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ARTICLE

Continental fishes from the Tambaba Environmentally Protected Area, Paraíba State, Brazil

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Abstract. Tambaba environmentally protected area is situated on the south coast of Paraíba State, within the Atlantic forest biome of the northeastern region in Brazil. The Tambaba environmentally protected area consists of a series of independent drainages: Graú, Mucatú, and Bucatú river micro-basins, and Caboclo River sub-basin that belongs to Gurugi River micro-basin. Ichthyological samples were collected in five scientific expeditions between months of June and July in 2015. Twenty-nine sites from different habitats (*e.g.,* spanning tributaries, streams, rivers, and estuaries) were accessed for sampling. A total of 44 species distributed within 38 genera, 25 families, and 17 orders were assigned to the Tambaba hydrographic region. Freshwater species comprised 36% (n = 16) and marine-estuarine species 64% (n = 28) of the total collected specimens. Two invasive species occur in the freshwater sites: *Cichla monoculus* and *Poecilia reticulata. Cheirodon jaguaribensis, Cichlasoma orientale,* and *Crenicichla brasiliensis* are endemic to the Brazilian Northeast region with the first species restricted to the Northeast Caatinga and Coastal drainages hydrographic ecoregion.

Key-Words. Atlantic forest ichthyofaunal; Endemism; Northeastern Caatinga, Coastal Drainages.

INTRODUCTION

The Atlantic Florest originally extended from the Rio Grande do Norte State (Northeastern region of Brazil) to the Rio Grande do Sul (Southern region) in Brazil. Throughout its distribution exhibits several types and subtypes of tropical and subtropical forests, comprising the second largest forest in South America (Gouveia *et al.,* 2017). Preservation and conservation of the Atlantic Forest rivers and ichthyofauna are imperative due to its high endemicity rate (*e.g.,* Gomiero & Braga, 2006; Oyakawa *et al.,* 2006; Menezes *et al.,* 2007; Miranda, 2012; Gouveia *et al.,* 2017) and exclusive ecological characteristics (*e.g.,* Barbosa & Costa, 2012; Pereira *et al.,* 2012). Menezes *et al.* (2007) listed 325 freshwater fish species for a portion of Atlantic forest in the Brazilian southeastern region. These authors called attention to the lack of taxonomic data related to the fish fauna for the Atlantic forest in the Brazilian northeast region; Abilhoa *et al.* (2011) recorded 269 freshwater species for streams in this region through data taken from the literature, and Camelier & Zanata (2014) recognized 169 native freshwater species for the northeastern Atlantic Forest ecoregion. Many species were recently described within this region (Barbosa & Costa, 2012; Pereira *et al.,* 2012; Zanata & Pitanga, 2016; Craig *et al.,* 2017; de Pinna *et al.,* 2018; Burger *et al.,* 2019) with achievements of several related studies on the systematics and biogeography of the continental ichthyofauna of the Forest Atlantic.

The Atlantic forest biome requires conservation efforts through the creation of conservation

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units (UCs) throughout its area of extension in relation to its high diversity and accelerated loss and fragmentation of the original habitat (Almeida, 2016). Despite having the largest number of environmentally protected areas among the South American regions and increased creation of reserves and natural parks in recent years, the conservation effort in the area is still insufficient (Tabarelli *et al.,* 2005; Almeida, 2016). Tambaba environmentally protected area (APA) is situated on the south coast of Paraíba State in Northeast Brazil within the Atlantic forest biome. This conservation unit (UC) was regulated in 2002 through the State Act (№ 22.882) and assigned to the category of conservation unities for sustainable use in order to guarantee compatibility between the sustainable usage of the natural resources and nature conservation as defined in the principal action plan for effective protection of the local fauna and flora (Costa, 2002).

A complex of small littoral hydrographic basins covers the hydrography of the Tambaba Environmentally Protected Area, located in the Northeastern Caatinga and Coastal Drainages – NCCD ecoregion (*sensu* Abell *et al.,* 2008). Several studies focused on assessing the ichthyofauna of hydrographic basins from the NCCD (*e.g.,* Rosa *et al.,* 2003; Ramos *et al.,* 2005; Paiva *et al.,* 2014; Silva *et al.,* 2014; Rodrigues-Filho *et al.,* 2016; Teixeira *et al.,* 2017; Gouveia *et al.,* 2017; Oliveira-Silva *et al.,* 2018; Ramos *et al.,* 2018). However, with exception to Paiva *et al.* (2014) and Gouveia *et al.* (2017), the diversity of fishes within the Atlantic forest biome of this ecoregion was not yet investigated. Thus, the present study aimed to provide an inventory of the ichthyofauna from the river basins present in the Tambaba Environmentally Protected Area, contributing towards the taxonomic knowledge related to the fish fauna of the Atlantic Forest biome in the NCCD ecoregion.

MATERIAL AND METHODS

Study area

Tambaba Environmentally Protected Area is located in the micro-region of the south coast of Paraíba State, Brazil between 07°25'00"S and 07°16'30"S and 34°55'00"W and 34°47'30"W, incorporating the municipalities of Conde, Pitimbú, and Alhandra within the Mata Paraibana mesoregion (Almeida *et al.,* 2008). It comprises 114,46 km² of total area extension, with its geographical limits defined by the local hydrographic basins (Fig. 1).

Graú, Mucatú and Bucatú river micro-basins and the Caboclo River sub-basin with the latter belonging to the Gurugi River micro-basin are located in the Tambaba Environmentally Protected Area (AESA, 2004). Graú River basin has 18,304 km of extension and its main course discharges at the north of Bela beach between Pitimbu and Conde municipalities. Mucatú River micro-basin has 9,690 km of extension and releases in the estuary of Bela beach in Pitimbu municipality. Bucatu River micro-basin extends approximately 3,265 km and it comprises a small drainage system located on the coast of Tabatinga beach in Conde municipality. Caboclo River sub-basin, a tributary of Gurugi River basin, comprises 6,435 km of extension and discharges in the main course of Gurugi River that later discharges at Jacumã beach in Conde municipality.

Data collection

Five scientific expeditions were undertaken in the hydrographic basins in Tambaba Environmentally Protected Area in June (three) and July (two) 2015. Sampling took place at 29 sites covering streams, rivers and estuaries in the municipalities of Alhandra, Conde, and Pitimbu (Fig. 1, Table 1). Of these, 13 sampling sites are located at Graú River basin, seven to Mucatú River basin, five to Bucatú River basin and four to the Caboclo River sub-basin in the Gurugi River basin. Specimens from the fish collection of Universidade Federal da Paraíba (UFPB) were also examined.

Specimens were collected using seine nets (4 m length, 5 mm mesh size; 10 m length, 5 mm mesh size; 20 m length, 12 mm mesh size), cast nets (20 mm mesh size), gillnets (10 m length, 20 mm mesh size) and dip nets (5 mm mesh size). Specimens were then anesthe-

Table1. List of sampling sites in the Tambaba APA, Paraíba State, Brazil.

