RESEARCH ARTICLE OPEN ACCESS

First Records of Length–Weight Relationships for Ten Fish Species From the Middle Stretch of the Uruguay River, Southern Brazil

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Received: 16 November 2025 | **Revised:** 19 March 2026 | **Accepted:** 24 March 2026

Academic Editor: Jacob Burbank

Keywords: allometry | fish conservation | growth | Neotropical ichthyofauna

ABSTRACT

This study estimated the length–weight relationships (LWRs) of 10 fish species from the middle stretch of the Middle Uruguay River basin, aiming to provide new morphometric data and contribute to the knowledge of Neotropical ichthyofauna. Fish were collected at seven sites with sampling conducted at each site during every season, totaling 84 sampling campaigns between May 2016 and February 2019. Different fishing gears were used, including gillnets (15–80 mm), three-panel nets (150.30.150; 150.40.150; 150.50.150 mm), a beach seine (8 mm), and longlines (100 m, 30 hooks, sizes 5/0 and 12/0) baited with small fish, maize, and snails. The parameters *a* and *b* of equation $W = aL^b$ were estimated for each species, revealing five species with positive allometry, two with isometry, and three with negative allometry. The *b* coefficient ranged from 2.456 in *Pseudoplatystoma corruscans* to 3.336 in *Acestrorhynchus pantaneiro*. These records expand the current database on the regional ichthyofauna and provide relevant information for conservation and fisheries management in the middle stretch of the Uruguay River basin.

1 | Introduction

Length–weight relationships (LWRs) are essential tools in fish biology and management, as they allow the conversion of length measurements into total body mass, enabling biomass estimation and the assessment of variation in body shape, performance, and growth [1, 2]. They also provide fundamental support for population analyses, environmental comparisons, condition studies, and stock monitoring [3, 4]. Moreover, LWRs can reflect ecological conditions, trophic status, and energy allocation strategies, serving as indicators of population health and environmental quality [5].

However, for many Neotropical species, LWR parameters remain unpublished or poorly documented, which hampers regional comparisons and limits the application of management models [6]. This situation is particularly evident in the Uruguay River, one of the main tributaries of the La Plata basin, which extends for approximately 2262 km and drains areas of Brazil, Argentina, and Uruguay. Among its main features is the division into three sections—Upper, Middle, and Lower Uruguay—which are delimited by natural and anthropogenic barriers [7]. Additionally, the river exhibits a wide variety of hydrogeomorphological patches [8], which create favorable conditions for hosting a highly diverse fish fauna of great ecological and economic relevance, including several migratory species of conservation interest [9]. Despite its importance, the available LWR data for native species remain scarce, largely due to the limited number of exploratory studies conducted in the region.

Therefore, this study aimed to estimate new LWRs for 10 fish species from the middle stretch of the Uruguay River basin, a free-flowing segment, in order to provide updated morphometric data and establish a baseline for these species to support comparisons with both unregulated and hydropower-regulated environments. The results are expected to contribute to the regional database on Neotropical ichthyofauna and support conservation and fisheries management efforts in one of the last unregulated stretches of the basin.

2 | Materials and Methods

Samples were collected at seven sites distributed along approximately 600 km (Table 1 and Figure 1), encompassing a broad fluvial gradient with distinct hydrogeomorphological features: a confined reach with shallow rapids, a confined reach with deep pools, and floodplain areas. A total of 112 field campaigns were conducted seasonally between May 2016 and February 2019. Multiple fishing gears were employed to maximize capture efficiency and to encompass littoral, benthic, and pelagic habitats. Fish were collected using a set of gillnets with different mesh sizes (20, 30, 40, 50, and 80 mm between opposite knots), each 20 m long and 2.0 m high, totaling 40 m^2 of net per mesh size. Two longlines were also used, each 100 m long with 30 hooks (hooks 5/0 and 12/0), baited with small fish, maize, and snails. All gears remained deployed for 12 h, preferably overnight. Gillnets were directed at capturing fish near the margins, whereas longlines targeted pelagic and carnivorous species. In addition, a beach seine (5-mm mesh, 10 m long, and 2 m high) was employed in littoral areas, with three hauls per site in each campaign.

