



Population dynamics of the yellow piranha *Serrasalmus spilopleura* Kner, 1858 (Characidae, Serrasalminae) in Amazonian floodplain lakes

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ABSTRACT. Fish is the main source of protein in the Amazon and fishing is one of the most important sources of income for the Amazonian population. *Serrasalmus spilopleura* is a species that have been increasingly consumed by riverside communities, although it is only occasionally commercialized at regional markets. Therefore, this work sought to generate information about the population biology of *S. spilopleura* captured in floodplain lakes, Jaitêua and São Lourenço, in Manacapuru, Amazonas State. The population parameters were estimated by analyzing the distribution of the length frequency with the help of the ELEFAN I routine of the FISAT II program. The weight/length relationship was estimated by linear regression, longevity by Taylor's method, rate of natural mortality by Taylor's and Pauly's methods, and growth type by a t-test ($\alpha = 0.05$). 669 specimens of *S. spilopleura* were captured measuring between 7 and 22 centimeters. The estimated population parameters were: $k = 0.34 \text{ year}^{-1}$, $L_{\infty} = 23.10 \text{ cm}$, $t_0 = 0$, and $A_{0.95} = 9$ years. 7 cohorts were identified, Taylor $M = 0.33 \text{ year}^{-1}$ and Pauly $M = 0.98 \text{ year}^{-1}$. The weight/length relationship equation was $W_t = 0.051320.L_t^{2.8727}$, and negatively allometric growth. The information on the population parameters of *S. spilopleura* could be used to provide evaluation models for this fishery resource.

Keywords: growth, mortality, freshwater fish, weight/length relationship, ELEFAN.

Dinâmica populacional da piranha amarela *Serrasalmus spilopleura* em lagos de várzea

RESUMO. O pescado é a principal fonte de proteína e uma das mais importantes fontes de renda da população na Amazônia. *Serrasalmus spilopleura* é uma das espécies consumidas pelos ribeirinhos, embora seja ocasionalmente comercializada nos mercados e feiras da região. Portanto, o trabalho propõe gerar informações da biologia populacional de *S. spilopleura* capturadas nos lagos Jaitêua e São Lourenço na região de Manacapuru, AM. Os parâmetros populacionais foram estimados através da análise de distribuição de frequência de comprimento com o auxílio da rotina ELEFAN I do programa FISAT II. A relação peso-comprimento foi estimada por regressão linear e verificado o tipo de crescimento pelo teste-t ($\alpha = 0,05$), a longevidade pelo método de Taylor e a mortalidade natural pelos métodos de Taylor e Pauly. Foram capturados 669 exemplares de *S. spilopleura* variando entre 7 e 22 cm de comprimento padrão. Os parâmetros populacionais estimados foram: $k = 0,34 \text{ ano}^{-1}$, $L_{\infty} = 23.10 \text{ cm}$, $t_0 = 0$, $A_{0.95} = 9$ anos, sete coortes identificadas, Taylor $M = 0,33 \text{ ano}^{-1}$, Pauly $M = 0,98 \text{ ano}^{-1}$, a equação da relação peso/comprimento foi $W_t = 0,051320.L_t^{2.8727}$ e o tipo de crescimento alométrico negativo. As informações geradas sobre os parâmetros populacionais de *S. spilopleura* poderão ser utilizados para subsidiar modelos de avaliação desse recurso pesqueiro.

Palavras-chave: crescimento, mortalidade, peixes de água doce, relação peso/comprimento, ELEFAN.

Introduction

In flooded areas of white water rivers that comprise the Solimões-Amazonas system, the rich and abundant fish fauna supports the fishing demands for commercially important fish populations, making fishing to be considered one of the most important and traditional economic activities in the region (BATISTA; PETRERE-JÚNIOR, 2003). The abundance and richness of fish justify its high consumption, 500 g day⁻¹ in rural areas (BATISTA, 2004). Although the composition of fish caught varies

from year to year, there is a group of 31 species that are responsible for the majority of the volume of commercialized fish in the Amazon (BATISTA; PETRERE-JÚNIOR, 2003). Furthermore, the data indicate that over the years the species not usually part of the catch have become commercialized and consumed. This is true for *Serrasalmus spilopleura*, commonly known as yellow piranha, a resident species and an important predator typical of lentic environments. Yellow piranhas are frequently captured in lakes, both in open water (SAINT-PAUL et al.,

2000) and aquatic vegetation (PETRY et al., 2003; SÁNCHEZ-BOTERO et al., 2003). In addition to being a source of animal protein for riverside populations, this specie is beginning to be exploited as an ornamental fish (MACIEL et al., 2011).

