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Allometric relationships of six fish species of the order Characiformes in oxbow lakes on the floodplain of the middle Purus river, Amazon

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Abstract. The length-weight relationship (LWR) was estimated for six fish species of the order Characiformes: *Curimatella meyeri*, *Hoplias malabaricus*, *Potamorhina altamazonica*, *Potamorhina latior*, *Pygocentrus nattereri*, *Schizodon fasciatus*, collected from oxbow lakes on the floodplain of the middle Purus River in western Brazilian Amazonia. The specimens were collected in January, May, and September 2012, during both diurnal and nocturnal periods. Allometric coefficients (b) for the studied species ranged between 2.98 and 3.34. The correlation coefficients for the LWR (r^2) ranged between 0.954 and 0.993. The data presented here provide important insights for the development of effective measures for the conservation and management of the study species.

[Keywords: Neotropical region, Amazon basin, Acre, aquatic biodiversity, ichthyofauna]

Resumo. Relações alométricas de seis espécies de peixes da ordem Characiformes em lagos de ferradura na planície de inundação do rio Purus médio, Amazonas. A relação comprimento-peso (LWR) foi estimada para seis espécies de peixes da ordem Characiformes: *Curimatella meyeri*, *Hoplias malabaricus*, *Potamorhina altamazonica*, *Potamorhina latior*, *Pygocentrus nattereri*, *Schizodon fasciatus*, coletados em lagos de ferradura na planície de inundação do médio rio Purus, no oeste da Amazônia brasileira. As amostras foram coletadas em janeiro, maio e setembro de 2012, durante os períodos diurno e noturno. As espécies apresentaram coeficientes alométricos (b) entre 2.98 e 3.34 e coeficientes de correlação (r^2) variando de 0.954 a 0.993. Os dados aqui apresentados fornecem informações importantes para o desenvolvimento de medidas efetivas para a conservação e manejo das espécies estudadas.

Introduction

The Amazon basin has by far the greatest diversity of fishes found in a freshwater system anywhere in the world, with approximately 2406 valid species (Reis et al. 2016; Jézéquel et al. 2020). The Purus River is one of the principal tributaries of the Amazon River, located in the southwestern Amazon basin, where it forms the second largest drainage in the Brazilian state of Acre (SEMA 2012).

Few data have been published on the ichthyofauna of the middle Purus basin, although studies of length-weight relationships (LWR) are available (e.g., Matos et al. 2019; Silva et al. 2020). Estimates of LWR are important tools for the assessment of the growth patterns and nutritional status of fish species (Froese 2006). These estimates can also provide important input for decision-making on the management and conservation of fish populations. Given these considerations, we investigated the allometric relationships of six species of the order Characiformes: *Curimatella meyeri* (Steindachner 1882), *Hoplias malabaricus* (Bloch 1794), *Potamorhina altamazonica* (Cope 1878), *Potamorhina latior* (Spix and Agassiz 1829), *Pygocentrus nattereri* (Kner 1858), *Schizodon fasciatus* (Spix and Agassiz 1829), found in oxbow lakes on the floodplain of the Purus river, providing important insights into the biology of the study species.

Materials and Methods

The source of the Purus River is located in Perú, where it first flows through the departments of Ucayali and Madre de Dios

