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inventory

Ichthyofauna from tributaries of Urubu and Amazonas rivers, Amazonas State, Brazil

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Abstract: The Amazonas River basin comprises the world's highest fish species diversity. Anthropogenic interferences in aquatic environments represent a pressure over the maintenance of ecological stability and biodiversity. We inventoried the ichthyofauna of 13 disturbed/modified tributaries of Urubu and Amazonas rivers in the region of the middle Amazon River, between June 2018 and March 2019. A total of 164 species were captured, represented by 11 orders, 37 families and 96 genera. Characiformes was the richest order, followed by Cichliformes and Siluriformes. The most representative families in number of species were Cichlidae, Serrasalmidae, and Characidae. *Hemigrammus levis* was the most abundant species, and *Acarichthys heckelii* the most common, registered in all sampled sites. In the present study, species with economic interest were collected, as well as many species recently described and one still waiting for formal description, identified provisionally as *Moenkhausia* aff. *colletii*. Therefore, the high fish diversity registered, even in disturbed environments in Middle Amazonas River, denotes the makeable ecological importance of this region for fishes resources and supports the necessity of evaluation of other aquatic environments in the region, as well as the potential impacts on composition, maintenance, and survival of ichthyofauna in environments directly affected by human activities.
Keywords: *Amazon fish, Environmental impacts, Ichthyofauna diversity, Inventory.*

Ictiofauna de afluentes dos rios Urubu e Amazonas, Estado do Amazonas, Brasil

Resumo: A bacia do rio Amazonas compreende a maior diversidade de espécies de peixes do mundo. Interferências antropogênicas em ambientes aquáticos representam uma pressão sobre a manutenção da estabilidade ecológica e da biodiversidade. Inventariamos a ictiofauna de 13 afluentes perturbados/modificados dos rios Urubu e Amazonas na região do médio do rio Amazonas, entre junho de 2018 e março de 2019. Foram capturadas 164 espécies no total, representadas por 11 ordens, 37 famílias e 96 gêneros. Characiformes foi a ordem mais rica, seguida por Cichliformes e Siluriformes. As famílias mais representativas em número de espécies foram Cichlidae, Serrasalmidae e Characidae. *Hemigrammus levis* foi a espécie mais abundante e *Acarichthys heckelii* a mais comum, registrada em todos os locais amostrados. No presente estudo foram coletadas espécies de interesse econômico, bem como muitas espécies recentemente descritas e uma ainda aguardando descrição formal, identificada provisoriamente como *Moenkhausia* aff. *colletii*. Portanto, a alta diversidade de peixes registrada, mesmo em ambientes perturbados no médio rio Amazonas, denota a importância ecológica marcante dessa região para os recursos pesqueiros e suporta a necessidade de avaliação de outros ambientes aquáticos da região, bem como os possíveis impactos na composição, manutenção e sobrevivência da ictiofauna em ambientes diretamente afetados pelas atividades humanas.
Palavras-chave: *Diversidade da ictiofauna, Impactos ambientais, Inventário, Peixes amazônicos.*

Introduction

The Amazonas River basin is the world's largest watershed (Goulding et al. 2003), and has an area over 8.000.000 km[2] (Sioli 1984). The associated channels and wetlands support high values of primary and secondary productivity (Junk 2013). This complex landscape harbors the highest diversity of freshwater fishes in the world, with more than 2,700 species currently considered valid (Dagosta & Pinna 2019). During the rain forest annual flooded pulse, the combination of flat terrain and variable rivers and streams discharge allows the presence of large areas of wetlands and floodplain forest (Junk 1970), resulting in a dynamic complex of seasonally flooded areas with marked ecological importance (Junk et al. 2011).

Unfortunately, the structure and function of Amazon freshwater ecosystems are being increasingly impacted by crescent human activities and territorial modifications (Castello et al. 2013). The main impacts evidenced are roads construction and expansion (Jones et al. 2000, Barber et al. 2014, Smith et al. 2018), deforestation (Renó et al. 2011, Barber et al. 2014, Inomata et al. 2018), construction and installation of hydroelectric dams (Junk et al. 2007, Alho 2015, Hurd et al. 2016, Reis et al. 2016, Inomata et al. 2018), pollution (Castello et al. 2013), and overfishing (Alho 2015, Inomata et al. 2018).

Itacoatiara is a municipality of Amazonas State, Brazil, situated on left bank of Amazon River, located downstream the confluences of Madeira and Urubu rivers, and upstream the confluence of Uatumã River. This region is drained by a complex fluvial system, composed of streams, channels, and lakes that integrate black and clearwater environments like igapós and campinaranas, as well as a vast area of floodplain enriched by alluvial deposits of rivers of white waters such as the Amazonas and Madeira (Cavallini 2014). The municipality is connected to Manaus by the road AM-010, which caused many impacts and even interrupted the course of some drainages of the region.

Despite the great diversity and the increase of anthropogenic pressures, studies on fish fauna of the region are usually concentrated on species with commercial interest. Smaller species, despite their high contribution of biomass and richness are subsampled, resulting in lack of knowledge to be filled with future studies (Barletta et al. 2010). Still, some rivers, like Urubu, remains poorly understood in terms of ichthyofauna composition, with few reports of species occurrence in the basin, rare cases of endemism and little information about species distribution (Dagosta & Pinna 2019). Thus, the aim of this investigation is to present an inventory of the ichthyofauna from watercourses from Urubu and Amazonas drainages near Itacoatiara.

Material and Methods

1. *Study area*

The city of Itacoatiara is drained by a complex fluvial system directly affected by the flood pulse (Figure 1). It is located in the left margin of