ID	Sampling sites	Geographical Coordinates
1	Mucatú stream, Mucatú village, Pitimbu	07°23'19.1"S; 34°51'41.0"W
2	Stream in Mucatú village, Pitimbu	07°23'06.0"S; 34°51'52.1"W
3	Graú River, under bridge at PB-008 road, Pitimbu	07°21'04.2"S; 34°49'04.4"W
4	Andreza River, Andreza village, Pitimbu	07°20'38.2"S; 34°50'52.3"W
5	Tributary of Andreza River, Pitimbu	07°20'51.4"S; 34°50'44.5"W
6	Tributary of Graú River, PB-008, Pitimbu	07°22'19.9"S; 34°49'19.0"W
7	Riacho do Boi stream, tributary of Mucatú River, Pitimbu	07°24'37.2"S; 34°50'45.7"W
8	Riacho do Boi stream, tributary of Mucatú, Nova Vida village, Pitimbu	07°24'18.1"S; 34°50'16.0"W
9	Riacho do Boi stream, tributary of Mucatú River, Pitimbu	07°24'04.1"S; 34°49'58.6"W
10	Estuary of Graú River, Pitimbu	07°22'42.4"S; 34°48'16.3"W
11	Graú River mouth, Bela beach, Pitimbu	07°23'13.6"S; 34°48'13.7"W
12	Mucatú River, Pitimbu	07°23'36.1"S; 34°49'57.7"W
13	Graú River, Pitimbu	07°20'52.1"S; 34°48'47.7"W
14	Tributary of Graú River, between Mata do Chica and Igarapú villages, Alhandra	07°19'09.6"S; 34°53'21.5"W
15	Igarapú River, Alhandra	07°18'38.9"S; 34°54'14.2"W
16	Tributary of Graú River, Alhandra	07°20'03.0"S; 34°53'34.7"W
17	Tributary of Graú River. Alhandra	07°20'09.9"S; 34°52'29.4"W
18	Graú River, under bridge of Alhandra road – Jacumã, Alhandra	07°20'18.5"S; 34°51'53.4"W
19	Jangada stream, tributary of Graú River, Pitimbu	07°20'50.1"S; 34°51'18.9"W
20	Estuary of Mucatú River, Bela beach, Pitimbu	07°23'57.8"S; 34°48'21.0"W
21	Left side of source from Bucatú River, Conde	07°19'37.6"S; 34°49'22.3"W
22	Bucatú River, Conde	07°19'18.0"S; 34°48'46.2"W
23	Right side of source from Bucatú River, Conde	07°18'22.0"S; 34°49'09.9"W
24	Estuary of Bucatú River, under bridge of PB-008 road, Conde	07°18'48.1"S; 34°48'30.4"W
25	Estuary of Bucatú River, Tabatinga beach, Conde	07°18'43.5"S; 34°48'09.0"W
26	Tributary of Caboclo River, Conde	07°17'42.0"S; 34°50'14.9"W
27	Tributary of Caboclo River, Conde	07°18'13.8"S; 34°50'22.9"W
28	Caboclo River, tributary of Gurugi River, Conde	07°18'22.0"S; 34°50'34.5"W
29	Caboclo River, tributary of Gurugi River, Conde	07°17'44.9"S; 34°50'18.4"W

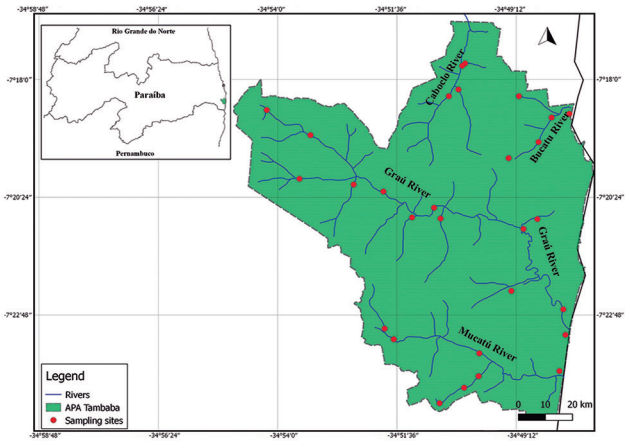

Figure 1. Map of Tambaba environmentally protected area (green area) in Paraíba State, Brazil, displaying the sampling sites (red dots) in Graú, Mucatú and Bucatú River basins, Caboclo River sub-basin and Gurugi River basin.

tized in eugenol solution diluted in alcohol and water, and then transferred to 10% formaldehyde for fixation. Later, scientific curatorial standards were undertaken such as specimen fixation in formaldehyde for a minimum of eight days, preservation in 75° GL ethyl alcohol solution, lot and specimen labeling, according to the methods of Malabarba & Reis (1987). Photographs of fresh specimens were taken whenever possible using a digital camera model Canon PowerShot SX60 HS. Sorting and taxonomic identification of specimens and subsequent labeling were performed at the Laboratório de Sistemática e Morfologia de Peixes of the Universidade Federal da Paraíba (LASEP/UFPB). Lots and specimens were registered and deposited at the UFPB Ichthyological Collection. Species identification was based on studies of Araújo *et al.* (2004), Britski *et al.* (1984), Figueiredo & Menezes (2000), Kullander (1988), Ploeg (1991), Ramos (2012) and Ramos *et al.* (2018). Taxonomic classification follows Fricke *et al.* (2019).

RESULTS

A total of 36 species were identified through examination of 1,124 specimens collected in the Tambaba APA (Figs. 2, 3, 4, and 5). In addition, eight species were identified based on the analysis of 54 specimens (23 lots) from the UFPB fish collection collected in the Graú River estuary in 2014. Thus, 44 species are recognized in the Tambaba APA hydrographic basins and are classified within 38 genera, 25 families, and 17 orders (Table 2). Of these, 36% (n = 16) are from freshwater and 64% (n = 28) are from estuarine-marine sites. *Cichla monoculus* Spix & Agassiz, 1831, the "tucunaré", and *Poecilia reticulata* Peters, 1859 are invasive species in the freshwater sites. *Cheirodon jaguaribensis* Fowler, 1941, *Cichlasoma orientale* Kullander, 1983, and *Crenicichla brasiliensis* (Block, 1792) are endemic to the Brazilian northeast region, in which the first species is restricted to the NCCD hydrographic ecoregion.

