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LENGTH-WEIGHT RELATIONSHIP AND RELATIVE CONDITION FACTOR OF 31 SMALL-SIZED FISHES OF THE PARANAPANEMA RIVER BASIN*

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ABSTRACT

Studies on length-weight relationships are of great importance in fishery assessments. These studies are substantial to evaluate fish population dynamics, and in communion with the relative condition factor, could provide an estimation of potential acting environmental conditions. In this paper, we evaluated the length-weight relationship and relative condition factor of small sized fish species. Fish were sampled quarterly between the years 2012-2013 and 2018-2020 in lagoons and tributaries of Rosana and Taquaruçu reservoirs, located at the lower Paranapanema River basin, Brazil. The standard length (*SL*) in millimeters and weight (*W*) in grams were measured, and the length-weight relationship was calculated using linear regression analysis ($W = \log(a) + b \log(SL)$). After, the relative condition factor (*Kn*) was calculated from the expression $We = a.SL^b$. Thus, the length-weight relationships of 31 species were calculated in each environment considered, giving rise to 74 population allometric coefficients (*b*) and relative condition factors (*Kn*). As result, 24 *b* coefficients were concentrated between 2.5 and 3.5 and seven were out of the confidence interval, while the 74 *Kn* values demonstrated close to the central mean and not statistical different. Our results are relevant to the conservation of fish fauna, improving knowledge regarding small-sized fish and those living environment.

Keywords: Neotropical ichthyofauna; reservoir; upper Paraná River basin; Southern Brazil.

RELAÇÃO PESO-COMPRIMENTO E FATOR DE CONDIÇÃO RELATIVO DE 31 ESPÉCIES DE PEIXES DE PEQUENO PORTE DA BACIA DO RIO PARANAPANEMA

RESUMO

Estudos sobre relações peso-comprimento são de grande importância nas avaliações de pesca. Esses estudos são substanciais para avaliar a dinâmica populacional de peixes e, em comunhão com a aplicação do fator de condição relativo, podem fornecer uma estimativa das condições ambientais potencialmente atuantes. Neste estudo, avaliamos a relação peso-comprimento e o fator de condição relativo de espécies de pequeno porte. Os peixes foram coletados trimestralmente entre os anos de 2012-2013 e 2018-2020 em lagoas e tributários dos reservatórios de Rosana e Taquaruçu, bacia do Baixo Rio Paranapanema, Brasil. O comprimento padrão (*SL*) em milímetros e o peso (*W*) em gramas foram mensurados, e a relação peso-comprimento foi calculada por meio de regressão linear ($W = \log(a) + b \log(SL)$). Em seguida, o fator de condição relativo (*Kn*) foi calculado a partir da expressão $We = a.SL^b$. Assim, as relações peso-comprimento de 31 espécies foram mensuradas em cada ambiente estudado, dando origem a 74 coeficientes alométricos (*b*) e fatores de condição relativo (*Kn*) populacionais. Como resultado, 24 coeficientes *b* se concentraram entre 2,5 e 3,5 e sete fora deste intervalo de confiança, enquanto os valores de 74 *Kn* se mostraram próximos à média central e não estatisticamente diferentes. Nossos resultados são relevantes para a conservação da ictiofauna, contribuindo para o conhecimento sobre os peixes de pequeno porte e seu ambiente de vida.

Palavras-chave: ictiofauna Neotropical; reservatório; Bacia do Alto Rio Paraná; Sul do Brasil.

INTRODUCTION

Damming can promote changes in the composition and structure of the ichthyofauna (Agostinho et al., 2016) as well as altering its trophic levels (Delariva et al., 2013;

Lima et al., 2018). For small-sized fish, species showing reproductive and feeding capacity may have higher chances of succeeding when colonizing reservoirs (Agostinho et al., 2007), while species which depend on preserved habitats to survive can be endangered (Vidotto-Magnoni et al., 2015). In this sense, small-sized fish species are notably neglected in environmental assessments, and a great portion of their habitat may undergo interference from anthropogenic activities (Castro and Polaz, 2020).

Length-weight relationships have been used to estimate the weight of individuals based on their length (Froese, 2006). These sorts of studies have provided estimates of fishery resources (Silva Lourenço et al., 2008; Ribeiro et al., 2017), being useful tools to evaluate population dynamics of fish in contrasting environments (Oliva-Paterna et al., 2009; Orsi and Britton, 2012). Although, the length-weight relationships may not be enough to state environmental conditions, due to taxonomic aspects and ontogenetic phases (Le Cren, 1951), as well as seasonality and sample heterogeneity or size could interfere in results (Froese, 2006). Thus, it is more appropriate to apply estimates that reflect the individuals' condition assuming the premise that fish of a certain length, the heavier, are health (Froese, 2006).

The fish physiological state results from the interaction between the life cycle and environmental circumstances, for example, feeding, reproduction and energy expenditures in cyclical activities, where variations in this state can be expressed by the condition factor (*K*) (Vazzoler, 1996). The application of this measure depends closely on the weight and length of the individuals (Froese, 2006). However, the relative condition factor (*Kn*) allows to evaluate the observed values in relation to the theoretically expected for each length, being more reliable to assess the fish healthiness (Anderson and Gutreuter, 1983) and distinguish environmental influential conditions (Barrilli et al., 2015; Caetano and Jané, 2018).

For the Paranapanema River basin, length-weight relationships have been largely described for 20 species of fishes in the Jurumirim Reservoir (Oliva-Paterna et al., 2009), and 37 in the Taquari River (Nobile et al., 2015), 15 in the Capivara Reservoir (Orsi and Britton, 2012), 18 in the Tibagi River (Orsi et al., 2002), and six in tributaries of the Taquaruçu Reservoir (Ribeiro et al., 2017). On the other hand, descriptions of the relative condition factor in the basin are less common, being reported to two species in the Tibagi River (Orsi and Shibatta, 1999; Orsi et al., 2004) and one species in the Cinzas River (Caetano and Jané, 2018), both tributaries of the Capivara Reservoir. Although rare so far for the basin, they can be an useful tool for the aquatic communities evaluation in response to the environmental impacts (Barrilli et al., 2015; Caetano and Jané, 2018) since this important tributary of the upper Paraná River were strongly impacted by dams (Orsi, 2010), deforestation (Rodrigues et al., 2019), discharge of human effluents (Cunico et al., 2006) and agriculture and pasture (Vidotto-Magnoni et al., 2015).

