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Short Communication

HYDROCHEMICAL PARAMETERS AND BIOMETRIC DATA OF FISH SPECIES FROM THE BORORÉ, BILLINGS RESERVOIR, SÃO PAULO, BRAZIL*

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ABSTRACT

The artisanal fishing is an important activity in Billings Reservoir (São Paulo, Brazil) and there is a paucity of biometric data about the fish in this region. Thereby, it is important to provide data about ichthyofauna that can be used for future management actions. The aim of this study was to present some data about the water quality and biometric data on fish species collected at the Bororé site (Billings Reservoir). In general, the obtained hydrochemical data raised a concern about the water quality because some parameters were above the established limit for body water class 2. A total of 170 fish were captured, corresponding to seven species and one genus. *Geophagus brasiliensis* was the most representative species (36%), followed by *Astyanax bimaculatus* (25%) and *A. eigenmanniorum* (20%). The hepatosomatic index (HSI) data showed differences in energy displacement between the species; the highest HSI values were observed in *Hoplias malabaricus* (HSI_{male}= 1.33 ± 0.20; HSI_{female}= 1.17 ± 0.82) while the smallest HSI was observed in *A. fasciatus* (HSI_{male}= 0.47 ± 0.14; HSI_{female}= 0.68 ± 0.35).

Keywords: water quality; fishes; weight; length; sex ratio; reservoir.

PARÂMETROS HIDROQUÍMICOS E DADOS BIOMÉTRICOS DE ESPÉCIES DE PEIXES DO BORORÉ, RESERVATÓRIO DE BILLINGS, SÃO PAULO, BRASIL

RESUMO

A pesca artesanal é uma atividade importante no reservatório Billings (São Paulo, Brasil) e há uma escassez de dados biométricos de peixes nesta região. Deste modo, é importante fornecer dados sobre a ictiofauna que possam ser usados para futuras ações de manejo. O objetivo deste estudo foi apresentar alguns dados sobre a qualidade da água e dados biométricos de espécies de peixes coletados no Bororé (Represa Billings). Em geral, os dados hidroquímicos obtidos revelam uma preocupação com a qualidade da água, pois alguns parâmetros estiveram acima do limite máximo estabelecido para corpos de água classe 2. Foram capturados 170 peixes, correspondendo a sete espécies e um gênero. *Geophagus brasiliensis* foi a espécie mais representativa (36%), seguida por *Astyanax bimaculatus* (25%) e *A. eigenmanniorum* (20%). Os dados do índice hepatossomático (IHS) mostraram diferenças quanto ao deslocamento de energia entre as espécies; os maiores valores de IHS foram observados em *Hoplias malabaricus* (IHS_{machos}= 1,33 ± 0,20; $IHS_{fêmeas}$= 1,17 ± 0,82), enquanto os menores IHS foram observados em *A. fasciatus* (IHS_{machos}: 0,47 ± 0,13; $IHS_{fêmeas}$= 0,68 ± 0,35).

Palavras-chave: Qualidade da água; peixes; peso; comprimento; proporção sexual; reservatório.

INTRODUCTION

Several freshwater ecosystems in tropical regions are subjected to anthropic disruptions, which promote the degradation of the water quality and the ecological patterns of resident species (Heath, 1990; Ogashawara et al., 2014; Ribeiro et al., 2020). The Billings Reservoir is in the Upper Tietê River Basin, on the Billings-Tamanduateí sub-basin and is the main reservoir for water supply in the Metropolitan Region of São Paulo (MRSP) (approximately 15% of the MRSP population) (SIGRH, 2009; Risso et al., 2018). However, during the last 40 years, the Billings reservoir has undergone an accelerated process of urban expansion and irregular occupation, with an absent or precarious sanitation infrastructure influxes of domestic and industrial waste (Porto, 2004; Wengrat and Bicudo, 2011; Cardoso-Silva et al., 2014; CETESB, 2019).

