

Research Article

Length—Weight and Length—Length Relationships of Freshwater Fish Species Caught by Professional Fishermen in the Itaipu Reservoir, Brazil

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Length—weight relationships (LWRs) and length—length relationships (LLRs) were estimated for 63 and 58 freshwater fish species, respectively, captured in the Itaipu Reservoir, Paraná River Basin, Paraná State, Brazil. Sampling was carried out from March 1987 to July 2024 at 63 professional fishing sites within the reservoir's area of influence. Statistically clear differences in LWR between sexes were detected in 26 species. Isometric growth ($b = 3$) was identified in 29 species. The b -value ranged from 1.14 to 3.89, with an average of 2.68 ($SE \pm 0.04$) across all species. For LLR, the b -value ranged from 0.713 to 1.440, with an average of 1.12 ($SE \pm 0.01$) across all species, with statistically clear differences between sexes observed in 19 species. In 16 species, females were larger than males. This study provides the first LWR references for 13 species and LLR references for 22 species, as well as new maximum total length records for 39 species and maximum total weight records for 41 species. These estimates are crucial for managing fish stocks and developing models related to fish growth, reproduction, and fisheries.

Keywords: allometry; ichthyofauna; individual growth models; large river; population structure

1. Introduction

Estimating fish biomass is essential for fisheries management, the conservation of endangered fish species, the implementation of catch regulations, and fishery research [1], especially in Neotropical aquatic environments [1–3]. Such information is critical for determining stock structure and for assessing key aspects of population dynamics, including growth patterns [4], reproductive biology [5], body condition [6, 7], and mortality or recruitment in response to local and seasonal habitat conditions [8], as well as life history traits [9].

As a result, the modeling of length—weight relationships (LWRs) and length—length relationships (LLRs) has gained increasing attention over time [10, 11]. These models are widely used to estimate fish weight from length, as length measurements are often easier to obtain in field settings. Moreover, LWR and LLR models are commonly applied in fisheries to convert standard length (SL) to total length (TL), providing practical tools for stock assessments and other fishery applications [12, 13].

Although these relationships are widely used in fishery management, data on LWR and LLR for many freshwater fish species caught by professional fishermen in the Itaipu

Reservoir remain limited. The Itaipu Reservoir, one of the oldest and most extensively studied large Neotropical reservoirs (e.g., [14–16]), hosts a rich diversity of fish, with approximately 172 species [17], including 81 species of commercial importance [18]. To address this gap, we estimated the LWR and LLR for 63 and 58 commercially relevant fish species, respectively, caught by professional fishermen in the Itaipu Reservoir, located in the Paraná River Basin, Paraná State, Brazil. These data are essential for informing management strategies and the sustainability of fish stocks.

2. Materials and Methods

Surveys were conducted in the Itaipu Reservoir (Figure 1), which was filled in October 1982 and is located on the Brazil–Paraguay border (24°05′–25°33′S, 54°00′–54°37′W). The reservoir covers a flooded area of 1350 km², is approximately 151 km long, and has an average depth of 22 m, reaching a maximum depth of 170 m near the dam. Its primary function is hydroelectric power generation, with secondary uses including fisheries, navigation, tourism, recreation, and water supply [19].

Fishing in the Itaipu Reservoir was prohibited during the initial years after its formation, and it officially began in March 1985. Since March 1987, Itaipu has been recording fish landings, a practice that continues to this day, except for interruptions in 1994, 1999, and 2006 due to granted suspensions. Fishery data were collected monthly between March and October from 1987 to 2024 at 15 fishing sites, randomly selected each month from a total of 63 professional fishing sites in the Itaipu Reservoir (Figure 1). No records are available for the remaining months due to fishing prohibitions during the fish reproduction period. Fish were caught with the assistance of local professional fishermen (ranging from one to seven per site) using various fishing gears to maximize the diversity and abundance of captured species and individuals.

Gill nets, with mesh sizes ranging from 8 to 16 cm between opposite knots, lengths of 20 to 100 m, and heights of 1 to 10 m, were deployed for 24 h and checked early in the morning. Cast nets (20 m²) were thrown during the day at certain fishing sites. Longlines, equipped with 40 to 1500 hooks ranging in size from 2/0 to 7/0, were also used. Additionally, other gear types were employed, such as the locally named *espera* or *anzol de galho*, which consist of a hook and line attached to a float or a tree branch and set near macrophyte stands, similar to a jug line. Another gear type, locally known as *boia louca*, features a similar setup but uses larger hooks that drift in the reservoir. These methods were used by professional fishers to catch fish during their daily activities.

From 2002 onward, when fish were landed alive, they were anesthetized and euthanized with an overdose of benzocaine solution (250 mg/L; [20]), following procedures recommended by ethical guidelines [21]. Fish were collected under permanent licenses to collect zoological material issued by Sistema de Autorização e Informação em Biodiversidade (SISBIO), authorization numbers [24438-

1], and in accordance with the approved procedure by the Ethics Committee on Animal Use of the Western Paraná State University (CEUA/UNIOESTE—License Number: Protocol No. 53/09—CEEAAP/Unioeste). Before this period, the fish were rendered insensible on ice for subsequent analysis. Following landing, the fish were analyzed on site, in the field. Each specimen was identified using the references CETESB [22], Britski et al. [23], Reis et al. [24], Graça and Pavanelli [25], and Pavanelli et al. [18]. Specimens that could not be identified were retained and sent to specialists for further identification. Measurements were taken for TL and SL to the nearest 0.1 cm, and total weight (TW) to the nearest 0.1 g. Additionally, the sex of each individual was determined through macroscopic visual inspection of the gonads, following the methodologies of Vazzoler [26] and Brown–Peterson et al. [27]. Voucher specimens (listed in Supporting Table S1) were preserved in 70% alcohol and deposited in the Ichthyological Collection of Nupelia (NUP) at Maringá State University, Paraná State, Brazil.

LWRs were determined using the equation $TW = aSL^b$ [28], where TW is the total weight; a is the intercept, which can be interpreted as a scaling factor that adjusts the curve to reflect the specific characteristics of the species or group of organisms under study [1, 29]; SL is the standard length; and b is the allometric coefficient. LLRs were estimated using the linear equation $TL = \alpha + \beta SL$, where TL is the total length; SL is the standard length; and α and β are regression parameters estimated using the least-squares method [30]. For the LWR, both variables (TW and SL) were log₁₀-transformed ($\log_{10}TW = \log_{10}a + b\log_{10}SL$), and the parameters were also estimated using the least-squares method.

Scatter plots were generated to visually inspect outliers, and extreme values (standardized residuals with absolute values ≥ 4 [31]) were excluded prior to regression analysis. Model fit was evaluated using the coefficient of determination (r^2), and 95% confidence intervals ($\alpha = 0.05$) were estimated for the parameters of each relationship. Student's t -test [30] was applied to assess whether the value of b significantly deviated from the isometric condition ($b = 3$) in the LWR.

Analysis of covariance (ANCOVA [32]) was used to test for differences in parameter estimates between males and females for both LWR and LLR. When significant differences were detected via ANCOVA, separate LWR and LLR models were adjusted for each sex. Conversely, when no significant differences were found, the parameters were presented for the combined group (indicated as 'B' for both sexes—males plus females—in the tables). To avoid overfitting and to improve the stability of the estimates, precision, and statistical validity, as recommended by Harrell Jr. [33], adjustments were made for species with $n > 20$ individuals. All statistical analyses were performed using R software [34], with a significance level of $p < 0.05$ set for all tests. A comprehensive guide for all analyses is available at <https://github.com/ICTES-UNIOESTE/LWR-and-LLR-of-fish-species-from-Itaipu-Reservoir>.

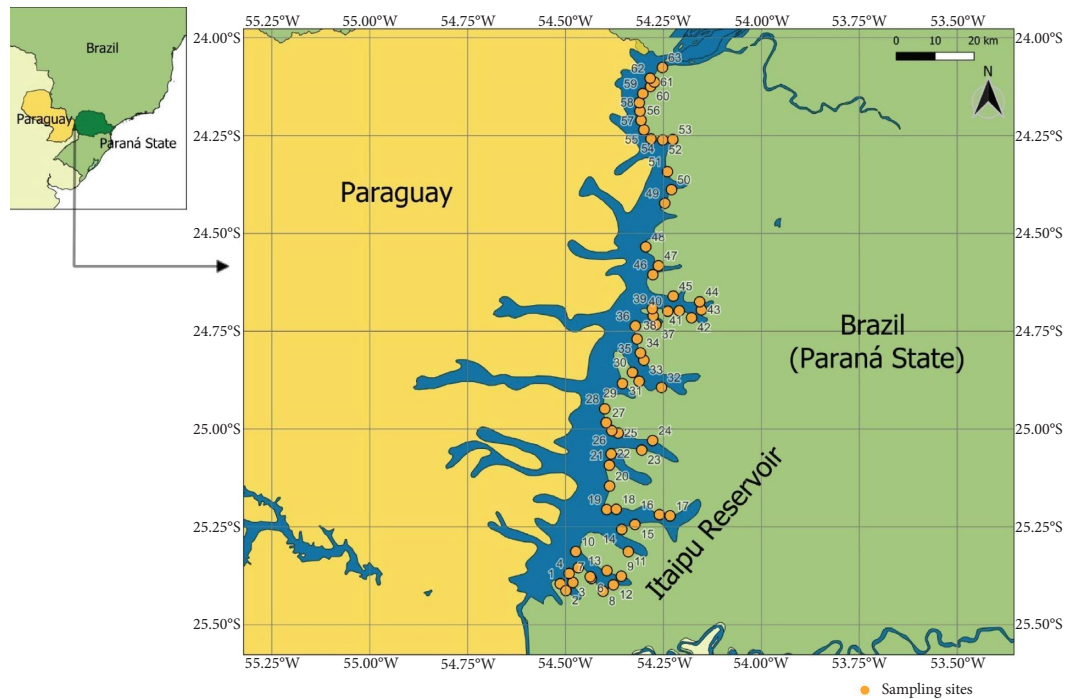


FIGURE 1: Sampling sites (from 1 to 63) in the Itaipu Reservoir, Paraná River Basin, Paraná State, Brazil.

