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Inventory

# Freshwater fishes of the Parque Nacional dos Lençóis Maranhenses and adjacent areas

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***Abstract:*** We present here an embracing freshwater fish inventory of the Parque Nacional dos Lençóis Maranhenses and adjacent areas, reporting 49 fish species, 33 of which were identified accurately at the species level, representing ten orders and 25 fish families that range from obligate freshwater to estuarine organisms. This number of species is much larger than two previous studies for the park, each reporting just 12 and 33 fishes occurring on freshwater environments. Among the 49 freshwater species recorded in this study, 14 are new records for the Parque Nacional dos Lençóis Maranhenses, and just one corresponds to an introduced species. Some of the 14 new records in the Parque Nacional dos Lençóis Maranhenses, cited above, as well as some of the 16 species which we are not able to identify accurately at the species level, could include undescribed species, but more study is necessary before sorting out which species are truly undescribed, and which are already described ones. The orders reported by this survey which comprise the highest percentage of species richness, excluding introduced species, were: Characiformes, Cichliformes and Siluriformes, in the same ranking position, and Gymnotiformes, as expected for Neotropical freshwater surveys. The families with the highest number of species, excluding non-native species, were: Characidae, followed by Cichlidae, and Loricariidae. Out of the 33 species herein identified accurately at the species level, five of them are species typically found in brackish water environments, and when occurring on freshwater environments, are restricted mainly to estuaries, or, occasionally, the lower portions of the rivers. Thus, we will not address them in our biogeographical comments. From the remaining 28 species, eight did not occur in the Amazon River basin, six of them being endemic to the Maranhão-Piauí ecoregion. The remaining species herein reported also have their distribution recorded for the Amazon River basin, which shows the great influence of the Amazon basin. In the last two decades efforts to inventory the freshwater fish fauna and to taxonomically solve some groups occurring on the Maranhão state have been made. However the knowledge regarding the composition of the Maranhão freshwater fishes is still insufficient and underestimated, with several groups still lacking adequate taxonomic and systematic resolution, and with many gaps of knowledge, something that is not appropriate for our current picture of "biodiversity crisis". As well as, the other Brazilian protected areas, the PNLM fails to preserve its freshwater environment properly, since it includes only fragments of the major river systems of the area, not including and conserving the hole river drainages, mainly excluding their headwaters. Thus, its water bodies are exposed to typical human impacts.

***Keywords:*** *Biodiversity, ichthyology, Periá River basin, Preguiças River basin.*

## Peixes de água doce do Parque Nacional dos Lençóis Maranhenses e áreas adjacentes

***Resumo:*** Nós apresentamos aqui um inventário de peixes de água doce do Parque Nacional dos Lençóis Maranhenses e áreas adjacentes, relatando 49 espécies de peixes, 33 dos quais foram identificados com precisão à nível de espécie, representando dez ordens e 25 famílias de peixes que variam de água doce à organismos estuarinos. Esse número de espécies é muito maior do que dois estudos anteriores para o parque, cada um registrando apenas 12 e 33 espécies de peixes ocorrendo em ambientes de água doce. Entre as 49 espécies de água doce registradas neste estudo, 14 são novos registros para o Parque Nacional dos Lençóis Maranhenses, e apenas um corresponde a uma espécie introduzida. Alguns dos 14 novos registros no Parque Nacional dos Lençóis Maranhenses, citados acima, bem como algumas das 16 espécies que não foram possíveis de serem identificadas com precisão no nível de espécie, podem incluir espécies não descritas. Entretanto, são necessários mais estudos antes de se ter certeza de quais espécies são verdadeiramente não descritas, e quais já são descritas. As ordens relatadas por esta pesquisa que compõem a maior porcentagem de riqueza de espécies, excluindo espécies introduzidas, foram: Characiformes, Cichliformes e Siluriformes na mesma posição do ranking, e Gymnotiformes, como esperado para levantamentos de água doce Neotropical. As famílias com maior número de espécies, excluindo espécies não nativas, foram: Characidae, seguida por Cichlidae e Loricariidae. Das 33 espécies aqui identificadas com precisão no nível de espécie, cinco delas são espécies tipicamente encontradas em ambientes de água salobra, e quando ocorrem em ambientes de água doce, são restritas principalmente a estuários, ou ocasionalmente, as porções mais baixas dos rios. Assim, não os abordaremos em nossos comentários biogeográficos. Das 28 espécies restantes, oito não ocorrem na bacia do rio Amazonas, sendo seis endêmicas da ecorregião Maranhão-Piauí. As espécies restantes aqui relatadas também têm sua distribuição registrada para a bacia do rio Amazonas, o que mostra sua grande influência. Nas últimas duas décadas foram feitos esforços para inventariar a fauna de peixes de água doce e resolver taxonomicamente alguns grupos que ocorrem no estado do Maranhão. No entanto, o conhecimento sobre a composição dos peixes de água doce do Maranhão ainda é insuficiente e subestimado, com vários grupos ainda sem resolução taxonômica e sistemática adequada, e com muitas lacunas de conhecimento, algo que não é apropriado para nosso quadro atual da "crise da biodiversidade". Assim como as demais áreas de proteção brasileiras, o PNLM falha em preservar seus ambientes de água doce de forma apropriada, já que ele inclui apenas fragmentos dos maiores sistemas fluviais da área, não incluindo e conservando as drenagens inteiramente, principalmente excluindo suas cabeceiras. Sendo assim, seus corpos de águas estão expostos a típicos impactos humanos.

