

## **Growth and reproduction aspects of *Pimelodus maculatus* Lacépède, 1803 (Siluriformes, Pimelodidae) of the Cachoeira Dourada reservoir, state of Goiás and Minas Gerais, Brazil**

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Received February 23, 2012 – Accepted June 5, 2012 – Distributed May 31, 2014  
(With 8 figures)

### **Abstract**

Growth and reproduction parameters of the yellow-mandi, *Pimelodus maculatus* Lacépède, 1803 (Siluriformes, Pimelodidae), were determined for the Cachoeira Dourada reservoir (GO/MG). The field work occurred throughout February 2007 to January 2008 (with the exception of December 2007). Gill nets with mesh sizes from 1.5 to 10 centimeters were placed in three different areas in the reservoir and were collected 24 hours later. A total of 538 specimens were captured, amongst which 242 were females, 219 were males and 77 could not have their sex determined. Sex ratio differed from 1:1 only during July 2007 and January 2008, with males and females predominating in each of those months. Males occupied the medium length classes (18.9 to 24.3 cm) while females were most abundant in the superior classes (from 27 to 37.8 cm). The growth constant K was statistically equal for males ( $K=0.1851$ ) and females ( $K=0.1708$ ), however, females *P. maculatus* may have a greater investment in reproductive tissue, a fact indicated by the elevated values of  $K_n$  and GSI during the summer. Bearing in mind that *P. maculatus* reproduces in the rainy season, a greater gain in weight is expected during the months before the reproduction season, and that after it occurs the fish loses fat and weight as a consequence of metabolic effort. Still, the absence of juveniles may be an indication that the species did not find in the reservoir the proper conditions for reproduction and growth of its fry.

*Keywords:* condition factor, GSI, length-weight relationship, Population Dynamics.

### **Aspectos da dinâmica populacional e reprodutiva de *Pimelodus Maculatus* (Siluriformes, Pimelodidae) no reservatório de Cachoeira Dourada (GO-MG), Brasil.**

### **Resumo**

O presente estudo procurou averiguar os parâmetros de crescimento e reprodução do mandi-amarelo, *Pimelodus maculatus* Lacépède, 1803 (Siluriformes, Pimelodidae), no reservatório de Cachoeira Dourada (GO/MG). As coletas ocorreram de fevereiro de 2007 a janeiro de 2008 (exceto em dezembro de 2007), em três pontos do reservatório, com auxílio de baterias de redes com malhas variando de 1,5 a 10,0 cm entre nós adjacentes durante 24 horas. Foi capturado um total de 538 indivíduos dentre os quais 242 fêmeas, 219 machos e 77 de sexo indeterminado. A proporção sexual diferiu de 1:1 em julho de 2007 e janeiro 2008, com o predomínio de machos e fêmeas, respectivamente. Os machos concentraram-se nas classes de comprimento medianas (18,9 a 24,3 cm) enquanto que as fêmeas nas superiores (de 27 a 37,8 cm). A constante de crescimento K foi estatisticamente igual entre machos ( $K=0.1851$ ) e fêmeas ( $K=0.1708$ ), no entanto, *P. maculatus* fêmeas parecem ter um maior investimento em tecido reprodutivo, fato indicado pelos elevados valores de  $K_n$  e IGS durante o verão. Tendo em vista sua desova durante o período chuvoso, é esperado um maior ganho de peso nos períodos que antecedem a reprodução e que após esse processo haja uma perda de gordura ou peso devido aos gastos metabólicos envolvidos. Ainda, a ausência de captura de *P. maculatus* juvenis pode ser uma indicação de que a espécie não encontrou na área condições adequadas para tal.

*Palavras-chave:* fator de condição, IGS, relação peso-comprimento, Dinâmica de Populações.

