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Inventory

Inventory of the fish fauna from Laranjinha River, Paranapanema River system, Brazil

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Abstract: This work is the most comprehensive survey of the Laranjinha River´s fishes, a tributary of the Cinzas River, Paranapanema River basin. Throughout its course, there is only a low-height dam, including a transposition system located 98 km from its mouth. The sampling was carried out in nine locations, from the source to the mouth, with six field incursions in each location, using different fishing gear. A total of 11,924 fish were collected, distributed in seven orders, 27 families, and 100 species. The most representative order in the number of species was Siluriformes, followed by Characiformes. As for the families, Loricariidae comprised 21% and Characidae 14% of species richness. *Phalloceros harpagos* was the species with the highest absolute abundance, representing 11.3% of the total, followed by *Hypostomus ancistroides* with 9.8%. However, considering the average abundance and frequency of occurrence, *Hypostomus ancistroides* was the most abundant species, followed by *Hypostomus* cf. *paulinus*, *Psalidodon* aff. *paranae* and *Phalloceros harpagos*. Among the collected species, the *Apteronotus acidops*, *Brycon orbygnianus*, *Brycon nattereri*, *Crenicichla jupiaensis*, and *Rhinelepis aspera* were classified as endangered on the most recent IUCN Red List. Also, from the total sampled fish, 9.8% are considered non-native species. Among the native species recorded, 10 species are large migratory species, which indicates that the Laranjinha River is a route for spawning and maintenance of species diversity in the middle Paranapanema River. Therefore, the Laranjinha River is a heritage of fish diversity and deserves special attention in its preservation.
Keywords: *Checklist; fish diversity; freshwater; upper Paraná River.*

Inventário da ictiofauna do rio Laranjinha, sistema do rio Paranapanema, Brasil

Resumo: Este é o levantamento mais abrangente de peixes do rio Laranjinha, um afluente do rio das Cinzas, bacia do rio Paranapanema. Ao longo de sua rota, existe apenas uma pequena barragem com um sistema de transposição localizado 98 km de sua nascente. A amostragem foi realizada em nove locais, desde a nascente até a foz, com seis incursões de campo em cada local, com o auxílio de diferentes artes de pesca. Foram coletados 11.924 indivíduos, distribuídos em sete ordens, 27 famílias e 100 espécies. A ordem mais representativa foi Siluriformes, seguida por Characiformes. Quanto às famílias, Loricariidae compôs 21% e Characidae 14% da riqueza de espécies. *Phalloceros harpagos* foi a espécie com maior abundância absoluta, representando 11,3% do total, seguida por *Hypostomus ancistroides*, com 9,8%. No entanto, considerando a abundância média e a frequência de ocorrência, *Hypostomus ancistroides* foi a espécie mais abundante, seguida por *Hypostomus* cf. *paulinus*, *Psalidodon* aff. *paranae* e *Phalloceros harpagos*. Entre as espécies coletadas, *Apteronotus acidops*, *Brycon orbygnianus*, *Brycon nattereri*, *Crenicichla jupiaensis* e *Rhinelepis aspera* estão listadas em categorias de ameaça na Lista Vermelha da IUCN mais recente.

Além disso, do total de indivíduos amostrados, 9,8% são considerados espécies não nativas. Entre as espécies nativas registradas, 10 espécies são migratórias de grande porte, o que indica que o rio Laranjinha é uma rota de desova e manutenção da diversidade de espécies no médio rio Paranapanema. Portanto, o rio Laranjinha é um patrimônio da diversidade de peixes e merece atenção especial em sua preservação.

Palavras-chave: *Água doce; alto rio Paraná; diversidade de peixes; lista de espécies.*

Introduction

In the last few decades, human actions have caused numerous environmental changes, which emphasizes the need to know the local biodiversity, in order to reduce harmful activities. To this extend, the creation of inventories contribute to the discovery and description of new species before their extinction, also contributing to the creation of new records, to the knowledge about geographical distribution, the documentation of non-native species, the defininition of biogeographic patterns, and the establishment of suitable conservation strategies (Costello et al. 2011, Ota et al. 2015, Frota et al. 2019).

The fishes of the upper Paraná River basin are the most studied in Brazil. The basin has more than 310 fish species (Langeani et al. 2007), a number currently outdated, considering new records and the recent discovery of new species (e.g. Frota et al. 2016, Froehlich et al. 2017, Cavalli et al. 2018, Ota et al. 2018, Jarduli et al. 2020). The Paranapanema River, a major tributary of the upper Paraná River, is currently fragmented by several hydroelectric dams (Britto & Carvalho 2006), and therefore, its dam-free tributaries are of great importance for the maintenance of fish species (Hoffmann et al. 2005, Silva et al. 2017, Galindo et al. 2019, Lansac-Tôha et al. 2019). Besides, the Cinzas River is an important tributary of the Paranapanema River basin, which is the main watercourse of the region known as "Norte Pioneiro" (Pioneer North) of the Paraná state, and it is essential for maintaining ichthyofauna biodiversity of the Capivara reservoir (Vianna & Nogueira 2008, Orsi 2010).

Fish inventories were carried out in the Paranapanema River tributaries, including the Cinzas, Jaguariaíva and Tibagi rivers (e.g., Shibatta et al. 2002, Castro et al. 2003, Cetra et al. 2012, Cionek et al. 2012, Costa et al. 2013, Hoffmann et al. 2005, Cetra et al. 2016, Frantine-Silva et al. 2015, Almeida et al. 2018, Jerep & Shibatta 2017, Claro-García et al. 2018, Frota et al. 2020, Jarduli et al. 2020, Garcia et al. 2020). However, a comprehensive checklist of the Laranjinha River ichthyofauna has not been published yet, except for a small streams (e.g., Costa et al. 2013), and the scientific knowledge of its fish species remains unknown. Furthermore, projects of Small Hydropower Plants (SHPs) are being developed, which represents a potential threat to the species of this river (Galindo et al. 2019). Thus, this study aimed to provide the first inventory of the Laranjinha River fish fauna.

