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ICHTHYOFAUNA OF THE MARIMBONDINHO RIVER, FURNAS RESERVOIR, MINAS GERAIS, BRAZIL

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Abstract: Ichthyofauna surveys are essential for conservation efforts in reservoirs. Here we present a list of fish species found in the Marimbondinho River, a tributary of the Furnas HPP reservoir in Minas Gerais, Brazil. Fish captures were conducted using gillnets and cast nets at five sampling points during six campaigns in 2018 and 2019. We recorded a total of 1,832 individuals belonging to 31 species, distributed in 16 families and four orders. Four fish species were considered long-distance migrants, and five were identified as non-natives. None of the captured species are listed as threatened on the official Brazilian list. Order Characiformes exhibited the highest species richness; in which Anostomidae and Characidae were the families with great species richness. *Hoplosternum littorale* was the most abundant species, presented in approximately 22% of all the captures. Overall, the results indicate that the ichthyofauna of Marimbondinho River is similar to those typically observed in Brazilian reservoirs, with the expected richness and number of migratory species. We expect this study can help in future monitoring programs and, fundamentally, to propose conservation and management measures on endemic and migratory species of Furnas reservoir.

Keywords: anthropic impacts; ichthyofauna survey; fish ecology; neotropical fishes.

The change from a lotic to lentic environment by the construction of a hydroelectric plant causes drastic variations in the ichthyofauna (Agostinho *et al.* 2008). For instance, Furnas Hydro Power Plant (Rio Grande, Upper Paraná River) is among the oldest reservoirs in Southeast Brazil — and has impacted fish assemblages since its construction. Studies on the ichthyofauna of this reservoir have focused, for example, on the aquaculture (Furnas 2007), biology of fish species (Santos *et al.* 2004, Ribeiro *et al.* 2007), and introduction of non-native species (Azevedo-Santos *et al.* 2011). However, many regions of the Furnas reservoir, especially in the mouths of tributaries, have no information on fish species or assemblages; this is the case, for example, of the Marimbondinho River. A survey on the ichthyofauna of this region can contribute in different ways, as in addition to generating information that supports new studies, it helps in the identification of migratory species that use the region to complete their reproductive cycle. Therefore, here we provide an ichthyofauna survey of the Marimbondinho River, a tributary located upstream of the Furnas reservoir, in the municipality of Boa Esperança, Minas Gerais, Brazil. This study is part of what was requested by the Public Prosecutor's Office of the District of Boa Esperança – Minas Gerais, in the records of the Civil Inquiry (IC) nº MPMG – MPMG-0071.19.000163-7.

The Furnas reservoir is one of the largest in Brazil, with 1.440 km^2 of flooded area (Azevedo-Santos *et al.* 2011). Dammed in 1963, it flooded part of its main rivers, such as the Grande and Sapucaí, and many tributaries, such as the Marimbondinho River, which flows into the upper part of the Grande River, near the municipality of Boa Esperança, Minas Gerais (21°

5’48.94” S, 45°33’21.98” W). Many cities bordering the Furnas reservoir make use of it for tourism, and this is the case of Boa Esperança municipality. Due to issues related to the large variation in the level of the reservoir that directly affected the region of the mouth of the Marimbondinho River and brought sanitary problems to the city of Boa Esperança, a dike was built in the middle course of the river, close to the city, giving rise to Lago dos Encantos. The presence of this dike, in addition to reducing the effects of the discharge of sewage from the city into its dammed waters, regulates the level of the dam upstream and allows tourism activities throughout the year in the city. In this way, the construction of the dike reduced the influence of the reservoir of the Furnas HPP in the upstream areas, while the downstream areas are susceptible to annual variation in its level. Thus, the sampling program was defined in order to sample five sites (S1 to S5) (Table 1; Figure 1), two located upstream of the dike, in Lago dos Encantos (S1 and S2), and three downstream from it, in the flooded arm of the reservoir of the Furnas HPP itself (S3 to S5).