3. Results

A total of 154,825 individuals were captured, comprising 63,086 males and 90,497 females. For 1242 specimens, sex could not be determined through macroscopic inspection of the gonads. These individuals represented 64 fish species distributed across eight orders, 21 families, and 46 genera (Supporting Table S1). LWRs were adjustment for 63 of the recorded fish species (Table 1; Supporting Figure S1). After excluding outliers and specimens whose sex could not be determined, 153,094 individuals were used to fit the LWRs (Table 1; Supporting Figure S1).

The total number of individuals ranged from 22 of *Cyprinus carpio* to 20,924 females of *Pterodoras granulosus* (Table 1). The smallest recorded SL was 7.80 cm for *Metynnis lippincottianus*, while the largest was 122.00 cm for *Pseudoplatystoma corruscans* (Table 1). New maximum total weights (Table 1) and total lengths (Table 2) were reported for 41 and 39 fish species, respectively, compared to the data available in FishBase [35]. The lowest TW was 11.00 g for males of *Iheringichthys labrosus*, and the highest was 20,000.00 g for *Zungaro jahu* (Table 1). The LWR for 26 fish species showed statistically clear differences between sexes (ANCOVA; $p < 0.05$; Table 1). In addition, the LWR could be fitted only for the females of *Loricariichthys platymetopon* (Table 1).

All LWR adjustments were statistically clear ($p < 0.01$). New LWR parameters were reported for 13 fish species (Table 1). The estimated values for parameter b ranged from 1.14 for males of *Rhamphichthys hahni* to 3.89 for males of *Myloplus tiete* (Table 1). The average b value was 2.68 (SE \pm 0.05), with a median of 2.73. Half of the b values fell within the range of 2.50 to 2.93. Nineteen fish species

exhibited isometric growth ($b = 3$; $p > 0.05$; Table 1; Supporting Figure S1), as well as in females of four species and in males of one species (Table 1; Supporting Figure S1). The coefficient of determination (r^2) ranged from 0.45 for females of *M. tiete* to 0.97 for *Z. jahu* (Table 1; Supporting Figure S1).

LLR adjustments were fitted for 58 species (Table 2; Supporting Figure S2). After excluding outliers, a total of 161,362 individuals were used to fit LLRs (Table 2; Supporting Figure S2). The total number of individuals ranged from 27 for *Hypostomus microstomus* to 21,204 for females of *P. granulosus* (Table 2). The minimum recorded TL was 7.00 cm for *Catathyrindium jenynsii* (Table 2; Supporting Figure S2), whereas the maximum value was 160.00 cm for *P. corruscans* (Table 2; Supporting Figure S2). Similarly, SL ranged from 5.00 cm for *C. jenynsii* to 141.00 cm for *P. corruscans* (Table 2; Supporting Figure S2).

All LLR models were statistically clear ($p < 0.05$). New LLR parameters were reported for 22 fish species (Table 2). The estimated parameter β ranged from 0.977 for males of *Trachelyopterus galeatus* to 1.401 for *H. microstomus* (Table 2). The average β value was 1.126 (SE \pm 0.007), with a median of 1.122, and 50% of the values ranged from 1.100 to 1.142. The intercept (α) was not statistically clear for 10 species (confidence interval included zero; Table 2). The r^2 values ranged from 0.80 for *Hoplosternum littorale* to 0.99 for *P. corruscans*, and *Salminus brasiliensis* (see Table 2).

A statistically clear difference in the LLR between sexes was detected for 19 fish species (ANCOVA; $p < 0.05$; Table 2; Supporting Figure S2). For most species showing statistically clear differences between sexes, females were larger than males (Table 2; Supporting Figure S2).

TABLE 1: Descriptive statistics and estimated parameters of length—weight relationships for 63 fish species captured in the Itaipu Reservoir, Paraná River Basin, Paraná State, Brazil, from March 1987 to July 2024.

Species	Sex	N	Length (cm)			Weight (g)			a	95% CI of a	SE (Log ₁₀ a)	b	95% CI of b	SE (b)	r ²	t-test (H ₀ = 3)		Growth type
			Min	Max	Min	Max	t _{0.05}	p value										
<i>Acestrorhynchus lacustris</i> (Lütken 1875)	B	86	13.2	34.0	30.1	460.0	0.033	0.013–0.085	0.040	2.73	2.42–3.03	0.154	0.79	-1.766	0.081	Isometric		
<i>Ageneiosus inermis</i> (Linnaeus, 1766)	F	744	15.0	49.0	80.0	2050.4	0.012	0.009–0.015	0.060	3.10	3.02–3.18	0.040	0.89	2.404	0.016	Allometric (+)		
	M	487	18.0	42.3	55.4	1360.2	0.004	0.002–0.005	0.091	3.44	3.32–3.57	0.062	0.86	71.483	< 0.001	Allometric (+)		
<i>Ageneiosus militaris</i> Valenciennes 1835	F	83	19.0	34.5	40.2	680.0	0.008	0.002–0.037	0.425	3.10	2.59–3.61	0.255	0.65	0.40	0.692	Isometric		
	M	45	14.2	26.0	60.1	180.1	0.453	0.126–1.628	0.441	1.80	1.38–2.23	0.209	0.63	-57.18	< 0.001	Allometric (-)		
<i>Ageneiosus ucayalensis</i> Castelnau, 1855	B	614	10.8	29.8	15.1	460.1	0.016	0.010–0.027	0.110	2.87	2.71–3.03	0.084	0.66	-1.534	0.125	Isometric		
<i>Astronotus crassipinnis</i> (Heckel, 1840)	B	238	11.3	29.4	120.0	1220.1	0.205	0.134–0.314	0.094	2.53	2.39–2.68	0.073	0.84	-63.686	< 0.001	Allometric (-)		
<i>Auchenipterus osteomystax</i> (Miranda Ribeiro, 1918)	F	1993	10.0	40.0	14.3	1035.0	0.034	0.028–0.042	0.045	2.69	2.62–2.76	0.035	0.75	-8.985	< 0.001	Allometric (-)		
	M	770	9.0	39.6	12.1	920.3	0.032	0.023–0.044	0.073	2.68	2.57–2.80	0.058	0.73	-53.868	< 0.001	Allometric (-)		
<i>Brycon orbignyanus</i> (Valenciennes 1850)	B	92	13.0	47.0	48.0	2300.4	0.032	0.017–0.060	0.141	2.90	2.70–3.09	0.099	0.91	-1.041	0.301	Isometric		
<i>Catathyridium jennynsii</i> (Günther 1862)	B	545	9.0	38.2	20.1	1000.2	0.137	0.102–0.183	0.065	2.58	2.48–2.68	0.052	0.82	-79.863	< 0.001	Allometric (-)		
<i>Cichla kelberi</i> Kullander and Ferreira, 2006	B	546	13.0	51.0	52.2	2065.5	0.047	0.036–0.061	0.057	2.78	2.70–2.86	0.041	0.90	-53.141	< 0.001	Allometric (-)		
<i>Cichla piquiti</i> Kullander & Ferreira, 2006	B	1141	15.8	48.2	120.3	2300.0	0.071	0.056–0.090	0.052	2.66	2.59–2.73	0.036	0.82	-9.305	< 0.001	Allometric (-)		
<i>Cyprinus carpio</i> Linnaeus, 1758	B	22	26.7	65.3	670.0	10370.0	0.072	0.020–0.253	0.980	2.77	2.43–3.10	0.161	0.94	-1.461	0.160	Isometric		
<i>Galeocharax gulo</i> (Cope 1870)	B	93	11.0	35.0	20.2	620.1	0.082	0.026–0.255	0.249	2.48	2.08–2.87	0.199	0.63	-2.638	0.010	Allometric (-)		
<i>Geophagus sveni</i> Lucinda, Lucena and Assis, 2010*	B	749	8.2	19.3	18.0	270.1	0.041	0.033–0.050	0.035	2.93	2.86–3.01	0.038	0.89	-1.70	0.090	Isometric		
<i>Gymnotus inaequilabiatus</i> (Valenciennes 1839)	B	35	30.0	99.0	257.0	1930.0	0.642	0.216–1.913	0.233	1.71	1.44–1.97	0.129	0.84	-10.010	< 0.001	Allometric (-)		
<i>Hemiodus orthonops</i> Eigenmann and Kennedy, 1903	F	1963	13.0	41.8	45.1	750.0	0.103	0.082–0.131	0.052	2.50	2.43–2.57	0.037	0.70	-13.445	< 0.001	Allometric (-)		
	M	305	12.4	40.2	40.3	665.0	0.095	0.056–0.163	0.118	2.50	2.32–2.66	0.088	0.72	-57.850	< 0.001	Allometric (-)		
<i>Hemisorubim platyrhynchos</i> (Valenciennes 1840)	B	89	16.2	45.4	55.0	1250.6	0.055	0.019–0.158	0.098	2.63	2.31–2.94	0.159	0.76	-2.340	0.022	Allometric (-)		

TABLE 1: Continued.

