Effects of Stocking Density on Growth, Body Composition, Yield and Economic Returns of Monosex Tilapia (*Oreochromis niloticus* L.) under Cage Culture System in Kaptai Lake of Bangladesh

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**Abstract**

A 120-day research was conducted to evaluate the effects of different stocking densities on growth, body composition, survival, and economic returns of monosex male Nile tilapia, *Oreochromis niloticus* in net cages in Kaptai Lake of Bangladesh. Juvenile monosex tilapia with an average weight of 15.20 ± 0.15 g (mean ± SD) were randomly stocked in 12 floating net cages (3 m × 3 m × 2 m) at densities of 50 fish/m\textsuperscript{3} (T\textsubscript{50}), 75 fish/m\textsuperscript{3} (T\textsubscript{75}), 100 fish/m\textsuperscript{3} (T\textsubscript{100}) and 125 fish/m\textsuperscript{3} (T\textsubscript{125}) in triplicate groups. Fish were fed with a commercial pelleted floating feed (29% protein) at 3-5% of body weight, twice daily in all the treatments. The physico-chemical parameters of lake water were within suitable ranges for fish cultured in cages. After 120 days of trial, growth in terms of body final length, final weight, weight gain, percent weight gain, daily weight gain and specific growth rate of fish from T\textsubscript{50} were significantly higher than those of fish from T\textsubscript{75}, T\textsubscript{100} and T\textsubscript{125}. Feed conversion ratio was significantly lower in T\textsubscript{50} followed by T\textsubscript{75}, T\textsubscript{100} and T\textsubscript{125} consecutively. Survival rate was not significantly different in T\textsubscript{75}, T\textsubscript{100} and T\textsubscript{125} while lowest survival was found in T\textsubscript{125}. Significantly lower amount of body lipid and carbohydrate contents were found in T\textsubscript{125} than those of fish from T\textsubscript{50}, T\textsubscript{75} and T\textsubscript{100}. Gross and net production levels from T\textsubscript{100} were significantly higher than those from T\textsubscript{50}, T\textsubscript{75} and T\textsubscript{125}. However, the benefit cost ratio from T\textsubscript{50} was better than those from T\textsubscript{75}, T\textsubscript{100} and T\textsubscript{125}. The results demonstrated that on the basis of growth and economic return 50 fish/m\textsuperscript{3} was the best stocking density for monosex tilapia culture in cages which might be technically feasible and economically viable.

**Keywords:** Cage culture; Stocking density; Growth; Economic return; Monosex tilapia; Kaptai lake

**Introduction**

Cage aquaculture is an important technology to increase fish production. A widespread and profitable culture of fish and prawns in cages has already been developed successfully in Asia, Europe and America [1,2]. This technique in South-East Asia first started from late 1800s, since then, many countries in this area were practicing cage culture in freshwater and marine environments, including open sea, estuaries, lakes, reservoirs, ponds and river [3,4]. However, in Bangladesh, aquaculture activities are still concentrated largely in pond culture system. Cage aquaculture in open water bodies could provide an opportunity for mitigating protein demand in the nation.

Kaptai Lake in Bangladesh (latitude 22°22’-23°18’ N, longitude 92°00’-92°26’ E), is the largest manmade lake of South-East Asia (comprised about 68,800 hectare water body) [5]. The present annual fish production of Kaptai Lake reached to 8,537 MT in 2012 [6] which plays a significant role in the national economy of Bangladesh. In addition, it may offer a tremendous scope for cage aquaculture in terms of animal protein intake.

