EFFECTS OF TEMPERATURE ON SURVIVAL OF PEACOCK BASS FINGERLINGS

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Abstract: Effects of temperature on survival of peacock bass (*Cichla ocellaris*) fingerlings were examined in the laboratory. Fish were acclimated to 25, 30 or 35 C prior to testing. The ultimate lower and upper lethal temperatures in freshwater were 15.6 and 37.9 C when the temperature change from acclimation was 1 C/day. Salinity (10°/oo) significantly reduced ($P<0.05$) the ultimate lower lethal temperature to 14.4 C. Acclimation temperature significantly affected the temperature at which peacock bass began losing equilibrium (LE_{50}) and dying (CTMin) when fish were exposed to a 1 C/h decrease. LE_{50}'s for the 35, 30 and 25 C acclimation temperatues were 18.9, 16.2 and 14.5 C, respectively. When fish were transferred abruptly from acclimation to 20, 15 and 10 C, median resistance times were longer when there was less difference between acclimation and test temperatures.

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Texas has 41 reservoirs used as cooling lakes for electro-power plants, and more are planned to meet future demands. Some of these reservoirs maintain nearly tropical water temperatures during the entire year (Smith 1971; Hodson 1973), and may require special management strategies to provide quality sport fisheries. The introduction of tropical predators could improve angling success by providing new species for sport fish harvest, and spreading fishing pressure to an additional predator fish.

Peacock bass was one tropical predator selected by the Texas Parks and Wildlife Department for possible introduction into cooling reservoirs. This decision was made after a world-wide survey of fishery scientists was conducted to identify predators most likely to control rough fishes (Thompson et al. 1977). However, before introducing any exotic fish, the environmental requisites of the fish should be investigated to determine the potential habitat range of the exotic if it proves detrimental to indigenous fishes. This paper reports the effects of temperature on the survival of peacock bass in the laboratory.

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METHODS

Peacock bass fingerlings (85-140 mm total length) were seined from a pond at Heart of the Hills Research Station, Kerr County, Texas during August and September 1977. Fish were maintained indoors in 400 or 1500 liter holding tanks receiving a continuous flow of aerated spring water. Laboratory lighting was regulated with timers to provide a 12-h photoperiod. Fish were fed live fathead minnows (*Pimephales promelas*) daily and tanks were cleaned as needed. Holding mortality was negligible.

Three experiments were conducted to determine the temperature tolerances of peacock bass fingerlings. The first experiment was to determine the ultimate lower and upper lethal temperature as defined by Otto and Rice (1977), and the effect of salinity on

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the ultimate lower lethal temperature. The other 2 experiments were designed to determine effects of gradual and abrupt temperature decreases on fish survival.

In all experiments, fish were acclimated to 25, 30 or 35 C. Fish were acclimted in 18 liter aerated aquaria held in 700 liter water baths. Water temperature in each bath was thermostatically controlled with a heater and a chiller. Two test aquaria and 1 control aquarium, each containing 4 fish, were used for each acclimation temperature in each experiment. Small sample sizes were necessary because of difficulty in providing suitable sized live prey for large numbers of fish. During the acclimation process, water temperatures were raised from an ambient temperature of 22 ± 1 C to acclimation at a rate of 1 C/day. Fish were held a minimum of 2 wk at acclimation before testing. Fish were fed daily during acclimation and testing and aquaria were cleaned daily.

The first experiment determined ultimate lower and upper lethal temperatures in freshwater through adjustments from acclimation at the rate of 1 C/day. The temperature at which fish stopped feeding was noted and number surviving was recorded daily. The temperature at which 50% of the fish had died ws determined by regression analysis (arcsine transformation was made on all percentage data) for determination of the ultimate lower or upper lethal temperatures.

The effect of 2 and 10°/oo salinity on the ultimate lower lethal temperature of peacock bass was also examined in this experiment. A salinity of 2°/oo was tested because a candidate reservoir for their possible introduction has this salinity. The authors determined the upper salinity tolerance of peacock bass held at 25 ± 1 C to be 18 ± 0.2 °/oo when salinity was increased 1 °/oo/day. Therefore 10 °/oo salinity was also tested to examine the effects of a higher salinity on their temperature tolerance. Fish were acclimated to each salinity by adding synthetic sea salts (Aquarium Systems Inc., Eastlake, Ohio) to aquaria at a rate which increased salinity 1 °/oo/day. Once acclimated the fish were subjected to the 1 C/day temperature decline. A two-factorial analysis of variance test (Sokal and Rohlf 1969) was used to analyze the results.

