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Population structure and reproductive biology of *Loricariichthys melanocheilus* Reis & Pereira, 2000 (Siluriformes: Loricariidae) in the rio Ibicuí, Brazil

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The objective of this study was to analyze population structure (spatial distribution, seasonal distribution and distribution by length classes, sex ratio and length-weight relationship) and aspects of the reproductive biology of *Loricariichthys melanocheilus*. Fish were sampled bimonthly using gillnets and trammel nets in lentic and lotic environments in the rio Ibicuí, between the years 2000 and 2001. Were collected 410 specimens: 230 females, 164 males and 16 specimens whose sex could not be determined. A greater number of specimens were collected in October/November and December/January and in lentic environments. The greater length classes had a higher amount of females ($p < 0.05$) and the sex ratio in all sampling periods was 1.38 females per male. Both males and females showed positive allometric growth (b = 3.299 and b =3.487, respectively). The highest values for gonadosomatic index (GSI) and gonadal condition factor (K) were observed from August/September and peaked in October/November, just like the highest frequencies of females at maturity stage C (mature), which is indicative that the breeding season occurs at this time.

O objetivo deste trabalho foi analisar a estrutura populacional (distribuição espacial, sazonal e por classes de comprimento, proporção sexual e relação peso-comprimento) e aspectos da biologia reprodutiva de *Loricariichthys melanocheilus*. Os peixes foram amostrados bimestralmente com redes de espera e feiticeiras em ambientes lêntico e lóticos no rio Ibicuí, entre os anos de 2000 e 2001. Foram capturados 410 indivíduos: 230 fêmeas, 164 machos e 16 indivíduos que não foi possível determinar o sexo. Foi capturado um maior número de indivíduos em outubro/novembro e dezembro/janeiro e em ambientes lênticos. As classes de comprimento superiores apresentaram maior quantidade de fêmeas ($p < 0.05$) e a proporção sexual em todos os períodos amostrados foi de 1,38 fêmeas para cada macho. Tanto os machos quanto as fêmeas apresentaram crescimento alométrico positivo (b = 3.299 and b =3.487, respectivamente). Os maiores valores do Índice Gonadossomático (IGS) e do fator de condição gonadal (K) foram observados a partir de agosto/setembro, com pico em outubro/novembro, assim com as maiores frequências de fêmeas em estádio de maturação C (maduro), indicando que o período reprodutivo se dá nesta época.

Keywords: Armored catfish, Breeding season, Condition factor, Gonadosomatic index, Hepatosomatic index.

Introduction

Loricariidae is the most representative among Siluriformes, with about 684 recognized species and several others being validated each year (Nelson, 2006). It is spread over almost the entire Neotropics, from Costa Rica to Argentina (Reis *et al*., 2003). *Loricariichthys* Bleeker, 1862, is comprised of 18 recognized species and is included in the Loricariinae, which consists of about 31 genera and 209 species (Ferraris Jr., 2003). The species addressed by this study, *Loricariichthys melanocheilus*, also known as armored catfish, was described by Reis & Pereira (2000) in the basins of the Paraná and Uruguay rivers, and it differs from other species of the genus mainly because its caudal peduncle is not either very compressed or straight in lateral view, in addition to pre-maxillary teeth and rostral edge, which are relatively short (Reis & Pereira, 2000).

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Studies addressing population and reproductive aspects of this family of fish have been conducted in several Brazilian basins, focusing on several species such as *Rhinelepis aspera* Spix & Agassiz, 1829 (Agostinho *et al*., 1987; Agostinho *et al*., 1990), *Hypostomus commersonii* Valenciennes, 1836 (Agostinho *et al*., 1991), *Rineloricaria latirostris* (Boulenger, 1900) (Barbieri, 1994), *Hypostomus ancistroides* (Ihering, 1911) (Viana *et al*., 2008), *Pareiorhina rudolphi* (Miranda Ribeiro, 1911) (Braga *et al*., 2009), among others. Studies conducted on the genus *Loricariichthys* have focused primarily on *L. anus* (Valenciennes, 1835), *L. platymetopon* Isbrücker & Nijssen, 1979 (Tos *et al*., 1997; Querol *et al*., 2002; Marcucci *et al*., 2005; Bailly *et al*., 2011) and *L. spixii* (Steindachner 1881) (Duarte & Araújo, 2001). So far, there is no record in the literature of studies addressing aspects of the biology of *Loricariichthys melanocheilus*, probably because it is a recently described species and is not widely distributed along several Brazilian basins, but rather, restricted only to the southern region of Brazil. An exception is a recent study by Teixeira de Mello *et al*. (2011), which addresses the length-weight relationship of various fish species of the río Negro, Uruguay, including *L. melanocheilus*.

Research studies that explore population and reproductive aspects have yielded important results for understanding the biology and ecological relationships among the species researched and the environment. Studies on reproductive dynamics are important for research on fishing activities in that they provide the necessary support for developing programs aimed at the rational exploitation and conservation of fish species in Brazilian rivers and lakes. In this line of research, studies particularly focus on breeding season, size and age of first gonadal maturity, fecundity, growth rate and type of spawning (Barbieri, 1994).

Several researchers have characterized the reproductive dynamics and their relationship with the breeding season through knowledge of some quantitative indexes such as gonadosomatic index, hepatosomatic index and condition factor (Araújo *et al*., 1999; Querol *et al*., 2002; Gomiero & Braga, 2006; Braga *et al*., 2009; Holzbach *et al*., 2009; Freitas *et al*., 2011; Moraes & Braga, 2011). The condition factor is indicative of specimens' health, and it is widely used both in research on aquaculture and fish ecology, in natural and laboratory environments (Camara *et al*., 2011). This index reflects recent nutritional conditions and/or expenditure of reserves in cyclical activities, which may be indicative of breeding season, a period of food and physiological changes, and accumulation of fat (Vazzoler, 1996; Gomiero & Braga, 2005). According to Vazzoler (1996), using these indexes is important to counterbalance the possible subjectivity of data on the maturity stages, thus making results more reliable when attempting to identify the breeding season of a species. Moreover, knowledge of the population structure of a given species is broadened when these studies are coupled with data such as length-weight relationship, sex ratio, and spatial distribution. This knowledge is of great importance, because several aspects of the survival strategy of the species during energy allocation, whether for growth, reproduction or maintenance, are interpreted through studies of this nature (Gurgel & Mendonça, 2001).

Given the above, the purpose of this paper is to characterize the population structure of *Loricariichthys melanocheilus* as regards seasonal and spatial distribution, distribution by length classes, and weight/length relationship, as well as determine the breeding season of this species by macroscopic evaluation of gonads and quantitative indexes.

