Reproductive biology of *Moenkhausia intermedia* (Eigenmann) (Pisces, Characiformes) in Itumbiara Reservoir, Goiás, Brazil

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ABSTRACT. To study the reproductive biology of *Moenkhausia intermedia* (Eigenmann, 1908) in Itumbiara reservoir, Paranaíba river, Goiás, Brazil, a total of 301 specimens (237 females and 64 males) were captured quarterly from January to December 1993. The gonadosomatic index of females and males were related to morphologic variations of the gonads in different reproductive cycle stages (RCS). Analysis of RCS frequency and variations in the gonadosomatic index showed that *M. intermedia* reproduces during the whole year with fractional spawning. The smallest standard length at advanced maturity stage was estimated as 6.6 cm for females and 6.0 cm for males. The stomach repletion and coelomic fat indexes of both sexes reached peak values in the rest stage, suggesting that this species probably store energy in this phase and consume its fat reserve during reproduction. In the Itumbiara reservoir there was female predominance (4:1). Males were smaller than females, indicating sexual dimorphism in *M. intermedia*.
KEY WORDS. Gonads, reproduction, sexual dimorphism, sexual maturation, spawning.

RESUMO. Para estudar a biologia reprodutiva de *Moenkhausia intermedia* (Eigenmann, 1908) no reservatório de Itumbiara, Goiás, Brasil, capturaram-se, trimestralmente, no período de janeiro a dezembro de 1993, 301 exemplares, sendo 237 fêmeas e 64 machos. O índice gonadossomático de fêmeas e machos acompanhou as variações morfológicas das gônadas nos diferentes estádios de maturação. Através da distribuição de freqüência dos estádios de maturação gonadal e das variações do índice gonadossomático constatou-se que *M. intermedia* reproduz o ano todo com desova do tipo parcelado. O comprimento padrão de primeira maturação sexual foi estimado em 6,6 cm para fêmeas e 6,0 cm para machos. Os índices de repleção estomacal e de gordura celômica foram maiores no estádio de repouso gonadal indicando que os peixes, provavelmente, acumulam energia nessa fase para ser consumida no período reprodutivo. No reservatório de Itumbiara houve predominância de fêmeas de *M. intermedia* na proporção de 4:1 e estas foram maiores que os machos indicando dimorfismo sexual para a espécie.
PALAVRAS CHAVE. Desova, dimorfismo sexual, gônadas, maturação sexual, reprodução.

The "lambari" or "lambari corintiano" *Moenkhausia intermedia* (Eigenmann, 1908), presents two dark, converging stripes on caudal fin. *M. intermedia* belongs to the family Characidae, subfamily Tetragonopterinae (Britski 1972). The Characidae is the biggest and most complex family of the order Characiformes, with 250 South American genera. Tetragonopterinae includes widely distributed small sized fishes, usually less than 10 cm of length. Most species of this sub-family are onivorous and very active swimmers (Britski *et al*. 1988).

Determining the reproductive cycle stages of teleosts is fundamental to understand the reproductive biology of a species within its native range (Vazzoler 1996). A fish's spawning types indicates the frequency of mature oocytes released within the same reproductive period (Vazzoler 1996). Fishes with fractional spawning have a long reproductive cycle (Rinchard & Kestemont 1996), whereas others spawn all their eggs (total spawning) over a short time period (Bazzoli 2003). In fresh waters, fractional spawning (batch spawning) occurs more frequently in stable habitats such lakes, ponds, and reservoirs (Bazzoli 2003).

The biologic indexes, gonadosomatic, hepatosomatic, stomach repletion and coelomic fat indicate how fish use the environment energy resourse to attend to different reproductive strategies (Vazzoler 1996).

The Itumbiara reservoir (18°25'S, 49°06'W), located in the Paranaíba river, Goiás state, has a dendrite shape, 814 Km^2 of flood area, 17.03 billion m^3 of water volume and 28 m of maximum depth, being classified as a higler capacity reservoir, according to Bernaczek (1984).

