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RESEARCH ARTICLE

Length-weight and length-length relationships of 10 fish species from headwater streams of the lower Iguassu River basin, Brazil

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ABSTRACT. Length-weight (LWR) and length-length (LLR) relationships are widely used in management programs and monitoring of fish stocks. We estimated the LWR and LLR of 10 fish species sampled from nine streams of the lower reach of the Iguassu River Basin, Paraná, Brazil. All LWR fits were significant, with *b* values ranging from 2.37 to 3.62 and an average value of 3.07. Most species showed isometric growth. Significant differences in the LWR between sexes were observed only for *Phalloceros harpagos* Lucinda, 2008 in the Três Barras stream. All LLR fits were significant, with *b* values ranging from 0.98 to 1.25 and an average value of 1.15. Significant differences between sexes for the LLR were observed for *Rhamdia voulezi* Haseman, 1911 in the Arroio Passo Liso stream. First records of the LWR for four species – *Ancistrus mullerae* Bifi, Pavanelli & Zawadzki, 2009, *Bryconamericus pyahu* Azpelicueta, Casciotta & Almirón, 2003, *Cambeva stawiarski* (Miranda Ribeiro, 1968), and *Cambeva taroba* (Wosiacki & Garavello, 2004) – and the LLR for six species – *A. mullerae*, *B. pyahu*, *C. davisi*, *C. stawiarski*, *C. taroba*, and *P. harpagos* – and a new record of maximum standard length for two species – *C. taroba* and *B. pyahu* – are presented.

KEY WORDS. Allometry, conservation, endemism, population structure, ichthyofauna, individual growth models.

INTRODUCTION

Knowing the length-weight (LWR) and length-length (LLR) relationships is useful in management programs and monitoring of fish stocks (Le Cren 1951, Froese 2006, Vicentin et al. 2012, Gubiani et al. 2020), especially to avoid capturing young or immature individuals. In addition, these relationships have important applications in species conservation programs, mainly in regions where species are threatened or highly endemic (Meretsky et al. 2000, Gubiani and Horlando 2014). Length-weight relationships may also be used to estimate various components (e.g., minimum, maximum, and average sizes and weights, and are essential for understanding the growth rate and age structure) of fish population dynamics models (Kohler et al. 1995).

In other words, from LWR models, we can estimate the weight of an individual corresponding to a given length (Le Cren 1951, Tesch 1968, Beyer 1991, Anderson and Gutreuter 1992, Almeida et al. 1995). In addition, growth in length can be converted to growth in weight, and vice versa (Özaydin and Taşkavak 2007, Cherif et al. 2008), to estimate the body condition of fish (Petrakis and Stergiou 1995, Peig and Green 2009, Gubiani et al. 2020) and, finally, to evaluate variations in the morphology of different populations between sexes, regions and periods of the year (Gonçalves et al. 1997, Froese 2006). The LLR, on the other hand, is very important to comparative growth models (Moutopoulos and Stergiou 2002) and conversion among different length measurements (Sinovčić et al. 2004).

Despite all these applications, the biological aspects of several Neotropical fish species are still poorly understood (see Azevedo-Santos et al. 2018). The ichthyofauna of the Iguassu River basin, for example, is very peculiar, with a high degree of endemism (Garavello et al. 1997, Baumgartner et al. 2012, Mezzaroba et al. 2021) and predominance of small fish (Baumgartner et al. 2012, Larentis et al. 2016, Baldasso et al. 2019, Mezzaroba et al. 2021), which inhabit small headwater streams to large reservoirs throughout the basin (Baumgartner et al. 2012, Mezzaroba et al. 2021). The Iguassu basin is located in an area of rugged relief, which forms a vast network of small streams and waterfalls (Baumgartner et al. 2012). This characteristic greatly affects the geographical distribution of fish species and, consequently, the estimation of biological parameters. Despite the relevance of understanding the LWR and LLR, few studies have been performed in this region to determine such relationships (e.g., Wolff et al. 2007, Gubiani et al. 2009, Gubiani and Horlando 2014).

We estimated the LWR and LLR of 10 fish species sampled from nine streams of the lower reach of the Iguassu River basin, Paraná, Brazil, to be used in programs aimed at managing and conserving them.

