



Full Length Article

Ichthyofauna of the Middle Tocantins River, Imperatriz, Maranhão, Brazil

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Abstract

Fish represent more than half of the vertebrate species in the world. In the Tocantins River, the second largest river by water flow in Brazil, there are a minimum of 520 species of fish. This work aims to list the diversity of the ichthyofauna present in the Cacaú River, a tributary of the Tocantins River, which flows into the municipality of Imperatriz, Maranhão. The collections took place over a period of one year, every first week of the month, both in the rainy season (November to April) and in the dry season (May to October). The specimens were captured using cast nets and gillnets with meshes of 8, 10, 12, and 14 cm between opposite nodes, which were submerged for approximately 4 h a day. Greater species diversity was demonstrated in the dry period, from April to October. The Neotropical ichthyofauna database consisted of a total of 263 individuals from the Cacaú River. The occurrence of 31 species was recorded, distributed in among 25 genera, 15 families, and 4 orders were recorded.

Keywords: Biodiversity; Characiformes; Freshwater ichthyofauna; Tocantins River

Introduction

Ichthyofauna, the diverse assemblage of fish species within a particular aquatic ecosystem, plays a crucial role in maintaining the ecological balance and health of freshwater and marine environments. This diverse group reflects the biodiversity of aquatic habitats and is vital for sustaining fisheries, supporting food chains, and contributing to the cultural and economic well-being of communities that rely on these resources.

Fish represent over more than half of the vertebrate species in the world, and exhibit exquisite morphological, physiological and behavioral diversity. Among the existing ichthyofauna, 43% are predominantly freshwater species (Costa *et al.* 2008), with 7,000 fish species inhabiting the Neotropics. More than 50% of this region is represented by the Brazilian area Brazil (Barroso *et al.* 2013).

With an approximate area of 4,800,000 km², the Amazon Basin boasts the highest species richness of freshwater fish in Brazil (Baumgartner *et al.* 2012a). The Tocantins River Basin covers an area of approximately

750,000 km². Despite historically being considered an independent system from the Amazon basin, the Tocantins River is essentially Amazonian in terms of its biota composition (Cetra 1998; Baumgartner *et al.* 2012b; Barbosa *et al.* 2020). The Tocantins River Basin is home to a minimum of 520 fish species, with 30% being of which are endemic to this system (Baumgartner *et al.* 2012 a, b).

The Tocantins River is the second-largest watercourse in Brazil, featuring a drainage network with reasonable density and significant tributaries (Chicrala *et al.* 2015). Originating in the municipalities of Ouro Verde and Petrolina in the state of Goiás, the river traverses Tocantins and Maranhão, with its mouth in Pará. At the boundaries of Tocantins and Pará, the watercourses of the Tocantins and Araguaia Rivers converge, forming the Tocantins-Araguaia Hydrographic Region, considered the largest entirely Brazilian freshwater basin, a constituent part of the freshwater region of the Amazon. Important hydroelectric plants are installed on the Tocantins River, including, from upstream to downstream: Serra da Mesa, Cana Brava, São Salvador, Peixe Angical, Lajeado, Estreito and Tucuruí (Filho *et al.* 2011).

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The Cacao River holds fundamental importance, and yet the hydrography of the Cacao River is being widely threatened by disordered housing constructions within its floodplain, causing significant environmental impacts and jeopardizing the healthy quality of life, as these areas are often affected by floods during periods of heavy precipitation (Santos 2016). Most of the six municipalities within the Cacao sub-basin subbasin lack adequate public policies for conservation policies (Viana *et al.* 2022). Thus, this scenario highlights the area as a plausible region for extinction, leading to severe loss of local aquatic biodiversity, especially ichthyofauna.

The hydrography hydrograph of the Cacao River encompasses six municipalities in Maranhão: Senador La Rocque, João Lisboa, Buritirana, Governador Edison Lobão, Davinópolis and Imperatriz (Ana 2020). According to the National Water Agency, the Cacao River originates in Buritirana, passing through Governador Edison Lobão, and the Jambu Stream originates in Senador La Rocque, passing through the municipality of João Lisboa. The Cacao River meets the Jambu stream in Davinópolis, becoming the Cacao Creek. Before the Cacao Creek meets the Tocantins River, it encounters the Cacaquinho stream, and together, they flow into the mighty Tocantins River. The current study was conducted considering the Cacao River, a tributary of the Tocantins River. The aim of the study was to potentially leverage the results for future analysis and the implementation of monitoring and conservation measures for aquatic fauna in the Tocantins region of Maranhão.