To complement the previous studies mentioned, we provided the length-weight relationships and relative condition factor for 31 small-sized species of fish in the Rosana and Taquaruçu reservoirs, which presented a gradient of environmental anthropogenic impact.

MATERIAL AND METHODS

Study area

The Paranapanema River is one of the main tributaries on the left bank of the upper Paraná River basin (Sampaio, 1944), flowing between the Southeast of the state of São Paulo (SP) and North of the state of Paraná (PR), Brazil (Maack, 1981). This hydrographic region has been heavily exploited for hydropower due to its high slopes, having its main channel being transformed into a cascade of reservoirs (Duke Energy, 2008). The lower Paranapanema River covers from upstream to downstream the reservoirs of Salto Grande, Canoas II, Canoas I, Capivara, Taquaruçu and Rosana (Sampaio, 1944).

Fish samplings were performed quarterly in two distinct periods, first from May 2012 to August 2013, and second from September 2018 to September 2020. To May 2012 to August 2013, three left bank tributaries of the Taquaruçu Reservoir (i.e., Centenário, Tenente and Capim rivers), which are part of a landscape altered by sugarcane crops (Vidotto-Magnoni et al., 2015), were sampled. To September 2018 to September 2020 in the Taquaruçu Reservoir, samples were placed in two left bank marginal lagoons and in the Anhumas River, a right bank tributary which have been undergone a reforestation process (Leme et al., 2015). For the same period (i.e., September 2018 to September 2020) in Rosana Reservoir, the sampling took place in two marginal lagoons of both banks and in the Pirapozinho River, a right bank tributary which has its surroundings displaying a landscape composed by pastures, agriculture, and a permanent preservation area mostly without forests (Rodrigues et al., 2019).

We sampled three sections of the tributaries (i.e., lower, middle and upper) (Vidotto-Magnoni et al., 2015) with the objective to contemplate the ichthyofauna extensively. Therefore, were sampled 15 sites in lotic and four in lentic environments (Figure 1, Table 1). The sampling sites were chosen in order to better represent the species populations of the environments. Thus, the analyses were performed considering the environments described below: Rosana lagoon (two marginal lagoons), Pirapozinho River (lower, middle and upper portion); Taquaruçu lagoon (two marginal lagoons), Anhumas River (lower, middle and upper portion); Capim River (lower, middle and upper portion), Centenário River (lower, middle and upper portion) and Tenente River (lower, middle and upper portion).

Samplings

We used trawls, sieves and cast nets to catch fishes under the vegetation in marginal zone and along aquatic macrophyte beds, when present. In all environments, we employed a two hours sampling effort at each site, covering an extension of 100 meters and exploiting as much as we could the microhabitats within the reaches. All individuals were anesthetized and euthanized by overexposure to Eugenol 1 g mL^{-1}, further fixed in 10% formaldehyde for 48 hours and stored in 70% alcohol. Approximately a week later, the biometric process was employed in the individuals to avoid tissues distortions due to alcohol conservation (Anzueto-Calvo et al., 2017). All samplings were authorized by The Animal Ethics Committee (CEUA N° 21149.2012.53; CEUA N° 24310.2017.78).

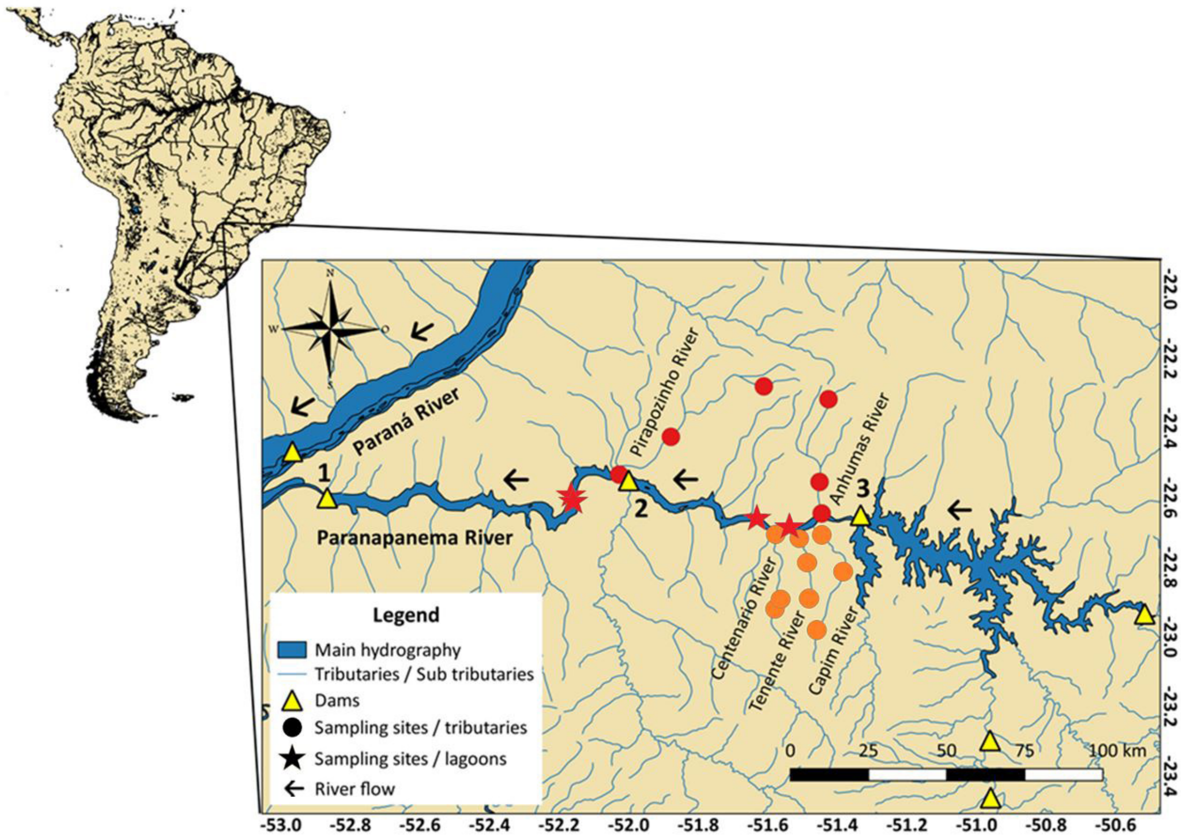

Figure 1. Sampling sites in contrasting environments of lower Paranapanema River, upper Paraná River basin. Orange color = sampling from May 2012 to August 2013; red color = sampling from September 2018 to September 2020. 1) Rosana Dam; 2) Taquaruçu Dam; 3) Capivara Dam.