In the Amazon, fishing and biological knowledge of various species that are caught is still limited when compared with the richness of fish species and the levels of biological and economic production of fishery resources (BARTHEM; FABRÉ, 2004). Important information about population parameters have been generated for various fish species in the Amazon (PAULY, 1994; BARTHEM; FABRÉ, 2004; PENNA et al., 2005; SILVA; STEWART, 2006; SOARES et al., 2009; CAMPOS; FREITAS, 2010; PRESTES et al., 2010); however, for *S. spilopleura*, growth parameters have been estimated only in other regions of Brazil, such as in the Bariri and Barra Bonita dams of the Tietê river in São Paulo State (RODRIGUES et al., 1978), the upper Paraná river, and the Itaipú reservoir in Paraná State (AGOSTINHO; MARQUES, 1994; ANGELINI; AGOSTINHO, 2005). In the Amazon, only studies on the feeding (MÉRONA; RANKIN-DE-MERONA, 2004) and reproduction (HUBERT et al., 2006; MACIEL et al., 2011) of yellow

piranha in floodplain lakes have already been performed.

In this context, this study sought to estimate the growth, mortality and the weight/length relationship of the yellow piranha in Central Amazonian floodplain lakes. This information can be used for decision making on the sustainable management of *S. spilopleura* in floodplain lakes.

Material and methods

Fish were caught monthly from July 2006 to April 2008 in Jaitêua Lake ($03^{\circ}13' S$ and $60^{\circ}44' W$) and São Lourenço Lake ($03^{\circ}17' S$ and $60^{\circ}43' W$), from the Lago Grande lacustrine complex in Manacapuru, Amazonas State (Figure 1). Fishing occurred in open water and flooded forest regions with groups of nets having mesh sizes varying from 30 to 120 mm between opposite knots. These nets were exposed for 24 hours and inspected every 6 hours. In the field, fish were preserved in 10% formaldehyde and taken to the laboratory, where they were transferred to 70% alcohol. In order to obtain the total weight, an analytical scale accurate to 0.001 g was used. The standard length of fish was determined by using an ichthyometer accurate to 0.1mm.

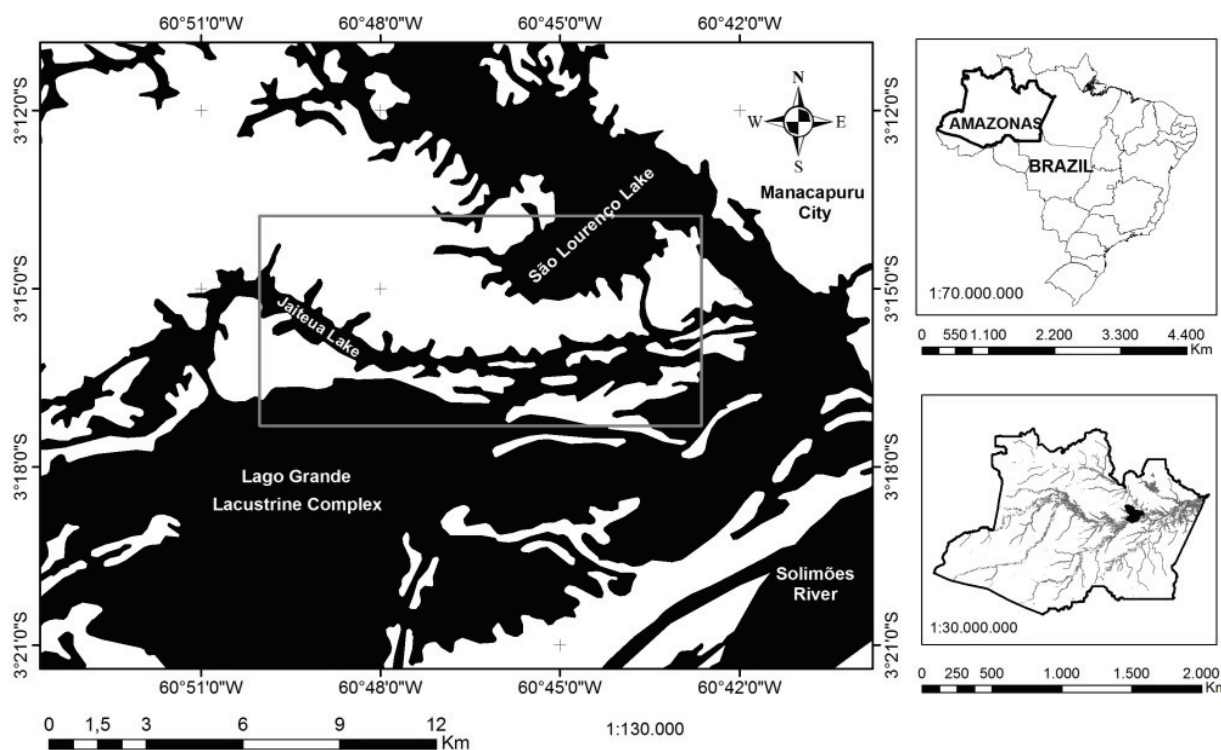


Figure 1. Location of Jaitêua and São Lourenço lakes (grey box) in the Lago Grande lacustrine complex, Manacapuru, Amazonas State, during the flood period.