Species	Sex	N	Length (cm)		Weight (g)		a	95% CI of a	SE (Log ₁₀ a)	b	95% CI of b	SE (b)	r ²	t _{0.05}	t-test (H ₀ = 3)	p value	Growth type
			Min	Max	Min	Max											
<i>Hoplias mbigua</i> Azpelicueta, Benítez, Aichino and Mendez, 2015*	B	1491	17.0	44.0	82.0	1585.0	0.094	0.075–0.117	0.048	2.51	2.45–2.57	0.033	0.80	-14.915	<	0.001	Allometric (-)
<i>Hoplias</i> sp. 2	F	33	20.0	40.3	150.1	1150.4	0.031	0.008–0.115	0.277	2.85	2.46–3.24	0.190	0.88	-0.789	0.436		Isometric
	M	47	20.3	45.0	160.0	1906.2	0.056	0.018–0.169	0.239	2.70	2.38–3.03	0.161	0.86	-1.835	0.073		Isometric
<i>Hoplosternum littorale</i> (Hancock 1828)	B	28	14.5	20.0	100.0	310.2	0.029	0.002–0.474	0.592	3.10	2.12–4.09	0.479	0.62	0.215	0.831		Isometric
<i>Hypophthalmus oremaculatus</i> Nani and Fuster de Plaza, 1947*	F	12877	15.0	54.5	33.1	1820.0	0.007	0.0065–0.0076	0.016	3.11	3.09–3.14	0.011	0.86	10.491	<	0.001	Allometric (+)
	M	8995	21.0	50.0	100.2	1570.0	0.021	0.020–0.023	0.020	2.79	2.76–2.81	0.013	0.83	-16.094	<	0.001	Allometric (-)
<i>Hypostomus ancistroides</i> (Ihering 1911)	B	25	11.0	43.0	40.3	1380.0	0.135	0.058–0.315	0.177	2.48	2.19–2.76	0.139	0.93	-3.760	0.001		Allometric (-)
<i>Hypostomus microstomus</i> Weber 1987*	B	27	14.6	29.9	50.0	810.0	0.023	0.004–0.128	0.360	3.08	2.51–3.64	0.276	0.83	0.275	0.786		Isometric
<i>Hypostomus regani</i> (Ihering 1905)	F	94	13.0	29.0	40.1	1200.0	0.041	0.019–0.088	0.165	2.88	2.63–3.14	0.129	0.84	-0.919	0.360		Isometric
	M	134	13.0	35.0	50.3	1200.0	0.021	0.011–0.039	0.138	3.08	2.87–3.29	0.106	0.87	0.773	0.441		Isometric
<i>Hypostomus ternetzi</i> (Boulenger 1895)	F	386	15.0	38.0	75.0	1300.5	0.061	0.039–0.093	0.095	2.80	2.66–2.94	0.072	0.80	-2.757	0.006		Allometric (-)
	M	442	15.0	37.0	100.0	1920.0	0.029	0.019–0.044	0.091	3.05	2.92–3.18	0.067	0.82	0.719	0.472		Isometric
<i>Iheringichthys labrosus</i> (Lütken, 1874)	F	2125	12.4	36.0	27.1	510.2	0.118	0.093–0.150	0.054	2.40	2.32–2.48	0.041	0.62	-14.850	<	0.001	Allometric (-)
	M	270	9.0	32.0	11.0	720.1	0.071	0.040–0.125	0.131	2.56	2.36–2.75	0.099	0.71	-44.320	<	0.001	Allometric (-)
<i>Leporinus friderici</i> (Bloch, 1794)	F	1533	14.0	47.5	90.2	2636.0	0.098	0.078–0.124	0.051	2.58	2.51–2.65	0.037	0.76	-11.434	<	0.001	Allometric (-)
	M	461	13.3	39.0	60.0	1475.0	0.088	0.059–0.131	0.089	2.60	2.47–2.73	0.065	0.78	-61.666	<	0.001	Allometric (-)
<i>Leporinus lacustris</i> Amaral Campos 1945	F	74	13.8	32.0	94.0	640.3	0.376	0.145–0.974	0.208	2.19	1.86–2.51	0.162	0.72	-50.239	<	0.001	Allometric (-)
	M	37	13.0	32.7	70.1	920.0	0.076	0.039–0.146	0.140	2.68	2.46–2.91	0.110	0.94	-2.864	0.007		Allometric (-)
<i>Loricariichthys platymetopon</i> Isbrücker and Nijssen 1979	F	186	21.0	33.5	75.3	300.3	0.093	0.030–0.291	0.252	2.29	1.94–2.63	0.175	0.48	-40.79	<	0.001	Allometric (-)
<i>Loricariichthys rostratus</i> Reis and Pereira, 2000*	B	54	17.5	33.2	32.0	190.0	0.046	0.011–0.183	0.899	2.39	1.96–2.82	0.214	0.71	-2.850	0.006		Allometric (-)
<i>Megalancistrus parananus</i> (Peters, 1881)	B	1127	12.0	62.0	50.4	6100.7	0.037	0.031–0.043	0.034	2.97	2.92–3.01	0.023	0.93	-1.471	0.142		Isometric

TABLE 1: Continued.

Species	Sex	N	Length (cm)		Weight (g)		a	95% CI of a	SE (Log ₁₀ a)	b	95% CI of b	SE (b)	r ²	t-test (H ₀ = 3)		Growth type
			Min	Max	Min	Max								t _{0.05}	p value	
<i>Megaleporinus macrocephalus</i> (Garavello and Britski, 1988)	F	456	16.5	60.8	170.0	7070.0	0.020	0.016–0.026	0.054	3.09	3.02–3.16	0.035	0.94	2.659	0.008	Allometric (+)
	M	239	18.0	58.6	110.0	5375.0	0.017	0.011–0.024	0.082	3.14	3.03–3.24	0.055	0.93	2.473	0.014	Allometric (+)
<i>Megaleporinus obtusidens</i> (Valenciennes, 1837)	F	288	18.0	56.4	148.0	4570.0	0.036	0.024–0.056	0.094	2.89	2.76–3.02	0.065	0.87	-1.673	0.095	Isometric
	M	285	14.0	44.5	29.1	2600.6	0.029	0.018–0.046	0.101	2.93	2.79–3.07	0.071	0.86	-0.964	0.336	Isometric
<i>Megaleporinus piavussu</i> (Britski, Birindelli and Garavello 2012)*	F	76	18.0	65.6	140.1	4700.5	0.032	0.020–0.051	0.100	2.93	2.80–3.07	0.069	0.96	-0.958	0.341	Isometric
	M	144	17.0	45.8	122.2	2518.3	0.065	0.039–0.107	0.111	2.70	2.54–2.86	0.082	0.88	-3.681	< 0.001	Allometric (-)
<i>Megalonema platanum</i> (Günther 1880)	B	41	17.0	35.0	50.1	370.1	0.021	0.004–0.103	0.338	2.85	2.34–3.36	0.252	0.77	-0.602	0.550	Isometric
<i>Metynnis lippincottianus</i> (Cope, 1870)	B	395	7.8	15.7	30.2	192.2	0.160	0.117–0.218	0.061	2.51	2.39–2.64	0.064	0.80	-76.000	< 0.001	Allometric (-)
<i>Myloplus tiete</i> (Eigenmann and Norris 1900)*	F	82	10.0	18.0	20.3	200.0	0.184	0.037–0.910	0.349	2.52	1.90–3.13	0.309	0.45	-1.564	0.122	Isometric
	M	49	9.0	14.0	15.0	200.0	0.005	0.001–0.061	0.532	3.89	2.89–4.89	0.496	0.57	1.798	0.079	Isometric
<i>Oreochromis niloticus</i> (Linnaeus, 1758)	B	71	13.0	35.5	95.0	1625.0	0.052	0.031–0.088	0.112	2.88	2.72–3.05	0.080	0.95	-1.433	0.156	Isometric
<i>Piaractus mesopotamicus</i> (Holmberg 1887)	B	348	15.0	59.0	100.1	7660.1	0.049	0.036–0.068	0.070	2.92	2.82–3.01	0.048	0.92	-1.719	0.086	Isometric
<i>Pimelodus maculatus</i> Lacepède, 1803	F	3526	9.0	41.0	14.0	1530.2	0.097	0.083–0.113	0.034	2.54	2.49–2.58	0.025	0.75	-18.766	< 0.001	Allometric (-)
	M	2297	12.0	36.0	33.0	866.3	0.170	0.141–0.206	0.042	2.35	2.29–2.41	0.031	0.71	-20.736	< 0.001	Allometric (-)
<i>Pimelodus mysteriosus</i> Azpelicueta 1998*	B	244	15.0	33.2	72.2	1110.0	0.157	0.084–0.293	0.138	2.43	2.23–2.62	0.100	0.71	-57.231	< 0.001	Allometric (-)
<i>Pimelodus ornatus</i> Kner, 1858	B	350	15.7	41.0	50.1	1310.0	0.008	0.005–0.014	0.122	3.27	3.10–3.44	0.086	0.81	3.137	0.002	Allometric (+)
<i>Pimelampus pirinampu</i> (Spix and Agassiz, 1829)	F	2944	15.0	79.8	40.3	4800.0	0.014	0.012–0.016	0.029	3.00	2.97–3.04	0.018	0.90	0.117	0.907	Isometric
	M	2459	13.0	68.0	29.1	4200.3	0.014	0.012–0.016	0.031	2.99	2.95–3.03	0.020	0.90	-0.332	0.740	Isometric
<i>Plagioscion squamosissimus</i> (Heckel, 1840)	F	16783	9.0	74.0	19.2	6700.7	0.032	0.031–0.034	0.010	2.85	2.84–2.87	0.008	0.90	-19.495	< 0.001	Allometric (-)
	M	15567	9.0	54.3	18.5	3620.3	0.069	0.065–0.074	0.014	2.61	2.59–2.63	0.010	0.80	-37.805	< 0.001	Allometric (-)
<i>Potamotrygon amandae</i> Loboda and Carvalho, 2013*	B	187	15.3	56.0	170.0	7000.1	0.102	0.062–0.168	0.110	2.73	2.58–2.88	0.075	0.88	-3.589	0.001	Allometric (-)
<i>Potamotrygon falkneri</i> Castex and Maciel 1963*	B	25	19.0	71.3	300.0	13500.0	0.085	0.035–0.206	0.187	2.79	2.54–3.04	0.121	0.96	-1.771	0.090	Isometric

TABLE 1: Continued.