## 1. Introduction

The pimelodid *Pimelodus maculatus* Lacepède, 1803 is found amongst the migratory species that represents monetary value in commercial and recreational fishing in waters from Brazilian southwestern rivers (Lundberg and Littmann, 2003) with a wide geographic distribution, comprising the main South American basins (Fowler, 1951; Ringuelet et al., 1967; Britski et al., 1988). In the Upper Paraná River basin *P. maculatus* is one of the four main species caught commercially (CESP, 1994; Agostinho, 1995). It was one of the most captured species in four reservoirs in the Paraná River basin during the 90's (Braga, 2000).

Migratory species are of great importance for fish farming as they can be needed for natural stock re-establishment as well as for sport fishing or inclusion in the market (Carolsfeld and Harvey, 2003). Pollution, deforestation, alteration and obstruction of water bodies are changes that influence the natural water flow blocking migration or eliminating barriers that once hindered the faunal exchange between basins (Smith, 1985). Species that persist are those capable of feeding and reproducing, adapting to the new ecosystem's characteristics (Fernando and Holčík, 1991).

As known, the balance of an aquatic community depends of the environmental conditions to which it is submitted thus habitat modifications caused by hydroelectric enterprises have direct influence over biological functions, such as feeding, reproduction, growth, birth and death rates of fish communities, having high impact on the ichthyofauna. The building of dams alters the natural ecosystem; however, it is an activity that has been done since the beginning of time (Agostinho, 1994). The effects of these constructions over the ichthyofauna have been the object of study in reservoirs such as Itaipú, Volta Grande and Segredo (Paiva, 1983; Agostinho, 1994; Cecilio et al., 1997; Braga, 2000) where the disappearance of large migratory fish species has been observed and the replacing of them for secondary species of low commercial value (Petrere et al., 2002).

Data on *Pimelodus maculatus* reproductive biology has been gathered by many authors (Godinho et al., 1974; Basile-Martins et al., 1975; Fenerich et al., 1975; Godinho et al., 1977; Barbosa et al., 1988; Braga 2000) while others have studied its omnivorous habit and feeding activity (Basile-Martins et al., 1986; Lolis and Andrian, 1996; Braga, 2000; Lobón-Cerviá and Bennamann, 2000; Lima-Junior and Goitein, 2003, 2004). However, even though *P. maculatus* is one of the most abundant fish in the Paraná River Basin, its condition throughout the year has only been studied by Nomura et al. (1972), Braga (2000) and Lima-Junior and Goitein (2006). The main aim of the present study was to analyse the growth, as well as reproductive and condition parameters of the yellow-mandi, *Pimelodus maculatus*, in the Cachoeira Dourada reservoir (GO/MG), Paraná River basin, Brazil throughout a whole year.

## 2. Material and Methods

The Cachoeira Dourada hydroelectric reservoir is located between the states of Minas Gerais and Goiás (between 18°30'11.47"S 49°29'18.78"W and 18°34'5.27"S 49°19'52.07"W). It is formed by the damming of the Paranaíba River, one of the main tributaries of the Parana River basin.

The hydroelectric complex operates with a total of 10 water turbines with an installed capacity of 658 MW (<http://www.endesageracaobrasil.com.br/>). With total area of 74 km<sup>2</sup>, the reservoir was constructed during the 50's in order to provide energy for the construction and development of Brasília. Nowadays the reservoir is surrounded by cattle fields and sugar cane, soy and pineapple crops (Figure 1).

Samplings occurred from February 2007 to January 2008 (with the exception of December when no sampling occurred). Specimens of *Pimelodus maculatus* were captured with the use of gillnets with mesh sizes varying from 1.5 to 10.0 cm in-between adjacent knots that stayed submerged for 24 hours in three areas along the reservoir (P1, P2 and P3 – Figure 1).

After the sampling the fishes were moved to the Population Dynamics Laboratory of the Federal University of São Carlos inside thermal boxes packed with ice for conservation. For biometrical analysis total length (Lt) and standard length (Ls) were measured in centimeters and total weight was measured in grams (precision balance model Gehaka BG 1000). Voucher specimen was deposited at the São José do Rio Preto zoological collection at the Paulista State University (DZSJRP010846).

