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Taxonomic Review

Fish species of the Paraiba River estuary, northeastern Brazil

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Abstract: The Paraiba River estuary is the largest and most important estuary of Paraiba state, northeastern Brazil. It is under intense environmental degradation by the surrounding human population, and possibly several fish species are at risk in this habitat. Scientific sampling of the ichthyofauna started in the late 1970's and proceeded until recently. We present a list of fish species captured in this estuary, based on voucher specimens housed at the Federal University of Paraiba collection. Four orders of Chondrichthyes and 26 orders of Osteichthyes were identified. A total of 187 fish species, including eight species of Chondrichthyes and 179 Osteichthyes, with 123 genera and 57 families were identified. Perciformes dominated in terms of richness (32 species), followed by Acanthuriformes and Clupeiformes. Comparing estuaries along the Brazilian northeastern coast and considering our large time sampling span, a higher richness would be expected. According to the IUCN Red List, *Urotrygon microphthalmum* is considered Critically Endangered and more seven species are classified as Vulnerable: *Rhizoprionodon porosus, Rhinoptera bonasus, Megalops atlanticus, Epinephelus itajara, Hyporthodus niveatus, Lutjanus cyanopterus,* and *Cynoscion acoupa*. Three of these species also appear in the same category in the threatened Brazilian list, all of which have declining population trends. Concerning the Elasmobranchii, *Carcharhinus porosus* is listed as Critically Endangered in our country and globally. This inventory organizes and broadens knowledge on the fish community that occurs in this important ecosystem, with inferences about life habits, ecological guilds and conservation status of the fish species.
Keywords: *richness, life habits, ecological guilds, conservation status, estuarine ecosystem.*

Espécies de peixes do estuário do Rio Paraíba, nordeste do Brasil

Resumo: O estuário do Rio Paraíba, maior e mais importante do estado da Paraíba, nordeste do Brasil, sofre intensa degradação ambiental pela população humana no seu entorno, e possivelmente várias espécies de peixes estão ameaçadas neste habitat. Nós apresentamos uma lista de espécies de peixes capturadas neste estuário, com base em espécimes tombados na coleção da Universidade Federal da Paraíba. Quatro ordens de Chondrichthyes e 26 ordens de Osteichthyes foram identificadas. Um total de 187 espécies de peixes foi registrado, incluindo oito espécies de Chondrichthyes e 179 Osteichthyes, com 123 gêneros e 57 famílias. Em relação à riqueza, Perciformes dominou com 32 espécies, seguido por Acanthuriformes e Clupeiformes. Comparando estuários ao longo do nordeste brasileiro e considerando nosso longo período de amostragens, seria esperada uma riqueza maior. De acordo com a lista vermelha da IUCN, *Urotrygon microphthalmum* é tida como Criticamente Ameaçada e mais sete espécies são classificadas como Vulnerável: *Rhizoprionodon porosus, Rhinoptera bonasus, Megalops atlanticus, Epinephelus itajara, Hyporthodus niveatus, Lutjanus cyanopterus* e *Cynoscion acoupa*. Três dessas espécies também aparecem na mesma categoria na lista brasileira de espécies ameaçadas, tendo todas elas, suas populações em declínio. Em relação aos Elasmobranchii, *Carcharhinus porosus* é listada como Criticamente Ameaçada em nosso país e globalmente. Esse inventário abrange e organiza o conhecimento acerca da comunidade de peixes que ocorre nesse importante ecossistema, com inferências sobre hábitos de vida, guildas ecológicas e status de conservação das espécies de peixes.
Palavras-chave: *riqueza, hábitos de vida, guildas ecológicas, conservação, ecossistema estuarino.*

Introduction

Estuaries have been considered an important ecological system due to the abundance of resources, representing spawning, development, recruitment, and connectivity areas for many species. They provide a rich habitat for the development of various organisms, including fish species. They are important to the proper functioning of the coastal aquatic environment by contributing available biomass in the food chain and they also provide important food resources for human consumption and source of income, mainly for the artisanal fishing community (Martins & Vendel 2014, Mérigot et al. 2017).

Estuaries throughout the world, especially in the tropics, have experienced high degrees of anthropic pressure. Similarly, estuarine fish species are often impacted by urban and industry effluents and agricultural activities (McLusky & Elliott 2004, Barletta et al. 2010), mainly juveniles, that use this environment as shelter and nursery grounds (Blaber et al. 2000).

Estuarine ichthyofauna exhibits considerable variation in terms of morphology and biology and its species inhabit or migrate among marine, estuarine, and freshwater environments (Elliott et al. 2007). The knowledge on the taxonomy and ecology of the species that occur in the estuarine system is essential (Mérigot et al. 2017), because it provides information about local diversity, and represents an important tool in the management and conservation of both species and ecosystem (González-Acosta et al. 2018).

The Paraiba River estuary is the largest and most important estuary of Paraiba state (Dominguez et al. 2016). Initial studies on the composition of the ichthyofauna of this estuary were conducted within the scope of the Estuary Project, developed between 1978 and 1980 with funds from FINEP. A total of 106 species were reported in this work, including also those collected in reef environments adjacent to the estuary mouth (Rosa 1980a). Another research project in fish ecology, funded by Science Without Borders/CAPES between 2012–2015 represented a major sampling effort of the fish assemblages along the salinity gradient of two estuaries in Paraiba, but no separate species list was provided for each one (Dolbeth et al. 2016).

Nonetheless, published results on the local fish taxonomic composition are partial and outdated (Rosa 1980b, Dolbeth et al. 2016). Therefore, we aimed in the present study to provide a first and comprehensive list of the fish species recorded in the Paraiba River estuary, Paraiba, Brazil, based on vouchers housed at the fish collection of the Universidade Federal da Paraiba (UFPB), collected along the entire estuary extension. Although sampling effort was highly irregular over time, as well as the use of different fishing gear in sampling, the results provide important insights on the changes in the fish community composition that occurred over 40 years.