***Palavras-chave:*** *Biodiversidade, ictiologia, Rio Periá, Rio Preguiças.*

## Introduction

South America presents a rich ichthyofauna, with an estimative of more than 9,100 valid species occurring in freshwater and marine environments of coastal areas (about 25% of all world fish species). Only for freshwater, there are about 5,100 described species; about a third of all freshwater fish species in the world (Reis et al. 2016). The published Check List of Freshwater Fish from South and Central America (CLOSSFCA) (Reis et al. 2003) listed about 4,500 valid species for the Neotropical region, also estimating that there was still at least 1,550 undescribed species. However, new estimates point that freshwater ichthyofauna diversity from the Neotropics may be even higher, with up to 8,000 or 9,000 species (Reis et al. 2016), a similar estimative proposed by Schaefer (1998). Since the publication of CLOFFSCA, an average of 104 new species have been described every year in South America, totalizing 1,142 new species. In other words, about 28% of the ichthyofauna known in South America has been described in the last 11 years, according to Reis et al. (2016).

Brazil concentrates the largest hydrographic networks of the Neotropics, which present high aquatic biodiversity, comprehending about 20% of all freshwater fish species in the world (Buckup et al. 2007). Under the conservationist lens, Brazil can be considered a nursery for aquatic biodiversity, especially when it comes to freshwater fish. In addition, Brazil comprises about 55% of freshwater fish species of the Neotropics (Reis et al. 2003, Buckup et al. 2007). Estimates predict that between 2,600 and 3,100 valid species belonging to the families that exclusively inhabit freshwater environments occur within the national territory, comparatively a much higher diversity than Brazil's marine ichthyofauna (Buckup et al. 2007, Fishbase 2019). Most of this diversity corresponds to small and medium size species, which are distributed mainly in small streams (Lowe-McConnel 1999).

Despite these attributes, the country has been suffering from severe environmental impacts caused by exploratory human activities, the degeneration and alteration of the natural habitats being the most harmful aspects in terms of conservation and consequently leading to the decline of biodiversity. Natural environments, both in Brazil and in the world, have been suffering a swift destruction, especially derived from anthropic actions, with a consequent loss and extinction of species and populations, many of them unknown to science (Wilson 1985, 1999, Brooks et al. 2002, Brook et al. 2006, Laurence 2007, Costa et al. 2012). These environmental impacts and habitats loss are not restricting to terrestrial ecosystems, but also occur in freshwater environments, caused by several human activities, such as construction of dams; hydropower expansion; aquaculture, introduction non-native species; agriculture; mining; among others (Agostinho et al. 2008, Azevedo-Santos et al. 2018, Lima Junior et al. 2018). This quick biodiversity loss and natural habitats degeneration create scarcity in data and complete information regarding fauna and flora.

This panorama becomes even more critic due to low investment in projects related to taxonomy, especially non-applied taxonomy (basic) and the training of taxonomists; lack of professionals and capable taxonomists; lack of funding for the maintenance and expansion of the collections of natural history museums and scientific collections; and the insufficient number of taxonomic studies associated to areas of great biodiversity. Such problematic can be translated as "the crisis of biodiversity" (Wheeler 2008). Information about the biological diversity and the identification and description of new species and other taxa is the starting point for all basic or applied studies related to the life sciences. The ability to name and identify them is crucial for any study that uses living organisms, such as ecological, conservation, ethology, evolutionary and other kinds of studies (Savage 1995, Wheeler 2008). The improvement of the knowledge related to systematics, taxonomy, ecology and distribution of our fauna and flora is of fundamental relevance in the current context of Brazilian and world development, mainly for the conservation of species (Wilson 1985, Brooks et al. 2002, Brook et al. 2006, Lewinsohn 2006, Laurence 2007, Wheeler 2008, Costa et al. 2012). Estimates indicate that about 90% of the living species in our planet are still unknown to science. Thus, we know nothing about morphology, ecology, behavior, and geographic distribution of most of our biodiversity (Wheeler 2008). The destruction of habitats at accelerated rates makes identification of new species, the conduction of regional inventories and the taxonomic resolution of species and species groups, before they are extinct, as priority actions. Just this way, appropriate actions and decisions concerning to conservation of species and environments can be made (Wilson 1985, Brooks et al. 2002, Brook et al. 2006, Lewinsohn 2006, Laurence 2007, Wheeler 2008, Nogueira et al. 2010, Costa et al. 2012, 2014, 2018, Thomson et al. 2018).

Most of the protected areas established in Brazil during the past three decades were constituted in order to conserve terrestrial fauna and flora, and many of these areas protect important water bodies (Agostinho et al. 2005). However, there is a huge possibility that the design and the coverage area of these protection units, because they are based on terrestrial biodiversity, are mismatched in the protection and conservation of aquatic ecosystems (Barletta et al. 2010, Herbert et al. 2010, Azevedo-Santos et al. 2018). This mismatch is probably related mainly to the fact that these areas only include stretches of the rivers, streams and hydrographic basins, thus, not including the essential regions that would guarantee a functional and protected freshwater biodiversity and fragmenting the conservation of the water bodies (Rodríguez-Olarte et al. 2011, Azevedo-Santos et al. 2018). Despite this gap, the inclusion of data on freshwater fish fauna, or even aquatic biota in the definition of protected areas has gathered greater attention (Rodríguez-Olarte et al. 2011); however, there still is the need for conducting inventories on ichthyofauna, since these aquatic environments present a significant risk of degradation (Barletta 2010, Azevedo-Santos et al. 2018).

