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Article

Ichthyofauna of the Mamanguape river basin, Northeastern, Brazil

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Abstract: The Mamanguape River Basin is located in a peripheral semi-arid area of South America, with its headwaters and middle reaches running through the Caatinga (from wetter to drier) and its lower reaches through the Atlantic Forest. The objective of this study was to inventory the fish fauna of the Mamanguape river basin through a comprehensive sampling and to discuss its ichthyofaunal dominance pattern. Sampling was conducted between 2015 and 2016 at 38 points throughout. The main river course was sampled at 18 fixed points during two expeditions (dry and wet seasons) using traw nets, cast nets, and dip nets, with a standardized effort. The tributaries were sampled during the dry season at 20 points using an adaptaptation of the AquaRAP methodology. A total of 32 freshwater fish species belonging to 26 genera, 16 families and six orders were recorded, predominantly from the order Characiformes and the family Characidae. *Astyanax fasciatus* had widest distribution and greatest abundance in the basin. Siluriformes were the second most prevalent order, with five species recorded. *Cichla* cf. *monoculus*, *Poecilia reticulata* and *Oreochromis niloticus* were non-native records for the basin. *Apareiodon davisi*, an Endangered species, was recorded.
Keywords: *Neotropical Region, Brazilian Semiarid, Freshwater Fish, Species List, Dominance, Endemism.*

Ictiofauna da bacia do rio Mamanguape, Nordeste, Brasil

Resumo: A bacia do rio Mamanguape está situada numa área periférica do semiárido, suas nascentes e porção média correndo em área de domínio da Caatinga – de mais úmida a mais seca, e sua porção baixa em área de Mata Atlântica. O estudo teve por objetivo inventariar a fauna de peixes da bacia do rio Mamanguape, através de uma amostragem abrangente de suas drenagens, e discutir o padrão de dominância de sua ictiofauna. O trabalho de coleta foi realizado entre os anos de 2015 e 2016, em 38 pontos distribuídos em toda a bacia. Dezoito pontos foram amostrados ao longo do curso principal do rio (Pontos Fixos), em duas expedições (seca e cheia), através de arrasto, tarrafa e puçá, com esforço padronizado. Os afluentes foram amostrados durante a estação seca, em 20 pontos, utilizando-se uma adaptação da metodologia AquaRap. Foram registradas 32 espécies de peixes de água doce pertencentes a 26 gêneros, 16 famílias e seis ordens, com predominância da ordem Characiformes e da família Characidae, sendo *Astyanax fasciatus* a espécie de maior distribuição e abundância na bacia. Siluriformes foi a segunda ordem de maior predominância, com cinco espécies. *Cichla* cf. *monoculus*, *Oreochromis niloticus* e *Poecilia reticulata* constituíram registros de introdução na bacia; foi registrada *Apareiodon davisi*, uma espécie ameaçada de extinção (Em Perigo).
Palavras-chave: *Região Neotropical, Semiárido brasileiro, Peixes de Água-Doce, Lista de Espécies, Dominância, Endemismo.*

Introduction

The greatest diversity of freshwater fish in the world is found in the Neotropics (Albert & Reis 2011), and Brazil contains approximately 43% of this diversity (Buckup et al. 2007). Reis et al. (2016) report 5,617 described neotropical freshwater fish species. Given that Reis et al. (2003) listed 4,475 described species, there has been a significant advance in the taxonomic knowledge of neotropical ichthyofauna, with approximately 28% of the ichthyofauna described in the last eleven years. Approximately 100 species have been described per year, and estimates suggest a total of roughly 9,000 neotropical freshwater fish species (Reis et al. 2016). However, there is still a lack of information on the composition and distribution of this fauna in certain regions of Brazil such as the many coastal basins in the Northeast region which is part of the Northeastern Caatinga and Coastal Drainages ecoregion (NCCD, sensu Abell et al. 2008). Sampling efforts in these regions are needed to increase the level of knowledge about the composition of these fish fauna and to support an understanding of their historical patterns, as suggested by Langeani et al. (2009).

The Mamanguape River Basin in the NCCD ecoregion is an example of an area with a poorly known freshwater fish taxocene. A single previous study was conducted in the basin (Rosa & Groth 2004), aiming to evaluate the number of species occurring in Brejos de Altitude (high altitude rainforest enclaves occurring in semiarid zone of Northeastern Brazil, Prado 2003) of the States of Paraíba and Pernambuco. However, no list of fish species to the that river basin was provided. The Mangaguape River basin is one of many small systems that drain to the Atlantic Ocean, and as most northeastern Brazilian coastal drainages, it is influenced by different morphoclimatic zones such as the Caatinga and the Atlantic Forest (Andrade 1997; Langeani et al. 2009). The basin is located in the peripheral region of South America, which is highlighted by Albert et al. (2011) as an area with low species richness but with high degree of endemism. The objective of the present study was to produce a comprehensive freshwater fish survey of the Mamanguape river basin and to provide an understanding on the dominance of fish groups along the basin.

Material and Methods

1. Study area

The Mamanguape River Basin has its headwaters located on the eastern slope of the Borborema mountain range, at a mesoregion named Agreste (characterized by a more humid Caatinga, as defined by Prado 2003), and extends towards the northern coast of Paraíba State, where it flows to the Atlantic Ocean. It drains an area of 3,525.00 km², and is bordered by the Curimataú and Camaratuba River Basins on the North, by the Paraíba do Norte and Miriri River Basins on the West and South, and by the Atlantic Ocean on the East (CERH/PB 2004). Two-thirds of the basin are under the influence of a semi-arid climate, which causes intermittent flow regime in most of the basin. Pools of varying sizes remains along the river bed when the flow is interrupted. The river is perennial near the coast, where the basin is influenced by tributaries from wetter areas (Andrade 1997). In the present study, the basin was classified into reaches (Upper, Middle and Lower) according with the variation of the relief and vegetation as suggested by Andrade (1997). The Upper Reaches comprise areas with elevations between 600 and 200 meters, and the vegetation is predominantly humid Caatinga, which is more arborescent and typical of Brejos; the Middle Reaches comprise areas with elevations between 200 and 70 meters and the vegetation is dry Caatinga, which is more shrubby and is typical of the Agreste; the Lower Reaches comprise areas with elevations below 70 meters associated to remnants of the Atlantic Forest (excluding estuarine domain).

