Aquaculture Research

Aquaculture Research, 2010, **41**, e357–e360 doi: 10.1111/j.1365-2109.2010.02511.x

SHORT COMMUNICATION

Effects of salinity on growth and survival of common snook *Centropomus undecimalis* (Bloch, 1792) larvae

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Common snook *Centropomus undecimalis*, herein referred to as 'snook', are a stenothermic estuarine fish found in the tropical and subtropical waters of North and South America (Rivas 1986). In Florida, adult snook spawn primarily in the spring and summer months from April through September (Taylor, Grier & Whittington 1998). Spawning events occur at inlets and tidal passes of estuaries and along sandy beaches (Taylor *et al*. 1998). Eggs and larvae of snook are thought to disperse from spawning areas by tidal and wind-driven currents (Tolley, Dohner & Peebles 1987). In Florida, a small number of preflexion and post-flexion snook larvae have been collected in nearshore waters, whereas young juveniles recruit to a variety of saltwater, brackish and freshwater shoreline habitats (Gilmore, Donohoe & Cooke 1983; Peters, Matheson & Taylor 1998).

In Florida, snook play an important role in supporting one of the state's highly popular recreational fisheries, and declining populations in the Gulf of Mexico have led to concern among resource managers (Muller & Taylor 2006). Over the years, increased fishing pressure and habitat loss (Bruger & Haddad 1986) have spurred a renewed interest in investigating the feasibility of snook stock enhancement (Brennan, Walters & Leber 2008). Although snook have been identified as a candidate for aquaculture, high mortalities in the early larval stage remains a culture constraint (Wittenrich, Rhody, Turingan & Main 2009). Despite initial successes in artificial propagation and rearing of snook (Lau & Shafland 1982; Neidig, Skapura, Grier & Dennis 2000), the development of reliable hatchery methods for intensive rearing through larval and juvenile stages is necessary.

Salinity can strongly influence physiological processes and morphological developments in marine finfish (reviews in Bœuf & Payan 2001; Varsamos, Nebel & Charmantier 2005). The successful establishment of a species in a given habitat depends 'on the ability of each developmental stage to cope with changes in salinity through osmoregulation' (Varsamos *et al*. 2005, p. 401). Most marine finfish larvae are able to osmoregulate at hatching (Alderdice 1988). Functional capability of osmoregulation improves throughout ontogeny as specialized tissues and organ systems develop, where the primary site for ionic regulation shifts from the skin to the gills (Rombough 2004). Because osmoregulation is an energy-demanding process, in some species, energetic cost is thought to be lower at iso-osmotic salinities. Here, gradients between body fluids and the external environment are minimal (Holliday 1969), and more energy is available for growth and/or survival. However, results vary among species, within species and across developmental stages.

Studies with gilthead seabream *Sparus aurata* (Tandler, Anav & Choshniak 1995), fat snook *Centropomus parallelus* (Araujo, Cerqueira & Alvarez-Lajonchère 2000), haddock *Melanogrammus aeglefinus* (Opstad 2003) and Brazilian flounder *Paralichthys orbignyanus* (Sampaio, Freitas, Okamoto, Louzada, Rodrigues & Robaldo 2007) larvae showed an increase in survival or growth at intermediate salinities (≥ 15 but $\leq 30\,g\,L^{-1}$). Others found improved growth or survival at higher salinities ($\geq 34\,g\,L^{-1}$), such as those conducted with southern flounder *Paralichthys lethostigma* (Henne & Watanabe 2003; Moustakas, Watanabe & Copeland 2004) and milkfish *Chanos chanos* (Swanson 1996) larvae. The lack of consistent results among species is further illustrated by trials conducted with cobia *Rachycentron canadum* larvae (Faulk & Holt 2006), where no significant differences in standard length (SL) were observed among individuals exposed to salinities of varying concentrations.

Snook are euryhaline, but evidence exists for early-stage preferences for lower salinity habitats (Peterson & Gilmore 1991). Early attempts to rear snook in low salinity conditions, during both the larval (Shafland & Koehl 1980) and juvenile (Quintero-Hunter & Torres 1993) stages, provide evidence that snook are physiologically capable of quickly adapting to rapid transitions regardless of varying osmotic gradients. However, a more comprehensive study is needed to examine the tolerance of snook to different salinities throughout the larval period. This information is important to establish successful culture techniques. The objective of this study was to examine the influence of rearing salinity on survival and growth of snook reared from hatching through yolk sac and first feeding stages, a 14-day period.

We used a balanced replicate design to examine the influence of rearing salinity on snook larval growth and survival. Eggs from captive broodstock were hatched, transferred to twelve 100 L black conical tanks (10 000 larvae tank^{-1}), and acclimated to salinities of 15, 25 and 35 g L^{-1} ($n = 4$ replicates). Larvae were fed enriched rotifers (*Brachionus* sp.) daily (maintained at 5 mL^{-1}), water temperature maintained at 26 °C, light intensity at 1000 lx and photoperiod at 12 L:12 D.