The second experiment determined the effect of a gradual temperature decline (1 C/h) on fish survival. Temperatures at which fish began losing equilibrium and died were determined by continuous observation. Regression analyses were used to calculate the temperature at which 50% of the fish had lost equilibrium (LE_{50}) and died (critical thermal minimum; or CTMin). Covariance analyses were used to examine the effect of acclimation temperature on LE_{50} and CTMin values.

The third experiment examined the effect of an abrupt temperature decline on peacock bass survival. Fish were transferred from acclimation to test temperatures of 20, 15 and 10 C. Fish were observed and times of death recorded continuously for the first 6 hours, then twice daily for the next 3 days. Mortality was indicated when respiration ceased; however, time of death was difficult to determine at 10 and 15 C because respiratory movements were greatly reduced at those temperatures. At low temperatures, fish thought to be dead were transferred to water at acclimation; if respiration resumed within 1 min fish were returned to the test temperature. Median resistance times for each acclimation-test temperature were estimated graphically by converting mortality data into probits and survival time into logrithms. All statistical evaluations were tested at the 0.05 significance level.

RESULTS

In the first experiment, no mortalities occurred in controls; there was no difference in mortalities between replicates and acclimation temperatures had no significant effect on lethal temperatures so they were combined to compute ultimate lethal temperatures.

As temperature decreased, reduced feeding was noted at 18.0 C; feeding ceased below 17.0 C in freshwater tests. Fish began dying at 16.0 C and all fish were dead at 15.0 C (Fig. 1). The ultimate lower lethal temperature was calculated to be 15.6 C. As the temperature

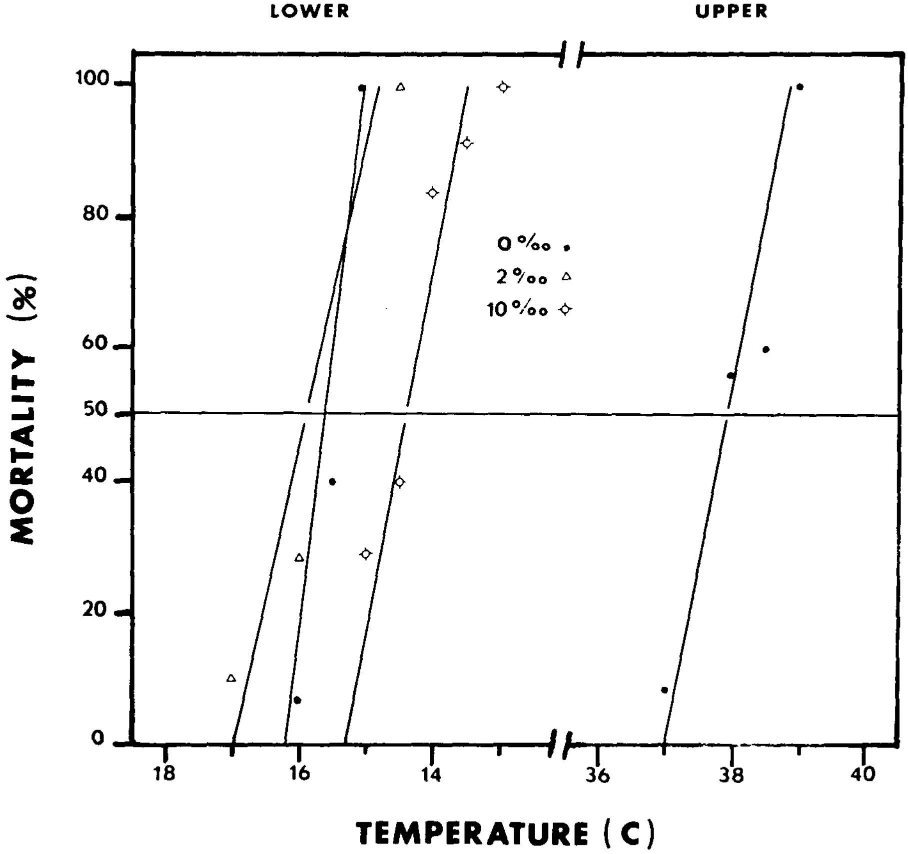

Fig. 1. Graph of temperature vs. cumulative mortality for peacock bass fingerlings exposed to 1 C/day temperature changes while being held in 0, 2 and 10 °/oo salinities. Regression lines used to determine ultimate lethal temperatures are all significant (P<0.05) and are superimposed on data for each salinity.