The most abundant freshwater species in the hydrographic basins in Tambaba Environmentally Protected Area are: *Hemigrammus unilineatus* (Gill, 1858) (32% of total collected specimens), *Poecilia vivipara* Bloch & Schneider, 1801 (27%) and *Astyanax* aff. *bimaculatus* (Linnaeus, 1758) (11%). *Poecilia vivipara* is a broadly distributed species that occurrs in 19 out of 29 sampling sites, and it is followed by *Geophagus brasiliensis* (Quoy & Gaimard, 1824) that occurs in 13 sampling sites and *Astyanax bimaculatus* and *Hoplias* aff. *malabaricus* (Bloch, 1794) in 12 sampling sites. Characiformes are the largest freshwater order with seven species (16% of total), with Characidae being the most speciose family represented by four autochthonous species. Cichliformes is the second largest freshwater order representing 9% of total collected species (n = 4), three autochthonous and one allochthonous species, all belonging to the family Cichlidae.

Atherinella brasiliensis (Quoy & Gaimard, 1825) (with 8%), *Mugil curema* Valenciennes, 1836 (3%), and *Eucinostomus argenteus* Baird & Girard, 1855 (3%) correspond to the most abundant estuarine-marine species. Perciformes is the largest marine-estuarine order, representing 20% (9 species) while Gobiiformes is the second largest order with 14% of total species (n = 6), of which Gobiidae is the most speciose family (n = 4) among the marine-estuarine representatives.

Other orders comprise Pleuronectiformes with 9%, Cyprinodontiformes, Tetraodontiformes and Syngnathiformes 5% each, Atheriniformes, Blenniiformes, Clupeiformes, Gymnotiformes, Myliobatiformes, Mugiliformes, Siluriformes and Synbranchiformes have one species each, representing 4% of the total species (Table 2).

Among the species recognized herein, none are currently classified as threatened species, according to the official list of threatened species of fishes and aquatic invertebrates from Brazil, Portaria MMA № 445, 17 December 2014, Ministério do Meio Ambiente (Brasil, 2014). *Gymnura micrura* (Bloch & Schneider, 1801), and *Lutjanus jocu* (Bloch & Schneider, 1801) are classified as Near Threatened (NT), and *Cheirodon jaguaribensis,* and *Mugil curema* are classified as Data Deficient (DD) (Brasil, 2014).

DISCUSSION

Freshwater fish species from Tambaba Environmentally Protected Area represent 16% (n = 15) of the 94 total species for the NCCD ecoregion (Oliveira-Silva *et al.,* 2018). Studies that were previously carried out in the nearby areas such as Torelli *et al.* (1997) and Gomes-Filho & Rosa (2001) listed 22 and 21 freshwater species, respectively, in Gramame River basin within the NCCD ecoregion of the Atlantic forest biome. These authors recognized a higher number of freshwater species than those observed for Tambaba Environmentally Protected Area and this discrepancy is probably due to differences in the historical evolution factors of these drains or sampling efforts. Paiva *et al.* (2014) recognized 22 species of which 13 are freshwater species in the

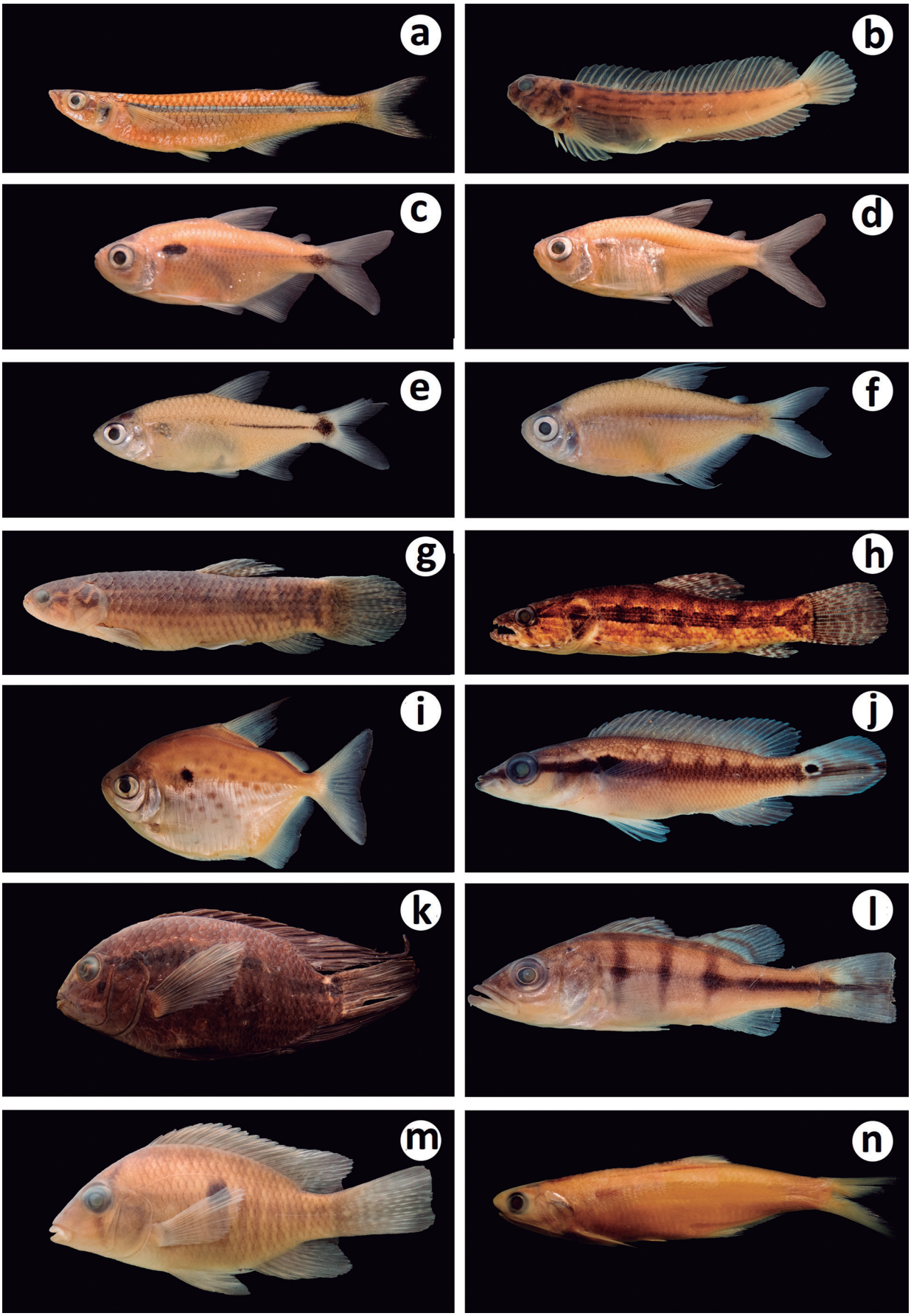

Figure 2. Species from Tambaba APA hydrographic basins: (a) *Atherinella brasiliensis,* 98.2 mm SL; (b) *Omobranchus punctatus,* 39.4 mm SL; (c) *Astyanax* aff. *bimaculatus,* 42.1 mm SL; (d) *Hemigrammus unilineatus,* 29.5 mm SL; (e) *Compsura heterura,* 27.7 mm SL; (f) *Cheirodon jaguaribensis,* 32.3 mm SL; (g) *Erythrinus erythrinus,* 91.6 mm SL; (h) *Hoplias* aff. *malabaricus,* 59.3 mm SL; (i) *Metynnis lippincottianus,* 51.7 mm SL; (j) *Crenicichla brasiliensis,* 35.3 mm SL; (k) *Cichlasoma orientale,* 60.6 mm SL; (l) *Cichla monoculus,* 55.6 mm SL; (m) *Geophagus brasiliensis,* 54.8 mm SL; (n) *Lycengraulis grossidens,* 60.3 mm SL.

