Acta Scientiarum
http://www.uem.br/acta
ISSN printed: 1679-9283
ISSN on-line: 1807-863X
Doi: 10.4025/actascibiolsci.v37i3.27356

Contribution of different mesohabitats to the maintenance of fish richness and diversity in the lower Preto River

Jaquelini Oliveira Zeni[1*], Ana Cláudia Santos[1] and Fernando Rogério Carvalho[2]

*[1]Departamento de Zoologia e Botânica, Laboratório de Ictiologia, Universidade Estadual Paulista "Júlio de Mesquita Filho", Rua Cristóvão Colombo, 2265, 15054-000, São José do Rio Preto, São Paulo, Brazil. [2]Programa de Pós-graduação em Zoologia, Instituto de Biociências, Universidade Federal de Mato Grosso, Cuiabá, Mato Grosso, Brazil. *Author for correspondence. E-mail: jackezeni@yahoo.com.br*

ABSTRACT. The presence of different mesohabitats in freshwater systems can support higher local and regional fish richness. Thus, their suppression by dam-building represents a real threat to aquatic biodiversity. Our aims were: (1) to survey the fish fauna in two different mesohabitats in lower Preto River: a riffle indirectly threatened by dam-building and a run with different physical structure; and (2) to analyze and compare the fish community structure in these different mesohabitats. Six samplings were made during one year in two reaches (R1 and R2). We conducted a 'one way' ANOSIM to assess the differences in fish community structure between R1 and R2. Fifty-three species were recorded, with the occurrence of *Aphyocheirodon hemigrammus* and *Myleus tiete*, two Brazilian threatened species. The highest richness was observed in R2. Nevertheless, diversity and evenness were significantly higher in R1. Rheophilic species were more common and restricted to R1 and species typical of lentic environments were predominant in R2. Fish community structure was different between R1 and R2 ($R = 1$, $p = 0.02$). Our results demonstrated that mesohabitats mosaic through rivers can contribute to the maintenance of a diverse fish assemblage.

Keywords: conservation, dam-building, ichthyofauna, riffles, threatened species.

Contribuição de diferentes meso-hábitats para a manutenção da riqueza e diversidade de peixes no baixo rio Preto

RESUMO. A presença de diferentes meso-hábitats em sistemas de água doce pode suportar alta riqueza local e regional de peixes. Assim, sua supressão pela construção de reservatórios representa uma ameaça real para a biodiversidade aquática. Nossos objetivos foram: (1) inventariar a ictiofauna de duas áreas na porção inferior do rio Preto, uma corredeira indiretamente ameaçada pela construção de um reservatório e um corredor com estrutura física diferente; e (2) verificar se esses meso-hábitats apresentam distintas estruturas de comunidade de peixes. Seis amostragens foram conduzidas durante um ano em dois trechos (R1 e R2). Uma ANOSIM *one way* foi realizada para investigar se R1 e R2 apresentavam estruturas de comunidade diferentes. Foram coletadas 53 espécies, com ocorrência de *Aphyocheirodon hemigrammus* e *Myleus tiete*, duas espécies brasileiras ameaçadas. A maior riqueza foi registrada em R2. Entretanto, diversidade e equabilidade foram significativamente maiores em R1. Espécies reofílicas foram mais comuns em R1, enquanto espécies de ambientes lênticos foram mais abundantes em R2. R1 e R2 apresentaram diferenças significativas na estrutura da comunidade ($R = 1$, $p = 0,02$). Nossos resultados demonstraram que um mosaico de meso-hábitats ao longo de ambientes aquáticos pode contribuir para a manutenção da diversidade das assembleias de peixes.

Palavras-chave: conservação, represamentos, ictiofauna, cachoeira, espécies ameaçadas.

Introduction

Brazil is the richest country in the world concerning freshwater fish, with approximately 3,000 species recorded to date (ICMBio, 2014). Despite this great richness and diversity, several Brazilian lotic systems are under strong anthropogenic pressure, especially related to dam-building, which modifies running (lotic) into standing (lentic) water ecosystems. This change has been associated with river homogenization, since it replaces the natural physical heterogeneity of the river by a large reservoir (AGOSTINHO et al., 2005). Different mesohabitats with particular characteristics (water velocity, depth, and substrate) in the same river can influence the fish community (YAN et al., 2011), supporting unique communities and contributing to species coexistence (TERESA; CASATTI, 2012). Thus, physical habitat can act as environmental filters by maximizing energy gain and reducing costs to different species (HALL et al., 1992). In this context, physical habitat homogenization caused by dam-building could be associated with deleterious consequences to aquatic biota (JOHNSON et al., 2008; WINEMILLER et al., 2008) and it may represent one of the most significant threats to diversity of freshwater fish (AGOSTINHO et al., 2005).