Material and Methods

1. *Study area*

The Laranjinha River is entirely situated in the northeastern portion of the state of Paraná, and it is the main tributary of the left bank of the Cinzas River, which pours to the left bank of the middle Paranapanema River (Figure 1 and 2). The headwater is in the municipality of Ventania (24°14'43.43"S; 50°14'32.78"W), at 984 m of altitude, and the mouth is situated 4 km from the town of Itambaracá (23°01'03.51"S; 50°24'22.68"W), at 348 m of altitude.

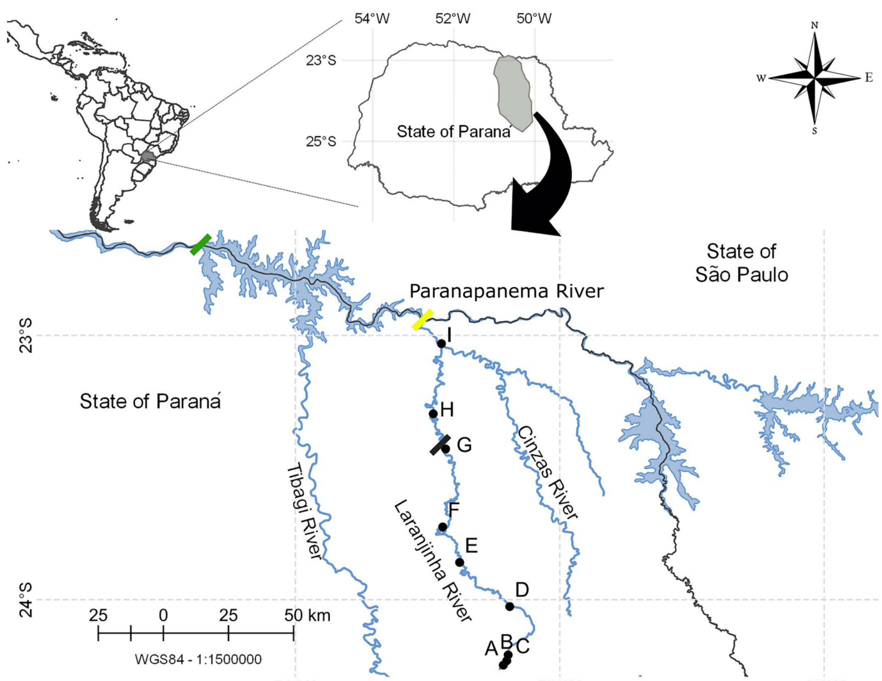

Figure 1. Map of the points sampled along the Laranjinha river (black circles). The green rectangle represents the Capivara reservoir, and the yellow rectangle represents the Canoas I reservoir, both on the Paranapanema River basin.

Figure 2. Partial view of collection points along the Laranjinha River, illustrating the environments and marginal vegetation. Points near source (a-c), points in the middle portion (d-f), and places near the mouth (g-i).

The Laranjinha River, with its meanders, extends through 350 km long, and it is situated in the sedimentary basin of the state of Paraná, with its source and mouth in the second and third plateaus, respectively (Santos et al. 2006). Between the years 1956 and 1960, a Small Hydropower Plant (SHP) was built 98 km from the mouth of the river. This dam never went into operation, and in 2006, a fish pass system was built in it (Schwartz 2006; Figure 2G).

2. *Data collection*

Nine sites for sampling were distributed from the source to the mouth of the Laranjinha River (Figures 1 and 2; Table 1). Six collections were carried out in each site, with the aid of different fish gears (seines, gill nets, cast nets and sieves), from October 2010 to April 2012. The collections were authorized by SISBIO (Sistema de Autorização e Informação em Biodiversidade), Ministério do Meio Ambiente, under the nº 23315-1.

After the capture of the fish, the specimens were anesthetized with 10% benzocaine. This substance promotes a reduction in gill ventilation due to the depression of spinal respiratory centers, promoting a decrease in blood flow through the gills (Mattson & Riple 1989; Tytler & Hawkins 1981). After performing the opercular movements, the fish were fixed in 10% formalin and preserved in 70% ethanol in the Laboratório de Genética e Conservação of the Universidade Estadual do Norte do Paraná (GECON/UENP-CCP) and identified in species-level. The validity of the species was checked using Fricke et al. (2019), and the classification was based using Van der Laan et al. (2020). The species were identified following Ota et al. (2018), Jarduli et al. (2020), Terán et al. (2020), and in the lack of information about the species from the authors before mentioned, personal communication with specialists took place (i.e., FC Jerep, CDCM de Santana, CAM Oliveira and CH Zawadzki).

The record of *Poecilia reticulata* Peters 1859 and *Imparfinis schubarti* (Gomes 1956) were based on Costa et al. (2013). Non-native species were based in Orsi & Agostinho (1999), Lobón-Cerviá & Bennemann (2000), Langeani et al. (2007), Júlio-Júnior et al. (2009), Britton & Orsi (2012), Ortega et al. (2015), Azevedo-Santos et al. (2016), Ota et al. (2018), Pelicice et al. (2018) and Jarduli et al. (2020) (Table 2). Vouchers of all species were deposited in the Museu de Zoologia of the Universidade Estadual de Londrina (MZUEL). The abundances of orders, families, and species were conducted using the Statistica 7.0 software (StatSoft Inc. 2011). The Kendeigh index of abundance (1944) of each species was calculated as KI = $\sqrt{FO.M}$; where KI is the abundance index, and FO is the frequency of occurrence calculated as the number of sites where the species were captured, and divided by the total number of sites multiplied by 100, and M is the mean number of specimens of each species. The classification of species was done by sorting the values in descending order. The dominance index and evenness were calculated with the program PAST v. 2.17c (Hammer et al. 2001).

