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COMPARISONS OF CRITICAL THERMAL MAXIMA AND MINIMA OF JUVENILE RED DRUM (*Sciaenops ocellatus*) FROM TEXAS AND NORTH CAROLINA

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ABSTRACT: The Texas Parks and Wildlife Department was interested in identifying cold-tolerant red drum (*Sciaenops ocellatus*) for a supplemental bay stocking program to help prevent massive fish kills when winter temperatures drop to potentially dangerous levels. Critical thermal maxima (CTMax) and minima (CTMin) of juvenile red drum from Texas and North Carolina were determined to test for possible geographically based differences in thermal tolerance limits. Juvenile red drum from the two regions acclimated to either 12°C or 20°C exhibited similar thermal tolerance limits while Texas red drum acclimated to 12°C exhibited a statistically higher CTMax, however the observed difference is not interpreted as biologically significant. The adjusted mean CTMin for the combined Texas and North Carolina red drum acclimated to 12°C was 1.6°C and adjusted mean CTMax for combined Texas and North Carolina red drum acclimated to 12°C was 29.5°C, and the adjusted mean CTMax for individuals acclimated to 20°C was 34.8°C. These results suggest red drum from nothern and southern parts of the species range have similar temperature tolerances.

The red drum (*Sciaenops ocellatus*) is an estuarine-dependent sciaeneid that supports economically important fisheries over much of its range. Population size and structure of this species has historically been unstable. Part of this instability has been attributed to growth and recruitment over-fishing (McEachron et al. 1987), phytoplankton blooms (Simmons and Breuer 1962), and periodic low temperature-related kills (Gunter 1941, Gunter and Hildebrand 1951, McEachron et al. 1984). Historically, efforts to manage red drum fisheries throughout their range focused on protecting habitat. However, efforts were expanded in the 1970's, especially in Texas, to regulating harvest (Anonymous 1985) and supplementing natural red drum populations by stocking artifically reared fish (Dailey 1991).

The fate of eggs, fry, and fingerlings stocked in Texas bays is determined by many factors including predation, disease, water quality, and metorologic conditions. However, cold temperatures are of special importance in Texas coastal waters. The bays and estuaries of Texas are shallow and insulated from the moderating effects of the open Gulf by barrier islands. Water temperature in these systems may change drastically (Moore 1976, and Holt and Holt 1983) resulting in massive mortality of resident red drum. If a red drum stock can be identified which has higher tolerance of rapid fluctuations in temperature, particularly temperature decreases, then success of stocking might be enhanced.

Red drum are occasionally found as far north as Massachusetts (Mercer 1984) and support recreational fisheries in North Carolina and Virginia (Manooch 1984). Frequent and severe winter temperature mortality in Atlantic coast red drum has not been reported. Whether this is due to differences in the rapidity and severity of low temperature onset, or whether the Atlantic coast red drum possess greater genetically based tolerance of low temperatures is not known. If the latter is true then populations inhabiting the Atlantic coast represent a potential source of a stock possessing relatively greater cold tolerance.

Thermal tolerance involves both environmental and genetic components (Brown 1971). Changes in tollerance associated with previous thermal experience represent nongenetic (Acclimation) responses, whereas ultimate tolerance limits are set genetically (Otto 1973). Recent studies involving both allozyme (Gold et al. in review) and mitochondrial DNA data (Gold et al. in press) found evidence of weak genetic subdivision between populations inhabiting the northern Gulf of Mexico and the southeastern Atlantic coast. Given genetic differentiation in this species, it is possible that genetically based differences in thermal tolerance may exist across the distribution of red drum. If so, red drum from the northern portions of the range may provide a beneficial trait that could be used in the Texas stocking program.

Studies of thermal tolerance are scarce. Miranda and Sonski (1985) found that when temperature was reduced 1°C/day the lower lethal temperature for fingerlings ranged from 3°C to 0.8°, and when temperature was reduced 0.33°C/day and held at 4°C fish survived 48 to 168 hours. Survival of red drum fingerlings of temperatures corresponding to a massive winter fish kill found that there were no significant differences in cold-tolerance of Atlantic coast and Gulf Coast fish (Procarione 1989).

Two important measures of thermal tolerance are the critical thermal maximum (CTMax) and critical thermal minimum (CTMin) which involve exposing animals to a constant change in temperature. CTMax and CTMin are defined, respectively, as the mean of the upper and lower temperatures at which an organism is so disabled as to be unable to escape from lethal conditions when exposed to constant change in temperature (Cox 1984). Thermal tolerance, as measured by the CTMax and CTMin, is an important concept with a variety of applications (Beitinger and McCauley 1990). Thermal tolerance parameters are useful in predicting the potential of an exotic species to exploit a new environment. In the culture of red drum, and other economically important species, such knowledge can be used to select temperature-tolerant strains for broodstock or deciding when transport into thermally-protected tanks is necessary. Finally, knowledge of the termal tolerance of a species may be used to assess the potential of different genetic stocks to survive under different environmental conditions.

