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Fishes of the Tibiri River basin: an urban insular hydrographic system located in the capital of the state of Maranhão, Northeastern Brazil

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Abstract

Background

The Tibiri River basin is a hydrographic system of the city of São Luís, the capital of the state of Maranhão located in the *Upaon-Açu* Island. It is an important watercourse in the region but has been increasingly impacted by urbanization, as well as other anthropic activities. The estuaries and mangroves of this river basin serve as nurseries for several fish species, providing shelter, food, and protection. Despite its ecological and biodiversity significance, the Tibiri River basin remains understudied, particularly concerning its ichthyofauna. Understanding its fish diversity is crucial, since this provides basic information that will serve as baseline for appropriate actions, and conservation policies and measures, aiming to mitigate the effects caused by anthropic actions in this river system.

New information

In this study, 7,465 fish specimens were collected in the Tibiri River basin, representing 65 species included in 17 orders and 37 families. The order Acanthuriformes had the highest species richness, followed by Carangiformes, Clupeiformes, and Gobiiformes. Of the 65 recorded species, three are non-native to the region: *Megaleporinus macrocephalus*, *Butis koilomatodon*, and *Poecilia reticulata*, documenting one of the most worrying human actions to natural ecosystems: the introduction of exotic species. The most abundant species was *Rhinosardinia amazonica*, while species such as *Megalops atlanticus*, *Scomberomorus cavalla* and *Bagre bagre* were rarely collected, besides being categorized by ICMBio as Vunerable (VU) and Near Threatened (NT), respectively. Additionally, a potentially undescribed species, *Hemigrammus* sp., was recorded. The study emphasizes that the Tibiri River basin hosts a high fish species richness, however, it is impaired by serious anthropic activities, facing problems for its species conservation and maintenance of the natural characteristics of its landscape. The introduction of exotic species, combined with habitat loss and environmental degradation, could lead to the loss of native biodiversity and changes in the natural landscape. Accurate species identification and an understanding of historical colonization processes are essential for preserving the local fauna. Our results suggest the need for additional studies that integrate taxonomic, molecular, and ecological approaches to improve the conservation of the Tibiri River basin, as well as to mitigate the human pressures that influence this ecosystem.

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Keywords

Coastal river basins, estuarine region, Ichthyology, Maranhão Island, Neotropical region, Upaon-Açu Island

Introduction

Freshwater ecosystems, such as river and lake systems, represent a tiny fraction of both the volume and the area of Earth (Miller 2021, Val et al. 2022), however, they includes an astonishing biodiversity (Dudgeon et al. 2006, Dudgeon 2019, Tickner et al. 2020,Miller 2021, Val et al. 2022). One of the most diverse groups of these ecosystems are fish (Miller 2021,Val et al. 2022). Despite the enormous importance in terms of biodiversity and ecology, anthropic activities has been posing severe negative impacts to these ecosystems and to the species inhabiting them, causing extinction of population and species at alarming rates, as well as modification and destruction of natural landscapes (Dudgeon et al. 2006, Darwall et al. 2018, Harrison et al. 2018, Dudgeon 2019, Reid et al. 2019, Tickner et al. 2020, Ottoni et al. 2023), a global phenomenon known as "The freshwater biodiversity crisis" (Harrison et al. 2018). It is also important to highlight that freshwaters provide important ecosystem services for both nature and human population, however, paradoxically, these ecosystems have been extremely threatened and impacted by human activities (Dudgeon et al. 2006, Dudgeon 2019, Pelicice et al. 2022, Ottoni et al. 2023). To illustrate this, in the last decades, changes in soil use associated with rapid urbanization and deforestation significantly altered a large proportion of ecosystems of tropical regions (Drigo et al. 2009). These impacts affect not only river flow, but also other water cycle compartments, such as groundwater, which may decrease during the dry season as a consequence of reducing infiltration volume (Costa et al. 2003). Therefore, studying hydrographic systems and conducting ichthyological surveys is extremely relevant in the current context of global conservation. These kinds of studies provide basic information that will serve as baseline for appropriate actions, and conservation policies and measures, aiming to mitigate the effects caused by anthropic actions in these ecosystems (Ferrazi et al. 2024).

Ichthyological surveys are conducted to assess the biodiversity of a stream, river, or lake (Guimarães et al. 2020, Ferrazi et al. 2024). Consequently, these studies may lead to new discoveries (e.g., new and first records, record of undescribed species, range extensions, and exotic species introductions), and may aid in new assessments of species conservation status (e.g., Nascimento et al. 2016, Brito et al. 2019, Dagosta and Pinna 2019 Lima et al. 2019, Guimarães et al. 2020, Oliveira et al. 2020, Vieira et al. 2023, Lopez et al. 2024, Acácio et al. 2024, Barbosa et al. 2024).

