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Scientific Article

Length–weight relationships of the estuarine fish species in the second largest mangrove area in the world, Brazil

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ABSTRACT

Length–weight relationship (LWR) parameters are necessary to understand the life cycle of fish to describe the biological aspects of species. In this sense, LWRs were determined for 17 estuarine species from the second largest mangrove area in the world, Northern Brazil. The sampling was carried out during the dry and wet seasons of 2015 and 2018 in three estuaries described as conservation units in the rivers Pará, Caeté, and Parnaíba. Fish were collected by using manual beach seine, block nets and sieves. Overall, 488 specimens were analyzed using the equation $W = a\ TL^b$. The a values ranged from 0.000001 to 0.000019, and b values ranged from 2.7230 to 3.2821. This study brings new data on estuarine fish from Brazil with additional information contributing to the conservation and management of the fish stocks.

Keywords: Amazon; Allometric coefficient; Growth; Ichthyofauna.

Relação peso-comprimento de espécies de peixes estuarinos da segunda maior área de manguezais do mundo, Brasil

RESUMO

Parâmetros de relações peso-comprimento são necessários para compreender o ciclo de vida dos peixes e descrever os aspectos biológicos das espécies. Dessa forma, foram determinadas relações peso-comprimento para 17 espécies estuarinas da costa equatorial brasileira. Nosso estudo foi realizado na segunda maior faixa de manguezais do mundo no período de 2015 e 2018 em três estuários que são descritos como unidades de conservação, Rio Pará (Baía do Marajó), Rio Caeté e Rio Parnaíba. Os peixes foram coletados com redes de arrasto manual, redes de tapagem e peneiras. O total de 488 indivíduos de 17 espécies de peixes foram analisados usando a equação $W = a\ TL^b$. Os valores de a variaram de 0,000001 a 0,000019, e os valores de b, de 2,7230 a 3,2821. Este estudo traz novos dados sobre peixes estuarinos do Brasil e informações adicionais que contribuem para a conservação e o manejo dos estoques de peixes.

Palavras-chave: Amazônia; Coeficiente alométrico; Crescimento; Ictiofauna.

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INTRODUCTION

Studies on length–weight relationships are useful tools for monitoring and controlling commercial fishing landings. Mainly when combined with other fishery information, they can provide background for studies on fishing biology and, consequently, for the sustainable management (Campanha et al., 2019; Tostes et al., 2019). Through the length–weight relationships, it is possible to estimate the age of fish, becoming a fundamental tool for determining minimum catch sizes and ensuring that juvenile fish have the opportunity to reach reproductive maturity before being caught (Famoofo and Abdul, 2020). Additionally, it enables the comparison of individuals of the same species in different regions and stocks through their growth patterns (Oliveira et al., 2013; Rotta and Yamamoto, 2021).

In the Brazilian states of Pará and Maranhão, there is the second largest continuous band of mangroves of the world, encompassing about 650 km and covering ~7,000 km² of coastal area (Souza Filho, 2005; Giri et al., 2011; Diniz et al 2019). These mangroves are natural zones of protection against storms, climate regulation, biological and pollution control, as well as providing food, shelter and nursery for several marine species (Menéndez et al., 2020; Kamil et al., 2021; Rahman et al., 2021). Playing a fundamental role in ecological relationships in mangroves, fish contribute to the maintenance of the food web, in addition to being economically important, since the capture of fish generates income for families in the community (Contente, 2014).

To investigate the length–weight relationship of fish with the aim of enhancing sustainable fisheries management establishes parameters that contribute to the definition of minimum catch sizes. The present study brings new estimations of length–weight relationships for estuarine fish species from the second largest continuous area of mangrove in the world.