was increased, fish began dying at 37.0 and all had died at 39.0 C. Fish still alive between 37.0 and 39.0 C continued to feed until losing equilibrium and died shortly thereafter. The calculated ultimate upper lethal temperature was 37.9 C (Fig. 1).

Salinity had a significant effect on survival at low temperatures (Table 1). Fish at 10 °/oo salinity began dying at 15.0 C, but some survived to 13.5 C (Fig. 1). Survival of fish in 2 °/oo salinity was not appreciably different from that of fish held in fresh water. The ultimate lower lethal temperature for fish held in 2 and 10 °/oo salinities were calculated to be 15.9 and 14.4 C, respectively.

The second experiment showed significant differences among acclimation temperatures for LE_{50} and CTMin values when the temperature was decreased 1 C/h (Fig. 2). As acclimation temperatures decreased, the temperatures at which fish lost equilibrium and died also decreased. Fish acclimated at 35 C began losing equilibrium at 19.0 C; whereas, those at 25 C began losing equilibrium at 14.5 C. CTMin values for fish acclimated at 35 and 25 C were 14.8 and 12.3 C, respectively.

TABLE 1. Mean temperature at death (standard error in parenthesis) for peacock bass fingerlings acclimated in 0, 2 and 10 °/oo salinities, 25, 30 and 35 C and exposed to a 1 C/day decrease in temperature. Asterick (*) denotes significant ($P < 0.05$) difference in mean temperature at death; no significant difference ($P > 0.05$) is dentoed by *NS*.

Salinity	Acclimation Temperature (C) 25	30	35	Salinity mean
0	15.3(0.1)	15.1(0.1)	15.4(0.1)	15.2(0.1)
2	15.3(0.2)	15.0(0.0)	16.1(0.2)	15.5(0.1)
10	13.7(0.1)	14.6(0.1)	14.6(0.2)	14.2(0.1)*
Acclimation Mean	14.8(0.2)	15.0(0.1)	15.3(0.2) *NS*	

