Role of the rain and macrophytes on temporal and spatial pattern of ichthyoplankton in the Caatinga Biome, Brazil

Papel da chuva e das macrófitas no padrão temporal e espacial do ictioplâncton no Bioma Caatinga, Brasil

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ABSTRACT

Semiarid areas are characterized by extremes of flood and drought. The flood is one of the best predictors of fish reproduction, however semiarid areas such as the Caatinga Biome, Brazil, are affected by prolonged drought (9 months), during which the fish are confined on ponds and reservoirs after the intermittent river drying. The aims of this work were evaluate the role of environmental variables, such as rain and subsequent flood, on fish reproduction, by analyzing the density of eggs and larvae in an intermittent river and a reservoir of Caatinga; and identify the spawning and nursery areas, accessing the role of macrophytes for ichthyoplankton distribution. Two years of samples were made, in eight sample locations: one in the intermittent river, one in the reservoir inlet, two in the middle and two in the reservoir dam, all open areas; and two in macrophyte beds. Our results show that the rain is the main triggering factor of the reproduction for the large amount of fish species in Caatinga, but some opportunistic species have a continuous reproduction. The macrophyte beds have
a strong role as shelter for ichthyoplankton since that harbored the highest densities of eggs and larvae. These results provide important information for fish conservation in semiarid areas once anthropogenic impacts such as eutrophication and river transposition can reduce the macrophyte occurrence, which would affect the diversity and the production of important fish species of the region.

**Keywords:** Semiarid, reservoirs, intermittent rivers, freshwater fishes, eggs and larvae.

**RESUMO**

As áreas semiáridas são caracterizadas por extremos de enchentes e secas. A enchente é um dos melhores preditores da reprodução dos peixes, porém, áreas semiáridas como o Bioma Caatinga, Brasil, são afetadas por estiagem prolongada (9 meses), durante a qual os peixes ficam confinados em lagos e reservatórios, após a seca intermitente do rio. Os objetivos deste trabalho foram avaliar o papel de variáveis ambientais, como chuva e consequente inundação, na reprodução dos peixes, por meio da análise da densidade de ovos e larvas em um rio intermitente e um reservatório da Caatinga; e identificar as áreas de desova e berçário, avaliando o papel das macrófitas na distribuição do ictioplâncton. Foram realizados dois anos de amostragem, em oito pontos de amostragem: um no rio intermitente, um na entrada do reservatório, duas no meio e duas na barragem do reservatório, todas áreas abertas; e dois em bancos de macrófitas. Nossos resultados mostram que a chuva é o principal fator desencadeante da reprodução para a grande quantidade de espécies de peixes da Caatinga, mas algumas espécies oportunistas apresentam reprodução contínua. Os bancos de macrófitas têm um papel importante como abrigo para o ictioplâncton, uma vez que comportavam as maiores densidades de ovos e larvas. Esses resultados fornecem informações importantes para a conservação de peixes em áreas semiáridas, uma vez que impactos antrópicos como eutrofização e transposição de rios podem reduzir a ocorrência de macrófitas, o que afetaria a diversidade e a produção de importantes espécies de peixes da região.

**Palavras-chaves:** Semiárido, reservatórios, rios intermitentes, peixes de água doce, ovos e larvas.

**1 INTRODUCTION**

Temporal and spatial pattern of fish reproduction has been broadly evaluated for floodplains and permanent rivers reporting the important role of flooding and water speed (Lowe-McConnell 1987; Turner et al 1994; Vazzoler 1996; Höök et al 2001; Grenouillet and Pont 2001; Bialetzki et al 2002; Ochoa-Orrego et al 2015), as well as the role of resource availability and shelter for ichthyoplankton distribution (Junk et al 1989; Turner et al 1994; Martin and Paller 2007; Reynalte-Tataje et al 2012). However, the spatial and temporal distribution of fish larvae on tropical semiarid areas with intermittent rivers are still poorly understood.