Species	Sex	N	Length (cm)		Weight (g)		a	95% CI of a	SE (Log ₁₀ a)	b	95% CI of b	SE (b)	r ²	t-test (H ₀ = 3)		Growth type
			Min	Max	Min	Max								t _{0.05}	p value	
<i>Prochilodus lineatus</i> (Valenciennes, 1837)	F	4911	13.3	68.9	70.1	7950.0	0.030	0.029–0.032	0.014	2.97	2.95–2.99	0.009	0.96	-3.297	0.001	Allometric (-)
	M	3672	12.2	63.8	68.2	5350.0	0.035	0.032–0.037	0.016	2.93	2.91–2.95	0.010	0.96	-63.840	< 0.001	Allometric (-)
<i>Pseudoplatystoma corruscans</i> (Spix and Agassiz, 1829)	B	543	26.3	122.0	220.1	19900.0	0.012	0.009–0.015	0.055	2.99	2.93–3.06	0.032	0.94	-0.253	0.800	Isometric
	F	20924	9.0	74.3	29.3	9840.1	0.040	0.039–0.042	0.010	2.87	2.86–2.89	0.007	0.90	-18.974	< 0.001	Allometric (-)
<i>Pterodoras granulatus</i> (Valenciennes, 1821)	M	14237	9.0	55.2	24.3	3025.2	0.072	0.068–0.076	0.013	2.67	2.65–2.69	0.009	0.85	-35.211	< 0.001	Allometric (-)
	F	1115	14.6	48.3	90.7	1980.0	0.123	0.100–0.151	0.046	2.51	2.44–2.57	0.032	0.85	-15.563	< 0.001	Allometric (-)
<i>Pterygoplichthys ambrossetii</i> (Holmberg, 1893)	M	634	14.8	51.8	80.8	1700.0	0.122	0.094–0.157	0.057	2.50	2.42–2.57	0.039	0.87	-12.842	< 0.001	Allometric (-)
	F	67	13.0	92.0	77.1	1250.0	2.273	0.826–6.254	0.220	1.32	1.08–1.56	0.121	0.65	-13.957	< 0.001	Allometric (-)
<i>Rhamphichthys halni</i> (Meinken 1937)*	M	47	17.0	97.0	158.0	1050.3	4.066	0.990–16.695	0.305	1.14	0.81–1.48	0.166	0.51	-11.177	< 0.001	Allometric (-)
	F	2517	18.6	75.6	40.0	3630.1	0.009	0.007–0.010	0.039	2.94	2.90–2.99	0.024	0.86	-2.383	0.017	Allometric (-)
<i>Rhamphodon vulpinus</i> Spix and Agassiz, 1829	M	756	21.3	61.8	70.2	1880.3	0.023	0.015–0.033	0.087	2.67	2.56–2.78	0.055	0.76	-60.160	< 0.001	Allometric (-)
	B	1309	13.0	44.0	89.0	1920.0	0.197	0.156–0.248	0.051	2.45	2.38–2.51	0.035	0.79	-15.982	< 0.001	Allometric (-)
<i>Salminus brasiliensis</i> (Cuvier 1816)	B	287	14.0	65.0	50.2	5830.2	0.022	0.016–0.029	0.068	2.97	2.88–3.06	0.047	0.93	-0.707	0.480	Isometric
<i>Satanoperca setepele</i> Ota, Deprá, Kullander, Graça and Pavanelli 2022*	B	2597	9.0	29.3	25.0	864.0	0.379	0.302–0.475	0.050	2.14	2.06–2.22	0.042	0.51	-20.739	< 0.001	Allometric (-)
<i>Schizodon altoparanense</i> Garavello and Britski 1990	B	119	18.0	38.0	107.1	1200.0	0.041	0.025–0.068	0.111	2.81	2.65–2.97	0.081	0.91	-2.372	0.019	Allometric (-)
<i>Schizodon borellii</i> (Boulenger, 1900)	F	2221	16.0	43.0	110.0	1600.2	0.189	0.153–0.233	0.047	2.37	2.30–2.43	0.033	0.69	-19.069	< 0.001	Allometric (-)
	M	1114	15.6	41.4	100.0	1730.4	0.301	0.231–0.391	0.058	2.20	2.18–2.28	0.042	0.71	-18.849	< 0.001	Allometric (-)
<i>Schizodon nasutus</i> Kner, 1858	B	156	18.0	36.0	160.0	960.0	0.837	0.385–1.823	0.171	1.88	1.64–2.12	0.121	0.61	-92.388	< 0.001	Allometric (-)
<i>Serrasalmus maculatus</i> Kner, 1858	F	1916	9.0	54.4	25.0	3400.0	0.038	0.033–0.044	0.034	3.00	2.95–3.05	0.026	0.87	0.094	0.925	Isometric
	M	915	10.0	34.9	25.1	1250.3	0.048	0.037–0.063	0.058	2.89	2.80–2.98	0.046	0.81	-2.274	0.023	Allometric (-)

TABLE 1: Continued.

Species	Sex	N	Length (cm)		Weight (g)		a	95% CI of a	SE (Log ₁₀ a)	b	95% CI of b	SE (b)	r ²	t-test (H ₀ = 3)	Growth type	
			Min	Max	Min	Max										t _{0.05}
<i>Serrasalmus marginatus</i> Valenciennes, 1837	F	1836	8.3	33.5	23.3	930.0	0.036	0.031–0.042	0.033	2.95	2.90–3.01	0.027	0.86	-1.729	0.084	Isometric
	M	1435	8.0	29.0	19.0	520.3	0.044	0.036–0.055	0.047	2.87	2.79–2.95	0.040	0.78	-3.286	0.001	Allometric (-)
<i>Sorubim lima</i> (Bloch and Schneider, 1801)	B	257	17.4	62.8	90.2	1685.0	0.106	0.063–0.178	0.115	2.33	2.19–2.47	0.073	0.80	-9.200	< 0.001	Allometric (-)
<i>Tracheopteris galeatus</i> (Linnaeus 1766)	B	1439	11.0	31.0	40.1	375.1	0.474	0.348–0.645	0.069	2.04	1.92–2.15	0.058	0.47	-16.760	< 0.001	Allometric (-)
<i>Trachydoras paraguayensis</i> (Eigenmann and Ward 1907)	B	29	9.0	18.0	24.0	100.2	0.687	0.245–1.925	0.999	1.78	1.36–2.21	0.208	0.73	-58.250	< 0.001	Allometric (-)
<i>Zungaro jahu</i> (Ihering 1898)*	B	99	15.0	93.0	100.1	20000.0	0.045	0.030–0.068	0.091	2.84	2.73–2.94	0.054	0.97	-3.033	0.003	Allometric (-)

Note: Bold values indicate new maximum total weights. (B) Both sexes, (M) males, (F) females, (N) total fish caught, (Min) minimum value reported, (Max) maximum value reported, (a) intercept, (b) slope, (CI) confidence interval, (SE) standard error, and (r²) determination coefficient.

*first report of LWR, both according to FishBase [35].

TABLE 2: Descriptive statistics and estimated parameters of length—length relationships for 58 fish species captured in the Itaipu Reservoir, Paraná River Basin, Paraná State, Brazil, from March 1987 to July 2024.