MATERIAL AND METHODS

Fish were collected quarterly from September 2014 to June 2015 from nine first-order streams (sensu Strahler 1957) located in the Iguassu River basin (Fig. 1; Table 1). For sampling, we used electrofishing equipment, which was powered by a portable generator (HONDA, 2.5 kW, 220 V, 3-4 A) connected to a DC transformer and two electrified net rings (anode and cathode). The output voltage varied from 400 to 600 V. The length of the sampling transect at each site was 50 m. Each transect was sampled three times from downstream to upstream by four people with a constant fishing effort of 30 minutes, following Esteves and Lobón-Cerviá (2001). Both extremities of the sampled transect were blocked by a net (0.5 cm mesh) to prevent fish from entering and exiting the sampling site.

The captured fish were anesthetized and euthanized with an overdose of benzocaine (250 mg/l; Avma 2001), according to the procedure approved by the Ethics Committee on the Use of Animals of the Universidade Estadual do Oeste do Paraná (Protocol 12/15 – CEUA/Unioeste). Subsequently, the fish were placed into plastic bags containing 10% formalin and packed in polyethylene bottles, where they were preserved and transported to the laboratory.

In the laboratory, one week after fish capture and fixation, the specimens were identified, according to Ingenito et al. (2004), Baumgartner et al. (2012) and Garavello et al. (2012), measured (total length, TL; standard length, SL, to the nearest 0.1 cm) and weighed (total weight, TW, to the nearest 0.01 g). In addition, the sex of each individual was determined following Vazzoler (1996), through macroscopic inspection of the gonads. When macroscopic inspection was not possible, the sex of the specimen was not determined, but morphological measurements were used to adjust the LWR and LLR for groups of each sex. Voucher specimens were preserved in 70% alcohol and deposited in the Ichthyological Collection of the GERPEL (CIG) at Universidade Estadual do Oeste do Paraná, Campus Toledo.

Length-weight relationships were determined by the equation $TW = a*SL^b$ (Ricker 1973) and LLRs were estimated by the equation $TL = a + b*SL$ by a linear regression model based on the least-squares method (Zar 1999). For LWRs, the variables TW and SL were log-transformed for linearized relationships before estimations ($\log_{10}TW = \log_{10}a + b \log_{10}SL$). Scatter plots were created for visual inspection of outliers, and extreme outliers (absolute value of the standardized

Table 1. Geographic coordinates and characteristics of the sampled streams of the Iguassu River basin, Brazil.

Stream	Latitude	Longitude	Average Depth (m)	Average Width (m)
São José	25º00’41.6”S	53º19’54.3”W	0.90	2.30
Lageado	25º02’24.8”S	53º20’35.9”W	0.25	2.10
Pedregulho	25º06’06.2”S	53º18’39.8”W	0.50	2.40
Rio do Salto	25º04’49.6”S	53º13’30.9”W	0.80	2.10
Arroio Passo Liso	25º12’15.3”S	53º08’56.6”W	0.20	2.00
Iapu	25º21’48.7”S	53º10’19.3”W	0.65	2.00
Três Barras	25º25’37.2”S	53º10’53.7”W	0.30	1.80
Aparecida	25º28’31.2”S	53º36’52.9”W	0.30	2.10
Caçula	25º31’15.2”S	53º36’03.3”W	0.40	4.14