Material and Methods

1. *Study area*

The Paraiba River estuary (34º47'07" to 34º55'37" S and 06º56'58" to 07º08'18" W) has a length of approximately 22 km and a width of 2.2 km at the mouth (Figure 1). The estuarine system itself has 3,012 ha and covers the municipalities of Santa Rita, Bayeux, João Pessoa, Lucena, and Cabedelo (Teixeira et al. 2020) and drains a fluvial-marine plain formed by the Paraiba River and its major tributaries: Sanhauá, Paroeira, Mandacaru, Tibiri, Tambiá, Ribeira, and Guia. The depth in the main channel is 3.0 m, except near the harbor, where frequent dredging maintains a depth of 11.0 m (Alves et al. 2016, Dolbeth et al. 2016). Along the estuary, small sandbanks are observed during low tide. The southern margin of the estuary mouth harbors a large rocky breakwater, which provides habitat for several reef fish species. Samples were collected mostly at the Paraiba main channel and at the Sanhauá and Mandacaru tributaries. Fishes from the adjacent marine environment to the south of the estuary in the Cabedelo municipality were not included in the checklist. On the other hand, fishes on the adjacent marine environment at the Lucena municipality, which borders

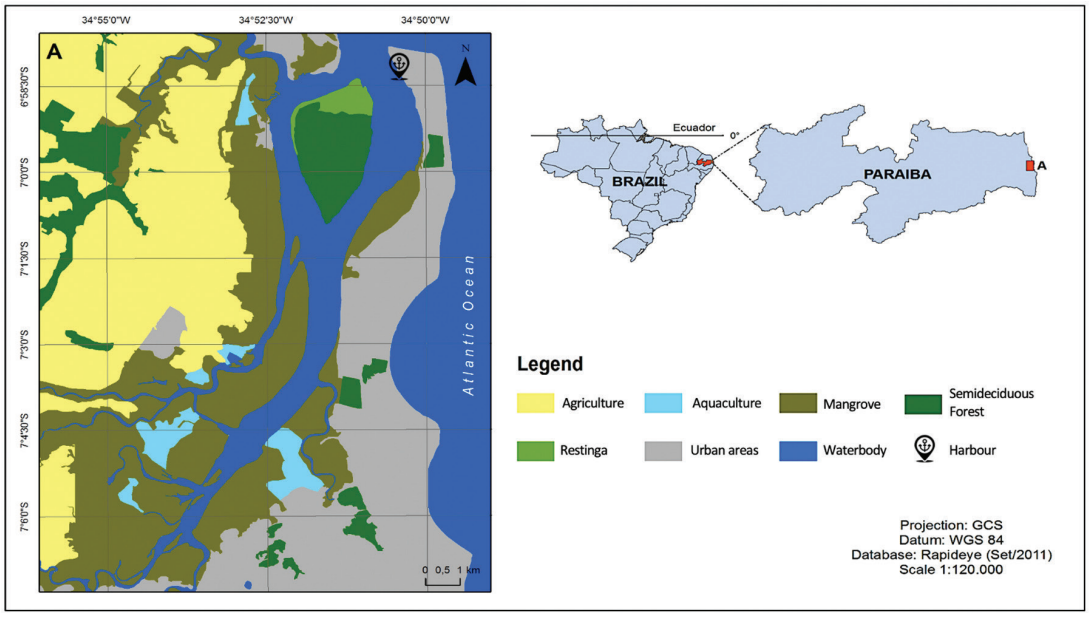

Figure 1. Paraiba River estuary, Paraiba, Brazil.

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the northern margin of the estuary, were considered in the checklist, due to great influence of the estuarine waters in this environment and the northern direction of the coastal drift current.

The Paraiba River basin drains a semi-arid region formed by the Caatinga biome and a thin coastal strip covered by Atlantic Forest remains and narrow strips of mangroves (Alves et al. 2016, Teixeira et al. 2020). Regarding land use and cover, this region is dominated by agriculture (14618 ± 582 ha), urban (9414 ± 470 ha), and mangrove (7842 ± 264 ha) (Teixeira et al. 2020). In fact, the Paraiba River estuary is surrounded by a large territory of urban areas with plus than one million inhabitants, shrimp aquaculture areas, and extensive sugar cane plantations that have almost completely replaced the original rain forest (Santana et al. 2018).

These economic activities together with the impact of urban wastewater, have been leading to an intense environmental degradation of the estuary. Recent studies have shown a higher degree of human disturbance in the Paraiba River estuary, such as a higher nutrient enrichment, microplastic pollution, and revealed a high activity of a cellular detoxification by fishes, which indicates a high concentration of pollutants in the water of the Paraiba River estuary (Alves et al. 2016, Dolbeth et al. 2016, de Moura et al. 2016, Santos et al. 2017, Vendel et al. 2017, David et al. 2018, Macêdo et al. 2019).

2. *Fish data*

The species listed in the Table 1 were identified following Figueiredo & Menezes (1978, 1980, 2000), Menezes & Figueiredo (1980, 1985), Britski et al. (1984), Allen (1985), Harrison (2002), Marceniuk (2005), Marceniuk & Menezes (2007), McBride et al. (2010), Lucena & Soares (2016), Marceniuk et al. (2017, 2019b, 2020), Chao et al. (2021). The fish species nomenclature followed Fricke et al. (2022) and the taxonomic order according to Nelson et al. (2016), except for Triportheidae and Labridae. The examined specimens are from the fish collection of the Federal University of Paraiba (UFPB); for more details see the 895 voucher numbers to listed species in Supplementary Material (Table A.1). The richest taxa were plotted using Prism 9.2.0 (Graphpad Software, CA).

