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Aging and growth parameter from the *Piaractus mesopotamicus* (pacu) from the Cuiabá river, Mato Grosso, Brazil

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ABSTRACT. This study has aims to determine the age and to estimate the growth parameters using scales of the species. Individuals of *Piaractus mesopotamicus* (Holmberg, 1887) used in this study were captured in the commercial fishery conducted in the region, along the year 2006. The model selected to express the growth of the species was the von Bertalanffy Sl= Sl∞*[1-exp$^{-k(t-to)}$]. To determine if scales are suitable for studying the growth of pacu, we analyzed the relation between standard length (Sl) and the radius of the scales through linear regression. The period of annuli formation was determined analyzing the variations in the marginal increment and evaluating the consistency of the readings through the analysis of the coefficient of variations (CVs) for the average standard lengths of each age (number of rings) observed in the scales. The relationship between Ls of the fish and the radius of the scales showed that scales can be used to study the age and growth of *P. mesopotamicus* (R= 0.79). CVs were always below 20%, demonstrating the consistency of the readings. Annuli formation occurred in February, probably related to trophic migration that occurs in this month in the region. Equations that represents the growth in length obtained for *P. mesopotamicus* are Sl=50.00*[1-exp$^{-0.18(t-(-3.00)}$] for males and Sl=59.23*[1-exp$^{-0.14(t-(-3.36)}$] for females. The growth parameters obtained in this study were lower compared to other studies previously conducted for the same species and can related to overexploitation that species is submitted by fishing in the region. These values show also that females of pacu attain greater asymptotic length than males that growth faster.

KEYWORDS. Growth rings, scales, von Bertalanffy model, Ford-Walford.

RESUMO. Estimativas dos parâmetros de crescimento e idade do *Piaractus mesopotamicus* (pacu) do rio Cuiabá, Mato Grosso, Brasil. Este estudo tem como objetivo determinar a idade e estimar os parâmetros de crescimento usando as escamas da espécie. Esta informação pode ser usada em outros estudos sobre dinâmica de estoques da espécie na área estudada. Os indivíduos do *Piaractus mesopotamicus* (Holmberg, 1887) usados nesse estudo foram capturados na pesca comercial, desenvolvida na região durante o ano de 2006. O modelo escolhido para analisar o crescimento da espécie foi o de Von Bertalanffy (Cp= Cp∞*[1-exp$^{-k(t-to)}$]. Para saber se as escamas são apropriadas para estudos de crescimento do pacu, nós analisamos a relação entre o comprimento padrão (Cp) e o raio das através de regressão linear. O período de formação dos anéis foi determinado analisando as variações no incremento marginal e a consistência das leituras foi avaliada através da análise do coeficiente de variação (CVs) do comprimento padrão médio para cada idade (número de anéis) observado nas escamas. A correlação entre o Ls do peixe e o raio das escamas mostrou que as escamas podem ser utilizadas para estudos de crescimento do *P. mesopotamicus* (R= 0.79). Os CVs foram sempre abaixo de 20% demonstrando consistência nas leituras. A formação dos anéis ocorreu em fevereiro provavelmente relacionada com a migração trófica que ocorre neste mês na região. As equações que representa o crescimento em comprimento obtidas para o *P. mesopotamicus* são: Cp=50.00*[1-exp$^{-0.18(t-(-3.00)}$] para machos e Cp=59.23*[1-exp$^{-0.14(t-(-3.36)}$] para fêmeas. Os parâmetros de crescimento encontrados neste estudo foram mais baixos quando comparados com outros estudos para a mesma espécie realizados anteriormente e pode estar relacionado com "overexplotation" pela pesca que a espécie é submetida na área. Esses valores mostram ainda que as fêmeas do pacu atingem comprimentos assintóticos maiores que os machos que crescem mais rápido.

PALAVRAS-CHAVE. Marcas de aposição, escamas, modelo de von Bertalanffy, Ford-walford.

We know that all models used in the management of fishery require not only biomass of the stock but also the age structure, whereas growth parameters are used in the estimation of fish stocks (Araya & Sverlij, 1999). They are fundamental components of most present-day fisheries management decisions (Campana, 2001), however, age determination of fish in tropical regions is a challenge, given the fact that growth rings are not as evident as in temperate regions, where seasonal variation of temperature and luminosity are more conspicuous (Santos & Barbieri, 1993). Despite of the difficulties of this type of study (See Curtis, 1934 for details), Ferreira & Russ, 1994; Fernandes *et al.*, 2002; Dei Tos *et al.*, 2010; Francisco *et al.*, 2011, also affirmed that age structure and growth parameters are fundamental components in management decisions specially in the area studied (tropical regions). According Ferreira & Russ, 1994, the fish diversity is high, particularly the Characiformes and Siluriformes. Resende *et al.* (1996) discussed the great economic importance of them in the area studied.

