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YANNE ALVES MENDES

EFEITO DOS NÍVEIS DA ÁGUA NA REPRODUÇÃO DA BICUDA *Boulengerella cuvieri* (CTENOLUCIIDAE) NO MÉDIO RIO XINGU, AMAZÔNIA ORIENTAL

BELÉM – Pa

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Dissertação de mestrado apresentada ao Programa de Pós-Graduação em Ecologia Aquática e Pesca do Instituto de Ciências Biológicas da Universidade Federal do Pará, como parte dos requisitos para obtenção do título de Mestre em Ecologia Aquática e Pesca.

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SUMÁRIO

RESUMO

A reprodução consiste no momento mais importante à vida das espécies, pois garante sua perpetuação em ambiente. Para alcançar o sucesso reprodutivo, os peixes exibem uma diversidade de táticas durante o seu ciclo de vida que podem ocorrer de acordo com as variações temporais do ambiente. Em rios tropicais, as variações pluviométricas e fluviométricas associado as características ambientais constituem os principais fatores moduladores da reprodução dos peixes que tendem a apresentar diferentes estratégias no ciclo reprodutivo. Neste sentido esse estudo objetivou avaliar a influência da variação fluviométrica do rio Xingu na reprodução da bicuda *Boulengerella cuvieri*. Foram analisados 140 fêmeas e 113 machos e, de acordo com o desenvolvimento gonadal foram observados cinco estádios de maturação para fêmeas e três para machos. Considerando o período como um todo e os diferentes períodos amostrados, foi observado uma proporção de 1:1 na população que apresentou crescimento alométrico positivo seguindo um padrão monofásico. O Índice Gonadossomático (IG%) e a frequência relativa dos estádios de maturação indicaram um pico reprodutivo na enchente do rio e dois momentos de desova. Foi estimado para fêmeas L_{50} de 29.39cm. No rio Xingu, a reprodução de *B. cuvieri* é influenciada pela variação fluviométrica apresentando sincronia entre o período reprodutivo na enchente e desova parcelada.

Palavras-chave: fluviometria; teleósteo; desenvolvimento gonadal; história de vida.

INTRODUÇÃO GERAL

A ictiofauna de água doce de regiões tropicais é composta por uma variedade de espécies dotadas de características morfológicas, fisiológicas e ecológicas que refletem numa diversidade de padrões reprodutivos (Lowe-McConnell, 1987). Estes padrões são observados através das diferentes estratégias no ciclo de vida das espécies a fim de alcançar principalmente o sucesso reprodutivo (Wooton, 1894; Vazzoler, 1996). A reprodução é considerada o evento mais importante na vida das espécies, pois garante a perpetuação destas nos ambientes (Suzuki & Agostinho, 1997).

Para atingir o sucesso reprodutivo as espécies dependem de fatores intrínsecos, como os hormônios, e extrínsecos, como temperatura, oxigênio dissolvido, pH, local para desova com condições favoráveis ao desenvolvimento de ovos e larvas, alocação de recursos para o evento reprodutivo e regime hidrológico (Wooton, 1984; Lowe-McConnell, 1987).

Tendo em vista a importância da reprodução nas espécies e os diferentes modos que estas apresentam, diversas investigações científicas têm estudado os padrões de histórias de vida nos teleósteos (Winemiller, 1989; Menezes & Caramaschi, 1994; Mazzoni & Petito, 1999; Mazzoni *et al*., 2002; Ribeiro *et al*., 2007; Santos *et al*., 2010; Freitas *et al*., 2011; Prudente *et al*., 2015; Souza *et al*., 2015), onde são estimados parâmetros sobre as táticas reprodutivas das espécies como, estrutura populacional; taxa de fecundidade; época e tipo de desova; tamanho da primeira maturidade sexual; índice gonadossomático e fator de condição, a fim de entender quais mecanismos adaptativos as populações exibem frente às variações temporais do ambiente natural para obter o sucesso reprodutivo.

Em regiões tropicais, como a região Amazônica, os dois principais fatores que influenciam a reprodução das espécies são as variações pluviométricas e fluviométricas que resultam em períodos hidrológicos distintos que afetam as concentrações de nutrientes dissolvidos e a densidade de peixes, e culmina com a formação de planícies de inundação que são utilizadas pelas espécies como área de reprodução (Rizzo *et al*., 1996). Tais variações temporais associadas a essas planícies desempenham papel importante na ecologia das populações de peixes (Schlosser, 1987; Lowe-McConnell, 1999; Bayley, 1987; Prudente *et al*., 2015).

O rio Xingu, na Amazônia Oriental (Fig. A), situado à margem direita do rio Amazonas, é caracterizado por uma heterogeneidade ambiental. Tal característica reflete numa diversidade de microambientes formados devido a geomorfologia e a hidrologia da bacia. Esta heterogeneidade favorece a diversidade íctica, levando ao isolamento das populações, através de barreiras geográficas e climáticas (IBAMA, 2008; Buckup *et al*., 2010). O rio apresenta uma distribuição irregular das chuvas caracterizando períodos hidrológicos distintos, marcados por regimes de cheias e secas ao longo do ano. Esta dinâmica reflete diretamente na ecologia reprodutiva das espécies de peixes que tendem a se adaptar às variações, a fim de obter o sucesso reprodutivo (Lowe-McConell, 1999).

Fig. A. Rio Xingu, situado na margem direita do rio Amazonas, Amazônia Oriental.

Dentre as espécies encontradas na ictiofauna do rio Xingu, destaca-se a bicuda, *Boulengerella cuvieri* Agassiz, 1829 (Fig. B). A espécie desempenha um papel importante para os ecossistemas aquáticos por apresentar hábito carnívoro, sendo considerada um predador de topo, podendo exercer impacto sobre a ictiofauna através do controle de populações de pequenos peixes, especialmente de representantes da família Characidae e Curimatidae. A espécie pertence a Ordem dos Characiformes, família Ctenoluciidae, gênero *Boulengerella*. Apresenta distribuição no Rio Orinoco, Rio Amazonas, bacia do Rio Tocantins, e os rios costeiros do Amapá e Pará, onde habita regiões de águas correntes (Vari, 1995).

Fig. B. Exemplar de *Boulengerella cuvieri.* Foto: Leandro Souza.

No gênero *Boulengerella* a espécie é considerada de elevado porte, apresenta maior espectro de variação morfológica e ainda possui uma ampla distribuição geográfica. Os exemplares da bicuda são explotados pelas pescas de subsistência, comercial e esportiva, embora tenha baixa representatividade (Vari 1995; PNDA 2008).

No Brasil são amplos os estudos sobre a reprodução de peixes de água doce, por exemplo: Mazzoni & Petito 1999; Andrade & Braga 2005; Gonçalves *et al*., 2006; Neuberger *et al*., 2007; Carvalho *et al*., 2009; Azevedo *et al*., 2010. Porém ainda apresenta lacunas sobre a biologia reprodutiva de muitas espécies, como as bicudas em geral. Poucos estudos encontrados sobre as bicudas relataram aspectos da ecologia alimentar, relação massa-comprimento e evolução de estruturas bucais, por exemplo: Giarrizzo *et al*., 2011; Datovo & Castro 2012; Pereira *et al*., 2012; Giarrizzo et al., 2015, resultando no desconhecimento do ciclo de vida destas espécies especialmente sob condições ambientais. Sabe-se que estas informações são essenciais para o melhor entendimento dos mecanismos adaptativos e fatores reguladores das populações afim de elaborar ações de conservação, manejo e explotação de estoques naturais (Nikolsky, 1969; Agostinho *et al*., 1995). Além disso, estes mecanismos possibilitam entender a capacidade que as espécies apresentam para serem bem sucedidas em ambiente natural com períodos hidrológicos distintos. Por isso, analisar as táticas reprodutivas da bicuda em diferentes períodos hidrológicos torna-se importante e tendo em vista a carência destes estudos, os dados podem informar sobre a ecologia reprodutiva da espécie em ambiente natural.

OBJETIVOS

GERAL

Estudar a Ecologia Reprodutiva de *Boulengerella cuvieri* sob o seguinte questionamento: Qual a influência da variação fluviométrica do rio Xingu na atividade reprodutiva da espécie?

ESPECÍFICOS

- Descrever os estádios de maturação sexual da espécie e relacioná-los com os diferentes períodos hidrológicos do rio Xingu;

- Analisar a estrutura da população (sexo e comprimento);

- Estimar a atividade reprodutiva (Índice Gonadossomático%) ao longo dos diferentes períodos hidrológicos amostrados;

- Estimar o período e tipo de desova;

- Estimar o comprimento mínimo de primeira maturidade sexual (L_{50}).

REFERÊNCIAS

Agostinho, A.A., Matsuura, Y., Okada, E.K., & Natakani, K. (1995). The catfish *Rhinelepis áspera* (Teleostei: Loricariidae) in the Guaíra region of the Paraná River: na example of population estimation from catch-effort and tagging data when emigration and immigration are high. *Fisheries Research* **23**: 333-344.