Table 1. Characterization of the sampling sites from the lower Paranapanema River, upper Paraná River basin, between May 2012 and August 2013 and September 2018 and September 2020. RES = Reservoir; LO = Location; RO = Rosana; TA = Taquaruçu; AN = Anhumas River; CA = Capim River; CE = Centenário River; LA = lagoon; PI = Pirapozinho River; TE = Tenente River.

RES /LO	Coordinates	Width (m)	Depth (m)	Flow	Bottom	Margin vegetation	Aquatic vegetation	Margin occupation
RO/LA1	22°38’4.52”S 52°9’40.86”W	144	2.6	Lentic	Sandy	Present	Present	-
RO/LA2	22°36’42.27”S 52°9’31.81”W	139	2.2	Lentic	Sandy	Absent	Present	Pasture
RO/PI1	22°32’1.13”S 52°1’38.28”W	30	3	Lotic	Sandy	Present	Ausent	Pasture
RO/PI2	22°25’30.45”S 51°52’43.98”W	12	0.8	Rapids/ Pools	Rocky/ Sandy	Absent	Ausent	Agriculture
RO/PI3	22°16’48.29”S 51°36’41.80”W	3	0.3	Lotic	Sandy	Absent	Ausent	Agriculture
TA/LA1	22°39’37.00”S 51°37’53.80”W	67	4	Lentic	Sandy	Absent	Present	Habitation
TA/LA2	22°41’10.80”S 51°32’20.90”W	103	3.4	Lentic	Sandy	Present	Present	-

Table 1. Continued...

RES /LO	Coordinates	Width (m)	Depth (m)	Flow	Bottom	Margin vegetation	Aquatic vegetation	Margin occupation
TA/CE1	22°42'19.38"S 51°34'38.51"W	9	1.2	Lotic	Sandy	Absent	Absent	Agriculture
TA/CE2	22°53'31.40"S 51°33'46.50"W	12	0.7	Lotic	Sandy	Absent	Absent	Agriculture
TA/CE3	22°55'11.60"S 51°34'46.80"W	7	1	Lotic	Sandy	Absent	Absent	Agriculture
TA/TE1	22°43'0.20"S 51°30'36.00"W	16	1.2	Lotic	Sandy	Absent	Absent	Agriculture
TA/TE2	22°47'11.20"S 51°29'14.60"W	17.5	1.1	Rapids/ Pools	Rocky	Present	Absent	-
TA/TE3	22°53'22.90"S 51°28'57.20"W	3.5	0.8	Lotic	Sandy	Absent	Absent	Agriculture
TA/CA1	22°42'23.60"S 51°26'42.60"W	25	1	Lotic	Sandy	Present	Absent	Agriculture
TA/CA2	22°48'45.80"S 51°23'0.60"W	19	2.5	Lotic	Sandy	Present	Absent	Agriculture
TA/CA3	22°58'50.00"S 51°27'36.20"W	6.5	1.5	Lotic	Sandy	Absent	Absent	Agriculture
TA/AN1	22°38'43.10"S 51°26'43.20"W	25	4	Lotic/ Lagoon	Sandy	Present	Present	Agriculture
TA/AN2	22°33'17.16"S 51°27'5.40"W	12	0.5	Rapids/ Pools	Rocky/ Sandy	Present	Present	Agriculture
TA/AN3	22°19'1.62"S 51°25'32.83"W	4	0.3	Lotic/ Lagoon	Sandy	Absent	Present	Agriculture

Data analyses

In the laboratory, fishes were identified (Ota et al., 2018) and the standard length (SL) in millimeters (precision caliper of 0.1 mm) and the weight (W) in grams (precision balance of 0.1 g) were measured. Further, the information acquired on length and weight were logarithmized, and thus the length-weight relationships were obtained using a linear regression approach: W = log (a) + b log (SL), where a was the regression curve interception (coefficient related to fish condition) and b was the regression coefficient (exponent indicating body shape) (Froese, 2006). We used a confidence interval of 95%, and for relationships having R^2 values <0.95, a plot log a versus b was used to detect and exclude outliers, being the regression recalculated. After obtaining the coefficients a and b, the relative condition factor were calculated using a derivation of the expression proposed by Le Cren (1951), where $We = a.SL^b$. This approach enables the comparison of the measured values (Wt) in relation to those theoretically expected (We) for each length and the statistical conference of population mean to the central value (Kn = 1.0) with the Student's t-test ($p < 0.05$) (Anderson and Gutreuter, 1983).

RESULTS

We acquired the length and weight from 4.693 individuals belonging to 74 populations of 31 species in the lower Paranapanema River. These species belonged to 11 families, where the most abundant were: Characidae (15 species; 3,749 individuals), Poeciliidae (two specie; 252 individuals), and Callichthyidae (one species; 141 individuals). The length-weight relationships of 74 populations are summarized in order of environments analyses (i.e., Table 2: Rosana lagoon, Pirapozinho River; Table 3: Taquaruçu lagoon, Anhumas River; Table 4: Capim River, Centenário River and Tenente River). Most of b coefficients were concentrated between 2.5 and 3.5, values considered adequate, but seven were out of confidence interval (Froese, 2006). About the relative condition factor (Kn), the 74 means demonstrated results close to the central value (minimum = 0.91, maximum = 1.06) in which all of these were not statistical different from 1.0 (Student's t-test = $p > 0.05$). They are summarized in order of environments analyses (i.e., Table 5: Rosana lagoon, Pirapozinho River; Table 6: Taquaruçu lagoon, Anhumas River; Table 7: Capim River, Centenário River and Tenente River).

