BIOTA AMAZÔNIA
OPEN JOURNAL SYSTEM

ARTICLE

DOI: http://dx.doi.org/10.18561/2179-5746/biotaamazonia.v7n2p4-7

Impacts of fish farm dams on temporal and spatial distribution of *Astyanax* cf. *bimaculatus* in microbasins of the Machado River (Rondônia, Brazil)

Marcos de Almeida Mereles[1], Jairo Ildefonso Guimarães Piñeyro[1], Bruce Gavin Marshall[2], Raniere Garcez Costa Sousa[1]

1. Departamento de Engenharia de Pesca (Universidade Federal de Rondônia, Brasil).
2. Department of Mining Engineering (University of British Columbia, Vancouver, Canada).
*Autor para correspondência: marcos.mdam@hotmail.com

ABSTRACT

The present study evaluated the effects of fish farm dams on spatial and temporal distribution of lambari *Astyanax* cf. *bimaculatus* in five headwater streams of the Machado River basin, Rondônia State, Brazil. The results show that fish farm dams are spatially separating wild lambari populations into upstream and downstream groups. Moreover, it was observed that the dry and rainy seasons influence the abundance and presence of *A.* cf. *bimaculatus* in these areas, while limnological parameters did not differ in the streams. Additionally, it was shown that fish farm dams built in the headwater stream areas impede the migratory routes of *A.* cf. *bimaculatus*, and also possibly the local movements of resident fish populations. Therefore, before the implementation of new farm dams using natural streams in the future, mitigation plans should include adequate access routes for fish to travel between upstream and downstream areas, in order to avoid adversely affecting their wild populations.

Keywords: Fish farm dams; lambari fish; Machado River; microbasins; population parameters.

Impactos das barragens de pisciculturas na distribuição temporal e espacial de *Astyanax* cf. *bimaculatus* em microbacias do Rio Machado (Rondônia, Brasil)

RESUMO

No presente estudo foi avaliado o efeito das pisciculturas de barragens na distribuição espacial e temporal do lambari *Astyanax* cf. *bimaculatus* em cinco canais de igarapés na bacia do Rio Machado em Rondônia (Brasil). Os resultados mostraram que estes empreendimentos separam espacialmente as populações desta espécie em regiões a montante e a jusante das represas. No entanto foi observado que o regime sazonal de estiagem e chuva na região também interfere na abundância e presença de *A.* cf. *bimaculatus* nessas áreas. Foi verificado também que os parâmetros limnológicos mensurados nas áreas a montante e jusante das pisciculturas não diferiram a ponto de inferir uma tendência na distribuição do lambari na área de estudo. Os resultados mostram que as pisciculturas de barragens construídas ao longo dos canais dos igarapés estudados interferem no fluxo migratório do lambari, assim para a manutenção das populações de *A.* cf. *bimaculatus*, as construções de futuras pisciculturas de barramentos usando igarapés devem ser avaliadas com mais critério levando em consideração estratégias de manejo que possam permitir o fluxo das comunidades desse peixe nas áreas de jusante e montante dos empreendimentos.

Palavras-chave: Barragens de piscicultura, lambari, Rio Machado, microbacias, parâmetros de populações.

Introduction

Rondônia State in the northern region of Brazil has the highest annual fish production from fish farms in the entire country, producing 75 thousand tons/year in 2014 (BRASIL, 2013). More than 800 registered fish farms have been built alongside or within headwater streams, which drain into major rivers found in the region (BRASIL, 2012). Consequently, fish farm dams have severely modified the aquatic environment by directly interrupting drainage patterns. Natural lotic environments have been transformed into lentic water bodies, which ends up affecting stream flow, limnological parameters and the behavior of local fish populations (ANDRIAN et. al., 2001; AGOSTINHO et al., 2007). This altered landscape results in the creation of new aquatic habitats, the loss of anterior habitats, stream erosion and sedimentation, increased water turbidity, and changes in seasonal water levels. Furthermore, dam construction for fish farming causes upstream areas to be inundated, while downstream reaches experience reduced water flow (WINEMILLER et al., 2016), which changes the distribution of food resources, thereby directly impacting local aquatic food webs (BAXTER, 1977). After construction of fish farm dams in stream areas, many local resident ichthyofauna begin to adapt and recover their ecological niche specificities, although it is clear that not all species are successful in recolonizing the altered environments (FERNANDO; HOLCÍK, 1982; AGOSTINHO et al., 1999).