Although a the importance of *P. mesopotamicus* in the fisheries in the Pantanal is great, basic information on the biology of the species are still not available, fact that difficult any assessment of its stocks and management actions. So, this study aims to determine the age and estimated the growth parameters of the von Bertallanfy model through readings of marks in scales of pacu. After, we analyzed the periodicity in ring formation and we used the coefficient of variation of mean standard length for each class to validate it.

MATERIAL AND METHODS

Study area. Individuals of *P. mesopotamicus* were collected in the Cuiabá River, a tributary of the Paraguay River and Manso River, in the stretch under the influence of APM-Manso Reservoir (Fig. 1). This area is located above the Pantanal of Mato Grosso in the Mid-west region of Brazil. The Pantanal begins just after the municipalities of Cuiabá and Várzea Grande, where the Cuiabá River begins to increase in size (OLIVEIRA *et al.*, 2005). Following the longitudinal gradient of the studied stretch (reservoir – upper part of the Pantanal) (Fig. 1), we divided it in nine fishing areas (border of municipalities), as follow: Manso Reservoir, Chapada dos Guimarães, Nobres, Rosário Oeste, Acorizal, Cuiabá, Várzea Grande, Santo Antonio de Leverger and Barão de Melgaço.

The reservoir is located in the geographical coordinates 16°32’-16°40’S and 54°40’-55°55’W, near the National Park of Chapada dos Guimarães. It was filled in 1999 and inundated a large area of the Manso River and the lower parts of the rivers Casca, Palmeiras and Quilombo. The APM-Manso reservoir is inserted in the municipalities of Chapada dos Guimarães and Nova Brasilândia and has an area of 42.700 ha in its maximum water level. The climate in the region is tropical with annual mean air temperature ranging between 22°C and 32°C, and the average annual rainfall between 1100 mm and 1200 mm (HASENACK *et al.*, 2003).

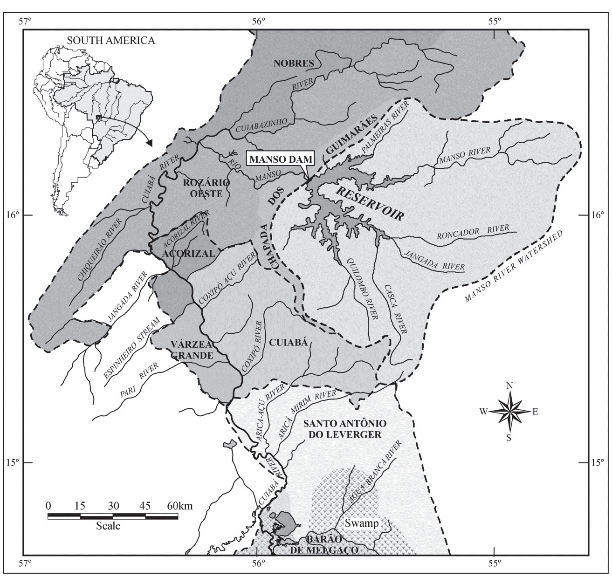

Fig. 1. Map of the the area where the scales were collected, Mato Grosso, Brazil.

Sampling procedure and data analysis. Individuals of *P. mesopotamicus* (606 individuals; 253 males and 353 females) were captured in the commercial (artisanal) fisheries conducted in the region (Manso Reservoir to the upper part of Pantanal), from January to December of 2006. In each of the nine fishing areas a detailed analysis of the captured fish was performed. The bone structure chosen was scales, collected in region located under the pectoral fin of each fish. These were removed and placed in envelopes including collector name, location of capture and number of the individual. For every fish, it was measured the standard length (Sl; cm), total weight (Wt; g.), and determined their sexes.

In laboratory, scales were cleaned and mounted between glasses slides following VAZZOLER *et al.* (1982) and had their radius measured. To investigate if the scales can be used to study the growth of pacu, we analyzed the relation between the standard length of the fish and the radius of the scales, through linear regression. The age rings were identified under stereomicroscope with micrometric lens. A complete and well-defined translucent zone was considered to be a growth rings or *annulus* (CASSELMAN, 1983). We conducted three readings of all scales and only the ones in which the number of growth rings was the same in two readings were included in the analysis.