In recent decades, due mainly to the construction of hydroelectric plants, that which can lead to a decrease or loss of aquatic organism diversity, data have been collected on the ichthyofauna of the Tocantins River. The current study, therefore, aims to list the current diversity of the ichthyofauna found in the Cacao River, a tributary on the right bank of the middle Tocantins River, which flows into the municipality of Imperatriz, Maranhão.

Materials and Methods

Study area

The municipality of Imperatriz (5°31'32"S; 47°26'39"W), located in the western mesoregion of Maranhão, is the second largest in the state. To the North it borders the municipalities of Cidelândia and São Francisco do Brejão; to the South Governador Edison Lobão; to the East João Lisboa, Senador La Rocque, and Davinópolis; and to the West the state of Pará. It has an average altitude of 116 meters above sea level, and the thermal variation throughout the year is small, with temperatures ranging between 21.5°C and 32.4°C. The region's climate, according to the Köppen classification, is tropical (AW) subhumid with two well-defined periods. During the dry season, precipitation varies from 6.4 to 85.5 mm per month, and during the rainy season, it ranges from 123.3 to 279

mm, with an annual average of around approximately 1,463 mm. The watercourses supplying the Imperatriz region come originate from the Tocantins River basin, belonging to the Tocantins – Araguaia Hydrographic Basin, which is divided into three distinct sections: Upper (sub-basins subbasin 20 and 21), Middle (sub-basins subbasin 22 and 23) and Lower (sub-basin subbasin 29) sections. The Tocantins region in Maranhão is located within sub-basin 23 (Costa *et al.* 2008).

The current study was conducted on the Cacao River, a tributary of the Tocantins River, that flows into the municipality of Imperatriz, Maranhão. The hydrography hydrograph of the Cacao River is located at coordinates 05°20'55" and 05°40'32"S and longitude longitudes 47°05'34" and 47°28'56"W, covering six municipalities in Maranhão: Senador La Rocque, João Lisboa, Buritirana, Governador Edison Lobão, Davinópolis and Imperatriz (Filho *et al.* 2011; Goldani 2012). According to the National Water Agency, the Cacao River originates in Buritirana, passing through several municipalities, until it meets the Cacaquinho stream and finally, it flows into the Tocantins River.

Sampling, identification and estorage

Sampling was conducted every first week of the month over a one-year period, covering both the rainy season (November to April) and dry season (May to October) of 2019. Collections were made at three points near Praia do Cacao, an area where the Cacao River is referred to as Cacao Creek, meeting the middle Tocantins River in sub-basin subbasin 23 (Fig. 1).

Approximately 27.7% of the area of the Cacao River basin is occupied by the presence of secondary vegetation (capoeira) resulting from the regeneration of damage caused to its natural characteristics, enabling the biological, social, and economic maintenance of the region (Santos *et al.* 2015). The captures were carried out in different seasons by artisanal fishermen who use simple fishing resources, without great sophistication. Specimens were captured using cast nets and gillnets (drift or gillnets) with mesh sizes of 8, 10, 12 and 14 cm between opposite nodes, which were submerged for around approximately 4 h a day. The nets have a rectangular shape and are kept vertical and suspended by a master cable with floats and by a lower cable with weights, the fish are directed into the net to be captured. The system is only efficient for a certain length range, thus excluding the capture of very small or very large fish (Goulding *et al.* 2003).

After collection, the specimens were identified and stored in the Genetics and Molecular Biology Laboratory of the State University of the Tocantina Region of Maranhão – Campus Imperatriz, following scientific literature specific to Brazilian neotropical freshwater ichthyofauna (Kavalco and Pazza 2007; Lucinda *et al.* 2007; Lima and Caires 2011; Lima *et al.* 2018; ANA 2022).