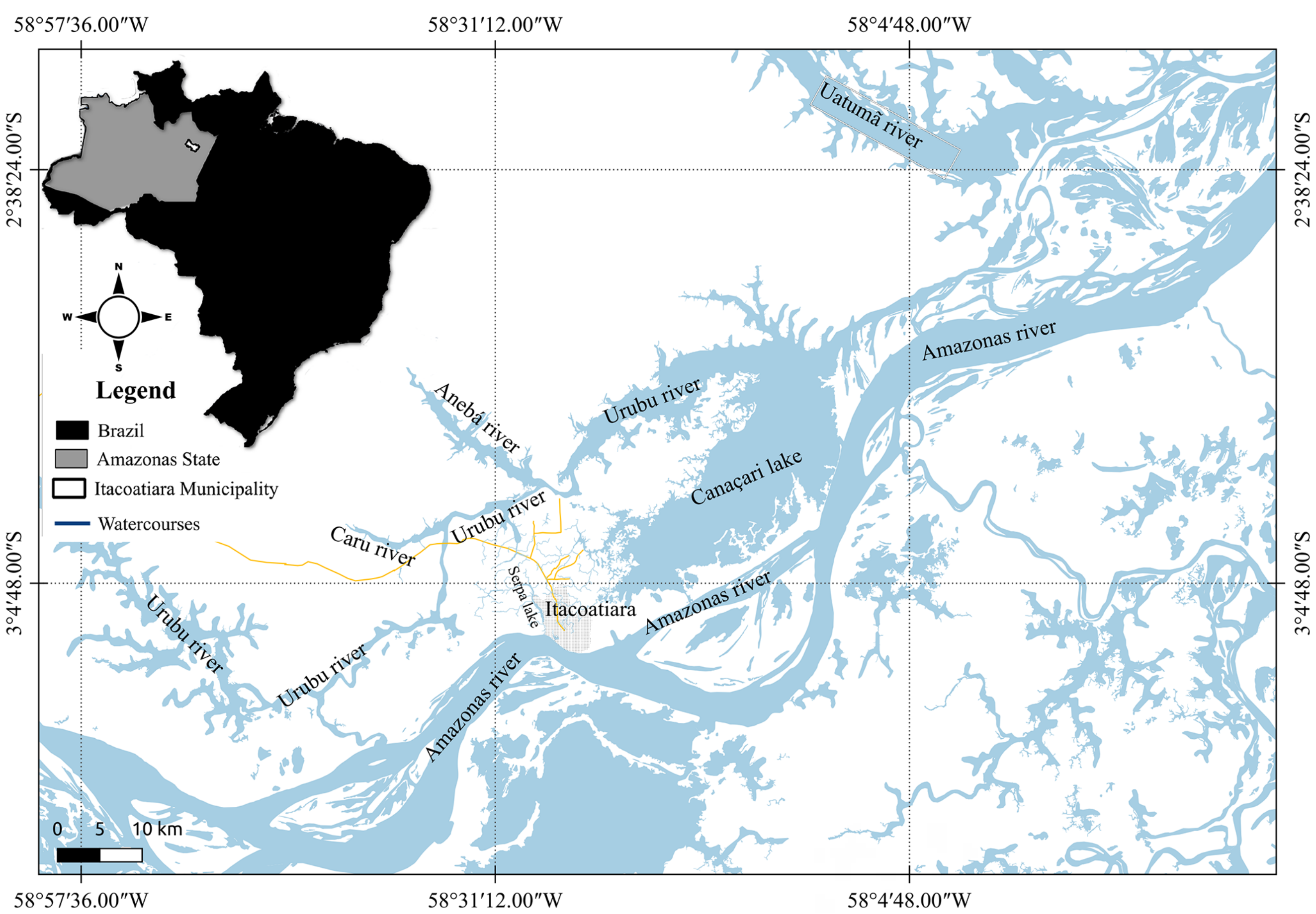

Figure 1. Map showing the complex fluvial system of Middle Amazonas River basin, Itacoatiara, Amazon State, Brazil.

Amazon River, upstream of the main connection between the Amazonas River and Canaçari Lake, and just downstream of the Amazonas-Madeira rivers confluence (Abril et al. 2014). The Canaçari Lake possesses clearwater and connects the Amazonas and Urubu rivers. It is disconnected from flooded forest most of the year, but during high water levels of Amazonas and Madeira rivers it is reconnected to these rivers (Polsenare et al. 2013). Approximately 12 km from its confluence with the Amazonas River, the Urubu River suffers a 90º inflection and its main course becomes parallel to the Amazonas River. On left margin it receives two tributaries, Caru and Anebá rivers, that drain into the Canaçari Lake. This lake is, in turn, connected to Uatumã River (Cavallini, 2014) (Figure 1). Both the Urubu and Uatumã rivers are clearwater basins that originate from the old plateaus of Guyana Shield and carry a lighter sediment load, are more acid and less productive than whitewater rivers (Hurd et al. 2016).

The west border of urban area of Itacoatiara is also influenced upstream by Serpa Lake, which is a tributary of Amazonas River. However, most of the connections between Serpa Lake and Amazonas River were barred due to roads construction (AM-010 and local roads), and the main connection with Amazonas River was barred and limited to a small artificial channel (close to site 4, Figure 2). In the flooded season the water flows from Amazonas River to Serpa Lak through this channel, and in the dry season the water flow suffers an inversion. During flood season connections between Serpa and Canaçari lakes can also appear. Most of the lakeshore has steep edges and is occupied by rural population.

The sampling occurred in 13 sites in the rural area of Itacoatiara (Figures 2 and 3, and Table 1). Sites 1 to 4 are located in Serpa Lake. Site 1 is the farthest from Amazon River and the nearest from Urubu River. This site is isolated from other parts of the lake during dry season, by coverage of aquatic plants (*Montrichardia arborescens* Schott). Sites 2 and 3 represent intermediate portions of the lake, and site 4 is closer to the lake connection with Amazonas River and farthest from Urubu River.

The remaining seven sampled sites (5, 7, 9, 10, 11, 12, and 13) are watercourses dammed by AM0-010 road, since its construction in the late 1960s. Trees stumps and wood debris are found in the bottom of these sites, the margins are flat and are subject to different impacts, such as deforestation, pasture, overfishing and recreational use. All these sites are tributaries of Urubu River (5, 6, 9, 10, and 11) or Canaçari Lake (7, 8, 12, and 13). Sites 6 and 8 are stream stretches downstream the barrier from sites 5 and 7, respectively.

