



Continental ichthyofauna from the Paraíba do Norte River basin pre-transposition of the São Francisco River, Northeastern Brazil

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Abstract: Freshwater ichthyofauna from Brazil Northeast region was considered as being poorly known until recent years, with a considerable number of publications becoming available in the last decade. The present study provides an inventory of freshwater fish species from the Paraíba do Norte River basin located in Paraíba State, Brazil. This inventory is intended to contribute to the of knowledge to the regional fish diversity, pre-transposition of the São Francisco River. Collecting data was obtained from ichthyological databases of both national and foreign institutions. A total of 47 freshwater fish species are registered within the Paraíba do Norte River basin, represented by 38 genera, 20 families and six orders. Characiformes, comprising 47% (22 species), Cichliformes, and Siluriformes are among the most representative orders, 19% (9 species) each, of total recorded species. Seven species of Cichliformes are reported as introduced species in this basin. Cyprinodontiformes and Gobiiformes also registered in this region and correspond to 5% (two species) and Gymnotiformes, Perciformes and Synbranchiformes, 2% (one species each) of total recorded species. Paraíba do Norte River basin stands out in the current national scenario as it comprises the first region from the Mid-Northeastern Caatinga freshwater ecoregion to receive water from the transposition of the São Francisco River. The current inventory is important as it provides scientific data related to the ichthyofauna of Paraíba do Norte River basin prior to the commencement of the river transposition process. An identification key is also given for the freshwater fish species of the region.

Keywords: Freshwater fishes, Neotropical Region, diversity, identification key.

Ictiofauna continental da bacia do Rio Paraíba do Norte pré-transposição do rio São Francisco, Nordeste do Brasil

Resumo: A ictiofauna de água doce do Nordeste brasileiro durante muito tempo foi considerada pouco conhecida. No entanto, este paradigma vem sendo mudado nas últimas décadas com aumento significativo no número de publicações desta ictiofauna. Para contribuir com mais informações sobre a diversidade de peixes do Nordeste brasileiro, o presente estudo realizou um inventário das espécies de peixes de água doce da bacia do rio Paraíba do Norte, localizada no Estado da Paraíba, pré-transposição do Rio São Francisco. Os dados foram provenientes de acervos ictiológicos de instituições nacionais e estrangeiras. Foram registradas 47 espécies, distribuídas em 38 gêneros, 20 famílias e seis ordens de peixes na bacia do rio Paraíba do Norte. As ordens mais representativas foram Characiformes (22 espécies/47% do total), Cichliformes e Siluriformes (9/19%). Sete espécies de Cichliformes são reportadas como introduzidas na bacia. Além das ordens citadas, foram registrados dois Cyprinodontiformes and Gobiiformes (2/5%), e Gymnotiformes, Perciformes e Synbranchiformes (1/2% cada). A bacia do Paraíba do Norte tem se destacado no cenário atual por ser a primeira da região Nordeste Médio-Oriental a receber águas da transposição do rio São Francisco. Com isso, este inventário é de fundamental importância, por apresentar dados da ictiofauna da bacia do rio Paraíba do Norte antes da transposição. Esse trabalho também apresenta uma chave para identificação das espécies de peixes da bacia.

Palavras-chave: Peixes de água doce, Região Neotropical, Inventário, Chave de identificação.

Introduction

Knowledge regarding freshwater fish fauna in Brazil used to be heterogeneous, with major studies focusing on the South and Southeast regions of the country with little emphasis being placed on the Northeast region (Rosa et al. 2003, Langeani et al. 2009, Ramos et al. 2014). Lack of research has limited the classification of the local ichthyofaunistic diversity and delayed biogeographic evaluation of groups of fishes from Brazilian Northeastern region (Rosa et al. 2003, Ramos et al. 2014). This paradigm has recently changed with the publication of a book chapter entitled "Diversity, patterns of distribution and conservation of fishes from Caatinga" in Rosa et al. (2003) listed 240 species of freshwater fishes for the Caatinga biome, comprising the broadest evaluation about the freshwater ichthyofauna from this region to date. Various studies have since been undertaken which the understanding of the regional ichthyofauna through publications, including: Ramos et al. (2005), Alves et al. (2008), Nascimento et al. (2011), Cardoso (2012), Gurgel-Lourenço et al. (2013), Novaes et al. (2013), Sánchez-Botero et al. (2013), Camelier & Zanata (2014), Nascimento et al. (2014), Paiva et al. (2014), Silva et al. (2014), Ramos et al. (2014), Silva et al. (2015), Gurgel-Lourenço et al. (2015), Rodrigues-Filho et al. (2016), Costa et al. (2017), Teixeira et al. (2017) and Oliveira-Silva et al. (2018).

Paraíba do Norte River basin is located entirely within the Paraíba State and it comprises one of the main basins from the Mid-Northeastern Caatinga freshwater ecoregion (MNCE - *sensu* Rosa et al. 2003, Albert et al. 2011). This ecoregion bears hydrographic basins situated between São Francisco and Paraíba River, and supplies water to Alagoas, Pernambuco, Paraíba, Rio Grande do Norte, Ceará States, as well as a small portion of Piauí State (Rosa et al. 2003). The hydrographic network Paraíba State is comprised basins of medium to short length such as those from Paraíba do Norte and Piranhas-Açu Rivers, as well as those of the Curimataú, Camarutuba, Mamanguape, Miriri, Gramame, Guaju and Abiaí Rivers, respectively (AESAs 2017). Knowledge about the ichthyofauna from these river basins is limited, with most of the data available in grey literature.