Captured individuals were identified using specialized literature [10–12], weighed on an analytical balance with 0.01 g precision, and measured on an ichthyometer with 0.1 cm precision. After in situ biometrics with fresh specimens, five individuals of each species were fixed in 10% formalin [13]. Voucher specimens are deposited in the Museum of Limnology, Ichthyology, and Aquaculture of the State University of Maringá (UEM), Paraná State, Brazil.

Weight–length relationships (WLRs) were described by the equation $W = aL^b$ and estimated by linear regression on log-transformed data ($\ln W = \ln a + b \ln L$), where W is total weight (g), *L* is total length (cm), *a* is the intercept, and *b* is the allometric coefficient [14].

3 | Results

A total of 10 fish species, belonging to two orders and eight families, including four migratory species, were analyzed (Table 2 and Figure 2). The number of individuals sampled ranged from 16, for *Pseudoplatystoma corruscans*, to 559, for *Cynopotamus argenteus*, representing species from different trophic guilds and habitats. Total length varied widely, from 2.9 cm in *Piabarchus stramineus* to 178 cm in *P. corruscans*, while body mass ranged from 0.21 g to 35,450 g, reflecting the capture of both small and large-bodied individuals. The LWRs showed a strong statistical fit ($R^2 > 0.94$), indicating that the estimated models adequately represent the growth patterns of the sampled populations.

The allometric coefficient (b) ranged from 2.456 in *P. corruscans* to 3.336 in *Acestrorhynchus pantaneiro*. Six species exhibited

TABLE 1 | Description of sampling areas along the Middle Uruguay River (RS, Brazil), including habitat characteristics, geographic coordinates (latitude and longitude), river width (m), depth range (m), altitude (m), and municipality.

Sampling site ([a])	Habitat description	Coordinates		Width (m)	Depth (m)	Altitude (m)	Municipality (RS, brazil)
S1 (16 km)	Rapids and pools	27°10′64″S	53°54′31″W	280	3–16	135	Derrubadas
S2 (41 km)	Pools	27°18′0.70″S	54°06′33″W	405	18	123	Esperança do Sul
S3 (175 km)	Pools	27°34′0.26″S	54°49′55″W	840	14	96	Alecrim
S4 (217 km)	Rapids	27°42′0.01″S	54°53′47″W	790	3	91	Porto Vera Cruz
S5 (332 km)	Rapids	28°04′0.44″S	55°25′38″W	1230	4	69	São Nicolau
S6 (450 km)	Floodplain and pools	28°34′0.15″S	56°0.9′51″W	1250	2–19	52	São Borja
S7 (600 km)	Floodplain and pools	29°24′49.96″S	56°46′39.40″W	1302	3	48	Itaqui

[a]Distance from the beginning of the Middle Uruguay River Basin.