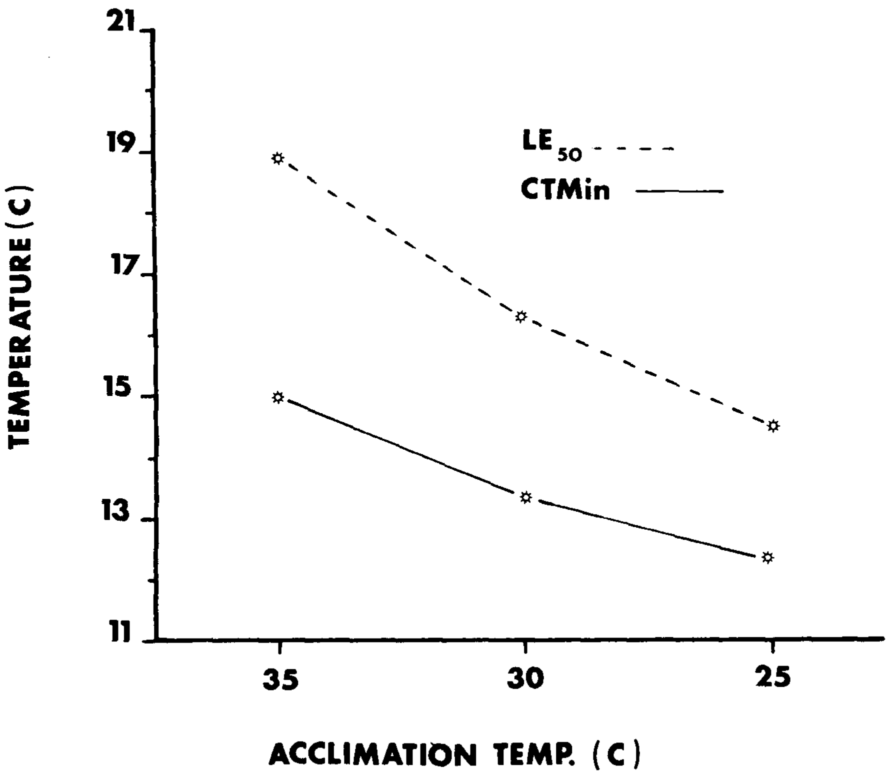

Fig. 2. Response of peacock bass fingerlings acclimated at 25, 30 and 35 C and exposed to a temperature decline of 1 C/h. Regression analyses were used to calculate the temperature at which 50% of the fish lost equilibrium (LE_{50}) and died (Critical thermal minimum; ie. CTMin).

In the third experiment, responses of fish transferred abruptly to lower temperatures varied with acclimation and severity of temperature change (Fig. 3). Fish at all acclimations lost equilibrium in from 1 min (35 C acclimation) to 5 min (30 and 25 C acclimation). Time to death was longer when there was less difference in acclimation and test temperature. For example, median resistance times for fish acclimated at 35 and 25 C and exposed to 15 C were 19 and 92 min respectivley. Fish exposed to 20 C (30 and 25 C acclimation) survived the 96 h test period.

DISCUSSION

The ultimate lower lethal temperature of 15.6 C for peacock bass fingerlings determined in this study is probably a good estimate of their lower lethal temperature since all fish acclimated at different temperatures died at approximately the same temperature. These results agree closely with findings of Swingle (1966) and Devick (1970). In their tests, where water temperature was decreased 0.5 C/day, peacock bass died between 16.0 and 15.0 C.

The lower lethal temperature of peacock bass was higher than those reported for certain other tropical species. Several species of *Tilapia* spp. died at temperatures ranging from 7.5 to 13.0 C (Avault and Shell 1968; Hauser 1977). Thompson et al. (1977) found the lower lethal temperature of 3 species of nile perch (*Lates* sp.) to be 11.0 C, and walking catfish (*Clarias batrachus*) died at 9.0-10.0 C (Shafland 1977).

Varying results have been reported on the effects of salinity on lower lethal temperatures of fishes (Brett 1952; Stanley and Colby 1971; Blader 1973). Some fish lose the ability to osmoregulate when exposed to acute cold temperatures (Block 1974; Stanley and Colby 1971). Peacock bass may have survived to lower temperatures in 10 °/oo salinity because of reduced energy expenditure for osmoregulation.

The ultimate upper lethal temperature (37.9 C) for peacock bass was similar to those found for several tropical and temperate eurythermal fishes (National Academy of Sciences and National Academy of Engineering 1973). Nile perch died at temperatures above 38.0 (Thompson et al. 1977) and the median lethal temperature for *Tilapia mossambica* was between 38.20 and 38.25 C (Allanson and Noble 1964).

In the gradual temperature decline experiment (1 C/h), CTMin values were lower than the ultimate lower lethal temperature (Fig. 1 and 2). This probably gives an indication of the resistance of these fish to temperatures outside their tolerance zone. However, several researchers noted that loss of equilibrium in nature is probalby fatal (Coutant et al. 1974; Becker et al. 1977; Thompson et al. 1977); therefore, LE_{50}'s are probably more useful in evaluting peacock bass survival where temperatures are decreased at a similar rate. Becker et al. (1977) stated that a 1 C/h cooling rate represented a minimum temperature decline in many situations involving terminated heated discharges. If this is true, peacock bass mortalities could be expected at temperatures as high as 19.0C (Fig. 2) during winter electro-power plant shutdowns.

Peacock bass showed response to abrupt temperature changes similar to those reported in other studies of this type (Fry et al. 1946; Banner and Van Arman 1973; Otto 1973; Becker et al. 1977). Peacock bass can survive abrupt changes up to 10 C if the minimum temperature does not fall below 20 C. However, loss of equilibrium or susceptibility to predation could affect survival under these conditions. Coutant et al. (1974) showed that fish become more subject to predation when exposed to acute temperature changes.