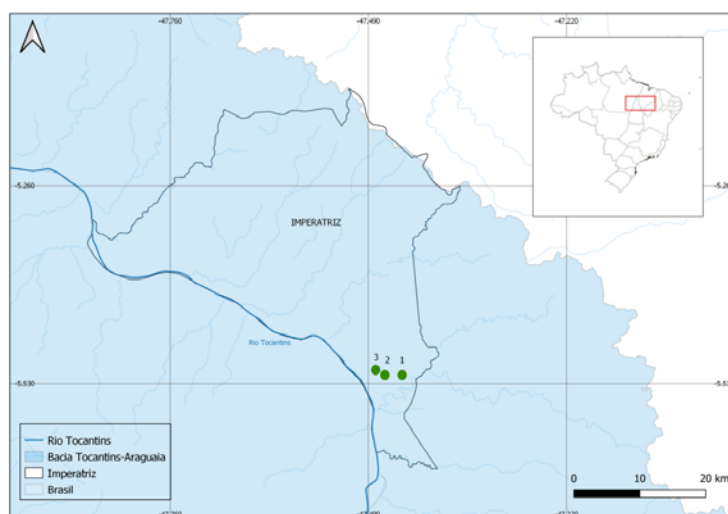


Fig. 1: Collection area, Rio Cacau, Imperatriz, Maranhão

(Source: LIMA 2019)

*Points 1, 2 and 3 indicate the exact locations where the gill nets were posted

Results

The sampling of neotropical ichthyofauna resulted in a total of 263 individuals from the fauna of the Cacau River, a tributary of the Tocantins River Basin. The occurrence of 31 species was recorded, distributed among 25 genera, 15 families and 4 orders were recorded. The order with the greatest species abundance was Characiformes, followed by Siluriformes, Perciformes and Clupeiformes (Table 1). In the sampling of this study, it was also possible to identify the present study five species of fish that are not native to the middle Tocantins River; they were identified as aracucaneta (*Laemolyta taeniata*), jatuarana (*Hemiodus argenteus*), pacu (*Metynnis hypsauchen*), white pacu (*Myloplus cf. torquatus*) and yam (*Australoheros ribeirae*).

In the current present study, the Triportheidae family was the most well-represented in terms of the number of individuals collected, accounting for a percentage of 28.5% and ranking was the second in most represented in terms of the number of species. Triportheidae was represented by *Agoniates halecinus*, *Triportheus albus*, *T. angulatus*, and *T. elongatus*. However, concerning species diversity, the most widely represented family was Serrasalminidae, with six species: *Colossoma brachypomum*, *M. hypsauche*, *M. cf. torquatus*, *Mylossoma duriventre*, *Serrasalmus eigenmanni* and *Serrasalmus* spp. Serrasalminidae ranked fifth in terms of the number of individuals captured. The Curimatidae family, comprising 20.1% of the captured individuals, was represented by *Curimata cyprinoides* and *C. amazonica*. A checklist was compiled of the species found in this study was compiled and below are photos of some of the specimens cataloged (Fig. 2).

The Pristigasteridae family, occupying the third position in terms of the highest number of individuals,

accounted for 19.7% and was represented by *Pellona castelnaeana* and *Pristigaster cayana* (Fig. 3). The families Triportheidae and Pristigasteridae belong to groups are popularly known as sardines, and are considered bioindicator species for water quality. The presence of these families in the river indicates that it is still a habitat for faunistic populations, despite existing threats to these groups. The numerical values presented by in the database showed higher abundance in the greater number of individuals during the months from May to October, marking the beginning of the dry season (Table 2) and the end of the spawning season.

Discussion

The scientific literature supports the predominance of Characiformes, Siluriformes and Perciformes in neotropical waters, with Clupeiformes being less common (Matta 2000; Pessler 2007; Nelson *et al.* 2016; Neto 2017; Polaz and Ribeiro 2017; Barbosa *et al.* 2024). These groups include species of commercial interest, whether native, migratory, or introduced. However, taxonomic and biogeographic knowledge remains limited, complicating efforts to understand these species' histories and distributions (Queiroz 2013a, b).

Fish populations, particularly juveniles, face significant threats from fishing during the dry season, when water levels drop and access to the river increases. This facilitates overfishing of juveniles, which have not reached sexual maturity (Matta 2000; Kavalco and Pazza 2007). The Loricariidae family, although typically abundant in neotropical waters, was poorly represented in this study (Nelson *et al.* 2016). This may be due to its morphology and behavior, which complicate its capture using the employed methods.

