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Age and growth parameters of the dourado *Salminus brasiliensis* (Cuvier, 1816) from the river Cuiabá, Mato Grosso State, Brazil

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ABSTRACT. Age and growth parameters of *Salminus brasiliensis* (Curvier, 1816) from the Manso Reservoir and from the river Cuiabá are estimated by their fish scales. Sampling was performed between January and December 2006. There was a linear relationship between the standard length of the fish (cm) and the scale radius (mm) (r = 0.93). The coefficients of variation of standard mean lengths calculated for fish of the same age class were low (>19.0%), while temporal variation analysis of mean marginal increment showed that growth ring was annually formed in November, possibly related to the species's reproductive period between November and January. The maximum number of rings was 12 for both sexes. The growth curve for length expressed by von Bertalanffy model was $Sl = 69.0[1-e^{-0.21(t-(-0.86))}]$ for males and $Sl = 77.9[1-e^{-0.17(t-(-0.41))}]$ for females. The growth curve in weight was $Wt = 7334.6[1-e^{-0.21(t-(-0.86))}]^{3.07}$ for males and $Wt = 10226.8[1-e^{-0.17(t-(-0.41))}]^{3.05}$ for females. Females attained greater length and weight than males. Since growth rate for the species was initially accelerated for both sexes, specimens attain size to start migration after the floods, avoiding predation and frequenting sites with greater food availability.

Keywords: scales, growth rings, von Bertalanffy, Characidae.

Idade e parâmetros de crescimento do dourado *Salminus brasiliensis* (Cuvier, 1816) no rio Cuiabá, Estado do Mato Grosso, Brasil

RESUMO. O objetivo deste estudo foi estimar a idade e os parâmetros de crescimento do *Salminus brasiliensis* (Curvier, 1816), do reservatório de Manso e do rio Cuiabá, utilizando as escamas. As coletas foram realizadas entre janeiro e dezembro de 2006. Observou-se a existência de proporcionalidade linear entre o comprimento padrão do peixe e o raio da escama (r = 0,93). Os coeficientes de variação calculados para o comprimento padrão médio para cada classe etária foram baixos (>19,0%). A análise temporal do incremento marginal médio mostrou que os anéis de crescimento são formados anualmente em novembro, sendo relacionados com a reprodução da espécie, que ocorre entre novembro e janeiro. O número máximo de anéis encontrados nas escamas foi 12 para ambos os sexos. A curva de crescimento em comprimento obtida pelo modelo de von Bertalanffy foi $Cp = 69{,}0[1-e^{-0{,}21(t-(-0{,}86))}]$ para os machos e $Cp = 77{,}9[1-e^{-0{,}17(t-(-0{,}41))}]$ para as fêmeas. A curva de crescimento em peso foi $Pt = 7334{,}6[1-e^{-0{,}21(t-(-0{,}86))}]^{3{,}07}$ para os machos e $Pt = 10226{,}8[1-e^{-0{,}17(t-(-0{,}41))}]^{3{,}05}$ para as fêmeas. As fêmeas alcançaram comprimentos e pesos maiores que os machos. A taxa de crescimento para a espécie foi inicialmente acelerada para ambos os sexos. Assim, os indivíduos alcançam tamanho para começar a migração depois das cheias, evitando a predação e buscando locais com maior disponibilidade de alimento.

Palavras-chave: escamas, marcas de aposição, von Bertalanffy, Characidae.

Introduction

Most fish show the growth process throughout their life span if environmental conditions are favorable. The analysis of the fish's biological aspects is important since growth is an indicator of their specimen's and population's health (Moyle & Cech, 1988). Growth-enhancing factors, such as food abundance, provide rapid growth and, conversely, the lack of such conditions has the opposite effect (Moyle & Cech, 1988). Changes in the environment (exogenous factors) or in endogenous factors, such as genotype and the physiological condition of the fish, influence growth, while their analysis provides knowledge on the variations that occur within and between fish populations (Wootton, 1991).

