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Effects of Hypersaline Conditions on the Growth and Survival of Larval Red Drum-(*Sciaenops ocellatus*)

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Abstract

Texas bays and estuaries experience salinity fluctuations (e.g., droughts, reduced freshwater inflows and hurricanes) caused by natural weather and climate change. This could have impacts on red drum *Sciaenops ocellatus* (Linnaeus) early life stages beacause red drum spend their early life stage at the shallow bays and estuarine waters of Texas Bay. The purpose of the present study is to evaluate the impact of high salinity concentrations on the survival, growth and development of red drum eggs and larvae. Red drum brood stocks were collected from wild stocks throughout the lower Texas coast and were held in hatchery tanks (13,250 L) until spawning. The water quality conditions were maintained at a salinity of 38ppt and seawater temperature of 25°C. The red drum eggs were hatched at a wide range of salinity treatments (28-48ppt). Egg hatch-out rates and larvae growth were reduced at the lowest (28ppt) and highest (48ppt) salinity treatments. Hypersalinity (≥ 40ppt) and a temperature of 25ºC affected the hatching success of red drum eggs. The percentage of egg hatching success and length of larvae were reduced in both lower (28ppt) and/or hypersalinity (48ppt). This study shows that red drum eggs can hatch within a wide range of salinities with best hatch-out and growth rates occurring between 33 – 43ppt. It also suggests that climate change that produces global warming can keep the increasing environmental salinity of the Texas bay which might have an impact on the development of the early stages of the red drum in their natural environment.

Keywords: Estuary, early life stages, hypersalinity,hatching success,red drum, Texas Bay.

1. Introduction

The red drum *Sciaenops ocellatus* (Linneaus) is an important commercial and recreational sciaenid that ranges from Tuxpan, Mexico in the Gulf of Mexico to Massachusetts in the Atlantic Ocean (Pattilo *et al*., 1997). In Texas, red drum was recognized as being overfished in the mid-1970’s which prompted state regulators to implement progressively restrictive rules to reduce fishing harvest levels (Swingle, 1990). The sale of wild- caught red drum was prohibited in 1981 (Matlock, 1990a), and as an alternative fisheries management tool hatchery production of juvenile red drum at state-operated facilities was initiated in Texas for stock enhancement purposes (Matlock, 1990b; McEachron *et al*., 1995; Blaxter, 2000). These measures were taken in order to reduce fishing pressures and supplement wild stock populations through the stock enhancement.

Red drum is a quasi-catadromous sciaenid (Rounsefell, 1975). The adult red drum migrate from estuaries to the near shore gulf to spawn during the fall (September – November) (Matlock, 1990a). Currents carry eggs and larvae into shallow bays and estuarine nurseries (Peters and McMichael, 1987; Holt *et al*., 1989; Comyns *et al*., 1991; Holt *et al.*, 1985 and Rooker *et al*., 1997). Red drum juveniles and sub-adults remain in estuaries for three-five years (Miles, 1950) before migrating offshore as adults (Swingle, 1990). In the shallow bays and estuaries, the temperature and salinity conditions can fluctuate within and between the seasons. Early life stages (age/size dependent) of red drum vary in their ability to tolerate shifts in environmental variables (Neill, 1990). Conditions beyond the environmental thresholds of tolerance may cause deformities, low hatching rates, reduced growth, and a decreased larva survival (Kucera *et al*., 2002). Knowing how early life stages of fishes cope with non-optimal conditions is an important consideration for their effective management (Holt and Holt, 2002).

Salinity in Texas bays and estuaries varies from brackish to hypersaline depending on the hydrographic condition such as freshwater inflow, tides, evaporation and currents (Holt and Holt, 2002). The coastal waters near passes are characterized by a wind-driven surface current, and can vary greatly in salinity (Ponwith and Neill, 1995). According to Buskey *et al*. (2001), mean salinities for Matagorda Bay in north of Corpus Christi and Upper Laguna Madre, south of Corpus Christi are 18 to 24ppt and

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40 to 50ppt respectively. High temperatures during the summer months can cause drought conditions due to increased evaporation rates.

Several studies investigating the effects of seawater salinity on the early development and larvae growth of different fishes had been conducted. However, to the researchers' knowledge, information on the early life development of the red drum in higher salinity (> 40ppt) as it occurs in their natural environment along the south Texas coast is still limited. Determining the effect of hypersalinity (> 40ppt) on hatching success rates of red drum may provide better habitat management and an insight into the successful early development of red drum in hypersaline Texas bays.

The purpose of the present study is to evaluate the impact of high salinity concentrations on the survival, growth, and development of red drum eggs and larvae.

