BOLETIM DO INSTITUTO DE PESCA
ISSN 1678-2305 online version
Scientific Article

STRUCTURE OF THE FISH ASSEMBLAGE AND FUNCTIONAL GUILDS IN THE ESTUARY OF MARACAÍPE, NORTHEAST COAST OF BRAZIL

Fernanda de Lima Toledo Favero[1]
Isabela Maria da Silva Araujo[1]
William Severi[1]

[1]Universidade Federal Rural de Pernambuco – UFRPE, Departamento de Pesca e Aquicultura, Laboratório de Ictiologia, Rua Dom Manoel de Medeiros, s/n, Dois Irmãos, Recife, PE, Brasil. E-mail: nandalimafavero@gmail.com (corresponding author).

Recebido: Junho 15, 2018
Aprovado: Agosto 02, 2018

ABSTRACT

The assemblage and functional structure of the fish fauna of the Maracaípe River, municipality of Ipojuca - PE, was characterized by monthly beach trawls carried out from March of 2012 to February of 2013. A beach trawl net (picaré) was used at three different points of the estuary (EST 1, EST 2 and EST 3) during day and night trawls. The captured specimens were measured and weighed in the laboratory, identified and separated into use and trophic guilds using appropriate literature. Abiotic variables (temperature, salinity, dissolved oxygen, pH, turbidity and chlorophyll-a) were analyzed as for differences between day periods (night and day) and seasons (dry and rainy), and correlated to fish abundance. No difference was detected between day periods ($p>0.07$ for all variables), but they differed between seasons for most variables ($p\leq0.02$), and between sampling points only for dissolved oxygen ($p=0.03$). In one year of collection, 11,513 specimens were captured, belonging to 92 species, 38 families and 15 orders. Gerreidae, Atherinopsidae, Clupeidae, Gobiidae and Hemiramphidae were responsible for 82.99% of the total abundance. The estuary of the Maracaípe River presents a rich ichthyofauna, but with the quantitative predominance of seven species (*Atherinella brasiliensis, Eucinostomus argenteus, E. melanopterus, Ulaema lefroyi, Lile piquitinga, Ctenogobius boleosoma* and *Hyporhamphus unifasciatus*). In the estuary, six species classified as vulnerable on the IUCN Endangered Species List were reported. The estuary presents a high diversity of species, most of them marine, carnivorous, and opportunistic, showing the high resilience of this environment. The predominance of juvenile fish underscores the importance of the Maracaípe River estuary for the maintenance of population stocks of coastal species, demonstrating the urgent demand of management of this environment.

Key words: abundance; richness; use guild; trophic guild; juvenile fish.

ESTRUTURA DA ASSEMBLEIA E GUILDAS FUNCIONAIS DE PEIXES NO ESTUÁRIO DO RIO MARACAÍPE, COSTA DO NORDESTE DO BRASIL

RESUMO

A assembleia e a estrutura funcional de peixes estuarinos do rio Maracaípe, município de Ipojuca - PE, foi caracterizada através de arrastos de praia mensais de março de 2012 a fevereiro de 2013. Uma rede tipo picaré foi utilizada em três pontos distintos do estuário (EST 1, EST 2 and EST 3), em arrastos diurnos e noturnos. Os exemplares capturados foram medidos e pesados em laboratório, identificados e separados quanto às guildas de ocupação e tróficas. Variáveis abióticas (temperatura, salinidade, oxigênio dissolvido, pH, turbidez e clorofila-a) foram analisadas quanto a diferenças entre períodos do dia (dia e noite) e estações (seca e chuvosa), e correlacionadas com a abundância de peixes. Não foram detectadas diferenças entre os períodos do dia ($p>0.07$ para todas as variáveis), mas diferiram entre as estações para a maioria delas ($p\leq0.02$), e entre os pontos de coleta apenas para oxigênio dissolvido ($p=0.03$). Em um ano de coleta, foram capturados 11513 exemplares, pertencentes a 15 ordens, 38 famílias e 92 espécies. Gerreidae, Atherinopsidae, Clupeidae, Gobiidae e Hemiramphidae foram responsáveis por 82,99% da abundância total. O estuário do rio Maracaípe apresenta uma ictiofauna rica, porém com predominância quantitativa de sete espécies (*Atherinella brasiliensis, Eucinostomus argenteus, E. melanopterus, Ulaema lefroyi, Lile piquitinga, Ctenogobius boleosoma* e *Hyporhamphus unifasciatus*). No estuário, ocorreram seis espécies integrantes da Lista de Espécies Ameaçadas, classificadas como vulneráveis. O estuário amostrado apresentou uma alta diversidade de espécies, sendo a maioria delas marinhas, carnívoras e oportunistas, evidenciando a elevada resiliência deste ambiente. A predominância de peixes juvenis ressalta a importância do estuário do rio Maracaípe para a manutenção de estoques populacionais de espécies costeiras, demonstrando a urgência de gerenciamento deste estuário.

Palavras-chave: abundância; riqueza; guilda de uso; guilda trófica; peixes juvenis.

