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LENGTH–WEIGHT RELATIONS OF FISHES (ACTINOPTERYGII) FROM KARST STREAMS IN THE BODOQUENA PLATEAU, WESTERN BRAZIL

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Abstract. The presently reported study provides the length–weight relations (LWR) for 23 species from headwater streams of the Bodoquena Plateau, which is located on the southern border of the Brazilian Pantanal. The following species were studied *Steindachnerina brevipinna* (Eigenmann et Eigenmann, 1889); *Characidium zebra* Eigenmann, 1909; *Bryconops melanurus* (Bloch, 1794); *Aphyocharax dentatus* Eigenmann et Kennedy, 1903; *Astyanax lacustris* Lütken, 1875; *Astyanax lineatus* (Perugia, 1891); *Brachychalcinus retrospina* Boulenger, 1892; *Creagrutus meridionalis* Vari et Harold, 2001; *Hemigrammus lunatus* Durbin, 1918; *Hyphessobrycon eques* (Steindachner, 1882); *Hyphessobrycon luetkeni* (Boulenger, 1887); *Jupiaba acanthogaster* (Eigenmann, 1911); *Moenkhausia bonita* Benine, Castro et Sabino, 2004; *Odontostilbe pequira* (Steindachner, 1882); *Piabarchus analis* (Eigenmann, 1914); *Serrapinus calliurus* (Boulenger, 1900); *Hoplerythrinus unitaeniatus* (Spix et Agassiz, 1829); *Hypostomus basilisko* Tencatt, Zawadzki et Froelich, 2014; *Otocinclus vittatus* Regan, 1904; *Rineloricaria parva* (Boulenger, 1895); *Cichlasoma dimerus* (Heckel, 1840); *Crenicichla lepidota* Heckel, 1840; *Poecilia reticulata* Peters, 1859. Specimens were collected in February and October of 2016. This study represents the first LWR data for 13 species and the maximum standard length for *Astyanax lacustris* and *Moenkhausia bonita*.

Keywords: Length–weight relation, LWR, Neotropical, fish assemblage, Pantanal, headwaters

INTRODUCTION

Body size is a key factor determining the metabolism and ecological interactions (Wootton 1998). Moreover, length–weight data are essential for improving the knowledge about growth patterns, condition factors, and biomass of fish species (Le Cren 1951, Froese 2006). Despite the increasing number of reports describing LWR of fish species, data are still lacking for large areas that harbour species-rich communities with high endemism, such as the Upper Paraguay River Basin, in particular, fish fauna that inhabits the headwaters.

The Serra da Bodoquena Plateau is a karst formation located on the southeast of the Pantanal floodplain, Mato Grosso do Sul state, about 200 km in the north–south extension and up to 800 m of altitude above sea level (Sallun Filho et al. 2004). This formation features headwater streams from important drainages of the Upper Paraguay River Basin: Apa in the south and Miranda in the north. In addition to biogeographic aspects, this region is economically important owing to thousands of ecotourists who, each year, are attracted by the transparency of its waters. In fact, this has become the main source of income in Bonito and surrounding towns (Klein et al. 2011). Notwithstanding the important economic aspects of this region, little is known about basic aspects of local fish fauna, especially fish species from small streams, despite recent efforts in the last decade (Casatti et al. 2010, Cordeiro et al. 2013, Severo-Neto et al. 2015, Ferreira et al. 2017). In this context, this work provides information about length–weight relations of 23 fish species from Serra da Bodoquena Plateau, a karstic environment of Pantanal headwaters.

MATERIAL AND METHODS

The fishes were collected in February and October of 2016 from 25 sample points on eighteen streams of

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the Formoso River sub-basin, Miranda River drainage (20°57′~12°12′S, 56°17′~56°41′W). Fishes were captured using a trawl net with 5 mm mesh, fixed in a 10% formalin solution for three days, and transferred to 70% alcohol prior to the measurements. For each specimen, we recorded the standard length (SL) to the nearest 0.01 cm with a digital calliper. Specimens were weighed to obtain the total weight (TW) to the nearest 0.001 g with a precision balance. Before the regression analysis, log-log plots of the length–weight pairs were performed to identify outliers, and extreme values were excluded from the analyses (Froese et al. 2011). Length–weight relations were given by linear regression analysis based on the following logarithm

$$\text{Log}\,(W) = \text{Log}\,(a) + b \times \text{Log}\,(L)$$

where W is the weight of the fish (g), L is the standard length (mm), a is a scaling constant, and b is a growth parameter (Ricker 1973).