Taxonomical studies related to freshwater fishes from Paraíba do Norte River basin are restricted to list of species from reservoirs such as those of Marinho et al. (2006), Montenegro et al. (2012) and Costa et al. (2017). Other studies are focused on ecological populational dynamics and communities, including those of Medeiros & Maltchik (2001), Montenegro et al. (2010), Montenegro et al. (2011), and Costa (2015). Studies on the taxonomy and systematics of freshwater fishes from Paraíba do Norte River basin is scarce. This is problematic and contributes to misleading future researches focusing on the biological aspects of the local species due to misidentifications.

Recently, the Paraíba do Norte River has been artificially connected to São Francisco River basin through a water transposition project (Integration Project of São Francisco River with hydrographic basins from the North Northeast – known as PISF). This project aims to eradicate hydrological shortage in the Northeast Semi-arid region (Pittock et al. 2009, Brasil 2004). The transposition began in March 2017, along the east axis, which takes the waters of the São Francisco River to the Paraíba do Norte River. Considering the difference in species composition (São Francisco, with 241 species and MNCE with 94, Barbosa et al. 2017; Oliveira-Silva et al. 2018, respectively) and its natural history, it is expected the occurrence of biological invasions between basins, a factor already observed in researches involving

the transposition of basins (e.g., Ellender & Weyl, 2014; Shelton et al. 2016), which could lead to the extinction of species in these ecosystems to the detriment of competition for space and resources (Pysek & Richardson, 2006). The current study aimed to provide an inventory of the ichthyofauna from Paraíba do Norte River basin prior to the transposition project. Additionally, this study provides the first identification key to freshwater species from this basin.

Material and Methods

1. Study area

The hydrographical basin of Paraíba do Norte River is located between latitudes 06°51'31" and 08°26'21" South, and longitudes 34°48'35" and 37°02'15" North (Lima & Melo 1985, Xavier et al. 2013) (Figure 1). Its area ranges a total of 20,071.83 km² (comprising 32% of the total extension of Paraíba State), and it is considered the second largest hydrographical basin of this State.

Paraíba do Norte River is the most extensive river that drains the Western of Borborema plateau in Northeastern Brazil. Its origin is located in Alto da Serra de Jabitacá (Monteiro municipality), and runs in a Southeast-Northeast direction for about 360 km until it reaches the Atlantic Ocean (Cabedelo municipality). This river crosses over one of the most drought stricken regions of the State (Cairiri Paraibano) and desembogues in the Littoral flatland. This area is characterized by a humid climate and prevalence of typical Atlantic forest vegetation (Silva 2003).

This river basin is divided into three portions, the higher, middle and lower portions. The main river course of the higher portion is named Meio River, and extends from its origin to Boqueirão municipality. Waters from Taperoá River, its main affluent, supply this region. The largest reservoir of this basin, Epitácio Pessoa, is currently located in the junction between these rivers. The middle portion extends from Taperoá River mouth to Paraibinha River confluency, among Itatuba and Natuba municipalities. The lower portion of this river basin begins downstream of this reservoir and extends until the river mouth which runs into the Atlantic Ocean (Lima & Melo 1985, Silva 2013, AESA 2017).

The region surrounding Paraíba do Norte River is characterized by irregular regimes of droughts and floods, semi-arid climate, and impermeable riverbeds in the high and middle portions. These characteristics induce an intermittent superficial water-flow (Silva 2013). Typical Caatinga vegetation prevails in these portions and it is characterized by the presence of deciduous shrubs and xerophytic plants (Simões et al. 2008). Semi-arid climate, type BS'h (warm and dry), has temperature of 26°C and a mean annual precipitation of 600 mm, respectively (Köppen, 1936; Sudene 1990). The lower portion of the basin is situated in the Atlantic forest vegetation with a perennial regime of superficial water-flow. The climate in this portion is humid tropical (*Am*) with temperatures between 24° and 27°C and a mean annual precipitation between 900 and 1800 mm, respectively (Lima & Melo 1985).

2. Data collection

Databases from ichthyological collections of Universidade Federal da Paraíba (UFPB) and Universidade Federal Rio Grande do Norte (UFRN) were accessed for collecting data. Other national and foreign

