

AGE AND GROWTH OF THE DUCKBILL CATFISH (*Sorubim cf. lima*) IN THE PANTANAL

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ABSTRACT

The Duckbill Catfish, *Sorubim lima*, is a predator of large South American rivers. The age and growth of *S. lima* were studied based on the pectoral fin-spines of samples collected from the Cuiabá River, Pantanal. The samples were taken from commercial and experimental hook-and-line fishing. An analysis of the marginal increment suggests that the growth rings are formed once a year during the dry season, from July to September (ANOVA type I: $F = 4.183$; $g.l. = 3$ and 104 ; $p = 0.008$). The estimate of the parameters that describe von Bertalanffy's growth curve by nonlinear regression of the observed lengths in the age were: $L_{\infty} = 56.0$ cm (fork length); $k = 0.245$ year⁻¹; $t_0 = -2.605$ years. The animals were estimated to have a life span of 9.6 years. The findings indicate that the fork length is a good predictor of the age of individuals of this fish species.

Key words: Duckbill Catfish, age, growth, fin spine, *Sorubim lima*, Pantanal.

RESUMO

Idade e crescimento do Jurupensém (*Sorubim cf. lima*) no Pantanal

O Jurupensém, *Sorubim lima*, é um predador dos grandes rios da América do Sul. A idade e o crescimento do *S. lima* foram estudados a partir de espinhos de nadadeiras peitorais de exemplares coletados no Rio Cuiabá, Pantanal Mato-grossense. Os exemplares provieram da pesca comercial e experimental, com linha e anzol. A análise do índice de incremento marginal sugere que os anéis de crescimento se formam uma vez ao ano, durante a estação da seca, entre julho e setembro (ANOVA tipo I: $F = 4,183$; $g.l. = 3$ e 104 ; $p = 0,008$). Os parâmetros que descrevem a curva de crescimento de von Bertalanffy, ajustados por meio de regressão não-linear aos comprimentos observados na idade, foram estimados em: $L_{\infty} = 56,0$ cm (comprimento furcal); $k = 0,245$ ano⁻¹; $t_0 = -2,605$ anos. A longevidade dos indivíduos foi estimada em 9,6 anos. Os resultados indicam que o comprimento furcal é um bom preditor de idade para os indivíduos dessa espécie de peixe.

Palavras-chave: idade, crescimento, *Sorubim lima*, Pantanal, Jurupensém.

INTRODUCTION

The Pimelodidae family encompasses important predators of large South American rivers. These predators constitute a considerable portion of the catch of all regional inland fishing (Novoa, 1982; Ferraz

de Lima & Chabalin, 1984; Ferraz de Lima, 1986; Bayley & Petrere Jr., 1989; Petrere Jr., 1989; Ribeiro *et al.*, 1995; Muñoz-Sosa, 1996; Alonso, 1998; Catella, 2001; Petrere Jr. *et al.*, 2002). As a member of the Pimelodidae family, the genus *Sorubim* comprises four species of deepwater catfish (Froese

& Pauly, 2002): *S. elongatus*, which lives in the basins of the Amazon, Essequibo, and Orinoco rivers (Littmann *et al.*, 2001); *S. cuspicaudus*, in the basins of the Magdalena, Maracaibo, and Sino rivers (Froese & Pauly, 2002); *S. trigonocephalus*, in the Madeira and Tapajós rivers (Burgess, 1989); and *S. lima*, which is the most widely distributed species, occupying the basins of the Amazon, Orinoco, Paraná, and Parnaíba rivers (Froese & Pauly, 2002).

The *S. lima* is one of the largest predators of the rivers flowing through the Pantanal, with a maximum standard length of 55 cm (Britski *et al.*, 1999). Although this species is sold in the regional markets, there is no record of landings in the northern portion of the Pantanal. Landings data in the southern portion indicate that the total catch of this species in 1999 was 21 tons. The accumulated catch of the period between 1994 and 1999 was 99 tons (Catella, 2001).

