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DIVERSITY IN TWO RIVERS AND CHALLENGES FOR CONSERVATION IN THE EASTERN AMAZON

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ABSTRACT

The present study investigated and compared the diversity of two nearby streams with explicit differences in urban exploration. Pointing to richness, dominance and diversity models in both environments, the Jacubinha and Neblina streams, tributaries of the Lontra sub-basin and tributaries of the Araguaia-Tocantins Basin in eastern Amazon, north of the state of Tocantins. Sampling took place between 2014 and 2020, using multiple methodologies (nets, cast nets, hauling, scoops and sieves). reaching 1374 individuals of 85 identified species, distributed in 26 families, and 8 orders. These identified families, Characidae, Cichlidae, Loricariidae were the most diverse. Thus, species with the greatest abundance in two environments were *Knodus heteresthes*, *Poecilia reticulata*, *Phenacogaster cf calverti*, *Astyanax novae* and *Psalidodon cf fasciatus*. Presenting a difference close to 80% in their taxon varieties, indicating biological impoverishment this stream. However, the species mentioned in this article show high richness, as estimated for an ecotonal environment such as the one between Cerrado and Amazon Forest, in eastern Amazon. Such distinct patterns of arrangement and abundance of taxa resemble the marked attributes of the sampled habitats, as well as their degree of deterioration.

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INTRODUCTION

The greatest diversity for freshwater fish is cited for South America, having great taxonomic and phylogenetic variety (Reis et al. 2016, Muniz et al. 2020), and large rates of endemism (Oliveira et al. 2020). The Amazon basin and the Paraná-Paraguay complex hold the greatest diversity on the South American continent (Jarduli et al. 2020). The richness of Amazonian species is considered one of the largest in the world, the existence of approximately 1000 species of fish (Ohara et al. 2015).

With more than 7 million km², the Amazon basin drains a large number of Brazilian states (Acre, Amazonas, Roraima, Rondônia, Mato Grosso, Pará and Amapá) and reaches some neighboring countries (Peru, Colombia, Ecuador, Venezuela, Guyana, Suriname and Bolivia). Its tributaries are almost all the great rivers in northern Brazil. In this large complex lies the Araguaia-Tocantins River basin, which was once considered one of the fishiest rivers in the world (Barbosa e Rubin 2020). The drainage has numerous tributaries and sub-tributaries in the northern portion of the states of Maranhão, Tocantins, Goiás, Mato Grosso and the Federal District. With 967,000 km², it is considered the largest basin entirely in Brazil, divided into

12 hydrographic regions, forming a hydrographic complex that permeates a large number of ecosystems (Lowe-McConnell 1999, Gomes et al. 2018). The Araguaia-Tocantins basin is a complex mosaic of lentic and lotic environments with high habitat diversity, which hold a large part of this diversity for the fish group (Jarduli et al. 2014). Considering its importance for Neotropical biodiversity, the Araguaia-Tocantins is seriously threatened, as around 80% of its basin is located in the most explored biome, the Cerrado. The causes of this environmental deterioration are agricultural activities, urban expansion, deforestation, mining and installation of hydro-energy dams (Saviato et al. 2020). Thus, we can highlight those urban settlements significantly impact nearby aquatic ecosystems. Because cities are full of environmental rearrangements, which often suppress natural habitats, with important interference in trophic synergies, nutrient cycling and environmental homeostasis (Sampaio et al. 2017, Silva et al. 2020a, Almeida et al. 2020). With urban growth and expansion, natural, remnant and adjacent areas are altered and de-characterized (Araújo et al. 2020), in addition to receiving the entire load of untreated effluents in their watercourses, which occurs in many cities (Borges et al. 2020). This fact does away with the environmental functions and the well-being of the fauna and flora that exist there. Environmental degradation in these places also directly influences the public health and well-being of the human population in these regions (Dimenstein e Siqueira, 2020, Santana et al. 2020), creating problems that can result in damage to human health and damage to public coffers (Albino e Vieira 2019, Nascimento et al. 2020). Thus, among the main negative attributes, it is highlighted that urban areas promote major changes in the landscape and environmental quality, and even when there are plans, they can negatively affect ecosystem services (Amorim 2019). Likewise, environmental quality is a major factor in determining the diversity of fauna (Zhang e Hu 2020) and flora in rivers (Felipe e Súarez 2010), however, the degradation of environmental properties results in irreparable losses to biodiversity.

Research indicates that environmental quality influences the availability of resources and the heterogeneity of habitats (Selhorst et al. 2016, Ponomarev 2019). Environmental risks are more important, particularly in small rivers that flow into urban centers, suffering impacts from urbanization, inducing the loss of biodiversity, especially in fish assemblages (Cunico et al. 2006, Yen et al. 2018, Silva e Porto 2020). These urban rivers are often altered not only by the environmental negligence of the population or public systems, but also by the misuse, linking them to these, as a discontinuity of urban sanitation in these areas (Fagundes 2020, Su et al. 2021). Likewise, environmental assessments of biodiversity make it possible to infer on the quality of the physical-chemical parameters of urban rivers, and express the environmental conditions in a macroscopic way (Guarda et al. 2020; Marcionilio et al. 2020). Such assessments make it possible to understand the synergies between the biota and the bouquet of environmental parameters (Silva and Lima 2020, Eros et al. 2020). Also, evidence of alterations in environmental homeostasis is mainly based on the decrease in diversity in altered locations (Barros et al. 2020). The scaring away of fauna or the disappearance of species is directly linked to the quality and quantity of available habitats, as well as the negative pressures arising from urbanization and its effects on the natural environment (Oliveira et al. 2020). Therefore, studies on biodiversity directly infer on the environmental capacity to support this biota (Morson e Grothues 2019, Silva et al. 2020b), and comparisons of diversity may point out that such differences are related to the environmental damage induced to these bodies of water (Alves et al. 2020). Biodiversity analyzes that measure wealth and its synergies are tools that facilitate the taking of action plans, which excel in restoring these water sources, affected and degraded by urbanization processes (Lianthuamluaia et al. 2019, Garcias et al. 2020). The restoration of ecosystem services ensures that their demands are met, especially in the cycling of nutrients and maintenance of biodiversity as a whole (Santos et al. 2020a). Thus, this study qualitatively and quantitatively evaluates fish assemblages from two typical Cerrado streams, the Jaubinha and Neblina streams, which are tributaries of the Lontra river sub-basin, Araguaia-Tocantins River basin.