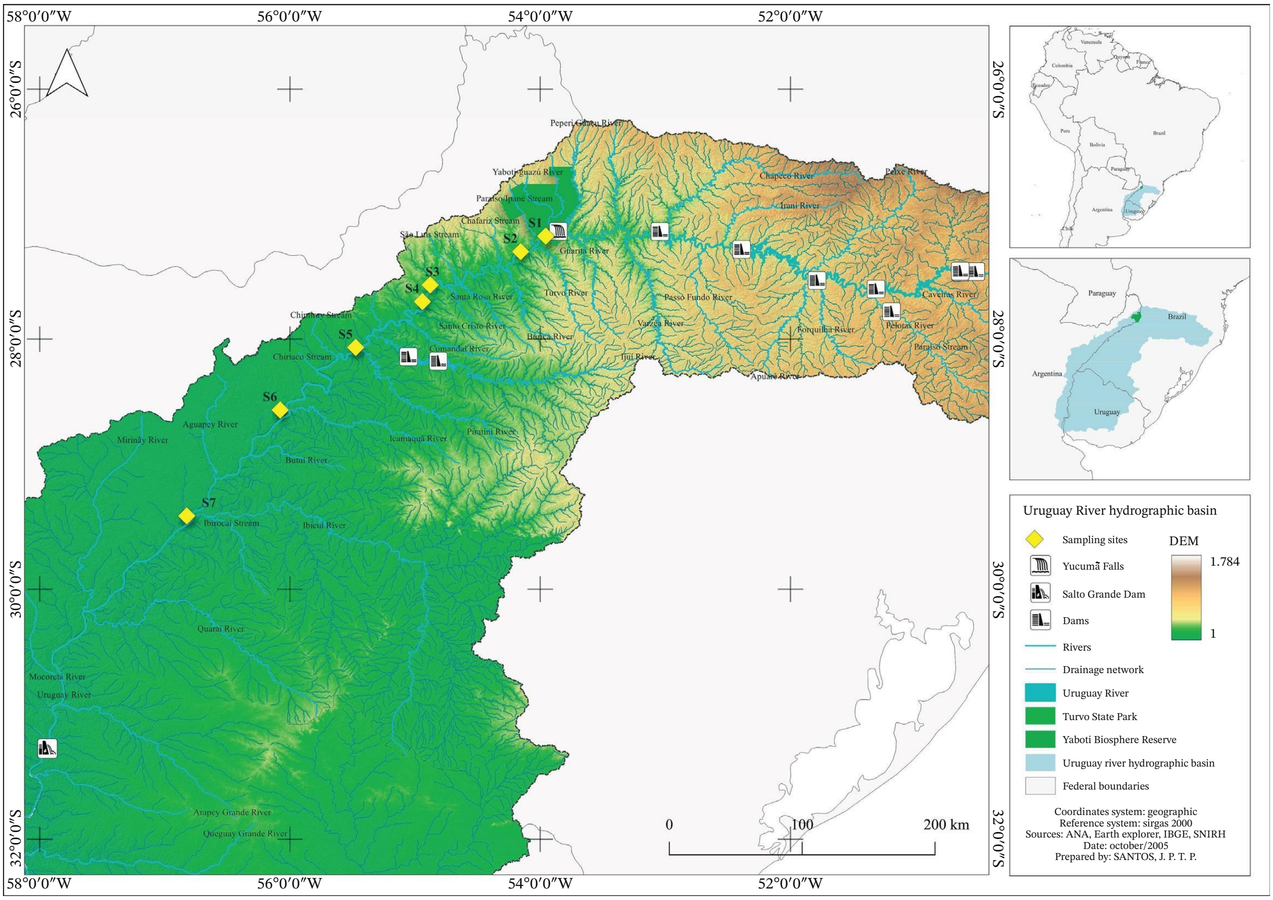

FIGURE 1 | Location of sampling sites along the Middle Uruguay River, RS, Brazil. Derrubadas (S1), Esperança do Sul (S2), Alecrim (S3), Porto Vera Cruz (S4), São Nicolau (S5), São Borja (S6), and Itaqui (S7).

positive allometry ($b > 3.0$) (*A. pantaneiro*, *Megaleporinus obtusidens*, *Cynopotamus argenteus*, *Apareiodon affinis*, *Prochilodus lineatus*, and *Sorubim lima*), whereas three exhibited negative allometry ($b < 3.0$) (*Piabarchus stramineus*, *Pimelodus maculatus*, and *P. corruscans*). One species presented a b value close to 3.0 (*Trachelyopterus teaguei*, $b = 3.019$).

The 95% confidence intervals indicated that estimates were statistically robust and that most species fell within the theoretical range expected for teleosts ($2.5 < b < 3.5$), as reported in the literature [14].

4 | Discussion

The LWRs obtained for the 10 analyzed species showed a good statistical fit ($R^2 > 0.94$), confirming the adequacy of the models in representing the growth patterns of the sampled populations. The allometric coefficients (b) mostly fell within the theoretical range of $2.5 < b < 3.5$ proposed for teleosts [2], indicating biologically consistent growth patterns. Interspecific differences may be associated with variability in the size ranges sampled, sex ratios, gonadal maturation, and environmental factors such as water temperature, hydrodynamics, and food availability [15, 16].