Table 1. Description of the sampled sites in the Laranjinha river, a tributary of the Paranapanema River, Paraná. "Localities from which coordinates were not originally georeferenced were determined through Google Earth, and are approximate."

Site	Locality	City	Coordinates	Environment Description
A	Pedreira	Ventania	24°15'8.55"S 50°12'1.35"W	The riparian vegetation is well-preserved on both river banks; substrate predominantly sandy and slabs; average width of approximately 4m. Near pastureland and agriculture areas.
B	Cachoeira	Ventania	24°14'37.57"S 50°12'24.48"W	The riparian vegetation is well-preserved on both river banks; substrate predominantly rocks and sand; average width of approximately 4m. Eight kilometers above receives a massive load of domestic effluents.
C	SANEPAR	Ventania	24°13'24.56"S 50°11'57.88"W	The riparian vegetation is well-preserved on the right river bank, a predominance of grass in the left river bank; mostly sedimentary and clayey substrate; average width of approximately 5m; great anthropic disturbance by the presence of a bridge and rural road.
D	Distrito da Moquém	Ventania	24°01'36.6"S 50°11'21.6"W	The riparian vegetation is well-preserved on both river banks (showing the best conditions among all stretches studied); some rocky walls, and predominantly sandy bottom; average width of approximately 13m. Stretch including a lake between a rapid and a small waterfall. It is inserted in a private property for exotic tree planting for logging.
E	Figueira	Figueira	23°51'34.73"S 50°22'43.04"W	The riparian vegetation is absent on both river banks (mostly grass); mainly rocky and sandy substrate; average width of approximately 14m. It is located in pastureland and agriculture areas, upstream of a thermal power plant.
F	Ibaiti	Ibaiti	23°43'31.88"S 50°26'34.42"W	The riparian vegetation is reduced on the left bank (significantly modified by agricultural activity) while the right bank is well-preserved; average width of approximately 40m; some rapids and predominantly rocky and sandy substrate. It is located upstream of a sugar and ethanol plant and surrounded by agriculture areas.
G	Barragem da Corredeira	Ribeirão do Pinhal	23°17'49.95"S 50°28'43.27"W	Riparian vegetation is present on both river banks, well-preserved, alternating sections with grass predominance stretches; includes a dam separating an upstream lake (average width of approximately 63m) and downstream stretch including rapids and some deeper wells (average width of 48m); sand and clayey substrate in the lake and a rocky substrate along downstream stretch; surrounded by pastureland and agriculture areas.
H	Santa Amélia	Santa Amélia	23°24'53.06"S 50°27'8.60"W	The riparian vegetation is poorly preserved on both river banks; large rapids and some deeper wells; predominantly rock substrate; average width of approximately 55m; surrounded by pastureland and agriculture areas.
I	Foz	Bandeirantes	23°1'53.90 S 50°26'51.90"W	The riparian vegetation is poorly preserved on both river banks; some upstream rapids, however, a calm water segment prevails until the confluence between Laranjinha and Cinzas Rivers, including a rocky and sandy (primary) substrate; average width of approximately 48m. It is surrounded by pastureland and agriculture areas.

Table 2. List of species captured along the Laranjinha River (sites A to I, see Figures 1 and 2, and Table 1 for location and characterization), Paraná, Brazil, and their respective catch abundance. ♠ Non-native species, according to, Langeani et al. (2007), Júlio-Júnior et al. (2009), Ota et al. (2018), Jarduli et al. (2020) and Orsi personal communication. ♦ Additional species recorded in the basin by Costa et al. (2013).

	Sampled Sections															
Táxon	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**Total**	**FO**	**FO%**	**Mean**	**FO%*Mean**	**KI**	**Voucher**
CYPRINIFORMES																
Cyprinidae																
Cyprinus carpio Linnaeus 1758♠							2			2	1.0	11.1	0.2	2.46	1.6	MZUEL 10559
CHARACIFORMES																
Crenuchidae																
Characidium aff. *zebra*						4	19	1		24	3.0	33.3	2.7	88.88	9.4	MZUEL 09350
Erythrinidae																
Hoplias gr. *malabaricus*			1	6	17	62	6	2	29	123	7.0	77.8	13.7	1062.96	32.6	MZUEL 19806
Parodontidae																
Apareiodon ibitiensis Campos 1944		1		4		1	10		2	18	5.0	55.6	2.0	111.11	10.5	MZUEL 16063
Apareiodon piracicabae (Eigenmann 1907)				35	45	44	91	79	143	437	6.0	66.7	48.6	3237.03	56.9	MZUEL 09257
Parodon nasus Kner 1859							25	2		27	2.0	22.2	3.0	66.66	8.2	MZUEL 09365
Serrasalmidae																
Metynnis lippincottianus (Cope 1870) ♠								1	6	7	2.0	22.2	0.8	17.28	4.2	MZUEL 09519
Piaractus mesopotamicus (Holmberg 1887)							3		6	9	2.0	22.2	1.0	22.22	4.7	MZUEL 09471
Serrasalmus maculatus Kner 1858							32	1	14	47	3.0	33.3	5.2	174.07	13.2	MZUEL 16059
Anostomidae																
Leporellus vittatus (Valenciennes 1850)							2	2		4	2.0	22.2	0.4	9.87	3.1	MZUEL 09556
Leporinus amblyrhynchus Garavello & Britski 1987				20	23	9	43	11	15	121	6.0	66.7	13.4	896.29	29.9	MZUEL 09262
Leporinus friderici (Bloch 1794)							3	9	43	55	3.0	33.3	6.1	203.70	14.3	MZUEL 09455
Leporinus octofasciatus Steindachner 1915				5	3	12	10		16	46	5.0	55.6	5.1	283.95	16.9	MZUEL 09440
Leporinus striatus Kner 1858						15		17	10	42	3.0	33.3	4.7	155.55	12.5	MZUEL 09520
Megaleporinus obtusidens (Valenciennes 1837)							10	1	7	18	3.0	33.3	2.0	66.66	8.2	MZUEL 09431
Schizodon borellii (Boulenger 1900)					4	1		1	79	85	4.0	44.4	9.4	419.75	20.5	MZUEL 09467
Schizodon nasutus Kner 1858					25	29	49	2	16	121	5.0	55.6	13.4	746.91	27.3	MZUEL 09356
Curimatidae																
Cyphocharax modestus (Fernández-Yépez 1948)				27	4	75	1	1	17	125	6.0	66.7	13.9	925.92	30.4	MZUEL 09448
Steindachnerina insculpta (Fernández-Yépez 1948)				2		12	109	12	37	172	5.0	55.6	19.1	1061.72	32.6	MZUEL 09451
Prochilodontidae																
Prochilodus lineatus (Valenciennes 1837)					120	40	29	4	4	197	5.0	55.6	21.9	1216.04	34.9	MZUEL 09437
Triportheidae																
Triportheus nematurus (Kner 1858) ♠								1	43	44	2.0	22.2	4.9	108.64	10.4	MZUEL 09458