Human activities, especially deforestation and the

Table 1: List of ichthyofaunal diversity of the middle Tocantins River, Imperatriz, Maranhão, Brasil. IUCN categories: DD- data deficient, LC- least concern, NT- near threatened, EM- endangered. UF- federative unit. AC- Acre, AM- Amazonas, AP- Amapá, GO- Goiás, MA- Maranhão, MG- Minas Gerais, MS- Mato Grosso do Sul, MT- Mato Grosso, PA- Pará, PR- Paraná, RO- Rondônia, RR- Roraima, RS- Rio Grande do Sul, SC- Santa Catarina, SP- São Paulo, TO- Tocantins

Taxon	Brazil threatened category (IUCN)	Common name	Biome Brazil	UF'S Brazil (IUCN)	Native
ORDER CHARACIFORMES					
Family Anostomidae					
<i>Laemolyta taeniata</i> (Kner 1858)	LC	Aracú-caneta	Amazon, Cerrado	AM, MA MT, PA, RO, RR	DD
<i>Leporinus tigrinus</i> (Borodin 1929)	LC	Flamengo	Amazon, Cerrado	GO, MT, PA, TO	X
<i>Leporinus trifasciatus</i> (Steindachner 1876)	-	Piau-açu			X
Family Bryconidae					
<i>Brycon falcatus</i> (Müller and Troschel 1844)	LC	Jatuarana miri	Amazon, Cerrado	AM, GO, MA, MT, PA, RO, RR, TO	X
Family Curimatidae					
<i>Curimata cyprinoides</i> (Linnaeus 1766)	LC	Branquinha baião	Amazon, Cerrado	AP, GO, MT, PA, RR, TO	X
<i>Curimata amazônica</i> (Eigenman and Eigenman - 1889)	-	Branquinha comum		DD	X
Family Cynodontinae					
<i>Rhaphiodon vulpinus</i> (Spix and Agassiz 1829)	LC	Cachorro-facão	Amazon, Cerrado, Mata atlântica, Pampa, Pantanal	AC, AM, AP, GO, MA, MG MS, MT, PA, PR, RO, RR, RS, SC, SP, TO	X
Family Ctenoluciidae					
<i>Boulengerella ocellata</i> (Schomburgk 1841)	-	Bicuda			X
Family Hemiodontidae					
<i>Hemiodus unimaculatus</i> (Bloch 1794)	LC	Voador	Amazon, Cerrado	AC, AM, AP, GO, MA, MT, PA, RO, RR, TO	X
<i>Hemiodus argenteus</i> (Pellegrin 1908)	LC	Jatuarana	Amazon	AM, PA	DD
Family Prochilodontidae					
<i>Prochilodus nigricans</i> (Spix and Agassiz 1829)	LC	Curimatã	Amazon, Cerrado	AC, AM, GO, MA, MT, PA, RO, RR, TO	X
Family Serrasalminae					
<i>Colossoma brachypomum</i> (Cuvier 1817)	-	Caranha			X
<i>Metynnis hipsauchen</i> (Müller and Troschel 1844)	-	Pacu			No
<i>Myloplus cf. torquatus</i> (Kner 1860)	LC	Pacu branco	Amazon	AM, MT, PA, RO, RR	No
<i>Mylossoma duriventre</i> (Cuvier 1817)	LC	Pacu manteiga	Amazon, Cerrado, Pantanal	MT, MS	X
<i>Serrasalmus eigenmanni</i> (Norman 1929)	LC	Pirambeba	Amazon, Cerrado	AC, AM, AP, GO, MA, MT, PA, RO, RR, TO	X
<i>Serrasalmus</i> spp.	-	Piranha			X
Family Triportheidae					
<i>Agoniatodes halecinus</i> (Müller and Troschel 1845)	LC	Sardinha-de-gato	Amazon, Cerrado	AM, AP, GO, MT, PA, RO, RR, TO	X
<i>Triportheus albus</i> (Cope, 1872)	LC	Sardinha	Amazon, Cerrado, Sistema costeiro marinho	AC, AM, AP, GO, MA, MT, PA, RO, RR, TO	X
<i>Triportheus angulatus</i> (Spix and Agassiz 1829)	LC	Sardinha papuda	Amazon, Cerrado	AC, AM, AP, MA, PA, RO, RR	X
<i>Triportheus elongatus</i> (Günther 1864)	-	Sardinha cumprida			X
ORDER CLUPEIFORMES					
Family Pristigasteridae					
<i>Pellona castelnaeana</i> (Valenciennes 1847)	LC	Dourada/Apapá amarelo	Amazônia	AC, AM, MA, PA, RO, RR	X
<i>Pristigaster cayana</i> (Cuvier 1829)	LC	Papudinha	Amazon, Cerrado	AC, AM, GO, MA, MT, PA, RO, RR, TO	X
ORDER SILURIFORMES					
Family Doradidae					
<i>Leptodoras acipenserinus</i> (Steindachner 1876)	LC	Mandi serra	Amazon	AC, RO	DD
Family Loricariidae					
<i>Hypostomus</i> spp. (Lacépède 1803)	-	Acari/Bodó			X
Family Pimelodidae					
<i>Hypophthalmus marginatus</i> (Valenciennes 1840)	LC	Mapará	Amazon, Cerrado	AC, AM, AP, MA, PA, RO, RR, TO	X
ORDER PERCIFORMES					
Family Cichlidae					
<i>Australoheros ribeirae</i> (Otoni et al. 2008)	LC	Cará/Acará	Mata atlântica	SP	DD
<i>Cichla</i> spp. (Schneider 1801)	-	Tucunaré			X
<i>Geophagus jurupari</i> (Heckel 1840)	LC	Acará bicudo	Amazon	AC, AM, AP, MT, PA, RO, RR	DD
Family Sciaenidae					
<i>Pachyurus junki</i> (Soares and Casatti 2000)	LC	Pescada amarela	Amazon, Cerrado	AM, GO, MA, MT, PA, RR, TO	X
<i>Plagioscion squamosissimus</i> (Heckel, 1840)	LC	Pescada branca	Amazon, Cerrado, Sistema costeiro marinho	AC, AM, AP, GO, MA, MT, PA, RO, RR, TO	X