Material and Methods

Study area. The rio Ibicuí is a major tributary of the rio Uruguay, formed in its initial stretch by the Ibicuí-Mirim and Santa Maria rivers, in the State of Rio Grande do Sul, southern Brazil. The rio Ibicuí has sand substrate and although it is narrow, there are many marshes along its banks and a broad floodplain (Rambo, 1994).

Sampling sites were chosen on the stretch between the municipalities of São Vicente do Sul and Itaqui. Point 1 is located below the mouth of the rio Santa Maria, between São Vicente do Sul and Cacequi (*ca*. 29°48'S 54°58W); point 2 is located in the middle stretch of the rio Ibicuí, between the municipalities of Manoel Viana and Alegrete (*ca*. 29º29'S 55º45'W); point 3 is located above the mouth of the rio Ibirocaí, between Itaqui and Alegrete (*ca*. 29º25'S 56º37'W) (Fig. 1).

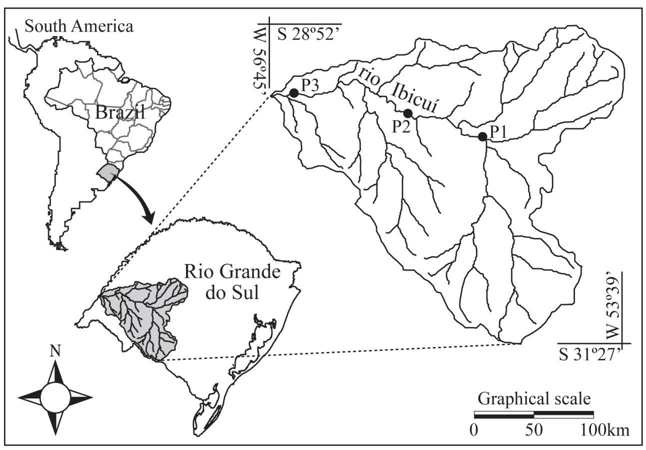

Fig. 1. Map with location of sampling points. P1 = Point 1; P2 = Point 2; P3 = Point 3.

At each point, the specimens were collected in lotic and lentic environments, respectively represented by the main axis of the river and the lakes and side channels that are connected with the river during most of the year. In addition to the geographical distance between them, lentic environments have other distinguishing features. At point 1, this environment is the channel of a small stream, but when the water level is high, it forms a lake located about 40 m away from the river. In periods of low water level, only the channel remains, without current, ranging in width between three and eight meters. At point 2, the lake is connected to the river by a narrow and short channel (two to three feet wide and about eight feet long). The lake is deep, and its banks are fully covered by shrubs and trees with many branches of fallen trees. This lake is about 150 m long and 70 m wide, and it is isolated from the river during low water. The lake of point 3 has great proportions, with almost the same width as the river (about 200 m). The widest point of the lake connects with the river. None of these lentic environments have abundant aquatic weeds.

Sampling was performed bimonthly from January 2000 to December 2001, in a total of 36 trips and 12 samplings at each point. For each environment, 10 m of gill nets were used with meshes of 1.5, 2.0, 2.5 and 3.0 cm; 20 m of gill nets with meshes of 4.0, 5.0, 6, 0, 8.0 and 10.0 cm; trammel nets with meshes of 4.0/20.0, 5.0/20.0 and 6.0/20.0 (all meshes measured between adjacent nodes). The nets remained in water for 24 hours, and attended at every six hours (6h, 12h, 18h and 24h). The fish were numbered, fixed with formalin 10% solution and then preserved in 70% alcohol as reported by Malabarba & Reis (1987). For each sample, the following data were recorded: date, time of collection, location and fishing tackle. Samples were collected with the permission of IBAMA (135/99). Voucher specimens were deposited in Museu de Ciências e Tecnologia da Pontifícia Universidade Católica do Rio Grande do Sul (MCP 28915 and MCP 44055).

In the laboratory, measures were taken for total length (L_t) and standard length (L_s), in centimeters, and total weight (W_t), in grams. The fish were dissected to determine sex, weight and stage of gonad maturity through a macroscopic evaluation, following the methodology suggested by Vazzoler (1996), which takes four maturity stages into account: A (immature), B (developing), C (mature) and D (spent).

Data analysis. The data were grouped and analyzed by bimesters, considering the two years of collections, as follows: December/January, February/March, April/May, June/July, August/September and October/November.

The population structure was evaluated by means of the following: seasonal and spatial distribution, bimonthly variations in average size and sex ratio (total, bimonthly, by points of collection and length classes). Distribution per length classes was calculated according to the Sturges rule (Sturges, 1926): $W = K/R$, where W is the width of the classes; K is the number of classes [1 + (3.222.log N)], N is the number of specimens collected and R is the total amplitude of the standard length data. To investigate the differences in sex ratio and the differences in distributions between length classes, the Chi-square test (X^2) was used. To evaluate the differences in average sizes and weights between sexes and between sampling periods, the Mann-Whitney and the Kruskal-Wallis tests were used with a significance level of 5%. To evaluate seasonal and spatial distribution, the Chi-square test (X^2) was used, with a significance level of 5%.

Weight/length relationship was obtained separately for males and females, and was expressed by the equation: $W_t = a \, x \, L_s^{\,b}$ (Le Cren, 1951), where: W_t = total weight; a = linear coefficient / condition factor, related to the degree of animal fattening; L_s standard length and b = standard length and angular coefficient/allometric coefficient related to growth form. The parameters a and b were obtained by adjusting the logarithm of the dependent variable (weight) and independent variable (length) by the least squares method, thus producing the following equation (Santos, 1978): $\log(W_t) = \log(a) + b \, x \log(L_s)$. In this way, a and b and were estimated from a linear regression and were then applied in the formula: $W_t = a \, x \, L_s^{\,b}$. Such formula allowed the estimation of weight as a function of length and vice versa, and the estimation of the type of growth of the species, represented by the allometric coefficient (b). The coefficient of determination (R^2) was calculated to express the proportion of total variation of weight (dependent variable), which is explained by the variation of length (independent variable).

The total condition factor and the somatic condition factor (K and K_I) (Le Cren, 1951; Vazzoler, 1996) were calculated by the formulas $K = W_t / L_s^{\,b}$, where: W_t = total weight; L_s = standard length; b = allometric coefficient, obtained from the linear regression and $K_1 = W_c / L_s^{\,b}$, where: $W_c = W_t - W_g$; W_g = gonad weight. The constant b was obtained separately by sex, and only one value was considered for all sampling periods to avoid possible distortions in the analyzed parameters (Lima-Júnior *et al*., 2002). The values for K and K_I were determined bimonthly and separately by sex, and the difference between the two values is the gonad condition factor (ΔK), which is indicative of the breeding season (Vazzoler, 1996). The bimonthly averages and between points of collection of the condition factor were compared using the nonparametric Kruskal-Wallis test, and the variations were analyzed graphically (Cantanhêde *et al*., 2007).