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	Sampled Sections															
Táxon	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**Total**	**FO**	**FO%**	**Mean**	**FO%*Mean**	**KI**	**Voucher**
Bryconidae																
Bryconinae																
Brycon nattereri Günther 1864				82	5					87	2.0	22.2	9.7	214.81	14.7	MZUEL 09470
Brycon orbygnianus (Valenciennes 1850)							50			50	1.0	11.1	5.6	61.728	7.9	MZUEL 09485
Salmininae										0						
Salminus brasiliensis (Cuvier 1816)								1		1	1.0	11.1	0.1	1.23	1.1	MZUEL 09527
Salminus hilarii Valenciennes 1850							1			1	1.0	11.1	0.1	1.23	1.1	MZUEL 09518
Acestrorhynchidae																
Acestrorhynchus lacustris (Lütken 1875)							56	38	61	155	3.0	33.3	17.2	574.07	24.0	MZUEL 09543
Characidae																
Stethaprioninae																
Astyanax lacustris (Lütken 1875)			1	18	42	96	242	106	134	639	7.0	77.8	71.0	5522.22	74.3	MZUEL 09538
Hyphessobrycon eques (Steindachner 1882) ♠									12	12	1.0	11.1	1.3	14.81	3.8	MZUEL 09464
Moenkhausia aff. *intermedia*									157	157	1.0	11.1	17.4	193.82	13.9	MZUEL 09457
Oligosarcus paranensis Menezes & Géry 1983				45	13	18				76	3.0	33.3	8.4	281.48	16.8	MZUEL 09534
Psalidodon bockmanni (Vari & Castro 2007)			1	36	70	7	4	21	17	156	7.0	77.8	17.3	1348.14	36.7	MZUEL 09354
Psalidodon aff. *fasciatus*				201	9	11	86	11	14	332	6.0	66.7	36.9	2459.25	49.6	MZUEL 09541
Psalidodon aff. *paranae*	571	134	70	14	9	22	2	1		823	8.0	88.9	91.4	8128.39	90.2	MZUEL 09441
Characinae																
Galeocharax gulo (Cope 1870)							118	42	43	203	3.0	33.3	22.6	751.85	27.4	MZUEL 09259
Aphyocharacinae																
Aphyocharax cf. *dentatus* Eigenmann & Kennedy 1903 ♠									1	1	1.0	11.1	0.1	1.23	1.1	MZUEL 09463
Cheirodontinae																
Odontostilbe weitzmani Chuctaya, Bührnheim & Malabarba 2018					7	3				10	2.0	22.2	1.1	24.69	5.0	MZUEL 09557
Serrapinnus notomelas (Eigenmann 1915)					26	48	2			76	3.0	33.3	8.4	281.48	16.8	MZUEL 09435
Stevardiinae																
Bryconamericus aff. *iheringii* (Boulenger 1887)				13	112	19	18	98		260	5.0	55.6	28.9	1604.93	40.1	MZUEL 09528
Piabarchus aff. *stramineus*					2	4	2	15		23	4.0	44.4	2.6	113.58	10.7	MZUEL 09433
Piabina argentea Reinhardt 1867							2	5		7	2.0	22.2	0.8	17.28	4.2	MZUEL 09348
GYMNOTIFORMES																
Apteronotidae																
Apteronotus acidops Triques 2011									1	1	1.0	11.1	0.1	1.23	1.1	
Apteronotus aff. *albifrons* (Linnaeus 1766)									1	1	1.0	11.1	0.1	1.23	1.1	MZUEL 09558
Apteronotus cf. *caudimaculosus* Santana 2003 ♠								3		3	1.0	11.1	0.3	3.70	1.9	MZUEL 09538