Tilapia is considered as the `aquatic chickens’ of warm-water aquaculture [7]. It is the second most important farmed fish in the world, after carps [8]. Tilapia culture is being practiced in most of the tropical, subtropical and temperate regions. In Bangladesh, tilapia production reached to 136,000 MT in 2012 [6] which is expected to increase up to 160,000 MT by 2015 [9]. The drawback of mixed sex tilapia culture is female tilapia shows precocious reproduction which results poor growth performance, overcrowding and feed competition [10,11]. Nowadays, great attention has been paid to sex-reversed male Nile tilapia, *Oreochromis niloticus* due to their sexual size dimorphism, males grow significantly faster, larger and are more uniform in size than females [12-14]. The sex-reversion process can be done by manual sexing, interspecific hybridization, hormonal sex reversal or YY male production [15]. In Bangladesh, hormonal sex reversal technique in genetically improved farmed tilapia (GIFT) has been disseminated by Bangladesh Fisheries Research Institute (BFRI) to public and private hatchery operators [9]. Presently, more than 400 monosex tilapia hatcheries are actively operating around the country and they are producing over 4 billion monosex male fry every year [9]. Experiences suggested that, this fish species can grow rapidly, require minimum oxygen, can tolerate wide range of temperature, are resistant to disease and has high yielding performance [16-18]. It can be successfully cultured in brackish water environment with shrimp in coastal ponds [19], Dan and Little [20] reported that monosex tilapia did not exhibit better growth performance over mixed sex tilapia in cage culture system. In another study, Kamruzzaman [11] proposed that monosex all male tilapia cage culture has no advantage over mixed sex tilapia in terms of growth performance.

In cage aquaculture, fish stocking density has great impact on growth, survival, health, water quality and production [21]. For

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the maximization of monosex tilapia production, profitability and sustainability in cage culture system, it is essential to determine its optimum stocking density. So far our knowledge, very little work has been done on the stocking density of monosex tilapia in cages. The aim of the research work was to investigate monosex male tilapia, Oreochromis niloticus as a potential culture species and to identify its suitable stocking density and yield in net cage culture system in Kaptai Lake of Bangladesh.

Materials and methods

Experimental site

The present experiment was conducted for a period of four months (120 days) from March to June 2012 in Kaptai Lake near to Riverine Sub-Station (Lake Fisheries) of Bangladesh Fisheries Research Institute (BFRI) in Rangamati Hill District of Bangladesh.

Cage construction and installation

In this experiment, 12 floating net cage each having an area of 3 m × 3 m × 2 m (L × W × H, 18 m³) made of synthetic nylon net (mesh size 1.1 cm) has been installed in the lake. Each net cage was tied and hanged with bamboo pole frame and covered at the top with another piece of plastic net (mesh size 2.5 cm) to prevent escape of fish by jumping and bird predation. The bamboo poles were covered with long pieces of wooden raft for easy movement, feeding and sampling of the experimental fish on the cage structure. Empty vacuum plastic drums of 250 liters size were used as cage float for buoyancy of cage structure. Empty vacuum plastic drums of 250 liters size were used as cage float for buoyancy of cage structure. The outer side of each experimental net was also covered with a fine meshed net (20 cm depth) according to surface of the lake water level to inhibit floating feeds to go out from the net and to reduce the entrance of non-caged fishes from wild sources [22]. The whole cage structure was tied with anchors at both shore sides by nylon rope to facilitate easy floating and moving of whole cage structure with 12 individual cages depending on water level.

Fish collection and stocking

In the present study, we tested four different stocking densities of monosex tilapia like 50 fish/m³, 75 fish/m³, 100 fish/m³ and 125 fish/m³ designated as T₅₀, T₇₅, T₁₀₀ and T₁₂₅, respectively, in triplicates for each treatment group. In brief, hatchery produced and hormonally sex-reversed juvenile monosex male tilapia, Oreochromis niloticus (GIFT strain) averaging 15.20 ± 0.15 g (mean ± SD) were transported to the experimental site by oxygenated polyethylene bags and they were kept in three net hapas for 24 hours for acclimation with environment and then initial length and weight of fish were recorded individually in ‘cm’ and ‘g’ with the help of a measuring scale and a digital electronic balance (OHAUS, Model CT 1200-S, USA), respectively. Finally, the cages were randomly stocked with monosex tilapia and the number of fish stocked in each cages (18 m³) were recorded simultaneously.

Feeding and rearing

A commercial floating pellet feed was used in the experimental period. The diet pellet size was 1.8-2.2 mm, and the feed contained 28.76% crude protein, 5.95% crude lipid, 14.23% crude ash and 9.43% moisture (Table 1). Feeding was done at 3-5% of the initial body weight. The total amount of feed was divided into two equal rations for feeding at 8 a.m. and 4 p.m. according to Chapman [23] and Cruz [24]. Feeding was done by hand very slowly and carefully to ensure ingestion of feed completely. Around 20% of fish in each treatment were sampled fortnightly in order to determine fish weight (TANITA digital kitchen scale, model KD-160, Japan, ± 1 g) and the feed amounts were adjusted as per changes of body weight in each trial. A record of supplied feed was maintained to determine the food conversion ratio (FCR).