Extremes of flood and drought characterize the semiarid areas, where an ample amount of water bodies is intermittent. The events of flood with the rivers run, and drought confining the biota into temporary ponds can have strong influence on reproductive patterns of fishes. Previous studies in arid and semiarid areas report two possible scenarios for fish reproduction: the flood triggering the reproduction and the low flow recruitment (Humphries et al 1999; Pease et al 2006; Balcombe et al 2007). Balcombe et al. (2007) show that some fish have a seasonal pattern of reproduction responding
to flow events, while other fishes reproduces on low-flow seasons. Alkins-koo (2000) and Maltchik and Medeiros (2006) discussed the activation of fish reproduction by flooding in intermittent rivers and the subsequent role of temporary ponds as breeding sites for fishes after drying of the rivers (Alkins-koo 2000; Maltchik and Medeiros 2006). During the dry season, the biota is confined to the temporary ponds with high availability of autochthonous resources like plankton and periphyton, providing good conditions for fish growth and reproduction (Alkins-koo 2000). Rainy season, otherwise, favors migratory fishes that depend on the water flow to reproduce.

The Caatinga Biome is a semiarid area located in northeastern Brazil in which most of the rivers dry up completely after the short rainy season (Maltchik and Medeiros 2006). The fish fauna is adapted to the drastic changes once the population dynamic and diversity seems to be driven by the hydrological regime (Medeiros and Maltchik 2001; Maltchik and Medeiros 2006). However, because of the dense human population in the semiarid, the construction of dams becomes an important strategy to ensure the water supply (Gurgel and Fernando 1994). The river dams has been a problem reported for many systems because can disrupt the migration patterns of several species of fishes (Agostinho et al 2004; Suzuki et al 2011; Fitzgeral et al., 2018), even relocating the spawning and nursery areas (Álvares et al 2017), since, recruitment depends heavily on the integrity of these environments (Andrade et al., 2014). On the other hand, given the intermittent nature of the rivers and the importance of the small ponds to sustain fish population (Alkins-koo 2000; Medeiros and Maltchik 2001), the dams on northeastern semiarid areas of Brazil may constitute an important shelter, at least, for non-migratory fishes.

Studies of fish spawning and conditions that favors the breeding in water bodies of the semiarid areas are scarce, and this is the first work to report the temporal and spatial pattern of ichthyoplankton in Caatinga. The aims of this paper is to evaluate the importance of environmental variables on temporal pattern of ichthyoplankton, and identify the spawning and nursery areas of fishes on Caatinga paying special attention for the reservoir and macrophyte as lentic areas with high availability of food, investigating the implications for conservation and management practices. So, we made samples in a intermitant river and a reservoir in Caatinga during two years, covering two periods of both rain and drought in eight sample locations.

2 MATERIAL AND METHODS

The study was performed on Taperoá River sub-basin, located on the semiarid area of Caatinga Biome, northeastern Brazil. This semiarid area has the lowest annual rainfall index of Brazil (a maximum of 400 and 800 mm), and the short rainy season lasts three or four months, in contrast with the long dry season (eight or nine months) (Maltchik and Medeiros 2006) in which most of the
rivers dry completely. The Taperoá II dam is part of the Taperoá River basin, located in the State of Paraíba (07°11'44" S and 07°13'44" S and 36°52'03" W and 36°50'09" W). The reservoir has a maximum capacity of water accumulation of 15,148,900 m³, with a maximum depth of 5.7 m and mean of 3.3 m.

The samples were performed semimonthly in the intermittent Taperoá river and in the Taperoá II dam during July 2009 to May 2011. We divided the sample stations in five areas related to placement and macrophyte presence. Four areas without macrophyte: river (P1); transition (P2 - a semi-lotic area in the reservoir inlet); middle of reservoir (P3 and 4); and, the reservoir dam (P5 and P6); and two areas with macrophyte beds, at the middle (P3M) and reservoir dam (P5M) (Fig. 1).

