Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1679-9283
ISSN on-line: 1807-863X
Doi: 10.4025/actascibiolsci.v38i3.31943

Influence of an artificial dam on the fish assemblage of a Neotropical stream

Dyego Leonardo Ferraz Caetano[1,2*], Rafael Rogério Rosa[1,3], Verônica Rodrigues de Moraes[1], Daniela Ribas Jané[1] and Alexandre Fernandes Oliveira da Silva[1]

*[1]Grupo de Estudos e Pesquisa em Recursos Hídricos e Ecologia Aplicada, Universidade Estadual do Norte do Paraná, Rua Padre Mello, 1200, 86400-000, Jacarezinho, Paraná, Brazil. [2]Programa de Pós-Graduação em Biologia Comparada, Universidade Estadual de Maringá, Maringá, Paraná, Brazil. [3]Programa de Pós-Graduação em Ecologia de Ambientes Aquáticos Continentais, Universidade Estadual de Maringá, Maringá, Paraná, Brazil. *Author for correspondence. E-mail: dyegojcz@gmail.com*

ABSTRACT. The objective of this study was to evaluate the influence of a dam on the ecological parameters of the fish assemblages of a stream of second order of the upper Paraná River basin, southern Brazil. Samplings of abiotic data and ichthyofauna occurred quarterly between September 2012 and June 2013. Were collected 3,128 individuals in six orders, eight families and 13 species. The Cluster analysis (Jaccard) based on species composition indicated the separation of the sampling units into two groups, demonstrating the dissimilarity between upstream and downstream units. The artificial dam was characterized as a discontinuity factor for diversity patterns and ecological processes related to biota. Thus, this study has indications that the creation of dams can significantly affect the richness and abundance of fish species of small lotic systems, as streams, by modifying their environments.

Keywords: conservation unit, geographical barrier, influence of anthropogenic factors, neotropical ichthyofauna, stream ecology.

Influência de um reservatório artificial na assembleia de peixes de um riacho Neotropical

RESUMO. O objetivo do presente estudo foi avaliar a influência de uma barragem sobre os parâmetros ecológicos das assembleias de peixes presentes em um riacho de segunda ordem da bacia do Alto rio Paraná, sul do Brasil. As amostragens dos dados abióticos e da ictiofauna ocorreram trimestralmente entre o período de setembro de 2012 e junho de 2013. Foram coletados 3.128 indivíduos distribuídos em seis ordens, oito famílias e 13 espécies. A análise de agrupamento com base no índice de Jaccard indicou a separação dos pontos em dois grupos com relação à composição de espécies, demonstrando distinção entre os pontos à montante e à jusante da barragem artificial. A barragem artificial se caracterizou como um fator de descontinuidade para os padrões de diversidade e para os processos ecológicos relacionados à biota. Sendo assim, o presente trabalho possui indicativos de que a criação de barragens, mesmo que para a formação de pequenas represas ou açudes, pode afetar de forma significativa a riqueza e abundância das espécies de peixes de pequenos sistemas lóticos, como riachos, por meio da modificação de seus ambientes.

Palavras-chave: unidade de conservação, barreira geográfica, influência de fatores antrópicos, ictiofauna neotropical, ecologia de riachos.

Introduction

The neotropical region has one of the highest diversities of freshwater fish on the planet, with estimates ranging from 4,400 (Reis, Kullander, & Ferraris Jr., 2003) to 8,000 (Schaefer, 1998) species. In Brazil, it is estimated that there are more than 2,400 species of freshwater fish (Buckup, Menezes, & Ghazzi, 2007) and approximately 600 species are present in the Paraná River basin (Agostinho et al., 2004). About 50% of the neotropical ichthyofauna comprises small species from small rivers or streams (Castro, 1999).

According to the River Continuum Concept (Vannote, Minshall, Cummins, Sedell & Cushing, 1980), in a lotic water system, such as a stream, increased complexity and habitat heterogeneity in the direction upstream to downstream causes an increase in the diversity of species and trophic structure in the same direction. However, continuity in the structure of the headwater of a stream's ecosystem can be broken, mainly by anthropogenic interference that can disrupt patterns of diversity and ecological processes related to the biota (Ward & Stanford, 1983). A common anthropogenic interference in basins in Brazil is the creation of dams. Dams cause various impacts on aquatic ecosystems, affecting physical, chemical and geomorphological characteristics. Blocking a lotic

environment modifies the primary productivity and channel structure, changes the diversity of fish and invertebrates by blocking migration, and causes changes in the planktonic biomass (Agostinho, Gomes, & Pelicice, 2007).