During the study period, dead fish were recorded and removed quickly. The cages were lifted from water at every 15 days interval to check the net and for cleaning purposes. Cages were cleaned with soft brush to remove algae, sponges and other organisms. Loose twine, net mesh torn by predators, anchors and sinkers were checked routinely and immediately mended or replaced as needed.

Sampling and data analysis

Physico-chemical parameters of water such as temperature (°C), transparency (cm), pH, dissolved oxygen, DO (mg/L), hardness (mg/L) and total alkalinity (mg/L) were monitored weekly in the morning between 7 and 8 a.m. during the whole culture period [25]. Water temperature was recorded with a glass Celsius thermometer, water transparency was recorded with a Secchi disc, pH and DO were measured using a digital pocket pH meter (model-HI 98107 pHep® HANNA Instruments, Carrollton, TX, USA) and DO meter (DO-5509, Lutron Electronic Enterprise Co. Ltd., Taipei, Taiwan), respectively. Other chemical parameters were measured using a HACH kit box (model FF-2, No. 243001, Loveland, CO, USA).

After 120 days of trial, the whole cage structure moored to shore of the lake and all fish were harvested by repeated scoop netting and then fish were counted, measured and weighed for each cage. To determine the growth response, yield and survivability of experimental fish, the following parameters were calculated:

- **Weight gain (WG)=final fish weight (g)-initial fish weight (g)**
- **Weight gain (%=(final weight-initial weight) × 100/initial weight)**
- **Average daily weight gain (ADWG)=(final fish weight-initial fish weight)/days**
- **Feed Conversation Ratio (FCR)=weight of feed given (g)/fish weight gain (g)**
- **Specific Growth Rate (SGR%)=100 × (ln final wt-ln initial wt)/days.**
- **Gross yield=fish production (kg)/cage (18 m³)**
- **Net yield=fish production (kg)/m³ of cage**
- **Survival Rate (SR%)=100 × (number of fish survived/number of fish stocked)**

**Table 1: Proximate composition of the experimental diet (% dry basis) for monosex tilapia.**

<table>
<thead>
<tr>
<th>Component</th>
<th>Composition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>9.43</td>
</tr>
<tr>
<td>Crude protein</td>
<td>28.76</td>
</tr>
<tr>
<td>Crude lipid</td>
<td>5.95</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>6.47</td>
</tr>
<tr>
<td>Crude ash</td>
<td>14.23</td>
</tr>
<tr>
<td>NFE*</td>
<td>35.16</td>
</tr>
<tr>
<td>Diet size (mm)</td>
<td>1.8-2.2</td>
</tr>
</tbody>
</table>

*NFE: Nitrogen Free Extract [100%-(protein+lipid+ash+fiber+moisture)], a measure of soluble carbohydrates [54].

**Proximate composition analyses**

Proximate composition analyses of experimental diet and whole fish body were performed by the standard methods of Association of Official Analytical Chemists [26]. After the completion of experiment, three fishes from each treatment were collected for further analyses.
of body carcass composition. For determining moisture content, samples of diets and wet fishes were dried at 135°C for 2 h. Ash content was determined by using a muffle furnace (600°C for 4 h). Crude lipid content was determined by the Soxhlet apparatus using Soxtec system 1046 (Foss, Hoganas, Sweden) and crude protein content by Kjeldahl method (N × 6.25) after acid digestion, distillation and titration of samples. The samples were analyzed in the Fish Nutrition Lab, Department of Aquaculture, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh, Bangladesh.

**Statistical analysis**

The mean values for water quality parameters, growth, survival and production of different treatments were subjected to one-way ANOVA followed by Duncan’s New Multiple Range test [27]. All statistical analyses were performed using SAS software version 9.1 (SAS Institute Inc, Cary, NC, USA). Standard deviation of each parameter and treatment was determined and expressed as mean ± SD. Treatment effects were considered with the significant level at P<0.05.