Fig. 1 Taperoá intermittent river and Taperoá II reservoir, semiarid area of Brazil. Sample points: P1 - Taperoá river; P2 – beginning of reservoir (transition area); P3-P6 open areas of reservoir; P3M and P5M – macrophytes beds

The ichthyoplankton were collected using a drift net and a rectangular net of 1.5 x 1.0 m, both of 500 μm mesh size. In the river, the drift net were anchored to the stream and rested for 10 minutes. Horizontal hauls of 10 minutes using the drift net were made on open water of the reservoir. The water speed was measured by a flowmeter for the calculation of filtered volume (Filtered volume = area x number of flowmeter rotation x calibration factor). The rectangular net was used in macrophyte beds inserting it below the macrophyte. As the movement performed describe an area of 1/8 of a cylinder, based on the radius (R) equal to the minor lateral and height (h) equal to the greater side of
the net, the sample volume (v) can be estimated following \( V = \frac{1}{8} \times h \pi R^2 \). The water volume filtered by the drift net and by the rectangular net was standardized on larvae or eggs by 10m³.

The eggs and larvae were identified by stages following Ahlstrom and Ball (1954), Kendall et al (1984) and Nakatani et al (2001). Stages of eggs: early cleavage (EC); early embryo (EE); free tail (FT); embryo end (EEnd). Larval stages: larval yolk (LY); pre-flexion (Pre-F); flexion (F); post-flexion (Post-F).

At each sample site was measured the water temperature, pH, electrical conductivity, dissolved oxygen, depth, nitrite, nitrate, ammonia, phosphate, chlorophyll-\( \alpha \) and zooplankton. Also, water volume and monthly precipitation were used. The colorimetric method was performed for nitrite (Eaton et al 1997); Nitrate by the cadmium reduction column (Eaton et al 1998); Ammonia by the phenol method (Eaton et al 1998); Total phosphorous was analyzed by ascorbic acid method after persulphate digestion (Eaton et al 1998). For chlorophyll-\( \alpha \), the samples were filtered in glass microfiber filter GF/C Whatman and the pigment were extracted with 90\% acetone during 24 hours (Lorenzen 1967; Lorenzen and Downs 1986). The zooplankton was preserved with a 4\% formalin saturated with sugar (Haney and Hall 1973), and was counted and identified to species or genus level with subsamples of 1ml in a Sedwick-Rafter chamber. Density was calculated by the mean of subsamples multiplied by the sample volume and divided by the filtered volume in the field.

2.1 DATA ANALYSIS

Non-parametric tests were chosen due to the high frequency of zero values of ichthyoplankton. Spearman correlation tests were performed considering physical, chemical and biological parameters and ichthyoplankton density. A glm with binomial function was used to know the main predictors of ichthyoplankton density, and the model averaging was chosen for model selection with Akaike’s information criterion (AIC). The model averaging calculates the weighted average of parameter estimates from the candidate models (Burnham and Anderson 2002). Only predictors of best models (ΔAIC<2) were used for model-averaging of estimates. Predictors variables were standardized before analysis.

A Permutation Multivariate Analysis of Variance (PERMANOVA) was used to examine the effect of habitat (open or macrophyte) and sample location (river, inlet, middle and reservoir dam) over ichthyoplankton density and predictors variables. A correspondence analysis was used to look for a spatial pattern of distribution of eggs and larval stages. To test if larval species had a heterogeneous distribution we used chi-squared test. All the analysis was performed with R software (R DEVELOPMENT CORE TEAM, 2011).
3 RESULTS

We identify 244 larvae into 13 taxa, *Apareiodon davisi* (Fowler, 1941), *Astronotus ocellatus* (Agassiz, 1831), *Astyanax bimaculatus* (Linnaeus, 1758), *Astyanax fasciatus* (Cuvier, 1819), *Characidium bimaculatum* (Fowler, 1941), *Hoplias malabaricus* (Bloch, 1794), *Leporinus piau* (Fowler, 1941), *Prochilodus brevis* (Seindachner, 1875), *Psectrogaster rhomboides* (Eigenmann & Eigenmann, 1889), *Steindachnerina notonota* (Miranda-Ribeiro, 1937), and non-identified species of Characiformes, Characidae and Hypoptopomatinae.