Table 2. Length-weight relationships of fishes of the Rosana Reservoir, lower Paranapanema River, between September 2018 and September 2020. Values out of confidence interval of *b* were represented in bold. * = non-native species; n = abundance by site; SL = range and average of the standard length; WT = range and average of the total weight; R^2 = coefficient of determination; *a* = confidence interval (95%) and coefficient of regression curve interception; *b* = confidence interval (95%) and exponent regression coefficient. RES = Reservoir; RO = Rosana; LA= lagoon; PI = Pirapozinho River.

Taxa	RES	n	Biological parameters		R^2	W= log (*a*) + *b* log (SL)	
Family / Species	RO		SL (cm)	WT(g)		*a*	*b*
Parodontidae							
Apareiodon affinis	LA	55	(1.5-6.3) 2.8	(0.1-4.3) 0.5	0.95	(0.011-0.015) 0.014	**(1.8-2.58) 2.19**
Curimatidae							
*Steindachnerina brevipinna**	PI	10	(2.3-7.0) 3.7	(0.3-10.00) 2.1	0.97	(0.013-0.175) 0.015	(2.64-3.44) 3.04
Lebiasinidae							
Pyrrhulina australis	PI	11	(1.6-3.3) 2.3	(0.1-1.1) 0.4	0.96	(0.014-0.019) 0.016	(2.51-3.87) 3.19
Characidae							
Aphyocharax anisitsi	LA	11	(2.5-3.7) 2.9	(0.2-0.7) 0.3	0.97	(0.019-0.023) 0.021	(3.07-3.97) 3.52
*Aphyocharax dentatus**	LA	51	(2.0-4.0) 3.1	(0.1-1.0) 0.5	0.95	(0.017-0.020) 0.019	(2.92-3.52) 3.22
	PI	88	(1.7-4.5) 3.2	(0.1-1.8) 0.8	0.97	(0.015-0.017) 0.016	(2.84-3.14) 2.99
Astyanax lacustris	LA	68	(1.5-8.1) 4.9	(0.1-17.8) 5.4	0.98	(0.012-0.014) 0.013	(2.72-2.91) 2.82
	PI	25	(1.7-6.0) 4.7	(0.2-6.0) 3.4	0.95	(0.009-0.014) 0.011	(2.17-2.85) 2.51
Hemigrammus marginatus	LA	322	(1.0-3.1) 2.2	(0.1-0.8) 0.3	0.95	(0.018-0.019) 0.018	(3.31-3.61) 3.4
*Hyphessobrycon eques**	LA	314	(1.0-2.8) 1.9	(0.1-0.6) 0.2	0.95	(0.016-0.017) 0.016	(2.77-3.11) 2.94
	PI	44	(1.0-3.0) 2.4	(0.1-0.6) 0.4	0.99	(0.016-0.016) 0.016	(2.87-3.05) 2.96
Moenkhausia intermedia	LA	26	(1.3-3.5) 2.9	(0.1-1.2) 0.8	0.95	(0.014-0.018) 0.016	(2.84-3.70) 3.30
Moenkhausia sanctaefilomenae	PI	10	(2.3-5.8) 4.1	(0.4-5.8) 3.2	0.98	(0.013-0.016) 0.015	(2.83-3.35) 3.09
Piabarchus stramineus	LA	47	(1.2-4.9) 2.7	(0.1-1.4) 0.4	0.95	(0.013-0.015) 0.014	**(1.92-2.38) 2.15**
	PI	10	(2.8-3.6) 3.2	(0.4-0.9) 0.6	0.88	(0.010-0.017) 0.014	**(1.61-3.09) 2.35**
Piabina argentea	PI	65	(2.5-6.0) 3.7	(0.3-4.5) 0.9	0.95	(0.016-0.018) 0.017	(2.84-3.19) 3.02
*Roeboides descalvadensis**	LA	76	(1.2-5.5) 2.8	(0.1-2.7) 0.5	0.95	(0.015-0.017) 0.016	(2.64-2.93) 2.78
	PI	11	(3.3-5.3) 4.1	(0.7-2.7) 1.4	0.98	(0.016-0.020) 0.018	(2.85-3.44) 3.17
Serrapinnus notomelas	LA	107	(1.3-3.0) 2.1	(0.1-0.8) 0.2	0.95	(0.018-0.019) 0.019	(3.29-3.78) 3.54
	PI	29	(1.2-4.8) 2.3	(0.1-5.9) 0.6	0.95	(0.013-0.018) 0.016	(2.54-3.80) 3.17
Callichthyidae							
Corydoras aeneus	PI	54	(1.9-4.7) 3.0	(0.4-4.8) 1.7	0.96	(0.010-0.012) 0.011	(2.60-2.89) 2.75
Poeciliidae							
Phalloceros harpagos	PI	14	(1.2-3.0) 1.7	(0.1-0.9) 0.3	0.96	(0.010-0.015) 0.012	(1.66-3.63) 2.64
Poecilia reticulata *	LA	20	(1.4-2.9) 2.0	(0.1-1.0) 0.4	0.96	(0.012-0.013) 0.013	(2.50-3.02) 2.76

Table 3. Length-weight relationships of fishes of the Taquaruçu Reservoir, lower Paranapanema River, between September 2018 and September 2020. Values out of confidence interval of *b* were represented in bold. * = non-native species; n = abundance by site; SL = range and average of the standard length; WT = range and average of the total weight; R^2 = coefficient of determination; *a* = confidence interval (95%) and coefficient of regression curve interception; *b* = confidence interval (95%) and exponent regression coefficient. RES = Reservoir; TA = Taquaruçu; LA = lagoon; AN = Anhumas River.