Voucher specimens were deposited at the fish collection of Coleção Zoológica de Referência da Universidade Federal de Mato Grosso do Sul. Identification of the species was based on Britski et al. (2007), Thomas et al. (2013), and Tencatt et al. (2014). Statistical analyses were performed using R software (R core team 2017).

RESULTS

A total of 1968 individuals, belonging to four orders, 8 families and 23 species, were studied: *Steindachnerina brevipinna* (Eigenmann et Eigenmann, 1889); *Characidium zebra* Eigenmann, 1909; *Bryconops melanurus* (Bloch, 1794); *Aphyocharax dentatus* Eigenmann et Kennedy, 1903; *Astyanax lacustris* Lütken, 1875; *Astyanax lineatus* (Perugia, 1891); *Brachychalcinus retrospina* Boulenger, 1892; *Creagrutus meridionalis* Vari et Harold, 2001; *Hemigrammus lunatus* Durbin, 1918; *Hyphessobrycon eques* (Steindachner, 1882); *Hyphessobrycon luetkeni* (Boulenger, 1887); *Jupiaba acanthogaster* (Eigenmann, 1911); *Moenkhausia bonita* Benine, Castro et Sabino, 2004; *Odontostilbe pequira* (Steindachner, 1882); *Piabarchus analis* (Eigenmann, 1914); *Serrapinus calliurus* (Boulenger, 1900); *Hoplerythrinus unitaeniatus* (Spix et Agassiz, 1829); *Hypostomus basilisko* Tencatt, Zawadzki et Froelich, 2014; *Otocinclus vittatus* Regan, 1904; *Rineloricaria parva* (Boulenger, 1895); *Cichlasoma dimerus* (Heckel, 1840); *Crenicichla lepidota* Heckel, 1840; *Poecilia reticulata* Peters, 1859. The coefficient of determination (R^2) ranged from 0.851 to 0.991, a values ranged from 0.0037 to 0.0359, and b values varied between 2.68 and 3.49. All values of a and b fit within the normal range proposed by Froese (2006) of a between 0.001 and 0.05 and b between 2.5 and 3.5. The descriptive statistics and the estimated LWR parameters are summarized in Table 1. Some species were represented by fewer than 30 individuals which is below the recommended number once that above 30 individuals would be the ideal since that may increase the chances of sampling all the length classes in a population and thus avoid a super or underestimation of b (Froese et al. 2011). However, we decided to keep LWR estimates for species with fewer than 30 individuals once they presented high values of R^2 (Table 1). This study represents the first LWR data for 13 species and the maximum standard length for *Astyanax lacustris* and *Moenkhausia bonita*.

DISCUSSION

This work reports the first LWRs to nine Neotropical species. The allometric coefficients of all species studied ranged from 2.7 to 3.5, as established by Froese (2006). From the 16 species, the LWRs of which are already listed on FishBase, seven had different growth results in our work. *Aphyocharax dentatus*, *Odontostilbe pequira*, *Piabarchus analis*, and *Otocinclus vittatus* presented positive allometric growth, while *Hyphessobrycon luetkeni* and *Crenicichla lepidota* showed negative allometric growth, and *Creagrutus meridionalis* showed an isometric growth. Variations of b values may be related to population differences, nutritional status, or even the ontogenetic stage of the individuals studied (Froese 2006, Froese et al. 2011). The differences assigned to *Astyanax lacustris* were possibly related to changes in the taxonomic status of the species, which has been expanded from the former "*Astyanax asuncionensis* Géry, 1972", harbouring populations of several hydrographic basins, including the Upper Paraguay River (Lucena and Soares 2016). These aspects strengthen the need for further efforts at understanding the growth patterns of a species, especially when species with large geographical distribution are involved.

Serra da Bodoquena streams share the same fate as that of rivers from different freshwater ecoregions which present high endemism and invasion of non-native fish (Daga et al. 2016). In this work, we report the first LWR data to *Hypostomus basilisko* and *Poecilia reticulata*. The former species is an armoured catfish species from Serra da Bodoquena and one example of the high endemism in this region, while *P. reticulata* is an exotic species in Brazil introduced through aquarium dumping or the control of mosquitoes. Although its dominance may be indicative of anthropogenic impacts (Cunico et al. 2006), it occurred in small populations in the sites that presented a considerable preserved riparian forest. However, the recent expansion of agriculture in the region may facilitate the populational growth of this species in the future, as a response to the impact and consequent loss of ecological integrity (Ruaro et al. 2018). In view of this, the present work presents preliminary data about fish species from the Formoso Basin and emphasizes the need for further studies to better understand the structure of fish assemblages in this unique region.

