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Short communication

# Stocking density of Nile tilapia in cages placed in a hydroelectric reservoir

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ABSTRACT

The Brazilian government has been encouraging fish farming in cages in federal water bodies, including hydroelectric reservoirs. Despite the government support, it is a new activity and the production model still needs some adjustment to reduce the production costs and achieve sustainability. The aims of this study were to determine the appropriate stocking density of Nile tilapia in cages in a hydroelectric reservoir and to evaluate to what extent fish size selection could improve their uniformity. Twelve cages (6 $m^3$) were placed at the Fish Farmers' Cooperative of Santa Fé do Sul and Region, Ilha Solteira reservoir, São Paulo, Brazil (20°12′10″S, 50°58′31.15″W). In stage I (initial fish weight, 78 g), four stocking densities were tested: D1—800, D2—2000, D3—2500 and D4—3000 fish/cage, with three replicates. At the end of this stage (average fish weight, 255 g), the fish were selected into three sizes, except for D1. In stage II, four stocking densities were tested, designed to obtain the following final production: D1—100 kg/$m^3$ (800 non-selected fish/cage), D2—80 kg/$m^3$ (600 fish/cage), D3—100 kg/$m^3$ (800 fish/cage) and D4—120 kg/$m^3$ (900 fish/cage). The trial ended when the fish weighed 800 g. By reducing the initial stocking density from 2500 to 800 tilapia juveniles per cage, there was no need for selection. The growth performance was higher, the feed conversion rate was better and the time taken to reach harvesting was shorter. Consequently, the production cost reduced and the operating profit increased. Using the lowest initial stocking density, the risk of disease outbreak was also lower, and there was no need to use drugs for disease control since the mortality rate and occurrences of disease and deformity decreased and the dissolved oxygen level inside the cages was higher.
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## 1. Introduction

The Brazilian government has been encouraging fish farming in cages in federal water bodies, including hydroelectric reservoirs, because of the large area of these reservoirs and lakes, which cover 6.5 million hectares (Halwart et al., 2007), and because of the low implementation costs of such systems. However, due to the absence of a specific methodology to evaluate the impacts of the cage culture on public waters and the carrying capacity of these areas, farmers have had great difficulty in obtaining environmental permits. To solve this problem, since 2004, the government has designated six reservoirs, containing 42 aquaculture parks, with a total area of 28,503.00 ha of water. Through this action, the aim has been to implement planned and orderly occupation of reservoirs by aquaculture in order to avoid environmental impacts and ensure multiple use of water bodies (BRASIL, 2012).

Altogether, an estimated 40 fish families have been cultivated in cages, but five families alone (Salmonidae, Sparidae, Carangidae, Pangasiidae and Cichlidae) make up 90% of the total production (Halwart et al., 2007). Tilapia production has undergone impressive growth, which makes this, after salmon and shrimp, one of the most successful aquaculture products entering international trade. Tilapias are hardy and omnivorous and feed at a low trophic level. Within intensive systems, this species can be fed formulated diets containing a high percentage of plant proteins and oils (Watanabe et al., 2002). The largest proportion of the production is probably derived from extensive aquaculture through land-based farms (Halwart et al., 2007).

The term 'stocking density' refers to the concentration at which fish are initially stocked in a system. However, it is generally used to refer to the density of fish at any point in time (Ellis et al., 2002). Fish welfare can be affected by density, and the evidence for this can be examined in terms of productivity, health, condition and stress level (Ellis et al., 2002). Aquatic production systems are unique in that the animals use a three-dimensional medium. In fish production,

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density incorporates the number of fish per unit of three-dimensional space, as influenced by the number of fish or weight of fish per volume of static water, and the fish biomass per volume of flowing water per unit of time (Beleau, 1990; Conte, 2004).

In tilapia cultivation, experiments conducted in cages in other countries have evaluated densities ranging from 2 to 50 kg/m$^3$ and have shown that there is a direct inverse relationship between stocking density and growth performance (Gibtan et al., 2008; Yi et al., 1996; Ouattara et al., 2003; Watanabe et al. 1990; Chakraborty et al., 2010). However, in Brazil, producers have been cultivating Nile tilapia in cages at higher densities (80 to 120 kg/m$^3$), and economic studies have shown that the production cost of this system is high (Ayroza et al., 2011; Marengoni, 2006).

Another problem of the Brazilian production model is the use of size selection of Nile tilapia in cages. Farmers adopt this management to improve size uniformity and make better use of the physical space of the cages (Carvalho et al., 2010). For this, all the fish are put on a table, where they are classified into three sizes. However, after this manipulation, the mortality rate increases because of the stress to which the fish are subjected.

Despite government support, cage cultivation is a new activity in Brazil and the production model still needs some adjustment to reduce the production costs and disease risk. Thus, the aim of this study was to determine the appropriate stocking density of Nile tilapia in cages in a hydroelectric reservoir and to evaluate whether fish size selection is necessary for this production model.