Thus, the objective of our study is to present the list of freshwater fish of the Parque Nacional dos Lençóis Maranhenses (PNLM), an area of environmental protection managed by the federal government, characterized by the presence of dunes, lagoons and small watercourses. Although it is an area of integral protection, the environments contained in the PNLM have been under intense pressure, especially those related to tourism, which is increasing in the region. Most of the areas targeted by tourism are freshwater environments, making them the main attraction (Miranda et al. 2012). In the past two decades, efforts have been made to inventory the freshwater fish fauna and to solve taxonomically some groups occurring on the Maranhão State. However, the knowledge regarding the composition of the Maranhão freshwater fishes is still insufficient and underestimated, with several groups still lacking adequate taxonomic and systematic resolution, and with many gaps of knowledge (Piorski 2010, Guimarães et al. 2018a). In a context of "freshwater biodiversity crisis" (sensu Harrison et al. 2018), this is not appropriate.

## Material and Methods

### *1. Study area*

The PNLM is a protected area located at the eastern coastal region of Maranhão, within the territorial limits of Primeira Cruz, Santo Amaro do Maranhão and Barreirinhas municipalities, with a coastline extending for 270 km and a total area of 155,000 hectares. This area is constituted by dunes interspersed by perennial and temporary lagoons, rivers, streams and lakes. It includes two main coastal river basins: Preguiças and Periá. The dunes present in the park, which are the reason for the denomination of Lençóis Maranhenses, are constituted of eolic and marine deposits of the Quaternary period, configuring an extensive area of free and fixed dunes (ICMBio 2003). Besides the dunes, the park also comprises a mosaic of ecosystems such as mangroves, riparian forest and restinga, the latter being predominant in the region (ICMBio 2003).

### *2. Sampling design*

Collection of samples was conducted at 21 collecting sites distributed within and outside the boundaries of PNLM, comprising rivers, streams, lagoons and lakes (Table 1, Figures 1, 2), along the basins of rivers Preguiças and Periá. Sampling was conducted in three expeditions: the first ones taking place in 2000 in the mouths of July and December, and in 2017 in the month of July.

### *3. Collection and identification of specimens*

Fishes were collected with two seines (20 m long, 2.5 m high, mesh size 10 mm; and 4 m long, 2 m height, mesh size 5 mm), cast nets (2 m height, mesh size 15 mm), gillnets of various mesh sizes (15, 25, 35, 45 and 55 mm), and dip nets (mesh size 5 and 10 mm). The ichthyological material obtained in the samples was fixed in the field using 10% formalin solution neutralized with sodium tetraborate. Some specimens were photographed alive in order to obtain records of their natural coloration. Sorting and identification of specimens were carried out at the Laboratório de Sistemática e Ecologia de Organismos Aquáticos of the Universidade Federal do Maranhão and at the Laboratório de Ecologia e Sistemática de Peixes, from the same institution, using specialized bibliography for each taxonomic group and consulting experts. The ichthyological material was deposited in the Coleção de Peixes da Universidade Federal do Maranhão (CPUFMA) and Coleção Ictiológica do Centro de Ciências Agrárias e Ambientais of the Universidade Federal do Maranhão (CICCAA). The taxonomic classification follows Nelson et al. (2016); and the name, authors, year of publication, validity, distribution and updated data of each species were checked in Fricke et al. (2019).

**Table 1.** Collecting sites within the Parque Nacional dos Lençóis Maranhenses and adjacent areas.

| Site | Locality | River basin | Municipality | Coordinates |
|---|---|---|---|---|
| 1 | Baixa Grande | Rio Preguiças | Barreirinhas | 2° 32.3'S 42° 59.10'W |
| 2 | Lago de Santo Amaro | Rio Periá | Santo Amaro | 2° 28.20'S 43° 13.98'W |
| 3 | Lago da Betânia | Rio Periá | Santo Amaro | 2° 33.05'S 43° 11.02'W |
| 4 | Lagoa da Esperança | Rio Preguiças | Barreirinhas | 2° 41.58'S 43° 2.35'W |
| 5 | Ponta do Mangue | Rio Preguiças | Barreirinhas | 2° 34.53'S 42° 47.51'W |
| 6 | Queimada dos Britos | Rio Preguiças | Barreirinhas | 2° 30.51'S 43° 1.87'W |
| 7 | Riacho Mata-Fome, Tucunzal | Rio Preguiças | Barreirinhas | 2° 39.68'S 42° 48.83'W |
| 8 | Rio Alegre em Boa Vista | Rio Periá | Primeira Cruz | 2° 28.60'S 43° 18.98'W |
| 9 | Rio Grande, na Ponta do Espigão | Rio Periá | Santo Amaro | 2° 32.36'S 43° 11.79'W |
| 10 | Rio Santo Inácio, em Atins | Rio Preguiças | Barreirinhas | 2° 34.44'S 42° 44.84'W |
| 11 | Rio Sucuriju | Rio Preguiças | Barreirinhas | 2° 39.21'S 42° 46.92'W |
| 12 | Lago de Travosa | Rio Periá | Santo Amaro | 2° 23.42'S 43° 15.76'W |
| 13 | Lagoa no Riacho Tucuns | Rio Preguiças | Barreirinhas | 2° 43.2'S 42° 51.19'W |
| 14 | Riacho Achuí - Tucuns | Rio Preguiças | Barreirinhas | 2° 43.24'S 42° 51.83'W |
| 15 | Riacho Sucuriju, Povoado Cedro | Rio Preguiças | Barreirinhas | 2° 42.07'S 42° 49.23'W |
| 16 | Rio Sucuriju, em Tucunzal | Rio Preguiças | Barreirinhas | 2° 39.91'S 42° 49.74'W |
| 17 | Riacho em Tucunzal | Rio Preguiças | Barreirinhas | 2° 39.79'S 42° 49.87'W |
| 18 | Rio das Pedras | Rio Periá | Santo Amaro | 2° 47.89'S 43° 15.37'W |
| 19 | Rio Juçaral | Rio Preguiças | Barreirinhas | 2° 49.42'S 43° 07.34'W |
| 20 | Riacho Passagem do canto | Rio Preguiças | Barreirinhas | 2° 50.77'S 42° 51.82'W |
| 21 | Morro do Boi | Rio Preguiças | Barreirinhas | 2° 37.19'S 42° 41.02'W |