The gonadosomatic (GSI) and hepatosomatic (HSI) indexes were calculated as the ratio between gonad weight, liver weight and total body weight, following the formulas suggested by Vazzoler (1996): $GSI = (W_g / W_t)$ x 100 and $HIS = (W_l / W_t)$ x 100, where: W_g = gonad weight and W_l = liver weight. The averages of these indexes were compared bimonthly by the nonparametric Kruskal-Wallis test, considering the 5% significance level. The averages of GSI were compared by point of collection too. In river of point 1, there is no sufficient data for analyses, and then these values were excluded.

Determination of breeding season took into account the bimonthly distributions of maturity stages C (mature) and D (spent) and the values of gonad condition factor (ΔK). The bimonthly distributions of maturity stages were compared using the chi-square test (x^2). Moreover, changes in the gonadosomatic index (GSI) and hepatosomatic index (HSI) were also used to contribute to the assessment of the breeding season.

Results

A total of 394 individuals were collected: 230 females and 164 males. The minimum standard length (L_s) recorded was 12 cm, and the maximum was 31.5 cm, with females reaching an average length of 19.18 cm (±2.25 cm) and males, 17.67 cm (±2.16 cm) ($p < 0.001$). Total weight (W_t) ranged between 9.88 g and 267.3 g; the heavier females reached an average weight of 59.79 g (±27.11 g) and males, 43.30 g (±22.70 g) ($p < 0.001$). In October/November period, the females had higher mean weight compared to other periods, but there was no significant difference. When average lengths were analyzed bimonthly, there were no significant differences, either.

Following the Sturges rule (Sturges, 1926), 18 length classes were established, each one cm long. A greater number of specimens was observed in classes between 17.5 and 20.7 cm ($X^2 = 623.93$; $p < 0.05$). There were more females in classes 19.7-20.7 ($X^2 = 34.59$; $p < 0.05$); 20.8-21.8 ($X^2 = 27.29$; $p < 0.05$) and 21.9-22.9 cm ($X^2 = 8.06$; $p < 0.05$). In the other classes, there was no significant difference in sex ratio (Fig. 2). In lagoon of point 1, there were a greater number of females in classes 19.7-20.7 ($X^2 = 11.57$; $p < 0.05$) and 20.8-21.8 ($X^2 = 18.24$; $p < 0.05$) (Fig. 3). In lagoon of point 2 there were a greater number of males in classes 18.6-19.6 ($X^2 = 5.0$; $p < 0.05$) and in river of point 2 a greater number of females in classes 18.6-19.6 and 19.7-20.7 ($X^2 = 15.0$; $p < 0.05$) (Fig. 4). There were a greater number of females in classes 19.7-20.7 ($X^2 = 6.0$; $p < 0.05$) in river of point 3 (Fig. 5).

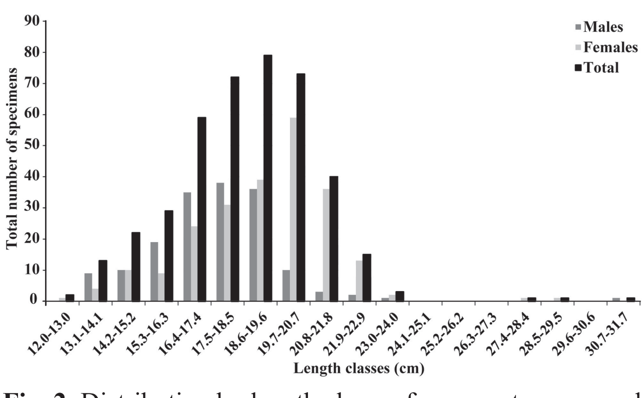

Fig. 2. Distribution by length classes for separate sexes and grouped sexes of *Loricariichthys melanocheilus* in the rio Ibicuí, Rio Grande do Sul.

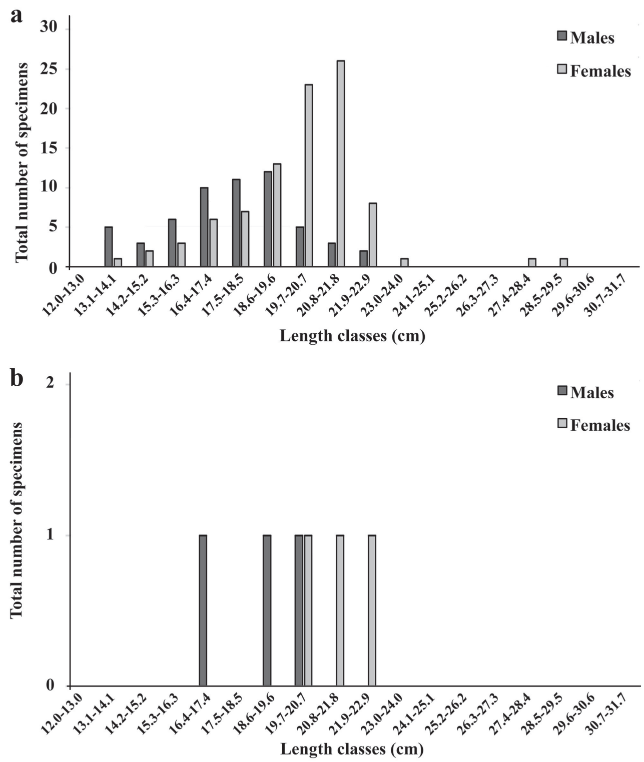

Fig. 3. Distribution of *Loricariichthys melanocheilus* in the rio Ibicuí by length classes for separate sexes in point 1. a: Lagoon and b: River.

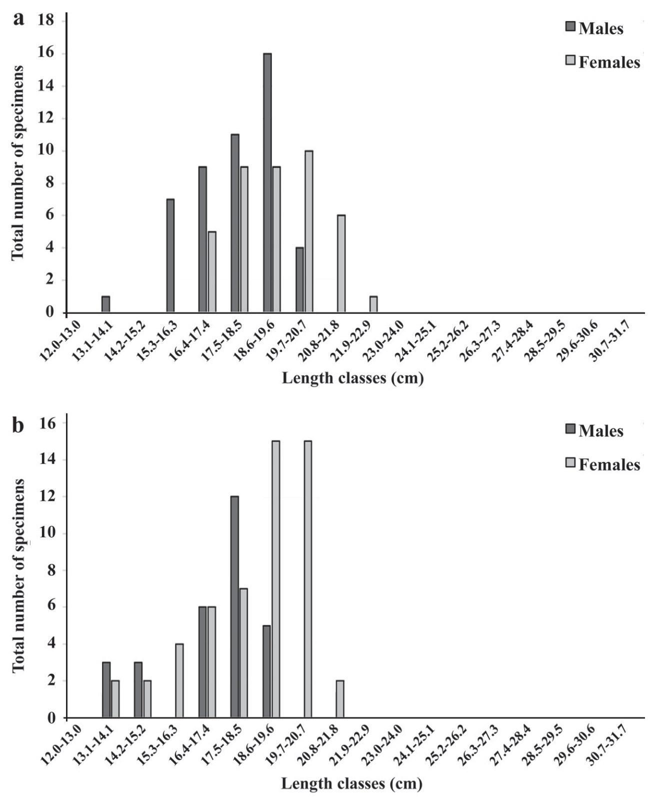

Fig. 4. Distribution of *Loricariichthys melanocheilus* in the rio Ibicuí by length classes for separate sexes in point 2. a: Lagoon and b: River.