**Economic analysis**

After the termination of experiment, an economic analysis was performed to estimate the net return and benefit–cost ratio on the basis of different stocking densities of monosex tilapia. The following simple equation was used according to Asaduzzaman *et al.* [28]:

$$R=I-(FC+VC+I)$$

Where, R=net return, I=income from monosex tilapia sale, FC=fixed/common costs, VC=variable costs and I=interest on inputs

The benefit-cost ratio was determined as:

Benefit cost ratio (BCR)=Total net return/Total input cost

At the end of the experiment, all fish were sold and the prices of fish were attributed to the Rangamati local fish market price in July 2012 and expressed in Bangladeshi takas (1US$=80 BDT). The local price per kg of monosex tilapia was 250 BDT for near or more than 250 g fish (T<sub>50</sub>), 200 BDT for 200-250 g fish (T<sub>75</sub> and T<sub>100</sub>) and 180 BDT for less than 200 g fish (T<sub>125</sub>). In the study, fish selling price was higher than normal price, because every year from April/May to June/July, Kaptai Lake is closed by the government authority for capture fishing. Kaptai Lake is closed by the government authority for capture fishing. In consideration of economic analysis, total cost of inputs in T<sub>50</sub> (BDT/cage) was lower than that in T<sub>75</sub>, T<sub>100</sub> and T<sub>125</sub> (Table 5). A highest input was obtained in T<sub>125</sub> followed by T<sub>100</sub>, T<sub>75</sub> and T<sub>50</sub> (P<0.05).

In the present study, we did not find any significant differences in whole-body moisture, protein and ash content in T<sub>100</sub>, T<sub>75</sub> and T<sub>125</sub> (P<0.05) (Table 4). However, significantly lower amount of body lipid and carbohydrate contents were found in T<sub>125</sub> than those of the other treatments (P<0.05) (Table 4).

In consideration of economic analysis, total cost of inputs in T<sub>50</sub> (BDT/cage) was lower than that in T<sub>100</sub>, T<sub>75</sub> and T<sub>125</sub> (Table 5). A highest total net return was also obtained in T<sub>50</sub> followed by T<sub>100</sub>, T<sub>75</sub> and T<sub>125</sub> (Table 5). In overall, the highest benefit cost ratio (BCR) was found in T<sub>50</sub> and a lowest in T<sub>125</sub>.

**Discussion**

In the present study, different physico-chemical parameters of water in the cages were within the suitable and safe ranges for monosex tilapia growth throughout the experimental period. The range of water temperature (26.3-31.8°C) in the experimental cages is in agreement with Boyd [29], who proposed that the range of water temperature from 26.60 to 31.97°C is suitable for tropical fish culture. Similarly, Dan and Little [20] suggested that tilapia is suitable for raising between April and December when temperatures range from 25°C to 35°C.

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**Table 2:** Mean values (± SD) and ranges (parentheses) of water quality parameters in cages over 120 days.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Stocking densities (fish/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T&lt;sub&gt;50&lt;/sub&gt;</td>
</tr>
<tr>
<td>Water temperature (°C)</td>
<td>30.2 ± 1.5&lt;sup&gt;a&lt;/sup&gt; (26.3-31.8)</td>
</tr>
<tr>
<td>DO (mg/L)</td>
<td>6.8 ± 1.2&lt;sup&gt;a&lt;/sup&gt; (6.5-7.8)</td>
</tr>
<tr>
<td>Free CO₂ (mg/L)</td>
<td>2.1 ± 0.3&lt;sup&gt;a&lt;/sup&gt; (1.8-2.6)</td>
</tr>
<tr>
<td>pH</td>
<td>6.8 ± 0.6&lt;sup&gt;a&lt;/sup&gt; (6.4-7.4)</td>
</tr>
<tr>
<td>Transparency (cm)</td>
<td>54.1 ± 1.2&lt;sup&gt;a&lt;/sup&gt; (51.4-58.4)</td>
</tr>
<tr>
<td>Total Hardness (mg/L)</td>
<td>44.6 ± 2.3&lt;sup&gt;a&lt;/sup&gt; (39.5-53.2)</td>
</tr>
<tr>
<td>Total Alkalinity (mg/L)</td>
<td>58.3 ± 3.2&lt;sup&gt;a&lt;/sup&gt; (48.4-67.4)</td>
</tr>
</tbody>
</table>

Values in each row having the same superscripts are not significantly different (P<0.05).