The Jacubinha stream is well preserved, with an PPA (Permanent Preservation Area) established and regulated, while the Neblina stream is fully inserted in the urban perimeter of the city of Araguaína – TO, including its springs and mouth. Therefore, given the intrinsic ecological relationships of headwater rivers and environmental quality, our hypothesis is that there are differences in species richness, diversity and patterns of fish dominance when we compare aquatic environments of the same magnitude and geographically similar, but that are under pressure of different intensities.

Material and Methods

Study area: The Jacubinha stream, as well as the Neblina stream, are tributaries of the Lontra sub-basin, being considered typical cerrado streams found in the Eastern Amazon. These constitute important tributaries that supply the aforementioned river, and make up the catchment basin of the SHP (Small Hydroelectric Power Plant) Corujão (Figure 1).

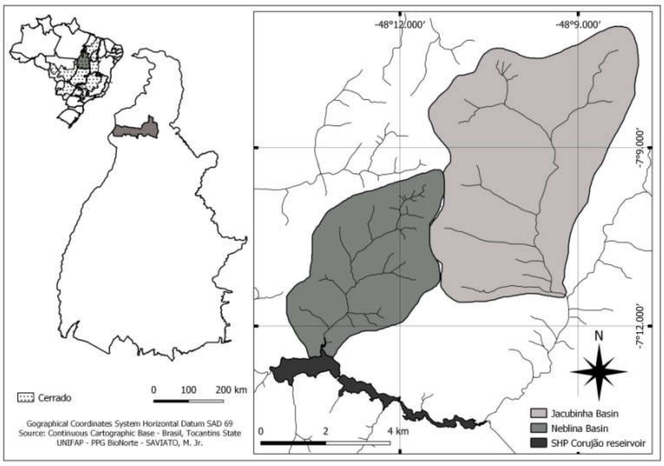

Figure 1. List of water bodies presented in this study

The drainage area of the Jacubinha stream is 38 km², being a third-order river, comprising allotments, small farms and farms, in the peripheral region of the urban area in the municipality of Araguaína. It is between the geographic coordinates 22M 822187.42m E; 9211895.75m S; and 802506.64m E; 9200865.03m S (Trindade e Sieben 2012). It is part of the ecological preservation area called APA das Margens do Rio Jacuba, Law No. 1227, of April 15, 1993, along the entire length of this watercourse, until its meeting with the Lontra river (SEPLAN-TO 2002). The Jacubinha stream has well-conserved regions, with few changes in its riparian strip, nor structural changes in the bed, with a matching biota (Saviato et al. 2017) (Figure 2).

Figure 2. Jacubinha stream with its riparian forest preserved

With a drainage area of 18 km², including all its springs and mouth, the Neblina stream is located in the urban perimeter of the city of Araguaína (Leite et al. 2020). This stream shares watersheds with the Jaubinha stream, distancing its main beds by approximately 6 km. The Neblina stream is also a third-order perennial body of water, as well as the Jacubinha, however, it is quite uncharacterized and anthropized by the pressures of urbanization, domestic and industrial evictions (Saviato et al. 2020). This stream is densely populated, with approximately 30 thousand inhabitants, segregated into almost 10 thousand residences (IBGE 2020). Of these, around 20% have sewage collections, but most discharge all their effluents into nearby water bodies, which are part of this drainage basin (Barbosa and Rubin 2020, Leite et al. 2020). This region is heavily exploited for urbanization, especially close to the main bed. However, even in less urbanized places, water from the stream is used for irrigation and land exploration for horticulture, cattle raising and installation of industrial and real estate projects (Figure 3).

Figure 3. Neblina stream near its mouth

Despite the significant difference in coverage, both streams are approximately 20 meters wide near the mouth and about 1 m deep in deeper places. The flow of these streams is also similar in spite of the difference in the catchment areas, with approximately 500m³/h, varying according to the season, which can increase tenfold during the floods, typical of the Amazon region.

Data collect: To compose the sampling frame in these environments, five collection points were taken in the main channel of each stream, five for the Jacubinha stream and five for the Neblina stream. Each collection point (from head to mouth) was selected by physiognomic similarity (width, depth, speed, approximate water volume and substrate), with its corresponding in each stream. These sampling sites underwent sampling effort during the dry and rainy seasons, also three campaigns per season at each point, during the period from March 2014 to December 2020. The captures were carried out using gear fishing gear such as: sieves (3mm mesh), pulleys (3mm mesh), cast net (5mm mesh), trawl (5mm mesh 30m long by 3.5m high), holding net (at 1.5, 2.0 and 4.0 cm meshes between knots, all 10m long by 1.5m high) and hooks (various sizes and different baits) with line and reel (Figure 4).