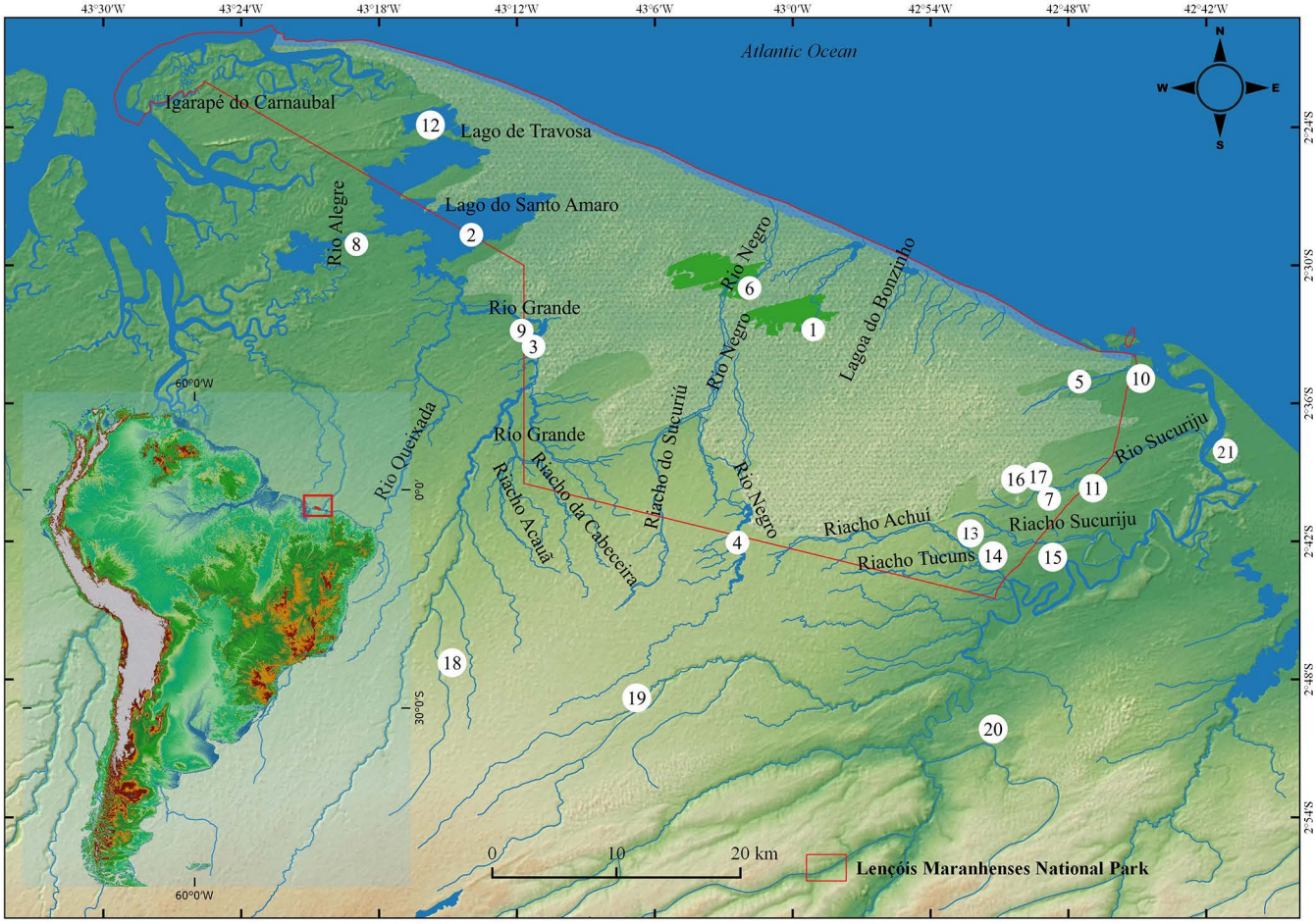


**Figure 1.** Collecting sites in the Parque Nacional Lençóis Maranhenses, northeastern Brazil, and adjacent areas.


**Figure 2.** Some collecting sites at PNLM.

## Results

The fish survey of the freshwater rivers (including some river estuaries) of Parque Nacional dos Lençóis Maranhenses reported 49 species, representing 10 orders and 25 fish families that range from obligate freshwater to estuarine organisms. Thirty-three of these species were identified accurately at the species level (Table 2). The Orders comprising the highest percentage of species richness, excluding non-native species, were: Characiformes (46%), Siluriformes (11%), Cichliformes (11%), and Gymnotiformes (10%) (Figure 3), representing 78% of the total species richness. Cyprinodontiformes (*Anablepsoides* Huber, 1992*, Melanorivulus* Costa 2006 and *Poecilia* Bloch & Schneider 1801), Perciformes (*Eucinostomus* Baird & Girard 1855 and *Polydactylus* Lacepède 1803), Clupeiformes (*Lycengraulis* Günther 1868), Gobiiformes (*Awaous* Steindachner 1861), Mugiliformes (*Mugil* Linnaeus 1758), Synbranchiformes (*Synbranchus* Bloch 1795), Pleuronectiformes (*Achirus* Lacepède 1802) complete the list with four, two, one species each respectively (Table 2, Figure 3). The families with the highest number of species, excluding non-native species, were: Characidae, with 11 species, representing 22% of the species, followed by Cichlidae, with five species (10%), and Loricariidae with three (6%) (Figure 4).

