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Original Article

Brycon hilarii produced in hapas: effects in allometric growth

Brycon hilarii produzido em hapas: efeitos no crescimento alométrico

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Abstract

Biometric evaluations are essential to determine the growth characteristics related to the weight and length of fish. This study aimed to determine the growth patterns of juvenile piraputangas (*Brycon hilarii*) produced in hapas within an excavated pond. The piraputangas were anesthetized and micro-chipped and their biometric characteristics were measured. Subsequently, the fish were distributed in six hapas of eight m^3 at the density of 20 fish/hapa, totaling 120 animals. During the experimental period six months, the fish were fed twice (5% of the biomass) a day. Every 30 days, all fish were sampled to measure the biometric characteristics of body weight (g); standard length; total length; head height; head length; body height and body width (cm). The calculations of the weight ratio with the biometric characteristics were determined using allometric equation and estimated by linear regression according to the equation log Y = log a + b log X. All tested relationships were significant by the Student t-test ($p < 0.05$). Allometric growth was positive for: weight x total length; standard weight x length; weight x head height; weight x head length and weight x body height. The relative condition factor of piraputangas observed in this study was 1.00. The study provided information on the allometric parameters of juvenile *Brycon hilarii* produced in hapas, and the relative condition factor indicated good growth conditions for piraputangas with positive allometric growth.

Keywords: condition factor, morphometric relationships, native fish, weight-length, piraputanga.

Resumo

As avaliações biométricas são essenciais para determinar as características de crescimento relacionadas ao peso e comprimento dos peixes. Este estudo teve como objetivo determinar os padrões de crescimento de juvenis de piraputangas (*Brycon hilarii*) produzidas em hapas dentro de um viveiro escavado. As piraputangas foram anestesiadas, microchipadas e suas características biométricas foram mensuradas. Posteriormente, os peixes foram distribuídos em seis hapas de oito m^3 na densidade de 20 peixes/ hapa, totalizando 120 animais. Durante o período experimental de seis meses, os peixes foram alimentados duas vezes (5% da biomassa) ao dia. A cada 30 dias todos os peixes foram amostrados para mensurar as características biométricas peso corporal (g); comprimento padrão; comprimento total; altura da cabeça; comprimento da cabeça; altura do corpo e largura do corpo (cm). Os cálculos das relações de peso com as características biométricas foram determinados por meio da equação alométrica e estimados por regressão linear de acordo com o log da equação Y = log *a* + *b* log X. Todas as relações testadas foram significativas pelo teste t de Student ($p < 0,05$). O crescimento alométrico foi positivo para: peso x comprimento total; peso x comprimento padrão; peso x altura da cabeça; peso x comprimento da cabeça e peso x altura do corpo. O fator de condição relativo das piraputangas observado neste estudo foi de 1,00. O estudo forneceu informações sobre os parâmetros alométrico de juvenis de *Brycon hilarii* produzidas em hapas, e o fator de condição relativo indicou boas condições de crescimento para piraputangas com crescimento alométrico positivo.

Palavras-chave: fator de condição, relações morfométricas, peixe nativo, peso-comprimento, piraputanga.

1. Introduction

Basic knowledge of animal growth is important for its application, as the growth process influences meat production almost directly (Albertini et al., 2013; Bartz et al., 2018), aiming at greater production in efficiency. The development of a body shape is what characterizes an animal grow and can be measured or compared by morphometric indexes and can be calculated from a set of data (Boussou et al., 2010; Kupren et al., 2014).

Morphometric is defined as the study of changes in shape and size, and the relationship between these two variables, and can also be related to several other variables, such as, for example, age and gender through quantitative analysis (Santos et al., 2007; Maciel et al., 2014). On the other hand, allometry is defined as the study of variation in the different dimensions of body parts that are closely related to changes in the entire body and aims to explain part of

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the quantitative differences between animals, considering the weight-to-weight ratio and not the time to reach it (Furusho-Garcia and Perez, 2006; Gomiero et al., 2010).

In this context, through biometrics we can measure the growth of aquatic organism in different types of environments, whether they be natural or experimental (Kumar et al., 2012; Varela et al., 2012). Based on these measurements, we can identify the type of growth, habitat conditions, and animal health (Froese, 2006). However, the morphometric measurements in fish may vary depending on the characteristics of each species, and influence the body weight and fillet yield (Melo et al., 2013).