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Táxon	Sampled Sections A	B	C	D	E	F	G	H	I	Total	FO	FO%	Mean	FO%*Mean	KI	Voucher
Sternopygidae																
Eigenmannia sp.					3	2	4	3	11	23	5.0	55.6	2.6	141.97	11.9	MZUEL 09552
Sternopygus macrurus (Bloch & Schneider 1801)							1	5	3	9	3.0	33.3	1.0	33.33	5.8	MZUEL 09454
Gymnotidae																
Gymnotus sylvius Albert & Fernandes-Matioli 1999			2		1	10	9	4	7	33	6.0	66.7	3.7	244.44	15.6	MZUEL 09546
Gymnotus omarorum Richer-de-Forges, Crampton & Albert 2009						10				10	1.0	11.1	1.1	12.34	3.5	MZUEL 09517
SILURIFORMES																
Trichomycteridae																
Cambeva diabola (Bockmann, Casatti & de Pinna 2004)	26	169	8	9	3					215	5.0	55.6	23.9	1327.16	36.4	MZUEL 09516
Callichthyidae																
Callichthys callichthys (Linnaeus 1758)							1			1	1.0	11.1	0.1	1.23	1.1	MZUEL 09535
Corydoras aeneus (Gill 1858)									1	1	1.0	11.1	0.1	1.23	1.1	MZUEL 09547
Hoplosternum littorale (Hancock 1828)							3			3	1.0	11.1	0.3	3.70	1.9	MZUEL 09544
Loricariidae																
Rhinelepinae																
Rhinelepis aspera Spix & Agassiz 1829									12	12	1.0	11.1	1.3	14.81	3.8	MZUEL 09549
Loricariinae																
Loricariichthys platymetopon Isbrücker & Nijssen 1979 ♠								10	38	48	2.0	22.2	5.3	118.51	10.9	MZUEL 09460
Proloricaria prolixa Isbrücker & Nijssen 1978								22	15	37	2.0	22.2	4.1	91.35	9.6	MZUEL 09525
Rineloricaria latirostris (Boulenger 1900)				3	2	2		1		8	4.0	44.4	0.9	39.50	6.3	MZUEL 09530
Rineloricaria pentamaculata Langeani & de Araujo 1994			1					1	2	4	3.0	33.3	0.4	14.81	3.8	MZUEL 09545
Hypoptopomatinae																
Curculionichthys insperatus (Britski & Garavello 2003)					45					45	1.0	11.1	5.0	55.55	7.5	MZUEL 09469
Neoplecostomus yapo Zawadzki. Pavanelli & Langeani 2008	35	29	5	2						71	4.0	44.4	7.9	350.61	18.7	MZUEL 09542
Otothyropsis biamnicus Calegari, Lehmann A. & Reis 2013				23	2					25	2.0	22.2	2.8	61.72	7.9	MZUEL 09071
Hypostominae																
Ancistrus cf. *cirrhosus* (Valenciennes 1836)							4	3	2	9	3.0	33.3	1.0	33.33	5.8	MZUEL 09522
Hypostomus albopunctatus (Regan 1908)				11	1		88	19		119	4.0	44.4	13.2	587.65	24.2	MZUEL 09362
Hypostomus ancistroides (Ihering 1911)			299	305	232	140	113	30	51	1170	7.0	77.8	130.0	10111.11	100.6	MZUEL 09450
Hypostomus cf. *paulinus* (Ihering 1905)			6	246	91	86	194	244	141	1008	7.0	77.8	112.0	8711.11	93.3	MZUEL 09480
Hypostomus cf. *topavae* (Godoy 1969)			1	1	1	40	32	74	56	205	7.0	77.8	22.8	1771.60	42.1	MZUEL 09355
Hypostomus hermanni (Ihering 1905)							73	166	162	401	3.0	33.3	44.6	1485.18	38.5	MZUEL 09363
Hypostomus iheringii (Regan 1908)						2			13	15	2.0	22.2	1.7	37.03	6.1	MZUEL 09473
Hypostomus nigromaculatus (Schubart 1964)				29	5	6	9	9	7	65	6.0	66.7	7.2	481.48	21.9	MZUEL 09361
Hypostomus regani (Ihering 1905)							11	5	5	21	3.0	33.3	2.3	77.77	8.8	MZUEL 09524
Hypostomus cf. *strigaticeps* (Regan 1908)				267	77	93	210	119	36	802	6.0	66.7	89.1	5940.74	77.1	MZUEL 09366
Megalancistrus parananus (Peters 1881)								5	5	10	2.0	22.2	1.1	24.69	5.0	MZUEL 09526
Pterygoplichthys ambrosettii (Holmberg 1893) ♠								1	7	8	2.0	22.2	0.9	19.75	4.4	MZUEL 09555