**Figure 1:** Growth increment of monosex tilapia at different stocking densities on each sampling day over 120 days of cage culture.
the most important stress factor which has direct impact on health and survival of caged fishes [30]. For optimal fish growth, dissolved oxygen (DO) levels should be above 5 ppm for warm water fish species [29]. In our experiment, concentration of DO in all the cages ranged between 6.3-7.8 mg/L. The pH (6.3-7.4) and transparency or Secchi disc depth (50.5-58.4) were within the favorable ranges for cage culture of tilapia [30]. The value of free CO2 ranged from 1.8 to 3.5 mg/L which supports the results of Rahman [31]. The alkalinity denotes the concentration of calcium or magnesium carbonate or bicarbonate in water. In this study, growth in terms of final length, final weight, weight gain, percent weight gain, average daily weight gain and specific growth rate of monosex tilapia were significantly higher in lower stocking density, T50 (50 fish/m3) compared to higher stocking densities followed by T75 (75 fish/m3), T100 (100 fish/m3) and T125 (125 fish/m3). Albeit a same feed was applied at an equal ratio, the growth performance differed significantly in all the stocking groups. The reason behind this might be due to lower density fishes got more spaces and there was less competition for feeds compared to higher density treatments [35]. This result is in agreement

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Stocking densities (fish/m3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T50</td>
</tr>
<tr>
<td>Initial length (cm)</td>
<td>9.15 ± 0.05a</td>
</tr>
<tr>
<td>Final length (cm)</td>
<td>23.10 ± 6.17a</td>
</tr>
<tr>
<td>Initial weight (g)</td>
<td>15.20 ± 0.15a</td>
</tr>
<tr>
<td>Final weight (g)</td>
<td>256.53 ± 16.36a</td>
</tr>
<tr>
<td>Weight gain (g)</td>
<td>240.33 ± 5.86a</td>
</tr>
<tr>
<td>Weight gain (%)</td>
<td>1581.12 ± 6.32a</td>
</tr>
<tr>
<td>Average daily weight gain (g)</td>
<td>2.01a</td>
</tr>
<tr>
<td>Specific growth rate (%)</td>
<td>2.35a</td>
</tr>
<tr>
<td>Feed conversion ratio (FCR)</td>
<td>1.81b</td>
</tr>
<tr>
<td>Survival rate (%)</td>
<td>96.8b</td>
</tr>
<tr>
<td>Gross fish yield (kg/cage/120 days)</td>
<td>223b</td>
</tr>
<tr>
<td>Net fish yield (kg/m3/120 days)</td>
<td>12.4a</td>
</tr>
</tbody>
</table>

Values are means from triplicate groups (n=3) of fish where the values in each row with different superscripts are significantly different (P<0.05).

Table 3: Growth performance, survival, feed utilization and yield of monosex tilapia in cages after 120 days of experimental period.

<table>
<thead>
<tr>
<th>Stocking density (fish/m3)</th>
<th>Moisture (%)</th>
<th>Protein (%)</th>
<th>Lipid (%)</th>
<th>Ash (%)</th>
<th>Carbohydrate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T50</td>
<td>69.02 ± 0.26a</td>
<td>15.05 ± 0.56a</td>
<td>10.38 ± 0.19a</td>
<td>4.02 ± 0.28a</td>
<td>1.53 ± 0.08a</td>
</tr>
<tr>
<td>T75</td>
<td>66.33 ± 0.42a</td>
<td>16.35 ± 0.72a</td>
<td>9.32 ± 0.12a</td>
<td>4.07 ± 0.18a</td>
<td>1.93 ± 0.16a</td>
</tr>
<tr>
<td>T100</td>
<td>71.08 ± 0.58a</td>
<td>14.51 ± 0.63a</td>
<td>8.33 ± 0.18a</td>
<td>4.00 ± 0.13a</td>
<td>2.08 ± 0.11a</td>
</tr>
<tr>
<td>T125</td>
<td>73.57 ± 0.32a</td>
<td>15.82 ± 0.52a</td>
<td>6.04 ± 0.27a</td>
<td>3.79 ± 0.22a</td>
<td>0.78 ± 0.21a</td>
</tr>
</tbody>
</table>

Values are means from triplicate groups (n=3) of fish where the values in each row with different superscripts are significantly different (P<0.05).

