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Scientific Article

Population parameters of the red-bellied piranha *Pygocentrus nattereri* (Kner, 1860) (Characiformes: Serrasalmidae) of the São Miguel River, Rondônia state, Brazil

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ABSTRACT

In this study, the structure and distribution of *Pygocentrus nattereri* populations in the São Miguel River basin, Rondônia state, Brazil, were evaluated. From August 2020 to July 2021, monthly fisheries were carried out, using gillnets with meshes ranging from 40 to 160 mm between opposite knots, which were in place for 48 hours and inspected at 6 a.m., 12 a.m., 6 p.m., and 12 p.m. Growth parameters and mortality were estimated using length-frequency data. The population values found for *P. nattereri* were $L\infty$ = 29 cm, k = 0.55·year^{-1}, with mortality values: M = 0.57, Z = 0.98 and F = 0.41·year^{-1}. The relationship between weight and length was described by $Wt = 0.0372 \cdot Lt^{2.983}$. The growth and mortality of *P. nattereri* are closely related to the intrinsic characteristics of the species, as well as the environmental characteristics of seasonality and food availability. Using the information on the growth and mortality parameters, it is possible to subsidize the models for the evaluation of this fishery resource.

Keywords: Artisanal fishing; Fish stocks; Population dynamics; Western Amazon.

Parâmetros populacionais da piranha-vermelha *Pygocentrus nattereri* (Kner, 1860) (Characiformes: Serrasalmidae) do Rio São Miguel, Rondônia, Brasil

RESUMO

Neste estudo, foram avaliadas a estrutura e distribuição das populações de *Pygocentrus nattereri* da bacia hidrográfica do Rio São Miguel, Rondônia, Brasil. No período de agosto de 2020 a julho de 2021, foram realizadas pescarias mensais, utilizando malhadeiras com pano de 40 a 160 mm entre nós opostos, as quais foram armadas por 48 horas e inspecionadas às 6, 12, 18, e 0 h. Os parâmetros de crescimento e mortalidade foram estimados por meio de dados de frequência de comprimento. Os valores populacionais encontrados para *P. nattereri* foram L_∞ = 29 cm e k = 0,55·ano^{-1}, sendo os de mortalidade: M = 0,57, Z = 0,98 e F = 0,41·ano^{-1}. A relação entre o peso e o comprimento foi descrita por $Wt = 0{,}0372 \cdot Lt^{2{,}983}$. Os dados apresentados indicam que os estoques de piranha da região do estudo não se encontram em sobrepesca. Portanto, medidas e ações para o ordenamento pesqueiro das populações de *P. nattereri* devem ser implementadas para evitar o aumento dessas populações e preservar as demais espécies de peixes de interesse comercial.

Palavras-chave: Amazônia Ocidental; Dinâmica populacional; Estoque pesqueiro; Pesca artesanal.

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INTRODUCTION

Currently, the effects of the damming of the Amazon water network by large and small enterprises impact seasonality and environmental balance, which directly affects migratory and resident ichthyofauna (Mereles et al., 2017; Sánchez-Gonzáles et al., 2018), in addition to the frequency of occurrence of exotic and invasive species that can also lead to an imbalance in the aquatic biota (Doria et al., 2018; Fragoso-Moura et al., 2016; Sousa et al., 2022).

Therefore, the lack of data related to aquatic communities is aggravated by the anthropogenic threats related to the development and well-being of human beings, who expand their populations and demand large amounts of electricity and food, which causes investments to grow uncontrollably. For example, the construction of dams and fish farms, as well as other cataclysmic factors (Sousa et al., 2018), which, together with the lack of environmental control, become problems with high-magnitude ecological effects that intensify in the medium and long term (Vicentin et al., 2013b).