Upon completion of the rearing trials, live snook larvae ($n = 5$ at 14 dph) were removed from each individual rearing tank and anaesthetized with tricaine methanesulphonate (Argent Chemical Laboratories, Redmond, WA, USA). Growth (SL, mm) measurements ($n = 20$ per salinity treatment) were recorded to the nearest ocular unit using an Olympus SZ40 stereomicroscope (Olympus America, Melville, NY, USA) fitted with an ocular micrometer. On the same day, all remaining larvae were collected from the individual tanks by draining the tank water through a 100 μm mesh sieve. Larvae were immediately preserved in 10% neutral-buffered formalin and later counted to obtain the total larval survival from each tank. A one-way analysis of variance (ANOVA) followed by Tukey's test for multiple comparisons among means were used to detect statistical differences in larval survival and mean body length at 14 dph. Statistical analyses were performed using SAS (SAS Institute, Cary, NC, USA) and statistical significance was assumed as $P < 0.05$.

Table 1 Survival and growth in common snook larvae (0–14 dph) reared in different salinities

Salinity (g L^{-1})	Standard length (mm)	Total survival (%)
15	3.4 ± 0.03^{a}	4.7 ± 3.19^{a}
25	3.5 ± 0.07^{ab}	14.3 ± 4.8^{b}
35	3.7 ± 0.23^{b}	18.4 ± 2.07^{b}

Mean standard length (± standard deviation; $n = 20$) and percent total survival (± standard deviation ($n = 4$) are presented. Means with different letters in the same column are significantly different ($P < 0.05$, Tukeys Studentized range test).

Mean larval lengths from the 35 g L^{-1} trials were significantly ($P = 0.03$) longer than those reared at 15 g L^{-1}, but not different from those reared at 25 g L^{-1} (Table 1). Although we detected increasing variation with the respective mean body lengths, it did not warrant the use of an alternative test to the ANOVA (McDonald 2009). Mean total survival at 15 g L^{-1} (4.7%) was significantly ($P = 0.001$) lower than at 35 g L^{-1} (18.4%) and 25 g L^{-1} (14.3%), but the latter were not different from each other (Table 1). These results are consistent with those previously reported for a number of marine fish species. Hart and Purser (1995) demonstrated that larvae of the greenback flounder *Rhombosolea tapirina* reared through metamorphosis exhibit significantly greater survival at 35 g L^{-1} than at 15 g L^{-1}. Similarly, Henne and Watanabe (2003) found growth and survival of southern flounder larvae was optimized at 34 g L^{-1} as did Lein, Tveite, Gjerde and Holmefjord (1997) when rearing Atlantic halibut *Hippoglossus hippoglossus* larvae in salinities of 27–32 g L^{-1}. However, where similar trials were conducted, our findings were not consistent with those reported for other snook species such as in trials conducted with larval (Araujo *et al.* 2000) and juvenile fat snook (Tsuzuki, Sugai, Maciel, Francisco & Cerqueira 2007), where survival and growth were significantly higher in 25 g L^{-1} salinity than at 35 g L^{-1}.

The effect of salinity on survival and growth is species specific, and euryhaline fish has been known to change throughout ontogenetic development. Common snook are euryhaline and known to explore different estuarine habitats ranging in salinity from 0 to 30 g L^{-1} (Yanes-Roca, Rhody, Nystrom & Main 2009). These variations in salinity can influence a number of physiological processes, particularly metabolic and osmoregulatory function in fish, where a portion of the metabolic energy is spent in the osmoregulatory process (Varsamos *et al.* 2005).

According to Bœuf and Payan (2001), salinity can change the amount of energy available for body growth by altering the energetic cost for osmotic and ionic regulation. One theory suggests that at an isosmotic medium, when gradients between blood and water are minimal, the cost for osmoregulation is reduced and therefore the energy saved is directed towards increased growth (Varsamos *et al.* 2005). In a review paper on the effect of salinity on growth, Bœuf and Payan (2001) discuss studies where osmoregulation required 10 to > 50% of a fish's total energy budget. They describe how large variations in energy costs among species are differential responses to complex relationships between external (ecological) and internal (endocrinological and neuroendocrinological) factors that synchronize or control many activities or functions, including growth capacity. Although all fish appear to be limited by the need for an osmoregulatory compromise (Nilsson 1986), the highly variable results seen in studies conducted among different species implies there are multiple factors at work at one time. At this time, there appears to be no general trend when considering the effect of salinity on the growth of larval fish, therefore more comprehensive studies are needed to examine the tolerance of larvae to a broad range of salinities throughout their growth. This information is important for the development of optimal culture techniques aimed at increasing larval survival and growth.

In summary, this study provides valuable life history data regarding the salinity requirement of common snook during the larval period (0–14 dph) and suggests that larvae may be successfully reared in salinities as low as $15\,g\,L^{-1}$, with optimal growth and survival at salinities of 25 and $35\,g\,L^{-1}$. In order to further assess the potential grow-out of this species, additional research is needed to examine the effects of salinity throughout the larval rearing and juvenile stage with particular emphasis on nutrient absorption and digestibility.

Acknowledgments

The authors thank Dr Nathan Brennan and Carole Neidig for reviewing this manuscript. This research was supported by the Florida Fish and Wildlife Conservation Commission and the National Oceanic and Atmospheric Administration funded research consortium, Science Consortium for Ocean Replenishment (SCORE).

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Keywords: salinity, osmoregulation, growth, snook, survival, larvae