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Hatchery methods and natural, hormone-implant-induced, and synchronized spawning of captive Atlantic croaker (*Micropogonias undulatus*) Linnaeus 1766

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ABSTRACT

The Atlantic croaker *Micropogonias undulatus* Linnaeus 1766 is a candidate for multiple purpose aquaculture production including use as a baitfish and foodfish. Controlled production of Atlantic croaker could alleviate seasonal availability, establish a steady supply, provide size-specific grades of bait, alleviate pressure on wild stocks, diversify aquaculture businesses, and contribute to foodfish sales. To achieve these potential benefits, development of commercial-scale spawning protocols must occur. Therefore, a study was conducted to determine: 1) if Atlantic croaker could be passively spawned in a captive environment; 2) if hormone implants could be used to actively spawn Atlantic croaker or improve fecundity; 3) if environmental control and hormone implants could be used to synchronize spawning of Atlantic croaker. Wild broodfish (mean ± SE; 329 ± 11 g; 28.7 ± 0.3 cm TL) were captured from Trinity Bay, Texas, pellet trained, and held under controlled photoperiod and temperature conditions. The treatments used were: 1) natural spawning (no hormone treatments); 2) pre-optimal temperature hormone implant (implant injected at 25 °C; 75 μg salmon gonadotropin-releasing hormone analogue; sGnRHa); 3) optimal temperature hormone implant (implant injected at 23 °C; 75 μg sGnRHa); or 4) post-optimal temperature hormone implant (implant injected at 21 °C; 75 μg sGnRHa). The total production from all treatments ($N = 36$ females; 24 males) included 30 total spawning events during the 120 day study, which yielded 2,922,510 eggs (3064 mL eggs). The mean water temperature and photoperiod at time of spawning were 19.9 °C and 10.1 h of daylight, respectively. The post-optimal implant treatment resulted in a greater number of spawning events per tank (5.0 ± 0.0), the shortest period of latency (3 ± 0 days), larger volume of eggs·spawning event (170 ± 40 mL), greater quantity of eggs·spawning event (160,203 ± 37,943), and greater fertilization rate (51.9 ± 5.6%) than the other hormone implant treatments. The fish allowed to spawn naturally or in the post-optimal treatment often produced similar results, but fish in the post-optimal treatment produced more spawns per tank (5.0 ± 0.0 compared to 1.7 ± 0.3), had greater fecundity (267,004 ± 33,191 eggs·female compared to 49,090 ± 22,061 eggs·female), and spawning was highly synchronized (5 days compared to 33 days). The results of this study demonstrate that Atlantic croaker can be spawned passively in a captive environment, but hormone implants used to actively induce spawning can improve fecundity and synchronize spawning for commercial production.

1. Introduction

The Atlantic croaker *Micropogonias undulatus* is a candidate for multiple purpose aquaculture production including use as a baitfish (Creswell et al., 2007) and foodfish (Davis and Arnold, 1997). Atlantic croaker is a popular live baitfish for several recreational angling species. Historically, Atlantic croaker has been a popular wild-caught foodfish (Avault et al., 1969) that supported important commercial and recreational fisheries (Diaz and Onuf, 1985).

Development of live, marine-baitfish culture industries has only recently garnered significant attention (Adams et al., 1997; Oesterling et al., 2004; Creswell et al., 2007). Marine bait species have greater potential market value than many marine foodfish (Oesterling et al., 2004). Atlantic croaker is a species demonstrating great potential for development as a high-value live bait, US$8.90·dozen, with prices seasonally higher (Adams et al., 1997; Oesterling et al., 2004; Creswell et al., 2007). Despite potential as a high-value marine baitfish, little work has occurred to develop this species for production.

Atlantic croaker are euryhaline (0.2 g·L to 75 g·L salinity, Simmons, 1957; Parker, 1971) and eurythermal (lethal temperature limits: 0.6° and 38 °C for juveniles, 3.3 °C and 36 °C for adults, Schwartz, 1964), grow quickly (Creswell et al. 2007), and mature within 1 year of age at 140 to 180 mm (Diaz and Onuf, 1985), which are ideal traits for a bait

Abbreviations: d, day; h, hours; min, minutes; sGnRHa, salmon gonadotropin-releasing hormone analog; SE, standard error; SL, standard length; TL, total length.

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species. Atlantic croaker has a protracted spawning season, from October to March with peak spawning occurring in November in the Gulf of Mexico (Pearson, 1929). Atlantic croaker has spawned successfully under laboratory conditions following administration of injections of human chorionic gonadotropin (HCG; 125 international units) three times weekly for 3 weeks with a 7-day period of latency prior to ovulation (Middaugh and Yoakum, 1974).

Successful growout of juveniles has occurred, although these attempts typically utilized wild-caught juveniles. Increasing fishing pressure, habitat destruction, and environmental pollution might threaten wild Atlantic croaker stocks (Davis and Arnold, 1997). Sustainable production cannot rely on capture of wild juveniles due to inconsistent availability and the possibility of reduced recruitment and damage to wild stocks.

Controlled production of Atlantic croaker could alleviate seasonal availability (Adams et al., 1997), establish a steady supply, provide size-specific grades of bait, alleviate pressure on wild-capture bait fisheries, diversify aquaculture businesses (Davis and Arnold, 1997), and contribute to foodfish sales. To achieve these potential benefits, development of commercial-scale spawning protocols must occur. Therefore, a study was conducted to determine: 1) if Atlantic croaker could be spawned naturally (passively) in a captive environment; 2) if less invasive (than daily or weekly injections) time released hormone implants could be used to spawn Atlantic croaker actively or improve fecundity compared to passive spawning; 3) if temperature, photoperiod, and hormone implants could be used to reduce the protracted spawning season and synchronize spawning events of Atlantic croaker for commercial production.