Ichthyofauna from the Paraíba do Norte River

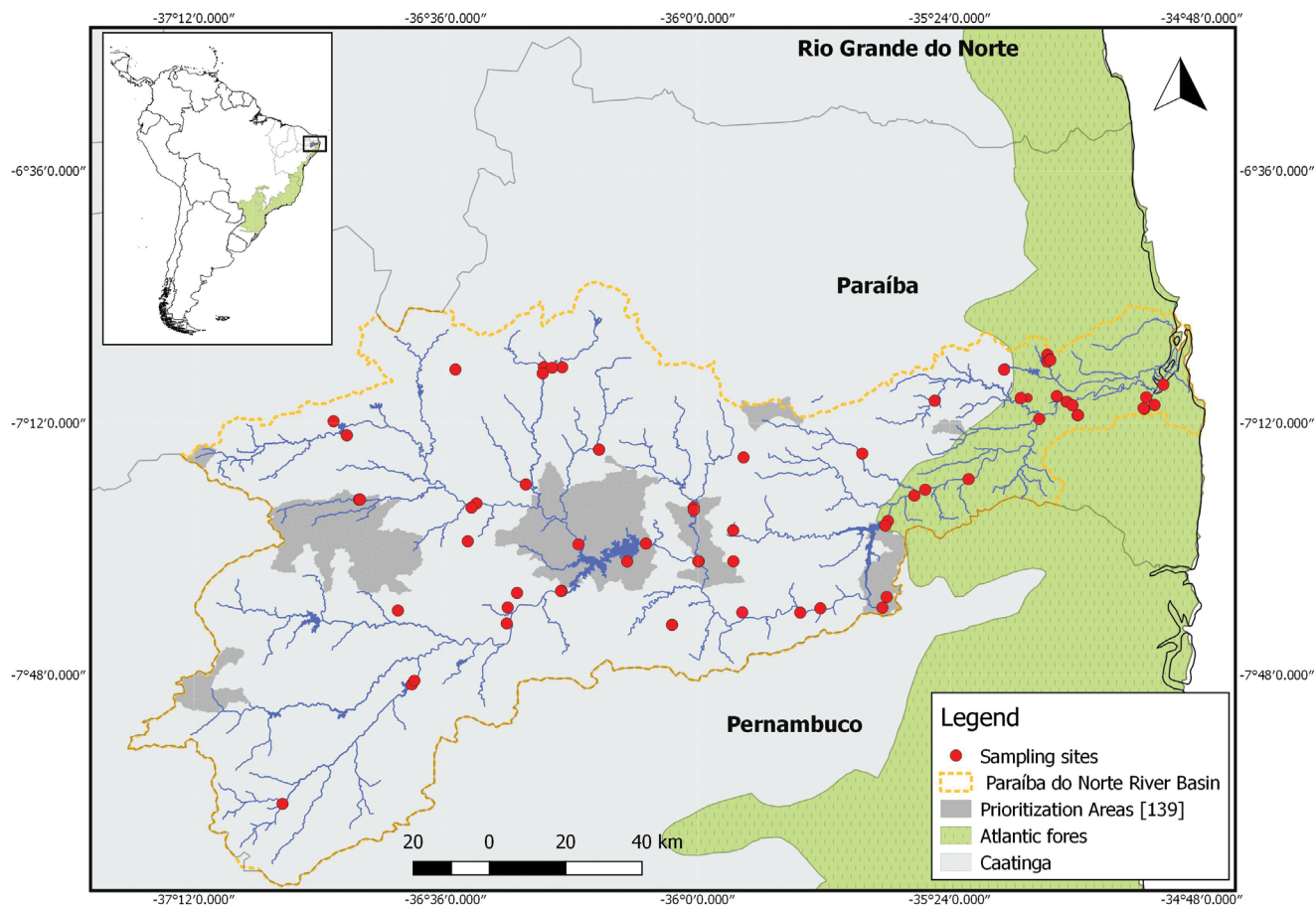


Figure 1. Map of Paraíba do Norte River basin, Paraíba State, Brazil, showing sampling sites.

institutions that bear a variety of representatives from the Neotropical region were also consulted, including: Museu Nacional, Rio de Janeiro (MNRJ), Museu de Zoologia da Universidade de São Paulo (MZUSP), Museu de Ciências e Tecnologia da Pontifícia Universidade Católica do Rio Grande do Sul (MCP), Universidade Federal da Bahia (UFBA), all located in Brazil; Museum of Comparative Zoology, Harvard University (MCZ) and Smithsonian National Museum of Natural History (NMNH) in the U.S.A.; Museum für Naturkunde, Berlin, Germany (ZMB); Muséum National d'Histoire Naturelle, Paris, France (MNHN); Natural History Museum (NHM), London, U.K. Digital database platforms were also accessed for obtaining data: PRONEX/Neodat (<http://www.mnrj.ufrj.br>), Specieslink (www.specieslink.org), GBIF (www.gbif.org), and Portal Biodiversidade/ICMBIO (<https://portaldabiodiversidade.icmbio.gov.br>). However, all the material included in the species list (Table 1) was analyzed and deposited in the UFPB and UFRN collections. Other institutions, whose curators claimed to have material from the studied basin, as well as data obtained from online platforms, did not register any different species when compared to the species found in the collections previously accessed (UFPB and UFRN). Therefore the data were used only to increase the distribution of the samples in the drainage. In total data from 71 sampling points were recorded (Figure 1). Some sampled areas were lacking geographic coordinates, displaying only the name of the municipalities they belonged to. In such cases, we used an approximated coordinate based on the municipality location. For that

reason, we did not present any list with the geographic information of the sampling areas.

Data available in the scientific collections and online databases are results from independent initiatives of a variety of research projects. Thus, these results do not represent equivalent samplings and/or standardized collecting methodology, indicating its unfeasibility on providing comparisons about the abundance of specimens between the collection sites.