Andrade, P.M., & Braga, F.M. (2005). Reproductive seasonality of fishes from a lotic stretch of the Grande river, High Paraná river basin, Brazil. *Brazilian Journal of Biology* **65**: 387-394.

Azevedo, M.A., Malabarba, L.R., & Burns, J.R. (2010). Reproductive biology and development of gill glands in the inseminating characid, *Macropsobrycon uruguayanae* Eigenmam, 1915 (Cheirodontinae: Compsurini). *Neotropical Ichthyology* **8**: 87-96. doi: 10.1590/S1679-62252010005000004.

Bayley, P. B. (1987). Factors affecting growth rates of young tropical floodplain fishes: Seasonality and density – Dependence. *Environmental Biology of Fishes* **21**: 127-142.

Buckup, P.A., & Santos, G.M. (2010). Ictiofauna da ecorregião Xingu-Tapajós: fatos e perspectivas. *Boletim da Sociedade Brasileira de Ictiologia*, 20p.

Carvalho, P.A., Paschoalini, A.L., Santos, G.B., Rizzo, E., & Bazzoli, N. (2009). Reproductive biology of *Astyanax fasciatus* (Pisces: Characiformes) in a reservoir in South eastern, Brazil. Braz. *Journal of Applied Ichthyology* **25**: 306-313. doi: 10.1111/j.1439-0426.2009.01238x.

Datovo, A., Castro, R.M.C. (2012). Anatomy and evolution of the mandibular, hopalatine, and opercular muscles in Characiform fishes (Teleostei: Ostariophysi). *Zoology* **115**: 84-116.

Freitas, T.M.S., Almeida, V.H.C., Montag, L.F.A., Rocha, R.M., & Fontoura, N.F. (2011). Seasonal changes in the gonadossomatic index, allometric condition fator and sex ratio of na auchnipterid catfish from eastern Amazonia. *Neotropical Ichthyology* **9**: 839-847.

Giarrizzo, T., Bastos, D., & Andrade, M. (2011). Technical Contribution: Length-weight relationships for selected fish species of Rio Trombetas Biological reserve: a reference study for the Amazonian basin. *Journal of Applied Ichthyology* **27**: 1422-1424. doi: 10.1111/j.1439-040426.2011.01820x.

Giarrizzo, T., Oliveira, R.R.S., Andrade, M.C., Pedrosa, A.G., Barbosa, T.A.P., Martins, A.R., Marques, D.K., Santos, J.L.B., Frois, R.P.S., Albuquerque, T.P.O., Montag, L.F.A., Camargo, M., & Sousa, L.M. (2015). Technical contribution: Length–weight and length–length relationships for 135 fish species from the Xingu River (Amazon Basin, Brazil). *Journal of Applied Ichthyology* **31**: 415-424.

Gonçalves, T.L., Bazzoli, N., & Brito, M.F.G. (2006). Gametogenesis and reproduction of the matrinxã *Brycon orthotaenia* Gunther, 1864 (Pisces: Characidae) in the São Francisco river, Minas Gerais, Brazil. *Brazilian Journal of Biology* **66**: 513-522.

INSTITUTO BRASILEIRO DO MEIO AMBIENTE E DOS RECURSOS RENOVÁVEIS - IBAMA. (2008). *Diagnóstico Ambiental da AHE - Belo Monte - Médio e Baixo Xingu - Ictiofauna e Pesca.* Universidade Federal do Pará / Museu Paraense Emílio Goeldi. Belém, 434p.

Lowe-McConnell, R.H. (1987). *Ecological Studies in Tropical Fish Communities*. Cambridge University Press.

Lowe-McConnell, R.H. (1999). *Estudos Ecológicos de comunidades de peixes tropicais.* EDUSP, São Paulo.

Mazzoni, R., & Caramaschi, E.P. (1995). Size structure, sex ratio and onset of sexual maturity of two species of Hypostomus Lacépede (Osteichthyes, Loricariidae). *Journal of Fish Biology* **47**: 841-849.

Mazzoni, R. & Petito, J.T. (1999). Reproductive biology of a Tetragonopterinae (Osteichthyes, Characidae) of the Ubatiba fluvial system, Maricá – RJ. Brazil. *Brazilian Archives of Biology and Technology* **42**: 455–461.

Mazzoni, R., Caramaschi, E.P., & Fenerich-Verani, N. (2002). Reproductive Biology of a Characidiinae (Osteichthyes, Characidae) from the Ubatiba river, Maricá – RJ. *Brazilian Journal of Biology* **62**: 487-494

Neuberger, A.L., Marques, E.E., Agostinho, C.S., & Oliveira, R.J. (2007). Reproductive biology of *Rhaphiodon vulpinus* (Ostariophysi: Cynodontidae) in the Tocantins River

Basin, Brazil. *Neotropical Ichthyology* **5**: 479-484. doi: 10.1590/S1679-62252007000400007.

Nikolsky, G.V. (1969). *Theory of fish population dynamics.* Edinburgh, Oliver & Boyd.

Pereira, J.G.M., Lima, M.G., Bellaver, S.M., Schuingues, C.O., & Costa, G.M. (2012). Análise morfológica do estômago de *Boulengerella cuvieri* (TELEOSTEI: CTENOLUCIIDAE). *Revisa de Ciências Agro-Ambientais* **10**: 93-98.

PROGRAMA NACIONAL DE DESENVOLVIMENTO DA PESCA AMADORA – PNDA. (2008). Brasilia-DF. Guia de recordes. Brasilia-DF: Editora Grafica Ltda, 2008.

Prudente, B.S., Ferreira, M.A.P., Rocha, R.M., & Montag, L.F.A. (2015). Reproductive biology of the piranha *Serrasalmus gouldingi* (Fink and Machado-Allison 1992) (Characiformes: Serrasalmidae) in "drowned" rivers of the Eastern Amazon. *Environmental Biology of Fish* **98**: 11-22. doi: 10.1007/s10641-014-0232-0.

Ribeiro, V.M.A., Santos, G.B., & Bazzoli, N. (2007). Reproductive biology of Steindachnerina insculpta (Fernandez-Yépez) (Teleostei, Curimatidae) in Furnas reservoir, Minas Gerais, Brazil. *Revista Brasileira de Zoologia* **24**:71-76.

Rizzo, E., Sato, Y., Ferreira, R.M.A., Chiarini-Garcia, H., & Bazzoli, N. (1996). Reproduction of *Leporinus reinhardti* Lutken, 1875 (Pisces: Anastomidae) from Três Marias Reservoir, São Francisco River, MG, Brazil. *Ciencia e Cultura* **4813:** 189-192.

Santos, R.N., Amadio, S., & Ferreira, E.J.G. (2010). Patterns of energy allocation to reproduction in three Amazonian fish species. *Neotropical Ichthyology* **8**:155-161.

Schlosser, I.J. (1987). A conceptual framework for fish communities in small warmwater streams. In W.J. Assemblage and evolutionary ecology of North American stream fishes, University of Oklahoma Press, Norman (Matthews & Heins, D.C., eds).

Souza, U.P., Ferreira, F.C., Braga, F.M., & Winwmiller, K.O. (2015). Feeding, body condition and reproductive investment of Astyanax intermedius (Characiformes, Characidae) in relation to rainfall and temperature in a Brazilian Atlantic Forest stream. *Ecology of Freshwater* **24**: 123-132.

Suzuki, H.I., & Agostinho, A.A. (1997). Reprodução de peixes do reservatório de Segredo. *In:* Agostinho, A. A. & Gomes, L. C. *Reservatório de Segredo, bases ecológicas para o manejo* Maringá. Eduem. p.163-182.

Vari, R.P. (1995). The Neotropical Fish Family Ctenoluciidae (Teleostei: Ostariphysi: Characiformes): Supra and Intra-familial Phylogenetic Relationships with a Revisionary Study. *Smithsonian Contributions to Zoology*, 1-91.

Vazzoler, A.E.A.M. (1996). *Biologia da reprodução de Peíxes Teleósteos: Teoria e prática.* EDUEM: Maringá.

Winemiller, K.O. (1989). Patterns of variation in life history among South American fishes in seasonal environments. *Oecologia* **81**:225-241.

Wootton, R.J. (1984). Strategies and Tatics in fish reproduction. p.1-12. In *Fish reproduction: Strategies and Tatics.* San Diego, Academic press (Potts, G.W., & Wootton, R.J., eds.).