The growth curve was obtained by means of the von Bertalanffy model, given by $L_t = L_\infty(1 - e^{-k(t-t_0)})$, where: L_t = length at age t ; L_∞ = maximum theoretical length, k = growth rate and t_0 = theoretical age at length zero. The growth parameters L_∞ (maximum theoretical length) and k (growth rate) were estimated using ELEFAN I method (Electronic Length Frequency Analysis) inserted in the computational package of FISAT (FAO – ICLARM Stock Assessment Tools) (GAYANILO et al., 1996; GAYANILO; PAULY, 1997), based on the distribution of the monthly length frequencies (1 cm classes).

Using the routine 'scan of k-values', various experiments were conducted in order to obtain better adjustments (adherence) of the growth curves combining the resulting values of k , L_∞ , and the number of cohorts that passed through the modal peaks (ANGELINI; GOMES, 2008). In these analyses, since t_0 is not a biological parameter, but rather only a mathematical mechanism used to better adjust the growth curve (MOREAU, 1987), it was set to zero.

Longevity ($A_{0.95}$), defined as the maximum age at which 99% of the cohort would die by natural means only, was estimated from the formula proposed by Taylor (1958) $A_{0.95} = t_0 + 2.996/k$ (SPARRE; VENEMA, 1997), where t_0 = theoretical age at length zero and k = growth rate.

Natural mortality (M) was estimated by Taylor's method (1958) $M = -\ln(1-0.95)/A_{0.95}$, where $A_{0.95}$ is the age at which 99% of the cohort would be dead as a result of natural means (SPARRE; VENEMA, 1997). It was also estimated by the empirical formula proposed by Pauly (1980) $\log(M) = -0.0066 - 0.279 \log(L_\infty) + 0.6543 \log(k) + 0.4634 \log(T^\circ)$, which relates the growth parameters (L_∞ and k) with the temperature of the lake water (T°), where L_∞ = theoretical maximum length, k = growth rate and T° = average temperature, in $^\circ\text{C}$, of the water surface in which the species was captured. The average temperature estimated for the entire collection period was 30°C .

The weight/length relationship describes the modifications in body weight in accordance with the increase in length and was estimated by means of the following expression: $W_t = aL_t^b$, where W_t = total weight, L_t = standard length, 'a' = regression constant related to the degree of fattening and 'b' = allometric coefficient, which is related to the type of fish growth and generally varies between 2.5 and 4.0 (FEITOSA et al., 2004). The type of growth was verified through the t-test where: $H_0: b = 3$ (isometric growth) and $H_1: b \neq 3$ (allometric growth) ($\alpha = 0.05$) (ZAR, 1996).

Results

669 specimens of *S. spilopleura* were captured with a standard length varying from 7 to 22 cm (mean =

11.14 ± 2.08 cm) and a total weight of 7 to 172 g (mean = 56.95 ± 32.34 g).

The estimates of the growth parameters using the distribution of length frequency for *S. spilopleura* were: $k = 0.34 \text{ year}^{-1}$, $L_\infty = 23.10$ cm, Von Bertalanffy's growth equation estimated $L_t = 23.10(1 - e^{-0.34(t-t_0)})$, $A_{0.95} = 9$ years and $M = 0.33 \text{ year}^{-1}$ and 0.98 year^{-1} by Taylor's (1958) and Pauly's (1980) methods, respectively.

The equation obtained through the total weight (W_t) and standard length (L_t) relationship was $W_t = 0.051320.L_t^{2.8727}$, indicating a negative allometric growth $b < 3$ ($t_{\text{cal}} -39.1582 < t_{\text{tab}} 1.645_{(0.05)669}$; $p < 0.05$), which explains 91% of the data (Figure 2). The growth curves of the cohorts obtained using the length frequency data for *S. spilopleura* estimated by the ELEFAN I method can be observed in Figure 3. Seven cohorts were identified and the input of young specimens occurred between the months of February and March.