Table 4: Proximate composition (% wet basis) of monosex tilapia after 120 days of cage culture.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Price rate (BDT)*</th>
<th>In Bangladesh Taka (BDT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed/common cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net cage (18 m3)</td>
<td>4000/unit</td>
<td>4000</td>
</tr>
<tr>
<td>Subtotal</td>
<td>6000</td>
<td>6000</td>
</tr>
<tr>
<td>Variable costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juvenile monosex tilapia</td>
<td>3/juvenile</td>
<td>2700</td>
</tr>
<tr>
<td>Feed cost</td>
<td>42/kg</td>
<td>16921</td>
</tr>
<tr>
<td>Auxiliary materials (bamboo, anchors etc) for supporting cage</td>
<td>5000</td>
<td>5000</td>
</tr>
<tr>
<td>Subtotal</td>
<td>24621</td>
<td>31936</td>
</tr>
<tr>
<td>Total</td>
<td>30621</td>
<td>37936</td>
</tr>
<tr>
<td>Interest on inputs (4 months)</td>
<td>10% annually</td>
<td>1021</td>
</tr>
<tr>
<td>Total inputs</td>
<td>31642</td>
<td>39200</td>
</tr>
<tr>
<td>Financial returns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monosex tilapia sale as total returns</td>
<td>250/kg</td>
<td>200/kg</td>
</tr>
<tr>
<td>Total net returns</td>
<td>55655</td>
<td>56820</td>
</tr>
<tr>
<td>Benefit cost ratio (BCR)</td>
<td>0.759</td>
<td>0.449</td>
</tr>
</tbody>
</table>

*1 US $=80 Bangladesh Taka (BDT)
†price of monosex tilapia of T50 group
‡price of monosex tilapia of T75 and T100 groups
¶price of monosex tilapia of T125 group

Table 5: Cost and return analysis of monosex tilapia in different stocking densities from single unit of cage (18 m3) after 120 days.
with those reported by Chakraborty [36] for monosex tilapia, Ouattara [37], Gbitan [30] and Osofero [38] for mixed sex tilapia, Hengsawat [39] for African catfish, Haque [40] for Thai silver barb and Ahmed [41] for common carp in cage culture system. In contrast, increased growth, survival and feed conversion ratio were also observed in high density culture of juvenile silver perch, *Bidyanus bidyanus* and tilapia, *Oreochromis sprialus* [42,43].

In the present study, the overall growth performance of monosex tilapia was higher than Gbitan [30] and Osofero [38] at *T* 50 and *T* 100. Similarly, Chakraborty [36] found lower performance than our study at *T* 50, *T* 75 and *T* 100. Mridha [44] found much lower growth performance of all male tilapia in rain fed rice-fish ecosystem after 4 months culture period than the present study. Contrary to our findings, Dan and Little [20] reported better final weight and daily weight gain in overwintered GIFT monosex tilapia at the density of 30 fish/m3. The performances were lower than our results in case of new-season (first production of tilapia in rain fed farming) with same strain of tilapia. Moreover, Dan and Little [20] confirmed that overwintered caged tilapia have better growth performance than that of earthen ponds, whereas in case of new season tilapia the phenomena were opposite. In comparison with our study, Ahmed [18] found lower final weight and average daily weight gain of monosex tilapia in earthen ponds. Shofiquzzoha [19] researched on polyculture of shrimp along with three strains of tilapia- hormonally sex-reversed Bangla FISHGEN (all male) and GenoMar Supreme Tilapia™ (all male), and BFRI-GIFT (mixed sex) tilapia in earthen brackish water ponds. The authors found best final weight in monosex GenoMar Supreme Tilapia™ (291 g) after 120 days of polyculture which was higher than the present study (255.53 g). However, other strains like BanglaFISHGEN (225.29 g) and BFRI-GIFT (193.10 g) showed lower final weight than our findings.

Weight gain and survival rate are the most important issues for a successful cage aquaculture because they determine the production performance and profit of the system. Yi and Lin [45] reported that higher biomass of caged tilapia had a significant negative effect on final body weight. In this experiment, lowest growth performance and survival rate (83.1%) was found in T125 (125 fish/m3). The result probably due to overcrowding effect for limited living spaces, oxygen depletion, limited surfaces for proper feeding which might cause serious feed competition and nutritional deficits, more energy expenditure and finally increased stress, stunted growth and overwhelming of fishes in net cages for stocking huge number of monosex tilapia [35,37,46,47].