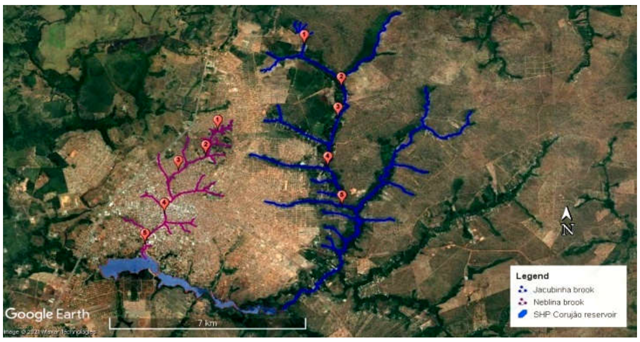

Figure 4 - map containing the collection points

Fish caught alive were, whenever possible, identified in the field and then released again. The others were anesthetized in a eugenol solution and fixed in 10% formalin for subsequent conservation in 70% alcohol. Specimens were identified down to the lowest taxonomic level, using specific literature and consultation with experts to check doubtful identifications. The taxonomic classification followed the *Catalog of Fishes* (Fricke 2021).

Data analysis: From the raw data of the number of individuals per species and sampling point, fish assemblages from the two streams were compared in relation to taxonomic composition, alpha and beta diversity and patterns of species dominance. The species were listed in their respective Orders and Families and the relative abundance of each taxonomic level was evaluated. Alpha diversity comparisons were based on the quantification of the number of species present (specific richness - *S*) and on the structure of the assemblages, that is, on the proportional distribution of the importance value of each species (Moreno 2001). Specific richness was then compared by the rarefaction method in number of individuals and through the non-parametric *Chao* 2 and 1 richness estimators, which are based, respectively, on the number of species occurring in one or two samples and on the number of species that occur with one or two individuals. The structure of the assemblages was evaluated using the Simpson dominance and Shannon-Wiener diversity indices. These analyzes were performed using the *EstimatesS* statistical program (version 9.1.0) with the data being randomized 1000 times (Colwell, 1997). Beta diversity was used as a measure of biotic change in an environmental gradient. It was evaluated by means of cluster analysis of species by sampling point, using Jaccard's similarity coefficients for qualitative data and the Bray-Curtis coefficient for quantitative data.

The dominance patterns of species by sampling point or stream were verified using a combination of relative abundance (RA), defined as the ratio between the number of individuals of a given species and the sum of all individuals in the sample multiplied by 100, and the frequency of occurrence (FO), defined as the ratio between the number of samples in which the species occurred and the total number of samples multiplied by 100. The AR and FO values are then compared to their respective means (µ) and species classified as: abundant and frequent (AR > µAR and FO > µFO); abundant and infrequent (AR > µAR and FO < µFO); not abundant and frequent (AR < µAR and FO > µFO); present (AR < µAR and FO < µFO). Species classified as abundant and frequent were considered dominant (Artioli et al. 2009).

RESULTS

In a sampling effort of approximately 250 hours per stream (about 3 hours per point / season / year), 1374 individuals were recorded, distributed in 85 species. Of these fish, 973 individuals (70.8%) most of the fish collected belong to the order Characiformes, 147 (10.7%) are Siluriformes and 138 (10.0%) Cichliformes, two very different order, but less represented, 72 (5.2%) Cyprinodontiformes, 26 (1.9%) are Gymnotiformes a very diverse order of predators, 15 (1.1%) Beloniformes, 2 (0.1%) Synbranchiformes and 1 (0.1%) Pleuronectiformes. Of the total of 85 species recorded, 51.8% are Characiformes, 24.7% Siluriformes, 11.8% Cichliformes, 7.1% Gymnotiformes, as well as, Beloniformes, Cypriniformes, Pleuronectiformes and Synbranchiformes, each with 1.2%, of total wealth. The Characidae family showed dominance over the others with 58.7% of the relative frequency, as well as Cichlidae with 9.5%, Loricariidae 5.8%, Heptapteridae 4.4%, Iguanodectidae 2.7%, Curimatidae 2.6%, Lebiasinidae 2.4%, Acestrorhynchidae 1.9%, Serrasalmidae and Sternopygidae with 1.8% each, Crenuchidae 1.4%, Anostomidae 1.3%, Belonidae 1.3%, Parodontidae, Erythrinidae and Pimelodidae with 1.0% each, Auchenipteridae 0.4%, Hypopomidae and Pseudopimelodidae with 0.3% each, Gymnotidae, and finally Rhamphichthyidae, Achiridae, Aspredinidae, Trichomycteridae and Synbranchidae with 0.1% each (Table 1). However, when we take the same increasing separation of household frequencies for Ribeirão

Table 1. List of species, taxonomic level, presence and absence in each stream and listed/classified by order, family and species