The logarithmic transformation of Huxley's equation (1932) as Y=aXb allows a description of the growth of different regions and tissues, and the whole organism. The coefficient of allometry b measures the relative speed of growth of "Y" about "X". This coefficient varies from 2.5 to 3.5, being considered isometric when b=3 and allometric when b ≠ 3. Isometric and allometric relationships based on regression analyses still prevail to estimate body composition in fish and production animals (Dumas et al., 2010).

The weight-length relationship of a species provides important data to evaluate fish populations and estimate the pattern of growth and weight (Mahmood et al., 2012; Antonetti et al., 2013). The empirical relationship between fish length and weight helps to understand the natural history of commercial fish species, aiming at its conservation, and knowledge about climate and environmental changes (Sarkar et al., 2013). Given this relationship, it is possible to estimate the condition factor, considered a quantitative indicator of the degree of health or well-being of the species, guaranteeing population success, since it influences growth, reproduction, and survival (Lê Cren, 1951; Vazzoler, 1996).

The genus *Brycon* comprises about 40 species, some of which stand out for their great productive potential and good attractiveness for sport fishing (Ceccarelli and Senhorini, 1996; Lima, 2003). Piraputanga (*B. hilarii*, Valenciennes, 1850) is widely distributed in main Brazilian River basins such as the Amazon, Paraguay and Parana (Antunes at al., 2010), has great ecological importance (Zaniboni Filho et al., 2006; Froese and Pauly, 2011). However, little is known about the morphometric, weight-length ratio, and growth pattern of this species.

Allometric growth data is an important tool to develop better management protocols for the production of high-quality juveniles, assisting in the management and welfare of production fish (Getso et al., 2017). Given this, it is possible to understand how animal development can be influenced by various environmental factors, sex and gonadal maturity, health status, populations and variations within species (Froese, 2006; Portella et al., 2021). Characiformes fish, for example, are capable to maintain their body size throughout their life cycle, which is why they tend to show isometric growth (Lizama and Ambrósio, 1999; Costa and Nunes, 2019; Urbanski et al., 2023)

The allometric growth of fish can be evaluated in different production systems such as nurseries, cages and hapas. Hapas are flexible net tanks, easy to manage and low in cost when compared to conventional net tanks. They are commonly used to allocate tilapia breeders for fingerling production (AIT, 1994; Bhujel, 2000). It is a great option for using limited resources to produce small quantities of fish species, but with high commercial value. Furthermore, it is environmentally friendly as it releases fewer residual nutrients into the environment (Hasan et al., 2010).

That study aimed to determine the allometric growth pattern of body measurements of piraputangas (*B. hilarii*) cultured in hapas inside an excavated pond.

2. Material and Methods

2.1. Animals and sample condition

Piraputangas juveniles (*B. hilarii*), weighing 18.35 ± 3.16 g and total length of 11.89 ± 0.63 cm (mean ± SD), were obtained from a commercial fish farm and acclimatized for 30 days in a multifilament hapa (5 mm) of 8 m^3 (4 m length x 2 m width x 1 depth) installed in an excavated pond, in the fish farming sector of the State University of Mato Grosso do Sul, Aquidauana Campus. The fish were fed twice daily with a commercial feed containing 360 g kg^{-1} crude protein, 80 g kg^{-1} ether extract, 150 g kg^{-1} mineral matter, and 600 mg kg^{-1} vitamin C, as specified by the manufacturer.

All procedures involving animals followed the guidelines for experimental procedures in animal research by the Animal Use Ethics Committee (AUEC) of the State University of Mato Grosso do Sul - UEMS, Aquidauana, MS, Brazil (Protocol No. 014/2021).

2.2. Biometric variables

After the acclimatization period of the two weeks, the fish were anesthetized in a eugenol solution (50 mg L^{-1}) (Fernandes et al., 2017) to collect morphometric data. Then, each fish received an identification microchip and were randomly distributed in six hapas of 8 m^3, at a density of 20 fish/hapa. The hapas were arranged in a 100 m^2 excavated pond, each hapa had an extra water intake to help with oxygenation and water renewal. During the experimental period, the fish were twice daily fed with extruded feed containing 36% CP in the first four months, and 32% CP in the following months, at 5% of the biomass. The amount of feed provided was adjusted according to the biometrics performed during production, every 30 days, for seven months.

