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Length–weight relationships comparison between juveniles and adults of fish species from the mangroves of south Brazil

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ABSTRACT. This study reports the length-weight relationships (LWRs) for 8 fish species that inhabit mangroves. Many fisheries depend on mangroves, which serve as nursery and feeding areas for the juvenile stage of fishes, shrimp, and other fishery resources. In this sense, mangroves provide many ecosystem services, therefore increasing the basic biological knowledge of these ecosystems can help to understand their functioning and create conservation strategies. The majority of LWR studies do not consider juveniles, and it is important to consider these differences as juveniles can grow differently from adults. The fishes were collected from Perequê mangrove, Paraná, Brazil between 2008 and 2010. A variety of fishery gears were employed, including trammel nets, fyke nets, and traps made with plastic bottles combined with four baits. The specimens were measured (weight and length), sexed and evaluated for maturational stage. For the adults, the LWRs were calculated separately by the sex, while juvenile LWRs were estimated together. In general, there were differences in growth type between sexes and life stages. Some species showed differences compared to FishBase estimations, but this could be due to the lengths (and life stage) of the individuals used in the present study compared to FishBase. The discrepancies between adult, juvenile and FishBase estimations showed the importance of considering these aspects in studies using LWR.

Keywords: b coefficient; fish growth; LWR; Paranaguá bay; subtropical estuary.

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Introduction

Mangroves are systems known to provide resources for adjacent ecosystems, and serve as the major exporter of matter and energy to the marine system, sustaining fisheries stocks by carbon provision (Odum & Heald, 1975; Bouillon et al., 2008; Twilley & Rivera-Monroy, 2009; Taylor, Gaston, & Raoult, 2018). Moreover, many species of economically important fishes and crustaceans use these areas as shelter, nursery and/or feeding areas (McLusky, 1990; Haimovici & Cardoso, 2017; Pelage, Domalain, Lira, Travassos, & Frédou, 2019; Taylor et al., 2018). Furthermore, the mangroves are used by many artisanal fisheries, including oyster, mussel and crab collection. Therefore, mangroves provide a long list of ecosystem services, and improving the basic biological knowledge for these ecosystems can help to understand their functioning and create conservation strategies.

Juveniles of fishes commonly use mangrove areas (McLusky, 1990; Haimovici & Cardoso, 2017; Pelage et al., 2019; Taylor et al., 2018), but some biological parameters for this life stage are missing in the literature since the majority of research on growth estimations, for example, are focused on adults (Morato et al., 2001). Length-weight relationship (LWR) is a species-specific biological index that is easy to obtain, and is very important for obtaining insights about population growth, reproduction, and health condition (Le Cren, 1951; Petrakis & Stergiou, 1995; Possamai, Zanlorenzi, Machado, & Fávaro, 2019).

The LWR is influenced by temperature, interspecific relationships, resource availability, sex, and life stage (Froese, 2006; Nallathambi et al., 2019; Possamai et al., 2019). Therefore, studies of fish stock structure and biomass estimations need to consider the geographic region of the coefficients used to estimate the LWR (LeCren, 1951; Petrakis & Stergiou, 1995; Gonçalves et al., 1997), as well as the life stage of the specimens (Petrakis & Stergiou, 1995; Gonçalves et al., 1997). Based on these concerns, we estimated and compared the LWR for juveniles, females and males of fish species that use mangroves in their life cycle.

Material and methods

The sampling site is located in Paraná state coast, South Brazil. Fishes were collected in a mangrove area of Gamboa do Perequê river (25°33'45.10" S, 48°25'4.97" W), near the mouth of Paranaguá Bay. This is a meandering shallow river, with great influence from tides (reaching 2.8 m), draining mangrove areas in all of its 2.6 km. The mangroves are mainly comprised of *Laguncularia racemosa* (Lana et al., 1989), and in lower proportions are covered by *Avicennia shauerianna* and *Rhizophora mangle*. Moreover, there are saltmarsh banks along the meandering river banks that are colonized by *Spartina alterniflora*, reaching a height less than 50 cm (Soares et al., 1996). The climate of the region is humid sub-tropical, with an average temperature of 18°C, annual rainfall average of 2,500 mm and humidity around 85% (Lana, Marone, Lopes, & Machado, 2001).

The fishes were collected monthly from August 2008 through June 2010 using different fishing gears: trammel nets (4 m of length; 2.5 x 1.5 x 2.5 mm mesh size between adjacent internodes), fyke nets (30 m of length and 1.5 m of width; 10 mm mesh size opposite internodes in the wings and 8 mm in the bag), and traps made with plastic bottles (superior section of the bottle was inverted forming a funnel; details in Possamai, Rosa, & Corrêa, 2014) combined with four baits (beef liver, broken corn, meat flavored dog food and commercial bait for amateur fishing). After collection, fishes were measured (total length in mm and weight in g) and their gonads were removed to assess sex and maturational stage following Vazzoler (1996).