Table 1. Characterization of each sampling site used in this study to perform ichthyofauna surveys along Marimbondinho River, Minas Gerais, Brazil.

Station	Coordinates	Position	Substrate	Riparian vegetation	Depth (m)
S1	21° 4’17.78”S; 45°33’43.73”W	Upstream	Sand	Absent	5
S2	21° 4’54.01”S; 45°31’46.43”W	Upstream	Sand	Absent	5
S3	21° 3’56.36”S; 45°33’13.45”W	Downstream	Organic matter	Macrophytes bank	1,5
S4	21° 2’59.80”S; 45°32’57.04”W	Downstream	Organic matter	Macrophytes bank	2,5
S5	21° 1’37.74”S; 45°32'50.52"W	Downstream	Organic matter	Macrophytes bank	4

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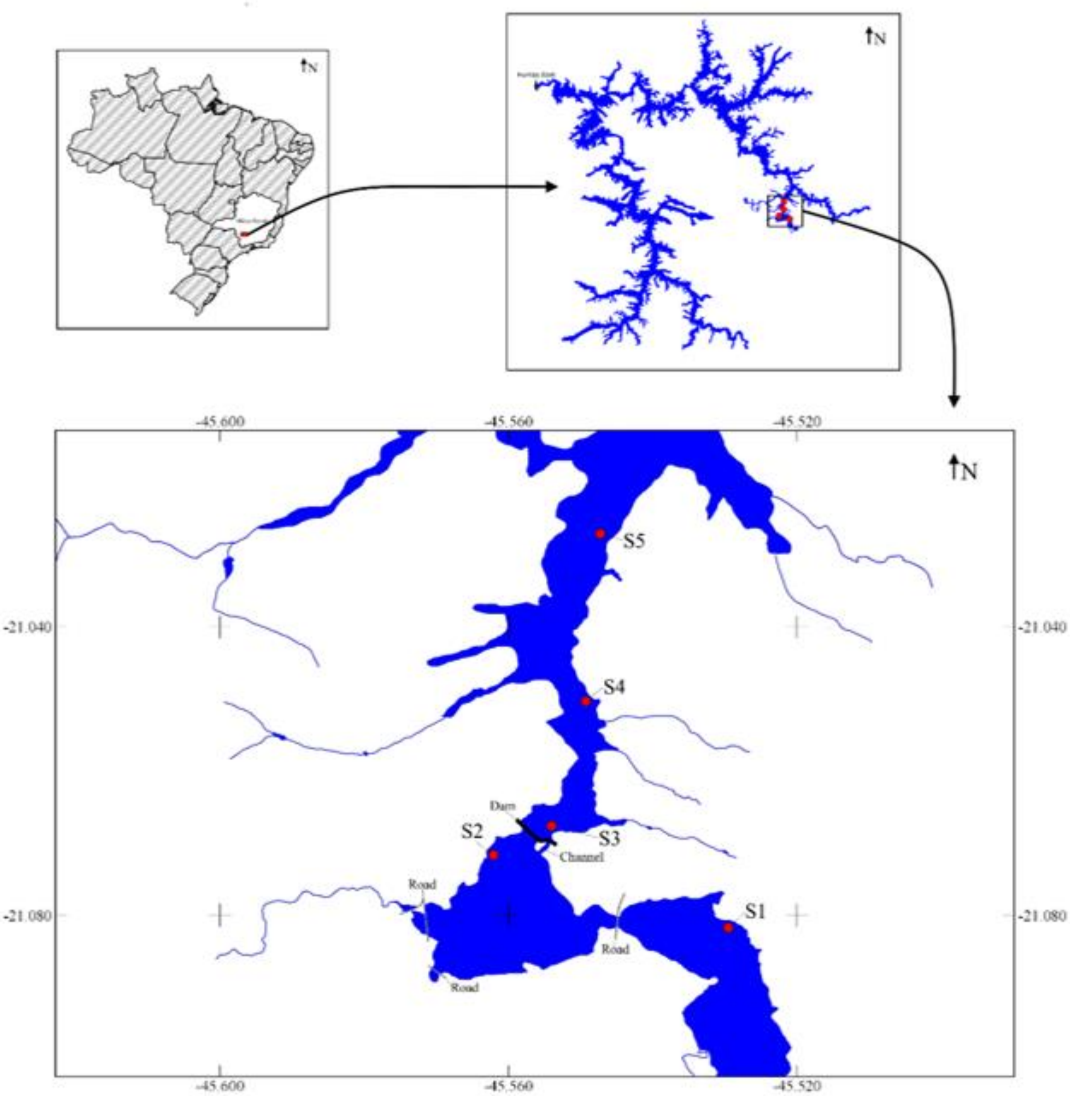