Dissection followed with the removal of the gonads for weighing (Wg), as well as the determination of sex and maturation with the observation of the gonads' colour, transparency, volume and number of blood vessels irrigating it. The gonads maturation state followed the classification proposed by Maia et al. (2007) for the same species: 1- immature/resting, 2- in maturation (initial, intermediate or advanced), 3- mature and 4- in reabsorption (after reproduction).

Sturges postulate (Silva and Souza, 1988) was applied for the determination of the number and the interval of classes of total length.

Sex ratio composition and total length (Lt) of *Pimelodus maculatus* population were analysed. The Yeats' qui-square test (95%) was applied over the absolute frequencies of males and females of each month in order to establish if the sex ratio between them followed the null hypothesis of 1:1.

The methodology proposed by Le Cren (1951) was used in order to determinate the weight/length relationship. After logarithmically adjusting the variables Wt and Lt and using the minimum square method to linearise it for both males and females. The parameters "a" (proportionality constant or intercept) and "b" (exponent) of the length-weight relationship of the form  $W=aL^b$  were estimated for males, females and combined sexes. The coefficient "b" expresses how size and weight are related to each other. When  $b = 3$ , its indicative that fishes grow in a isometric



**Figure 1.** Satellite image of the Cachoeira Dourada Reservoir and its placement between Goiás and Minas Gerais States, Brazil. BA=dam; P1, P2 and P3 = sampling areas 1, 2 and 3. Source: Wikipedia and Google Maps.

way; when  $b > 3$ , growth form is positive allometric; in the case of  $b < 3$ , negative allometric growth (Le Cren, 1951). It is important to note that according to Froese (2006), if  $b=3$ , then small specimens have the same form and condition as large specimens, while if  $b>3$  large specimens may presents ontogenetic changes in body shape with size or they are fatter than small specimens, and if  $b<3$  large specimens may have changed their body shape to become more elongated or small specimens are in better nutritional condition.

The expression of growth in length was obtained by the observation of how the modes of the monthly distributed

frequency of occurrence evolved at each month sampled. When  $\Delta t$  was variable, a linear transformation between the increase in length and the average of the modes was done following Santos (1978), who uses the Von Bertalanffy (1938) mathematical expression for the growth curve, reviewed by Beverton and Holt (1957) after its validity was checked by the Ford-Walford method (Ford, 1933; Walford, 1946). The Von Bertalanffy mathematical expression was used as follows:  $L_t = L_\infty [1 - e^{-k(t-t_0)}]$ , where the growth constant  $K$  was calculated on the expression:  $K = \ln(b)$ .

The relative condition factor was determined according to Le Cren (1951), calculated by the expression:  $Kn = Wt/W$

We, where  $W_e$  is the estimated weight obtained by applying the observed lengths in the weight-length relationship formula. With the relative condition factor it is possible to distinguish between and measure separately the influences on condition of length and other factors, such as feeding conditions and reproductive periods, whereas these are not readily and separated when the ordinary condition factor is used.

After calculating the  $K_n$  for males and females, the means and the confidence interval were estimated of each season (Autumn, Winter, Spring and Summer). The  $K_n$  was chosen for its practical advantages, its values being compared to the standard relative condition factor value of 1.0 by the Student  $t$ -test ( $\alpha=0.05$ ). The Kruskal-Wallis test, complemented by the Dunn test for multiple non parametric comparison, was used in order to verify differences between the values of  $K_n$  for each season (BioEstat 5.0).

After the macroscopic analysis of the gonads, the gonad somatic index was calculated (GSI) (Vazzoler, 1996). The values obtained were plotted in graphs relating the average values of GSI in each season with the frequency of occurrence of the gonads' maturation state.

### 3. Results

A total of 538 specimens were captured, amongst which 242 were females, 219 males and 77 could not be identified because of advance decomposition or the small size of the gonads (Table 1).

