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The fish fauna of Itutinga reservoir, 30 years after the first survey

A ictiofauna do reservatório de Itutinga, após 30 anos do primeiro levantamento

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Abstract: Aim: Monitoring altered environments is crucial to understand the impacts and the possible changes in the local fish fauna. Therefore, we aimed to compare the ichthyofauna within a 67-year-old small run-of-the-river reservoir with surveys carried out in 1986 and 2019-2021 and update the checklist of this reservoir. **Methods:** We used the data provided by Alves et al. (1998) and sampled fish in two sites inside Itutinga reservoir using gill nets, seine nets and hand nets and at the one tributary of the area using only hand nets. **Results:** We collected a total of 12,978 individuals belonging to 37 fish species, and the species accumulation curve showed a tendency to the asymptote. Five of the sampled species are non-native and five are migratory. Alves et al. (1998) sampled a total of 25 fish species, 17 genera, 9 families and 3 orders. We added 12 fish species to the checklist that were not recorded by Alves et al. (1998), including four non-native and two migratory. On the other hand, two migratory species and one rheophilic were registered only in the preview study. In addition, we observed important changes in the species abundance rank. **Conclusions:** The differences in the fish assemblage structure comparing both studies indicate important changes in fish assemblages over more than 33 years. Our results highlighted the importance of long-term fish monitoring in altered environments to assess temporal variation in fish assemblages and their responses to the multiple possibilities of external stressors, such as the shift in abundance of non-native species in these environments.

Keywords: fish assemblage variation; dam; reservoir; long-term fish monitoring.

Resumo: Objetivo: O monitoramento de ambientes alterados é crucial para o entendimento dos impactos e avaliação de mudança na ictiofauna local. Dessa forma, o objetivo do nosso trabalho foi comparar a fauna de peixes de um pequeno reservatório do tipo fio d'água de 67 anos de idade com amostragens realizadas em 1986 e entre 2019 e 2021, além de atualizar a lista de espécies de peixes deste reservatório. **Métodos:** Nós utilizamos dados provenientes do estudo de Alves et al. (1998) e de peixes amostrados em dois pontos no interior do reservatório de Itutinga utilizando redes de emalhar, arrasto e peneira e em um ponto no único tributário da região utilizando peneira. **Resultados:** Coletamos um total de 12.978 indivíduos pertencentes a 37 espécies de peixes, sendo que a curva de acumulação de espécies mostrou tendência à assíntota. Destas, cinco espécies eram não nativas e cinco eram migradoras. O estudo de Alves et al. (1998) coletou um total de 25 espécies, 17 gêneros, 9 famílias e 3 ordens. Adicionamos 12 espécies à lista que não haviam sido registradas por Alves et al. (1998), incluindo quatro não nativas e duas migradoras. Por outro lado, duas espécies migradoras e uma reofílica foram registradas apenas no estudo anterior. Ademais, observamos alterações importantes no ranking de abundância de espécies entre os dois estudos. **Conclusões:** As diferenças na estrutura das assembleias de peixes comparando os dois estudos indicam importantes mudanças na comunidade 33 anos após o primeiro estudo. Nossos resultados destacam a importância da realização de monitoramentos de longa duração em ambientes alterados para avaliar temporalmente as variações na assembleia de peixes e as suas respostas às múltiplas possibilidades de estressores externos como o aumento da abundância de espécies não nativas nestes ambientes.

Palavras-chave: mudança na assembleia de peixes; barramento; reservatório; monitoramento de peixes de longa duração.

1. Introduction

Hydropower plants often provide essential energy, particularly in developing countries, but their long-term impacts are mostly underestimated (Winemiller et al., 2016). The construction of dams is one of the major drivers of fish community alterations (Agostinho et al., 2016). Changing the hydrological dynamics and separating populations and habitats by blocking the river cause significant environmental impacts to the ichthyofauna (Vera-Escalona et al., 2018). The reservoir creation also facilitates non-native species colonization and can lead to poorer assemblages with less stable communities (Agostinho et al., 2007c; Bueno et al., 2021; Gao et al., 2019; Pelicice et al., 2018). It can also enhance local extinctions (Blackburn et al., 2019), mainly of reophilic species (Santos,2010). In addition, the construction of the dam usually alters the composition, abundance, and dominance of fish species both downstream and upstream, but mainly within the reservoir (Agostinho et al., 2016; Loures & Pompeu, 2018).

