POPULATION STRUCTURE AND REPRODUCTIVE TRAITS OF PACU *PIARACTUS MESOPOTAMICUS* (HOLMBERG, 1887) (PISCES: CHARACIDAE) IN THE CUIABÁ RIVER BASIN, MATO GROSSO, BRAZIL

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INTRODUCTION

The beginning of reproduction is a critical phase in the life of an individual, because the energy heretofore directed at growth and survival is now spent in a potential conflict between the time and resources allocated for reproduction, or for survival and growth (Wootton, 1998). This event is related with the growth rate, which in turn depends on environmental conditions and individual characteristics (Nikolsky, 1969).

Individuals must reach a given age or size before they are able to reproduce. This size is the mean length at first maturity, defined as the length at which 50% of the individuals of a population are sexually mature (King, 1995). This is an important life - history trait, information that must be known for successful fish management, since it is fundamental for the establishment of measures that avoid the exploitation of juveniles and the resulting depletion of spawning stock (Hilborn & Walters, 1992).

Piaractus mesopotamicus(Holmberg, 1887), popularly known as pacu, belongs to the Family Characidae, subfamily Myleinae (Britski *et al.*, 999). Geographically, it is widely distributed in the La Plata River basin formed by the Paraguay, Paraná and Uruguay rivers and their tributaries (Reis *et al.*, 003). This fish lives in lotic environments and spawns after a period of migration upriver (Ferraz de Lima & Chabalin, 1981). It is a highly important species in the Paraguay River basin due to its commercial value, and is one of the species most sought after by amateur and professional fishermen (Catella, 2001; Vaz, 2001). Statistical fisheries data from the 1980s indicate that the species ranked third in landings from the Cuiabá River (Ferraz de Lima, 1986). Moreover, some studies indicate that the pacu fish stock is overexploited in the Cuiabá River (Vaz, 2001) and in the southern reaches of the Pantanal of Mato Grosso (Catella, 2001; Peixer & Petrere, 2007). Despite the species economic importance, more detailed data about its reproductive strategy in natural environments are scanty, making it difficult to establish effective management measures to ensure the maintenance of its stock.

OBJECTIVES

Based on the hypothesis that reproductive processes respond differently to locations, the present work consisted of a comparative analysis of the reproductive strategy and the life - history traits involved in the reproductive processes of *P. mesopotamicus* in two regions of the Cuiabá River: one encompassing the headwaters of the basin (Cuiabazinho River-Rosário Oeste) and the other the flood area of the Cuiabá River (Porto Cercado-Poconé). The reproductive process was evaluated over a one - year period in order to: (i) characterize the population structure in terms of total length and sexual proportion; (ii) determine the reproductive period, considering the microscopic analysis of the stages of gonadal maturity and the gonadosomatic index (IG); (iii) estimate the quantitative indices of the nutritional condition (stomach somatic index-IS) and energy reserves (hepatosomatic index-IH) and their correlation with the reproductive stages; (iv) estimate the length at first maturation (LT50); and (v) determine the type of spawning and fecundity of the species under study.

MATERIAL AND METHODS

Data Collection

P. mesopotamicus specimens were collected monthly from August 2006 to July 2007. The fish were caught using fishing nets with mesh openings varying from 17 to 20 cm, throw nets with mesh openings of 18 to 20 cm, fishing hooks, sweep nets and boulters.

Records were made of each specimen's total length (LT; cm) and total mass (MT; kg). After the biometric measurements, each specimen was subjected to a longitudinal incision along the abdominal surface from the urogenital

opening to the head for inspection of the abdominal cavity and identification of the sex.

The gonads, liver and stomach of all the captured specimens were removed and weighed (g). Then, to classify the stages of maturation and confirm the sex, the whole gonads were fixed in 10% formalin for five days, then stored in 70% alcohol and subjected to routine histological techniques with inclusion and impregnation in paraffin and staining with Hematoxilin and Eosin. The stages of gonadal development were classified as: Immature (IM, juveniles), Maturing (MG), Mature (MA), Spawned (SP), and Rest (RE) (Vazzoler, 1996). To determine the spawning period and type, the diameters of 10 ovarian follicles per female were measured randomly using the MOTIC® 3.0 program with 10x magnification.