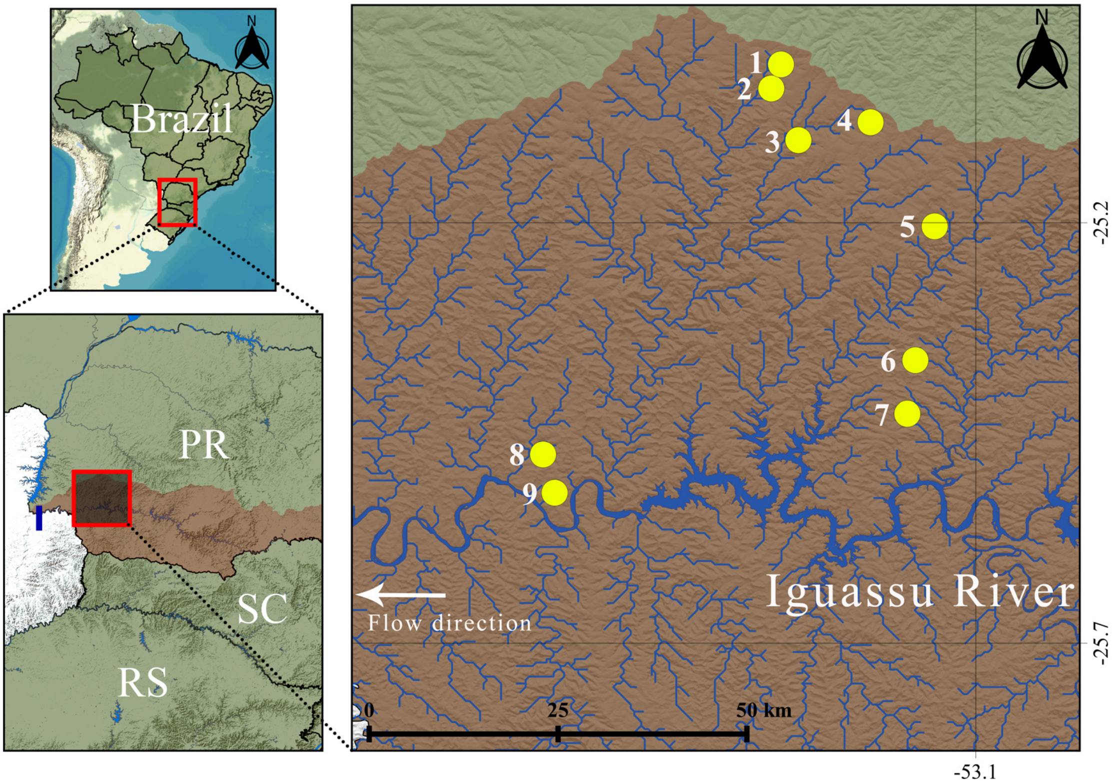

Figure 1. Sampled streams in the Iguassu River basin, Brazil: 1) São José Stream, 2) Lageado Stream, 3) Pedregulho Stream, 4) Rio do Salto Stream, 5) Arroio Passo Liso Stream, 6) Iapu Stream, 7) Três Barras Stream, 8) Aparecida Stream and 9) Caçula Stream. PR, Paraná State; SC, Santa Catarina State; RS, Rio Grande do Sul State.

residual ≥ 4) were excluded prior to regression analysis. The degree of adjustment of the models was determined by the determination coefficient (r^2). The confidence interval (± 0.95; α = 0.05) of parameters *a* and *b* was also estimated for each relationship. Student's t test (Zar 1999) was used to test for possible significant differences in the isometric condition (*b* = 3 for the LWR). Analysis of covariance (ANCOVA; Goldberg and Scheiner 1993) was used to test for differences between parameters adjusted for males and females for the LWR and LLR. When the ANCOVA was significant, the LWR and LLR were adjusted for separate sexes; if it was not significant, the adjusted parameters were presented for the groups of sexes (B = both in the tables). All statistical analyses were performed using R software (R Core Team 2022). The significance threshold used for all analyses was $p < 0.05$.

RESULTS

In all fish sampling periods combined, a total of 996 specimens were captured, including 299 males and 143 females (for 554 specimens, it was not possible to determine sex through macroscopic inspection of the gonads) belonging to 10 species in six families, which were used to estimate the LWR and LLR. After excluding the outliers, 979 individuals were used to fit the LWR. The total number of individuals per species varied from seven for *Phalloceros harpagos* Lucinda, 2008, to 163 for *Psalidodon bifasciatus* (Garavello & Sampaio, 2010) (Table 2). The minimum standard length recorded was 1.40 cm for *Poecilia reticulata* Peters 1859, while the maximum standard length was 12.90 cm for *Rhamdia voulezi* Haseman, 1911 (Table 2). The lowest value for total weight was 0.03 g for *Cambeva taroba* (Wosiacki & Garavello, 2004) and *P. reticulata*, and the highest value was 27.76 g for *R. voulezi* (Table 2). Only one species (*P. harpagos* in the Três Barras stream) showed a significant difference in the LWR between sexes (ANCOVA; $p < 0.05$; Table 2).

All LWR fits were significant ($p < 0.01$). The estimated value for parameter *b* varied from 2.37 to 3.62 (Table 2), the average *b*-value was 3.07 (SE = ± 0.061), and the median *b*-value was 3.11, whereas 50% of the values varied from 2.91

Table 2. Descriptive statistics and estimated parameters of length-weight relationships for fish species captured in the nine streams in the Iguassu River basin, Brazil. (B) Both sexes, (M) males, (F) females, (N) total fish captured, (Min) minimum value reported, (Max) maximum value reported, (*a*) intercept, (*b*) slope, (CI) confidence interval, (SE) standard error, (r^2) determination coefficient, (bold) new maximum total length.

