ARTIGO

Effect of Organic and Chemical Fertilizers on the Growth Rate of Tambaqui Fish (*Colossoma Macropomum*) (Pisces; Characidae) in Floodplain Fish Ponds in the Eastern Amazon, Pará State, Brazil

Alex da Silva Lobão Souza¹, Raimundo Aderson Lobão de Souza², Alberto Carvalho Peret³, Nuno Filipe Alves Correia de Melo² & Jorge Luiz Rodrigues Filho³

¹Instituto Federal de Educação, Ciência e Tecnologia do Pará, Campus Abaetetuba, Pará-Brasil.
²Universidade Federal Rural da Amazônia - Belém-Pará-Brasil.
³Universidade Federal de São Carlos, São Carlos - São Paulo - Brasil
E-mail: alexlobao@globo.com

ABSTRACT: The effect of organic and chemical fertilizers in fish ponds on the growth rate of tambaqui (*Colossoma macropomum*) from Pará state, Brazil, was the objective of this work. Three 600 m² fish ponds located in the floodplain of the Guamá River near the city of Belém, at 01°27'20"S; 48°30'15"W, were used where juvenile fish were subjected to three treatments: organic fertilizer (in fish pond 1); organic and chemical fertilizers (fish pond 2); and a control that was not treated with any kind of fertilizer (fish pond 3). The weight to length ratio was calculated and adjusted by the method of the least squares applied to the logarithmic transformations relevant to the data of length and weight. It was found that the application of only organic fertilizer was more efficient for biomass gain than using chemical and organic fertilizers together in floodplain fish farming.

Key words: Amazon River Basin, fishes; fish-farming; water quality

***O Efeito da Adubação Orgânica e Química Sobre o Desempenho em Crescimento do Tambaqui (*Colossoma Macropomum*) (Pisces: Characidae) em Viveiros na Várzea do Pará, Amazônia Oriental, Brazil

RESUMO: O efeito da adubação orgânica e inorgânica em viveiros de piscicultura sobre o crescimento do tambaqui (*Colossoma macropomum*) no Estado do Pará, Brasil. Foram utilizados três viveiros de piscicultura de 600 m² capacidade, onde os juvenis de tambaqui foram submetidos a três tratamentos: fertilizante orgânico (viveiro 1); fertilizante orgânico + fertilizante químico (viveiro 2) e o controle sem aplicação de fertilizante (viveiro 3). A comparação do crescimento individual foi realizada através da análise das retas de regressão linear entre os incrementos em comprimento e os comprimentos médios respectivos. Foi constatado que a aplicação de apenas adubo orgânico foi mais eficiente no ganho de biomassa do que usando fertilizantes químicos e orgânicos juntos na piscicultura de várzea.

Palavras-chave: Bacia amazônica, peixes; piscicultura; qualidade da água

Introduction

Amazonian floodplains are rich in nutrients due to the sedimentation of particles brought by white water rivers (LIMA, 1956; JUNK, 1983; LIMA & TOURINHO, 1994). However, fish breeding needs liming as well as organic and chemical fertilizers to improve water quality and fish production (TOLEDO & CASTRO, 2001; AVAULT, 2003).

The roles of fertilizers in aquaculture are reported by numerous authors (SANTEIRO & PINTO-COELHO, 2000; MISCHKE & ZIMBA, 2004; PEREIRA & MERCANTE, 2005; SIPAÚBA-TAVARES & BRAGA, 2007) and involve the stimulation of phytoplankton productivity and increase of natural food availability to the reared organisms. Avault (2003) reports that the production of natural food in aquaculture is induced mainly by fertilization of the fish ponds.

As a result, most fish breeders understand as
extremely necessary and indispensable the fertilization procedures in fish culture ponds. Hence, there is need to investigate the role of artificial eutrophication in a naturally fertile ecosystem to enhance the knowledge of producers with fish ponds.

The tambaqui (Colossoma macropomum) is one of the most popular species in Amazonian fish farming (FILHO, 2007), and this study aimed to evaluate the effect fertilization in fish ponds located in floodplains on the growth of tambaquis.

Material and Methods

The study was carried out during 12 months, between October 2006 and September 2007, at the Federal Rural University of Amazonia (UFRA), located in the municipality of Belém, Pará state, Brazil (01°27'20"S, 48°30'15"W).