After dam installation, it is expected that the reservoir fish assemblage will become stable after some period (Agostinho et al., 2007a; Agostinho et al., 2016). However, this time may vary depending on various characteristics such as previous fish fauna, reservoir location, dam operation, interaction with other reservoirs, fish pre-adaptation to lacustrine environments and life strategy (Agostinho et al., 2007a; Agostinho et al., 2016, Loures & Pompeu, 2019). Dam operation patterns, non-native species introduction and reservoir fluctuations can also cause important disturbances to the system, which can affect the assemblage stabilization process (Agostinho et al., 2016; Petrere Junior, 1996). Therefore, it can take a few years or decades to stabilize (Loures & Pompeu, 2019; Orsi & Britton, 2014; Pereira et al., 2021; Perônico et al., 2020).

Long term monitoring is an important tool for understanding temporal variation in fish assemblages as well as the main drivers of these variations, especially in cascade reservoirs (Loures & Pompeu, 2018; Pereira et al., 2021; Perônico et al., 2020). On the other hand, short term monitoring with temporal gaps can provide useful information about the reservoir fish fauna over long time periods, representing an opportunity to investigate temporal variation when information is lost and sampling is non-continuous (Agostinho et al., 2016; Loures & Pompeu, 2018; Nieman et al., 2021).

The Grande River basin presents 12 hydropower dams along its main stem due to the large hydroelectric potential of the basin (Cachapuz, 2006). The Itutinga hydroelectric plant is the second dam in the Grande River reservoir cascade, and it is located downstream of Camargos hydroelectric plant (CMHP) (Borges & Abjaudi, 2016). There is no significant tributary draining to the Itutinga reservoir, but only a small third order stream.

Only a single study (i.e., Alves et al., 1998) investigated the fish assemblage in the Itutinga reservoir, more than 30 years ago. Therefore, in this work, we compared the structure and some biological aspects of the ichthyofauna within a 67-year-old small run-of-the-river reservoir, where initial surveys were carried out in 1986 (Alves et al., 1998) but have not been completed toto current data.

2. Material and Methods

2.1. Study area

The Itutinga Hydropower Plant (ITHP) is located in the Grande River basin (21° 17’ 30. 27” S and 44° 37’ 29. 67” O) in southeastern Brazil (Figure 1). The Grande River basin has a drainage area of 143,437.79 km^2 (IPT, 2008) and contains 12 hydropower dams along the main stem, where ITHP is the second from upstream (Cachapuz, 2006).). In the region, the climate is humid subtropical characterized by dry winters and wet summers (Borges & Abjaudi, 2016). The average annual temperature is between 18 to 29 °C (Peel et al., 2007) and mean annual precipitation ranges from 1450 to 1600 mm (Borges & Abjaudi, 2016).

The ITHP started operating in 1955 and has a power generation capacity of 52 MW (Cachapuz, 2006), and it is a run-of-the-river dam. The Itutinga

Reservoir (IR) is small, with 7 km of length and a surface area of 1.72 km^2 (Cachapuz, 2006). Besides, it has only one third-order stream as a tributary. The first dam upstream, the Camargos Hydropower Plant, operating since 1960, is located only 8 km upstream from the ITHP (Alves et al., 1998; Cachapuz, 2006) (Figure 1). At the present survey, three sites were sampled: the Grande River immediately upstream of the reservoir near the tailrace of Camargos Hydropower Plant (S1; -21.322170º S; -44.614583º W), the central region of the IR (S2; -21.294487º S; -44.617696º W), and the lower stretch of the third-order stream tributary (S3; -21.307397º S; -44.604863º W) (Figure 1.). The uppermost site (S1) presents lotic characteristics, but it is highly influenced by Itutinga reservoir.

2.2. Fish sampling

The Itutinga Reservoir (S1 and S2) was sampled between March 2019 and December 2021 over 14 surveys, including both dry and wet seasons. Sampling was carried out with ten 10-meter-long gillnets per site (3,4,5,6,7,8,10,12,14 and 16 cm mesh size, opposite knots), set in the afternoon, and checked in the following morning. We also sampled using beach seines (5 m long, 2 m high, 5 mm mesh size) with a standardized effort of five seining operations along 25 m per sampling site, and two semicircular hand nets (80 cm in diameter, 1 mm mesh size) operated with a standardized effort of 20 min per sampling site.