TAXONS (ORDER/Family)	*Popular name*	*Jacubinha Stream*	*Neblina Stream*
BELONIFORMES			
Belonidae			
Potamorrhaphis guianensis *(Jardine, 1843)*	*Piolho de boto*	*X*	
CHARACIFORMES			
Acetrorhynchidae			
Acestrorhynchusfalcatus *(Bloch, 1794)*	*Peixe cachorro*	*X*	
Anostomidae			
Abramites cf. hypselonotus *(Günther, 1868)*		*X*	
Leporinus friderici *(Bloch, 1794)*	*Piau*	*X*	
Leporinus unitaeniatus *Garavello e Santos, 2009*	*Piau*	*X*	
Parodontidae			
Apareiodon machrisii *Travassos 1957*	*Piauzinho*	*X*	
Iguanodectidae			
Bryconops caudomaculatus *(Günther, 1864)*	*Lambari*	*X*	
Characidae			
Aphyocharax alburnus *(Günther, 1869)*	*Lambari*	*X*	*X*
Astyanax microlepis *Eigenmann, 1913*	*Lambari*	*X*	*X*
Astyanax novae *Eigenmann, 1911*	*Lambari*	*X*	*X*
Chalceus cf. macrolepidotus *Cuvier, 1818*		*X*	
Deuterodon sp.	*Lambari*	*X*	*X*
Hemigrammus cf. melanochrous *Fowler, 1913*	*Lambarizinho*	*X*	
Hemigrammus cf. stictus *(Durbin, 1909)*	*Lambarizinho*	*X*	
Hemigrammus hyanuary *Durbin, 1918*	*Lambarizinho*	*X*	
Hemigrammus levis *Durbin, 1908*	*Lambarizinho*	*X*	
Hyphessobrycon cf. copelandi *Durbin, 1908*	*Lambarizinho*	*X*	
Hyphessobrycon cf. stegemanni *(Géry, 1961)*	*Lambarizinho*	*X*	
Knodus heteresthes *(Eigenmann, 1908)*	*Lambarizinho*	*X*	*X*
Knodus sp.	*Lambarizinho*	*X*	*X*
Moenkhausia chrysargyrea *(Günther, 1864)*	*Lambari*	*X*	
Moenkhausia collettii *(Steindachner, 1882)*	*Lambari*	*X*	
Moenkhausia oligolepis *(Günther, 1864)*	*Lambari do rabo dourado*	*X*	*X*
Odontostilbe sp.	*Lambarizinho*	*X*	
Phenacogaster cf. calverti *(Fowler, 1941)*	*Lambarizinho*	*X*	*X*
Poptella compressa *(Günther, 1864)*	*Pataca*	*X*	
Psalidodon cf. fasciatus *(Cuvier, 1819)*	*Lambari*	*X*	
Serrapinnus kriegi *(Schindler, 1937)*	*Lambarizinho*	*X*	*X*
Tetragonopterus chalceus *Spix e Agassiz, 1829*	*Pataca do olhão*	*X*	
Thayeria boehlkei *Weitzman, 1957*		*X*	
Crenuchidae			
Ammocryptocharax sp.	*Mocinha*	*X*	
Characidium etheostoma*Cope, 1872*	*Mocinha*	*X*	
Curimatidae			
Curimatella dorsalis *(Eigenmann e Eigenmann, 1889)*	*Branquinha*	*X*	*X*
Cyphocharax cf. gouldingi *Vari, 1992*	*Branquinha*	*X*	
Erythrinidae			
Hoplerythrinus unitaeniatus *(Spix e Agassiz, 1829)*	*Jejú*		*X*
Hopliascurupira *Oyakawa e Mattox, 2009*	*Trairão*	*X*	
Hoplias malabaricus *(Bloch, 1794)*	*Traira*	*X*	*X*
Lebiasinidae			
Nannostomus cf. eques *Steindachner, 1876*		*X*	
Pyrrhulina cf. brevis *Steindachner, 1876*	*Trairinha*	*X*	
Serrasalmidae			
Metynnis lippincottianus *(Cope, 1870)*	*Pacú*	*X*	
Myloplus arnoldi *Ahl, 1936*	*Pacú*	*X*	
Myloplus cf. rubripinnis *(Müller e Troschel, 1844)*	*Pacú*	*X*	
Pygocentrus nattereri *Kner, 1858*	*Piranha vermelha*	*X*	
Serrasalmus geryi *Jégu e dos Santos, 1988*	*Piranhinha*	*X*	
Serrasalmus gibbus *Castelnau, 1855*	*Piranha pintada*	*X*	
GYMNOTIFORMES			
Gymnotidae			
Electrophorus electricus *(Linnaeus, 1766)*	*Peixe elétrico*	*X*	
Hypopomidae			
Brachyhypopomus brevirostris *(Steindachner, 1868)*	*Tuvira*	*X*	
Microsternarchus bilineatus *Fernández-Yépez, 1968*	*Tuvira*	*X*	
Rhamphichthyidae			
Gymnorhamphichthys rondoni *(Miranda Ribeiro 1920)*	*Ituí*	*X*	
Sternopygidae			
Eigenmannia cf. limbata (Schreiner e Miranda Ribeiro, 1903)	*Tuvira*	*X*	
Sternopygus xingu Albert e Fink, 1996	*Tuvira*	*X*	
CYPRINODONTIFORMES			
Poeciliidae			
Poecilia reticulata Peters, 1859	*Guppy, barrigudinho exótico*		*X*

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CICHLIFORMES			
Cichlidae			
Apistogramma sp.	*Acarázinho*	*X*	
Biotodoma cupido *(Heckel, 1840)*	*Acarázinho*	*X*	*X*
Cichlasoma amazonarum *Kullander, 1983*	*Acarázinho*	*X*	
Crenicichla labrina *(Spix e Agassiz, 1831)*	*Mariana*	*X*	*X*
Crenicichla lugubris *Heckel, 1840*	*Mariana*	*X*	
Geophagus proximus *(Castelnau, 1855)*	*Acará azul*	*X*	*X*
Heros efasciatus *Heckel, 1840*	*Acará*	*X*	
Laetacara araguaiae *Ottoni e Costa, 2009*	*Acarázinho*	*X*	*X*
Mesonauta acora *(Castelnau, 1855)*	*Acarázinho*	*X*	
Satanoperca acuticeps *(Heckel, 1840)*	*Acará bicudo*	*X*	*X*
PLEURONECTIFORMES			
Achiridae			
Hypoclinemus mentalis *(Günther, 1862)*	*Peixe folha, linguado*	*X*	
SILURIFORMES			
Aspredinidae			
Bunocephalus coracoideus *(Cope, 1874)*		*X*	
Auchenipteridae			
Centromochlus sp.	*Cachorro do padre*	*X*	
Tatia cf. neivai *(Ihering, 1930)*		*X*	
Trachelyopterus galeatus *(Linnaeus, 1766)*	*Cachorro do padre*	*X*	
Heptapteridae			
Mastiglanis cf. asopos *Bockmann, 1994*	*Madizinho*	*X*	
Phenacorhamdia cf. somnians *(Mees, 1974)*		*X*	
Pimelodella cristata *(Müller e Troschel, 1849)*	*Mandizinho*	*X*	
Pimelodella lateristriga *(Lichtenstein, 1823)*	*Mandizinho listrado*	*X*	
Rhamdia cf. muelleri *(Günther, 1864)*	*Mandi*	*X*	
Loricariidae			
Ancistrus hoplogenys *(Günther 1864)*	*Carizinho roseta*	*X*	
Farlowella smithi *Fowler, 1913*		*X*	
Hemiodontichthys acipenserinus *(Kner, 1853)*	*Carizinho chicote*	*X*	
Hypoptopoma gulare *Cope, 1878*	*Carizinho*	*X*	
Hypostomus cf. carinatus *(Steindachner, 1881)*	*Cari*	*X*	*X*
Hypostomus faveolus *Zawadzki, Birindelli e Lima, 2008*	*Cari de lagoa*	*X*	*X*
Otocinclus sp.		*X*	
Sturiosoma sp.	*Carizinho*	*X*	
Pimelodidae			
Pimelodus blochii *Valenciennes, 1840*	*Mandi*	*X*	
Pseudopimelodidae			
Microglanis sp.		*X*	
Pseudopimelodus schutzi *(Dahl, 1955)*	*Jaúzinho*	*X*	
Trichomycteridae			
Ituglanis sp.		*X*	
SYNBRANCHIFORMES			
Synbranchidae			
Synbranchus cf. marmoratus *Bloch, 1795*	*Muçum*	*X*	*X*