Despite the importance of this species for ecosystem functioning and for the regional economies it inhabits, little is known about its biology. This study consisted of estimating the age and growth of *S. lima* based on a count of the rings on the pectoral fin-spines. Pectoral fin-spines are structures easily available in fish markets, since their removal does not affect price. So that, in addition to being validated for several fish species (Brennan & Cailliet, 1989; Rien & Beamesderfer, 1994; McFarlane & King, 2001), this technique offers a relatively low-cost solution. The objective of the present study was determining the age, and estimating the parameters of the von Bertalanffy growth curve and the longevity of individuals of this species, as an aid in developing strategies for its management.

MATERIAL AND METHODS

Study area

The Pantanal, wetland formed by the seasonal flooding of the Paraguay River and its tributaries, comprises an area of approximately 140,000 km² located between latitudes 55° and 58° and longitudes 16° and 22° (Da Silva, 2000). Most of the Pantanal is located in the states of Mato Grosso and Mato Grosso do Sul in Brazil; smaller portions are in Bolivia and Paraguay.

The fishes used for this study were collected from the Cuiabá River, one of the largest tributaries of the Paraguay River, in the northern part of the Pantanal. The region is in a humid and hot climatic zone, with rainy summers and dry winters (Köppen, 1948). The rainfall pattern creates four hydrological periods: the rising water period (normally lasting from October to December), the flooding period (usually January to March), the receding water period (generally from April to June), and the dry period (commonly from July to September) (Da Silva & Esteves, 1995). However, these periods may be delayed by up to two months as the distance from the rivers increases (Heckman, 1994).

Sampling procedure and data analysis

Measurements from Duckbill Catfish ($n = 211$) were registered between April 2000 and October 2001. Most of the individuals ($n = 166$) were collected monthly between April and October 2000 and in March, April, and October 2001, from the *Antônio Moysés Nadaf* street market in the city of Cuiabá, Mato Grosso. Owing to the reproductive season during which fishing is forbidden, additional samples ($n = 45$) were collected by means of experimental fishing between November 2000 and February 2001. All the samples were taken from fish caught with hook and line.

Using a knife, the left pectoral fin-spine was extracted from each fish, placed in numbered plastic bags, and frozen for subsequent analysis. The following measurements from each fish were recorded: total length (L_t – cm), fork length (L_f), total weight (W_t – g), and eviscerated weight (W_e). The lengths were measured to the closest centimeter, and the weight to the closest gram. The spines were washed in running water, immersed in commercial acetone for 24 hours, and transferred to hot water (around 50°C). This procedure helped remove adhered tissue. The length and diameter at the proximal portion of each spine were then measured with the aid of a ruler and a vernier caliper. Three to six cross sections were made at the base of each spine, with thicknesses varying from 0.4 to 1 mm, using a rock cutting saw with a diamond disc manufactured by Wolfgang Conrad Clausthal-Zellerfeld. The sections were immersed in 70%

alcohol on petri dishes. Readings and measurements were carried out under a Carl Zeiss (Jena) stereomicroscope with a micrometric lens, 40 times magnification, and incident light. Sections with marks that were difficult to view were polished.

The sections revealed wide opaque zones alternating with narrow translucent ones. The opaque zones were considered indicative of rapid growth periods while the translucent ones indicated periods of slow growth (Casselman, 1983). A complete well-defined translucent zone was considered to be a growth ring (or annulus), while an unclear, irregular, or incomplete translucent zone was considered a false mark (Casselman, 1983). Two complete translucent marks, whose distance from each other was less than the distance from the preceding and following marks, were considered a double mark (Megalofonou, 2000). All growth rings were counted, and their radii at zero degree – the distance from the center of the spine to the ring – were measured (Fig. 1). Only spines in which the number of growth rings was repeated in at least two sections were included in the analysis.

A problem commonly encountered when fin spines are used to determine the age of fish is that the cores of these structures may be reabsorbed as the fish ages (Casselman, 1983). The core is replaced by a hole that may cause the first growth rings to disappear, leading to age underestimations (Casselman, 1983). In the present study, the evidence of reabsorption of the first ring through the appearance of holes in older individuals was evaluated by Kruskal-Wallis's nonparametric test (Sokal & Rohlf, 1995). The decision to analyze the data using a nonparametric test was based on non-normality of the residues. The analysis was conducted considering the age (number of rings) as a factor and the radius of the first ring at 0° (Rz) as a response variable. The a posteriori comparisons were made using the *Q*-test (Zar, 1996). In the presence of the phenomenon of reabsorption of the first ring, individuals from older age groups should show larger first ring radii than individuals from younger age groups.