3.1 TEMPORAL PATTERN

The highest catches of total larvae were observed on rainy periods, showing a significant correlation with precipitation ($r=0.83$, $p<0.01$; Fig. 2a). However, total eggs did not show any significant relationship with precipitation ($r=0.37$, $p=0.22$). The highest eggs density took place shortly after the rain (Fig. 2a). Eight of the 13 taxa found had a significant correlation with precipitation (*P. rhomboides*, $r=0.59$; *P. brevis*, $r=0.83$; *L. piau*, $r=0.82$; *H. malabaricus*, $r=0.56$; *C. bimaculatum*, 0.55; *A. fasciatus*, $r=0.68$; Non-identified Characidae, $r=0.67$; Non-identified Characiforme, $r=0.75$) (Fig. 2b). Precipitation was among the best predictors for total larval density, and for larvae of *H. malabaricus*, *L. piau*, *P. brevis* and *P. rhomboides* (Table 1). Also, phosphate, pH and chl-$a$ were important predictors for total larvae. Only temperature was important for total eggs density, showing that high eggs densities were caught on lower temperatures. Further, temperature was important for *H. malabaricus* and *A. fasciatus*. The density of *L. piau* and *P. brevis* also increased with water volume and zooplankton density. In addition, phosphate was a predictor for *H. malabaricus* and *P. rhomboides*. 
Fig. 2 a) Precipitation and abundance of total larvae (open triangle) and eggs of fish (filled square); b) Abundance of larval species in the Taperoá River and Taperoá II Reservoir in the Bioma Caatinga, Brazil. *A. bimaculatus* (open square); *A. fasciatus* (open triangle); *L. piau* (open diamond); *S. notonota* (open circle); *H. malabaricus* (filled square); *P. rhomboids* (filled triangle); *P. brevis* (filled diamond); *A. oscelattus* (cross); *A. davisi* (plus); *C. bimaculatum* (star); non-identified Hypoptomatinae (filled circle); non-identified Characidae (grey square); non-identified Characiforme (grey circle).
Table 1 Parameter estimates by the model-averaged standardized regression for the temporal relationship among eggs and larval densities and environment variables. Only predictors of best models (AIC<2) were used for model-averaging of estimates. Absence of estimates means non-important variable.

| Parameter estimates | Precip. | Water Vol. | DO | Temp. | pH  | Depth | Phosph. | Ammonia | Nitrite |
|---------------------|---------|------------|----|-------|-----|-------|---------|---------|---------|
| Larvae              | 0.701   | -          | -  | 0.062 | -0.498| -     | -       | -       | -       |
| Eggs                | -       | -          | -  | -     | -   | -0.372| -       | -       | -       |
| A. davisi           | -       | -          | -  | -     | -   | -     | -       | -       | -       |
| A. oscelatus        | -       | -          | -  | -     | -   | -     | -       | -       | -       |
| A. bimaculatus      | -       | -          | -  | -     | -   | -     | -       | -       | -       |
| A. fasciatus        | -       | -          | -  | -     | -   | -0.338| -1.227  | -       | -       |
| S. notonota         | -       | -          | -  | -     | -   | -     | -       | -       | -       |
| C. bimaculatum      | -       | -          | -  | -     | -   | -     | -       | -       | -       |
| H. malabaricus      | 31.751  | -24.43     | -  | 51.821| -   | 79.468| -       | -       | -       |
| L. piau             | 1.885   | 2.277      | -  | -     | -   | -     | -       | -       | -       |
| P. brevis           | 2.069   | 3.516      | -  | -     | -   | -     | -       | -       | -       |
| P. rhomboides       | 1.851   | -          | -  | -     | -   | -     | 1.462   | -       | -       |
| NI Hypoptomatinae   | -       | -          | -  | -     | -   | -     | -       | -       | -       |
| NI Characidae       | -       | -          | -  | -     | -   | -     | -       | -       | -       |
| NI Characiformes    | -       | -          | -  | -     | -   | -     | -       | -       | -       |