The Tibiri River basin is a small coastal basin located in the capital of the State of Maranhão, São Luís. Maranhão is the westernmost state in the northeast region of Brazil. Spanning approximately 140 km², this watershed has historically been impacted by various anthropogenic disturbances, such as heavy metal contamination (Campos et al. 2009), leachate from accumulated waste within its boundaries (IMESC 2011), removal of riparian vegetation (Martins 2008), infestations of invasive plants (Pinheiro and Linhares 2019), improper disposal of domestic sewage, and the construction of black pits—holes dug in the ground used as disposal sites for local bathroom waste—near water sources (Coelho et al. 2017). In addition to these impacts, the expansion of São Luís urban area compromises the quality of the environments within this watershed.

The city of São Luís, is included in a metropolitan island, called as *Upaon-Açu* Island. The Tibiri River watershed faces numerous threats due to unplanned urban development and is heavily impacted by human activities. Despite this, there are no studies in the literature focusing on a comprehensive survey of its ichthyofauna. To understand the fish fauna of this small basin, we provide a fish survey of the Tibiri River basin, from its source to its mouth, covering various microhabitats. Additionally, we discuss the consequences of urban growth for the conservation of the species present in this river basin, emphasizing the need for studies to understand the colonization by freshwater species in this river system.

Materials and methods

Study area

The study was conducted on São Luís Island, also known as Ilha Grande, *Upaon-Açu* Island, and Maranhão Island. This island includes four municipalities: São Luís, São José de Ribamar, Paço do Lumiar, and Raposa, covering a area of approximately 831.7 km² (Bandeira 2018). The São Luís Island includes the Anil, Bacanga, Tibiri, Paciência, Maracanã, Calhau, Pimenta, Coqueiro, and Cachorros river systems, as well as the Bacanga Reservoir. These river systems are small, and they flow in several directions, covering areas of dunes and beaches.

The Tibiri River basin covers an area of approximately 140 km² and is located in the City of São Luís. It is bordered to the east by the Tijupá River basin and the Jeniparana River basin; to the west by the São Luís Industrial District; to the north by the Marechal Cunha Machado Airport and the Agricultural Exhibition Park; and to the south by the São José de Ribamar bay, into which it flows (Fig. 1).

The Tibiri River basin is an integral part of the Maranhão Gulf drainage system and encompasses a complex drainage area with a network of tributary and sub-tributary channels that converge to form the main river course. This system is responsible for the transport of sediments and dissolved materials. The basin originates in the central region of *Upaon-Açu* Island, with a maximum elevation of about 70 meters, and flows southeast into São José Bay, within the municipality of São Luís. The main waterways in this river basin include the Santa Bárbara and Tibiri igarapés, with the latter receiving the Meio and Saúde igarapés (small rivers or streams, with etymology in Portuguese from Brazil). These igarapés feed into the main channel, which is further supplemented by other tributaries such as the Sabino and Maracujá igarapés on the right bank, and the Tajaçuaba, Andiroba, and two unnamed igarapés on the left bank. The basin's boundaries are defined by small elevations along the coastal plain, which separate the Tibiri River basin from neighboring basins on this island (Silva 2021).

Collection and identification of specimens

The fishing gear used included fish traps, drag nets, seine nets, sieves, and scoop nets of various mesh sizes. The collected fish were euthanized using a solution of water and tricaine methanesulfonate (TMS), which is used for anesthesia, sedation, or euthanasia of fish, and were subsequently preserved in 10% formalin. For specimens 15 cm or longer, formalin was injected into the abdominal cavity and the dorsal and lateral muscles.

In the Fish Ecology and Integrated Aquaculture Laboratory at the State University of Maranhão (LABIPI-UEMA), the collected fish were sorted, identified, and preserved in 70% diluted alcohol. Species identification was carried out to the lowest possible taxonomic level based on specific literature (particularly original descriptions and/or taxonomic revisions), and primarily through the analysis of the most relevant morphological features (e.g., meristic, morphometric, general morphology, color pattern) for each group. Taxonomic classification, taxa names, species validity, authors and year of publication, habitat of occurrence, and geographic distribution were based on the compilations proposed in Eschmeyer's Catalog of Fishes (Fricke et al. 2024a, Fricke et al. 2024b), where the authors gather the most recent classifications for each fish group. Species conservation status was accessed based on Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio 2024), a Brazilian government agency responsible for monitoring, inspecting, gathering information, and preserving the country's biodiversity and ecosystems. All collected material was deposited in the Ichthyological Collection of the State University of Maranhão (CIUEMA) and Ictiological Collection of the Center for Agricultural and Environmental Sciences (CICCAA) (see Examined Material).