The aim of the present paper is to analyze the reproductive biology of *M. intermedia* in Itumbiara reservoir, by determining the reproductive cycle stages, reproductive period, type of spawning and biologic indexes related to reproduction.

MATERIAL AND METHODS

A total of 301 specimens of *M. intermedia* (237 females and 64 males) were captured quaterly in the Itumbiara reservoir, from January to December 1993 by gill nets with 3, 4 and 5 cm mesh size (stretched measure). The nets were set at dusk and removed approximately 14 hours later. Specimens were preserved in 10% formalin solution.

Standart length (SL) and body weight (BW) were recorded for all sampled individuals.

After dissection of each specimen the following parameters were recorded: sex, RCS and weight of the gonads (GW), stomach (SW), liver (LW) and coelomic fat (CFW). Based on biometric data obtained, the following biologic indexes were calculated: gonadosomatic (GSI = GW/BW x 100), hepatosomatic (HSI = LW/BW x 100), stomach repletion (SRI = SW/BW x 100) and coelomic fat (CFI = CFW/BW x 100).

The RCS were established by macroscopic analysis of the gonads and the type of spawning by the use of quaterly frequency of the RCS and variations in the GSI (Bazzoli 2003).

The population structure for each reproductive cycle stage was determined for males and females using 10 standard length classes (0.5 cm intervals). The sex ratio was established by proportion of females to males expressed in percent of total sample.

The mean biologic index values calculated by sex for each RCS were compared using one-way ANOVA, followed when necessary by Duncan's multiple range test to determine significant differences between mean values at $p < 0.05$.

RESULTS

Ovaries and testes of *M. intermedia* were paired, elongated and fusiforms organs located in the coelomic cavity, ventrally to the kidneys, dorsally to the digestive tube and latero-ventrally attached to the swim bladder by the mesovarium and mesorquium, respectively. Both organs were joined caudally to form, respectively, the common ovarian and spermatic ducts, which open on the urogenital papilla.

According to variations in volume, turgidity and color, the following RCS were determined for ovaries and testes: 1) rest, 2) initial ripening, 3) advanced ripening/mature, 4A) partially spawned for females, or partially spent for males, and 4B) totally spawned for females; or totally spent for males (Tab. I).

Analysis of the quaterly distribution of the RCS showed females and males in advanced ripening/mature and spawned or spent during all colleting period. For females a peak at the advanced ripening/mature stage occurred from October to December and for males from July to December. The high frequency of partially spawned females during the entire year indicates that *M. intermedia* presents a long and fractional spawning (Fig. 1).