The effects of a dam depend on its size and the surrounding ecological and environmental structure (Poff & Hart, 2002). In Brazil, there are more than 700 large reservoirs, and the area most affected by dams is the upper Paraná River basin (Agostinho, Pelicice, & Gomes, 2008). There are several works that focus on the ichthyofauna of dammed areas in neotropical river basins (Pelicice & Agostinho, 2008; Gubiani, Gomes, & Agostinho, 2012; Vasconcelos, Alves, & Gomes, 2014; Ortega, Júlio, Gomes, & Agostinho, 2015); however, there are few studies that characterize the interference of dams on fish assemblages of small aquatic environments, such as streams (Gardner, Coghlan Jr., Zydlewski, & Saunders, 2011). Streams are hydrologically very important for surrounding rivers of a hydrographic basin because they directly influence the recharge (Alekseevskii, Grinevskii, Efremov, Zalavskaya, & Grigoreva, 2003), provide habitats for benthic invertebrates that process thick and fine organic particulate (Vannote et al., 1980), and act as breeding grounds for fish species that occupy other parts of the drainage basin (Rêgo, Pinese, Magalhães, & Pinese, 2008).

The persistence and conservation of fish in a lotic system, such as a stream, depends on the maintenance of appropriate conditions of the aquatic and terrestrial environments. Therefore, the availability and quality of food resources, reproduction sites, and the microhabitats for fish species in lotic systems are influenced in multiple ways by both internal and external factors (Caramaschi, Mazzoni, Bizerril, & Peres-Neto, 1999), which can be altered by human impacts, such as the creation of a dam.

Thus, the aim of this study was to evaluate the influence of a dam on the ecological parameters of the fish assemblages of Chumbeiro Stream, a second order stream in the upper Paraná River basin in southern Brazil. The hypotheses of this study are: i) the continuity in the patterns of richness and diversity of stream fish species broken by the artificial dam, ii) the environmental factors in sections located upstream and downstream of the dam influence the fish assemblage composition of Chumbeiro Stream, and iii) the abundance of the fish assemblages changes temporally, independently of the artificial barrier.

Material and methods

Study area

The Paranapanema River basin (22º-26º S, 47º-54º W) is in the system of the upper Paraná River basin, in southern Brazil, extends approximately 930 km, and has a drainage area of 109,600 km^2. About 630 km of the Paranapanema River are located in São Paulo and 300 km are on the border between the states of São Paulo and Paraná (Sampaio, 1944). Chumbeiro Stream (23°11'8,47" S, 49°57'56,95" W), in the Paranapanema basin, is a second order stream in the municipality of Jacarezinho, Paraná State, Brazil. The stream is the sixth tributary of the left margin of the Água Feia River, with a drainage area of about 2 km. It starts on the margin of the highway BR-153 and runs to the *Refúgio de Vida Silvestre de Jacarezinho* (RVSJ) conservation unit in the municipality of Jacarezinho, Paraná State. The Fish and abiotic data were sampled at six points upstream and downstream of Chumbeiro Stream. Three points were located upstream (P1, P2 and P3) and three were located downstream (P4, P5 and P6) of a small dam constructed in order to provide water for irrigating plants in RVSJ (Figure 1).

Sampling

The abiotic data and fish were sampled quarterly between September 2012 and June 2013. The physical and chemical characteristics measured at each sample unit were the following: maximum width and depth of the channel (with the aid of a 10 m tape measure), water temperature, and pH (Tecnopon® MPA-210P). The fish were collected with two round sieves (0.5 cm mesh x 0.78 m diameter) and a rectangular sieve (0.5 cm mesh x 1.02 m long x 0.81 m wide). Each section was blocked with 3 mm mesh networks in an area of 50 m. The sampling occurred during the day for a standard time of 50 minutes, with five collectors. The individuals captured were anesthetized, sacrificed by immersion in eugenol (active principle: phenoliceugenol 4-alil-2-metoxifenol-C10H12O2, derived from the stems, flowers and leaves of the trees *Eugenia caryophyllata* and *Eugenia aromatica*; Griffiths, 2000), fixed in 10% formalin solution and then preserved in 70% alcohol. Identification of species was carried out according to Reis et al. (2003), Oyakawa, Akama, Mautari, and Nolasco (2006) and Graça and Pavanelli (2007). A voucher of each species was deposited in the Museum of Ichthyology of the *Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura*, at the *Universidade Estadual de Maringá* (Nupelia/UEM).