Fecundity was estimated based on the ovaries of all the mature females, using the gravimetric method (Vazzoler, 1996). All the oocytes were counted according to Ivankov's method (1985), which is based on Potential Fecundity (PF), i.e., the initial vitellogenic oocyte reserve, the resource for the formation of final fecundity by the gradual reabsorption of excess vitellogenic oocytes.

The pluviometric and fluviometric data of the Rosário Oeste and Porto Cercado (Poconé) Station were obtained from the Civil Defense Department of the state of Mato Grosso and from Brazil's National Water Agency (ANA).

Data Analysis

The data on fish length were grouped by site into classes of 5 cm to determine the absolute frequency distribution of juveniles and adults during the sampling period. To investigate the possible differences in LT between the sexes and sites, a factorial analysis of variance was applied. The hypothesis that the sexual proportion differs from the expected 1:1 was tested by the chi - square test (x2) to verify the possible significant differences at the sampled sites.

The reproductive period was established by the monthly relative frequency distribution of the gonadal maturation stages identified considering only adult individuals (MG, MA, SP and RE) for the collection period (months), and by the monthly analysis of variance of the values of the gonadosomatic index (IG = MG x 100/MT, where: MG is gonad mass and MT is total mass). Because the supposition of normality of the IG data was not reached, a comparison of the months was made by the Kruskal - Wallis test (H - test).

To quantitatively analyze feeding activity during the reproductive and sampling period, a calculation was made of the stomachsomatic index (IS) and the hepatosomatic index (IH), which represent the percent of the organ's mass (M) in relation to the total mass (MT) of the fish. Since the indices did not show a normal distribution, the Kruskal - Wallis test was applied to test differences in the values of these indices by gonadal maturation stage separately for females and males.

To estimate the mean length at first maturity (LT50) and the length at which all the individuals were ready to participate actively in the reproductive cycle (LT100), distributions were built of the proportion of adults in each total length class at both sites, including all the adult specimens (which were in the gonadal maturation stages of MG, MA, SP and RE). The resulting curve was adjusted by the following expression of King, 1995.

An analysis was made of the relative frequency distribution of the ovarian follicle diameter grouped into classes with a 100 m interval. The relative frequency of the class of ovarian follicle diameter was calculated for each period and site to identify the time of gonadal maturation and to identify the type of spawning and to determine possible variations in the oocyte development phase between the sites. The relative frequency analysis of ovarian follicle diameter indicates the phase of gonadal development.

To ascertain possible Fecundity (F) relationships between the LT, total fish mass and total gonad mass, by sampling site, a simple linear regression was applied, estimating the a and b coefficients after logarithmically transforming the values of the variables. To check whether there was a difference in gonad mass between the sites, an analysis of covariance (ANCOVA) was made.

RESULTS AND DISCUSSION

A total of 391 individuals were sampled. Seven juveniles and 152 adults were captured in the Cuiabazinho River. Juveniles were found in the months of September, April, May, June and July. The specimens analyzed from the Cuiabá River comprised 32 juveniles and 200 adults. Juveniles were not found only in the months of October, November and December. The analysis of the 159 individuals from the Cuiabazinho River showed a mean LT of 47.34 cm (SD=9.58), a minimum LT of 34 cm, and a maximum LT of 75 cm. The LT varied from 34 to 75 cm in females (n=105), and from 34 to 74 cm in males (n=54). The 232 individuals from the Cuiabá River showed a mean LT of 41.51 cm (SD=4.90), a minimum LT of 28 cm, and a maximum LT of 58 cm. The LT varied from 29 to 55 cm in females (n=89), and from 28 to 58 cm in males (n=143). There was an interaction between the sex and site factors (F1;387=10.26; p=0.0014), with the females in the Cuiabazinho River, on average, larger than the males, but no difference in length was found between females and males in the region of Porto Cercado.

In the Cuiabazinho River there was a significant difference in the sexual proportion (X2=16.35; P=0.000, n=159), with a predominance of females (105) in relation to males (54) in almost all the LT classes. A significant difference in the sexual proportion (X2=12.56; P=0.000, n=232) was also found in the Cuiabá River, but here males predominated (143) over females (89) in most LT classes.