Taxa	RES	n	Biological Parameters		R^2	W = log (*a*) + *b* log (SL)	
Family / Species	TA		SL (cm)	WT (g)		*a*	*b*
Crenuchidae							
Characidium zebra	AN	13	(2.5-5.9) 4.0	(0.3-2.5) 1.3	0.95	(0.013-0.019) 0.016	(2.42-3.27) 2.85
Parodontidae							
Apareiodon affinis	LA	43	(2.8-9.0) 5.0	(0.3-15.0) 2.5	0.97	(0.019-0.022) 0.021	(3.25-3.56) 3.41
Serrasalmidae							
*Metynnis lippincottianus**	LA	32	(1.4-11) 5.1	(0.1-50.0) 14.8	0.99	(0.014-0.015) 0.014	(3.02-3.18) 3.10
Curimatidae							
Cyphocharax modestus	AN	14	(4.9-8.2) 7.0	(2.8-14.4) 9.4	0.95	(0.013-0.021) 0.017	(2.65-3.64) 3.15
*Steindachnerina brevipinna**	LA	16	(3.4-9.6) 7.8	(0.7-25.8) 14.7	0.97	(0.016-0.022) 0.011	(3.05-3.73) 3.39
Steindachnerina insculpta	AN	74	(2.0-10.2) 4.6	(0.3-26.7) 5.5	0.98	(0.013-0.014) 0.014	(2.74-2.92) 2.83
Characidae							
Aphyocharax anisitsi	LA	15	(2.0-3.3) 2.8	(0.1-0.5) 0.3	0.96	(0.016-0.020) 0.018	(2.45-3.33) 2.89
*Aphyocharax dentatus**	AN	45	(2.5-4.2) 3.3	(0.2-1.0) 0.5	0.96	(0.016-0.018) 0.017	(2.60-3.06) 2.83
	LA	220	(1.8-4.3) 3.1	(0.1-1.1) 0.4	0.95	(0.016-0.018) 0.017	(2.67-2.92) 2.79
Astyanax lacustris	AN	46	(2.4-3.96) 3.3	(0.4-1.97) 1.17	0.95	(0.009-0.013) 0.011	**(2.06-2.67) 2.37**
	LA	99	(1.9-12.2) 5.4	(0.2-65.0) 10.3	0.98	(0.016-0.017) 0.016	(3.09-3.23) 3.16
Bryconamericus iheringii	AN	250	(1.7-6.2) 3.2	(0.1-5.3) 0.9	0.97	(0.016-0.016) 0.016	(2.95-3.07) 3.01
*Hyphessobrycon eques**	LA	217	(1.0-3.9) 2.3	(0.1-0.7) 0.3	0.95	(0.016-0.017) 0.016	(2.81-3.12) 2.97
Moenkhausia intermedia	LA	99	(1.8-8.0) 5.6	(0.1-11.7) 5.4	0.96	(0.018-0.020) 0.019	(3.22-3.49) 3.35
Piabarchus stramineus	AN	273	(1.3-5.5) 3.1	(0.1-2.7) 0.7	0.96	(0.017-0.018) 0.017	(2.91-3.11) 3.01
	LA	13	(1.8-5.4) 3.1	(0.1-1.5) 0.3	0.99	(0.023-0.026) 0.024	**(3.44-3.92) 3.68**
Piabina argentea	AN	51	(3.1-6.8) 4.3	(0.7-6.1) 1.9	0.98	(0.014-0.016) 0.015	(2.71-2.93) 2.82
Psalidodon aff. *fasciatus*	AN	23	(3.1-4.4) 3.8	(0.6-2.1) 1.4	0.95	(0.013-0.017) 0.015	(2.48-3.30) 2.89
Psalidodon paranae	AN	52	(1.8-4.1) 2.8	(0.2-2.1) 0.7	0.95	(0.013-0.015) 0.014	(2.57-3.03) 2.80
*Roeboides descalvadensis**	LA	138	(1.6-5.9) 3.6	(0.1-3.54) 0.68	0.98	(0.017-0.018) 0.017	(2.62-2.84) 2.73
Serrapinnus notomelas	LA	117	(1.1-3.2) 2.3	(0.1-0.7) 0.3	0.95	(0.015-0.018) 0.016	(2.70-3.33) 3.02
Callichthyidae							
Corydoras aeneus	AN	87	(1.5-4.5) 2.9	(0.2-4.8) 1.4	0.96	(0.011-0.012) 0.011	(2.63-2.85) 2.74
Loricariidae							
Hisonotus francirochai	AN	61	(2.1-3.9) 3.2	(0.1-1.1) 0.6	0.95	(0.014-0.017) 0.016	(2.39-3.12) 2.76
Otothyropsis polyodon	AN	25	(1.3-4.0) 3.0	(0.1-1.3) 0.6	0.95	(0.011-0.017) 0.014	(1.93-3.01) 2.5
Cichlidae							
Crenicichla britskii	LA	10	(7.2-16.0) 11.0	(5.0-115.0) 39.8	0.96	(0.016-0.028) 0.022	**(3.50-4.18) 3.61**
Poeciliidae							
*Poecilia reticulata**	AN	75	(1.4-3.3) 2.1	(0.1-1.1) 0.4	0.95	(0.014-0.015) 0.015	(2.84-3.30) 3.07
	LA	14	(1.4-2.2) 1.7	(0.1-0.2) 0.1	0.95	(0.014-0.020) 0.017	(2.22-4.40) 3.34

Table 4. Length-weight relationships of fishes of the Taquaruçu Reservoir, lower Paranapanema River, between May 2012 and August 2013. Values out of confidence interval of *b* were represented in bold. * = non-native species; n = abundance by site; SL = range and average of the standard length; WT = range and average of the total weight; R^2 = coefficient of determination; *a* = confidence interval (95%) and coefficient of regression curve interception; *b* = confidence interval (95%) and exponent regression coefficient. RES = Reservoir; TA = Taquaruçu; CA = Capim River; CE = Centenário River; TE = Tenente River.