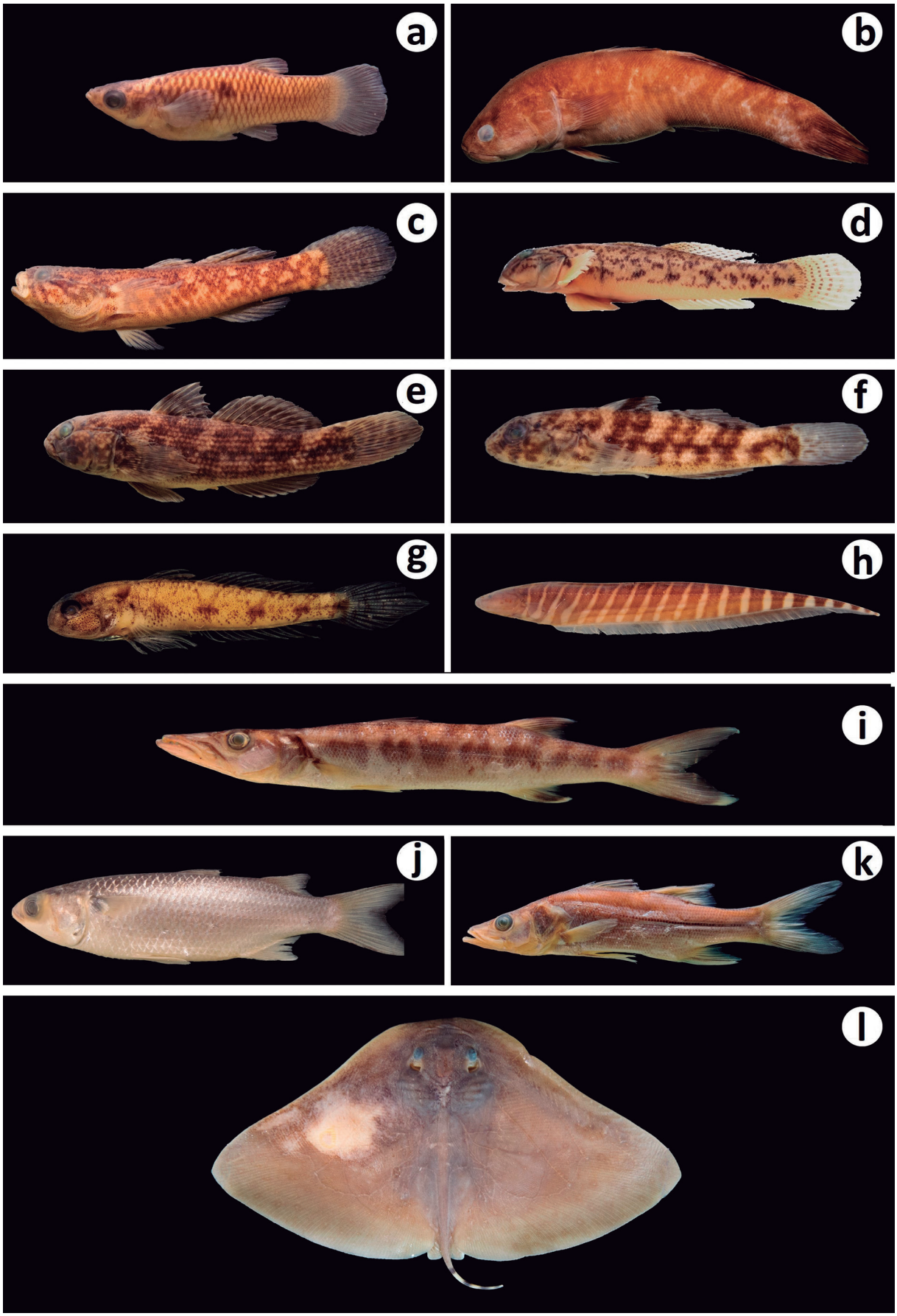

Figure 3. Species of fish from Tambaba APA hydrographic basins: (a) *Poecilia vivipara,* 32.7 mm SL; (b) *Dormitator maculatus,* 67.3 mm SL; (c) *Eleotris pisonis,* 65.7 mm SL; (d) *Awaous tajasica,* 70.6 mm SL; (e) *Bathygobius soporator,* 71.9 mm SL; (f) *Evorthodus lyricus,* 90.9 mm SL; (g) *Ctenogobius boleosoma,* 16.6 mm SL; (h) *Gymnotus carapo,* 86.1 mm TL; (i) *Sphyraena barracuda,* 153.8 mm SL; (j) *Mugil curema,* 86.9 mm SL; (k) *Centropomus undecimalis,* 121.8 mm SL; (l) *Gymnura micrura,* 94.9 mm SL.