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	Sampled Sections															
Táxon	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**Total**	**FO**	**FO%**	**Mean**	**FO%*Mean**	**KI**	**Voucher**
Aspredinidae																
Bunocephalus larai Ihering 1930								3	1	4	2.0	22.2	0.4	9.87	3.1	MZUEL 09521
Auchenipteridae																
Ageneiosus militaris Valenciennes 1835									1	1	1.0	11.1	0.1	1.23	1.1	MZUEL 09459
Glanidium cesarpintoi Ihering 1928								1		1	1.0	11.1	0.1	1.23	1.1	MZUEL 09539
Tatia neivai (Ihering 1930)			1			1	3	11	2	18	5.0	55.6	2.0	111.11	10.5	MZUEL 09533
Doradidae																
Rhinodoras dorbignyi (Kner 1855)									13	13	1.0	11.1	1.4	16.04	4.0	MZUEL 09550
Heptapteridae																
Cetopsorhamdia iheringi Schubart & Gomes 1959							3			3	1.0	11.1	0.3	3.70	1.9	MZUEL 09483
Imparfinis mirini Haseman 1911				1	2		13	3	1	20	5.0	55.6	2.2	123.45	11.1	MZUEL 09553
Imparfinis schubarti (Gomes 1956)♦																
Phenacorhamdia tenebrosa (Schubart 1964)							2			2	1.0	11.1	0.2	2.46	1.6	MZUEL 09484
Pimelodella meeki Eigenmann 1910				1	3	8				12	3.0	33.3	1.3	44.44	6.7	MZUEL 09532
Rhamdia quelen (Quoy & Gaimard 1824)			36	5	4	3	4	2	14	68	7.0	77.8	7.6	587.65	24.2	MZUEL 09548
Pimelodidae																
Iheringichthys labrosus (Lütken 1874)				4	16	37	24	16	44	141	6.0	66.7	15.7	1044.44	32.3	MZUEL 09551
Megalonema platanum (Günther 1880)									5	5	1.0	11.1	0.6	6.17	2.5	MZUEL 09474
Pimelodus maculatus Lacépède 1803				1			14	8	28	51	4.0	44.4	5.7	251.85	15.9	MZUEL 09445
Pimelodus microstoma Steindachner 1877				57	6	9	103	39	7	221	6.0	66.7	24.6	1637.03	40.5	MZUEL 09360
Pimelodus paranaensis Britski & Langeani 1988							8	2		10	2.0	22.2	1.1	24.69	5.0	MZUEL 09438
Pinirampus pirinampu (Spix & Agassiz 1829)									4	4	1.0	11.1	0.4	4.93	2.2	MZUEL 09475
Pseudoplatystoma corruscans (Spix & Agassiz 1829)									1	1	1.0	11.1	0.1	1.23	1.1	MZUEL 09461
Sorubim lima (Bloch & Schneider 1801) ♠									3	3	1.0	11.1	0.3	3.70	1.9	MZUEL 09462
Pseudopimilodidae																
Rhyacoglanis paranensis Shibatta & Vari 2017							115			115	1.0	11.1	12.8	141.97	11.9	MZUEL 14120
SYNBRANCHIFORMES																
Synbranchidae																
Synbranchus marmoratus Bloch 1795							1			1	1.0	11.1	0.1	1.23	1.1	MZUEL 09439
CICHLIFORMES																
Cichlidae																
Australoheros tavaresi Ottoni 2012					1					1	1.0	11.1	0.1	1.23	1.1	MZUEL 09447
Crenicichla britskii Kullander 1982								4	9	13	2.0	22.2	1.4	32.09	5.7	MZUEL 09453
Crenicichla jaguarensis Haseman 1911							7	8	22	37	3.0	33.3	4.1	137.03	11.7	MZUEL 09261
Crenicichla jupiaensis Britski & Luengo 1968									1	1	1.0	11.1	0.1	1.23	1.1	MZUEL 09468
Geophagus iporangensis (Haseman 1911)			11	182	238	183	3	10		627	6.0	66.7	69.7	4644.44	68.2	MZUEL 09353
Oreochromis niloticus (Linnaeus 1758) ♠	2	1					3	7	1	14	5.0	55.6	1.6	86.41	9.3	MZUEL 09482

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Táxon	Sampled Sections A	B	C	D	E	F	G	H	I	Total	FO	FO%	Mean	FO%*Mean	KI	Voucher
CYPRINIDONTIFORMES																
Poeciliidae																
Phalloceros harpagos Lucinda 2008	278		1043		27	3				1351	4.0	44.4	150.1	6671.60	81.7	MZUEL 09429
Poecilia reticulata Peters 1859♦♠																
Number of species	5	5	15	31	38	38	57	60	64							
Dominance	0.49	0.42	0.54	0.12	0.1	0.07	0.06	0.08	0.05							
Evenness	0.49	0.52	0.17	0.39	0.39	0.49	0.43	0.34	0.46							

Results

A total of 11.934 specimens were collected, comprising seven orders, 27 families, and 100 species (Table 2; Appendix 1 - 5). Among these, the most representative order was Siluriformes (44.5%), followed by Characiformes (38.6%), Gymnotiformes (6.9%), and Cichliformes (5.9%). Cyprinodontiformes, Cypriniformes, and Synbranchiformes were represented by only one specimen each. Regarding the families, Loricariidae had 20 species (21%) and Characidae 16 species (14%). Together, these families showed the highest species richness (representing 35% of total richness), followed by Pimelodidae and Anostomidae, both composed of eight species each (8%), Heptapteridae and Cichlidae, both with six species each (6%), and Bryconidae with four species (4%; Figure 3).

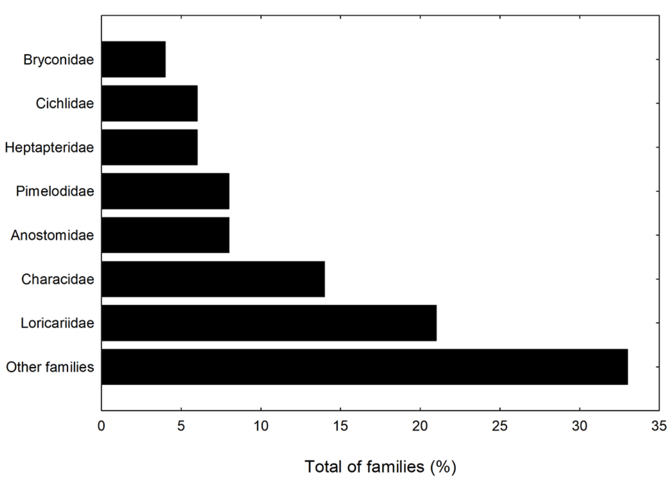

Figure 3. Percentage composition of representative families of the ichthyofauna from the Laranjinha River, Upper Parana River basin, Paraná State, Brazil.

Among the sampling sites, A and B showed the lowest number of species (five species each), while sampling site I had a higher number of species (64 species). There is a progressive tendency of species richness from the source to the mouth ($r^2 = 0.964$). The dominance (D) is higher in the upper Laranjinha River (sites A, B, and C showing D = 0.49, 0.42, and 0.54, respectively), and this dominance drops expressively on the sites D (0.12) until I (0.05).