Our findings suggest peacock bass are more stenothermal than other tropical species and the possibility of establishing a surviving population of peacock bass in cooling reservoirs in Texas is limited. Temperature data presently available from existing heated reservoirs in Texas indicate that only 2 of them have winter water temperatures warm

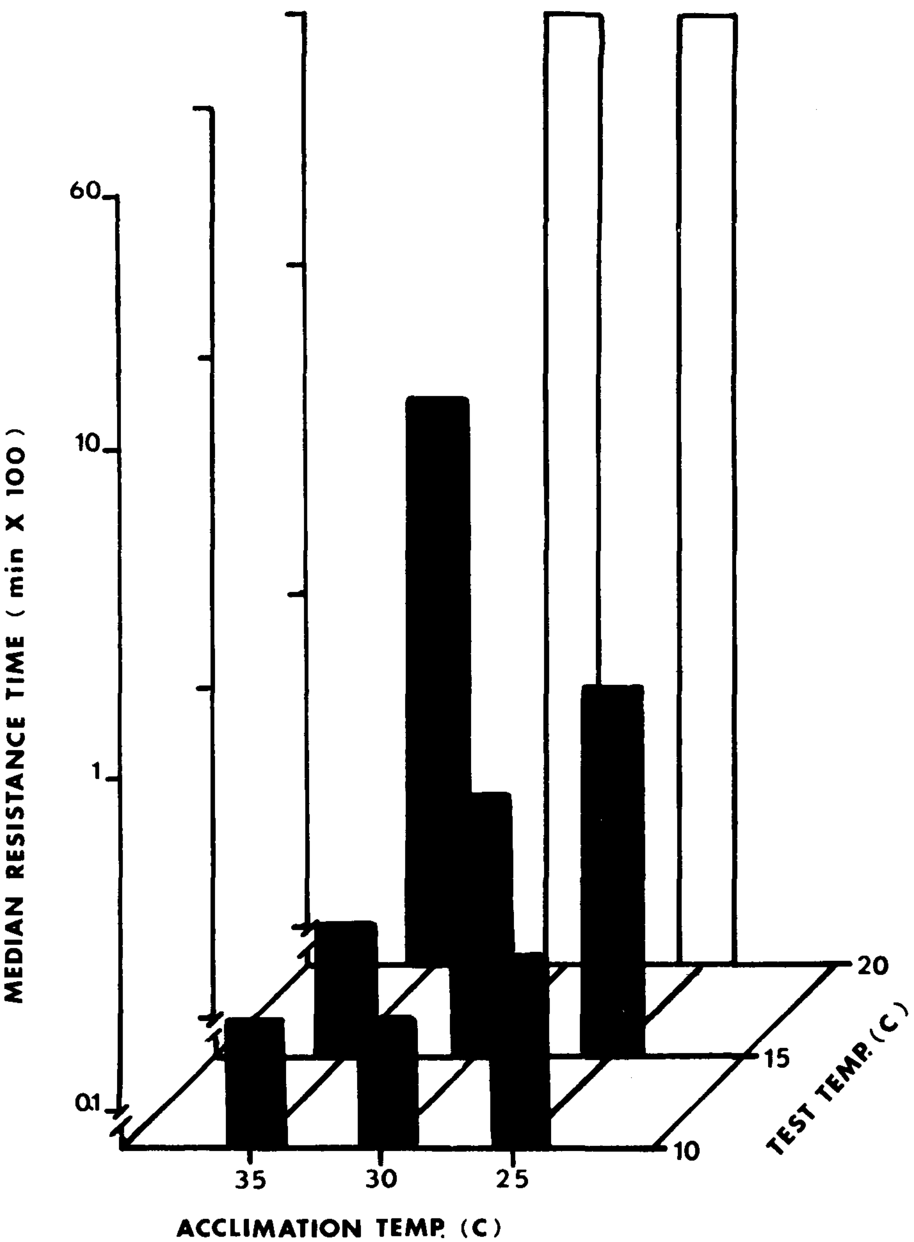

Fig. 3. Median resistance times for fingerling peacock bass acclimated at 25, 30 and 35C and exposed to test temperatues of 10, 15 and 20 C for 96 h. White bars indicate 100% survival.

enough to sustain peacock bass. However, if a population were established in a reservoir and found to be undesirable, winter water temperature manipulation could be used as a control mechanism.

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