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Reproduction of the surubim catfish (Pisces, Pimelodidae) in the São Francisco River, Pirapora Region, Minas Gerais, Brazil

[*Reprodução do surubim (Pisces, Pimelodidae) do Rio São Francisco, Região de Pirapora, Minas Gerais*]

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ABSTRACT

The reproductive biology of the surubim, *P. coruscans* of the São Francisco River, in the Pirapora region was studied from December/98 to November/99. Reproduction occurred between October and January with high frequency of fishes in the advanced ripening/mature and spawned/spent stages along with higher values of the gonadosomatic index. Macroscopic and microscopic analyses indicated that *P. coruscans* presents total spawning. The reproductive period coincided with highest rainfall and water turbidity values in the region. The smallest male captured had a total length of 63.3cm and the smallest female 92.0cm in total length. The largest male in the maturation stage was recorded to be 97.0cm and the largest female 144.1cm in total length. Surubim were more frequently captured than females, at a proportion of approximately one female to three males. The gonadosomatic, hepatosomatic, stomach repletion, and coelomic fat indexes, as well as the condition factor were related to stages of the reproductive cycle.

Keywords: surubim catfish, *Pseudoplatystoma coruscans*, reproduction, spawning, São Francisco River, Brazil

RESUMO

Estudou-se a biologia reprodutiva do surubim Pseudoplatystoma coruscans *do Rio São Francisco, na região de Pirapora, Minas Gerais no período de dezembro/98 a novembro/99. A reprodução ocorreu entre outubro e janeiro, com alta freqüência de peixes em maturação avançada/maduros e desovados/espermiados, e os maiores valores do índice gonadossomático nesse período. Análises macro e microscópicas indicaram que P. coruscans apresenta desova total. A época reprodutiva coincidiu com maior turbidez da água e maior incidência de chuva na região. O menor e maior macho capturado em maturação apresentou 63,3cm e 97,0cm e a menor e maior fêmea neste estádio 92,0cm e 144,1cm de comprimento total, respectivamente. Registraram três machos para cada fêmea e somente as fêmeas apresentaram comprimento acima de 100cm. Os índices biológicos gonadossomático, hepatossomático, repleção estomacal, gordura celômica e fator de condição foram relacionados aos estádios do ciclo reprodutivo.*

Palavras-chave: surubim, Pseudoplatystoma coruscans*, reprodução, índice gonadossomático, Rio São Francisco*

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INTRODUCTION

The surubim catfish, *Pseudoplatystoma coruscans* (Spix, Agassiz, 1829), also known in the São Francisco River Valley as "moleque", belongs to the order Siluriformes and also occurs in the Paraná, Paraguai and Uruguai rivers (Fowler, 1951). In other regions, its spotted body has earned the popular name of "pintado". The surubim catfish is an essentially piscivorous species (Marques, 1993), and its corporal weight can exceed 100kg (Sato, 1999). As a result of constant changes in the environment of the São Francisco River, the capture of this fish has declined from 86.3% in 1987 to 27% in 1999 (Godinho et al., 2001).

The high commercial value of the surubim catfish is due to the excellent quality of its meat, its high marketability, and its marked participation in commercial fishing (Marques, 1993). The possibility of inducing spawn by hypophysation has created promising prospects for the artificial breeding of the surubim catfish (Sato, 1999). The zootechnical indexes and carcass characteristics of this species confirm that it has a high potential for commercial production (Ribeiro, Miranda, 1997). The objective of this work is to study the reproductive biology of the wild surubim catfish in the São Francisco River.

MATERIAL AND METHODS

The specimens, 29 females and 75 males, were collected monthly by fishermen, using casting and drifting nets, in the São Francisco River, in the Pirapora region (17º20'45''S and 44º56'55''W), State of Minas Gerais, Brazil, between December/98 and November/99.