3.2 SPATIAL PATTERN

The density of total larvae and eggs were influenced by habitat type (macrophyte banks, open water lentic, open water lotic), but did not vary in relation to sample position (river, inlet, middle and reservoir dam) (PERMANOVA results on Table 2). A marginal interaction was found among habitat type and sample position for eggs density. Higher densities of larvae and eggs occur in the macrophyte beds and lower densities in the open areas, regardless if they are lentic areas of reservoir or in the river (Fig. 3). The limnetic areas in the middle and reservoir dam had the lowest densities.

Table 2 Permanova results for effects of sample location and habitat type

| Location | Habitat | Location x habitat |
|----------|---------|--------------------|
| F        | P       | F                  | P        | F         | P       |
| Ichtyoplankton |         |                    |          |           |         |
| Eggs density   | 0.948   | 0.452              | 2.797    | 0.024***  | 3.666   | 0.081*  |
| Larval density | 0.415   | 0.736              | 7.137    | 0.003***  | 0.576   | 0.801   |
| Environmental variables |         |                    |          |           |         |
| Dissolved oxygen | 1.770   | 0.170              | 0.089    | 0.762     | 0.268   | 0.606   |
| pH            | 0.335   | 0.801              | 0.111    | 0.746     | 0.439   | 0.507   |
| Depth         | 22.438  | 0.000***           | 7.568    | 0.007***  | 0.082   | 0.780   |
| Electric conductivity | 0.946   | 0.425              | 0.054    | 0.812     | 0.167   | 0.675   |
| Temperature   | 0.185   | 0.903              | 0.049    | 0.825     | 0.022   | 0.884   |
| Zooplankton   | 0.856   | 0.441              | 0.281    | 0.644     | 0.108   | 0.761   |
| Chlorophyll-a | 0.464   | 0.719              | 0.638    | 0.433     | 0.031   | 0.862   |
| Nitrite       | 1.438   | 0.229              | 0.590    | 0.453     | 0.116   | 0.729   |
| Nitrate       | 3.380   | 0.030***           | 0.071    | 0.794     | 0.405   | 0.524   |
| Ammonia       | 0.124   | 0.960              | 0.143    | 0.709     | 0.254   | 0.625   |
| Phosphorous   | 1.573   | 0.195              | 0.318    | 0.577     | 0.001   | 0.973   |

***p<0.01; **p<0.05; * p<0.10
Fig. 3 Spatial variation of ichthyoplankton along Taperoá II reservoir, Paraíba, Brazil. P1 - Taperoá river; P2 – beginning of reservoir (transition area); P3-P4 – middle of reservoir; P5 and P6 reservoir dam; MB(P3) and MB(P5) macrophytes beds. Each bar represent the mean and standard deviation of larvae and eggs densities along all the studied years.

Only depth and nitrate were significant different among sample areas (Table 2). However, solely depth shows a negative correlation with eggs (Spearman r=-0.52, p<0.01) and a marginal relation with larvae (Spearman r=-0.38, p=0.06).

The correspondence analysis to test the distribution of larval and eggs stages along the reservoir shows that the early stage of eggs (early cleavage) was primarily associated to samples in the river, while early embryo stage was found in inlet, middle and macrophyte beds, and free tail associated to the reservoir dam (Fig. 4a). A similar pattern occurred for larval stages. Larval yolk were associated to river, pre-flexion to the inlet and middle of reservoir, flexion to the dam, and post-flexion larval stages at macrophyte beds (Fig. 4b).
The river and reservoir inlet showed the highest number of species (12 species). Nine species were found in the middle of reservoir and macrophyte bed, and five species in the reservoir dam (Fig. 5). The most abundant species were *A. bimaculatus*, *A. fasciatus* e *C. bimaculatum*. The main species found in macrophytes were *P. brevis*, *L. piau*, *A. ocellatus*, *A. bimaculatus*, *A. fasciatus* e *C. bimaculatum*. While, *H. malabaricus* and Hypoptomatinae exhibit the highest abundance in river and
inlet samples. A chi-square test showed that the most abundant species had heterogeneous distribution in the sample areas (A. bimaculatus \( \chi^2 = 61.13; \) g.l. = 7; \( p < 0.01 \)), A. fasciatus \( \chi^2 = 40.00; \) g.l. = 7; \( p < 0.01 \) and L. piau \( \chi^2 = 27.14; \) g.l. = 7; \( p < 0.01 \)).