To validate the rings as indicators of the fish's age, ring count and measurement data were subjected to two indirect analyses (Lai *et al.*, 1996). The first consisted of evaluating whether the rings on the spine could be considered indicators of the fish's growth. To be considered a growth indicator, the number of

rings must show a directly proportional relation to spine size and fish length. To define whether the number of rings varies with spine size, a visual inspection is made of a box-plot correlating ring number and spine radii. This correlation is particularly important for back-calculation. The correlation between spine size and Lf was investigated by linear regression. The second analysis consisted of determining the period of formation of the annuli which, in the present study, was investigated by marginal increment analysis (MI) (Lai *et al.*, 1996):

$$MI = (R - r_i)/(r_i - r_{i-1}) * 100$$

where *R* represents spine radius, and *r_i* and *r_{i-1}* annular radii of the last and penultimate annuli, respectively. The MI differences were evaluated by one-way ANOVA (Sokal & Rohlf, 1995). Owing to the small number of observations, the comparisons were conducted on seasonal MIs of individuals having 2 and 3 annuli. The a posteriori analyses were carried out using the Tukey test (Sokal & Rohlf, 1995). The period of annuli formation was considered the one for which the MI displayed the smallest value.

The total weight versus fork length relationship was adjusted by non-linear regression. The non-linear adjustment was based on the minimum squares method, Gauss-Newton algorithm.

To carry out the back-calculation, an analysis was first made to determine whether the correlation between the spine's zero degree radii (*zdr*) and the Lf was linear. Three regression models were tested: the potential ($Lf = a(zdr)^b$), exponential ($Lf = ae^{b(zdr)}$), and linear ($Lf = a + b(zdr)$). The decision about which of the models best fit the data was based on a joint analysis of the coefficient of determination (*r*²) and the residual variance (SQM). The functional regression parameters were then estimated, following the procedure described by Ricker (1992). Fraser-Lee's equation was used to back-calculate the size of the fish at the time when the annuli were formed (Francis, 1990):

$$Li = c + (Lc - c)(Si/Sc)$$

where *Li* is length at time of annuli formation (*i* = 1, 2, 3, ..., *n*); *c* is the intercept of the regression between body size versus spine size, estimated by the functional regression; *Lc* is length of fish when caught; and *Si* and *Sc* are the annuli-radius *i* and the total radius of spine at capture, respectively.

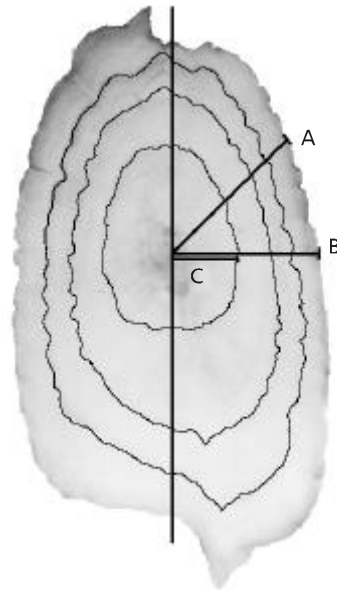


Fig. 1 — Schematic drawing of the pectoral fin-spine of *S. lima*, showing the measurements taken: A = radius at 45°; B = radius at 0°; C = radius of the first ring.

In order to describe the species' growth, von Bertalanffy's growth model (Bertalanffy, 1938) was adjusted to the lengths at each age, both observed and back-calculated. The parameters of the equation were estimated by nonlinear regression using the minimum squares method, Gauss-Newton algorithm. The parameters of the growth curve were subsequently used to produce an estimate of the longevity of individuals in the stock. For this purpose, the Taylor method (Taylor, 1957) – which estimates the average time required for the individuals of the stock to reach 95% of the L_{∞} – was used.

$$A_{0.95} = t_0 + 2,996/k$$

All the statistical analyses were conducted using the SYSTAT software program (SYSTAT, 1997).