The sex ratio for the *P. maculatus* population differed significantly from 1:1 only during the months of July 2007, with males predominating ( $\chi^2=6.54$   $gl=1$   $p<0.05$ ), and January 2008 with females more abundant ( $\chi^2=7.84$   $gl=1$   $p<0.05$ ) (Table 2).

Analysing the sex ratio between the different length classes (Figure 2), the smaller total length class intervals show a greater number of males, having the first four classes shown statistical differences in the sex ratio. Females occupied classes of greater size, fact that caused

the appearance of similar proportions between sexes when the whole sampled population was analysed.

The total length of females varied from 13.5 to 39.8 cm while males varied from 13.6, 34.2, where both sexes were distributed in 10 classes with an amplitude of 2.7 cm (Figure 3), showing a mode within the size classes from 18.9 to 29.7 cm. Winter and Spring were the seasons with the greater number of individuals distributed in all classes.

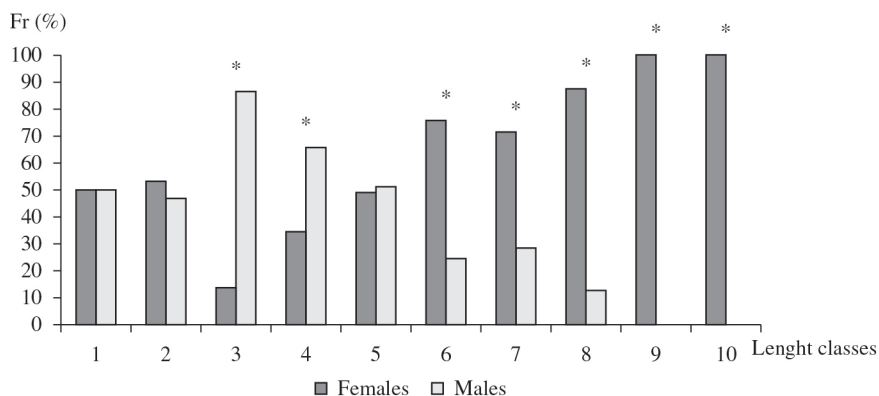
The growth curves for males (A) and females (B), according to the Von Bertalanffy model, using the length frequency distribution method, are shown in Figure 4. The equations that represent the growth of the species are  $L_t=42.17(1-e^{-0.1851t})$  for males and  $L_t=43.86(1-e^{-0.1708t})$  for females. The growth constant was slightly greater for males ( $K=0.1851$ ) than for females ( $K=0.1708$ ), revealing an accelerating growth rate for *P. maculatus* males compared to females (Figure 4).

The weight/length relationship was established after a linear regression by the equation  $W_t=0.007L_t^{3.099}$  (Figure 5), after verification of the separate individual equations for males ( $W_t=0.0073L_t^{3.1004}$ ) and females ( $W_t=0.0095L_t^{3.0175}$ ).

The average  $K_n$  values for females during summer, autumn, winter and spring in 2007 and for the summer of 2008 are shown in Figure 6 and for males in Figure 7. The calculated  $K_n$  values for females did not show significant difference when compared between seasons with the Kruskal-Wallis test (Dunn method). On the other hand, the same analysis for males showed differences in the

**Table 1.** Numeric frequency of *Pimelodus maculatus* according to sex for each season in the Cachoeira Dourada reservoir (GO/MG/MG), sampled from February 2007 to January 2008 (M=males; F=females; Und.=undetermined).