Before conducting the other analysis, we have to verify if males and females grow similarly. To evaluate that, we calculated the total weight (Wt) x standard length (Sl) relationship for each sex through the methods proposed by (LE CREN, 1951), using expression:

$Wt = a * Sl^b$, where: Wt = total weight (g); Sl = standard length (cm); a = intercept; b = slope.

To verify if males and females of *P. mesopotamicus* presented different length x weight relationship, we performed an ANCOVA (Sl log10 and Wt log10 transformed to meet the assumption of linearity), using the software Statistica 7.1 (STATSOFT Inc., 2005). First we tested the assumption of parallelism of the ANCOVA (same slope). If not met, we conducted a separate-slope model analysis.

After confirming if sex has to be dealt together or separated, the consistency of the readings was evaluated through the analysis of the coefficient of variations (CVs) for the standard lengths average of each age class observed in the scales (LAI *et al.*, 1996).

The period of annuli formation was determined by marginal increment analysis, which may be considered a method to validate the age observed in a bone structure (proposed by LAI *et al.*, 1996), as follow:

$$I = \frac{R - R_i}{R_i - R_{i-1}} * 100$$

where: R: distance between the focus or nucleus and the edge of the scales (scale radius); R_i: distance between the last annuli and the edge of the scale; R_{i-1}: distance between the penultimate annuli and the edge of the scale.

The model selected to express the growth of *P. mesopotamicus* was the von Bertalanffy (BERVERTON & HOLT, 1957), fitted using the Ford-Walford transformation (WALFORD, 1946). This transformation was selected because results can be compared with other studies on the same species in other regions. After estimating the parameters k (growth rate) and Sl_∞ (asymptotic standard length), it was possible to determine the growth curve in length (K and Sl_∞ are the parameters of the von Bertallanfy model), described by the expression:

$Sl = Sl_\infty [1-e^{-k(t-to)}]$, where: Sl = standard length of the individuals with age "t" (cm); Sl_∞ = maximum standard (asymptotic) length that individuals can achieve (cm); e = neperian logarithm; k = parameter related to growth rate ($year^{-1}$); t = age of individuals (years); t_o= age at which the individual would have had size equal zero.

The parameter t_o was estimated using the expression presented in Vazzoler (1981). To obtain the growth curve in weight, we solved the length x weigh relationship for the asymptotic length (Sl_∞), estimating the asymptotic total weight (Wt_∞).

Then, we determined the equation which represents the growth in weight of the species, using the direct method described by Antoniutti *et al.*, 1985 and also used by Ambrósio *et al.*, 2003, as follow:

$Wt = Wt_\infty * [1-exp^{-k(t-(to)}]^b$, where: Wt = total weight; Wt_∞ = asymptotic total weigh; K and t_o = parameters of the von Bertallanfy equation; b= slope of the relationship between total weight and standard length.

RESULTS AND DISCUSSIONS

In this study, the maximum of seven growth rings were found in the scales of males and females. However, individuals with 3 and 4 rings in the scales were more abundant (totaling 450 individuals).

The choice of the most appropriate bone structure to estimate age is not an easy task. To evaluate if the structure can be used, we must take into account the degree of accuracy required regarding the age estimation and the phase of the life cycle to be studied (Morales-Nin & Pantifili, 2001). It should also be considered that the growth increments are easily distinguishable and identifiable, have constancy in their periodicity and present the same synchronicity in any population. In this study, scales were chosen because their preparation, collection, and analysis are easier; their removal also does not require sacrifice of the animal (Casselman, 1983; Isely & Grabowski, 2007). In our case, the removal of the scales did no alter the appearance of the fish to be sold on local markets. In addition, the linear relationship between the standard length of fish (Sl) and the radius of the scale was significant (F = 949.3; p<0.01) and the Pearson correlation was equal 0.79. The anti-log model that describes this relationship is:

$Sl = 0.08*8.7^X$. Thus, these results show that the scales of *P. mesopotamicus* can be used to study its age because as the fish grows, the scales also grow proportionally, indicating that marks in the scales can be assigned to growth rings.