CAPÍTULO I

EFEITO DOS NÍVEIS DA ÁGUA NA REPRODUÇÃO DA BICUDA *Boulengerella cuvieri* (CTENOLUCIIDAE) NO MÉDIO RIO XINGU, AMAZÕNIA ORIENTAL

Título abreviado: Reprodução de *Boulengerella cuvieri*

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Effect of water levels on the reproduction of pike-characids *Boulengerella cuvieri* (CTENOLUCIIDAE) in the middle Xingu river, Eastern Amazon

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ABSTRACT

In tropical rivers the variations in fluviometric levels related to environmental characteristics modulate fish reproduction, which tend to exhibit different strategies in the reproductive cycle. Therefore, this study evaluates how the variations fluviometric of the Xingu River affect the reproduction of *Boulengerella cuvieri*. 140 females and 113 males were analyzed and based on the gonadal development five maturation stages were observed for females and three for males. The overall ratio was 1:1 and the population exhibited positive allometric growth following a single phase pattern. The Gonadosomatic Index (*IG*) and relative frequency of maturation stages indicated one reproductive peak during the river filling period and two spawning times. L_{50} of 25.39cm was estimated for the females. In the Xingu River, the reproduction of *B. cuvieri* is affected by the fluviometric variations, showing a synchronized reproductive period in the filling season and the species exhibit partitioned spawning, which has proved to be a common pattern in the Characiformes of tropical regions.

Key words: fluviometry; teleosts; gonadal development; life history.

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INTRODUCTION

In tropical regions fish reproduction is modulated especially by variations in the hydrological regime of rivers, caused by the fluvial dynamics in its sources. Under these conditions, the varying river levels related to environmental characteristics affect nutrient concentrations in the middle and also fish density. Consequently, these animals exhibit different reproduction strategies (Magalhães *et al.*, 2003; Olden *et al.*, 2006; Winemiller *et al.*, 2014).

To understand fish reproduction and their adaptive mechanisms in the natural environment one needs to know the various aspects of their biology, including: population behavior; reproductive period; spawning type; fecundity and minimum size at first sexual maturity (Wootton *et al.*, 1984; Winemiller & Rose, 1992; Núñez & Duponchelle, 2009).

The Characiformes have different reproductive strategies and are affected by the variations of the river levels as a strategy for reproductive success. These environments, which are formed by the rising river levels, provide spawning resources and habitats for the development of larvae, juveniles and adults (Goulding, 1980; Gonçalves *et al.*, 2006; Bailly *et al.*, 2008; Azevedo *et al.*, 2010; Oliveira *et al.*, 2010; Freitas *et al.*, 2011).

The Xingu River, a tributary of the Brazilian Amazon basin, has a heterogeneous environment where the uneven rainfall distribution characterizes a hydrological regime marked by wet and dry seasons (Buckup *et al.*, 2010). This trait reflects the composition and ecological aspects of river fish populations (Lowe-McConell, 1999). Some of the fish found in this environment is *Boulengerella cuvieri* (Agassiz 1829) (Characiformes: Ctenoluciidae). This species is a predator component of the Xingu River fish populations that is ecologically engaged in the structure of fish communities and ecosystems (Zaret, 1980). *Boulengerella cuvieri* is an important socioeconomic activity representing a source of income for most of the population, because it is exploited by subsistence, ornamental, sports and commercial fishing (Vari, 1995; PNDA, 2008).

Therefore, the focus of this study is to evaluate the effect of variations in the fluviometric levels on the reproduction of *B. cuvieri* in the middle Xingu River, Eastern Amazon, based on the assumption that reproduction of this species is driven by rising river levels due to increased floodplain habitat availability and low predation risk, providing conditions that are conducive to offspring growth and survival.

MATERIAL AND METHODS

Study Area

Species were collected along the middle stretch of the Xingu River, one of the tributaries of the right bank of the Amazon River (Fig. 1). The river is characterized by slightly acidic water, pH ranging between 6.2 and 7.0, high dissolved oxygen concentrations (6-7 mg/l), with average temperatures ranging between 25ºC and 27ºC and average annual rainfall ranging between 2067 mm and 2379 mm (Peel *et al.*, 2007).

The hydrological characteristics of the region and fluviometric variations (cm) of the river enabled to determine the four distinct hydrologic cycles: ebb (June – August), dry (September – November), filling (December – February), flood (March – May).

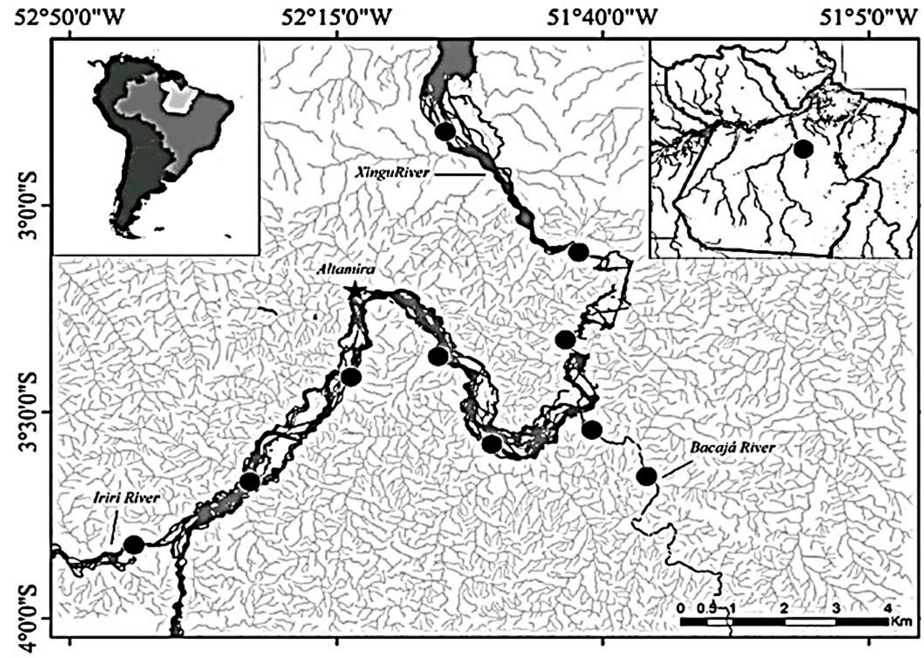

Fig. 1. The middle Xingu river region, highlighting the sampled collection points along the river between 2012 and 2014. (●, collecting points).

Fish sampling

The specimens were collected bimonthly from July 2012 to July 2014 along the middle Xingu River – Pará. This procedure used a series of gill nets - each net 20m length, a total of 140m of nets in each series, with approximately 12h of exposure in the water.

At the site, the animals were measured for total body mass in grams and total and standard length in centimeters. After the biometrics, the animals were anesthetized with benzocaine (0.1 $g.L^{-1}$) and euthanized in accordance with the Guidelines of the National

Council of Animal Experimentation Control (Conselho Nacional de Controle de Experimentação Animal – CONCEA), and the gonads were removed through a longitudinal ventral incision, which were measured for total weight in grams using a digital balance (accuracy of 0.001g).

The gonads were fixed in 10% formalin and subjected to routine histological techniques and embedded in paraffin (Prophet *et al.*, 1995). 5µm thick sections were obtained and stained with hematoxylin and eosin analyzed using light microscope and photomicrography (NIKON Eclipse A) coupled to a digital camera (NIKON DS-Ril) (www.nikoninstruments.com). The gonadal stages were established following the classification adapted from Núñez & Duponchelle (2009).

Data Analysis

The sex ratio was based on the absolute frequency of females and males, which considered the study period as a whole and the different sampling periods. The analyses were evaluated using the Chi-Square test (χ^2), with 5% significance level, based on the null hypothesis that the sex ratio of the population does not differ from 1:1, as proposed by Sokal & Rohlf (1981).

The mass-length ratio was determined for females and males following the modified model proposed by Huxley (1924) $Mt = \alpha \cdot Ct^b$ where Mt is the total mass of the animal (g); Ct is the length of the animal (cm); α is the coefficient of proportionality and b is the allometric coefficient. The equation was adjusted using the Solver routine, where the proportional residues were plotted against the standard length for both sexes and were subsequently tested using a t test with a 5% significance level to check for differences between the growth pattern of females and males.

The allometric condition factor (K) was estimated separately for females and males, based on the equation of the Le Cren (1951) applied to each individual $K = Mt/Ct^b$ where Mt is the total mass of the specimen (g); Ct is the total length of the specimen (cm) and b is the allometric coefficient previously calculated in the mass-length ratio. The K value was obtained separately for females and males and the variation between the hydrological period was tested using the Kruskal-Wallis test (H) with a 5% significance level, followed by *a posteriori* test Nemenyi for the evaluation differences (Zar, 1999).

The gonadosomatic index (IG) was calculated for each individual in order to verify changes in the reproductive activity, obtained from the equation $IG\% = (Mg/Mt)*100$ where Mg is the mass of the gonad and Mt is the total mass of the individual

(Nikolsky, 1963). After verifying the assumptions, the *IG*% values were tested to determine the variations between the hydrological periods studied using the Kruskal-Wallis test (*H*) with a 5% significance level, followed by *a posteriori* test Nemenyi for the evaluation differences (Zar, 1999), based on the hypothesis that fluviometric variations do not affect the reproductive activity of the species. Over the sampling periods, the behavior of the sexual maturity stages was studied and also the reproductive activity was assessed through the relative frequency of occurrence of different sexual maturity stages of females and males.