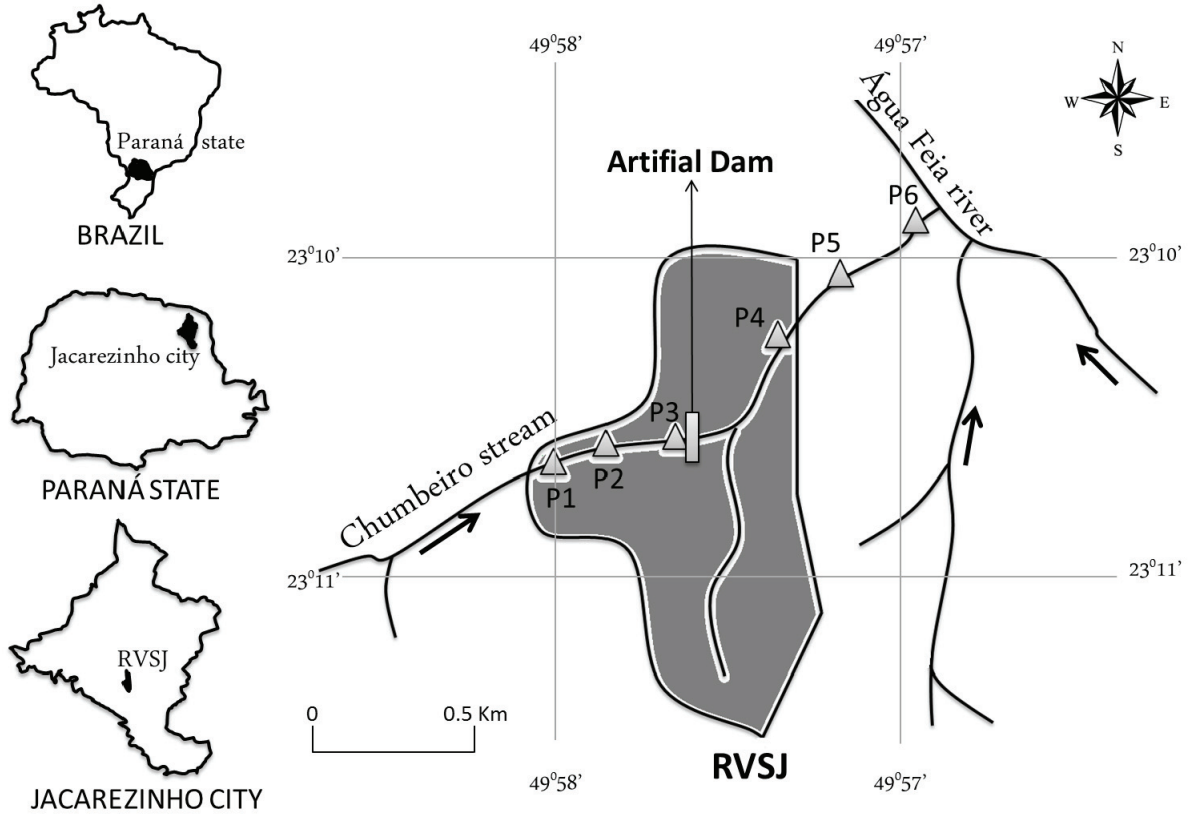

Figure 1. Fish collection points along Chumbeiro Stream (P1, P2, P3, P4, P5 and P6), Paranapanema River basin, upper Paraná River, showing the area of *Refúgio de Vida Silvestre de Jacarezinho* (RVSJ) and the region with the artificial dam.

Data analysis

The structure of the Ichthyofauna of Chumbeiro Stream was analyzed in terms of absolute frequency and abundance, and relative frequency and abundance, for each point, as well as by the Shannon-Wiener diversity index ($H' = - \Sigma pi \, log pi$, where pi is the relative frequency of species i), equitability ($J = H'/H'_{max}$, where H' is the Shannon diversity index and H'_{max}[maximum diversity] is the logarithm of species richness) and Simpson's dominance index ($D = \Sigma \, pi^2$; Ludwig & Reynolds, 1988). In addition, a cluster analysis was made with the species composition (Jaccard index) for the six sampling points. An analysis of variance (ANOVA One Way) was also made, according to the assumptions, to detect possible significant differences ($p < 0,05$) for the abiotic data and composition and abundance of the fish species among all sampling points separately, between sampling points upstream and downstream of the artificial dam, and among sampling periods. Finally, a canonical correspondence analysis (CCA) was made in order to relate the abiotic factors with the fish assemblage structure. The diversity and cluster analyses were performed using Statistica 7.1 (Statsoft, 2005), the analyses of variance with ECOSIM (Entsminger, 2012), and the CCA with the Vegan package (Oksanen et al., 2013) of R (R Core Team, 2013).

Results

There was a significant difference between the abiotic data of the sampling points only for the maximum depth parameter (ANOVA: $F = 4.596$ and $p < 0.05$), where P3, P5 and P6 were the points with the greatest depths (Figure 2). Maximum width, pH and temperature were not significantly different among the sampled points.