The assumption of parallelism for the ANCOVA was not met ($p < 0,05$), indicating that the slopes of the length * weight relationship are different between sexes. Then, we conducted the separate-slope model analysis (Fig. 2). The anti-log models that describe this relationship are: $Wt = 0.186 * Sl^{2.54}$ (R= 0.91) for males and $Wt = 0.093 * SL^{2.74}$ for females (R= 0.92). This relationship allows an estimate of the weigh from length and vice-versa. According Le Cren, 1951, the values of "b" in fishes vary between 2.5 and 4.0. So, the values found for *P. mesopotamicus* in Cuiabá River are within these values. Differences in growth of males and females are well reported in the literature; females grew faster and get greater sizes in several fish species (Vazzoler, 1996), with purpose to maximize egg production (Wootton, 1990).

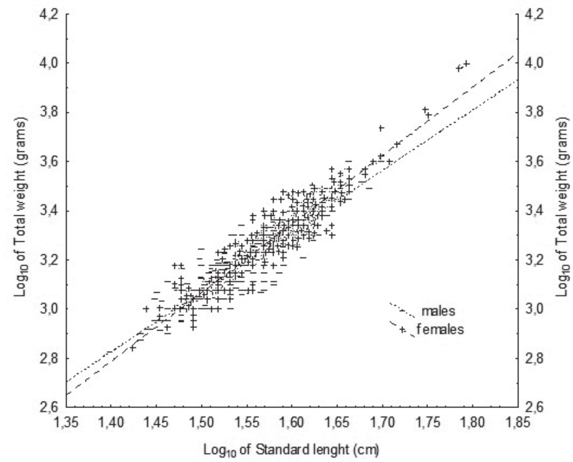

Fig. 2. Graphical representation of the Log_{10} of total weight and Log_{10} of standard length for males and females of *Piaractus mesopotamicus* (Holmberg, 1887) collected in Cuiabá River, state of Mato Grosso, Brazil, in 2006.

In all studies of age and growth, it is mandatory to validate growth rings, to obtain unbiased estimates of the parameters for the von Bertalanffy model (Casselman, 1983; Cyterski & Spangler, 1996; Jepsen *et al.*, 1999; Francisco *et al.*, 2011). In the review of Dei Tos *et al.*, 2010, it is show that 52.9% of the aged species of South America did not have their data on age validated as recommended by Campana (2001). Dei Tos *et al.* (2010) argument that this lack of validation is probably because, for the fish of the Neotropical region, it requires the application at least two methods. Most studies analyzed by the same authors, validated growths rings using the mean length of the fish with the same number of rings along time (19.6%), followed the analysis of marginal increment (18.3%).

We know that the process of estimating age incorporates biases associated with the non-formation of rings as fish grow, and these biases can lead to under or overestimated ages (Campana, 2001). This author also alert the existence of subjectivity in the estimates of age or accuracy [(interpretation of the numbers of rings and precision (numbers of fish studied)]. Thus, to evaluate these problems, we used the coefficient of variation (CV) of the standard length of fish with the same number of rings. In this study, values of CV were considered low (below 20%; Tab. I) attesting the consistency of the readings (number of rings in the scales), and reinforcing that scales can be used to estimate age and growth parameters of *P. mesopotamicus* (Witherel & Burnett, 1993). Campana (2001) also affirms that CVs are a statistically sound measure of aging precision in fish, but he calls attention because CV may be influenced by the species, the bone structure analyzed, as well as the reader.

Tab. I. Sample size (N), mean standard length (Ls, cm) for each age group and coefficient of variation (CV) of the mean standard length observed for each ring, for males and females of pacu *Piaractus mesopotamicus* (Holmberg, 1887) collected in 2006 in Cuiabá River, state of Mato Grosso, Brazil.

Machos				Fêmeas			
Idade	N	Ls médio	CV	Idade	N	Ls médio	CV
1	5	24.64	15.14	1	4	27.50	15.14
2	35	30.89	7.21	2	29	30.80	7.21
3	117	33.79	9.73	3	124	34.90	9.73
4	74	35.97	8.47	4	131	38.59	8.47
5	19	37.85	10.43	5	58	41.67	10.43
6	1	39.8	---	6	4	43.60	---
7	2	42	13.47	7	3	45.10	13.47

The least average of the marginal increment in the scales occurred in February 2006, indicating that one ring is formed annually (Fig. 3). The formation of only one growth ring is considered common for fish from the Neotropical region (Ambrósio *et al.*, 2003; Francisco *et al.*, 2011).