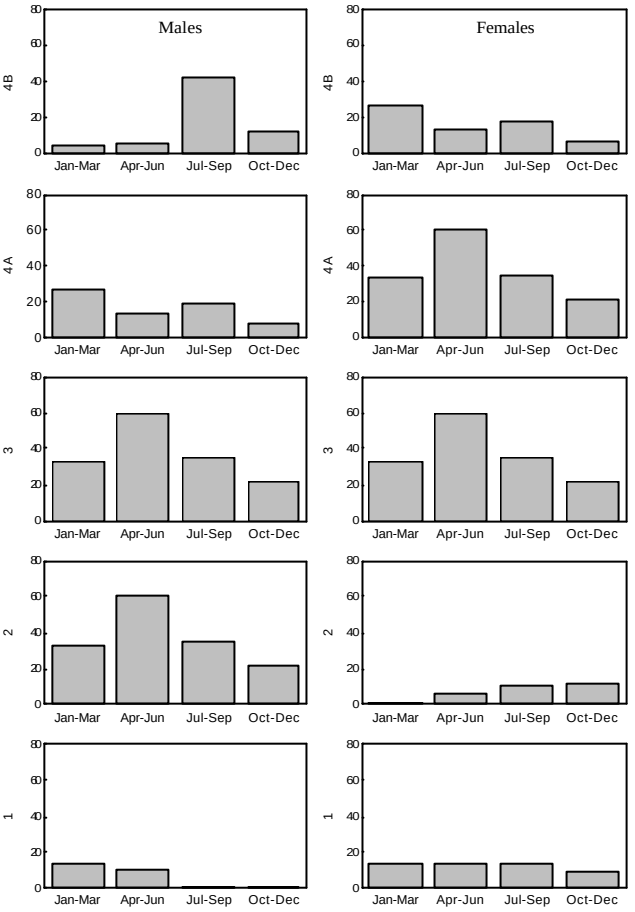

Figure 1. Quaterly relative (RF%) frequency for each reproductive cycle stage (RCS) of females and males of *M. intermedia* in Itumbiara reservoir, from January to December 1993. (1) Rest, (2) initial ripening, (3) advanced ripening/mature, (4A) partially spawned for females/partially spent for males, (4B) totally spawned for females/totally spent for males.

The IGS values of both, females and males, were related to morphologic variations of the gonads in the different RCS, that is, the values gradually increased from the rest to the advanced ripening/mature stage, followed by gradual decrease during the partially/totally spawned and spent stages. The HSI values of females were not statistically significant between the reproductive cycle stages, whereas the highest HSI values of males occurred in the advanced ripening/mature stage. The SRI and CFI of females and males reached peak values during stage rest (Fig. 2).

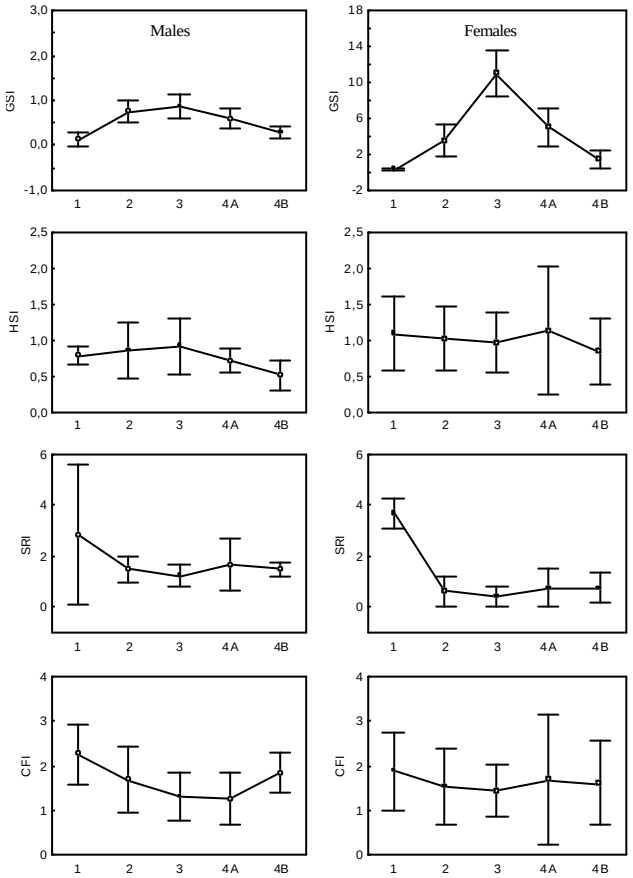

Figure 2. Mean values of the gonadosomatic (GSI), hepatosomatic (HSI), stomach repletion (SRI) and coelomic fat (CFI) indexes for each reproductive cycle stage (RCS) of females and males of *M. intermedia* in Itumbiara reservoir, from January to December 1993. (1) Rest, (2) initial ripening, (3) advanced ripening/mature, (4A) partially spawned for females/partially spent for males, (4B) totally spawned for females/totally spent for males.

The highest number of females and males occurred, respectively, in the 7.6-8.0 and 7.1-7.5 cm standard length classes. Most captured fish were in the advanced ripening/mature stage. The largest female was found in stage 4A, with 11.0 cm of standard length and 29.2 g of body weight, whereas the largest male was in stage 3, with 10.2 cm of standard length and 23.2 g of body weight. The smallest females in stage 3 measured 6.6 cm, whereas the smallest male in the same stage presented 6.0 cm of standard length. The sex ratio showed female predominance (78.7%) with approximately four females for each male (Tabs II and III).