MATERIAL AND METHODS

Fish specimens were collected in Marajó Bay (0º44’31’’S; 48º30’24’’W) and Caeté River estuary (0º50’24’’S; 46º37’07’’W) in January 2018 (wet season) and July 2018 (dry season), and in Parnaíba River delta (2º45’49’’S; 41º50’21’’W) in April 2015 (wet season). These areas are considered conservation units by the Brazilian Ministry of Environment and were chosen due to the availability of the same species in the three locations.

These fish specimens were caught in the intertidal zones with manual beach seine (3 × 1.3 m, with 3 m of bag and 10 mm between nodes), in tidal channels. Block nets were used (10 × 3 m, 12 mm between nodes), and in hard-to-reach aquatic habitats (e.g. mangrove roots and salt marshes) collections were carried out using sieves (50 cm in diameter, 2 mm between nodes). To minimize the effects associated with intraspecific changes due to ontogenetic differences in feeding behavior, only juveniles were selected. Juvenile classification was based on L_{50} estimates of each species using the life history tool of the FishBase website (Froese and Pauly, 2023). Fishes were identified according to the specific literature (e.g., Cervigón, 1991; Nizinski and Munroe, 2002).

Fishes were measured in total length (*TL*) to the nearest 0.1 cm with a graded ruler, and weighted (*W*) using a spring scale to the nearest 0.1 g (Fig. 1). Outliers were inspected and removed using a biplot of the logarithmized length–weight relationship (Froese et al., 2011). The length–weight relationship (LWR) were calculated using the Eq. 1 (Pauly, 1984):

$$W = a\, TL^{b} \tag{1}$$

It was logarithmically transformed into Eq. 2:

$$\log W = \log a + b \log TL \tag{2}$$

Where: *W*: the total weight of the fish (g); *TL*: the total length of the fish (cm); *a*: a constant; *b*: the allometric coefficient (Froese, 2006).

The coefficient of determination (Pearson *r*-squared, r^2) and the confidence limits (95% CL) were used as indicators of quality of the parameters *a* and *b* (Froese, 2006; Froese et al., 2011).

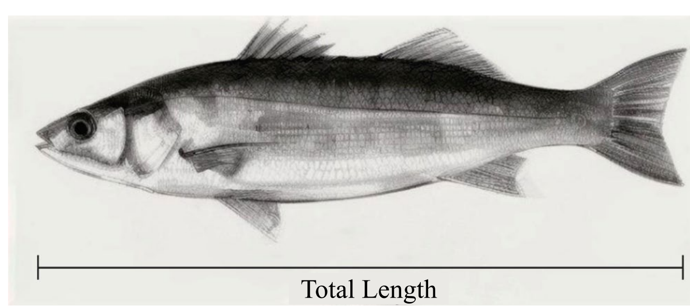

Figure 1. Measurement taken from collected individuals.

RESULTS

Overall, 488 individuals from 17 fish species were collected and analyzed. To illustrate, we have presented in Table 1 the quantity of fish collected in each season and at each study site. In terms of number of individuals, the most abundant species were *Achirus achirus* (Linnaeus 1758) (38 individuals) and *Pterengraulis atherinoides* (Linnaeus 1766) (35 individuals).

Table 2 shows the length–weight relationships and length characteristics for 17 species belonging to 12 families, the number of specimens, length ranges (minimum and maximum), parameters of length–weight relationship (*a* and *b*) and coefficient of determination (r^2). All relationships were highly significant ($p < 0.001$) with the coefficient of determination (r^2) above 0.97. The parameter *a* ranged from 0.000001 to 0.000019, and the parameter *b* ranged from 2.7230 to 3.2821.

Table 1. Quantity of fish collected in each location and rainy season. Family order following Nelson et al. (2016).