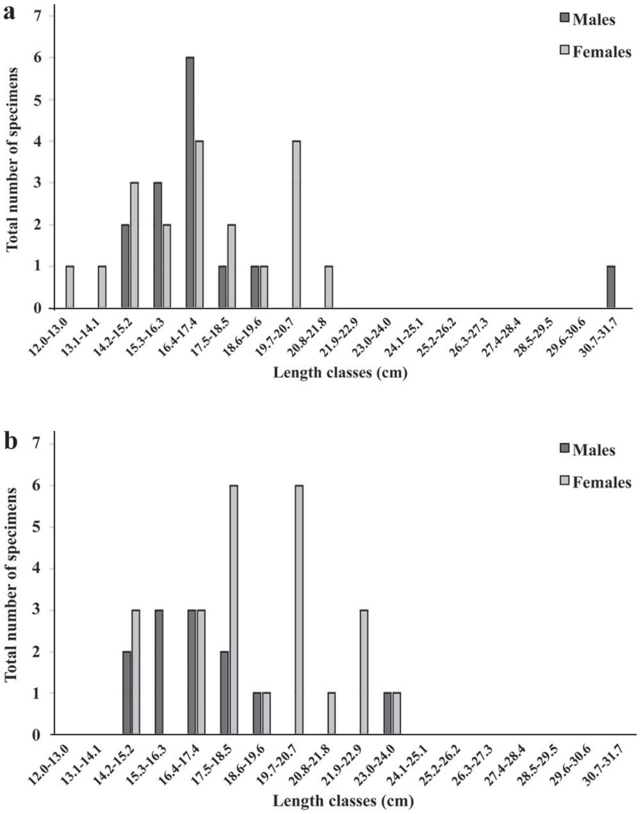

Fig. 5. Distribution of *Loricariichthys melanocheilus* in the rio Ibicuí by length classes for separate sexes in point 3. a: Lagoon and b: River.

The sex ratio (F:M) found when all periods were grouped was 1.38:1 (X^2 = 10.39; $p < 0.05$). There was a greater collection of males in February/March and females in October/November; in the other months, the ratio was 1:1, as expected (Table 1). The total number of collections was higher in December/January (X^2 = 143.41; $p < 0.05$) (Table 1). The species *Loricariichthys melanocheilus* showed preference for lentic environments, with 282 specimens captured in adjacent lakes and 128 in the main channel of the river (X^2 = 57.84; $p < 0.05$). There was a greater number of specimens collected in the lake of point 1 (X^2 = 217.73; $p < 0.05$) (Table 2).

The equation for weight/length relationship obtained for males was: $W_t = 0.003057 \times L_s^{3.307}$, and the linear regression between the logarithms of total weight (W_t) and standard length (L_s) resulted in the equation: $LnW_t = -5.790 + 3.307 \times LnL_s$ ($F = 2488.2$ $p < 0.001$). For females, the equation obtained was: $W_t = 0.001884 \times L_s^{3.487}$ and log transformation was: $LnW_t = -6.274 + 3.487 \times LnL_s$ ($F = 3778$ $p < 0.001$). Thus, both males and females showed positive allometric growth, with b = 3.307 for males and b =3.487 for females ($p < 0.05$). Fig. 6 shows the equations and linear regressions with the values of weight and length, their respective coefficient of determination (R^2) and overlapping lines between males and females.

Table 1. Total and bimonthly sex ratio of *Loricariichthys melanocheilus* in the rio Ibicuí, Rio Grande do Sul.

Months	Females	Males	Total	X^2	Ratio F:M
Dec-Jan	70	53	123	2.34 (p > 06)	1:1
Feb-Mar	37	57	94	4.25 (p < 06)	1:1.54
Apr-May	7	10	17	0.52 (p > 06)	1:1
Jun-Jul	12	9	21	0.42 (p > 06)	1:1
Aug-Sep	19	20	39	0.02 (p > 06)	1:1
Oct-Nov	85	15	100	49.0 (p < 06)	5.6:1
Total	230	164	394	10.39 (p < 06)	1.38:1

Table 2. Distribution by sampling points and their respective sex ratios for *Loricariichthys melanocheilus* in the rio Ibicuí, Rio Grande do Sul. (1R, 2R and 3R = Points 1, 2 and 3 in the river; 1L, 2L and 3L = Points 1, 2 and 3 in lagoons).

Points	Females	Males	Total	X^2	Ratio F:M
1R	3	3	6	0 (p > 06)	1:1
2R	53	29	82	7.02 (p < 06)	1.82:1
3R	23	13	36	2.77 (p > 06)	1:1
1L	92	57	149	8.22 (p < 06)	1.61:1
2L	40	48	88	0.72 (p > 06)	1:1
3L	19	14	33	0.75 (p > 06)	1:1
Total	230	164	394		

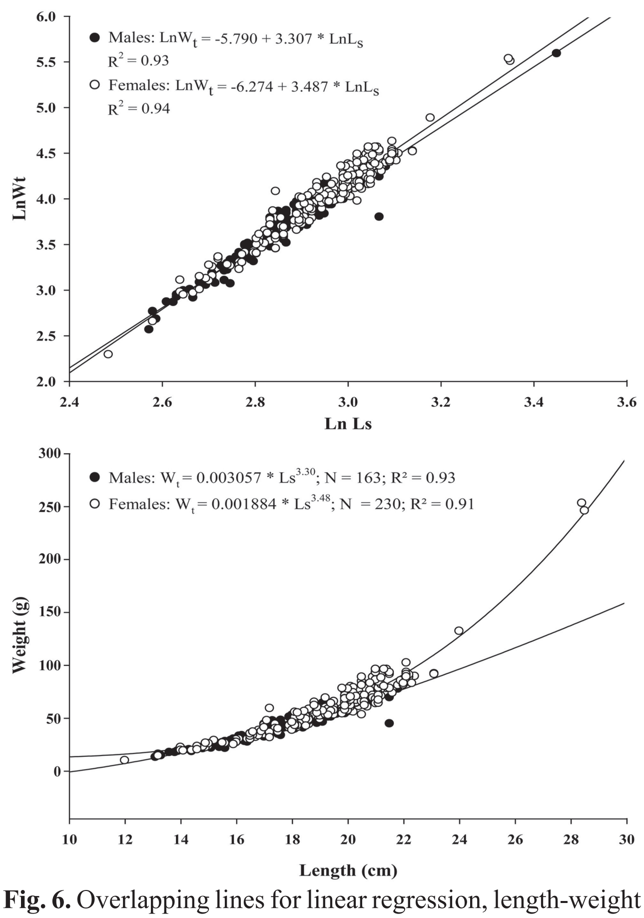

Fig. 6. Overlapping lines for linear regression, length-weight relationship and their respective equations between separate sexes of *Loricariichthys melanocheilus* in the rio Ibicuí, Rio Grande do Sul.

