ZOOLOGY

Length-weight relationship and condition factor of eight fish species from the upper Araguari River, State of Amapá, Brazil

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ABSTRACT. The present study estimated parameters of the length-weight relationship (LWR) and allometric condition factor for eight fish species from the upper Araguari River, in the State of Amapá, Brazil. A total of 615 fish of eight species were analyzed: *Acestrorhynchus falcatus*, *A. falcirostris*, *Ageneiosus inermis*, *Hemiodus unimaculatus*, *Hoplias aimara*, *Myloplus asterias*, *M. ternetzi* and *Tometes trilobatus*. The allometric condition factor varied from 0.742 to 1.435. The coefficient of allometry ranged from 2.723 to 3.225. The coefficient of determination (R^2) of the LWR ranged from 0.742 to 0.985. This is the first estimate of the length-weight relationship for fish from the Araguari River and the first record of these parameters for *Myloplus ternetzi* and *Tometes trilobatus*.

Keywords: growth; fish stocks; eastern Amazon; stock assessment.

Introduction

Continental fishing in the State of Amapá (Brazil), although commercially inexpressive, is relevant for riverine populations that practice artisanal fishing, since fish is the main source of animal protein for these populations. Part of the state's fish comes from the Araguari River and its tributaries. The Araguari River acts as a border of part of the territories of the Sustainable Use Conservation Unit Amapá National Forest (Flona) and the State Forest of Production of the State of Amapá (Flota). In these units, subsistence fishing of great local importance is practiced, but the fish is also sold in fairs and markets in the region (Brandão & Silva, 2008; Sá-Oliveira, Vasconcelos, Pereira, Nahum, & Junior, 2013; Oliveira, Prestes, Florentino, Soares, & Cavalcante, 2013).

Knowledge of the richness of marine and freshwater fish fauna in the State of Amapá is still poor and few studies have generated length-weight relationship parameters (LWR) (Silva, Oliveira, Florentino, & Tavares□Dias, 2015; Oliveira, Silva, Prestes, & Tavares□Dias, 2018) which are essential for the management of fish stocks, knowledge of the ecological behavior of fish species, biomass estimates, and determine fish welfare using the allometric condition factor (Vazzoler, 1996; Froese, 2006; Giarrizzo, Bastos, & Andrade, 2011; Soares, Santos, Mendes, Barthem, & Montag, 2015; Loureiro, Mourão Júnior, & Giarrizzo, 2017; Oliveira et al., 2018). Among such studies only one deeper investigation was conducted, as it evaluated the Maximum Sustainable Yield (MRS) of fishery resources in the Araguari River, and observed that the effort and yield of Characiformes and Siluriformes - target fisheries are above what the environment supports, characterizing it as an overexploited resource (see Oliveira et al., 2013). The present study estimated the LWR parameters and allometric condition factor (Ka) of eight fish species of the Upper Araguari River, in the State of Amapá, northern Brazil.

Material and methods

Fish were collected in the Araguari River within the Sustainable Use Conservation Units of the Amapá National Forest (North between the coordinates 51º 30' 25" W and 1º 51' 42" N, and South between 51º 35' 41" W and 0º 55' 27" N) and the Amapá State Forest of Production, in section III (South 51° 47' 25" W and 00° 40' 12" N to 51° 15' 27" W and 00° 54' 42" N) (ICMbio, 2014; IEF/SEMA, 2014)) (Figure 1).

Sampling was conducted during the period of rainy season (October/November) and dry season (February/April) in 2011–2014 using gillnets (30 - 100 mm between knots), 'trapo' (piece of nylon fishing line with hook size 15), 'trapinho' (piece of nylon rope with hook size 15), 'float' (consists of a PET bottle, nylon fishing line, hook size 15 and a piece of Styrofoam to make the bait to remain on the surface) and 'caniço' (wooden fishing rod, fishing line, hook and sinker). The fishing gears were set up in different habitats (river bank, igarapé, varzea and backwater) remaining exposed for 12 hours in the case of the hand net and 6 hours in the case of trapo and trapinho, and inspections were carried out every 6 hours. The fishing with float was performed by always launching it upstream of rapids, remaining adrift for a period of up to 15 min. Fishing with caniço was performed down the stream by the river bank. After capture, fish were measured for standard length (SL, to the nearest 0.1 cm), weighed (W, to the nearest 0.1 g).