**Fig. 5** Relative abundance of larval species in the semiarid intermittent Taperoá river and Taperoá II reservoir (inlet, middle, reservoir dam and macrophyte beds), Brazil. Ad, A. davisii; Ao, A. ocellatus; Ab, A. bimaculatus; Af, A. fasciatus; Cb, C. bimaculatum; Hm, H. malabaricus; Lp, L. piau; Pb, P. brevis; Pho, P. rhomboides; Sn, S. notonota; Hy, non-identified Hypopominae; Ch, non-identified Characidae; Cf, non-identified Characiforme

4 **DISCUSSION**

In the Caatinga, the reproductive response to the rain suggests that semiarid fishes have a similar reproductive pattern as fishes in other tropical areas (Alkins-koo 2000; Castro et al 2002; Suzuki et al 2009; Reynalte-Tataje et al 2012; Pareja-Carmona et al 2014; Dourado et al 2017; Chaves et al 2017; Zacardi et al 2017), as highest densities of larvae occur on rainy months and densities of eggs just after the rainy. Balcombe et al (2007), studying the relationship of fish larvae in an arid zone of Australia, shows that the spawning of some species occurred even before the flood, which provides better habitat conditions and food for ichthyoplankton. In our study, we cannot infer the exact moment of fishes spawning, but the increase in larval density and the highest eggs density after rainy indicates a possible role of rainy trigging the fish reproduction.

The increase in water volume by the rainfall expands the habitat and decreases the crowding and the predation pressure (Alkins-koo 2000), but also, increases the foraging area and the availability of allochthonous resources (Agostinho et al. 2004). During dry season, the reduction of water volume in ponds or reservoirs causes the nutrient concentration and increase autochthonous resources like algae and invertebrates. As large amount of tropical fish are omnivorous (Lowe-McConnell 1987;
González-Bergonzoni et al. (2012), they can be opportunistic and benefit in both seasons. Although most of the species have shown a significant correlation with the rain, the selection of models showed that rain was a decisive factor for only four species, among them three are migratory (L. piau, P. brevis and P. rhomboïdes) that depends of water flow to reproduce. Other species, such as the omnivorous A. bimaculatus, A. fasciatus and the non-identified Characiforms showed a less clear pattern of response to rain, and seems to have parcelled spawning throughout the year. The multiple spawning is an important behavior for small species like the above, which are susceptible to strong predation (Winemiller 1989). The multiple spawning reduces the generation time and the investment per offspring, but allow a constant input of new individuals in the system, comprising r-selection proposed by (Pianka 1970). Therefore, our results do not seem indicate a reproductive pattern related to low-flow events, but correspond to seasonal patterns linked to rain or the opportunistic strategies of continuous reproduction related to evolutionary life-history traits.

The macrophyte presence and low depth seems to provide the best conditions for fish eggs and larvae. According to Reynalte-Tataje et al. (2008), breeding sites of fish larvae may be permanent or temporary habitat, however, it provides favorable conditions for the development of a particular species. This development and even the survival of the larvae of different species are affected by water temperature, pH, dissolved oxygen concentration, interactions with other organisms and mainly the water velocity, food availability and the predation. However, our study demonstrate that chemical and biological variables play a little role on the ichthyoplankton spatial distribution, except the depth, once the highest densities of eggs and larvae are in the low depth areas with macrophyte.