Despite these well-known negative impacts of dam-building, there are many hydroelectric projects in several Brazilian drainages, including in relative small rivers (AGOSTINHO et al., 2007). According to the hydroelectric sector, Small Hydroelectric Plants (SHPs) cause less impact due to small reservoir area. However, the hydropower potential of these systems is usually low in contrast with high fish richness and endemism (SCOTT; HELFMAN, 2001). The upper Paraná River basin comprises nearly 12% of the Brazilian fish diversity, and also contains an increasing number of new taxa, with more than 40 species described across the last five years (CARVALHO; LANGEANI, 2013). According to Liermann et al. (2012), the upper Paraná River basin is one of the most threatened ecoregions, due to heavy dam obstruction (more than 40% of the basin water surface) and above-average species richness and endemism. In the northwestern São Paulo State, two areas from the lotic drainage of the upper Paraná River basin, 'Cachoeira do Talhadão', in the Turvo River and 'Cachoeira de São Roberto', in the lower Preto River, are targeted by hydroelectric projects such as SHPs (HABTEC... 2010). However, the environmental cost associated with the impoundment in these areas could be very high, especially due to the lack of information about their importance concerning the fish richness, diversity, and conservation.

Therefore, in view of the dam-building pressure in this region and the physical and biological homogenization caused by the conversion of lotic to lentic habitats, the goals of this study were: (1) to survey the fish fauna in two different mesohabitats in lower Preto River, a riffle indirectly threatened by dam-building and a run with different physical structure; and (2) to analyze and compare the fish community structure in these different mesohabitats.

Material and Methods

Study area

This study was performed in the Preto River, one of the most important rivers of the northwestern São Paulo State. The Preto River runs approximately 230 km from the headwaters (Cedral, São Paulo State) to its confluence with the Turvo River, in the upper Paraná River basin (COMITETG, 2009). Along its continuum, the upper Preto River is highly altered within an urban area at São José do Rio Preto city (São Paulo State), by stream flow channeling and impoundments. Near to its mouth, in the Turvo River, Preto River has a series of riffles, a tourist and recreation area targeted by dam-building (CETESB), popularly known as 'Cachoeira de São Roberto' (Pontes Gestal, São Paulo State).

To conduct our study two structurally different reaches were sampled in the lower Preto River (Figure 1). The reach 1 (R1), 'Cachoeira de São Roberto', near the confluence (approximately 5 km) with the Turvo River (20°11'09.3"S 49°41'06.4"W), is characterized by high water velocity with some slope, substrate primarily composed of slab and basaltic boulders, and sparse riparian forest composed by few trees. The reach 2 (R2) is located 1.8 km upstream from R1 (river distance), near the mouth of the Botelho stream (20°11'38.3"S 49°41'30.1"W), and it is characterized by low water velocity, sandy substrate with pebbles, and marginal vegetation consisting of grasses (Poaceae) (Figure 2).

Sampling and data analysis

Six samplings were conducted during one year (April 2013 to February 2014) in both sections. Fish were sampled using a small net (2.0 x 0.95 m, 2 mm mesh size) and a dip net (0.8 x 0.4 m, 2 mm mesh size). Standardized sampling effort (involving three collectors) was performed for two hours over a distance of approximately 150 m at each site. Fish were fixed in 10% formalin for 72 hours and then transferred to 70% alcohol for final preservation. Specimens were identified, counted, weighed, and vouchered in the fish collection of the Department of Zoology and Botany at Universidade Estadual Paulista "Júlio de Mesquita Filho", *campus* of São José do Rio Preto, São Paulo State (DZSJRP).

Species abundance in R1 and R2 was grouped and randomized as a function of the sampling effort, *i.e.*, the number of sampling events (12 events, 6 from R1 plus 6 from R2), to generate an accumulation curve for the area (lower Preto River). The Chao 1 index (with 100 permutations), a function of the ratio of the number of species with only one specimen in a sample ('singletons') to the number of species with two specimens ('doubletons') was used to estimate the fish richness of the area. According to Magurran (2011), richness estimators based on Chao 1 are robust and are useful for revealing the true richness of an area. All analyses described above were performed in R statistical software. The Shannon index (based on natural logarithms) (alpha diversity) and Pielou evenness were calculated for each site (R1 and R2) in the software Primer 6 (CLARKE; GORLEY, 2006), and then compared by a t-test in the software Statistica 7.0.