The objective of this research was to test the null hypothesis that there is no significant difference in CTMax or CTMin for fingerling red drum spawned by brood fish collected from either Texas or North Carolina. If North Caroloina red drum are more tolerent of temperature extremes, then their use as a source for stocking in Texas may reduce the severity of future temperature-related fish kills.

MATERIALS AND METHODS

Red drum were collected from the

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Atlantic Coast by rod and reel near Ocracoke Inlet, North Carolina in late summer 1990 and were transported by vehicle to the Perry R. Bass Marine Fisheries Research Station (PRBMRS), Palocios, Texas. Upon arrival, fish were held in 5000 l fiberglass tanks and subjected to a temperature-photoperiod regime (Arnold et al. 1977) designed to induce spawning in summer 1991.

Gulf of Mexico red drum collected from various localities on the Texas coast were maintained at the Gulf Coast Conservation Association-Central Power and light-Marine Development Center, Corpus Christi, Texas. Spawning was induced by temperature-photoperiod conditions similar to the regime to which the North Carolina fish had been exposed. The fry produced by the Texas red drum were transported to PRBMRS on the second day after spawning.

Two-day-old fry spawned by Texas and North Carolina adults were held in six 0.1-hectare replicated ponds at a rate of 75,000/pond and cultured for 30-35 days (culture procedures were modifications of Colura, et al. 1976). At harvest, 2,000 fingerlings from each group were randomly selected and held in 100 l recirculating fiberglass tanks at 25°C for four weeks. Fish were fed to satiation three times daily with a combination of brine shrimp (San Francisco Bay, Jungle Laboratories, Cibolo, Texas) and pelleted diet (Hikari, Kyorin Company, Himeji, Japan). At the end of the four week period surviving fish were randomly assigned to groups that were acclimated to either 12°C or 20°C by decreasing the tank temperature 1°C per day. Groups were held at acclimation temperature for a minimum of 4 weeks.

At the end of the acclimation period, individuals were randomly selected from each of the four groups for either CTMin or CTMax determinations. Prior to a CTMin trial, three fish were randomly selected from each of the Texas and North Carolina groups and were placed individually in one of six clear tubular plexiglass experimental chambers (diameter = 120 mm) filled with one l of water obtained from the acclimation tanks. Chambers were fitted with circular airstone bottoms to facilitate water movement. The experimental chambers were then placed in an environmental chamber (LabLine Instruments Inc., Melrose Park, Illinois) with a temperature set to 10°C below the appropriate acclimation temperature. Temperature of the environmental chamber was then decreased at a constant rate of 0.1°C/min^{-1}. Temperatures within each test chamber were recorded (+/− 0.1°C) with a digital thermometer (Model 8528-20, Cole-Parmer Instrument Co., Chicago, Illinois) and a multichannel temperature recorder (Model 46TLKUC, Yellow Springs Instrument Co., Yellow Springs, Ohio). Fish were continuously observed through the glass door of the environmental chamber, and the temperature at which final loss of equilibrim was reached was recorded. Final loss of equilibrium was defined as the point at which obvious deviation from normal orientation was not quickly followed by a righting response. Following each trial, wet weight (+/− 0.01 g) and total length (+/− 1 mm) of each fish were measured. Four replicates of this procedure were conducted for the 12°C acclimation temperature groups, for a total of 12 individuals tested under this condition from each geographic group. Ten replicates of this procedure were conducted for the 20°C acclimation groups, for a total of 30 individuals from each geographic source.

CTMax trials were conducted in six tubular plastic chambers (diameter = 80mm) with bottoms lined with nyon mesh. The plastic chambers were immersed in a 57-l aquarium filled with 43 l of water obtained from the acclimation tank. Three individuals were randomly selected from each group and placed individually in the test chambers. Temperature in the chambers was then increased at a constant rate of 0.1 °C/min^{-1} by heating the water in the aquarium with two circulating temperature controllers (Haake E-52, Haake Co., Saddle Brook, N. J.) placed at each end of the aquarium. Endpoint was determined using the same criteria as CTMin trials. Further treatment of test fish was identical to that in the CTMin trials. Ten replicates of this procedure were conducted for both acclimation temperature groups, for a total of 30 individuals per acclimation temperature for each of the two geographic regions.