2. Methods

2.1. Broodfish collection, transport, holding, and initial feeding

Wild Atlantic croaker broodstock ($N=110$) were captured by hook and line (Cooke and Mooney, 1973) from August 17 to 19, 2009. The broodfish were collected from Trinity Bay (Gulf of Mexico) in the NRG Energy power plant water discharge (30 °C; 24 g·L salinity) outside of Baytown, Texas. The minimum fish size retained was 23.0 cm TL to provide a safety margin relative to the reported size range at maturation (14.0 to 18.0 cm; Diaz and Onuf, 1985). The fish were transported in oxygenated bay water (3 L·min·tank) non-stop to the University of Arkansas at Pine Bluff (UAPB) Aquaculture Research Station in Pine Bluff, Arkansas.

The broodfish were transferred to 29 °C, 25 g·L salinity water (artificial seawater mix) buffered to pH 8.3 in an 11,000 L outdoor recirculation system. The broodfish were tempered to the tank water by 25% water replacement with holding tank water every 30 min for 2 h. No mortalities occurred during transport or tempering. Six fish (5.5% of population) were removed for a health check (terminal) at the UAPB Fish Pathology Laboratory. No bacterial pathogens or parasites were found on the skin, gill, liver, or kidney tissue of the health check sample. A minor infestation of the intestine by unknown trematodes was found in two specimens. Feeding began 2 days after being placed into the holding tank with chopped (roughly 2 cm^2) striped mullet *Mugil cephalus*, ladyfish *Elops saurus*, pinfish *Lagodon rhomboides*, and bait shrimp *Penaeus* spp. being offered in combination at 0.5% of body weight daily.

Two delayed hooking mortalities occurred on August 20. Weather and resulting temperatures in the above ground tank began to fluctuate dramatically on August 21 with extreme overnight temperature decreases. Daily water temperature changes of 6 to 9 °C were observed for five consecutive days. "Sick" fish appeared at the surface, swimming lethargically and were unresponsive to touching with a net. Mortalities ($N=6$) began to occur on August 22, with 10, 10, and 4 mortalities occurring on subsequent days. Freshly dead and dying fish were taken for a health check, but no bacterial pathogens were found. Water quality was examined and considered to be within acceptable ranges to support Atlantic croaker.

On August 26, four "sick" fish were moved to 1135 L recirculation tanks in an indoor hatchery. The tanks contained the same well water and salt formulation (16–18 g·L) as the outdoor system, but the temperature was maintained at a steady 29 °C. All four fish recovered within 6 h and began feeding the next day. The outdoor tank temperatures (20 °C to 31 °C) were within tolerances of Atlantic croaker (lethal temperature limits: 3.3 °C and 36 °C for adults; Schwartz, 1964), but the large daily variations (up to 9 °C) combined with the stress of capture and transport were believed to be the cause of mortality. On August 27, the remaining fish ($N=68$) were moved to indoor tanks. No further mortalities occurred prior to the stocking date, and subsequent indoor daily changes of up to 6 °C resulted in no mortalities.

2.2. Broodfish pellet training and feeding

Several methods of pellet training were attempted over 4 weeks, and the simplest way to pellet train croakers was to withhold feed (48% protein, 18% lipid; Burris 4818 Marine Grower FK; Cargill Animal Nutrition, Franklinton, Louisiana) for 7 days, then offer 1% of body weight on the eighth day. If the fish did not consume the pellets, feed was withheld for two additional days before offering pellets again. Most of the fish began to feed within 8 to 10 days of this regimen. When a single fish began consuming pellets, other fish in the tank would also start to consume pellets. Once a tank of fish was pellet trained, fish in that tank could be placed into other tanks with non-feeding fish to stimulate them to eat. Two methods of feeding were examined to prepare the fish for spawning. Offering 10% of body weight every other day resulted in greater food consumption and growth than offering 5% daily. Therefore, 10% of body weight every other day was used for all fish throughout the spawning study.

2.3. Experimental system

The spawning experiment was conducted in three recirculation systems, each consisting of 4 circular, 1135 L tanks, a settling basin (528 L), two cartridge filters, and a bead biofilter. Each tank was covered with vinyl mesh (0.5 cm mesh size) cover to contain fish, yet still allow light penetration. The tanks contained a circular bubble ring around each standpipe designed to carry eggs out of the tank into egg collectors. Each system had individual temperature and photoperiod controls. Temperature was regulated in each system by a 5000-watt immersion heater in the settling basin and a 30,000 British thermal unit heat pump. Photoperiod was controlled for each system by mechanical timers and two 1.5 m, 40-watt fluorescent lights and a single 100-watt halogen flood lamp placed 1.2 m above each tank. Water quality in each system was sampled every 2 weeks for total ammonia nitrogen, un-ionized ammonia, total hardness, alkalinity, and pH. Water temperature and salinity in each system were monitored daily.

2.4. Photoperiod, temperature, and salinity

The photoperiod (Fig. 1) was maintained as the natural photoperiod (adjusted in 15 min increments) for the study location as determined by the sunrise and sunset tables calculated by the United States Navy's Astronomical Applications Department (U.S. Navy, 2009). The temperature (Fig. 2) was changed daily to mimic seasonal fluctuations in mean daily water temperature recorded by the United States' National Oceanic and Atmospheric Administrations data buoy (station 42035) located in Trinity Bay 40.7 km east of Galveston, Texas (NOAA, 2009). The mean daily temperature was rounded to the nearest whole degree Celsius and each system's temperature was programmed with a maximum variation of ±1 °C. The fish were initially held at salinities of 15 to 18 g·L and salinity was increased by 3 g·L·days beginning on August 19, 2009 until it reached 32 to 35 g·L.