2. Data collection

Sampling was performed at 38 collection points; 18 of which were distributed along the main river (named Fixed Points), and 20 were distributed along the northern and southern tributaries of the basin (named AquaRAP points) (Figure 1, Table 1). The18 points along the main river were sampled during the wet season (September to October 2015) and the dry season (February to August 2016) using a trawl net (4 m long, 5 mm mesh), a cast net (15 mm mesh) and a dip net (5 mm mesh) with a standardized number of throws for each method of collection. The sampling of the tributaries was conducted during the months of February and March of 2016 using the same tools but following the adaptation of Willink et al. (2000)'s AquaRAP methodology: the three collection tool were used when the site's characteristic allowed its use the most frequent circumstance; when the collection site was restricted, only dip net was used. During the AquaRAP survey, some tributaries or their reaches closer to the headwaters were not sampled due to lack of access or pools. Sampling was permitted by ICMBio/SISBIOthroughlicense #48004-1/2015. The specimens were anesthetized with eugenol (10 ml of eugenol in 90 ml of ethyl alcohol, Lucena et al. 2013), fixed in 10% formalin for 2 to 8 days, and then transferred to a 70% ethanol solution (Malabarba & Reis 1987). Sorting and taxonomic identification of specimens and subsequent labeling was performed at the Laboratório de Sistemática e Morfologia de Peixes of the Federal University of Paraíba (LASEP/UFPB). Available material from the study area deposited at UFPB Ichthyological Collection but not collected during the field work was included in the list of species (SR, secondary records of table 2). Specimens were photographed in the field and in the laboratory. After identification, the lots were registered and deposited in the UFPB Ichthyological Collection (number of voucher specimens in Table 2).

3. Data analysis

Sampling effectiveness was evaluated using a rarefaction curve (Colwell et al. 2012). Richness was assessed using bootstrap (Efron 1979) estimator. A heatmap (Singh et al. 2011) was generated using a species presence/absence matrix to provide a visual profile of occurrence throughout the basin. For this visualization, points were ordered according to the position in the basin (Upper, Middle and Lower Reaches) and were identified by the abbreviations FP (Fixed Point, mainstream wet and dry season data) or AP (AquaRAP Point) added the number of the collection point. The analysis used the *vegan, indicspecies, cluster* and *gplots* packages in R (R Development Core Team 2015). The statistical analyses and subsequent results consider only the 29 species sampled. The species list follows the classification order of Nelson et al. (2016).

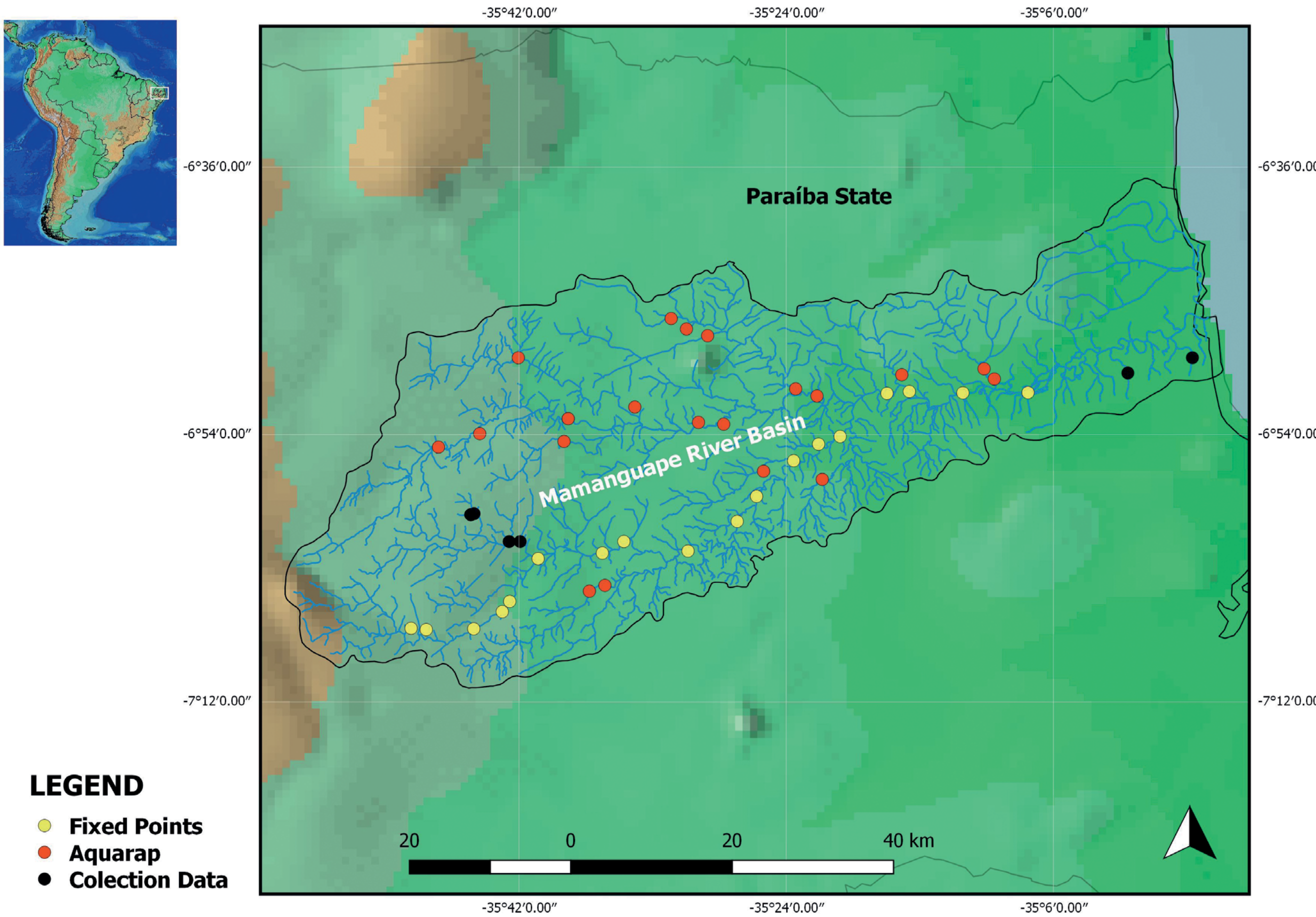

Figure 1. Distribution of the sampling points in the Mamanguape River Basin, State of Paraíba, Brazil.