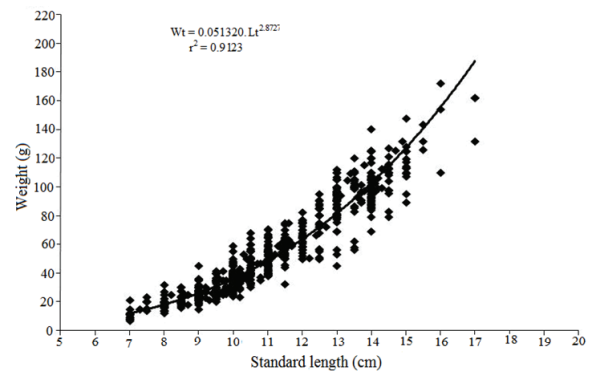


Figure 2. Weight/length relationship of the *S. spilopleura* specimens captured in the Jaitêua and São Lourenço lakes in the Lago Grande lacustrine complex, Manacapuru, Amazonas State.

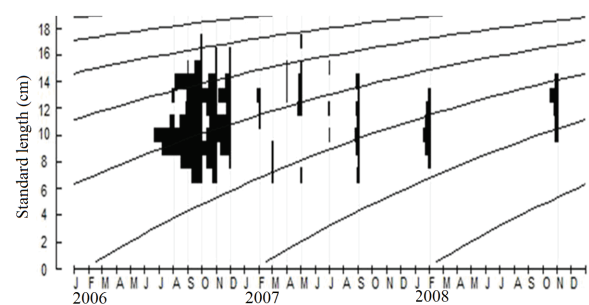


Figure 3. Growth curve fitted to the *S. spilopleura* cohorts, obtained by means of the ELEFAN I system (FISAT computational package), captured in the Jaitêua and São Lourenço lakes in the Lago Grande lacustrine complex, Manacapuru, Amazonas State.

Discussion

The most frequently used equation to predict the fish growth is that of von Bertalanffy (PENNA et al., 2005; MATEUS; PENHA, 2007; ANGELINI; GOMES, 2008). When the calcified structures of fish are not available or a reading of growth rings is unclear,

the use of indirect methods is suggested (Modal progression by ELEFAN I) for the estimate of the variables in von Bertalanffy's equation (k , L_{∞} and t_0). The growth parameters of many Amazonian fish, such as tambaqui, *Colossoma macropomum* (PENNA et al., 2005), red piranha *Pygocentrus nattereri* (BEVILAQUA; SOARES, 2010), curimatã *Prochilodus nigricans*, aracu *Schizodon fasciatum*, surubim-lenha *Pseudoplatystoma tigrinum*, surubim-tigre *P. fasciatum*, dourada *Brachyplatystoma flavicans*, mapará *Hypophthalmus marginatus* (RUFFINO; ISAAC, 1995), tucunaré *Cichla monoculus* (RUFFINO; ISAAC, 1995; CAMPOS; FREITAS, 2010), and sardinhas *Triporthus albus*, *T. angulatus* and *T. auritus* (PRESTES et al., 2010), were estimated using indirect methods based on the analysis of length frequency. However, two essential conditions for the utilization of this method are: 1) that the species presents total spawning and 2) various length classes are present in the sample.

In the Jaitêua-São Lourenço lakes, *S. spilopleura* was represented in all of the length classes, with the variations of these classes in accordance with the minimum and maximum values described for this species in other studies (JÉGU; SANTOS, 1988). In the analysis of the growth curves, it was possible to identify 7 cohorts of the population of *S. spilopleura*, with the input period of young specimen between February and March, once a year. This result agrees with studies performed in the Jaitêua and São Lourenço lakes (MACIEL et al., 2011), where *S. spilopleura* was described as having total spawning, reproducing between December and May, during the rising water period. Therefore, the yellow piranha meets the two necessary requirements for the use of indirect methods.

The growth rate k determines the type of growth and the velocity at which fish approaches L_{∞} and is related to the metabolic rate (PAULY, 1980; KING, 1995). The comparison between the estimated k -value in this study ($k = 0.34 \text{ year}^{-1}$) for combined sexes and the estimated k -values for Rodrigues et al. (1978) ($k = 0.26 \text{ year}^{-1}$) for females, Agostinho and Marques (1994) ($k = 0.21 \text{ year}^{-1}$) for females and ($k = 0.17 \text{ year}^{-1}$) for males, and Angelini and Agostinho (2005) in the Itaipú reservoir ($k = 0.55$) and the upper Paraná river ($k=0.34 \text{ year}^{-1}$), both for combined sexes, indicated differences between the k -values among males, females, combined sexes and the environment that fish were caught.

