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Length-weight relationships for freshwater fish species from humid forest enclaves at the Brazilian semiarid

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Summary

We report the length-weight relationships (LWR) for 11 fish species inhabiting headwater streams in the Araripe and Ibiapaba plateaus, Brazilian semiarid. Values of r^2, *a* and *b* ranged respectively from .953 to .998, 0.010 to 0.043 and 2.81 to 3.69. Our reports on LWR are pioneer in humid forest enclaves at the Caatinga biome. Such enclaves of forest can be a checkpoint to climate change, but are under strong human pressure and remain under low investigation.

1 | INTRODUCTION

Basic data reporting the length-weight relationships (LWR) are unavailable for headwater stream fishes in the Brazilian semiarid, despite the high endemism in the Caatinga biome (Rodrigues-Filho et al., 2016; Rosa, Menezes, Britski, Costa, & Groth, 2003). While this region is suffering strong human pressure through impoundment and introduction of non-natives fish species (Rosa et al., 2003), LWR data enable the assessment of climate change effects and stimulates fisheries research, taken together ecology, evolution, conservation and management (Froese & Pauly, 1998; Nahum, Castello, & Rosenthal, 2009; Vergés et al., 2016). LWR also reflects suitable conditions to fish populations in time and space and enables a comparison of sexual maturity and feeding conditions (Chaves, Sánchez-Botero, Garcez, & Reis, 2013; Wootton, 1998).

An adequate description of traits (including LWRs) indeed remains incipient in humid forest enclaves at the Brazilian semiarid, if considering non-target fish species inhabiting humid forest enclaves. This is the report on LWRs considering more than a group of target fish species in riverine basins in the Caatinga biome (Nascimento et al., 2011; Novaes, Costa, Mourato, & Peretti, 2014) and the first report in humid forest enclaves in the Araripe and Ibiapaba plateaus, Ceará State. Therefore, we are also contributing to the toolbox employed in the conservation of the Neotropical fish biodiversity, adding to their life history, beyond the taxonomic variation in riverine environments (Rosa & Groth, 2004).

2 | MATERIALS AND METHODS

We sampled the fish fauna at humid forest enclaves into tablelands of Araripe (AR) and Ibiapaba (IB), located in the Northeastern Brazil in the coordinates limits 7°48′19″S 39°20′16″W – 7°28′33″S 39°44′27″W at the AR and 3°40′17″S 40°53′44″W – 3°52′00″S 40°51′53″W at the IB. IB plateau ranges from 900 m to 1,000 m of elevation (Claudino-Sales & Lira, 2011), mean rainfall of 1,000 mm in the rainy season (Sá, Riché, & Fotius, 2004), bordering Ceará and Piauí States, while AR borders Ceará and Pernambuco States. In the IB side of Ceará State, stretches of the Coreaú river basin were sampled; while stretches of the Jaguaribe and São Francisco river basins were sampled in AR at the Ceará and Pernambuco States, respectively. The area and elevation in AR are respectively 8,000 km^2 and ~1,000 m over sea level (DNPM, 1996).

Fishes were captured in 23 streams, only in rainy periods (from February to May) due to the intermittent regime of the running waters in such semiarid areas. AR was sampled in April/2011 and IB from 2012 to 2014 (April and May). All the captures were authorized by national agencies of environmental protection in Brazil (Ministério do Meio Ambiente – MMA and Instituto Chico Mendes de Conservação da Biodiversidade – ICMBio) in the permissions #26174-2 and #32921-4. Fishes were captured using specific tools for a variety of habitats (aquatic macrophytes, ponds, pools, rapids and waterfalls) as recommended by Uieda and Castro (1999). After captured, the individuals were adequately anesthetized in Eugenol, transferred to formalin 10% and maintained in alcohol 70%. In laboratory, fish species were identified with taxonomic guides for the Northeastern Brazilian region, and then the author names and years of description confirmed in the FishBase (Froese & Pauly, 2016). Individuals were standard length measured with a digital calliper rule scaled in millimetre (0.01 mm), then converted to centimetre (cm); and weighted in grams (g), with 0.01 g of accuracy.

We calculated general LWRs for the species, which means the individuals of the same species that were measured for the two plateaus were combined for the calculation of the LWRs due to non-standardization of temporal sampling, where it would not be possible to compare the plateaus because of pluviometrical variability. The classical length-weight relationship ($W = aSL^b$) was log-log transformed in the linear form: ln W = ln $a + b \times$ ln SL, wherein, W is the

TABLE 1 Descriptive statistics and estimates of LWRs parameters ($W = aL^b$) for fish species from humid forest enclaves in the Brazilian semiarid. Maximum values of standard length (SL-max) higher than that published in FishBase are in bold