In total, 3,128 specimens were collected, including six orders, eight families and 13 species (Table 1). Chacaciformes was the most abundant order (80.53%) and had the highest species richness (46%), followed by Cyprinodontiformes (relative abundance: 9.37%; relative richness: 15.39%) and Siluriformes (relative abundance: 0.67%; relative richness: 15.39%). Perciformes, Gymnotiformes and Synbranchiformes accounted for only one species each. *Astyanax bockmanni*, *Astyanax* sp., *Bryconamericus iheringii* and *Hypostomus ancistroides* were the only species shared between sampling points upstream

and downstream of the artificial dam. The other species were found only at points downstream of the dam.

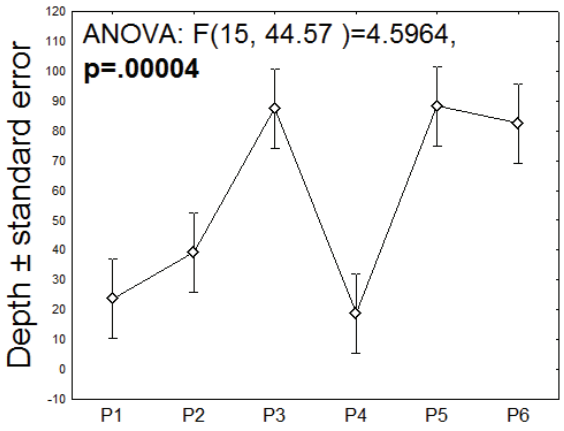

Figure 2. Significant difference between the depths of the sampling points of fish in Chumbeiro Stream, Paranapanema basin, upper Paraná River, by analysis of variance (ANOVA One-Way).

Table 1. Taxonomic position and occurrence points (X) of the Chumbeiro Stream fish species, Paranapanema basin, upper Paraná River.

ORDER / Family / *Species*	P1	P2	P3	P4	P5	P6	Voucher
CHARACIFORMES							
Characidae							
Astyanax lacustris (Lütken, 1875)				X	X	X	NUP 14802
Astyanax bockmanni Vari & Castro, 2007	X	X	X	X	X	X	NUP 14786
Astyanax sp.	X	X	X	X		X	NUP 14776
Bryconamericus iheringii (Boulenger, 1887)	X	X	X	X	X	X	NUP 14787
Serrapinnus notomelas (Eigenmann, 1915)					X	X	NUP 14798
Erythrinidae							
Hoplias sp.				X	X	X	NUP 14793
SILURIFORMES							
Callichthyidae							
Corydoras aeneus (Gill, 1858)						X	NUP 14791
Loricariidae							
Hypostomus ancistroides (Ihering, 1911)	X				X	X	NUP 14782
GYMNOTIFORMES							
Gymnotidae							
Gymnotus inaequilabiatus (Valenciennes, 1842)					X	X	NUP 14794
CYPRINODONTIFORMES							
Poeciliidae							
Phalloceros harpagos Lucinda, 2008						X	NUP 14792
Poecilia reticulata Peters, 1859				X	X	X	NUP 14803
SYNBRANCHIFORMES							
Synbranchidae							
Synbranchus marmoratus Bloch, 1795						X	NUP 14801
PERCIFORMES							
Cichlidae							
Geophagus brasiliensis (Quoy & Gaimard, 1824)				X	X	X	NUP 14804

Astyanax bockmanni had the highest (55.85 %) and *Coridoras aeneus* had the lowest (0.03 %) relative abundance. Regarding the diversity parameters, the mouth of Chumbeiro Stream (P6) had the highest value in the Shannon-Wiener diversity index and the lowest dominance. The least diverse unit was P1, and P5 showed the least equitability. The results of the diversity index are presented in Table 2.

Table 2. Values of species richness and diversity indices applied to the fish assemblage in sampling units of Chumbeiro Stream (P1: upstream, P6: downstream), Paranapanema River basin, upper Paraná River.

Index / Sampling unit	P1	P2	P3	P4	P5	P6
Richness	3	4	3	7	9	13
Shannon-Wiener diversity	0.9394	1	1,058	1,186	1,259	1.51
Equitability	0.855	0.469	0.9632	0.6095	0.573	0.5887
Simpson Dominance	0.4479	0.6893	0.3616	0.4083	0.4269	0.3076

The cluster analysis (Jaccard index) indicated the separation of two sampling units in the species composition, demonstrating the similarity between sampling units upstream of the artificial dam (P1, P2 and P3), and among P4, P5 and P6 located downstream of the dam. The sampling units P1 and P3 presented the same species composition (Figure 3).