The SR reported by some researchers, Liti [48] and Abou [49] found much lower growth performance to all stocking densities. Therefore, stocking density of monosex tilapia. Benefit-cost ratio (BCR) of each treatment was determined on the basis of input costs of fish, feeds and cage materials and it returns from total fish sale. In this experiment, very cheap bamboo poles were used for cage structure. Moreover, durable net cages and plastic drums could be use up to 5-6 harvests. So, in initiating year or during the first harvest, the profit index will be lower than in the following years because of the fixed costs. In this study, we used little bit bigger size of cages (18 m3 each) to reduce input costs. McGinty and Rakocy [47] proposed that as cage size increases, cost per unit volume also decreases. In the present study, near about 50-60% input cost came from feed which is usual in any aquaculture operation [8]. Through the economic analysis we found that even though *T* 100 (100 fish/m3) attributed best production performance, *T* 100 (50 fish/m3) showed the highest economic return due to preferred market size and selling price of fish which is in agreement with Zonneveld and Fadhili [53]. In addition, the lowest economic return was found in *T* 125 (125 fish/m3) possibly due to smallest size, lowest total production and lowest selling price of monosex tilapia which is in agreement with Mridha [54,55].

Conclusions

In conclusion, it can be corroborated that on the basis of growth performance and economic return, 50 fish/m3 exhibited the highest performance to all stocking densities. Therefore, stocking density of 50 fish/m3 could be recommended for the successful cage culture of monosex tilapia. This study has implications of sustainable and cost-effective cage culture practices in lake environment. However, further research could be addressed on the fish stocking size and cage size.

Acknowledgments

This research work was funded by Fish production, Conservation and Strengthening Management at Kaptai Lake (Component - C, BFRI Part) Project (Code no. 05-4405-5470) under the Ministry of Fisheries & Livestock (MoFL) of the government of Bangladesh. The present study, production economics was affected by stocking densities of monosex tilapia. Benefit-cost ratio (BCR) of each treatment was determined on the basis of input costs of fish, feeds and cage materials and it returns from total fish sale. In this experiment, very cheap bamboo poles were used for cage structure. Moreover, durable net cages and plastic drums could be use up to 5-6 harvests. So, in initiating year or during the first harvest, the profit index will be lower than in the following years because of the fixed costs. In this study, we used little bit bigger size of cages (18 m3 each) to reduce input costs. McGinty and Rakocy [47] proposed that as cage size increases, cost per unit volume also decreases. In the present study, near about 50-60% input cost came from feed which is usual in any aquaculture operation [8]. Through the economic analysis we found that even though *T* 100 (100 fish/m3) attributed best production performance, *T* 100 (50 fish/m3) showed the highest economic return due to preferred market size and selling price of fish which is in agreement with Zonneveld and Fadhili [53]. In addition, the lowest economic return was found in *T* 125 (125 fish/m3) possibly due to smallest size, lowest total production and lowest selling price of monosex tilapia which is in agreement with Mridha [54,55].

In the present study, there was an increasing trend of gross and net fish yield with increasing stocking density. However, the total yield was increased from 50 fish/m3 (*T* 50) up to 100 fish/m3 (*T* 100) then declined at highest stocking density, 125 fish/m3 (*T* 125). Significantly highest biomass was found in *T* 100 which agree with that reported for caged tilapia at the same density [52]. The negative correlation between stocking density and fish production at *T* 125 might be postulated for density-dependent mortality and poor growth performance. In line with our study, Hengsawat [39] reported that final harvest and production values were directly related to stocking density and there must be a limit where mortality will be severe and growth and production will be reduced. In contrast, Ridha [8] found better growth and production performance in mixed sex GIFT tilapia at *T* 125 than the present study.

Conclusions

In conclusion, it can be corroborated that on the basis of growth performance and economic return, 50 fish/m3 exhibited the highest performance to all stocking densities. Therefore, stocking density of 50 fish/m3 could be recommended for the successful cage culture of monosex tilapia. This study has implications of sustainable and cost-effective cage culture practices in lake environment. However, further research could be addressed on the fish stocking size and cage size.

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References