Biometrics were performed using ichthyometer (total and standard length), calipers for other measurements and semi-analytical digital scale, and the following biometric characteristics were evaluated (Figure 1):

- Body weight (g);
- Standard length (cm) (SL - from the anterior end of the head to the smallest perimeter of the peduncle - insertion of the caudal fin);
- Total length (cm) (TL - from the anterior end of the head to the end of the caudal fin);
- Height of the head (cm) (HH): measurement between the bottom and top of the head;
- Length of the head (cm) (LH) - between the anterior end of the head and the caudal edge of the operculum);

- Body height (cm) (BH - measured in front of the 1st ray of the dorsal fin);
- Body width (cm) (BW – measured in front of the 1st dorsal-fin ray);

Water quality parameters were measured three times a week and were within acceptable levels for fish farming according to Boyd (1990). In the period of the morning, pH (6.48 ± 0.19); dissolved oxygen (5.44 ± 1.13 mg L^{-1}); and temperature (28.70 ± 1.79 °C); and in the afternoon, pH (6.64 ± 0.26); dissolved oxygen (6.19 ± 0.69 mg L^{-1}); and temperature (32.06 ± 1.70 °C).

2.3. Biometric and statistical analysis

Weight calculations about morphometric measurements were determined using Huxley's (1932) allometric equation, Y = *a* X*b*, where Y is the total weight (g), X is the morphometric characteristic (cm), *a* is the intersection point related to body shape and *b* is growth coefficient (Ricker, 1973). Parameters *a* and *b* were estimated by linear regression according to the equation log Y= log *a* + *b* log X. The values obtained by the growth coefficient or angular coefficient (*b*) of the morphometric variables were tested by Student's t- test to assess whether the parameters differ from zero.

The angular coefficient characterizes the type of growth: isometric when b = 3 (the growth rates of X and Y are similar); positive allometric when b > 3, (Y grows proportionally more than X) and negative allometric when b < 3 (growth of Y is less than that of X).

The Fulton condition factor (K) was determined by the formula: K = (W / Lb), where W and L represent body weight (g) and total length (cm), respectively, and b is the angular coefficient of the regression between the weight ratio -length (Fulton, 1904; Vazzoler, 1996). The relative condition factor was determined by Kn = Wt / We, where Wt is the individual total weight of the fish and We is the expected weight (estimated by the equation obtained from the weight-length relationship). When Kn ≥ 1 indicates good growth conditions for the fish, while kn<1 indicates that the fish is in low growth about the average individual with the same growth (Lê Cren, 1951).

3. Results and Discussion

The descriptive analysis of the biometric data of juvenile piraputangas *B. hilarii*, the mean, standard deviation, minimum and maximum values, and coefficient of variation can be observed in Table 1. The data of the variables of total and standard length, head height, head length and body height had a variation of less than or close to 10%, characterizing a small variation.

The coefficient of variation (sampling) was higher for fish weight and may be related to several factors, such as hierarchical behavior, but it was expected to be higher for weight. Variations in fish weight and length occur frequently in production systems, due to the existence of larger fish in the batch. Therefore, it is relevant to classify the fish, to make the batch homogeneous and reduce the predominance within the tanks (Aydin et al., 2011; Baloi et al., 2016).

Figure 2 shows the weight gain of *B. hilarii* juveniles as a function of time. Up to 150 days the weight growth was accentuated, however, in the following months the weight growth had a slower development. Overall, the average weight was low over time, even with a stocking density of 2.5 fish/m^2, which was adequate for the species. There are no records of the growth of this species in hapas, possibly because this system is not adequate to get better development for the species.

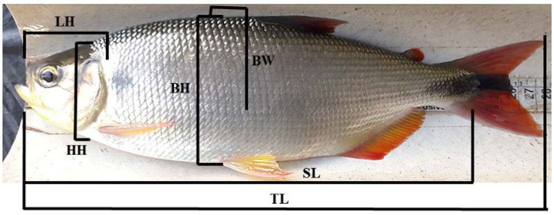

Figure 1. Biometric measurements of juvenile piraputangas *Brycon hilarii* grown in hapas. standard length (SL), total length (TL), head height (HH), head length (HL), body height (BW) and body width (BW).

Table 1. Descriptive analysis, mean, standard deviation (SD), minimum and maximum value and coefficient of variation (CV%) of the biometric variables of juvenile piraputangas *Brycon hillarii* cultivated in hapas (n=108).