Figure 1. Location of sampling points along the Marimbondinho stream, Boa Esperança, Minas Gerais, Brazil (modified from Azevedo-Santos et al. 2019).

Six samplings were carried out at each station (ABIO authorization No. 1099/2019), in the months of May, August, November and December of 2019 and January and February of 2020. The samplings were carried out using a set of eight gill nets (meshes of 3, 5, 6, 7, 8, 10, 12, 14 cm, between opposite nodes for 25 meters in length), which were installed perpendicular to the bank, at dusk, and removed the following day (approximately 14 hours of exposure). Due to fluctuations in the level of the reservoir at Furnas HPP, the complete set was installed in all campaigns only at points S1, S2 and S5 (Supplementary Material 1). Cast nets (diameter of 3 m and meshes of 2 to 3 cm) were also used with a total of 15 castings of netting at each point.

The captured individuals were placed in plastic bags containing data on the location and mesh size. Then, fish were identified using keys (Menezes 1987, Oyakawa & Mattox 2009, Ota *et al.* 2018, Peixoto *et al.* 2015), counted, photographed, weighed and the total length (TL) and standard (SL) measured. Representative specimens (*i.e.*, vouchers) of species were fixed in formaldehyde (10%) and preserved in alcohol (70%) and deposited in the collection of the Laboratory of Fish Biology (LBP), at the Universidade Estadual Paulista "Júlio de Mesquita Filho", in Botucatu, São Paulo, Brazil.

The species were classified according to their origin and their migratory behavior based on the literature (Langeani *et al*. 2007, Vazzoler 1996, Agostinho *et al*. 2003, Vasconcelos *et al*. 2014, Santos 2010). The classification of families into orders, and species into families, followed the Eschmeyer's Catalog of Fishes (Fricke *et al.* 2023, Van der Laan *et al.* 2023). The species rarefaction curve was estimated, considering all samples taken at all points as replicates. The observed richness (Sobs) and Bootstrap were used as estimators. These analyses were performed using Primer 6.0 software (Anderson *et al.* 2008).

A total of 1,892 individuals was captured, representing 31 species, 16 families and four orders (Supplementary Material 2). Four species were classified as long-distance migratory, *Prochilodus lineatus* (Valenciennes 1837) (N = 6), *Salminus hilarii* Valenciennes 1850 (N = 1), *Megaleporinus obtusidens* (Valenciennes 1837) (N = 6) and *Pimelodus maculatus* Lacepède 1803 (N = 97) (Supplementary Material 2). Five species were classified as non-native, three allochthonous (*Cichla piquiti* Kullander & Ferreira 2006, *Hoplosternum littorale* (Hancock 1828) and *Metynnis lippincottianus* (Cope 1870)), and two exotics (*Coptodon rendalli* (Boulenger 1897) and *Oreochromis niloticus* (Linnaeus 1758)).

Characiformes was the order with greater richness and abundance, with 18 species (58% of the total) and 1,026 individuals (54.2%), followed by Siluriformes, with seven species (22% of the total) and 728 individuals (38.5%) (Figure 2). Among the 16 families, the highest richness was observed in Anostomidae, with five species, followed by Characidae and Cichlidae, both with four species (Figure 2). In terms of abundance, Characidae was the most important family, with 526 individuals (27.8%), followed by Callichthyidae (22.2%) and Curimatidae (19.3%). *Hoplosternum littorale* (Hancock 1828) was the most abundant, with 419 individuals (22.1%), followed by *Steindachnerina insculpta* (Fernández-Yépez 1948) (18.5%) and *Psalidodon fasciatus* (Cuvier 1819) (15.9%) (Figure 3).

