

Reproductive biology of *Leporinus taeniatus* Lütken (Pisces, Anostomidae) in Juramento Reservoir, São Francisco River basin, Minas Gerais, Brazil

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ABSTRACT. The reproductive biology of the piau-jejo *Leporinus taeniatus* Lütken, 1875, an endemic species from the São Francisco River basin, was studied by using macroscopical and histological techniques. A total of 121 males and 94 females were captured quarterly, between March 2002 and February 2003 in the Juramento Reservoir. Females were larger than males, indicating sexual dimorphism. Stages of gonadal maturation were defined from histological analyses and gonadosomatic index. Peaks of maturing / mature and spawned / spermated fishes has occurred in period December-February. *L. taeniatus* presented total spawning and group-synchronic development of the oocytes. The gonadosomatic index accompanied gonad maturation in both sexes, and coelomic fat presented lower levels during maturing/mature stage, indicating fat consumption during the reproductive period. Stomach repletion index presented higher values during spawned and spermated stages, indicating greater food ingestion after the reproductive period.

KEY WORDS. Characiformes, gonadal maturation, piau-jejo, reproduction, total spawning.

RESUMO. **Biologia reprodutiva de *Leporinus taeniatus* Lütken (Pisces, Anostomidae) do reservatório de Juramento, bacia do rio São Francisco, Minas Gerais, Brasil.** A biologia reprodutiva do piau-jejo *Leporinus taeniatus* Lütken, 1875, espécie endêmica da bacia do rio São Francisco, foi estudada utilizando-se técnicas biométricas, macroscópicas e microscópicas. Capturaram-se no reservatório de Juramento, MG, em coletas trimestrais, 121 machos e 94 fêmeas, no período de março de 2002 a fevereiro de 2003. Observou-se que fêmeas são maiores do que os machos indicando dimorfismo sexual. Determinaram-se os estádios de maturação gonadal através de análise histológica e do índice gonado-somático. Os picos de maturação / maduro e de peixes desovados / espermiados ocorreram no trimestre dezembro / janeiro / fevereiro. *L. taeniatus* apresentou desova total e desenvolvimento grupo-sincrônico dos ovócitos. O índice gonadossomático acompanhou a maturação das gônadas e o índice de gordura celômica apresentou menores valores no estádio maturação / maduro, indicando consumo de reservas graxas no período reprodutivo. O índice de repleção estomacal apresentou maiores valores no estádio desovado / espermiado, indicando que a espécie alimenta-se mais após a reprodução.

PALAVRAS CHAVE. Characiformes, desova total, maturação gonadal, piau-jejo, reprodução.

Analyses of the gonadal maturation of native fishes are important to the understanding of the reproductive behavior of a species in an ecosystem. In teleosts, there are two spawning types: total and fractional. In total spawning, oocyte development is group-synchronic and the oocytes are released during a short period, while in fractional spawning, the oocyte development is asynchronous and oocytes are released during longer periods (BAZZOLI 2003). Spawning type can be determined by analyses of the oocyte development dynamics and by frequency of spawned fishes during the reproductive period (VAZZOLER 1996).

The variations of the biological indexes such as gonadosomatic, hepatosomatic, stomach repletion, coelomic fat and condition factor (K) during the reproductive cycle, represent the way the species uses energetic resources from the environment, defining its life history strategies (VAZZOLER 1996). Condition factor (K) indicates health condition by the amount of stored coelomic fat; the general well being of the animal, its gonadal development and the environmental adaptability (LE CREN 1951).

Sexual proportion in fishes varies along their life cycles because of recurrent events, such as mortality and differential growth, however, generally it is in a ratio of 1:1 in a popula-

tion (VAZZOLER 1996). Differences in size at first gonadal maturation between males and females can indicate sexual dimorphism and, between fishes from different habitats, are related to resource availability and differential growth (NIKOLSKY 1963).

The Juramento reservoir (16°45'-16°48'S; 43°41'-43°37'W), located near to city of Montes Claros, Minas Gerais (MG), has 7,6 km² of flooded area, being formed by the Canoas, Saracura and Juramento Rivers, from Verde Grande River sub-basin, which in turn, belongs to the São Francisco River basin. It was built in 1981 by COPASA (Companhia de Saneamento Ambiental de Minas Gerais) for water supply purposes.