This work was developed in accordance with the principles adopted by the Brazilian College of Animal Experimentation (Cobea) and the authorization of the Ethics Committee on Animal Use of Embrapa Amapá (N 014 - Ceua/Cpafap) and ICMBio (31301-1 and 42203-1).
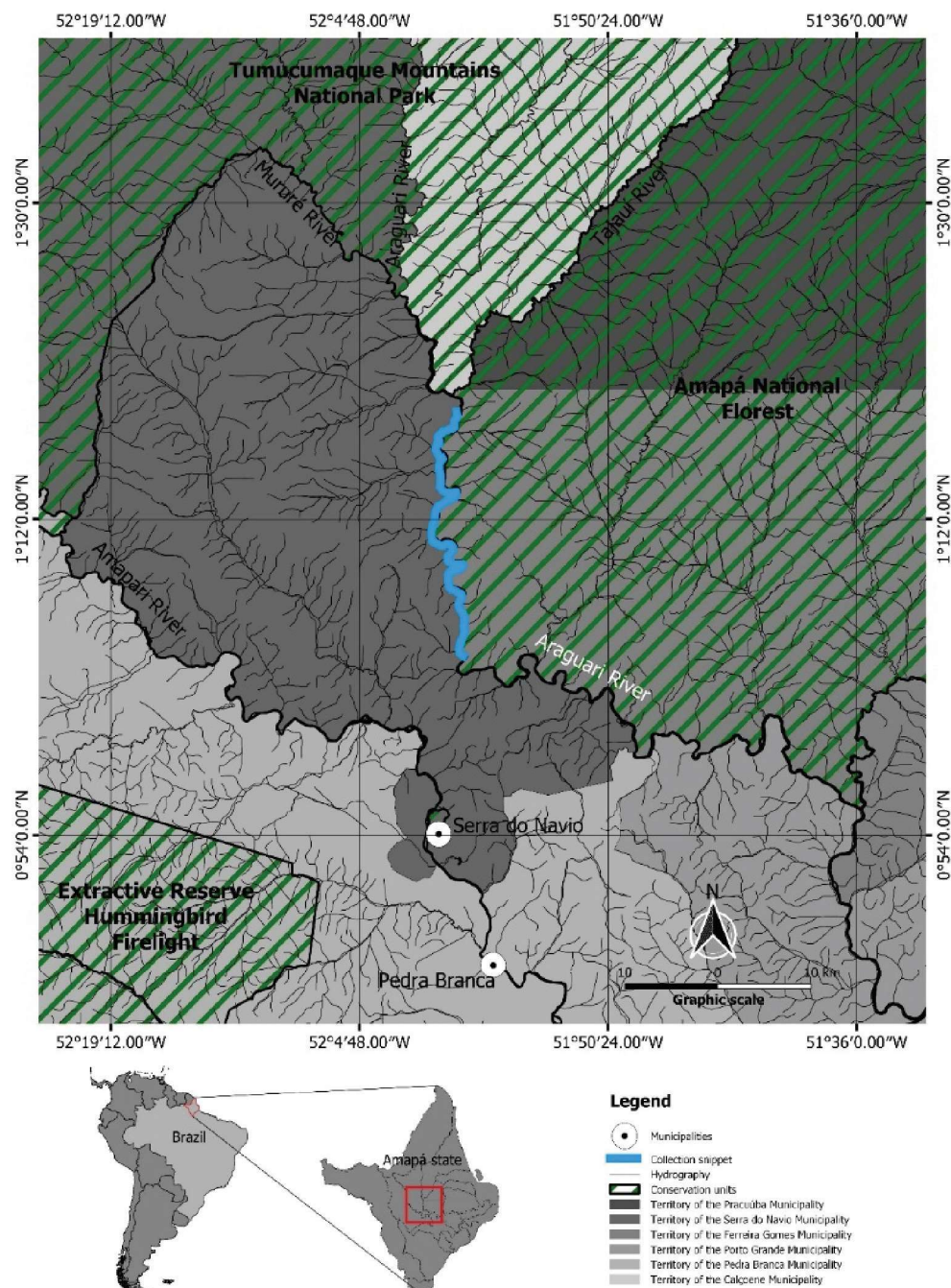

Figure 1. Geographic location of the collection sites in the upper reaches of the Araguari River, State of Amapá (Brazil).

