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Length-weight relationship of four species of ornamental fish from the lower Rio Negro basin in the Brazilian Amazon

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ABSTRACT. The present study describes the length-weight relationship of four species of ornamental fish caught on the banks of Tupé lake in lower Rio Negro, Amazonas state, Brazil in the months of September and December 2017, and February, March, and April 2018 with the aid of gillnets (20 m x 2 m, with 5 mm between knots), and landing nets, which were used specifically for collections close to the trunks. *Acarichthys heckelii* (b= 2.9444) and *Nannostomus unifasciatus* (b=3.0887) were the only species to show isometric growth, while *Pseudoloricaria laeviuscula* (b=3.273) showed positive allometric growth and *Hemigrammus levis* (b=2.5216) presented negative allometric growth. All length-weight-relationships presented herein are recorded for the first time from the Rio Negro basin.

Keywords: Allometry; allometric coeficiente; Amazon basin; ichthyofauna; LWR.

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Introduction

Studies on the length-weight relationship (LWR) of fishes have been published in great numbers in recent years (Santos, Sampaio, Barroso, Nunes, & Piorski, 2018; Carvalho, Bot, & Spach, 2020; Lubich, Santos, Freitas, & Souza, 2020; Lubich, Olentino, Freitas, & Yamamoto, 2021; Olentino, Lubich, Leal, & Yamamoto, 2021; Oliveira, Silva, Prestes, & Dias, 2020; Possamai, Passos, & Carvalho, 2020; Prestes, Oliveira, Dias, Soares, & Cunha, 2019). As a result, knowledge about the biology of the species has increased through the analysis of the growth pattern and body conditions, by using the allometric coefficient, and by estimating fish weight based on length and vice versa (Froese, 2006).

The Amazon basin has the greatest diversity of freshwater fish in the world (Oberdorff et al., 2019), where we find many small ornamental fish with different color patterns (Alho, 2008; Moreau & Coomes, 2007; Olentino, Furtado, & Yamamoto, 2020) that are caught mainly in the Rio Negro basin (Zehev, Vera, Asher, & Raimundo, 2015). These species are highly exploited (Araújo, Santos, Rebello, & Isaac, 2017; Ladislau et al., 2020) however few published studies provide the LWR parameters for ornamental species in the Rio Negro region (Barros, Althoff, Pereira, Lazzarotto, & Caramaschi, 2018; Lemos et al., 2015; Olentino et al., 2021; Santos et al., 2012). As such, basic population biology studies, such as LWR, provide information that may help in the conservation of these species. Thus, the description of the length-weight relationship of four species of ornamental fish from the lower Rio Negro basin has been performed in order to increase knowledge about these species in the hope that this information can be used for conservation and management studies of the species, since some ornamental fish in the region are being exploited unsustainably.

Material and methods

Samples of the fish were obtained from the Tupé lake, which is located in an environmental protection area (*Reserva de Desenvolvimento Sustentável Tupé* – RDS Tupé), 25 km in a straight line from the city of Manaus, Amazonas, Brazil (see Figure 1), with the authorization of the *Secretaria Municipal de Meio Ambiente e Sustentabilidade de Manaus* (SEMMAS, N ° 016/2016).