The length-weight relationship was performed using the equation $Wt=aLt^b$, where Wt is total weight; Lt is total length; *a* is the linear coefficient and; *b* is the slope (both coefficients were determined using the least-squares method) (Le Cren, 1951). The LWR was determined for females, males, juveniles (sexed and unsexed together) and for all conspecifics together (General = combined sexes + juveniles + undetermined). The model fit was verified using the determination coefficient (r^2). The isometry of *b* was tested with a t-test (α=0.05), using b=3 as H_0. To verify the similarity of b among life stages (juveniles x adults) and sexes, Covariance Analysis ANCOVA was performed, comparing the slopes of each model. All statistical analyses were performed in the software R 3.5.3 (R Core Team, 2019) using the 'FSA package'.

Results

A total of 880 specimens belonging to 7 families and 8 genera were sampled, ranging in length from 19 to 160 mm. The LWR parameters for these species can be accessed in Table 1. Concerning growth types, 62.5% of the species exhibited isometric growth, 25.0% were allometric positive and 1 species (12.5%) was allometric negative for the size range analyzed.

Regarding types of growth for the different sexes, adult females presented isometric growth, except for the silverside *A. brasiliensis* that presented allometric positive growth. Concerning the males, all adults presented isometric growth (Table 1). The killifish *P. vivipara* males showed allometric positive growth, but all individuals of this species were juveniles. Furthermore, two species were not sexed; *Centropomus parallelus* individuals were all juveniles, and this species is a protandric hermaphrodite, so the LWR between sexes could not be calculated. The second species, *Diapterus rhombeus*, could not be sexed due to the difficulty of macroscopic determination of sex in this species.

The juveniles presented different values for b and growth types from the adults in almost all species tested (Table 1). When examining the differences between the b coefficients and the sexes, only two of the six species did not differ. However, when we analyzed the sexed-b and the general-b values for each species, these same two species had discrepancies with the general-b value that did not allow the same b value to be used for both sexes (Table 1).

Table 1. Length–Weight relationship parameters of the estuarine fish species of Perequê mangrove, Paraná, Brazil. Sampling events took place from 2008 through 2010.

Species	Life stage/Sex	n	Total Length		Total Weight		Equation parameters			t-test (b=3)		F-test ($b_j = b_{f,m}$)		F-test ($b_f = b_m$)	
			min	max	min	max	a	b	r^2	t	p-value	F	p-value	F	p-value
GOBIIDAE															
	Juvenile	15	19	60	0.028	2.664	$3x10^{-7}$	3.871	0.94	3.242	0.006				
Bathygobius soporator	Adult F	13	59	115	3.253	28.100	$6x10^{-6}$	3.182	0.91	0.619	0.548	13.069	<0.001	-3.58	<0.001
(Valenciennes. 1837)	Adult M	7	81	128	6.739	29.258	0.00005	2.944	0.94	-0.179	0.865	13.340	<0.001		
	General	35	19	128	0.028	29.258	$8x10^{-7}$	3.603	0.98	7.939	<0.001				
ATHERINOPSIDAE															
	Juvenile	20	69	105	2.132	6.329	0.00008	2.405	0.81	-2.963	0.005				
Atherinella brasiliensis	Adult F	20	88	157	3.909	29.346	$3x10^{-7}$	3.665	0.97	5.086	<0.001	19.21	<0.001	-7.83	<0.001
(Quoy & Gaimard. 1825)	Adult M	9	86	140	3.765	18.782	$2x10^{-6}$	3.232	0.98	1.727	0.127	14.51	<0.001		
	General	68	68	157	2.132	29.346	$2x10^{-6}$	3.267	0.89	1.971	0.053				
POECILIDAE															
	Juvenile F	19	19	70	0.069	4.286	$9x10^{-6}$	3.046	0.99	0.601	0.555				
Poecilia vivipara	Juvenile M	16	22	51	0.117	1.470	$7x10^{-6}$	3.121	0.95	0.672	<0.001			0.854	0.394
Bloch & Schneider. 1801	Adults	only one adult was collected													
	General	37	14	70	0.059	4.286	0.00001	2.928	0.97	-0.925	0.361				
CENTROPOMIDAE															
	Juvenile	67	27	136	0.137	22.900	0.00002	2.703	0.92	-3.122	0.002				
Centropomus parallelus	Adult F	all specimens immature													
Poey. 1860	Adult M														
	General	67	27	136	0.137	22.900	0.00002	2.703	0.92	-3.122	0.002				
GERREIDAE															
	Juvenile														
Diapterus rhombeus	Adult F	sex and stage of maturation were not accessed													
(Cuvier. 1829)	Adult M														
	General	54	31	100	0.299	10.73	0.00001	2.939	0.91	-0.476	0.636				
SCIAENIDAE															
	Juvenile	19	51	160	1.708	46.022	0.00005	2.671	0.97	-2.898	0.010				
Bairdiella ronchus	Adult F	22	107	139	14.07	29.901	$9x10^{-6}$	3.047	0.84	0.158	0.875	5.871	<0.001	-0.486	0.628
(Cuvier. 1830)	Adult M	9	102	160	12.779	55.025	0.00001	2.980	0.93	-0.067	0.948	6.648	<0.001		
	General	50	51	160	1708	55025	0.00001	2.966	0.94	-0.334	0.739				
TETRAODONTIDAE															
	Juvenile	all specimens were adults													
Sphoeroides greeleyi	Adult F	11	68	111	6.819	33.358	$8x10^{-6}$	3.211	0.93	0.774	0.458			-2.199	0.029
Gilbert. 1900	Adult M	13	67	112	5.159	28.795	$7x10^{-6}$	3.140	0.96	0.769	0.457				
	General	25	66	112	3.199	33.358	$3x10^{-6}$	3.392	0.94	2.235	0.035				
	Juvenile	136	30	100	0.595	20.733	0.00002	2.947	0.91	-0.663	0.508				
Sphoeroides testudineus	Adult F	26	50	137	2.500	56.167	0.00003	2.960	0.97	-0.363	0.719	0.119	0.906	-3.405	<0.001
(Linnaeus. 1758)	Adult M	76	57	130	3.534	46.123	0.00004	2.816	0.89	-1.666	0.099	-4.468	<0.001		
	General	246	30	137	0.595	56.167	0.00001	3.078	0.94	1.550	0.122				