In small streams, the consequences of fish farm dams are intensified, as this type of environment is more susceptible to antrophic action (LUIZ, 1998). The main species affected are migratory fish, which move up and down the stream channels based on changes in water level. Obstruction of stream channels makes it difficult for fish to migrate, thereby causing fragmentation of populations. In addition, dam construction has been shown to affect fish reproduction through the loss of nursery areas, due to inundation of upstream areas and diminished water flow downstream (AGOSTINHO et al., 2007). These altered environments contribute to the proliferation of opportunistic fish species, which often influence the reduction or extinction of local fish species (ANDRIAN et. al., 2001).

One of the predominant fish species found in small, headwater streams in Rondônia State in northern Brazil is *Astyanax* cf. *bimaculatus* LINNAEUS, 1758, commonly known as 'lambari' (VAZZOLER, 1992). This is a small, migratory, forager fish important to local aquatic food webs, which belongs to the Actnopterygii class, as part of the Characiformes order in the Characidae family (BARBIERI et al., 1982; HARTZ et al., 1996; ANDRIAN et al., 2001). Lambari is a common food fish, which is also used as bait in sport fisheries (MEURER et al., 2005) and is much desired for the ornamental fish market, due to its multicolored characteristics (ORSI, 2004). It has a large geographical distribution in the northeast region of South America (STERBA, 1973; GIAMAS, 1992) and is found in large numbers in streams of the Machado River basin in Rondônia (CASATTI et al., 2013).

In Brazil, there are few studies that have examined the influence of fish farm dams, constructed in small streams, on fish assemblage distribution. In addition no study has previously investigated the interference of headwater dams on the distribution of *A.* cf. *bimaculatus*. Therefore, the results of this research will hopefully aid in assisting future decisions related to dam construction in streams, as well as taking into consideration effective management plans for fisheries conservation in headwater areas. The present study aims to evaluate the effects of fish farm dams on the temporal and spatial distribution of *A.* cf. *bimaculatus* in micro-basins of the Machado River.

Methods

Study area

The sampling sites are located in five headwater streams of the Machado River basin, in the municipality of Presidente Medicí, Rondônia State, in northern Brazil (Figure 1).

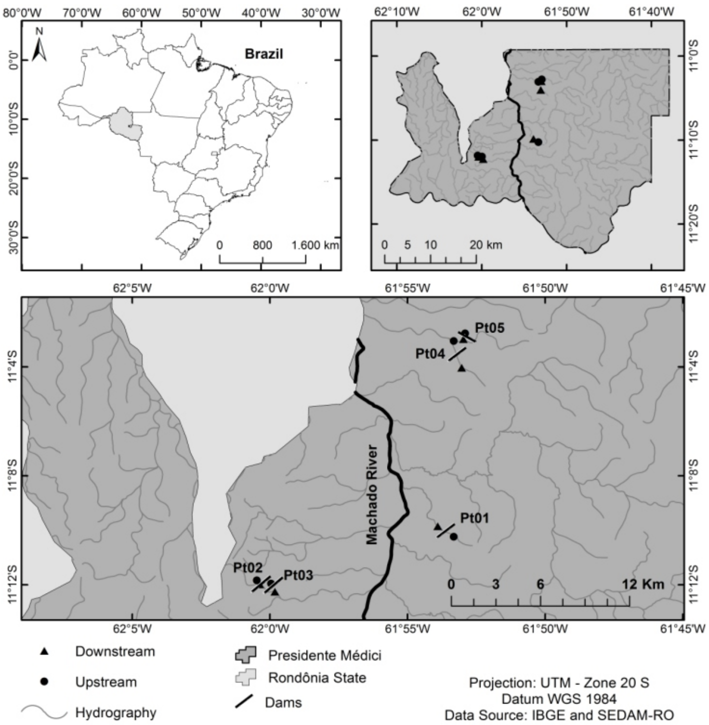

Figure 1. Location of headwater sampling sites in micro-basins of the Machado River.

