Acta Limnologica Brasiliensia

Publication of the Brazilian Association of Limnology

Original Article
Acta Limnologica Brasiliensia, 2023, vol. 35, e26
https://doi.org/10.1590/S2179-975X0823
ISSN 2179-975X on-line version

Fish assemblage and current status of the upper São Francisco River basin floodplain

Assembleia de peixes e status atual da planície de inundação da bacia do alto rio São Francisco

Marina Ferreira Moreira[1*], Alexandre Peressin[1,2], João de Magalhães Lopes[3] and Paulo Santos Pompeu[1]

[1]Departamento de Ecologia e Conservação, Universidade Federal de Lavras – UFLA, Trevo Rotatório Professor Edmir Sá Santos, s/n, CP 3037, CEP 37200-000, Lavras, MG, Brasil

[2]Centro de Ciências da Natureza, Universidade Federal de São Carlos – UFSCar, Câmpus Lagoa do Sino, Rodovia Lauri Simões de Barros, Km 12, SP 189, CEP 18290-000, Buri, SP, Brasil

[3]Complexo Cultural e Científico de Peirópolis, Universidade Federal do Triângulo Mineiro – UFTM, Rua Estanislau Collenghi, 194, CEP 38039-755, Uberaba, MG, Brasil

*e-mail: marina.moreira10@gmail.com

Cite as: Moreira, M.F. et al. Fish assemblage and current status of the upper São Francisco River basin floodplain. *Acta Limnologica Brasiliensia*, 2023, vol. 35, e26.

Abstract: Aim: This study aimed to evaluate whether the upper São Francisco River basin floodplain is still used as a nursery by migratory fish and present the current status of the area's ichthyofauna after almost 40 years since the only survey was conducted in the region. **Methods:** Sampling occurred in seven perennial lagoons and six temporaries from São Francisco River or its direct tributaries using gillnets and trawls. Temperature, pH, and transparency of each lagoon were measured. The estimated richness was calculated, and the fish assemblage from both perennial and temporary lagoons was compared using NMDS and ANOSIM. **Results:** Forty species were captured, of which four were non-native and three were migratory. Although there was a low abundance of migratory species, most captured individuals were juveniles. Moreover, the perennial lagoons showed higher species richness. **Conclusions:** After almost 40 years, the floodplain lagoons of the upper São Francisco basin remain important for the recruitment of migratory species and harbor an impressive proportion of fish fauna in the upper São Francisco area. However, the reduction of migratory species and the presence of non-natives may be a sign of the degradation of these environments, emphasizing the need for conservation measures in this area.

Keywords: juvenile fish; marginal lagoons; migratory fish; nursery habitat.

Resumo: Objetivo: O objetivo desse estudo foi avaliar se a planície de inundação da bacia do alto rio São Francisco ainda é usada como berçário pelos peixes migradores, além de apresentar o status atual da ictiofauna da área após quase 40 anos desde o único estudo feito na região. **Métodos:** A amostragem foi feita em sete lagoas perenes e seis temporárias, do rio São Francisco ou de seus tributários diretos, usando redes de espera e de arrasto. Foram medidos a temperatura, pH e transparência de cada lagoa. A riqueza estimada foi calculada e a assembleia de peixes das lagoas perenes e temporárias foi comparada usando NMDS e ANOSIM. **Resultados:** Quarenta espécies foram capturadas, destas, quatro são não-nativas e três migradoras. Apesar da baixa abundância de espécies migradoras, a maioria dos indivíduos capturados eram juvenis. Além disso, as lagoas perenes apresentaram uma maior riqueza. **Conclusões:** Depois de quase 40 anos, as lagoas da planície de inundação da bacia do alto rio São Francisco continuam sendo importantes para o recrutamento de espécies migradoras, além de abrigar uma porção impressionante da fauna de peixes do alto rio São Francisco. Apesar disso, a redução de espécies migradoras e a presença de espécies não-nativas podem ser sinais de degradação desses ambientes, enfatizando a necessidade de medidas de conservação nessa área.

Palavras-chave: peixes juvenis; lagoas marginais; peixes migradores; berçário.

1. Introduction

Floodplains are seasonally flooded areas along rivers. In the tropics, a large portion of fish communities use these areas as habitats for feeding, breeding, and refuge

(Agostinho & Zalewski, 1995; Lowe-McConnell, 1999). Flooding in these areas enables the river to connect with perennial marginal lagoons and create temporary lagoons, that are completely dry during the dry season. The connection of the river with marginal lagoons provides additional resources, high-quality food for adult fish (Bowen, 2022), and increases the spatiotemporal heterogeneity of habitats, contributing to the maintenance of high biodiversity (Ward et al., 1999; Wootton, 1992; Pompeu & Godinho, 2006).

The larvae of migratory fish use floodplains as habitats for growth and refuge because these environments present ideal conditions for the initial developmental phase (Godinho & Kynard, 2006; Meschiatti et al., 2000). In the São Francisco River basin, the importance of its floodplains as nurseries and its role in recruiting migratory species have long been recognized (Pompeu & Godinho, 2003; Sato et al., 1988) and only one migratory fish of this basin, *Conorhynchos conirostris* (Valenciennes, 1840), does not use this habitat in its life cycle (Sato et al., 2019).