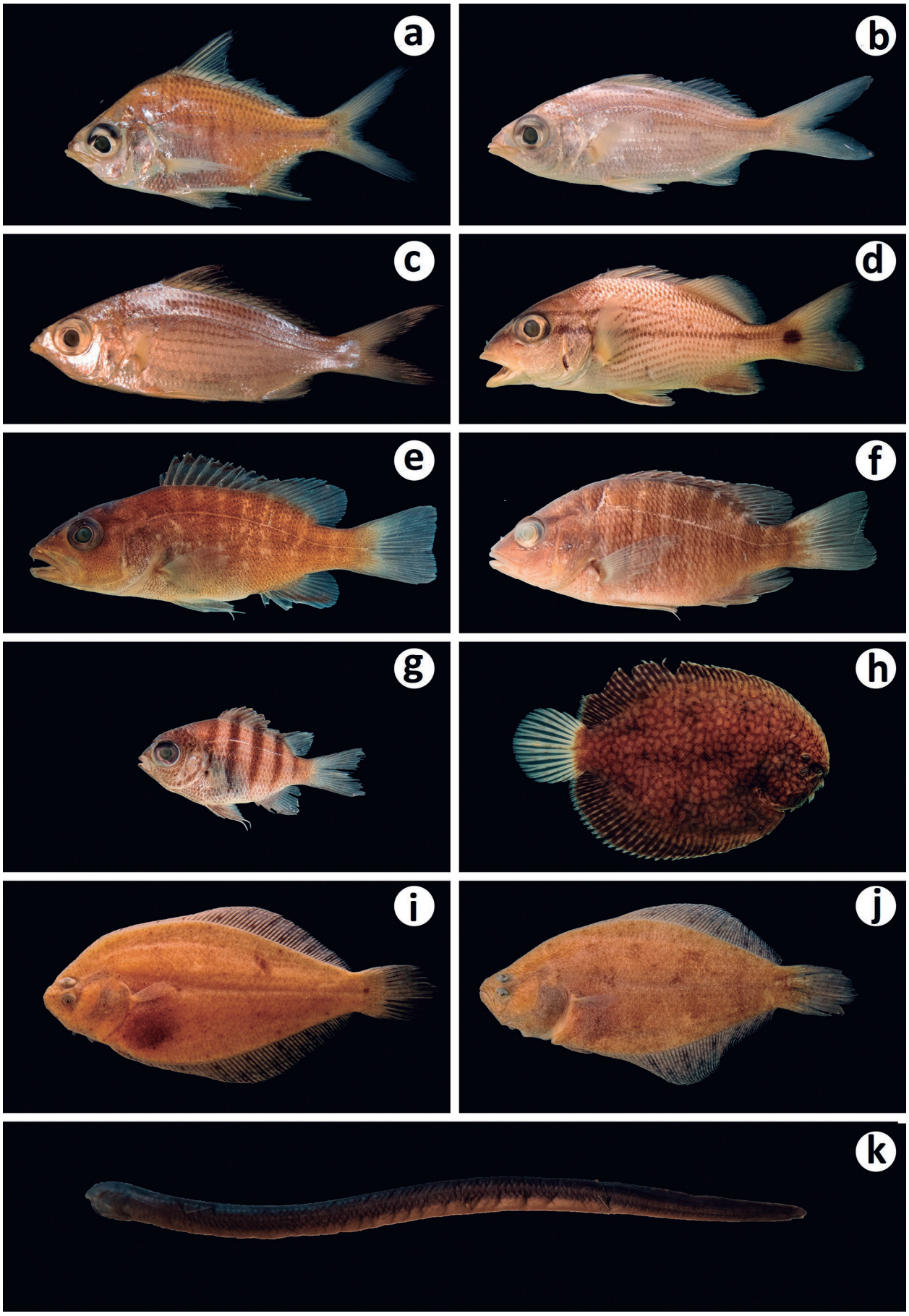

Figure 4. Species of fish from Tambaba APA hydrographic basins: (a) *Diapterus auratus,* 57.4 mm SL; (b) *Eucinostomus argenteus,* 69.7 mm SL; (c) *Eucinostomus gula,* 61.4 mm SL; (d) *Haemulon aurolineatum,* 90.2 mm SL; (e) *Lutjanus alexandrei,* 55.6 mm SL; (f) *Lutjanus jocu,* 45.6 mm SL; (g) *Abudefduf saxatil,* 17.8 mm SL; (h) *Trinectes inscriptus,* 46.9 mm SL; (i) *Citharichthys* sp., 95.9 mm SL; (j) *Citharichthys spilopterus,* 103.1 mm SL; (k) *Synbranchus* aff. *marmoratus,* 315.3 mm TL.

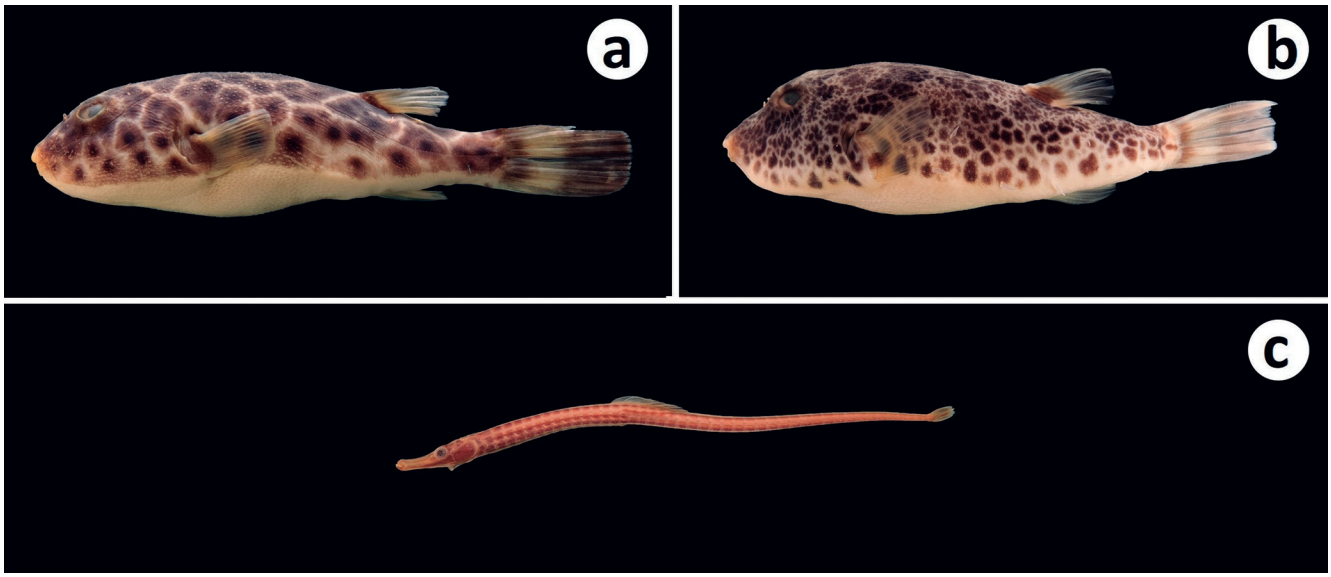

Figure 5. Species of fish from Tambaba APA hydrographic basins: (a) *Sphoeroides spengleri,* 90.3 mm SL; (b) *Sphoeroides testudineus,* 73.3 mm SL; (c) *Syngnathus pelagicus,* 153.8 mm SL.

Pratagi River micro-basin in Rio Grande do Norte State, Brazil. Gouveia *et al.* (2017) registered 18 freshwater species, distributed within seven families and five orders in Guaribas Biological Reserve UC and surrounding areas from the Camaratuba River hydrographic basin. These studies are incongruent with the present analysis but it is noticed a similar number of species to that those registered for the coastal rivers of the Atlantic Forest in NCCD ecoregion.

Characiformes, Characidae is the most representative group among the freshwater fishes in the Tambaba APA. This result is congruent with previous studies on the freshwater ichthyofauna from the NCCD hydrographic basins (*e.g.,* Torelli *et al.,* 1997; Ramos *et al.,* 2005; Paiva *et al.,* 2014; Silva *et al.,* 2014; Rodrigues-Filho *et al.,* 2016; Costa *et al.,* 2017; Gouveia *et al.,* 2017; Teixeira *et al.,* 2017; Oliveira-Silva *et al.,* 2018; Ramos *et al.,* 2018). These results differ from the general pattern of dominance that is noticed for the NCCD ecoregion as provided in Lima *et al.* (2017); Siluriformes has the highest number of species (143 *vs.* 132 Characiformes). However, species of Characiformes dominate when each basin of the NCCD is evaluated individually as pointed out in Oliveira-Silva *et al.* (2018), and according to the authors the greatest number of Siluriformes for this ecoregion occurs due to the greater number of endemic species of this order for each individual basin that would explain the apparent dominance of Siluriformes when these numbers are put together.