Data collection

Specimens of *A.* cf. *bimaculatus* were sampled in the field over the course of four field excursions, which occurred during two main seasonal periods: the rainy season (December/2014 and March/2015) and dry season (September/2014 and June/2015). In each of the five streams, the fish samples were caught in two transects of 150 meters each, located both downstream and upstream of a fish farm dam. The specimens were caught using two deep-set gillnets of 2 m high and 5 m long, with 20 mm meshing between adjacent knots. A 2 m diameter and 10 mm mesh circle net was also used, including a 1 m^2 dipnet with 2 mm mesh. The deep-set gillnets were submerged for a period of two hours both nocturnally (06:00 p.m. to 08:00 p.m.) and diurnally (06:00 a.m. to 08:00 a.m.), in areas upstream and downstream of the fish farm dams. The deep-set gillnets were inspected at 20 minute intervals. The circle net and dipnet were used randomly over the course of two hours along the stream channel transects. At the same time, physical-chemical parameters such as water temperature (T), dissolved oxygen (DO), pH and electrical conductivity (EC) were measured. All fish samples were identified, labeled, stored in plastic bags and transported to the Aquiculture Laboratory at UNIR (Fundação Universidade Federal de Rondônia) facilities in Porto Velho, Rondônia, Brazil. All data samples were organized in an Excel table for statistical analysis.

Data analysis

The quantitative data was primarily submitted for descriptive analysis (BEIGUELMAN, 2002) in order to obtain the frequency, average and standard deviation (±) values. The frequency data was then used in a Correspondence Function Analysis (GOTELLI; ELLISON, 2011) to verify the seasonal (rainy and dry seasons) and spatial (collection points) distribution of *A.* cf. *bimaculatus* among sampling sites. After attending to assumptions of homogeneity and normality, a Student "t" test was applied to the limnological data to verify differences in average frequencies from upstream and downstream locations relative to the fish farm dams. All statistical analysis was performed using Statistic 9.0 software (STATSOFT, 2009), considering $\alpha \leq 0.05$ as statistically significant.

Results

Over the course of the field sampling, a total of 405 specimens of *A.* cf. *bimaculatus* were collected, with average standard length varying between 1.8 and 9.3 cm (Table 1). The largest number of lambari (56.54%) were found at stream 3, followed by streams 1, 2 and 4, which contributed with 17.28, 16.05 and 9.38% of the total, respectively. Stream 5 showed the lowest frequency, with only 0.74% (n=3) of the total number of captured individuals (Table 1; Figure 2).

Table 1. Distribution of *A.* cf. *bimaculatus* during the dry and rainy seasons at sampling sites upstream and downstream of fish farm dams.

Sampling sites	Seasons			
	Dry		Rainy	
	Upstream *n* (*min–max)	Downstream *n* (*min–max)	Upstream *n* (*min–max)	Downstream *n* (*min–max)
1	3 (4.0 - 6.6)	39 (3.5 - 6.7)	1 (4.0)	27 (3.5 - 6.7)
2	42 (3.5 - 9.3)	4 (6.0 - 8.0)	19 (2.7 - 7.8)	na
3	18 (3.5 - 8.5)	32 (4.0 - 8.0)	92 (2.4 - 8.5)	87 (1.8 - 8.7)
4	26 (2.0 - 5.8)	na	12 (2.8 - 4.5)	na
5	na	2 (3.0 - 5.7)	na	1 (4.0)

n = number of fish (*standard length in centimeters). min. = minimum, max. = maximum, and na = not available samples.

The Correspondence Function Analysis (CFA) displayed abundance distribution in the first two ordination axes (λ_1 = 0.5484 and λ_2 = 0.1999) in relation to seasonal (dry and rainy seasons) and spatial data (upstream and downstream of the fish farm dams). Dimension 1 (x axis) was structured both in terms of collection periods and sampling locations, with the upper right quadrant showing fish caught at sites upstream of the dams, while on the left side are fish specimens from downstream areas (Figure 2). On the other hand, Dimension 2 was structured more in relation to seasonal data, with fish from the dry period in the lower left quadrant, while fish from the rainy season were grouped in the top left (Figure 2). In general, spatial patterns were more evident than the grouping of seasonal variations.