Measures	Average	±SD	Minimum	Maximum	CV %
Body weight (g)	164.62	37.26	98.00	276.00	22.58
Total length (cm)	23.00	1.89	15.50	27.00	8.26
Standart lenght (cm)	17.72	1.38	12.00	20.50	7.82
Head height(cm)	3.96	0.29	3.30	5.30	8.16
Head lenght (cm)	4.57	0.37	3.50	5.80	7.82
Body height (cm)	6.00	0.62	3.80	7.50	10.58
Body width (cm)	2.60	0.32	1.50	3.25	12.38
Relative condition factor	1.00	0.11	0.65	1.55	11.60
Allometric condition factor	0.89	0.11	0.45	1.99	12.42

Couto et al. (2014) evaluated the stocking density of piraputangas in net cages and after 60 days of cultivation, they reached an average weight of 40.40 g, which is higher than the present study, which presented an average weight of 33.45 g. Although the species *Brycon hilarii* has great potential for animal production, its creation is still very regional and there are reports of producers pointing out that its growth becomes slower from 600 to 700 g. There are few studies on the species performance, and some focus of its ecological role as a seed disperser during migration periods (Reys et al., 2009).

Length-weight ratio and allometric condition factor are shown in Figure 3. The standard length-weight ratio was established using the equation y= 0.0089 x 3.1081 (R^2) 0.9696. The value of *b* was greater than 3.0, and shows that the piraputangas have a positive allometric growth. This suggests that the fish's increase weight was greater than the increase of length, and the fish became less elongated and more rounded as they grew (Froese and Pauly, 2011). This relationship provides important data on fish weight and biomass and can be compared to different populations or species, among other studies (Tavares-Dias et al., 2006; Froese, 2006). From the scatterplot plot of Figure 3, we can see that some fish are heterogeneous in terms of the range of variation, which is normal in the culture system.

The allometric condition factor indicates the state of well-being or good body condition of the fish, and cannot vary with the length, being correlated with the constant weight-length ratio, expressed by P = aCb (Gomiero et al., 2010). According to Seher and Süleyman (2012), the physiological condition of fish is related to the weight and length of the animal, fish with greater weight at a given length are considered healthier. Therefore, information about the condition factor can be fundamental for managing the cultivation system. Given that it is used as an indicator of fish welfare, its value reflects the nutritional and environmental conditions in which the animal develops, providing the producer with relevant information (Araneda et al., 2008; Seher and Suleyman, 2012).

The relative condition factor (Figure 4) of the piraputangas observed in this study was 1.00, indicating that the culture system did not affect the growth of the fish, suggesting a healthy state. These data can be used as a reference for this species, as there are no studies evaluating the condition factor. In matrinxã, (*Brycon amazonicus*) we can find relative condition factor ranging from 1.12 (Benacon et al., 2015) to 1.00 from nursery (Tavares-Dias et al., 2008).

The relationship between body weight and morphometric measurements was estimated using a simple linear regression equation and adjusted to the tested model Table 2. All tested correlations were significant using Student's t-test ($p<0.05$), suggesting that body weight and body length has a dependent relationship with body measurements, just as standard length has a strong relationship with head length and body height. The type of growth was determined from the values obtained for b and was determined as positive allometric growth: weight x total length; standard weight x length; weight x head height; weight x head length and weight height of the body. Negative allometric growth was observed in the relationships between weight x body width, standard length x head length and standard length x body height. Benacon et al. (2015) observed negative allometric growth (b=1.809) in *Brycon amazonicus* collected in Lago do Breu - Amazonas.

Fish of the genus *Brycon* have an elongated body and a small head, so the value of b for the standard length x head length and standard length x body height ratios was less than 3, indicating that length development was greater than the development in head and body height.

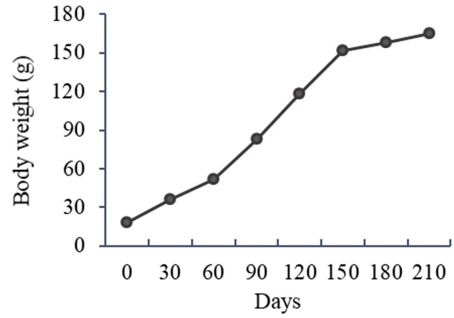

Figure 2. Growth in weight (average) of *Brycon hilarii* as a function of production time.