Stream	Order/Family	Species	Voucher	Sex	N	Standard Length (cm)		Total Weight (g)		Regression parameters							t-test (H_0=3)		Growth type
						Min	Max	Min	Max	*a*	95% CI of *a*	SE(*a*)	*b*	95% CI of *b*	SE(*b*)	r^2	$t_{0,05}$	p-value	
São José	Characiformes Characidae	*Psalidodon bifasciatus*	CIG 2675, 2678, 2702, 2718, 2719, 2720, 2721, 2722, 2723	B	33	1.80	6.50	0.10	6.23	0.014	0.012–0.016	0.030	3.29	3.18–3.40	0.055	0.99	4.566	0.045	Allometry (+)
Lageado	Siluriformes Trichomycteridae	*Cambeva taroba**	CIG 2693, 2694, 2695, 2696, 2697, 2700, 2715, 2716	B	47	2.50	**6.50**	0.17	3.31	0.009	0.007–0.012	0.060	3.10	2.90–3.29	0.096	0.96	0.859	0.481	Isometric
Lageado	Characiformes Characidae	*Psalidodon bifasciatus*	CIG 2675, 2678, 2702, 2718, 2719, 2720, 2721, 2722, 2723	B	59	1.80	9.40	0.08	15.84	0.015	0.014–0.016	0.021	3.14	3.08–3.21	0.033	0.99	3.816	0.062	Isometric
Pedregulho	Characiformes Stevardiinae	*Bryconamericus pyahu**	CIG 2672, 2674, 2676	B	30	2.80	**5.00**	0.44	2.36	0.044	0.018–0.108	0.193	2.37	1.72–3.01	0.314	0.67	-1.701	0.231	Isometric
Pedregulho	Siluriformes Trichomycteridae	*Cambeva stawiarski**	CIG 2698, 2701, 2717	B	28	3.50	8.20	0.47	4.86	0.013	0.007–0.026	0.139	2.79	2.42–3.15	0.177	0.90	-1.012	0.418	Isometric
Pedregulho	Siluriformes Trichomycteridae	*Cambeva taroba**	CIG 2693, 2694, 2695, 2696, 2697, 2700, 2715, 2716	B	14	2.30	5.00	0.12	1.25	0.013	0.006–0.030	0.161	2.89	2.31–3.48	0.268	0.91	-0.316	0.782	Isometric
Pedregulho	Cyprinodontiformes Poeciliidae	*Phalloceros harpagos*	CIG 2686, 2687	B	22	2.00	3.30	0.17	0.70	0.022	0.013–0.036	0.109	2.91	2.41–3.41	0.238	0.88	-0.312	0.785	Isometric
Pedregulho	Characiformes Characidae	*Psalidodon bifasciatus*	CIG 2675, 2678, 2702, 2718, 2719, 2720, 2721, 2722, 2723	B	22	3.90	8.80	1.12	15.50	0.013	0.007–0.022	0.112	3.26	2.96–3.56	0.143	0.96	1.501	0.272	Isometric
Rio do Salto	Siluriformes Trichomycteridae	*Cambeva taroba**	CIG 2693, 2694, 2695, 2696, 2697, 2700, 2715, 2716	B	72	1.70	6.20	0.03	3.97	0.007	0.006–0.010	0.052	3.32	3.15–3.49	0.084	0.96	3.260	0.083	Isometric
Rio do Salto	Characiformes Characidae	*Psalidodon bifasciatus*	CIG 2675, 2678, 2702, 2718, 2719, 2720, 2721, 2722, 2723	B	61	1.70	7.20	0.06	6.99	0.016	0.014–0.019	0.032	3.11	2.94–3.28	0.085	0.96	1.121	0.379	Isometric
Arroio Passo Liso	Siluriformes Trichomycteridae	*Cambeva davisi*	CIG 2691, 2692, 2699, 2713, 2714	B	37	3.60	8.10	0.55	5.96	0.015	0.011–0.022	0.076	2.82	2.63–3.02	0.096	0.96	-1.569	0.257	Isometric
Arroio Passo Liso	Siluriformes Heptapteridae	*Rhamdia voulezi*	CIG 2705, 2736	B	106	2.20	12.90	0.43	27.76	0.028	0.025–0.031	0.029	2.69	2.64–2.74	0.024	0.99	-10.739	0.008	Allometry (–)
Iapu	Characiformes Characidae	*Astyanax dissimilis*	CIG 2712, 2731, 2732	B	93	2.80	6.60	0.44	6.77	0.012	0.010–0.014	0.035	3.35	3.23–3.46	0.058	0.97	5.220	0.035	Allometry (+)
Iapu	Characiformes Characidae	*Psalidodon bifasciatus*	CIG 2675, 2678, 2702, 2718, 2719, 2720, 2721, 2722, 2723	B	163	2.00	9.00	0.15	15.21	0.018	0.016–0.019	0.021	3.04	2.97–3.11	0.037	0.98	0.990	0.427	Isometric
Três Barras	Cyprinodontiformes Poeciliidae	*Phalloceros harpagos*	CIG 2686, 2687	M	7	1.80	2.70	0.08	0.32	0.015	0.010–0.023	0.078	3.14	2.54–3.75	0.236	0.97	0.410	0.721	Isometric
Três Barras	Cyprinodontiformes Poeciliidae	*Phalloceros harpagos*	CIG 2686, 2687	F	9	2.10	3.40	0.17	1.00	0.014	0.008–0.025	0.110	3.40	2.82–3.97	0.243	0.96	1.195	0.355	Isometric
Três Barras	Cyprinodontiformes Poeciliidae	*Poecilia reticulata*	CIG 2685, 2688, 2689, 2690, 2703	B	16	2.60	4.60	0.34	2.08	0.025	0.012–0.054	0.154	2.92	2.33–3.51	0.275	0.89	-0.235	0.836	Isometric
Aparecida	Siluriformes Hypostominae	*Ancistrus mullerae**	CIG 2679, 2710, 2729	B	26	1.50	7.70	0.08	12.74	0.031	0.028–0.035	0.024	2.97	2.85–3.09	0.059	0.99	-0.433	0.707	Isometric
Aparecida	Cyprinodontiformes Poeciliidae	*Poecilia reticulata*	CIG 2685, 2688, 2689, 2690, 2703	B	30	1.40	3.00	0.03	0.67	0.012	0.006–0.021	0.125	3.62	2.95–4.29	0.326	0.81	1.603	0.250	Isometric
Caçula	Characiformes Stevardiinae	*Bryconamericus pyahu**	CIG 2672, 2674, 2676	B	52	2.30	**5.00**	0.18	2.26	0.014	0.012–0.017	0.039	3.19	3.05–3.33	0.071	0.98	2.351	0.143	Isometric
Caçula	Characiformes Characidae	*Psalidodon bifasciatus*	CIG 2675, 2678, 2702, 2718, 2719, 2720, 2721, 2722, 2723	B	52	2.00	10.00	0.12	17.75	0.014	0.012–0.017	0.032	3.19	3.08–3.30	0.054	0.98	2.992	0.096	Isometric