The temporal variation was more evident from fish caught upstream of site 2, where fish group occurrence varied between the rainy and dry seasons. In comparison, the canonic values spatially influenced the fish distribution from stream 3 among specimens from the rainy season and in relation to upstream and downstream locations. The spatial distribution of sites 1, 4 and 5 was structured mainly in function of the dry season collections, which inferred a low frequency of specimens caught downstream in stream 1 and 5 (left lower quadrant) and a high frequency of individuals caught upstream of fish farm dams (right upper side) (Figure 2).

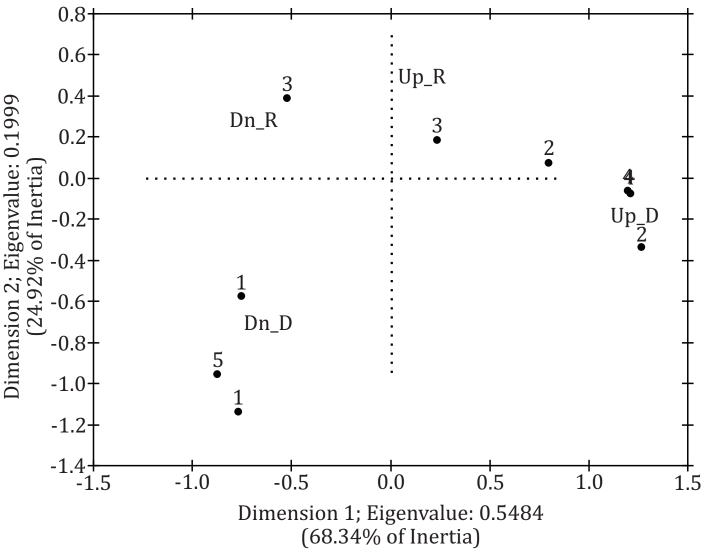

Figure 2. Spatial and seasonal ordination of *Astyanax* cf. *bimaculatus* sampled in five streams (1-5) used for fish farm dams in the Machado River basin. Up = upstream, Dn = downstream, R = rainy season, D = dry season.

Limnological parameters, when submitted to the Student "t" test, did not present differences ($p > 0.05$) between upstream and downstream sites (Table 2).

Table 2. Average values with standard deviations of limnological parameters measured at sampling sites.

Dam locations	Parameters	Sampling sites				
		1	2	3	4	5
Upstream	DO (mg/L^{-1})	3.65±1.32	2.07±0.79	3.47±1.23	4.85±0.61	4.67±1.45
	pH	6.02±0.87	6.37±0.66	5.97±1.18	5.47±0.83	6.02±0.44
	Temperature (°C)	27.50±1.58	26.67±2.49	25.31±0.76	24.85±0.61	26.42±3.46
	EC ($\mu S/cm^{-1}$)	55.60±12.97	97.00±17.32	103.07±12.97	60.17±15.36	13.50±2.69
Downstream	DO (mg/L^{-1})	4.60±2.99	3.65±2.08	4.75±0.66	5.72±2.19	5.31±0.78
	pH	6.17±1.32	6.64±0.79	6.26±1.08	5.73±1.31	6.00±0.17
	Temperature (°C)	28.30±0.94	26.92±0.89	26.30±1.14	27.72±2.19	27.98±1.80
	EC ($\mu S/cm^{-1}$)	59.52±9.73	119.80±24.8	112.20±14.07	51.15±32.62	13.60±2.77

EC = electrical conductivity; DO = Dissolved oxygen

Discussion

It has been reported that changes in the structural composition of fish communities in relation to dam construction are inevitable, especially in relation to migratory fish species (NOVAKOWSKI et al., 2007). When a dam impedes the movements of migratory fish species, various life cycle characteristics are impacted, including the ability to reproduce, seek shelter and to feed (SILVE; POMPEU, 2008). This, in turn, forces these fish to adapt to new environmental conditions and modify certain life cycle aspects, which may cause populational instability. To better understand fish behavior in areas affected by dams, it is necessary to investigate whether life cycle modifications occurred after the dams' implementation (AGOSTINHO et al., 2007).