Results

A total of 26,805 specimens of 29 species, 24 genera, 14 families and six orders were collected (Table 2, figures 2 and 3). *Callichthys callichthys*, *Gymnotus* cf. *carapo*, and *Hemigrammus unilineatus*, were not sampled in the present study, but had been previously recorded in the UFPB Ichthyological Collection. Thus, the total number of taxa recorded from the basin is 32 species, 26 genera, 16 families and six orders.

Visual inspection of the rarefaction curve shows that the asymptote was reached (Figure 4), indicating an effective sampling of the studied area. The richness estimator yielded numbers of species approximately equal to that recorded in the field (29): boot, 28.8. Figure 5 shows that the different sampling approaches used in different areas of the basin produced similar results. The pattern of species dominance observed in the main river, which was sampled at fixed points during the wet and dry seasons, was similar to that of the tributaries, which were sampled by AquaRAP during the dry season.

Seven families were recorded from the order Characiformes, comprising 15 species and 52% of the species collected (including introduced species); one family was recorded from the order Cichliformes, comprising five species (two introduced) and 17% of the registered species; and two families were recorded from the order Siluriformes, comprising four species (12.5%) (Table 2). Characidae was the family with the highest species richness (nine species or 31%), followed by Cichlidae (five species, 17%), Loricariidae (three species, 9%) and Poeciliidae (two species, 6%). Only one species was recorded from each of the other families, each representing 3% of the total species richness (Table 2).

Eight individuals of *Apareiodon davisi,* a threatened species (Endangered, according to Portaria nº 445, December 17, 2014) (Brasil 2014), were recorded at five sampling points in areas of perennial flow or high to moderate flow (FP18, AP4, AP11, AP12 and AP14) and were recorded in all three reaches of the basin. Three exotic species were recorded to the Mamanguape River Basin: two from the family Cichlidae, the tucunaré *Cichla* cf. *monoculos* and the tilápia (or Xilapo, Xilapa) *Oreochromis niloticus*, and the guarú (or Barrigudinho) *Poecilia reticulata* (Poeciliidae). Two undescribed species of the genus *Parotocinclus* were recorded. *Parotocinclus* sp. 1, sampled at Upper and Middle Reaches (FP3, FP6 and FP7) of the main river, and *Parotocinclus* sp. 2, sampled at a single point in the Middle Reaches, the Jacaré River (AP11), one of the major tributaries of the basin. *Apareiodon davisi*, *Cheirodon jaguaribensis* and *Hypostomus pusarum* are endemic to the NCCD (Rosa et al. 2003).

The species *Astyanax bimaculatus, Astyanax fasciatus, Characidium bimaculatum, Cheirodon jaguaribensis, Cichlasoma orientale, Compsura heterura, Geophagus brasiliensis, Hoplias malabaricus, Hypostomus pusarum, Leporinus piau, Poecilia reticulata, Poecilia*

Table 1. Municipalities, elevation (m), and geographical coordinates of the 38 collection points distributed throughout the Mamanguape river basin.

Collect point	Municipalities	Elevation	Geographical Coordinates
FP1	Lagoa Seca	494	07°07'13"S, 035°49'34"W
FP2	Lagoa Seca	495	07°07'22"S, 035°48'32"W
FP3	Matinhas	321	07°07'16"S, 035°45'12"W
FP4	Matinhas	269	07°06'01"S, 035°43'20"W
FP5	Matinhas	239	07°05'32"S, 035°42'70"W
FP6	Alagoa Grande	151	07°02'44"S, 035°40'78"W
FP7	Alagoa Grande	133	07°02'06"S, 035°36'46"W
FP8	Alagoa Grande	119	07°01'28"S, 035°35'01"W
FP9	Mulungu	111	07°01'92"S, 035°30'69"W
FP10	Mulungu	94	06°59'93"S, 035°27'38"W
FP11	Mulungu	97	06°58'24"S, 035°26'07"W
FP12	Guarabira	69	06°55'84"S, 035°23'57"W
FP13	Araçagi	59	06°54'73"S, 035°21'89"W
FP14	Araçagi	45	06°54'21"S, 035°20'44"W
FP15	Itapororoca	25	06°51'31"S, 035°17'28"W
FP16	Itapororoca	36	06°51'19"S, 035°15'78"W
FP17	Mamanguape	17	06°51'27"S, 035°12'17"W
FP18	Mamanguape	20	06°51'25"S, 035°07'78"W
AP1	Areia	546	06°54'93"S, 035°47'50"W
AP2	Areia	445	06°54'02"S, 035°44'72"W
AP3	Solânea	434	06°48'91"S, 035°42'14"W
AP4	Pilões	208	06°51'42"S, 035°34'61"W
AP5	Pilões	458	06°54'55"S, 035°39'04"W
AP6	Pilões	390	07°04'89"S, 035°38'12"W
AP7	Alagoa Grande	233	07°04'99"S, 035°37'96"W
AP8	Pirpirituba	106	06°46'97"S, 035°30'79"W
AP9	Pirpirituba	103	06°46'27"S, 035°31'82"W
AP10	Pirpirituba	196	06°47'43"S, 035°29'37"W
AP11	Guarabira	109	06°53'38"S, 035°28'28"W
AP12	Cuitegi	101	06°53'26"S, 035°29'98"W
AP13	Alagoa Grande	173	07°04'21"S, 035°36'19"W
AP14	Itapororoca	87	06°50'06"S, 035°16'29"W
AP15	Araçagi	69	06°51'00"S, 035°23'44"W
AP16	Mulungu	88	06°57'10"S, 035°21'64"W
AP17	Mamanguape	43	06°49'65"S, 035°10'74"W
AP18	Mamanguape	61	06°50'34"S, 035°10'05"W
AP19	Araçagi	62	06°51'48"S, 035°22'03"W
AP20	Mulungu	68	06°56'55"S, 035°25'60"W

Table 2. List of freshwater fish species of the Mamanguape River Basin identified in the present study: (I) Introduced; (T) Threatened; (SR) Secondary record (i.e., not collected during the present study).