When compared with previously published data, the estimated b values for most species were within the range reported for other Neotropical basins. For example, the b value obtained for *M. obtusidens* (3.051) is similar to that reported for the Paraná River basin (3.08) [17]. Likewise, *P. lineatus* (3.053) presented values consistent with previous studies conducted in southern Brazil (3.060; Upper Uruguay River) [18] and in southeastern Brazil (2.94–3.07) [17, 19]. For *S. lima*, few LWRs have been previously described. The coefficient estimated in the present study (3.155) represents the first record for the Uruguay River basin and is close to values reported for the Yacyretá passage region (3.163) [20] and for the Iguatemi River (3.080) [21].

Species with $b > 3.0$, such as *A. pantaneiro* (3.3368) and *C. argenteus* (3.1055), exhibited positive allometry, typical of populations in good trophic condition, with greater accumulation of body reserves and reproductive energy [1, 22]. In contrast, *P. corruscans* presented a b value of 2.456, slightly below the theoretical lower limit, suggesting negative allometric growth. This result differs from what has been reported for the species in other regions, such as the Paraná River basin, where $b = 3.170$ [17]; the São Francisco River basin, where $b = 3.523$ [23]; and the Pantanal basin, where $b = 3.310$ [24]. Although this species is piscivorous, the reduced value may reflect morphophysiological adaptations to naturally preserved, free-flowing river stretches, where swimming effort is high and energy accumulation is reduced. This pattern is consistent with the trade-off between linear growth and mass gain described by ecological theory of fish growth [1, 14, 25]. Additionally, the captures were concentrated after the reproductive period of this species in the Uruguay River basin [26], which may have influenced weight loss due to the

TABLE 2 | Descriptive statistics and estimated parameters of length–weight relationships of 10 fish species from the middle stretch of the Uruguay River, southern Brazil.

Species	N	Voucher	TL min–max (cm)	Weight min–max (g)	α	95% CL of α	b	95% CL of b	R^2
Characiformes									
Acestrorhynchidae									
Acestrorhynchus pantaneiro (Menezes, 1992)	210	NUP 20649	13.8–32.3	19.2–279.8	0.002	0.002–0.003	3.336	3.243–3.429	0.959
Anostomidae									
Megaleporinus obtusidens (Valenciennes, 1837)*	197	NUP 20627	17.1–52.3	48.7–1563	0.129	0.116–0.143	3.051	2.985–3.117	0.977
Characidae									
Cynopotamus argenteus (Valenciennes, 1837)	559	NUP 20560	10–32	10.6–307	0.112	0.105–0.120	3.105	3.054–3.156	0.961
Parodontidae									
Apareiodon affinis (Steindachner, 1879)	345	NUP 20583	11.3–16.3	13–45	0.006	0.005–0.007	3.021	2.959–3.084	0.963
Prochilodontidae									
Prochilodus lineatus (Valenciennes, 1837)*	67	NUP 20559	12.9–59.0	23.1–2603.0	0.134	0.112–0.159	3.053	2.947–3.160	0.980
Stevardiidae									
Piabarchus stramineus (Eigenmann, 1908)	74	NUP 20574	2.9–8.3	0.21–4.44	0.129	0.115–0.144	2.944	2.776–3.113	0.941
Siluriformes									
Auchenipteridae									
Trachelyopterus teaguei (Devincenzi, 1942)	46	NUP 20592	9.5–21.5	13.9–157.9	0.166	0.134–0.206	3.019	2.821–3.188	0.967
Pimelodidae									
Pimelodus maculatus (Lacepède, 1803)	112	NUP 20646	12.7–41.7	13.1–640.0	0.132	0.110–0.158	2.979	2.855–3.103	0.953
Pseudoplatystoma corruscans (Spix and Agassiz, 1829)*	16	NUP 22081	93–178	7050–35450	0.386	0.257–0.580	2.456	2.268–2.643	0.982
Sorubim lima (Bloch and Schneider, 1801)*	24	NUP 20630	18.4–66.3	24.2–1586	0.073	0.051–0.104	3.155	2.939–3.370	0.976

*Fish migratory.