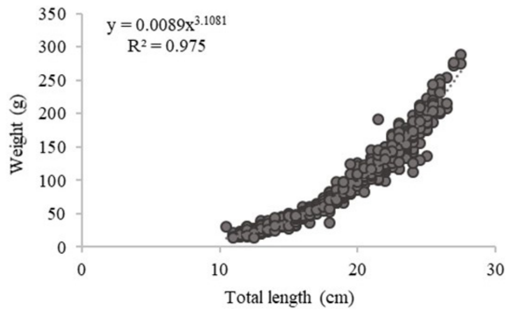

Figure 3. Length-weight scatterplot of *Brycon hilarii* juveniles produced in hapas for 210 days.

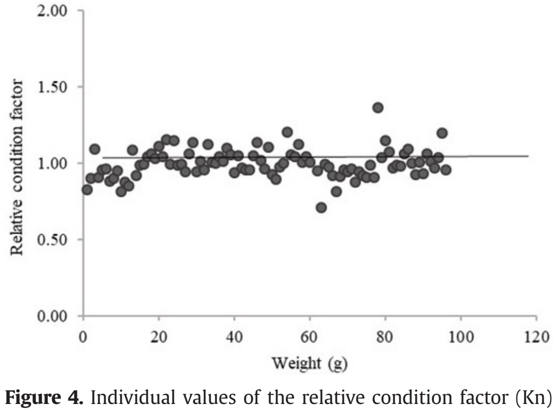

Figure 4. Individual values of the relative condition factor (Kn) in relation to the weight of *Brycon hilarii* produced in hapas after 210 days. Default value of Kn=1.0.

Table 2. Regression equations for the relationships between morphometric variables of juvenile piraputangas *Brycon hilarii* produced in hapas during 210 days. Correlation coefficient (r), determination coefficient (R^2), coefficient of variation (CV%).

Variables related	r	Regression equation (log W= log a +b logL)	R^2	*P* (values)	CV(%)
Weight x TL	0.98	LogW= - 4.725 + 3.108 logTL	0.97	< 0.001	28.26
Weight x SL	0.98	LogW= - 4.219 + 3.185 logSL	0.96	< 0.001	24.83
Weight x HH	0.95	LogW= - 0.039 + 3.439 logHH	0.91	< 0.001	56.70
Weight x HL	0.97	LogW= - 0.831 + 3.903 logHL	0.94	< 0.001	58.20
Weight x BH	0.98	LogW= 0.519 + 2.501 logBH	0.96	< 0.001	51.97
Weight x BW	0.97	LogW= 2.625 + 2.267 logBW	0.94	< 0.001	74.55
SL x HL	0.97	LogSL= 1.095 + 1.202 logHL	0.94	< 0.001	35.78
SL x BH	0.98	LogSL= 1.508 + 0.771 logBH	0.96	< 0.001	30.72

Weight (W), length (L), total length (TL), standard length (SL), head height (HH), head length (HL), body height (BH) and body width (BW). $p < 0.05$.

The determination coefficient (R^2), ranged from 0.91 to 0.97, and its highest correlation was observed between total weight-length, indicating a constant relationship between the two variables.

All correlation coefficients were positive and above 0.95, which is a strong correlation between the studied variables. The value of the correlation coefficient between body weight and total length was 0.98, higher than that observed by Benacon et al. (2015) in *Brycon amazonicus* (0.85) and equal to that found by Tavares-Dias et al. (2006) in *Brycon orbignyanus* (0.92). Correlation coefficients (r) are mathematical models that measure the relationships between variables and what they represent.

There are several studies on the length-weight relationships of different species of fish. Olentino et al. (2021) with 16 species of fish that occur along the lower Rio Negro basin in the Brazilian Amazon. Freitas et al. (2017) and Campanha et al. (2019) in studies of native freshwater fish. Therefore, records help to describe the growth patterns of specific species in different habitats and its change, to better understand how each species develops in its environment. There are several factors that can interfere and affect the body composition of fish, such as nutrition, fish size, and environmental parameters (Ali et al., 2001; Ebrahimi and Ouraji, 2012). Morphometric measurements such as body length, width and height can determine the slaughter weight and fillet yield of tilapia (*Oreochromis niloticus*) (Gonçalves et al., 2001; Rutten et al., 2005).

4. Conclusion

This study identified the allometric growth pattern of *Brycon hilarii* juveniles reared in hapas. Allometric growth was positive for five of the eight variables verified and the relative condition factor indicates good fish growth. These data are important for characterizing the growth pattern of piraputangas in this production system.

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