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Order/Family/ Species	N (%)	Estimated parameters							Published values			
		TL (cm) (min-max)	TW (g) (min - max)	a (95% CL)	b (95% CL)	r^2	P	Growth type	TL (cm) max (Source)	N	Growth type	Source
Characiformes												
Anostomidae												
Schizodon fasciatus (Spix and Agassiz 1829)	115 (16.8)	10.0-34.0	15.0-40.7	0.092 (0.0009-0.0941)	2.98 (2.910-3.056)	0.99	<0.01	Isometric	40 (Froese and Pauly 2022)	439	Negative Alometry	Cella-Ribeiro et al. (2015)
Curimatidae												
Curimatella meyeri (Steindachner 1882)	25 (3.6)	9.5-18.0	14.7-80.0	0.0898 (0.0033-0.0329)	3.01 (2.533-3.373)	0.96	<0.01	Isometric	18 (This study)	45	Positive Alometry	Cella-Ribeiro et al. (2015)
Potamorhina altamazonica (Cope 1878)	98 (14.3)	8.0-24.0	7.0-145.0	0.0093 (0.0010-0.0727)	2.98 (2.815-3.101)	0.97	<0.01	Isometric	27 (Froese and Pauly 2022)	928 635	Negative Alometry	Tribuzy-Neto et al. (2015)
Potamorhina latior (Spix and Agassiz 1829)	89 (13.0)	8.5-22.8	9.0-138.0	0.0048 (0.0034-0.0783)	3.04 (2.832-3.275)	0.95	<0.01	Isometric	24 (Cella-Ribeiro et al. 2015; Froese and Pauly 2022)		Negative Alometry	Tribuzy-Neto et al. (2015)
Erythrinidae												
Hoplias malabaricus (Bloch 1794)	56 (8.2)	4.5-45.0	1.0-1234.0	0.0019 (0.0004-0.0029)	3.17 (3.062-3.240)	0.99	<0.01	Positive Alometry	65 (Froese and Pauly 2022; Giarrizzo et al. 2015)	160 81 67	Isometric Positive Alometry Isometric	Nobile et al. (2015) Silveira and Vaz-dos-Santos (2015) Oliveira et al. (2020)
Serrasalmidae												
Pygocentrus nattereri (Kner 1858)	303 (42.2)	3.6-28.0	1.02-651	0.0779 (0.0005-0.0898)	3.26 (3.156-3.346)	0.97	<0.01	Positive Alometry	50 (Froese and Pauly 2022)	822 50	Positive Alometry	Cella-Ribeiro et al. (2015) Giarrizzo et al. (2015)

Abbreviations. N (%): number of specimens (numeric percentage of species). TL (min-max): total length (range of values). TW (min-max): total weight (range of values). a: coefficient related to body shape. b: allometric coefficient. CI: confidence interval. r^2: correlation coefficient.

Abreviações. N (%): número de espécimes (porcetagem númerica das espécies). CT (min-max): comprimento total (faixa de valores). PT (min-max): peso total (faixa de valores). a: coeficiente relacionado à forma do corpo. b: coeficiente alométrico. IC: intervalo de confiança. r^2: coeficiente de correlação.

Table 1. Estimated parameters for the six species of Characiformes collected in oxbow lakes in the floodplain of the middle Purus river, Amazon, Brazil, between January, May and September 2012, and values already published by other authors.

Tabela 1. Parâmetros estimados para as seis espécies de Characiformes coletadas em lagos de ferradura na planície de inundação do médio rio Purus, Amazônia, Brasil, entre Janeiro, Maio e Setembro de 2012, e valores já publicados por outros autores.

before reaching the Brazilian states of Acre, and then, Amazonas, with a total drainage area of 372000 km² (SEMA 2012). The study area (oxbow lakes) is located on the middle Purus between the municipalities of Boca do Acre (8°42'39.75'' S - 67°23'20.40'' W) and Pauini (7°44'33.32'' S - 67°1'20.35'' W) in the Brazilian state of Amazonas. The fish specimens were collected from 12 oxbow lakes in January, May and September 2012 (SISBIO #58295-1), using 12 sets of gillnets, 80 m long and 4 m high, with meshes of between 1.5 cm and 12.0 cm. These nets were installed in the early afternoon parallel to the margin of each lake, where they remained for 24 hours, being checked every 4 hours, with the fish being removed, anesthetized with Eugenol (Keene et al. 2008) and later fixed in formalin (10%).

In the laboratory, the species were identified based on taxonomic keys and the voucher specimens (MUFAC-IC 778 until MUFAC-IC 935) were deposited in the ichthyological collection of the Federal University of Acre, in Rio Branco. Each specimen was measured (total length [TL, cm] with an accuracy of 0.01 cm) and weighed (total weight [TW, g], with an accuracy of 0.01 g). The length-weight relationships of the species were determined using the equation $W=a*L^b$ (Le Cren 1951; Froese 2006), where W=total weight of the specimen, L=total length, and a and b are constants. These parameters (a and b) were estimated by linear regression using the formula: log(W)=log(a)+b*log(L), run in PAST 3.0 (Hammer et al. 2001), with the extreme outliers being excluded. The interpretation of b, the slope or growth coefficient, was based on Santos (1978). This parameter allows to determine the type of growth for each species. The growth type was estimated using the confidence interval (Froese 2006) and the taxonomic classification of the species followed Fricke et al. (2020).