Artisanal fishing is one of the most economically important activities in the North of Brazil, serving the national and international markets (Doria et al., 2012; Inomata & Freitas, 2015). Studying the behavior of fish species captured through this activity is extremely important for the conscious and sustainable management of fishing resources (Pantoja et al., 2021; Raseira et al., 2022). Because it is located in the Amazon basin, the state of Rondônia shares the great riches of this region of Brazil, including the abundant freshwater network and the diverse ichthyofauna of the rivers (Doria et al., 2012; Junk, 1984; Neill et al., 2006). This ichthyofauna is distributed throughout the Amazon basin, which has an area of approximately 7 million km².

The edaphoclimatic characteristics, added to the geomorphological age of this hydrographic basin, the flood pulse and the high spatial variety, promote the dispersion of fish assemblages along the adjacent floodable areas of the São Miguel River, a tributary of the Guaporé River, which in turn is a tributary of the Mamoré River, which is a tributary of the Madeira River, the largest tributary of the Amazon River (Costa et al., 2017).

The red-bellied piranha *Pygocentrus nattereri* (Kner, 1860) (Characiformes: Serrasalmidae) is a commercially important species and frequently caught in Amazonian fisheries landings (Cárdenas et al., 2012). It has an ichthyophagous feeding habit and is one of the main predators of fish in floodplain areas (Vital et al., 2011). Its diet is not composed solely of fish, as it also consumes mollusks, arthropods, organic matter, and small invertebrates (Cárdenas et al., 2012).

It is also of great ecological importance, as it performs environmental services by consuming weakened fish and the remains of dead animals found in aquatic environments (Goulding, 1980). During periods of high water in floodplain and marsh areas, *P. nattereri* performs its reproductive processes in flooded forests and takes advantage of the flood pulse to search for food (Brito et al., 2014), where parental care has been observed during reproductive periods that occur throughout the year (Queiroz et al., 2010). This species has relatively fast growth, and its longevity may be greater in protected areas, such as the Pantanal, where fishing pressure is reduced, and its population dynamics are influenced by biotic and abiotic factors, present sexual maturity around 15.4 cm after 1.6 year (Vicentin et al., 2013a).

Several authors have been applying methods to understanding the population dynamics of fish populations, such as growth and mortality (Bevilaqua et al., 2010), population dynamics of *Prochilodus nigricans* and *Calophysus macropterus* (Bonilla-Castillo et al., 2018, 2022), advancing the understanding of the life processes of aquatic biota, providing crucial information for decision-making for public bodies and researchers.

Understanding the behavior of fish species and their occupational dynamics provides extremely important information for the sustainable management of fish stocks, as they promote the maintenance of the ecological balance of these environments (Hurd et al., 2016; McGrath et al., 2015) and also preserve natural water sources (Castello et al., 2013).

In summary, population dynamics data can be used to estimate key parameters such as fishing mortality rate (F), natural mortality rate (M), and total mortality rate (Z). These indicators, together with the F/Z ratio, can provide crucial information and help to assess the level of exploitation of fish stocks and determine whether current fishing practices are sustainable. Furthermore, information on minimum size at first capture and age and growth parameters can guide the establishment of size limits and fishing quotas, ensuring recruitment and regulation of fish populations (Cutrim & Batista, 2005; Fernandes et al., 2002; Ferreira et al., 2014; Rubio et al., 2012).

In this context, the present study evaluated the dynamics of *P. nattereri* populations in the São Miguel River basin at different times of the year, especially in the development of their dispersal paths along the river. The results of the research can help understand the distribution of this species and, thus, assist in better management of the region's fishing resources (Zacardi et al., 2017), mainly because fishing is the main economic base of the fishing colonies and associations that depend on this activity to support their families (Barthem et al., 2019; Sousa et al., 2018).

MATERIALS AND METHODS

Bioethical considerations

The experimental fisheries and all procedures involving animals were approved by the Biodiversity Authorization and Information System, under license number 75092-1, and were also approved by the Ethics Commission for the Use of Animals of the Universidade Federal de Rondônia (approval No. 006/2020).