The specimens were measured, weighed and had their sex identified, followed by macroscopic determination of the stages of the reproductive cycle. The viscera were fixed in 10% formalin solution and dissected, after which the following was recorded for each specimen: standard (SL) and total length in centimeters, body weight in grams (BW), and weight in grams of gonads (GW), liver (LW), stomach (SW), and coelomic fat (CFW). The biometric data obtained were used for calculating the gonadosomatic (GSI = GWx100/BW), hepatosomatic (HSI= LWx100/BW), stomach repletion (SRI= SWx100/BW) and coelomic fat (CFI= CFW×100/BW) indexes, as well as the condition factor ($K= BW\times100/SL^3$).

For histological determination of the stages of the reproductive cycle and type of spawning, fragments of gonads from each specimen were fixed in Bouin's fluid for 10 to 12 hours and subjected to histological routine techniques such as embedding in paraffin, sectioning at 3-5µm and staining with haematoxylin/eosin.

Macroscopically, the stages of the reproductive cycle were determined based on the volume, color, blood supply and turgidity of the gonads and visualization of oocytes. Microscopically, these stages were confirmed by the distribution of oocytes and spermatogenic cells. For determining the type of spawning, the bimonthly frequency distribution of the stages of the reproductive cycle were analyzed, as well as the histological characteristics of the spawned ovaries (Bazzoli, 2003).

Daily records of rainfall and water turbidity in Pirapora were related to the bimonthly GSI of males and females. The data on rainfall were obtained from the "Estação Climatológica Principal de Pirapora" and that on turbidity from the "Serviço Autônomo de Água e Esgoto de Pirapora".

The populational structure and sex ratio were calculated using the total number of specimens captured. Variations in the sex ratio were analysed using to the chi-square (χ^2) test, with a significance level of $P<0.05$.

Analysis of variance was used to test variations in the mean values of the indexes calculated by sex and by stage of the reproductive cycle. Duncan's test was used to compare mean values, whenever statistically significant differences ($P<0.05$) were recorded.

RESULTS

The ovaries of the surubim catfish were paired, sac-like, elongated organs located in the coelomic cavity, ventrally to the gas bladder and laterally to the stomach. The ovaries were joined in their caudal ends to form the common ovarian

duct, which opened in the urogenital papilla. As maturation progressed, the ovaries increased in volume, attaining maximum development at the time of reproduction, and then regressed in size in the post-spawning period.

Macroscopically, the testes were paired structures joined at their caudal ends to form the common spermatic duct, which opened in the urogenital papilla. The testes of the surubim catfish showed fringes along their entire length; these increased in volume proportionately to the number of spermatozoa produced, with maximum turgidity being attained at the time of reproduction.

Based on the macro and microscopic characteristics of the gonads, the following stages of the reproductive cycle were determined: 1 = rest; 2 = initial ripening; 3 = advanced ripening/mature; 4 = spawned for females, spent for males (Tab.1 and Fig.1 and 2).

Males and females in all stages of the reproductive cycle were captured, and the frequency distribution of these stages varied according to the time of the year (Fig. 3). The highest frequency of maturing, mature and spent/spawned fishes was recorded between October and January. The observation of peak numbers of spawned females and females in the advanced ripening stage within a short period of time (October to January), was associated with the histological characteristics of the spawned ovaries, i.e., containing post-ovulatory follicles, as well as young (O1), previtellogenic (O2) and rare atresic vitellogenic (O4) oocytes, indicated that the spawn of the surubim catfish is of the total type.

Table 1. Macro and microscopic characteristics of ovaries and testes of *P. coruscans* collected in the São Francisco River, Pirapora region, Minas Gerais State, between December/98 and November/99

