



Stocking densities of juvenile *Brycon orthotaenia*: production parameters and economic benefits in net cages

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ABSTRACT. Developing a rearing technology requires the determination of the optimum stocking density. This study aimed to determine the best stocking density for *Brycon orthotaenia* juveniles grown in net cages, during the rearing phase. The research was conducted at the Experimental Farm of EPAMIG, in Felixlândia, Minas Gerais State, in the Três Marias Reservoir. 9,000 fingerlings were distributed into 12 net cages, 2 m³ each, according to a completely randomized design with three replications and four different stocking densities (150, 300, 450, 600 fish m⁻³). Random samples were taken from each net cage, at the onset of the experiment and at 60 rearing days, to assess production parameters, specific growth rate and uniformity. We verified a positive linear relationship ($p < 0.05$) for final biomass ($r^2 = 0.88$), weight gain ($r^2 = 0.87$), productivity ($r^2 = 0.86$), apparent feed conversion ($r^2 = 0.96$) and economic viability ($r^2 = 0.96$). For survival ($r^2 = 0.98$), the relationship was negative ($p < 0.05$). There were no significant differences between treatments ($p > 0.05$) for growth parameters, uniformity and final weight. It can be concluded that the density of 300 fish m⁻³ is the most suitable, because it provides higher net revenue, survival, and a good feed conversion.

Keywords: aquaculture, intensive system, survival, profitability, São Francisco river.

Densidades de estocagem de juvenis de *Brycon orthotaenia*: parâmetros produtivos e benefícios econômicos em tanques-rede

RESUMO. Para o desenvolvimento de uma tecnologia de cultivo é necessária a determinação da densidade de estocagem ideal. Objetivou-se determinar a melhor densidade de estocagem para juvenis de *Brycon orthotaenia*, cultivados em tanques-rede, durante a fase de recria. A pesquisa foi conduzida na Fazenda Experimental da Epamig, em Felixlândia, Estado de Minas Gerais, na represa de Três Marias. Foram utilizados 9.000 alevinos, distribuídos em 12 berçários com 2 m³ em tanques-rede, seguindo o delineamento inteiramente casualizado, com três repetições e quatro diferentes densidades de estocagem (150, 300, 450, 600 peixes m⁻³). Amostras aleatórias de cada tanque-rede foram coletadas para as avaliações, no início do experimento e aos 60 dias de cultivo. Foram estimados os parâmetros produtivos, índice de crescimento específico e uniformidade. Obteve-se uma relação linear positiva ($p < 0,05$) para biomassa final ($r^2 = 0,88$), ganho de peso da biomassa ($r^2 = 0,87$), produtividade ($r^2 = 0,86$), conversão alimentar aparente ($r^2 = 0,96$) e para viabilidade econômica ($r^2 = 0,96$). Para sobrevivência ($r^2 = 0,98$), a relação linear foi negativa ($p < 0,05$). Não houve diferença significativa entre os tratamentos ($p > 0,05$) para os parâmetros de crescimento, uniformidade e peso final. Conclui-se que a densidade de 300 peixes m⁻³ é a mais indicada, pois, proporciona maior receita líquida, sobrevivência e boa conversão alimentar.

Palavras-chave: aquicultura, sistema intensivo, sobrevivência, rentabilidade, rio São Francisco.

Introduction

Brycon orthotaenia commonly known as matrinxã has a great potential for production, whose national production in 2010 reached 5000 tons (BRASIL, 2010). This species is appreciated in sport fishing for its aggressive behavior, shows good indices of growth for commercial production like weight gain and feed conversion, besides high quality meat (IZEL et al., 2004).

However in order to attract the interest of fishermen and small farmers, research has to provide technologies and technical and economic information on the cultivation of native species, highlighting their competitiveness and economic sustainability. In this way, there is not yet mastery of techniques at all stages of production. Studies related to growth performance of *Brycon orthotaenia* in net cages during the rearing phase have been

carried out (PEDREIRA et al., 2010; MATTOS et al., 2013). Nevertheless, for intensification of native fish farming in net cages in Brazil it is necessary to develop technologies especially designed for rearing, the critical breeding phase when occur high mortality rates, which corresponds to the stage of producing juveniles (BRANDÃO et al., 2005).

An important step in the development of a technological package for the production of a fish species in captivity is to determine the optimum stocking density, which aims to provide greater productivity per area, optimizing the rates of survival, growth and profitability (BRANDÃO et al., 2004; CHATTOPADHYAY et al., 2013). A comparative analysis of profitability and high stocking density is required before selecting the best stocking density that can generate the highest production and profit for economic sustainability of net cage culture system (ISLAM et al., 2006; CONTE et al., 2008).