RESULTS

The results indicate that pectoral fin-spines of *S. lima* are appropriate structures for annuli counts. Of the 211 spines analyzed, 205 (97%) showed visible annuli. In some cases, the sections displayed

grooves, with marks crossing over the rings from the core to the edge of the spine; in others, the rapid growth zones were more translucent. However, the annuli stood out even in such situations. From the total number of spines with visible annuli ($n = 205$), 63% displayed only single ones, while 37 showed double marks as well as single annuli; 44.5% of the spines also displayed false marks. These false marks appeared more commonly between the second and fifth annuli, while the double marks were present between the first and second annuli. Although annuli were detected on 205 spines, only in 197 (93.5%) of them were the number of annuli repeated in at least 2 sections. Therefore, only data from the readings of these 197 spines were considered reliable and used in subsequent analyses.

The sample used in this study comprised individuals with L_f varying from 23 to 53.5 cm. The mean size of the individuals of the sample ($L_{f_{\text{mean}}}$) was 39.64 cm, with standard error (*s.e.*) of 0.46. The spines showed up to 5 annuli, representing 5 age groups; the predominating age class had 3 annuli. The mean age (t_{mean}) was 2.55 annuli (*s.e.* = 0.074) and the median (t_{median}) was 3 annuli.

No evidence was found of reabsorption of the first annulus of older individuals through the appearance of a hole in the core of the spine. The Kruskal-Wallis test revealed significant differences among the age groups ($H = 26.064$; $g.l. = 4$; $p = 0.000$). The Q -test for comparisons of a posteriori ranks indicated that age groups 1 and 2 had larger first annulus radii than did groups 3 and 4, and that group 5 did not significantly differ from the other groups. This finding was contrary to what was expected in the presence of the phenomenon of reabsorption of the first annulus in older age groups and, hence, increased the reliability of the readings done on the rings.

The analyses of the correlations between the numbers of rings, the size of the spine and L_f indicated that the rings on the spines were, indeed, indicators of growth. The visual analysis of the box-plot between spine radius and ring number indicated that the larger spines contained more annuli (Fig. 2).

In addition to this important conclusion, the linear models indicated that larger individuals had larger spines. The variation in fork length explained 85% of the variation in spine length and 84% of

the variation in diameter, as well as 69% of the variation of spine zdr and 63% of the variation in the 45° radius (Fig. 3). In short, a positive correlation was found between the number of annuli in the spines and the size of the individuals from which those spines were extracted.

The spine's border growth data indicated that growth marks are formed annually during the dry season. Owing to the non-normality of the residues, the tests were conducted using the square root of the data. This transformation was used because it was the only one that normalized the residues. The ANOVA test revealed significant differences between the seasonal MI_s (one-way ANOVA: $F_{obs} = 4.183$; $g.l. = 3$ and 104 ; $p = 0.008$). The ANOVA was validated through an analysis of the residues, which indicated its normality ($g1 = 0.166$; $g2 = -0.266$; $p > 0.05$; $n = 108$) and Bartlett's test, which showed homoscedasticity of variances ($X^2 = 2.375$; $g.l. 3$; $p > 0.05$). Lastly, the a posteriori Tukey test indicated that the MI_s in the dry season were significantly smaller than those in the rising water season ($n = 108$; $p = 0.003$).

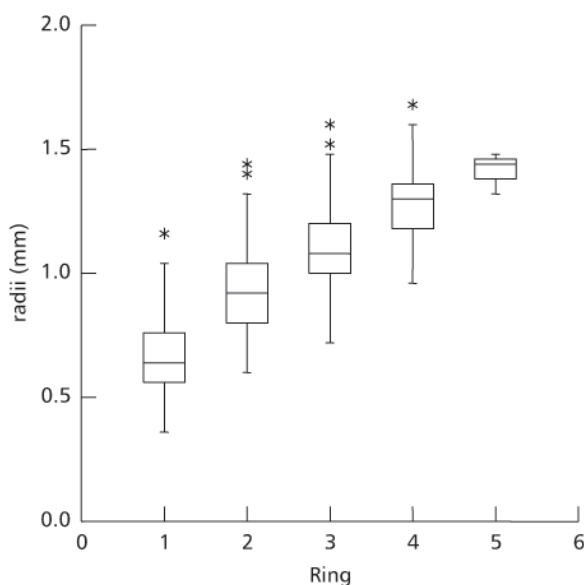


Fig. 2 — Box-plot of the correlation between the radius of the spine at 0° and the number of growth rings in the cuts. The upper portion of the boxes is given by the third quarter and the lower one is given by the first. The horizontal line passing through the box represents the median. The vertical bar indicates the minimum and maximum values. The stars indicate discrepant observations.