In order to determine the average length of *B. cuvieri* for first sexual maturity (L_{50}), we followed the model proposed by Fontoura *et al.* (2009) only applying it to the females, since the males showed no juveniles. The values of the Gonadosomatic Index were converted into percentages and used as reference for differentiating adult juveniles, namely 10% of the maximum value observed. Posteriorly, a dispersion diagram was obtained between the standard length class (range of 2.5 cm) and the frequency of adult individuals. The curve was fitted by the non-linear least squares method based on the Microsoft Excel 2010 data analysis pack using the Solver tool, through the equation $P = A/(1+e^{(r.(Cp-L_{50}))})^{-1}$ where P is the proportion of adults in each length class; A is the asymptote curve; r is the ratio related to the change across stages between individuals; Cp is the standard length in centimeters and L_{50} is the average length of first sexual maturity.

RESULTS

A total of 253 individuals were analyzed, of these 140 were females with total length of 34.9cm ±8.64 (max. 65.0 – min. 20.5), total average mass of 365.5g ± 350.1 (max. 2250.2 – min. 47.12), and 113 males with mean total length of 33.8cm ±6.25 (max. 57.0 – min. 23.5), total mass average of 296.3g ± 202.87 (max. 1070.0 – min. 88.2).

Macroscopically examined, there is a pair of elongated gonads, dorsally situated in the coelomic cavity of the fish and surrounded by fibrous connective tissue. The histological analysis of the ovary evidenced ovigerous lamellae containing oogonia and oocytes surrounded by follicular cells. Five maturation stages were determined based on oocyte development:

Immature stage: The appearance of the ovary is elongated, slender, transparent and not vascularized. Ovigerous lamellae were characterized by the presence of round shape oogonia adhered to the lamellar wall and oocytes type I (previtellogenic) whose cytoplasm was basophilic and homogeneous with prominent nucleolus and central or peripheral nucleoli [Fig. 2(a)].

Maturing stage: the ovary is slightly larger, light yellow, and early vascularization. There are numerous type II oocytes (initial vitellogenesis), these cells showed cytoplasm with cortical alveoli and some yolk granules, nucleus with peripheral nucleoli, and type III oocytes (advanced vitellogenesis) whose cell volume was higher when compared to the other oocytes cited, showing a well-defined radiata zone, numerous cortical alveoli, lipid globules and yolk granules dispersed in the cytoplasm, central or sub central nucleus containing peripheral nucleoli [Fig. 2(b)].

Mature stage: the ovary is voluminous and highly vascularized, containing large amounts of type IV oocytes (vitellogenic), the cytoplasm was filled with yolk granules, with no obvious nucleus. Some oocytes I, II and III were also observed in this stage [Fig. 2(c)].

Spawning stage: flaccid ovary, with hemorrhagic regions, the ovigerous lamellae and ovarian wall are thin, containing post-ovulatory follicles of irregular appearance and evident lumen, atretic oocytes that were not eliminated in the spawning stage and follicle atresia characterized by the disruption of the nucleus and cytoplasmic components, along with some type I and II oocytes that were still under development [Fig. 2(d)].

Resting stage: flaccid ovary with ovigerous lamellae and visible lumen area containing oogonia nests, type I oocytes and a well-defined fibrillar network [Fig. 2(e)].

Males showed testes consisting of anastomosing seminiferous tubules, the tubule showed cells of the spermatogenic strain, and based on the gonadal development of these cells three gonadal stages were determined:

Maturing stage: slightly voluminous testes with a whitish color and low degree of vascularization. They showed seminiferous tubules containing round shape spermatogonia and varied locations on the tubule wall, cysts of spermatocytes, spermatids and few sperm in the lumen [Fig. 2(f), (g)].

Mature stage: the testes were whitish, highly vascularized. A large amount of sperm was observed in the lumen of the tubule [Fig. 2(h), (i)].

Spent stage: The testes were flaccid with hemorrhagic regions. The testicular parenchyma showed seminiferous tubules of irregular shape and the lumen practically empty with few residual sperm [Fig. 2(j)].

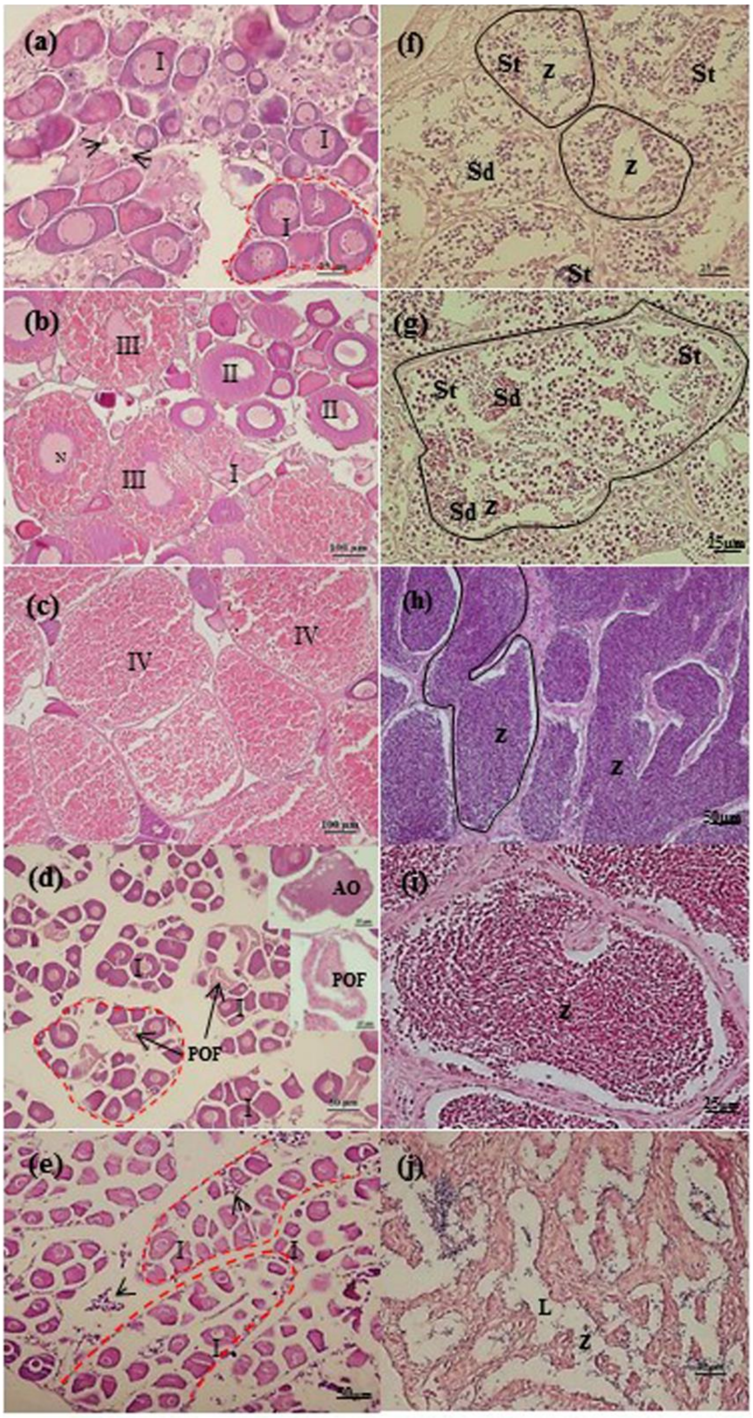

Fig. 2. Photomicrograph of gonadal development of *Boulengerella cuvieri* in different stages of maturation. A-E: Ovary. F-J: Testis. (a) Immature – ovigerous Lamellae (dashed line) containing oogonia (arrow), type I oocytes (I), (b) Maturing – abundance of oocytes type II (II) and type III (III), (c) Mature – oocytes type IV (IV), (d) Spawning – ovigerous lamellae with thin wall containing post-ovulatory follicles (POF), atretic oocytes (AO) and oocytes type I, (e) Rest - ovigerous lamellae containing oogonia nests and oocytes type I, (f) Maturing – seminiferous tubules (solid line) containing spermatocytes (St), spermatids (Sd) and sperm (z), (g) detail of maturing seminiferous tubule, (h) Mature –

Anastomosing seminiferous tubules filled with sperm, (i) Detail of mature tubule, (j) Spent – Tubules with lumen (L) containing residual sperm.