A dichotomous identification key was prepared using material held in the fish collections from UFPB and UFRN. Meristic and morphometric data were taken from Hubbs & Lagler (2004). Classification follows Eschmeyer et al. (2018). The conservation status was classified according to the Brazilian lists of endangered species, Portaria nº 445, December 17, 2014 (Brasil 2014), and 'data deficiency' (DD) species lists (ICMBio 2016).

Results

Material from Paraíba do Norte River basin are available in the fish collections at MCT and MCZ only. A total of 47 species of freshwater fishes are recorded and classified into 38 genera, 20 families and six orders (Table 1). There are 22 species of Characiformes that represents 47% of total recorded species, which comprises the largest order in the region (Figure 2). Species of Characiformes are

Table 1. List of Fish species of Paraíba do Norte River basin, Paraíba State, Brazil. Endemic: of MNCE; Allochthonous: introduced from other regions; Autochthonous: native to the region; Exotic: introduced from other countries. DD = deficient data, LC = Last concern, NE = not evaluated, EN = endangered, UFPB = Universidade Federal da Paraíba, UFRN = Universidade Federal do Rio Grande do Norte.

ORDER/Family/Species	Origin	Status	Caatinga	Forest Atlantic	Voucher
CHARACIFORMES					
Prochilodontidae					
<i>Prochilodus brevis</i> Steindachner, 1875	Autochthonous	LC	X		UFPB 04069
Triporthetidae					
<i>Triporthetus signatus</i> (Garman, 1890)	Autochthonous	LC	X	X	UFPB 10600
Anostomidae					
<i>Leporinus piau</i> Fowler, 1941	Autochthonous	LC	X	X	UFPB 03665
<i>Leporinus taeniatus</i> Lütken 1875	Autochthonous	LC	X		UFPB 04167
Characidae					
<i>Astyanax bimaculatus</i> (Linnaeus, 1758)	Autochthonous	LC	X	X	UFPB 03668
<i>Astyanax fasciatus</i> (Cuvier, 1819)	Autochthonous	LC	X	X	UFPB 02888
<i>Cheirodon jaguaribensis</i> Fowler, 1941	Endemic	DD	X	X	UFPB 11194
<i>Compsura heterura</i> Eigenmann, 1915	Autochthonous	LC	X	X	UFPB 11200
<i>Hemigrammus marginatus</i> Ellis, 1911	Autochthonous	LC	X	X	UFPB 11202
<i>Hemigrammus rodwayi</i> Durbin, 1909	Autochthonous	NE	X	X	UFPB 11203
<i>Hemigrammus unilineatus</i> (Gill, 1858)	Autochthonous	NE		X	UFPB 11245
<i>Hyphessobrycon parvellus</i> Ellis, 1911	Autochthonous	LC		X	UFPB 11284
<i>Serrapinnus heterodon</i> (Eigenmann, 1915)	Autochthonous	LC	X	X	UFPB 11283
<i>Serrapinnus piaba</i> (Lütken, 1875)	Autochthonous	LC		X	UFPB 11207
Crenuchidae					
<i>Characidium bimaculatum</i> Fowler, 1941	Endemic		X	X	UFPB 11199
Curimatidae					
<i>Psectrogaster rhomboides</i> Eigenmann & Eigenmann, 1889	Autochthonous	LC	X		UFPB 10607
<i>Steindachnerina notonota</i> (Miranda Ribeiro, 1937)	Autochthonous	LC	X	X	UFPB 11206
Erythrinidae					
<i>Erythrinus erythrinus</i> (Bloch & Schneider, 1801)	Autochthonous	LC		X	UFPB 11247
<i>Hoplerythrinus unitaeniatus</i> (Spix & Agassiz, 1829)	Autochthonous	LC		X	UFPB 11603
<i>Hoplias malabaricus</i> (Bloch, 1794)	Autochthonous	LC	X	X	UFPB 01075
Parodontidae					
<i>Apareiodon davisii</i> Fowler, 1941	Endemic	EN	X	X	UFPB 00741
Serrasalminidae					
<i>Metynnops lippincottianus</i> (Cope 1870)	Autochthonous	LC		X	UFPB 11286
SILURIFORMES					
Callichthyidae					
<i>Callichthys callichthys</i> (Linnaeus, 1758)	Autochthonous	LC		X	UFPB 04077
<i>Megalechis thoracata</i> (Valenciennes, 1840)	Autochthonous	NE		X	UFPB 11246
Auchenipteridae					
<i>Trachelyopterus galeatus</i> (Linnaeus, 1766)	Autochthonous	LC	X		UFPB 03667
Heptapteridae					
<i>Pimelodella enochi</i> Fowler, 1941	Endemic	LC	X		UFRN 00443
<i>Rhamdia quelen</i> (Quoy & Gaimard, 1824)	Autochthonous	LC		X	UFPB 11240
Loricariidae					
<i>Hypostomus puseorum</i> (Starks, 1983)	Endemic	LC	X	X	UFPB 06183

Continuation Table 1.