During the 1960s, the fishing activity in the Billings Reservoir was intensified, with the practice of intentional introduction of fish species being carried out to establish and increase fisheries in the region (Rocha et al., 1985; Fundação Energia e Saneamento, 2020). The first group of species to be introduced were carp (*Cyprinus carpio*) and tilapia (*Tilapia rendalli* and *T. melanopleura*). Some migratory species such as dorado (*Salminus brasiliensis*), guinea fowl (*Pseudoplatystoma corruscans*) and jurupocas (*Hemisorubim platyrhychos*) had their reproductive routes altered due to the barring of the courses of large rivers; this contributed to the reduction of the species in the Billings Reservoir, giving way to more sedentary species, mainly traira (*Hoplias malabaricus*), cara (*Geophagus brasiliensis*), lambaris (*Astyanax bimaculatus*, *A. fasciatus*, *A. eigenmanniorum*) and catfish (*Rhamdia* sp.) (Rocha et al., 1985). According to Froese and Pauly (2019), these species are of commercial interest for ornamental fishkeeping (one of the most popular hobbies in the world), aquaculture and/or artisanal fishing. They have specific eating habits and range from carnivorous species such as *H. malabaricus*, to omnivores such as *Astyanax* sp.

Although the Billings Reservoir is an environment with highly degraded points such as the Corpo Central I (CETESB, 2019), artisanal fishing is still recurrent in the region, serving as support for many families that depend on fishing for subsistence. Alves da Silva et al. (2009) report the existence of ten fishing nuclei. Knowledge about the ichthyofauna, as well as the dynamics of the abiotic parameters' indicative of water quality to which the organisms are subjected in these aquatic compartments, are essential to the observation of changes over time, ensuring the safety of fishermen and other local users, as well as providing biological data concerning fish species that can be used for conservation purposes.

Biometric data, such as length and weight of fish, can be used to provide information concerning their biological health and environment, because fish are poikilotherms and are unable to actively regulate their body temperature. They are also subject to physical and chemical modifications in the aquatic environment (Matthews, 1998; Gomiero and Braga, 2006). In this context, the availability of food resources, as well as ecological interactions, such as competition and changes in physical and chemical factors, can also change biological responses such as the species' growth (Adams and Ryon, 1994). With respect to specimens, increases in weight, growth, and the accumulation of energy reserves in liver tissue are some of the metrics used to characterize responses to environmental stress in the aquatic ecosystem (Le Cren, 1951; Lizama and Takemoto, 2008).

Somatic indexes such as the hepatosomatic index (HSI) are important for the estimation of fish energy storage, as well as the identification of the reproductive period of species and its association with the mobilization of energy reserves during this period (Wootton et al., 1978). Regarding abiotic parameters, temperature, for example, is an important factor for the regulation of survival, the reproductive process, several physiological processes, and the distribution of fish in the environment (Heath, 1990; Matthews, 1998; Galib et al., 2020).

Finally, since the introduction of the first fish species in the Billings Reservoir, there has been a paucity of data with which to continuously monitor the biometric aspects of the fish species within this environment. Regarding to fish, the most recent studies in the Billings reservoir are focused on the evaluation of different biomarkers (Furlan et al., 2018; Tolussi et al., 2018; Escalante-Rojas et al., 2021), with a paucity of data regarding population structure. Therefore, the goal of this study was to present some data of water quality and biometric data, such as the weight, length, and sex ratio of fish species with ecological and commercial importance concerning the community of the Bororé site (Billings Reservoir, SP, Brazil).

MATERIAL AND METHODS

Study area

In this study, fish and hydrochemical data were collected in the Bororé region. With the inclusion of part of the Upper Tietê River basin (UGRHI 6), together with Rio Pequeno, Rio Grande and Taquacetuba, Bororé is one of the tributaries of the Billings-Tamanduateí sub-basin, located in the extreme south of the São Paulo and São Bernardo do Campo municipalities (SIGRH, 2009). Regarding the political-administrative framework, Bororé is part of the administrative district of Grajaú and borders the Atlantic Forest of Serra do Mar and the Billings Reservoir, which bathes 90% of its extension (Porto, 2004; SIGRH, 2009). In this region, there is an important fishing community of several fishing families, who contribute to the local economy (Alves da Silva et al., 2009).

In the Bororé region, the spread of the metropolitan urban fleck is noticeable, with the presence of a remarkable amount of precarious and irregular residences (SIGRH, 2009; Alves et al., 2010). The Bororé district is located within the Bororé-Colônia Environmental Protection Area (APA) (State Law n°. 14.162/2006; São Paulo, 2006) and, in accordance with the National System of Conservation Units (SNUC - Federal Law n° 9.985/2000; Brasil, 2000), it is a Conservation Unit of Sustainable Use (Porto, 2004). With respect to land use, approximately 14.63% of the Billings hydrographic basin's territory is occupied for urban use and 53% of its total area is covered by native forest (Capobianco and Whately, 2002). The climate in the region is tropical and humid, with a mean daily temperature of 23.8°C and an annual rainfall of 1,591 mm (Marcuzzo, 2016; CETESB, 2019).