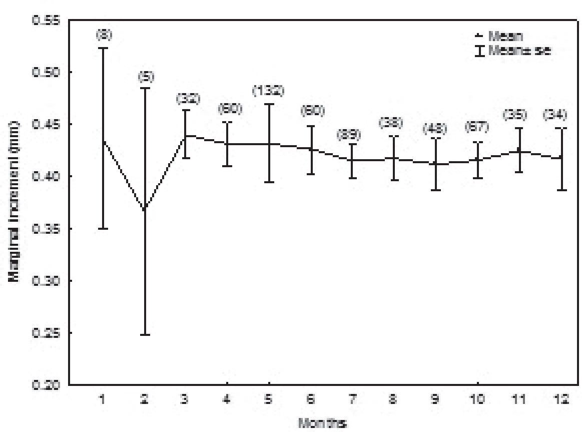

Fig. 3. Monthly variation in the mean marginal increment ± standard error (SE), observed in scales of *Piaractus mesopotamicus* (Holmberg, 1887) collected in 2006 in Cuiabá River, state of Mato Grosso, Brazil (numbers in bracket are sample size for each month).

The formation of rings in the Neotropics is usually associated with spawning (Girard *et al.*, 2003; Feitosa *et al.*, 2004). Dei Tos, *et al.* (2010) found the same explanation for ring formation in 40.7% of the studies they analyzed. During this period, species allocate energy for gonadal maturation, migration towards appropriate habitats for spawning. However, other factors may affect fish growth, such as pluviometric level (Cutrim & Batista, 2005), temperature and variation in rainfall (Mateus & Petrere Jr, 2004; Araya *et al.*, 2008). For *P. mesopotamicus* we determined that growth rings are formed in February and they appear to be related to the trophic migration in the region, which usually occurs in February (Fig. 3), as already discussed by Peixer *et al.* (2007) studying the same species below the study area.

Females presented greater asymptotic length than males (59.23 cm and 50.00 cm, respectively). However, the growth rate (K) presented opposite tendency (0.14 $year^{-1}$ for females and 0.18 $year^{-1}$ for males (Fig. 4).

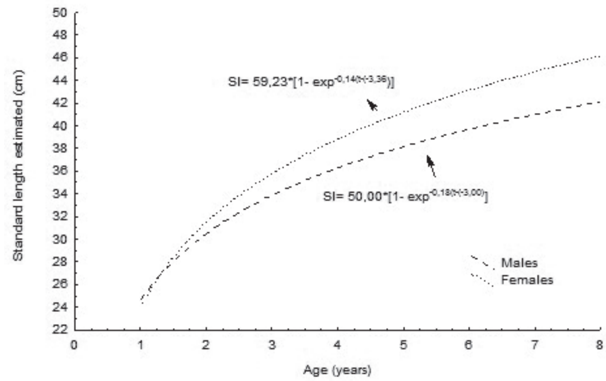

Fig. 4. Growth curves in length for males and females of *Piaractus mesopotamicus* (Holmberg, 1887) collected in 2006 in Cuiabá River, state of Mato Grosso, Brazil.

are harvested at an average size that is smaller than the size that would produce the maximum yield per recruit. This makes the total yield less than it would be if the fish were allowed to grow to an appropriate size. Pauly, 1983 affirm it can be countered by reducing fishing mortality to lower levels and increasing the average size of harvested fish to size that will allow maximum yield per recruit.

Piaractus mesopotamicus is a species considered a long-distance migrant (Resende, 2003) and identified as seasonal strategy by Winemiller, 1989, like others large Characiformes. So, this species has a burst of reproduction with the early rains, followed by gradual reduction in population size due largely to predation on immature in the early dry season (Winemiller, 1989). The adults moving downstream to spawn in floodplains during the wet season (Reproductive migration), moving upstream more later to escape from predation and the harsh conditions of floodplain during the dry season (Trophic migration). As mentioned above, this period probably the emergence of a new growth rings for species.

To obtain the asynmptotic weight we solved the equations $Wt_\infty = 0.093*50^{2.54}$ for males and $Wt_\infty = 0.186*59.23^{2.74}$ for females for the asymptotic length (Sl_∞) (Antoniutti *et al.*, 1985). These values were: 3845 g for males and 6688 g for females. Then, the equations that represent the growth in weigh are: $Wt_\infty = 3845*[1-exp^{-0.18(t-(-3.00)}]^{2.54}$ for males and $Wt_\infty = 6688*[1-exp^{-0.14(t-(-3.36)}]^{2.76}$ for females.

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