The raw data of species abundance was square-root transformed to reduce the contribution of highly abundant species and used to create a Bray-Curtis similarity matrix. To assess the differences in fish community structure between R1 and R2, this Bray-Curtis matrix was then compared using a 'one way' ANOSIM with 999 permutations, at significance level of 0.05. A SIMPER routine was used to identify which species contributed most to the dissimilarity between sites. Analyses referring to fish community structure were performed in Primer 6.0 (CLARKE; GORLEY, 2006).

Results

A total of 53 species was identified in both sites, R1 and R2, distributed into five orders: Characiformes (31 spp.), Siluriformes (14 spp.), Gymnotiformes (4 spp.), Cyprinodontiformes (1 sp.), and Perciformes (3 spp.) (Table 1). Characiformes and Siluriformes were the most species-rich orders, with more than 80% of the total number of species. Four species are non-native to the Preto River and upper Paraná River basin: *Erythrinus erythrinus* (Block & Schneider, 1801), *Laetacara araguaiae* Ottoni & Costa, 2009, *Leporinus macrocephalus* Garavello & Britski, 1988, *Metynnis lippincottianus* (Cope, 1858), and *Poecilia reticulata* Peters, 1859.

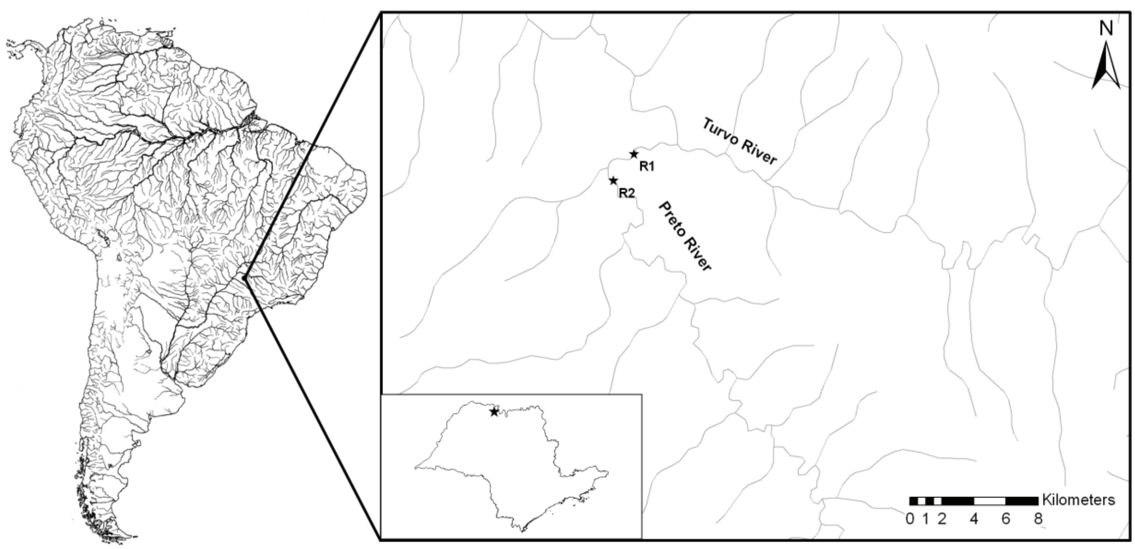

Figure 1. Location of the two stretches (R1 - Cachoeira de São Roberto and R2 - near the mouth of the Botelho stream) in the lower Preto River, Northwestern São Paulo State, Brazil.

Figure 2. Stretches sampled in the lower Preto River. R1 – Cachoeira de São Roberto, a riffle mesohabitat with high water velocity with some slope, substrate primarily composed of slab and basaltic boulders; R2 – near the mouth of the Botelho stream, a run mesohabitat with low water velocity, sandy substrate and marginal grasses.

Table 1. Species abundance (N) and biomass (g) sampled in the lower Preto River. Fish classification followed Reis et al. (2003), except for Serrasalmidae, according to Calcagnotto et al. (2005).