The three most abundant freshwater species, *Hemigrammus unilineatus, Astyanax bimaculatus* (Characidae), and *Poecilia vivipara* (Poeciliidae), are small-sized autochthonous species. The first two species belong to the group commonly known as "piabas" (in Portuguese), which do not provide any commercial interest to most of the local population. Local fishermen often employ these species as bait for capturing larger species. The abundance of "piabas" is due to schooling behavior, which facilitates the collection of specimens in the field (Ramos, 2012). A small-sized species, *Poecilia vivipara,* popularly known as "guarú", "guru" or "barrigudinho" also holds no commercial interest to local fishing communities. These three species combined correspond to 67% of the total captured specimens. Small-sized species are often used in the aquarium trade, as is the case for species from Characidae and Poeciliidae (Nelson, 2006; Magalhães & Jacobi, 2013), although this secondary activity was not observed within the Tambaba APA.

Hemigrammus unilineatus was recognized in coastal rivers from the Atlantic forest biome in the Brazilian northeast region (Buckup *et al.,* 2007; Menezes *et al.,* 2007; Langeani *et al.,* 2009; Gouveia *et al.,* 2017) even though the type-locality of this species is in Trinidad Island, West Indies (Reis *et al.,* 2003). Historical relationships between the Atlantic and Amazonian forests explain the natural distribution of this species in the Brazilian northeast region (Wang *et al.,* 2004; Menezes *et al.,* 2007; Dagosta & de Pinna, 2017; Teixeira *et al.,* 2017).

In the marine-estuarine ichthyofauna, Perciformes is one of the largest groups of the study area as previously observed in other Brazilian northeastern estuaries (*e.g.,* Teixeira & Falcão, 1992; Alves & Soares-Filho, 1996; Santos, 2000; Araújo *et al.,* 2000; Paiva *et al.,* 2008; Reis-Filho *et al.,* 2010; Oliveira-Silva *et al.,* 2008; Teixeira *et al.,* 2017). Among the species recognized for this order, the occurrence of *Centropomus undecimalis* (known as "robalo-flexa" or "camorim") must be highlighted due to its commercial importance such as it is noticed for most sea bass species in the artisanal, industrial and recreational fisheries (Fujimoto *et al.,* 2009). This species occurs from North Carolina (U.S.A.) to Uruguay, including Gulf of Mexico and Caribbean Sea (Fricke *et al.,* 2019).

Atherinella brasiliensis and *Mugil curema,* popularly known as "sauna" and "tainha" respectively, are the most abundant marine-estuarine species that also exhibit schooling behavior, which explains the large number of specimens collected. The former species is considered generalized, opportunistic omnivorous feeders in estuar-

Table 2. List of species from Tambaba APA, Paraíba State, Brazil observed in the Graú, Mucatú, and Bucatú river basins, Caboclo River sub-basin and Gurugi River basin. DD = deficient data, LC = Last concern, NE = not evaluated, UFPB = Universidade Federal da Paraíba, UFRN = Universidade Federal do Rio Grande do Norte, NT = not threatened.

ORDER/Family/species	PHISIOLOGY	STATUS	VOUCHER
ATHERINIFORMES			
Atherinopsidae			
Atherinella brasiliensis (Quoy & Gaimard, 1825)	Marine-estuarine	LC	UFPB 11559
BLENNIIFORMES			
Blenniidae			
Omobranchus punctatus (Valenciennes, 1836)	Marine-estuarine	LC	UFPB 11569
CHARACIFORMES			
Characidae			
Astyanax aff. *bimaculatus* (Linnaeus 1758)	Freshwater	LC	UFPB 10418
Cheirodon jaguaribensis Fowler, 1941	Freshwater	DD	UFPB 11617
Compsura heterura Eigenmann, 1915	Freshwater	LC	UFPB 9790
Hemigrammus unilineatus (Gill, 1858)	Freshwater	NE	UFPB 10425
Erythrinidae			
Erythrinus erythrinus (Bloch & Schneider, 1801)	Freshwater	LC	UFPB 10431
Hoplias aff. *malabaricus* (Bloch, 1794)	Freshwater	LC	UFPB 10417
Serrasalmidae			
Metynnis lippincottianus (Cope, 1870)	Freshwater	LC	UFPB 9906
CICHLIFORMES			
Cichlidae			
Crenicichla brasiliensis (Bloch, 1792)	Freshwater	LC	UFPB 10649
Cichlasoma orientale Kullander, 1983	Freshwater	LC	UFPB 10686
Cichla monoculus Spix & Agassiz, 1831	Freshwater	LC	UFPB 10644
Geophagus brasiliensis (Quoy & Gaimard, 1824)	Freshwater	LC	UFPB 10420
CLUPEIFORMES			
Engraulidae			
Lycengraulis grossidens (Spix & Agassiz, 1829)	Marine-estuarine	LC	UFPB 9927
CYPRINODONTIFORMES			
Poeciliidae			
Poecilia reticulata Peters, 1859	Freshwater	LC	UFPB 10688
Poecilia vivipara Bloch & Schneider, 1801	Freshwater	NE	UFPB 10416
GOBIIFORMES			
Eleotridae			
Dormitator maculatus (Bloch, 1792)	Marine-estuarine	LC	UFPB 10419
Eleotris pisonis (Gmelin, 1789)	Marine-estuarine	LC	UFPB 10421
Gobiidae			
Awaous tajasica (Lichtenstein, 1822)	Marine-estuarine	LC	UFPB 10669
Bathygobius soporator (Valenciennes, 1837)	Marine-estuarine	LC	UFPB 9904
Evorthodus lyricus (Girard, 1858)	Marine-estuarine	LC	UFPB 9920
Ctenogobius boleosoma (Jordan & Gilbert, 1882)	Marine-estuarine	NE	UFPB 9903
GYMNOTIFORMES			
Gymnotidae			
Gymnotus cf. *darwini* Campos-da-Paz & de Santana, 2019	Freshwater	LC	UFPB 10679
MUGILIFORMES			
Mugilidae			
Mugil curema Valenciennes, 1836	Marine-estuarine	DD	UFPB 11572
MYLIOBATIFORMES			
Gymnuridae			
Gymnura micrura (Bloch & Schneider, 1801)	Marine-estuarine	NT	UFPB 11556
PERCIFORMES			
Centropomidae			
Centropomus undecimalis (Bloch, 1792)	Marine-estuarine	LC	UFPB 11561
Gerreidae			
Diapterus auratus Ranzani, 1842	Marine-estuarine	LC	UFPB 9919
Eucinostomus argenteus Baird & Girard, 1855	Marine-estuarine	LC	UFPB 11558
Eucinostomus gula (Quoy & Gaimard, 1824)	Marine-estuarine	LC	UFPB 9902
Haemulidae			
Haemulon aurolineatum Cuvier, 1830	Marine-estuarine	LC	UFPB 11568
Lutjanidae			
Lutjanus alexandrei Moura & Lindeman, 2007	Marine-estuarine	LC	UFPB 11562
Lutjanus jocu (Bloch & Schneider, 1801)	Marine-estuarine	NT	UFPB 9917
Pomacentridae			
Abudefduf saxatilis (Linnaeus, 1758)	Marine-estuarine	LC	UFPB 1566
Sphyraenidae			
Sphyraena barracuda (Edwards, 1771)	Marine-estuarine	LC	UFPB 11560
PLEURONECTIFORMES			
Achiridae			
Trinectes inscriptus (Gosse, 1851)	Marine-estuarine	LC	UFPB 11571
Trinectes paulistanus (Miranda Ribeiro, 1915)	Marine-estuarine	LC	UFPB 9922
Paralichthyidae			
Citharichthys sp.	Marine-estuarine	NE	UFPB 10671
Citharichthys spilopterus Günther, 1862	Marine-estuarine	LC	UFPB 9910
SILURIFORMES			
Callichthyidae			
Megalechis thoracata (Valenciennes, 1840)	Freshwater	NE	UFPB 10654
SYNBRANCHIFORMES			
Synbranchidae			
Synbranchus aff. *marmoratus* Bloch, 1795	Freshwater	NE	UFPB 10658
SYNGNATHIFORMES			
Syngnathidae			
Microphis brachyurus (Bleeker, 1854)	Marine-estuarine	LC	UFPB 9905
Syngnathus pelagicus Linnaeus, 1758	Marine-estuarine	LC	UFPB 9916
TETRAODONTIFORMES			
Tetraodontidae			
Sphoeroides spengleri (Bloch, 1785)	Marine-estuarine	LC	UFPB 11557
Sphoeroides testudineus (Linnaeus, 1758)	Marine-estuarine	LC	UFPB 9909