Studies on age and growth in fish provide important information on the age at which the species reaches sexual maturity, longevity, mortality, growth and production of a population (Barbieri, Sales & Cestarolli, 2001), coupled to in-depth knowledge on the population dynamics of fish species (Barreto Sáes, Rico, & Jaureguizar, 2011; Dei Tos, Gomes, Ambrósio, & Goulart 2010). Beyond the ecological aspect, studies on the commercial aspect are required to estimate the production of a population of fish that may be useful in the management of fishery resources (Weatherley & Gill, 1987). The basin of the Paraguay river is a prime area for fish species, such as *S. brasiliensis* (Cuvier, 1816), popularly known as *dourado* (Fabichak, 1995), considered an umbrella species in conservation programs. In other words, their protection involves the protection of many other species (Agostinho, Gomes, Suzuki, & Julio Jr., 2003).

Salminus brasiliensis, order Characiformes and family Characidae, reaches more than a meter in length and is found in fast waters. Its diet varies throughout ontogeny, with plankton-feeding in the larval stage, feeding on larvae of other fish and insects in the juvenile phase, and exclusively piscivorous as adult (Esteves & Pinto Lôbo, 2001; Morais-Filho & Schubart, 1955). The species is migratory and may displace itself above 1000 km to spawn (Petrere, 1985), requiring wetlands and margins of lakes for the larvae to complete their development where, during the juvenile phase, they find food and shelter (Agostinho et al., 2003; Resende, 2008; Resende & Palmeiras, 1996, Resende et al., 1996). The dourado is a great source of income and protein for a large number of fishermen in the area studied. Current paper investigates age and growth of *S. brasiliensis* captured in the river Cuiabá (immediately above the Pantanal) and in the Manso Reservoir, in the State of Mato Grosso, Brazil, by reading the growth rings in scales. The following factors were determined: i) whether scales are enough for the study of age and growth of *S. brasiliensis*; ii) whether time and frequency in the formation of growth ring may be observed by marginal increment analysis; iii) whether males and females have different growth; iv) whether Rosa Lee's phenomenon, common in data from commercial fishing, may be employed; v) the parameters for the curve of growth in length and weight. This information is essential for the evaluation of future fish stocks in a region where the fishing effort is high and where people depend on these stocks to survive.

Material and methods

Samples were collected in the river Cuiabá, a tributary of the Paraguay river, Manso river, the main tributary of the Manso Reservoir, Manso Reservoir and its area of influence (immediately above the Mato Grosso Pantanal). The Manso Reservoir (Figure 1) lies in the State of Mato Grosso, at 16°32' - 16°40' S and 54°40'- 55°55' W, near the Chapada dos Guimarães National Park.