ORDER/Family/Species	Origin	Status	Caatinga	Forest Atlantic	Voucher
<i>Parotocinclus</i> cf. <i>cearensis</i> Garavello, 1977	Autochthonous	DD	X	X	UFRN 01583
<i>Parotocinclus jumbo</i> Britski & Garavello, 2002	Autochthonous	LC	X		UFPB 04189
<i>Parotocinclus spilosoma</i> (Fowler, 1941)	Endemic	LC	X	X	UFPB 04107
CYPRINODONTIFORMES					
Poeciliidae					
<i>Poecilia reticulata</i> Peters, 1859	Allochthonous	NE	X	X	UFPB 10209
<i>Poecilia vivipara</i> Bloch & Shneider, 1801	Autochthonous	LC	X	X	UFPB 01076
GYMNOTIFORMES					
Gymnotidae					
<i>Gymnotus carapo</i> Linnaeus, 1758	Autochthonous	LC		X	UFPB 11273
GOBIIFORMES					
Gobiidae					
<i>Awaous tajasica</i> (Lichtenstein, 1822)	Autochthonous	LC	X	X	UFPB 04104
Eleotridae					
<i>Eleotris pisonis</i> (Gmelin, 1789)	Autochthonous	LC		X	UFPB 11191
CICHLIFORMES					
Cichlidae					
<i>Astronotus ocellatus</i> (Agassiz, 1831)	Allochthonous	NE	X		UFPB 10605
<i>Cichla monoculus</i> Spix & Agassiz, 1831	Allochthonous	NE	X	X	UFPB 10609
<i>Cichla ocellaris</i> Bloch & Shneider, 1801	Allochthonous	NE	X	X	UFPB 06693
<i>Cichlasoma orientale</i> Kullander, 1983	Endemic	LC	X	X	UFPB 11234
<i>Coptodon rendalli</i> (Boulenger, 1896)	Exotic	NE	X	X	UFPB 02883
<i>Crenicichla menezesi</i> Ploeg, 1991	Autochthonous	LC	X	X	UFPB 11225
<i>Geophagus brasiliensis</i> (Quoy & Gaimard, 1824)	Autochthonous	LC	X	X	UFPB 10619
<i>Oreochromis niloticus</i> (Linnaeus, 1758)	Exotic	NE	X	X	UFPB 09985
<i>Parachromis managuensis</i> (Günther, 1867)	Exotic	NE	X		UFRN 01971
PERCIFORMES					
Sciaenidae					
<i>Plagioscion squamosissimus</i> (Heckel, 1840)	Allochthonous	NE	X		UFPB 09983
SYNBRANCHIFORMES					
Synbranchidae					
<i>Synbranchus</i> sp.	Autochthonous	NE	X	X	UFPB 06245

spread among 17 genera and nine families. No introduced species of Characiformes were verified in this basin. The second largest order is Cichliformes and Siluriformes with 9 species each (representing 19% of total recorded species, each). Cichliformes is divided into eight genera and one family. Six introduced species of Cichliformes were registered (*Astronotus ocellatus*, *Cichla ocellaris*, *Cichla monoculus*, *Coptodon rendalli*, *Parachromis managuensis* and *Oreochromis niloticus*). The nine species of Siluriformes are distributed in seven genera and four families. Cyprinodontiformes and Gobiiformes with two species each, representing 5% of total recorded species. Within of Cyprinodontiformes, *Poecilia reticulata*, is considered an exotic species. Gymnotiformes, Perciformes and Synbranchiformes comprise one species each, representing 2% of total recorded species.

Characidae (Characiformes) is the most diverse family with 10 species (or 21.3% of total recorded species) followed by Cichlidae (Perciformes) and Loricariidae (Siluriformes) with nine and four species corresponding to 19.2% and 8.5% of total recorded species, respectively (Figure 3). Three species of Cichlidae are native to this region. Thus, Loricariidae comprises the second most representative group in the basin when considering only native species. Cichlidae is the third most representative group together with Erythrinidae, both with three species each (6.4% of total recorded species). Anostomidae, Callichthyidae, Curimatidae, Heptapteridae and Poeciliidae two species each, representing 4.3% of total recorded species for each family. Poeciliidae has one introduced species, *Poecilia reticulata*. A single species is verified for each of the other ten families (Auchenipteridae,