ORDER/Family/*species*	N	VOUCHER
CHARACIFORMES		
Parodontidae		
Apareiodon davisi Fowler, 1941(T)	7	UFPB 10919
Curimatidae		
Steindachnerina notonota Miranda-Ribeiro, 1937	1901	UFPB 10736
Prochilodontidae		
Prochilodus brevis Steindachner, 1875	11	UFPB 10706
Anostomidae		
Leporinus piau Fowler, 1941	53	UFPB 10731
Crenuchidae		
Characidium bimaculatum Fowler, 1941	683	UFPB 10910
Characidae		
Astyanax bimaculatus (Linnaeus, 1758)	2220	UFPB 10690
Astyanax fasciatus (Cuvier, 1819)	9683	UFPB 10691
Compsura heterura Eigenmann, 1915	1991	UFPB 10699
Cheirodon jaguaribensis Fowler, 1941	784	UFPB 10717
Hemigrammus marginatus Ellis, 1911	370	UFPB 10784
Hemigrammus rodwayi Durbin, 1909	352	UFPB 10782
Hemigrammus unilineatus (Gill, 1858)(SR)	28	UFPB 11208
Hyphessobrycon parvellus Ellis, 1911	250	UFPB 10825
Serrapinnus heterodon (Eigenmann, 1915)	3297	UFPB 10822
Serrapinnus piaba (Lutken, 1875)	739	UFPB 10818
Erythrinidae		
Hoplias malabaricus (Bloch, 1794)	143	UFPB 10901
SILURIFORMES		
Callichthyidae		
Callichthys callichthys (Linnaeus, 1758)(SR)	3	UFPB 4534
Loricariidae		
Hypostomus pusarum (Starks, 1913)	60	UFPB 10776
Parotocinclus sp.1	11	UFPB 10064
Parotocinclus sp.2	18	UFPB 10500
Heptapteridae		
Rhamdia quelen (Quoy & Gaimard, 1824)	24	UFPB 10766
GYMNOTIFORMES		
Gymnotidae		
Gymnotus cf. *carapo* Linnaeus, 1758(SR)	1	UFPB 5686
CYPRINODONTIFORMES		
Poeciliidae		
Poecilia reticulata Peters, 1859(I)	1130	UFPB 10744
Poecilia vivipara Bloch & Schneider, 1801	2310	UFPB 10752

Continued Table 2.

ORDER/Family/*species*	N	VOUCHER
SYNBRANCHIFORMES		
Synbranchidae		
Synbranchus aff. *marmoratus* Bloch, 1795	6	UFPB 10801
CICHLIFORMES		
Cichlidae		
Cichla cf. *monoculus* Agassiz, 1831[I]	6	UFPB 10075
Cichlasoma orientale Kullander, 1983	136	UFPB 10753
Crenicichla menezesi Ploeg, 1991	70	UFPB 10788
Geophagus brasiliensis (Quoy & Gaimard, 1824)	455	UFPB 10837
Oreochromis niloticus (Linnaeus, 1758)[I]	88	UFPB 10904
GOBIIFORMES		
Gobiidae		
Awaous tajasica (Lichtenstein, 1822)	5	UFPB 10784
Eleotridae		
Eleotris pisonis (Gmelin, 1789)	2	UFPB 10812

vivipara, Serrapinnus heterodon, Serrapinnus piaba and *Steindachnerina notonota* are distributed throughout the drainage network and form the main cluster in the heatmap (Figure 5, cluster 1). In contrast, the heat map shows that some species were restricted to individual collection points such as *Parotocinclus* sp. 2, recorded at point AP11, and *Eleotris pisonis*, collected at point FP18 (clusters 6 and 7, respectively). *Rhamdia quelen* and *Synbranchus* cf. *marmoratus*, although collected at only four and six points, respectively, were recorded in all three Reaches of the basin (clusters 2 and 6, respectively). *Awaous tajasica* occurred only in the lower reaches (cluster 4), whereas *Parotocinclus* sp. 1 occurred in the upper and lower reaches (cluster 2). The introduced species *Cichla* cf. *monoculus* was recorded at only two points in the lower reaches (cluster 4), and *Oreochromis niloticus* was recorded at six points in the middle and lower reaches (cluster 5).

The primary group produced by the heatmap (cluster 1) consisted of fifteen species belonging to eight families: Characidae (6 species), Cichlidae (2 species), Poeciliidae (2 species), Anostomidae (1 species), Crenuchidae (1 species), Curimatidae (1 species), Erythrinidae (1 species) and Loricariidae (1 species). The family Characidae had the broadest distribution and was the most common family in the entire basin, with one or more species present at 35 of 38 collection points. At the Fixed Points, which had more regular and extensive sampling, Characidae had an average of 30% of the species occurring in the three reaches. The species *Astyanax bimaculatus*, *Astyanax fasciatus*, *Compsura heterura, Serrapinnus heterodon* and *Serrapinnus piaba*, which occurred in all three reaches, co-occurred at 14 points (36.8% of the points). The species *Cheirodon jaguaribensis*, *Hyphessobrycon parvellus* and *Hemigrammus rodwayi* co-occurred with one or more species of Characidae at seventeen, ten and six points, respectively, whereas *Hemigrammus marginatus* co- occurred with other Characidae at five points, but only in the lower reaches (Figure 5).