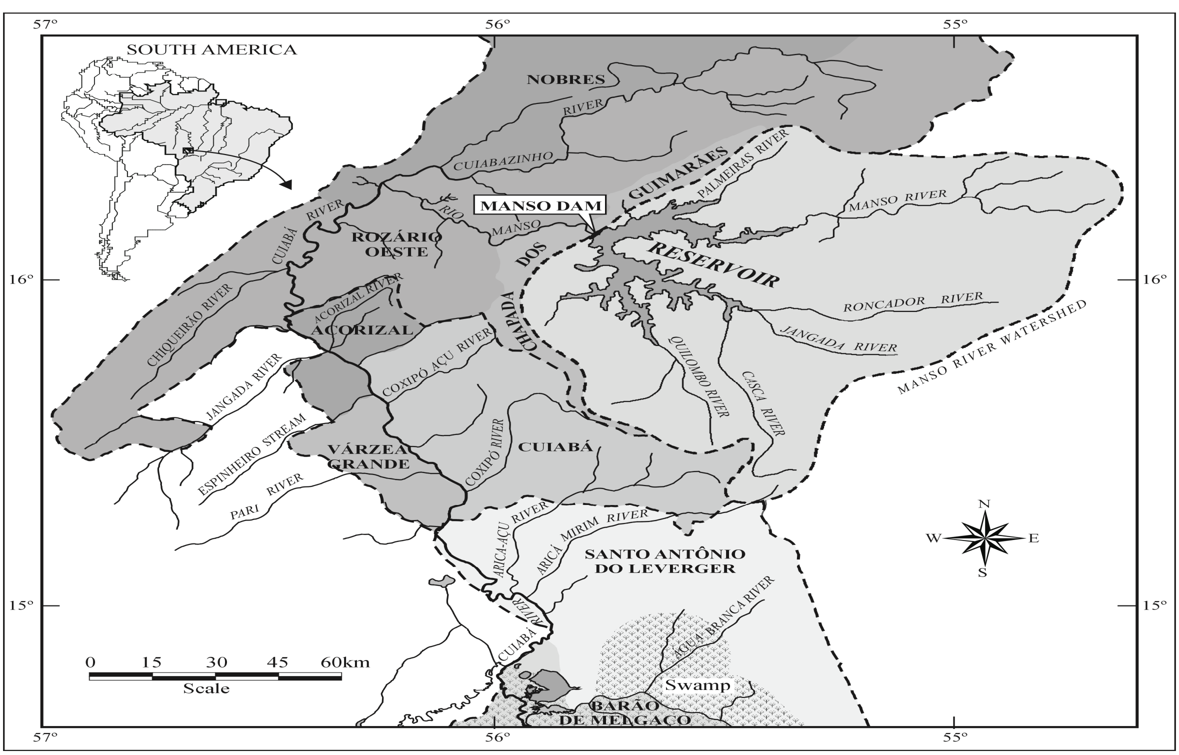

Figure 1. Collection area of specimens of *S. brasiliensis,* State of Mato Grosso, Brazil.

Specimens of S. *brasiliensis* were collected monthly from January to December 2006 from the landings of professional fisheries conducted in the region. Fishermen employed several gears with hooks, such as long lines, rods, and line and hooks attached to branches (or attached to trees in the margins). The scales was retrieved from under the pectoral fins and stored in labeled envelopes.

In the laboratory, the scales were prepared between glass slides, following Vazzoler, Wongtschowiski & Braga (1982) for further analysis. Standard length (Ls; cm), total weight (Wt, g) and sex were reported from the external characteristics of the gonads (Brown-Peterson, Wyanski, Saborido-Rey, Macewicz, & Lowerre-Barbieri, 2011).

The number of growth rings on the scales was checked with a stereoscopic microscope and an ocular micrometer to obtain the distance between center (focus or nucleus) and anterior margin of scale (radius, mm) and the distance from the center to growth ring (mm). A temporal analysis of the monthly means of the marginal increment was performed to verify the time and frequency of growth rings' formation for the species (Lai, Han-Lin., Gallucci, Gunderson, & Donnelly, 1996). The following expression was employed:

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

where:

R = centrum-radii, the distance between the center of the scales (focus or nucleus) and its anterior margin;

r_i = ultimate annulus-radii (the distance between the center of the scales and the ultimate annulus);

r_{i-1}= penultimate annuli-radii (the distance between the center of the scale and the penultimate annulus.

The number of the growth rings on each scale was verified by three different people and the final results comprised the number of the most frequent growth rings. In case of disagreement on the three readings, the scales were discarded or replaced.

Coefficients of variation of the mean standard lengths for each age group were analyzed with methodology by Lai et al. (1996) to verify whether the scales were adequate for estimating the species age and growth parameters,.

Ancova in Statistica 7.1 program Data analysis software system (Statsoft Inc., 2005) was applied to check significant differences in species growth with regard to sex. First, the assumption of parallelism (same inclination) was tested and, if reached, the test was conducted to assess differences in intercepts. If the assumption of parallelism was not reached, the adjustment of model was conducted for the sexes separately.