Data analysis

The LWR was calculated using the Equation 1:

$$Wt = a \cdot Lt^b \qquad (1)$$

where:

Wt is the total weight in g and Lt is the standard length in cm, while *a* and *b* are constants. The parameters *a* and *b* were estimated by linear regression of the transformed Equation 2:

$$\log Wt = \log a + b \log Lt \qquad (2)$$

In a few cases, some outliers were removed and the regression was re-evaluated (Le Cren, 1951).

The type of growth was defined by the value of *b* of the LWR, and the significance was tested by the t-test using Equation (3 and 4),

$$t = \frac{b-3}{Sb} \qquad (3)$$

$$Sb = \sqrt{\frac{S^2 y \cdot x}{\Sigma x^2}} \qquad (4)$$

where:

a and *b* were estimated by linear regression, S^2 y.x is the standard error of the regression, and ∑x is the sum of the values of the length (Lt) of each fish (Zar, 2010). If $t_{calculated} > t_{critical}$, H0: *b* = 3 (isometric growth), $t_{calculated} < t_{critical}$, H1: *b* ≠ 3 allometric growth, with *b* > 3 positive allometric growth and *b* < 3 negative allometric growth (α = 0.05) (Zar, 2010). After log-transformation, the allometric condition factor (Ka) was calculated according to Equation 5:

$$Ka = W_t / Lt^b \qquad (5)$$

where:

Wt is the total weight in g, Lt is the standard length in cm and b were estimated by linear regression (Vazzoler, 1996). The calculations of the LWR were using all data together (rainy and dry season) mostly cause the N samples is too low for which season.

Results and discussion

A total of 8 fish species of five families were collected: *Acestrorhynchus falcatus*, *A. falcirostris* (Acestrorhynchidae), *Ageneiosus inermis* (Auchenipteridae), *Hemiodus unimaculatus* (Hemiodontidae), *Hoplias aimara* (Erythrinidae), *Myloplus asterias*, *M. ternetzi* and *Tometes trilobatus* (Serrasalmidae). The number of fish sampled ranged from 45 specimens for *H. aimara* to 201 for *T. trilobatus*. The minimum standard length of fish species varied from 10 to 24 cm and the maximum length ranged from 15 to 70 cm. The weight varied from 16 to 127 g and the maximum from 57 to 5,300 g (Table 1).

The coefficient of allometry b ranged from 2,723 to 3,225. The coefficient of determination (R2) of the LWR ranged from 0.686 to 0.928 (Figure 2). Five species (62.5%) presented negative allometric growth (b < 3), and three (35.5%) presented isometric growth (*b* = 3). The allometric condition factor (Ka) varied from 0.742 to 1.436. In general, *H. unimaculatus*, *M. asterias* and *M. ternetzi* presented higher values of Ka (Table 1).

In the present study, the species were small to medium-sized. The R2 values of the LWR relationship of all fish species were higher than 0.737, and b values are within expected range for fish (Froese, 2006). *Acestrorhynchus falcirostris*, *A. inermis*, *M. asterias*, *M. ternetzi* and *T. trilobatus* presented negative allometric growth, which is expected for fish species with an elongated and/or rounded body shape, which is the case of species of the present study (Araújo & Vicentini, 2001); However, this pattern indicates that the fish is growing in length as expected, but its biomass gain is not corresponding to its length, different from what happens when the growth is isometric that is ideal for fish (Tavares-Dias, Araújo, Gomes, & Andrade, 2010), as occurred for *A. falcatus*, *H. unimaculatus* and *H. aimara* of the present study. However, *b* values of LWR are strongly influenced by gonadal maturity, feeding, seasonality, habitat and fish life stage (Froese, 2006; Prestes, Soares, Silva, & Bittencourt, 2010; Oliveira et al., 2018). Of the eight species studied here, only *A. falcirostris*, *A. inermis*, *H. unimaculatus*, *H. aimara*, *M. asterias*, *M. ternetzi* and *T. trilobatus* have LWR