Stream dams and continuous deforestation are anthropogenic impacts that occur frequently in the Machado River basin (FERNANDES; GUIMARÃES, 2002), causing the transformation of riparian vegetation to grasslands, now encompassing almost the entire area of micro-basins in the region. The occurrence of pasture was observed in the present study, mainly in areas located downstream of the fish farm dams. This is also where a high frequency of lambari was found, which could be indicative of the adaptability of this fish species to colonize open areas. On the other hand, this could also be related to the dams blocking access to upstream locations, forcing the lambari to congregate more intensively in downstream areas. Large areas of grassland were seen mainly at sites 1 and 3, where the highest abundance of *A.* cf. *bimaculatus* was also observed in downstream locations. This result was corroborated by Santos (1995), who observed similar grouping behavior of migratory fish species below a hydroelectric dam.

In the study area, all fish farm dams were constructed in the main channel of streams and did not have filters to prevent feces, leftover food rations and other sediments from moving downstream, thereby possibly affecting the natural food chain structure in these areas. This, in turn, could influence the feeding behavior of lambari, which is a generalist and omnivorous fish species (DIAS et al., 2005; ANDRIAN et al., 2001). To confirm this hypothesis, more studies are needed to investigate its food strategies, including analyses of stomach contents.

Lambari individuals were also found in large numbers in areas upstream of sites 2 and 4 (CFA: Eigenvalue of 0.5484 and 68.34% of inertia), where riparian forest is predominant. In comparison with inundated grassland areas, riparian vegetation normally offers a wider array of food sources for fish populations, especially during the dry season, when a higher density of organisms competes for diminished availability of food resources (WINEMILLER; JEPSEN, 1998). In contrast, the lowest frequency of *A.* cf. *bimaculatus* at site 5 could be explained by two possible reasons: 1) this region has intensive cattle ranching and widespread grasslands, with no riparian forest or allochthonous fish resources for fish populations; and 2) a water pipeline was being installed at the headwaters in this area in order to operate a waterwheel. Both scenarios would make it impossible for lambari individuals to circumnavigate these barriers and have access to the headwater areas.

Another factor which clearly influences the spatial distribution of lambari is the regional hydrological cycle, which is characterized by low water during the dry season (between March and September) and high water during the rainy season (between October and February-March) (FERNANDES; GUIMARÃES, 2002). It is also well documented that the spatial distribution of fish is directly associated with fluctuations in water quality, which typically involve variations in limnological parameters (OLIVEIRA; GOLART, 2000). In the present study, no significant differences were found in relation to physical-chemical properties measured both downstream and upstream of fish farm dams. This emphasizes the assumption that lambari distribution, in relation to construction of fish farm dams in the Machado River basin, is more strongly correlated to spatial and temporal variations than changes in limnological parameters, especially in regards to differences between upstream and downstream locations.

The seasonal differences in distribution may be the most pronounced, as water level drops significantly during the low water period, with some areas downstream of the dams becoming completely devoid of water after a prolonged dry season. This likely explains why lambari distribution downstream of the dams showed the lowest frequency during the dry period, with higher values for the same locations found during the rainy season. In comparison, the higher frequency values found in some upstream locations relative to downstream sites could be related to continuous flooding of upstream areas, due to dam construction. Furthermore, upstream areas appear to have a higher incidence of riparian vegetation, which offers a greater availability of food resources, refuge and conditions suitable for fish reproduction (PANKHURST; MUNDAY, 2011) than shallow grasslands more commonly found below the fish farm dams. Therefore, the results presented in this study indicate that installation of fish farm dams in small tributaries of the Machado River basin can affect the spatial and temporal distribution of *A.* cf. *bimaculatus*, possibly due to the restriction of upstream and downstream movement and reduced water flow below the impoundments. In conjunction, other fish species endemic to the region may also be affected, causing disruptions in feeding, reproduction and population structure. However, further studies are needed to confirm these hypotheses.

From the findings in this study, it is clear that future decisions regarding the further installation of fish farms in the Machado River basin need to consider the ecological needs of ichthyofauna in the region, especially migratory fish species which depend on unimpeded movement up and down small tributaries as part of their life cycle. Therefore, conservation plans must be implemented to ensure that natural fish stocks are not compromised by the construction of artificial dams, in order to guarantee the long-term environmental sustainability of this type of aquaculture in the region.