Back-calculated data obtained with methodology by Francis (1990) were employed to verify the occurrence of Rosa Lee's phenomenon (Ricker, 1975). Since the method has an initial requirement for the existence of linear proportionality between length of fish and scale radius, adjusted by the least squares method, the phenomenon may cause errors in estimates on growth parameters.

Von Bertalanffy model was adjusted to obtain the equation which represents length growth (Beverton & Holt, 1957) by transforming Ford-Walford (Walford, 1946). Thus, the expression which describes increase is:

$$Ls = Ls\infty \, [1 - e^{-k(t-to)}]$$

where:

Ls= standard length (cm) of specimens at age "t";

Ls∞= maximum standard length (cm) that species may achieve, also called asymptotic length;

e= Napierian logarithm;

k= parameter related to growth rate ($year^{-1}$);

t= age of specimens (years);

t_o= age at which the organism would have had size equal to zero (parameter to best fit the model).

Value of t_o was estimated according to methodology established by Vazzoler, Wongtschowiski & Braga (1982). The relationship between standard length (cm) and total weight (g) was analyzed by methodology described by Le Cren (1951), represented by the equation:

$$Wt = a.\, Ls^b$$

where:

Wt= total weight (g);

Ls= standard length (cm);

a= intercept;

b= inclination of relationship between standard length (cm) and total weight (g).

To achieve the required linearity assumption for the least squares method, the length and weight data were transformed into $\log_{10}$.

When the asymptotic length and the relationship between standard length and total weight was obtained, the growth curve weight was determined by direct method (Antoniutti, Ranzini-Paiva, Godinho, & Paiva, 1985). Asymptotic weight (Wt∞) was estimated by equation $Wt = a * Ls^b$ to the asymptotic length (Ls∞). The expression that represents growth in weight was:

$Wt = Wt\infty\ [1- e^{-k(t-to)}]^b$

where:

Wt= total weight of specimens at age "t" (g);

Wt∞= maximum total weight that specimens may achieve (g), also called asymptotic weight;

e= Napierian logarithm;

k= parameter related to growth rate ($year^{-1}$);

t= age of specimens (years);

t_o= age at which the organism would have had size equal to zero (parameter to best fit the model);

b= inclination of relationship between standard length (cm) and total weight (g).

Results and discussion

Age and growth studies are normally performed on bone structures affixed to scales, otolith, inter-opercular and opercular bones or the first ray of the pectoral fins. Scales were selected for current analysis since they are much easier to prepare, collect, analyze, without killing the animal. Moreover, growth marks are easily distinguished and identified (Wright, Panfili, Morales-Nin, & Geffen, 2002). It has been verified that in analyses on age and growth in fish developed in South America, scales were chosen in 50% of fish growth studies (Dei Tos et al., 2010). Scales of 189 specimens of *S. brasiliensis* (69 males and 120 females) were collected and analyzed. The maximum number of rings observed for the species was 12 for both sexes. Only a male with 15 rings was checked and discarded (Table 1).

Table 1. Sample size (N); mean standard length (Ls mean; cm) for each growth ring observed and coefficient of variation (CV) of mean standard lengths observed for ring of specimens of *Salminus brasiliensis* (Curvier, 1816) collected between January and December of 2006 in Manso Reservoir and Cuiabá river, state of Mato Grosso, Brazil.

	MALES			FEMALES		
Age	N	Ls mean	CV	N	Ls mean	CV
1	1	16.8	-	1	17.2	-
2	7	22.0	13.0	1	21.0	-
3	5	25.0	8.9	1	23.0	-
4	2	31.5	6.7	1	33.0	-
5	6	34.5	12.2	12	52.8	16.5
6	8	45.7	17.6	12	53.2	18.3
7	6	46.3	17.4	18	56.1	18.9
8	12	53.8	10.8	21	60.0	8.4
9	13	55.5	9.1	23	61.0	7.6
10	6	56.6	7.2	20	64.1	9.2
11	1	61.0	-	8	65.4	9.0
12	1	65.0	-	2	67.5	15.7
13	-	-	-	-	-	-
14	-	-	-	-	-	-
15	1	72.0	-	-	-	-

Since the coefficients of variation of the standard mean lengths of fish with the same age class did not exceed 19%, scales proved to be appropriate for studies on age and growth of the species. They resulted in consistent data which may adequately be used to estimate the age, while the parameters of the von Bertalanffy equation did not lead to biased estimates (Witherell & Burnett, 1993).