The presence of macrophyte was the determining factor for the spatial distribution of the ichthyoplankton, where the larger densities of eggs and larvae were found. The initial stages of the fishes are critical due to high susceptibility to predation and the need for easily available food resources for growth. In this way, the macrophyte provide shelter and food resource to increase the habitat heterogeneity for young fishes (Fischer and Eckmann 1997; Grenouillet and Pont 2001; Sánchez-Botero et al. 2007). We did not detect a significant correlation of food resource (zooplankton and phytoplankton) with total larval and eggs density, once no difference among sample locations was found for these resources. However, it may indicate a large role of macrophyte as shelter for initial stages of fishes.

Because macrophyte increase the habitat complexity, species richness are commonly increased in macrophyte beds (Petry et al. 2003). However, although our results show that the macrophyte beds have the highest larvae and eggs densities, they do not indicate a trend toward the greater number of species, once other areas also account for a high number of species (maximum of 10 species in macrophyte bed and open areas, and 12 species on the river). The similarity between
the number of species inside and outside of the macrophyte indicates that species occupy the entire area of the reservoir, although they are found mainly in macrophyte. The macrophyte provide shelter also for larvae of migratory fishes like *Prochilodus brevis* and *Leporinus piau*. Although, the construction of reservoir interrupts the river course, our results shows that the migratory species reproduce when the river flows and macrophyte serve as a nursery site for these species.

The river flow is one of the main processes on the transport of fish larvae leading the larvae from higher portions of rivers to the nursery sites (Nakatani et al 1997; Araújo-lima and Oliveira 1998; Silva et al 2011; Lima et al 2013; Ponte et al 2017; Mounic-Silva et al 2019). The results show a gradient of development stages from the river to the dam and macrophyte beds. Most of the early larval and eggs stages (early cleavage of eggs and larval yolk) were found in the river, while late stages of eggs (free tail, embryo end of eggs, and pre-flexion, flexion and post-flexion) were found along the reservoir (from the middle to the dam). The longitudinal gradient of development stages can demonstrate the importance of river flow for the fish spawning. The presence of early eggs stages in lotic areas and larvae in lentic areas or in macrophyte have well been demonstrated by Bialetzki et al (2002), Baumgartner et al (1997) on floodplain and e Ávila-Simás et al (2014). Despite of this, in our study the highest amount of eggs and larvae were found in macrophyte beds, but, early eggs and larval stages tended to occur more in the river and inlet while larval stages were found in the middle and in the reservoir dam.

Our results demonstrate that fish reproduction in tropical semiarid areas is strongly driven by the rainfall, and that the macrophyte beds in reservoirs play a major role on the sustainability of fish community, providing data for environmental policies of semiarid rivers and reservoirs. Although our work have not been able to perform collections in temporary ponds, our results indicate the role of reservoirs and the importance of protecting the macrophyte beds for the permanence of fish species in Caatinga. In this semiarid area, a river transposition, for permanent waters, is coming soon, so the lack of high and low waters can produce a negative impact in fish reproduction, since water flow regime is one of the most important clues to induce reproduction in fish species. Still, the river transposition can keep the water quality more homogeneous and lead a lack of macrophyte, since several macrophyte species only occur during low water volume period of the reservoir. The monitoring of fish reproduction must be conducted in order to register the presence or not of these impacts.

In addition, the eutrophication is an important way of macrophyte reduction in shallow lakes (Scheffer et al 1993; Scheffer and Jeppesen 2007). The absence of macrophyte can promote huge implications for fish diversity and fishery sustainability of semiarid. Important fish species for local human population like *Prochilodus brevis* and *Leporinus piau* can be doubly affected by the human
actions of river dams and macrophyte reductions. Also, changes in fish community driven by the presence or absence of macrophyte may lead to changes on trophic structure of semiarid reservoirs. Further comparative studies about water bodies in semiarid areas with different macrophyte coverage could clarify the macrophyte role on the fish spatial and temporal dynamic.

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