Taxa	RES	n	Biological Parameters		R^2	W = log (*a*) + *b* log (SL)	
Family / Species	TA		SL (cm)	WT (g)		*a*	*b*
Parodontidae							
Apareiodon affinis	CA	10	3.2-10.5 (5.5)	0.8-18 (5.1)	0.99	(0.012-0.014) 0.013	(2.45-2.72) 2.59
	TE	13	1.7-5.7 (3.7)	0.1-3.5 (1.3)	0.98	(0.017-0.020) 0.018	(3.07-3.58) 3.32
Characidae							
Astyanax lacustris	CE	10	4.6-6.2 (5.8)	0.4-5.12 (6.35)	0.95	(0.012-0.038) 0.013	(2.44-3.8) 2.69
Bryconamericus iheringii	CA	30	2.3-6.2 (3.5)	0.3-4.5 (1.2)	0.95	(0.014-0.016) 0.015	(2.59-3.05) 2.82
	TE	15	1.9-4.0 (2.8)	0.1-1.4 (0.6)	0.96	(0.015-0.018) 0.017	(2.71-3.47) 3.09
Moenkhausia sanctaefilomenae	CE	10	4.5-6.2 (5.5)	3.4-10.8 (7.1)	0.97	(0.005-0.006) 0.005	(3.10-3.56) 3.31
Piabarchus stramineus	CA	276	1.9-6.8 (4.0)	0.1-4.9 (1.5)	0.96	(0.169-0.017) 0.017	(2.97-3.10) 3.03
	TE	216	1.2-2.4 (3.1)	0.1-5.8 (0.8)	0.96	(0.018-0.191) 0.018	(3.15-3.31) 3.23
Piabina argentea	CA	35	2.8-5.3 (4.4)	0.4-3.9 (2.1)	0.97	(0.017-0.019) 0.018	(3.11-3.49) 3.30
	TE	11	2.4-6.6 (3.8)	0.2-6.6 (1.4)	0.99	(0.017-0.019) 0.018	(3.06-3.42) 3.24
Psalidodon bockmanni	CA	17	3.4-6.0 (4.4)	1.3-6.5 (2.9)	0.96	(0.010-0.015) 0.013	(2.34-3.15) 2.74
	CE	57	1.7-7.3 (3.9)	0.1-13.4 (2.9)	0.95	(0.013-0.016) 0.015	(2.70-3.32) 3.01
	TE	37	1.4-7.3 (3.5)	0.1-12.5 (1.8)	0.96	(0.015-0.017) 0.016	(2.94-3.29) 3.14
Psalidodon paranae	CA	29	3.1-8.5 (5.4)	0.8-17.8 (6.2)	0.96	(0.013-0.017) 0.015	(2.76-3.21) 2.99
	CE	11	2.9-7.6 (5.4)	0.6-13.7 (5.9)	0.98	(0.013-0.017) 0.015	(2.68-3.24) 2.96
	TE	30	3.0-8.7 (5.1)	0.7-12.6 (4.0)	0.96	(0.010-0.013) 0.011	(2.20-2.71) 2.51
*Roeboides descalvadensis**	CE	10	4.0-7.0 (5.2)	1.3-6.8 (3.2)	0.98	(0.013-0.018) 0.015	(2.47-3.14) 2.81
Loricariidae							
Hisonotus francirochai	CA	14	1.5-3.8 (2.8)	0.1-1.0 (0.5)	0.96	(0.015-0.018) 0.016	(2.58-3.25) 2.91
	TE	39	2.2-3.7 (3.1)	0.1-1.0 (0.5)	0.96	(0.020-0.023) 0.021	**(3.47-4.12) 3.80**
Heptapteridae							
Cetopsorhamdia iheringi	TE	11	2.8-9.6 (6.2)	0.3-16.8 (6.0)	0.98	(0.018-023) 0.020	(3.07-3.76) 3.42
Cichlidae							
Cichlasoma paranaense	TE	29	0.9-7.1 (2.0)	0.1-22.0 (2.5)	0.96	(0.013-0.016) 0.015	(2.95-3.66) 3.31
Geophagus brasiliensis	CE	71	1.0-8.9 (2.6)	0.1-27.8 (1.8)	0.95	(0.012-0.013) 0.013	(2.73-3.01) 2.87
Poeciliidae							
*Poecilia reticulata**	CE	19	1.3-3.1 (2.0)	0.1-0.9 (0.3)	0.97	(0.014-0.016) 0.015	(2.87-3.38) 3.12
	TE	110	0.1-2.8 (1.7)	0.1-1.0 (0.2)	0.95	(0.015-0.017) 0.016	(2.55-3.32) 2.94

Table 5. Relative condition factor of fishes of the Rosana Reservoir, lower Paranapanema River, between September 2018 and September 2020. * = non-native species; n = abundance by site; sd = standard deviation; *p* = Student's t-test result. RES = Reservoir; RO = Rosana; LA = lagoon; PI = Pirapozinho River.

Taxa	RES	n	We = *a.SL*^{b}		*p*
Family / Species	**RO**		***Kn* mean ± sd**	***Kn* range**	**(*Kn* = 1.0)**
Parodontidae					
Apareiodon affinis	LA	55	0.95±1.00	0.64-1.53	0.34
Curimatidae					
*Steindachnerina brevipinna**	PI	10	0.09±0.15	0.83-1.38	0.99
Lebiasinidae					
Pyrrhulina australis	PI	11	0.96±.0.28	0.77-1.88	0.84
Characidae					
Aphyocharax anisitsi	LA	11	0.97±0.06	0.87-1.10	0.55
*Aphyocharax dentatus**	LA PI	52 88	0.97±0.15 0.97±0.11	0.76-1.48 0.70-1.38	0.94 0.67
Astyanax lacustris	LA PI	68 25	1.00±0.23 0.94±0.22	0.64-1.20 0.68-1.53	0.32 0.74
Hemigrammus marginatus	LA	322	0.95±0.30	0.69-1.65	0.10
*Hyphessobrycon eques**	LA PI	314 26	0.96±0.42 0.98±0.05	0.48-1.70 0.63-1.10	0.10 0.25
Moenkhausia intermedia	LA	44	0.99±0.08	0.86-1.14	0.96
Moenkhausia sanctaefilomenae	PI	10	0.99±0.10	0.79-1.15	0.90
Piabarchus stramineus	LA PI	47 10	0.98±0.23 0.99±0.07	0.66-1.64 0.83-1.13	0.69 0.79
Piabina argentea	PI	65	0.99±0.09	0.70-1.23	0.50
*Roeboides descalvadensis**	LA PI	76 11	1.02±0.17 1.00±0.06	0.61-1.64 0.86-1.06	0.87 0.58
Serrapinnus notomelas	LA PI	107 29	1.03±0.21 0.98±0.05	0.74-1.60 0.60-1.21	0.44 0.44
Callichthyidae					
Corydoras aeneus	PI	54	0.99±0.13	0.80-1.59	0.97
Poeciliidae					
Phalloceros harpagos	PI	14	1.02±0.44	0.62-1.58	0.53
*Poecilia reticulata **	LA	20	0.98±0.11	0.80-1.26	0.90

Table 6. Relative condition factor of fishes of the Taquaruçu Reservoir, lower Paranapanema River, between September 2018 and September 2020. * = non-native species; n = abundance by site; sd = standard deviation; *p* = Student's t-test result. RES = Reservoir; TA = Taquaruçu; LA = lagoon; AN = Anhumas River.