Conclusions

The results of this study show that fish farm dams are causing spatial separation of lambari populations into upstream and downstream groups. Moreover, it was observed that the dry and rainy seasons also influence the presence and abundance of *A.* cf. *bimaculatus* in these areas. Therefore, before the implementation of new fish farm dams using streams in the future, mitigation plans should include adequate access routes for endemic fish species to travel between upstream and downstream areas, in order to avoid adversely affecting their populations.

References

AGOSTINHO, A. A.; GOMES, L. C.; PELICICE, F. M. **Ecologia e manejo de recursos pesqueiros em reservatórios do Brasil**. Maringá: Eduem, 2007.

ANDRIAN, I. F.; SILVA H. B. R.; PERETTI, D. Dieta de *Astyanax bimaculatus* (Linnaeus, 1758) (Characiformes, Characidae), da área de influência do reservatório de Corumbá, Estado de Goiás, Brasil. **Acta Scientiarum Biological Sciences**. v. 23, n. 2, p. 435-440, 2001.

BARBIERI, G.; DOS SANTOS, M. R.; DOS SANTOS, J. M. Época de reprodução e relação peso/comprimento de duas espécies de *Astyanax* (Pisces, Characidae). **Pesquisa Agropecuária Brasileira**. v. 17, n. 7, p. 1057-1065, 1982.

BRASIL - Ministério da Pesca e Aquicultura (2012) Boletim Estatístico da Pesca e Aquicultura – 2010. Disponível em http://sinpesq.mpa.gov.br (Acessada em 05/04/2016).

BRASIL - Ministério da Pesca e Aquicultura (2013) Balanço 2013 Pesca e Aquicultura. Disponível em http://sinpesq.mpa.gov.br (Acessada em 06/04/2016).

CASATTI, L.; PÉREZ-MAYORGA, M. A.; CARVALHO, F. R.; BREJÃO, G. L.; COSTA, I. D. The stream fish fauna from the rio Machado basin, Rondônia State, Brazil. **Check List**. v. 9, n. 6, p. 1496-1504, 2013.

DIAS, A. C. M. I.; BRANCO, C. W. C.; LOPES, V. G. Estudo da dieta natural de peixes no reservatório de Ribeirão das Lajes, Rio de Janeiro, Brasil. **Acta Scientiarum Biological Sciences**, v. 27, n. 4, p. 355-364, 2005.

FERNANDES, L. C.; GUIMARÃES, S. C. P. **Atlas geoambiental de Rondônia**. Porto Velho: Secretaria de estado do Desenvolvimento Ambiental, 2002.

GIAMAS, M. T. D.; SANTOS, R. A.; VERMULM JR., H.; CAMPOS, E. C.; CAMARA, J. J. C. Determinação da curva de crescimento através da lepidologia em diferentes áreas do corpo de *Astyanax bimaculatus* (Linnaeus, 1758) (Pisces, Characidae), na Represa de Ibitinga, SP. **Brazilian Journal of Veterinary Research and Animal Science**, v. 29, n. 2, p. 185-192, 1992.

GOTELLI, N. J.; ELLISON, A. M. **Princípios de Estatística em Ecologia**. Porto Alegre: Artmed, 2011.

KRUSCHE, A.V.; BALLESTER, M. V. R.; VICTORIA, R. L.; BERNARDES, M. C.; LEITE, N. K.; HANADA, L.; VICTORIA, D. C.; TOLEDO, A. M.; OMETTO, J. P.; MOREIRA, M. Z.; GOMES, B. M.; BOLSON, M. A.; NETO, S. G.; BONELLI, N.; DEEGAN, L.; NEILL, C.; THOMAS, S.; AUFDENKAMPE, A. K.; RICHEY, J. E. Efeitos das mudanças do uso da terra na biogeoquímica dos corpos d'água da bacia do rio Ji-Paraná, Rondônia. **Acta Amazonica**, v. 35, n. 2, p. 197-205, 2005.

LOWE-MCCONNELL, R. H. **Ecological studies in tropical fish communities**. Cambridge: Cambridge University Press, 1987.