Discussion

Although two sampling methods were employed (Fixed Points in both wet and dry seasons vs. AquaRAP in the dry season) and performed in different areas of the basin (main river vs. tributaries), the results showed a similar pattern of species occurrence for both methods in both areas of the basin. This reinforces the existence of such patterns of distribution, as indicated by the heatmap. The pattern of species occurrence in the main river (higher frequency by collection point) may be due to the greater sampling effort: all gear types were used at all collection points, and a higher number of throw per gear type vs. selective gear used depending on the environmental structure. Moreover, the total mainstream sampling área was greater (greater volume of water sampled) than that of the tributaries, given the greater channel width and the formation of larger pools in themainstream.

The species grouped in the main cluster (cluster 1) were generalists, as is common for small fishes (Pelicice & Agostinho 2006, Fiori et al. 2016), or piscivorous such as *Hoplias malabaricus* (Rodrigues et al. 2017). *Prochilodus brevis*, a specialist detritivore (mud eaters – Silva et al. 2010), occurred only in the lower and middle reaches of the basin. Ramos (2012), citing the River Continuum Concept (Vannote et al. 1980), suggested the higher occurrence of detritivores, such as those of the genus *Prochilodus*, should be expected in the lower reaches of the basin, which have a larger amount of accumulated material in the river bottoms. Consistent with this prediction, the heatmap shows that *Prochilodus brevis* is more abundant in the lower reaches. *Awaous tajasica* and *Eleotris pisonis* were among the less common species and were collected only in the Lower Reaches of the main river. These two species are widely distributed in the coastal region of South America and are of marine-estuarine origin (Pezold & Cage 2002, Sarmento- Soares 2007). *Poecilia reticulata* and *P. vivipara* are widely distributed, the first was introduced into neotropical freshwater environments by release from aquariums or from use as controller of biological vectors (Ramos 2012).

Rosa et al. (2003) emphasized that Siluriformes dominate over Characiformes in the ecoregions under the influence of the Caatinga (101 *vs*. 89 species), a statement also made by Lima et al. 2017 (143 *vs*. 132). However, it differs from the results of the present study, with 16 species distributed in seven families of Characiformes, whereas the Siluriformes are represented by five species belonging to three families (Callichthyidae, Loricariidae and Heptapteridae). In all the previously surveyed basins in NCCD, it was recorded a similar pattern of species composition in which the number of Siluriformes is smaller than those of Characiformes: in the Curimataú basin (12 characiform *vs*. one siluriform species, Ramos et al. 2005), in the Seridó basin (21 *vs*. 6, Silva et al. 2014), in a general survey of the ichthyofauna of the Rio Grande do Norte State basins (21 *vs*. 6, Nascimento et al. 2004) and in a survey of the ichthyofauna of the Mundaú River (16 *vs*. 6, Teixeira et al. 2017); the same was recorded in Parnaíba ecoregion (59 *vs*. 48, Ramos et al. 2014) and in Northeastern Mata Atlântica ecoregion (91 *vs*. 75, Camelier & Zanata, 2014). Only in the