The piau-jejo *Leporinus taeniatus*, is an abundant endemic species from the São Francisco River basin. It is a medium-sized species with a longitudinal stripe along its body's lateral line. The species belongs to the Order Characiformes, Family Anostomidae, which includes mainly herbivorous fresh water species that live in great rivers (BRITSKI *et al.* 1984). Piaus are also found in lakes and reservoirs, being appreciated in recreational fisheries (SATO *et al.* 2003), but despite its importance, there are no studies on the reproduction of *L. taeniatus*. In this context, the main objective of the present study was to analyze different reproductive parameters of the *L. taeniatus* population from Juramento Reservoir.

MATERIAL AND METHODS

A total of 215 specimens of *L. taeniatus*, 94 females and 121 males, were collected quarterly in the Juramento reservoir between March 2002 and February 2003. Fishes were caught using gillnets with mesh sizes ranged from 3 to 8 cm (stretched measure). These nets had 10 m long with height varying from 1.5 to 1.8 m. Two nets were utilized by sample with soaking time of approximately 15 h.

Specimens fixed in 10% formaldehyde solution were measured for determining the standard length (SL), body weight (BW), sex and visceral weight: gonads (GW), liver (LW), stomach (SW) and coelomic fat (CFW). Gonadosomatic index (GSI = $GW / BW \times 100$), hepatosomatic index (HSI = $LW / BW \times 100$), stomach repletion index (SRI = $SW / BW \times 100$), coelomic fat index (CFI = $CFW / BW \times 100$) and condition factor based on the weight/length relationship angular coefficient (b) ($K = BW / SL^b \times 100$), were calculated.

Gonad fragments from each captured specimen were fixed in Bouin's solution for 8 to 12 hours, embedded in paraffin, cut in 4-6 µm sections and stained with haematoxylin-eosin (HE) using routine histological techniques.

Gonadal maturation was analyzed on the basis of histological characters, distribution of cells from the oogenic and spermatogenic lineages, and variations in the GSI. Spawning type was determined by taking into account the frequency distribution of the different gonadal maturation stages and the histological characteristics of spawned ovaries (BAZZOLI 2003).

To study population structure, standard length (SL) and body weight (BW) from males and females were analyzed separately. The size of the smallest males and females reproductively active was used to define size at first gonadal maturation.

One way analysis of variance (ANOVA) followed by Duncan's test ($p < 0,05$) was used to compare differences between calculated biological indexes in different gonadal maturation stages.

RESULTS

Ovaries and testes are paired, elongated and fusiform organs, located inside the coelomic cavity and attached to the air bladder by the mesovarium and the mesorchium, respectively. By light microscopy, gonads appeared coated by the tunica albuginea, which emitted septae to the interior of the ovaries forming ovigerous lamellae with oocytes, or lobes with seminiferous tubules containing spermatogenic lineage cells in testes.