Study area

The São Miguel River is one of the tributaries of the Guaporé River basin and covers an area of 10,293.61 km^2 (Simões et al., 2017). Its source is located in the Guaporé Biological Reserve, in the municipality of São Miguel do Guaporé, in the state of Rondônia, Brazil. It has up a great diversity of aquatic environments, such as floodplain areas and their lakes, that connect to the river in the flood period (Fachín-Téran & Vogt, 2004). The biotic and abiotic data of the survey were collected at three different points along the river basin:

- Point 1: source (11°40'34.33" S 62°49'14.10" W);
- Point 2: middle section (12°5'19.01" S 63°7'23.08" W);
- Point 3: mouth (12°30'22.90" S 63°33'0.75" W) (Fig. 1).

Data collection

Experimental fisheries were conducted out monthly from August 2020 to July 2021, totaling 12 field expeditions. For the capture of fish, gillnets were used for a period of 48 hours. The gillnets were 2.5 m high by 20 m long, had meshes ranging from 40 to 160 mm between opposite knots and were tied next to each other at their ends. These remained submerged and were inspected every six hours (6 a.m., 12 a.m., 6 p.m., and 0 a.m.). Later, ring nets (8 cm mesh) were used for 30 minutes, in random places on the banks of the river and at the sampling points.

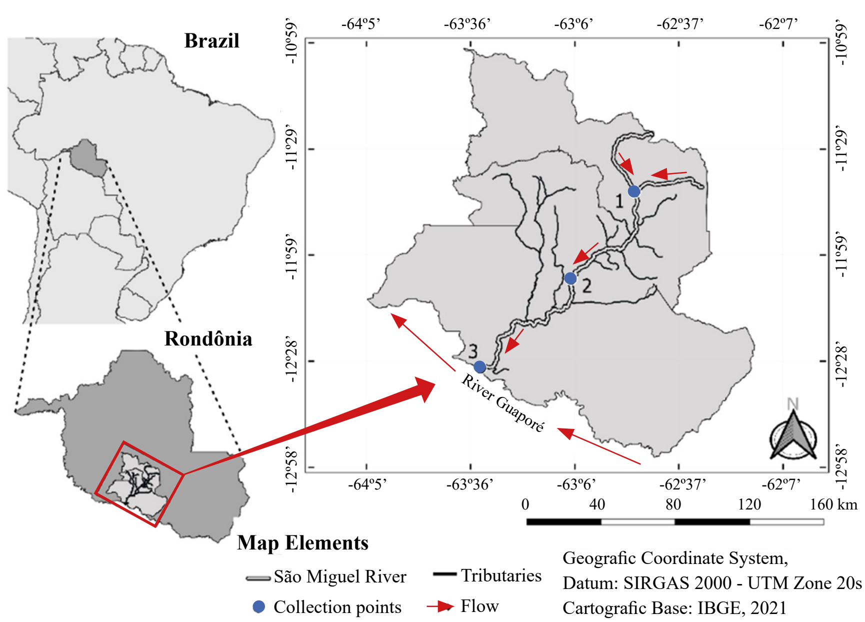
Soon after being captured, the fish were submitted to euthanasia via thermonarcosis (thermal shock at 0°C using ice and benzocaine in the proportion of 100 mg·L^{-1} of water) until vital signs were absent. The specimens were identified according to Ohara et al. (2017) and Queiroz et al. (2013) and, while still in the field, submitted to biometrics in which the values of total length (cm) and total weight (g) were obtained with the aid of an ichthyometer (with a ruler in cm) and a precision scale (0.01 g).

Data analysis

For each captured individual, weight (Wt, g) and total length (Lt, cm) data were obtained for the analyses of the weight-length relationship. These results were subjected to a non-linear regression, as per the mathematical expression shown in Eq. 1.

$$Wt = a \cdot Lt^b \quad (1)$$

The intercept (a), the regression coefficient (b), and the coefficient of determination (R^2) (Santos, 1978) were determined



1: Source; 2: middle section; 3: mouth of the river.