Season	M	F	Und.	Total
Summer 2007	11	20	10	41
Autumn 2007	24	16	16	56
Winter 2007	77	84	20	181
Spring 2007	73	71	23	167
Summer 2008	34	51	8	93

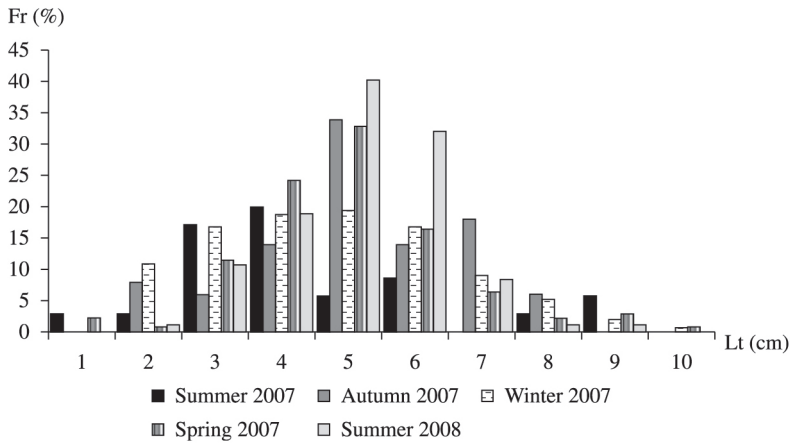


**Figure 2.** Relative frequency of males and females of *Pimelodus maculatus* from the Cachoeira Dourada reservoir (GO/MG), sampled from February 2007 to January 2008, according to sex and total length classes, from 13.5 to 40.5 cm with 3 cm of interval. Significant differences (\*) were found after the chi-square test ( $p<0.05$ ).

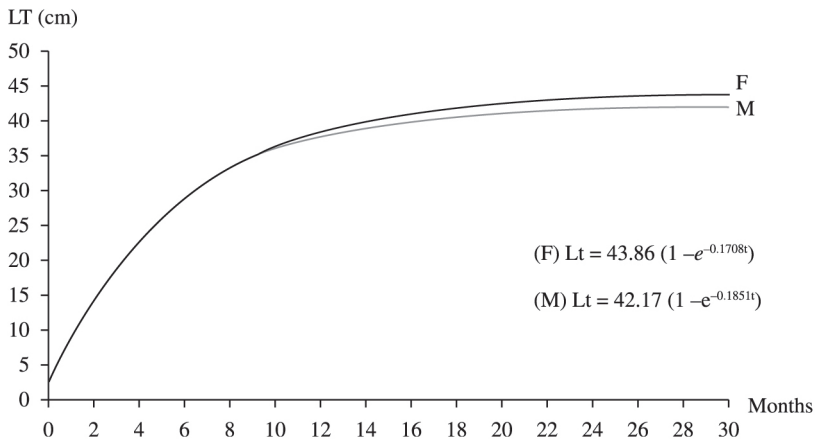
**Table 2.** Absolute (FA) and relative (FR) frequencies of females and the Yates'qui-square test ( $\chi^2$ ) results for sex ratio of *Pimelodus maculatus* from the Cachoeira Dourada reservoir (GO/MG) in each sampled month.  $\chi^2_{critical} = 3,841$ ;  $\alpha = 0,005$ ; 1 gl  $H_0 = 1:1$ .

	Females		Males		$\chi^2$
	n	FR(%)	n	FR(%)	
Feb	7	2.892562	9	4.109589	1.32
Mar	0	0	1	0.456621	x
Apr	9	3.719008	11	5.022831	0.81
Mai	7	2.892562	13	5.936073	8.41 (*)
Jun	26	10.7438	29	13.24201	0.19
Jul	5	2.066116	17	7.762557	28.67 (*)
Aug	16	6.61157	8	3.652968	10.45 (*)
Ste	37	15.28926	23	10.50228	4.99 (*)
Oct	34	14.04959	32	14.61187	0.04122
Nov	37	15.28926	41	18.72146	0.17042
Dec	0	0	0	0	x
Jan	64	26.44628	36	16.43836	7.29 (*)
Total	242	100	219	100	0.15913

Significant differences (\*) were found after the chi-square test ( $p < 0.05$ ).



**Figure 3.** Relative frequency of *Pimelodus maculatus* from the Cachoeira Dourada reservoir (GO/MG) sampled from February 2007 to January 2008 according to total length classes, from 13.5 to 40.5 cm with 3 cm of interval, in each sampling season.



