Effect of Continuous Water Movement on Growth and Body Composition of Juvenile Rabbitfish, *Siganus rivulatus*

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Marbled spinefoot rabbitfish, *Siganus rivulatus*, is a euryhaline, herbivorous marine fish widely distributed along the Eastern Mediterranean and Indo-West Pacific region (Woodland 1983). Marbled spinefoot typically lives in schools inhabiting shallow coastal waters and can reach a size of 31.9 cm and 318.2 g in length and body weight, respectively (Bariche 2005). It is an economically valuable fishery species and is considered of great potential for warmwater aquaculture diversification (Saoud et al. 2008a, 2008b). Aquaculture suitability of the species lies in its herbivorous feeding habits, tolerance of high-stocking conditions and environmental extremes such as salinity (Saoud et al. 2007) and temperature (Saoud et al. 2008a). Farming of the marbled spinefoot, generally in floating cages or self-cleaning circular tanks is rapidly developing in some countries (Cyprus, Saudi Arabia) but efficiency is constrained due to the paucity of information on protocols for commercial production and lack of information for design of fish culture systems.

Modern aquaculture facilities are opting more frequently for intensive culture systems. Fish food production in fewer but larger systems, with effective management strategies, achieves higher economic benefits (Timmons et al. 1998). The preferred shape of growout basins is the circular culture tank because it provides uniform water quality, it is self-cleaning, and rapidly flushes settleable wastes. Moreover, round tank systems can be designed and operated to provide wide ranges of water velocities that would optimize growth and condition for some fish species (Timmons et al. 1998; see Davidson and Summerfelt 2004). Water flow induced growth in these species is associated with increased protein synthesis (Houlihan and Laurent 1987), resulting in hypertrophy of white muscle fiber which is important for fish flesh quality (Leon 1986; Totland et al. 1987). Thus, from a commercial point of view, exposure of some fish species to water currents increases growth rates, improves feed conversion ratio (FCR) and improves flesh texture (Jobling et al. 1993; Bjørnevik et al. 2003). Nevertheless, in other fish species, exposure to water current can lead to no differences in growth or growth impairment (Davison 1997).

To date there are no studies to determine whether there is an effect of water current on growth and survival of juvenile *S. rivulatus*. Such knowledge would have important implications for optimizing growth performance and also culture system design and operation in commercial production. In this study, juvenile rabbitfish, *S. rivulatus*, were reared in circular tanks with or without water currents and the effects of flow on survival, growth,
condition index, and body composition were evaluated.

**Materials and Methods**

Juvenile rabbitfish were caught in traps off the beach south of Beirut and transported to the marine research laboratory at the American University of Beirut (AUB). For 5 wk prior to the start of the experiment, the fish were reared outdoors in a recirculating system and offered a commercial dry feed. The research system consisted of six 1 m³ circular tanks (1.14 m diameter; 1 m depth) connected to a biological filter, a water pump, and a sand filter. Water level in all tanks was maintained using internal standpipes. Outer standpipes with bottom openings and tops above water level were placed around the internal standpipes. Water flowed through the standpipes into a common drain that emptied into the biofilter and from there it was pumped back to the growout tanks. In three tanks, water current was created by orienting inflow (8.6 ± 0.36 L/min) at an angle to the water surface. In the other tanks, water inflow (8.6 ± 0.36 L/min) was perpendicular to the surface, thus creating no circular flow. Water velocity at the edge of the tanks was estimated by placing a ping-pong ball in the water and measuring the time it took to go around the tank at the edge. Average surface water velocity in the three tanks at the edge was (13.3 ± 0.72 cm/sec; mean ± SD).