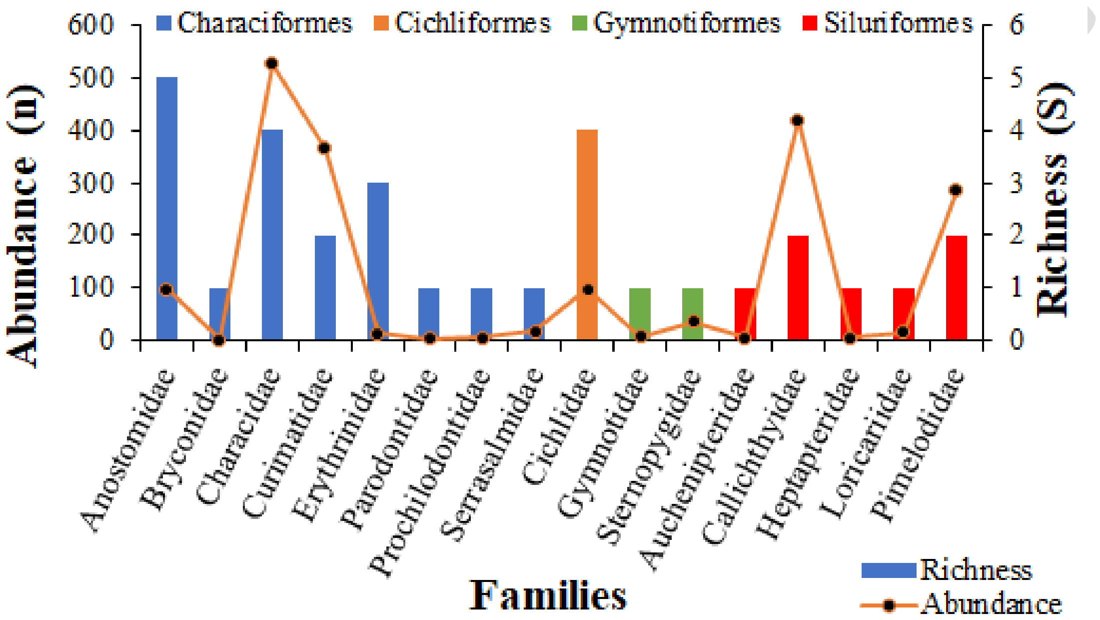

Figure 2. Abundance and richness by orders and families recorded along the Marimbondinho stream, Boa Esperança, Minas Gerais, Brazil. line = abundance; columns = richness.