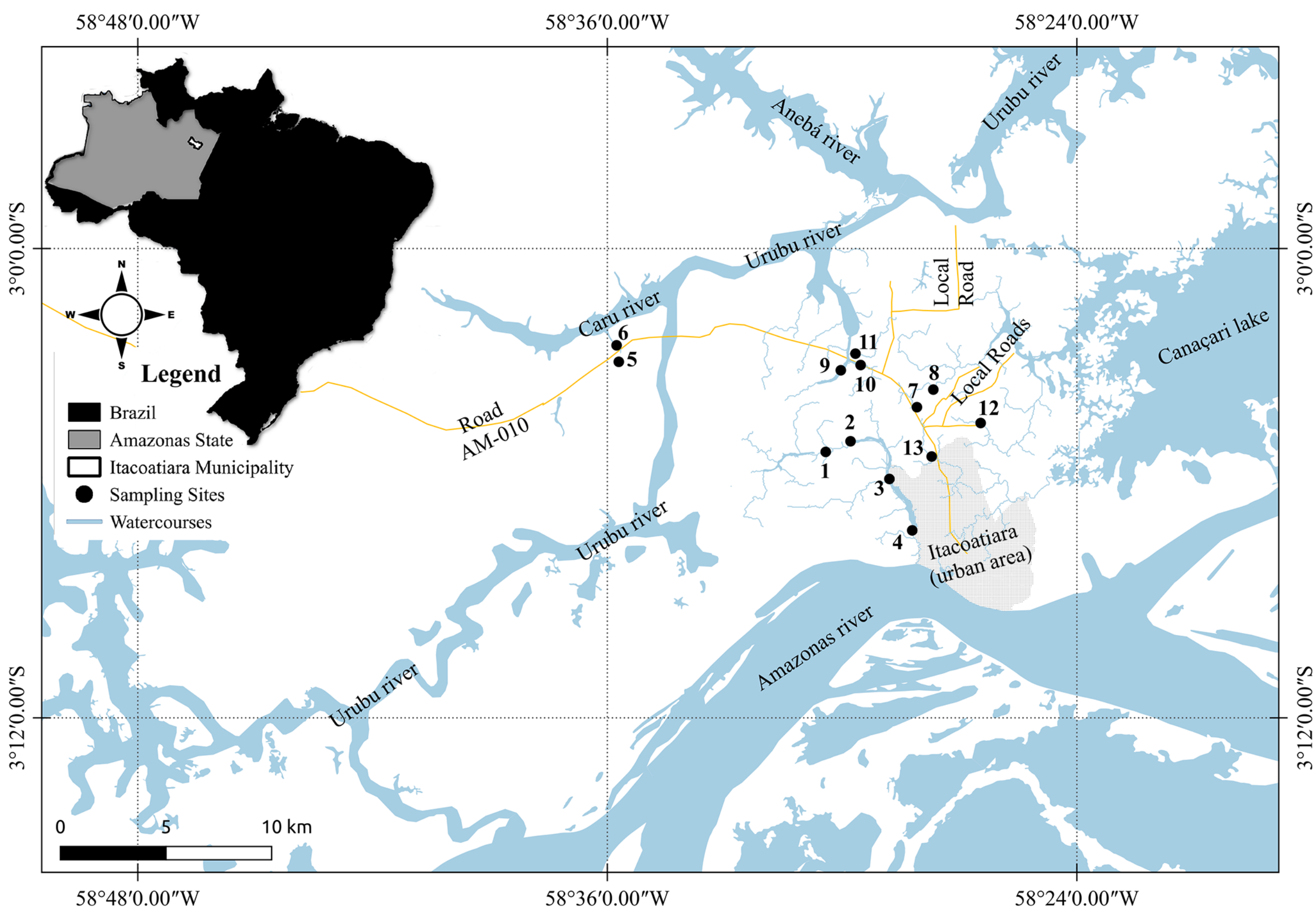

Figure 2. Map of the study area showing the sampled sites (black dots) on tributaries of Amazonas and Urubu rivers, in Middle Amazonas river basin, in Itacoatiara, Amazon State, Brazil.

Figure 3. Collecting sites (a) Serpa lake 1 (Site 1), (b) Serpa lake 2 (Site 2), (c) Serpa lake 3 (Site 3), (d) Serpa lake 4 (Site 4), (e) Km 24 stream (Site 5), (f) Km 24 stream (Site 6), (g) Km 8 lake (Site 7), (h) Km 8 stream (Site 8), (i) Km 13 lake (Site 9), (j) Km 13 lake (Site 10), (k) Km 13 lake (Site 11), (l) Almeida lake (Site 12) and (m) Km 6 lake (Site 13).

Table 1. Description of sampling sites on tributaries of Amazonas and Urubu rivers, in middle Amazonas river basin, Brazil.

Site	Local	Coordinates	Characteristics/ use of the margin areas	Deep and extension
1	Serpa 1 lake (lentic)	3°05'11.9"S 58°30'25.3"W	Lake's northwest side; connection to Urubu river (water input); emerging aquatic macrophytes; subsistence fisheries; moderate humans impacts	5.48 meters deep and 170 meters between the shores in samplings station
2	Serpa 2 lake (lentic)	3°04'55.6"S 58°29'47.2"W	Northwest-middle section of the lake; subsistence fisheries; marginal and floating habitations; intense navigation.	5.90 meters deep and 270 meters between the shores in samplings station
3	Serpa 3 lake (lentic)	3°05'53.4"S 58°28'47.6"W	Middle section of the lake; subsistence fisheries; marginal and floating habitations.	8.10 meters deep and 170 meters between the shores in samplings station
4	Serpa 4 lake (lentic)	3°07'12.3"S 58°28'12.6"W	Southeast section of the lake; connection to Amazonas river (water output in droughts and water input in floods).	5.20 meters deep and 120 meters between the shores in samplings station
5	AM-010 km 24 lake (lentic)	3°02'39.1"S 58°35'40.8"W	Artificial lake connected to Caru river (stream dammed by AM-010 road).	2.5 meters deep and 53,800 m^2 of surface area
6	AM-010 km 24 stream (lotic)	3°02'34.4"S 58°35'41.3"W	Tributary of Caru river; moderate human impacts.	1.50 meters deep and 10 meters between the shores in samplings station
7	AM-010 km 8 lake (lentic)	3°04'03.3"S 58°28'05.4"W	Artificial lake connected to Canaçari lake (stream dammed for recreational use).	1.7 meters deep and 12,700 m^2 of surface area
8	AM-010 km 8 stream (lotic)	3°03'30.2"S 58°27'35.9"W	Tributary of Canaçari lake; moderate human impacts.	1.50 meters deep and 5 meters between the shores in samplings station
9	AM-010 km 13 lake (lentic)	3°02'49.1"S 58°29'53.5"W	Artificial lake connected to Urubu river (stream dammed by AM-010 road).	3.1 meters deep and 336,700 m2 of surface area
10	AM-010 km 13 lake (lentic)	3°02'53.3"S 58°29'47.4"W	Artificial lake connected to Urubu river (stream dammed by local road); disabled aquaculture site; pastures on lakeshore.	2.9 meters deep and 59,900 m2 of surface area
11	AM-010 km 13 lake (lentic)	3°02'41.6"S 58°29'44.5"W	Artificial lake connected to Urubu river (stream dammed by local road); suppressed riparian forest; pastures on lakeshore.	2.2 meters deep and 20,600 m2 of surface area
12	Almeida lake (lentic)	3°04'27.6"S 58°26'27.7"W	Artificial lake connected to lake Canaçari (stream dammed by local road); recreational use.	2.5 meters deep and 71,100 m2 of surface area
13	AM-010 km 6 lake (lentic)	3º05'19.0"S 58º27'42.8"W	Artificial lake connected to lake Canaçari; seasonally connected to Serpa lake (on floods); suppressed riparian forest; pastures on lakeshore.	4.5 meters deep and 96,000 m^2 of surface area