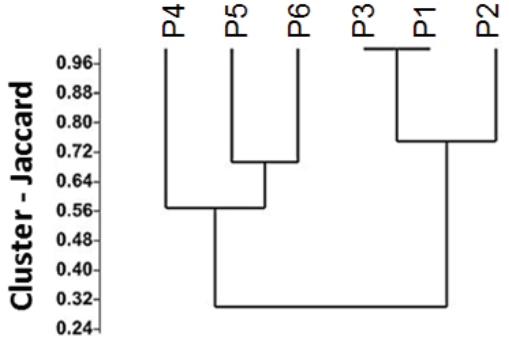

Figure 3. Cluster analysis demonstrating the similarity, according to the fish composition, among the sampling units in Chumbeiro Stream, Paranapanema River basin, upper Paraná River (P1: upstream, P6: downstream).

The analysis of variance (ANOVA One Way, p = 0.04) showed a significant difference between the mouth unit of the Chumbeiro Stream (P6) and the units upstream of the dam (P6-P1: F = 5.303 and p = 0.005; P6-P2: F = 4.634 and p = 0.02; P6-P3: F = 5.168 and p = 0.006).

The analyses related to the temporal pattern and assemblage abundance of Chumbeiro Stream did not show significant differences for the four sampling periods. However, it can be seen that the highest abundance was recorded during the second sampling period (December 2012) and the lowest was recorded during the fourth period (June 2013).

The CCA diagram did not demonstrate a significant relationship of the width, depth and temperature with the fish assemblages (ANOVA: F = 0.54 and $p > 0.05$). However, abiotic factors had a greater influence on the fish assemblage of P5 (Figure 4).

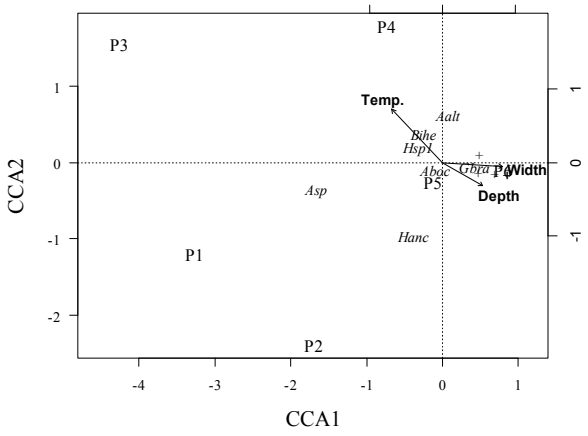

Figure 4. Ordination diagram representing the first two axes of the canonical correspondence analysis (CCA), showing the sampling units in Chumbeiro Stream, the physical and chemical variables (Temp: temperature) and the fish species (+).

Discussion

The higher species richness and abundance of the order Characiformes found in this study reflect a common standard for streams of the upper Paraná River (Abes & Agostinho 2001; Castro et al., 2003; Araújo, Delariva, Bonato, & Silva, 2011) and for the Neotropics (Lowe-Mcconnell, 1999). The high representativeness of order Cyprinodontiformes is due to the large abundance of *Poecilia reticulata* captured in the sections downstream of the artificial dam (P4, P5 and P6). *Poecilia reticulata*, known as lebiste, is not native from the upper Paraná River system; it was introduced in order to control the malaria mosquito (Langeani et al., 2007) and was released from aquariums (Oliveira et al., 2014). This species is a cause for concern because it is considered invasive and could possibly harm the biodiversity of ecosystems (Mack et al., 2000). *Gymnotus inaequilabiatus* was another species found in this study that is not native from the upper Paraná River system; however, its origin in this basin is unknown (Langeani et al., 2007).

Concerning the temporal analysis, the largest abundances found in the summer (December 2012) may reflect the increase in fish metabolisms at the end of the winter (September 2012), which causes an increase in reproduction after the end of this drier and colder season (Oliveira, Goulart, & Minte-Vera, 2004). Thus, for most species, an increase was found in the number of individuals during the hottest and rainiest season (summer - December 2012) and a decrease in June 2013 (early winter).

The Shannon-Wiener diversity index values among the sampling units support the River Continuum Concept by Vannote et al. (1980). The artificial dam situated downstream of P3 is a factor that may have accentuated this trend, preventing the flow of the downstream populations to the upstream units and reducing the diversity in them.