Figure 1. Location of the São Miguel River, Rondônia state, Brazil, and the respective locations of the experimental fisheries.

using the ordinary least squares (method, implemented in the R programming language. This method minimizes the sum of squared residuals between the observed and predicted values of fish weight based on their total length.

Student's t-test was applied to determine whether (*b*) differed significantly from 3 (isometric or allometric growth), which defines the type of growth (Le Cren, 1951; Zar, 1984). In addition, the relative condition factor (Kn) for the species was also verified (Froese, 2006; Le Cren, 1951), using Eq. 2.

$$Kn = Wt/a{\cdot}Lt^{b} \quad (2)$$

Where: *Kn*= relative condition factor; *a* and *b*= constants obtained from the regression between weight and length.

For the analysis of the biometrics, the total length (Lt) in cm was used, and the minimum length (C_{min}), average length (C_{av}), and maximum length (C_{max}) of *P. nattereri* were established. Additionally, growth and mortality parameters were estimated using length-frequency data, following the empirical relationships described by Froese and Binohlan (2000, 2003). The growth model was performed according to Von Bertalanffy (1938), and the parameter estimates (L∞, k, t_0) were based on length-frequency analysis using the ELEFAN I algorithm (Pauly & David, 1981).

$$Lt = L\infty\,[1 - e^{-k\,(t-t0)}] \quad (3)$$

Where: *Lt*= size of individuals at age *t*; *L∞*= maximum asymptotic; *K*= growth constant of the Von Bertalanffy growth equation; *t*= age of the individuals; t_0= theoretical hatch age.

The maximum age (age for 95% of the length) was estimated using Taylor's (1958) Eq. 4:

$$A_{0.95} = t_0 + 2.996/k \quad (4)$$

Where: $A_{0.95}$= longevity or maximum age.

The growth performance index (Φ') was calculated using the equation proposed by Pauly and Munro (1984) (Eq. 5):

$$\Phi' = log10(k) + 2{\cdot}log10(L\infty) \quad (5)$$

Where: *k*= the growth rate (year^{-1}); L∞= the asymptotic length (cm).

The length at first maturation (L_{50}) was estimated by fitting a logistic model to the proportion of mature individuals per length class using Eq. 6:

$$P(L) = 1/[1+e^{-r(L-L50)}] \quad (6)$$

Where: P(L)P(L)P(L)= the proportion of mature individuals in a given length class; rrr= the steepness of the curve; L_{50}= the length at which 50% of the individuals are mature.

Total mortality (Z) was estimated using the linearized capture curve method. In this model, discussed in Pauly (1983, 1990), the frequency distribution data by length class and growth parameters obtained from a regression curve are used. The methodology for choosing the points on this curve corresponds to the length at which most specimens are vulnerable to fishing. The Eq. 7 for this method is expressed as:

$$ln(N) = a - Z{\cdot}t \quad (7)$$

Where: N= number of fish in each age (or length) class; t= age (or midpoint of the length class); Z= total mortality coefficient.

Natural mortality (M) was estimated using Pauly's (1983) model, relating the natural death of fish to water temperature as a function of growth, using Eq. 8.

$$Log(M) = -0.006 - 0.279{\cdot}Log(L\infty) + Log(k) + 0.4634{\cdot}Log(T)" \quad (8)$$

Where: *L∞* and *k*= von Bertalanffy growth parameters; M= natural mortality; T= average annual water temperature (27°C for the studied region), proposed by Pauly (1983).

To estimate fishing mortality, Eq. 9, described by Pauly (1983), was used.

$$F = Z\,(M+F) - M \quad (9)$$

Where: M= natural mortality; Z= total mortality.

The F/M interaction was used as an indicator of overfishing in the stock, which in this case is when the values exceed 1 (ICES, 2015).