In the experiment were three 600 m$^2$ ponds (P1, P2, and P3) with an average height of the water column varying between 0.8 and 1.0 m and supplied with water from the Guamá River.

Liming was done in all three ponds using lime hydroxide [Ca(OH)$_2$] as prevention. For each pond, 60 kg of lime hydroxide was added, corresponding to 1000 kg/ha, following the method of Kubitza (2003). The ponds were left to rest for five days. Afterwards, the ponds were filled, and the fish were added seven days later.

The fish pond fertilization followed the methodology proposed by Kubitza (2003): for P1, addition of 1500 kg/ha of organic fertilizer (pure and curried chicken manure) in quotas of 90 kg every six month; for P2, in addition to organic fertilization 30 kg/ha (1.8 kg every six months) of a chemical fertilizer constituted by superphosphate [Ca(H$_2$PO$_4$)$_2$·Ca(SO$_4$)$_2$] was added, presenting 20% of P$_2$O$_5$ (in which 7.92% was P), 20.16% of Ca and 12.00% of S; and P3 which did not receive any kind of fertilizer and served as an experimental control.

From the Orion Nina Ribeiro fishery station, a facility that belongs to the Pará State Agricultural Secretary (SAGRI) in the municipality of Terra Alta, Pará, 300 tambaqui juveniles (Colossoma macropomum) were packed in each 1.024 m$^3$ floating holding cage (1.60 m x 0.80 m x 0.80 m). The young fish showed an average total length of 2.59 cm ± 0.19 cm (CV=7%) and an average weight of 0.26 g ± 0.05 g (CV=21%) and were maintained in the floating cages for three months in order to avoid predation. In this period, the minnows were fed daily on feed in amounts equal to 10% of their biomass. These amounts were divided into two portions per day. During the first month, the feed was “Crifry” bran containing 45% brute protein (PB). During the second month, feed was Initial “Pira Tropical” extruded ration (4 mm), with 32% PB. During the third month, the minnows received Growth “Pira Tropical” extruded ration (8 mm) with 28% PB (proportions are given in Table 1).

From the fourth month and on, the fish were let loose in the ponds with stocking densities corresponding to 1 fish per square meter and were fed on the same growth ration but with amounts equal to 3% of their biomass.

Samples of 39 individuals were taken at approximately one-month intervals. Total length (cm) and weight (g) were measured for each specimen. At the last sampling all individuals were counted in order to obtain the survival rates per pond.

The weight to length relation was established and adjusted by the least squares method applied in logarithmic transformations relevant to the weight and length data:

\[ W_t = \phi L_t^\theta \]

Where:

- $W_t$ is the total weight (g);
- $\phi$ is the condition factor in the mathematical expression;
- $L_t$ is the total length of the fish (cm);
- $\theta$ is the exponent related to the growth form.

The relative growth of the tambaquis in the three experimental ponds was analyzed by comparison of the respective values of the relative condition factor:

\[ Kr = \frac{W_t}{W_e} \]

Where:

- $W_t$ is the total weight (g) observed;
- $W_e$ is the theoretical expected weight for the length data in all ponds, estimated by the weight/length equation).

The growth comparison between the individuals submitted to each treatment was done using linear transformations of von Bertalanffy growth equation, as shown by Santos (1978), where the increase in length is related to the average successive lengths. This procedure involves the transformation of the variables as demonstrated in the formula below:

\[ \frac{L_{t+\Delta T} - L_t}{\Delta T} = \frac{L_e (1 - e^{-\Delta T})}{\Delta T} - \frac{(1 - e^{-\Delta T})}{\Delta T} L_e + \xi \]

The weight increase involves the association between the von Bertalanffy growth equation and the weight to length relation, according to the expression bellow:

\[ W_t = W_\infty [1 - e^{-k(t-t_e)}]^{\theta} \]

Where:

- $W_t$ is the total weight of the individuals;
- $W_\infty$ is the asymptotic weight;
- $k$ is the growth index;
- $t_e$ is an index associated with the stocking age;
- $\theta$ is the weight/length relation exponent.
The biomass curves were obtained by the multiplication of the population densities in each pond, discovered by considering the mortality rate – constant during the experiment – and by the individual weight calculated by the curve of weight increase. The following model was then applied

\[ B_t = RS^*W_\infty \left[ 1 - e^{-kt} \right]^\theta \]

Where:
- \( B_t \) is the biomass at the end of time \( t \);
- \( R \) is the stocking density (Recruitment);
- \( S^* \) is the asymptotic weight of the growth curve;
- \( W_\infty \) is the monthly survival rate;
- \( k \) is the individual growth constant;
- \( t_e \) is the constant related to recruitment age;
- \( \theta \) is the weight/length relation constant.