At S3, we conducted four qualitative surveys from November 2021 to March 2022 using a hand net (0.5 mm mesh and 0.83 m^2 rectangular area) along the stream banks. We used this sampling gear to be able to sample the stream assemblage including juveniles since it is the only tributary in the area. We sampled only during the rainy season because this stream may dry out and is highly influenced by the water level reservoir during the dry season. This tributary is a third order stream that present one meter of average width and depth, varying greatly according to flooding events, from 50 cm to 1.5 meters.

We anesthetized all sampled fish with Eugenol solution 50mg/l, fixed them in 10% formalin solution, identified to the species level, and classified them as native, non-native, or migratory (Agostinho et al., 2003, 2007b; Ota et al., 2018; Ribeiro et al., 2019) they were later transferred to 70% alcohol solution. The literature information on first sexual maturation size (Lopes et al., 2000; Nakatani et al., 2001) of the migratory fish was used to classify the individuals as juveniles and adults. We deposited voucher specimens in the Ichthyological Collection of Federal University of Lavras – UFLA (CI – UFLA).

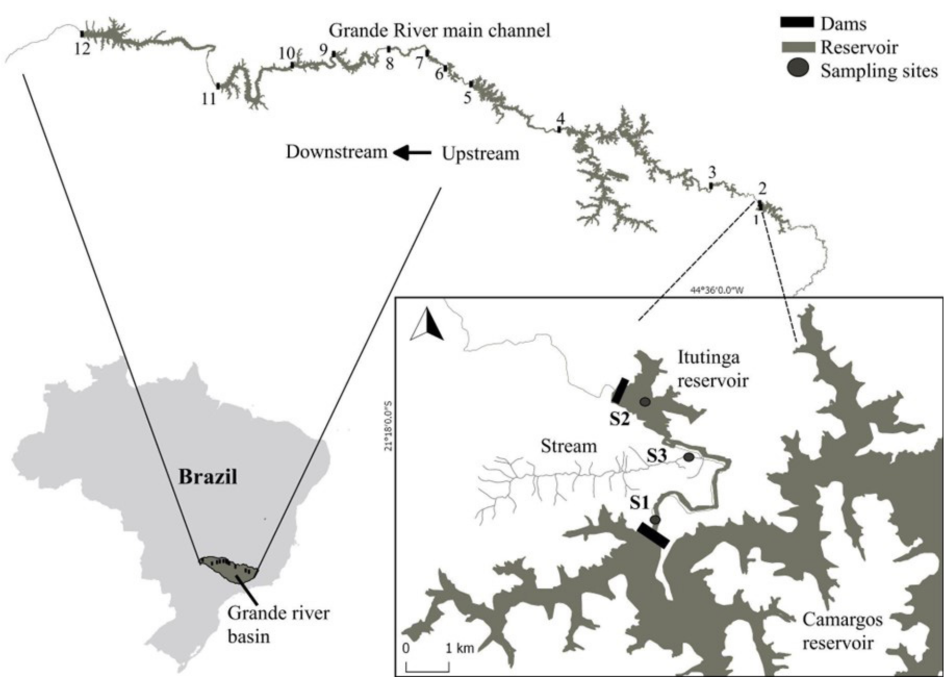

Figure 1. Sampling site's location (S1, S2 and S3) at the Itutinga reservoir, Grande River basin. 1-UHE Camargos, 2-Itutinga, 3-Funil, 4-Furnas, 5-Mascarenhas de Moraes, 6-Estreito, 7-Jaguara, 8-Igarapava, 9-Volta Grande, 10-Porto Colômbia, 11-Marimbondo, 12-Água vermelha.

2.3. Alves et al. (1998) sampling design

The two sites surveyed between December 1988 and June 1990 by Alves et al. (1998) are similar to the sites currently sampled: the central region of the IR (S2), and in the Grande River upstream of the reservoir (S1). In both sampling sites, and in the five campaigns carried out, Alves et al. (1998) used ten 20-meters-long gillnets (3,4,5,6,7,8,10,12,14 and 16 cm mesh size, opposite knots),),set in the afternoon and checked in the following morning. Beach seines were also used along the reservoir bank, to sample small size fish.