All analyses were performed in R, with $p < 0.05$ considered statistically significant.

RESULTS

In the collections carried out between the years 2020 and 2021, a total of 105 specimens of red-bellied piranha (*P. nattereri*) was captured and analyzed, without determining the sexes. Total length (Lt) of the individuals ranged from 15.5 to 36 cm, with an average of 23.33 ± 3.42 cm. As for the total weight (Wt), a variation of 111.9 to 975 g was obtained, with an average of 464 ± 182.1 g. Stretches of the São Miguel River where the highest capture of *P. nattereri* occurred were the middle stretch (Point 2) and the mouth (Point 3), as shown in Table 1.

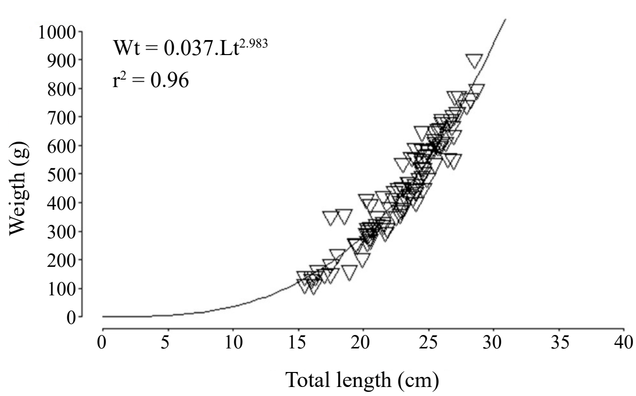
Table 1. Absolute capture frequency of red-bellied piranha (*Pygocentrus nattereri*) at each collection point in the São Miguel River, Rondônia state, Brazil.

Years/Months	2020					2021						
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July
Source (Point 1)	3			2			2					
Middle section (Point 2)		41			3			2			8	
Mouth (Point 3)			14			5						25

The mathematical model used for the length-weight relationship was of the potential type $Wt = 0.037 \cdot Lt^{2.983}$, and a highly coefficient of determination ($R^2 = 0.96$) was obtained between the variables, with the grouping of genders. This made it possible to determine the negative allometry, which showed a lower increment in weight than in length. The t-test ($t = 2.97$; $p = 0.05$) inferred that the length of the fish grows at a relatively higher rate than the weight (Fig. 2).

The growth parameters of *P. nattereri* were $L\infty = 29$ cm, $k = 0.55 \cdot year^{-1}$, $\Phi' = 2.29$ and $A_{0,95} = 5.2$ years. Estimates of the average length at first maturation (L_{50}) suggest that *P. nattereri* is able to reproduce at 1.6 year of age, when it reaches an average length of 17 cm (Table 2).

The probability of capture was estimated through experimental fishing, which showed a greater number of individuals captured after the length at first maturation (L_m). The capture length (L_c) and the average length (L_{av}) were above the L_m, with $L_c = 23$ cm. Fishing mortality (F) was calculated using Taylor's M (1958). The F/M interaction, used to verify the occurrence of overfishing, was $0.72 \cdot year^{-1}$ (Fig. 3a).



r^2: coefficient of determination; Wt: total weight; Lt: total lenght.

Figure 2. Length-weight relationship for red-bellied piranha (*Pygocentrus nattereri*) in the São Miguel River, Rondônia state, Brazil.

Table 2. Estimation of growth and mortality index of red-bellied piranha (*Pygocentrus nattereri*) populations in the São Miguel River sub-basin, Rondônia state, Brazil.