DISCUSSION

According to Hahn *et al.* (1998), insectivorous species in Itaipu reservoir (Paraná state, Brazil), such as *Astyanax fasciatus* (Cuvier, 1819), *Astyanax altiparanae* (Linnaeus, 1758) and *M. intermedia* were highly captured after the impoundment, since the early successional vegetation might have favoured them. However, these species eventually declined. Conversely, in Itumbiara reservoir, populations of *M. intermedia* were stable. In fact, despite the impoundment had occurred 20 years ago, this species continues to be one of the most abundant (Durães *et al.* 2000).

In this study, the macroscopic morphology of the gonads during the reproductive period and the fractional spawning of *M. intermedia* were similar to results reported by Braga & Genari-Filho (1990) for the same species as well as to that of other Characiformes of the sub-family Tetragonopterinae such as: *A. fasciatus* (Barbieri *et al.* 1982, Jamett *et al.* 1997), *A. altiparanae* (Barbieri *et al.* 1982, Rodrigues *et al.* 1989, Barreto *et al.* 1998, Bazzoli *et al.* 1998); *Astyanax scabripinnis paranae* (Eigenmann, 1927) (Barbieri 1992, Veregue & Orsi 2003); *Hemigrammus marginatus* (Ellis, 1911) and *Moenkhausia costae* (Steindachner, 1907) (Bazzoli *et al.* 1997); *Bryconops cf. affins* (Günther, 1864) (Nogueira *et al.* 1997) and *Tetragonopterus chalceus* (Agassiz, 1829) (Ricardo *et al.* 1998). Based on these observations, the extended duration of the reproductive period and the fractional spawning may be a frequent reproductive strategy in Tetragonopterinae species.

The gonadosomatic index is a suitable indicator of the gonads development that can be used for determination of fish reproductive period, when increasing GSI values are associated with maturation and decreasing values with gamete extrusion or absorption (Le Cren 1951). In the present study, GSI was used as an auxiliary resource to determine RCS, in agreement with other authors who have studied the reproduction of the "lambari" (Barbieri *et al.* 1982, Barbieri 1992, Jamett *et al.* 1997, Barreto *et al.* 1998). For female maturation, the GSI peak value means higher body weight as well as higher number of vitellogenic oocytes, leading to higher ovary weight in comparison to that of the testes (Braga & Genari-Filho 1996). In fact, in the present work, variations in the GSI of males were lower than that of females, which has also been reported for *M. costae* and *H. marginatus* (Bazzoli *et al.* 1997).

It is known that vitellogenic proteins (vitellogenin) are synthesized by the liver and transferred to the ovaries during maturation (Wallace & Selman 1981). Thus, variations in HSI of females have been used to correlate this transference. However, studies indicate that vitellogenin is secreted directly into the blood plasma, without hepatocyte storage (Matsubara & Sawano 1995). This fact may explain the lack of significant variations in HSI of females captured in this study. On the other hand, despite the HSI of males have shown peak values in the advanced ripening/mature stage, specific hepatic proteins (vitellogenin) are absent in males and apparently, the liver does not influence testes development (Wallace & Selman 1981). In addition, variations in the HSI are not only related to the transfer of vitellogenin, but may result from liver glycogen and lipid storage, besides physiologic conditions, feeding habits and food availability (Tavares-Dias *et al.* 2000).

Table I. Macroscopic characteristics of the gonads for each reproductive cycle stage (RCS) of females and males of *M. intermedia* in Itumbiara reservoir, Goiás, Brazil, from January to December 1993.