Sampling design

For the fish sampling, nine collection expeditions were conducted between August 2021 and July 2024. A total of 13 collecting sites were sampled (Table 1, Fig. 1, Fig. 2, Fig. 3), ranging from marginal pools and small tributaries to the main channel of the Tibiri River. The collection efforts were spread across different sections of the rivers (headwaters, midstream, lower reaches, and estuary) to ensure a comprehensive representation of the fish species. All sampling points were georeferenced using GPS.

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Cartographic procedures

All mapping procedures and georeferenced data analyses for this study were conducted using the GIS (Geographic Information System) software Quantum GIS version 3.10. The delineation of the Tibiri Basin was based on the Digital Elevation Model (DEM) from the *Shuttle Radar Topography Mission* (SRTM) of 2002, with a spatial resolution of one arc-second (thirty meters), obtained from the *Earth Explorer* virtual catalog of the United States Geological Survey.

Checklist of the fish fauna of the Tibiri River Basin

Class Actinopteri

Notes: The checklist is presented in Table 2.

Analysis

A total of 7,465 specimens were sampled, representing 17 orders, 37 families, and 65 fish species (Table 2). The order with the highest species richness was Acanthuriformes, represented by 10 species, followed by Carangiformes, Clupeiformes, and Gobiiformes, each represented by eight species (Fig. 4A and Table 2). Engraulidae was the family comprising the highest species richness, represented by seven species, followed by

Sciaenidae with five species, and Oxudercidae with four species(Fig. 4B and Table 2). From these 65 fish species only 13 are considered as strictly freshwaters, and seven as strictly marine The remaining species occur in brackish waters, and/or transit between fresh, brackish and marine waters.

Rhinosardinia amazonica (Steindachner 1879) was the most abundant species, with approximately 1,416 specimens sampled. *Megalops atlanticus* Valenciennes 1847, *Amphiarius rugispinis* (Valenciennes, 1840), *Scomberomorus cavalla* (Cuvier 1829), *Selene vomer* (Linnaeus 1758), *Pomacanthus paru* (Bloch 1787), *Macrodon ancylodon* (Bloch & Schneider 1801), and *Serrasalmus* sp. were rarely collected, each one represented by only one collected specimen (see examined material). The highest species richness was found at Sample Site 1, with 44 species, followed by Site 2 with 34 species, Site 9 with 31 species, Site 5 with 10 species, Sites 4 and 10 with seven species each, Site 12 with four species, and Sites 3, 11, and 13 with three species each. Sites 6, 7, and 8 had only one species each (Table 2). Of the 65 recorded species, three are non-native for the studied region: *Megaleporinus macrocephalus* (Garavello & Britski, 1988), an Anostomidae native to the Paraguay River basin, *Butis koilomatodon* (Bleeker 1849), an Eleotridae native to the Indo-West Pacific region, and *Poecilia reticulata* Peters 1859, a Poeciliidae native to the coastal basins of Venezuela and Trinidad (Fricke et al. 2024b). Additionally, *Hemigrammus* sp. possibly represents a new species that requires further study for formal description.

Regarding the threat status of species, *Megalops atlanticus* is categorized as Vulnerable (VU), and *Bagre bagre* (Linnaeus 1766), *Lutjanus jocu* (Bloch & Schneider 1801) and *Scomberomorus cavalla* (Cuvier 1829) as Near Threatened (NT). The remaining species were categorized as Data Deficient (DD), Least Concern (LC) or have not yet been evaluated (ICMBio 2024).

Discussion

Taxonomic compositio

Here, we carried out the first long-term fish inventory using different collection methodologies, covering almost the entire Timbiri River basin (Fig. 1 e Fig. 2, Table 1). In general, coastal river environments including estuaries and mangroves guarantee great importance for juvenile fish in their processes, as in these environments they find a large supply of food, shelter and a lower risk of predation (Blaber and Blaber 2006;Ottoni et al. 2021b;Whitfield et al. 2023). These characteristics provide ideal environments to be used as nursery areas by a large number of species, as observed at sampling sites 1, 2, 9 and 12, as also described for coastal ecosystems, such as mangroves (Nagelkerken et al. 2000; Nagelkerken et al. 2002; Paterson and Whitfield 2000; Laegdsgaard and Johnson 2001; Blaber and Blaber 2006; Short et al. 2007; Lasiak 2015; Ottoni et al. 2021b).

From the 65 species recorded here, 35 (almost the half) are typically found in brackish water environments (see Table 2). These species, when present in freshwater environments, tend to be concentrated in estuaries or in the lower sections of rivers (observed at the points 1, 2, 9 e 12). In additon, only 13 species are considered as strictly freshwaters (Table 2). This demonstrates that the Tibiri River basin, as well as its fish species composition, are greatly influenced by the marine environments, being composed by several diadromous fish species. The low representation of exclusively freshwater species can be explained by the physiological difficulties and restrictions imposed by the presence of salinity, in addition to the difficulties in adapting to changes in salinity that freshwater fish face.