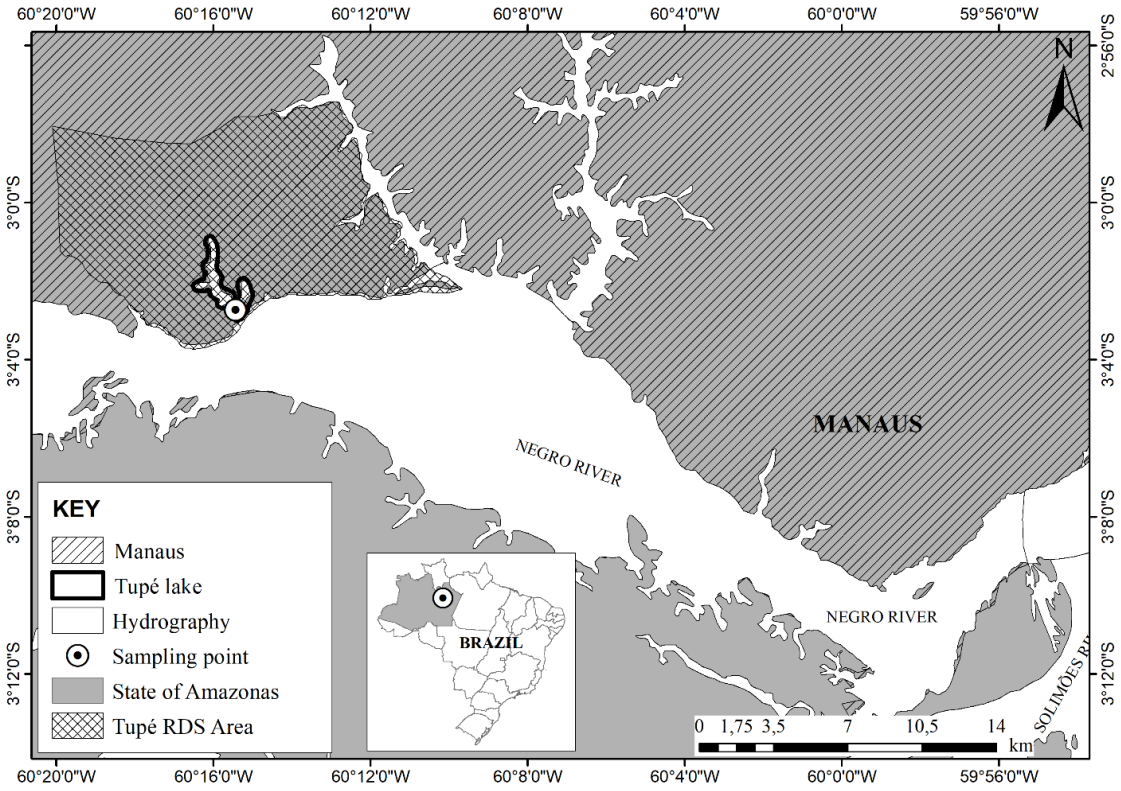

Figure 1. Sampling site of specimens in the environmental protection area - *Reserva de Desenvolvimento Sustentável Tupé* (lower Rio Negro, Amazonas state, Brazil).

The samplings took place for two days in each month, (September and December 2017, and February, March and April 2018), totaling ten days of sampling. The samplings were carried out in these months, in order to capture fish according to the hydrological cycle (low water - September and December 2017, and high water - February, March and April 2018) (Bittencourt & Amadio, 2007), since the composition of the fish assembly is strongly influenced by the flood pulse (Freitas, Souza, Prado, Yamamoto, & Hurd, 2010; Röpke et al., 2017; Silva, Arantes, Freitas, Petrere Jr., & Ribeiro, 2021; Soares & Yamamoto, 2005). The specimens were captured in the morning (9 - 11 am) and in the afternoon (3 - 5 pm), close to the shore, where the river bed is comprised mainly of sand and has submerged trunks, with the aid of gillnets (20 m long x 2m high, with 5 mm between knots), and landing nets, which were used specifically for collections close to the trunks.

The specimens were identified using appropriate ichthyological keys (Queiroz et al., 2013; Zuanon et al., 2015), as well as assistance from specialists. The species chosen from the catch were *Nannostomus unifasciatus,* Steindachner, 1876*, Hemigrammus levis,* Durbin, 1908*, Pseudoloricaria laeviuscula* (Valenciennes, 1840) and *Acarichthys heckelii* (Muller & Troschel, 1849). They were subsequently submitted to biometrics to measure the total weight (to the nearest 0.01 g) and total length (to the nearest 0.1cm). These procedures were carried out with the approval of the Committee on Ethics in the Use of Animals at the *Universidade Federal do Amazonas* (CEUA/UFAM Approval number– 016/2017).