The species were grouped into the following ecological guilds (modified from Elliott et al. 2007): R = resident: species that complete their whole life cycle within the estuarine environment; M = marine migrants: species that remain in the estuary for a trophic or reproductive ecophase; Om = Occasional marine and Of = Occasional freshwater, whose presence in the estuary is irregular. This classification includes data from literature about migration, life cycle, frequency by which the species occur in estuaries or personal observations. The same was applied

Table 1. List of fish species sampled in the Paraiba River estuary, the conservation status follows last-known IUCN's assessment (2022), their ecological guild, and life habit. Asterisk **(*)** corresponds to species with data based on direct personal observations and plus **(+)** represents exotic species. **Ecological guild**: (R) Resident, (M) Marine migrant, (Om) Marine occasional, (Of) Freshwater occasional. **Life habit**: (E) Estuarine, (Sb) Soft bottom, (R) Reef, (Wc) Water column, (P) Pelagic, (PB) Benthopelagic, (B) Benthic. **Ref**: references to ecological guild, life habits and previous citations in the Paraiba River estuary.

Taxonomy	IUCN Status	Ecological guild	Life habit	Ref
CHONDRICHTHYES				
CARCHARHINIFORMES				
Carcharhinidae				
Carcharhinus porosus (Ranzani, 1839)	CR	Om	PB	1
Rhizoprionodon porosus (Poey, 1861)	VU	Om	PB	1
TORPEDINIFORMES				
Narcinidae				
Narcine brasiliensis (Olfers, 1831)	NT	Om	B	1,8
PRISTIFORMES				
Rhinobatidae				
Pseudobatos percellens (Walbaum, 1792)	EN	Om	B	1
MYLIOBATIFORMES				
Dasyatidae				
Hypanus guttatus (Bloch & Schneider, 1801)	NT	Om	R	1,8
Hypanus marianae (Gomes, Rosa & Gadig, 2000)	EN	Om	R	1,5
Urotrygonidae				
Urotrygon microphthalmum (Delsman, 1941)	CR	Om	B	1
Myliobatidae				
Rhinoptera bonasus (Mitchill, 1815)	VU	Om	B	1
OSTEICHTHYES				
ELOPIFORMES				
Elopidae				
Elops smithi (McBride et al., 2010)	DD	Om	P	*

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Taxonomy	IUCN Status	Ecological guild	Life habit	Ref
Megalopidae				
Megalops atlanticus (Valenciennes, 1847)	VU	Om	E, R, Wc, P	8
ALBULIFORMES				
Albulidae				
Albula vulpes (Linnaeus, 1758)	NT	Om	E, R, PB	2,8
ANGUILLIFORMES				
Muraenidae				
Gymnothorax funebris (Ranzani, 1839)	LC	Om	E, R, B	2
Gymnothorax moringa (Cuvier, 1829)	LC	Om	E, R, B	2
Gymnothorax ocellatus (Agassiz, 1831)	LC	Om	E, Sb, B	2,8
Ophichthidae				
Myrichthys ocellatus (Lesueur, 1825)	LC	Om	B	2
Myrophis punctatus (Lütken, 1852)	LC	Of	PB	4
Ophichthus cylindroideus (Ranzani, 1839)	LC	Om	E, Sb, PB	2
CLUPEIFORMES				
Pristigasteridae				
Chirocentrodon bleekerianus (Poey, 1867)	LC	Om	E, Wc, P	2,8
Odontognathus mucronatus (Lacépède, 1800)	LC	Om	E,Wc, P	2
Pellona harroweri (Fowler, 1917)	LC	Om	E, Wc, P	2
Engraulidae				
Anchoa januaria (Steindachner, 1879)	LC	Om	E, R, Wc, P	2,8
Anchoa lyolepis (Evermann & Marsh, 1900)	LC	R	E, R, Wc, P	2
Anchoa marini (Hildebrand, 1943)	LC	Om	E, R, Wc, P	8*
Anchoa spinifer (Valenciennes, 1848)	LC	Om	E, R, Wc, P	8,*
Anchoa tricolor (Spix & Agassiz, 1829)	LC	Om	E, R, Wc, P	*
Anchovia clupeoides (Swainson, 1839)	LC	R	E, R, Wc, P	2,8
Anchovia surinamensis (Bleeker, 1865)	LC	R	E, R, Wc, P	2
Anchoviella lepidentostole (Fowler, 1911)	LC	R	E, R, Wc, P	2
Cetengraulis edentulus (Cuvier, 1829)	LC	R	E, R, Wc, P	2,8
Lycengraulis grossidens (Agassiz, 1829)	LC	R	E, R, Wc, P	2,8
Clupeidae				
Harengula clupeola (Cuvier, 1829)	LC	R	E, R, Wc, P	2
Lile piquitinga (Schreiner & Miranda Ribeiro, 1903)	LC	R	E, R, Wc, P	*
Opisthonema oglinum (Lesueur, 1818)	LC	R	E, R, Wc, P	2,8
Rhinosardinia cf. *bahiensis* (Steindachner, 1879)	LC	R	E, Wc, P	2
Sardinella brasiliensis (Steindachner, 1879)	DD	R	E, R, Wc, P	2
CHARACIFORMES				
Curimatidae				
Steindachnerina notonota (Miranda Ribeiro, 1937)	–	Of	WC, P	*
Characidae				
Psalidodon fasciatus (Cuvier, 1819)	LC	Of	Wc, P	*