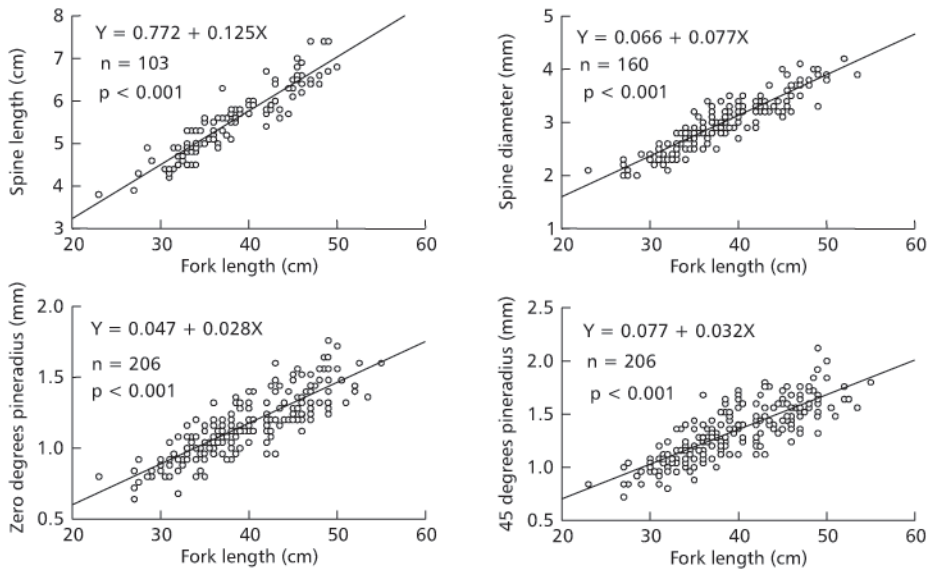


Fig. 3 — Correlation between the characteristic associated with the size of the spine and the fork length of *S. lima* from the Cuiabá River.

Considering that *S. lima* spawns at the onset of the rainy season in several South American rivers and, hence, at the beginning of the rising water period (Goulding, 1981; Vazzoler *et al.*, 1997; Mago, 1970, *apud* Lowe-McConnell, 1999), spawning in the Pantanal should occur sometime between October and December. If this inference is correct, the first annulus is formed between the 7th and 11th month of the cohort's life. However, since the environmental conditions tend to deteriorate as the dry season progresses, becoming critical towards the end, the first annulus most likely appears, on average, 1 year after the cohort's birth.

The relationship between Wt and Lf was described by a power function ($Wt = 0.001 * Lf^{3.457}$). The variation in Lf explained 93% of the variation in Wt . The value of the b of the Wt - Lf relationship, estimated at 3.457, is considerably greater than 3 (confidence interval for the estimated $b = 3.275$ to 3.639). This figure indicates that *S. lima* increases its weight at a rate exceeding that required to maintain a constant corporal proportion.

The analyses of residual variances and coefficients of determination indicate that all the models described the correlation between the spine's Lf and zdr consistently (r^2 : power = 0.692; exponential = 0.67; and linear = 0.688). Therefore,

the simplest model – the linear – was chosen as the one that best describes this correlation in *S. lima* ($Y = 11.194 + 24.483X$; $n = 206$; $p < 0.001$).

Fraser-Lee's equation produced consistent results. As expected, the back-calculated lengths were shorter than those observed, the differences decreasing with age (Table 1). Nevertheless, the average length attained in the cohort's first year, shown in column $Lf1$ of Table 1, decreased with the age of the cohort from which it was estimated, the only exception being the oldest cohort, for which there were the least number of observations, and thus less reliable estimates. This fact suggests the presence of the Rosa-Lee phenomenon (Lee, 1912, *apud* Ricker, 1969). When this is present, the average calculated size of the younger fish is smaller, the older the fish from which it was estimated (Ricker, 1969, 1979).