The relationship between optimum stocking density and production parameters, such as growth, may be positive or negative, and species specific (MERINO et al., 2007; TOLUSSI et al., 2010). Commonly, at low stocking densities, fish have higher survival rates and good growth rate, however the production per area is low. On the other hand, fish kept at higher densities have lower growth, high levels of stress and social interactions, such as increased aggression (GOMES et al., 2000; IGUCHI et al., 2003). Even though cannibalism is most commonly found in the larval stage, this behavior can also be observed in the growing phase of *Brycon* species (MARQUES et al., 2004). Given the above, the present study aimed to determine stocking densities of the matrinxã *B. orthotaenia*, during the rearing period, in nurseries installed in net cages. In this context, aimed to determine the stocking densities for matrinxã (*Brycon orthotaenia*), during the rearing phase in nurseries installed in net cages.

Material and methods

The trials were conducted in an arm of the Três Marias hydroelectric power plant reservoir, inside the Centro de Pesquisa, Demonstração e Treinamento de Cultivo de Peixes em Tanques-rede of the *Empresa de Pesquisa Agropecuária de Minas Gerais* – EPAMIG's experimental farm, in Felixlândia, Minas Gerais State, Brazil.

For this study, 9,000 fingerlings of *Brycon orthotaenia* with average weight of 0.74 (0.11) g and length of 3.4 (2.0) cm were distributed into 12

nurseries of 2.0 m³ each and mesh of 5.0 mm between opposite knots, installed in 4.0 m³ net cages with mesh of 20 mm between opposite knots; each net cage corresponded to an experimental unit. The experiment was a completely randomized design with 4 treatments and 3 replications per treatment. The treatments consisted of four different stocking densities: 150, 300, 450, and 600 fish m⁻³.

Fish were fed to apparent satiation, four times daily for the first month, with 0.8 mm-commercial extruded feed containing 56% crude protein and, from the second month, the frequency was reduced to three times a day with 1.7 mm extruded feed containing 40% crude protein (Table 1). The amount of feed was recorded daily to calculate feed intake at the end of the experiment.

Table 1. Assurance levels of the commercial feeds used.

Assurance levels	0.8 mm	1.7 mm
Crude protein - CP (min.)	56 %	40 %
Moisture (max.)	12 %	10 %
Ether extract (min.)	5 %	4 %
Mineral matter (max.)	11 %	15 %
Fibrous matter (max.)	8 %	6 %
Calcium (max.)	8 %	5 %
Phosphorus (min.)	1.5 %	1.5 %

Water quality parameters were measured in each net cage. Temperature and dissolved oxygen were determined daily in the morning and in the afternoon with a digital oximeter (YSI 55 Hexis), pH, weekly, using a digital pH meter (pHep®4 HI 98127 Hanna).

At the start of the experiment, after the acclimation period of 7 days and at the end of the rearing phase, with 60 days, random samples of 10% of the total population of each net cage were taken. Fish were anesthetized with 50 mg L⁻¹ clove oil (INOUE et al., 2003), weighed and measured to estimate the growth parameters.

With the data obtained, the following parameters of final productivity were evaluated: survival (%), final number of fish, final biomass (kg), weight gain (final biomass – initial biomass), productivity (fish m⁻³) and apparent feed conversion (feed intake/weight gain), specific growth rate ($[\ln \text{ final weight} - \ln \text{ initial weight}] / \text{days of cultivation} \times 100$), which evaluates daily growth (%), and coefficient of variation of length ($[\text{length standard deviation} / \text{average length}] \times 100$), which determines the uniformity of batches (%), both proposed by Brandão et al. (2005).

The economic viability was estimated considering the effective operational cost (EOC) - which is the sum of the costs with labor and inputs (feed and buying fingerlings), that is, the costs

related only to expenses incurred in conducting the activity. In the calculations, the fixed costs were not considered. Profitability indicators considered were: Gross Revenue, determined by the sale of juveniles; Net Revenue, the difference between gross revenue and effective operational cost (EOC), considering the unit selling price of juveniles at R\$ 1.00.