Results

A total of 686 individuals were collected, all representatives of the order Characiformes, including 6 species in 4 families. Half (3) of these species were members of the family Curimatidae, and were represented by 212 individuals, while the other three families were each represented by a single species, that is, the Anostomidae (115 individuals), Erythrinidae (56 fish) and Serrasalmidae (303 individuals). The abundance of each species ranged from 25 individuals (4% of the total) in *Curimatella meyeri* to 303 individuals (44%) in *Pygocentrus nattereri*. The largest species collected during the present study was *Hoplias malabaricus*, which had a total length (TL) of up to 45 cm, and the smallest was *P. nattereri*, with a minimum TL of 3.6 cm. The allometric coefficient (b) ranged from 2.98 in *Potamorhina altamazonica* to 3.34 in *Schizodon fasciatus*, while the correlation coefficients for the LWR (r^2) ranged from 0.95 in *Potamorhina latior* to 0.99 in *H. malabaricus* (Table 1, Figure 1).

Discussion

The estimates of the LWR for the six fish species collected from the oxbow lakes on the floodplain of the middle Purus (Table 1) indicated that *S. fasciatus*, *C. meyeri*, *P. altamazonica* and *P. latior* have isometric growth (b=3), whereas *H. malabaricus* and *P. nattereri* have positive allometric growth (b>3). These values are within a previously defined

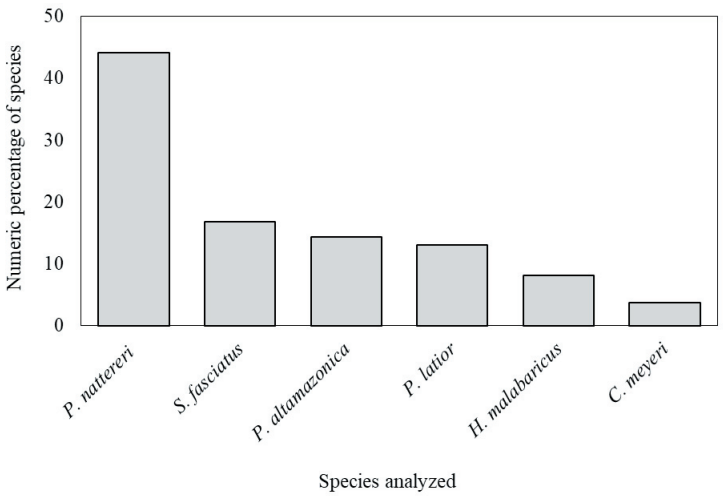

Figure 1. Numeric percentage of species of Characiformes collected in oxbow lakes in the floodplain of the middle Purus river, Amazon, Brazil, in January, May and September 2012.

Figura 1. Porcentagem numérica de espécies de Characiformes coletadas em lagoas de ferradura na planície de inundação do médio rio Purus, Amazonas, Brasil, entre janeiro, maio e setembro de 2012.

range for fish species, which range between 2.5 and 3.5, as recorded by Carlander (1969), Froese (2006) and Freitas et al. (2014).

The isometric growth herein recorded for *S. fasciatus* differs from the negative allometric growth recorded for the species in the Amazon River basin (Cella-Ribeiro et al. 2015). In the same study, *C. meyeri* showed positive allometric growth (Cella-Ribeiro et al. 2015), differing from the isometric growth recorded here for this species. Additionally, in contrast to the isometric growth type of our results, *P. altamazonica* and *P. latior* showed negative allometric growth in floodplain lakes in the Amazon basin (Tribuzy-Neto et al. 2015). In *H. malabaricus*, the positive allometric growth was reported in specimens from southern Brazil (Silveira and Vaz-dos-Santos 2015). In contrast, an isometric growth was recorded in *H. malabaricus* from a southeastern Brazilian basin (Nobile et al. 2015) and in a small estuary tributary of the Amazon River basin (Oliveira et al. 2020). In *P. nattereri*, positive allometric growth was also recorded in specimens (Table 1) from rivers in the Amazon basin (Cella-Ribeiro et al. 2015; Giarrizzo et al. 2015).

A range of factors may influence the variation in allometric coefficients, including the ecosystem structure and spatial scale (Froese 2006), given that different environmental conditions (e.g., temperature and land use) result in different life cycle parameters for the same species (Freitas et al. 2017), food availability (Lima et al. 2017) and nutritional parameters (Freitas et al. 2017) also influence the type of growth of species. Other potentially important factor may be the differences in the techniques used to collect the specimens, since variations in the type of net, mesh or even the sampling schedule may determine more or less subtle variations in the types of specimen or body sizes collected. However, the effective standardization of specimen collection procedures is extremely complicated. Despite these potential limitations, the data presented here provide important insights for the development of effective measures for the conservation and management of the study species, although there is a clear need for further research on the fish fauna of these Neotropical lakes.

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