Species	Sex	N	Total length (cm)			Standard length (cm)	α	95% CI of α		β	95% CI of β		r^2	
			Min	Max	Min			Max	SE (α)		SE (β)	Min		Max
			Min	Max	Min			Max	SE (α)		SE (β)	Min		Max
<i>Acestrorhynchus lacustris</i> (Lütken 1875)*	B	88	15.6	40.0	13.2	34.0	1.500	0.570–2.430	0.468	1.110	1.068–1.152	0.021	0.97	
<i>Ageneiosus inermis</i> (Linnaeus, 1766)	B	1149	18.6	59.0	15.0	49.0	1.955	1.594–2.317	0.184	1.122	1.110–1.133	0.006	0.97	
<i>Ageneiosus militaris</i> Valenciennes 1835	F	113	20.0	40.1	16.0	34.5	1.523	0.288–2.758	0.623	1.142	1.087–1.198	0.028	0.94	
	M	66	18.0	32.0	14.2	27.8	4.176	2.804–5.548	0.687	1.015	0.950–1.080	0.033	0.94	
<i>Ageneiosus ucayalensis</i> Castelnau, 1855	B	855	13.6	44.0	10.8	49.6	3.507	3.006–4.007	0.255	1.044	1.020–1.068	0.012	0.90	
<i>Astronotus crassipinnis</i> (Heckel, 1840)	B	242	14.3	36.9	11.3	29.4	2.880	2.280–3.480	0.305	1.074	1.044–1.104	0.015	0.96	
<i>Auchenipterus osteomystax</i> (Miranda Ribeiro, 1918)	F	3009	13.0	47.0	10.0	40.0	1.786	1.593–1.979	0.099	1.101	1.092–1.110	0.005	0.95	
	M	1379	12.0	47.6	10.0	39.6	1.554	1.273–1.835	0.143	1.108	1.093–1.123	0.008	0.94	
<i>Brycon orbignyanus</i> (Valenciennes 1850)*	B	81	22.0	52.5	19.0	43.5	0.953	–0.494–2.400	0.727	1.181	1.130–1.233	0.026	0.96	
<i>Catathyráidum jennynsii</i> (Günther 1862)*	B	800	7.0	37.0	5.0	33.0	1.779	1.559–1.999	0.112	1.117	1.104–1.131	0.007	0.97	
<i>Cichla kelberi</i> Kullander and Ferreira, 2006	B	758	15.0	50.2	13.0	43.2	1.181	0.862–1.501	0.163	1.136	1.124–1.149	0.006	0.98	
<i>Cichla piquiti</i> Kullander and Ferreira, 2006	B	976	20.0	53.3	13.6	46.4	2.056	1.690–2.423	0.187	1.111	1.098–1.125	0.007	0.96	
<i>Galeocharax gulo</i> (Cope 1870)*	B	114	13.0	42.0	11.0	35.0	0.024	–0.836–0.884	0.434	1.189	1.142–1.236	0.024	0.96	
<i>Geophagus sveni</i> Lucinda, Lucena and Assis, 2010*	F	2890	10.4	33.3	8.2	28.0	3.426	3.170–3.702	0.136	1.018	1.001–1.036	0.009	0.82	
	M	1863	10.5	31.6	8.3	27.1	3.033	2.685–3.381	0.177	1.050	1.028–1.073	0.012	0.81	
<i>Hemiodus orthonops</i> Eigenmann and Kennedy, 1903	F	1628	16.5	38.0	13.0	33.0	2.839	2.361–3.317	0.244	1.098	1.078–1.117	0.010	0.89	
<i>Hemisorubim platyrhynchos</i> (Valenciennes 1840)	M	249	15.5	45.3	12.7	36.2	1.735	0.828–2.642	0.460	1.137	1.096–1.178	0.021	0.92	
	B	77	19.6	48.9	16.2	44.2	2.221	0.393–4.049	0.918	1.124	1.061–1.186	0.032	0.94	
<i>Hoplias mbigua</i> Azpelicueta, Benítez, Aichino and Mendez, 2015*	B	1337	21.5	52.0	17.0	44.0	2.741	2.255–3.228	0.248	1.120	1.103–1.136	0.008	0.93	
<i>Hoplias</i> sp. 2	B	73	25.0	54.0	20.0	45.0	2.796	0.858–4.734	0.972	1.118	1.055–1.181	0.032	0.95	
<i>Hoplosternum littorale</i> (Hancock 1828)	B	50	16.0	26.0	13.0	20.0	2.324	–0.442–5.091	1.376	1.094	0.934–1.254	0.080	0.80	
<i>Hypophthalmus oreamaculatus</i> Nani and Fuster de Plaza, 1947*	F	10674	18.0	63.8	14.1	54.3	2.135	1.975–2.295	0.082	1.108	1.103–1.112	0.002	0.95	
	M	8689	14.0	53.9	12.0	47.2	1.849	1.631–2.067	0.111	1.127	1.120–1.134	0.004	0.92	
<i>Hypostomus ancistroides</i> (Ihering 1911)*	B	28	16.6	51.4	11.0	43.0	4.342	2.524–6.159	0.884	1.100	1.011–1.190	0.044	0.96	
<i>Hypostomus commersoni</i> Valenciennes 1836	B	131	21.0	47.0	15.0	36.0	1.207	–0.339–2.753	0.781	1.227	1.212–1.342	0.033	0.92	
<i>Hypostomus microstomus</i> Weber 1987*	B	27	20.1	41.7	14.6	29.9	–0.860	–3.347–1.628	1.208	1.401	1.281–1.520	0.058	0.96	
<i>Hypostomus regani</i> (Ihering 1905)*	B	307	17.0	49.0	13.0	35.0	0.941	0.336–1.547	0.308	1.292	1.263–1.321	0.015	0.96	
<i>Hypostomus ternetzi</i> (Boulenger 1895)*	B	1401	16.0	53.0	8.0	39.0	3.356	2.647–4.065	0.361	1.273	1.242–1.305	0.016	0.81	
<i>Iheringichthys labrosus</i> (Lütken, 1874)	B	2656	10.0	39.0	9.0	49.3	1.988	1.606–2.370	0.195	1.174	1.156–1.193	0.009	0.86	
<i>Leporinus friderici</i> (Bloch, 1794)	B	1666	16.0	57.5	12.0	47.5	2.018	1.634–2.402	0.196	1.134	1.119–1.149	0.008	0.93	
<i>Leporinus lacustris</i> Amaral Campos 1945	B	156	16.0	40.1	13.0	32.7	1.492	0.949–2.036	0.275	1.123	1.094–1.152	0.015	0.97	
<i>Loricariichthys platymetopon</i> Isbrücker and Nijssen 1979	F	250	18.7	36.0	14.3	33.0	4.676	3.444–5.908	0.626	0.982	0.937–1.027	0.023	0.88	
	M	49	23.9	40.2	19.3	34.7	2.195	0.160–4.229	1.012	1.059	0.977–1.141	0.041	0.94	
<i>Loricariichthys rostratus</i> Reis and Pereira, 2000*	B	51	20.0	35.5	17.0	30.1	3.156	1.053–5.259	1.047	1.035	0.948–1.122	0.043	0.92	

TABLE 2: Continued.

Species	Sex	N	Total length (cm)			Standard length (cm)	α	95% CI of α			β	95% CI of β			r^2
			Min	Max	Min			Max	Min	Max		SE (α)	SE (β)		
														Min	
<i>Megalancistrus parananus</i> (Peters, 1881)	B	1604	11.0	77.0	9.0	64.0	2.761	2.447	-3.075	0.160	1.213	1.202	-1.223	0.005	0.97
<i>Megaleporinus macrocephalus</i> (Garavello and Britski, 1988)	F	361	21.3	67.5	16.5	59.7	2.072	1.491	-2.652	0.295	1.124	1.108	-1.140	0.008	0.98
	M	192	21.0	58.4	18.3	48.5	1.885	1.121	-2.648	0.387	1.122	1.098	-1.145	0.012	0.98
<i>Megaleporinus obtusidens</i> (Valenciennes, 1837)	F	201	22.0	68.0	18.0	56.4	0.029	-0.748	-0.806	0.394	1.208	1.182	-1.233	0.013	0.98
	M	192	23.0	54.5	19.0	44.5	1.961	1.081	-2.841	0.446	1.138	1.105	-1.171	0.017	0.96
<i>Megaleporinus piavussu</i> (Britski, Birindelli and Garavello 2012)*	B	171	17.0	67.0	13.0	55.0	0.544	-0.039	-1.127	0.295	1.193	1.171	-1.216	0.011	0.98
<i>Megalonema platanum</i> (Günther 1880)*	B	52	19.0	37.0	15.0	30.0	1.182	-0.307	-2.672	0.742	1.202	1.133	-1.271	0.034	0.96
<i>Metynnis lippincottianus</i> (Cope, 1870)*	B	1890	10.0	36.6	7.8	29.5	1.404	1.201	-1.608	0.104	1.143	1.128	-1.160	0.008	0.92
<i>Myioplus tiete</i> (Eigenmann and Norris 1900)*	F	146	12.0	22.0	10.0	18.0	2.186	1.307	-3.065	0.445	1.106	1.041	-1.171	0.033	0.89
	M	79	11.0	18.0	9.0	14.0	1.685	0.289	-3.081	0.701	1.126	1.008	-1.243	0.059	0.82
<i>Piaractus mesopotamicus</i> (Holmberg 1887)	B	324	15.0	72.0	12.0	60.0	1.225	0.609	-1.842	0.313	1.158	1.138	-1.178	0.010	0.98
<i>Pimelodus maculatus</i> Lacepède, 1803	F	2909	11.0	49.0	9.0	40.0	1.312	0.980	-1.644	0.169	1.201	1.187	-1.214	0.007	0.91
	M	1861	13.0	41.0	10.0	33.0	1.823	1.363	-2.283	0.235	1.184	1.163	-1.204	0.011	0.87
<i>Pimelodus mysterosus</i> Azpelicueta 1998*	B	222	18.0	39.0	15.0	33.2	1.431	0.013	-2.849	0.719	1.158	1.099	-1.217	0.030	0.87
<i>Pimelodus ornatus</i> Kner, 1858*	B	304	19.8	44.8	15.7	38.4	1.906	1.106	-2.707	0.407	1.124	1.094	-1.155	0.016	0.95
<i>Piniirampus pirinampu</i> (Spix and Agassiz, 1829)	F	2764	17.0	84.0	12.0	70.0	3.236	2.860	-3.612	0.192	1.140	1.131	-1.150	0.005	0.95
	M	2570	16.0	82.0	12.0	68.0	4.362	4.059	-4.666	0.155	1.108	1.099	-1.117	0.004	0.96
<i>Plagioscion squamosissimus</i> (Heckel, 1840)	F	17437	12.0	75.0	9.0	68.0	2.265	2.204	-2.326	0.031	1.122	1.120	-1.125	0.001	0.98
	M	16825	11.0	65.0	8.0	54.0	2.771	2.685	-2.856	0.044	1.102	1.098	-1.106	0.002	0.95
<i>Prochilodus lineatus</i> (Valenciennes, 1837)	B	5478	8.9	86.0	13.3	66.5	1.816	1.641	-1.991	0.089	1.153	1.148	-1.158	0.002	0.98
<i>Pseudoplatystoma corruscans</i> (Spix and Agassiz, 1829)	B	528	28.0	160.0	24.0	141.0	2.318	1.744	-2.891	0.292	1.106	1.096	-1.117	0.005	0.99
<i>Pterodoras granulosus</i> (Valenciennes, 1821)	F	21204	14.0	84.0	9.0	71.0	4.183	4.075	-4.291	0.055	1.101	1.098	-1.105	0.002	0.95
	M	18124	13.0	61.0	9.0	53.0	3.695	3.585	-3.805	0.056	1.119	1.115	-1.123	0.002	0.94
<i>Pterygoplichthys ambrosetii</i> (Holmberg, 1893)	B	1731	18.4	60.0	14.6	53.0	4.006	3.684	-4.327	0.164	1.098	1.086	-1.109	0.006	0.95
<i>Rhaphiodon vulpinus</i> Spix and Agassiz, 1829	F	2365	22.0	83.7	18.6	75.6	2.101	1.769	-2.433	0.169	1.075	1.067	-1.082	0.004	0.97
	M	902	14.1	68.0	11.0	61.8	3.470	2.784	-4.155	0.349	1.033	1.015	-1.051	0.009	0.93
<i>Rhinelepis aspera</i> Spix and Agassiz 1829*	B	1516	10.0	50.0	12.0	44.0	3.825	3.291	-4.360	0.273	1.133	1.115	-1.151	0.009	0.91
<i>Salminus brasiliensis</i> (Cuvier 1816)	B	204	19.0	82.0	16.0	67.0	0.720	0.257	-1.184	0.235	1.172	1.158	-1.186	0.007	0.99
<i>Satanoperca setepele</i> Ota, Deprá, Kullander, Graça, and Pavanelli 2022*	F	1993	12.0	37.0	9.0	32.0	2.439	2.143	-2.736	0.151	1.106	1.087	-1.124	0.009	0.88
	M	1946	11.0	32.0	9.0	26.0	2.052	1.718	-2.387	0.170	1.141	1.120	-1.161	0.011	0.86
<i>Schizodon altoparanae</i> Garavello and Britski 1990	B	74	22.0	47.0	18.0	38.0	-0.362	-1.672	-0.947	0.657	1.211	1.157	-1.264	0.027	0.97
<i>Schizodon borellii</i> (Boulenger, 1900)	F	1807	18.8	42.0	14.8	37.0	2.246	1.862	-2.629	0.196	1.096	1.081	-1.111	0.008	0.92
	M	928	18.8	49.0	14.9	41.4	1.522	1.014	-2.030	0.259	1.124	1.103	-1.146	0.011	0.92
<i>Schizodon nasutus</i> Kner, 1858*	B	136	23.0	38.0	18.0	33.5	3.127	2.092	-4.161	0.523	1.075	1.034	-1.116	0.021	0.95
<i>Serrasalmus maculatus</i> Kner, 1858	B	2879	11.0	49.0	9.0	43.2	1.053	0.919	-1.187	0.069	1.137	1.130	-1.144	0.003	0.97