2. *Data collection and analysis*

The samples were taken in June, September and November 2018, and March 2019. In sites 5, 7, 9, 10, 11, and 12 the fishes were collected using gill nets with different mesh sizes (20, 30, 40, 60, 80, 100, and 120 mm), and also a seine net (1,3 high and 10-meter-long, mesh size 5 mm) was used in the shallow littoral habitats of these sites. In sampling sites in Serpa lake (sites 1, 2, 3, and 4) only the gill nets were used, and in sample sites 6 and 8 (streams stretch) seine net and/or sieves with mesh size of 2 mm were used. All the specimens collected were anesthetized in benzocaine hydrochloride, fixed with formalin 10% solution and preserved in 70% ethanol for taxonomic identification. Voucher specimens were deposited in fish collection of Instituto Nacional de Pesquisas da Amazônia (INPA).

Nomenclatural arrangement and classification of family and higher levels followed Betancur-R. et al. (2017). Sub-families of Acestrorhynchidae, Characidae, Auchenipteridae, and Loricariidae followed Oliveira et al. (2011), Mirande (2018), Birindelli (2014), and Armbruster (2004), respectively. The classification of families and subfamilies were presented in alphabetical order as consequence of incongruence between molecular and morphological phylogenetic proposes, or lack of resolution of relationships between them. Identification follows Géry (1960), Weitzman & Cobb (1975), Kullander (1986), Ploeg (1991), Vari (1992), Langeani (1996), Weitzman & Palmer (1997), Zarske & Géry (1999), Lasso & Machado-Allison (2000), Merckx et al. (2000), Toledo-Piza (2000), Machado-Allison (2002), Staeck (2003), López-Fernández & Taphorn (2004), Malabarba (2004), Chernoff & Machado-Allison (2005), Santos et al. (2006), Bleher et al. (2007), Sarmento-Soares & Martins-Pinheiro (2008), Sousa (2010), Costa (2011), Mendonça & Wosiacki (2011), Queiroz et al. (2013), Menezes & Lucena (2014), Peixoto et al. (2015), Walsh et al. (2015), Marinho & Langeani (2016), Ota et al. (2016), Marinho & Menezes (2017), Melo & Oliveira (2017), Ribeiro et al. (2017), Mateussi et al. (2018), and de Souza et al. (2019).

All collect individuals and species were listed and quantified for each sampling site. The relative abundance in percentage was estimated for each site through the percentage of fish collected in each site in relation of the total collected. Richness for each sampling site was defined by the total number of species registered in each site.

Results

A total of 164 species were captured (Table 2), distributed in 11 orders, 37 families and 96 genera. The orders with the highest number of species were Characiformes (56.7%, 93 species) followed by Cichliformes (17.1%, 28 species) and Siluriformes (16.4%, 27 species).

Table 2. Taxonomic classification of fishes collected in tributaries of Amazonas and Urubu rivers, in middle Amazonas river basin, Brazil. Localities: 1 – Serpa lake, 2 – Serpa lake, 3 – Serpa lake, 4 – Serpa lake, 5 – Km 24 stream, 6 – Km 24 stream, 7 – Km 8 lake, 8 – Km 8 stream, 9 – Km 13 lake, 10 – Km 13 lake, 11 – Km 13 lake, 12 – Almeida lake and 13 – Km 6 lake.

Classification	Locality	Voucher INPA
TELEOSTEI		
ACTINOPTERI		
OSTEOGLOSSIFORMES		
Osteoglossidae		
Osteoglossum bicirrhosum (Cuvier, 1829)	3,4	58811
CLUPEIFORMES		
Engraulidae		
Anchoviella carrikeri Fowler, 1940	4	58810
Anchoviella guianensis (Eigenmann, 1912)	4, 5, 6, 9, 10, 11	57918
Lycengraulis batesii (Günther, 1868)	4	58883
Pristigasteridae		
Pellona flavipinnis (Valenciennes, 1837)	4	58875
CHARACIFORMES		
Acestrorhynchidae		
Acestrorhynchinae		
Acestrorhynchus falcatus (Bloch, 1794)	8	58827
Acestrorhynchus falcirostris (Cuvier, 1819)	1, 2, 3, 4, 5, 12, 13	58971
Acestrorhynchus isalineae Menezes & Géry, 1983	8	58825
Acestrorhynchus microlepis (Jardine, 1841)	5, 6, 8, 13	58790
Acestrorhynchus minimus Menezes, 1969	5, 6, 8, 9, 13	57902
Acestrorhynchus cf. pantaneiro	4	58850
Heterocharacinae		
Gnathocharax steindachneri Fowler, 1913	6	58844
Heterocharax macrolepis Eigenmann, 1912	12, 13	57882
Heterocharax virgulatus Toledo-Piza, 2000	5, 8, 9, 10, 13	57922
Hoplocharax goethei Géry, 1966	8	58834
Anostomidae		
Laemolyta taeniata (Kner, 1858)	2, 3, 4	58817
Leporinus fasciatus (Bloch, 1794)	2, 3, 4, 6, 8	58814
Leporinus friderici (Bloch, 1794)	1, 2	58867
Leporinus klausewitzi Géry, 1960	6, 8	58831
Rhytiodus microlepis Kner, 1858	2, 3, 4	58880
Schizodon fasciatus Spix & Agassiz, 1829	2, 3, 4	58881
Bryconidae		
Brycon amazonicus (Agassiz, 1829)	3	58922
Brycon melanopterus (Cope, 1872)	3, 4	58857
Chalceidae		
Chalceus erythrurus (Cope, 1870)	2, 3, 4	58813