Family/Species	Marajó		Caeté		Delta
	Wet	Dry	Wet	Dry	Wet
Engraulidae					
Anchovia clupeoides (Swainson 1839)	11	8	8	0	5
Lycengraulis grossidens (Spix & Agassiz 1829)	7	6	7	5	5
Pterengraulis atherinoides (Linnaeus 1766)	3	8	3	14	7
Clupeidae					
Rhinosardinia amazonica (Steindachner 1879)	3	6	6	4	6
Ariidae					
Cathorops spixii (Agassiz 1829)	6	3	8	5	7
Sciades herzbergii (Bloch 1794)	5	9	8	5	7
Batrachoididae					
Batrachoides surinamensis (Bloch & Schneider 1801)	6	1	7	1	5
Mugilidae					
Mugil curema (Valenciennes 1836)	5	7	7	8	7
Belonidae					
Strongylura timucu (Walbaum 1792)	7	8	6	5	7
Tetraodontidae					
Colomesus psittacus (Bloch & Schneider 1801)	5	0	7	3	7
Achiridae					
Achirus achirus (Linnaeus 1758)	7	8	8	8	7
Centropomidae					
Centropomus undecimalis (Bloch 1792)	7	5	8	0	8
Gerreidae					
Diapterus auratus (Ranzani 1842)	7	4	2	5	6
Lutjanidae					
Lutjanus jocu (Bloch & Schneider 1801)	2	1	8	6	7
Sciaenidae					
Cynoscion acoupa (Lacepède 1801)	3	1	6	4	2
Macrodon ancylodon (Bloch & Schneider 1801)	8	8	6	7	1
Stellifer naso (Jordan 1889)	9	8	6	4	7

Wet: rainy season; Dry: dry season.

Table 2. Descriptive statistics and length–weight relationship parameters of the 17 estuarine fishes caught in the Caeté, Marajó and Parnaíba estuaries from northern and northeast Brazilian coast in the period of January and July 2018, and April 2015. Family order following Nelson et al. (2016).

Family/Species	n	Total length (mm)	Weight (g)	LWR parameters				Bayesian LWR				r^2
				a	*b*	95% CL of *a*	95% CL of *b*	*a*	*b*	95% CL of *a*	95% CL of *b*	
Engraulidae												
Anchovia clupeoides (Swainson 1839)	32	63.55–144.94	1.81–25.1	0.000003	3.1720	0.000002–0.000005	3.1152–3.2488	0.00501	3.17	0.00404–0.00621	3.11–3.23	0.997
Lycengraulis grossidens (Spix & Agassiz 1829)*	30	48.98–111.48	1.01–12.52	0.000010	2.9381	0.000007–0.000016	2.8598–3.0164	0.00562	3.16	0.00465–0.00681	3.10–3.22	0.991
Pterengraulis atherinoides (Linnaeus 1766)*	35	56.13–212.32	1.15–52.75	0.000010	2.9106	0.000006–0.000014	2.8288–2.9924	0.00501	3.08	0.00312–0.00805	2.94–3.22	0.987
Clupeidae												
Rhinosardinia amazonica (Steindachner 1879)*	25	66.18–95.87	1.92–6.93	0.000002	3.2716	0.000001–0.000006	3.0611–3.4820	0.00676	3.10	0.00435–0.01052	2.97–3.23	0.978
Ariidae												
Cathorops spixii (Agassiz 1829)	29	58.05–307	1.72–280.72	0.000006	3.0316	0.000005–0.000008	3.0383–3.1049	0.00724	3.04	0.00611–0.00858	2.99–3.09	0.999
Sciades herzbergii (Bloch 1794)	34	58.05–257	1.24–147.69	0.000003	3.1741	0.000002–0.000003	3.1723–3.2625	0.00575	3.13	0.00474–0.00698	3.07–3.19	0.998
Batrachoididae												
Batrachoides surinamensis (Bloch & Schneider 1801)	20	105.71–391	13.86–1034.5	0.000003	3.2821	0.000003–0.0000034	3.2695–3.2947	0.00776	3.15	0.00485–0.01241	3.01–3.29	0.999
Mugilidae												
Mugil curema (Valenciennes 1836)*	34	64.76–162.12	4.14–55.59	0.00002	2.8996	0.00002–0.00003	2.8726–2.9265	0.0117	2.94	0.01004–0.01375	2.91–2.97	0.998
Belonidae												
Strongylura timucu (Walbaum 1792)	33	96.98–383.32	2.06–138.8	0.000002	3.0367	0.000001–0.000003	2.9792–3.0943	0.00162	3.10	0.00104–0.00254	2.97–3.23	0.995
Tetraodontidae												
Colomesus psittacus (Bloch & Schneider 1801)	22	109.37–256	29.57–295.75	0.00005	2.8212	0.00005–0.000050	2.8111–2.8312	0.02512	2.86	0.01608–0.03923	2.74–2.98	0.999
Achiridae												
Achirus achirus (Linnaeus 1758)	38	58.35–155.21	3.29–61.03	0.000019	2.9760	0.000015–0.000024	2.9206–3.0314	0.00912	3.04	0.00548–0.01519	2.90–3.18	0.995
Centropomidae												