Males reached a distinctly larger condition factor (*K*) than females ($U = 5430.5$; $p < 0.001$) and this parameter varied bimonthly both for males and females during the study period, being higher in June/July for males ($H = 12.72$; $p < 0.05$) and October/November for females ($H = 35.2$; $p < 0.05$). Figs. 7 and 8 shows the variations in the total condition factor (*K*), somatic condition factor (*K´*) and gonad condition factor (Δ*K*), represented by the difference between the two parameters, which is indicative of breeding season. For females, the values of *K* and Δ*K* was higher in the lagoon of point 1, when compared to other points $H = 31.43$; $p < 0.05$ (Table 3).

The gonadosomatic index (GSI) for both males and females showed variations during the study period. For males, GSI was lower in April/May, and higher in the months of August/September, but a significant difference was observed only between the months of December/January and October/November ($H = 13.71$; $p < 0.05$). Females had higher GSI in October/November ($H = 72.49$; $p < 0.05$). The values of GSI did not show significant variations between points of collection ($p > 0.05$). For both males ($H = 39.89$; $p < 0.05$) and females ($H = 51.60$; $p < 0.05$), HSI was higher in June/July and lower in April/May (Figs. 9-10).

As for the stages of gonadal maturity, males had a higher frequency of stages C and D (mature and spent, respectively) in the months of December/January and February/March ($X^2 = 52.84$; $p < 0.05$ and $X^2 = 53.15$; $p < 0.05$). Only 12 immature specimens were found, and developing specimens (stage B) were found in all sampled months (Fig. 11). Only five immature females (stage A) were found throughout the sampling period. Developing females (stage B) were mainly observed in August/September and December/January ($X^2 = 13.05$; $p < 0.05$). The higher frequency of females in stage C (mature) was observed in October/November ($X^2 = 168.31$; $p < 0.05$), ($X^2 = 176.65$; $p < 0.05$), and in stage D (spent), in February/March (Fig. 12). Males in stage C was observed abundantly in lagoons of point 1 ($X^2 = 24.07$; $p < 0.05$) and 2 ($X^2 = 15.73$; $p < 0.05$) and females in lagoons of point 1 ($X^2 = 45.16$; $p < 0.05$) and river of point 2 ($X^2 = 41.86$; $p < 0.05$) (Figs. 13-14).

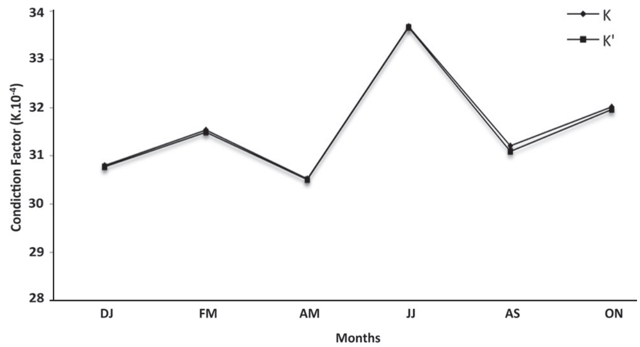

Fig. 7. Bimonthly variations in the total (*K*) and somatic (*K´*) condition factors for *Loricariichthys melanocheilus* males in the rio Ibicuí, Rio Grande do Sul. (DJ = December/January, FM = February/March, AM = April/May; JJ = June/July, AS = August/September, ON = October/November).

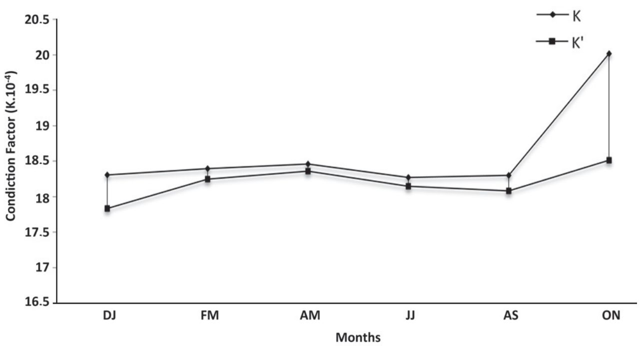

Fig. 8. Bimonthly variations in the total (*K*) and somatic (*K´*) condition factors for *Loricariichthys melanocheilus* females in the rio Ibicuí, Rio Grande do Sul. (DJ = December/January, FM = February/March, AM = April/May; JJ = June/July, AS = August/September, ON = October/November).

Table 3. Gonadosomatic Index (GSI), Total Condition Factor (*K*), Somatic Condition Factor (*K'*), Gonad Condition Factor (ΔK) and his standards deviation of *Loricariichthys melanocheilus* in rio Ibicuí by points of collection. (1R, 2R and 3R = Points 1, 2 and 3 in the river; 1L, 2L and 3L = Points 1, 2 and 3 in lagoons). *Different letters in rows indicates significance (p < 0.05).

	Males					
	Point 1L	Point 1R	Point 2L	Point 2R	Point 3L	Point 3R
GSI	0.17 ±0,03	-	0.08 ±0.009	0.29 ±0.19	0.03 ±0.009	0.04 ±0.01
K	31.76 ±0.42	-	31.56 ±0.33	30.57 ±0.43	29.71 ±0.7	32.00 ±0.75
K’	31.71 ±0.42	-	31.53 ±0.33	30.48 ±0.44	29.70 ±0.69	31.99 ±0.74
ΔK	0.05 ±0.01	-	0.03 ±0.003	0.09 ±0.06	0.01 ±0.003	0.01 ±0.006
	Females					
	Point 1L	Point 1R	Point 2L	Point 2R	Point 3L	Point 3R
GSI	2.80 ±0.27	-	1.94 ±0.31	3.34 ±0.31	0.68 ±0.25	2.83 ±1.13
K	19.78^{a} ±0.21	-	18.19^{b} ±0.19	18.42^{b}±0.28	17.96^{b} ±0.40	18.66^{ab} ±0.36
K’	18.84 ±0.18	-	17.83 ±0.19	17.81 ±0.28	17.83 ±0.38	18.15 ±0.42
ΔK	0.60^{c} ±0.05	-	0.35^{ac} ±0.05	0.61^{ac} ±0.05	0.13^{b} ±0.05	0.51^{abc} ±0.2