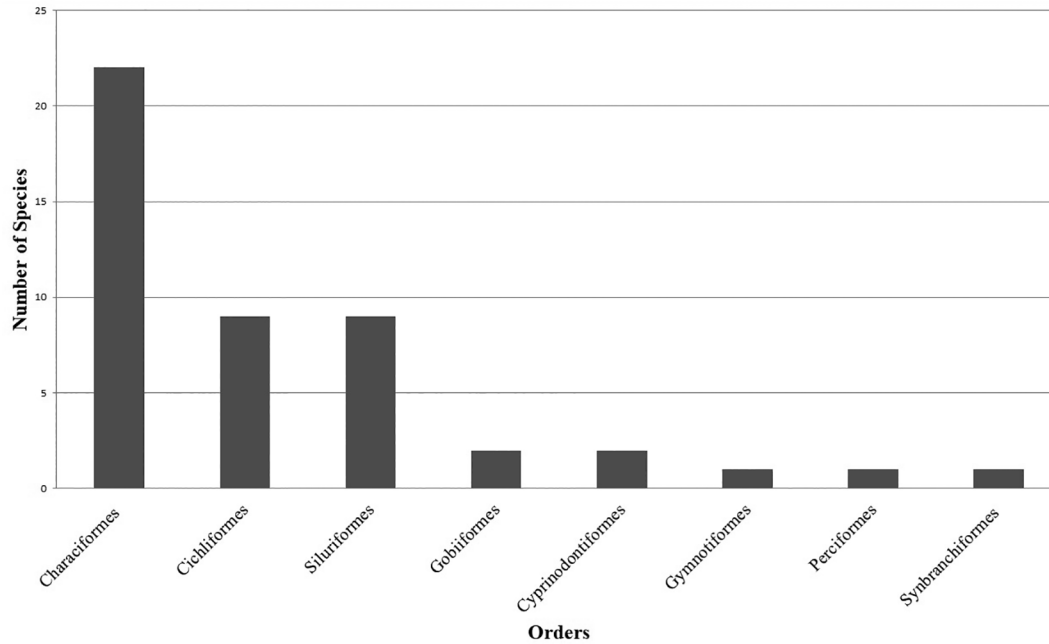


Figure 2. Number of species by order caught in Paraiba do Norte River basin, Paraiba State, Brazil.

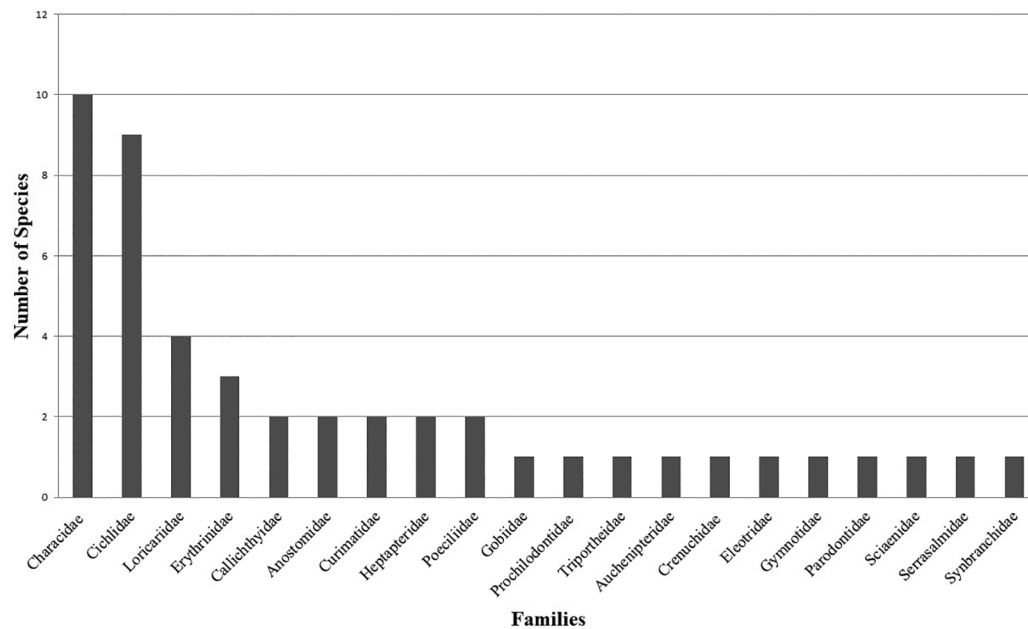


Figure 3. Number of species by family caught in Paraiba do Norte River basin, Paraiba State, Brazil.

Crenuchidae, Eleotridae, Gobiidae, Gymnotidae, Parodontidae, Prochilodontidae, Serrasalminidae, Sciaenidae, Synbranchidae and Triportheidae). *Plagioscion squamosissimus* is also an introduced species that belongs to the family Sciaenidae.

Eight introduced species and 39 native species are observed out of 47 species registered in Paraiba do Norte River basin. A total of 37 native species are exclusively from freshwater environment and two species are marine-estuarine, including *Awaous tajasica* and *Eleotris pisonis*. Seven freshwater species are endemic to the MNCE (*stricto* Rosa et al. 2003) (Table 1), in which *Parotocinclus spilosoma* is endemic to Paraiba do Norte River basin. *Apareiodon davisii* is the only

threatened species among those endemic species from the MNCE. This species is currently classified as “in danger” according to the Official National List of Threatened Faunistic Species – Fishes and Aquatic Invertebrates (Brasil 2014).

Species herein evaluated are recorded from 74 sampling sites distributed throughout the three portions (higher, middle, and lower) of Paraiba do Norte River basin. A total of 5,498 specimens were counted within the 597 sampling sites. Twelve collecting sites are located within the limits of prioritization areas for conservation of the Caatinga biome (Figura 1) and 14 inside the Conservation Units.