	R1		R2	
	N	Biomass	N	Biomass
CHARACIFORMES				
Acestrorhynchidae				
Acestrorhynchus lacustris (Lütken, 1875)	0	0	4	0.2
Anostomidae				
Leporinus friderici (Bloch, 1794)	7	150.6	1	0.9
Leporinus macrocephalus Garavello & Britski, 1988	1	4.9	0	0
Leporinus octofasciatus Steindachner, 1915	2	19.0	0	0
Leporinus striatus Kner, 1858	0	0	1	1.2
Characidae				
Aphyocheirodon hemigrammus Eigenmann, 1915	0	0	1	0.1
Astyanax altiparanae Garutti & Britski, 2000	26	107.5	13	5.2
Astyanax fasciatus (Cuvier, 1819)	280	358.1	12	5.0
Bryconamericus stramineus Eigenmann, 1908	860	404.4	3	1.1
'*Cheirodon*' *stenodon* Eigenmann, 1915	10	2.5	58	11.6
Galeocharax gulo (Cope, 1870)	0	0	1	0.4
Hemigrammus marginatus Ellis, 1911	0	0	6	2.5
Hyphessobrycon eques (Steindachner, 1882)	0	0	1561	449.0
Moenkhausia intermedia Eigenmann, 1908	18	64.2	14	14.2
Moenkhausia cf. *sanctaefilomenae* (Steindachner,1907)	0	0	3	2.1
Odontostilbe sp.	4	1.2	20	1.5
Oligosarcus pintoi Campos, 1945	0	0	2	0.1
Piabina argentea Reinhardt, 1867	30	29.6	26	8.2
Planaltina britskii Menezes, Weitzman & Burns, 2003	85	23.2	5	1.2
Serrapinnus heterodon (Eigenmann, 1915)	8	3.2	37	14.2
Serrapinnus notomelas (Eigenmann, 1915)	1	0.1	87	22.1
Crenuchidae				
Characidium cf. *zebra* Eigenmann, 1909	25	31.2	16	3.5
Curimatidae				
Cyphocharax modestus (Fernández-Yépez, 1948)	0	0	5	9.1
Steindachnerina insculpta (Fernández-Yépez, 1948)	2	26.2	6	32.1
Erythrinidae				
Erythrinus erythrinus (Bloch & Schneider, 1801)	0	0	1	0.6
Hoplias cf. *malabaricus* (Bloch, 1794)	0	0	3	0.9
Parodontidae				
Apareiodon affinis (Steindachner, 1879)	14	42.7	0	0
Parodon nasus Kner, 1859	2	24.4	0	0
Serrasalmidae				
Myleus tiete (Eigenmann & Norris, 1900)	0	0	1	0.5
Metynnis lippincottianus (Cope, 1870)	1	48.0	0	0
Serrasalmus maculatus Kner, 1858	1	2.3	5	1.6
CYPRINODONTIFORMES				
Poeciliidae				
Poecilia reticulata Peters, 1859	1	0.1	11	0.7
GYMNOTIFORMES				
Sternopygidae				
Eigenmannia guairaca Peixoto, Dutra & Wosiacki, 2015	0	0	15	71.6
Eigenmannia virescens (Valenciennes, 1836)	3	15.4	3	27.5
Sternopygus macrurus (Bloch & Schneider, 1801)	0	0	4	86.7
Gymnotidae				
Gymnotus sylvius Albert & Fernandes-Matioli, 1999	23	157.8	41	155.2
PERCIFORMES				
Cichlidae				
Crenicichla britskii Kullander, 1982	1	4.5	5	31.9
Crenicichla jaguarensis Haseman, 1911	1	8.3	2	12.0
Laetacara araguaiae Ottoni & Costa, 2009	0	0	1	1.7
SILURIFORMES				
Callichthyidae				
Corydoras aeneus (Gill, 1858)	0	0	1	2.5
Hoplosternum littorale (Hancock, 1828)	0	0	3	90.4
Heptapteridae				
Cetopsorhamdia iheringi Schubart & Gomes, 1959	5	5.0	0	0
Imparfinis schubarti (Gomes, 1956)	5	21.1	0	0
Pimelodella avanhandavae Eigenmann, 1917	4	21.4	5	11.9
Rhamdia cf. *quelen* (Quoy & Gaimard, 1824)	4	12.3	2	1.6
Pimelodidae				
Pimelodus maculatus Lacepède, 1803	1	65.9	0	0
Loricariidae				
Hisonotus insperatus Britski & Garavello, 2003	1	0.3	0	0
Hypostomus albopunctatus (Regan, 1908)	25	803.8	0	0
Hypostomus ancistroides (Ihering, 1911)	58	118.8	49	148.9
Hypostomus cf. *iheringii* (Regan, 1908)	58	471.5	3	35.6
Hypostomus nigromaculatus (Schubart, 1964)	47	253.3	0	0
Hypostomus strigaticeps (Regan, 1908)	1	7.3	0	0
Pterygoplichthys ambrosettii (Holmberg, 1893)	0	0	10	0.1

The species boundaries overlapped in some cases, with 35 species recorded in R1 and 41 in R2. However, alpha diversity was significantly greater (t = 2.38; p = 0.03) in R1 (mean = 1.58; SD = 0.34) than in R2 (mean = 1.12; SD = 0.31). Likewise, evenness was statistically higher (t = 3.66; p = 0.004) in R1 (average = 0.57; SD = 0.09) than in R2 (mean = 0.38; SD = 0.08). Abundance was higher in R2 (2,047 individuals) than in R1 (1,615 individuals) while, higher biomass was found in R1 (3.3 kg) than in R2 (1.25 kg). In general, rheophilic species with physical and behavioral adaptations to survive in high flow environments were more common and restricted to R1 and species typical of lentic environments were predominant in R2. The estimated richness for the studied area (lower Preto River) was 65 species (± 8).