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Taxonomy	IUCN Status	Ecological guild	Life habit	Ref
Triportheidae				
Triportheus guentheri (Garman, 1890)	–	Of	Wc, P	*
SILURIFORMES				
Ariidae				
Aspistor luniscutis (Valenciennes, 1840)	–	R	E, Sb, PB	2,7
Bagre filamentosus (Swainson, 1839)	–	M	E, Sb, PB	8,*
Cathorops agassizii (Eigenmann & Eigenmann, 1888)	–	R	E, B	2,7
Cathorops spixii (Agassiz, 1829)	–	R	E, Sb, PB	2,7
Notarius parmocassis (Valenciennes, 1840)	–	R	E, Sb, PB	*
Sciades herzbergii (Bloch, 1794)	LC	R	E, Sb, PB	2,7,8
Sciades proops (Valenciennes, 1840)	–	R	E, Sb, PB	2,7,8
AULOPIFORMES				
Synodontidae				
Synodus foetens (Linnaeus, 1766)	LC	M	E, Sb, R, PB	2,8
Synodus synodus (Linnaeus, 1758)	LC	M	R, B	2
BATRACHOIDIFORMES				
Batrachoididae				
Porichthys kymosemeum (Gilbert, 1968)	–	Om	E, Sb, R, B	2,8
Thalassophryne nattereri (Steindachner, 1876)	LC	Om	E, Sb, R, B	2
GOBIIFORMES				
Eleotridae				
Dormitator maculatus (Bloch, 1792)	LC	Om	E, B	2,8
Eleotris pisonis (Gmelin, 1789)	LC	Om	E, B	2
Erotelis smaragdus (Valenciennes, 1837)	LC	R	E, B	4,8
Guavina guavina (Valenciennes, 1837)	LC	Om	E, B	2,8
Gobiidae				
Bathygobius soporator (Valenciennes, 1837)	LC	Om	E, R, B	2,8
Ctenogobius boleosoma (Jordan & Gilbert, 1882)	LC	Om	E, R, B	2
Ctenogobius shufeldti (Jordan & Eigenmann, 1887)	LC	Om	E, R, B	2
Ctenogobius smaragdus (Valenciennes, 1837)	LC	Om	E, R, B	2,8
Ctenogobius stigmaticus (Poey, 1860)	LC	Om	E, R, B	2,8
Gobioides broussonnetii (Lacépède, 1800)	LC	Om	E, B	2,8
Gobionellus oceanicus (Pallas, 1770)	LC	Om	E, B	2,8
Gobionellus stomatus (Starks, 1913)	–	Om	E, B	8,*
Microgobius meeki (Evermann & Marsh, 1899)	LC	Om	E, B	2
MUGILIFORMES				
Mugilidae				
Mugil brevirostris (Miranda Ribeiro, 1915)	–	M	E, R, Wc, P	2
Mugil curema (Valenciennes, 1836)	LC	M	E, R, Wc, P	2,8
Mugil curvidens (Valenciennes, 1836)	–	M	E, R, Wc, P	2
Mugil liza (Valenciennes, 1836)	DD	M	E, R, Wc, P	2
CICHLIFORMES				
Cichlidae				
Oreochromis niloticus (Linnaeus, 1758) +	LC	Of	Wc, P	*

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Taxonomy	IUCN Status	Ecological guild	Life habit	Ref
ATHERINIFORMES				
Atherinopsidae				
Atherinella blackburni (Schultz, 1949)	LC	Om	R, Wc, P	*
Atherinella brasiliensis (Quoy & Gaimard, 1825)	LC	R	E, R, Wc, P	2
BELONIFORMES				
Hemiramphidae				
Hemiramphus brasiliensis (Linnaeus, 1758)	LC	R	E, R, Wc, P	2,8
Hyporhamphus roberti (Valenciennes, 1847)	LC	R	E, R, Wc, P	2
Hyporhamphus unifasciatus (Ranzani, 1841)	LC	R	E, R, Wc, P	2,8
Belonidae				
Strongylura marina (Walbaum, 1792)	LC	R	E, R, Wc, P	2
Strongylura timucu (Walbaum, 1792)	LC	R	E, R, Wc, P	2,8
CYPRINODONTIFORMES				
Poeciliidae				
Poecilia reticulata (Peters, 1859) +	LC	Of	Wc, P	*
Poecilia vivipara (Bloch & Schneider, 1801)	–	Of	Wc, P	*
CARANGIFORMES				
Echeneidae				
Echeneis naucrates (Linnaeus, 1758)	LC	M	R, Wc, P	2,8
Carangidae				
Caranx bartholomaei (Cuvier, 1833)	LC	M	E, R, Wc, P	2
Caranx hippos (Linnaeus, 1766)	LC	M	E, R, Wc, P	2
Caranx latus (Agassiz, 1831)	LC	M	E, R, Wc, P	2,8
Chloroscombrus chrysurus (Linnaeus, 1766)	LC	M	E, Wc, P	2
Oligoplites palometa (Cuvier, 1833)	LC	M	E, Wc, P	2
Oligoplites saliens (Bloch, 1793)	LC	M	E, R, Wc, P	2
Oligoplites saurus (Bloch & Schneider, 1801)	LC	M	E, R, Wc, P	2,8
Selar crumenophthalmus (Bloch, 1793)	LC	M	R, Wc, P	2
Selene setapinnis (Mitchill, 1815)	LC	M	E, R, Wc, P	2
Selene vomer (Linnaeus, 1758)	LC	M	E, R, Wc, P	2,8
Trachinotus falcatus (Linnaeus, 1758)	LC	M	E, R, Wc, P	2
Trachinotus goodei (Jordan & Evermann, 1896)	LC	M	E, R, Wc, P	2
ISTIOPHORIFORMES				
Sphyraenidae				
Sphyraena barracuda (Edwards, 1771)	LC	Om	E, R, Wc, P	2,8
PLEURONECTIFORMES				
Paralichthyidae				
Citharichthys macrops (Dresel, 1885)	LC	Om	E, Sb, R, B	2
Citharichthys cf. *arenaceus* (Evermann & Marsh, 1900)	LC	R	E, Sb, R, B	2
Citharichthys spilopterus (Günther, 1862)	LC	R	E, Sb, R, B	2,8
Etropus crossotus (Jordan & Gilbert, 1882)	LC	R	E, Sb, R, B	2
Paralichthys brasiliensis (Ranzani, 1842)	LC	Om	E, Sb, R, B	2
Syacium micrurum (Ranzani, 1842)	LC	Om	E, Sb, R, B	2