The length-weight relationships were estimated using non-linear regression and the Levenberg-Marquardt algorithm (Lourakis, 2005), using the equation: $W=a.L^b$ (Le Cren, 1951), where W is the individual's total weight (g), L is the standard length, *a* is the intercept and *b* is the allometric coefficient. The confidence limit (CL) of 95% was determined for parameters *a* and *b* (Froese, 2006). Length-weight plots were constructed for detection of outliers that were subsequently removed (Froese, 2006). The isometry of b was tested with a t-test (α=0.05), using b=3 as H_0. Nonlinear regression was performed using the software STATISTICA (StatSoft, 2011), while the t-test was performed using the software R 4.1.0 (R Core Team, 2021).

Results

A total of 307 specimens belonging to four families and four genera were sampled ranging in length from 0.7 to 23 cm. The LWR parameters for these species can be observed in Table 1. The coefficient of

determination (r^2) ranged from 0.9894 to 0.9997, *a* values ranged from 0.0029 to 0.0340, and *b* values ranged from 2.5216 to 3.2173.

Hemigrammus levis presented negative allometric growth, which is expected for fish species with an elongated and/or rounded body shape, while *Pseudoloricaria laeviuscula* showed positive allometric growth, and increase in relative body thickness. *Acarichthys heckelii* and *Nannostomus unifasciatus* were the only species to show isometric growth.

Table 1. Length-weight relationship (LWR) of four species of ornamental fish caught in the *lower Rio Negro basin, Brazilian Amazon.*

Order/Family/Species	N	Total Length (cm)		Total Weight (g)		Equation parameters			Test-$t_{0,05}$ (H_0=3)	Growth type
		Min.	Max.	Min.	Max.	*a* (±95% CL)	*b* (±95% CL)	r^2		
CHARACIFORMES										
Lebiasinidae										
Nannostomus unifasciatus, Steindachner, 1876	25	0.7	3.5	0.01	0.4	0.0091 (0.0072-0.0111)	3.0887 (2.8642-3.3132)	0.9975	0.20177	isometric
Characidae										
Hemigrammus levis, Durbin, 1908	155	0.8	4.6	0.01	1.1	0.0340 (0.0294-0.0386) [a]	2.5216 (2.4108-2.6324) [b]	0.9997	0.00001	- allometric
SILURIFORMES										
Loricariidae										
Pseudoloricaria laeviuscula (Valenciennes, 1840)	84	1.4	23.0	0.04	69.9	0.0029 (0.0014-0.0045)	3.2173 (3.0465-3.3880)	0.9894	0.00663	+ allometric
CICHLIFORMES										
Cichlidae										
Acarichthys heckelii (Muller & Troschel, 1849)	43	1.4	10.0	0.03	24.9	0.0300 (0.0254-0.03458)	2.9444 (2.8756-3.0133)	0.9993	0.05515	isometric

Key: N = sample size; Min = minimum; Max = maximum; *a* = intercept; *b* = slope; r^2 = coefficient of determination of the length-weight relationship; 95% CL = confidence limit (95%); [a]Value above 95% confidence limit of Bayesian prediction [b]Value below 95% confidence limit of Bayesian prediction.

Discussion

The values obtained for the allometric coefficient varied within the expected range for most of the fish species, as suggested by Carlander (1969), i.e., the exponent *b* should normally be between 2.5 and 3.5. This was later endorsed by Froese (2006), who obtained 90% of the values of *b* ranging from 2.7 to 3.4.