Continue...

Table 2. Continuation.

Family/Species	n	Total length (mm)	Weight (g)	LWR parameters				Bayesian LWR				r^2
				a	***b***	**95% CL of *a***	**95% CL of *b***	***a***	***b***	**95% CL of *a***	**95% CL of *b***	
Centropomus undecimalis (Bloch 1792)*	28	64.32–244.11	2.18–111.53	0.00001	2.9282	0.00001–0.000014	2.8878–2.9686	0.00741	3.02	0.00587–0.00936	2.97–3.07	0.997
Gerreidae												
Diapterus auratus (Ranzani 1842)	24	51.04–137.3	2.19–56	0.000006	3.1262	0.000003–0.000011	3.1223–3.4001	0.01122	3.08	0.00941–0.01337	3.03–3.13	0.991
Lutjanidae												
Lutjanus jocu (Bloch & Schneider 1801)*	24	4.9–257.48	4.9–327.98	0.00003	2.9142	0.00003–0.000033	2.8925–2.9359	0.01479	2.97	0.01304–0.01678	2.95–2.99	0.999
Sciaenidae												
Cynoscion acoupa (Lacepède 1801)	16	60.39–284.09	1.76–208.46	0.000006	3.0791	0.000006–0.0000059	3.0768–3.0814	0.00759	3.06	0.00489–0.01176	2.93–3.19	0.999
Macrodon ancylodon (Bloch & Schneider 1801)*	30	74.75–220.09	2.81–87.3	0.000003	3.1257	0.000002–0.0000029	3.1244–3.2295	0.00708	3.05	0.00657–0.00763	3.03–3.07	0.999
Stellifer naso (Jordan 1889)*	34	51.11–208,79	1.37–76.63	0.00003	2.7230	0.00003 – 0.00004	2.6797–2.7663	0.00794	3.00	0.00525–0.01202	2.88–3.12	0.996

N: sample size; TL: total length; W: weight; *a* and *b*: parameters of the relationship; CL: confidence limits; r^2: Pearson r-squared for log–log regression (all relationships significant at $p < 0.001$); *a and b values outside the 95% confidence limit of Bayesian LWR.

DISCUSSION

According to the classification found in the FishBase website (Froese and Pauly, 2023) and other studies (i.e., Souza and Imbiriba, 1978; Lessa and Nobrega, 2000), among the 17 fish species studied herein, seven of them (i. e. *Batrachoides surinamensis; Mugil curema; Colomesus psittacus; Centropomus undecimalis; Lutjanus. jocu; Cynoscion acoupa;* and *Macrodon ancylodon*) are of the highest commercial importance and represent great amount of the Brazilian northern coast economy (Isaac and Almeida, 2011).