The obtained data were submitted to the Lilliefors test to verify the normality of the data, analysis of variance and linear regression at 5% of probability, opting for the better adjusted equation. In order to perform the statistical analysis, were used the SAEG – *Sistema para Análises Estatísticas* – computer program, version 9.1 (SAEG, 2007). The analysis of variance was performed according to the following statistical model: $Y_{ij} = \mu + D_i + e_{ij}$, in which, Y_{ij} – observation j performed in density i ; μ – general mean of Y ; D_i – effect of the stocking density i , $i = 1, 2, 3$ and 4 ; e_{ij} – error associated to each observation, $NID \sim (\mu, \sigma)$.

Results and discussion

The water quality parameters were maintained inside the levels adequate to the development of the fish (Table 2), according with limits recommended by Resolution No. 357 of 2005 of the National Council of the Environment - CONAMA (BRASIL, 2005).

Table 2. Mean values and standard deviation of physical and chemical parameters of the water during the experimental period.

Water quality parameters	Stocking density (fish m ⁻³)				Conama 357*
	45	70	95	120	
Mean temperature (°C)	22.5 (0.50)	22.0 (0.35)	23.0 (0.00)	22.0 (0.00)	--
Dissolved oxygen (mg L ⁻¹)	5.76 (0.25)	5.59 (0.03)	5.6 (0.04)	5.6 (0.04)	≥5
pH	7.1 (0.10)	7.1 (0.00)	7.1 (0.00)	7.1 (0.00)	6–9

*Resolution n.º 357 (BRASIL, 2005), from March 17th, 2005 – Provides the classification of water bodies and environmental guidelines for such classification and establishes conditions and standards for discharge of effluents and other measures.

The effect of the stocking densities over the productive parameters was determined by the analysis of variance. The effect was significant ($p < 0.05$) for survival, final biomass, biomass gain, apparent food conversion, apparent ration intake and productivity. However, did not observe significant differences for final weight between the stocking densities ($p > 0.05$).

For survival (Figure 1), the linear relationship was negative ($p < 0.05$), with 98% accuracy, i.e., the higher stocking density the lower survival of animals. The treatment of 150 fish m⁻³ showed the highest survival index (88.11%) (Table 3). *B. orthotaenia* has an aggressive behavior, commonly shows

cannibalism in the larval stage, but in the initial period of our experiment, we observed an abnormal aggressive behavior in fish stocked at densities of 450 and 600 fish m⁻³, evidenced by cannibalism. The presence of possibly secondary infectious diseases was also frequent in net cages with high densities. Marques et al. (2004) used an intensive system to examine *Brycon cephalus* fingerlings, at different stocking densities (24, 48, 72, and 96 fish m⁻³), reported a low survival rate (66.67, 43.33, 41.67, and 48.33%, respectively) and also attributed their results to cannibalism observed during the rearing period. On the other hand, several studies observed the lack of influence of stocking density on survival (BARCELLOS et al., 2004; BRANDÃO et al., 2004; BRANDÃO et al., 2005). Survival can be affected by the social behavior of the studied species, variable among species, besides the management employed during rearing and development stage. Although not evaluated in this study, stress is always present in net cage farming. Stressors, such as high stocking densities, provoke a reduction in disease resistance under chronic stress (FIGUEIREDO; FARIA, 2005; IGUCHI et al., 2003; JOBLING, 1994). When assessing the effects of stocking densities on responses to stress, Lupatsch et al. (2010) registered significantly higher levels of cortisol in fish kept at high densities. The response to stress is a mechanism that allows the fish to preserve their health against the threat of stressors. Depending on the severity of the stressor, the response mechanism may become dysfunctional and impact negatively the physiology of the animal (LIMA et al., 2006).

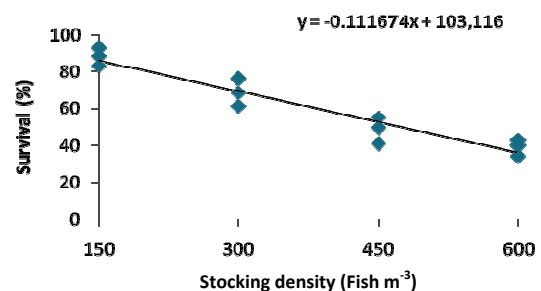


Figure 1. Linear regression for Survival at 5% of probability.

The stocking densities had a positive linear effect in relation to the final number of fish ($p < 0.05$). However, was observed that, in densities above 150 fish m⁻³, mortality improved the cultivation environment due to the reduction in the quantity of fish, tending to approximately 400 fish, equivalent to an average density of 200 fish m⁻³. A possible explanation for this, is that for some species there is a considered optimal density which depends on behavioral characteristics, suggesting that in the conditions in which the experiment was conducted, the ideal

stocking density would be between 150 and 300 fish m^{-3} , in the rearing phase.