As for equitability, two sampling units upstream of the artificial dam (P1 and P3), which showed higher values in the index,also had the smallest richness values, with only three species each (*Astyanax bockmanni*, *Astyanax* sp. and *Bryconamericus iheringii*). The low species richness in P1 may have been caused by lower values of depth and flow rate, which reduces the possibility of new habitats, microhabitats, and reproduction sites (Kaufmann & Pinheiro, 2009). However, the dam can be considered responsible for the lower richness upstream, also verified in P3, because these units does not receive species from the Água Feia River, where the Chumbeiro Stream ends. Thus, the artificial dam has disconnected the Água Feia River from the upstream units of Chumbeiro Stream, and the dam (in P3) probably made the upstream units more similar to each other and dissimilar to the downstream units. This makes the artificial dam a discontinuity factor in the patterns of diversity and ecological processes related to the biota. Silva, Guibiani, Piana, and Delariva (2016) detected similar results with a natural barrier, checking greatest richness of unique species from the downstream of the barrier, and found a significant difference in the richness, equitability and abundance between upstream and downstream. Also in a survey conducted in China (Sui, Lu, Yan, Chen, & Jia, 2014), in streams of the first to the fifth order, the construction of dams apparently decreased the number of species upstream substantially.

The dam affects the stream fish communities in various ways, but two of the main direct impact mechanisms are the alteration of habitat upstream and downstream of dam and the fragmentation in the flow of fish populations. Consequently, this fragmentation of the fish populations can cause a reduction in gene flow, resulting in lower effective size of the populations and deleterious effects of endogamy (Hayes, Dodd, & Lessard, 2006). Transposition stairs of fishes can be built, but it not solves the problems caused by barrier, since the fish cannot cross this system efficiently (Fontes Jr., Castro-Santos, Makrakis, Gomes, & Latini, 2012). Fish cannot leave the stream or river that they are living in or migrating through to bypass a barrier, unlike other animals (Ottburg & Blank, 2015). Thus, the dam removal can restore connectivity of the river for fish movement (Poulos et al., 2014).

The sampling units P1 and P3 were without representative species in the CCA, were more

equitable and had lower species richness. The units P1 and P3 were also without representative species in the CCA, were more equitable and presented lower species richness, which was different from P5, which had several associated species. This result was expected because P5 was the only section with exclusive species (*Corydoras aeneus*, *Phalloceros harpagos* and *Synbranchus marmoratus*), in addition to being the unit with the highest richness and Shannon-Wiener diversity values, and the larger number of fish species increased the possible associations.

The results of this study indicate that Chumbeiro Stream, of the upper Paraná River, is strongly influenced by the environmental disruption caused by human impact, which is the artificial dam. Thus, this research indicates that the creation of dams, even when small, can significantly affect the richness and abundance of fish species from small lotic systems, such as streams, by modifying their environments.

Acknowledgements

The authors thank the following: *Universidade Estadual do Norte do Paraná* (UENP), Jacarezinho *campus*, for the research infrastructure; Cristina Pisicchio and Fernando Vieira for their scientific and personal contributions during sampling; and the *Instituto Chico Mendes de Conservação da Biodiversidade* (ICMBio/IBAMA) for granting license number 38779-1.

References

Abes, S. S., & Agostinho, A. A. (2001). Spatial patterns in fish distributions and structure of the ichthyocenosis in the Agua Nanci stream, upper Paraná River basin, Brazil. *Hydrobiologia, 445*(1), 217-227.

Agostinho, A. A., Bini, L. M., Gomes, L. C., Júlio Jr., H. F., Pavanelli, C. S., & Agostinho, C. S. (2004). Fishe assemnblages. In S. M. Thomaz, A. A. Agostinho, & N. S. Hahn (Eds.), *The Upper Paraná River and its foodplain: physical aspects, ecology and conservation* (p. 223-246). Leiden, NL: Backhuys Publishers.

Agostinho, A. A., Gomes, L. C., & Pelicice, F. M. (2007). *Ecologia e manejo de recursos pesqueiros em reservatórios do Brasil*. Maringá, PR: Eduem.

Agostinho, A. A., Pelicice, F. M., & Gomes, L. C. (2008). Dams and the fish fauna of the Neotropical region: impacts and management related to diversity and fisheries. *Brazilian Journal of Biology, 68*(4), 1119-1132.

Alekseevskii, N. I., Grinevskii, S. O., Efremov, P. V., Zalavskaya, M. B., & Grigoreva, I. L. (2003). Small Rivers and the ecological State of an Area. *Water Research, 30*(5), 540-549.

Araújo, M. I., Delariva, R. L., Bonato, K. O., & Silva, J. C. (2011). Fishes in first order stream in Ivaí River drainage basin, upper Paraná River basin, Paraná state, Brazil. *Check List, 7*(6), 774-777.