Classification	Locality	Voucher INPA
Characidae		
Characinae		
Charax condei (Géry & Knöppel, 1976)	6, 8, 9	57921
Roeboides myersii Gill, 1870	4, 6	58830
Stethaprioninae		
Hemigrammus analis Durbin, 1909	5, 6, 8, 9, 12, 13	57891
Hemigrammus bellottii (Steindachner, 1882)	6, 8, 9, 10, 12	57917
Hemigrammus coeruleus Durbin, 1908	5, 6, 7, 8	58826
Hemigrammus diagonicus Mendonça & Wosiacki, 2011	5, 8, 12	57881
Hemigrammus levis Durbin, 1908	5, 6, 7, 8, 9, 10, 11, 12, 13	57912
Hemigrammus aff. *melanochrous*	12	57880
Hemigrammus ocellifer (Steindachner, 1882)	12	58803
Hemigrammus stictus (Durbin, 1909)	6, 7, 8, 5, 9, 10, 12, 13	57915
Hyphessobrycon bentosi Durbin, 1908	6	58836
Hyphessobrycon eques (Steindachner, 1882)	4	57924, 58846
Moenkhausia aff. *colletii*	12	LBP 26690
Moenkhausia cf. *cotinho*	6	58835
Moenkhausia lepidura (Kner, 1858)	9	58805
Moenkhausia mikia Marinho & Langeani, 2010	8	57932
Chilodontidae		
Chilodus punctatus Müller & Troschel, 1844	6, 8	57930, 58824
Crenuchidae		
Crenuchus spilurus Günther, 1863	8	58842
Ctenoluciidae		
Boulengerella maculata (Valenciennes, 1850)	3, 4, 5, 6	58792
Curimatidae		
Curimatella alburnus (Müller & Troschel, 1844)	6	58829
Curimatopsis cryptica Vari, 1982	5	57933
Curimatopsis evelynae Géry, 1964	6, 7	58821
Curimatopsis macrolepis (Steindachner, 1876)	5, 6, 7, 8, 12	57883
Curimatopsis pallida Melo & Oliveira, 2017	8	58833
Cyphocharax abramoides (Kner, 1858)	9, 5, 10, 11	57900
Cyphocharax leucostictus (Eigenmann & Eigenmann, 1889)	4	58860
Cyphocharax plumbeus (Eigenmann & Eigenmann, 1889)	5, 6, 8	57927
Cyphocharax spiluropsis (Eigenmann & Eigenmann, 1889)	8, 9	58804, 58849
Potamorhina latior (Spix & Agassiz, 1829)	4	58877
Psectrogaster essequibensis (Günther, 1864)	2, 3, 4	58878
Cynodontidae		
Rhaphiodon vulpinus Spix & Agassiz, 1829	2, 3, 4	58812
Erythrinidae		
Hoplias malabaricus (Bloch, 1794)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	58795
Gasteropelecidae		
Carnegiella strigata (Günther, 1864)	8	58843

Classification	Locality	Voucher INPA
Hemiodontidae		
Anodus elongatus Agassiz, 1829	2, 4	58852
Hemiodus argenteus Pellegrin, 1909	4	58867
Hemiodus gracilis Günther, 1864	6, 8, 9, 13	57919
Hemiodus immaculatus Kner, 1858	2, 3, 4	58815
Hemiodus unimaculatus (Bloch, 1794)	6, 9	58802
Hemiodus sp. 1	2, 3, 4	58864
Hemiodus sp. 2	4	58865
Iguanodectidae		
Bryconops caudomaculatus (Günther, 1864)	5, 6, 7, 8	57895
Bryconops giacopinii (Fernández-Yépez, 1950)	4	58808
Bryconops melanurus (Bloch, 1794)	6, 7, 8, 9, 13	57896
Iguanodectes spilurus (Günther, 1864)	8	58846
Lebiasinidae		
Copella callolepis (Regan, 1912)	12	57894
Copella nattereri (Steindachner, 1876)	5, 6, 7, 8	58807
Nannostomus digrammus (Fowler, 1913)	5, 6, 8, 9, 10, 12, 13	57892
Nannostomus eques Steindachner, 1876	5, 6, 8, 9, 10, 12, 13	57901
Nannostomus harrisoni (Eigenmann, 1909)	6, 8, 10, 12	57893
Pyrrhulina cf. *australis*	5, 6, 8, 9, 10, 11, 12, 13	57885
Prochilodontidae		
Semaprochilodus insignis (Jardine, 1841)	2, 4	58927
Semaprochilodus taeniurus (Valenciennes, 1821)	2, 3	58928
Serrasalmidae		
Catoprion mento (Cuvier, 1819)	3, 4, 5, 8, 9, 10, 13	57920
Colossoma macropomum (Cuvier, 1816)	12	58793
Metynnis altidorsalis Ahl, 1923	3, 4	57911
Metynnis guaporensis Eigenmann, 1915	3	58938
Metynnis hypsauchen (Müller & Troschel, 1844)	3	57910
Metynnis lippincottianus (Cope, 1870)	1, 3, 4, 7, 8, 9, 10, 12, 13	57884, 58818
Metynnis luna Cope, 1878	4	57909
Metynnis maculatus (Kner, 1858)	7, 8	58818
Metynnis melanogrammus Ota, Rapp Py-Daniel & Jégu 2016	6, 8, 9	57925
Myloplus aff. *asterias*	3	58873
Mylossoma albiscopum	3, 4	58874
Pygocentrus nattereri Kner, 1858	2, 3, 4	58879
Pygopristis denticulata (Cuvier, 1819)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	57899
Serrasalmus altispinis Merckx, Jégu & Santos, 2000	3, 4	58929
Serrasalmus compressus Jégu, Leão & Santos, 1991	2, 3, 4	58931
Serrasalmus eigenmanni Norman, 1929	4, 8	58820
Serrasalmus maculatus Kner, 1858	4	58933
Serrasalmus rhombeus (Linnaeus, 1766)	2, 3	58932
Serrasalmus spilopleura Kner, 1858	3, 4	58930
Triportheidae		
Triportheus albus Cope, 1872	3, 4	58935
Triportheus auritus (Valenciennes, 1850)	2, 3, 4	58937
Triportheus rotundatus (Jardine, 1841)	3, 4	58936