With regard to gonadal maturation stages, 178 females were analyzed, 101 from the Cuiabazinho River and 77 from the Cuiabá River. In the Cuiabazinho in October and July, there was a high frequency of maturing (MG) females. Mature (MA) females were found in October, January, February and March, with the highest frequency occurring in January and the lowest in March, indicating that the reproductive period occurred from October to March. A low frequency of spawned (SP) specimens was found in February. Individuals at rest (RE) occurred practically throughout the entire year, with a low frequency in October.

In the Cuiabá River, a high frequency of maturing (MG) specimens was found in August, September and July. October and November were the months of high frequency of mature (MA) stage, indicating the greater reproductive activity in those months. No individuals in the spawned (SP) stage were found. Specimens at rest (RE) were found in every month except October and November.

The IG presented a significant difference among the sampling periods for females (H=39,997; d.f.=9; P <0.001); (H=39,230; d.f.=11; P <0.001) and males (H=17,783; d.f.=7; P=0.013); (H=83,353; d.f.=11; P <0.001) in the Cuiabazinho and Cuiabá rivers, respectively. We found that, in the Cuiabazinho, the females presented a higher variation in IG in October, January, February and March, and the males in September and October. In the Cuiabá River, the IG of the females presented higher variations in October and November, while that of males showed variations in September, October, November, December, January and February.

The local rains and the rising water levels are related to the maturation phase of the pacu. In the Cuiabazinho River, a relation was found between the pluviometric index and the water level, with the reproductive period of P. mesopotamicus males peaking in February. In the Cuiabá River, the pluviometric index and water level increase in October, coinciding with the peak of the female reproductive period in October and November.

The IS and IH of the females showed significant differences in the maturation stages (IS: H=12.14; P=0.017; IH: H= 16.29; P=0.003), with the females at rest showing a higher IS and the immature females a higher IH. The males presented significant differences only in the IH (H=15.11; P=0.004), with males with spawned gonads presenting a higher IH relative to the other stages of maturity.

The mean total length at first maturity (LT50) was estimated to be 34.89 cm, with a confidence interval between 32.57 and 37.21 cm ($\alpha = 0.397$; r2=0.713). The estimated mean total length at which all the individuals were ready to reproduce (LT100) was 44 cm.

For the Cuiabazinho River, 1050 ovarian follicles from 105 females (juveniles and adults) were measured, which varied from 9.76 μm to 1023 μm. The mean follicle diameter was 156.07 μm (SD=191.81 μm). In all the months, the relative frequency distribution of follicle diameters was concentrated in lower diameters. In October this distribution shifted to intermediary diameters. No female specimens were caught in November. In October, January, February and March, the relative frequency of follicle diameter was distributed in larger diameters, displaying two modes that represent the peak of spawning in the Cuiabazinho River.

In the Cuiabá River, 890 ovarian follicles from 89 females were measured, varying from 9.76 μm to 1016 μm. The mean follicle diameter was 165.79 μm (SD=196.67 μm). In all the months, the relative frequency distributions of follicle diameter were concentrated in smaller diameters. However, in October and November the relative frequency of follicle diameters was distributed in larger diameters, displaying two modes and indicating that spawning was total; hence, the smaller mode represented the reserve stock while the higher one corresponded to mature oocytes.

Fifteen mature females were analyzed, 7 from the Cuiabazinho and 8 from the Cuiabá River. Fecundity was positively correlated with total length, total mass and gonad mass at both sampling sites, i.e., fecundity was found to increase with body size. The gonad mass did not differ between sites (F1;13=0.722; P=0.410); thus, there was no difference between the fecundity rates of the Cuiabazinho and Cuiabá rivers.

CONCLUSION

In summary, the set of aspects the determines the reproductive strategy of *P. mesopotamicus* in the Cuiabá River basin reflects expressions of traits closely related to fitness, such as the reproductive period, maturation size, spawning type and fecundity in the life of the individual, according to the life - history, the trade - off between the adopted strategy and the optimal period of life ensures the maintenance of the species. These parameters are fundamentally important in the evaluation and management of the stock. Therefore, measures that ensure the stock's protection during the period of reproduction from October to March, and the size of first maturity, are crucial for the maintenance of the population in this environment, as well as for fish preservation, conservation and management.

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