Table 3. Means and standard deviation of juvenile matrinxã (*B. orthotaenia*) performance variables submitted to different stocking densities in net cages and their respective coefficients of variation.*

Parameters	Stocking density (fish m^{-3})				CV(%)	r^2
	150	300	450	600		
Final number of fish	264 (14)	413 (62)	438 (65)	469 (55)	13.06	0.86**
Final number of fish	264 (14)	413 (62)	438 (65)	469 (55)	13.06	0.86**
Final standard length (cm)	14.1 (0.24)	14.0 (0.22)	14.4 (0.95)	14.1 (0.34)	3.94	0.05
Final biomass (kg)	17.2 (1.9)	27.3 (1.5)	30.8 (7.2)	32.3 (11.6)	27.56	0.88**
Biomass gain (kg)	16.9 (1.9)	26.8 (1.5)	29.9 (7.3)	31.2 (11.6)	28.40	0.87**
Productivity (fish m^{-3})	132 (7)	207 (31)	219 (32)	235 (27)	13.06	0.86**
Survival (%)	88.1 (4.7)	68.8 (10.4)	48.7 (7.2)	39.1 (4.6)	10.75	0.98**
Apparent food conversion	0.99 (0.09)	1.18 (0.08)	1.45 (0.13)	1.89 (0.45)	18.39	0.96**
Specific growth (%)	6.26 (0.36)	6.67 (0.33)	6.56 (0.31)	6.57 (0.39)	5.43	0.35
Uniformity (%)	8.19 (1.12)	8.08 (0.15)	8.51 (3.46)	9.20 (1.51)	24.68	0.78

*Variables submitted to regression analysis ($p < 0.05$) ** ($p < 0.05$), was significant, for *t* test.

Juvenile final weight was not affected by the stocking densities ($p > 0.05$). Similar results were found by Mattos et al. (2013) in a study of *Brycon orthotaenia* in net cages in the initial fattening phase in different stocking densities (45, 70, 95, and 120 fish m^{-3}); Brandão et al. (2005) and Carvalho et al. (1997), studying *Brycon amazonicus*, and also denominated *Brycon cephalus*. However, Pedreira et al. (2010), studying the effect of stocking densities over the final weight of *Brycon orthotaenia* juveniles in the fattening phase, observed a negative linear effect, that is, the final weight was inversely proportionate to the density. Contrary results were found by Piaia and Baldisserotto (2000) who, evaluating the stocking density of *Rhamdia quelen* fingerlings, observed an increase in final weight in more elevated stocking densities. In the context of the information found, may affirm that the stocking density effect over the final weight of the fish may be directly related to growth phase, species, age, size, management and time of year (MATTOS et al., 2013).

Were obtained a positive linear relation for final biomass and biomass gain ($p < 0.05$). Both variables increased proportionately according to the stocking density, reaching higher values in the density of 600 fish m^{-3} . Results reported by Pedreira et al. (2010), in a study of *Brycon orthotaenia* in net cages in the initial fattening phase in different stocking densities (20, 40, and 60 fish m^{-3}), and by Brandão et al. (2005), who obtained a larger final biomass in the density of 500 fish m^{-3} , compared to the other densities (200, 300, and 400 fish m^{-3}) of their study with *B. cephalus* juveniles, corroborate with the results obtained in the present study. In addition, the quantity of fish maintained in confinement infers directly on the final biomass, that

is, higher densities will present proportionately larger biomass, not necessarily considering feeding management and weight.

The apparent food conversion (Figure 2) obtained a positive linear relation with the increase of density ($p < 0.05$). However, these values are relative, because the provision of rations remained according to the established density, without considering mortality, which was only evaluated at the end of the experiment, masking the actual values. However, another consequence of high densities is the worsening of conversion rates. The apparent food conversion observed at the density of 150 fish m^{-3} , with 0.99 (0.09), was higher to that observed for *B. amazonicus*, in different cultivating phases, in net cages as well as in nurseries, ranging from 1.31 to 2.5 (GOMES et al., 2000; IZEL et al., 2004; BRANDÃO et al., 2005; TORTOLERO et al., 2010).