2.4. Data analysis

In order to verify if the number of samples and sampling methods used in our study were representative, we calculated a species accumulation curve based on the number of sampled individuals. in RStudio environment (v4.1.0), using the packages 'iNEXT' (Hsieh et al., 2022), 'ggplot2' (Wickham, 2016) and 'grid' (R Core Team, 2022).

We compared the composition of fish fauna recorded in both studies (current and Alves et al., 1998), considering all fishing gears combined. The structure of the fish communities in the reservoir was also compared between periods. For this, only data from gillnets were used, and the numerical abundance of each species was standardized by the total abundance captured in each study in RStudio environment (v4.1.0), with the packages 'ggplot2' (Wickham, 2016) and 'forcats' (Wickham, 2023). For migratory species, we present their size distribution (cm) through histograms, in order to allow inferences about possible recruitment or stocking in the reservoir also in RStudio environment (v4.1.0) with the package 'ggplot2' (Wickham, 2016). The study area map was drawn in QGIS (v2.18.22) with GRASS 7.4.

3. Results

We collected a total of 12,978 individuals belonging to 37 fish species, 28 genera, 14 families, and 6 orders (Table 1). Characiformes (57.1%), Siluriformes (25.2%), Cichliformes (10.3%), and Cyprinodontiformes (5.5%) were the most representative orders. Five of the recently sampled species are non-native (13.5%) and five are considered migratory (Table 1). Among the latter, most of the captures were represented by adults. orders. For this group, only juveniles of *Pimelodus maculatus* (Lacepède, 1803) were registered (Figure 2), while juveniles of all non-native captured species were found. Species accumulation curve showed a tendency to asymptote (Figure 3), although new additional records are expected. Alves et al. (1998) captured 25 species distributed in 17 genera, 9 families, and 3 orders.

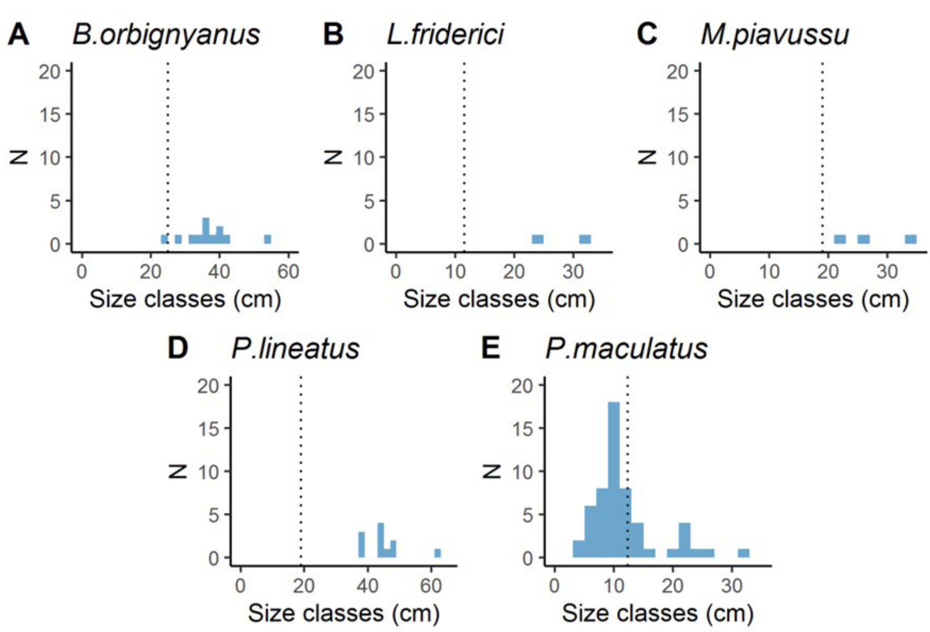

Figure 2. Histograms of the length of the individuals of each migratory species sampled in Itutinga reservoir (S1, S2 and S3). The dashed line indicates length at first maturation according to Lopes et al. (2000) and Nakatani et al. (2001). A- *Brycon orbignyanus*, B- *Leporinus friderici*, C- *Megaleporinus p*iavussu, D- *Prochilodus lineatus* and E- *Pimelodus maculatus.*

Table 1. Fish species collected in the present study in the Itutinga Reservoir (S1, S2 and S3) compared to samples collected by Alves et al. (1998).