Most of the cataloged species were small and medium in size, however, some of them were large-sized species, especially marine and estuarine ones, such as: *Micropogonias atlanticus*, *Lutjanus jocu*, *Stellifer herzbergii*, *Bairdiella bagre*, *Gramma luteus*, *Micropogonias ancylodon*, *Mugil incilis*, *Mugil brevirostris*, *Mugil curema*, *Ocyurus saliens* and *Ostomycter palometa*, recorded at the collecting sites S1, S2, S9, and S12. Furthermore, the presence of marine species in the lower regions highlight the importance of this river basin as a nursery area for marine and estuarine fish species. Some works estuaries (e.g. Parsons et al. 2014; Whitfield et al. 2023) advocated that many marine fish juveniles are associated with estuaries, which evidence the relevance of this river basin for the conservation and ecology of these species.

At collecting sites S3, S4, S5, S6, S7, S8, S10, S11, and S13, which are exclusively freshwaters, a predominance of species from the Order Characiformes was observed, corroborating the pattern commonly found in the Neotropical Region (Langeani et al. 2007, Vari et al. 2009, Brito et al. 2019 Dagosta and Pinna 2019; Guimarães et al. 2021, Vieira et al. 2023). Comparing our findings (65 species for the Tibiri River basin) with the data compilation published by the “Checklist of the freshwater fishes of Maranhão, Brazil” (CLOFFBR-MA) (Koerber et al. 2022,Koerber et al. 2023), which reported only nine fish species occurring in freshwaters, we can conclude that the hydrographic systems of the *Upaon-Açu* Island is undersampled, and consequently its fish diversity is underestimated. Although, it is important to highlight that the works published by (Koerber et al. 2022; Koerber et al. 2023) focused mainly on freshwater fish species. This is not a characteristic only of this island, but also of several other hydrographic systems of the State of Maranhão, as already pointed out by (0Guimarães et al. 2020; Vieira et al. 2023) Therefore, our findings contributed significantly to increase the knowledge on the composition of ichthyofuna from the river systems of the *Upaon-Açu* Island.

Challenges in identifying freshwater species in the Tibiri basin

The Tibiri River basin, with its mouth at the Arraial Bay, near the São José Bay (Fig. 1 and Fig. 2), hosts species found in the upper reaches of the basin (S3, S4, S5, S6, S7, S8, S10, S11, and S13) that are exclusively freshwater and may have colonized this region thousands of years ago. The São José Bay receives the mouth of the Itapecuru River, close to Arraial Bay (Barros et al. 2011), a location that also receives the mouth of the Munim River (Vieira et al. 2023). Historically, this region's formation was heavily influenced by sea-level fluctuations and, consequently, by marine transgressions and regressions that shaped the current drainage systems (Lovejoy et al. 1998, Albert and Reis 2011, Thomaz and Knowles 2018, Abreu et al. 2020). In the state of Maranhão, these drainage systems were affected by sea-level variations during different periods: during the Miocene, the sea level was about 75 meters above the current level; in the Lower Miocene-Pliocene, the sea level was 35 meters above the current level; in the Middle and Upper Pleistocene, the sea level was 6 meters above the current level; and in the Holocene, the sea level was 2 meters above the current level (Abreu et al. 2020). These paleogeographic changes indicate that tectonic and climatic events acted as significant driving factors in shaping the fish fauna of Maranhão by altering the connectivity of river basins and impacting the rates of dispersal, speciation, and extinction of riverine species (Abreu et al. 2020). Therefore, the colonization of freshwater species in the upper part of the Tibiri River basin likely occurred through historical hydrological connections and dispersal routes, shaped by these tectonic and climatic processes over time. However, these processes are still not fully understood. So far, there are no taxonomic, molecular, or ecological explanations that clarify the extent of the geographical distribution of freshwater species in the Tibiri basin and other basins on *Upaon-Açu* Island.