Stage of reproductive cycle	Macro and microscopic characteristics	
	Ovaries	**Testes**
1	- Translucent and not very voluminous. - Histologically, only young (O1) and previtellogenic (O2) oocytes are present (Fig. 1A).	- Whitish, poorly developed, with reduced fringes. - Presence of spermatogonia; lumen of seminiferous tubules closed (Fig. 2A).
2	- Yellowish, with increased volume and vascularization. - Presence of young (O1), pre-vitellogenic (O2), and cortical alveoli (O3) oocytes (Fig. 1B).	- White, with voluminous fringes. - Presence of all spermatogenic cells and small quantity of spermatozoa in the lumen of seminiferous tubules (Fig. 2B).
3	- Yellow, maximum volume, occupying a large part of the coelomic cavity and vitellogenic oocytes visible with the naked eye. - Presence of young (O1), pre-vitellogenic (O2), cortical alveoli (O3) and vitellogenic (O4) oocytes (Fig. 1C).	- Milky-whitish, maximum volume, turgid fringes. - Large quantity of spermatozoa in the lumen of seminiferous tubules (Fig. 2C).
4	- Hemorrhagic and flaccid, with rare opaque oocytes visible with the naked eye. - Presence of post-ovulatory and atresic follicles, in addition to young (O1) and pre-vitellogenic (O2) oocytes (Fig. 1D).	- With hemorrhagic areas and flaccid fringes. - Seminiferous tubules with open lumen, at times containing residual spermatozoa, and wall made up of spermatogonia, only (Fig. 2D).

1= rest; 2= initial ripening; 3= advanced ripening/mature; 4= spawned/spent.

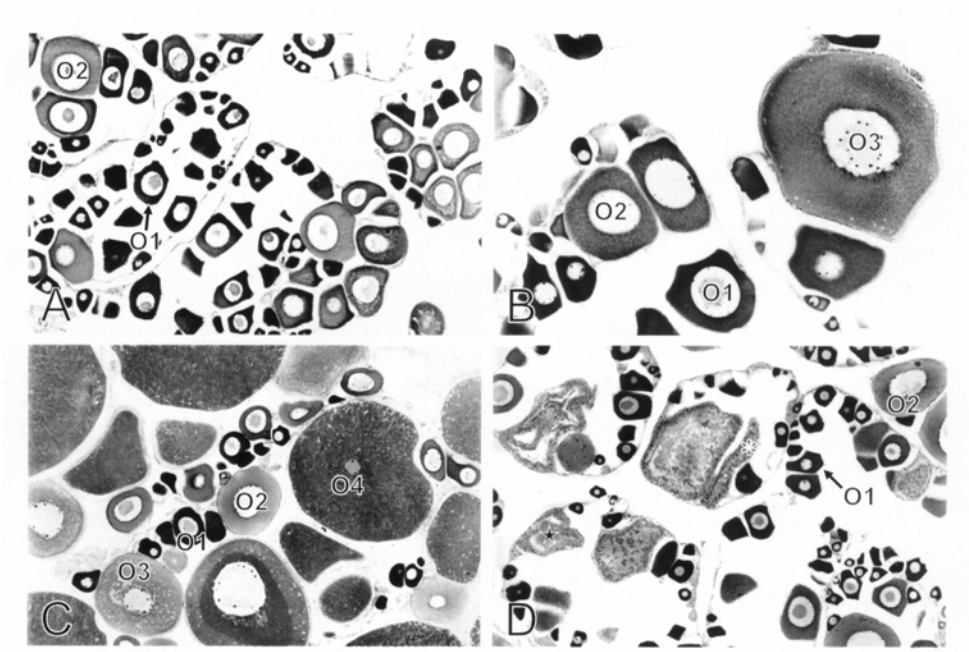


Figure 1. Histological sections of *P. coruscans* ovaries in the various stages of the reproductive cycle, haematoxylin-eosin, 60×. A- Rest: only young (O1) and pre-vitellogenic (O2) oocytes are present. B- Initial ripening: young (O1), pre-vitellogenic (O2) and cortical alveoli (O3) oocytes are seen. C- Advanced ripening/mature: young (O1), pre-vitellogenic (O2), cortical alveoli (O3) and vitellogenic (O4) oocytes are present. D- Spawned: young (O1) and pre-vitellogenic (O2) oocytes, and post-ovulatory (*) and atresic (★) follicles.