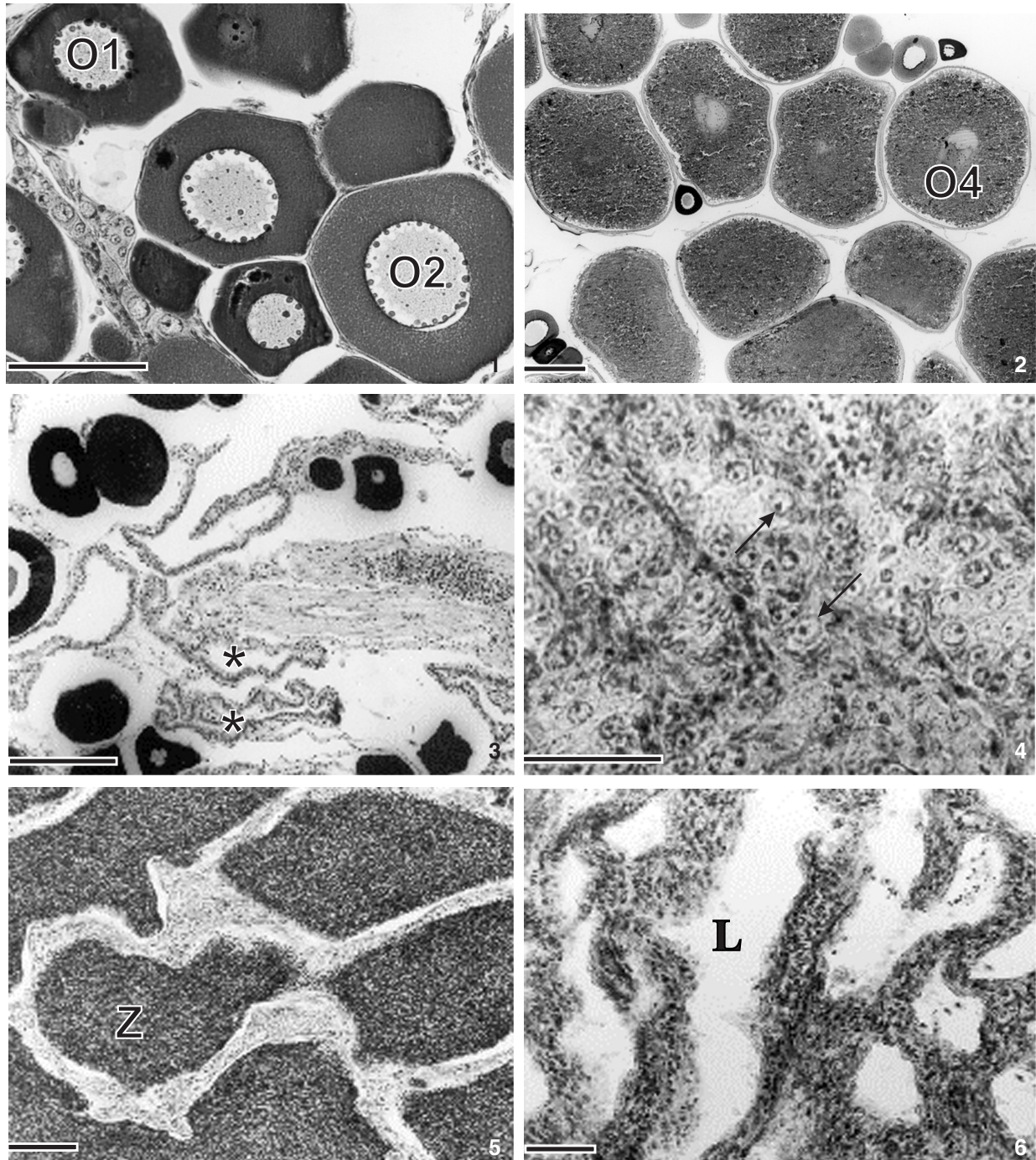
Based upon the distribution of oocytes and spermatogenic lineage cells, three different maturation stages were defined: 1) resting, 2) maturing/mature and 3) spawned/ spermiated (Figs 1-6).

Resting fishes predominated during the period June-August while the peak of maturing/mature stage occurred during the period December-February for both sexes. Spawned females were captured only in the last period, matching with the peak of spermiated males (Tab. I).

Short spawning period, absence of partially spawned females, and spawned ovaries, presenting only perinucleolar oocytes, post-ovulatory and atretic follicles, indicated that *L. taeniatus* presented total spawning.

Table I. Frequency of the gonadal maturation stages of *L. taeniatus* males and females captured in the Juramento Reservoir, Minas Gerais, between March 2002 and February 2003. Stages: 1) Resting, 2) Maturing/mature, 3) Spawned (females) or Spermiated (males).

Period/year	Females			Males			Total
	1	2	3	1	2	3	
Mar-Apr-May/2002	3	6	–	–	8	4	21
Jun-Jul-Aug/2002	13	–	–	10	–	5	28
Sep-Oct-Nov/2002	–	20	–	–	21	2	43
Dez/02-Jan-Feb/2003	–	45	7	–	54	17	123
Total	16	71	7	10	83	28	215