Our results demonstrate that the accurate identification of freshwater species remains a challenge (Table 2). For instance, it was not possible to identify morphotypes such as *Hemigrammus* sp. and *Serrasalmus* sp. to the species level. *Hemigrammus* sp., for example, belongs to a group of species that is still poorly understood in the region, presenting multiple morphotypes, such as *Hemigrammus* sp. 1 and sp. 2 *sensu* (Oliveira et al. 2020), *H*. cf. *rodwayi* has been recorded in the Munim River basin (Oliveira et al. 2020,Vieira et al. 2023) and in the Mearim River basin [*Hemigrammus* aff. *ocellifer* and *Hemigrammus* cf. *rodwayi*] (Guimarães et al. 2020). Since these basins drain near *Upaon-Açu* Island, they may influence the species composition of the island's basins. Therefore, *Hemigrammus* sp. from the Tibiri River basin could represent one of the cited morphotypes, possibly with variations related to local environmental characteristics, or it might even be a new species. Another possibility is that it is an introduced species in the basin, given the recurring history of fish species introductions on São Luís Island (Bragança et al. 2019, Bragança et al. 2020, Ottoni et al. 2021a, Trevisan et al. 2022a). Thus, additional studies, including approaches such as integrative taxonomy, biogeography, paleogeography, and microsatellite analysis, are necessary to better understand the colonization processes and accurately identify the species present in the

Tibiri basin. Furthermore, it is important to expand these studies to other basins on *Upaon -Açu* Island, including estuarine and saltwater areas around the island, where the survival of freshwater species is more limited.

Ecosystem and fish fauna conservation

Although the urbanization process of the Maranhão population is recent, being accelerated from 1997, anthropogenic changes such as the construction of dams, deforestation, urbanization without proper planning, dumping of ichthyotoxins in the habitat to eradicate harmful species, and changes in the rivers course have already been recorded in the Tibiri River basin. In addition, the introduction of non-native species in river systems is also very common on *Upaon-Açu* Island (e.g. Nogueira and Luvizotto-Santos 2018, Bragança et al. 2019, Bragança et al. 2020, Ottoni et al. 2021a).

In our survey, we reported three non-native fish species to this region. The first is *Butis koilomatodon*, popularly known as "mudsleeper" or "amoré", a fish of the family Eleotridae, native to the Indo-Western Pacific region, including Thailand, Indonesia, Vietnam, southern China, Papua New Guinea, and northern Australia (Fricke et al. 2024b). Bonfim et al. 2017 argued that, In Brazil, the introduction of this species is probably related to the ship traffic around oil platform. In the *Upaon-Açu* Island the introduction of this fish species is probably related to the ship traffic between ports near the mouth of the Amazon River. However, the expansion of this species along the coast of America, through larval dispersal, following the currents towards the north, cannot be disregarded Guimarães et al. 2017). It is worth mentioning that *Butis koilomatodon* was recorded for the first time for Maranhão, in a tide pool by Guimarães et al. (2017).

The second species is *Poecilia reticulata*, popularly know as "barrigudinho" or "Guppy", which is one of the most widely introduced freshwater fish species around the world, with established populations in tropical and subtropical regions of all continents (Deacon et al. 2011). This species does not naturally occur in Brazil, neither in the Amazon River basin, and its southernmost geographic limit is likely to be in one of the Guyanan coastal river drainages, between the Essequibo River and Orinoco River delta (Bragança et al. 2020). Its introduction is probably related to releases by aquarium hobbyists, from fish farms and/or introductions to mosquito larvae control (Dias et al. 2020). On the *Upaon-Açu* Island, this species was recorded in the brackish waters of the Anil River estuary (Bragança et al. 2020) and in polluted streams near the municipality of São Luís (Nogueira and Luvizotto-Santos 2018).

The third species *Megaleporinus macrocephalus*, popularly know as "piau-açu", occurs naturally in the Paraguay River basin, but currently it is widely introduced (Fricke et al. 2024b). This fish species is usually introduced due to accidental escapes from fish farming (Langeani et al. 2007, Bertaco et al. 2016, Almeida et al. 2022). In the State of Maranhão, this species has already been recorded for the Mearim River basin (Guimarães et al. 2020, Almeida et al. 2022) and Itapecuru basin (Almeida et al. 2022).

The presence of non-native species, such as the three mentioned above, raises concern that these species become dominant in this river basin. Once a invasive species become dominat, this dominance can lead to serious consequences, such as habitat modification and the subsequent loss of native species (Didham et al. 2005). Furthermore, the introduction non-native species is considered one of the main causes of loss of local biodiversity and threats to natural ecosystems (Vitule and Pozenato 2012,Ricciardi et al. 2021, Rocha et al. 2023), being a issue that deserves a special attention in the current panorama of biodiversity crisis.