The map that indicates the study area and locations where the fishing nets were placed, was made using QGIS software through the collection of information about the body of water, municipalities, state limits and urban areas from IBGE (2019). Information about the hydrographic basin was obtained using DataGEO (online) (São Paulo, 2020). The projected Datum coordinate system, Sirgas 2000/UTM zone 23S, was also used.

Hydrochemical data, Fish collection and Biometric Data

Fish were collected in February 2020 in Bororé, Billings Reservoir, São Paulo State, Brazil (Figure 1). Prior to the biological sampling, the hydrochemical data were measured on surface and bottom at the fishing net sites to characterize the sampling sites. A measurement of the local depth was obtained in meters using a cable with a metal weight. Temperature (°C), pH, electric conductivity (mS cm^{-1}), turbidity (NTU; nephelometric turbidity unit), dissolved oxygen (DO; mg L^{-1}) and dissolved total solids (DTS; g L^{-1}) were registered using a Horiba multiparameter probe.

With respect to fish sampling, this study prioritized the collection of fish species normally caught by artisanal fishermen on Billings Reservoir, either for subsistence purposes or as live bait. Therefore, six monofilament gill nets [mesh size 2.5 (n: 1), 8 (n: 2) and 10 (n: 3) cm], of different heights and lengths, were placed at reservoir margins during the 12 hours between dusk and sunrise. The geographic coordinates of the gillnets place are shown in Figure 1. All collected and analyzed fish specimens were authorized by ICMBio (Instituto Chico Mendes de Conservação da Biodiversidade - Sisbio process nº 72470-2) and approved by the Ethics Committee on the Use of Animals of the Universidade Federal de São Paulo (UNIFESP, Brazil - CEUA process nº 5619100719).

The captured fish were removed from the nets, maintained for five minutes in cold water (0°C) to reduce sensitivity, and anesthetized with 250 mg L^{-1} benzocaine hydrochloride. The specimens were then kept on ice, and in the laboratory, the biometric data were registered as the total body size of the fish measured as the length from the tip of snout to the end of the caudal fin using an ichthyometer (± 0.01 cm). The total fish weight and liver weight were obtained using a precision scale (± 0.0001 g, Shimadzu AY 220). The fish were dissected, and their sex was identified using ovarian and testicular morphological characteristics (position, color, and size of gonads as well as the presence of veins, eggs, and sperm) (Vazzoler, 1996). After dissection, specimens were fixed in 70% alcohol and the identification of the species was based on the identification keys by Britski et al. (1984) and Yoshida et al. (2016). Voucher specimens were deposited in the Aquatic Toxicology and Fish Ecophysiology Group (AquaTox) of the Universidade Federal de São Paulo (UNIFESP, Brazil).

The hepatosomatic index (HSI) was calculated as: HSI = LW/TW*100, where LW was the liver weight and TW was the total weight. The sex ratio was given as M:F calculated in relation to the total number of males/total number of females (Vazzoler, 1996).

RESULTS AND DISCUSSION

During the sampling period (18 and 19 February 2020), although the air humidity was high (about 78.4%), there was