The highest absolute abundance was observed in *Phalloceros harpagos* Lucinda 2008 (11.3%), *Hypostomus ancistroides* (Ihering 1911) (9.8%), *Hypostomus* cf. *paulinus* (Ihering 1905) (8.4%), *Psalidodon* aff. *paranae* (6.9%), *Hypostomus* cf. *strigaticeps* (Regan 1908) (6.7%), and *Astyanax lacustris* (Lütken 1875) (5.3%; Table 2). Concerning the frequency of occurrence, the most frequent species of Laranjinha River were *Psalidodon* aff. *paranae* (FO = 88.8%), *Hoplias* gr. *malabaricus*, *Astyanax lacustris*, *Psalidodon bockmanni* (Vari & Castro 2007), *Rhamdia quelen* (Quoy & Gaimard 1824), *Hypostomus ancistroides*, *Hypostomus* cf. *paulinus*, and *Hypostomus topavae* (Godoy 1969) (FO = 77.7%). The classification of species from Kendeigh abundance index highlights the following ranking: *Hypostomus ancistroides*, *Hypostomus* cf. *paulinus*, *Psalidodon* aff. *paranae*, *Phalloceros harpagos* Lucinda 2008, *Hypostomus* cf. *strigaticeps*, and *Astyanax lacustris*. Among these species, *Psalidodon* aff. *paranae* and *Phalloceros harpagos* were frequent and dominant in the headwater region (sites A, B, and C), while the others were frequent downstream those sites.

From all recorded species, 9.8% were non-native: *Aphyocharax* cf. *dentatus* Eigenmann & Kennedy 1903, *Apteronotus* cf. *caudimaculosus* Santana 2003, *Cyprinus carpio* Linnaeus 1758, *Hyphessobrycon eques* (Steindachner 1882), *Loricariichthys platymetopon* Isbrücker & Nijssen 1979, *Metynnis lippincottianus* (Cope 1870), *Oreochromis niloticus* (Linnaeus 1758), *Poecilia reticulata* Peters 1859, *Pterygoplichthys ambrosettii* (Holmberg 1893), *Sorubim lima* (Bloch & Schneider 1801), and *Triportheus nematurus* (Kner, 1858). Of these species, two were exotic: *Cyprinus carpio*, which is a carp from Asia, and *Oreochromis niloticus*, know as Nile-tilapia, from Africa.

Ten long-distance migratory species were recorded in the Laranjinha River basin: *Brycon orbygnianus* (Valenciennes 1850), *Megaleporinus obtusidens* (Valenciennes 1837), *Piaractus mesopotamicus* (Holmberg 1887), *Pinirampus pirinampu* (Spix & Agassiz 1829), *Prochilodus lineatus* (Valenciennes 1837), *Pseudoplatystoma corruscans* (Spix & Agassiz 1829), *Rhinelepis aspera* Spix & Agassiz 1829, *Salminus brasiliensis* (Cuvier 1816), and *Salminus hilarii* Valenciennes 1850. Additionally, *Leporinus friderici* (Bloch 1794), *Pimelodus maculatus* Lacepède 1803, *Rhamdia quelen*, and *Schizodon nasutus* Kner 1858, which are considered short-migratory species, were also recorded herein (Agostinho et al. 2007, Oliveira et al. 2015).

Among the collected species, *Apteronotus acidops* Triques 2011, *Brycon orbygnianus*, *Brycon nattereri* Günther 1864, *Crenicichla jupiaensis* Britski & Luengo 1968, and *Rhinelepis aspera* Spix & Agassiz 1829 are classified as endangered in the most recent IUCN Red List. It is worth mentioning that two species are possibly new to science, *Piabarchus* aff. *stramineus* (*sensu* Frota et al., 2016), and *Eigenmannia* sp.

Discussion

The results presented in this study showed a high diversity of fishes (100 species) among the fish collected in the Laranjinha River. Such results follow the pattern found in the Neotropical regions, showing the dominance of Siluriformes and Characiformes (Agostinho et al. 1997, Lowe-McConnell 1999, Jarduli et al. 2020). Furthermore, among Paranapanema River tributaries, the number of species is lower if compared to the Tibagi River basin, where 158 species were registered (Lobón-Cerviá & Bennemann 2000, Bennemann et al. 2006, 2011, Shibatta & Cheida 2003, Hoffmann et al. 2005, Oliveira & Bennemann et al. 2005, Jerep et al. 2006, Sant'Anna et al. 2006, Shibatta et al. 2002, 2006a, 2006b, 2007, 2008, Galves et al. 2007, Vieira & Shibatta 2007, Orsi 2010, Raio & Bennemann 2010, Garcia et al. 2014, 2015, Silva et al. 2015, Frantine-Silva et al. 2015, Almeida et al. 2018, Jerep & Shibatta 2017, Claro-Garcia et al. 2018), and to the Cinzas River, with 114 species (Hoffmann et al. 2005, Vianna & Nogueira, 2008, Orsi 2010, Bennemann et al. 2011, Costa et al. 2013, Frantine-Silva et al. 2015, Almeida et al. 2018).

It is noteworthy that the most frequent species of Laranjinha River was *Psalidodon* aff. *paranae*, captured in eight sites. The higher abundance were in the uppermost site A, and along the downstream, the number of specimens decreased until site H, which corroborate the hypothesis that this species has a preference regarding the headwater region (Britski 1972), but it is not restricted to that. *Psalidodon* aff. *paranae* is an insectivorous species, feeding mainly of allochthonous resources from the riparian forest. However, it can gather enough food resources from environments with different levels of degradation (Ferreira et al. 2012).