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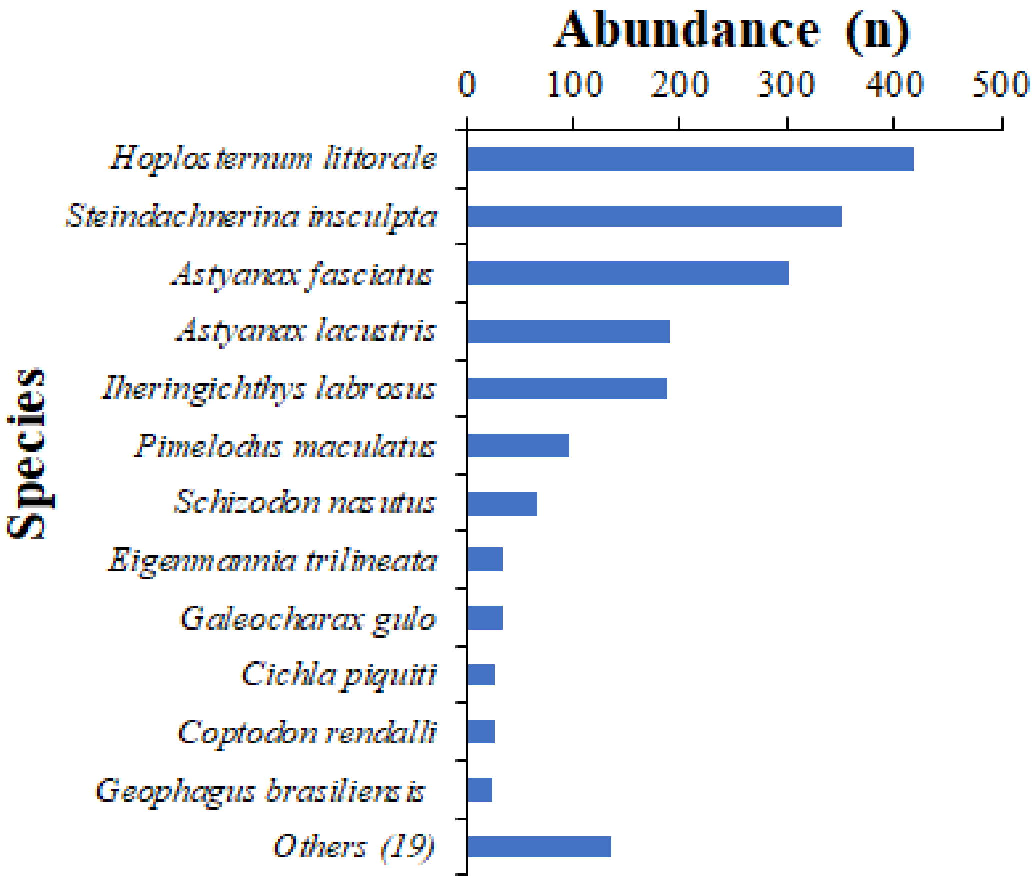

Figure 3. Number of individuals recorded for the most abundant species along the Marimbondinho stream, Boa Esperança, Minas Gerais, Brazil.

The highest abundance was found in S5, which was captured 680 individuals, followed by S1, with 547 (Figure 4). The site with the highest species richness was S2, with 22 species, followed by S5, with 21 (Figure 5). The species accumulation curve (Figure 6) approached the plateau, according to the methods used (Sobs = 31; Bootstrap = 32.72).

The data presented here indicate that the ichthyofaunistic richness of the sampled sites is lower than expected for dammed environments, where between 40 and 50 species were found by other authors (*e.g.*, Pelicice *et al*. 2018, Nobile *et al*. 2019b, Queiroz-Sousa *et al*. 2019). However, it is important to point out that the use of gillnets may have exerted sample selectivity on the ichthyofauna, preventing the capture of small-sized species, such as the Poeciliidae and Characidae family.

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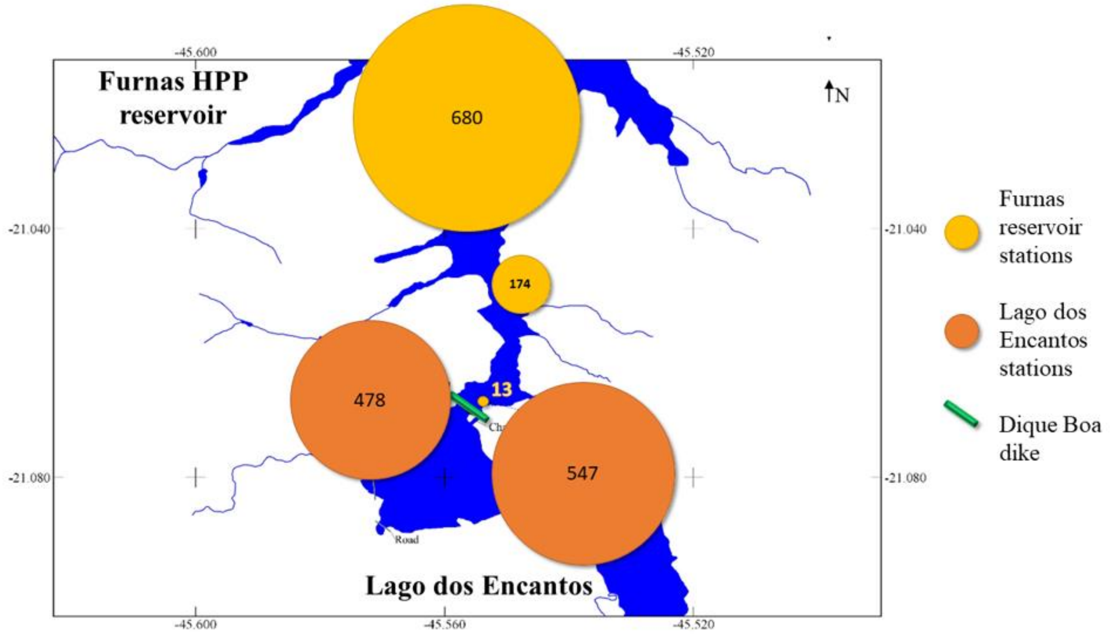