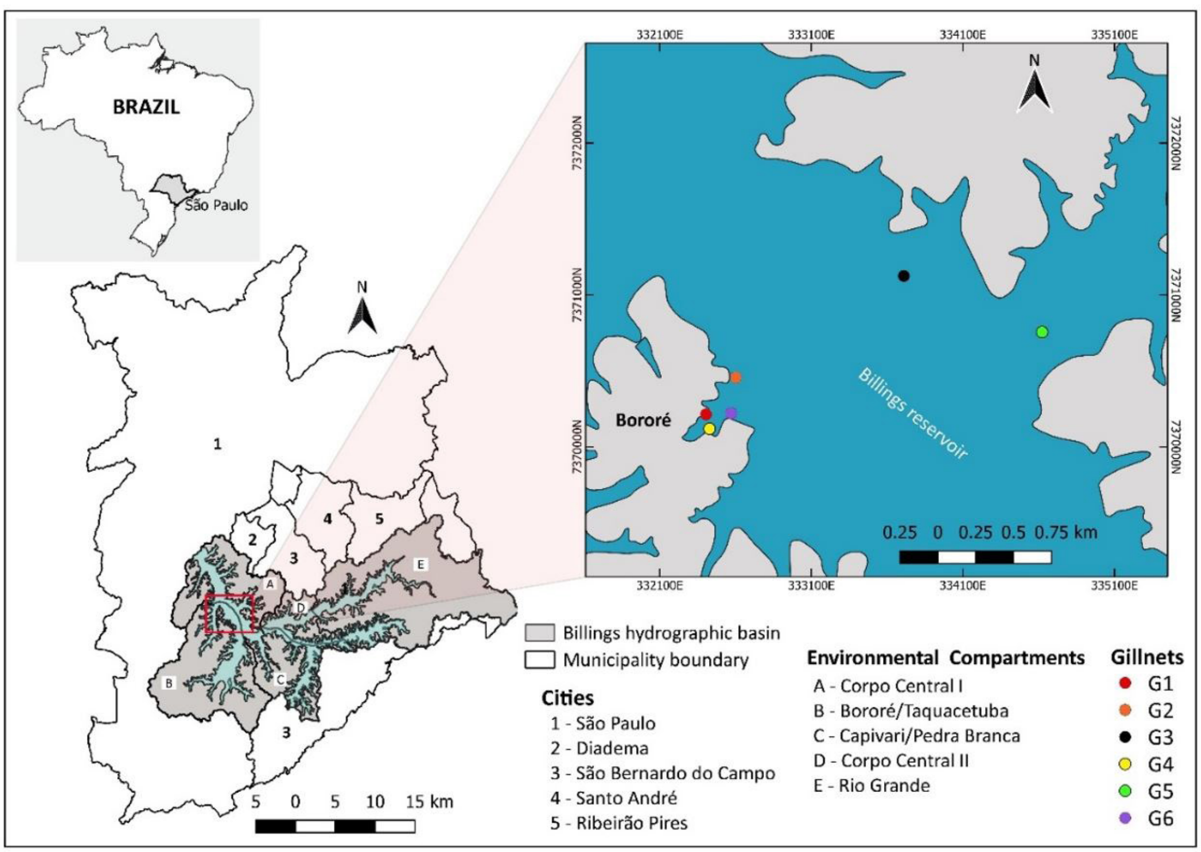

Figure 1. Map of the sampling site with indication of the gill nets disposal in Bororé, Billings Reservoir (SP, Brazil).

no precipitation. Because the samples were collected during the summer period (February 2020), the water temperature was between 24.5°C and 28.0°C, and except for G5 gillnet, the surface water (SW) showed a higher value than the bottom water (BW) (Table 1). Considering the hydrochemical data from the surface and bottom water, despite the shallow depth, differences were observed. In general, the highest values were found in the surface water for DO (G1 = 15.40 mg L^{-1}), temperature (G5 = 28.0°C), conductivity (G2 = 0.162 mS cm^{-1}) and pH (G6 = 9.36). However, an inverse profile was found for turbidity in G3 (SW = 25.30 NTU and BW = 269.00 NTU), G4 (SW = 23.00 NTU and BW = 263.00 NTU) and G5 (SW = 20.80 NTU and BW = 367 NTU), as well as an absence of significant differences for DTS in all collected points, which ranged from 0.097 to 0.102 g L^{-1} (Table 1). The high DO levels observed at all gill net disposal sites ranged from 5.40 to 15.40 mg L^{-1} (Table 1), with absence of significant differences between the surface and bottom water and are probably associated with the shallow depth. In the reservoir, the margins were associated with a more accentuated mixing process caused by the wind at the time of collection (mean: 7.8 m s^{-1}).

In relation to the Ordinance nº 10.755/1977 (São Paulo, 1977) concerning the framing of the receiving water bodies, the Billings basin, composed of the Billings Reservoir, Bororé, Taquacetuba, Pedra Branca, Capivari and their tributaries, are part of Class 2. Except for turbidity data of the bottom water in G3, G4 and G5, in general, the water parameters complied with the limits established by CONAMA Resolution nº 357/2005 (Brasil, 2005) for body water Class 2. However, conductivity values above 0.100 mS cm^{-1}, such as those found in this study, indicate that the environment is impacted (CETESB, 2019). Although still within the CONAMA Resolution limit, the pH values obtained in this study, with values slightly above 9.0 in some gillnet disposal sites, are a sign worthy attention. pH values up 9.0 are an indicative of algae proliferation (Von Sperling, 2005). Since some parts of the Billings Reservoir are highly degraded with low water quality, such as Corpo Central I (Cardoso-Silva et al., 2014; CETESB, 2019), the pH data shown in this study can be associated with the reduction of water quality in the Bororé region. In fact, in recent studies, other authors report similar values as those obtained in this study in the Bororé region, with impacted and degraded tributaries of the Billings-Tamanduateí sub-basin, such as Corpo Central I and II (Cardoso-Silva et al., 2014; CETESB, 2019).