Taxa	**RES**	**n**	**We = *a*.SL^b**		***p***
Family / Species	**TA**		***Kn* mean ± sd**	***Kn* range**	**(*Kn* = 1.0)**
Crenuchidae					
Characidium zebra	AN	13	1.00±0.12	0.67-1.20	0.94
Parodontidae					
Apareiodon affinis	LA	43	0.96±0.11	0.79-1.26	0.64
Serrasalmidae					
*Metynnis lippincottianus**	LA	32	0.98±0.13	0.76-1.28	0.97
Curimatidae					
Cyphocharax modestus	AN	14	1.00±0.11	0.73-1.29	0.87
*Steindachnerina brevipinna**	LA	16	1.02±0.16	0.83-1.29	0.97
Steindachnerina insculpta	AN	74	0.95±0.24	0.77-1.50	0.69
Characidae					
Aphyocharax anisitsi	LA	15	1.02±0.08	0.86-1.11	0.68
*Aphyocharax dentatus**	AN	45	1.00±0.08	0.81-1.13	0.47
	LA	220	0.97±0.15	0.72-1.60	0.82
Astyanax lacustris	AN	64	1.02±0.16	0.67-1.34	0.75
	LA	99	0.97±0.15	0.73-1.48	0.97
Bryconamericus iheringii	AN	250	0.99±0.13	0.67-1.69	0.76
*Hyphessobrycon eques**	LA	217	0.99±0.31	0.66-1.60	0.30
Moenkhausia intermedia	LA	99	1.02±0.26	0.61-1.58	0.44
Piabarchus stramineus	AN	273	1.00±0.41	0.66-1.43	0.31
	LA	13	0.94±0.13	0.82-1.27	0.81
Piabina argentea	AN	51	0.98±0.07	0.86-1.29	0.46
Psalidodon aff. *fasciatus*	AN	23	1.00±0.09	0.73-1.14	0.74
Psalidodon paranae	AN	52	0.98±0.16	0.65-1.62	0.89
*Roeboides descalvadensis**	LA	138	1.00±0.11	0.76-1.35	0.76
Serrapinnus notomelas	LA	117	1.02±0.26	0.61-1.54	0.10
Callichthyidae					
Corydoras aeneus	AN	87	1.00±0.10	0.70-1.26	0.79
Loricariidae					
Hisonotus francirochai	AN	61	0.97±0.20	0.62-1.64	0.75
Otothyropsis polyodon	AN	25	0.91±.056	0.73-1.58	0.52
Cichlidae					
Crenicichla britskii	LA	10	1.03±0.15	0.70-1.20	0.95
Poeciliidae					
*Poecilia reticulata**	AN	75	0.96±0.24	0.61-1.65	0.59
	LA	14	0.99±0.22	0.72-1.35	0.82

Table 7. Relative condition factor of fishes of the Taquaruçu Reservoir, lower Paranapanema River, between May 2012 and August 2013. * = non-native species; n = abundance by site; sd = standard deviation; *p* = Student's t-test result. RES = Reservoir; TA = Taquaruçu; CA = Capim River; CE = Centenário River; TE = Tenente River.

Taxa	RES	n	We = *a*.SL^b		*p*
Family / Species	**TA**		***Kn* mean ± sd**	***Kn* range**	**(*Kn* = 1.0)**
Parodontidae					
Apareiodon affinis	CA	10	0.98±0.47	0.91-1.08	0.62
	TE	13	0.95±0.12	0.80-1.26	0.86
Characidae					
Astyanax lacustris	CE	10	0.98±0.05	0.92-1.09	0.77
Bryconamericus iheringii	CA	30	0.98±0.16	0.75-1.46	0.96
	TE	15	0.98±0.13	0.72-1.22	0.94
Moenkhausia sanctaefilomenae	CE	10	0.99±0.05	0.87-1.09	0.63
Piabarchus stramineus	CA	276	0.99±0.16	0.67-1.51	0.89
	TE	216	0.98±0.20	0.70-1.65	0.57
Piabina argentea	CA	35	0.98±0.10	0.74-1.34	0.68
	TE	11	0.98±0.05	0.90-1.07	0.55
Psalidodon bockmanni	CA	17	0.98±0.15	0.85-1.56	0.99
	CE	57	1.06±0.20	0.74-1.50	0.21
	TE	37	0.98±0.19	0.68-1.45	0.78
Psalidodon paranae	CA	29	0.99±0.18	0.82-1.47	0.81
	CE	11	0.97±0.13	0.84-1.27	0.95
	TE	30	0.99±0.14	0.71-1.32	0.91
*Roeboides descalvadensis**	CE	10	0.99±0.06	0.86-1.06	0.72
Loricariidae					
Hisonotus francirochai	CA	14	0.96±0.12	0.78-1.24	0.92
	TE	39	0.96±0.14	0.75-1.34	0.85
Heptapteridae					
Cetopsorhamdia iheringi	TE	11	1.00±0.16	0.63-1.27	0.99
Cichlidae					
Cichlasoma paranaense	TE	29	0.95±0.18	0.63-1.53	0.37
Geophagus brasiliensis	CE	71	0.99±0.33	0.65-1.33	0.47
Poeciliidae					
*Poecilia reticulata**	CE	19	1.05±0.12	0.70-1.15	0.96
	TE	110	1.04±0.14	0.60-1.66	0.17