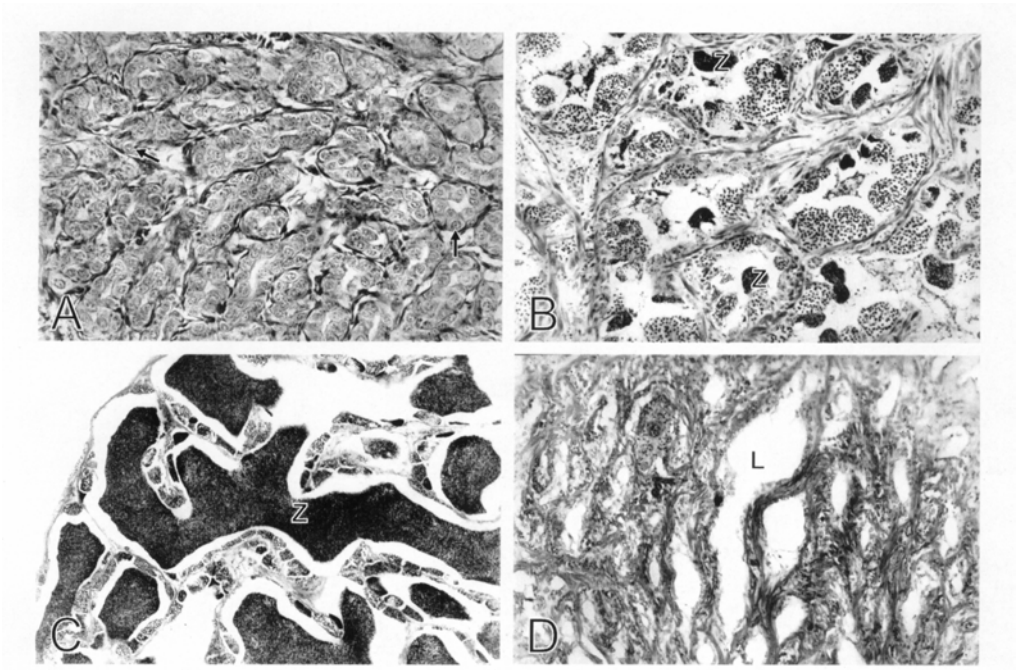
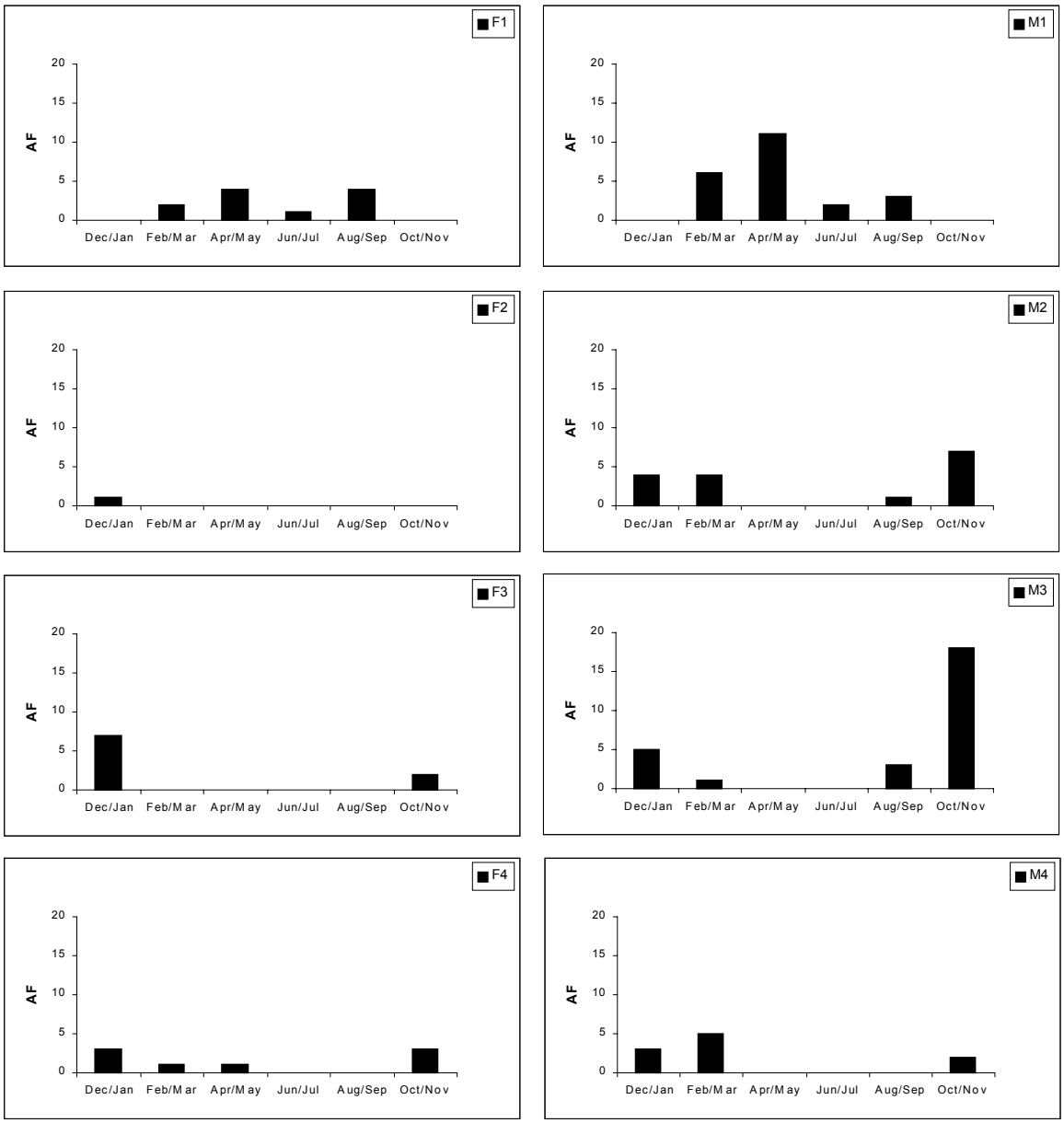