The floodplain of the São Francisco River basin has been studied, especially in its middle course (Luz et al., 2012; Pompeu & Godinho, 2003) where the importance of marginal lagoons for the fish community has been described. In the upper São Francisco River, there are abundant perennial and temporary lagoons, both along the main channel and in the lower portions of the main tributaries. Preliminary mapping revealed the presence of 186 lagoons in this region (Araújo et al., 2020). Migratory routes towards such tributaries have been recently described (Lopes et al., 2019), reinforcing the importance of these lagoons in the recruitment of local migrants.

In the 1980s, the ichthyofauna of the upper São Francisco River floodplain system was studied. Many juveniles were captured, representing half of the species pool described for the Três Marias region, indicating the importance of these environments as nurseries, particularly for migratory species (Sato et al., 1988). The same study showed the need for urgent measures for the conservation of marginal lagoons that already suffered from several anthropic impacts, such as those from nearby sugarcane plantations. Almost four decades after this publication, these concerns remain current, and conservation strategies have become even more necessary due to how quickly the land use changes throughout the entire region (Sato & Godinho, 2003). Hence, in the present study, we aimed to evaluate whether these areas are still used as nursery areas by migratory species and present the current status of the area's ichthyofauna after almost 40 years since the only survey was done in the region.

2. Material and Methods

2.1. Study area

The São Francisco River basin covers 7.6% of the Brazilian territory, passing through six states (Godinho & Godinho, 2003). We conducted this study in the upper São Francisco River basin, upstream of the Três Marias Reservoir (Três Marias hydroelectric plant). In this region, the São Francisco mainstream is a free-flowing river more than 400 km in length. Migratory fish populations are able to complete their life cycle along this area (Lopes et al., 2018, 2019), where an important floodplain region is found (Araújo et al., 2020).

2.2. Sampling

Sampling occurred at the end of the rainy season (April 2019) in 13 marginal lagoons from the São Francisco River or its direct tributaries, in the same region of the previously study (Sato et al., 1988). Seven lagoons are perennial and six are temporary (Figure 1).

Fish sampling was carried out using gillnets and seines (Table 1), in accordance with the authorization by the ethics board on the use of animals at the Universidade Federal de Lavras (CEUA-UFLA nº 003/2019) and sample license SISBIO nº 72563. We used four gillnets with mesh of 1.2, 1.5, 2, and 2.5 cm between adjacent nodes (10.0 m long and 1.5 m high). The nets were placed perpendicular to the margin between 3 p.m. and 6 p.m. and removed the following morning. We also carried out up to seven trawls along the margins, depending on the availability of environments. For this, we used a 5-by-1.5-meter seine with a mesh of 0.3 mm between adjacent nodes. The fishes were euthanized in eugenol solution, fixed in 10% formaldehyde and taken to the laboratory for taxonomic identification, where they were washed and transferred to 70% alcohol. The species names were updated according to Fricke et al. (2023). Temperature and pH for each lagoon were measured using a multiparameter probe and transparency was measured with a Secchi disc.

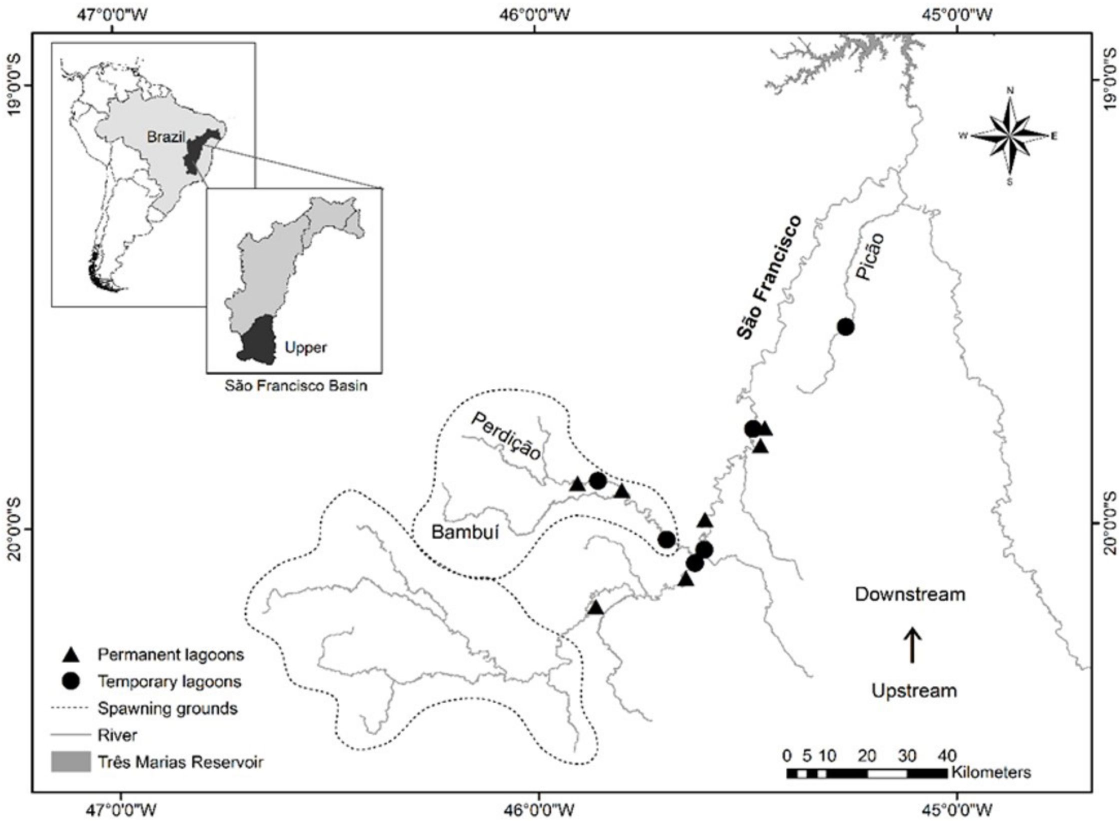

Figure 1. The upper São Francisco River basin, indicating the sampling sites. Spawning sites are those described for *P. costatus* in Lopes et al. (2019).