Hemigrammus levis was the only species that presented values of *a* and *b* outside the range of the Bayesian estimate, available on the FishBase database (www.fishbase.org). This difference can be explained by the fact that in Bayesian estimates, total length data are used and are based on LWR estimates for species families that exhibit similar body shapes (Froese & Pauly, 2021; Froese, Thorson, & Reyes Jr., 2014). Regarding the growth pattern, *Hemigrammus levis* and *Pseudoloricaria laeviuscula* show an inverted pattern when compared, and the former shows greater growth on the body surface (length) than biomass gain. This is contrary to what happens with the second species, since it has a greater increase in biomass than in length. However, the other two species, *Acarichthys heckelii* and *Nannostomus unifasciatus,* showed isometric growth. According to Froese (2006), Oliveira, Silva, Prestes, and Dias (2018) and Santana, Tondato, and Súarez (2019), *b* values can be influenced by many factors, such as biological (e.g., gonadal maturation, life stage and sex) and environmental (e.g., food availability, habitat, seasonality) factors.

Although information on parameters *a* and *b* can be found on FishBase (www.fishbase.org), the values are based on Bayesian prediction and may not be exact. Notwithstanding, LWR estimates have already been published elsewhere for *Pseudoloricaria laeviuscula* (Giarrizzo et al., 2015; Hashiguti, Begot, Prudente, Freitas, & Montag, 2017), *Nannostomus unifasciatus* (Santos et al., 2012), *Hemigrammus levis* (Salvador et al., 2019; Sampaio, Santos, Anjos, Freitas, & Souza, 2019) and *Acarichthys heckelii* (Matos et al., 2019; Lubich et al., 2020).

Giarrizzo et al. (2015) presented the value of *b*= 3.26 for the species *P. laeviuscula,* which is similar to that found in this study (b =3.21). However, Hashiguti et al. (2017) presented values of *a*=0.001 and *b*=3.56, which are respectively below and above the Bayesian prediction of 0.00145-0.00456 and 3.01-3.33, and also diverge from those estimated by Giarrizzo et al. (2015), as well as the values reported in the present study. Santos et al. (2012) found *b*=3.38, which are values that are higher than the Bayesian estimate (2.86-3.28) and those reported here (*b*=3.08). Although the values of *a* are within the range of the Bayesian estimate.

H. levis is the only species whose available estimates (Salvador et al., 2019; Sampaio et al., 2019) are within the range of the Bayesian estimate, including that reported in the present study. Although the values of *b* reported by Salvador et al. (2019) of *b*=3.17, and Sampaio et al. (2019) of *b*=3.20, are similar to each other and different to the value reported herein (*b*=2.52). For *A. heckelii,* we obtained *a*=0.03 and *b*=2.94, which are similar to that reported by Lubich et al. (2020), i.e., *a*=0.03 and *b*=2.96. These values are within the range of the Bayesian estimate (0.007-0.038 and 2.85 - 3.23). However, Matos et al. (2019) found higher values of *a* (0.08) than these, as well lower values of *b* (2.67).

In general, these differences can be explained by the number of samples and the length class, as well as differences between individuals from different environments. The parameters available for the species *Pseudoloricaria laeviuscula* and *Hemigrammus levis* is restricted to other watersheds that are geographically distant from the Rio Negro basin. Thus, there may be changes in the values of the LWR parameters, due to environmental differences between species from different hydrographic basins.

The results obtained from analysis of the LWR of small species of ornamental fish can provide information that will help us to fully understand the growth patterns. As these species are of interest to the aquarist market, there is a need for monitoring so that this resource can be exploited in a sustainable way, since over-exploitation can negatively affect the integrity and functioning of an ecosystem.

Conclusion

In conclusion, this work revealed that *Nannostomus unifasciatus* and *Acarichthys heckelii* showed isometric growth. While, *Hemigrammus levis* and *Pseudoloricaria laeviuscula* showed negative and positive allometric growth, respectively. As well as, the data compared to the literature, point that the LWR parameters can change due to number of samples and the length class, as well as differences between individuals from different environments.

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