The use of back-calculated data increased the precision of the estimates (smaller asymptotic standard error – A.S.E.). Nevertheless, the L_{∞} value estimated with these data ($L_{\infty} = 46.5$ cm; A.S.E. = 3.294) was considered well below the average size of the larger individuals of the sample (53.5 cm) and, hence, biologically unreal. Thus, we consider that the best estimate of the growth parameters was generated with the use of the lengths observed ($r^2 = 0.41$). The values of $k = 0.245$ year⁻¹ (A.S.E. = 0.165)

e $L_{\infty} = 56.0$ cm ($A.S.E. = 11.032$) estimated with these data are considered typical of a slow-growing species (Fig. 4).

The estimates of the L_f reached in the first year of life varied from 26.9 cm, using back-calculated

data, to 32.8 cm, using observed data. Therefore, although the species approaches its L_{∞} slowly, its initial growth is fast.

The longevity ($A_{0.95}$) of the individuals in stock was estimated at 9.6 years.

TABLE 1

Mean fork length values (L_f) at back-calculated ages. The highlighted values are the mean lengths of the cohorts.

N	$L_{f_{obs.}}$	Age	L_{f_1}	L_{f_2}	L_{f_3}	L_{f_4}	L_{f_5}
37	32.703	1	<u>26.46</u>				
55	38.191	2	26.356	<u>35.185</u>			
69	41.529	3	23.569	32.241	<u>37.573</u>		
32	45.094	4	22.651	31.424	38.083	<u>42.151</u>	
4	47.500	5	25.72	34.504	39.439	42.754	<u>45.26</u>
Mean			24.785	33.146	37.8	42.218	45.26
Increment			24.785	8.361	4.654	4.418	3.042
N			197	160	105	36	4

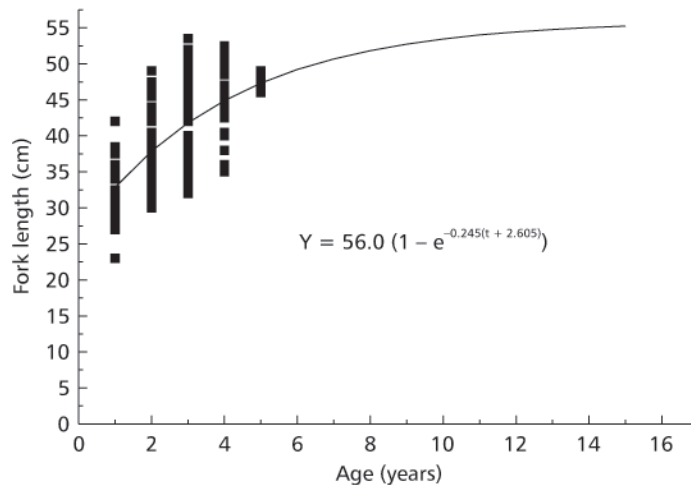


Fig. 4 — Growth curve in length for *Sorubim lima* from the basin of the Cuiabá River, Pantanal, Mato Grosso, Brazil.

DISCUSSION

The results indicate that the pectoral fin-spine is a suitable structure by which to evaluate the age of *S. lima*. The positive correlation between the number of annuli and the *Lf* indicates that the former express the fish's growth. Besides this characteristic, the annuli on the spine can be identified confidently. The spines of old fish were generally more difficult to interpret. However, although reabsorption of the core may occur in this age group, the greatest difficulty involved separating the more recently formed rings. As Casselman (1983) pointed out, in some cases the distal translucent zones may be so close to each other than they seem to coalesce, rendering it difficult or even impossible to obtain a good optical resolution and to correctly evaluate the number of annuli. Nonetheless, this same author states that the identification of growth marks on fish scales and spines becomes more inconsistent from the 6th mark on (Casselman, 1983). Since 5 was the maximum number of annuli observed here, the readings can be considered reliable.