Table 1. Relative abundance of the species registered by Sato et al. (1988) and in the current study, and their occurrence in perennial or temporary lagoons.

Species	Relative Abundance (%)		Occurrence (current study)	
	Sato et al. (1988)	Current study	Perennial	Temporary
CHARACIFORMES				
ACESTRORHYNCHIDAE				
Acestrorhynchus britskii Menezes, 1969	1.82	0.09	x	
Acestrorhynchus lacustris (Lütken, 1875)	4.61	1.21	x	x
ANOSTOMIDAE				
Leporinus piau Fowler, 1941	1.59	0.05	x	
Leporinus taeniatus [3] Lütken, 1875	0.04			
Megaleporinus obtusidens [3] (Valenciennes, 1850)	0.35			
Megaleporinus reinhardti [1,3] (Lütken, 1875)	3.07	0.27	x	x
Schizodon knerii (Steindachner, 1875)	4.53	0.11	x	x
BRYCONIDAE				
Salminus franciscanus [3] Lima & Britski, 2007	0.12			
Salminus hilarii [3] Valenciennes, 1850	2.10			
CHARACIDAE				
Astyanax lacustris (Lütken, 1875)	9.27	30.9	x	x
Hasemania nana (Lütken, 1875)		2.03	x	x
Hemigrammus marginatus Ellis, 1911	2.34	2.35	x	x
Knodus aff. *moenkhausii* [2] (Eigenmann & Kennedy, 1903)		0.01		x
Moenkhausia costae (Steindachner, 1907)	4.61	5.08	x	x
Orthospinus franciscensis (Eigenmann, 1914)	4.00	1.87	x	x
Psalidodon fasciatus (Cuvier, 1819)	0.76			
Psalidodon aff. *fasciatus* (Cuvier, 1819)		4.91	x	x

[1]Species with at least one juvenile individual captured in current study. [2]Non-native species. [3]Migratory species. *Species that we could not update the identification since was captured only by Sato et al. (1988).

Table 1. Continued...

Species	Relative Abundance (%)		Occurrence (current study)	
	Sato et al. (1988)	Current study	Perennial	Temporary
Roeboides xenodon (Reinhardt, 1851)	3.68	0.06	x	
Serrapinnus heterodon (Eigenmann, 1915)		12.06	x	x
Serrapinnus piaba (Lütken, 1875)	0.12	5.30	x	x
Tetragonopterus chalceus Spix & Agassiz, 1829	3.07	1.48	x	
CRENUCHIDAE				
Characidium fasciatum Reinhardt, 1867	1.17			
Characidium zebra Eigenmann, 1909		0.04	x	
CURIMATIDAE				
Curimatella lepidura (Eigenmann & Eigenmann, 1889)	19.23	0.60	x	x
Steindachnerina elegans (Steindachner, 1875)	5.62	0.78	x	x
ERYTHRINIDAE				
Hoplias intermedius (Günther, 1864)	0.44	0.05	x	x
Hoplias aff. *malabaricus* (Bloch, 1794)	3.19	0.09	x	x
PARODONTIDAE				
Apareiodon hasemani Eigenmann, 1916		0.06	x	x
PROCHILODONTIDAE				
Prochilodus argenteus[1,3] Spix & Agassiz, 1829	5.18	0.01	x	
Prochilodus costatus[1,3] Valenciennes, 1850	3.84	0.17	x	x
SERRASALMIDAE				
Metynnis lippincottianus [2] (Kner, 1858)		0.17	x	
Pygocentrus piraya (Cuvier, 1819)	0.60	0.35	x	
Serrasalmus brandtii Lütken, 1875	3.32	1.39	x	x
TRIPORTHEIDAE				
Triportheus guentheri (Garman, 1890)	3.15	24.4	x	x
CICHLIFORMES				
CICHLIDAE				
Australoheros oblongus (Jenyns, 1842)	2.79			
Cichlasoma sanctifranciscense Kullander, 1983		0.01	x	
Geophagus brasiliensis (Quoy & Gaimard, 1824)		0.02	x	x
ENGRAULIDAE				
Anchoviella vaillanti (Steinbdachner, 1908)	1.45	0.01		
CYPRINODONTIFORMES				
POECILIIDAE				
Poecilia reticulata [2] Peters, 1859		0.92		
GYMNOTIFORMES				
GYMNOTIDAE				
Gymnotus aff. *carapo* Linnaeus, 1758	0.24	0.08	x	
STERNOPYGIDAE				
Eigenmannia microstoma (Reinhardt, 1852)		0.19	x	
Eigenmannia sp. *	0.16			
SILURIFORMES				
AUCHENIPTERIDAE				
Trachelyopterus galeatus (Linnaeus, 1766)	1.74	0.01	x	
CALLICHTHYIDAE				
Hoplosternum littorale [2] (Hancock, 1828)		1.92	x	x
HEPTAPTERIDAE				
Pimelodella vittata (Lütken, 1874)	0.20	0.02		x
Rhamdia aff. *quelen* (Quoy & Gaimard, 1824)	0.35			
PIMELODIDAE				
Pimelodus maculatus Lacepède, 1803	0.32	0.04	x	
Pimelodus pohli Ribeiro & Lucena, 2006		0.06	x	
Pimelodus sp. *	0.85			
Pseudoplatystoma corruscans [3] (Spix & Agassiz, 1829)	0.08			
SYNBRANCHIFORMES				
SYNBRANCHIDAE				
Symbranchus aff. *marmoratus* Bloch, 1795		0.04	x	