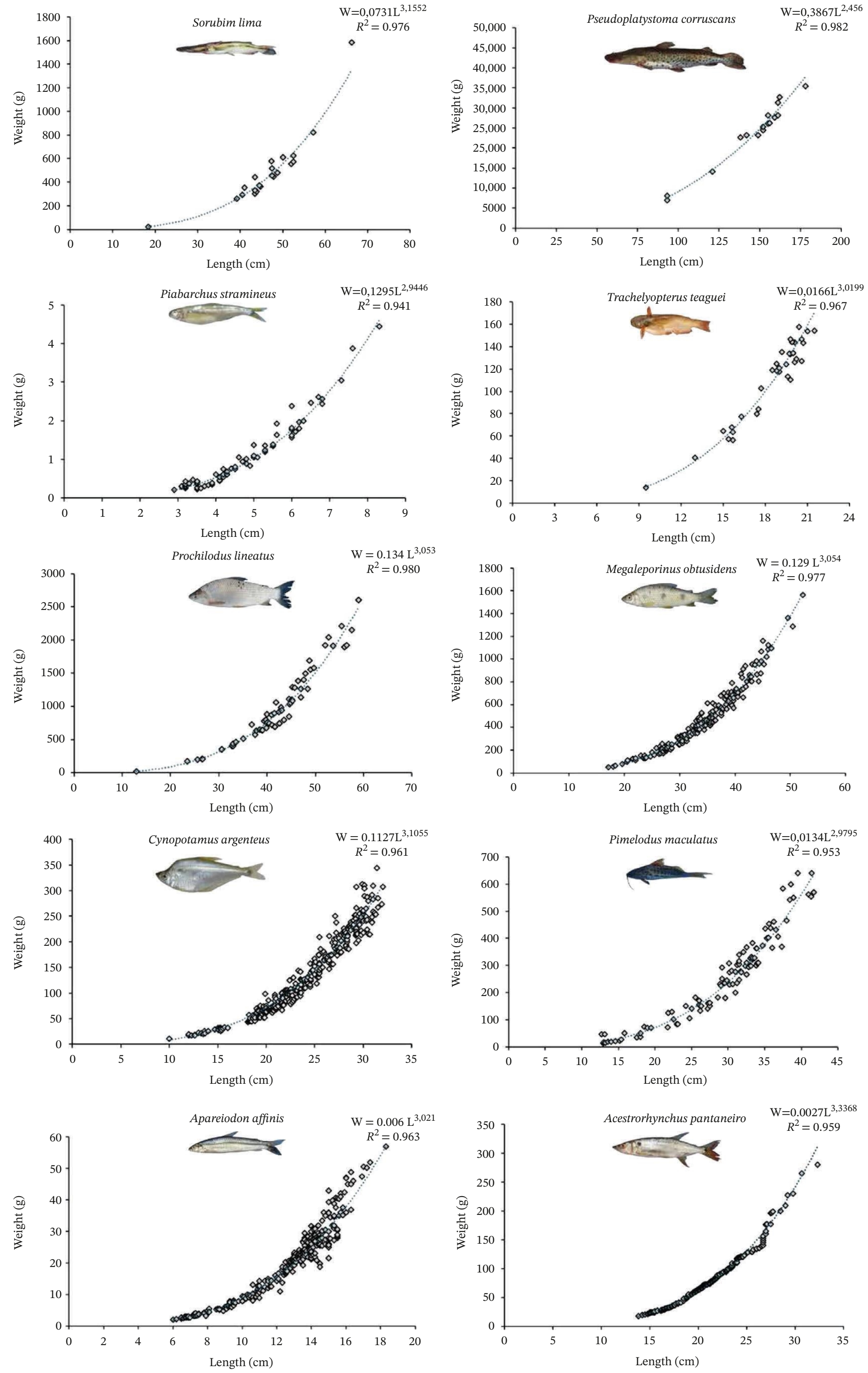

FIGURE 2 | Length–weight relationships (LWRs) for 10 fish species collected in the middle stretch of the Uruguay River, southern Brazil. Each panel shows the relationship between total length (TL, *x*-axis, in cm) and body weight (W, *y*-axis, in g). Points represent sampled individuals, and the dashed line indicates the fitted power model $W = \alpha L^b$. The equation parameters (α and b) and the coefficient of determination (R^2) are provided in each panel.

energetic cost of reproduction, contributing to the negative allometric relationship observed.