2. Materials and Methods

All experiments were performed at the laboratory of the Texas Parks and Wildlife Department Coastal Conservation Association, Marine Development Center (MDC) hatchery in Corpus Christi, Texas, USA during November 2013. Red drum brood stocks were collected from wild stocks throughout the lower Texas coast and were transported to the MDC. Broodstocks were held in hatchery tanks (13,250 L) and were subjected to a photoperiod and temperature cycle of 150 days to induce spawning (Arnold *et al*., 1976). During the spawning time, water quality conditions were maintained at a salinity of 38ppt and a seawater temperature of 25°C. A fiberglass egg collector (230 L) lined with a 300 µm mesh bag was connected to each brood tank. Seawater was moved by means of a mechanical air-lift from the brood tanks to the egg collectors via a surface skimmer located inside each tank. The spawned eggs came from five parental fish (3 females and 2 males) kept in the tank. After spawning, eggs flowed from the brood tanks to the collectors and were concentrated into 100 mL graduated-cylinders and volumetrically enumerated. Viable eggs floated to the surface within one-five minutes, and non-viable eggs sank to the bottom of the cylinder. Fertilized eggs were transported to the laboratory/aquariums for experiment.

Fifteen aquariums sized 48x34x30 cm were used for the experiment and were filled with the filtered seawater. Those aquariums were set up randomly for three replicates of each salinity of 28, 33, 38, 43, 48ppt (5ppt increments). Treatment of salinities was obtained using deionized freshwater to lower salinities or by adding artificial sea salt to increase salinity, while the salinity of 38ppt was a control salinity. The room temperature was set up at 27°C during the experimenta and the water temperature in all fifteen aquariums were kept at 25°C. Salinity, temperature and pH parameters were measured at the beginning and the end of the experiments using Hydrometer Model YSI 556 MPS meter. Aeration was provided to each aquarium. A photoperiod of twelve hours of light and twelve hours of dark was maintained during the trials.

A subsample of 130 eggs was examined using a dissecting microscope (4x, magnification) with an ocular micrometer to measure the egg diameter and oil globule to the nearest 1 µm. Fertilized eggs were placed into plastic egg containers that had two sides in openings condition covered only by a net of a 300 µm mesh size to facilitate seawater flow through the containers. Three egg containers were placed in each aquarium and 130 fertilized eggs were stocked in each egg container. A total of nine egg containers (1,170 eggs) per salinity treatment were tested. All the eggs were in the embryo stage. Egg distribution into the containers was completed within one hour, and the experimental trials were conducted for thirty-six hours. The hatching success of eggs was determined after exposure. All yolk-sac larvae from each container were collected by pouring them unto a plastic tray for enumeration. Larval characteristics were determined by the number of eggs hatched (%), normal and deformity of larvae were counted for each container, and a sub-sample of thirty larvae from each container were measured in terms of the total length (TL) using Micron 1 Imagine software. Larvae were measured from the tip of the snout to the end of the notochord to the nearest 0.01 mm (Zacharia and Kakati, 2004). The hatching rate was calculated by dividing the number of larvae by the total number of eggs in a container. Descriptive statistical analysis was performed using Excel 2010. All data were analyzed using SPSS®software. A one-way ANOVA ($\alpha = 0.05$) was used to analyze salinity effects on the larval length between and within the test salinities and was followed by post hoc test in the ANOVA to test the difference between mean of red drum yolk sac larvae and TL at different salinities. Salinity was an independent variable, whereas the dependent variable was the TL of larval.

3. Results

Mean seawater temperature (± SD) and pH in all tanks during the experiment were 24.65±0.22ºC and 8.08±0.03 respectively. Mean salinity for each treatment was 28.41±0.20, 33.33±0.28, 38.14 ±0.999, 43.21 ± 0.16 and 48.4±0.22ppt. The ranges of salinity selected below 43ppt were representative of conditions occurring in coastal waters during the normal spawning season of red drum and the high salinity (≥ 43ppt) was representative of lower Texas coast bay conditions.

The fertilized red drum eggs contain one oil globule. Diameters of 100 fertilized eggs ranged between 0.91 and 0.99mm, and the mean ± SD diameter was 0.96± 0.03mm and with an average of oil globules ranged from 0.17–0.20mm with the mean ± SD diameter was 0.23± 0.02mm. Those numbers indicated that the eggs were almost of uniform size, and based on the visual observations using microscope, those eggs were all in a normal condition; that they were spherical and transparent with buoyancy (Song *et al*., 2013). Salinity affected both egg hatching and development (length) of yolk-sac larvae (Table 1). Successful hatching occurred at all the salinities tested, but the lowest rate occurred at the 48ppt treatment. Red drum eggs held at the 38ppt showed the highest percentage of hatching success, and the longest in TL of larvae compared to other salinity treatments. Mean TL of yolk sac larvae reared in the lower (28ppt) and higher (48ppt) salinities was shorter in length than in other salinities (Table 1), and the average TL of yolk-sac larvae was 2.525±0.133mm.