Classification	Locality	Voucher INPA
GYMNOTIFORMES		
Hypopomidae		
Brachyhypopomus brevirostris (Steindachner, 1868)	5, 7, 8, 10	57929
Brachyhypopomus sp.	1, 3, 4	58934
Sternopygidae		
Eigenmannia muirapinima Peixoto, Dutra & Wosiacki, 2015	7, 8, 9, 10, 11	57907
SILURIFORMES		
Auchenipteridae		
Auchenipterinae		
Ageneiosus dentatus Kner, 1858	4	58855
Ageneiosus inermis (Linnaeus, 1766)	4	58863
Ageneiosus lineatus Ribeiro, Rapp Py-Daniel & Walsh, 2017	1, 2, 3, 4	58882
Auchenipterichthys coracoideus (Eigenmann & Allen, 1942)	9, 11	58800
Auchenipterus nuchalis (Spix & Agassiz, 1829)	4	58853
Trachelyichthys exilis Greenfield & Glodek, 1977	5, 6, 9, 13	57923
Trachelyopterichthys taeniatus (Kner, 1858)	3	58868
Trachychoristis porosus Eigenmann & Eigenmann, 1888	2, 3, 4	58876
Tympanopleura atronasus (Eigenmann & Eigenmann, 1888)	4	58854
Tympanopleura rondoni (Miranda Ribeiro, 1914)	2, 4	58862
Centromochlinae		
Tatia nigra Sarmento-Soares & Martins-Pinheiro, 2008	2	57906
Tatia strigata Soares-Porto, 1995		58840
Callichthyidae		
Hoplosternum littorale (Hancock, 1828)	2, 4	58816
Doradidae		
Anadoras grypus (Cope, 1872)	3	58856
Oxydoras niger (Valenciennes, 1821)	9, 11	58787
Heptapteridae		
Rhamdia quelen (Quoy & Gaimard, 1824)	10, 11	58801
Loricariidae		
Hypostominae		
Ancistrus dolichopterus Kner, 1854	1, 2, 4	58851
Dekeyseria amazonica Rapp Py-Daniel, 1985	3	58861
Loricariinae		
Loricariichthys acutus (Valenciennes, 1840)	2, 3	58871
Loricariichthys sp.	2, 4	58872
Pimelodidae		
Calophysus macropterus (Lichtenstein, 1819)	4	58925
Hemisorubim platyrhynchos (Valenciennes, 1840)	4	58924
Hypophthalmus edentatus Spix & Agassiz, 1829	2, 3, 4, 11	58789
Pimelodus blochii Valenciennes, 1840	4	58869
Pinirampus pirinampu (Spix & Agassiz, 1829)	4	58926
Pseudoplatystoma tigrinum (Valenciennes, 1840)	2	58923
Sorubim elongatus Littmann, Burr, Schmidt & Isern, 2001	2, 4	58884
GOBIIFORMES		
Eleotridae		
Microphilypnus ternetzi Myers, 1927	5, 8, 13	57928

Classification	Locality	Voucher INPA
SYNBRANCHIFORMES		
Synbranchidae		
Synbranchus sp.	5, 6, 9, 10	57903
CICHLIFORMES		
Cichlidae		
Acarichthys heckelii (Müller & Troschel, 1849)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	57914
Acaronia nassa (Heckel, 1840)	1,2, 5, 6, 7, 8, 9, 10, 11, 12, 13	57887
Aequidens pallidus (Heckel, 1840)	5	58806
Aequidens tetramerus (Heckel, 1840)	10, 11, 12, 13	58798
Apistogramma agassizii (Steindachner, 1875)	7, 10, 12 13	57904
Apistogramma gephyra Kullander, 1980	8	58839
Apistogramma pertensis (Haseman, 1911)	8, 10, 11, 12	57908
Apistogramma resticulosa Kullander, 1980	8, 10, 11, 12, 13	57905
Biotoecus opercularis (Steindachner, 1875)	5, 9, 10, 11, 12, 13	57913
Cichla monoculus Spix & Agassiz, 1831	2, 5, 7, 8, 9, 10, 11, 12, 13	58796
Cichla temensis Humboldt, 1821	2, 3, 4, 5, 9, 10, 12, 13	58794
Crenicichla lenticulata Heckel, 1840	1, 5, 10, 13	58797
Crenicichla lugubris Heckel, 1840	4	58858
Crenicichla regani Ploeg, 1989	7	58823
Crenicichla sp.	4	58859
Geophagus altifrons Heckel, 1840	2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	57886
Heros spurius Heckel, 1840	4, 10, 11, 12, 13	57890
Hypselecara coryphaenoides (Heckel, 1840)	8	58838
Hypselecara temporalis (Günther, 1862)	5, 8, 9, 10, 11, 12	58799
Laetacara thayeri (Steindachner, 1875)	6, 7, 8, 5, 9, 10, 11, 12, 13	57888
Mesonauta festivus (Heckel, 1840)	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	57916
Pterophyllum scalare (Schultze, 1823)	4, 8	58809
Satanoperca acuticeps (Heckel, 1840)	1, 3, 4, 8, 9, 10, 11, 13	57888
Satanoperca jurupari (Heckel, 1840)	2, 4, 5, 9, 12, 13	57931
Satanoperca lilith Kullander & Ferreira, 1988	1, 2, 3, 4, 5, 6, 7, 9, 10,11, 12	57898
Symphysodon discus Heckel, 1840	1	57897
Taeniacara candidi Myers, 1935	7, 8, 13	57926
Uaru amphiacanthoides Heckel, 1840	11, 12	58788
CYPRINODONTIFORMES		
Fluviphylacidae		
Fluviphylax pygmaeus (Myers & Carvalho, 1955)	5, 6, 8	58819
Rivulidae		
Anablepsoides ornatus (Garman, 1895)	8	58837
BELONIFORMES		
Belonidae		
Belonion dibranchodon Collette, 1966	6	58828
Potamorrhaphis guianensis (Jardine, 1843)	8	58832
PERCIFORMES		
Polycentridae		
Monocirrhus polyacanthus Heckel, 1840	8	58822
Sciaenidae		
Plagioscion squamosissimus (Castelnau, 1855)	4	5887

The most representative families were Cichlidae (28 species), Serrasalmidae (19 species), and Characidae (16 species). In terms of genera, the families that were most representative were Cichlidae (17 genera), Serrasalmidae and Auchenipteridae (both with eight genera).

The most common species were *Acarichthys heckelii*, *Geophagus altifrons*, *Mesonauta festivus*, *Satanoperca lilith*, and *Pygopristis denticulata* (Figure 3). Important species for commercial aquarium trade like *Monocirrhus polyacanthus* (site 8), *Symphysodon discus* (site 1), *Pterophyllum scalare* (sites 4 and 8) (Figure 4) and species of genera *Apistogramma* (sites 7, 8, 10, 11, and 13), and *Nannostomus* (sites 5, 6, 8, 9, 10, 12 and 13) were registered. Additionally, important species for fisheries were captured, like *Brycon amazonicus*, *Cichla monoculus*, *C. temensis*, *Colossoma macropomum*, *Osteoglossum bicirrhosum, Semaprochilodus insignis*, and *S. taeniurus.* One species that remains unknown for science, but is in process of formal description, identified as *Moenkhausia* aff. *colletii* was registered in site 12 (Figure 4).

The most abundant species in this study were *Hemigrammus levis* (62.1%), *Hemigrammus stictus* (8.7%), and *Acarichthys heckelii* (3.3%), the last one was very abundant in the barred watercourses (sites 5, 7, 9, 11, 12, and 13). The sites with the lowest relative abundance were located in Serpa Lake. The site 12 presented the highest relative abundance (Figure 5). In number of species, the sites with the highest and lowest number were site 4 and 1, respectively (Figure 6).