The sex ratio was 1:1 (χ^2 = 1.44; P > 0.05) throughout the study period and at different periods. As for morphology, the mass-length ratio obtained for both sexes used the following equation $Pt=0.0019*Ct^{3.3661}$ (R^2 = 0.9799) allowing to infer that *B. cuvieri* shows positive allometric growth (Fig. 3). The distribution of proportional residues showed no difference in the growth patterns between the sexes, showing a single-phase increase (t = 1.246; d.f = 246; P > 0.05).

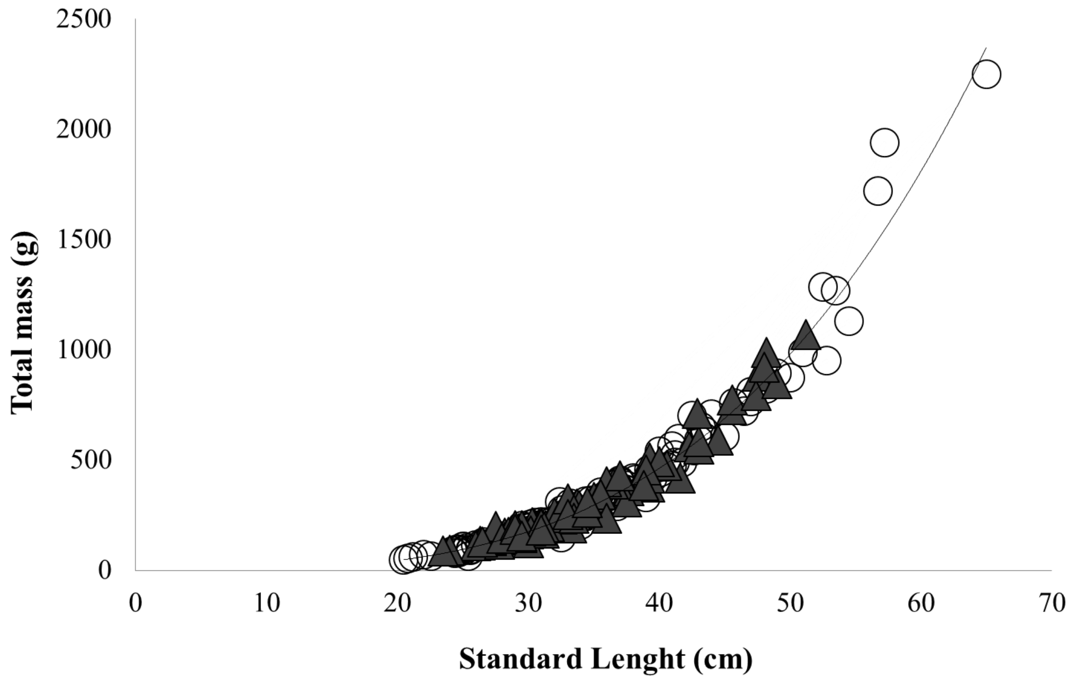

Fig. 3. Mass-lenght ratio of females and males of *Boulengerella cuvieri* collected in the middle Xingu river between 2012 and 2014. (○, female; ▲, male).

According to the analysis of the condition factor for both sexes there was no difference between the sampling periods ($H_{3,136}$ = 7.672; P > 0.05) for females and ($H_{3,110}$ = 9.452; P > 0.05) for males. The Gonadosomatic Index showed that females and males had higher reproductive activity during the filling periods ($H_{3,134}$ = 22.202; P = 0.0001) and ($H_{3,110}$ = 19.690; P = 0.0002), respectively [Fig. 4(a), (b)]. Table I shows the differences between the sampling periods.

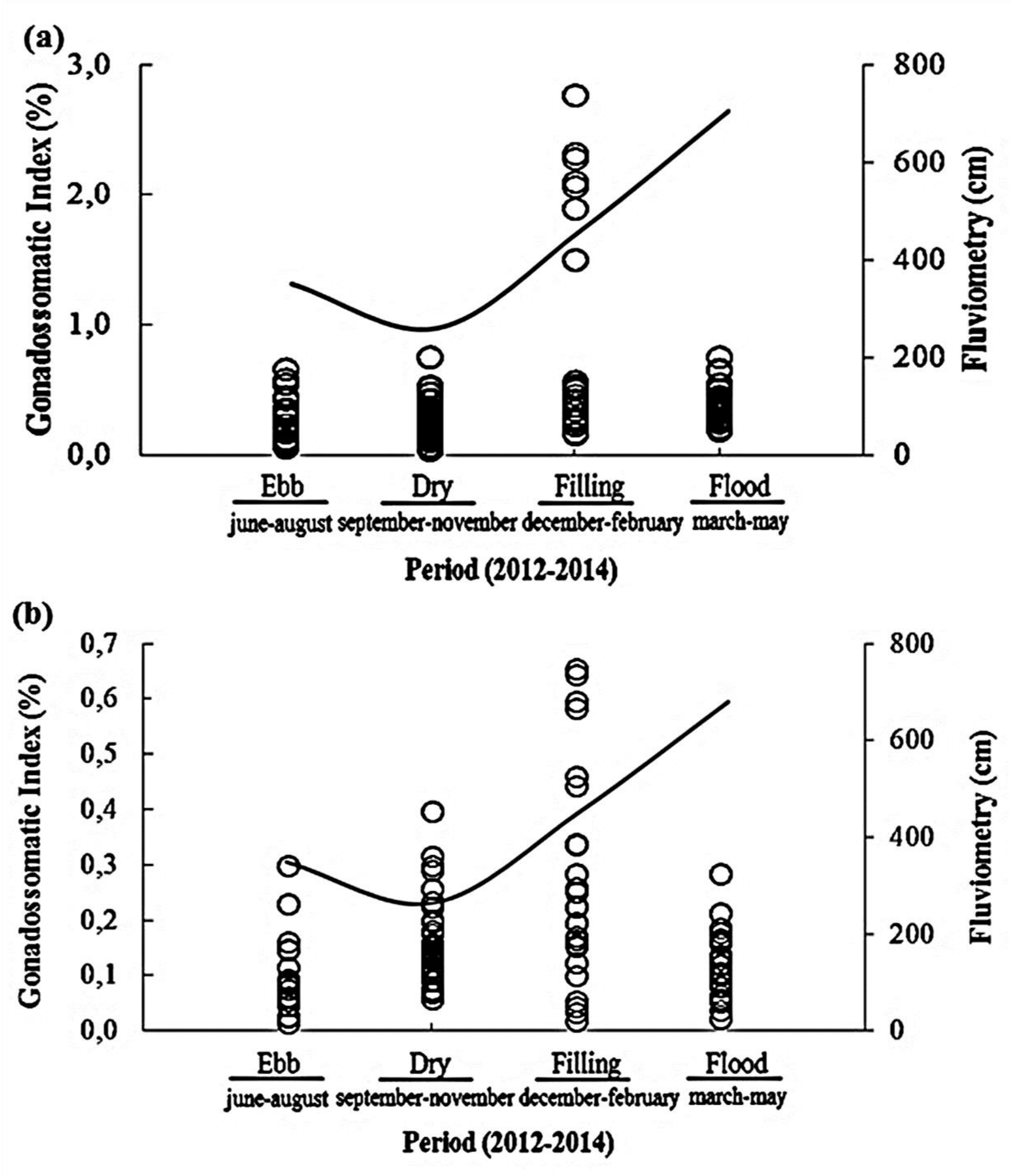

Fig. 4. Variations in the Gonadossomatic Index for the females and males of *Boulengerella cuvieri* collected in the middle Xingu river between 2012 and 2014. (a) Female, (b) Male. (○, individuals; —— , Fluviometry).

Table I. The *a posteriore* test values of the *IG*(%) of males and females of *Boulengerella cuvieri* collected in the middle Xingu river between 2012 and 2014. The values in bold indicate significance diferences.

Male	Ebb	Dry	Filling	Flood
Ebb				
Dry	0.0582			
Filling	**0.0002**	0.2325		
Flood	1.0000	0.8519	**0.0077**	
Female				
Ebb				
Dry	1.0000			
Filling	0.2155	**0.0221**		
Flood	**0.0126**	**0.0001**	1.0000	

The relative frequency of occurrence of the maturity stages for females showed a reproductive peak in the river filling period [Fig. 5(a)], characterized by the occurrence of mature specimens, followed by spawning during flood and ebb period. The females at rest were observed throughout the study period [Fig. 5(a)]. While for males the relative frequency of occurrence of maturity stages was observed in maturing and mature individuals in all sampled months, with a peak of mature males in the filling periods, and the spent phase occurred in the other periods [Fig. 5(b)].