Figures 1-6. Microscopic characteristics of the different stages of gonadal maturation stages in females (1-3) and males (4-6) of *L. taeniatus* captured in the Juramento reservoir, Minas Gerais in the period between March 2002 and February 2003, HE. (1) Resting: ovaries containing only initial perinucleolar oocytes (O1) with strongly basophilic cytoplasm, and advanced perinucleolar oocytes (O2) with fine granulated cytoplasm; (2) Maturing/mature: ovaries with predominance of vitellogenic oocytes (O4) full of yolk globules; (3) Spawned: with initial and advanced perinucleolar oocytes (O1 and O2), and characteristic post-ovulatory follicles (*) that remain after the spawn; (4) Resting: seminiferous tubules with closed lumen and spermatogonia in the walls (arrows); (5) Maturing/mature: seminiferous tubules with lumen full of spermatozoa (Z); (6) Spermiated: emptied seminiferous tubules with opened lumen, presenting some residual spermatozoa. HE.

Both sexes presented the highest GSI and lowest CFI values during the maturing/mature stage. The lowest values of HSI in females were founded when fishes were resting or in maturing/mature stage. SRI values for both sexes were higher during the spermiated/spawned stage. HSI values in males and K values in both sexes did not present significant differences between the different maturation stages (Tab. II).

Females were larger than males and the ratio females/males was approximately 1:1.3. The greatest female captured had a standard length of 19.2 cm and the greatest male was 18.0 cm. The smallest reproductively active female captured was a spawned one of 10.5 cm, while the smallest maturing/mature male captured had 10.3 cm (Tab. III).

DISCUSSION

The morphology of the gonads in *L. taeniatus* is similar to what is described for other Brazilian anostomids (TAVARES & GODINHO 1994, RIZZO et al. 1996, RICARDO et al. 1997, BRITO et al. 1999). Cystovarian ovaries and tubular testes of *L. taeniatus* are similar to the majority of fresh water teleosts (HOAR 1969, GRIER 1981). In the literature, the number of gonadal maturation stages registered varies depending on the criteria used to define them, the characteristics of the gonads and sample size (BAZZOLI 2003).

In females, initial maturation precedes vitellogenesis, when cortical vesicles are formed in the oocytes periphery. This is a short stage that indicates the beginning of the gonadotrophic-dependent phase (TYLER & SUMPTER 1996). In the present study three stages were defined, one of them grouping together the stages of initial and advanced maturing, since there was a low frequency of females founded to be in the former.

Females of *L. taeniatus* from the Juramento reservoir, presented a peak in the frequency distribution of the maturing/mature and spawned stages during December-February period, coinciding with the reproduction season of other Brazilian Anostomidae, such as *Leporinus piau* Fowler, 1941 (TAVARES & GODINHO 1994), *Leporinus reinhardti* Lütken, 1874 (RIZZO et al. 1996), *Leporinus striatus* Kner, 1859 (RICARDO et al. 1997) and *Leporinus friderici* Bloch, 1794 (BRITO et al. 1999). Reproduction of these fishes during the summer is probably related to higher temperatures, rainfall and photoperiod, all of these environmental factors that stimulate the hypothalamus-hypophysial-gonad axis, being essential for the regulation of reproduction in teleosts (NAGAHAMA 1983). The species here studied, presented total spawning, a reproductive strategy common to other species of this genus, such as *L. piau* (TAVARES & GODINHO 1994), *L. reinhardti* (RIZZO et al. 1996), *L. striatus* (RICARDO et al. 1997) and *L. friderici* (BRITO et al. 1999). However, in the species *Leporinus*

Table II. Values of gonadosomatic index (GSI), hepatosomatic index (HSI), stomach repletion index (SRI), coelomic fat index (CFI), and Fulton's condition factor (K) grouped by gonadal maturation stage (GMS) of *L. taeniatus* males and females, captured in the Juramento Reservoir, Minas Gerais, between March 2002 and February 2003.