The invasion of exotic species in aquatic ecosystems is one of the major threats to biodiversity, causing serious impacts on native species, such as competition for resources and habitat, which can lead to the local extinction of these species (Bellay et al. 2016). Coastal basins, due to their isolated nature and the presence of various endemic species, are particularly vulnerable to these invasions. The introduction of non-native species, coupled with vegetation loss and siltation, further exacerbates the loss of biodiversity in rivers and lakes (Leão et al. 2011). In the Tibiri River basin, located on an island, this situation is particularly concerning. Of the 65 species cataloged, four are classified as threatened by ICMBio. Megalops atlanticus is categorized as Vulnerable (VU), while Bagre bagre, Lutjanus jocu, and Scomberomorus cavalla are classified as Near Threatened (NT) (ICMBio 2024). The presence of these species in an environment already impacted by environmental changes and biological invasions highlights the need to develop and implement effective conservation strategies in the Tibiri basin.

Conclusions and future perspectives

In addition to the fish species inventory presented for the Rio Tibiri, there are currently no studies focused on the biology of this fauna available in the literature. Research on other regional faunas is also limited. This nascent understanding of biodiversity makes the Rio Tibiri a critical site for taxonomic, molecular, and ecological studies. It is imperative to understand both historical processes and the current dynamics of fish species dispersion, especially those unique to freshwater, to preserve local biodiversity. This understanding will clarify how species have established themselves and how they may be affected by environmental changes. Regarding conservation, the main challenge faced in the Rio Tibiri is the effective implementation of public policies aimed at protecting this basin.

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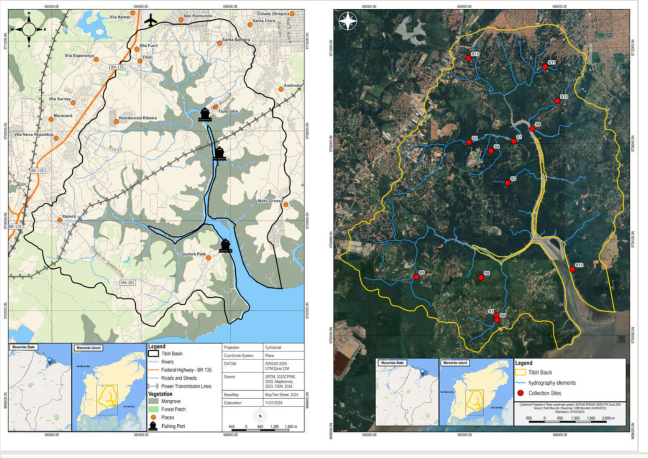

Figure 1.

Map of the study area. The Tibiri River Basin is outlined, highlighting rivers, the Federal Highway BR-135 in orange, other roads and streets on Upaon-Açu Island, along with transmission lines, railways, and power lines represented by dashes and dots. Red points on the second map (S1-S13) indicate sampling sites within the Tibiri River Basin.

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Figure 2.

Samples sites: S1-S5 according to Table 1.

Figure 3.

Samples sites: S11-S13 acording to Table 1.

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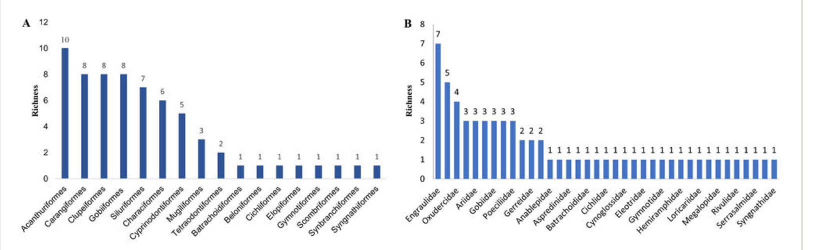

Figure 4.

Ranking of richness by orders and family observed in the studied area. The numbers in the left column correspond to the number of species.

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Table 1.

Localidades amostradas na bacia do rio Tibiri, estado do Maranhão, Brasil.

Site	Coordinates	Remarks
S01	-2.640631, -44.225786	Left bank tributary of the Tibiri River, São Luis, Maranhão.
S02	-2.641069, -44.242653	Left bank tributary of the Tibiri River, São Luis, Maranhão.
S03	-2.656383, -44.228075	Left bank tributary of the Tibiri River, São Luis, Maranhão.
S04	-2.644247, -44.234342	Left bank tributary of the Tibiri River, São Luis, Maranhão.
S05	-2.691833, -44.262667	Left bank tributary of the Tibiri River, São Luis, Maranhão.
S06	-2.692100, -44.238075	Left bank tributary of the Tibiri River, São Luis, Maranhão.
S07	-2.706531, -44.232239	Left bank tributary of the Tibiri River, São Luis, Maranhão.
S08	-2.708067, -44.232089	Left bank tributary of the Tibiri River, São Luis, Maranhão.
S09	-2.635839, -44.218806	Tibiri River, São Luis, Maranhão.
S10	-2.625292, -44.209306	Right bank tributary of the Tibiri River, São Luis, Maranhão.
S11	-2.612500, -44.213889	Right bank tributary of the Tibiri River, São Luis, Maranhão.
S12	-2.688889, -44.203333	Tibiri River, São Luis, Maranhão.
S13	-2.609275, -44.242864	Right bank tributary of the Tibiri River, São Luis, Maranhão.