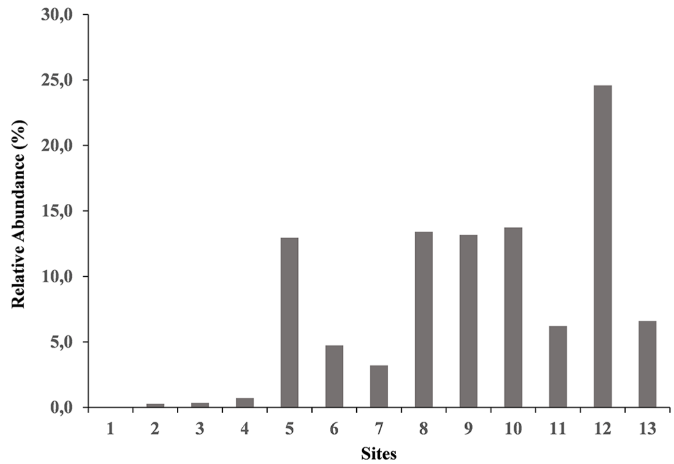

Figure 5. Relative abundance of fishes in sampling sites on tributaries of Amazonas and Urubu rivers, in middle Amazonas river basin, Brazil.

Discussion

The predominance of Characiformes, Siluriformes and Cichliformes corroborates the pattern observed for freshwater environments in South America (Lowe-Mcconnell 1999, Siqueira-Souza & Freitas 2004, Fernandes et al. 2012, Freitas et al. 2013, Queiroz et al. 2013,

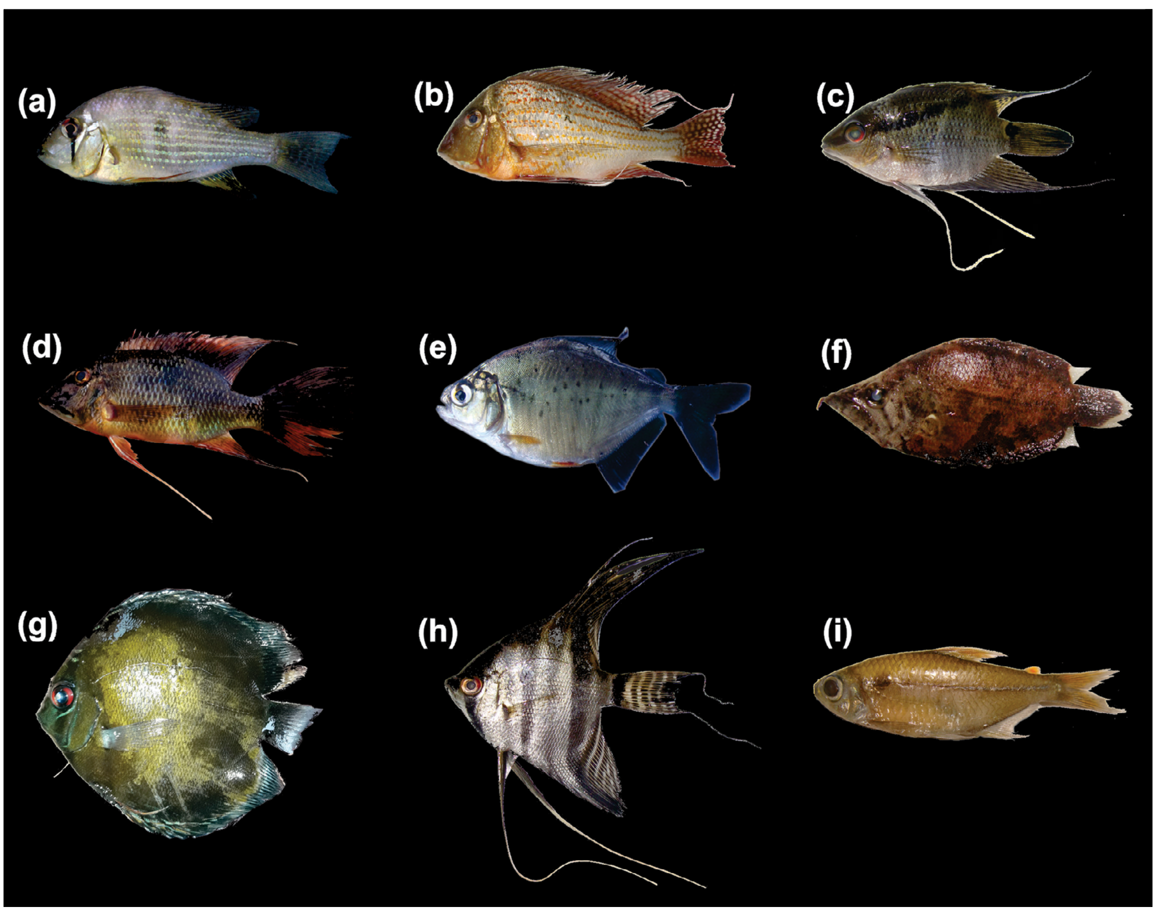

Figure 4. Representative individuals of nine species collected: (a) *Acarichthys heckelii*, 75 mm SL; (b) *Geophagus altifrons*, 197 mm SL; (c) *Mesonauta festivus*, 55 mm SL; (d) *Satanoperca lilith*, 185 mm SL; (e) *Pygopristis denticulata*, 165 mm SL; (f) *Monocirrhus polyacantus*, 15 mm SL; (g) *Symphysodon discus*, 161 mm SL; (h) *Pterophyllum scalare*, 85 mm SL and (i) *Moenkhausia aff. colletii*, 65 mm SL.

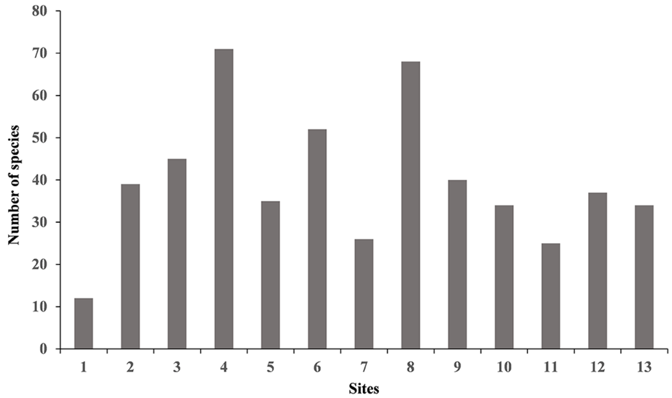

Figure 6. Total number of species in each sampling site on tributaries of Amazonas and Urubu rivers, in middle Amazonas river basin, Brazil.