The ichthyological collection at UFPB holds the largest number of representatives from Paraíba do Norte River basin with 4,001 specimens available and comprising 46 fish species, and distributed within 396 lots. Thus, it contains 97.9% of total ichthyofauna from the studied basin. UFRN has another important fish collection representing the diversity of the studied basin. It bears 905 specimens available, comprising 28 species (59.6% of total ichthyofauna), and distributed within 142 lots. MCZ has 219 specimens distributed within 30 lots for 30 species (63.8% of total ichthyofauna). MCT holds 366 specimens with 24 lots for 17 species (36.2% of total ichthyofauna). MZUSP only has three lots belonging to the type series of *Parotocinclus jumbo* (MZUSP 69513 – Holotype; MZUSP 69514 and MZUSP 69519 – Paratypes), a species described in Britski & Garavello (2002). The type locality of this species is Paraíba do Norte River, under bridge from PB-408 road, near Umbuzeiro municipality, Paraíba State, Brazil. MNRJ has a single lot from this basin (MNRJ 21924) that is regarded to be the paratype of *P. jumbo*, with same collecting data as the holotype of this species.

Twenty-two native species out of 39 species recorded from the studied basin occur in regions under dominion of both Caatinga and Atlantic forest biomes. Six and 11 species occur exclusively in these biomes, respectively (Table 1). Five exotic species out of eight species recorded in the area occur in both biomes. Three exotic species occur exclusively in the Caatinga biome while no exotic species are found exclusively in the Atlantic forest biome.

Discussion

Paraíba do Norte River basin has 47 fish species that correspond to 54.6% of total ichthyofauna from MNCE and 19.5% of total ichthyofauna from Caatinga biome when compared to the number of species registered in these areas (86 and 240 species, respectively, according to Rosa et al., 2003).

Siluriformes becomes the most representative group when considering only autochthone ichthyofauna. Cichliformes comprises the second most representative order in the region. This result is in agreement with Bizerril (1994), Mazzoni (1998), Castro (1999), Reis et al. (2003), Rosa et al. (2003), Backup et al. (2007), Serra et al. (2007), Albert & Reis (2011), and Ramos et al. (2014) that supported Characiformes and Siluriformes as the group of greatest representation in the neotropical riverine systems. Lowe-McConnell (1999) reported that Siluriformes exceeds Characiformes in number of species in the South American ichthyofauna. However, the taxonomical composition varies in different basins (Bizerril 1994). Characiformes order stands out from those groups in the, Paraíba, São Francisco and Paraná basins. At family level, Characidae and Loricariidae are the most representative groups in the neotropical region when considering native species (Reis et al. 2003, Backup et al. 2007), which is in accordance to the current results for Paraíba do Norte River basin.

One collecting site from this basin is available at the list of species from MCZ. The collectors are Maj. J.M.S. Coutinho and Dr. Justa from the expedition Thayer that occurred between 1865 and 1866 in Brazil under leadership of Louis Agassiz. The collecting site is Paraíba do Norte River near João Pessoa municipality and collecting date is 2 August 1865 (Dick 1977, Higuchi 1996). This material is very valuable because it contributes to the ichthyofauna database from this region prior

to environmental impacts that have since taken place in the Northeast Brazilian region.

Environmental degradation is common in this region, directly affecting the local freshwater ichthyofauna. Anthropogenic changes such as dam constructions, deforestation, implementation of powerplants and distilleries, and distribution of ichthyo-toxics in the natural habitat for eradication of weed species, introduction of allochthonous species, and alterations on river courses are examples. Reduction of fish populations or extinction of local species may have occurred due to these anthropic interferences (Rosa et al. 2003). Introduction of exotic species is also very common in Northeast Brazil (Leão et al. 2011, Levis et al. 2013) as observed in other areas of the country (Gomes et al. 2008, Biagioni et al. 2013, Frota et al. 2016). Many allochthonous species were intentionally introduced in this region through national campaigns from the Departamento Nacional de Obras Contra a Seca (DNOCS) in the 1930 decade, especially in the MNCE basin. Tucunaré (*Cichla ocellaris* and *C. temensis*) and pescada-do-Piauí (*Plagioscion squamosissimus*), originally from Amazonas and Paraíba basins respectively, are examples of introduced species through DNOCS campaigns. African tilapias (*Oreochromis niloticus* and *Coptodon rendalli*) (Gurgel & Fernando 1994, Reaser et al. 2005, Paiva & Mesquita 2013) are also examples of species introduced through DNOCS. *Parachromis managuensis* is registered for the first time in Paraíba do Norte River basin at Soledade dam. This Cichlidae species is originally from the east side of Central America (Conkel 1993), and has been introduced in many countries, including Brazil (Agasen et al. 2006, Barros et al. 2012). Barbosa et al. (2006) first recorded *P. managuensis* in Northeast Brazil at the middle portion of São Francisco River. It piscivorous and aggressive species that reaches up to 65 cm total length (Conkel 1993, Barbosa et al. 2006, Barros et al. 2012).

Metynnis lippincottianus, known locally as “peixe CD”, is reported to occur at the lower portion of Paraíba do Norte River basin according to the fishing community. This species was previously recorded in other regional basins such as Gramame in Paraíba State (Beltrão et al. 2009), Pratagi (Paiva et al. 2014), Maxaranguape, Ceará-Mirim and Pirangí River basins (Nascimento et al. 2014), all located in Rio Grande do Norte State. Beltrão et al. (2009) considers *M. lippincottianus* as an introduced species in Gramame River basin. However, other authors recognize it as a native species from Northeast river basins Canan & Gurgel (1997), Rosa et al. (2003), Morais et al. (2012), Nascimento et al. (2014), and Paiva et al. (2014). *Metynnis roosevelti* Eigenmann, 1915 is usually cited in many studies although this species has been considered a junior synonym of *M. lippincottianus* (Cope 1870) in Zarske & Géry (1999). The oldest record of *Metynnis* in the MNCE region is provided in Starks (1913) as *M. maculatus* (Kner 1858), collected in Papary lake, Trairi River basin, Rio Grande do Norte State. The species was collected 20 years prior to the introduction of fish species in the region as described earlier in this study. There is no species from this genus listed as introduced species from the Northeast region (Leão et al. 2011, Levis et al. 2013, Gurgel & Oliveira, 1987). Thus, *M. lippincottianus* is supported herein as a non-introduced species in the MNCE region.