*First report of the LWR.

to 3.26. Most species showed isometric growth (*b* = 3; Table 2), except for *P. bifasciatus* (*b* = 3.29; t = 4.566; p = 0.045; Table 2) in the São José stream and *Astyanax dissimilis* Garavello & Sampaio, 2010 (*b* = 3.35; t = 5.220; p = 0.035; Table 2) in the Iapu stream, which showed positive allometry (b > 3), and *R. voulezi* (*b* = 2.69; t = -10.739; p = 0.008; Table 2) in the Arroio Passo Liso stream, which showed negative allometry (*b* < 3). The *a* intercept value was significant for all fits ($p < 0.05$; in Table 2, no confidence interval included zero).

The r^2 value varied from 0.67 for *Bryconamericus pyahu* Azpelicueta, Casciotta & Almirón, 2003 in the Pedregulho stream to 0.99 for *P. bifasciatus* in the São José and Lageado streams, *R. voulezi* in the Arroio Passo Liso stream and *Ancistrus mullerae* Bifi, Pavanelli & Zawadzki, 2009 in the Aparecida stream (Table 2).

Nine hundred and six individuals were used to fit the LLR (90 individuals were considered outliers and thus were excluded). The total number of individuals per species varied from nine for females of *R. voulezi* sampled in the Arroio Passo Liso stream to 156 for *P. bifasciatus* sampled in the Iapu stream (Table 3). The minimum total length recorded was 1.70 cm for *P. reticulata* sampled in the Aparecida stream, whereas the maximum value was 13.40 cm for males of *R. voulezi* sampled in the Arroio Passo Liso stream (Table 3). Similarly, the minimum standard length recorded was 1.40 cm for *P. reticulata* sampled in the Aparecida stream, whereas the maximum length was 11.90 cm for males of *R. voulezi* sampled in the Arroio Passo Liso stream (Table 3).

All LLR fits were significant ($p < 0.05$). The estimated value for parameter *b* varied from 0.98 for *P. harpagos* in the Pedregulho stream to 1.25 for *P. reticulata* in the Aparecida stream; the average *b*-value was 1.15 (SE = ± 0.017), and the median *b*-value was 1.18, whereas 50% of the values varied from 1.10 to 1.20. The *a* intercept value was significant for 10 fits ($p < 0.05$; in Table 3, no confidence interval included zero). The r^2 value varied from 0.77 for *P. harpagos* in the Pedregulho stream to 1.00 for *A. mullerae* in the Aparecida stream (Table 3). A significant difference between sexes for the LLR was observed for *R. voulezi* in the Arroio Passo Liso stream (ANCOVA; $p < 0.05$; Table 3).