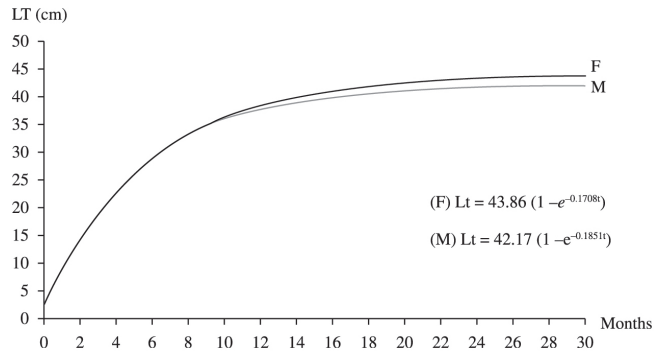
**Figure 4.** Growth curve for *Pimelodus maculatus* from the Cachoeira Dourada reservoir (GO/MG) sampled from February 2007 to January 2008: females (F)  $Lt = 43.86(1 - e^{-0.1708t})$  and males (M)  $Lt = 42.17(1 - e^{-0.1851t})$ .

comparisons between autumn/winter, autumn/spring and autumn/summer of 2008, the relative condition factor being lower during the autumn for this species. The “t” Student test did not indicate differences between the average female  $K_n$  with the ideal value of 1, while for males the null hypothesis was rejected.

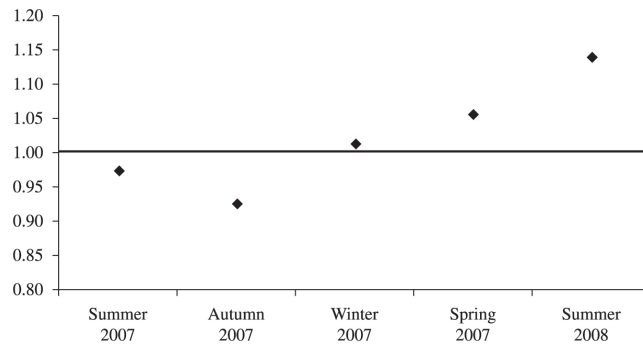
The average GSI values for males and females were plotted together with the occurrence frequency of the gonad maturation state for each season (Figure 8). The minimum and maximum values of GSI for females can be viewed in Table 3. During the summers of 2007 and 2008 we see

only females maturing or in reproduction. In the other seasons we see maturation increasing up until summer, the reproductive season.

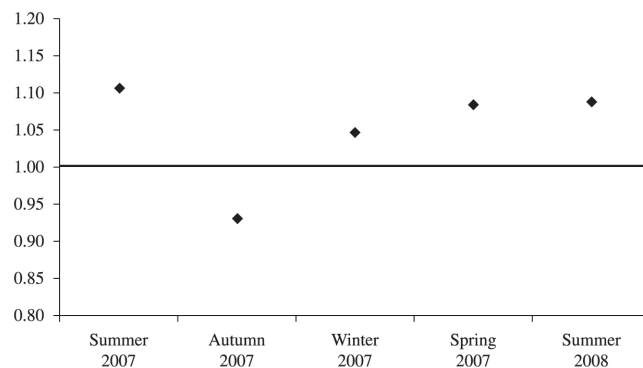
Spawmed females are also seen in seasons other than summer. No mature female was found during the autumn (state 3). The female GSI evidenced that reproduction is occurring during the summer. The values found for individuals in State 1 (immature/resting) were not used in the construction of this graph since they do not participate in reproduction.