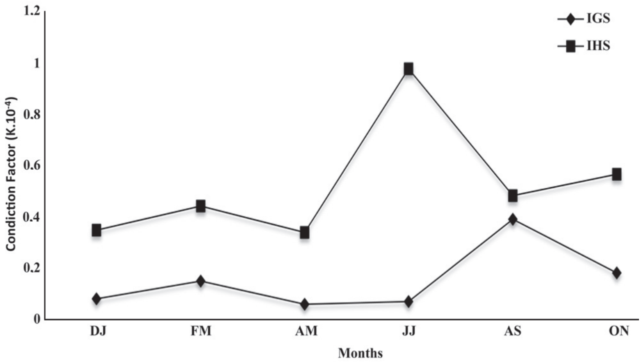

Fig. 9. Bimonthly variations in the gonadosomatic index (GSI) and hepatosomatic index (HSI) for *Loricariichthys melanocheilus* males in the rio Ibicuí, Rio Grande do Sul. DJ = December/January, FM = February/March, AM = April/May; JJ = June/July, AS = August/September, ON = October/November.

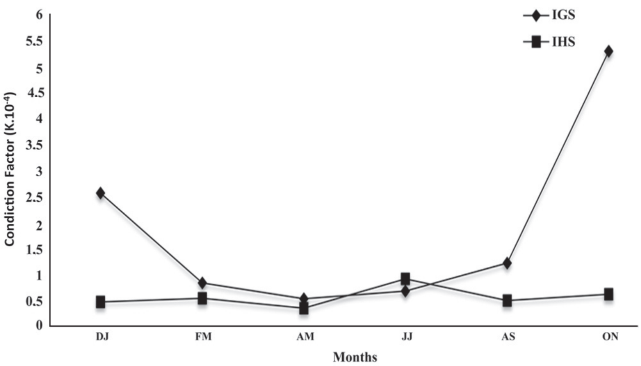

Fig. 10. Bimonthly variations in the gonadosomatic index (GSI) and hepatosomatic index (HSI) for *Loricariichthys melanocheilus* females in the rio Ibicuí, Rio Grande do Sul. DJ = December/January, FM = February/March, AM = April/May; JJ = June/July, AS = August/September, ON = October/November.

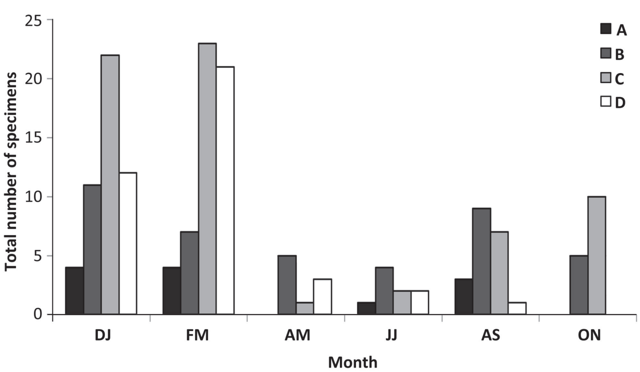

Fig. 11. Bimonthly distribution of gonad maturity stages of *Loricariichthys melanocheilus* males in the rio Ibicuí, Rio Grande do Sul. DJ = December/January, FM = February/March, AM = April/May; JJ = June/July, AS = August/September, ON = October/November); A = immature, B = developing, C = mature D = spent.

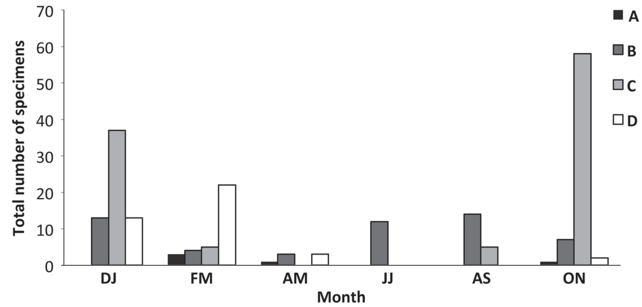

Fig. 12. Bimonthly distribution of gonad maturity stages of *Loricariichthys melanocheilus* females in the rio Ibicuí, Rio Grande do Sul. DJ = December/January, FM = February/March, AM = April/May; JJ = June/July, AS = August/September, ON = October/November); A = immature, B = developing, C = mature D = spent.

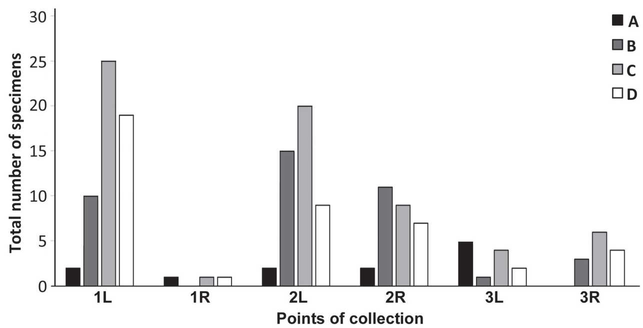

Fig. 13. Distribution of gonad maturity stages of *Loricariichthys melanocheilus* males in the rio Ibicuí by point of collection. 1L, 2L and 3L = Lagoon of points 1, 2 and 3 respectively, 1R, 2R and 3R = River of points 1, 2 and 3 respectively.

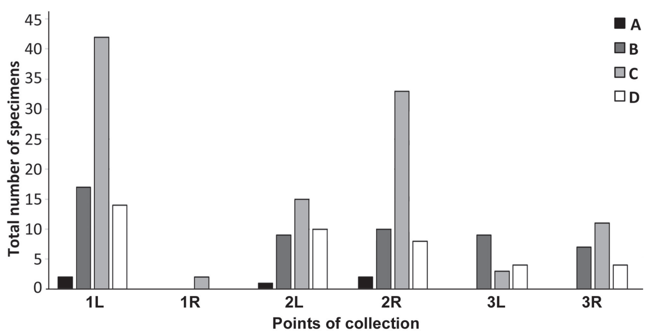

Fig. 14. Distribution of gonad maturity stages of *Loricariichthys melanocheilus* females in the rio Ibicuí by point of collection. 1L, 2L and 3L = Lagoon of points 1, 2 and 3 respectively, 1R, 2R and 3R = River of points 1, 2 and 3 respectively.

Discussion

The maximum sizes recorded for *Loricariichthys melanocheilus* in the rio Ibicuí are higher than those recorded by Reis & Pereira (2000), who found specimens measuring until 20.9 cm SL in rivers and streams of the rio

Uruguay basin. However, the maximum size recorded for this species is 43 cm SL (Teixeira de Mello *et al*., 2009), in the río Negro, Uruguay.