Equation parameters include linear coefficient (a) and angular coefficient or slope (b). Deviation from isometric growth was tested using a t-test and b was tested between sexes (f = female, m = male) and life stages (j = juvenile) with an ANCOVA. Family names are listed in ALL CAPS above species names. Sex is represented by (F) for females and (M) for males. Both tests considered α = 0.05 and bold values denotes p < 0.05.

Discussion

Here, we present the LWR of 8 estuarine species which use the mangrove areas as adults (separate sexes) and juveniles, and showed differences in parameters between sexes and life cycle. The majority of the species had values for *b* similar to the average found in FishBase (Froese & Pauly, 2019), except for *P. vivipara* and *C. parallelus* (Table 2). In the present study, we found that *b*=2.92 for the combined killifish, whereas the average in FishBase is 3.42. For the fat snook, we found *b*=2.70 compared to a 3.03 average from FishBase.

The killifish also presented differences in b between the combined and separated sexes, which is curious because the value for b was similar between sexes. However, despite the similarity of slope values between females and males, the growth type differed. This is a dimorphic species, where males have gonopods (modification of an anal fin into a sexual organ) and females are bigger to carry embryos and give birth to live young (Constantz, 1989; Neves & Monteiro, 2003). This sexual dimorphism could result in differences between the sex-specific growth types, which would explain the isometric growth found in females and the allometric positive growth found in males. Moreover, the sexual differences may have resulted in these discrepancies of b (general x separated sexes) when we grouped the individuals and compared them to the separated sexes, since their growth types are different.

Table 2. Comparison of *b* estimated for the fishes of Perequê mangrove, Paraná, Brazil and the FishBase estimates. F for female and M for males.

Species/ English name/ Local name	Adult Female	Adult Male	Juvenile	FishBase
Bathygobius soporator Frillfin goby Amborê	3.18	2.94	3.87	3.00
Atherinella brasiliensis Silverside Peixe-rei	3.66	3.23	2.40	3.10
Poecilia vivipara Killifish Barrigudinho	not estimated		F = 3.09 M = 3.12	3.42
Centropomus parallelus Fat snook Robalo-peva	not estimated		2.70	3.03
Diapterus rhombeus Caitipa mojarra Caratinga	General = 2.93			3.09
Bairdiella ronchus Ground croaker Cangauá	3.04	2.98	2.67	3.08
Sphoeroides greeleyi Green puffer Baiacu-pinima	3.21	3.14	not estimated	3.09
Sphoeroides testudineus Checkered puffer Baiacu-pintado	2.96	2.81	2.94	2.92

Concerning the fat snook, we presented the LWR for juveniles, while FishBase and other studies in near areas showed this relationship for adults (Froese & Pauly, 2019; Possamai et al., 2019). The juveniles here showed an allometric negative growth, which demonstrates the species is investing more in length than in weight. This is different from the adults which exhibit allometric positive growth (Possamai et al., 2019). When the fat snook reaches maturity (about 194 mm) (Chaves & Nogueira, 2018), it starts as a male and then becomes female (protandric hermaphroditism). It is possible that juveniles utilize this allometric negative growth as a strategy to compensate for the length they need to reach sexual maturity, since its reproductive strategy demands different ages/sizes for each sex.

The differences found in the slopes between the sexes and the life stages highlights the importance of sexing the specimens when determining LWR. These differences in b can cause distortions in studies that estimate stocks biomass but are understandable for the use of combined estimates in feeding studies of seabirds and marine mammals, for example, where sexing is not an option (Possamai et al., 2019). Moreover, the life stage can also cause differences in the slope and the growth type (Morato et al., 2001), and consequently affect biomass estimations.

Conclusion

In conclusion, this work demonstrated that growth parameters can change along the life stage and the sex in fishes. In this sense, we recommend taking into account the sex of individuals for estimations that use the *b* coefficient (Froese, 2006), as well as the life stage of the fish.

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