Taxon	Alves et al. (1998)	Current study		
		S1	S2	S3
Characiformes				
Anostomidae				
Leporellus vittatus (Valenciennes 1850)	X			
Leporinus amblyrhynchus (Garavello & Britski, 1987)		1	7	
Leporinus friderici (Bloch, 1794) **	X	1	1	
Leporinus octofasciatus (Steindachner, 1915)	X	5	2	
Leporinus striatus (Kner, 1858)	X	7		
Megaleporinus piavussu (Britski *et al*., 2012) **		3		
Schizodon nasutus (Kner, 1858)	X	51	43	
Bryconidae				
Brycon orbignyanus (Valenciennes, 1850) **		13	1	
*Salminus hilarii (*Valenciennes 1850) **	X			
Salminus brasiliensis (Cuvier 1816) **	X			
Characidae				
Astyanax lacustris (Lütken, 1875)	X	15	18	4
Bryconamericus turiuba (Langeani *et al*., 2005)	X	354	1114	
Hasemania af. *Nana* (Lütken, 1875)			6	49
Hyphessobrycon bifasciatus (Ellis, 1911)				3
Knodus moenkhausii (Eigenmann & Kennedy, 1903) *		1299	7507	346
Oligosarcus paranensis (Menezes & Géry, 1983)		1		
Piabina argentea (Reinhardt, 1867)	X	3	10	1
Psalidodon bockmanni (Vari & Castro, 2007)				9
Psalidodon fasciatus (Cuvier, 1819)	X	261	50	4
Serrapinnus notomelas (Eigenmann, 1915)				4
Erythrinidae				
Hoplias intermedius (Günther, 1864)	X	4	2	1
Hoplias malabaricus (sp3) (Bloch, 1794)	X	3	18	
Parodontidae				
Apareiodon piracicabae (Eigenmann, 1907)		416	312	17
Prochilodontidae				
Prochilodus lineatus (Valenciennes, 1836) **	X	11		
Cichliformes				
Cichlidae				
Australoheros cf. tavaresi (Ottoni, 2012)			1	
Cichla kelberi (Kullander & Ferreira, 2006) *		8	16	
Cichla piquiti (Kullander & Ferreira, 2006) *		2	1	
Coptodon rendalli (Boulenger, 1897) *	X		42	10
Geophagus brasiliensis (Quoy & Gaimard, 1824)	X	31	35	11
Cyprinodontiformes				
Poeciliidae				
Poecilia reticulata (Peters, 1859) *		228	380	6
Gymnotiformes				
Gymnotidae				
Gymnotus sp.		1		
Sternopygidae				
Eigenmannia dutrai (Peixoto *et al*., 2021)	X	2	10	
Siluriformes				
Loricariidae				
Hypostomus cf. *iheringii* (Regan, 1908)		38	8	
Hypostomus cf. *egain* (Ihering, 1905)		11	2	
Hypostomus aff.*myersi* (Gosline 1947)	X			
Hypostomus aff. *Strigaticeps* (Regan, 1908)	X			
Hypostomus spp.	X		1	
Pimelodidae				
Iheringichthys labrosus (Lütken, 1874)	X	8	78	
Pimelodus maculatus (Lacepède, 1803) **	X	52	18	
Pseudopimelodidae				
Pseudopimelodus mangurus (Valenciennes, 1835)	X	1		
Synbranchiformes				
Synbranchidae				
Synbranchus marmoratus (Bloch, 1795)			1	
Total		2830	9683	465

The symbol * denotes non-native species and ** indicates migratory species.