Table 1. Number of viable larvae, hatching success (%) of red drum eggs and mean total length (TL) of red drum larvae maintained at different salinities

Salinity (ppt)	n±SD	Egg hatch (%)	n	Mean TL±SD (mm)
28	66±2.7	61	30	2.426 ± 0.092
33	71±9.5	69	30	2.591 ± 0.075
38	87±1.4	76	30	2.659 ± 0.059
43	66±6.6	63	30	2.620 ± 0.057
48	52±3.1	48	30	2.410 ± 0.099

The one-way ANOVA results show that the TL of yolk sac larvae are affected both by the lowest (28 ppt) and by the highest (48ppt) salinity treatments ($P < 0.05$).

The post hoc test shows that the TL of yolk-sac larvae differ significantly among salinities, and they can be divided into two groups. Yolk-sac larvae from lower (28ppt) and hyper salinity (48ppt) have no significance difference, but they are significantly different ($P < 0.05$) with the other treatments (33, 38 and 43ppt).

4. Discussion

Salinity is an important environmental factor for the hatching of red drum eggs and larval survival (Holt *et al.*, 1981), and it can affect fish egg fertilization rates, reduce hatchability rates, change buoyancy (Holliday, 1969), cause morphological deformities and decrease larvae survival rates (Kucera *et al*., 2002). Moreover, it was a significant factor affecting energy in juvenile red drum development (Norris, 2016). Red drum spawn during the fall along the Texas coast and tidal currents carry the eggs and larvae into estuarine nursery grounds (Holt *et al*., 1985, Rooker *et al.,* 1997) that have salinity varying from brackish to hypersaline (Holt and Holt, 2002).

In this study, red drum eggs were hatched at a wide range of salinity treatment. Egg hatch-out rates and larvae growth were reduced at the lowest and highest salinity treatment. Hypersalinity (≥ 40ppt) and a temperature of 25ºC affected the hatching success of red drum eggs. The brood fish for this study were growing at the salinity of 38ppt and 24ºC, and the results show that the highest percentage of hatching success was in the 38ppt. Early life stage development of other sciaenid fish such as Greenback flounder (*Rhombosolea tapirina*), summer flounder (*Paralichthys dentatus*), and Southern flounder (*Paralichthys lethostigma*) was affected by salinity concentrations (Smith *et al.,* 1999; Specker *et al.,* 1999; Hart and Purser, 1995; Lee *et al.,* 1984). Holt *et al.* (1981) and Lee *et al.,* (1984), investigated the early life history stages of red drum as affected by different temperature and salinity combinations from 22-33ºC and 20-40ppt. Hatching occurs within twenty-eight to twenty-nine hours when water is maintained at a 22ºC, and it takes a slightly longer time in cooler water and a slightly shorter time in warmer waters.

The salinity of the water in which the parents lived affected the response of developing cyprinodont fish to salinity (Kinne and Kinne, 1962). Other studies have demonstrated that the larvae of another sciaenid spotted seatrout (*Cynoscion nebulosus*) hatched from eggs spawned at high salinities are more tolerate for higher salinities than larvae hatched from the eggs spawned at lower salinities (Holt and Holt, 2002; Kucera *et al.*, 2002). The seatrout seemed to be better suited to conditions that were typical of their habitats. This study demonstrated that the percentage of egg hatching success and length of larvae were reduced in both lowest (28ppt) and/or hypersalinity (48ppt). As described by Bakun (1996) for marine fishes, it seems that the success of other salinity treatments is associated more with mean conditions than extreme conditions. Less saline seawater has lower density and red drum egg yolks are absorbed faster by the larva to maintain their position in the water column (Ponwith and Neill, 1995) and there may not be enough energy left for larval growth. If red drum yolk-sac larvae are unable to survive through their first feeding stage, this may be a contributing factor to year-class strength. The salinity tolerances observed provide additional information about the survival of red drum in the early life stages.

5. Conclusion

This study demonstrates that red drum eggs can hatch within a wide range of salinities with the best hatch-out and growth rates occurring between 33 – 43ppt. Because Texas bays and estuaries experience salinity fluctuations caused by natural weather events (e.g., droughts, reduced freshwater inflows, and hurricanes), this might leave an impact on red drum early life stages in their wild population.

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