Oxygen concentration, salinity, and water temperature were checked daily using a portable dissolved oxygen conductivity salinity and temperature meter (YSI model 85, YSI incorporated, Yellow Springs, OH, USA). The experiment was carried out at the end of the summer season, thus temperature ranged from 29.0 C at start of experiment to 22.9 C by the end of the experiment. Dissolved oxygen concentrations and salinity remained above 6 mg/L and at 35–37 ppt, respectively. Total ammonia-N and nitrite-N concentrations remained below 0.04 and 0.2 mg/L, respectively. Total ammonia and nitrite concentration were measured once weekly using the Solorzano (1969) method and Parsons et al. (1985) method, respectively.

At the beginning of the experiment, fish were hand sorted to similar size and individual weight and total length of 35 randomly chosen fish were recorded. Five fish were removed at random for proximate analysis. Fifteen fish were stocked in each of the six tanks. Two treatments (water current and no current) with three replicate tanks each were established. In three of the tanks, the average weight of the fish was slightly greater than in the other three tanks and those were assigned the treatment with water current.

Fish were maintained in the recirculating system for 5 wk. They were offered a 50% protein, 20% lipid trout commercial diet (Golden Extruded, Chile) at 3% body weight daily, divided into two feedings: morning (0800 h) and evening (1700 h). Every week from the start of the experiment the daily ration was increased by 10%. Although we were not able to observe if any feed was uneaten due to the depth of the tank and the color of the water, fish were swimming to the surface and actively consuming the feed as soon as it was deposited into the tanks. At the end of the 5 wk, all fish were harvested, anesthetized, group weighed and then individual weight and length determined for each fish. Three fish from each tank were taken, homogenized and dried to constant weight at 90 C, ground fine and stored at −20 C for further analysis.

**Proximate Analysis**

All samples were analyzed for protein content using an elemental nitrogen analyzer (Thermo Finnigan/EA1112 elemental analyzer, Thermo Electron Corporation, Madison, WI, USA) with aspartic acid as a calibration standard. Nitrogen values were multiplied by 6.25 to estimate protein content of samples (Alavanese and Orto 1963). Total lipids were extracted using a Reflux extractor (AnkomXT10 Extractor, Ankom Technology Corporation, Macedon, NY, USA) with petroleum ether as solvent. A known sample weight was combusted in a furnace at 500 C for 5.5 h to estimate ash content. All proximate analysis results were then reported on a dry weight basis.
Data Analysis and Statistics

Survival and weight gain for each treatment were determined. The Fulton condition index (CI) of the fish was estimated using the formula; CI = (W/L^3) × X, where W = fish weight (g), L = total length (mm), and X is a constant equal to 100,000 (Anderson and Gutreuter 1983). The specific growth rate (SGR) for each tank in percent per day was calculated as: SGR = 100 × (LnW_f − LnW_i)/t, where W_f is the final weight, W_i is the initial weight, and t is the time in days (Hopkins 1992). FCR was calculated as: FCR = F/(W_f − W_i), where F is the dry weight of feed offered to the fish (Hopkins 1992). Protein efficiency ratio (PER) was calculated as: PER = (protein gain [g]/protein offered to fish [g]). Survival, growth, SGR, FCR, PER, and CI were analyzed using one-way ANOVA to determine significant differences (P < 0.05) among treatment means. All statistical analyses were carried out by SPSS statistical software (V.12 for Windows, SPSS Inc., Chicago, IL, USA).

Results

Survival for both treatments was 100%. Juvenile S. rivulatus reared in tanks with water current grew less in terms of weight as compared to juveniles reared in tanks with no water current. Although average initial body weight of fish reared in tanks with no current (7.0 ± 0.15 g) (mean ± SE) was significantly less (P < 0.05) than average body weight of fish reared in tanks with water current (7.6 ± 0.17 g) (mean ± SE), average final body weight of fish reared in tanks with no water current (15.4 ± 0.49 g) (mean ± SE) was significantly greater (P < 0.05) than the weight of fish reared in tanks with water current (13.7 ± 0.40 g) (mean ± SE). Consequently, SGR was significantly greater for fish reared in tanks with no water current (2.13 ± 0.08%) (mean ± SE) than fish reared in tanks with water current (1.60 ± 0.09%) (mean ± SE). There were no significant differences in final total length among fish in both treatments. Initial CI of fish was similar in both treatments, but final CI was significantly greater for fish reared in tanks with no water current (1.24) than for fish reared in tanks with water current (1.17) (Table 1).