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Table 2.

List of species recorded he Tibiri River basin, State of Maranhão, Northeastern Brazil.

Class/Order/Family/Species	**Abundance**	**Habitat of occurrence**	**Local name (in Portuguese)**
Class Actinopteri			
Order Elopiformes			
Family Megalopidae			
Megalops atlanticus Valenciennes, 1847 [VU,•]	1	Freshwater, Brackish, Marine	Pirapema, Camurupim
Order Clupeiformes			
Family Dorosomatidae			
Rhinosardinia amazonica (Steindachner, 1879) [LC,•]	1416	Freshwater, Brackish	Sardinha de água doce
Family Engraulidae			
Anchoa spinifer (Valenciennes, 1848) [LC,•]	18	Freshwater, Brackish, Marine	Sardinha amarela
Anchovia clupeoides (Swainson, 1839) [LC,•]	355	Marine	Sardinha
Anchoviella guianensis (Eigenmann, 1912) [LC,•]	52	Freshwater, Brackish	Sardinha do rio
Cetengraulis edentulus (Cuvier, 1829) [LC,•]	68	Marine	Sardinha do rabo amarelo
Lycengraulis batesii (Günther, 1868) [LC,•]	697	Freshwater, Brackish	Sardinha amarela
Lycengraulis grossidens (Spix & Agassiz, 1829) [LC,•]	37	Freshwater, Brackish, Marine	Manjubão
Pterengraulis atherinoides (Linnaeus, 1766) [LC,•]	46	Freshwater, Brackish	Sardinha de asa
Order Characiformes			
Family Anostomidae			
Megaleporinus macrocephalus (Garavello & Britski, 1988) [♦]	2	Freshwater	Piau
Family Characidae			
Astyanax bimaculatus (Linnaeus, 1758) [LC,•]	51	Freshwater	Lambari
Hemigrammus sp. [•]	85	Freshwater	Piaba
Family Erythrinidae			
Hoplias malabaricus (Bloch, 1794) [LC,•]	27	Freshwater	Traíra
Family Lebiasinidae			

Nannostomus beckfordi Günther, 1872 LC,•	393	Freshwater	Peixe lápis
Family Serrasalmidae			
Serrasalmus sp. •	1	Freshwater	Piranha
Order Gymnotiformes			
Family Gymnotidae			
Gymnotus carapo Linnaeeus,1758 LC,•	3	Freshwater	Sarapó
Order Siluriformes			
Family Ariidae			
Amphiarius rugispinis (Valenciennes, 1840) LC,•	1	Freshwater, Brackish, Marine	Jurupiranga
Bagre bagre (Linnaeus,1766) NT,•	4	Brackish, Marine	Bandeirado
Sciades herzbergii (Bloch, 1794) LC,•	14	Brackish, Marine	Bagre
Family Aspredinidae			
Aspredo aspredo (Linnaeus, 1758) LC,•	77	Freshwater, Brackish, Marine	Banjo, Rebeca
Family Callichthyidae			
Callichthys callichthys (Linnaeus, 1758) LC,•	9	Freshwater	Tamoatá
Family Loricariidae			
Hypostomus watwata Hancock, 1828 LC,•	6	Freshwater	Cascudo
Family Auchenipteridae			
Pseudauchenipterus nodosus (Bloch 1794) LC,•	83	Freshwater, Brackish	Papista
Order Batrachoidiformes			
Family Batrachoididae			
Batrachoides surinamensis (Bloch & Schneider 1801) LC,•	17	Brackish, Marine	Pacamão
Order Syngnathiformes			
Family Syngnathidae			
Pseudophallus brasiliensis Dawson, 1974 LC,•	3	Freshwater, Brackish	Peixe cachimbo
Order Scombriformes			
Family Scombridae			
Scomberomorus cavalla (Cuvier, 1829) NT,•	1	Marine	Cavala