[1]Species with at least one juvenile individual captured in current study. [2]Non-native species. [3]Migratory species. *Species that we could not update the identification since was captured only by Sato et al. (1988).

2.3. Data analysis

The fish were classified as adults or juveniles based on the available literature on first maturation (Bazzoli, 2003; Boncompagni-Júnior et al., 2013; Rizzo et al., 1996). Species were also classified as migratory (Rizzo et al., 1996; Sato et al., 2003; Sato & Godinho, 2003; Thomé et al., 2005) and native or non-native (Bueno et al., 2021). We used the Chao index in the vegan package (Oksanen et al., 2020) to calculate the estimated richness. To compare perennial and temporary lagoons, we performed Non-metric Multidimensional Scaling (NMDS) and an Analysis of Similarities (ANOSIM), also using the vegan package. All the statistical analyses were performed in RStudio 1.3.959 (R Core Team, 2021).

3. Results

We captured 7,262 fish from 40 species (Table 1), belonging to seven orders, with Characiformes being the most abundant (~96%). The Characiformes *Astyanax lacustris* (Lütken, 1875) and *Triportheus guentheri* (Garman, 1890) together represented most of the catches (55.3%) and the former was the only species captured in all sampled lagoons.

The estimated richness indicated the presence of 50.6 species across all lagoons. The perennial ones had greater richness, with this number varying between 9 and 21 species. In temporary lagoons, we captured a maximum of 14 species (Figure 2). The Ordination and ANOSIM analyses showed that although there was some overlap, the fish communities from these two types of lagoons differed ($p<0.01$; Figure 3). In addition, we found differences for some physicochemical water parameters among the two groups of lagoons. In general, the perennial ones presented lower water temperatures and higher transparency and depth (Table 2).

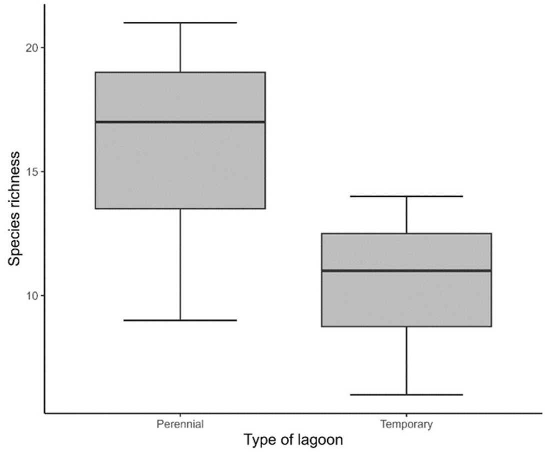

Figure 2. Species richness at each type of lagoon. The line in the middle of the box represents the median, and the lower and upper ends of the box are the 25% and 75% quartiles, respectively. The horizontal lines outside the box represents minimum and maximum values.

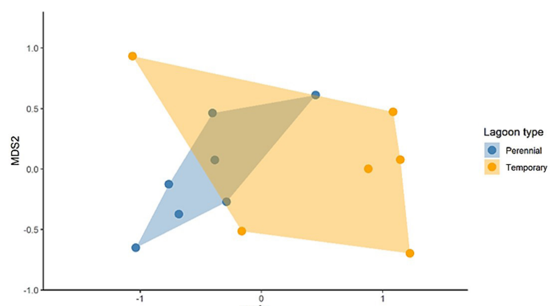

Figure 3. Non-metric multidimensional ordination of species composition of fish assemblage at the lagoons of upper São Francisco River. Stress = 0.11. Each point represents a sample.

Table 2. Limnological data and depth of perennial and temporary lagoons in the upper São Francisco River.

Lagoon	Type	pH	Temperature (°C)	Conductivity (µs)	Transparency (cm)	Depth (cm)
SF1	Perennial	7.51	27.5	226.0	92	>400
SF2	Perennial	-	25.5	45.5	82	>200
SF3	Temporary	7.7	29.7	205.0	15	<100
SF4	Perennial	6.73	27.0	65.6	95	>200
SF5	Perennial	7.38	27.5	156.5	161	>200
SF6	Temporary	7.04	32.0	85.5	0	< 30
SF7	Perennial	7.18	28.1	76.5	88	>200
Bam1	Temporary	6.63	29.0	260.0	>30	<50
Bam2	Perennial	6.05	27.0	40.5	72	>200
Bam3	Perennial	6.94	27.0	33.0	>100	<100
Bam4	Temporary	7.15	32.0	36.1	>30	<80
Pr1	Temporary	7.16	26.8	148.0	41	<140
Pic1	Temporary	7.12	27.8	326.0	26	<40

Four species of non-native fish were recorded: *Hoplosternum littorale*, *Knodus* aff. *moenkhausii*, *Metynnis lippincottianus*, and *Poecilia reticulata*. In addition, we found three migratory species: *Megaleporinus reinhardti*, *Prochilodus costatus*, and *P. argenteus*. They were sampled from six lagoons, two temporary and four perennials. The most abundant was *M. reinhardti* with 20 individuals, followed by *P. costatus*, with 13. While for *P. argenteus*, we captured only one fish. All specimens captured of *M. reinhardti* and *P. costatus* were juveniles, whereas the *P. argenteus* was an adult.