Fish community structure showed significant differences between R1 and R2 (R = 1, p = 0.02), in which the species that contributed most to dissimilarity (78.82%) were *Astyanax fasciatus* (Cuvier, 1819), *Bryconamericus stramineus* Eigenmann, 1908, '*Cheirodon*' *stenodon* (Eigenmann, 1915), *Hyphessobrycon eques* (Steindachner, 1882), *Planaltina britskii* Menezes, Weitzman & Burns 2003, *Piabina argentea* Reinhardt, 1867, *Serrapinnus notomelas* (Eigenmann, 1915), *Hypostomus ancistroides* (Ihering, 1911), *Hypostomus* cf. *iheringii* (Regan, 1908), *Hypostomus nigromaculatus* (Schubart, 1964), and *Gymnotus sylvius* Albert & Fernandes-Matioli, 1999.

Discussion

According to our results, habitat characteristics can influence several community aspects, like fish richness, diversity, abundance, and biomass. The section R2, with lower water velocity, sand substrate and marginal grasses, showed higher fish richness and abundance, while R1 (Cachoeira de São Roberto) presented greater fish biomass, diversity, and evenness. Additionally, the community structure was different between R1 and R2. Species sampled in the lower Preto River represent 15% of the total species recorded in the upper Paraná River basin (CARVALHO; LANGEANI, 2013), and this number can be higher in view of the richness estimate (65 spp.) for the area. The high species richness found in this study (53 spp.) showed the importance of this river portion to the maintenance and conservation of the ichthyofauna in this basin.

The lower alpha diversity and evenness registered in R2 were due to the dominance of the characids *Hyphessobrycon eques* and *Serrapinnus notomelas*. Both species are associated with grasses (Poaceae) and macrophytes on the riverbanks, similarly to other studies (*i.e.* CASATTI et al., 2003; CETRA; PETRERE JR., 2007). Marginal grasses associated with deforestation are usually responsible for physical, biological, and functional stream homogenization (BUNN et al., 1997; CORTELEZZI et al., 2013; CASATTI et al., 2015). Nevertheless, in large rivers less connected to riparian vegetation and, consequently with lower input of wood debris (important resource to stream habitat complexity), these marginal grasses can promote physical habitat heterogeneity and increase the availability of microcrustaceans (CORTELEZZI et al., 2013) and aquatic insects (CENEVIVA-BASTOS; CASATTI, 2014), food resources consumed by small opportunistic species, such as *Hyphessobrycon eques* (PELICICE; AGOSTINHO, 2006) and *Serrapinnus notomelas* (ZENI; CASATTI, 2014), respectively. The presence of marginal grasses can also favor medium and large-sized species, since juveniles of *Acestrorhynchus lacustris* (Lütken, 1875), *Erythrinus erythrinus*, *Galeocharax gulo* (Cope, 1870), *Hoplias* cf. *malabaricus* (Block, 1794), *Myleus tiete* (Eigenmann & Norris, 1900), and *Pterygoplichthys ambrosettii* (Holmberg, 1893) were found along the banks during the period of fish migration and reproduction ('piracema'). According to Rozas and Odum (1988), submerged aquatic vegetation can provide refuges from predators, reducing predation pressure and increasing survival of large-bodied species juveniles. One of them, *Myleus tiete*, just as well *Aphyocheirodon hemigrammus*, are listed as threatened for Brazil and São Paulo State (AGOSTINHO et al., 2003; OYAKAWA et al., 2009; ICMBio, 2014). In this context, marginal areas occupied by grasses in large rivers can play a nursery role, besides increasing spatial heterogeneity, important factors for the maintenance of different fish species, which can play different functional roles in the community.