information in FISHBASE, which are restricted to other watersheds geographically distant from the Araguari River basin (Froese & Pauly, 2018). This is the first estimate of the LWR parameters for *M. ternetzi* and *T. trilobatus*.
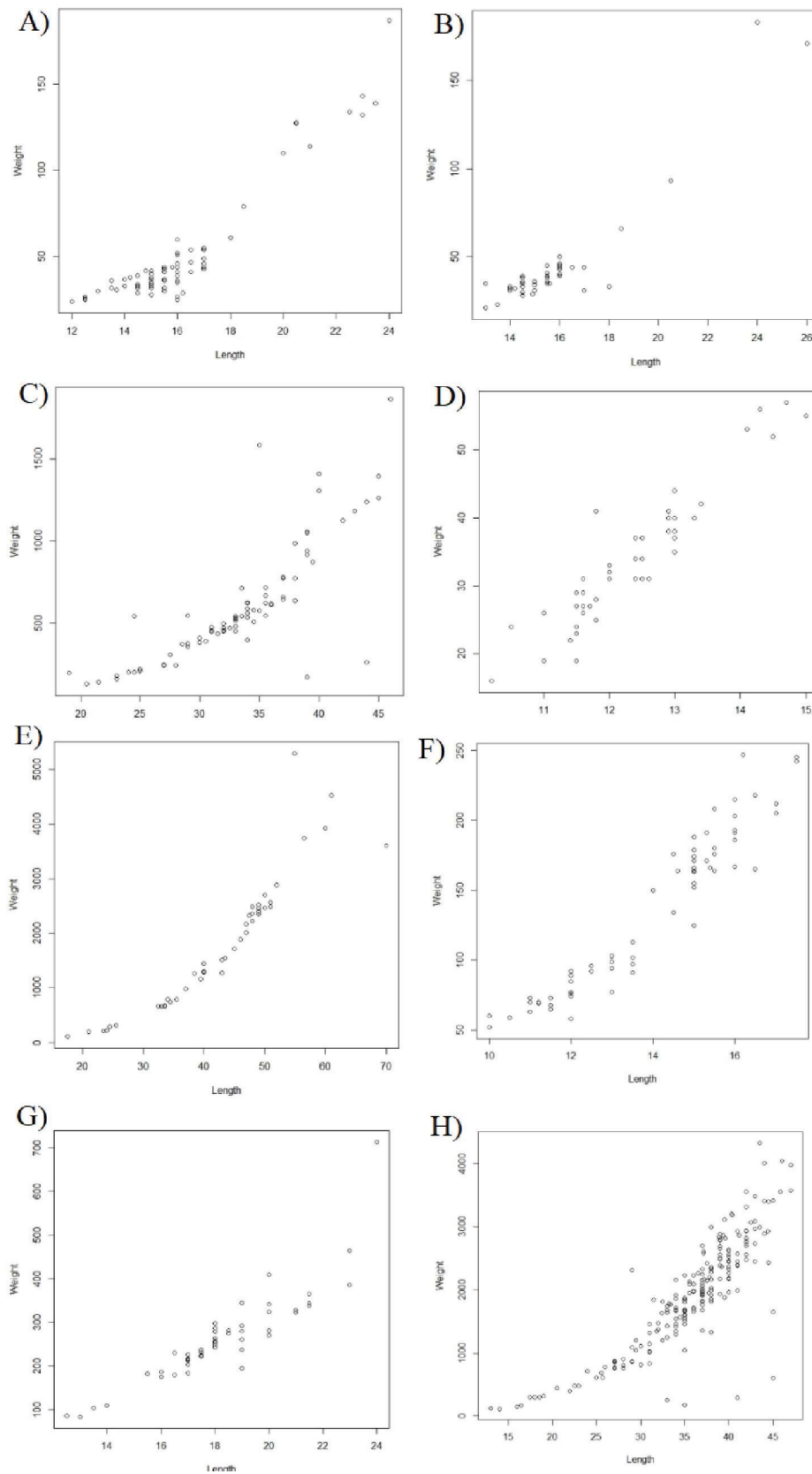

Figure 2. Data of weight (gr) -length (cm) relation (LWR) of eight fish species of the upper of the Araguari River, State of Amapá (Brazil). A) *A. falcatus* B) *A. falcirostris* C) *A. inermis* D) *H. unimaculatus* E) *H. aimara* F) *M. asterias* G) *M. ternetzi* and H) *T. trilobatus*.