DISCUSSION

Our results showed that the *b* values for the LWRs varied from two to four, as demonstrated by Tesch (1971). This same author stated that the estimates for parameter *b* usually have a value close to three for fish. This same pattern was observed in our results; of the 21 fits, 18 showed isometric growth (*b* = 3; Table 2). These regularities in the *b* value have been observed for many fish species in different aquatic environments. For example, Froese (2006), in a review of the LWRs of fish, observed that most *b* values were 2.5 < *b* < 3.5. Similarly, Gubiani et al. (2009) estimated the *b* value for 48 fish species from different reservoirs in the state of Paraná, Brazil, and obtained values varying between 2.49 and 3.46. Nobile et al. (2015) estimated the LWRs of 37 fish species from the Taquari River, Paranapanema Basin, Brazil, and registered *b*-values ranging from 2.76 to 3.32. Freitas et al. (2017) estimated the LWRs for 10 fish species from the Nhamundá River, the Amazon Basin, Brazil, and recorded *b*-values ranging from 2.68 to 3.70. Lubich et al. (2021) estimated the LWRs of 16 fish species from the Negro River basin, Amazonas state, Brazil, and recorded *b*-values ranging from 2.53 to 3.55. Therefore, all these authors showed that estimates of parameter *b* consistently vary between two and four.

The parameter *b* depends primarily on the shape and fatness of the fish species. According to Bagenal and Tesch (1978), however, parameter *b*, unlike parameter *a*, may vary temporally and spatially. Therefore, the LWR is affected by a number of factors, including gonadal maturity, sex, diet, stomach fullness, health and preservation methods, as well as season and habitat (Pauly 1984, Froese 2006). Except for sex, fixation and preservation methodologies, which were controlled, no other factors were considered in this study. As highlighted above, most species showed isometric growth. This condition reflects rates of increase, both in weight and length, similar to those in different parts of the body (Benedito-Cecilio and Agostinho 1997). On the other hand, Gubiani and Horlando (2014), who estimated the LWRs of 20 fish species from the Salto Santiago Reservoir, Iguassu River, Brazil, and Gubiani et al. (2009), who estimated the LWRs of 48 fish species in 30 reservoirs in the State of Paraná, Brazil, observed positive allometric growth for most fish species. In this case, weight increased more than length, and the *b* values must be greater than three (Ricker 1979). In our results, we observed positive allometry for *P. bifasciatus* and *A. dissimilis.*

However, spatial differences in allometry were observed for *P. bifasciatus*. As recorded in our results (see Table 2), at five sampling sites, this species showed isometric growth. Therefore, spatial changes in the LWR for the same species are common and can be promoted by several factors, such as seasonality or annual variation in environmental conditions (Froese 2006), resource availability, degree of gastric repletion, stage of gonadal development, sex, health and differences in the size of captured individuals (Tesch 1971, Wootton 1998, Cherif et al. 2008).

Table 3. Descriptive statistics and estimated parameters of length-length relationships for fish species captured in the nine streams in the Iguassu River basin, Brazil. (B) Both, (M) males, (F) females, (N) total fish captured, (Min) minimum value reported, (Max) maximum value reported, (*a*) intercept, (*b*) slope, (CI) confidence interval, (SE) standard error, (r^2) determination coefficient.