Significant differences in community structure between the sections may result from the interaction between structural characteristics (physical heterogeneity and microhabitat availability), food resource availability and from their consequences on the species fitness. Species are usually more abundant at sites where energy gain is maximized, *i.e.*, where the ratio of the energy obtained vs the energy spent on maintenance is high (HALL et al., 1992). In this way, habitat structural characteristics, such as water velocity, substrate and depth, can be 'species-selective' through their influence on this energetic relationship, increasing or decreasing the maintenance costs of the organism. Thus, it is possible to observe a set of morphological features shared among the most frequent and abundant species in each site. In R1, Loricariidae (*i.e.*, *Hypostomus* spp.) with a low body depth, ventral mouth and pectoral fins (used to deflect water flow) can attach to rocky substrates, decreasing the energy required for establishment and maintenance at sites with high water velocity. A shallow depth and a rocky substrate provide suitable surfaces for periphyton growth, a food item generally used by these species (GARAVELLO; GARAVELLO, 2004). Furthermore, drift feeders such as *Astyanax fasciatus*, *Bryconamericus stramineus*, and *Planaltina britskii* obtain the maximum input of food in sites with running water flow. For these species, energy efficiency, namely, the energy acquired from food resources minus the energy spent in uninterrupted swimming, is high in riffles, increasing the abundance of these species in R1. The differences in these species abundance between R1 and R2 were the major factor accounting for the dissimilarity on the fish community structure.

In this context, spatial heterogeneity of the mesohabitat represents a crucial conservation measure, because it allows the coexistence of different species in the same environment. However, a general trend towards the homogenization of aquatic ecosystems has been observed worldwide (RAHEL, 2002) and dam-building is one of the most significant impacts related with all levels of homogenization: physical, biological, and functional. The loss of the natural river mesohabitat mosaic caused by an artificial reservoir, usually lead to changes on species composition by replacing high trophic level specialist into low trophic level generalist species (HOEINGHAUS et al., 2009). The negative consequences of dam-building on fish community structure can be observed in the upper Preto River, which has a complex of three dams used to supply water to São José do Rio Preto city, São Paulo State. In a study performed in these artificial reservoirs, Andrade (2003) found higher frequency of non-native species, especially *Tilapia rendalli* (Boulenger, 1897) and *Oreochromis niloticus* (Linnaeus, 1758). At the present moment, the construction of Small Hydroelectric Plants on the lower Preto River (R1) has not been approved by the “Companhia Ambiental do Estado de São Paulo” (CETESB) because the alterations caused by these projects are environmentally impracticable (CETESB, 2012). According to our findings, the presence of different mesohabitats in the lower Preto River can support higher fish richness with occurrence of rare species or threatened with extinction, such as *Aphyocheirodon hemigrammus* and *Myleus tiete*. Thus, the fish community that will be affected by this impoundment has to be taken in consideration, especially because this change may affect the local and regional pool of species. In this way, the fish fauna surveys in these areas are important not only in terms of the diverse and unknown fauna of the region, but can also guide and/or support management and conservation measures of aquatic systems. As a matter of fact, this paper can bring one important contribution that can support government decisions regarding fish conservation.

Conclusion

The results demonstrate that the mosaic of mesohabitats along a river can contribute to the maintenance of a diverse fish assemblage, consequently promoting higher local and regional fish richness. It is possible that abiotic characteristics, such as water velocity, substrate composition, and marginal area interact with biotic aspects (competition and predation pressure) and influence species occurrence. In this context, the physical habitat homogenization due to the suppression of these mesohabitat patches by impoundments will threaten not only fish richness and diversity in the lower Preto River, but also the regional pool of species of the upper Paraná River basin. Thus, studies conducted before damming can represent a valuable tool for governmental decisions toward fish conservation.

Acknowledgements

We are grateful to Carla Cristina Gonçalves, José Carlos dos Santos, Mateus Jordão dos Santos, Carlos Henrique Gonçalves, Serly Cristina da Silva Gonçalves, Elena Maria Jordão Santos, and Tony Carlos Martins Barão for fieldwork assistance; to Profa. Lilian Casatti (DZSJRP) for valuable contribution to this paper; to Prof. Cláudio Henrique Zawadzki (UEM) for the identification of *Hypostomus*; to Fernanda Martins (DZSJRP) for the identification of Hypoptopomatinae; Gabriel Lourenço Brejão (DZSJRP) for the help with figure 1; to Prof. Francisco Langeani (DZSJRP) for the laboratorial access. Collection permission was provided by “Instituto do Meio Ambiente e dos Recursos Naturais Renováveis – IBAMA” (#4574-1). FRC and JOZ are financially supported by Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) through the grants #2011/11422-8 and #2012/20280-5, respectively, and ACS is finacially supported by CAPES/MEC (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior do Ministério da Educação).