The absence of hydropower regulation and the presence of extensive protected areas along the Middle Uruguay River, such as Turvo State Park (Brazil) and the Yabotí Biosphere Reserve (Argentina), favor the maintenance of connected lotic habitats and ecologically balanced populations [8, 27]. Thus, the LWRs reported here reflect not only the conservation status of the basin, but also its value as a reference for river systems that remain free from hydrological regulation. These results provide a foundation for monitoring biomass and fish condition and may support management and conservation efforts in the face of increasing pressure from hydropower development in the region.

Despite the ecological relevance of the Middle Uruguay River as a reference for a free-flowing system, a continuum exceeding 900 km with equally unregulated tributaries, the available literature on basic population parameters, particularly LWRs, remains notably scarce for most native species of this basin, being limited to few studies [28]. This knowledge gap constrains our ability to assess temporal trends, support evidence-based conservation targets, and anticipate population responses under intensifying anthropogenic pressures such as hydropower expansion, agricultural intensification, and riparian habitat fragmentation. In this context, generating primary data in systems that remain functionally intact is strategic, as it not only enables the calibration of ecological and biometric models with realistic information but also provides a baseline reference to guide preventive policies and avoid management plans that are reactive and delayed, as historically observed in already regulated and degraded rivers. Thus, given the rarity of previous LWR studies in the Middle Uruguay, the results presented here constitute a key reference for conservation and management in one of the last large, connected lotic segments in South America.

5 | Conclusion

This study presents the first records of LWRs for 10 fish species from the middle stretch of the Uruguay River, including four migratory species. The observed allometric coefficients were mostly consistent with theoretical expectations, and the analyzed species exhibited good body condition. *P. corruscans*, however, showed negative allometric growth ($b = 2.456$), contrasting with values reported for other basins. This may reflect morphophysiological adaptations to naturally preserved, free-flowing river stretches, as well as postreproductive conditions. These findings highlight the ecological relevance of the studied segment and the importance of its conservation. Furthermore, the data presented here fill important gaps regarding the morphometry of the regional ichthyofauna and serve as a baseline for future ecological and fisheries management comparisons in both regulated and unregulated systems.

Author Contributions

Lucas Adriano Pachla: conceptualization, developing methods, conducting the research, data interpretation, writing data analysis, and preparation of figures and tables. Marthoni Vinicius Massaro: conceptualization, developing methods, data analysis, preparation of figures and tables, data interpretation, and writing. David Augusto Reynalte-Tataje: conceptualization, developing methods, data interpretation, and writing. Sandra Maria Hartz: conducting the research, data interpretation, and writing.

Acknowledgments

The Federal University of the Southern Frontier (UFFS) and the Federal University of Rio Grande do Sul (UFRGS) are acknowledged for providing the infrastructure necessary for the development of this study. We also thank the Research Support Foundation of the State of Rio Grande do Sul (FAPERGS), the Coordination for the Improvement of Higher Education Personnel (CAPES), and the National Council for Scientific and Technological Development (CNPq) for granting research scholarships, including a Research Productivity Fellowship (PQ), Process No. 305549/2018–9.

This study was conducted under licenses No. 55011–2 (ICMBio) and No. 104/2017 (Secretariat of Environment and Infrastructure of the State of Rio Grande do Sul), the latter authorizing fish sampling within protected areas (Turvo State Park).

Funding

This study was funded by the Conselho Nacional de Desenvolvimento Científico e Tecnológico, , 305549/2018–9; Fundação de Amparo à Pesquisa do Estado do Rio Grande do Sul.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data used in this study are available upon reasonable request from the corresponding author.

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