## 2. Materials and methods

Nile tilapia (*Oreochromis niloticus*) were used in this study, which was carried out in twelve cages (6 m$^3$) at the Fish Farmers' Cooperative of Santa Fé do Sul and Region, Ilha Solteira reservoir, São Paulo, Brazil (20°12′10″S, 50°58′31.15″W). This cooperative is made up of 40 small farmers and has 100 cages of 6 m$^3$ (2 × 2 × 1.5 m) positioned in parallel lines in the perpendicular direction to the flow of water from the stream where they are installed. The usual management adopted by the cooperative includes removal of dead and moribund fish in the mornings; the fish are fed twice a day (8:00 h and 16:00 h), in accordance with the recommendations of the feed manufacturer, taking into consideration the size of the fish and water temperature. Fish ($n$ = 2500) weighing around 50 g are stocked in each cage until they reach 250 g, when they are selected and redistributed among the cages at a stocking density of 800 fish per cage. For the selection method, all the fish are put on a table, where they are manually classified into three sizes and referred to cages that will contain fish with homogeneous size. The fish are harvested when their average weight reaches 800 g.

The fish are sold to cold storage plants to be processed and filleted. Fish weighing 50 g to 250 g are fed with Supra Aqualine® Juvenil Gaiola commercial feed, in 2.5-mm pellets (dry matter: 88%, digestible energy: 3800 kcal/kg, crude protein: 42%, ether extract 9%). From 250 g to 800 g, the producers use Supra Aqualine® Tilapia Gaiola commercial feed, in 5-mm pellets (dry matter: 88%, digestible energy: 3500 kcal/kg, crude protein: 32%, ether extract: 7%).

A completely randomized design was used to test four stocking densities. The experiment was divided into two stages. Before the first day of the trial, size selection took place to ensure the size uniformity of fish. In stage I (initial weight 78 g), the stocking densities tested were 800, 2000, 2500 and 3000 fish/cage, with three replicates. At the end of this stage, lasting 41 days, the fish (average fish weight, 255 g) were subjected to size selection, with classification into three sizes (small, medium and large), except for the fish from the lowest density. The medium-sized fish were used to start stage II, in which four stocking densities were tested, with three replicates. Stage II was designed to obtain the following final production: 100 kg/m$^3$ (800 non-selected fish/cage), 80 kg/m$^3$ (600 fish/cage), 100 kg/m$^3$ (800 fish/cage) and 120 kg/m$^3$ (900 fish/cage). The trial finished when the fish weighed 800 g.

### 2.1. Growth performance

To evaluate growth performance and size uniformity of the batch, individual biometry was performed on 5% of the fish per cage, at the beginning and at the end of each stage. Feed intake was registered daily.

Before the end of stage II, biometry was performed on five samples (around 15 fish each) in each cage every week to ascertain whether the average weight of the fish had reached 800 g.

The parameters evaluated were as follows: weight gain (WG) = final weight − initial weight; feed conversion rate (FCR) = WG / feed intake; specific growth rate (SGR) = 100 × (Ln final weight − Ln initial weight) / number of days; coefficient of variation (CV) = standard deviation of fish weight / average weight.

### 2.2. Fish health

Fish health was evaluated twice during each stage of growth, and when the mortality rate was higher than normal, in order to identify the cause of fish death. In the mornings, before removal of moribund and dead fish, two Nile tilapias were collected from each cage, totaling six per treatment. The fish collected could be either with or without clinical signs of disease, but preference was given to moribund fish. These fish were packed individually in plastic bags, stored in an insulated box with ice and transported to the Aquatic Animal Disease Laboratory, which is at a distance of 120 km from the cooperative.

Upon arrival at the laboratory, the fish were weighed and smears were prepared from the skin and gills for microscopic examination to evaluate occurrences of parasites. After this procedure, the fish were taken to a laminar flow, and their body surfaces were disinfected with alcohol (70° GL) for 10 min. Microbiological samples consisting of swabs were taken aseptically from the brain and kidney of the fish. The samples were identified by means of routine tests, including colony morphology, Gram staining, hemolysis on agar containing sheep blood 5% v/v, catalase, oxidase and phenotypic profile in API 20 E and API 20 Strep (BioMerieux, France). The prevalence of pathogens (number of infected or infested fish/total number of fish evaluated) was calculated as described by Bush et al. (1997).

### 2.3. Water quality

Water samples from inside the cages (50 cm deep) were collected twice during each stage, on the same day as collecting fish for health assessments. At the fish farm, the water temperature and dissolved oxygen (mg/L) in each cage were measured using an YSI 700 oximeter. One 500-mL sample of water was collected from each cage in a sterile flask, to evaluate the number of heterotrophic bacteria. Nitrite (ppm), total ammonia nitrogen (mg/L) and pH were measured using a commercial kit (ALFAKIT; Alfa Techno Chemistry Company, Florianópolis, SC, Brazil). Counts of viable heterotrophic bacteria (CFU) were made in tryptic soy agar (Difco 236950) after 24 hours of culturing at 28 °C. Dilutions were prepared in the same agar and plates were set up in duplicate for each plated dilution.

### 2.4. Production cost

The total operational cost was determined for each of the two production stages studied. Real data were obtained during the trial and according to the usual management of the cooperative. Thus, for each treatment, the cost per tank, per unit and per kilogram was determined. In stage II, the gross revenue and operating profit per tank and per kilogram were also determined.

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