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Taxonomy	IUCN Status	Ecological guild	Life habit	Ref
Bothidae				
Bothus ocellatus (Agassiz, 1831)	LC	Om	Sb, R, B	2,8
Achiridae				
Achirus achirus (Linnaeus, 1758)	LC	Om	E, Sb, B	2,8
Achirus declivis (Chabanaud, 1940)	LC	Om	E, Sb, B	2
Achirus lineatus (Linnaeus, 1758)	LC	R	E, Sb, B	2
Trinectes microphthalmus (Chabanaud, 1928)	LC	R	E, Sb, B	2
Trinectes paulistanus (Miranda Ribeiro, 1915)	LC	M	E, Sb, B	2
Cynoglossidae				
Symphurus plagusia (Bloch & Schneider, 1801)	LC	M	E, Sb, B	2,8
Symphurus tessellatus (Quoy & Gaimard, 1824)	LC	M	E, Sb, R, B	2
SYNGNATHIFORMES				
Syngnathidae				
Bryx dunckeri (Metzelaar, 1919)	LC	M	R, B	2
Cosmocampus elucens (Poey, 1868)	LC	M	R	*
Hippocampus reidi (Ginsburg, 1933)	NT	M	E, R, B	2
Microphis lineatus (Kaup, 1856)	–	M	E, PB	2
Syngnathus pelagicus (Linnaeus, 1758)	LC	M	E, P	2
Fistulariidae				
Fistularia petimba (Lacépède, 1803)	LC	Om	E, R, Wc, P, PB	2
Fistularia tabacaria (Linnaeus, 1758)	LC	M	E, R, Wc, P	8
Dactylopteridae				
Dactylopterus volitans (Linnaeus, 1758)	LC	Om	E, Sb, R, B	2,8
SCOMBRIFORMES				
Trichiuridae				
Trichiurus lepturus (Linnaeus, 1758)	LC	Om	E, Sb, R, Wc, P, PB, B	2,8
Scombridae				
Scomberomorus brasiliensis (Collette, Russo & Zavala–Camin, 1978)	LC	M	R, Wc, P	2
LABRIFORMES				
Labridae				
Nicholsina usta (Valenciennes, 1840)	LC	Om	Sb, R, PB	2
Sparisoma radians (Valenciennes, 1840)	LC	Om	R, PB	2
PERCIFORMES				
Centropomidae				
Centropomus ensiferus (Poey, 1860)	LC	Om	E, Sb, R, PB	2
Centropomus parallelus (Poey, 1860)	LC	Om	E, Sb, R, PB	2
Centropomus pectinatus (Poey, 1860)	LC	Om	E, Sb, R, PB	2
Centropomus undecimalis (Bloch, 1792)	LC	Om	E, Sb, R, PB	2,8
Gerreidae				
Diapterus auratus (Ranzani, 1842)	LC	R	E, Sb, R, PB	2,8
Diapterus rhombeus (Cuvier, 1829)	LC	R	E, Sb, R, PB	2
Eucinostomus argenteus (Baird & Girard, 1855)	LC	R	E, Sb, R, PB	2,8

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Taxonomy	IUCN Status	Ecological guild	Life habit	Ref
Eucinostomus gula (Quoy & Gaimard, 1824)	LC	R	E, Sb, R, PB	2,8
Eucinostomus melanopterus (Bleeker, 1863)	LC	R	E, Sb, R, PB	2,8
Eugerres brasilianus (Cuvier, 1830)	LC	R	E, Sb, R, PB	2
Mullidae				
Pseudupeneus maculatus (Bloch, 1793)	LC	M	Sb, R, PB	2,8
Kyphosidae				
Kyphosus sectatrix (Linnaeus, 1758)	LC	M	E, R, Wc, P	8
Serranidae				
Alphestes afer (Bloch, 1793)	LC	Om	E, Sb, R, PB	2,8
Diplectrum formosum (Linnaeus, 1766)	LC	Om	E, Sb, R, PB	2
Epinephelus itajara (Lichtenstein, 1822)	VU	Om	E, Sb, R, PB	2
Hyporthodus niveatus (Valenciennes, 1828)	VU	Om	Sb, R, PB	2
Rypticus randalli (Courtenay, 1967)	LC	M	E, Sb, R, PB	2,8
Haemulidae				
Conodon nobilis (Linnaeus, 1758)	LC	Om	E, R, PB	2
Genyatremus luteus (Bloch, 1790)	DD	Om	E, PB	1
Haemulon aurolineatum (Cuvier, 1830)	LC	M	R, PB	2
Haemulon plumieri (Lacépède, 1801)	LC	Om	Sb, R, PB	2
Haemulopsis corvinaeformis (Steindachner, 1868)	LC	M	E, Sb, R, PB	2,8
Orthopristis scapularis (Fowler, 1915)	–	M	E, Sb, R, PB	2
Pomadasys ramosus (Poey, 1860)	–	M	E, PB	2
Rhonciscus crocro (Cuvier, 1830)	DD	M	E, Sb, PB	2
Lutjanidae				
Lutjanus alexandrei (Moura & Lindeman, 2007)	–	M	E, Sb, R, PB	2
Lutjanus buccanella (Cuvier, 1828)	DD	M	Sb, R, PB	2
Lutjanus cyanopterus (Cuvier, 1828)	VU	M	E, Sb, R, PB	2
Lutjanus jocu (Bloch & Schneider, 1801)	DD	M	E, Sb, R, PB	2,8
Lutjanus synagris (Linnaeus, 1758)	NT	M	E, Sb, R, PB	2,8
Lutjanus vivanus (Cuvier, 1828)	LC	M	E, Sb, R, PB	2
Polynemidae				
Polydactylus virginicus (Linnaeus, 1758)	LC	M	E, Sb, R, PB	2,8
SCORPAENIFORMES				
Scorpaenidae				
Scorpaena brasiliensis (Cuvier, 1829)	LC	Om	E, Sb, R, B	2
Scorpaena plumieri (Bloch, 1789)	LC	Om	E, Sb, R, B	2,8
Triglidae				
Prionotus punctatus (Bloch, 1793)	LC	M	E, Sb, R, B	2,8
MORONIFORMES				
Ephippidae				
Chaetodipterus faber (Broussonet, 1782)	LC	M	E, Sb, R, Wc, P, PB	2,8

Continue...