4. Discussion

The presence of migratory juveniles as well as the species richness confirm that the floodplain of the upper São Francisco basin continues to act as a nursery for migratory species. They are also essential in maintaining an important portion of the fish diversity in the basin, which has currently 211 recorded species (Reis et al., 2016). Although the number of fish species recorded here by Sato et al. (1988) was very similar, aspects of their communities has changed over the past 40 years. It was observed a decrease of migratory species richness and the presence of non-native species that were not sampled before (Table 3).

Even though a significantly larger number of individuals were captured, the species richness of native species recorded in this study did not differ from that observed. Among the 40 sampled species, 30 were also registered in lagoons in the middle São Francisco basin (Luz et al., 2012; Pompeu & Godinho, 2006), where Characiformes was also the predominant order. The most abundant species observed in this study, the Characiformes *A. lacustris* and *T. guentheri*, are known to be herbivorous and insectivorous, respectively, in lagoons of the Middle São Francisco region (Pompeu & Godinho, 2003). The high abundance of macrophytes and insects in floodplain areas due the high productive of this environment (Junk et al., 1989), along with the small size of both species, likely contribute to their high abundance. *Astyanax* species, in addition, also exhibit reproductive traits, such as adhesive eggs and high relative fecundity, which may confer an advantage for successful reproduction in lentic environments (Sato et al., 2003).

The lowest richness observed in the temporary lagoons was also observed in middle São Francisco (Pompeu & Godinho, 2006). Floodplain lagoons exhibit stressful conditions during drought periods, such as high predation, declined availability of food resources (Junk et al., 1989; Lowe-McConnell, 1999). These aspects can decrease the richness and are exacerbated in temporary lagoons, which present lower water levels and higher temperatures (Escalera-Vázquez & Zambrano, 2010). Such conditions end up favoring sedentary species, smaller in size, and with tolerance to hypoxia (Pompeu & Godinho, 2006).

None of the four recorded non-native species had been found by Sato et al. (1988), but *H. littorale* and *P. reticulata* had already been registered in lagoons in the middle São Francisco basin (Luz et al., 2012). The recent colonization of floodplains by non-native species has been reported in other basins of the world (Sarkar et al., 2021). Among the species sampled in the present study, *Poecilia reticulata* has been identified as an indicator of environmental degradation due to its presence in environments with poor water quality (Carvalho et al., 2019; Pinto & Araújo, 2007; Terra et al., 2013). This species introduction is linked to aquarium trade and biological control, while *Knodus* aff. *moenkhausii* and *M. lippincottianus* are associated only with the former (Bueno et al., 2021). *H. littorale* is known to tolerate low oxygen levels by breathing atmospheric air (Jucá-Chagas & Boccardo, 2006), and its use as bait is the possible pathway of its introduction (Bueno et al., 2021). In upper São Francisco, the species probably uses floodplain lagoons as stepping stones for colonizing the main channel as well (Salvador-Jr. & Silva, 2011). These findings provide valuable insights into the dynamics of non-native species in floodplains, and underscore the importance of monitoring and managing their spread.

The migratory species found here were also sampled before (Sato et al., 1988), but even sampling four more lagoons than Sato et al. (1988), there were five migratory species that we did not capture in our study: *L. taeniatus*, *M. obtusidens*, *S. franciscanus*, *S. hilarii*, and *P. corruscans*. Furthermore, individuals of *S. hilarii* and *L. reinhardti* were also found in the early 1990's in one lagoon in the upper São Francisco basin (Pompeu et al., 2000).

Table 3. Comparison between fish assemblage data from Sato et al. (1988) and the current study.

Attribute	Sato et al. (1988)	Current study
Sampled lagoons	9	13
Perennial lagoons	2	7
Temporary lagoons	7	6
Captured fishes	2469	7261
Richness	37	40
Non-native species	0	4
Migratory species	8	3

Although we captured juveniles of migratory fish, the current absence of some of these species and the low abundance of others is worrisome and has been reported in floodplains of another river basins (Esteves et al., 2000). This is true, especially for 'dourado' (*S. franciscanus*) and 'surubim' (*P. corruscans*), in which we did not capture any individuals. These two are the largest fish species in the basin and are the target of intense fishing (Barbosa et al., 2017). Together with the species of *Prochilodus*, they used to represent the main catches (95%) in the upper São Francisco basin (Sato & Godinho, 2003). The disappearance of the 'surubim' was not only noticed in the lagoons sampled in this study. The species practically disappeared from catches according to reports from former fishermen in the region, culminating in its inclusion in the list of endangered species as vulnerable (Brasil, 2022). In addition to the fishing and blocking of migratory routes (Mello et al., 2009), *P. corruscans* populations have probably been affected by coexisting with the hybrid *P. corruscans* vs. *P. reticulatum* (Bueno et al., 2021). The introduction of a hybrid species in the rivers can lead to extinction of the native species because of an increase in competition and can lead to unsuccessful reproduction (Freitas-Souza et al., 2022).