Figure 4. Fish abundance per sampling sites along the Marimbondinho River arm, Boa Esperança, Minas Gerais, Brazil.

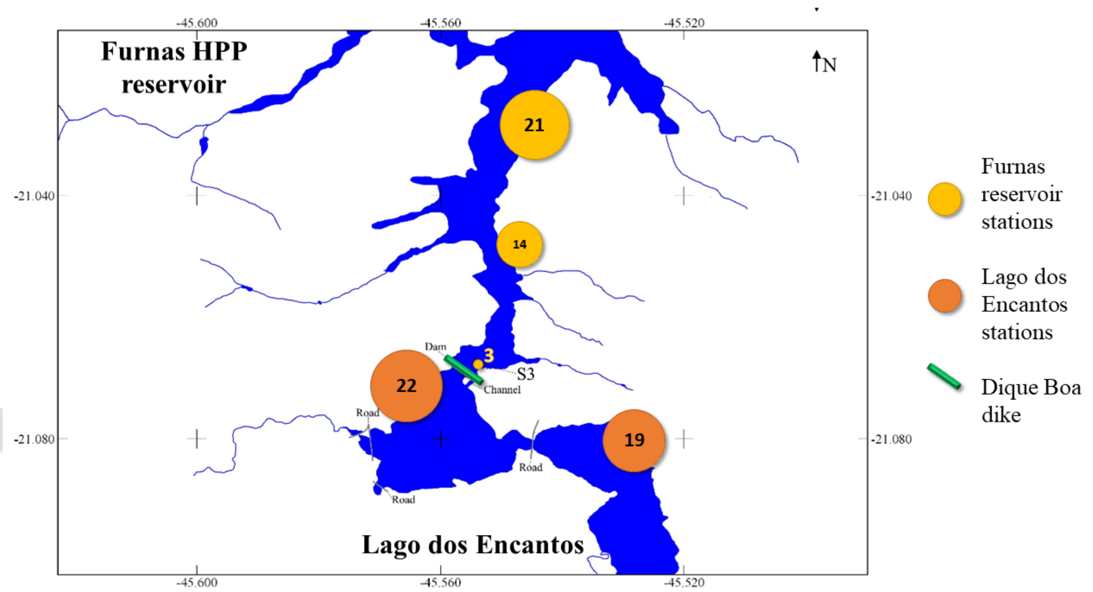

Figure 5. Fish richness per sampling sites along the Marimbondinho River arm, Boa Esperança, Minas Gerais, Brazil.