ies with tolerance to several distinct environmental conditions (Contente *et al.,* 2011). The second species also tolerates environments with different levels of salinity since it is a migratory species inhabiting the ocean in adult stage and estuaries while juvenile that functioning as nursery areas (Carvalho *et al.,* 2007). Abundance of these marine-estuarine species is also noticed in other estuarine areas from the Northeastern region of Brazil as seen in Reis-Filho *et al.* (2010), Costa & Camara (2012), Reis-Filho *et al.* (2012), and Campos *et al.* (2015). These species are of commercial importance to artisanal fisheries throughout the Brazilian coast (Soares-Filho *et al.,* 2010).

The occurrence of *Cichla monoculus*, the "tucunaré", is recorded in a single sampling site in Caboclo River, a tributary of Gurugi River in Conde municipality. The allochthonous species *C. monoculus* occurs originally along the riverbeds from the Rio Napo, Ucayali, Solimões-Amazonas, Araguari and Oiapoque (Reis *et al.,* 2003). Species of *Cichla* have been largely introduced in the Brazilian hydrographic basins, especially in northeastern Brazil dams, through government fish breeding programmers and also in order to eliminate piranha species of *Pygocentrus* and *Serrasalmus* (Gurgel & Oliveira, 1987; Leão *et al.,* 2011). They have also been introduced intensively by

recreational fisheries and are possibly responsible for local extinctions of native species (Leão *et al.,* 2011). *Cichla* comprises a genus of carnivorous species with very aggressive predation behavior (Leão *et al.,* 2011), which might cause a reduction in the abundance and threat the diversity of native species from hydrographic basins in Tambaba Environmentally Protected Area.

Deforestation and civil construction areas are evident in the mangroves from the estuaries of Graú, Mucatú, and Bucatú Rivers. Mangroves correspond to merely 2.43 km² or 2.13% of the total area from Tambaba Environmentally Protected Area (Almeida *et al.,* 2008), indicating a massive reduction of the native mangrove coverage when compared to other major hydrographic basins such as Mamanguape and Paraíba do Norte River basins, located in Paraíba State. Many marine fish species seasonally inhabit mangroves for feeding and reproduction while others utilize them permanently (Lowe-McConnell, 1999). Mangrove roots are often employed as nursery and refuge sites against predators for a variety of species for instance *Lutjanus alexandrei* Moura & Lindeman, 2007, *L. jocu, Mugil curema, Sphoeroides testudineus* (Linnaeus, 1758), and *Sphyraena barracuda* (Edwards, 1771) that are observed in Tambaba Environmentally Protected Area (Osório *et al.,* 2011). Mangroves and estuaries from Tambaba APA (comprising the Mucatú, Bucatú, and Graú Rivers) require eminent conservation management due to its ecological role to the aquatic fauna as feeding, nursery, and home grounds (Thayer *et al.,* 1987).

The Atlantic forest biome is one of the world biodiversity hotspots characterized by its high endemism and richness of species and habitats, although it is currently under risk of extinction (Myers *et al.,* 2000). The ichthyofauna assessment of Tambaba Environmentally Protected Area demonstrates the diversity of species present within its coastal and hydrographic limits which is of major ecological and conservational value as it is situated within the Atlantic forest biome in the northeastern region of Brazil. This environmentally protected area is a national and international renowned region because its scenic nature landscapes. This region has been under considerable and fast-growing urban development for touristic purposes, especially in the hospitality industry. Besides that, the production of agricultural stocks such as banana, sugar cane and bamboo in the inner limits of Tambaba Environmentally Protected Area also contributes to environmental pressures, including intensive deforestation and deterioration (Almeida *et al.,* 2008). Agricultural activities as well as livelihood in the region, including livestock, sediment extraction, and civil construction also entails anthropogenic impacts in the hydrographic basins and surrounding areas resulting in deforestation of the riparian forest in many rivers and streams. These latter two activities also contribute to the deposition of chemical waste in the river basins.

Forests with origin in river bases are considered permanently protected areas (APPs), according to the Brazilian Forest Code (Law № 12.651/2012). Thus, the conservation efforts of river sources as well as the riparian forest associated to it are essential for the natural maintenance of water springs. Restoration of the natural environments through environmental and conservation management is crucial in order to reach the natural stability from Tambaba Environmentally Protected Area as proposed in Meneses *et al.* (2005), Almeida *et al.* (2008), and Sobrinho Jr. & Araújo (2016). Finally, the results presented herein contribute to the taxonomic knowledge of the fish fauna from the Tambaba APA and more generally to the understanding of the ichthyological diversity of the NCCD ecoregion.