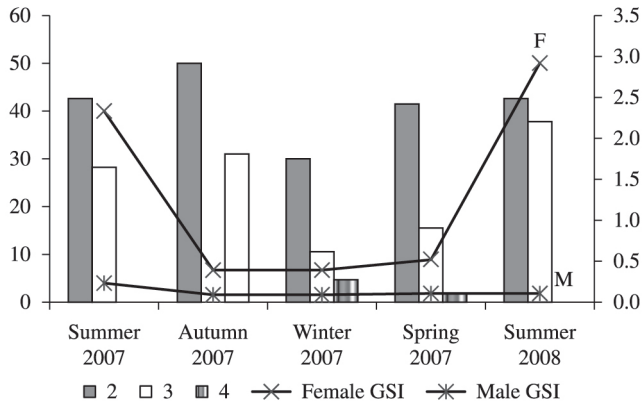
**Figure 5.** Weight-length relationship for males and females of *Pimelodus maculatus* from the Cachoeira Dourada reservoir (GO/MG) sampled from February 2007 to January 2008.



**Figure 6.** Average condition factor values, in each sampling season, for females of *Pimelodus maculatus* from the Cachoeira Dourada reservoir (GO/MG) sampled from February 2007 to January 2008.



**Figure 7.** Average condition factor values, in each sampling season, for males of *Pimelodus maculatus* from the Cachoeira Dourada reservoir (GO/MG) sampled from February 2007 to January 2008.



**Figure 8.** Average seasonal values of GSI for males and females of *Pimelodus maculatus* and relative frequency distribution of the gonadal development state for females from the Cachoeira Dourada reservoir (GO/MG), sampled from February 2007 to January 2008, where the stages of gonadal maturation of each female was classified as: 2) maturation (initial, intermediate and advanced), 3) mature or 4) spawned.

**Table 3.** Minimum and maximum GSI values for females in each sampling season, from the Cachoeira Dourada reservoir (GO/MG/MG).

Season	Minimum GSI (%)	Maximum GSI (%)
Summer 2007	0.2041	8.6521
Autumn 2007	0.0695	1.0362
Winter 2007	0.0123	3.3477
Spring 2007	0.0161	3.9143
Summer 2008	0.0530	12.3706

**4. Discussion**

The number of males and females can vary among species, but in most cases it is close to 1:1 (Nikolsky, 1963), however during its life cycle the sex ratio for fish varies in function of successive events that act in a distinct fashion on each sex (Vazzoler, 1996). In the present study the sex ratio differed from 1:1 in July of 2007 for males and in January of 2008 for females respectively. Variations in proportions may be related to sexual different growth rates between the sexes, selectivity of fishing gear and stratification of populations (Barbieri, 1992). In this case, the observed difference can be understood as a reflection of the reproductive season, which occurs during the summer, terminating at the end of January and the beginning of February when females predominate.

Analysing sex ratio by size class, a concentration of males was observed in the intermediate length classes (18.9 to 24.3 cm) and of females in the superior length classes (27 to 37.8 cm). The fact of females being noticeably bigger was commented on by Braga (2000) for the Volta Grande reservoir (MG) where the male captures occurred within the 26.6 to 31.6 cm range while that of females occurred within the 31.1 to 38.9 cm range, corroborating the results obtained during the 70’s and 80’s in the studies of Fenerich et al. (1975) and Basile-Martins et al. (1986) for the Mogi-Guaçu and Jaguari Rivers respectively.

In warm tropical waters growth rates are higher and fish mature earlier (Lowe-McConnell, 1975). Abundant food supply is also a factor increasing growth rates (Nikolsky, 1963), and when it comes to an omnivorous species with a tendency to carnivorousness and that is constantly feeding (Lolis and Andrian, 1996), there are no problems in finding food in the reservoir.

Fenerich et al. (1975) studying *P. maculatus* in the Jaguari river, determining growth rates on the basis of otoliths, did not find significant differences between female and male fish, despite a higher K for the latter. The same occurred in the present study with the determination of growth rates via distribution of modal classes of total length. Males end up having slightly elevated growth rates due to a smaller investment for sperm production when compared to the elevated energy demand required for the formation of female gonad tissue.

The growth of fish is a result of the consumption of food and its assimilation. Pauly (1998) suggests that the most important attribute of an organism is its size once the fact of being “big” or “small” influences most of its interaction with other organisms in nature beyond its demographic characteristics. In this way, analyses that involve weight and length as variables lead to important information about the population of a determined species, as an indicator of the condition in which the specimens are found (Barros et al., 2001).

