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Effect of salinity on the upper lethal temperature tolerance of early-juvenile red drum

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ABSTRACT

Previous work investigating the temperature tolerance of juvenile red drum ranging 18–50 mm TL found evidence for positive size dependence (smaller fish less tolerant to higher temperatures) suggesting smaller size classes (< 18 mm TL) potentially may succumb to extreme summer water temperatures. Here, we explored the upper lethal temperature tolerance (ULT) in smaller-sized red drum which ranged from 10 to 20 mm TL across multiple salinities to further understand the thermal limitations of this propagated game fish. In order to investigate the combined effect of temperature and salinity on ULT, temperature trials were conducted under three levels of salinity which commonly occur along the coast of Texas (25, 35, and 45 ppt). The rate of temperature increase (+0.25 °C/h) was designed to mimic a natural temperature increase of a summer day in Texas. We determined that the lethal temperature at 50% (LT_{50}) did not differ between the three salinities examined statistically; median lethal temperature for individuals exposed to 25 ppt ranged from 36.4 to 37.7 °C, 35 ppt ranged from 36.4 to 37.7 °C, and 45 ppt ranged from 36.1 to 37.4 °C. Further, LT_{50} data obtained here for early-juvenile red drum did not differ from data of a similar experiment examining 25 mm TL sized fish.

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1. Introduction

Understanding the thermal limitations of hatchery reared fish species helps aquaculturists maximize return by minimizing stocking mortality in situations of water temperature extremes. The upper lethal temperature tolerance (ULT; upper temperature at which mortality occurs in a species), in particular can be especially useful for fish harbored in outdoor grow out ponds in regions which experience high summer temperatures. However, there are numerous factors which influence the ULT in fishes (i.e. body size, acclimation, and environmental factors; Cossins and Bowler, 1987; Rutledge and Beitinger, 1989). Previous temperature studies have found that larger fish are more adept at thermoregulation when compared to smaller fish (Spigarelli et al., 1974; Becker and Genoway, 1979). Body size appears to be a limiting factor of thermal tolerance for fish species that naturally occur in thermally variable environments (Atwood et al. 2003; Ospina and Mora, 2004; McDonald et al., 2011; Zhang and Kieffer, 2014). Therefore, the variability of temperature within an aquatic species' environment need not be overlooked when designing ULT studies due to the potential for associated size dependence with thermal limitations.

The Coastal Fisheries Division of the Texas Parks and Wildlife Department (TPWD-CF) has been rearing and stocking red drum *Sciaenops ocellatus,* a popular sportfish, since 1983 as a means of stock enhancement. The TPWD-CF red drum hatcheries maintain broodstock, induce spawning, and grow out larvae to the juvenile stage at which point juveniles are stocked in Texas bay systems. Stocking of these juveniles occurs from spring through the fall seasons until cooler temperatures inhibit fish culture. Based on previous tagging and genetic studies, survival of stocked red drum was highest during the spring and fall rather than the summer seasons (Willis et al., 1995; Smith et al., 1997; Sherwood et al., 2004; Karlsson et al., 2008). This information is critical, because smaller/younger red drum (< 35 mm TL) do not naturally occur in Texas bay systems during the summer season. Red drum typically spawn during the fall season in situ, which results in larger juveniles during the summer season (~240 mm TL; range=200–290 mm TL) as compared to out-of-season fish stocked by TPWD-CF (~35 mm TL; range=14–100; TPWD-CF, unpublished data). McDonald et al. (2011) found that stock-sized juvenile red drum (size range 18–50 mm TL) displayed a high tolerance to warmer temperatures (LT_{50}=37.0–38.7 °C) with evidence of positive size dependence when exposed to a temperature increase of +0.25 °C/h using a temperature ramping environmental chamber. Further, Holt et al. (1981) found that yolk-sac larvae are vulnerable at temperatures > 30 °C. These findings may suggest that early-juvenile red drum (< 18 mm in TL) have the potential to be

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particularly vulnerable to warmer temperatures of the summer season and warrants an investigation. Additionally, observing lethal temperatures across a range of salinities that commonly occur within grow-out ponds would allow for a determination of whether high salinities have any influence on the ULT. The Marine Development Center, a TPWD operated marine hatchery frequently encounters pond salinities ≥ 45 ppt during warming summer months and primarily stocks hypersaline bays (TPWD-unpublished data). The objectives of this study were therefore to determine whether (1) the ULT of early-juvenile red drum (< 18 mm TL) are influenced by increasing salinity and (2) the ULT values continue with the positive size dependence previously indicated. Results from this study should give insight into the thermal limitations and salinity tolerances of early-juvenile red drum harbored in grow out ponds for the purpose of stock enhancement.