Moisture content of fish reared in tanks with water current (71.5 ± 0.23%) (mean ± SE) was significantly greater than moisture content of fish reared in tanks with no water current (70.6 ± 0.24%). Percent protein was similar in fish from both treatments (17.0–17.5% of wet weight, WW). Lipid proportion was significantly greater for fish reared in tanks with no water current (7.9 ± 0.28%, WW) than fish reared in tanks with current (7.1 ± 0.13%, WW). Percent ash content was significantly greater for fish reared in tanks with water current (13.7 ± 0.55%, WW) than fish reared in tanks with no water current (13.0 ± 0.04). PER values were lower for fish reared in tanks with water current (0.20 ± 0.02) than fish reared in tanks with no water current (0.28 ± 0.01) (Table 1).

Discussion

Juvenile S. rivulatus inhabit calm shallow coastal areas where water flow is generally

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Without water current</th>
<th>With water current</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>S (%)</td>
<td>100</td>
<td>100</td>
<td>.</td>
</tr>
<tr>
<td>W_i (g)</td>
<td>7.0 ± 0.15</td>
<td>7.6 ± 0.17</td>
<td>.015</td>
</tr>
<tr>
<td>TL_i (cm)</td>
<td>8.9 ± 0.05</td>
<td>9.1 ± 0.06</td>
<td>.064</td>
</tr>
<tr>
<td>CI_i</td>
<td>0.99 ± 0.01</td>
<td>1.02 ± 0.01</td>
<td>.108</td>
</tr>
<tr>
<td>W_f (g)</td>
<td>15.4 ± 0.49</td>
<td>13.7 ± 0.40</td>
<td>.007</td>
</tr>
<tr>
<td>TL_f (cm)</td>
<td>10.7 ± 0.10</td>
<td>10.5 ± 0.09</td>
<td>.161</td>
</tr>
<tr>
<td>CI_f</td>
<td>1.24 ± 0.01</td>
<td>1.17 ± 0.01</td>
<td>&lt;0.000</td>
</tr>
<tr>
<td>SGR (%/d)</td>
<td>2.13 ± 0.08</td>
<td>1.60 ± 0.09</td>
<td>.013</td>
</tr>
<tr>
<td>FCR</td>
<td>1.30 ± 0.04</td>
<td>1.80 ± 0.11</td>
<td>.010</td>
</tr>
<tr>
<td>PER</td>
<td>0.28 ± 0.01</td>
<td>0.20 ± 0.02</td>
<td>.015</td>
</tr>
</tbody>
</table>
Table 2. Proximate analysis of marbled spinefoot rabbitfish reared for five weeks in two treatments: with and without water current. Percentage protein, % lipid and % total ash reported on a wet weight basis. Values are mean of three replicates ± SE.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Initial sample</th>
<th>Without water current</th>
<th>With water current</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>74.7</td>
<td>70.6 ± 0.24</td>
<td>71.5 ± 0.23</td>
<td>0.017</td>
</tr>
<tr>
<td>Crude protein (%)</td>
<td>16.8</td>
<td>17.5 ± 0.16</td>
<td>17.0 ± 0.15</td>
<td>0.060</td>
</tr>
<tr>
<td>Crude lipid (%)</td>
<td>3.4</td>
<td>7.9 ± 0.28</td>
<td>7.1 ± 0.13</td>
<td>0.032</td>
</tr>
<tr>
<td>Total ash (%)</td>
<td>4.2</td>
<td>3.5 ± 0.06</td>
<td>3.7 ± 0.05</td>
<td>0.007</td>
</tr>
</tbody>
</table>