Table 2. Relation of species, number of individuals (Σ) in each stream and relative frequency (F)

TÁXONS	*Jacubinha Stream*		*Neblina Stream*	
	Σ	*F*	*Σ*	*F*
A. cf. hypselonotus	*1*	*0,08%*		
A. falcatus	*23*	*1,93%*		
Ammocryptocharax sp.	*2*	*0,17%*		
A. hoplogenys	*15*	*1,26%*		
A. machrisi	*12*	*1,01%*		
A. alburnus	*41*	*3,45%*	*5*	*2,70%*
Apistogramma sp.	*3*	*0,25%*		
A. fasciatus	*63*	*5,30%*		
A. microlepis	*35*	*2,94%*	*12*	*6,49%*
A. novae	*34*	*2,86%*	*3*	*16,22%*
B. cupido	*16*	*1,35%*	*4*	*2,16%*
B. brevirostris	*2*	*0,17%*		
B. caudomaculatus	*32*	*2,69%*		
B. coracoideus	*1*	*0,08%*		
Centromochlus sp.	*1*	*0,08%*		
C. cf. macrolepidotus	*3*	*0,25%*		
C. etheostoma	*15*	*1,26%*		
C. amazonarum	*5*	*0,42%*		
C. labrina	*3*	*0,25%*	*3*	*1,62%*
C. lugubris	*8*	*0,67%*		
C. dorsalis	*26*	*2,19%*	*12*	*6,49%*
C. cf. gouldingi	*5*	*0,42%*		

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Deuterodon sp.	*15*	*1,26%*	*2*	*1,08%*
E. cf. limbata	*6*	*0,50%*		
E. electricus	*1*	*0,08%*		
F. smithi	*1*	*0,08%*		
G. proximus	*14*	*1,18%*	*1*	*0,54%*
G. rondoni	*1*	*0,08%*		
H. cf. melanochrous	*35*	*2,94%*		
H. cf. stictus	*42*	*3,53%*		
H. hyanuary	*25*	*2,10%*		
H. levis	*47*	*3,95%*		
H. acipenserinus	*3*	*0,25%*		
H. efasciatus	*12*	*1,01%*		
H. unitaeniatus	*0*		*1*	*0,54%*
H. curupira	*5*	*0,42%*		
H. malabaricus	*7*	*0,59%*	*3*	*1,62%*
H. cf. copelandi	*14*	*1,18%*		
H. cf. stegemanni	*5*	*0,42%*		
H. mentalis	*1*	*0,08%*		
H. gulare	*25*	*2,10%*		
H. cf. carinatus	*3*	*0,25%*	*1*	*0,54%*
H. faveolus	*14*	*1,18%*	*3*	*1,62%*
Ituglanis sp.	*1*	*0,08%*		
K. heteresthes	*65*	*5,47%*	*7*	*3,78%*
Knodus sp.	*11*	*0,93%*	*1*	*0,54%*
L. araguaiae	*9*	*0,76%*	*9*	*4,86%*
L. friderici	*10*	*0,84%*		
L. unitaeniatus	*5*	*0,42%*		
M. cf. asopos	*32*	*2,69%*		
M. acora	*25*	*2,10%*		
M. lippincottianus	*7*	*0,59%*		
Microglanis sp.	*1*	*0,08%*		
M. bilineatus	*1*	*0,08%*		
M. chrysargyrea	*33*	*2,78%*		
M. collettii	*31*	*2,61%*		
M. oligolepis	*42*	*3,53%*	*1*	*0,54%*
M. arnoldi	*2*	*0,17%*		
M. cf. rubripinnis	*6*	*0,50%*		
N. cf. eques	*5*	*0,42%*		
Odontostilbe sp.	*12*	*1,01%*		
Otocinclus sp.	*4*	*0,34%*		
P. cf. calverti	*65*	*5,47%*	*5*	*2,70%*
P. cf. somnians	*1*	*0,08%*		
P. cristata	*12*	*1,01%*		
P. lateristriga	*6*	*0,50%*		
P. blochii	*12*	*1,01%*		
P. cf. fasciatus	*63*	*5,30%*		
P. reticulata			*72*	*38,92%*
P. compressa	*17*	*1,43%*		
P. guianensis	*15*	*1,26%*		
P. schutzi	*2*	*0,17%*		
P. nattereri	*1*	*0,08%*		
P. cf. brevis	*23*	*1,93%*		
R. cf. muelleri	*1*	*0,08%*		
S. acuticeps	*18*	*1,51%*	*8*	*4,32%*
S. kriegi	*25*	*2,10%*	*4*	*2,16%*
S. geryi	*3*	*0,25%*		
S. gibbus	*2*	*0,17%*		
S. xingu	*15*	*1,26%*		
Sturiosoma sp.	*4*	*0,34%*		
S. cf. marmoratus	*1*	*0,08%*	*1*	*0,54%*
T. cf. neivai	*1*	*0,08%*		
T. chalceus	*15*	*1,26%*		
T. boehlkei	*23*	*1,93%*		
T. galeatus	*3*	*0,25%*		
Total	*1189*		*185*	