Figure 2. Histological sections of *P. coruscans* testes in the various stages of the reproductive cycle, haematoxylin-eosin. A- Rest: the lumen of seminiferous tubules is closed and only spermatogonia are seen on wall (arrows), 240×. B- Initial ripening: small amount of spermatozoa (Z) in the lumen of seminiferous tubules, 120×. C- Advanced ripening/mature: lumen of seminiferous tubules is filled with spermatozoa (Z), 60×. D- Spent: seminiferous tubules are disorganized and their lumen is open (L), 120×.



Note: AF= absolute frequency; F1= female in stage of rest; F2= female in initial ripening stage; F3= female in advanced ripening/mature stage; F4= spawned female; M1= male in stage of rest; M2= male in initial ripening stage; M3= male in advanced ripening/mature stage; M4= spent male.

Figure 3. Absolute frequency, by stage of reproductive cycle, of *P. coruscans* males and females captured in the São Francisco River, Pirapora region, Minas Gerais State, between December/98 and November/99.

The GSI of both males and females reached its highest value in stage 3 (Tab. 2 and 3). In both sexes, significant differences in the GSI were observed between the advanced ripening/mature stage and the other stages. In females, the HSI reached its lowest value in stage 3 and was

statistically different from the HSI in the other stages, whereas the variations in the HSI of males were discreet and no significant differences were recorded (Tab. 2 and 3). In the females, there were significant differences in the SRI between stages 3 and 4, as compared with stage 1 but no significant variations in SRI were found among the males (Tab. 2 and 3). The CFI and K of males and females showed no significant variations over the reproductive cycle (Tab. 2 and 3).

Table 2. Mean values of gonadosomatic (GSI), hepatosomatic (HSI), stomach repletion (SRI), and coelomic fat (CFI) indexes and condition factor (K) by stage of the reproductive cycle of *P. coruscans* females in the São Francisco River, Pirapora region, Minas Gerais State

SRC	N	GSI	HSI	SRI	CFI	K
F1	11	0.28±0.15b	0.61±0.20a	2.17±0.54a	0.70±0,63a	1.20±0,23a
F2	1	1.43b	0.36b	1.77a,b	0.56a	1.19a
F3	9	4.61±2.10a	0.21±0.09c	1.24±0.45b	0.29±0.25a	1.19±0.18a
F4	8	1.12±0.70b	0.53±0.70a	1.40±0.46b	0.45±0.31a	1.15±0.19a

N= number of specimens by stage of the reproductive cycle. Values followed by identical letters in the same column are statistically similar. SRC= stages of reproductive cycle; F1= female in stage of rest; F2= female in initial ripening stage; F3= female in advanced ripening/mature stage; F4= spawned female.