The estimated values of *a* and *b* for all species were within the expected range of 2.5–3.5 (for a full description, see Froese, 2006), whereas for the obtained values from Bayesian predictions available in FishBase (Froese et al., 2014), eight species (*Lycengraulis grossidens; Pterengraulis atherinoides; Rhinosardinia amazonica; M. curema; C. undecimalis; L. jocu; M. ancylodon* and *Stellifer naso*) had *a* and *b* values outside the 95% confidence limit (Table 2). However, these values can be justified since LWR estimates are based on general taxonomic data with similar body shapes and total lengths. The differences in the values of *b* can be attributed to one or more factors, including the season, effects from different areas, changes in water temperature and salinity, gender, food availability, variations in the number of specimens examined, as well as in the observed length ranges of the captured species.

According to Froese (2006), positive allometry (b > 3) indicates that individuals increased more quickly in height or width (weight) than in length, while negative allometry (b < 3) suggests specimens with a more elongated body shape. The great majority of these species presented positive allometric growth (nine species: *Anchovia clupeoides; Rhinosardinia amazonica; Cathorops spixii; Sciades herzbergii; Batrachoides surinamensis; Strongylura timucu; Diapterus auratus; Cynoscion Acoupa;* and *Macrodon ancylodon*) corroborating the results found by other studies performed in the same area (i.e., Giarrizzo et al., 2006; Silva-Júnior et al., 2007; Joyeux et al 2009; Ferraz and Giarrizzo, 2015). The remaining species presented negative allometric growth suggesting growth in a faster rate than weight gain.

The maximum lengths for the species *C. spixii* was updated to 307 mm, prior recorded size was 300 mm (Taylor and Menezes, 1978), and *S. naso* had the maximum length updated to 208 mm with previous record at 200 mm (Giarrizzo et al., 2006). The data from this work bring new information about the LWR of estuarine species from the second largest mangrove area of the world. Along with additional information such as size at first maturity, it will serve as a baseline for conservation, management purposes and sustainable development of these estuarine fish in their natural environment.

Except for *C. acoupa*, which is characterized as vulnerable according to the IUCN Red List of Threatened Species (Chao et al., 2021), all other species are considered least concern. The population decline of this species is related to the overexploitation because this is the fish species most consumed in the region (Mourão et al., 2009). Besides that, *C. acoupa* is caught also for the commercialization of its swim bladder, which reaches higher costs in the international market for use as emulsifiers and clarifiers for beverages, perfumes and others (Cervigón, 1991; Wolff et al., 2000).

CONCLUSION

This study focuses on the length–weight relationships of fish in mangrove areas in Pará, Maranhão and Parnaíba Delta, Brazil. Such relationships help in managing sustainable fisheries by providing data for determining minimum catch sizes and understanding the age and growth patterns of fish. The research collected and analyzed 488 individuals from 17 fish species, with the most abundant species *A. achirus* and *P. atherinoides*. The study presents tables with the quantity of fish collected in different seasons and locations, along with biological parameters like TL, W, and LWR coefficients. The positive allometric growth of most species suggests a faster increase in weight or width than in length. The findings contribute with valuable information for conservation, management, and sustainable development of estuarine fish in the mangrove ecosystem, highlighting the importance of preserving these habitats.

CONFLICT OF INTEREST

Nothing to declare.

DATA AVAILABILITY STATEMENT

Data will be available upon request from the author.

AUTHORS' CONTRIBUTION

Conceptualization: Aquino GGES, Giarrizzo T, Ândrade M; **Methodology:** Ândrade M; **Investigation:** Oliveira RRS, Giarrizzo T; **Formal analysis:** Aquino GGES, Oliveira RRS; **Validation:** Giarrizzo T, Ândrade M; **Resources:** Giarrizzo T, Ândrade M; **Supervision:** Giarrizzo T, Ândrade M; **Writing – original draft:** Aquino GGES, Oliveira RRS; **Writing – review & editing:** Aquino GGES, Oliveira RRS, Giarrizzo T, Ândrade M; **Final approval:** Aquino GGES,

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