Growth index		
Asymptotic length (L_∞, cm)	29.00	
Average length (L_{av}, cm)	20.60	
Length at first maturation (L_m, cm)	17.10	
Capture length (Lc, cm)	23.00	
Years at first maturation ($year^{-1}$)	1.60	
Longevity ($A_{0,95}$, $year^{-1}$)	5.50	
Growth rate (k, $year^{-1}$)	0.55	
Mortality index		
	Methods	**Values**
Total mortality (Z $year^{-1}$)	Pauly (1983)	0.98
Natural mortality (M $year^{-1}$)	Pauly (1983)	1.90
Taylor (1958)	0.57	
Fishing mortality (F $year^{-1}$)	Z-M	0.41
Fishing mortality ($year^{-1}$)	F/M	0.72

Weight and length data for *P. nattereri* were fitted to the Chapman-Richard model (Pienaar & Turnbull, 1973) to obtain more robust population estimates, since no age data were collected for this species. This method allowed the derivation of population parameters based on the weight-length relationship and the verification of the species' performance in relation to the generated growth curve. The fit indicated a positive increase in growth, considered optimal for the species (Fig. 3b).

DISCUSSION

The system that encompasses the life cycle of a fish population is related to a characteristic biological and demographic profile, which is formed by a set of particular attributes, such as age, length of first sexual maturation, fertility, and mortality rates specific to each age group and type of social organization (Junk, 1984). In regions that

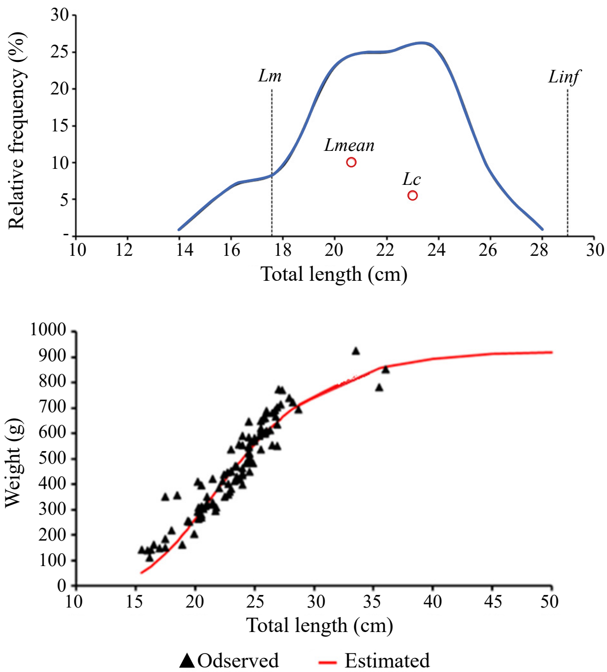


Figure 3. Graphical representations of dispersion. (a) Relative capture frequency of red-bellied piranha (*Pygocentrus nattereri*) (L_{inf}= L∞) and (b) growth curve of the Von Bertallanfy's model for *P. nattereri* captured in the São Miguel River, Rondônia state, Brazil.

are subject to flooding, seasonal changes occur in the proportions of the water body, in the number of habitats, in the physicochemical characteristics of the water and in the quality and quantity of available food resources (Bevilaqua et al., 2010; Junk, 1986).

In study conducted by Prudente (2012) with fish of the species *Serrasalmus gouldingi*, in the region of the lower Anapu River, between the Xingu and Tocantins rivers, in the Eastern Amazon, the fish had length values of between 9.1 and 29.4 cm, for males and females, and an average value of 15.5 ± 2.9 cm, which is similar to those in the current study (between 15.5 and 36 cm). However, in the study by Carvalho et al. (2021), in Lake Cajari in the Baixada Maranhense region, where specimens of *P. nattereri* were studied, the values of the length-weight ratio for females ($Wt = 0.03Lt^{2.98}$) and males ($Wt = 0.03Lt^{2.95}$) were similar to those found in the study by Prudente (2012) ($Wt = 0.037Lt^{2.98}$), which showed a negative allometry in all the comparisons, indicating that the fish developed more in length than in weight (Prudente, 2012). This reflected in results of the Student's t-test ($t = 2.97$; $p > 0.05$) which confirmed a significant difference in the isometric value (b = 3).