Order Gobiiformes			
Family Eleotridae			
Butis koilomatodon (Bleeker, 1849) ♦	27	Freshwater, Brackish, Marine	Amuré, Mudsleeper
Family Gobiidae			
Bathygobius soporator (Valenciennes, 1837) LC,•	3	Freshwater, Brackish, Marine	Amuré
Microgobius meeki Evermann & Marsh, 1899 LC,•	4	Marine	Amuré bocão
Priolepis dawsoni Greenfield, 1989 LC,•	3	Marine	Amuré de pijama
Family Oxudercidae			
Ctenogobius boleosoma (Jordan & Gilbert, 1882) LC,•	2	Freshwater, Brackish, Marine	Amuré de garça
Gobionellus oceanicus (Pallas, 1770) LC,•	8	Freshwater, Brackish, Marine	Muré banana
Gobionellus stomatus Starks, 1913 LC,•	6	Brackish	Amoré
Gobioides broussonnetii Lacepède, 1800 DD,•	3	Freshwater, Brackish, Marine	Muçurango
Order Synbranchiformes			
Family Synbranchidae			
Synbranchus marmoratus Bloch, 1795 LC,•	6	Freshwater	Mussum
Order Carangiformes			
Family Achiridae			
Achirus achirus (Linnaeus, 1758) LC,•	19	Freshwater, Brackish, Marine	Solha
Achirus declivis Chabanaud, 1940 LC,•	11	Freshwater, Brackish, Marine	Solha
Trinectes maculatus (Bloch & Schneider, 1801) •	23	Freshwater, Brackish, Marine	Solha
Family Carangidae			
Oligoplites palometa (Cuvier, 1832) LC,•	70	Freshwater, Brackish, Marine	Timbira
Oligoplites saliens (Bloch, 1793) LC,•	114	Brackish, Marine	Timbiro
Selene vomer (Linnaeus, 1758) LC,•	1	Brackish, Marine	Peixe-galo
Family Cyclopsettidae			

Citharichthys spilopterus Günther, 1862 LC,•	68	Freshwater, Brackish, Marine	Língua de areia
Family Cynoglossidae			
Symphurus tessellatus (Quoy & Gaimard, 1824) LC,•	12	Brackish, Marine	Língua de mulata
Order Cichliformes			
Family Cichlidae			
Cichlasoma zarskei Ottoni, 2011 LC,•	61	Freshwater	Cará preto
Order Cyprinodontiformes			
Family Anablepidae			
Anableps anableps (Linnaeus, 1758) LC,•	20	Freshwater, Brackish	Tralhoto
Family Poeciliidae			
Poecilia sarrafae Bragança & Costa, 2011 LC,•	1042	Freshwater	Barrigudinho, Guppy
Poecilia vivipara Bloch & Schneider, 1801 LC,•	3	Freshwater, Brackish	Barrigudinho, Guppy
Poecilia reticulata Peters, 1859 ♦	11	Freshwater, Brackish	Barrigudinho, Guppy
Family Rivulidae			
Anablepsoides urophthalmus (Günther, 1866) LC,•	446	Freshwater	-
Order Beloniformes			
Family Hemiramphidae			
Hyporhamphus roberti (Valenciennes, 1847) LC,•	72	Brackish, Marine	Peixe agulha
Order Mugiliformes			
Family Mugilidae			
Mugil brevirostris (Ribeiro,1915) DD,•	8	Freshwater, Brackish, Marine	Caíca, Tainha
Mugil curema Valenciennes, 1836 DD,•	16	Brackish, Marine	Caíca, Tainha branca
Mugil incilis Hancock, 1830 DD,•	8	Brackish, Marine	Caíca, Tainha-de-olho amarelo
Order Acanthuriformes			
Family Gerreidae			
Diapterus auratus Ranzani, 1842 LC,•	208	Freshwater, Brackish, Marine	Carapeba
Eucinostomus harengulus (Goode & Bean, 1879) LC,•	72	Marine	Bico doce

Family Haemulidae			
Genyatremus luteus (Bloch, 1790) [LC,•]	43	Brackish, Marine	Peixe pedra
Family Lutjanidae			
Lutjanus jocu (Bloch & Schneider, 1801) [NT,•]	10	Freshwater, Brackish, Marine	Carapitanga, Dentão
Family Pomacanthidae			
Pomacanthus paru (Bloch, 1787) [DD,•]	1	Marine	Paru preto
Family Sciaenidae			
Ctenosciaena gracilicirrhus (Metzelaar, 1919) [LC,•]	172	Marine	Carioquinha
Macrodon ancylodon (Bloch & Schneider, 1801) [LC,•]	1	Brackish, Marine	Pescada gó
Stellifer naso (Jordan, 1889) [LC,•]	222	Brackish, Marine	Curuca, Cabeçudo-preto
Stellifer rastrifer (Jordan,1889) [•]	47	Brackish, Marine	Curuca
Stellifer stellifer (Bloch, 1970) [LC,•]	109	Brackish, Marine	Curuca, cabeçudo-vermelho
Order Tetraodontiformes			
Family Tetraodontidae			
Sphoeroides psittacus (Bloch & Schneider, 1801) [LC,•]	991	Freshwater, Brackish, Marine	Baiacu açu
Sphoeroides testudineus (Linnaeus, 1758) [LC,•]	56	Freshwater, Brackish, Marine	Baiacu pintado