Buckup, P. A., Menezes, N. A., & Ghazzi, M. S. (2007). *Catálogo das espécies de peixes de água doce do Brasil*. Rio de Janeiro, RJ: Museu Nacional.

Caramaschi, E. P., Mazzoni, R., Bizerril, C. R. S. F., & Peres-Neto, P. R. (Eds.). (1999). *Ecologia de peixes de riachos* (Oecologia Brasiliensis, Vol. 6). Rio de Janeiro, RJ: UFRJ. Instituto de Biologia, Programa de Pós-Graduação em Ecologia.

Castro, R. M. C. (1999). Evolução da ictiofauna de riachos sul americanos: padrões gerais e possíveis processos casuais. In E. P. Caramaschi, R. Mazzoni, C. R. S. F. Bizerril, & P. R. Peres-Neto (Ed.), *Ecologia de peixes de riachos* (Oecologia Brasiliensis, Vol. 6, p. 139-155). Rio de Janeiro, RJ: UFRJ. Instituto de Biologia, Programa de Pós-Graduação em Ecologia.

Castro, R. M. C., Casatti, L., Santos, H. F., Ferreira, K. M., Ribeiro, A. C., Benine, R. C., Dardis, G. P., ... Lima, F. C. T. (2003). Estrutura e composição da ictiofauna de riachos do rio Paranapanema, sudeste e sul do Brasil. *Biota Neotropica, 3*(1), 1-14.

Entsminger, G. L. (2012). *EcoSim Professional: null modeling software for ecologists, version 1*. Montrose, CO: Acquired Intelligence Inc., Kesey-Bear, & Pinyon Publishing. Retrieved from: http://www.garyentsminger.com/ecosim/index.htm

Fontes Jr., H. M., Castro-Santos, T., Makrakis, S., Gomes, L. C., & Latini, J. D. (2012). A barrier to upstream migration in the fish passage of Itaipu Dam (Canal da Piracema), Paraná River basin. *Neotropical Ichthyology, 10*(4), 697-704.

Gardner, C., Coghlan Jr., S. M., Zydlewski, J., & Saunders, R. (2011). Distribution and abundance of stream fishes in relation to barriers: implications for monitoring stream recovery after barrier removal. *River Research and Applications, 29*(1), 65-78.

Graça, W. J., & Pavanelli, C. S. (2007). *Peixes da planície de inundação do alto rio Paraná e áreas adjacentes*. Maringá, PR: Eduem.

Griffiths, S. P. (2000). The use of clove oil as an anesthetic and method for sampling intertidal rockpool fishes. *Journal of Fish Biology, 57*(6), 1453-1464.

Gubiani, E. A., Gomes, L. C., & Agostinho, A. A. (2012). Estimates of population parameters and consumption/biomass ratio for fishes in reservoirs, Paraná State, Brazil. *Neotropical Ichthyology, 10*(1), 177-188.

Hayes, D. B., Dodd, H., & Lessard, J. (2006). Effects of small dams on cold water stream fish communities. *American Fisheries Society Symposium*, 587-602.

Kaufmann, V., & Pinheiro, A. (2009). Relações entre diversidade íctia e fatores hidrodinâmicos de um riacho na bacia do rio Uruguai. *Biota Neotropica, 9*(1), 47-53.

Langeani, F., Castro, R. M. C., Oyakawa, O. T., Shibatta, O. A., Pavanelli, C. S., & Casatti, L. (2007). Diversidade da ictiofauna do Alto Rio Paraná: composição atual e perspectivas futuras. *Biota Neotropica, 7*(3), 181-197.

Lowe-Mcconnell, R. H. (1999). *Estudos ecológicos de comunidades de peixes tropicais*. São Paulo, SP: Edusp.

Ludwig, J. A., & Reynolds, J. F. (1988). *Statiscal ecology: a primer on methods and computing*. New York, NY: John Wiley & Sons Inc.

Mack, R. N., Simberloff, D., Lonsdale, W. M., Evans, H., Clout, M., & Bazzaz, F. (2000). Biotic invasions: causes, epidemiology, global consequences, and control. *Ecological Applications, 10*(3), 689-710.

Oksanen, J., Blanchet, F. G., Kindt, R., Legendre, P., Minchin, P. R., O'hara, R. B., … Wagner, H. (2013). *Vegan: community ecology package. Version 2.0-8*. Retrieved from http://CRAN.R-project.org/package=vegan

Oliveira, E. F., Goulart, E., & Minte-Vera, C. V. (2004). Fish diversity along spatial gradients in the Itaipu Reservoir, Paraná, Brazil. *Brazilian Journal of Biology, 64*(3A), 447-458.