Sousa et al. (2013) studied fish of the species *Serrasalmus spilopleura*, in the lakes Jaiteua and São Lourenço of the Lago Grande complex, in the municipality of Manacapuru, in Amazonas state, Brazil. In the fish, they found length-weight ratio values of $Wt = 0.05 \cdot Lt^{2.87}$, indicating a negative allometry, which corroborates the data found for *P. nattereri* in the current study. Allometry is associated with the adaptation characteristic of species in relation to the environment in which individuals are found (Oliveira et al., 2022). Therefore, reproduction and growth are processes that compete for the same limited resources. This association was confirmed by Carvalho et al. (2021), who studied the allometry and reproduction of *P. nattereri* in Lake Cajari, in Maranhão state, Brazil. In general, all the energy obtained from food is stored in the body and used in tissue synthesis and during metabolic processes. Above all, it is used for development or reproduction depending on the age group (Carvalho et al., 2021).

In wild fish in their juvenile phase, all allocated energy is used for linear growth and development of somatic structures, thus triggering the investment in length, and characterizing negative allometry. During the adult phase, all the energy allocated is destined to the development of reproductive structures and to the storage of energy reserves that will be used during maturation and spawning, which characterizes the investment in body weight, reflected in the positive allometry. Thus, allometric variations occur according to the availability of resources and the life stages of the fish (Carvalho et al., 2021).

Pygocentrus nattereri is usually abundant in the environments it inhabits and is a key element for the environmental balance between trophic levels (Queiroz & Magurran, 2005). *Pygocentrus nattereri* has negative allometry, and changes its shape to a more elongated one, which facilitates its locomotion dynamics during the pursuit and capture of prey (Luz et al., 2015), thus increasing its body size, with minimal energy expenditure (Sainsbury, 1986). One of the parameters that is widely used to verify the state of animal welfare is the allometric condition factor (Kn). These temporal variations have been also used in the interpretation of changes in biological parameters such as nutritional aspects, fat accumulation, and gonadal development of fish species (Froese, 2006; Le Cren, 1951).

Analyzing the relationship between adult individuals and their length resulted in an estimate of the average size at first sexual maturation, in which 50% of the population are able to reproduce when they reach L_{50} = 17 cm. This result is similar to that found by Prudente (2012) for *Serrasalmus gouldingi*, with L_{50} = 16.13 cm for females and 12.24 cm for males, in populations found in the region of the lower Anapu River, between the Xingu and Tocantins Rivers, in Pará state, Brazil. In the study carried out by Carvalho et al. (2021), similar results to the current study were also found, with L_{50} = 14.3 cm, for fish from the Baixada Maranhense, in the Brazilian Amazon.

The variation in estimates of natural mortality (M) obtained using Pauly's (1980) method indicates M = 1.9·year^{-1} as a function of k, L∞ and T. However, when calculating Z using Pauly's (1983; 1990) method, and considering that most biological processes accelerate under conditions of high temperature, it may be an indication that the natural mortality of *P. nattereri* is also related to environmental temperature (Sparre & Venema, 1997). On the other hand, Taylor's (1958) method (M = 0.57·year^{-1}) relates natural mortality (M) to longevity ($A_{0.95}$), which is defined as the age at which 95% of the cohort would be dead if exposed only to natural mortality (M). Models for estimating growth parameters originated in marine species, which have slow growth and late maturity (Stergious, 2002); thus, for *P. nattereri*, a larger amount of data is needed in order to produce more robust estimates. The indicator used to check for overfishing, the F/M ratio, was below 1, with the value of 0.72. Therefore, there is no evidence of overfishing.

The population parameters of *P. nattereri*, with fast growth and lower natural mortality, characterize this species as an r-strategist, in a continuum as proposed by Jones (1976), corroborating what Ruffino and Isaac (1995) stated. It is recommended that such information on *P. nattereri* population dynamics be incorporated into management plans for the management of this resource.