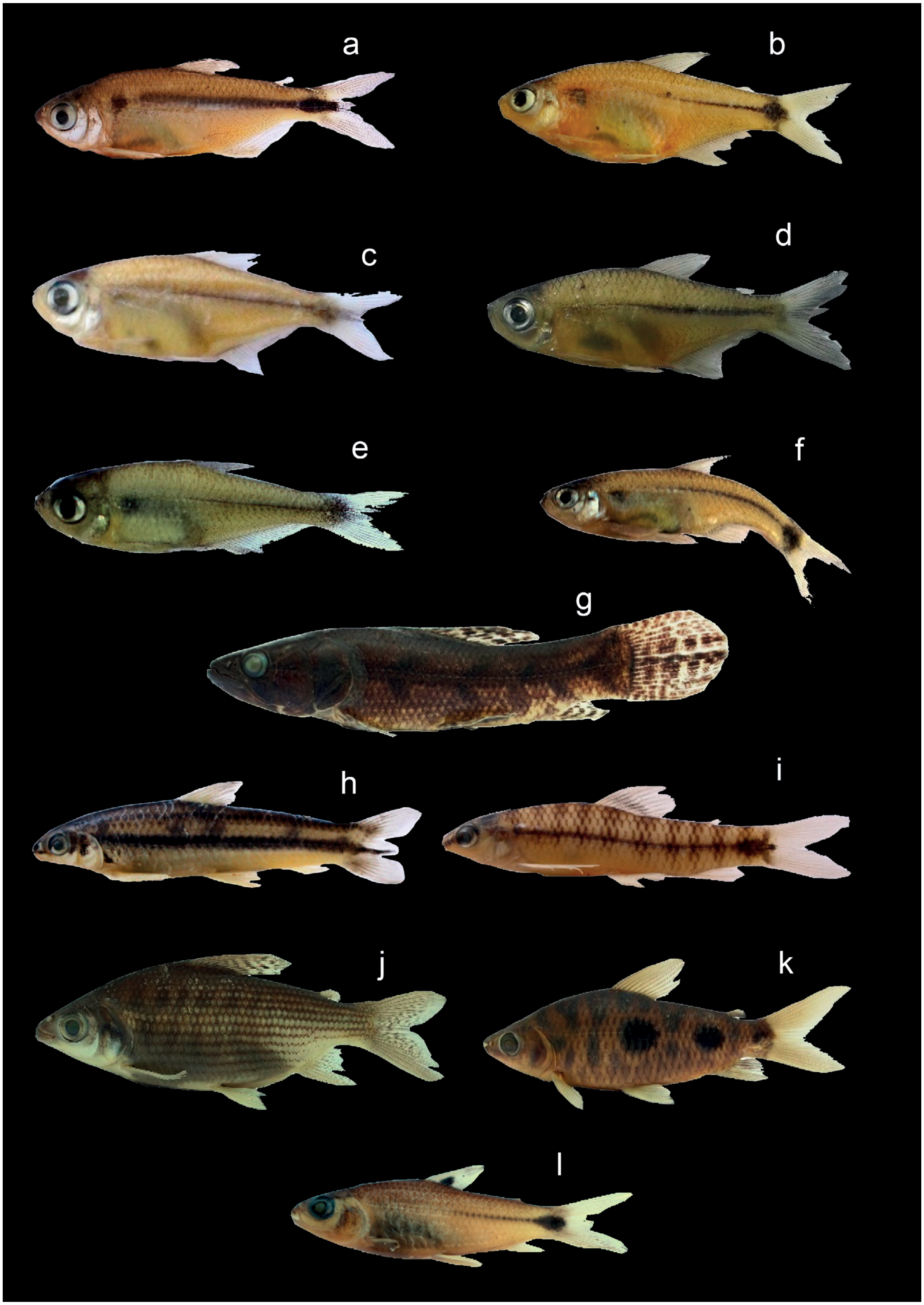

Figure 2. Species of the order Characiformes collected in the Mamanguape River Basin. a) *Astyanax fasciatus* (58.3 mm SL), b) *Compsura heterura* (39.2 mm SL), c) *Cheirodon jaguaribensis* (41.3 mm SL), d) *Hemigrammus marginatus* (38.8 mm SL), e) *Hyphessobrycon parvellus* (33.8 mm SL), f) *Serrapinnus heterodon* (35.6 mm SL), g) *Hoplias malabaricus* (105.5 mm SL), h) *Apareiodon davisi* (71.8 mm SL), i) *Characidium bimaculatum* (34.6 mm SL), j) *Prochilodus brevis* (98.5 mm SL), l) *Leporinus piau* (83.8 mm SL), m) *Steindachnerina notonota* (68.9 mm SL).

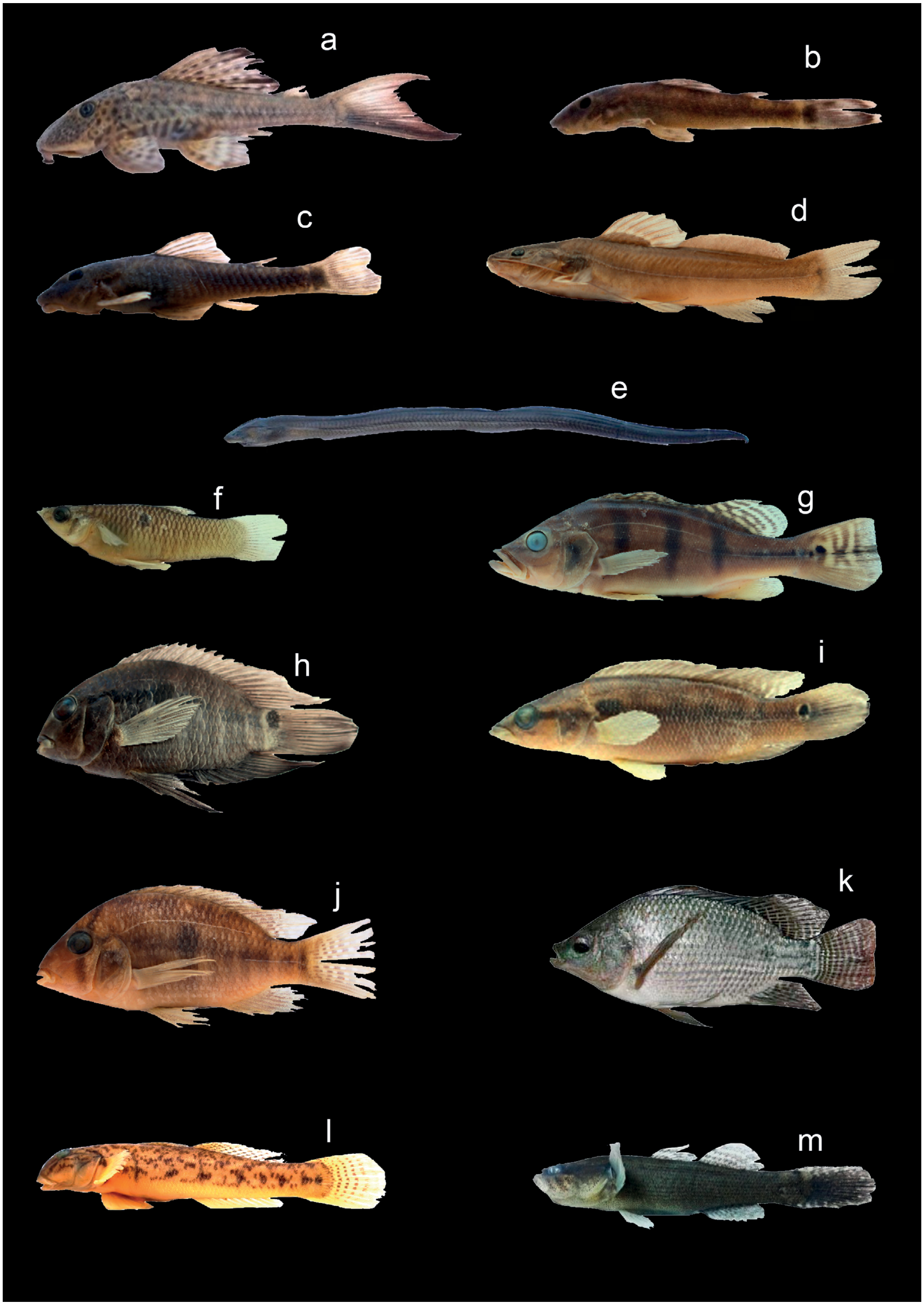

Figure 3. Species belonging to the orders Siluriformes: a) *Hypostomus pusarum* (102.4 mm SL), b) *Parotocinclus* sp.1 (38.3 mm SL), c) *Parotocinclus* sp.2 (41.1 mm SL), d) *Rhamdia quelen* (104.5 mm SL); Synbranchiformes: e) *Synbranchus* aff. *marmoratus* (178.8 mm SL); Cyprinodontiformes: f) *Poecilia vivipara* (28.6 mm SL); Cichliformes: g) *Cichla* cf. *monoculus* (91.7 mm SL), h) *Cichlasoma orientale* (81.3 mm SL), i) *Crenicichla menezesi* (89.6 mm SL), j) *Geophagus brasiliensis* (97.8 mm SL), l) *Oreochromis niloticus* (102.3 mm SL); and Gobiiformes: m) *Awaous tajasica* (113.5 mm SL), n) *Eleotris pisonis* (89.4 mm SL), collected in the Mamanguape River Basin.