Source: ICMBio, 2024. Sistema de avaliação do risco de extinção da biodiversidade – SALVE. Disponível em: <https://salve.icmbio.gov.br/>. Acesso em 02 de set. de 2024

construction of hydroelectric dams, are the primary threats to the ichthyofauna of the Tocantins River. Dams, particularly the Lajeado HR hydroelectric plant, have permanently altered the hydrological environment, with negative consequences for fish diversity (Matta 2000; Lucinda et al. 2007). These changes disrupt seasonal migrations and affect genetic diversity (Santos et al. 1984).

Additionally, factors such as overfishing, pollution, and the introduction of exotic species exacerbate the ecological degradation of the river (Costa et al. 2008).

Exotic species, introduced accidentally or deliberately, pose a serious risk by competing with native species for resources and acting as disease vectors (Moreira 2021). Control and eradication efforts have proven difficult, making prevention and early detection essential to preserving the river's biodiversity (ICMCB 2019).

The study area, located in the Mesoregion of Maranhão, is part of an ecotone between the Amazon and semi-arid northeastern climates, further complicating the environmental dynamics (Costa et al. 2008). Given these

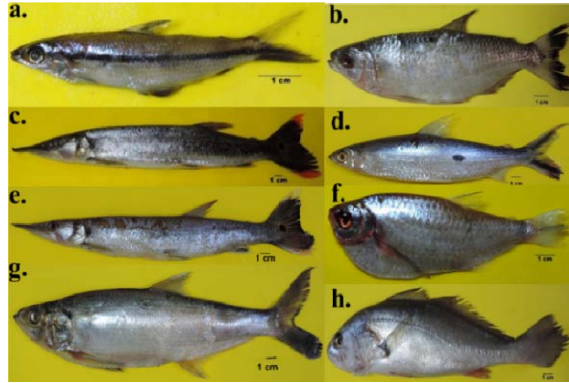


Fig. 2: Fish from the ichthyofauna of the Tocantins River. **a:** *Laemolyta taeniata* **b:** *Brycon falcatus*; **c:** *Boulengerella ocellata*; **d:** *Hemiodus unimaculatus*; **e:** *Boulengerella cuvieri*; **f:** *Triportheus angulatus*; **g:** *Pellona castelnaeana*; **h:** *Plagioscion squamosissimus*. Source: Authors

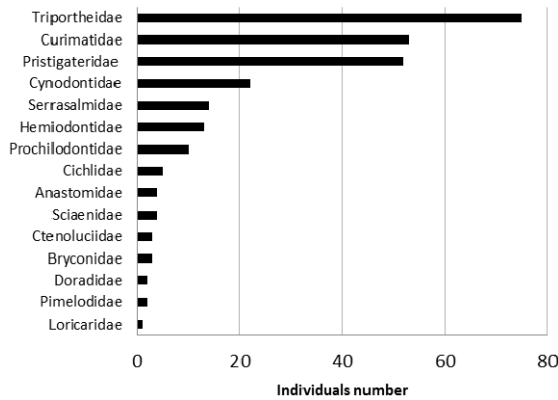


Fig. 3: Composition of ichthyofauna by families in the middle Tocantins River, Cacao Beach, Imperatriz, Maranhão, Brasil. Source: Authors

challenges, protecting the river's native ichthyofauna and preventing biological homogenization requires robust conservation efforts, including continuous monitoring and stricter regulation of human activities.