Along with the cited threats, *S. franciscanus*, *S. hilarii* and *P. corruscans* populations could be declining due to the degradation of the basin. Because these species are top predators (Resende et al., 1996; Sato & Godinho, 2003), they have naturally low population sizes and therefore can be specially affected by a decline in environmental quality. In addition, the low richness and abundance of migratory fishes in comparison with Sato et al. (1988) can be related to the differences in the flooding within the years of capture, since the biota in floodplain areas are affected by period, the duration of the flood, and the rise and fall rate (Junk et al., 1989).

The floodplain lagoons of the upper São Francisco basin remain important for the recruitment of migratory species and harbor an impressive proportion of the fish fauna in the upper São Francisco area. However, the reduction of migratory species and the presence of non-natives may be a sign of degradation of these environments, emphasizing the need for conservation measures, which was already pointed out as necessary in the previous study. An efficient strategy would be to assign the floodplain as an area of priority for conservation, carry out conservation efforts, management, and research actions as suggested by Brazilian laws (Brasil, 2004, 2005). Only more stringent protection measures would ensure that such environments continue to fulfill their role in the life cycle of many fish species, including the migratory ones.

Acknowledgements

We thank the Aneel - Programa de Pesquisa e Desenvolvimento - P&D - GT 612 and Companhia Energética de Minas Gerais - CEMIG GT for funding and the Laboratório e Ecologia de Peixes of the UFLA team for the support.

References

Agostinho, A.A., & Zalewski, M., 1995. The dependence of fish community structure and dynamics on floodplain and riparian ecotone zone in Parana River, Brazil. Hydrobiologia 303(1-3), 141-148. http://dx.doi.org/10.1007/BF00034051.

Araújo, R.R.S., Silva, N.J., Oliveira, D.A., & Aarão, G.M., 2020. Mapeamento preliminar da ocorrência das lagoas marginais do alto curso do rio São Francisco. In: Anais do III Simpósio da Bacia Hidrográfica do Rio São Francisco. Belo Horizonte: CBHSF. Retrieved in 2023, January 24, from https//www.even3.com.br/anais/IIISBHSF/291139-MAPEAMENTO-PRELIMINAR-DA-OCORRENCIA-DAS-LAGOAS-MARGINAIS-DO-ALTO-CURSO-DO-RIO-SAO-FRANCISCO

Barbosa, J.M., Soares, E.C., Cintra, I.H.A., Hermann, M., & Araújo, A.R.R., 2017. Perfil da ictiofauna da bacia do rio São Francisco. Acta Fish. Aquat. Res 5(1), 70-90. https://doi.org/10.2312/Actafish.2017.5.1.70-90.

Bazzoli, N. 2003. Parâmetros reprodutivos de peixes de interesse comercial na região de Pirapora. In: Godinho, H.P., & Godinho, A.L., eds. Águas, peixes e pescadores do São Francisco das Minas Gerais. Belo Horizonte: PUC Minas, 291-306, 1 ed.

Boncompagni-Júnior, O., Normando, F.T., Brito, M.F.G., & Bazzoli, N., 2013. Reproductive biology of *Prochilodus argenteus* Agassiz, 1829 (Pisces: Prochilodontidae) in São Francisco River, Brazil. J. Appl. Ichthyology 29(1), 132-138. http://dx.doi.org/10.1111/jai.12018.

Bowen, S.H., 2022. The river flood pulse, benthic biofilm, and the nutrition of *Prochilodus lineatus*. Environ. Biol. Fishes 105(2), 213-230. http://dx.doi.org/10.1007/s10641-022-01211-1.

Brasil, 24 maio 2004. Decreto nº 5.092, de 21 de maio de 2004. Diário Oficial da União [da] República Federativa do Brasil, Poder Executivo, Brasília, DF. Retrieved in 2023, January 24, from http://www.planalto.gov.br/ccivil_03/_ato2004-2006/2004/decreto/d5092.htm

Brasil, 2005. Deliberação CONABIO nº 39, de 14 de dezembro de 2005. Diário Oficial da União [da] República Federativa do Brasil, Poder Executivo, Brasília, DF. Retrieved in 2023, January 24, from http://areasprioritarias.mma.gov.br/images/arquivos/Delib_039.pdf

Brasil. Ministério do Meio Ambiente – MMA, 8 jun. 2022. Portaria MMA nº 148, de 7 de junho de 2022. Lista Nacional de Espécies Ameaçadas de Extinção. Diário Oficial da União [da] República Federativa do Brasil, Poder Executivo, Brasília, DF.

Bueno, M.L., Magalhães, A.L.B., Andrade Neto, F.R., Alves, C.B.M., Rosa, D.M., Junqueira, N.T., Pessali, T.C., Pompeu, P.S., & Zenni, R.D., 2021. Alien fish fauna of southeastern Brazil: species status, introduction pathways, distribution and impacts. Biol. Invasions 23(10), 3021-3034. http://dx.doi.org/10.1007/s10530-021-02564-x.

Carvalho, D.R., Flecker, A.S., Alves, C.B.M., Sparks, J.P., & Pompeu, P.S., 2019. Trophic responses to aquatic pollution of native and exotic livebearer fishes. Sci. Total Environ. 681, 503-515. PMid:31128341. http://dx.doi.org/10.1016/j.scitotenv.2019.05.092.