Two marine-estuarine species were observed at the studied basin, *Awaous tajasica* and *Eleotris pisonis*. These species have broad distributions along the Brazilian coast, and occasionally occur in the freshwater environment (Kullander 2003). It is important to notice that the first species also occurs in the Caatinga biome, which is an

area outside the Atlantic forest region. Another important record is the presence of the, *Cheirodon jaguaribensis*, described from Jaguaribe River, Ceará State in Fowler (1941) and considered restricted to this basin (Reis et al. 2003, Buckup et al. 2007). However, the current results also recognize this species to occur in Paraíba do Norte River basin. Occurrences of this species in other basins within the MNCE ecoregion in Teixeira et al. (2017) and Gouveia et al. (2017) indicate that *C. jaguaribensis* is not restricted to the Jaguaribe River.

There are seven official Conservation Units (UCs) in Paraíba do Norte hydrographic network: Parque Estadual do Poeta e Repentista Juvenal de Oliveira (419,51 ha), Parque Estadual Mata do Xém-Xém (182,00 ha), Área de Proteção Ambiental (APA) do Cariri (18.560,00 ha), Área de Proteção Ambiental (APA) das Onças (36.000,00 ha) all under State supervision; and three private reserves, including Reservas Particular do Patrimônio Natural (RPPN), RPPN Fazenda Almas (3.505,00 ha), RPPN Fazenda Santa Clara (750,50 ha) and RPPN Fazenda Pacatuba (266,53 ha) with a total of 59.685,54 ha of protected land. There are fish records in RPPN Fazenda Almas and Fazenda Pacatuba, and at the Parque Estadual Mata do Xém-Xém. Twenty-seven species were recorded from the UCs, comprising 71% of the native ichthyofauna of Paraíba do Norte River basin.

The source of the Paraíba do Norte River is located at Serra de Jabitacá, a region known to also separate water to the Pajeú River sub-basin which is an affluent from the São Francisco River. Paraíba do Norte River basin shares 20 native species with São Francisco River basin out of 38 native species recognized in the present study. Ten species originally from this basin were introduced at MNCE basins: *Brycon hilarii* (Valenciennes, 1850), *Conorhynchos conirostris* (Valenciennes, 1840), *Franciscodoras marmoratus* (Lütken, 1874), *Megaleporinus elongatus* (Valenciennes, 1850), *Myleus micans* (Lütken 1875), *Pachyurus francisci* (Cuvier, 1830), *Pachyurus squamipennis* Agassiz, 1831 and *Pimelodus maculatus* Lacepède, 1803 (Gurgel & Oliveira 1987). Neither of these species was recorded in the Paraíba do Norte river basin in this work.

Water transposition between different river basins has contributed to impacts in the diversity and abundance of local fish fauna (Izique 2005). Transposition of waters from São Francisco River to MNCE basins aimed to supply water for local populations that suffer from regular drought crises due to intermittent river flows. Paraíba do Norte (Paraíba), Apodi-Mossoró (Rio Grande do Norte), Jaguaribe (Ceará) and Piranhas-Açu (Paraíba, Rio Grande do Norte) river basins were connected artificially to water channels from São Francisco River (Pitcock et al. 2009). The first basin to receive waters from this process was Paraíba do Norte River basin, and thus it has its regime changed to perennial. According to Moreira-Filho & Buckup (2005), changes in species composition and abundance are imminent after water transposition took place. Consequences include competition among species, propagation of populations over others, and possibly extinction of native species.

The current inventory of freshwater fish species from Paraíba do Norte River basin is of importance as it provides an updated list of the local ichthyofauna, and contributes to the improvement of the knowledge about the diversity and evolutionary history of freshwater fish species from the region. The current study also provides an ichthyological overview of its composition prior to systemic anthropic interferences in the environment through the water transposition from

São Francisco River, which will contribute to future comparative studies for understanding the environmental changes in the region.

Supplementary material

The following online material is available for this article:

Appendix: Identification key to fish species from Paraíba of North River basin

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Author Contributions

Telton Pedro Anselmo Ramos: participated in the data collection, wrote the text and confirmed the identifications.

Jéssica Alcoforado de Sena Lima: participated in the data collection and wrote the text.

Silvia Yasmin Lustosa Costa: participated in the data collection and wrote the text.

Márcio Joaquim da Silva: participated in the data collection and wrote the text.

Raizze da Costa Avellar: participated in the data collection and wrote the text.

Leonardo Oliveira-Silva: participated in the data collection and wrote the text.

Conflicts of interest

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

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