The biomass efficiency index (\( t_s \)) was obtained by the ratio of maximum biomass in each pond to the time spent for the achievement of these values, calculated by the second derive equal to zero in the biomass curve equation (SANTOS, 1978).

\[ T_{bs} = -\frac{1}{k} \ln \frac{M}{M + \theta K} - t_e \]

\[ B_m = \text{Re}^{\frac{M}{M + \theta K}} W_\infty \left( \frac{M}{M + \theta K} \right)^\frac{M}{\theta K} \left( \frac{M + \theta K}{M + \theta K} \right)^\theta \]

\[ I_s = B_m / T_{bs} \]

Where:
- \( M \) is the mortality coefficient obtained as:
  \[ M = -\ln S^* \]
Results

Among the constants involved in the growth curve which are listed in Table 2, it is evident that the parameter for individual growth (k) was lower in P1 (liming + organic fertilization). However, such treatment gave the longest body length (L∞) when compared with the other treatments.

A graphic comparison of the growth curves, adjusted by the von Bertalanffy equation, is found in Figure 1 and the linear equations in Figure 2.

Table 2. The von Bertalanffy constants for each treatment.

<table>
<thead>
<tr>
<th>Constants</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>0.114962</td>
<td>0.131819</td>
<td>0.1715</td>
</tr>
<tr>
<td>L∞</td>
<td>53.42357</td>
<td>48.80243</td>
<td>43.97779</td>
</tr>
<tr>
<td>Te</td>
<td>-0.50272</td>
<td>-0.48129</td>
<td>-0.41198</td>
</tr>
</tbody>
</table>

The comparison of the weight-increase curves

Figure 1. Graphic comparison of the growth curves adjusted to each treatment.

Figure 2. Linear growth curves obtained for each treatment and adjusted to the von Bertalanffy equation.
can be observed in Figure 3, where P1 with organic fertilization shows the best efficiency, while P3 with liming and without fertilizations exhibits the worst efficiency. For each pond, the biomass observation was done with the assistance of mathematical equations of biomass-increase curves, which relate theoretical data from the weight-increase curves with different densities along the cultivation months, considering mortality constant during the entire experiment.

Comparison with the biomass-increase curves is shown in Figure 4, in which P1 reached the highest biomass gain, while P3 presented the lowest.

The instants of biomass ($I_g$) were obtained through the ratio of maximum biomasses of each treatment to the respective time for the culture to reach such maximum biomasses. These values are found in the Table 3, where the highest was presented by P1.

Table 3. $I_g$ values for the different treatments.

<table>
<thead>
<tr>
<th></th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_g$</td>
<td>15594.22</td>
<td>14116.81</td>
<td>12378.32</td>
</tr>
</tbody>
</table>
Discussion

One of the greatest challenges in evaluations regarding the growth of organisms when submitted to different treatments in fish culture is the development of a comparative index, since parametrical statistics be used to compare events described by functions of the curve, leading constantly to errors of interpretation. Growth is one of the most noticeable biological facts and is targeted by different evaluation techniques with many elaborated indexes. (ZIVKOV et al, 1999).

Some authors, such as Galucci & Quinn (1979) among others, rely on the combined observations of the constants $k$ and $L_v$ constants from the von Bertalanffy growth equation. The multiplication of these constants (the “ $\omega = kL_v$ ” index) was proposed by the authors since each constant does not provide adequate data when considered apart from the other. Other authors, like Munro & Pauly (1983), propose a different coefficient, “ $\phi = \log k + 2 \log L_v$ ”, which they call the growth and development index.

However, in order to obtain these constants using the same estimators, only one numerical interaction is imposed in which the greater the $v$ value, the smaller the $L_v$ value becomes. This condition hinders the comparison of growth among different treatments in fish cultures.

Santos et al. (2010), investigating protein needs of juvenile tambaqui after food privation, observed that the condition factor (K) showed results similar to when food was short, giving better fish development in unrestricted food regimes with rations of 32%, 36%, and 40% PB.