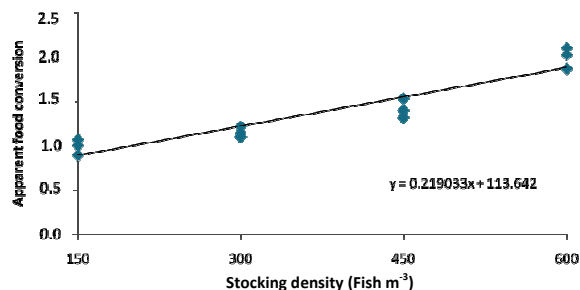


Figure 2. Linear regression for Apparent food conversion at 5% of probability.

The considered growth variables showed no significant differences ($p > 0.05$) between the densities. These results indicate that, for the studied cultivating period, space availability did not present an adverse effect over the growth of the matrinxã, because the fish reached the expected final average size for the rearing phase, close to 14 cm, in all densities, and the specific growth was not affected by the stocking densities ($p > 0.05$). Similar results were obtained for *C. macropomum*, *B. cephalus*, *Bidyanus bidyanus* and *Heterobranchus longifilis* (BRANDÃO et al., 2004; BRANDÃO et al., 2005; ROWLAND et al., 2006; TOKO et al., 2007).

Low or close to 10% standard length coefficient of variation values, characterize homogeneity in the size of cultivated fish (JOBLING, 1994). Therefore, the lots in all studied densities were considered homogeneous, with final weight and standard length similar between each. According to Soares et al. (2002), the uniformity of the fish lots present a quadratic behavior regarding stocking density, with the best values in the intermediate densities. However, Gomes et al. (2000), in their studies with *B. cephalus* larvae, reported that an increase in density promotes a directly

proportionate worsening in uniformity. Divergent to all the presented results, Marques et al. (2004), evaluating *B. cephalus* fingerlings in experimental conditions, observed that the uniformity suffered a linear increase ($p < 0.05$) with the increase in density, thus suggesting that the uniformity varies according to the management employed in production.

Productivity presents a positive linear effect between stocking densities ($p < 0.05$). However, the average production observed in the densities of 450 and 600 fish m^{-3} was relatively high, 219 (32) and 235 (27) fish m^{-3} , respectively, presenting high mortality. The production must be evaluated in relation to the studied cultivating phase, the final size of the animals and economic variability, because the reduction in the average performance of the animals may be compensated by the increase in productivity per volume. Evaluating jundiá (*Rhamdia quelen*) juveniles, Barcellos et al. (2004) reported that, even if the density of 100 jundiá juveniles m^{-3} in net cages might produce larger fish, the density of 300 fish m^{-3} triples juvenile production, although with smaller weight.

In regard to economic variability (Table 4), the total cost and unit cost variables presented a positive linear relation ($p < 0.05$) between the stocking densities. The objective of the producer, whether to produce juveniles for sale by unit or fattening for sale by kg, interferes with the production results (GOMES et al., 2000).

Table 4. Economic viability in the rearing phase of matrinxã (*Brycon orthotaenia*) at different stocking densities in net cages*.

	Stocking density (fish m^{-3})			
	150	300	450	600
Fingerlings (R\$)	90.00	180.00	270.00	360.00
Feed 56% CP (R\$)	9.31	17.93	26.23	34.55
Feed 40% CP (R\$)	34.98	65.26	94.18	111.98
Effective operational cost (R\$)	134.30	263.19	390.41	506.53
Gross revenue (R\$)	264.00	413.00	438.00	469.00
Net revenue (R\$)	129.70	149.81	47.59	-37.53

*unit selling price of juveniles R\$1.00.

The effective operational cost had a positive linear relationship ($p < 0.05$) between stocking densities. Given the peculiarity of the system used, we cannot compare these results with other studies. The comparison of results for each stocking density shows that the production achieved at a density of 600 fish m^{-3} is economically unfeasible, with a negative net revenue (R\$-37.53), which causes losses to the producer. Theoretically, higher densities lead to higher net revenues, although production costs are also higher. The variable expenditure, particularly cost of feed and buying fingerlings, increases with increase in stocking density (CHATTOPADHYAY et al., 2013) which was not observed in this study due to high mortality at highest stocking densities.

The density of 300 fish m^{-3} showed the highest net revenue, 13.42% higher in relation to that of 150 fish m^{-3} , thus considered the most suitable under the experimental conditions.

Conclusion

In summary, the stocking density of 300 fish m^{-3} is the most suitable for rearing matrinxã in net cages. This density promotes the highest net revenue, a satisfactory apparent feed conversion, and is not different from the others as for growth parameters and weight of animals.

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