LUIZ, E. A.; AGOSTINHO, A. A.; GOMES, L. C.; HAHN, N. S. Ecologia trófica de peixes em dois riachos da bacia do rio Paraná. **Revista Brasileira de Biologia**, v. 58, n. 2, p. 273-285, 1998.

MEURER, F.; HAYASHI, C.; BOSCOLO, W. R.; KAVATA, L. B.; LACERDA, C. H. F. Nível de arraçoamento para alevinos de lambari-do-rabo-amarelo (*Astyanax bimaculatus*). **Revista Brasileira de Zootecnia**, v. 34, n. 6, p. 1835-1840, 2005.

MYERS, N.; MITTERMEIER, R. A.; MITTERMEIER, C. G.; FONSECA, G. A. B.; KENTS, J. Biodiversity hotspots for conservation priorities. **Nature**, v. 403, p. 853-845, 2000.

NOVAKOWSKI, G. C.; HAHN, N. S.; FUGI, R. Alimentação de peixes piscívoros antes e após a formação do reservatório de Salto Caxias, Paraná, Brasil. **Biota Neotropica**, v. **7**, n. 2, p. 149-154, 2007.

OLIVEIRA, A. K. C.; OLIVEIRA, I. S. A influência da temperatura nas histórias de vida de vertebrados. **Revista da Biologia**, v. 12, n. 2, p. 8-15, 2014.

OLIVEIRA, E. F.; GOULART, E. Distribuição espacial de peixes em ambientes lênticos: interação de fatores. **Acta Scientiarum**, v. 22, n. 2, p. 445-453, 2000.

ORSI, M. L.; CARVALHO, E. D.; FORESTI, F. Biologia populacional de *Astyanax altiparanae* Garutti & Britski, 2000 (Teleostei, Characidae) do médio rio Paranapanema, Paraná, Brasil. **Revista Brasileira de Zoologia**, v. 21, n. 2, p. 207-218, 2004.

SANTOS, G. M. Impactos da hidrelétrica Samuel sobre as comunidades de peixes do rio Jamari (Rondônia, Brasil). **Acta Amazonica**, v. 25, n. 3, p. 247-280, 1995.

SILVE, E. M.; POMPEU, P. S. Análise crítica dos estudos de ictiofauna para o licenciamento ambiental de 40 PCH no estado de Minas Gerais. **PCH Notícias**, v. 9, p. 22-26, 2008.

STATSOFT. 2009. STATISTICA (Data Analysis Software System). Version 9.0. [on line] URL: Disponível em http:// www.statsoft.com (Acessada em 10/04/2016).

VAZZOLER, A. E. A. M. Reprodução de Peixes. In: A.A. Agostinho & E. Benedito-Cecilio (eds) **Situação atual e perspectivas de ictiologia no Brasil**, Maringá: Eduem, 1992.

WINEMILLER, K. O.; JEPSEN, D. B. Effects of seasonality and fish movement on tropical river food webs. **Journal of Fish Biology**, v. 53, p. 267-296, 1998.

WINEMILLER, K. O.; MCINTYREP, B.; CASTELLO, L.; FLUET-CHOUINARD, E.; GIARRIZZO, T.; NAM, S.; BAIRD, I. G.; DARWALL, W.; LUJAN, N. K.; HARRISON, I.; STIASSNY, M. L. J.; SILVANO, R. A. M.; FITZGERALD, D. B.; PELICICE, F. M.; AGOSTINHO, A. A.; GOMES, L. C.; ALBERT, J. S.; BARAN, E.; PETRERE JR., M.; ZARFL, C.; MULLIGAN, M.; SULLIVAN, J. P.; ARANTES, C. C.; SOUSA, L. M.; KONING, A. A.; HOEINGHAUS, D. J.; SABAJ, M.; LUNDBERG, J. G.; ARMBRUSTER, J.; THIEME, M. L.; PETRY, P.; ZUANON, J.; TORRENTE VILARA, G.; SNOEKS, J.; OU, C.; RAINBOTH, W.; PAVANELLI, C. S.; AKAMA, A.; VAN SOESBERGEN, A.; SÁENZ, L. Balancing hydropower and biodiversity in the Amazon, Congo, and Mekong Basin-scale planning is needed to minimize impacts in mega-diverse rivers. **Science**, v. 351, n. 6369, p. 128-129, 2016.