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Notes and Comments

Length at first sexual maturity of the freshwater fish fauna of the Baixada Maranhense Environmental Protection Area

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Despite ongoing research efforts, the ichthyofauna of the coastal basins of Maranhão State, Brazil remains poorly described (Abreu et al., 2019). In recent years the number of research publications on fish diversity in this region has increased (e. g. Brito et al., 2019; Guimarães et al., 2020; Oliveira et al., 2020), however important work remains to be done. An accurate assessment of population parameters related to fish reproduction is an essential component of effective fisheries management (Brown-Peterson et al., 2011; Nascimento et al., 2015; Nunes et al., 2019).

The Baixada Maranhense Environmental Protection Area is a RAMSAR site consisting of a complex ecosystem in which human beings play an essential role in managing, using, and conserving several components. Due to the abundance of regional water resources, fishing is among the most important socioeconomic activities (Araujo and Pinheiro, 2008). In recent decades this region has undergone substantial anthropogenic changes, decreased river water flow, siltation, damming, and other anthropic activities compounded by changes in rainfall patterns (Cantanhêde et al., 2017). Monitoring the ichthyofauna in rivers is essential to identify environmental responses to human actions and provides subsidies to regulate the use of water resources, thus enabling the development of alternatives to minimize river degradation (Santos et al., 2017; Lima et al., 2018).

This study describes the minimum size at first maturation (L_{50}) of commercially important fish species in two distinct habitats (a river and a lake) within the Pindaré River Hydrographic Basin. We use data from monthly collections that were carried out for 18 months (January 2015 to June 2016), in Lake Viana and the Pindaré river in the state of Maranhão, in northeastern Brazil. The study area is a designated RAMSAR Site, protected by Brazil under the RAMSAR intergovernmental treaty (Brasil, 2010). It is characterized by seasonal changes in rainfall that influence both the reproductive behavior and adaptations of fish species and the dynamics of the local fishing industry. When there is a shortage of fish stocks, extractive activity is intensified to meet demand, and the seasonal reduction in floods that occur annually triggers annual overfishing (Carvalho et al., 2017; Carvalho et al., 2021).

We purchased specimens used for this work from local fish markets, then stored them on ice for transport to the laboratory, where they were subsequently identified to the lowest possible taxonomic level. We then analyzed all specimens morphologically to assess total length (TL) and total weight (TW) with the aid of an ichthyometer and an electronic caliper with a precision of 1 mm and 0.01 g, respectively. Then we made a longitudinal incision on the ventral portion of each specimen to remove the gonads. We then fixed the gonads in a 5% formalin solution for subsequent preservation in 70% ethanol. We deposited all specimens in the Collection of tissues and DNA of the fauna of Maranhão, UEMA (CoFauMA), and in the teaching collection of fishes of the Laboratory of Fisheries and Aquatic Ecology, UEMA (LabPEA).

We assessed the reproductive state for each specimen through macroscopic identification of the stage of gonadal maturation and characterization of the gonads according to the scale proposed by Brown-Peterson et al. (2011) and Lowerre-Barbieri et al. (2011). We calculated minimum size at first maturation (L_{50}) based on the cumulative curve of occurrence frequencies of adult individuals by total length class adjusted to the logistic function. We characterized the maturation as A (immature); B (under development); C (able to spawn); D (regressing), and E (regenerated). We calculated the percentage of adult organisms (stages B, C, D, and E) by length class and considered as a dependent variable (Y) and the total length as an independent variable (X). Subsequently, we fitted these values to a logistic curve, using the Statistica 7 Program according to the following formula: $\boldsymbol{P = 1/(1+exp[-r\,(L - Lm)])}$. ***P*** is the proportion

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of mature individuals, ***r*** is the slope of the curve, ***L*** is the length, and ***Lm*** is the average length of sexual maturity.

Overall, we analyzed 1,324 fish (Table 1) representing ten species: *Curimata* sp. (n = 61), *Platydoras brachylecis* Piorski, Garavello, Arce, Sabaj and Pérez, 2008 (n = 97), *Prochilodus lacustris* Steindachner, 1907 (n = 61), *Plagioscion squamosissimus* Heckel, 1840 (n = 205), *Hoplias malabaricus* Bloch,1784 (n = 94), *Trachelyopterus galeatus* Linnaeus, 1766 (n = 211), *Ageneiosus dentatus* Kner, 1858 (n = 91), *Schizodon dissimilis* Garman, 1890 (n = 252), *Hassar affinis* Steindachner, 1881 (n = 14), and *Pygocentrus nattereri* Kner, 1858 (n = 105).

Our study showed that *P. squamosissimus*, *H. affinis*, *H. malabaricus* and *P. lacustris* had a L_{50} higher than that calculated in the literature, as shown in Table 2. The increase in the minimum length at first maturity can be an indication of stock recovery or an increase in the availability of food resources for the species (Santos et al., 2015). On the other hand, the species *S. dissimilis*, *P. nattereri* and *T. galeatus* presented L_{50} with values lower in this survey (Table 2). According to Camargo and Lima Junior (2007), the decrease in the L_{50} could mean a potential danger of overfishing. This decrease may indicate that fish are reaching the minimum length of first maturation early as a need for stock renewal (Ikeda, 2003). Finally, the individuals *A. dentatus*, *Curimata* sp., and *P. brachylecis* still do not have literature with L_{50} records, precluding historical comparisons.