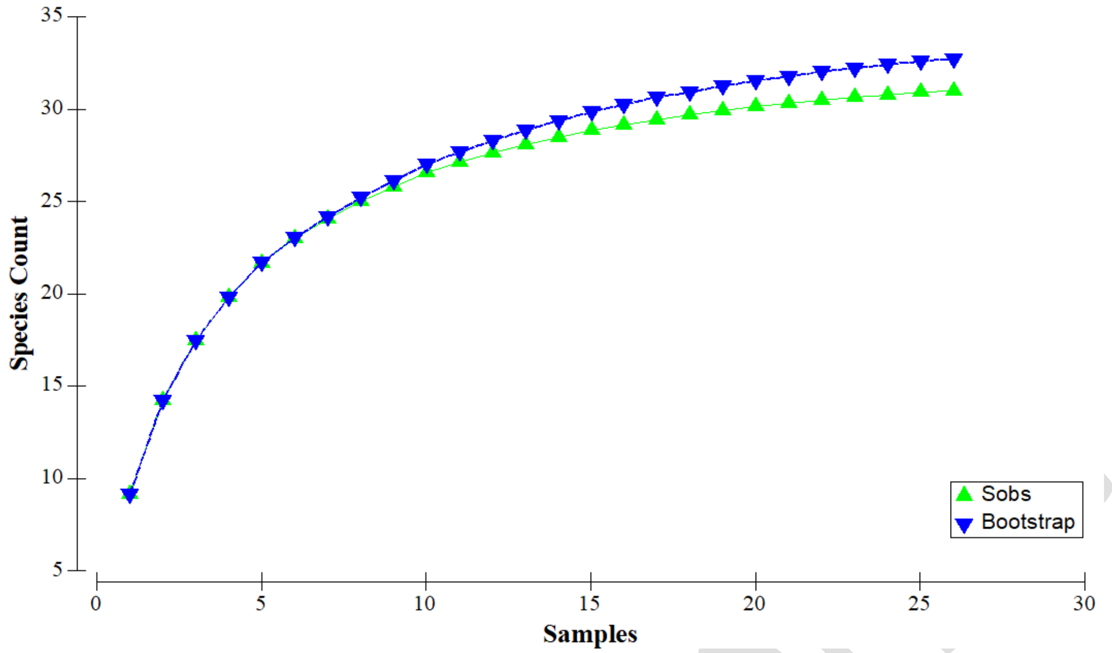

Figure 6. Species accumulation curve considering all samplings and collection stations in the Marimbondinho River, Boa Esperança, Minas Gerais, Brazil.

Regarding the four migratory species recorded, it was observed that except for *Salminus hilarii*, which had only one individual captured upstream of the dike at S2, the others had greater abundance recorded at sites downstream of the dike. The Furnas HPP reservoir receives several tributaries, from streams to rivers, the main tributaries being the Grande and Sapucaí rivers, which have upstream stretches that have not yet been dammed. Migratory fish need dam-free stretches, as they do not reproduce in lentic ecosystems, which is one of the main reasons why dams represent disturbances to migratory populations (Marques *et al*. 2018, Agostinho *et al*. 2008). The capture of these long-distance migrants in the upper reaches of the Furnas HPP reservoir indicates that its tributaries can play an important role in maintaining these populations and, in this sense, the preservation of the natural flow of these waterbodies becomes crucial. However, this does not seem to be the case in the Marimbondinho River region, due to the occurrence of few migratory species and the low abundance recorded for these, with no schools being recorded even in the spawning months, only the presence of a few individuals.

Five non-native species were recorded. *Hoplosternum littorale* is attributed as a native of the upper Paraná system (Langeani *et al.* 2007). However, Santos (2010) reported that the species was introduced into the Rio Grande basin. *Cichla piquiti* probably occurs in the studied area due to sport fishing activities, and fishing tournaments still occur in neighboring municipalities. On the other hand, the presence of *C. rendalli* and *O. niloticus* in the reservoir is consequence of the aquaculture activity, since these species were widely introduced in Brazil by this activity (Nobile *et al*. 2019a), including in the Furnas HPP reservoir (Azevedo-Santos *et al.* 2011). The occurrence of *M. lippincottianus* in the region may be result of aquarium dumping, since this is one explanation to its introduction in other regions of the country (Assis *et al*. 2017).