The result estimated of k in this study for combined sexes is similar to that found by Angelini and Agostinho (2005) in the upper Paraná river. However, Lowe-McConnell (1999) mentioned that fish of the genus *Serrasalmus* present differences in the growth rate between the sexes. Agostinho and Marques (1994) observed that *S. spilopleura* males, besides the energy spent during maturation and spawning, care for their

offspring, showing a smaller growth rate than females. Additionally, species of freshwater fish are considered generalist, feeding on items available in the environment. These conditions influence the calculations for the k -values, sometimes with very high variations for the same species (LIZAMA; TAKEMOTO, 2000).

The values for the maximum theoretical length may be influenced by both food supply and population density (SPARRE; VENEMA, 1997). In the present study, the value of maximum theoretical length ($L_{\infty} =$ standard length's 23.1 cm) calculated for *S. spilopleura* is similar to the maximum values described by Jegú and Santos (1988), standard length's 25.0 cm. However, there is a mathematical interaction between the parameters involved, with k being dependent on the variation of L_{∞} (KING, 1995; SPARRE; VENEMA 1997). Thus, since the k -value was slightly high, the tendency of L_{∞} was to lower, a pattern that has already been described for other species in the Amazon (RUFFINO; ISAAC, 1995; SOARES et al., 2009).

The value of natural mortality rate estimated for *S. spilopleura* by Pauly's method (1980) was high ($M = 0.98 \text{ year}^{-1}$) and that estimated by Taylor's method (1958) was low ($M = 0.33 \text{ year}^{-1}$). Pauly (1994) and Bevilaqua and Soares (2010) have estimated the natural mortality rate for *P. nattereri* utilizing Pauly's formula (1980), showing that the greater the temperature of the water in which the species resides, the greater the value of the natural mortality rate. Agostinho et al. (1997) verified that piranhas attack their prey with greater frequency under higher temperatures. The same authors reported that piranhas of the genus *Serrasalmus*, under the influence of temperature, perform cannibalism, influencing the calculations of the natural mortality rate. Sparre and Venema (1997) stated that Taylor's method for calculating the death rate uses the value of longevity, that is, the longer a cohort survives, the smaller the natural death rate. Thus, natural death may change with age, population density, food supply, abundance of predators, water temperature, fishing pressure, size, disease and parasites (CERGOLE; VALENTINI, 1994).

The value of the 'b' constant indicates the type of body growth of fish where: if 'b' is equal to 3, the growth is isometric (the increment in weight accompanies the increment in length); if it is greater than 3, it is positively allometric (the increment is greater in weight than in length); and if lower than 3, it is negatively allometric (the increment in weight is lower than in length) (GURKAN; TASKAVAK, 2007).

In this study, the value estimated for the b constant was 2.8727, for combined sexes, statistically lower than 3, indicating a negative allometric growth. Some values for this constant for *S. spilopleura* were calculated for combined sexes by Agostinho and Marques (1994)

($b = 3.0852$) in the upper Paraná river/Paraná State and Raposo and Gurgel (2001) ($b = 3.249$) in the Entremoz lake/Rio Grande do Norte State. Moreau (1987) registered that fish of the same species that live in different places show variations in the values of the b constant. This may be caused by environmental variations, nutritional conditions, difference in sex, and growth phases.

Conclusion

Serrasalmus spilopleura, according to the parameters established by Winemiller and Tarphorn (1989) and Winemiller (1995), can be defined as a k -strategist species. This because this fish presents (i) resident species characteristics (non-migratory); (ii) a high maximum theoretical length value ($L_{\infty} = 23.1$ cm); (iii) low growth rate ($k = 0.34$ year⁻¹); (iv) long lifespan for a cohort ($A_{0.95} = 9$ years); (v) low natural mortality rate related to longevity ($M = 0.33$ year⁻¹) and (vi) high natural mortality rate related to k , L_{∞} and to the water temperature ($M = 0.98$ year⁻¹).

However, studies on the biology of the yellow piranha and its interactions with the environment are further required, especially because the yellow piranha is a resource that has begun to appear in the catch and in ornamental fish market. The information about growth and mortality parameters can provide models for the conservation and use of this fishery resource in these lakes.

Acknowledgements

We thank to MCT/CNPQ/PPG7, FINEP/CTPetro, and Project PIATAM for financial support, to members of the Fish Bioecology Laboratory at the National Institute for Amazonian Research (INPA) for help in collecting the fish and processing the material, and the technicians Valter do Santos Dias, João de Sousa Pena and Francisco da Fonseca (INPA) for substantial contribution during the field work, which was only possible as a result of their invaluable experiences and dedication.

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Received on January 16, 2012.

Accepted on July 27, 2012.

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