Stream	Order/Family	Species	Voucher	Sex	N	Total Length (cm)		Standard Length (cm)		Regression parameters						
						Min	Max	Min	Max	*a*	95% CI of *a*	SE(*a*)	*b*	95% CI of *b*	SE(*b*)	r^2
São José	Characiformes Characidae	*Psalidodon bifasciatus*	CIG 2675, 2678, 2702, 2718, 2719, 2720, 2721, 2722, 2723	B	30	2.50	8.00	2.10	6.50	0.075	-0.076–0.226	0.074	1.21	1.17–1.25	0.019	0.99
Lageado	Siluriformes Trichomycteridae	*Cambeva taroba**	CIG 2693, 2694, 2695, 2696, 2697, 2700, 2715, 2716	B	47	2.80	7.40	2.50	6.50	0.157	-0.013–0.327	0.084	1.10	1.06–1.14	0.019	0.99
Lageado	Characiformes Characidae	*Psalidodon bifasciatus*	CIG 2675, 2678, 2702, 2718, 2719, 2720, 2721, 2722, 2723	B	50	2.50	11.10	2.00	9.40	0.048	-0.076–0.172	0.062	1.21	1.19–1.24	0.013	0.99
Pedregulho	Characiformes Stevardiinae	*Bryconamericus pyahu**	CIG 2672, 2674, 2676	B	30	3.50	6.10	2.80	5.00	0.647	0.197–1.096	0.219	1.06	0.95–1.17	0.053	0.93
Pedregulho	Siluriformes Trichomycteridae	*Cambeva stawiarski**	CIG 2698, 2701, 2717	B	28	4.00	9.40	3.50	8.20	0.115	-0.194–0.424	0.150	1.13	1.08–1.18	0.024	0.99
Pedregulho	Siluriformes Trichomycteridae	*Cambeva taroba**	CIG 2693, 2694, 2695, 2696, 2697, 2700, 2715, 2716	B	14	2.70	5.80	2.30	5.00	-0.072	-0.462–0.318	0.179	1.18	1.08–1.28	0.044	0.98
Pedregulho	Cyprinodontiformes Poeciliidae	*Phalloceros harpagos**	CIG 2686, 2687	B	21	2.70	4.10	2.00	3.30	0.861	0.124–1.598	0.352	0.98	0.72–1.23	0.122	0.77
Pedregulho	Characiformes Characidae	*Psalidodon bifasciatus*	CIG 2675, 2678, 2702, 2718, 2719, 2720, 2721, 2722, 2723	B	22	4.90	10.80	3.90	8.80	0.168	-0.289–0.625	0.219	1.20	1.13–1.27	0.035	0.98
Rio do Salto	Siluriformes Trichomycteridae	*Cambeva taroba**	CIG 2693, 2694, 2695, 2696, 2697, 2700, 2715, 2716	B	71	1.90	7.20	1.70	6.20	0.052	-0.108–0.213	0.081	1.16	1.12–1.20	0.019	0.98
Rio do Salto	Characiformes Characidae	*Psalidodon bifasciatus*	CIG 2675, 2678, 2702, 2718, 2719, 2720, 2721, 2722, 2723	B	38	2.00	8.60	1.70	7.20	0.110	0.006–0.215	0.051	1.18	1.14–1.22	0.020	0.99
Arroio Passo Liso	Siluriformes Trichomycteridae	*Cambeva davisi**	CIG 2691, 2692, 2699, 2713, 2714	B	37	4.20	9.10	3.60	8.10	0.230	-0.062–0.522	0.144	1.09	1.05–1.14	0.022	0.98
Arroio Passo Liso	Siluriformes Heptapteridae	*Rhamdia voulezi*	CIG 2705, 2736	M	75	2.70	13.40	2.20	11.90	0.462	0.311–0.613	0.076	1.10	1.08–1.12	0.010	0.99
Arroio Passo Liso	Siluriformes Heptapteridae	*Rhamdia voulezi*	CIG 2705, 2736	F	9	6.70	11.60	5.50	10.20	1.308	0.744–1.872	0.238	1.00	0.93–1.06	0.027	0.99
Iapu	Characiformes Characidae	*Astyanax dissimilis*	CIG 2712, 2731, 2732	B	84	3.70	8.10	2.80	6.60	0.004	-0.122–0.131	0.064	1.24	1.21–1.27	0.016	0.99
Iapu	Cyprinodontiformes Poeciliidae	*Psalidodon bifasciatus*	CIG 2675, 2678, 2702, 2718, 2719, 2720, 2721, 2722, 2723	B	156	2.60	10.90	2.00	9.00	0.135	0.059–0.212	0.039	1.20	1.18–1.22	0.010	0.99
Três Barras	Cyprinodontiformes Poeciliidae	*Phalloceros harpagos**	CIG 2686, 2687	B	28	2.30	5.00	1.80	4.00	0.161	-0.015–0.337	0.086	1.19	1.13–1.25	0.030	0.98
Três Barras	Cyprinodontiformes Poeciliidae	*Poecilia reticulata*	CIG 2685, 2688, 2689, 2690, 2703	B	16	3.30	5.50	2.60	4.60	0.543	0.374–0.711	0.079	1.06	1.02–1.11	0.021	0.99
Aparecida	Siluriformes Hypostominae	*Ancistrus mullerae**	CIG 2679, 2710, 2729	B	26	1.90	9.50	1.50	7.70	0.210	0.138–0.281	0.034	1.22	1.19–1.24	0.012	1.00
Aparecida	Cyprinodontiformes Poeciliidae	*Poecilia reticulata*	CIG 2685, 2688, 2689, 2690, 2703	B	30	1.70	3.70	1.40	3.00	-0.020	-0.293–0.253	0.133	1.25	1.14–1.36	0.054	0.95
Caçula	Characiformes Stevardiinae	*Bryconamericus pyahu**	CIG 2672, 2674, 2676	B	45	2.90	6.00	2.30	5.00	0.245	0.079–0.412	0.826	1.16	1.12–1.20	0.022	0.98
Caçula	Characiformes Characidae	*Psalidodon bifasciatus*	CIG 2675, 2678, 2702, 2718, 2719, 2720, 2721, 2722, 2723	B	49	2.50	12.00	2.00	10.00	0.208	0.080–0.337	0.064	1.20	1.17–1.23	0.014	0.99