Neblina, we observe that this body of water, despite having only 27% of the households sampled in this study as a whole, the segregation of values becomes more equidistant. Noting that the highest relative frequency family in this stream was Poeciliidae with 38.9% of the sampled individuals (not being included in the previous stream), followed by Characidae with 36.2%, Cichlidae 13.5%, Curimatidae 6.5%, Loricariidae and Erythrinidae both with 2.2% and finally Synbranchidae with 0.5% of the presences. In the streams studied, the Jacubinha presented greater absolute richness (*Taxa_S* = 85) and greater abundance (*Individuals* = 1189).

The lowest richness was observed in the Neblina stream (*Rate_S* = 21) and also the lowest abundance (*Individuals* = 185) (Table 3). From the characteristics implicit in the ichthyofaunistic diversity of this region, the presence of fish with dominance over the relative abundance of other species stands out. In the Jacubinha stream, 97.6% of the species described in this work were found, and an abundance distribution with greater equity than in the Neblina stream (Table 1). However, of all species contemplated for this stream, seven species stood out with their frequency of occurrence in 100% of the samples,

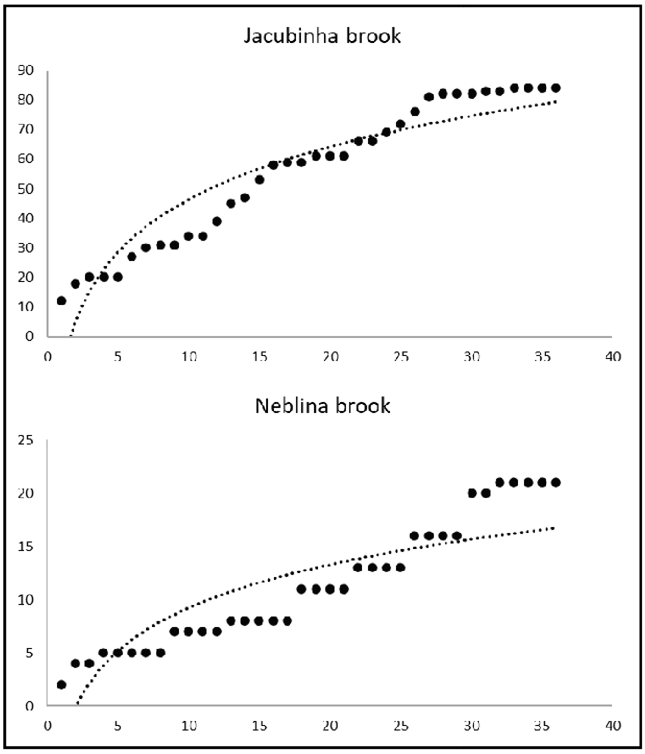

Figure 5. Comparison between species accumulation data for both streams

they are *P. cf. fasciatus*, *A. novae*, *B. caudomaculatus*, *H. levis*, *K. heteresthes*, *M. chrysargyrea* and *M. oligolepis*. As for the Neblina stream, in which only 21 taxa were considered, and the species with the highest frequency of occurrence in the samples were, A. novae in all collection points and in all campaigns (100%), *S. acuticeps* (80%), *C. dorsalis* (80%), *A. microlepis* (60%), *S. kriegi* (60%) and *P. reticulata* (60%), the other species showed values below 40% of appearance. It is noteworthy that the highlighted species for all collections at all points was A. novae, with presence in 100% of these samples (Table 2).

Analyzing the recurrence patterns and new taxa encounters for each location and in general, it was possible to generate cumulative graphs for the number of species per sampled area (Figure 5).

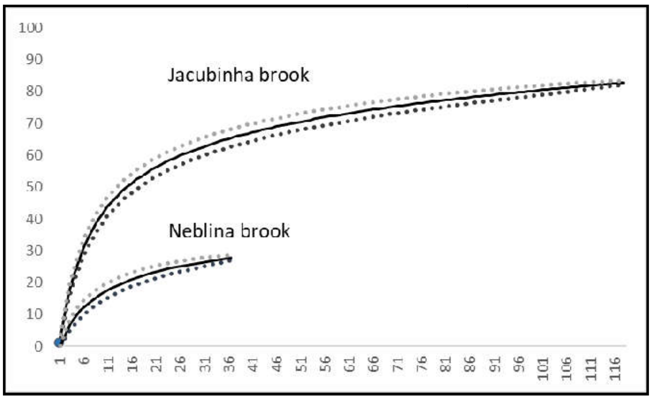

Figure 6. Graph of rarefaction of species showing the relative comparison between the streams studied.

The richness found for this study sums up a total of 85 species in 250 hours of sampling effort accumulated by stream. However, the Jacubinha stream presented 89.36% (*Chao_2* with 5.37% certainty) of the estimated richness for the region (Figure 6). Comparing only the streams, it was possible to identify that the *Shanno_H*, *Dominace_D* and *Equitabilit_J* diversity indices, as well as the primary data, numbers of species and total individuals, have a notable discrepancy between the studied environments.