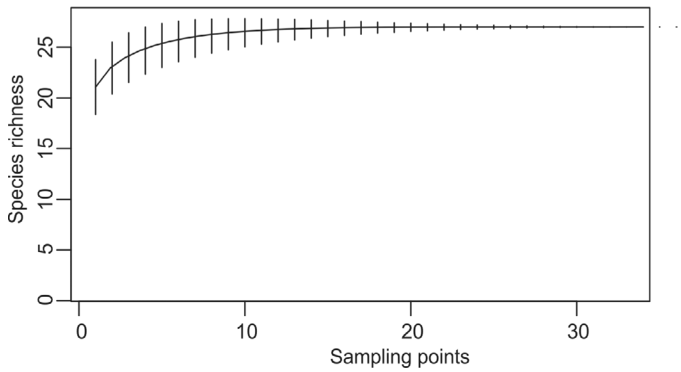

Figure 4. Rarefaction curve generated from the species abundance matrix for the Mamanguape River Basin. Vertical bars represent the confidence interval.

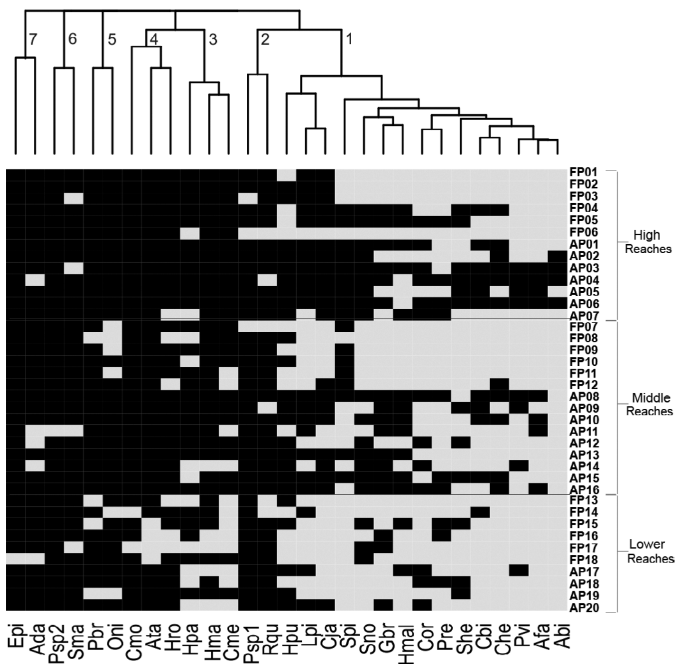

Figure 5. Heatmap generated from the species presence/absence matrix for the Mamanguape River Basin. Black represents the absence of species, and gray represents the presence of species. FP – fixed point; PA – AquaRap point. Epi = *Eleotris pisonis*; Ada = *Apareiodon davisi*; Psp2 = *Parotocinclus* sp2; Sma = *Synbranchus* cf. *marmoratus*; Pbr = *Prochilodus brevis*; Oni = *Oreochromis niloticus*; Cmo = *Cichla* cf. *monoculus*; Ata = *Awaous tajasica*; Hro = *Hemigrammus rodwayi*; Hpa = *Hyphessobrycon parvellus*; Hma = *Hemigrammus marginatus*; Cme = *Crenicichla menezesi*; Psp1 = *Parotocinclus* sp1; Rqu = *Rhamdia quelen*; Hpu = *Hypostomus pusarum*; Lpi = *Leporinus piau*; Hja = *Cheirodon jaguaribensis*; Spi = *Serrapinnus piaba*; Sno = *Steindachnerina notonota*; Gbr = *Geophagus brasiliensis*; Hmal = *Hoplias malabaricus*; Cor = *Cichlasoma orientale*; Pre = *Poecilia reticulata*; She = *Serrapinnus heterodon*; Cbi = *Characidium bimaculatum*; Che = *Compsura heterura*; Pvi = *Poecilia vivipara*; Afa = *Astyanax fasciatus*; Abi = *Astyanax bimaculatus*.

São Francisco ecoregion Siluriformes dominate over Characiformes (85 *vs*. 77 species) (Barbosa et al. 2017). The above observations suggest that instead of the pattern of species dominance recorded in the whole Caatinga (Rosa et al. 2003, Lima et al. 2017), when comparing the dominance of Siluriformes and Characiformes in each particular basin of this domain, no siluriform dominance is recorded. In truth, the particular basins seem to include a relatively larger number of endemic siluriform than endemic characiform species to each of them, explaining the apparent dominance of Siluriformes when the numbers of the Caatinga basins are put together. However, it should be only a differential effect of the peripheral high level of endemism of South America (Albert et al. 2011) which is larger in Siluriformes than in Characiformes in each particular basin of the Caatinga domain, although the dominance pattern of the basins running in a large part of the Caatinga reveals a Characiform dominance.