References

AGOSTINHO, A. A.; THOMAZ, S. M.; GOMES, L. C. Conservação da biodiversidade em águas continentais do Brasil. **Megadiversidade**, v. 1, n. 1, p. 70-78, 2005.

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

AGOSTINHO, A. A.; GOMES, L. C.; SUZUKI, H. I.; JÚLIO, H. F. Migratory fishes of the upper Paraná river Basin, Brazil. In: CAROLSFELD, J.; HARVEY, B.; ROSS, C.; BAER, A. (Ed.). **Migratory fishes of South America**: biology, fisheries and conservation status. Washington, D.C.: World Fisheries Trust, World Bank, IDRC, 2003. p. 19-98.

ANDRADE, V. X. L. **Ictiofauna da represa municipal de São José do Rio Preto, SP, rio Preto, afluente do rio Turvo, drenagem do rio Grande**: diversidade e reprodução. 2003. 53f. Dissertação (Mestrado em Aquicultura)-Universidade Estadual Paulista "Júlio de Mesquita Filho", Jaboticabal, 2003.

BUNN, S. E.; DAVIES, P. M.; KELLAWAY, D. M. Contributions of sugar cane and invasive pasture grass to the aquatic food web of a tropical lowland stream. **Marine and Freshwater Research**, v. 48, n. 2, p. 173-179, 1997.

CALCAGNOTTO, D.; SCHAEFER, S. A.; DeSALLE, R. Relationships among characiform fishes inferred from analysis of nuclear and mitochondrial gene sequences. **Molecular Phylogenetics and Evolution**, v. 36, n. 1, p. 135-153, 2005.

CARVALHO, F. R.; LANGEANI, F. *Hyphessobrycon uaiso*: new characid fish from the rio Grande, upper rio Paraná basin, Minas Gerais State (Ostariophysi: Characidae), with a brief comment about some types of *Hyphessobrycon*. **Neotropical Ichthyology**, v. 11, n. 3, p. 525-536, 2013.

CASATTI, L.; MENDES, H. F.; FERREIRA, K. M. Aquatic macrophytes as feeding site for small fishes in the Rosana Reservoir, Paranapanema River, Southeastern Brazil. **Brazilian Journal of Biology**, v. 63, n. 2, p. 213-222, 2003.

CASATTI, L.; TERESA, F. B.; ZENI, J.O.; RIBEIRO, M. D.; BREJÃO, G. L.; CENEVIVA-BASTOS, M. More of the same: high functional redundancy in stream fish assemblages from tropical agroecosystems. **Environmental Management**, v. 55, n. 6, p. 1300-1314, 2015.

CENEVIVA-BASTOS, M.; CASATTI, L. Shading effects on community composition and food web structure of a deforested pasture stream: Evidences from a field experiment in Brazil. **Limnologica**, v. 46, n. 1, p. 9-21, 2014.

CETESB-Companhia Ambiental do Estado de São Paulo. **Parecer técnico n.º 024/12/IE**, 2012. Available from: <http://www.cetesb.sp.gov.br/noticia/382>. Access on: July 2, 2014.

CETRA, M.; PETRERE JR., M. Associations between fish assemblage and riparian vegetation in the Corumbataí River Basin (SP). **Brazilian Journal of Biology**, v. 67, n. 2, p. 191-195, 2007.

CLARKE, K. R.; GORLEY, R. N. **Primer v6**: user manual/tutorial. Plymouth: Plymouth Marine Laboratory, 2006.

COMITETG-Comitê da Bacia Hidrográfica do Turvo/Grande. **Plano ambiental para a bacia de contribuição da represa de abastecimento de São José do Rio Preto**. São José do Rio Preto, SP: CBH/TG, 2009.

CORTELEZZI, A.; SIERRA, M. V.; GÓMEZ, N., MARINELLI, C.; CAPÍTULO, A. R. Macrophytes, epipelic biofilm, and invertebrates as biotic indicators of physical habitat degradation of lowland streams (Argentina). **Environmental Monitoring and Assessment**, v. 185, n. 7, p. 5801-5815, 2013.

GARAVELLO, J. C.; GARAVELLO, J. P. Spatial distribution and interaction of four species of the catfish genus *Hypostomus* Lacépède with bottom of Rio São Francisco, Canindé do São Francisco, Sergipe, Brazil (Pisces, Loricariidae, Hypostominae). **Brazilian Journal of Biology**, v. 64, n. 3, p. 591-598, 2004.

HABTEC ENGENHARIA AMBIENTAL LTDA. **RIMA** - Relatório de impacto ambiental. Pequenas Centrais Hidrelétricas de Talhado e Foz do Preto. Departamento de Avaliação Ambiental de Empreendimentos – IE, São José do Rio Preto, 2010.