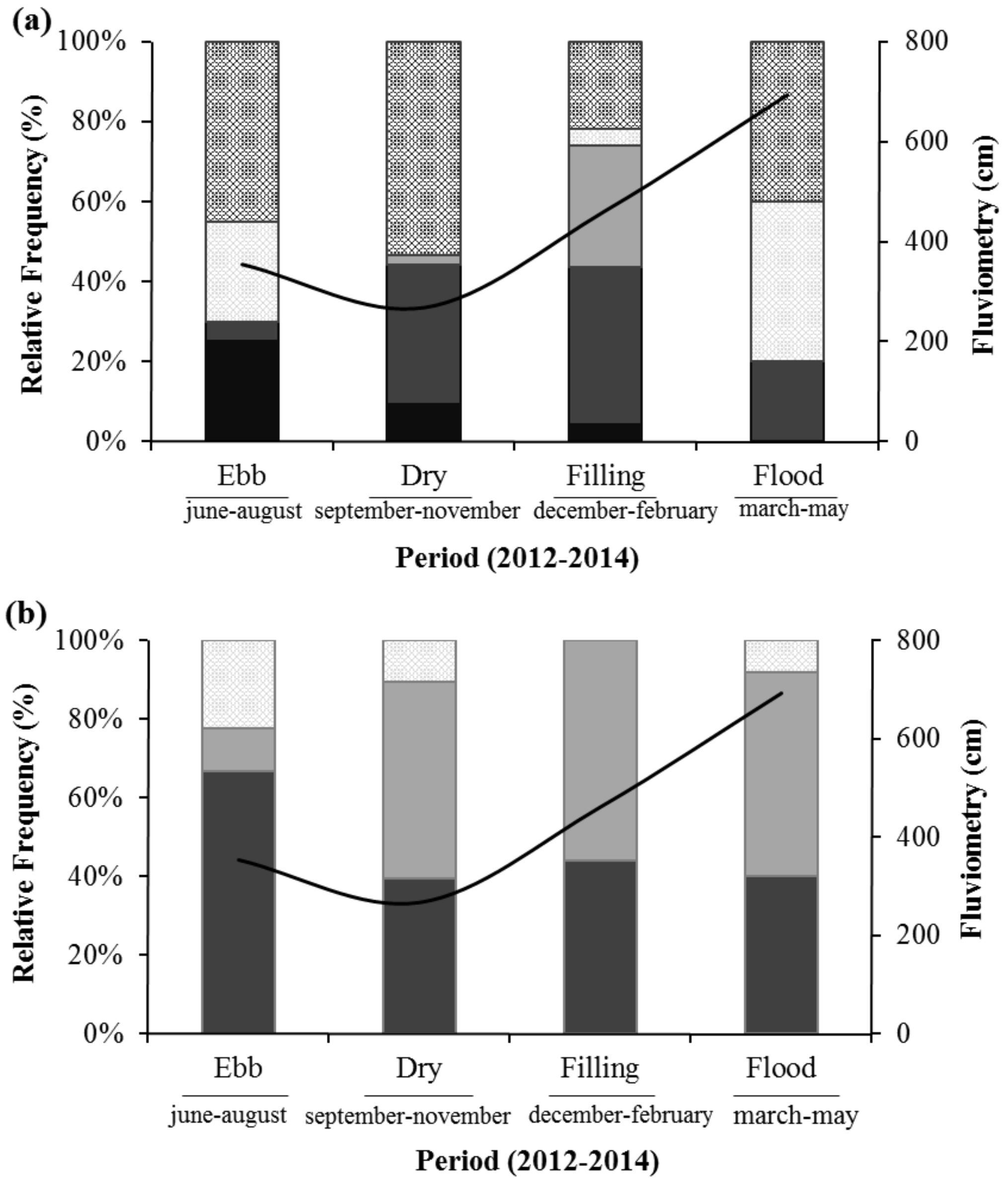

Fig. 5. Relative frequency of ocurrence (%) of gonadal maturity stages of females and males of *Boulengerella cuvieri* collected in the middle Xingu river between 2012 and 2014. (a) Ovarian stages, (b) Testicular stages. (, Immature; , Maturing; , Mature; , Spawned/Spent; , Resting; —— , Fluviometry).

The ratio between the frequency of reproductive females and their standard length showed an estimated average size of 25.39cm at first sexual maturity (Fig. 6).

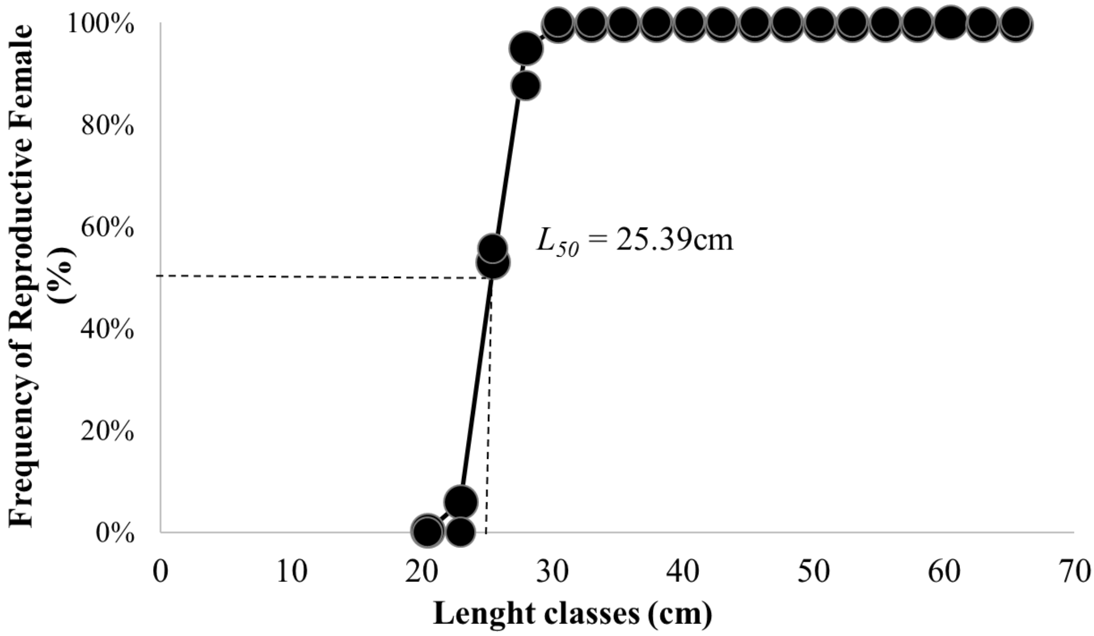

Fig. 6. Medium lenght of first sexual maturity (L_{50}) for females of *Boulengerella cuvieri* collected in the middle Xingu river between 2012 and 2014.

DISCUSSION

The macroscopic description of gonadal development is an important parameter for the study of reproductive biology and ecology of fishes and has been used by several authors (Gonçalves *et al.*, 2006; Neuberger *et al.*, 2007; Núñez & Duponchelle, 2009; Wildner *et al.*, 2013; Prudente *et al.*, 2015). But this macroscopic pattern is not always similar to that observed in histology. Therefore a histological classification is necessary to determine the reproductive stages.

In *B. cuvieri* an asynchronous development of germ cells was observed, which characterizes the various stages of maturity for both males and females. This type of gonadal development was observed in *Astyanax fasciatus* (Cuvier 1819) in the Furnas reservoir (Carvalho *et al.*, 2009), *Astyanax bimaculatus* (Linnaeus 1758) in the Paraguay River, *Hoplias lacerdae*, Miranda-Ribeiro 1908 and *Hoplias malabaricus* (Bloch 1794) in the São Francisco River (Gomes *et al.*, 2007).

The morphology of the ovary and testis of *B. cuvieri* throughout the study period were similar to those of other Teleostei. However, there is a difference in the classification of gonadal development as seen in *A. fasciatus* (Carvalho *et al.*, 2009) and in *Brycon* *orthotenia* (Gunther 1864) in the São Francisco River (Gonçalves *et al.*, 2006), where the authors differ in the number of gonadal stages described and the nomenclature used to describe these stages and the types of oocytes. In the present study we describe oogonia and four types of oocytes, which based on the gonadal development characterized five maturity stages for females. Thus, in this study we adapted the classification proposed by Núñez & Duponchelle (2009) to unify the standard of gonadal development, mainly in the Characiformes.

The sex ratio is a parameter that can vary among the natural populations and reflects reproductive strategies related to the environment (Nikolsky, 1969), where factors such as birth, mortality, susceptibility to predation, mortality related to the size or selective capture method can behave differently between the sexes (Mazzoni & Caramaschi, 1995; Garcia *et al.*, 2004; Agostinho *et al.*, 2007). *B. cuvieri* showed no difference between the sex ratios, suggesting that the above factors do not affect the sexes. The 1:1 ratio is expected for most of the populations, as observed in *Leporinus fasciatus* (Lutken 1875) (Thomé *et al.*, 2005), *B. orthotenia* (Nunes *et al.*, 2015) and *Colossoma macropomum* (Cuvier 1818) in the Solimões River (Vitule *et al.*, 2008). However, there are studies that show differences between the sex ratio of some fish species, as evidenced in *Rhaphiodon vulpinus* (Spix & Agassiz 1829) in the Tocantins River (Neuberger *et al.*, 2007) where males predominate and *Triportheus trifurcatus* (Castelnau 1855) in the Araguaia River, where females predominate (Martin & Queiroz, 2009).