*First report of the LLR.

On the other hand, *R. voulezi* showed negative allometry ($b < 3$), where the increase in length was greater than that in weight. In contrast to our results, Gubiani and Horlando (2014) recorded positive allometric growth for this same species in the Salto Santiago Reservoir, Iguassu River, Brazil. Similarly, spatial changes in environmental conditions may be responsible for this divergence, since our estimates were made for fish caught in low-order streams of the lower Iguassu basin. In addition to the spatial changes, Rêgo et al. (2008) suggested that the negative allometry observed for *Leporinus friderici* (Bloch, 1794) caught in the Nova Ponte Reservoir, Araguari River, Brazil, could also be attributed to the age of the individuals, and we sampled predominantly juveniles.

Differences in body size between males and females of the same species have been observed in many species (Rêgo et al. 2008, Gubiani et al. 2009, Gomieiro et al. 2010, Gubiani and Horlando 2014), and this feature is one of the promoters of sexual dimorphism. We recorded a difference in the LWR between the sexes of only one species, *P. harpagos*, in the Três Barras stream, in which females grew more than males, both in weight and length. This pattern is common in this species. Several authors have recorded the predominance of females of *P. harpagos* in the largest length classes (Aranha and Caramachi 1999, Wolff et al. 2007, Mendonça et al. 2014). These same authors stated that this was possibly associated with the fact that females invest more energy in reproduction. According to Vazzoler (1996), there is a positive relationship between body size and fecundity. In the case of *P. harpagos*, it promotes the transport of eggs and embryos, since most species of Poecillidae are viviparous and present internal fertilization and development (Lucinda 2003). Similarly, Santos et al. (2018), evaluating the LWR of *P. reticulata*, observed similar results for this species, which is taxonomically related to *P. harpagos*. Therefore, this seems to be a pattern for cyprinodontids.

Differences in the LLR between sexes for *R. voulezi* indicated that males have a longer caudal fin, which gives them a greater swimming capacity. According to Rêgo et al. (2008), who evaluated the LWR of *Prochilodus lineatus* (Valenciennes, 1837) and *L. friderici* in the Nova Ponte Reservoir, Araguari River, a longer caudal fin in males is related to sexual attraction, variation in metabolism and, finally, greater genetic variability.

It is important to highlight that all weight and length measurements were taken immediately after the fish were caught and fixed (only in 10% formalin); therefore, it was considered that the formalin solution did not impact the model fits. According to Anzueto-Calvo et al. (2017), who evaluated the effect of preserving fish in formalin and ethanol on LWRs and condition factors in *Tlaloc labialis* (Günther, 1866), the use of specimens treated with the same preservation regimes is highly recommended, and there is no evidence that storage in formalin for short periods alters LWRs and consequently LLR results. Therefore, no correction of the data was needed.

This study provides the first reference on the LWRs of four species – *A. mullerae*, *B. pyahu*, *Cambeva stawiarski* (Miranda Ribeiro, 1968), and *C. taroba* – and a new record of the maximum standard length of two species – *C. taroba* and *B. pyahu* – (Table 2, species marked with an asterisk and a section sign, respectively). The LLRs of six species – *A. mullerae*, *B. pyahu*, *C. davisi*, *C. stawiarski*, *C. taroba*, and *P. harpagos* – are recorded for the first time (Table 3, species marked with an asterisk), according to information available in FishBase (Froese and Pauly 2023). Estimating the parameters of different population structure metrics helps us to understand the different strategies of individual growth, which allows us to correlate these variables with environmental, ecological and physiological aspects. The importance of this information is even more evident when the fish fauna presents a high degree of endemism and belongs to headwater environments, which are subject to frequent environmental changes, often resulting from human actions, as in the Iguassu River basin (e.g., Baumgartner et al. 2012, Daga and Gubiani 2012, Mezzaroba et al. 2021). We believe that our results will contribute to the conservation of the ichthyofauna of the basin.

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