In the upper region of Laranjinha River, *Phalloceros harpagos*, a native species, was the most abundant one, being dominant in the site C. The value of dominance index (D=0.54) and evenness (E=0.17) of that site, reflected the disturbance in the observed environment. Biological features of *P. harpagos* like constant reproduction (Wolff et al. 2007), adaptability, tolerance to heat, variations in salinity (Nascimento & Gurgel 2000), and high trophic plasticity (Casatti et al. 2009, Rocha et al. 2009) may be related to the success of the species at that location. This species has a wide geographical distribution (Thomaz et al. 2019), which may also be related to its ecological plasticity.

Hypostomus ancistroides, *H.* cf. *paulinus,* and *H.* cf. *strigaticeps* were abundant and frequent from C to I sites. A factor that possibly has favored these rheophilic species is the presence of running water in the Laranjinha River (Cecilio et al. 1997; Garcia et al. 2020). Several species of *Hypostomus* were collected in running waters showing a substrate with pebbles and rocks (Garavello & Garavello 2004; Perez-Junior & Garavello 2007), but in Laranjinha River these species also occur in some places with a sand bottom. *Hypostomus ancistroides*, the most abundant of these species, had higher abundance in the site C, which decreased until site I, and such data demonstrates that this species is the least rheophilic one among congeners.

In general, the non-native fish species recorded in this study were introduced from other drainages in Brazil. All these species are associated with human activities like aquarium trade (possibly *Aphyocharax* cf. *dentatus*, *Apteronotus albifrons*, *Hyphessobrycon eques* and *Poecilia reticulata*), fish ladders (possibly *Metynnis lippincottianus*, *Pterygoplichthys ambrosetti* and *Triportheus nematurus*), fish farming (certainly *Cyprinus carpio*, *Oreochromis niloticus* and *Sorubim lima*), and control of insect larvae (possibly *Poecilia reticulata*). It is worth mentioning that among these non-native species, two of them are considered exotic (*Cyprinus carpio* and *Oreochromis niloticus*). These records are alarming, as *C. carpio* is known to promote bioturbation by continually revolving the sediment (Ritvo et al. 2004). However, only two individuals were sampled, being exclusive on site G, an area surrounded by pastures and agriculture. On the other hand, *O. niloticus* was more abundant and widely distributed, being sampled in five sites, which corresponds to an area surrounded by pasture and agriculture, and specifically in site B with the discharge of effluents. In addition, this species changes the environment due to the excess of nitrogen excreta, thus favoring the proliferation of algae, which decreases light and dissolved oxygen (Britton et al. 2007, Vicente & Fonseca-Alves 2013). Besides that, *Poecilia reticulata* was registered by Costa et al. (2013) in the study of the Penacho stream, a small tributary on the right bank of the Laranjinha River that flows into the Cinzas River. The high abundance of *P. reticulata* indicates an instability of the environment, including factors such as the lack of food resources for other species and the low level of dissolved oxygen (De Souza & Tozzo 2013).

The occurrence of 13 medium- to large-size migratory fishes highlights the importance of Laranjinha River for the maintenance of the diversity and viability of the ichthyofauna of the middle Paranapanema River. Other studies also highlight the Cinzas River basin and the Laranjinha River as migratory routes to the fish fauna from the Capivara dam (Dias et al. 2004, Lopes et al. 2007, Vianna & Nogueira 2008, Orsi 2010). As the Laranjinha River has only a little dam, including a fish pass system built in it, it extends a long stretch without dams, enabling migratory fish species to use its free-flowing stretches to complete their reproductive cycles. Long-distance migratory species with high commercial value have been using tributaries of rivers intensely affected by dams as migratory routes (Agostinho et al. 2008). The pressure caused by power plant dam constructions is intense in freshwater systems (Agostinho et al. 2005), because the transformation of lotic areas into lentic ones interrupts the displacement of migratory fish (Agostinho et al. 2008, Pelicice et al. 2018). The impact is not restricted to migratory species, and it also impairs the local fauna that depends on the tributaries for the viability of spawning and survival of early life stages (Oliveira et al. 2015). Studying the dynamics of eggs and larvae in the Cinzas River, Vianna & Nogueira (2008), found that the fishes of the middle Paranapanema River use this tributary to spawn. In general, biological communities are under heavy pressure due to environmental instability caused by habitat fragmentation and loss of natural environments, which affect species abundance and richness (Pusey & Arthington 2003, Di Giulio et al. 2009, Shandas & Alberti, 2009).

Furthermore, the conservation of the Laranjinha River is essential to preserve the species already categorized as threatened by extinction in the IUCN's Red List (*Apteronotus acidops*, *Brycon orbygnianus* and *Crenicichla jupiaensis* as Endangered; *Brycon nattereri* as Vulnerable; and *Rhinelepis aspera* as Near Threatened) (ICMBio 2018). The fact that some of these fish appear on a list of endangered species is concerning and it reinforces that the focused area needs appropriate conservation strategies (Simic et al. 2007). Studies on *B. nattereri* reinforce the importance of Laranjinha River conservation, since this migratory and threatened species has been able to maintain a satisfactory population genetic diversity due to the quality of that environment (Galindo et al. 2019).

Finally, the Laranjinha River is a heritage of fish diversity due to the presence of large numbers of species (among migratory, threatened, and new species to science). Thus, it deserves special attention regarding its preservation.

Supplementary Material

The following online material is available for this article:

Appendix 1

Appendix 2

Appendix 3

Appendix 4

Appendix 5

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Author Contributions

Bruno Ambrozio Galindo: Substantial contribution in the concept and design of the study; Contribution to data collection; Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision, adding intelectual content.

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Silvia Helena Sofia: Substantial contribution in the concept and design of the study; Contribution to data analysis and interpretation; Contribution to manuscript preparation.

Oscar Akio Shibatta: Substantial contribution in the concept and design of the study; Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision, adding intelectual content.

Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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