There was a greater number of collections in December/January, October/November and February/March as well as a greater number of collections in lentic environments. Tos *et al*. (1997) and Duarte & Araújo (2001) also observed preference for lentic environments by *Loricariichthys platymetopon* and *L. spixii* in the rio Paraná and in the Lajes reservoir (State of Rio de Janeiro), respectively. Lowe McConnell (1999) states that a higher concentration of fish is expected in lakes during the dry season because of water retraction in wetlands. As water level of the rio Ibicuí was observed to be lower during the summer, it can be said that this fact has contributed to increased collections in lakes.

Sex ratio skewed to females when we considered the total of collections is mainly due the larger number of females catches in October / November. In other studies with species of the genus *Loricariichthys*, *e.g. L. platymetopon* in the Paranapanema and the Paraná rivers (Marcucci *et al*., 2005; Bailly *et al*., 2011) and *L. spixii* in the Lajes reservoir (Duarte *et al*., 2007) this pattern also were observed. Although registered for some species, the 1:1 ratio is seldom found. According to Nikolsky (1963), variations in sex ratio can occur between populations of the same species and between different periods within a single population. Furthermore, an adaptation of the species itself ensures the prevalence of females when conditions are very favorable to egg production, such as during colonization of a new environment or even when the species undergoes intensive fishing.

Many other factors can influence the predominance of one sex over the other, *e.g.*, mortality, growth, different behavior of males and females, higher predation rates in a particular sex or even factors related to the selectivity of collections (Vazzoler, 1996; Raposo & Gurgel, 2001). In the present study, there were variations in sex ratio in different environments, and a greater number of females was found in the lake of point 1 and in the river of point 2, and the difference in growth of males and females seems to be the most influential factor in sex ratio in different length classes in the present study. Females were longer and heavier than males, and when this study analyzed length classes in more depth, it could be observed that the classes of greater length have a higher number of females. This pattern was also found by other researchers working with species of the same genus. Marcucci *et al.* (2005), working with *Loricariichthys platymetopon* in the rio Paranapanema, found a larger number of males in the classes below 20 cm, and there was greater collection of females in the following classes: 20 to 28 cm SL. Tos *et al.* (1997) also reported that females of *Loricariichthys platymetopon* were larger than males. According to these researchers, in species of the family Loricariidae, where the behavior of males is that of protecting their offspring in the nest, males are usually larger than females because they may have to face situations of struggle; this behavior is mainly observed for species of the genus *Hypostomus* (Agostinho *et al*., 1991). However, this does not seem to be the case for species of the genus *Loricariichthys*, because as already observed by some researchers (Tos *et al*., 1997; Marcucci *et al*., 2005; Duarte *et al*., 2007), the males of these species carry the eggs, protecting them with a well-developed labial expansion; in a state of disorder, males abandon the egg mass with no defense behavior, and return to it as soon as the situation of stress or disturbance ends (Tos *et al*., 1997). For *Loricariichthys melanocheilus*, males had smaller sizes than females and in some cases, it was possible to observe this lip expansion; thus, it is assumed that this behavior is similar to that of the other species of *Loricariichthys* cited above.

The parameters of length-weight relationship (*a* and *b*) are used in various ways in studies on fish; for example, to estimate the weight of specimens from length, to calculate the condition factor, to compare the life history and morphology of populations of different regions, and to study allometric ontogenetic changes (Petrakis & Stergiou, 1995; Teixeira de Mello *et al*., 2006). Le Cren (1951) states that values for *b* range from 2.0 to 4.0, assuming a value of 3.0 for "ideal fish", maintaining the same shape during ontogenic growth. Values lower or higher than 3.0 are indicative that specimens respectively become more "longilineal" or "round" throughout their growth (Araújo & Vicentini, 2001). According to the allometric coefficient obtained in the present study, this species has a positive allometric growth and a greater increase in weight than in length along its development. This pattern was not found for some species of the family Loricariidae; isometric growth was found for *Rhinelepis aspera* (Agostinho *et al*., 1990) and *Hypostomus ancistroides* (Viana *et al*., 2008), while highly negative allometric growth was observed for *Pareiorhina rudolphi* (Braga *et al*., 2009). However, the allometric coefficient appears to be also associated with the body shape of a given species. Bruschi Jr. *et al.* (1997) argue that the positive allometry observed in *L. anus* is due to the shape of the body, which, unlike that of the aforementioned catfish, is flattened dorso-ventrally, suggesting that positive allometry is related to larger lateral dimensions compared to the ends of the body. Thus, the positive allometry found in *Loricariichthys melanocheilus* in this study can be explained by body shape, which resembles that of *L. anus*, as well as the allometry found for other species of the same genus (Bruschi Jr. *et al*., 1997; Tos *et al*., 1997). Teixeira de Mello *et al*. (2009, 2011) observed positive allometric growth and isometric growth, respectively ($a = 3.38$; $b = 3.02$), for two different populations of *Loricariichthys melanocheilus* in low and middle stretches of the río Negro in Uruguay at different times. Here, the length-weight relationship was obtained from populations that had different sizes; in the first study, the standard length of the specimens ranged between 7.3

and 43 cm, and in the second study, it ranged between 6.5 and 17.8 cm. When this ratio was recalculated by Teixeira de Mello *et al*. (2011) with the use of specimens of similar sizes, the allometric coefficient of the first population increased from 3.38 to 3.44. This increase showed that there may be changes in allometry, depending on the ontogenetic development of the fish, as well as changes to the environment of each population.

By analyzing the curve of the length-weight relationship, it can be seen that females are heavier than males at a given length and are more likely to gain weight throughout their development, probably because their gonads give a greater contribution to total weight. Isaac-Nahum & Vazzoler (1983) stated that the intense pace in the development of female gonads usually have a direct influence on total weight and changes to body shape throughout the reproductive cycle.