Sex	GMS	N	GSI	HSI	SRI	CFI	K
Females	1	16	0.32 ± 0.24 c	0.38 ± 0.17 b	0.66 ± 0.32 b	1.56 ± 0.87 a	3.31 ± 0.39 a
	2	71	11.41 ± 4.06 a	0.33 ± 0.19 b	0.78 ± 0.43 b	0.10 ± 0.09 c	3.34 ± 0.40 a
	3	07	4.54 ± 2.98 b	0.55 ± 0.23 a	1.65 ± 0.91 a	1.12 ± 0.41 b	3.25 ± 0.19 a
Males	1	10	0.19 ± 0.08 c	0.31 ± 0.24 a	0.53 ± 0.35 b	1.53 ± 0.63 a	3.68 ± 0.13 a
	2	83	3.29 ± 1.49 a	0.38 ± 0.29 a	0.78 ± 0.58 b	0.43 ± 0.36 c	3.79 ± 0.41 a
	3	28	1.18 ± 0.79 b	0.41 ± 0.21 a	1.25 ± 0.74 a	0.86 ± 0.72 b	3.69 ± 0.38 a

Stages: 1) Resting, 2) Maturing/mature, 3) Spawned (females) or Spermiated (males). In a column, different letters indicate significant differences ($p < 0,05$).

Table III. Values of standard length and body weight grouped by gonadal maturation stage (GMS) of *L. taeniatus* males and females, captured in the Juramento Reservoir (MG) between March 2002 and February 2003.

Sex	Standard length (cm)			Body weight (g)	
	GMS	Mean ± SD	Minimum-maximum	Mean ± SD	Minimum-maximum
Females	1	14.08 ± 2.59	9.00 – 18.10	71.05 ± 32.91	20.00 – 139.00
	2	15.72 ± 1.85	11.30 – 18.60	94.66 ± 29.82	28.40 – 148.46
	3	12.54 ± 2.99	10.50 – 19.20	51.85 ± 41.05	26.80 – 144.01
Males	1	13.99 ± 1.52	11.20 – 16.20	62.68 ± 16.97	35.20 – 89.53
	2	14.33 ± 2.06	10.30 – 18.00	71.09 ± 27.96	27.15 – 129.98
	3	13.04 ± 2.00	10.50 – 17.40	53.88 ± 25.06	25.45 – 113.56

Stages: 1) Resting, 2) Maturing/mature, 3) Spawned (females) or Spermiated (males).

copelandii Steindachner, 1875 (NOMURA 1976) and *Leporinus amblyrhynchus* Garavello & Britski, 1987 (RICARDO *et al.* 1997), and also in the white piau *Schizodon knerii* Steindachner, 1875 (FERREIRA & GODINHO 1990), spawning is of the fractional type. Fishes that present total spawning generally make reproductive migrations, while fishes with fractional spawning reproduce in lentic environments (BAZZOLI 2003, SATO *et al.* 2003). As *L. taeniatus* shows total spawning, this species probably could make short reproductive migrations to the tributaries of Juramento reservoir during its spawning period.

In the present study, the highest GSI values were found during the maturing/mature stage as occurs in the majority of teleosts (VAZZOLER 1996). Values of HSI in females generally decreased during the maturing/mature stage due to the transfer hepatic substances during vitellogenesis (SELMAN & WALLACE 1989). However, from *L. taeniatus* this tendency, was not observed, whereas no significant differences in HSI values were registered between fishes in the maturing/mature and resting stages. The SRI values were greater during the spawned/spermiated stages, indicating that both sexes increased food consumption to replace the energy lost due to reproduction according to other teleost species (SANTOS 1980, BAZZOLI *et al.* 1998, MADDOCK & BURTON 1999, RATTON *et al.* 2003). The CFI was lowest during the maturing/mature stage, indicating the consumption of stored body fat during gonadal maturation, as has already been observed in *L. piau* (TAVARES & GODINHO 1994). K values in *L. taeniatus* did not present significant differences along the reproductive cycle, as registered for *L. friderici* (BRITO *et al.* 1999).

In *L. taeniatus* we observed sexual dimorphism with the females being larger than the males, according to *L. friderici* in Corumbá reservoir, Goiás (LOPES *et al.* 2000) and *L. amblyrhynchus* in Miranda reservoir, MG (VONO *et al.* 2002). The predominance of males found in the present study could be related to differential trapping caused by the fishing devices used (BARBIERI 1992).

As there were no immature specimens captured, it was not possible to determine the first gonadal maturation size by the L_{50} method, which establishes the size at which 50% of the population is immature (VAZZOLER 1996). Thus, size at first gonadal maturation was defined by the size of the smallest males and smallest females found in reproductive activity i.e. in maturing/mature and spawned/spermiated stages (BAZZOLI 2003).

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