Table 3. Mean values of gonadosomatic (GSI), hepatosomatic (HSI), stomach repletion (SRI), and coelomic fat (CFI) indexes and condition factor (K) by stage of the reproductive cycle of *P. coruscans* males in the São Francisco River, Pirapora region, Minas Gerais State

SRC	N	GSI	HSI	SRI	CFI	K
M1	22	0.07±0.04c	0.37±0.12a	0.90±0.39a	0.99±0.39a	1.08±0.25a
M2	16	0.72±0.26b	0.36±0.13a	0.85±0.41a	1.52±0.30a	1.10±0.12a
M3	27	1.97±0.48a	0.39±0.11a	0.84±0.45a	0.61±0.45a	1.11±0.12a
M4	10	0.79±0.62b	0.38±0.12a	0.85±0.14a	0.72±0.23a	1.18±0.27a

N= number of specimens by stage of the reproductive cycle. Values followed by identical letters in the same column are statistically similar. SRC= stages of reproductive cycle; M1= male in stage of rest; M2= male in initial ripening stage; M3= male in advanced ripening/mature stage; M4= Spent male.

Spawning started in October-November, at the beginning of the rains and also when the water showed high turbidity values (Fig. 4). The end of the rainy season also coincided with the end of the reproductive cycle.

The ratio females and males in this study was approximately 1:3. The chi-square test show this difference in the number of males and females to be statistically significant. The largest male captured had a total length of 100.0cm, and the smallest 59.4cm. The largest female had a total length of 144.1 cm and the smallest 59.8cm. The heaviest body weight (26,900g) was recorded for a female in the advanced ripening mature stage and the lowest (1,000g) for a male in the resting stage. The smallest female in the advanced ripening mature stage had a total length of 92.0cm, whereas the smallest male in the same stage measured 63.3cm in total length.

DISCUSSION

The flesh quality and high market value have inspired the examination of the aquaculture potencial of the surubim, *P. coruscans* (Ribeiro, Miranda, 1997), nevertheless studies on the reproductive biology of this catfish are scarce.

Fish ovaries may be of two types: gymnovarian or cystovarian. In the first type, the oocytes are released directly into the coelomic cavity and then eliminated. In the second type, the oocytes are conveyed to the exterior through the oviduct (Hoar, 1969). The ovaries of *P. coruscans* were of the cystovarian type and the tunica albuginea that covered them was thick, making it difficult to visualize the vitellogenic oocytes with the naked eye.