On the basis of the weight-length relationship, we can obtain information on the structural characteristic of individuals in the population (Le Cren, 1951; Barros et al., 2001). After observing graphically that this relationship is not different for males and females, there is only one equation for both sexes. In this equation, the coefficient b is considered as a measure of relative growth, also reflecting feeding conditions in the species is encountered (Le Cren, 1951).

The value of b in our study is similar to that found by Basile-Martins et al. (1986) for *P. maculatus* sampled

along the Jaguari and Piracicaba Rivers, and that in the study by Lima-Junior and Goitein (2006) also along the Piracicaba, as well as being significantly equal to 3 in Student "t" test, confirming the isometric growth of the specimens, that is to say, they grow proportionally in all directions (length and volume) (Fragoso, 2000).

Once we had the weight-length in hand, it was possible to calculate the theoretical weight for the determination of the relative condition (Kn) for the individuals in each season. The utilisation of this condition factor was made due to the possibility for statistical comparison of its estimated values with value 1.0, independently of species and of length of each specimen, as cited by Anderson and Gutreuter (1983), allowing for a future comparison with the values for other Siluriformes of the same reservoir.

The estimated values for Kn are related to various factors, such as the cyclic changes that occur in the gonads during the reproductive season, the growth and accumulation of fat, the degree of fullness in the stomach and environmental variations (Barbieri and Verani, 1987). For both males and females the average values for Kn were superior to 1 except during the Autumn, probably as a consequence of weight loss by the end of the reproductive season. For this reason, the Kruskal-Wallis analysis showed statistically significant differences for males in the comparisons between Autumn-Winter, Autumn-Spring and Autumn-Summer in 2008.

Since *P. maculatus* spawns during the summer through the beginning of autumn (Lima-Junior and Goitein, 2006), the increase in the water volume being the stimulus for spawning either through flooding or a simple rise in river levels (Basile-Martins et al., 1975), a gain in weight for the months that precede reproduction and afterwards a loss in weight due to the metabolic expense involved is expected. The subpar bodily condition indexes during the autumn were also registered for the mandis of the Piracicaba river and the Volta Grande reservoir (Lima-Junior and Goitein, 2006; Braga, 2000). In the present study, even if the water levels do not rise significantly due to the opening of floodgates in the reservoir, the set of environmental changes that occur in the summer, such as the rise in temperature and the increase in photoperiod, will trigger reproduction.

On the Paraná River flood plain, Vazzoler et al. (1997) registered that period for reproduction of the *P. maculatus* occurred between October and March, while Sato et al. (1999), working with the same species in the São Francisco river, determined the reproductive season as occurring between November and February, the same as the present study for the Cachoeira Dourada reservoir.

Maia et al. (2007) studying *P. maculatus* from Igarapava reservoir (the Paraná River basin), attributed the absence of juvenile *P. maculatus* to the lack of adequate conditions for its recruitment.

In the present study, in accordance with the results obtained in the GSI analysis and in the distribution of the frequency of occurrence for gonadal states, corroborated by Kn values, there are indications that reproduction is happening in the Cachoeira Dourada reservoir and that

this occurs between the end of October and the month of February. Nevertheless, as juvenile fishes and invertebrates often use habitats of high structural heterogeneity as a refuge against predators and as feeding areas (Matěna, 1995; Lewin et al., 2004), juveniles of *Pimelodus maculatus* might be found in non-sampled environments, as, for example, among macrophytes where food and shelter are abundant, requiring further research in this area to confirm this hypothesis.

*Acknowledgements* – The authors would like to thank the São Carlos Federal University (UFSCar) Graduate Program in Ecology and Natural Resources; fellow colleagues from the Ichthyology and Populations Dynamics Laboratory at UFSCar, for their assistance in the field, and in the data analysis; Endesa for allowing and financing part of this study; and CAPES for a graduate scholarship.

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