Conclusion

From the analysis of the data and interpretation of the results obtained, we can conclude that the middle Tocantins River is a habitable ecosystem, with significant species richness. However, the advance of urbanization and lack of urban planning pose increasing risks to the floristic and faunistic species of this environmentally, socially, economically, and politically relevant system. The drainage pattern formed by watercourses directly affects the behavior of species. Greater species diversity was demonstrated during the dry period, spanning from April to October. The order with the highest species richness was Characiformes. The species with the highest abundance of individuals was *T. angulatus*, appearing in different seasons, with a higher frequency

Table 2: Fish catch frequency during the dry season, rainy season, and total over 1 year in the Tocantins River, Cacao Beach, Imperatriz, Maranhão, Brazil. S= Dry period; C= Rainy period; A= Annual

SPECIES	PERIOD		
	S	C	A
<i>Agoniatus halecinus</i> (Müller and Troschel 1845)	-	2	2
<i>Australoheros ribeirae</i> (Ottoni et al. 2008)	3	-	3
<i>Boulengerella ocellata</i> (Schomburgk 1841)	-	3	3
<i>Brycon falcatus</i> (Müller and Troschel 1844)	3	-	3
<i>Cichla</i> spp. (Schneider 1801)	1	-	1
<i>Colossoma brachypomum</i> (Cuvier 1817)	1	-	1
<i>Curimata cyprinoides</i> (Linnaeus 1766)	12	3	15
<i>Curimata amazônica</i> (Eigenman and Eigenman 1889)	11	27	38
<i>Geophagus jurupari</i> (Heckel 1840)	1	-	1
<i>Hemiodus argenteus</i> (Pellegrin 1908)	2	-	2
<i>Hemiodus unimaculatus</i> (Bloch 1794)	11	-	11
<i>Hypophthalmus marginatus</i> (Valenciennes 1840)	2	-	2
<i>Hypostomus</i> spp. (Lacépède 1803)	1	-	1
<i>Laemolyta taeniata</i> (Kner 1858)	2	-	2
<i>Leporinus tigrinus</i> (Borodin 1929)	1	-	1
<i>Leporinus trifasciatus</i> (Steindachner 1876)	1	-	1
<i>Leptodoras acipenserinus</i> (Steindachner 1876)	2	-	2
<i>Metynnis hipsauchen</i> (Müller and Troschel 1844)	3	-	3
<i>Myloplus cf. torquatus</i> (Kner 1860)	1	-	1
<i>Mylossoma duriventre</i> (Cuvier 1817)	1	-	1
<i>Pachyrurus junki</i> . (Soares and Casatti 2000)	2	-	2
<i>Pellona castelnaeana</i> (Valenciennes 1847)	8	41	49
<i>Plagioscion squamosissimus</i> (Heckel 1840)	2	-	2
<i>Pristigaster cayana</i> (Cuvier 1829)	3	-	3
<i>Prochilodus nigricans</i> (Spix and Agassiz 1829)	10	-	10
<i>Rhaphiodon vulpinus</i> (Spix and Agassiz 1829)	13	9	22
<i>Serrasalmus eigenmanni</i> (Norman 1929)	1	2	3
<i>Serrasalmus</i> spp.	5	-	5
<i>Triportheus albus</i> (Cope 1872)	-	14	14
<i>Triportheus angulatus</i> (Spix and Agassiz 1829)	12	43	55
<i>Triportheus elongatus</i> (Gunther 1864)	-	4	4
Total	115	148	263

Source: Authors

during rainy periods.

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Author Contributions

All of them contributed to all parts of this article.

Conflicts of Interest

All authors declare no conflicts of interest.

Data Availability

Data presented in this study will be available on a fair request to the corresponding author.

Ethics Approval

Not applicable.

Funding Source

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