**Table 2.** List of species collected at the PNLM. New records marked with*.

| Classe ACTINOPETRYGII | |
|---|---|
| Ordem CLUPEIFORMES | |
| **Família Engraulidae** | |
| *Lycengraulis batesii* (Günther, 1868) | CPUFMA001178 |
| Ordem CHARACIFORMES | |
| **Família Acestrorhynchidae** | |
| *Acestrorhynchus falcatus* (Bloch, 1794) | CPUFMA172189 |
| **Família Anostomidae** | |
| *Leporinus* aff. *friderici* | CPUFMA001137 |
| **Família Characidae** | |
| *Astyanax* cf. *lacustris* | CPUFMA172807 |
| *Brachychalcinus parnaibae* Reis, 1989* | CPUFMA001268 |
| *Hyphessobrycon piorskii* Guimarães, Brito, Feitosa, Carvalho-Costa & Ottoni 2018 | CICCAA02051 |
| *Hemigrammus* sp1. * | CICCAA02140 |
| *Hemigrammus* sp.2* | CICCAA02158 |
| *Hemigrammus* sp.3* | CICCAA02119 |
| *Moenkhausia cotinho* Eigenmann, 1908 | CICCAA02085 |
| *Moenkhausia oligolepis* (Günter, 1864) * | CICCAA02102 |
| *Moenkhausia* sp. | CPUFMA172770 |
| *Poptella compressa* (Günther 1864) * | CPUFMA001194 |
| *Serrapinus* sp. * | CPUFMA001293 |
| **Família Curimatidae** | |
| *Steindachnerina notonota* (Miranda Ribeiro, 1937) | CPUFMA001180 |
| *Curimatopsis* aff. *cryptica* | CPUFMA172802 |
| **Família Erythrinidae** | |
| *Hoplias malabaricus* (Bloch, 1794) | CPUFMA172190 |
| *Hoplerythrinus unitaeniatus* (Agassiz, 1829) | CPUFMA172196 |
| **Família Iguanodectidae** | |
| *Bryconops* cf. *affinis* * | CPUFMA172773 |
| *Bryconops* cf. *melanurus** | CPUFMA172806 |
| **Família Lebiasinidae** | |
| *Nannostomus beckfordi* Günther, 1872 | CPUFMA172204 |
| **Família Serrasalmidae** | |
| *Serrasalmus rhombeus* (Linnaeus, 1766) | CPUFMA001158 |
| *Metynnis lippincottianus* (Cope, 1870) | CPUFMA001176 |

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| | |
|---|---|
| Ordem CICHILIFORMES | |
| **Família Cichlidae** | |
| *Apistogramma piauiensis* Kullander, 1980 | CPUFMA172193 |
| *Aequidens tetramerus* (Heckel, 1840) | CPUFMA001230 |
| *Cichlasoma* cf. *zarskei* | CPUFMA172191 |
| *Crenicichla brasiliensis* (Bloch 1792) | CPUFMA001288 |
| *Oreochromis* sp. | CPUFMA001191 |
| *Satanoperca jurupari* (Heckel, 1840) | CPUFMA001251 |
| Ordem CYPRINODONTIFORMES | |
| **Família Poeciliidae** | |
| *Poecilia vivipara* Bloch & Schneider, 1801 | CPUFMA001214 |
| *Poecilia sarrafae* Bragança & Costa, 2011* | CPUFMA001216 |
| **Família Rivulidae** | |
| *Melanorivulus* cf. *parnaibensis* * | CPUFMA172782 |
| *Anablepsoides vieirai* Nielsen 2016* | CPUFMA172801 |
| Ordem GYMNOTIFORMES | |
| **Família Apteronotidae** | |
| *Apteronotus albifrons* (Linnaeus, 1766) | CPUFMA001173 |
| **Família Gymnotidae** | |
| *Gymnotus carapo* Linnaeus, 1758 | CPUFMA001174 |
| **Família Hypopomidae** | |
| *Brachyhypopomus* sp.* | CPUFMA172800 |
| **Família Sternopygidae** | |
| *Eigenmannia virescens* (Valenciennes, 1836) | CPUFMA001165 |
| *Sternopygus macrurus* (Bloch & Schneider, 1801) | CPUFMA001166 |
| Ordem MUGILIFORMES | |
| **Família Mugilidae** | |
| *Mugil curema* Valenciennes, 1836 | CPUFMA001181 |
| Ordem PERCIFORMES | |
| **Família Gerreidae** | |
| *Eucinostomus* cf. *argenteus* | CPUFMA001218 |
| **Família Polynemidae** | |
| *Polydactylus virginicus* (Linnaeus, 1758) | CPUFMA001195 |
| **Família GOBIIFORMES** | |
| Ordem GOBIIDAE | |
| *Awaous tajasica* (Lichteinstein, 1822) | CPUFMA001183 |
| Ordem PLEURONECTIFORMES | |
| **Família Achiridae** | |
| *Achirus achirus* (Linnaeus, 1758) | CPUFMA001186 |
| Ordem SILURIFORMES | |
| **Família Auchenipteridae** | |
| *Trachelyopterus galeatus* (Linnaeus, 1766) | CPUFMA001131 |
| **Família Callichthyidae** | |
| *Megalechis thoracata* (Valenciennes,1840) * | CPUFMA172194 |
| **Família Heptapteridae** | |
| *Pimelodella parnahybae* Fowler, 1941 | CPUFMA00242 |
| **Família Loricariidae** | |
| *Loricaria* cf. *parnahybae* | CPUFMA001160 |
| *Hypostomus johnii* (Steindachner, 1877) | CPUFMA002174 |
| Ordem SYNBRANCHIFORMES | |
| **Família Synbranchidae** | |
| *Synbranchus marmoratus* Bloch, 1795 | CPUFMA001192 |

