of fish, bath temperatures increased by 0.1 to 0.3° C, but returned to their nominal values within 2 hours.

No fish died during the first 5 hours; 42 of the 90 bass were dead at 7 days (Fig. 1). At every temperature at which fish died, individuals of the Florida subspecies were first to die. Survival was higher for both subspecies at higher test temperatures. In the 5.3 to 5.9° C range, 18 Florida and 11 northern bass died of the 36 tested (18 of each subspecies). Nine Florida and 2 northern bass died when tested in the 7.7 to 8.4° C range; within this range, 15 of each subspecies were tested. Only 2 deaths occurred among the 24 bass tested in the 9.8 to 13.5° C range; both were Florida bass.

Over all tests, more than twice as many Florida bass (29) died as did northern bass (13) during the 7 days of observation. The proportions of Florida bass and northern bass that died were significantly different ($P < 0.01$, Kolmogorov-Smirnov two-sample test; Siegel 1956). For these bass, acclimated at 21 ° C, we estimated by computerized probit analysis (Barr et al. 1976) that the 96-hr median tolerance limit was about 6° C for the northern subspecies and about 8.5° C for the Florida subspecies.

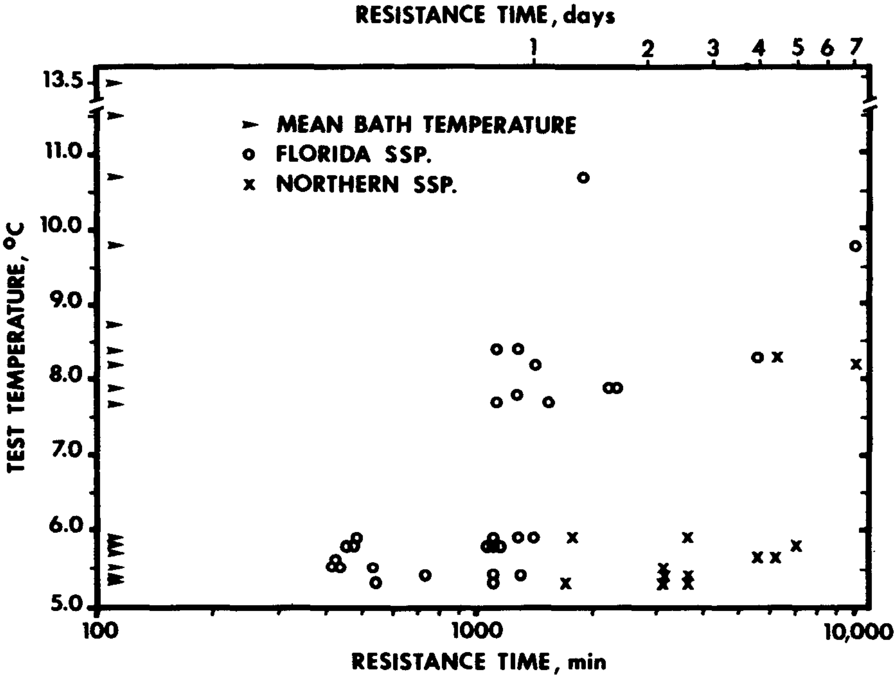

Fig. 1. Comparative lethal-resistance times of 21° C-acclimated Florida and northern largemouth bass subjected to cold shock. A paired test, involving 3 fish of each subspecies, was performed at each mean bath temperature indicated along the vertical axis.

Data from fish that died were subjected to computerized multiple regression analysis (Barr et al. 1976). The full model included the logarithm of resistance time as the dependent variable and subspecies, bath temperature, and individual fish weight as the independent variables. Statistical analysis confirmed that, for fish dying within 7 days, Florida bass died at any particular temperature before northern bass ($P < 0.0001$) and that resistance time increased as temperature increased ($P < 0.0001$). Weight had no significant effect ($P > 0.10$).

DISCUSSION

Our study provides additional evidence that the Florida largemouth bass is less cold tolerant than its northern counterpart, at least when both are acclimated to a common temperature near 21° C.

The experimental design admitted only slight probability that the outcome reflected environmental rather than genetic differences between representatives of the 2 subspecies. All fish had environmental histories, from about 3 weeks of age to the conclusion of lethal-temperature tests, that were nearly identical in every respect. Thus, we were able to avoid the complications that have weakened the conclusions of other similar studies.

Our results are consistent with those of Johnson (1975), but not with those of Hart (1952). Johnson, working with largemouth bass averaging 280 mm in length and "acclimated" to 21° C for 48 h, monitored the fish for 7 days after water temperature declined from 21° C to 4° C in 12 h, thereafter remaining at 4° C. Only 1 of 6 northern bass died, while all 6 Florida bass died. In a second experiment, Johnson acclimated 20 individuals of each subspecies, averaging 203 mm in length, to 15° C for 2 weeks. Temperature was then reduced about 1° C per day until 4° C was reached; 4° C was maintained for 5 additional days. At termination of the experiment, all Florida bass but only 3 northern bass were dead.

For fish acclimated to either 20° C or 30° C, Hart (1952) found that Florida bass tested at Welaka, Florida, were slightly more cold tolerant than northern bass tested at Put-in-Bay, Ontario. Florida bass from Welaka also were less heat tolerant than northern bass from either Ontario or Tennessee. Hart's results may have been influenced by the effects of seasonal and water-quality differences among sites and experiments.

We think it likely that high overwinter mortality among transplanted Florida bass is largely attributable to this subspecies' inadequate cold tolerance. But, before one can project the likelihood that Florida bass will successfully overwinter in a given reservoir or pond, much more extensive experimentation will be required. Rate of seasonal temperature-decline and fish size may be of particular importance, judging by preliminary results of research now underway at Texas Parks and Wildlife Department's Heart of the Hills Research Station (W. Clell Guest, pers. comm.). Also crucial for development of predictive capability is better information on the role of temperature preference in the within-habitat distribution of Florida largemouth bass during winter.

Neither bass subspecies, when acclimated to temperatures near 20° C, should be stocked during periods when low water-temperatures are likely to cause severe cold stress. If 20° C-acclimated northern and Florida largemouth bass must be stocked at temperatures below about 10 and 14° C, respectively, we suggest that the fish first be held at an intermediate temperature for at least 1 week so that some downward thermal acclimation can occur.

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