These calculated indices had different results for each stream. Jacubinha having the highest diversity value (*H*=3.911) in contrast to Neblina with a lower value (*H*=2.172), elucidating the difference in diversity already established by a few species identified for this stream in the present work. In addition to this disagreement in values, the Jacubinha stream showed equity (*J*=0.885), which means a better distribution in number of individuals per species, elucidating a lower dominance of a few and equidistant classification between abundances (Table 3).

Table 3. Comparison between diversity indices for both water bodies

Indexes	Jacubinha	Neblina
Taxa_S	84	21
Individuals	1189	185
Dominance_D	0,02595	0,2043
Shannon_H	3,911	2,172
Equitability_J	0,885	0,7133

In this way, when comparing diversity, even if using multiple indexes, it is possible to identify a large discrepancy between them. Since the Jacubinha Stream had the highest number of taxa, with 84 species identified in the place, and the Neblina Stream, in addition to adding only 21 taxa, showed an expressive dominance of 3 species, which totaled 64% of the animals collected in this creek. It was also pointed out that there is greater dominance (*D*=0.2043), where a few species outnumber the others. Unlike the Jacubinha stream, which has a better distribution of taxa (*D*=0.0295, approximately 90% less dominance), respecting only what is expected for this assemblage in a conserved environment, with many preys and few predators. However, when comparing the collection points with each other for each stream separately, it is possible to observe that there is equity between such indices for each stream. Pointing out that the differences in diversity are inherent to the streams and the points reflect the same inferences for each microbasin distinctly (Figure 7).

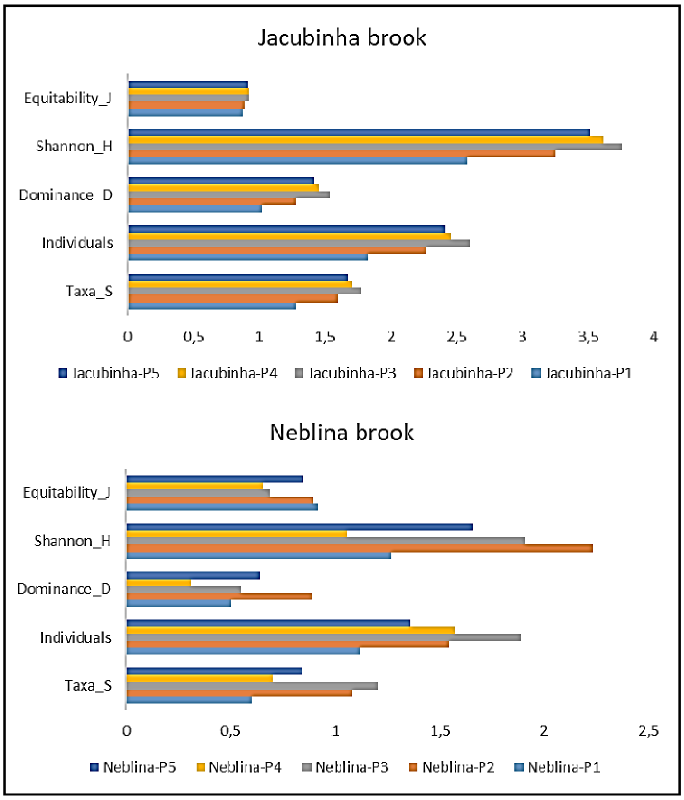

Figure 7. Comparison of the distributions of diversity indices per point for each stream

The distribution of the number of individuals per species shows more equidistant numbers for the Jacubinha stream, which even with a pronounced dominance of only 3 species, yet the others have a number of close and subsequent individuals.

Distinguishing this assertion with regard to the Neblina stream, with only one utterly dominant species, the others are distributed in a few individuals in suppressed populations and little compete with the dominant one (Figure 8).

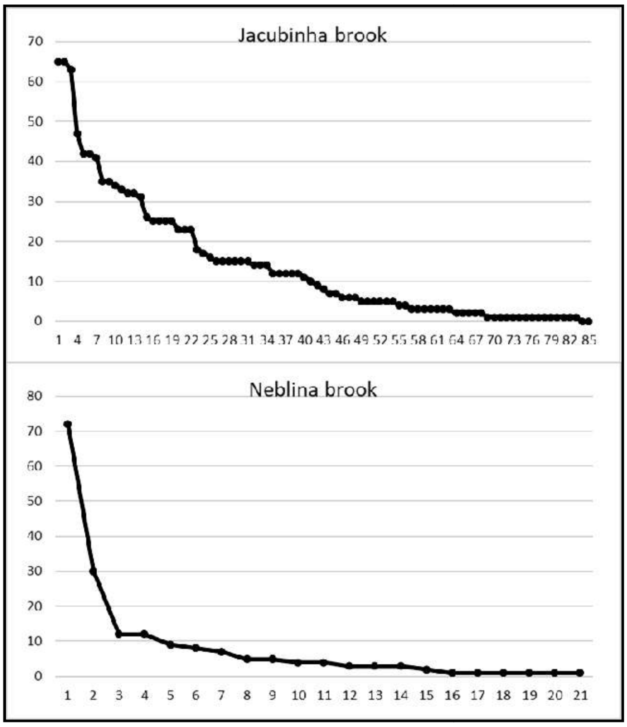

Figure 8. Species distribution by total abundance for the entire study

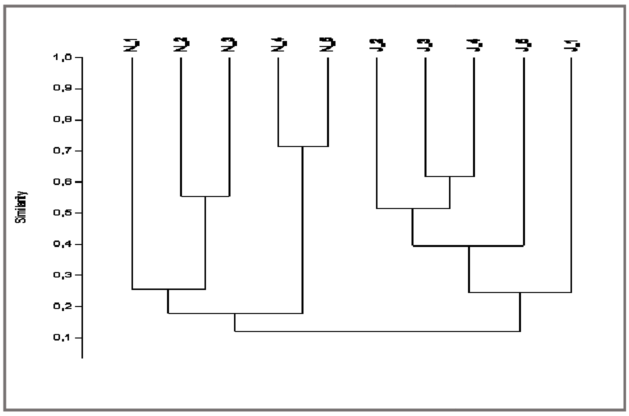

Figure 9. Similarity between the two rivers comparing the collection points between the Neblina (Nn) and Jacubinha (Jn) streams clustered by Cluster ordered by the Jaccard similarity index