The analysis of the marginal increment indicated that the growth rings on the spine of *S. lima* are formed once a year during the dry season. This pattern was also found for other Pimelodidae, such as the *Pseudoplatystoma corruscans* in the Pantanal (Resende *et al.*, 1996; Mateus & Petrere Jr., in press), the *P. fasciatum* and *P. tigrinum* in the Apure River (Reid, 1983) and in the Bolivian Amazon (Loubens & Panfili, 2000), the *Pimelodus maculatus* in the Paraná River Basin (Fenerich *et al.*, 1975), the *Paulicea lietkeni* of the Meta River (Reina *et al.*, 1995), and the *Brachyplatystoma filamentosum* and *B. flavicans* of the Colombian Amazon (Muñoz-Sosa, 1996). On the other hand, the Amazonian *Calophysus macropterus* forms two annual growth rings: one in August as the river waters recede, and the other in January, as the rivers rise (Pérez Lozano, 1999). The ring formed during the receding is assumed to be associated with migration, and the one formed during the rising, to reproduction (Pérez Lozano, 1999).

The studies cited in the previous paragraph and others listed by Lowe-McConnell (1999) and Welcome (1992) suggest that low temperature, drought, and reproductive activity are critical events affecting the growth of fish in large river systems with floodplains. However, elucidation of the causes leading to annuli formation on the pectoral fin-spines

of *S. lima* inhabiting the Cuiabá River is a complex one, owing to the temporal overlap of the winter, the dry season, and the reproductive migration. Thus, progressive deterioration of water quality and the probable food scarcity during the dry season, allied to the energy investment required in reproductive migration, appear to be the main factors influencing the formation of growth rings in this fish species.

These conclusions about the period of formation of growth marks should be viewed cautiously. A large part of the studies were validated using the marginal increment. As pointed out by Campana (2001), the marginal increment is a problematic validation method because it depends on the accurate identification of rings located on a structure's edge, which is particularly difficult and highly subject to error (Casselman, 1983). Hence, definitive conclusions can only be obtained based on the results of studies using more robust validation methods, such as those involving chemical staining of bone structure.

The back-calculated lengths indicated the presence of the Rosa-Lee phenomenon in the population studied. Several hypotheses have been offered to explain this phenomenon, the main ones being: biased sampling, technical problems (incorrect use of the correlation between spine size versus body size), size-dependent mortality (natural or by fishing) (Ricker, 1969, 1979), and spatial stratification of the different ontogenetic phases (Stanley, 1980). The Rosa-Lee phenomenon in the species studied here appears to be the result of biased sampling. Although there are few published studies describing the shape of the selectivity curve for fishing hooks, some authors suggest that it is bell-shaped (Gayaniilo Jr. & Pauly, 1997; Sparre & Venema, 1997). Under such conditions, if one assumes that the age groups making up the population present normal distribution sizes, in this study only the larger individuals (the right-hand tail of the curve) would be included in the age group displaying 1 annulus. Slow-growing individuals would only be included in the analysis when there are 2 annuli. The result is that the older the individual, the smaller the size estimated for its first year of life.

Although the value of *k* estimated for *S. lima* indicates slow growth, the size attained at the end of the first year is not. High growth rates in the first year have been determined for other predator fish species (all the above listed Pimelodidae). This strategy seems to enable ichthyophagous fish to feeding on the juvenile cohorts of their habitual prey

as they grow (Araújo & Haimovici, 2000). Moreover, rapid growth during the first year of life may ensure that smaller predators escape from larger ones, since they are all limited by the size of their mouth.

The estimates of the growth parameters presented here serve as a basis for future assessment of the stock of *S. lima* in the Cuiabá River. It is not known, however, if these estimates can be extrapolated to the entire Pantanal region. After all, the Pantanal floodplain is formed by the periodic flooding of the Paraguay River and its tributaries. Each tributary displays a specific flooding pattern (Hamilton *et al.*, 1996). The characteristics and pressure of fishing vary from one river to another (Catella, 2001). Therefore, this complex of ecosystems raises the question of how the regional fish populations are structured. Does each river have its own stock of *S. lima*, or is there just one stock for the entire Pantanal? The answer to this question is urgent and should be useful in devising more efficient fishery management strategies for the region.

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