...Continuation

Taxonomy	IUCN Status	Ecological guild	Life habit	Ref
ACANTHURIFORMES				
Sciaenidae				
Bairdiella goeldi (Marceniuk et al., 2019)	LC	M	E, PB	2,8
Cynoscion acoupa (Lacépède, 1801)	VU	M	E, Sb, PB	2
Cynoscion jamaicensis (Vaillant & Bocourt, 1883)	LC	M	E, Sb, PB	6
Cynoscion leiarchus (Cuvier, 1830)	LC	M	E, Sb, PB	6,8
Cynoscion microlepidotus (Cuvier, 1830)	LC	M	E, Sb, PB	6
Cynoscion virescens (Cuvier, 1830)	LC	M	E, Sb, PB	6
Isopisthus parvipinnis (Cuvier, 1830)	LC	M	E, Sb, PB	6
Larimus breviceps (Cuvier, 1830)	LC	M	E, Sb, PB	6,8
Macrodon ancylodon (Bloch & Schneider, 1801)	LC	M	E, Sb, PB	6
Menticirrhus martinicensis (Cuvier, 1830)	–	M	E, Sb, PB	*
Menticirrhus cuiaranensis (Marceniuk et al., 2020)	–	M	E, Sb, PB	8,*
Micropogonias furnieri (Desmarest, 1823)	LC	M	E, Sb, PB	6
Nebris microps (Cuvier, 1830)	LC	M	E, Sb, PB	6
Odontoscion dentex (Cuvier, 1830)	LC	M	R, PB	2
Paralonchurus brasiliensis (Steindachner, 1875)	LC	M	E, Sb, PB	2
Stellifer brasiliensis (Schultz, 1945)	LC	M	E, Sb, PB	2
Stellifer collettei (Chao, Carvalho-Filho & Santos, 2021)	–	M	E, Sb, PB	*
Stellifer gomezi (Cervigón, 2011)	LC	Om	Sb, PB	*
Stellifer menezesi (Chao, Carvalho-Filho & Santos, 2021)	–	Om	Sb, PB	*
Stellifer musicki (Chao, Carvalho-Filho & Santos, 2021)	–	Om	Sb, PB	*
Stellifer naso (Jordan, 1889)	LC	M	E, Sb, PB	2,8
Stellifer punctatissimus (Meek & Hildebrand, 1925)	LC	Om	Sb, PB	8,*
Stellifer rastrifer (Jordan, 1889)	LC	M	E, Sb, PB	2
Stellifer stellifer (Bloch, 1790)	DD	M	E, Sb, PB	2
Umbrina coroides (Cuvier, 1830)	LC	M	E, Sb, R, PB	2,8
LOPHIIFORMES				
Antennariidae				
Antennarius striatus (Shaw, 1794)	LC	Om	E, Sb, R, B	2
Ogcocephalidae				
Ogcocephalus vespertilio (Linnaeus, 1758)	LC	Om	E, Sb, R, B	2,3,8
TETRAODONTIFORMES				
Tetraodontidae				
Colomesus psittacus (Bloch & Schneider, 1801)	LC	M	E, Sb, PB	2
Lagocephalus laevigatus (Linnaeus, 1766)	LC	M	E, R, Wc, P, PB	2,3
Sphoeroides greeleyi (Gilbert, 1900)	LC	R	E, Sb, R, PB	2,3
Sphoeroides spengleri (Bloch, 1785)	LC	Om	Sb, R, PB	2,3
Sphoeroides testudineus (Linnaeus, 1758)	LC	R	E, Sb, R, PB	2,3,8
Diodontidae				
Chilomycterus antillarum (Jordan & Rutter, 1897)	LC	M	Sb, R, PB	2
Chilomycterus spinosus (Linnaeus, 1758)	LC	M	E, Sb, R, PB	2
Diodon holocanthus (Linnaeus, 1758)	LC	M	E, Sb, R, PB	8

1 – Marceniuk et al. 2019; 2 – Marceniuk et al. 2021; 3 – Barbanti et al. 2013; 4 – Tubino et al. 2008; 5 – Gomes et al. 2000; 6 – Chao 2002; 7 – Dantas et al. 2010; 8 – Listed by Rosa 1980b; * Personal data; IUCN – International Union for Conservation of Nature; – unspecified data.