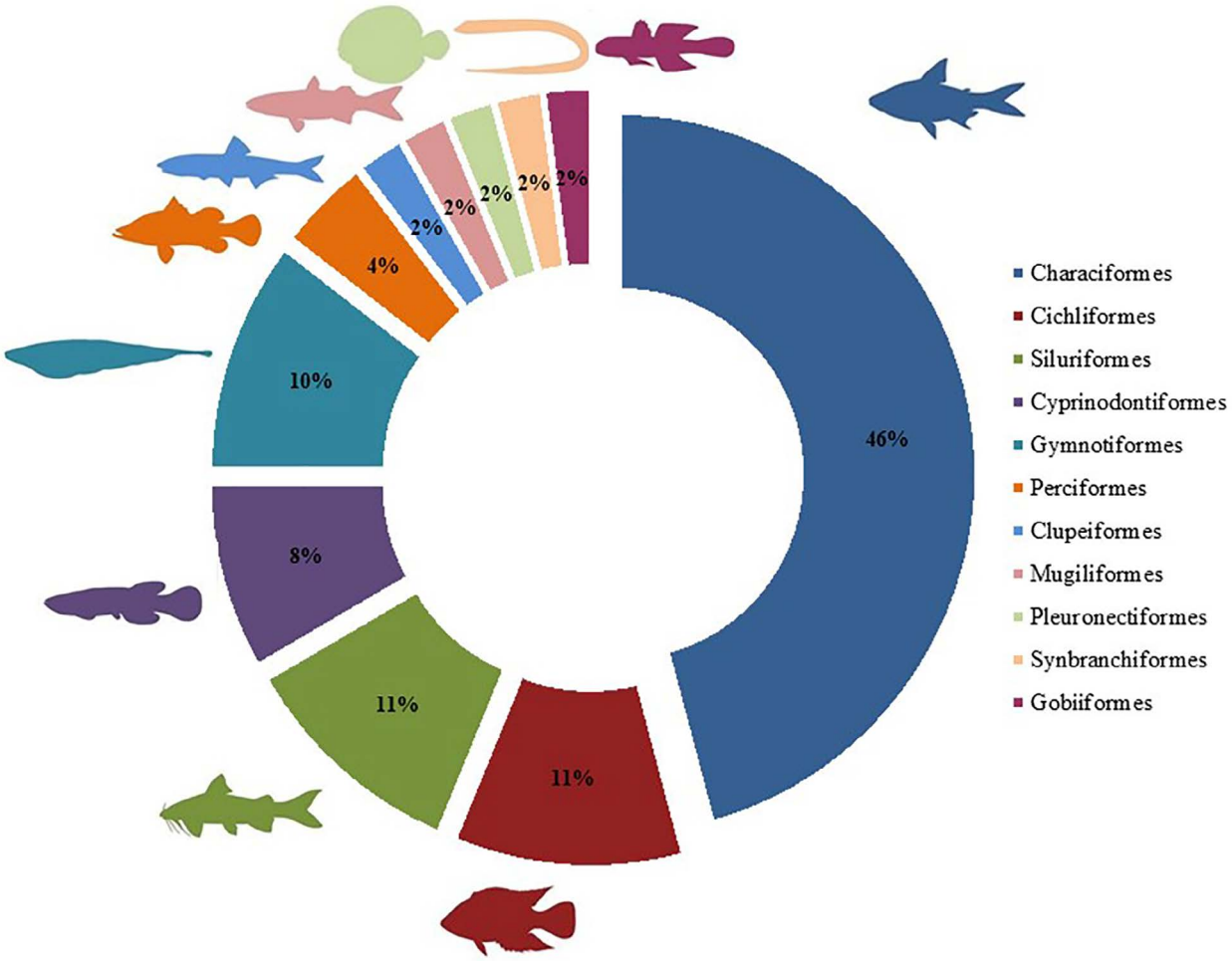


**Figure 3.** Ranking of richness by Orders observed in the PNLM, excluding non-native species.

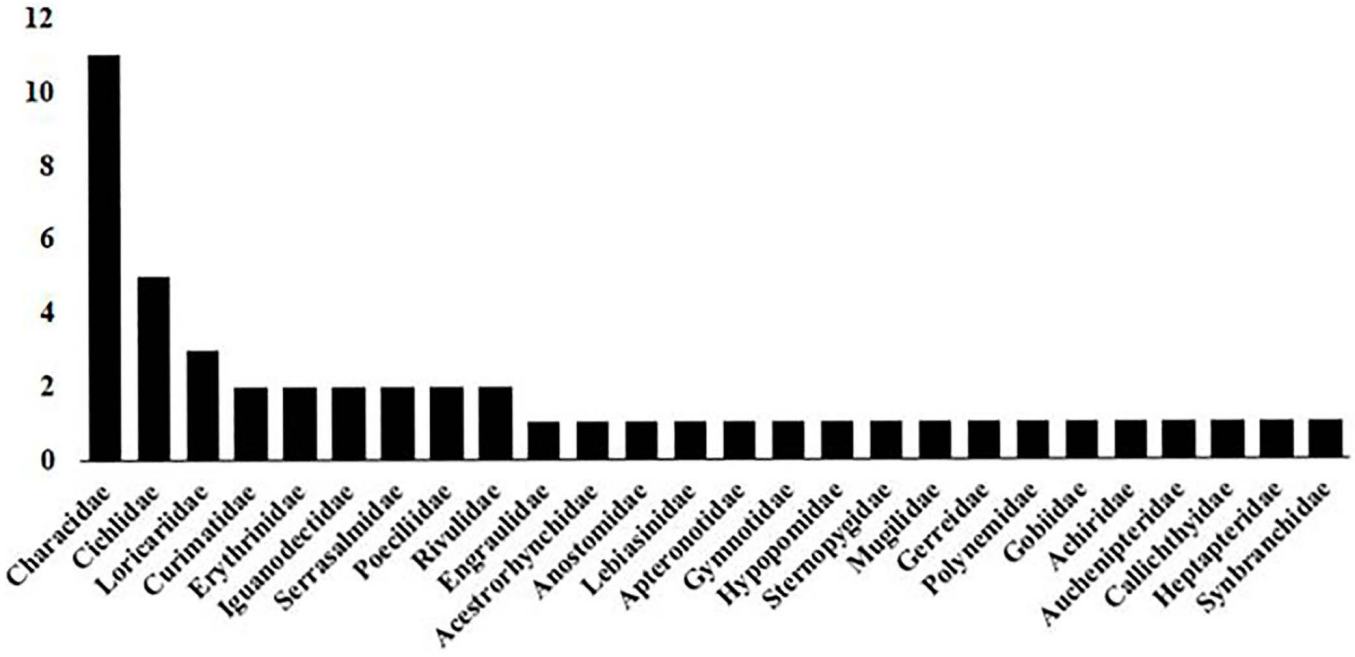


**Figure 4.** Ranking of richness by families observed in the PNLM, excluding non-native species.

## Discussion

One of the few ichthyofauna studies conducted at the PNLM was the paper published by Garavello et al. (1998) which provided a preliminary list of fishes occurring on the sand dune lagoons of the park. They listed 13 species, one of them possessing a marine habit [*Arius spixii* (Agassiz, 1829)], and 12 freshwater species. In this preliminary list of fishes, Characiformes was the most diverse order; and despite the small number of species recorded by Garavello et al. (1998), the pattern of species richness did not differ from other freshwater fish inventories [e.g. Barros et al. 2011 (Itapecuru river basin), Claro-Garcia & Shibatta 2013 (upper Tocantins river basin), Ramos et al. 2014 (Parnaíba river basin), Melo et al. 2016 (Parnaíba river basin)]. The fish survey provided by our work reported 49 species occurring on freshwater habitats at the PNLM (including some river estuaries), representing ten orders and 25 fish families, that range from obligate freshwater to estuarine organisms (Table 2, Figure 1). This is more than three times the number of freshwater species (12) reported by Garavello et al. (1998) and furthermore added 16 species to the list provided by Piorski et al. (2017), including 14 new records for PNLM (Table 2). From the 12 freshwater species listed by Garavello et al. (1998), all the species, four of them except, were reported by our survey: *Curimata* sp., *Colossoma* sp., *Crenicichla* aff. *lugubris*, and *Aequidens pallidus* (Heckel 1840). Therefore, we opted