Further, significant linear relationship between the standard length of the fish and the radius of the scale; $F = 979.59$; $p < 0.01$ and Pearson Correlation = 0.93 confirmed using the scale appropriately. The equation describing the relationship is: $R = -0.783+0.8787 \star \log_{10} X$ (X= radius of scale).

Ancova for the assumption of parallelism was reached ($p = 0.54$) and indicated that slopes in the relationship between standard length and total weight may be considered equal (Figure 2).

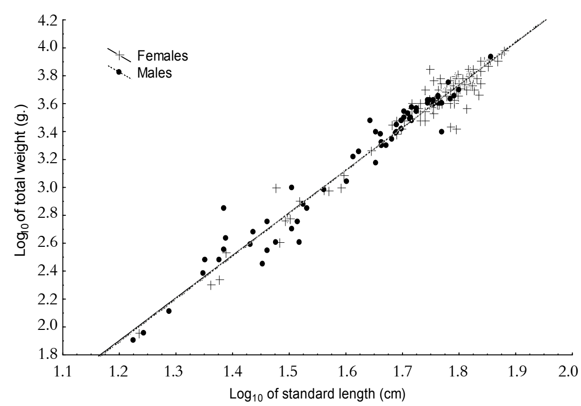

Figure 2. Graphical representation of logarithms (Log10) of standard length and logarithms of the total weight for males and females of *Salminus brasiliensis* (Curvier, 1816) collected between January and December of 2006 in Manso Reservoir and Cuiabá River, state of Mato Grosso, Brazil.

There was no difference between the intercepts ($p = 0.32$). Moreover, the fact that females achieve asymptotic greater lengths than males is widely described in the literature (Lowe-McConnell, 1999; Godinho, 2007) and was chosen to estimate the growth parameters for the sexes separately.

Temporal analysis variations of monthly means of marginal increment demonstrated the formation of one ring growth during the year, in November, when the mean monthly mean increase was smaller (Figure 3), coinciding with the reproductive process. Casselman (1987) reported that breeding in tropical regions is the most relevant factor for the formation of growth rings. The reproductive process has been identified as causing decline in the growth rate of several fish species, because a larger amount of energy is diverted for gonad development and maturation (Barbieri, 1995; Braga, 1999; Amaral, Aranha & Menezes, 1999; Dei Tos et al., 2010; Francisco et al., 2011).

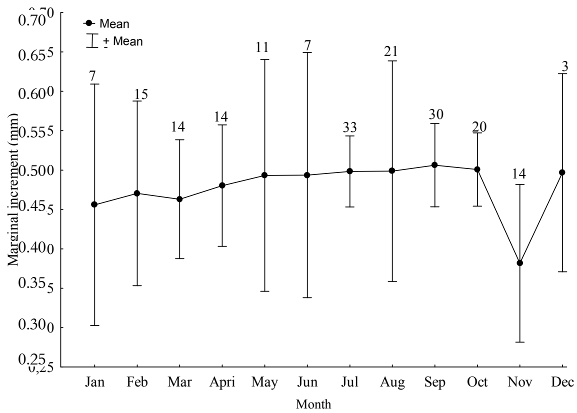

Figure 3. Monthly variation of marginal increment measured in scales of *Salminus brasiliensis* (Curvier, 1816) collected between January and December of 2006 in Manso Reservoir and Cuiabá River, State of Mato Grosso, Brazil (in brackets is the number of individuals analyzed).