The order Characiformes dominated in terms of richness and abundance, followed by the order Siluriformes (Figure 2). In the Neotropical region as a whole, whether in reservoirs or in environments under lower anthropic pressure, this pattern has been treated as expected, with some inversion between these orders (Lowe-McConnell 1987, Agostinho & Júlio Jr 1999, Langeani *et al*. 2007, Jarduli *et al*. 2020).

In this study, the highest species richness per family was recorded for Anostomidae. This constitutes a peculiarity, since, generally, Characidae and Loricariidae are the families with the greatest richness (Langeani *et al*. 2007, Jarduli *et al*. 2020, Pelicice *et al*. 2018). These results may also be linked to the selectivity of the capture methods, and, in this study, the low richness observed for the Characidae family corroborates with some studies that used only gillnets (Britto & Carvalho 2006, Nobile *et al.* 2019b). As anostomids generally reach medium to large sizes, they may have been captured more frequently with the methods employed, contributing to greater richness.

Despite the lower richness, the highest abundances per family were recorded for Characidae, Curimatidae and Callichthyidae. In environments under the effect of dams, such as those sampled in this study, changes in the composition and structure of assemblages may occur, generally with a decrease in large species, more common in lotic environments, and an increase in small ones (Agostinho *et al*. 2016, Lima *et al*. 2016, Nobile *et al*. 2019b). In this scenario, in the upstream environments (S1 and S2), Characidae, represented by *A. lacustris* and *P. fasciatus*, and Curimatidae, represented by *S. insculpta*, express a population explosion, since those species adjusted very well to these new environments (Ribeiro *et al*. 2007, Peressin *et al*. 2012, Lopes *et al*. 2016). The third most abundant family, Callichthyidae, was more representative at the downstream points (S3 to S5) (Figure 2), represented almost exclusively by *H. littorale*, the most abundant species in this study (22% of catches) (Figure 3). *Hoplosternum littorale* exhibits parental care (Vazzoler 1996); builds nests (Ramnarine 1995) and before and after hatching they protect the offspring against predators, which can explain its success. Also, they do not depend on running water to reproduce (Vazzoler 1996), feed on various types of items (Vazzoler *et al*. 1997, Souto *et al*. 2016) and tolerate environments with less oxygenation (Brauner *et al*. 1995), as that observed downstream.

In this study, *Oligosarcus argenteus* Günther 1864 was a new record for the Furnas reservoir. Azevedo-Santos *et al*. (2019), studying streams, provided the report of its occurrence for the Paraná River basin. This species probably occurs naturally both in streams and in the reservoir at Furnas HPP. Thus, this record is an expansion in the distribution of *O. argenteus* in the Paraná basin.

Eigenmannia cf. *trilineata* (López & Castello 1966) is considered a species very similar to other congeners with subterminal mouths, as previously described (Peixoto *et al*. 2015, Peixoto & Wosiacki 2016, Campos-da-Paz & Queiroz 2017). Apparently, the species we captured in the region is the same one reported by Azevedo-Santos *et al.* (2019) from an affluent creek of the reservoir of Furnas HPP. The exact identification of the species will depend on new morphological analyses (and involving osteological characteristics). With these new assessments, it will be possible to determine whether this is a species already described (*e.g.*, *E. besouro* Peixoto & Wosiacki 2016 or if it is a possibly undescribed species of the "*E. trilineata* group" (*sensu* Peixoto *et al*. 2015).

The ichthyofauna of the Marimbondinho River was highly impacted by humans, with reduced species diversity, with low abundance of migrants, but with species adapted to lentic and/or dammed environments, as well as the presence of non-native species. We hope that our study will provide base line values to help future monitoring programs determine if there are changes over time and provide information the help establish appropriate conservation and management measures for these artificial ecosystems — with a focus on endemic and migratory species.

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SUPPLEMENTARY MATERIAL

Supplementary Material 1. Effort applied at each sampling point, in different campaigns.

Supplementary Material 2. Taxa (orders, families, and species) and abundance (in each sampling station) found in the Furnas HPP reservoir, Boa Esperança region, Minas Gerais, southeastern Brazil. * non-natives; ** migrators.

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