When comparing the structure of fish assemblages in the reservoir (S2) with the 1998 study, important differences were observed. Regarding species composition, we registered 12 fish species that were not recorded by Alves et al. (1998), including four non-native (*Knodus moenkhausii* Eigenmann & Kennedy, 1903, *Cichla kelberi* Kullander & Ferreira, 2006, *Cichla piquiti* Kullander & Ferreira, 2006, and *Poecilia reticulata* Peters, 1859) and two migratory species (*Megaleporinus piavussu* Britski *et al.*, 2012 and *Brycon orbignyanus* Valenciennes, 1850) (Table 1). On the other hand, two migratory species (*Salminus hilarii* Valenciennes, 1850 and *S. brasiliensis* Cuvier 1816) as well as the rheophilic species *Leporellus vittatus* were registered only by Alves et al. (1998) (Table 1). Changes in the species abundance rank were also observed (Figure 4). *Pimelodus maculatus* and *Hoplias intermedius* Günther, 1864, the most abundant species found by Alves et al. (1998), which represented 40% of the past captures, only accounting for 5% of the CPUE in this study. The most abundant species currently were *Iheringicthys labrosus* Lütken, 1874 and *Psalidodon fasciatus* (Cuvier, 1819) (Figure 4).

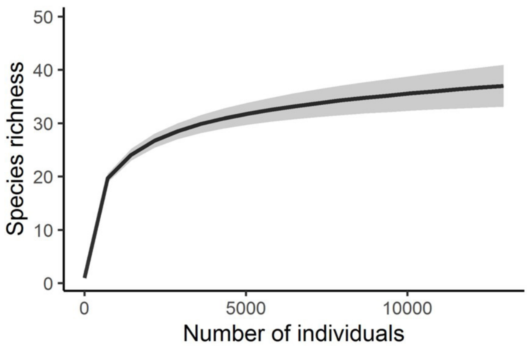

Figure 3. Species accumulation curve considering all samples and catching methods in the sampled sites in Itutinga reservoir area.

4. Discussion

In our study, we characterized the fish fauna of a small segment of the Grande River basin, confined between two dams, more than 30 years after the first assessment, the only available study to this day. Although Alves et al. (1998) suggested that fish assemblages in IR seemed to be stable, we observed important differences 33 years later, which can be related to several factors, including sample sufficiency. In fact, Loures and Pompeu (2019) showed that even 20 years after dam construction, fish assemblages from a cascading reservoir system in the Araguari River were still in the process of stabilizing, often with trends of increasing non-native fish species. Orsi and Britton (2014) found substantial shifts in fish assemblages in the Capivara Reservoir over 20 years, including the disappearance of 27 of 50 native species and the addition of 11

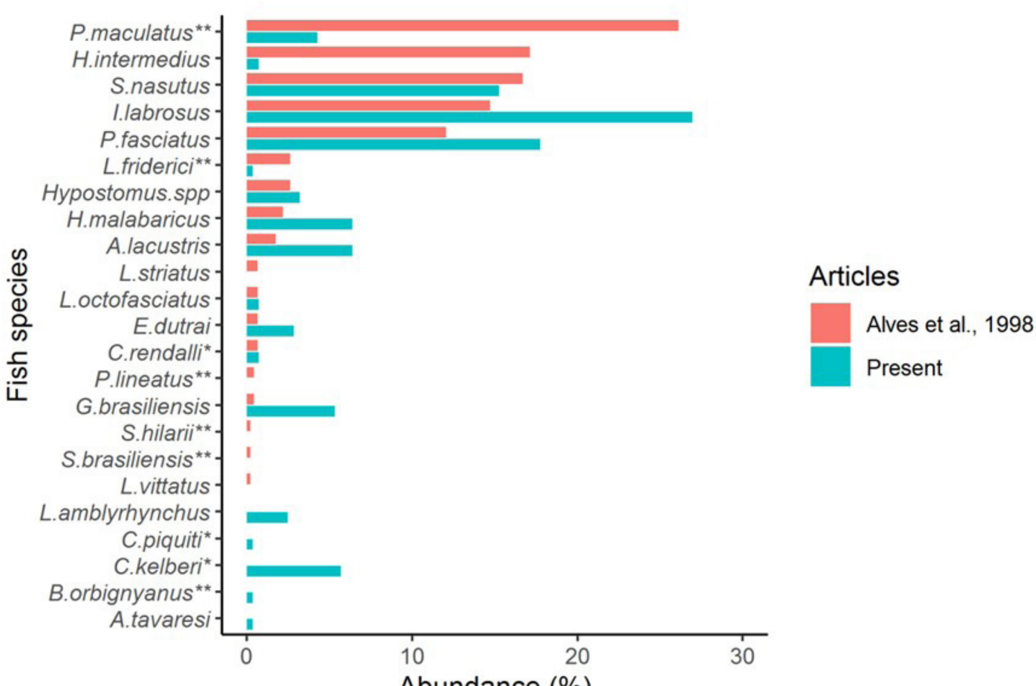

Figure 4. Species ranks based on the percentage of total abundance of fish species sampled with gillnets in this study (only S2) compared to Alves et al. (1998). The symbol ** denotes migratory species and * denotes non-native species.