slow. Thus, these fish do not have to swim against current to feed and probably their feed conversion is better the less they have to swim. This study demonstrates that *S. rivulatus* juveniles reared in circular tanks without water current grow faster (SGR, 2.13%) and have better FCRs (1.30) than when maintained in tanks with water movement (SGR, 1.60%; FCR, 1.80). It is possible that uneaten feed was removed from the tanks with water current and thus fish in tanks with no water current consumed more. However, the fact that fish were observed to consume feed voraciously as soon as it was dropped into the tanks and that FCR was 1.8, suggests that most of the feed was consumed and variation in growth is most probably because of water movement. The only other report we could find on the effects of water current on rabbitfish was by Kawamata and Hasegawa (2006) who found that when rabbitfish, *Siganus fuscens*, were subjected to water currents above 1.1–1.4 m/sec they were unable to swim against the current and thus feed, whereas when no current was present fish swam freely in the tanks and maintained position near food. Although such results support findings of this work where growth rate decreased when juvenile *S. rivulatus* were reared in moving water, the reasons for growth differential was less food consumption in the Kawamata and Hasegawa (2006) report, but is probably because of increased swimming exercise in this study.

In this study, the observed growth differential is probably associated with an increase in energy demands required to hold position against currents (Jobling et al. 1993). Furthermore, the increased body fat in fish reared in nonmoving waters suggests that they spent less energy than their counterparts that were in moving water. According to Yogata and Oku (2000), such results are normal because of an increase in body lipid content in fish where swimming exercise improves growth or a decrease in body lipid content when exercise fails to improve growth.

Ogata and Oku (2000) stated that the existence of positive or negative effects of exercise on growth is dependent on swimming ability. For fish that are naturally active swimmers such as most salmonids, swimming exercise leads to improved growth (Davison and Goldspink 1977; Totland et al. 1987; Christiansen and Jobling 1990; Jobling et al. 1993; Davison 1997; Grünbaum et al. 2008). Similarly, some nonsalmonid species such as coalfish, *Gadus virens* (Walker 1971), and California halibut, *Paralichthys californicus* (Merino et al. 2007), grow faster in moving waters. However, in species that are less active swimmers, such as Japanese flounder, *Paralichthys olivaceus* (Ogata and Oku 2000), and red seabream (*Forster and Ogata 1996*), swimming exercise impairs growth performance. Results of this study suggest that growth performance of *S. rivulatus* is also affected by water flow when reared in circular tanks. More studies are needed to determine the effects of a wider range of current velocities on performance of this species.

The fish body weight proportion of crude protein was not affected by water movement in juvenile *S. rivulatus* and this is
generally observed for moderately exercised fish (see reviews by Jobling et al. 1993; Davison 1997). However, fish reared in tanks with water current had lower fat content compared to their counterparts in tanks with no water current and the increase in lipid content was accompanied by a decrease in moisture content. Such results are generally observed for moderately exercised fish where increase in lipid content is associated with decrease in moisture content (see review by Jobling et al. 1993). Percent ash was significantly greater for fish reared in flowing water than in fish reared in static waters. Similar results were reported for Nile tilapia, *Oreochromis niloticus* (Belal 2008), where percent ash content increased with an increase in water velocity. However, in this work, the difference in body weight proportion of ash is probably because the fish in the two treatments had similar lengths but different weights. When ash content was calculated as weight per unit length for each individual fish we found no difference among treatments. This is because most ash in fish comes from the bones which were probably of similar weight in both treatments.

Results of this work suggest that juvenile (8.9–10.7 cm) marbled spinefoot rabbitfish should not be reared in self-cleaning circular tanks with constantly moving water (13.3 ± 0.72 cm/sec; mean ± SD). If such tanks are to be used, we suggest a circular motion of the water be created periodically to flush settled material and then water movement stopped.

**Acknowledgments**

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**Literature Cited**