A total of 170 fish were captured during the reproductive period (February 2020), seven classified up to the species level (7) and one (1) up to genus: *Geophagus brasiliensis* (Cichliformes, Cichlidae) (n = 60), *Astyanax bimaculatus* (Characiformes, Characidae) (n = 43), *Astyanax eigenmanniorum* (Characiformes, Characidae) (n = 33), *Astyanax fasciatus* (n = 10), *Hoplias malabaricus* (Characiformes, Erythrinidae) (n = 6), *Oreochromis niloticus* (Cichliformes, Cichlidae) (n = 6), *Rhamdia quelen* (Siluriformes, Heptapteridae) (n = 1) and *Hypostomus sp.* (Siluriformes, Loricariidae) (n = 11). Biometric data, sex ratio, and somatic indexes, such as the hepatosomatic index (HSI) are shown in Table 2. *G. brasiliensis* was the most representative species (36%), followed by *A. bimaculatus* (25%) and *A. eigenmanniorum* (20%). The other species had a frequency of occurrence ranging from 0.6 to 6%. The fish species ranged from 8.2 to 37.1 cm with a weight of 8.23 to 617 g. The shortest and lightest species was A. *eigenmanniorum* (TL: 8.2 to 10.6 cm and TW: 5.77 to 14.32 g). On the other hand, the longest and heaviest species was *H. malabaricus* (TL: 20.2 to 37.10 cm and TW: 157.22 to 616.90 g).

Most species had a higher proportion of females than males in their population. In addition, *Hypostomus* sp. was the only species that had more males than females in its population. In this study, the analyzed fish species were sampled during the summer period (February 2020), which is the reproductive period for these

Table 1. Hydrochemical data of surface (SW) and bottom water (BW) for the different points of gillnets disposal of the fish sampling in Bororé, Billings Reservoir (SP, Brazil).

Gillnet	Depth (m)	DO (mg L^{-1})	Temperature (°C)	Conductivity (mS cm^{-1})	pH	Turbidity (NTU)	DTS (g L^{-1})
G1 (SW)	0	15.40	27.40	0.154	9.03	24.40	0.100
G1 (BW)	3.7	10.64	26.70	0.153	8.40	24.05	0.099
G2 (SW)	0	13.00	26.67	0.162	9.25	28.00	0.102
G2 (BW)	>15	7.80	24.50	0.153	8.00	14.10	0.099
G3 (SW)	0	9.65	27.45	0.161	9.29	25.30	0.101
G3 (BW)	3.3	5.40	24.85	0.154	7.37	269.00	0.100
G4 (SW)	0	13.50	27.27	0.151	9.35	23.00	0.097
G4 (BW)	4.0	8.88	24.77	0.152	6.68	263.00	0.099
G5 (SW)	0	12.17	28.00	0.153	9.24	20.80	0.099
G5 (BW)	3.9	12.08	26.16	0.151	8.55	367.00	0.098
G6 (SW)	0	13.00	26.84	0.156	9.36	23.40	0.099
G6 (BW)	2.9	12.90	26.05	0.151	8.57	28.03	0.097

DO = dissolved oxygen; DTS = dissolved total solids; NTU = nephelometric turbidity unit.

Table 2. Absolute (n) and relative (%) frequency, biometric data (TL; TW), sex ratio (M:F) and hepatosomatic index (HSI) of the fish species collected in Bororé, (Billings Reservoir), São Paulo, Brazil. TL, TW and HSI are expressed as mean ± standard deviation.