According to Velasco-Hogan et al. (2021), rivers and reservoirs in a state of overfishing and greater fishing effort, *P. nattereri* tend to have a more elongated snout, greater distance between the eyes, and a less rhomboid body. In addition, there is a visible slowdown in body growth, and in fishing there is a predominance of small fish. *P. nattereri*, like many teleost fish, alternate their diets according to age and ontogenetic and phylogenetic scales. Some studies indicate body morphological changes as a result of these factors (Giesen et al., 2013; Schartl et al., 2019). Due to dietary restrictions, body morphology tends to be more elongated and less rhomboid in relation to the head (longer snout) and posterior body (reduced post-orbital region).

Tropical fisheries are generally multispecific and require management approaches that are adapted to the high. Therefore, an alternative for solving this problem is the use of fisheries management semi-quantitative methods. Ecological risk assessments as presented in the current study are the analysis of productivity and susceptibility. Pereira et al. (2023) used data from 3,211 questionnaires applied in various Amazonian sub-basins, to assess the vulnerability to overfishing of 37 commercially exploited fish species at seven fishing landing points in the Amazon. Vulnerability remained between 0.9 and 2.6, with *Brachyplatystoma rousseauxii*, *Brachyplatystoma filamentosum*, *Pinirampus pirinampu*, and *Zungaro zungaro* being the most vulnerable species ($V > 2.0$), and *P. nattereri* ($V > 2.0$), studied by Santos et al. (2016), also in all the sampled Amazonian sub-basins. Given the complexity of the interactions in regional fisheries, it is noteworthy that productivity susceptibility analysis has proven to be an efficient alternative for an initial overfishing risk assessment. A holistic approach, with new regulations or the improvement of current regulations, should have a positive impact on inventories, thus reducing the risk of overfishing and the potential loss of economic and social benefits for the region's population.

Given the factors mentioned above, it is suggested that studies be carried out to reexamine the post-transformational allometry of the body shape of *P. nattereri* from overexploited rivers and/or in times of a water crisis (intense drought).

CONCLUSION

Despite the unique hydrography of the studied region compared to most Amazonian ecosystems, local fluviometry remains a key factor influencing the biology of the red-bellied piranha (*P. nattereri*). Given its critical role as a top predator within the fish assemblage, variations in fluviometry may exert effects on the ichthyofauna of the São Miguel River. Furthermore, the data indicate that *P. nattereri* stocks in the study area are not overexploited, providing valuable insights for research institutions and management agencies.

These findings can support the development of sustainable management policies that take into account seasonal hydrological fluctuations, population dynamics, and habitat conservation, aiming to mitigate the impacts of overfishing and to maintain ecological balance in Amazonian aquatic ecosystems.

CONFLICT OF INTEREST

Nothing to declare.

DATA AVAILABILITY STATEMENT

The data will be available upon request.

AUTHORS' CONTRIBUTIONS

Formal Analysis: Dias, J.O. Sant'Anna, I.R.A.; **Investigation:** Dias, J.O., Sant'Anna, I.R.A.; **Methodology:** Dias, J.O., Dantas Filho, J.V.; **Writing – original draft:** Dias, J.O., Sant'Anna, I.R.A.;

Conceptualization: Sant'Anna, I.R.A.; **Data curation:** Bezerra Neto, E.B.; **Validation:** Bezerra Neto, E.B., Sousa, R.G.C.; **Visualization:** Bezerra Neto, E.B.; **Resources:** Bezerra Neto, E.B.; **Supervision:** Sousa, R.G.C.; **Project administration:** Sousa, R.G.C.; **Writing – review & editing:** Sousa, R.G.C., Dantas Filho, J.V.; **Funding acquisition:** Dantas Filho, J.V.; **Software:** Dantas Filho, J.V. ; **Final approval:** Dantas Filho, J.V.

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