Escalera-Vázquez, L.H., & Zambrano, L., 2010. The effect of seasonal variation in abiotic factors on fish community structure in temporary and permanent pools in a tropical wetland. Freshw. Biol. 55(12), 2557-2569. http://dx.doi.org/10.1111/j.1365-2427.2010.02486.x.

Esteves, K.E., Sendacz, S., Lôbo, A.V.P., & Xavier, M.B., 2000. Características físicas, químicas e biológicas de três lagoas marginais do Rio-Mogi-Guaçu (SP) e avaliação do seu papel como viveiro natural de espécies de peixes reofílicos. Bol. Inst. Pesca 26, 169-180.

Freitas-Souza, D., Nobile, A.B., Prado, F.D., Serrano, É.A., Lima, F.P., Foresti, F., Porto-Foresti, F., & Oliveira, C., 2022. Genetic markers indicate that hybrids of *Pseudoplatystoma* (Siluriformes, Pimelodidae) are reproducing in natural environments in southeastern Brazil. Biol. Invasions 24(4), 1049-1058. http://dx.doi.org/10.1007/s10530-021-02701-6.

Fricke, R., Eschmeyer, W.N., & van der Laan, R., 2023. Eschmeyer's catalog of fishes: genera, species, references. San Francisco: California Academy of Sciences. Retrieved in 2023, January 24, from http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp

Godinho, A.L., & Godinho, H.P., 2003. Breve visão do São Francisco. In: Godinho, H.P., & Godinho, A.L., eds. Águas, peixes e pescadores do São Francisco das Minas Gerais. Belo Horizonte: PUC Minas, 15-24, 1 ed.

Godinho, A.L., & Kynard, B., 2006. Migration and Spawning of Radio-Tagged Zulega *Prochilodus argenteus* in a Dammed Brazilian River. Trans. Am. Fish. Soc. 135(3), 811-824. http://dx.doi.org/10.1577/T04-176.1.

Jucá-Chagas, R., & Boccardo, L., 2006. The air-breathing cycle of *Hoplosternum littorale* (Hancock, 1828) (Siluriformes: Callichthyidae). Neotrop. Ichthyol. 4(3), 371-373. http://dx.doi.org/10.1590/S1679-62252006000300009.

Junk, W.J., Bayley, P.B., & Sparks, R.E., 1989. The flood pulse concept in river-floodplain systems. Can. Spec. Publ. Fish. Aquat. Sci. 106, 110-127.

Lopes, J.M., Pompeu, P.S., Alves, C.B.M., Peressin, A., Prado, I.G., Suzuki, F.M., Facchin, S., & Kalapothakis, E., 2019. The critical importance of an undammed river segment to the reproductive cycle of a migratory Neotropical fish. Ecol. Freshwat. Fish 28(2), 302-316. http://dx.doi.org/10.1111/eff.12454.

Lopes, J.M., Alves, C.B.M., Peressin, A., & Pompeu, P.S., 2018. Influence of rainfall, hydrological fluctuations, and lunar phase on spawning migration timing of the Neotropical fish *Prochilodus costatus*. Hydrobiologia 818(1), 145-161. http://dx.doi.org/10.1007/s10750-018-3601-4.

Lowe-McConnell, R., 1999. Estudos ecológicos de comunidades de peixes tropicais. São Paulo: Edusp.

Luz, S.C.S., Lima, H.C., & Severi, W., 2012. Composição da ictiofauna em ambientes marginais e tributários do médio-submédio rio São Francisco. Agraria 7(2), 358-366. http://dx.doi.org/10.5039/agraria.v7i2a1436.

Mello, P.H., Venturieri, R.L.L., Honji, R.M., & Moreira, R.G., 2009. Threatened fishes of the world: *Pseudoplatystoma corruscans* (Agassiz, 1829) (Siluriformes: Pimelodidae). Environ. Biol. Fishes 85(4), 359-360. http://dx.doi.org/10.1007/s10641-009-9508-1.

Meschiatti, A.J., Arcifa, M.S., & Fenerich-Verani, N., 2000. Fish communities associated with macrophytes in Brazilian floodplain lakes. Environ. Biol. Fishes 58(2), 133-143. http://dx.doi.org/10.1023/A:1007637631663.

Oksanen, J., Blanchet, F.G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P.R., O'Hara, R.B., Simpson, G.L., Solymos, P., Henry, M., Stevens, H., Szoecs, E., & Wagner, H., 2020. vegan: Community Ecology Package. Vienna: R Foundation for Statistical Computing. Retrieved in 2023, January 24, from https://cran.r-project.org/package=vegan

Pinto, B.C.T., & Araújo, F.G., 2007. Assessing of biotic integrity of the fish community in a heavily impacted segment of a tropical river in Brazil. Braz. Arch. Biol. Technol. 50(3), 489-502. http://dx.doi.org/10.1590/S1516-89132007000300015.

Pompeu, P.S., & Godinho, H.P., 2003. Ictiofauna de três lagoas marginais do médio São Francisco. In: Godinho, H.P., & Godinho, A.L., eds. Águas, peixes e pescadores do São Francisco das Minas Gerais. Belo Horizonte: PUC Minas, 167-182, 1 ed.