TABLE 2: Continued.

Species	Sex	N	Total length (cm)		Standard length (cm)		α	95% CI of α	SE (α)	β	95% CI of β	SE (β)	r^2
			Min	Max	Min	Max							
<i>Serrasalmus marginatus</i> Valenciennes, 1837	F	2040	11.4	47.0	8.3	40.0	1.502	1.356–1.648	0.074	1.118	1.109–1.126	0.004	0.97
	M	1530	11.0	39.0	8.0	33.0	1.725	1.506–1.944	0.112	1.098	1.083–1.112	0.007	0.93
<i>Sorubim lima</i> (Bloch and Schneider, 1801)	B	202	22.6	58.0	17.4	52.2	3.665	2.406–4.923	0.638	1.063	1.030–1.096	0.017	0.95
<i>Tracheopteris galeatus</i> (Linnaeus 1766)	F	626	14.0	35.9	11.0	30.3	2.745	2.195–3.295	0.280	1.034	0.997–1.071	0.019	0.83
	M	986	13.7	39.0	11.0	33.0	3.724	3.261–4.187	0.236	0.977	0.947–1.006	0.015	0.81
<i>Trachydoras paraguayensis</i> (Eigenmann and Ward 1907)	F	66	12.0	24.0	9.0	18.0	1.414	-0.108–2.937	0.762	1.139	1.010–1.269	0.065	0.83
<i>Zungaro jahu</i> (Ihering 1898)*	B	111	19.0	128.0	15.0	110.0	4.534	2.881–6.187	0.834	1.133	1.103–1.163	0.015	0.98

Note: Bold values indicate new maximum total lengths. (B) Both sexes, (M) males, (F) females, (N) total fish caught, (Min) minimum value reported, (Max) maximum value reported, (α) intercept, (β) slope, (CI) confidence interval, (SE) standard error, and (r^2) determination coefficient.

*first report of LLR, both according to FishBase [35].

4. Discussion

Our results indicated that the b values for the LWRs ranged from 1.14 to 3.89, which generally falls within the range commonly reported for fish [1, 29], with the exception of the lowest value (1.14). The exceptionally low estimates can be attributed to a variety of factors, such as a very narrow size range; biological aspects such as life-history, body condition, and nutritional status; environmental variables; inadequate sampling; and the sampling period, all of which are known to bias b values downward [36]. According to Tesch [29], b values typically cluster around three, with most fish species exhibiting values between two and four. This pattern has been consistently observed among various fish species in diverse aquatic systems [1, 13, 37–39].

Our data were derived from fishing landing records obtained through a long-term monitoring program conducted by Itaipu Binacional. Fishing by professional fishermen in the reservoir is subject to legal restrictions, including prohibition on using nets with mesh sizes smaller than 8 cm between opposite knots. As a result, our b estimates may be slightly overestimated, since accurate estimates should be based on the full size range of individuals (as recommended by Froese et al. [10]). Nonetheless, our results offer valuable insights for fish stock assessments and provide a robust foundation for future research on population dynamics and the mechanisms driving both spatial and temporal changes in relationship parameters. These results also have practical applications for fishery management models, supporting the development of improved management strategies within the Paraná River Basin. LWRs are practically applied in fishery management to estimate biomass, assess stocks, and set size-based catch regulations that help sustain fish populations [1, 7, 10]. However, the estimates presented here should be interpreted with caution when applied beyond the ecological context analyzed in this study.

The b parameter can be used to determine whether the growth of a fish species is isometric or allometric [1, 10]. Our results revealed isometric growth for 19 fish species and negative allometric growth for 35 fish species (Table 1). According to González-Acosta et al. [40], who studied demersal fish from northwestern Baja California, Mexico, noted that changes in body shape during ontogeny, particularly before sexual maturity, influence growth type. In addition, as reported by Barros et al. [41], growth patterns often differ between sexes in adulthood, with females typically exhibit negative allometry, while males tend toward positive allometry. Thus, due to the sampling limitations described earlier, our analyses were conducted exclusively on adult specimens. Thus, our findings suggest that, for most fish stocks, the predominant growth pattern is negatively allometric ($\approx 60\%$), regardless of sex. In such cases, fish gain less weight than expected relative to their increase in length, a pattern consistent with fishing activities disproportionately harvest larger, generally heavier, and rounder individuals from the stocks [42, 43].

Isometric growth was recorded for 29 adjustments (33%). This condition reflects potential growth rates in both weight and length, indicating that different body parts grow

at similar rates [44]. Isometry is a broader pattern reported in the literature [13, 37, 45, 46]. For example, Lubich et al. [38], who estimated the LWR for 16 fish species from the Negro River Basin, Brazil, reported isometric growth for all species studied. Likewise, Genovai et al. [39], who estimated the LWR for 10 fish species from headwater streams of the lower Iguassu River Basin, Brazil, observed that most fish species exhibited isometric growth. Although we observed negative allometry in most of the fits, isometric growth was also relevant in our results.

Conversely, predominantly positive allometric growth for the majority of fish species evaluated also have been recorded in LWR estimates [3, 47]. These conditions promote a higher weight gain relative to length growth in fish, resulting in a b exponent above three [48]. In our study, we observed positive allometry only for three fish species.

Differences in growth type between sexes were observed in only one fish species. Females of *H. oreamaculatus* exhibited positive allometric growth, while males showed negative allometry. Nevertheless, LWR often varies between sexes within a species, reflecting the influence of multiple biological and ecological factors, including resource availability [36, 49, 50], degree of gastric fullness [36, 49, 51], preservation techniques [51–53], gonadal development stage [36, 49, 51, 54], environmental conditions [1, 39, 50, 55], geographic region [9, 39, 54, 55], fish health [50, 56], size distribution of captured individuals [29, 54, 56–58], and climatic changes [9, 59, 60].

Sexual size dimorphism is well documented in fish, particularly in terms of body size differences (e.g., Haas [61]), and is often associated with different growth patterns. In our study, we recorded statistically clear differences in the LWR between sexes for 30 fish species, in which females grew more than males in 19 species, and males grew more than females in 11 species. França and Gubiani [13] recorded similar pattern estimating LWR for fishes in the lower Araguaia River Basin, Brazil. Additionally, as noted by Vazzoler [26], in studies on the reproduction of Neotropical fish, females frequently allocate more energy to reproductive processes, which often leads to larger body sizes than those of males within the same species.

Statistically clear differences in the LLR between sexes were observed in 19 fish species, with females usually presenting greater caudal fin length than males. On the other hand, males exhibited greater caudal fin length than females in only five fish species. Similar pattern was recorded by França and Gubiani [13] estimating LWRs for fish in the lower Araguaia River Basin, Brazil. In their study of *Prochilodus lineatus* and *L. friderici* in the Nova Ponte Reservoir, Araguari River, Brazil, Rêgo et al. [54] found that males often exhibit longer caudal fins, a trait linked to reproductive behavior, metabolic variation, and enhanced genetic variability.

5. Conclusions

In summary, our study provides the first reference values for the LWRs and LLRs of 13 and 22 fish species, respectively. It also reports new maximum total lengths for 39 species and new maximum total weights for 41 species, based on

comparisons with FishBase data [35]. Estimating these parameters for various population structure metrics offers valuable insights into the diverse growth strategies of individual species, enabling correlations with environmental, ecological, and physiological factors. These estimates provide critical information to support the management and conservation of key Neotropical freshwater fish species, particularly those that support provisioning services for local fishing communities.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

Caroline Henn is affiliated with Itaipu Binacional, which may have a potential interest in the subject of this study. Additionally, Luiz Guilherme dos Santos Ribas, Anderson Luís Maciel, Geuza Cantanhêde, and Laís Thayse Meier received funding from Itaipu Binacional for this research. The authors declare that these affiliations and funding sources did not influence the study design, data collection, analysis, interpretation, or the decision to publish the results. All potential conflicts are disclosed here to ensure transparency and maintain the integrity of the research. All other authors declare no conflicts of interest.

Author Contributions

Data analysis and manuscript writing: Éder André Gubiani and Luiz Guilherme dos Santos Ribas; sample collection: all authors contributed equally to the collections; laboratory analysis: Anderson Luís Maciel, Geuza Cantanhêde, and Laís Thayse Meier; review and editing: all authors contributed equally to the review and editing; conceptualization and funding acquisition: Éder André Gubiani, Pitágoras Augusto Piana, and Caroline Henn.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.