A graphical inspection showed no great differences on back-calculated standard lengths and observed data standard lengths (direct method) (Figure 4). This fact indicated that the Rosa Lee's phenomenon was not an issue in this study and it was not necessary to exclude any age group to estimate the parameters of von Bertalanffly equation.

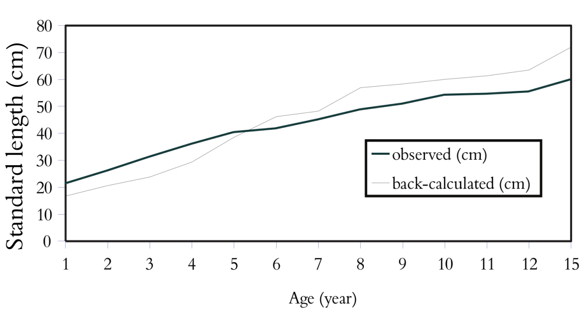

Figure 4. Graphical representation of observed and back-calculated standard lengths of scales for each age class of Salminus brasiliensis (Curvier, 1816) collected between January and December 2006 in Manso Reservoir and Cuiabá River, state of Mato Grosso, Brazil.

Figure 5 shows that the species growth rate has been initially accelerated for both sexes, but the females reach greater sizes than males.

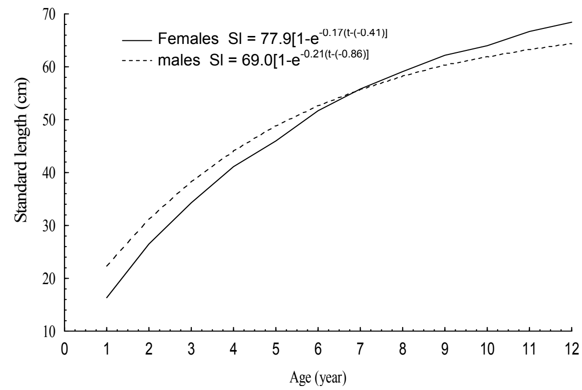

Figure 5. Length growth curve for males and females of *Salminus brasiliensis* (Curvier, 1816) collected between January and December 2006 in Manso Reservoir and Cuiabá river, State of Mato Grosso, Brazil.

The relationship between total weight and standard length for the species was expressed by the following equations:

Males: $Wt= 0.0166.Ls^{3.07}$

Females: $Wt= 0.0174.Ls^{3.05}$

Thus, the equations that describe growth in weight of *S. brasiliensis* are:

Males: $Wt= 7334.6[1 – e^{-0.21\ (t-(-0.86)}]^{3.07}$

Females: $Wt\ 10226.8[1 – e^{-0,17\ (t-(-0.41)}]^{3.05}$

K rates obtained in this study (0.21 for males and 0.17 for females) were lower than those by Feitosa, Fernandes, Gomes, and Agostinho (2004) for the same species (0.28 for males and 0.26 for females). On the other hand, Dei Tos, Gomes & Agostinho (2009) recorded rates equal to 0.77 for males and 0.52 for females, and Sverlij & Spinach-Ros (1986) found the rate 0.31 for both sexes. The asymptotic lengths obtained in this study were 69.0 cm for males and 77.9 cm for females. The rates were higher than those registered by Dei Tos, Gomes & Agostinho (2009) (37.1 cm for males and 56.6 cm for females) and lower than those recorded by Feitosa et al. (2004) (74.8 cm for males and 86.0 cm for females) and Sverlij & Spinach-Ros (1986) (76.7 cm for males and 81.1 cm for females). Despite different rates, it may be observed that females are bigger than males, confirming the sexual dimorphism with regard to species growth. In other words, the male grows at a faster rate than females, but reach smaller sizes, a trend also detected in the studies above. It has also been noted that the growth rate for the species was initially accelerated for both males and females. Thus, specimens achieve sizes to start migration after the floods, avoiding predation and migrating to sites with greater food availability (Welcomme, 1985).

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