The Condition Factor is a widely used index in the study of fish biology, as it provides important information about the physiological state of the animals by assuming that specimens with greater mass in a given length are in better condition (Lima-Junior *et al*., 2002). Variation in this index over the year can be used as additional data in the study of seasonal cycles of feeding and reproduction (Braga, 1986; Lima-Junior *et al*., 2002.) The condition factor and gonadosomatic indexes, which reflect the development of ovaries or testicles as percentages of total weight, can indicate the breeding season of a given species, and they are being frequently used for this purpose by many researchers in several Brazilian basins (Vazzoler, 1996; Costa *et al*., 2005; Ribeiro *et al*., 2007; Holzbach *et al*., 2009). Both males and females showed greater differences between K and K' from August/September through February/March. These values are more striking in females because the ovaries are larger and, thus, heavier than testicles. According to these values and the seasonal distribution of maturity stages C (Mature) and D (spent), which were more frequent from October/November through February/March for both males and females, it can be stated that the breeding season of *Loricariichthys melanocheilus* begins in August/September, with a peak of maturity in October/November and December/January, while spawning takes place in December/January and February/March, coinciding with the period of higher temperatures. The values for GSI also began to rise in August/September, peaking in October/November for females and August/September for males. Similar results were found in other Loricariidae in various regions of Brazil, for example, *Rhinelepis aspera* (Agostinho *et al*., 1990), *Hypostomus commersonii* (Agostinho *et al*., 1991), *H. ancistroides* (Viana *et al*., 2008), *Rineloricaria latirostris* (Barbieri, 1994), *Loricariichthys platymetopon* (Bailly *et al*., 2011; Marcucci *et al*., 2005), *L. spixii* (Duarte *et al*., 2007), among others. Males showed distinctly greater condition factor than that of females throughout the study period, probably because of higher energy expenditure of females during the maturation process (Cantanhêde *et al*., 2007), a feature also reported by Agostinho *et al*. (1990) for *Rhinelepis aspera* in the rio Paranapanema (state of Paraná). The explanation for a higher condition factor in males in the period preceding the breeding season can be explained by a greater accumulation of reserves during that period for use in the maturation period, when such reserves are spent. This is behavior also observed in other species (Agostinho *et al*., 1990; Freitas *et al*., 2011; Holzbach *et al*., 2009). In females, the total condition factor (K) is greater in October/November, probably as a result of a greater influence of gonad weight during this period, as it is the peak period of gonadal maturity. When gonad weight is disregarded, a decrease in the somatic condition factor (K') can be observed in December/January, but as there was no significant difference, it cannot be stated whether this is due to energy expenditure with spawning. In other periods, no significant changes were identified in the condition factor of females, which is indicative of few environmental and physiological changes.

Seasonal reproductive cycles may be strongly influenced by biotic factors such as food availability and competition, and abiotic factors such as variations in temperature, photoperiod and rainfall (Dala-Corte & Azevedo, 2010). In tropical regions of Brazil, where the level of the rivers determines the availability of habitat and food, rainfall seems to be the factor that most influences the reproductive cycles of fish (Vazzoler *et al*., 1997; Agostinho *et al*., 2004; Bailly *et al*., 2008; Freitas *et al*., 2011). This pattern is well documented by Vazzoler *et al*. (1997), who associated the increase in the reproductive intensity of fish from the floodplain of the upper rio Paraná with increased photoperiod, temperature and river level. However, in subtropical regions, the breeding season of fish seems to be more influenced by temperature and photoperiod than by rainfall, because there are not well defined periods of drought and flood in subtropical regions, compared to tropical ones (Vazzoler & Menezes, 1992). Thus, the breeding season of *Loricariichthys melanocheilus* in the rio Ibicuí is strongly influenced by increased temperature and photoperiod, but it was not associated with the increase in river level, a feature also found for several species studied in Rio Grande do Sul, such as *Serrapinus calliurus* (Boulenger, 1900) (Gelain *et al*., 1999), *Cheirodon ibicuhiensis* Eigenmann, 1915 (Oliveira *et al*., 2002), *L. platymetopon* (Querol *et al*., 2002), *Bryconamericus iheringii* (Boulenger, 1887) and *B. stramineus* Eigenmann, 1908 (Lampert *et al*., 2004, 2007). Something that is worth of notice is the large amount of specimens collected in the lake of point 1, located in the upper stretch of the rio Ibicuí in the breeding season, and a low number of specimens collected at point 3 in the lower stretch of the river. Moreover, there was a great number of males and females in stage C in lagoons of point 1 and point 2 and in river of point 2, in case of the females. In females, the gonad condition factor was higher in lagoon of point 1 and river of point 2, suggesting that *Loricariichthys melanocheilus* may perform small breeding migrations using these sites for spawning. To contribute with this fate, there was a greater number of females in superior classes in these points, suggesting the use of these sites by matures females. However, there are no records of such activity for species of this genus in the literature, and these species are known for not performing this type of migration (Nakatani *et al*., 2001; Bailly *et al*., 2008).

Some researchers have established relationships between hepatosomatic index and reproductive cycles of several species (Agostinho *et al*., 1990; Querol *et al*., 2002; Andrade *et al*., 2003; Costa *et al*., 2005; Cantanhêde *et al*., 2007; Viana *et al*., 2008). According to Agostinho *et al*. (1990), gonad maturity and reproductive activity imply the use of materials obtained from ingested food and mostly from energy reserves deposited in different parts of the body. Therefore, it is expected that the weight of liver and other reserve organs reflect this event. This fact holds true in the present study, where an increase was observed in liver weight in the months of June/July for both males and females. In the case of males, HSI increased as the condition factor increased during the period preceding the onset of reproduction. This reinforces the idea that there is an accumulation of reserves for reproductive activity. Similar results were found for *Loricariichthys platymetopon* and *Rhinelepis aspera* (Agostinho *et al*., 1990; Querol *et al*., 2002), and also for Characiformes, such as *Leporinus copelandii* Steindachner, 1875 (Costa *et al*., 2005), *Steindachnerina insculpta* (Fernández & Yépez, 1948) (Ribeiro *et al*., 2007), *Astyanax henseli* de Melo & Buckup, 2006 (Dala-Corte & Azevedo, 2010), among others. According to Svedäng & Wickström (1997), in the case of females, the decrease in HSI during the maturation period is mainly due to the depletion of liver reserves as a result of depletion of glycogen and lipids in hepatocytes, where the synthesis of vitellogenin (Mommsen & Korsgaard, 2008) and transfer to oocytes take place.

Thus, it is concluded that the species in study shows preference for lentic environments, with specimens being more easily collected in periods of lower hydrological levels, which coincide with the highest temperatures recorded. There was a predominance of females when considering the entire period of the study, however this is because there was a great capture of females in October/November. They reached greater sizes than males, and a greater number of females was observed in classes of greater size. The data on the length-weight relationship led to the conclusion that both sexes have positive allometric growth, with females reaching larger weights in a given length. Based on bimonthly distributions of gonad maturity stages, comparisons of GSI values and gonad condition factor, and on the valuation of changes in HSI, it can be concluded that the breeding season of *L. melanocheilus* in the rio Ibicuí goes from October/November through February/March, months when temperatures reach the highest values and river levels are lower, and the species appears to show some migratory movements rising over the river.

Knowledge of these and other aspects related to the biology and ecology are essential for the establishment of tools and strategies focusing for proper management and operation as well as conservation of this species in the ecosystem studied. However, it should be noted that these studies should be further explored and extended in order to obtain more precise information, especially with regard to the reproductive biology of fish.

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