Supporting Information 1. Supporting Table S1: List of fish species captured in the Itaipu Reservoir, Paraná River Basin, Paraná State, Brazil, from March 1987 to July 2024 used to estimate length—weight (LWR) and length—length (LLR) relationships and the corresponding voucher specimens. Ichthyological collection: NUP = Núcleo de Pesquisas em Limnologia, Ictiologia e Aqüicultura-Ichthyological Collection of Nupelia, Maringá State University, Paraná State, Brazil. The classification followed that of Van der Laan et al. [62] and Fricke et al. [63].

Supporting Information 2. Supporting Figure S1: Length—weight relationships for 63 fish species captured in the Itaipu Reservoir, Paraná River Basin, Paraná State, Brazil, from March 1987 to July 2024. Black circles indicate no statistically clear differences between sexes (adjustments for grouped sexes); blue circles (males) and red circles (females) indicate statistically clear differences between sexes (adjustments for separate sexes). Images of the fish *Ageneiosus militaris*, *C. carpio*, and *M. tiete* were obtained and modified from Ota et al. [64].

Supporting Information 3. Supporting Figure S2: Length—length relationships for 58 fish species captured in the Itaipu Reservoir, Paraná River Basin, Paraná State, Brazil, from March 1987 to July 2024. Black circles indicate no statistically clear differences between sexes (adjustments for grouped sexes); blue circles (males) and red circles (females) indicate statistically clear differences between sexes (adjustments for separate sexes). Images of the fish *Ageneiosus militaris* and *Myloplus tiete* were obtained and modified from Ota et al. [64].

References

- [1] R. Froese, “Cube Law, Condition Factor and Weight–Length Relationships: History, Meta-Analysis and Recommendations,” *Journal of Applied Ichthyology* 22, no. 4 (2006): 241–253, <https://doi.org/10.1111/j.1439-0426.2006.00805.x>.
- [2] M. Petrere Jr, “River Fisheries in Brazil: A Review,” *Regulated Rivers: Research & Management* 4, no. 1 (1989): 1–16, <https://doi.org/10.1002/rrr.3450040102>.
- [3] É. A. Gubiani and S. d. S. Horlando, “Length-Weight and Length-Length Relationships and Length at First Maturity for Freshwater Fish Species of the Salto Santiago Reservoir, Iguaçú River Basin, Brazil,” *Journal of Applied Ichthyology* 30, no. 5 (2014): 1087–1091, <https://doi.org/10.1111/jai.12444>.
- [4] V. Lugert, G. Thaller, J. Tetens, C. Schulz, and J. Krieter, “A Review on Fish Growth Calculation: Multiple Functions in Fish Production and Their Specific Application,” *Reviews in Aquaculture* 8, no. 1 (2016): 30–42, <https://doi.org/10.1111/raq.12071>.
- [5] J. He, Z. Wu, L. Huang, et al., “Length-Weight Relationships of Twenty-Nine Native Fish Species From Hongshui River, Southern China,” *Journal of Applied Ichthyology* 2023 (2023): 1744641–1744644, <https://doi.org/10.1155/2023/1744641>.
- [6] K. Ao, F. O. Omolara, and N. Eteobong, “Comparative Study on Length-Weight Relationship of the Grey Mullet *Mugil cephalus* (Linnaeus, 1758) and Sickie Fin *Liza falcipinnis* (Valenciennes, 1836) From Lagos Lagoon, Nigeria,” *International Journal of Fisheries and Aquatic Studies* 5, no. 5 (2017): 17–20.

- [7] É. A. Gubiani, R. Ruaro, V. R. Ribeiro, and Ú. M. G. d. S. Fé, “Relative Condition Factor: Le Cren’s Legacy for Fisheries Science,” *Acta Limnologica Brasiliensia* 32, no. 3 (2020): e3, <https://doi.org/10.1590/s2179-975x13017>.
- [8] M. Tsoumani, R. Liasko, P. Moutsaki, I. Kagalou, and I. Leonardos, “Length–Weight Relationships of an Invasive Cyprinid Fish (*Carassius gibelio*) From 12 Greek Lakes in Relation to Their Trophic States,” *Journal of Applied Ichthyology* 22, no. 4 (2006): 281–284, <https://doi.org/10.1111/j.1439-0426.2006.00768.x>.
- [9] R. Chandran, R. K. Singh, A. Singh, et al., “Evaluating the Influence of Environmental Variables on the Length–Weight Relationship and Prediction Modelling in Flathead Grey Mullet, *Mugil cephalus* Linnaeus, 1758,” *Peer Journal* 11 (2023): 14884.
- [10] R. Froese, A. C. Tsikliras, and K. I. Stergiou, “Editorial Note on Weight–Length Relations of Fishes,” *Acta Ichthyologica et Piscatoria* 41, no. 4 (2011): 261–263, <https://doi.org/10.3750/aip2011.41.4.01>.
- [11] B. Rios, “Weight–Length Relationship for Freshwater Fish in Brazil: A Systematic Review,” (Western Paraná State University, 2024), Master Dissertation.
- [12] A. S. Keast and D. Webb, “Mouth and Body Form Relative to Feeding Ecology in the Fish Fauna of a Small Lake, Lake Opinicon, Ontario,” *Journal of the Fisheries Research Board of Canada* 23, no. 12 (1966): 1845–1874, <https://doi.org/10.1139/f66-175>.
- [13] F. M. d. S. França and É. A. Gubiani, “Length–Weight and Length–Length Relationships for Freshwater Fish Species From the Lower Araguaia River, Tocantins–Araguaia Basin, Tocantins State, Brazil,” *Neotropical Ichthyology* 23, no. 1 (2025): e240046, <https://doi.org/10.1590/1982-0224-2024-0046>.
- [14] S. M. Thomaz, L. M. Bini, M. C. D. Souza, K. K. Kita, and A. F. M. Camargo, “Aquatic Macrophytes of Itaipu Reservoir, Brazil: Survey of Species and Ecological Considerations,” *Brazilian Archives of Biology and Technology* 42, no. 1 (1999): 15–22, <https://doi.org/10.1590/s1516-89131999000100003>.
- [15] S. Makrakis, L. C. Gomes, M. C. Makrakis, D. R. Fernandez, and C. S. Pavanelli, “The Canal Da Piracema at Itaipu Dam as a Fish Pass System,” *Neotropical Ichthyology* 5, no. 2 (2007): 185–195, <https://doi.org/10.1590/s1679-62252007000200013>.
- [16] F. B. Mussi, A. B. Mendes, A. Catapan, and U. Tortato, “Ecosystem Services and Environmental Investments: A Case Study of the Itaipu Hydroelectric Plant,” *Produto & Produção* 24, no. 3 (2023): 97–116.
- [17] A. A. Agostinho, H. F. Júlio Jr, and M. Petrere Jr, “Itaipu Reservoir (Brazil): Impacts of the Impoundment on the Fish Fauna and Fisheries,” in *Rehabilitation of Freshwater Fisheries*, ed. I. G. Cowx (Oxford: Fishing News Books, 1994), 171–184.
- [18] C. S. Pavanelli, W. J. Graça, C. H. Zawadzki, et al., *Commercial Fish of the Itaipu Reservoir [Peixes Comerciais do Reservatório de Itaipu]* (EDUEM, 2023).
- [19] E. F. de Oliveira, C. V. Minte-Vera, and E. Goulart, “Structure of Fish Assemblages Along Spatial Gradients in a Deep Subtropical Reservoir (Itaipu Reservoir, Brazil–Paraguay Border),” *Environmental Biology of Fishes* 72, no. 3 (2005): 283–304, <https://doi.org/10.1007/s10641-004-2582-5>.
- [20] Panel on Euthanasia and American Veterinary Medical Association (AVMA), “Report of the AVMA Panel on Euthanasia,” *Journal of the American Veterinary Medical Association*, 218, no. 5, 669–696.
- [21] Federal Council of Veterinary Medicine (CFMV), in *Provides Guidelines on Procedures and Methods of Euthanasia in Animals and Other Provisions, Federal Council of Veterinary Medicine (Brazil: Brasília, 2002)*.
- [22] Environmental Sanitation Technology Company (CETESB), in *Itaipu Binacional: Ichthyofauna – Supplement to the Ichthyofaunistic Inventory* (CETESB, 1981).
- [23] H. A. Britski, K. Z. S. Silimon, and B. S. Lopes, *Fish of the Pantanal: Identification Manual* (EMBRAPA, 1999).
- [24] R. E. Reis, S. O. Kullander, and C. J. Ferraris Jr, *Checklist of the Freshwater Fishes of South and Central America* (EDIPUCRS, 2003).
- [25] W. J. Graça and C. S. Pavanelli, *Fish of the Floodplain of the Upper Paraná River and Adjacent Areas [Peixes da Planície de Inundação do Alto Rio Paraná e Áreas Adjacentes]* (EDUEM, 2007).
- [26] A. E. A. M. Vazzoler, *Reproductive Biology of Teleost Fish: Theory and Practice [Biologia da Reprodução de Peixes Teleosteos: Teoria e Prática]* (EDUEM, 1996).
- [27] N. J. Brown-Peterson, D. M. Wyanski, F. Saborido-Rey, B. J. Macewicz, and S. K. Lowerre-Barbieri, “A Standardized Terminology for Describing Reproductive Development in Fishes,” *Marine and Coastal Fisheries* 3, no. 1 (2011): 52–70, <https://doi.org/10.1080/19425120.2011.555724>.
- [28] W. E. Ricker, “Linear Regressions in Fishery Research,” *Journal of the Fisheries Research Board of Canada* 30, no. 3 (1973): 409–434, <https://doi.org/10.1139/f73-072>.
- [29] F. W. Tesch, “Age and Growth,” in *Methods for Assessment of Fish Production in Fresh Waters*, ed. W. E. Ricker (Blackwell Scientific Publications, 1971), 98–130.
- [30] J. H. Zar, *Biostatistical Analysis* (Prentice Hall, 1999).
- [31] A. Field, *Discovering Statistics Using IBM SPSS Statistics*, 4th ed. (Sage Publications, 2013).
- [32] D. E. Goldberg and S. M. Scheiner, “ANOVA and ANCOVA: Field Competition Experiments,” in *Design and Analysis of Ecological Experiments*, ed. S. M. Scheiner and J. Gurevitch (New York: Chapman & Hall, 1993), 69–93.
- [33] F. E. Harrell Jr., *Regression Modeling Strategies: With Applications to Linear Models, Logistic and Ordinal Regression, and Survival Analysis*, 2nd ed. (Springer, 2015).
- [34] R Development Core Team, in *R: A Language and Environment for Statistical Computing* (R Foundation for Statistical Computing, 2024), <https://www.R-project.org>.
- [35] R. Froese and D. Pauly, *FishBase, World Wide Web Electronic Publication, Sebastopol, CA, USA* (2024), <https://1shbase.mnhn.fr/search.php>.
- [36] D. Pauly, “Fish Population Dynamics in Tropical Waters: A Manual for Use With Programmable Calculators,” *ICLARM Studies and Reviews* 8 (1984): 325.
- [37] A. B. Nobile, E. M. Brambilla, P. P. Lima, D. Freitas-Souza, I. L. Bayona-Perez, and E. D. Carvalho, “Length–Weight Relationship of 37 Fish Species From the Taquari River (Parapanema Basin, Brazil),” *Journal of Applied Ichthyology* 31, no. 3 (2015): 580–582.
- [38] C. C. F. Lubich, J. Aguiar-Santos, C. E. C. Freitas, and F. K. Siqueira-Souza, “Length–Weight Relationship of 16 Fish Species From the Negro River Basin (Amazonas State, Brazil),” *Journal of Applied Ichthyology* 37, no. 2 (2021): 342–346, <https://doi.org/10.1111/jai.14112>.
- [39] N. Genovai, A. L. Maciel, P. A. Piana, and É. A. Gubiani, “Length–Weight and Length–Length Relationships of 10 Fish Species From Headwater Streams of the Lower Iguassu River Basin, Brazil,” *Zoologia* 41 (2024): e23025, <https://doi.org/10.1590/s1984-4689.v41.e23025>.