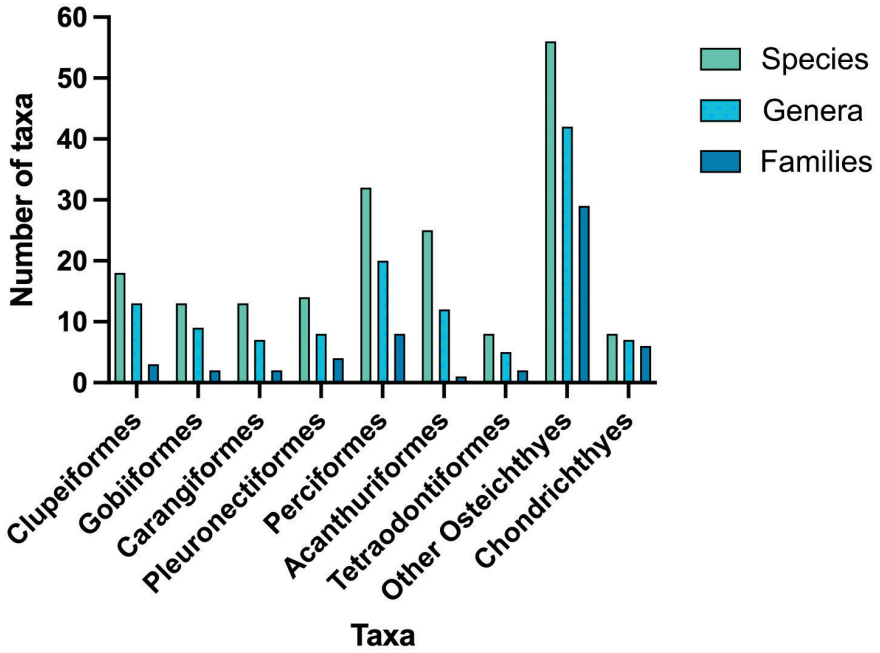

Figure 2. Number of families, genera, and species by higher taxonomic groups of Paraiba River estuary fish fauna, Paraiba, Brazil.

to the seven life habit's categories (estuarine, soft bottom, reef, water column, pelagic, benthopelagic, and benthic), due to the lack of previous studies for all species, for some the assignment to a guild, it was based on their distribution, size, and density in the literature (see Table 1).

Results

The checklist of fishes from Paraiba River estuary includes a total of 187 species, 123 genera, 57 families, 4 orders of Chondrichthyes, and 26 orders of Osteichthyes (Table 1). The class Osteichthyes was the most diverse comprising 95.7% of the total ichthyofauna caught (n = 179). Belonging to this class, Perciformes was the most representative order in terms of richness, with 32 species, followed by Acanthuriformes (n = 25), Clupeiformes (n = 18), and Pleuronectiformes (n = 14) (Figure 2). Among the families, Sciaenidae had the largest number of species (n = 25), followed by Carangidae (n = 12), Engraulidae (n = 10), Gobiidae (n = 9) and Haemulidae (n = 8), which altogether represent 34.2% of the richness in the estuary. The class Chondrichthyes represented only 4.3% of the total ichthyofauna caught (n = 8). All Chondrichthyes families but two were not represented by single species, as well as other 20 Osteichthyan families (Elopidae, Megalopidae, Albulidae, Curimatidae, Characidae, Triportheidae, Cichlidae, Echeneidae, Sphyraenidae, Bothidae, Dactylopteridae, Trichiuridae, Scombridae, Mullidae, Kyphosidae, Polynemidae, Triglidae, Ephippidae, Antennariidae, Ogcocephalidae). Out of the 187 species listed in this study, 128 are new records for the estuary, as only 59 were in a survey carried out 40 years ago in the Paraiba state (Table 1).

All listed species presented coastal habits, were classified by ecological guild, and life habit (Table 1). The resident fish fauna was represented by fewer species (n = 37 – 19.8%) as compared to marine and occasional marine ones (n = 73 and 70 species, respectively – 76.5% both), while the occasional freshwater ones were represented by only seven species (3.7%), two of them exotics (*Oreochromis niloticus* and *Poecilia reticulata*).

According to the International Union for Conservation of Nature Red List categories and criteria in IUCN, five species are classified as Near Threatened (*Narcine brasiliensis*, *Hypanus guttatus*, *Albula vulpes*, *Hippocampus reidi* and *Lutjanus synagris*), seven other species (*Rhizoprionodon porosus*, *Rhinoptera bonasus*, *Megalops atlanticus*, *Epinephelus itajara*, *Hyporthodus niveatus*, *Lutjanus cyanopterus* and *Cynoscion acoupa*) are classified as Vulnerable, two (*Carcharhinus porosus* and *Urotrygon microphthalmum*) are considered Critically Endangered. The other species listed herein are classified as Least Concern or Data Deficient.

Discussion

The fish richness reported herein for Paraiba River estuary (187 species) is greater than that reported for some northeastern estuaries by Reis-Filho et al. (2010) (124 species – Paraguaçu River, Todos os Santos bay, Bahia), Favero et al. (2019) (92 species – Maracaípe River, Ipojuca, Pernambuco), and Melo et al. (2021) (49 species – Timonha and Ubatuba Rivers, Ceará). This is because this study covers a longer sampling effort over time. About forty years ago, a preliminary survey of coastal marine fishes was carried out in Paraiba; 136 fish species were listed, including 59 species that occurred strictly in the Paraiba River estuary (Rosa 1980b). Several species were misidentified in that study or are currently considered as synonym, for instance *Hypanus marianae* was listed as *Dasyatis say* (Lesueur 1817), *Bagre filamentosus* was listed as *Bagre marinus* (Mitchill 1815), and *Diapterus auratus* was listed as *Diapterus olisthostomus* (Goode & Bean 1882).

An updated and more complete fish checklist was pending for this important estuarine system, therefore the taxonomic effort herein

provides records of 187 fish species occurring in the largest estuary in Paraiba state, representing a reliable source of information to scientists, decision makers and the general public.

The predominance of the order Perciformes is a common pattern for estuarine fish inventories from Brazil (Carvalho Neta & Castro 2008, Reis-Filho et al. 2010, Lamas et al. 2016), and this is also the order of greatest richness among teleost fish (Menezes et al. 2007). Regarding the richest families, Sciaenidae, Engraulidae and Gobiidae are frequently reported from tropical estuaries and their species are very abundant in Northeast Brazil (Paiva et al. 2009, Reis-Filho et al. 2010, Martins & Vendel 2014, Dolbeth et al. 2016). In contrast, it seems that, within Brazilian estuaries, a higher biomass of Sciaenidae and Ariidae represents a general pattern, especially in those estuaries with higher mean annual rainfall and under influence of extensive river plume such as the Amazon (Vilar et al. 2013; Marceniuk et al. 2017).