to not consider them in our survey, since we collected other congeners or close related genera to these four species registered by Garavello et al. (1998), and a hypothesis of misidentification of these species by them is not rejected. In addition, neither *A. pallidus* nor *C. lugubris* have official distribution records for the studied area, nor for nearby regions, and their type localities are very far from PNLM (see Kullander 2003, Fricke et al. 2019), what makes the records of these two species for this protected area unlikely.

Among the 49 freshwater species recorded in this study, 14 are new records for the PNLM. From these 49 species, just one corresponds to an introduced one (*Oreochromis* sp.). The occurrence of this non-native species highlights the importance of long-term monitoring the populations of this species, attempting to control the populations, reducing the possible impacts over the natural freshwater community. Protected areas with non-native species are more challenge. Among the 14 new records in the PNLM, cited above, as well as some of the 16 species which we were unable to identify accurately at the species level, could include undescribed species, but more study is necessary before sorting out which species are truly undescribed and which are already described ones. The orders reported by this survey comprising the highest percentage of species richness were Characiformes (46%), Siluriformes (11%), Cichliformes (11%), and Gymnotiformes (10%), excluding non-native species (Figure 2), as expected for Neotropical freshwater surveys (e.g. Langeani et al. 2007, Lucinda et al. 2007, Sarmento-Soares et al. 2007, Vari et al. 2009, Casatti et al. 2013, Ramos et al. 2014, Polaz et al. 2014, Fagundes et al. 2015, Melo et al. 2016, Cetra et al. 2016).