Table 1. Weight-length relation (LWR) of eight fish species of t che upper of the Araguari River, State of Amapá (Brazil).

Species	Standard length (cm)			Total weight (g)		Parameters of LWR			Test-$t_{0.05(2)}$		Growth type	Ka
	N	Max	Min	Max	Min	a (±95% CL)	b (±95% CL)	R^2	$t_{calcutated}$	$t_{critical}$		
*Acestrorhynchus falcatus**	79	16	24	187	24	0.006 (0.002 - 0.018)	3.181 (2.809 - 3.553)	0.873	9.634	1.992	$b = 3$ (ISO)	0.917 ± 0.069
*Acestrorhynchus falcirostris**	48	26	13	183	21	0.019 (0.007 - 0.054)	2.763 (2.397 - 3.130)	0.854	-12.063	2.013	$b \neq 3$ (ALO -)	0.979 ± 0.054
*Ageneiosus inermis**	78	46	19	1867	127	0.023 (0.004 -0.143)	2.847 (2.331 - 3.362)	0.686	-6.063	1.992	$b \neq 3$ (ALO -)	0.831 ± 0.076
*Hemiodus unimaculatus**	50	15	10.2	57	16	0.009 (0.002 - 0.050)	3.225 (2.568 - 3.881)	0.823	12.304	2.011	$b = 3$ (ISO)	1.142 ± 0.053
*Hoplias aimara**	45	70	17.5	5300	107	0.016 (0.009 - 0.028)	3.045 (2.899 - 3.191)	0.928	3.343	2.017	$b = 3$ (ISO)	0.742 ± 0.096
*Myloplus asterias**	63	17.5	10	247	52	0.061 (0.035 - 0.105)	2.898 (2.688 - 3.108)	0.905	-20.158	2.000	$b \neq 3$ (ALO -)	1.436 ± 0.117
*Myloplus ternetzi***	51	24	12.5	714	83	0.092 (0.040 - 0.211)	2.723 (2.437 - 3.009)	0.871	-18.574	2.010	$b \neq 3$ (ALO -)	1.311 ± 0.083
*Tometes trilobatus***	201	47	13	4333	111	0.045 (0.030 - 0.066)	3.005 (2.893 - 3.118)	0.737	1.194	1.972	$b \neq 3$ (ALO -)	0.881 ± 0.115

N: sample size of collected species; Min: Minimum; Max: Maximum; a: Intercept; b: Slope; R^2: Coefficient of determination of length-weight relationship; 95% CL confidence limit level; Ka: Allometric condition factor; ISO: Isometric; ALO -: Negative allometric; **First LWR record; *First record of LWR for the Araguari River.

In the LWR, the value of the parameter *b* depends primarily on the shape of the fish body, and differently from parameter *a*, may vary spatio-temporally (Bagenal & Tesch, 1978). Therefore, the current value of the parameter *b* of a population is the most adequate to calculate the fish condition factor, since it represents the real growth of the species at a given time and place, ideal for a better management of the fish stocks (Oliveira et al., 2018). The fish condition factor of this study ranged from 0.742 (*H. aimara*) to 1.435 (*A. falcatus*), within the range recorded for fish populations of the Igarapé Fortaleza basin, in the State of Amapá, Brazil (Oliveira et al., 2018). Nevertheless, the condition factor can be influenced mainly by the feeding, reproductive period and health status of fish (Le Cren, 1951; Vazzoler, 1996; Gomiero & Braga, 2003), which may have influenced the variations of Ka values between the species, providing better body conditions for *H. unimaculatus*, *M. asterias* and *M. ternetzi*.

That is the first approach for this species in Araguari river so, the values of R^2 was satisfactory and, the data showed a tight fit with all the data together for each species in Kn and LWR. Although in this study, the influence of rainy and dry period in the LWR values don´t was investigated cause the samples are too low to separate the analysis between the seasons.

Conclusion

These estimates of the LWR parameters for these fish from the Araguari River system complement information that may help to monitor fish stocks in the Brazilian Amazon, especially to the increasing participation of these species in fish landings in the studied region.

Acknowledgements

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