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APPENDIX

Identification key to species from the Tambaba APA, Graú, Mucatú, and Bucatú river basins, Caboclo River sub-basin and Gurugi River basin in Paraíba State, Brazil

1. Gill slits ventrally located, dorsal and anal fins very reduced or absent 2
1′. Gill slits laterally located, dorsal and/or anal fins well-developed 3
2. Five gill slits ventrally, body conspicuously depressed and disc shaped ..... *Gymnura micrura*
2′. A single gill slit ventrally, body conspicuously eel-like ..... *Synbranchus marmoratus*
3. Body lacking scales ..... *Omobranchus punctatus*
3′. Body with scales, bony plates or a series of articulated bony rings 4
4. Body covered by bony plates or series of articulated rings 5
4′. Body covered by typical scales 7
5. Body fusiform and covered by bony plates ..... *Megalechis thoracata*
5′. Body tube-like and covered by series of articulated rings 6
6. 38-47 rays in dorsal fin, 24-30 rings in caudal region ..... *Microphis brachyurus*
6′. 27-28 rays in dorsal fin, 27-34 rings in caudal region ..... *Syngnathus pelagicus*
7. Fins with soft rays only 8
7′. Fins with rigid (spines) and soft rays 23
8. Body markedly compressed and both eyes located on one side of the body 9
8′. One eye on each side of the body 12
9. Both eyes located on left side of body 10
9′. Both eyes located on right side of body 11
10. First dorsal-fin ray inserted above and adjacent to the anterior nostril on the blind side of the body ..... *Citharichthys* sp.
10′. First dorsal-fin ray inserted above and remote to the posterior nostril or equidistant to the two nostrils ..... *Citharichthys spilopterus*
11. Body brown and 10 to 11 transversal lines black in color present ..... *Trinectes paulistanus*
11′. Body brown, transversal lines absent, light markings rounded, forming a mosaic ..... *Trinectes inscriptus*
12. Dorsal and pelvic fins absent, anal fin markedly elongate with more than 140 rays ..... *Gymnotus carapo*
12′. Dorsal and pelvic fins present, anal fin markedly small with less than 140 rays 13
13. Premaxilla protruding, caudal fin not bifurcated 14
13′. Premaxilla non-protruding, caudal fin bifurcated or not bifurcated 16
14. Presence of a small and oval dark humeral spot ..... *Poecilia vivipara*
14′. Absence of a small and oval dark humeral spot 15
15. Lateral region of body with many colorful spots ..... *Poecilia reticulata* (male)
15′. Lateral region of body without colorful spots ..... *Poecilia reticulata* (female)
16. Lateral line and adipose fin absent ..... *Lycengraulis grossidens*
16′. Lateral line and adipose fin presents 17
17. Adipose fin absent and caudal fin rounded 18
17. Adipose fin present and caudal fin forked 19
18. Maxilla with conical teeth only ..... *Hoplias malabaricus*
18′. Maxilla with conical and canine teeth ..... *Erythrinus erythrinus*
19. Abdomen compressed, forming a keel prior to the pelvic fins ..... *Metynnis lippincottianus*
19′. Abdomen rounded not forming a keel prior to the pelvic fins 20
20. Premaxilla with a single series of teeth ..... *Compsura heterura*
20′. Premaxilla with two series of teeth 21
21. Lateral line complete ..... *Astyanax bimaculatus*
21′. Lateral line incomplete 22
22. Blackish marking on the caudal peduncle or under the median caudal rays present, dorsal and hyaline fins with black vertical bar absent ..... *Cheirodon jaguaribensis*
22′. Blackish marking on the caudal peduncle absent, dorsal and anal fins with black vertical bar presents ..... *Hemigrammus unilineatus*
23. Pelvic fins absent 24
23′. Pelvic fins present 25
24. Dermal appendix present dorsal and laterally on body ..... *Sphoeroides spengleri*
24′. Dermal appendix absent ..... *Sphoeroides testudineus*
25. Pelvic fins fused, forming a suction disk 26
25′. Pelvic fins not fused and not forming a suction disk 29
26. Eight to nine rays in anal fin ..... *Bathygobius soporator*
26′. More than 10 rays in anal fin 27
27. Eleven rays in anal fin ..... *Awaous tajasica*
27′. More than 11 rays in anal fin 28

28. Dorsal fin with six spines and 14 rays ..... *Ctenogobius boleosoma*
28′. Dorsal fin with six spines and 12 rays, anal fin with 13 rays ..... *Evorthodus lyricus*
29. Lateral line absent 30
29′. Lateral line present 33
30. Caudal fin bifurcated 31
30′. Caudal fin rounded 32
31. Silver bar present horizontally, one spine and 17-19 rays in anal fin ..... *Atherinella brasiliensis*
31′. Silver horizontal bar absent, 2-3 spines and nine or 10 rays in anal fin ..... *Mugil curema*
32. 29-31 rows of longitudinal scales on body ..... *Dormitator maculatus*
32′. 57-64 rows of longitudinal scales on body ..... *Eleotris pisonis*
33. Lateral line discontinuous with upper (anterior) and lower (posterior) branches 34
33′. Lateral line continuous 37
34. Dorsal fin incised between anterior and posterior portions ..... *Cichla monoculus*
34′. Dorsal fin without a fork between anterior and posterior portions 35
35. Upper branch of first gill slit with prominent lobe, black vertical bar over the eye present, reaching the corner of preopercle ..... *Geophagus brasiliensis*
35′. Upper branch of first gill slit without prominent lobe, black vertical bar over the eye absent 36
36. Body elongated and fusiform, posterior margin of preopercle serrated ..... *Crenicichla brasiliensis*
36′. Body tall and oval, posterior margin of preopercle straight ..... *Cichlasoma orientale*
37. Caudal fin truncate 38
37′. Caudal fin bifurcated 39
38. Six scales between the dorsal fin origin and the lateral line ..... *Lutjanus alexandrei*
38′. Nine to 10 scales between the dorsal fin origin and the lateral line ..... *Lutjanus jocu*
39. Body elongate with two dorsal fins present 40
39′. Body tall with one dorsal fin present 41
40. Mouth with large canine teeth, two spines and 8-9 rays in anal fin ..... *Sphyraena barracuda*
40′. Mouth with villous teeth, three spines and 5-6 rays in anal fin ..... *Centropomus undecimalis*
41. Three spines in anal fin 42
41′. Two spines or spines absent in anal fin 44
42. Margin of preopercle straight 43
42′. Margin of preopercle with small dentations ..... *Diapterus auratus*
43. Premaxilla furrow discontinuous anteriorly by scales ..... *Eucinostomus gula*
43′. Premaxilla furrow continuous not interrupted anteriorly by scales ..... *Eucinostomus argenteus*
44. Two spines in anal fin, dorsal-fin rays without scales ..... *Abudefduf saxatilis*
44′. Anal fin without spines, dorsal-fin rays completely covered of scales ..... *Haemulon aurolineatum*

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