When comparing the present survey with inventories from other river drainages from the Maranhão State, we can conclude that the freshwater fish fauna of the state is probably still underestimated, as argued by Piorski (2010) and Guimarães et al. (2018a). In hydrographic terms, the PNLM boundaries include the Preguiças and Periá river basins. These two coastal river basins are very small when compared to the major coastal river basins of the Maranhão-Piauí ecoregion, such as Parnaíba, Mearim, Turiaçu, Itapecuru and Gurupi river basins. However, in terms of recorded biodiversity, we have a substantial number of species from these two basins. The 49 species herein recorded represent three times the number of freshwater species (13) reported by Matavelli et al. (2015) for the Munim, Parnaíba and other smaller coastal river basins, as well as more than twice the number of species (20) reported by Ribeiro et al. (2014) for the Munim river basin. It has just 11 species less than the number of species (60) reported by Soares (2013) for the Mearim river basin; just 20 species less than the number of species (69) reported by Barros et al. (2011), and 15 species less than the survey (64) performed by Nascimento et al. (2016), respectively, for the Itapecuru river basin, one of the major coastal river basins of this ecoregion; and just 16 species less than the inventory (65) published by Melo et al. (2016) for the Parnaíba river basin, the major coastal river basin of the Maranhão-Piauí ecoregion and one of the main river basins of Brazil. The two surveys including more species recorded from coastal river basins of the Maranhão state were the works published by Ramos et al. (2014) for the Parnaíba river basin, and the survey provided by Castro & Dourado (2011) for the Mearim, Pindaré, Pericumã and upper Turiaçu river drainages, including 146 and 109 species, respectively. The first one was an exhaustive inventory of one of the main and largest river basin of Brazil (Parnaíba), and the second one included three distinguished river drainages: Mearim and Pindaré from the Mearim river system, the second major river system of the Maranhão-Piauí ecoregion, and Turiaçu, one of the main river basins of this ecoregion. Even so, our survey recorded about a half to one third of the number of species than these two surveys cited above, what demonstrates the effort put in the inventory here presented.

From the 33 species herein identified accurately at the species level, five of them, *Achirus achirus* (Linnaeus 1758), *Awaous tajasica* (Lichtenstein 1822), *Mugil curema* Valenciennes 1836, *Poecilia vivipara* Bloch & Schneider 1801 and *Polydactylus virginicus* (Linnaeus 1758), are species typically found in brackish water environments, and when occurring on freshwater environments, are restricted mainly to estuaries, or, occasionally, the lower portions of the rivers. Thus, we will not address them in our biogeographical comments. From the remaining 28 species, eight did not occur in the Amazon River basin (*Anablepsoides vieirai* Nielsen 2016, *Apistogramma piauiensis* Kullander 1980, *Crenicichla brasiliensis* (Bloch 1792), *Hyphessobrycon piorskii* Guimarães, Brito, Feitosa, Carvalho-Costa & Ottoni 2018, *Hypostomus johnii* (Steindachner 1877), *Poecilia sarrafae* Bragança & Costa 2011, *Pimelodella parnahybae* Fowler 1941 and *Steindachnerina notonota* (Miranda Ribeiro 1937); six of them (*A. vieirai, A. piauiensis, H. piorskii, H. johnii, P. sarrafae* and *P. parnahybae*) being endemic to the Maranhão-Piauí ecoregion (see Fricke et al. 2019). All the remaining species herein reported have their distribution recorded for the Amazon River basin (see Fricke et al. 2019), which shows the great influence of the Amazon basin.

According to Rosa et al. (2003), the fish fauna on Maranhão-Piauí ecoregion was historically pointed out as poorly endemic. Otherwise, the low level of endemism recorded during the past decades would be related to less sampling effort on the whole region (Piorski 2010, Ramos et al. 2014, Guimarães et al. 2018a). Several species in the Maranhão-Piauí rivers are known to occur along the Amazon basin (including coastal rivers in Suriname and the Guianas), a distribution pattern suggested by Barros et al. (2011),

who observed a predominance of Amazonian species in the Itapecuru basin, as well as corroborated for some putative species by Guimarães et al. (2016, 2017a, b). In addition, this influence of the Amazon River basin in the ecoregion was advocated by Hubert & Renno (2006) and Dagosta & de Pinna (2017), in their biogeographic analyses. However, these same authors also advocated the possibility of the coastal river basin of the Maranhão state constituting one or more areas of endemism. However, both papers suggest that data related to the freshwater ichthyofauna from this region are too scarce to have a more conclusive hypothesis. Guimarães et al. (2018a) provided a list of several species that are endemic to the river drainages of the Maranhão state or occur just on neighboring areas. This fortifies the hypothesis that the coastal river basins of the Maranhão state could constitute one or more areas of endemism. In addition, a new species (*H. piorskii*) was recently described by Guimarães et al. (2018b) with its distribution known to be restricted to the Munim and Preguiças River basins (including the freshwater bodies of the PNLM). As pointed out above, some of the species which we were not able to identify accurately at the species level could be undescribed ones, and more studies and research need to be done, preferably including molecular data, since many of them are member of species complexes (some of them including cryptic species) or groups still poorly resolved taxonomically. In terms of conservation, the PNLM has a key role in the conservation of the six species, cited above, endemic to the Maranhão-Piauí ecoregion, since it is the most internationally appreciated and subsidized protected area of the ecoregion, which contributes to the preservation of these species, especially the endemic species of the region.

The PNLM presents a unique scenic beauty, appreciated internationally. However, knowledge about existing biodiversity does not follow the same standards. Information on the biota diversity in the limits of its area dates back to the beginning of the 2000s when studies were carried out to prepare the management plan of the protected area (ICMBio 2003). According to these studies, the fauna diversity is relatively low compared to other regions. In general, the fauna consists of 17 groups of mammals, 112 bird species, including migratory species (ICMBio 2003) and 42 species of reptiles (Miranda et al. 2012). As well as the other Brazilian protected areas, the PNLM fails to preserve its freshwater environment properly, since it includes only fragments of the major river systems of the area, not including and conserving the hole river drainages, mainly excluding their headwaters (see Figure 2). Thus, its water bodies are exposed to typical human impacts, as discussed by Azevedo-Santos et al. (2018).

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Erick Cristofore Guimarães: Contribution for data collection, to taxonomic identification of fishes, contributed to manuscript preparation, critical revision and adding intellectual

Beldo Rywllon Abreu Ferreira: Contribution for data collection, to taxonomic identification of fishes and contributed to manuscript preparation

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## Conflicts of Interest

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

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