A revision on the use of these indexes was made by Zivkov et al (1999), who concludes that the best way to compare growth is by observing the behaviour of the growth rates.

In addition to this statement of Zivkov, this study shows that the observation of the rates might not be possible without considering the relative size of the individuals in each growth period. Santos (1978), proposed a linear transformation of the von Bertalanffy equation that allows us to relate the successive increases with the average length:

$$\frac{L_{T+\Delta T} - L_T}{\Delta T} = L_v\left(1 - e^{-k\Delta T}\right) - \frac{(1 - e^{-k\Delta T})}{\Delta T} L_T$$

When dealing with straight lines it is possible to evaluate development by the slope of the line. This collaborates what Penna et al, (2005), using the mathematical model of Schnute, affirm, namely that the best fitting curve is the von Bertalanffy.

In demonstrate this comparison showing better development in pond P1 where organic fertilization was the only type used (Figure 1). The weight-increase curves show this difference in an accentuated way (Figure 2). The asymptotic values between individuals show differences that reach almost 1 kg between ponds 1 and 3 and more than 0.5 kg between ponds P2 and P3 for each individual.

Such values multiplied by the monthly densities (which show low mortality) lead these differences between P1 and P3 to be approximately 200 kg in the maximum biomasses (Figure 4).

The biomass-efficiency index allows us to conclude that P1 showed better conditions for rearing tambaqui, corroborating the statement by Avault (2003) that fertilization in fish ponds favours the increase of aquacultural yields. Santana (2006) demonstrated that the effect of organic fertilizers is similar to the inorganic effects with regard to the stimulus of the production of natural food in the shrimp farming. Silva, Gomes & Roubach (2007), however, did not observe any effect on growth when researching the effects of different management regimes on juvenile tambaqui.

The floodplain of the white water Guamá River, in Pará state, is rich in nutrients, and therefore does not need chemical fertilization. The prophylactic measure of adding calcium hydroxide is sufficient to allow adequate growth.

In the last months of the experiment fish weight was greater in P3, followed by P2 and P1. However, the increase in weight curve, when adjusted to the data of these treatments, shows an inverse behaviour. The curve obtained for P1 is the one that reaches the greater asymptotic values, for both weight and length, thusly showing the best biomass yield, followed by P2 and P3. In P3, growth ceased during June, July and August – a fact that led the asymptotic curve to smaller values. The comparison among the values from the last month of the experiment (September) by Kruskall-Wallis analysis (nonparametric ANOVA) showed significant differences between all treatments, with the greater values found in P3 followed by P2 and P1.

Pondering these discrepant results, the growth development of the tambaquis under different treatments cannot be concluded based only on the biomass yield curve, nor on the instant maximum biomass.

Although the control condition in P3 (with no organic nor chemical fertilizer) showed the lowest biomass yield, the of growth during June, July, and August, followed by a new growth period in September, indicates that the farming could be continuous in providing general biometrical data for all sizes and weights, avoiding working with projected curves. For this reason, we definitely believe that the observed differences between P1 and P2 are not very important, but the control condition to which the organisms were submitted in P3 be dismissed. Thus, while the influence of fertilizers is well know, the nutrient richness of the waters from the Guamá River can not be ignored.

Size variability of the tambaqui at the initial and final phases in this study is considered low with regard to length as well as weight. In the Pará state tambaqui minnow supply tanks variability found
ranged between 5% and 6% with regard to the fish weight (SOUZA et al., 1998). Núñez & Salaya (1983) in their one-year experiment carried out in Venezuela with caged tambaquis found variability with the lowest values for initial length equal to 7% and 6% to the final length; for weight, the initial value was 23% and the final 20%. It is likely that the low variability values for tambaqui size in this study can be attributed to the low survival rate during larval cultures and to the minnow storage process, a fact that would be quid pro quo for a non intentional selection process in which the bigger and more fit individuals survive in smaller numbers.

Conclusions

The rearing of tambaqui (Colossoma macropomum) in floodplain ecosystem fish ponds, without continuous water renewal, and this method is a way to minimize environmental impacts; The growth rate of tambaqui is influenced by different levels of eutrophication in the fish ponds and unmixed chicken dung used as fertilizer works more efficiently than its mixture with chemical fertilizers for the growth of Colossoma macropomum in floodplain areas.

References


xxx-xxx. 2007.