	N	SL (cm) (min–max)	*W* (g) (min–max)	*a*	CI *a*	*b*	CI *b*	r^2
Characiformes								
Curimatidae								
Steindachnerina notonota (Miranda Ribeiro, 1937)	21	1.61–8.41	0.09–14.62	0.0244	0.0196–0.0301	2.993	2.891–3.100	.998
Crenuchidae								
Characidium bimaculatum Fowler, 1941	60	1.42–**6.70**	0.02–4.13	0.0195	0.0171- 0.0221	2.816	2.748–2.888	.995
Characidae								
Serrapinnus heterodon (Eigenmann, 1915)	254	0.86–**8.29**	0.007–16.45	0.0105	0.0098–0.0113	3.461	3.428–3.495	.997
Serrapinnus piaba (Lütken, 1875)	29	1.51–3.49	0.05–0.93	0.0121	0.0099–0.0147	3.478	3.304–3.658	.986
Siluriformes								
Callichthyidae								
Aspidoras menezesi Nijssen & Sbrücker, 1976	11	0.92–2.70	0.01–0.74	0.0364	0.0121–0.0766	3.101	2.314–4.253	.961
Aspidoras rochai Ihering, 1907	37	1.68–**4.42**	0.11–2.25	0.0212	0.0179–0.0249	3.115	2.997–3.239	.987
Aspidoras spilotus Nijssen & Sbrücker, 1976	109	1.33–**4.32**	0.06–2.27	0.0268	0.0239–0.0299	3.015	2.918–3.111	.960
Corydoras garbei Ihering, 1911	23	1.25–**3.88**	0.04–3.34	0.0212	0.0142–0.0308	3.696	3.394–4.019	.989
Loricariidae								
Parotocinclus cearensis Garavello, 1977	100	1.63–4.07	0.06–1.78	0.0140	0.0119–0.0165	3.440	3.296–3.584	.953
Cyprinodontiformes								
Poeciliidae								
Poecilia reticulata Peters, 1859[‡]	840	0.63–4.13	0.004–1.85	0.0216	0.0208–0.0224	3.107	3.071–3.143	.966
Perciformes								
Cichlidae								
Cichlasoma orientale Kullander, 1983	12	2.74–7.51	0.86–15.40	0.0437	0.0322–0.0580	2.906	2.756–3.064	.995

SL, Standard Length (cm, min–max); *W*, Weight (g, min–max); *N*, sample size; min, minimum size; max, maximum size; *a*, intercept; *b*, slope; CI, confidence interval; r^2, determination coefficient; [‡]introduced species.

weight in g; SL is the standard-length in cm; *a* is the intercept and *b* is the regression slope. Model adjustment was measured through the Pearson's coefficient (r^2). Obvious outliers ($r^2 < .95$) were not considered, when plotting log SL vs. log W, and data were re-analysed after the removal of outliers (Froese, 2006). Confidence Intervals (95% CI) were estimated from *a* and *b* to assure the hypothetical isometry in $b = 3$ (Huo, Yuan, & Jiang, 2011). The analysis was conducted in R environment (R Development Core Team, 2016).

3 | RESULTS

A total of 11 species belonging to seven families and four orders were measured, with five species being indeed new registers of maximum SL. The intercept *a* ranged from 0.010 (*Serrapinnus heterodon*) to 0.043 (*Cichlasoma orientale*), the coefficient *b* from 2.81 (*Characidium bimaculatum*) to 3.69 (*Corydoras garbei*) and r^2 from .953 to .998 (Table 1).

4 | DISCUSSION

We presented new LWRs previously available only from Bayesian estimates in the Fishbase (Froese & Pauly, 2016). Such data can now be included in this database, the main electronic basis used by ichthyologists in the world. We believe this novel data will be useful for basic research and conservation purposes. Six species presented coherence (*Steindachnerina notonota*, *Aspidoras menezesi*, *A. rochai*, *A. spilotus*, *Poecilia reticulata* and *Cichlasoma orientale*) and the other five species presented discrepancies from the Bayesian estimates of the Fishbase (*Characidium bimaculatum*, *Serrapinnus heterodon*, *S. piaba*, *Corydoras garbei* and *Parotocinclus cearensis*). *Corydoras garbei* ($b = 3.69$) is an endemic fish from the São Francisco ecoregion (Rosa et al., 2003) and was the single species outside the range expected for *b* in the LWR model (2.5–3.5). The species *Aspidoras menezesi* was found with small sample size but the congeners *A. rochai* and *A. spilotus* had similar values of *b*.

Studies over several years will be required to assure whether the size ranges are truly representative of the species in these habitats because some LWRs were obtained from reduced amplitude sizes (standard length), like to *A. menezesi*, *C. orientale* and *S. notonota*. Moreover, local variation is conspicuous in the Brazilian semiarid due to the irregularities in the precipitation regime. Then, we re-emphasize the intermittent regime of the streams sampled here. Sampling was always carried out in the rainy period and seasonal variations could not be assessed.

No fish species sampled here are included in the IUCN Red List of Threatened Species (IUCN, 2016), despite the human pressure at the regional level and importance of these areas to the nearly ~240,000 inhabitants. The underestimated species pool used as a proxy to the building of the IUCN Red Lists is broadly recognized, especially in South America (Vitule et al., 2017). Therefore, we achieved the current knowledge about endemic fish species in the Brazilian semiarid, also contributing to the conservation of the Neotropical biodiversity.

Thus, we contributed to the improvement of investigations on the Neotropical biodiversity, precisely at humid forest enclaves of the Caatinga biome, since LWR can provide complementary information at the population level to those obtained in taxonomic and functional approaches at the assembly level, where the structures of the fish communities were similar between the plateaus (Rodrigues-Filho, Gurgel-Lourenço, Lima, Oliveira, & Sánchez-Botero, 2017). We then encourage future investigations including functional comparisons long/short-term assessments, modeling, climate change effects, as well as conservation and management of biodiversity in riverine drainages in the Brazilian semiarid, as well as other regions with similar environmental conditions worldwide.

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