Among the recorded species, only *Apareiodon davisi* is listed as endangered (Brasil 2014), with distribution restricted to points with perennial flow. This species, and the entire family Parodontidae, prefers environments with more turbulent waters, where it lives in proximity to the substrate (Graça & Pavanelli 2007). Ramos et al. (2005), Medeiros et al. (2006; 2010) and Costa et al. (2017) recorded this species in lentic environments at Seridó and Paraíba do Norte rivers, which are rocky residual environments within intermittent rivers and are probably lotic during the flood period, which is consistent with the observations reported by Graça & Pavanelli (2007). This species was considered endemic to the coastal drainages of the mid-northeastern Caatinga (Rosa et al. 2003), which corresponds to the Caatinga region of the NCCD. The occurrence of *A. davisi* is currently recorded for the Jaguaribe, Piranhas-Açu, Paraíba do Norte, Curimataú, Ipojuca (Reis et al. 2003, Ramos et al. 2005, Costa et al. 2017, ICMBio 2017) and Mamanguape (present study) rivers. *Characidium bimaculatum*, previously considered to be endemic to NCCD (Rosa et al. 2003), is known from records in the São Francisco ecoregion (Melo & Espindola 2016) and possibly from Parnaíba basin (Ramos et al. 2014, listed as *Characidium bimaculatum*).

Some surveys of the freshwater fish of the NCCD ecoregion have been published, usually with limited sampling efforts or partial evaluating of the fish fauna composition. Rosa & Groth (2004), as mentioned above, surveyed a limited area of the Mamanguape River Basin but did not report the presence or abundance of species. Ramos et al. (2005) recorded 22 species in the Curimataú River Basin. The same richness (22 species) was observed by Torelli et al. (1997) and Gomes-Filho & Rosa (2001) in the Gramame River drainage (Paraíba State). Silva et al. (2014) recorded 35 species in the middle reaches of the Piranhas-Açu River Basin (Paraíba and Rio Grande do Norte States); Paiva et al. (2014) recorded 13 species in the Pratagi River Basin (Rio Grande do Norte State). The richness recorded in the present study, (32 species) apparently reflects a good estimate of the local fish fauna composition, as indicated by the estimators used. Moreover, the sampling showed a consistent pattern of ichthyofaunal composition for both the main course and its tributaries (Figure 5) despite different sampling methods.

Albert et al. (2011) state that the periphery of South America is characterized by low species richness and a high level of endemism (in contrast to central South America's core of high diversity and low endemism). Rosa et al. (2003) mentioned 30 endemic species occurring in the named Nordeste Médio-Oriental ecoregion (sensu Rosa et al. 2003). When characterizing this ecoregion, the authors describe it as a hydrographic region of the Caatinga domain (Rosa et al. 2003: 140), although they acknowledge that species can occur outside of this domain, in upper and low stretches of the rivers, and highlights that endemism is stated for the ecoregion, not for the domain (Rosa et al. 2003: 137). Albert et al. (2011) listed 38 endemic

Figure 6. Human impacts recorded in the Mamanguape River Basin. a) removal of riparian vegetation (FP10), b) silted section from which sand was removed to form an artificial pool (FP2), c) at the bottom, upper right corner of the photo is a sand dredging tower (see arrow, AP12), d) animal rearing and disposal of garbage (see arrows, FP8).

species in the NCCD. Among the species considered endemic to this ecoregion *Apareiodon davisi*, *Cheirodon jaguaribensis* and *Hypostomus pusarum* (according to Rosa et al. 2003, Reis et al. 2003, and Buckup et al. 2007) were recorded in the Mamanguape River basin.

Reis et al. (2016) treated the NCCD and Parnaíba ecoregions as a unit termed Northeast Atlantic basin complex (ecoregions 325 and 326 of Abell et al. 2008, respectively) based on a low species diversity (<200 species). The authors documented 65 endemic species in their proposed basin complex. However, the authors did not cite Ramos et al. (2014), which recorded 146 species in the Parnaíba basin, 54 of which endemic. Addionally, Silva et al. (2015) surveyed the Gurgueia river, the main tributary of the Parnaíba basin. Adding their list to the survey carried out by Ramos et al. (2014) of Parnaíba basin, established its ichthyofauna as composed of 152 species. Rosa et al. (2003) cite a diversity of 82 species, 30 endemic to the NCCD, whereas Albert et al. (2011) proposed to the same region a list of 88 species, 38 of which endemic. Recent descriptions have added six more endemic species to the ecoregion: *Anablepsoides cearensis* (Costa & Vono 2009), *Hypostomus sertanejo* Zawadzki, Ramos & Sabaj 2017, *Hypsolebias longignatus* Costa 2008, *H. faouri* Britzke, Nielsen & Oliveira 2016, *Parotocinclus seridoensis* Ramos, Barros-Neto, Britski & Lima 2013 and *Serrapinnus potiguar* Jerep & Malabarba 2014, bringing the total to 94 species, 44 of which are endemic. In addition to the number of occurrence and endemic species of the Parnaíba (152/54; Ramos et al. 2014; Silva et al. 2015) and NCCD ecoregions (94/44, present compilation), the number of species is 246 with 98 endemic species. Thus, the two ecoregions should be treated separately, based on the criterion used by Reis et al. (2016). In this case, the number of endemic species is considerable, which corroborates the results of Albert et al. (2011).

In the field, it was possible to observe the direct result of human action on the environment, primarily at the margins of rivers and streams. The suppression of riparian vegetation, the development of agricultural practices, the dredging of sand from the river bed and the breeding of animals were the most evident human activities. Elimination of riparian vegetation was observed throughout the Mamanguape basin, primarily in the middle and lower reaches (Figure 6). This habitat modification, besides of other harms imposed to the ecossistem, opens the area for human activities, which further compromises the stability of the system as previously mentioned by Andrade (1997). The damage to the river's health and to the organisms inhabiting it caused by the removal of riparian vegetation is already well explored in the literature (Sweeney et al. 2004; Casatti et al. 2009; Teresa & Casatti 2010; Cruz et al. 2013).

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Author Contributions

Katherine Morais Porto Viana, Raizze da Costa Avellar: contributed with data collection.

Leonardo Oliveira Silva: contributed with data collection, manuscript preparation, data analysis and interpretation.

Robson da Costa Tamar Ramos: contributed with the manuscript preparation, data analysis and interpretation.

Telton Pedro Anselmo Ramos: contributed with data collection, and data analysis and interpretation.

Yuri Gomes Ponce Carvalho-Rocha: contributed with data collection, and data analysis and interpretation.

Conflicts of interest

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

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