Pompeu, P.S., & Godinho, H.P., 2006. Effects of extended absence of flooding on the fish assemblages of three floodplain lagoons in the middle São Francisco River, Brazil. Neotrop. Ichthyol. 4(4), 427-433. http://dx.doi.org/10.1590/S1679-62252006000400006.

Pompeu, P.S., Godinho, H.P., & Pinto, M.T.C., 2000. Abundância e diversidade da ictiofauna de uma lagoa marginal do alto São Francisco. Bios 8, 97-106.

R Core Team, 2021. R: a language and environment for statistical computing. Vienna: R Foundation for Statistical Computing. Retrieved in 2023, January 24, from https://www.r-project.org/

Reis, R.E., Albert, J.S., Di Dario, F., Mincarone, M.M., Petry, P., & Rocha, L.A., 2016. Fish biodiversity and conservation in South America. J. Fish Biol. 89(1), 12-47. PMid:27312713. http://dx.doi.org/10.1111/jfb.13016.

Resende, E.K., Catella, A.C., Nascimento, F.L., Palmeira, S.S., Pereira, R.A.C., Lima, M.S., & Almeida, V.L.L., 1996. Biologia do Curimbatá (*Prochilodus lineatus*), Pintado (*Pseudoplatystoma corruscans*) e Cachara (*Pseudoplatystoma fasciatum*) na bacia hidrográfica do Rio Miranda, pantanal do Mato Grosso do Sul, Brasil. Corumbá: EMBRAPA-CPAP.

Rizzo, E., Sato, Y., Ferreira, R.M.A., Chiarini-Garcia, H., & Bazzoli, N., 1996. Reproduction of *Leporinus reinhardti* Lütken, 1874 (Pisces: Anostomidae) from the Três Marias Reservoir, São Francisco River, Minas Gerais, Brazil. Cienc. Cult. 48, 189-192.

Salvador-Jr, L.F., & Silva, F.A., 2011. Actinopterygii, Siluriformes, Callichthyidae, *Hoplosternum littorale* (Hancock, 1828): distribution extension in the upper São Francisco River region, southeast Brazil. Check List 7(5), 621. http://dx.doi.org/10.15560/7.5.621.

Sarkar, U.K., Mishal, P., Borah, S., Karnatak, G., Chandra, G., Kumari, S., Meena, D.K., Debnath, D., Yengkokpam, S., Das, P., DebRoy, P., Yadav, A.K., Aftabuddin, M., Gogoi, P., Pandit, A., Bhattacharjya, B.K., Tayung, T., Lianthuamluaia, L., & Das, B.K., 2021. Status, Potential, Prospects, and Issues of Floodplain Wetland Fisheries in India: Synthesis and Review for Sustainable Management. Rev. Fish. Sci. Aquacult. 29(1), 1-32. http://dx.doi.org/10.1080/23308249.2020.1779650.

Sato, Y., & Godinho, H.P., 2003. Migratory fishes of the São Francisco river. In: Carolsfeld, J., Harvey, B., Ross, C., & Baer, A., eds. Migratory fishes of South America: biology, fisheries and conservation status. Victoria: IDRC/The World Bank, 195-232, 1 ed.

Sato, Y., Cardoso, E. L., & Amorim, J. C. C., 1988. Peixes das lagoas marginais do Rio São Francisco a montante da represa de Três Marias (Minas Gerais). Brasília: Codevasf, 3 ed.

Sato, Y., Fenerich-Verani, N., Nuñer, A.P.O., Godinho, H.P., & Verani, J.R., 2003. Padrões reprodutivos de peixes da bacia do São Francisco. In: Godinho, H.P., & Godinho, A.L., eds. Águas, peixes e pescadores do São Francisco das Minas Gerais. Belo Horizonte: PUC Minas, 229-274, 1 ed.

Sato, Y., Miranda, M.O.T., Santiago, K.B., Boschi, M.B., & Tavares, M.P., 2019. Peixes de médio e grande tamanhos, nativos da Bacia do Rio São Francisco, que não utilizam lagoas marginais como berçário. Brasília: IBAMA.

Terra, B.D.F., Hughes, R.M., Francelino, M.R., & Araújo, F.G., 2013. Assessment of biotic condition of Atlantic Rain Forest streams: a fish-based multimetric approach. Ecol. Indic. 34, 136-148. http://dx.doi.org/10.1016/j.ecolind.2013.05.001.

Thomé, R.G., Bazzoli, N., Rizzo, E., Santos, G.B., & Ratton, T.F., 2005. Reproductive biology of *Leporinus taeniatus* Lütken (Pisces, Anostomidae) in Juramento Reservoir, São Francisco River basin, Minas Gerais, Brazil. Rev. Bras. Zool. 22(3), 565-570. http://dx.doi.org/10.1590/S0101-81752005000300006.

Ward, J.V., Tockner, K., & Schiemer, F., 1999. Biodiversity of floodplain river ecosystems: ecotones and connectivity. Regul. Rivers 15(1-3), 125-139. http://dx.doi.org/10.1002/(SICI)1099-1646(199901/06)15:1/3<125::AID-RRR523>3.0.CO;2-E.

Wootton, R.J. 1992. Effects of abiotic environmental identities on distribution. In: Wootton, R.J., ed. Fish ecology. Dordrecht: Springer, 25-58. http://dx.doi.org/10.1007/978-94-011-3832-1_2.

Received: 24 January 2023
Accepted: 05 September 2023

Associate Editor: Ronaldo Angelini.