Sexual dimorphism is based on the larger body size of females. This characteristic is related to an evolutionary reproduction advantage, where a larger body size is represented by a larger coelomic cavity, increase in the fertility rate and fat accumulation for gonad development (Breder & Rosen, 1966; Agostinho & Julio Junior, 1999; Braga, 2005). In our study, we observed positive allometric growth for both sexes of *B. cuvieri*, suggesting the species show a greater investment in length, this investment was also observed in *B. maculata* (Valenciennes 1850) in the Trombetas River (Giarrizzo *et al.*, 2011). There was no difference between the mass-length ratio of males and females of *B. cuvieri*.

The *K* indicates the general condition of the fish, which reflects the interaction between the physiological aspect and the environment (Weatherley, 1972; Lima-junior *et al.*, 2002; Lizama & Ambrósio, 2002; Camara *et al.*, 2011). In *B. cuvieri* there was no difference between the *K* of females and males during the study period. Similar results were observed in males of *Serrasalmus gouldingi* (Prudente *et al.*, 2015). However different results were observed by Lizama & Ambrósio (2002) in studies of characids in a Parana River floodplain area, showing that the *K* can vary between species, sexes and populations.

When analyzing the *IG* of *B. cuvieri* in the study period, we evidenced synchrony in the reproductive peak of females and males, predominantly during the river filling. It should be noted that during the filling the Xingu River expand to marginal areas, and the plains are flooded with the rising river levels, favoring the exploration of new habitats and thus increased availability and consequently greater availability of environments for future spawning (Goulding, 1980; Barthem & Fabré, 2002).

The reproduction of tropical fish, especially in the Amazon, is related to fluviometric and pluviometric levels (Rizzo *et al.*, 1996; Andrade & Braga, 2005), as observed in *Rhaphiodon vulpinus* (Neuberger *et al.*, 2007), *A. fasciatus* (Carvalho *et al.*, 2009), in which the reproductive period is synchronized with the filling of rivers, similar in *B. cuvieri*. However, in subtropical regions some species appear to have their reproduction influenced by temperature and/or photoperiod, because these regions do not have well-defined hydrological periods (Azevedo *et al.*, 2000; Gonçalves *et al.*, 2005; Oliveira *et al.*, 2010).

The fluviometric level in the Xingu River revealed an important fact related to *B. cuvieri,* the identification of two spawning times, one during the flood and another during the ebb of the river, whose environment provided favorable conditions for the release of gametes. In the flood, besides habitat availability for spawning, there was a low predation rate, and the organic matter availability from the riverbanks results in food supply for the initial stages, ensuring the survival and growth of these stages and the perpetuation of the species in the environment (Agostinho *et al.*, 2004; Godinho *et al.*, 2007). During the ebb, although the aquatic environment begins to shrink due to the water volume discharge and the consequent biomass loss, we believe there still were favorable spawning conditions and dispersion of eggs, justifying spawning in two times. Spawning in two times was also evidenced in *A. fasciatus* (Carvalho *et al.*, 2009), *S. maculatus* (Kner 1858) in the high Paranapanema River (Wildner *et al.*, 2013) and *S. gouldingi* (Prudente *et al.*, 2015).

Information about medium length at first sexual maturity is important for the fishery resource management as it can be used to control fishing activities (Gonçalves *et al.*, 2006; Fontoura *et al.*, 2009). With the method used it was estimated to be L_{50} of 25.39cm for females of *B. cuvieri*, while for males, because of the absence of immature individuals in the sampling, the estimate could not be performed. In the reproduction dynamics of neotropical fish, sexual maturity of females is usually reached at longer lengths, when compared to males (Freitas *et al.*, 2011). It is possible that this characteristic shows that females invest more energy for ovary maturation and therefore their larger sizes at the start of gonadal maturation (Bromley, 2003).

The results obtained in this study provide evidence that the reproduction of *B. cuvieri* is influenced by the fluviometric level variations in the Xingu River. We believe this situation is especially due to its increasing water level, culminating in the reproductive period of the species and a spawning strategy on two occasions, during the flood and ebbs of the river. We highlight that in the current situation of the Xingu River there are environmental questions regarding the construction of the Belo Monte hydroelectric plant, as this impact can affect the life cycle of this top predator, since the construction could result in changes in the hydrological cycle of the river, modifying the flow and flood pulses.

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REFERENCES

Agostinho, A.A., & Julio Junior, H.F. (1999). Peixes da bacia do alto Paraná. In *Estudos ecológicos de comunidade de peixes tropicais,* (Lowe McConnell R. H., ed), pp. 374-399.São Paulo: Ed. da Universidade de São Paulo.

Agostinho, A.A., Gomes, L.C., Susuki, H.I., & Júlio Junior, H.F. (2004). Migratory fishes of the upper Paraná river basin Brazil. In *Migratory fishes of South America*, (Carosfield, J., Harvey, B., Ross, C., & Baer, A., eds), pp. 19-98. Vitória: World Fisheries Trust.

Agostinho, A.A., Marques, E.E., Agostinho, C.S., Almeida, D.A., Oliveira, R.J., & Melo, J.R.B. (2007). Fish ladder of Lajeado dam: migrations on one-way routes? *Neotropical Ichthyology* **5**:121-130.

Andrade, P.M., & Braga, F.M. (2005). Reproductive seasonality of fishes from a lotic stretch of the Grande river, High Paraná river basin, Brazil. *Brazilian Journal of Biology* **65**:387-394.

Azevedo, M.A., Malabarba, L.R., & Fialho, C.B. (2000). Reproductive biology the inseminated Glandulocaudinae *Diapoma speculiferum* Cope (Actinopterygii: Characidae). *Copeia*, 983-989.

Azevedo, M.A., Malabarba, L.R., & Burns, J.R. (2010). Reproductive biology and development of gill glands in the inseminating characid, *Macropsobrycon uruguayanae* Eigenmam, 1915 (Cheirodontinae: Compsurini). *Neotropical Ichthyology* **8**:87-96. doi: 10.1590/S1679-62252010005000004.

Bailly, D., Agostinho, A.A., & Suzuki, H.I. (2008). Influence of the flood regime on the reproduction of fish species with diferente strategies in the Cuiabá river, upper Pantanal, Brazil. *River Research and Applictions* **24**:1218-1229.

Barthem, R.B., & Fabré, N.N. (2004). Biologia e diversidade dos recursos pesqueiros da Amazônia. Pró várzea. 17-62. In *A pesca e os recursos pesqueiros na Amazônia Brasileira*. *Pró Várzea*. (Ruffino, M.L., ed), 272p.

Braga, F.M.S. (2005). Feeding and condition factor of Characidinn fish in Ribeirão Grande system, Southeastern Brazil. *Acta Scientiarum Biological Sciences* **27**: 271-276.

Breder, C.M., & Rosen, D.R. (1966). *Modes of reproduction in fishes*. Neptune City. New York. T.F.H. Publications American Museum of Natural History by the Natural History Press. Garden City, N.Y.

Bromley, P.J. (2003). The use of market sampling to generate maturity ogives and to investigate growth sexual dimorphism and reproductive strategy in central and south-western North Sea sole (*Soleasola* L.). ICES. *Journal of Marine Science* **60**, 52-65.

Buckup, P.A., & Santos, G.M. (2010). Ictiofauna da ecorregião Xingu-Tapajós: fatos e perspectivas. *Boletim da Sociedade Brasileira de Ictiologia*, 20p.

Camara, E.M., Caramaschi, E.P., & Petry, A.C. (2011). Fator de condição: Bases conceituais, aplicações e perspectivas de uso em pesquisas ecológicas com peixes. *Oecologia Australis* **15**, 249-274.

Carvalho, P.A., Paschoalini, A.L., Santos, G.B., Rizzo, E., & Bazzoli, N. (2009). Reproductive biology of *Astyanax fasciatus* (Pisces: Characiformes) in a reservoir in South eastern, Brazil. Braz. *Journal of Applied Ichthyology* **25**, 306-313. doi: 10.1111/j.1439-0426.2009.01238x.

Fontoura, N.F., Braun, A.S., & Milani, P.C. (2009). Estimating size at first maturity (L50) from Gonadossomatic Index (GSI) data. *Neotropical Ichthyology* **7**, 217-222.

Freitas, T.M.S., Almeida, V.H.C., Montag, L.F.A., Rocha, R.M., & Fontoura, N.F. (2011). Seasonal changes in the gonadossomatic index, allometric condition fator and sex ratio of na auchnipterid catfish from eastern Amazonia. *Neotropical Ichthyology* **9**, 839-847.