Oliveira, T. D., Reis, A. C., Guedes, C. O., Sales, M. L., Braga, E. P. R., Ratton, T. F., … Magalhães, A. L. B. (2014). Establishment of non-native guppy *Poecilia reticulata* (Peters, 1859) (Cyprinodontiformes: Poeciliidae) in an Municipal Park located in Minas Gerais State, Brazil. *Pan-American Journal of Aquatic Sciences, 9*(1), 21-30.

Ortega, J. C. G., Júlio, H. F., Gomes, L. C., & Agostinho, A. A. (2015). Fish farming as the main driver of fish introductions in Neotropical reservoirs. *Hydrobiologia, 746*(1), 147-158.

Ottburg, F., & Blank, M. (2015). Solutions to the Impacts of Roads and Other Barriers on Fish and Fish Habitat. In R. Van der Ree, D. J. Smith, & C. Grilo (Ed.), *Handbook of road ecology*. Chichester, UK: John Wiley & Sons. doi: 10.1002/9781118568170.ch45

Oyakawa, O. T., Akama, A., Mautari, K. C., & Nolasco, J. C. (2006). *Peixes de riachos da Mata Atlântica*. São Paulo, SP: Neotropica.

Pelicice, F. M., & Agostinho, A. A. (2008). Fish-passage facilities as ecological traps in large neotropical rivers. *Conservation Biology, 22*(1), 180-189.

Poff, N. L., & Hart, D. D. (2002). How dams vary and why it matters for the emerging science of dam removal. *Bio-science, 52*(8), 659-668.

Poulos, H., Miller, K., Kraczkowski, M., Welchel, A., Heineman, R., & Chernoff, B. (2014). Fish Assemblage Response to a Small Dam Removal in the Eightmile River System, Connecticut, USA. *Environmental Management, 54*(5), 1090-1101.

R Core Team. (2013). *R: a language and environment for statistical computing*. Vienna, Au: R Foundation for Statistical Computing. Retrieved from: http://www.R-project.org/

Rêgo, C. L., Pinese, O. P., Magalhães, P. A., & Pinese, J. F. (2008). Relação peso-comprimento para *Prochilodus lineatus* (Valenciennes, 1836) e *Leporinus friderici* (Bloch, 1794) (Characiformes) no reservatório de Nova Ponte-EPDA de Galheiro, rio Araguari, MG. *Revista Brasileira de Zoociências, 10*(1), 13-21.

Reis, R. E., Kullander, S. O., & Ferraris Jr., C. J. (Org.). (2003). *Check list of the freshwater fishes of South and Central America*. Porto Alegre, RS: EdiPUCRS.

Sampaio, T. (1944). Relatório dos rios Itapetininga e Paranapanema. *Revista do Instituto Geográfico e Geológico de São Paulo, 2*(3), 30-81.

Schaefer, S. A. (1998). Conflict and resolution: impact of new taxa on phylogenetic studies of the neotropical cascudinhos (Siluroidei: Loricariidae). In L.R., R. E. Malabarba, R. P. Reis, Z. M. S. Vari, & C. A. S. Lucena (Eds.), *Phylogeny and classification of neotropical fishes* (p. 375-400). Porto Alegre, RS: EdiPUCRS.

Silva, J. C., Gubiani, É. A., Piana, P. A., & Delariva, R. L.. (2016). Effects of a small natural barrier on the spatial distribution of the fish assemblage in the Verde River, Upper Paraná River Basin, Brazil. *Brazilian Journal of Biology*, Epub May 17, 2016. doi.org/10.1590/1519-6984.01215

Statsoft Inc. (2005). *Statistica (data analysis software system) version 7.1.* Tulsa, OK.

Sui, X-Y., Lu, Z., Yan, Y-Z., Chen, Y-F., & Jia, Y-T. (2014). Influence of a large dam on the longitudinal patterns of fish assemblages in Qingyi Stream. *Dong wu xue yan jiu, Zoological Research, 35*(5), 362-72.

Vannote, R. L., Minshall, G. W., Cummins, K. W., Sedell, J. R., & Cushing, C. E. (1980). The river continuum concept. *Canadian Journal of Fisheries and Aquatic Sciences, 37*(1), 130-137.

Vasconcelos, L. P., Alves, D. C., & Gomes, L. C. (2014). Fish reproductive guilds downstream of dams. *Journal of Fish Biology, 85*(5), 1489-1506.

Ward, J. V., & Stanford, J. A. (1983). The serial discontinuity concept of lotic ecosystems. In T. D. Fontaine, & S. M. Bartell (Eds), *Dynamics of lotic ecosystems* (p. 29-42). Ann Arbor, MI: Ann Arbor Science.

Received on May 15, 2016.
Accepted on June 15, 2016.

License information: This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.