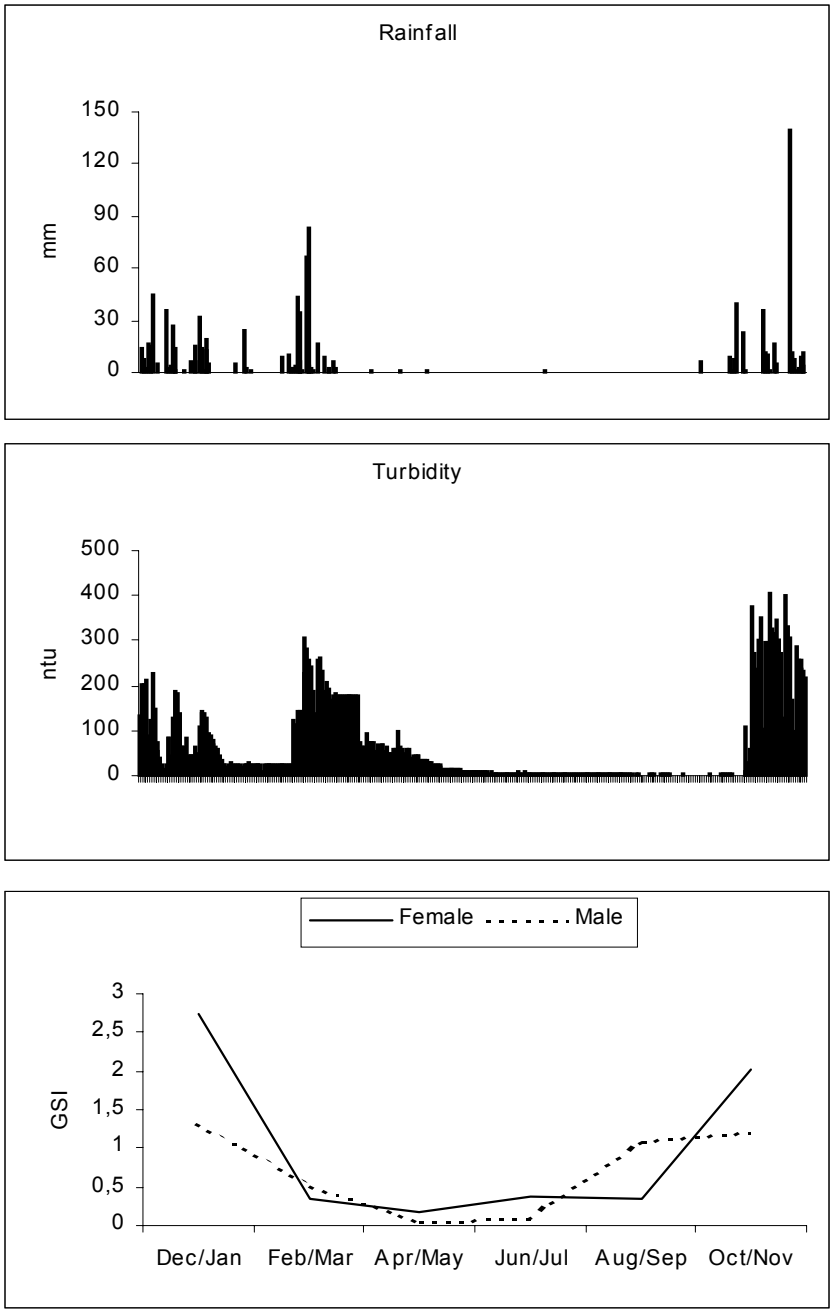


Figure 4. Bimonthly values of gonadosomatic index (GSI) of *P. coruscans* males and females, and daily turbidity values for the São Francisco River and rainfall measurements in Pirapora between December/98 and November/99.

Oocytes are gonadotrophic-independent up to the stage in which they develop cortical alveoli, the other phases being dependent on gonadotrophic action (Wallace, Selman, 1981). The morphological characteristics of *P. coruscans* oocytes, with respect to the yolk nucleus, cortical alveoli, yolk globules, zona pellucida and follicular cells, in the various stages of

development, were similar to those reported by Bazzoli (2003).

According to Grier et al. (1980), fish testes exhibit two basic patterns of spermatogonia distribution in the seminiferous tubules, i.e., spermatogonia along the entire length or spermatogonia restricted to the distal portion of the seminiferous tubules. In the testes of *P. coruscans* spermatogonia were observed along the entire length of the seminiferous tubule. The testes of *P. coruscans* showed fringes - projections of the tunica albuginea - in all stages of the reproductive cycle, these fringes being more prominent at the time of reproduction. The presence of fringes or lobules appears to be typical of the testes of Siluriforrmes (Loir et al., 1989). Testicular fringes or lobules were also reported in some Brazilian Pimelodidae (Marques, 1993; Santos et al., 2001; Bazzoli, 2003).

In the testes of some species of Siluriformes, organs and structures such as a spermatogenic cranial region and a secretory caudal region (Santos et al., 2001) are observed, in addition to the presence of seminal vesicles in the caudal region (Loir et al., 1989). In this study, macro- and microscopic examination of *P. coruscans* testes showed neither secretory caudal region nor associated secreting organs or structures.