RCS	Ovaries	Testes
1	Fusiform and translucent	Fusiform and transparent
2	Thick and of a yellowish color	Voluminous, of a whitish color
3	Voluminous, turgid, of a yellowish color, filing most of the coelomic cavity containing oocytes visible to the naked eye	Maximum volume, of a milky white color
4A	Flaccid, hemorrhagic and areas without oocytes visible to the naked eye	Reduced volume, flaccid, of a milky white color and transparent areas
4B	Very flaccid, hemorrhagic without oocytes visible to the naked eye	Very reduced volume, flaccid and hemorrhagic

1) Rest, 2) initial ripening, 3) advanced ripening/mature, 4A) partially spawned for females/partially spent for males, 4B) totally spawned for females/totally spent for males.

Table II. Distribution of standard length classes by reproductive cycle stage (RCS) of females and males of *M. intermedia* in the Itumbiara reservoir, from January to December 1993.

Standard length clases (cm)	Females						Males					
	1	2	3	4A	4B	N	1	2	3	4A	4B	N
6.0 – 6.5	-	-	-	-	-	-	-	2	1	-	-	3
6.6 – 7.0	5	3	4	5	5	22	-	9	6	1	1	17
7.1 – 7.5	2	-	16	12	10	40	2	5	6	3	2	19
7.6 – 8.0	3	10	33	21	8	75		3	5	1	4	13
8.1 – 8.5	8	5	25	9	4	51	2	2	2	1	-	7
8.6 – 9.0	4	2	15	1	3	25	-	-	1	-	-	1
9.1 – 9.5	1	1	1	5	2	10	1	1	1	-	-	3
9.6 – 10.0	1	2	-	5	1	9	-	1	-	-	-	1
10.1 – 10.5	1	-	-	3	-	4	-	-	1	-	-	1
10.6 – 11.0	-	-	-	1	-	1	-	-	-	-	-	-
Total	25	23	94	62	33	237	5	23	23	6	7	64

1) Rest, 2) initial ripening, 3) advanced ripening/mature, 4A) partially spawned for females/partially spent for males, 4B) totally spawned for females/totally spent for males.

Table III. Maximum and minimum standard length (SL) and body weight (BW) by reproductive cycle stage (RCS) of females and males of *M. intermedia* in Itumbiara reservoir, from January to December 1993.

RCS	Females					Males				
	1	2	3	4A	4B	1	2	3	4A	4B
SL -Maximum (cm)	10.1	9.6	9.1	11.0	9.7	9.4	9.7	10.2	8.3	8.0
SL -Minimum (cm)	6.6	6.9	6.6	7.0	6.9	7.1	6.5	6.0	6.9	6.7
BW -Maximum (g)	18.1	14.9	18.4	29.2	18.8	13.8	10.1	23.2	10.9	13.5
BW -Minimum (g)	14.6	7.6	7.7	6.7	8.4	7.9	6.4	6.3	7.1	7.9

1) Rest, 2) initial ripening, 3) advanced ripening/mature, 4A) partially spawned for females/partially spent for males, 4B) totally spawned for females/totally spent for males.

For both sexes of *M. intermedia*, the highest SRI and CFI values occurred in the rest stage, indicating better feeding conditions before the reproductive period. It is possible that the fish accumulate energy and consume their fat reserve during reproduction, similar to the reports of Bazzoli *et al.* (1998) for *A. altiparanae* in Furnas reservoir.

Female predominance (4:1) registered in the present study could be explained by the different growth rates between sexes, selectivity of fishing devices and population stratification (Barbieri 1992).

In this study, females were larger than males, in agreement with the results reported for *A. altiparanae* (Barbieri *et al.* 1982) and *T. chalceus* (Ricardo *et al.* 1998). This sexual dimorphism is advantageous, since fecundity increases exponentially with length (Nikolsky 1963).

Fishing devices (gill nets) used in this work hinder immature fish capture, making impossible to determine standard length first maturity by the L_{50} method (Santos 1978), that estimates the length in which 50% of the population is mature and 50% is immature. Therefore, standard length at first maturity was suggested based on the standard length of the smallest female and male captured in the advanced ripening/mature stage, according to Bazzoli (2003).

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