non-native fish species. Therefore, the differences in fish assemblage over more than 30 years found in the present study indicate the importance of fish long-term monitoring as suggested by other studies (Andrade et al., 2017; Loures & Pompeu, 2019; Reid et al., 2019).

Three new non-native species were recorded in IR, namely *Knodus moenkhausii*, *Cichla kelberi* and *Cichla piquiti*. The new records of non-native species, such as *C. kelberi* and *C. piquiti* seem to be mostly related to fish stocking and sport fishing activities and may be responsible for inducing changes in the fish assemblage structure (Bueno et al., 2021). This anthropogenic disturbance can affect the system in many ways: non-native species can change habitats, compete for resources, and modify the function of the system as well as entire community dynamics (Agostinho et al., 2007c; Bueno et al., 2021; Leal et al., 2021; Pelicice & Agostinho 2009; Silva et al., 2021). The presence of both adults and juveniles of these non-native species suggests that they have successfully established populations in the studied river stretch (Blackburn et al., 2011), especially in the Itutinga Reservoir.

The presence of migratory species (*M. piavussu* and *B. orbignyanus*) in such an old and confined reservoir is probably associated with fish stocking programs and the presence of a hatchery facility nearby IR, as already highlighted by Alves et al. (1998). The replacement of some species can also be explained by the different target species used in these programs, since these species depend on lotic environments, mainly for reproduction, demanding adequate habitat conditions for breeding, spanning, early development, and dispersion (Agostinho et al., 2016; Lopes et al., 2018; Pompeu et al., 2012). While most migratory fish species sampled were adults, juveniles of *P. maculatus* were collected. The migratory status of this species is controversial (Arcifa & Esguícero, 2012; Oldani et al., 2007; Zaniboni-Filho & Schulz, 2003). According to Agostinho et al. (2003), small free stretches of river can be sufficient for *P. maculatus* to complete their life cycle. The presence of *P. maculatus in* the sampled area may also be explained by the possibility of passage downstream through the turbines and spillway of the Camargos Dam, as also proposed by Alves et al. (1998).

The change in the most abundant species from *P. Maculatus* (Alves et al., 1998) to *I. labrosus* (present study) involves two species with similar benthic behavior (Agostinho et al., 2007c) and morphological characteristics. The abundance of *I. labrosus* in comparison with *P. maculatus* can be related to the fact that *I. labrosus* is considered a sedentary species while *P. maculatus* may depend at least partially on lotic environments to complete its life cycle (Agostinho et al. 2003). In addition, *I. labrosus* has a smaller dependence on allochthonous resources (Silva et al., 2019), an important characteristic in a reservoir, that presents less marginal vegetation contribution than a free-flowing river with preserved riparian forest. However, comparing two periods of sampling separated by 30 years does not elucidate whether there was a gradual replacement between the two species, or cyclical fluctuations in their abundances.

The sharp decrease in the abundance of *H. Intermedius*, one of the main local predatory species (Gandini et al., 2012), may be associated with the establishment of species of the genus *Cichla*, as already verified in other lacustrine environments (Fugi et al., 2008; Gomiero & Braga, 2004). Individuals of this genus present a plasticity in diet that was associated with a successful colonization in reservoirs (Novaes et al., 2004). Fugi et al. (2008) observed that *Cichla kelberi* invasion affected the top predator fish species diet modifying their diet and abundance. *Cichla kelberi* has also been related to community disassembly and can generate decline of several ecosystem functions led by predation and competition (Leal et al., 2021).

By assessing the fish fauna of the Itutinga Reservoir 33 years after its first survey, we updated the fish species list and showed some important differences in the fish assemblage structure. We highlight the importance of long-term fish monitoring in reservoirs to assess temporal variation in fish assemblages and their responses to the multiple possibilities of external stressors, such as the shift in the abundance of non-native species in these environments.

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