HALL, C. A. S.; STANFORD, J. A.; HAUER, F. R. The distribution and abundance of organisms as a consequence of energy balances along multiple environmental gradients. **Oikos**, v. 65, n. 3, p. 377-390, 1992.

HOEINGHAUS, D. J.; AGOSTINHO, A. A.; GOMES, L. C.; PELICICE, F. M.; OKADA, E. K.; LATINI, J. D.; KASHIWAQUI, E. A. L.; WINEMILLER, K. O. Effects of river impoundment on ecosystem services of large tropical rivers: embodied energy and market value of artisanal fisheries. **Conservation Biology**, v. 23, n. 5, p. 1222-1231, 2009.

ICMBio-Instituto Chico Mendes de Conservação da Biodiversidade. **Lista de espécies ameaçadas**. 2014. Available from: <http://www.icmbio.gov.br/portal/biodiversidade/fauna-brasileira/lista-de-especies.html?option=com_icmbio_fauna_brasileira&task=listaEspecie>. Access on: June 4, 2014.

JOHNSON, P. T. J.; OLDEN, J. D.; ZANDEN, M. J. V. Dam invaders: impoundments facilitate biological invasions into freshwaters. **Frontiers in Ecology and the Environment**, v. 6, n. 7, p. 357-363, 2008.

LIERMANN, C. R.; NILSSON, C.; ROBERTSON, J.; NG, R. Y. Implications of dam obstruction for global freshwater fish diversity. **BioScience**, v. 62, n. 6, p. 539-548, 2012.

MAGURRAN, A. E. **Medindo a diversidade biológica**. Curitiba: Editora da UFPR, 2011.

OYAKAWA, O. T.; MENEZES, N. A.; SHIBATTA, O. A.; LIMA, F. C. T.; LANGEANI, F.; PAVANELLI, C. S.; NIELSEN, D. T. B.; HILSDORF, A. W. S. Peixes de água doce. In: BRESSAN, P. M.; KIERULFF, M. C. M.; SUGIEDA, A. M. (Ed.). **Fauna ameaçada de extinção no Estado de São Paulo**: Vertebrados. São Paulo: Fundação Parque Zoológico de São Paulo, Secretaria do Meio Ambiente, 2009. p. 350-424.

PELICICE, F. M.; AGOSTINHO, A. A. Feeding ecology of fishes associated with *Egeria* spp. patches in a tropical reservoir, Brazil. **Ecology of Freshwater Fish**, v. 15, n. 1, p. 10-19, 2006.

RAHEL, F. J. Homogenization of freshwater faunas. **Annual Review of Ecology, Evolution, and Systematics**, v. 33, n. 1, p. 291-315, 2002.

REIS, R. E.; KULLANDER, S. O.; FERRARIS-JR., C. F. **Check list of the freshwater fishes of South and Central America**. Porto Alegre: Editora PUCRS, 2003.

ROZAS, L. P.; ODUM, W. E. The role of submerged aquatic vegetation in influencing the abundance of nekton on contiguous tidal fresh-water marshes. **Journal of Experimental Marine Biology and Ecology**, v. 114, n. 2, p. 289-300, 1988.

SCOTT, M. C.; HELFMAN, G. S. Native invasions, homogenization, and the mismeasure of integrity of fish assemblages. **Fisheries**, v. 26, n. 11, p. 6-15, 2001.

TERESA, F. B.; CASATTI, L. Influence of forest cover and mesohabitat types on functional and taxonomic diversity of fish communities in Neotropical lowland streams. **Ecology of Freshwater Fish**, v. 21, n. 3, p. 433-442, 2012.

WINEMILLER, K. O.; LÓPEZ-FERNÁNDEZ, H.; TAPHORN, D. C.; NICO, L. G.; DUQUE, A. B. Fish assemblages of the Casiquiare River, a corridor and zoogeographic filter for dispersal between the Orinoco and Amazon basins. **Journal of Biogeography**, v. 35, n. 9, p. 1551-1563, 2008.

YAN, Y.; XIANG, X.; CHU, L.; ZHAN, Y.; FU, C. Influences of local habitat and stream spatial position on fish assemblages in a dammed watershed, the Qingyi Stream, China. **Ecology of Freshwater Fish**, v. 20, n. 2, p. 199-208, 2011.

ZENI, J. O.; CASATTI, L. The influence of habitat homogenization on the trophic structure of fish fauna in tropical streams. **Hydrobiologia**, v. 726, n. 1, p. 259-270, 2014.

Received on April 10, 2015.
Accepted on September 8, 2015.