Species	*n*	Freq. (%)	TL (cm)	TW (g)	Sex ratio (M:F)	HSI
Astyanax bimaculatus	43	25.0	9.11±0.60	10.50±1.79	1:5	M: 0.77±0.52 F: 0.77±0.33
Astyanax eigenmanniorum	33	19.0	9.28±0.50	9.86±2.12	1:10	M: 0.61±0.34 F: 1.10±0.50
Astyanax fasciatus	10	6.0	10.47±1.40	14.30±4.50	4:7	M: 0.47±0.13 F: 0.68±0.35
Geophagus brasiliensis	60	36	19.21±2.00	153.10±38.97	3:2	M: 1.22±0.48 F: 1.67±0.77
Hoplias malabaricus	6	3.7	33.03±6.38	501.44±174.18	1:1	M: 1.33±0.20 F: 1.17±0.82
Oreochromis niloticus	6	3.7	23.78±5.75	311.17±225.89	1:5	M: 0.83±0.26 F: 1.58
Hypostomus sp.	11	6.0	22.91±1.68	157.39±40.65	9:2	M: 0.90±0.36 F: 1.17
Rhamdia quelen	1	0.6	22.60	208.39	1:0	---

n = sample number of fish; Freq.= frequency; TL= total length; TW = total weight; M = male; F = female.

species in the Billings Complex. Therefore, the higher proportion of females in the most species can be explained as a reproductive strategy in order to preserve the success of these species. In a study on the reproductive strategies of neotropical freshwater fish from Rio Grande do Norte, Barros et al. (2016) observed that *Hypostomus pusarum* is a seasonal strategist species, that is, with body size ranging from intermediate to large, intermediate to high fertility and without parental care. This strategy may be common in *Hypostomus* sp. captured in Billings Reservoir, explaining the higher proportion of males than females. However, this hypothesis must be confirmed by conducting studies on reproductive strategies and population structure in the species presented here. Another important point refers to abiotic influences. In healthy fish populations, the expected sex ratio is 1:1. However, abiotic factors such as temperature, dissolved oxygen and turbidity of the water, besides ecological aspects like vulnerability to predation and exposure to chemical compounds can change the sex composition of fish species (Galib et al., 2020; Magqina and Mhere, 2020). Despite of the hydrochemical data obtained (Table 1) are in accordance with the established limit for body water (CONAMA Resolution nº 357/2005; Brasil, 2005), the general profile of eutrophication in the Billings Reservoir (Matsumura-Tundisi et al., 2010; Ribeiro et al., 2020) is an important fact that can promote disruptions in the sex ration on these species. The HSI is associated with the mobilization of energy reserves during the reproductive period (Vazzoler, 1996; Querol et al., 2002). Thereby, the HSI data shown in this study may be used in the future for comparative purposes with new samples taken during different periods and sites of the Billings Reservoir. The HSI data shows the differences in energy displacement between the species; the highest HSI values were observed in *H. malabaricus* (HSI_{male}: 1.33 ± 0.20; HSI_{female}: 1.17 ± 0.82) while the smallest HSI was observed in *A. fasciatus* (HSI_{male}: 0.47 ± 0.13; HSI_{female}: 0.68 ± 0.35).

The decrease in species richness over time is reported for several reservoirs (Gido et al., 2010; Clavero and Hermoso, 2011; Agostinho et al., 2015; Dagas et al., 2015). Despite the low diversity found in this study, since the first intentional introduction of fish species to this aquatic system, the capacity of reproduction in lentic environments and a wide feeding spectrum of these analyzed species were important factors to promote their successful colonization, survival, and maintenance in the Billings Reservoir. In general, r-strategist species such as Caracids are the dominant because they are sedentary, occupy the shallow areas of the reservoir, have less longevity, higher reproduction rate and smaller size (Agostinho et al., 2015). However, in older reservoirs like Billings, a greater abundance of k-strategist species, such as Cichlids, can be found, due to more complex reproductive strategies (Agostinho et al., 2015). Briefly, the most abundant species found in this study, correspond to sedentary, omnivorous or piscivorous fishes, which were captured in marginal areas of the Reservoir. Finally, to obtain future data about fish population structure in fish species from this reservoir, it is important to construct an ichthyofauna data bank that can be used for management actions in the future. Ideally, field expeditions should prioritize, where possible, on increasing the sampling effort to minimize the impact on fauna. This strategy is important to establish a more sustainable conservation strategy.

CONCLUSIONS

This study presented data regarding the biometric and hepatosomatic index of fish species adapted to lentic environments, such as that evidenced in the Billings Reservoir. Data on sex ratio, size, weight and somatic index provide subsidies for the adequate management of aquatic resources, notably in the case of a reservoir with highly anthropized points such as Billing's complex. Thus, although preliminary, the presented data is important to drive further studies regarding populational structure on these species. Besides, since the water quality of Bororé site (an important fishing nucleus) showed sign worthy attention (i.e.: pH and conductivity), is fundamental to monitor the degree of conservation and/or fragility of the Billings system, providing tools that can subsidize actions for the management of ichthyofauna.

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