CTMax or CTMin, mean weight (WT), mean total length (TL), and standard deviations were calculated for each group. In an attempt to control for differences in TL and WT, these variables (if statistically significant) were treated as covariates in analyses of covariance (ANCOVAs) which tested for differences in mean CTMax and CTMin between Texas and North Carolina red drum acclimated to either 12° or 20°C. All descriptive and inferential statistics were generated using the Statistial Analysis System (SAS Institute 1985) with an alpha = 0.05.

RESULTS AND DISCUSSION

Statistically significant differences in TL were discerned between Texas and North Carolina individuals in all four test groups, and WT was significantly different in two of the four groups (Table 1). In all cases where a significant difference in size was found, North Carolina fish were larger. We attribute this difference to a higher survival percentage during pond culture among Texas fish which resulted in a smaller average size.

The only statistically significant temperature tolerance difference found between Texas and North Carolina red drum was in the mean CTMax (all mean CTMax and CTMin values are least squares means adjusted for significant differences in size) of individuals acclimated to 12°C (Table 1). The mean CTMax of Texas red drum (29.84 °C) was greater than that of North Carolina (29.23 °C). The absolute difference (0.61 °C) between these two CTMax values was small, and we consider it to lack biological importance.

The combined mean CTMin for Texas and North Carolina red drum acclimated to 12 °C was 1.57 °C (N = 42, SD = 0.93). The acclimation temperature of a red drum has an obvious effect on its response to low temperature. On the average, each 1 °C decrease in temperature of acclimation corresponds to a 0.4 °C gain in cold tolerance. This has implications for overwintering of hatchery broodstock, for stocking of fingerlings into bays in fall and winter, and possibly for predicting freeze mortality in both natural and hatchery situations. Fish acclimated to sublethal low temperatures will be more successful in surviving a low temperature challenge than individuals acclimated to higher temperatures.

The combined mean CTMax for Texas and North Carolina red drum acclimated to 12 °C was 29.54 °C (N = 60, SD = 0.93), and the mean CTMas for individuals acclimated to 20 °C was 34.84 °C (N = 60, SD = 0.55). Again, acclimation results in an increased tolerance of thermal stress. On the average, for each 1 °C increase in acclimation temperature there is a 0.66 °C gain in heat tolerance.

Failure to find biologically important differences between thermal tolerances of individuals from the western Gulf of Mexico and the mid-Atlantic coast casts doubt on the idea that stocking the coastal waters of Texas with red drum

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Table 1. Mean [SD] weight, total length, critical thermal maxima (CTMax)/minima (CTMin) and F values for (TX) and North Carolina (NC) fingerling red drum acclimated to 12°C and 20°C. Probabilities of significant F values are: **P < 0.001, *P <0.05[A] Least square mans adjusted for significant size differential.

Test	Acclimation temperature	Stock	N	Mean weight(g)	F	Mean length(mm)	F	Mean CTM(°C)[A]	F
		TX	12	1.25		49.4		1.27	
				[0.36]		(7.8)		[1.21]	
	12°C				23.47**		31.70**		0.98
		NC	12	2.38		64.6		1.86	
				[0.51]		[5.1]		(1.21)	
CTMin									
		TX	30	1.85		55.0		4.60	
				[0.96]		[8.3]		[0.93]	
	20°C				0.07		7.06*		2.48
		NC	30	2.17		60.6		4.98	
				(0.77]		[7.2]		[0.93]	
		TX	30	1.11		47.9		29.34	
				[0.59]		[7.3]		[0.93]	
	12°C				35.39**		54.71**		4.71**
		NC	30	2.31		62.8		29.23	
				[0.94]		[8.3]		[0.93]	
CTMax									
		TX	30	1.87		54.3		34.83	
				[0.73]		[7.0]		[0.55]	
		NC	30	1.95	59.8		34.85		
				[0.51]		[6.51]		[0.55]	

from the Atlantic Ocean will prevent massive fish kills due to rapid decreases in temperature. It should be emphasized that generalization of the results of this study beyond the size class of red drum employed in this study should be attempted only with great care. However, it is normally fingerling red drum which are actually stocked in Texas' bays, and it is probable that the survival of this size class is crucial to the success of an enhancement program.

Active stocking of a strain or species of sportfish outside its area of natural occurrence should only be done under the most extraordinary of circumstances. Such stocking is only justifiable if no other source of broodfish is available for an endangered fishery, or if the non-native strain is so superior in some important qualities as to make questions concerning genetic integrity of the population unimportant. Such does not seem to be the case for the red drum in Texas.

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