Garcia, A.M., Vieira, J.P., Winemiller, K.O., & Raseira, M.B. (2004). Reproductive cycle and spationaltemporal variation in abundance of the one-sided livebear *Jenynsia multidentada*, in Patos Lagos, Brazil. *Hydrobiologia* **515**, 39-48.

Giarrizzo, T., Bastos, D., & Andrade, M. (2011). Technical Contribution: Length-weight relationships for selected fish species of Rio Trombetas Biological reserve: a reference study for the Amazonian basin. *Journal of Applied Ichthyology* **27**, 1422-1424. doi: 10.1111/j.1439-040426.2011.01820x.

Godinho, A.L., Kynard, B., & Godinho, H.P. (2007). Migration and spawning of female surubim (*Pseudoplastystoma corruscans*, Pimelodidae) in the São Francisco river, Brazil. *Environmental Biology of Fish* **80**, 421-433. doi: 10.1007/s10641-006-9141-1.

Gomes, B.V.C., Scarpelli, R.S., Arantes, F.P., Sato, Y., Bazzoli, N., & Rizzo, E. (2007). Comparative oocyte morphology and early development in three species of Trahiras from São Francisco river basin, Brazil. *Journal of Fish Biology* **70**, 1412-1429. doi: 10.1111/j.1095-8649.2007.01420. x.

Gonçalves, T.K., Azevedo, M.A., Malabarba, L.R., & Fialho, C.B. (2005). Reproductive biology and development of sexually dimorphic structures in *Aphyocharax anisitsi* (Ostariophysi: Characidae). *Neotropical Ichthyology* **3**, 433-438.

Gonçalves, T.L., Bazzoli, N., & Brito, M.F.G. (2006). Gametogenesis and reproduction of the matrinxã *Brycon orthotaenia* Gunther, 1864 (Pisces: Characidae) in the São Francisco river, Minas Gerais, Brazil. *Brazilian Journal of Biology* **66**, 513-522.

Goulding, M. (1980). *The Fishes and the forest.* Berkeley, C.A: University California Press.

Huxley, J.S. (1924). Constant differencial growth-ratios and their significance. *Nature* **14**, 896-897.

Le Cren, E.D. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in the Perch (*Perca fluviatilis*). *Journal of Animal Ecology* **20**, 201-219.

Lima-Junior, S.E., Cardone, I.B., & Goitein, R. (2002). Determination of a method for calculation of Allometric Condition Factor of Fish. *Acta Scientiarum* **24**, 397-400.

Lizama, M.A.P., & Ambrósio, A.M. (2002). Condition factor in nine species of fish of the Characidae family in the upper Paraná river, floodplain, Brazil. *Brazilian Journal of Biology* **62**, 113-124.

Lowe-McConnell, R.H. (1987). *Ecological Studies in Tropical Fish Communities*. Cambridge University Press.

Magalhães, M.F., Schlosser, I.J., & Collares-Pereira, M.J. (2003). The role of life history in the relationship between population dynamics and environmental variability in two Mediterrnean stream fishes. *Journal of Fish Biology* **63**, 300-317. doi: 10.1046/j.1095.-8649.2003.00148x.

Mazzoni, R., & Caramaschi, E.P. (1995). Size structure, sex ratio and onset of sexual maturity of two species of Hypostomus Lacépede (Osteichthyes, Loricariidae). *Journal of Fish Biology* **47**, 841-849.

Neuberger, A.L., Marques, E.E., Agostinho, C.S., & Oliveira, R.J. (2007). Reproductive biology of *Rhaphiodon vulpinus* (Ostariophysi: Cynodontidae) in the Tocantins River Basin, Brazil. *Neotropical Ichthyology* **5**, 479-484. doi: 10.1590/S1679-62252007000400007.

Nikolsky, G.V. (1969). *Theory of fish population dynamics.* Edinburgh, Oliver & Boyd.

Nikolsky, G.V. (1963). *The ecology of fishes*. Nova York, Academic.

Nunes, D.M.F., Magalhães, A.L.D., Weber, A.A., Gomes, R.Z., Normando, F.T., Santiago, K.B., Rizzo, E., & Bazzoli, N. (2015). Influence of a large dam and importance of an undammed tributary on the reproductive ecology of the threatened fish matrinxã *Brycon orthotaenia* Günther, 1864 (Characiformes: Bryconidae) in southeastern Brazil. *Neotropical Ichthyology* **13**, 317-324. doi: 10.1590/1982-0224-20140084.

Núñez, J., & Duponchelle, F. (2009). Towards a universal scale to acess sexual maturation and related life history traits in oviparous teleost fishes. *Fish Physiology and Biochemistry* **35,** 157-180. doi: 10.1007/s10695-008-9241-2.

Olden, J.D., Poff, N.L., & Bestgen, K.R. (2006). Life history strategies predict fish invasions and extirpations in the Colorado River basin. *Ecological Monographs* **76**, 25-40.

Oliveira, C.L.C., Fialho, C.B., & Malabarba, L.R. (2010). Reproductive period fecundity and histology of gonads of two cheirondotines (Ostariophysi: Characidae) with different reproductive strategies insemination and external fertilization. *Neotropical Ichthyology* **8**, 351-360.

Peel, M.C., Fynlayson, B.L., & McMahon, T.A. (2007). Update world map of the Koopen-Geiger climate classification. *Hydrology Earth System Sciences* **11,** 1633-1644.

PROGRAMA NACIONAL DE DESENVOLVIMENTO DA PESCA AMADORA – PNDA. (2008). Brasilia-DF. Guia de recordes. Brasilia-DF: Editora Grafica Ltda, 2008.

Prophet, E.B., Milis, B., Arrington, J.B., & Sobin, L.H. (1995). *Métodos Histotécnicos*. Instituto de Patologia de Las Fuerzas Armadas de Los Estados Unidos de America (AFIP), Washington (DC).

Prudente, B.S., Ferreira, M.A.P., Rocha, R.M., & Montag, L.F.A. (2015). Reproductive biology of the piranha *Serrasalmus gouldingi* (Fink and Machado-Allison 1992) (Characiformes: Serrasalmidae) in “drowned” rivers of the Eastern Amazon. *Environmental Biology of Fish* **98**, 11-22. doi: 10.1007/s10641-014-0232-0.

Rizzo, E., Sato, Y., Ferreira, R.M.A., Chiarini-Garcia, H., & Bazzoli, N. (1996). Reproduction of *Leporinus reinhardti* Lutken, 1875 (Pisces: Anastomidae) from Três Marias Reservoir, São Francisco River, MG, Brazil. *Ciencia e Cultura* **4813,** 189-192.

Sokal, R.R., & Rohlf, F.J. (1981). *Biometry: principles and practice of statistics and biological research.* 2nd. Freeman, W.H., & co. San Francisco.

Thomé, R.G., Bazzoli, N., Rizzo, E., Santos, G.B., & Ratton, T.F. (2005). Reproductive biology of *Leporinus taeniatus* Lutken (Pisces, Anastomidae) in Juramento Reservoir, São Francisco River basin, Minas Gerais, Brazil. *Revista Brasileira de Zoologia* **22**, 565-470.

Vari, R.P. (1995). The Neotropical Fish Family Ctenoluciidae (Teleostei: Ostariphysi: Characiformes): Supra and Intra-familial Phylogenetic Relationships with a Revisionary Study. *Smithsonian Contributions to Zoology*, 1-91.

Vitule, J.R.S., Braga, M.R., & Aranha, J.R.M. (2008). Population Structure and reproduction of *Deuterodon langei* Travassos, 1957 (Teleostei, Characidae) in a Neotropical Stream basin from the Atlantic Forest, Southern Brazil. *Brazilian Archives of Biology and Technology* **51**, 1187-1198.

Weartheley, A.H. (1972). *Growth and ecology of fish populations*. Academic Press Inc: London.

Wildner, D.D., Grier, H., & Quagio-Grassioto, I. (2013). Female germ cell renewal during the annual reproductive cucle in Ostariophisians fish. *Theriogenology* **79**, 709-724.

Winemiller, K.O., & Rose, K.A. (1992). Patterns of life-history diversification in North American fishes: Implications for publication regulation. *Canadian Journal of Fisheries and Aquatic Sciences* **49,** 2196-2218.

Winemiller, K.O., Montanã, C.G., Koelke, D.L., Cotner, J.B., Montoya, J.V., Sanchez, L., Castillo, M.M., & Layman, C.A. (2014). Pulsing hydrology determines top-down control of basal resources in a tropical river – floodplain ecosystem. *Ecological Monographs* **84**, 621-635.

Wootton, R.J. (1998). *The ecology of teleost fishes.* Kleewer Academic Publisher, Dordrecht.

Zar, J.H. (1999). *Biostatistical analysis*. Prentice Hall, New Jersey.

Zaret, T.M. (1980). Life-history and growth relationships of *Cichla ocellaris*, a predator South American cichlids. *Biotropica* **121,** 144-157.