DISCUSSION

In this study we report the length-weight relationship and relative condition factor of 74 populations of 31 species of the lower Paranapanema River. Our results differed from previous studies of fish allometry patterns occurring in the Paranapanema River basin (i.e., the same species examined here in this study) as Orsi et al. (2002), Oliva-Paterna et al. (2009), Orsi and Britton (2012), Nobile et al. (2015) and Ribeiro et al. (2017). Thus, our report yielded additional contributions to the knowledge of the local ichthyofauna. Nevertheless, seven coefficients were out of *b* confidence interval. Some factors may affect length-weight relationships, such as taxonomic aspects, ontogenetic phases, sample heterogeneity and size (Froese, 2006), seasonality, sex ratio and gonadal activities (Le Cren, 1951; Vazzoler, 1996). According to Orsi and Britton (2012), this out-of-range values are not reliable.

The relative condition factor did not differ significantly between species and environments studied. So, it was not possible to carry out additional analysis to relate the fish condition with environmental circumstances, as in previous studies (Barrilli et al., 2015; Caetano and Jané, 2018). We can interpret the results not assuming that the environments are in good conditions, but from the fish populations in these sites. In general, in damming environments, is expected the decrease of species richness (Agostinho et al., 2016) and shifts on dominance patterns, where some species could rise (Delariva et al., 2013; Lima et al., 2018). In this way, only species pre-adapted for survive in lentic environments and able to complete all stages of their life cycle in reservoirs or remaining dams-free stretches (i.e., tributaries) will remain in the new environment (Agostinho et al., 2007). Small-sized fish can successfully colonize reservoirs due to their trophic position (e.g., generalist or opportunistic diet) (Delariva et al., 2013), and reproductive aspects (e.g., short life cycle, high fertility, eggs and pelagic larvae and non-migration) (Agostinho et al., 2016), which could support the *Kn* adjusted observation in all environments.

Non-native fish species with those same characteristics mentioned above can also establish themselves in habitats influenced by damming (Agostinho et al., 2007). Therefore, the presence of non-natives with adjusted *Kn* values may indicate the healthiness of these populations (Barrilli et al., 2015) and the adaptive capacity to successfully explore food resources available in such environments (Zatti et al., 2012; Fiori et al., 2016). However, the aging of the reservoir may lead to altering food resources and, consequently, simplifying the trophic levels (Delariva et al., 2013; Lima et al., 2018). In dammed rivers, fish can suffer from flow control that may restrain the flooding dynamics and decrease the influx of nutrients and availability of food (Agostinho et al., 2007). But, from the results of the relative condition factor, this does not seem to be a problem for the small-sized species in Rosana and Taquaruçu reservoirs. Since fishes could present the capacity of explore other food resources (i. e., trophic plasticity) (Zatti et al., 2012; Fiori et al., 2016) in response of environment impacts (Delariva et al., 2013; Lima et al., 2018), our results provide important information about ecological responses of local fishes populations.

In reservoirs, small-sized fish may become widespread and abundant in marginal zones (Orsi, 2010). Hence, the adjusted *Kn* values in the lentic environments (lagoons) demonstrates the supply of these populations, might be related to fish feeding habits (Silva Lourenço et al., 2008; Caetano and Jané, 2018) and the investment that adults individuals put on reproduction (Orsi et al., 2002, 2004). Additionally, it is a known that the aggregation of higher biodiversity in marginal lagoons is responsible for providing food resources (e.g., autochtones and alochtones items) to fishes, such as invertebrate, algae, and plant material (Ferrareze and Nogueira, 2011).

The removal of riparian vegetation, agriculture, pasture, waste disposal, and urbanization can contribute to the decrease of fish populations in rivers, since small-sized fishes, especially in streams, depend on the marginal zone and the alochtone items to feed on (Zatti et al., 2012; Castro and Polaz, 2020). However, we observed fish populations in tributaries which do not respond to these harms (once condition factor showed adjusted). So, this may be related over again to the ichthyofauna composition in these environments, which probably selected species able to maintain populations in these conditions (Agostinho et al., 2007, 2016). Therefore, the Pirapozinho River, which has some of the worse land use rates and degradation of the riparian vegetation (Rodrigues et al., 2019), impacts also observed in the Tenente River (Vidotto-Magnoni et al., 2015), showed species resistant to degradation, such as *A. affinis* (Vidotto-Magnoni et al., 2015), *P. bockmanni* (Furlan et al., 2013) and *P. reticulata* (Cunico et al., 2006).

Moreover, the same *Kn* results in the Anhumas River did not necessarily infer in equal environmental conditions as Pirapozinho and Tenente rivers, only shows that populations of this tributary are well adapted to survive in particular conditions. As our analyses did not detect differences between populations, an alternative could be verified the environmental condition by the observance of samples and species composition. Accordingly, the high abundance of juveniles that we found on the site, which suggested that these areas have been utilized for growth (Orsi et al., 2002), and the catch of threatened species by damming as *Prochilodus lineatus* (Valenciennes, 1836) and *Salminus hilarii* Valenciennes, 1850 by Leme et al. (2015), highlight the Anhumas River as an important maintenance spot of the ichthyofauna in the Taquaruçu Reservoir.

In summary, this study provides valuable biological data for 31 freshwaters species of an important South American watershed, once small-sized fish's data are scarce for many species in the Neotropics. Due to the threats to these fishes in Brazil (Castro and Polaz, 2020), this report could help fisheries management and future research of Southern (Orsi and Britton, 2012; Nobile et al., 2015; Ribeiro et al., 2017).

CONCLUSIONS

We report valuable biological data of length-weight relationship and relative condition factor on 74 populations of 31 species of the lower Paranapanema River, upper Paraná basin. Our results of length-weight relationships differed from previous studies in the region, being an additional contribution to the knowledge of the local ichthyofauna. Moreover, the relative condition factor provided important information about ecological responses of local populations facing environmental impacts, once some fish species have great adaptive response capacity. Thus, studies must be maintained in these environments adding another diagnosis method, as well as the continuous monitoring of fisheries under human activities in the region.

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