Leite et al. 2015, Reis et al. 2016); although Cichliformes, represented exclusively by one family (Cichlidae), presents the same number of species as Siluriformes, with six families. Cichlidae was the most diverse family in number of species, comprising 17.1% of all richness registered. This family is known to represent one of the largest groups of freshwater teleost fishes (Kullander 2003, Nelson 2016), presenting large reproductive success in anthropic environments (Baumgartner et al. 2012), with many species having opportunistic diet resistant to environmental disturbances standing out over other species sensitive to disorders (Santos & Ferreira 1999, Oliveira & Bennemann 2005). A representative species of this pattern is *Acarichthys heckelii* that was registered in all sampling sites, with makeable abundance in the barred watercourses (sites 4, 5, 7, 9, 11, 12, and 13). Thus, the habitat changing due to damming and flow modification in sites along AM-010 and the connection between Serpa Lake and Amazonas River may provide favorable conditions to ciclids survival. Nevertheless, sampling using seine nets in the shallow littoral habitats in these sites should increased the number of ciclids, due to its feeding habitats that includes aquatic invertebrates, detrital macrophytes, filamentous algae and terrestrial invertebrates (Bayley 1988).

Among the ciclids collected, some species are important in aquarium market like *Symphysodon discus*, *Pterophyllum scalare*, *Mesonauta festivus*, and *Apistogramma* spp. Species of this family are exported from the middle Solimões (Reserva Mamirauá and Anamã), Madeira and Uatumã rivers (Anjos et al. 2009). Besides the ciclids, many species of Characidae, popularly known as tetras or piabas, were captured in the present study, as *Hemigrammus ocellifer*, *Hemigrammus stictus*, *Hyphessobrycon bentosi*, *Hyphessobrycon eques*, and *Hyphessobrycon rosaceus*, which possess beautiful color patterns, small size and are commonly found in aquariums. Approximately 100 million ornamental fish were exported from the Amazonas State between 2002 and 2005 (Anjos et al. 2009).

Despite the high number of fish species in the Amazon region, the fisheries are concentrated in few species, in which about 80% is composed of only 6 to 12 species, such as *Brycon*, *Hypophthalmus*, *Pellona*, *Pimelodus*, *Pseudoplatystoma*, *Semaprochilodus*, and *Triportheus* (Barthem & Fabré 2004). Representatives of all these genera were registered by us in this study, some of them very common in Itacoatiara fish markets, as the popularly known as jaraquis (*Semaprochilodus insignis* and *S. taeniurus*), matrinxã (*Brycon amazonicus* and *B. melanopterus*), sorubim (*Pseudoplatystoma tigrinum*), and sardinhas (*Triportheus albus*, *T. auritus*, and *T. rotundatus*), with the addition of aruanã (*Osteoglossum bicirrhosum*), pacu (*Mylossoma albiscopum*), and tucunarés (*Cichla monoculus* and *C. temensis*), also appreciated by local population. This indicates that besides environmental disturbances caused mainly by human activities in this region, the sampling areas are important resources of commercial fish species, and more attention to conservation and management efforts should be addressed to this region.

The lowest values of relative abundance were registered in the four Serpa lake sampling sites, possibly due to the use of a unique sampling method (gill net). Moreover, in Serpa lake were registered the highest richness (almost 70 species in site 4 - nearest to Amazonas river) and lowest richness (a little more than 10 species in site 1- nearest to Urubu river). However, *Symphysodon discus*, popularly known as disco, was exclusivelly caught in the site with the lowest abundance and lowest richness (site 1). Disco is an endemic cichlid from the Amazon basin, and is one of the most popular ornamental fish species, extensively used in aquarium (Ferraz 1999). Sequencially, the second (approximately 70 species in site 8) and the third (approximately 70 species in site 6) sites with the highest richness comprise small streams, located downstream the barrier from sites 5 and 7, respectively, suggesting less habitat changing and flow modification downstream the damming. Moreover, all barred water coursers presented no more than 40 species. Changes in connectivity (Hurd et al. 2016, Benoni et al. 2018) and damming (Anderson et al. 2018) are well-reported causes of modification in structure and composition of fish fauna.

About 28% of South America's known fauna has been described in the last 11 years, due to the unique environmental aspects of the Amazon basin, which contribute to new species discoveries (Reis et al. 2016). We recorded six species described for the Amazonas river basin in the last decade, *Moenkhausia mikia*, *Hemigrammus diagnonicus*, *Eigenmannia muirapinima*, *Metynnis melanogrammus*, *Curimatopsis pallida*, and *Ageneiosus lineatus* (Marinho & Langeani, 2016, Mendonça & Wosiacki 2011, Peixoto et al. 2015, Ota et al. 2016, Melo & Oliveira 2017, Ribeiro et al. 2017), along with a common species that was recently redescribed as *Mylossoma albiscopum* (Mateussi et al. 2017). Still, a new species for science, identified here as *Moenkhausia* aff. *colletii* is being formally described by one of the authors of this investigation (RPO) and I. M. Soares.

The sampled region is composed by a complex fluvial system river system with channels, holes, paranas and lakes that integrate both black and clearwater environments such as igapós and campinaranas, as well as a vast floodplain area enriched by alluvial deposits of whitewater rivers such as the Amazonas and Madeira rivers (Cavallini 2014). The Madeira river drains one-third of the Amazonian lowlands and is the richest tributary of Amazonas river (Dagosta & Pinna 2019). Therefore, the confluence of Madeira and Amazonas rivers just upstream the studied area and the proximity to Urubu and Uatumã rivers may explain the high number of fish species recorded in this study, due the hydrological connectivity and biological exchanges among these lowland aquatic environments, mainly in high waters. Additionally, attention to the different anthropogenic impacts that occur in the sampling sites, evolving human occupancy, emission of effluents without sanitary treatment, barrage for construction of artificial beaches for recreational use, and disruption of water body flow for AM-010 road construction should be reinforced. In this way, cataloging fish fauna in modified environments in order to access the fish diversity is a fundamental step to support investigation on the potential impacts of fish fauna composition, maintenance, and survival in these environments directly affected by human activities.

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Author Contributions

Rafaela Priscila Ota: 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 intellectual content.

Rayane da Silva Pereira: 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 intellectual content.

Rayanna Graziella Amaral da Silva: 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 intellectual content.

Bruno Ferezim Morales: 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 intellectual content.

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Rafael Hinnah: Substantial contribution in the concept and design of the study; Contribution to data collection; Contribution to data analysis and interpretation.

Erico Luis Hoshiba Takahashi: Substantial contribution in the concept and design of the study; Contribution to manuscript preparation; Contribution to critical revision, adding intellectual 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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