- [40] A. F. González-Acosta, C. H. Rábago-Quiroz, G. Ruiz-Campos, J. A. García-Borbón, M. C. Alejo-Plata, and F. J. Barrón-Barraza, “Length-Weight and Length-Length Relationships of 39 Demersal Fish Species of an Estuarine-Coastal Ecosystem From the Northwestern of the Baja California Peninsula, Mexico,” *Journal of Applied Ichthyology* 2024 (2024): 6408697.
- [41] F. J. T. Barros, E. L. C. Rodrigues, M. C. d. S. Moura, R. d. A. Torres, E. A. Paula, and L. M. Sousa, “Weight-Length and Length-Length Relationships of the Endangered Zebra Pleco *Hypancistrus zebra* (Siluriformes, Loricariidae) From the Xingu River, Amazon, Brazil,” *Journal of Applied Ichthyology* 2023 (2023): 1–7, <https://doi.org/10.1155/2023/5158180>.
- [42] R. Hilborn and C. J. Walters, *Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty* (Chapman & Hall, 1992).
- [43] R. Law, “Fishing, Selection, and Phenotypic Evolution,” *ICES Journal of Marine Science* 57, no. 3 (2000): 659–668, <https://doi.org/10.1006/jmsc.2000.0731>.
- [44] E. Benedito-Cecílio and A. A. Agostinho, “Population Structure of Fish in the Segredo Reservoir,” in *Segredo Reservoir: Ecological Bases for Management*, ed. A. A. Agostinho and L. C. Gomes (Brazil: EDUEM, 1997), 113–139.
- [45] T. Giarrizzo, R. R. de Sena Oliveira, M. Costa Andrade, et al., “Length-Weight and Length-Length Relationships for 135 Fish Species From the Xingu River (Amazon Basin, Brazil),” *Journal of Applied Ichthyology* 31, no. 2 (2015): 415–424, <https://doi.org/10.1111/jai.12677>.
- [46] M. P. Camargo, J. M. R. Aranha, and M. S. Menezes, “Length-Weight Relationship (LWR) of Fish Species in the Morato River, Paraná, Brazil,” *Journal of Applied Ichthyology* 34, no. 5 (2018): 1186–1187, <https://doi.org/10.1111/jai.13658>.
- [47] É. A. Gubiani, L. C. Gomes, and A. A. Agostinho, “Length-Weight and Length-Weight Relationships for 48 Fish Species From Reservoirs of the Paraná State, Brazil,” *Lakes & Reservoirs: Science, Policy and Management for Sustainable Use* 14, no. 4 (2009): 289–299, <https://doi.org/10.1111/j.1440-1770.2009.00411.x>.
- [48] W. E. Ricker, “Growth Rates and Models,” in *Fish Physiology, Bioenergetics and Growth*, ed. W. S. Hoar, D. J. Randall, and J. R. Brett (New York: Academic Press, 1979), 677–743.
- [49] R. J. Wootton, *Ecology of Teleost Fishes* (Chapman & Hall, 1998).
- [50] S. K. Mazumder, S. K. Das, Y. Bakar, and M. A. Ghaffar, “Effects of Temperature and Diet on Length-Weight Relationship and Condition Factor of the Juvenile Malabar Blood Snapper (*Lutjanus malabaricus* Bloch & Schneider, 1801),” *Journal of Zhejiang University-SCIENCE B (Biomedicine & Biotechnology)* 17, no. 8 (2016): 580–590, <https://doi.org/10.1631/jzus.B1500251>.
- [51] M. Cherif, R. Zarrad, H. Gharbi, H. Missaoui, and O. Jarboui, “Length-Weight Relationships for 11 Fish Species From the Gulf of Tunis (SW Mediterranean Sea, Tunisia),” *Pan-American Journal of Aquatic Sciences* 3, no. 1 (2008): 1–5.
- [52] M. J. Anzueto-Calvo, E. Velázquez-Velázquez, W. A. Matamoros, B. G. A. Cruz Maza, and A. Nettel-Hernanz, “Effect of Conservation of Fish in Formalin and Ethanol on Length-Weight Relationships and Condition Factor in Tlaloc Labialis (Günther, 1866),” *Journal of Applied Ichthyology* 33, no. 6 (2017): 1184–1186.
- [53] S. Andrade, V. Dias, N. Bezerra, et al., “Length-Weight Relationship of 22 Fish Species (Osteichthyes) From the Surf Zone Caught by Seine Net on the Northern Coast of Pernambuco – Brazil,” *Ocean and Coastal Research* 70 (2022): e22029, <https://doi.org/10.1590/2675-2824070.21095sa>.
- [54] A. C. L. Rêgo, O. P. Pinese, P. A. Magalhães, and J. F. Pinese, “Weight–Length Relationship for *Prochilodus lineatus* (Valenciennes, 1836) and *Leporinus friderici* (Bloch, 1794) (Characiformes) in the Nova Ponte Reservoir – Galheiro EPDA, Araguari River, MG,” *Revista Brasileira de Zootecias* 10, no. 1 (2008): 13–21.
- [55] G. Shepherd and C. B. Grimes, “Geographic and Historic Variations in Growth of Weakfish, *Cynoscion regalis*, in the Middle Atlantic Bight,” *Fishery Bulletin* 81, no. 4 (1983): 803–813.
- [56] M. Haimovici and G. Velasco, “Length-Weight Relationship of Marine Fishes From Southern Brazil,” *Naga: The ICLARM Quarterly* 23, no. 1 (2000): 19–23.
- [57] R. Froese, J. T. Thorson, and R. B. Reyes Jr, “A Bayesian Approach for Estimating Length-Weight Relationships in Fishes,” *Journal of Applied Ichthyology* 30, no. 1 (2014): 78–85, <https://doi.org/10.1111/jai.12299>.
- [58] O. F. Matos, D. V. Pereira, J. Aguiar-Santos, A. d. S. Sampaio, C. E. Carvalho Freitas, and F. K. Siqueira-Souza, “Length-Weight Relationships of Five Fish Species From Lakes of the Central Amazonian Floodplains,” *Journal of Applied Ichthyology* 35, no. 3 (2019): 799–801, <https://doi.org/10.1111/jai.13901>.
- [59] A. N. Rountrey, P. G. Coulson, J. J. Meeuwig, and M. Meekan, “Water Temperature and Fish Growth: Otoliths Predict Growth Patterns of a Marine Fish in a Changing Climate,” *Global Change Biology* 20, no. 8 (2014): 2450–2458, <https://doi.org/10.1111/gcb.12617>.
- [60] Y. Li, M. Feng, L. Huang, et al., “Weight–Length Relationship Analysis Revealing the Impacts of Multiple Factors on Body Shape of Fish in China,” *Fishes* 8, no. 5 (2023): 269, <https://doi.org/10.3390/fishes8050269>.
- [61] R. Haas, “Sexual Selection in *Nothobranchius guentheri* (Pisces: Cyprinodontidae),” *Evolution* 30, no. 3 (1976): 614–622, <https://doi.org/10.2307/2407584>.
- [62] R. Van der Laan, R. Fricke, and W. N. Eschmeyer, eds., *Eschmeyer’s Catalog of Fishes: Classification* (2025), <https://www.calacademy.org/org/scientists/catalog-of-fishes-classification>.
- [63] R. Fricke, W. N. Eschmeyer, and R. Van der Laan, *Eschmeyer’s Catalog of Fishes: Genera, Species, References* (2025), <http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp>.
- [64] R. R. Ota, G. d. C. Deprá, W. J. d. Graça, and C. S. Pavanelli, “Peixes da Planície de Inundação do Alto Rio Paraná e Áreas Adjacentes: Revised, Annotated and Updated,” *Neotropical Ichthyology* 16, no. 2 (2018): e170094, <https://doi.org/10.1590/1982-0224-20170094>.