2. Materials and methods

2.1. Experimental fish collection and setup

Red drum juveniles (< 18 mm in TL) were collected from earthen ponds at the Perry R. Bass Marine Fisheries Research Station, Palacios, Texas (PRB) and transferred to an onsite experimental lab. Fish used in trials were hatchery spawned fish being raised for the stock enhancement program operated by TPWD-CF. Fry were spawned from wild-caught broodstock held at Sea Center Texas, Lake Jackson, Texas (SCT) or at the Marine Development Center, Flour Bluff, Texas (MDC) and stocked on various dates in PRB rearing ponds. Early-juvenile red drum were collected from three separate ponds during the summer season at different dates for three independent trials. Fish were naturally acclimatized to seasonal pond conditions prior to experimental trials by being exposed to fluctuating diurnal water temperatures within 0.8–1.6 ha grow out ponds for a minimum of 10 days prior to collection for trials, a procedure used in similar studies (Heath et al., 1993; Whitehurst and Robinette, 1994). Pond water temperature was monitored three times daily (0700, 1500 and 2200 hours) from stock date until the start of trials using a YSI Model 550 dissolved oxygen/temperature probe (YSI, Inc., Yellow Springs, Ohio) set at 0.45 m water depth over the deepest portion of the pond (Depth range 1.5–2.0 m). Water temperature data is critical prior to conducting temperature tolerance studies since fish that are exposed to fluctuating temperatures during the summer are generally conditioned to the upper level of the cycle rather than to its mean (Lowe and Heath, 1969; Feldmeth et al., 1974; Otto, 1974; Threader and Houston, 1983), and this conditioning can be reportedly lost in

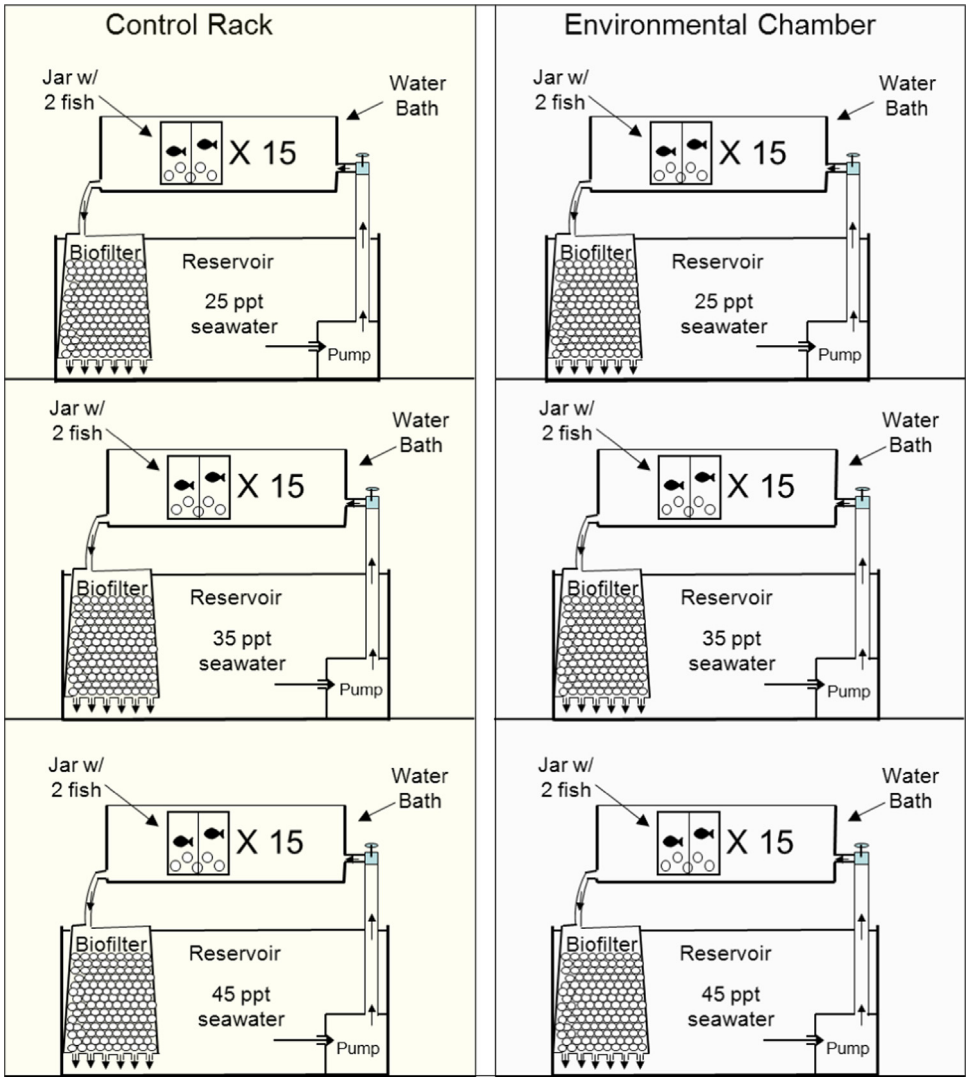

Fig. 1. Experimental setup schematic detailing each identical recirculating systems used for individual trials. Each trial used three recirculating systems for controls and three recirculating systems used within an environmental chamber. Each recirculating system held 30 red drum juveniles within 15 compartmentalized jars.