Based on a robust sample size from a previously poorly-characterized ichthyofauna, we showed that the estimates of L_{50} for several species collected in the Baixada Maranhense Environmental Protection Area differ from those reported in the literature. Although fishing activity

Table 1. Variation in total length and L_{50} for freshwater fish from northeastern Brazil.

SPECIES	Total length (cm)			Immature (%)	L50 considering both sexes (cm)	MALE				FEMALE			
	MIN	MAX	M ± SD			MIN	MAX	Immature (%)	Maturity equation	MIN	MAX	Immature (%)	Maturity equation
Ageneiosus dentatus (kner, 1858)	13.2	26.7	19.44 ± 2.33	35.16	17.19	14.6	24.0	52.00	y=1/(1+exp(-(0.35)*(x-(17.99))))	13.2	26.7	14.63	y=1/(1+exp(-(0.74)*(x-(15.30))))
Curimata sp	11.3	49.0	16.72 ± 8.12	16.39	13.98	11.9	33.0	25.00	y=1/(1+exp(-(0.62)*(x-(19.61))))	11.3	49.0	10.81	y=1/(1+exp(-(0.51)*(x-(14.83))))
Hassar affinis (Steindachner, 1881)	11.1	17.0	13.89 ± 1.33	38.1	12.98	11.1	17.0	39.02	y=1/(1+exp(-(0.60)*(x-(13.06))))	11.3	17.0	36.92	y=1/(1+exp(-(0.77)*(x-(13.04))))
Hoplias malabaricus (Bloch, 1784)	17.3	32.1	24.05 ± 2.98	30.85	20.67	18.0	28.2	60.71	y=1/(1+exp(-(0.56)*(x-(22.21))))	17.3	32.1	18.18	y=1/(1+exp(-(1.21)*(x-(18.44))))
Plagioscion squamosissimus (Heckel, 1840)	15.5	39.8	24.03 ± 3.63	36.59	25.32	15.5	39.8	34.31	y=1/(1+exp(-(0.25)*(x-(25.16))))	17.0	34.5	39.71	y=1/(1+exp(-(0.30)*(x-(21.15))))
Platydoras brachylecis (Piorski, Garavello, Arce, Sabaj e Pérez, 2008)	10.5	23.0	14.78 ± 1.88	28.87	13.23	10.5	18.5	56.52	y=1/(1+exp(-(0.59)*(x-(14.46))))	11.7	23.0	3.94	y=1/(1+exp(-(2.28)*(x-(10.95))))
Prochilodus lacustris (Steindachner, 1907)	13.9	21.3	17.54 ± 1.74	4.92	15.07	13.9	21.1	3.23	y=1/(1+exp(-(2.10)*(x-(15.01))))	14.9	21.3	6.67	y=1/(1+exp(-(1.57)*(x-(15.16))))
Pygocentrus nattereri (Kner, 1858)	12.4	19.2	15.39 ± 1.59	31.43	13.9	12.4	18.9	31.37	y=1/(1+exp(-(0.61)*(x-(13.88))))	12.4	19.2	31.48	y=1/(1+exp(-(0.96)*(x-(14.05))))
Schizodon dissimilis (Garman, 1890)	16.5	38.5	23.22 ± 3.49	36.9	20.25	17.4	31.9	40.00	y=1/(1+exp(-(0.36)*(x-(20.22))))	16.5	38.5	34.87	y=1/(1+exp(-(0.43)*(x-(20.37))))
Trachelyopterus galeatus (Linnaeus, 1766)	1.4	17.4	12.37 ± 1.56	33.65	11.13	1.4	17.4	36.52	y=1/(1+exp(-(0.24)*(x-(11.16))))	1.4	14.8	30.21	y=1/(1+exp(-(0.44)*(x-(9.53))))

Caption: MIN = minimum total length (cm); MAX = maximum total length (cm); SD = standard deviation.

Table 2. Differences in estimated L_{50} between the present work and previously published analyses.

Species	Authors	L50 Previous estimate	L50 Present study	Classification
Hassar affinis	Cantanhêde et al. (2016) and Carvalho et al. (2021)	11.52 and 12.3	12.98	Upper
Hoplias malabaricus	Carvalho et al. (2021)	19.0	20.67	Upper
Plagioscion squamosissimus	Carvalho et al. (2017, 2021)	15.3 and 17.3	25.32	Upper
Prochilodus lacustris	Carvalho et al. (2021)	14.4	15.07	Upper
Pygocentrus nattereri	Carvalho et al. (2021)	14.3	13.00	Less
Schizodon dissimilis	Carvalho et al. (2021)	25.0	20.25	Less
Trachelyopterus galeatus	Garcia et al. (2019)	14.5	11.13	Less

characteristic of this RAMSAR site may affect estimates of L_{50}, this study can help to understand the renewal of fish stocks, emphasizing species that do not yet have records of minimum capture size (*Ageneiosus dentatus*, *Curimata* sp. and *Platydoras brachylecis*). Thus, it will serve as a basis for adopting measures that make viable the practice of sustainable fishing, contributing to inspection and adjustment in the sizes of fishing gear.

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