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Table 1

Data from length–weight relations for 23 fish species from the Rio Formoso drainage, western Brazil; the taxonomic order followed Fricke et al. (2018)

Family and species	*n*	SL range [cm]	*W* range [g]	*a*	*b*	95% IC of *a*	95% IC of *b*	R^2
Curimatidae								
Steindachnerina brevipinna	24	3.47–10.38	0.895–28.020	0.0146	3.31	0.0111–0.0193	3.17–3.46	0.986
Crenuchidae								
Characidium zebra	36	2.67–5.1	0.200–2.700	0.0098	**2.88**	0.0068–0.0141	2.46–3.30	0.879
Iguanodectidae								
Bryconops melanurus	32	2.8–9.38	0.271–12.880	0.0098	**3.23**	0.0077–0.0125	3.11–3.36	0.990
Characidae								
Aphyocharax dentatus	62	2.73–5.4	0.279–2.700	0.0110	3.28	0.0073–0.0164	2.94–3.62	0.862
Astyanax lacustris†	174	2.75–9.3	0.400–25.340	0.0184	3.13	0.0160–0.0211	3.05–3.22	0.968
Astyanax lineatus	538	1.61–9.43	0.110–22.710	0.0311	2.81	0.0287–0.0337	2.76–2.87	0.949
Brachychalcinus retrospina	10	2.49–4.61	0.400–3.200	0.0163	3.41	0.0113–0.0236	3.14–3.68	0.989
Creagrutus meridionalis	52	2.08–5.10	0.100–2.424	0.0147	**3.00**	0.0106–0.0203	2.75–3.25	0.925
Hemigrammus lunatus‡	29	2.80–3.74	0.400–1.000	0.0108	3.49	0.0064–0.0183	3.04–3.93	0.902
Hyphessobrycon eques	43	1.99–2.87	0.150–0.530	0.0185	3.12	0.0134–0.0260	2.74–3.51	0.864
Hyphessobrycon luetkeni	93	2.42–4.81	0.200–2.600	0.0231	**2.92**	0.0177–0.0320	2.69–3.15	0.875
Jupiaba acanthogaster‡	31	2.88–4.33	0.400–1.900	0.0149	3.25	0.0079–0.0284	2.75–3.74	0.858
Moenkhausia bonita‡	172	2.10–8.53	0.100–7.700	0.0193	**2.97**	0.0158–0.0235	2.81–3.13	0.889
Odontostilbe pequira	202	2.20–3.70	0.100–0.717	0.0117	**3.24**	0.0103–0.0132	311–3.38	0.895
Piabarchus analis	61	1.97–3.43	0.097–0.489	0.0112	**3.17**	0.0091–0.0137	2.96–3.37	0.947
Serrapinus calliurus‡	143	1.70–3.90	0.100–1.070	0.0187	**3.10**	0.0150–0.0234	2.89–3.32	0.851
Erythrinidae								
Hoplerythrinus unitaeniatus‡	11	4.40–14.82	2.178–68.400	0.0282	2.86	0.0155–0.0512	2.51–3.20	0.972
Loricariidae								
Hypostomus basilisko‡	27	1.90–13.07	0.100–62.840	0.0117	3.38	0.0093–0.0148	3.25–3.52	
Otocinclus vittatus	110	2.10–3.19	0.210–0.730	0.0171	3.27	0.0140–0.0210	3.06–3.49	0.985
Rineloricaria parva‡	34	2.70–7.44	0.070–2.610	0.0037	3.10	0.0015–0.0090	2.58–3.62	0.886
Cichlidae								
Cichlasoma dimerus‡	23	2.40–8.50	0.479–33.340	0.0254	3.29	0.0211–0.0305	3.11–3.48	0.991
Crenicichla lepidota	12	1.84–17.06	0.100–31.900	0.0123	**2.68**	0.0251–0.0516	2.26 a 3.10	0.948
Poecilidae								
Poecilia reticulata‡	49	1.50–3.29	0.083–1.030	0.0219	3.09	0.0189–0.0254	2.92–3.26	0.965

n = number of analysed specimens, SL = standard length, *W* = total weight, *a* = coefficient of proportionality, *b* = allometric coefficient, IC = confidence limit, R^2 = coefficient of determination; † = new maximum standard length, ‡ = no data about LWR in FishBase (Froese and Pauly 2018); Bold indicates contrasting growth based on FishBase data up to May 2018.

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