The genus *Stellifer* with nine species was the richest genus in the Paraiba River estuary, followed by *Lutjanus* with six species, *Anchoa* and *Cynoscion* with five species each. This pattern was not identical in nearby estuaries, but little differences were observed regarding the most abundant genera. In the Barra de Camaratuba estuary, Paraiba, *Lutjanus* and *Centropomus* were the richest genera (Martins & Vendel 2014), whereas *Anchoa*, *Ctenogobius*, and *Oligoplites* were the richest in the Paraguaçu River estuary, Bahia (Reis-Filho et al. 2010). Despite this, all the richest genera from the nearby estuaries were also captured in the Paraiba River estuary with at least three species each.

The inventory presented here, includes six species from freshwater environments, three of which, *Psalidodon fasciatus*, *Triportheus guentheri* and *Steindachnerina notonota* were captured exceptionally in 2008 during an El Niño event, when the rains were more intense and freshwater species expanded their range into the estuary. *Oreochromis niloticus* and *Poecilia reticulata* were the only introduced exotic species, both known from freshwater origin. The occurrence of these invading species may be either related to their commercial potential, in terms of food for human consumption (*O. niloticus*) or the aquarium trade (*Poecilia* spp.). The introduction of these species may have resulted from fish farms along rivers that empty into the estuary (Leão et al. 2011) or the improper discard of specimens obtained through the ornamental fish trade, as documented for *Xiphophorus maculatus* (Günther 1866) in a tributary to the Paraiba River estuary, but not recorded herein (Magalhães & Jacobi 2010, Ramos et al. 2020). As it is established that alien species are one of the human-driven threats to biodiversity, the occurrence of two exotic species here leads us to reaffirm the importance of estuaries conservation (Vitousek et al. 1997, Bellard et al. 2016).

On the taxonomic uncertainties, *Citharichthys arenaceus* is a species that occurs in the Caribbean, from the Gulf of Mexico to Venezuela. Here in Brazil we have an undescribed species (misidentified as *C. arenaceus*) which is in the process of description (Rocha 2017), therefore considered in this study *Citharichthys* cf. *arenaceus*. Also, *Rhinosardinia* cf. *bahiensis* might not represent a single species; in the present study most specimens keyed out as *R. amazonica* based on counts of lateral line scales (Carvalho-Filho 1999) and a few specimens tentatively as *R. bahiensis*. We treated all as *Rhinosardinia* cf. *bahiensis*, but future studies should evaluate if such variation may correspond to a single species occurring from Venezuela to Northeastern Brazil.

The catfishes *Cathorops agassizii*, *C. spixii* and S*ciades herzbergii*, the toadfish *Thalassophryne nattereri*, are dangerous species, as already mentioned for this estuary (Macêdo et al. 2017). They are common species on the Brazilian coast (Haddad Jr et al. 2003, Haddad Jr 2003) and their registration herein is important due to the risks of injury caused by them in estuary areas (Haddad Jr 2016).

As expected, fishes that complete their life cycle in the estuarine environment represent few species with large numbers of individuals, which is a recurring pattern in estuarine ecosystems (Barletta et al. 2005, Paiva et al. 2009, Vendel et al. 2010, Vilar et al. 2011). In fact, this may be explained by the fact that resident species are typically euryhaline and tolerate the spatial and temporal fluctuations widely found in estuarine ecosystems (Elliott et al. 2007), especially salinity, which is considered the main factor influencing the distribution of fishes in estuaries (Barletta et al. 2005, Vilar et al. 2011).

It is well known that freshwater inflow is one of the main drivers to the estuarine diversity, in this region the high water consumption by damming, associated with a low freshwater input in the rainy season, might have an influence over nutrient cycling, fish guilds, and in the salinity itself into the estuary (Garcia et al. 2004, Possamai et al. 2018, Possamai et al. 2020), this favors marine species predominance as shown here. Moreover, the damming along the Paraiba river basin, generated by needs towards water consumption, by human, on agriculture, and on livestock (Teixeira et al. 2020) affect the maintenance of annual hydrological regime as a whole, which is characterized by rainy and dry seasons typical of the semiarid Paraiba state region.

Regarding the conservation status of the species listed here, three species classified as Vulnerable according to the IUCN (*M. atlanticus*, *H. niveatus*, *L. cyanopterus*) also appear in the same classification in the red book of the Brazilian fauna threatened of extinction and *E. itajara* as Critically Endangered, all of which have an indication of declining population trends (Lindeman et al. 2016a, Bertoncini et al. 2018, Lindeman et al. 2016b, Pollom et al. 2020). These species have population declines stemming from intense fishing activity in regions where they occur (MMA 2020). Regarding the Elasmobranchii, only *Carcharhinus porosus* is listed as Critically Endangered in Brazil (Pollom et al. 2020) and also globally, according to the last IUCN (2022) assessment. This species has not been captured again in the estuary or in other locations of Paraiba state since the 70's. Another species, *Porichthys kymosemeum*, not evaluated by the IUCN, also has not been captured in the estuary or in other locations of Paraiba since the early 1980's. This reinforces the importance of recording and monitoring the fish species occurrence over time.

Conclusions

This inventory of fish species from the Paraiba River estuary organizes and expands the knowledge about the fish community that occurs in this ecosystem, providing knowledge about richness, life habits, ecological guilds and conservation status of fish species, important data for the proper management of local species as ecological and economic resources.

Supplementary Material

The following online material is available for this article:

Table A.1 – Taxonomic list with voucher numbers of fish species collected in the Paraiba River estuary, deposited at the fish collection of Universidade Federal da Paraiba (UFPB). The fish species nomenclature followed Fricke et al. (2022), taxonomic order according to Nelson et al. (2016).

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Conflicts of Interest

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

Data Availability

The entire dataset supporting the results of this study was published in the article and in the section “Supplementary materials”.

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