In spite of the small number of specimens collected for this study, both sexes were present throughout the period of collection, with the peak number of specimens captured occurring in the period between October and January. The largest movements of shoals of migratory fishes are known to take place during the reproductive period (Godoy, 1975), which may account for the higher number of specimens captured in the aforementioned period. The greater frequency of spawned females and females in the advanced ripening/mature between October and January suggests that the spawn of the surubim catfish may occur in the region of Pirapora. This is supported by reports from fishermen and corroborated by the recording of a high density of embryos in the river channel (Jiménez-Segura, 2000).

Even though the spawn of *P. coruscans* is of the total type, it was found that the elimination of vitellogenic oocytes takes place in an asynchronous way during each reproductive season, which is concordant with the reports of Kunkel and Flores (1996) for this species. In general, total-spawn fishes, such as the surubim catfish, that make reproductive migrations, do not exhibit parental care, and have external fertilization and high fecundity (Sato, 1999). According to fishermen, the spawn, locally referred to as "carujo", occurs on the surface of the water, in a lotic environment. The female keeps her ventral surface, on the surface of the water, and several males, usually more than 15, swim over it, releasing their semen at the same time as the oocytes are eliminated. Since the eggs of the surubim catfish are of the free type (Sato, 1999), their dispersion is facilitated.

In this study, the decline in the HSI of females in the reproductive period, when the GSI values were high, is probably due to the fact that, in this stage, vitelline precursors are supplied to the oocytes by the liver (Wallace, Selman, 1981). Gonadal maturation, reproductive activity and migration demand energy, which the fishes obtain from ingested food. During the reproductive period, feeding activity is reduced or interrupted, and fat reserves are consumed (Bennemann et al., 1996). In this study, this tendency was not statistically confirmed, even though the SRI and CFI values were lower during the maturation and spawned/spent stages. On the other hand, in *Salminus maxillosus*, feeding activity increased during the rainy season, which is when this species reproduces, as a result of the greater availability of preys (Esteves, Pinto-Lôbo, 2001).

During the reproductive cycle, the condition factor may vary according to the feeding conditions and gonadal development and may be used, for some species, as an indicator of the spawn period (Barbieri, Verani, 1987). Similarly to the findings of Brito et al. (1999), the variations in the condition factor over the reproductive cycle were not significant in *P. coruscans*.

The synchronism between the stages of the hydrological cycle and the events of gonadal maturation, migration and spawning, in addition to the density of eggs and larvae and the occurrence of juvenile individuals, demonstrates the importance of flooding for fish reproduction

(Godoy, 1975). The greatest capture of surubim catfishes in the region of Pirapora occurred during the reproductive period, which in tropical regions, coincides with the time of heavier rainfall and rising of the river level (Lowe-McConnell, 1987). These exogenous factors, as well as changes in the chemical composition, turbidity, pH, oxygen and temperature of the water are what trigger the reproductive process (Munro et al., 1990).

Growth analysis of *Pseudoplatystoma fasciatum* and *P. tigrinum* from the Mamoré River basin (Bolivian Amazon), showed that, following gonadal maturation, the females of both species grow faster than the males, even though the males are sexually more precocious (Loubens, Panfili, 2000). The same was observed in this study: the smallest *P. coruscans* male that apted for reproduction had a smaller size than that exhibited by the females. The predominance of *P. coruscans* females was absolute in specimens measuring over 100cm in total length. A similar finding was reported for the same species by Marques (1993) and for *P. fasciatum* by Valderrama et al. (1988).

Surubim males are more numerous than females, at a proportion of approximately three males to one female. The higher frequency of males occur in others species in the São Francisco basin (Bazzoli, 2003). Despite the small number of specimens sampled, fishing gear selectivity may have been responsible for this predominance of males.

According to the IBAMA regulations currently in effect (Decree 92 of November 6, 1995), the minimum size allowed for capture of the surubim catfish in the São Francisco river is 80 cm total length. In the present study, however, 85% of the males and 7% of the females captured were under this size limit, even though the fishing gear used was in strict compliance with the legal specifications. Thus, it is suggested that a revision be made of both the minimum sizes for capture and the fishing gear allowed, with a view to the establishment of a new fishery policy.

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