Regarding the comparison of diversity, it is important to highlight the result for similarity of approximately 20% between these water bodies. Because they exhibit very different and apparent diversity in other indices such as Shannon (Jacubinha *H*=3.867 and Neblina *H*=2.468), consolidating this difference in diversity, visible for both streams. It also manifested, when we observed the value of alpha diversity extracted from the comparisons between the values of this index, indicating a better distribution of values for the Jacubinha stream than for Neblina. Thus, presenting greater equality of diversity values for Jacubinha at all sampling points, differing from Neblina, which had higher indices at points further upstream. Comparing the streams by similarity (*Jaccard*), for both streams, the mean values were close to 0.25, indicating a large distance between these assemblages. Since these values remained similar even when comparing the points with each other, which led to a grouping of points forming two distinct groups, systematically identical to the grouping by stream. And somehow grouping these points by their geographic proximity, in sequence, from the source to the mouth. When analyzing the data visualizing the presences and absences (Table 1), it is possible to identify that the Jacubinha stream encompassed a greater number of taxa and the Neblina, visibly, had a lower number of species. Thus, considering the results of diversity indices such as Similarity (*Jaccard*) they only present 22.53% similarity to each other. And in the same way, when we group the data by collection point (*Cluster – Jaccard*) there is a sensible similarity between the points in each stream, as well as the drastic separation of both streams in the same graph (Figure 9).

DISCUSSION

There is a subtle divergence in the relative richness for the fish orders expressed in this study, in relation to work carried out in other locations, such as for the other regions of water sources of the great Brazilian rivers, such as the Amazon headwaters (Farias et al. 2017), from the São Francisco River (Carvalho et al. 2017), Paranapanema (Jarduli et al. 2020, Pelicice et al. 2018, Bergamo et al. 2018, Galindo et al. 2020), Alto Paraná (Froehlich et al. 2017) , coastal basins of southern Brazil (Bizerril e Lima, 2000, Hostin-Silva et al. 2002, Duboc and Abilhoa, 2003, Pinheiro and Anni, 2007, Veríssimo et al. 2010), and the Lagoa dos Patos complex (Artioli et al. al. 2009, Malabarba et al. 2013; Becker et al. 2013; Quintella et al. 2019, Lampert et al. 2018). Some data are similar in works carried out close to the area explored in this article, as well as the study developed in the Cantão State Park - TO (Ferreria et al. 2011), presenting diversity and composition similar to that found for the Jacubinha stream, far from the composition of species from the Neblina stream, which is less rich than the previously mentioned ones. In this way, Tocantins presents a pattern of diversity in relation to other regions (Ferreira et al. 2011, Saviato et al. 2017, 2020), noting that the diversity of habitats is superior to other regions because it is a Ecotone zone.

In the diversity character, the most biodiverse families were Characidae with 23 species and Cichlidae with 10, a fraction of the total, of 85 valid taxa. The other families being limited to less than 10 different taxa each. According to Leal et al. (2017), the diversity of taxa is directly linked to environmental quality, since these families were more biodiverse, they have the potential to be biological indicators of the ecosystem (Parker et al. 2018). And as expected for the Jacubinha stream, greater diversity was found in these same families than in the Neblina stream, being Characidae with 23 taxa for the Jacubinha and 10 taxa for the Neblina, as well as Cichlidae with 10 and 6 taxa respectively. However, such preliminary and generalist analyzes already point out that the place with the greatest anthropogenic pressure, has the presence of disturbed landscapes, which may provide inadequate conditions for the conservation of some more sensitive species (Stoeckle et al. 2020). Considering that the different indices denote different aspects of populations, such as: possible phylogenetic relationships, morphotypes, phenotypic similarity or divergence and also the absolute or relative size of a given population, it is possible to identify a similarity in the distribution of these indices. As well as, the Jacubinha stream had a greater amplitude of indices, diverging from the Neblina stream, which has greater restriction of numerical presentation of these indices. An important indication that the Neblina Brook is a body of water less rich in biological diversity than the Jacubinha creek. Considering the anthropogenic activity in Neblina, indicating that they interfere in the composition of the ichthyofauna, as well as in their ecological functions (Oliveira et al. 2017, Can-Gonzáles et al. 2020). Above all, these indices are given as non-parametric, since the P value is always smaller than the meaning of the “test”, to be statistically important. Thus, it is possible to conclude that the Jacubinha Brook has greater diversity than the Neblina Brook, based on the analysis of these indices. To consolidate these statements, the *Bootstrap* comparison with 95% confidence was used, in order to establish a more concise metric for this comparison of environments. This work highlights that the change in the diversity of species in these two drainages has evidence that may lead to believe that the less diverse environment is due to the impacts suffered by urban expansion.

Otherwise, the diversity estimates of the studied structures point to sample sufficiency and explicit discrepancies in the comparison between such environments. Indicating that these indices respond directly to the interrelationship between biota and environmental quality, since the abiotic environment provides strong pressure on organisms. However, one must take into account the current changes and construction of drainages that can forcefully drive these animals away from the studied places, allowing their return at the end of civil activities, thus enabling an environmental constancy that may change the diversity results (Andreotti et al. 2021). Therefore, such areas must be monitored and applied other techniques of environmental approaches, such as analysis of the water parameters of these streams so that we can correlate these differences in diversity and their possible cause, crucially contributing to the understanding of dynamics in fish communities' urban areas.

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