INTRODUCTION

Estuaries are highly productive environments, which favors their use by fish, mainly in their early stages of life, whether they are resident or from different coastal environments, where they find shelter against predators, abundant food and calm waters for reproduction (Able et al., 2010; Barbieri et al., 2014). Fishes represent most of the nektonic species found in estuaries, being of high ecological importance for their role either by transferring energy to higher trophic levels, or by switching energy to neighboring environments through species moving between different coastal environments (Potter et al., 2011).

As transitional ecosystems between rivers and the sea, estuarine waters are subject to spatial and temporal variations in abiotic parameters, such as temperature, salinity, pH, dissolved oxygen and turbidity. These occur between day and night, throughout the year and between the dry and rainy seasons, according to the variation of the continental water intake (Whitfield and Elliott, 2011). These variations determine the estuarine ichthyofauna, composed of species that use or depend on this environment for some periods or all its life cycle (Elliott and Quintino, 2007).

In studies of the distribution and use of estuaries by fish assemblages, in addition to the analysis of the taxonomic diversity found in this environment, the approach of functional guilds in its characterization has been increasingly used, enabling comparative analyses with other coastal environments (Elliott et al., 2007; Potter et al., 2015).

Guilds are defined as grouping of different species that share the same resources, such as food or space. The classification of estuarine fish into functional guilds, used for the description of assemblage structure, serves for a better characterization of the trophic and occupational use of the environment, by considering the ecological patterns of the ichthyofauna and fish behavior during its permanence in the estuary (Elliott et al., 2007).

The characterization of the fish assemblage and its spatial and temporal variation is paramount for environmental quality assessment, since fish occupy several habitats and trophic levels (Dolbeth et al., 2008), whose analysis is relevant to understanding species distribution in estuaries and the role of these environments in their life cycle (Mclusky and Elliott, 2007).

Studies on functional guilds of estuarine fish in Brazil have been mainly developed along its northern (Barletta et al., 2003; Barletta and Blaber, 2007; Giarrizzo and Krumme, 2007) and southern (Garcia et al., 2003; Possamai et al., 2018) coast. Fewer studies are reported for the northeastern coast, mainly for the State of Pernambuco, where Vasconcelos-Filho and Oliveira (1999) assigned fish species from the Canal de Santa Cruz (northern coast) into use guilds, and Paiva et al. (2008) characterized the trophic guilds of the ichthyofauna of the Formoso River, located on the southern coast.

In spite of being one of the thirteen Conservation Units (UC's) of the state of Pernambuco, northeastern Brazil, with a character of sustainable use, according to state law No. 9,931/1986 (Brasil, 1986), the estuary of the Maracaípe River, located on its southern coast, is an important tourist location in the region, but has been submitted to an increasing urban occupation of its shoreline in recent decades.

In this context, faced with the environmental and socio-economic importance of the region, it is necessary to know the local biodiversity and evaluate its ecological importance for marine coastal fish fauna, for which there is no scientific record of compiled and monitored data so far.

MATERIAL AND METHODS

Study area

The estuary of the Maracaípe River is inserted in the northeastern coast of Brazil, on the southern coast of Pernambuco, with an area of 33.35 km^2 and an approximate length of 4.3 km, located in the municipality of Ipojuca, about 70 km from the metropolitan region of the capital, Recife (Nova and Torres, 2012). The estuary has a total vegetated area of 8.95 km^2, being 35% (3.2 km^2) of mangrove composed by *Rhizophora mangle* (L.), *Avicennia schaueriana* Stappf & Leechm and *Laguncularia racemosa* (L.) Gaerth (Nova et al., 2017). Maracaípe is a coastal plainland river basin with an open estuary (sensu Harrison and Whitfield, 2008), although its catchment is small (<500 km^2) and with a low river discharge, but tidal currents provide a permanent connection of the estuary with the sea.

The region has a climate of type Ams' (Köppen, 1931), with average air temperatures between 25 and 30°C, being October, November, December, January, February, and March, the hottest months; and April, May, June, July, August and September, with milder temperatures (average 23°C) (Macêdo et al., 2010). The average annual rainfall in the region is 2,000 mm, and during the study period, the months of March to August 2012 corresponded to the rainy season (>100 mm $month^{-1}$), and from September 2012 to February 2013, to the dry season (<100 mm $month^{-1}$).

Field procedure

For the present study, three collection points equally distributed within the estuary were selected (Figure 1), with an approximate distance of 1.5 km between them. The upper collection point, EST 1 (08°31'52.3"S and 35°00'45.0"W), is located in an urbanized region, subject to the discharge of domestic effluents and vegetation suppression from the left river bank due to house building. The midpoint, EST 2 (08°32'20.4"S and 35°00'50.0"W) is located in the best-preserved portion of the mangrove and subject to less direct anthropic influence. The lower point of the Maracaípe River, EST 3 (08°32'28.8"S and 35°00'22.6"W), is located near the river mouth and subject to tourist activity, with intense movement of rafts and swimmers.

Monthly collections were held in the period from March of 2012 to February of 2013. The collections were carried out in the new moon phase (syzygy tide), in day ebb tide and night ebb tide, by three consecutive trawls parallel to the coastline with an approximate duration of 10 minutes each, using a beach trawl net (picaré) measuring 20 m in length, 2.5 m of height and 5 mm mesh size. Before each trawl, water temperature, salinity,

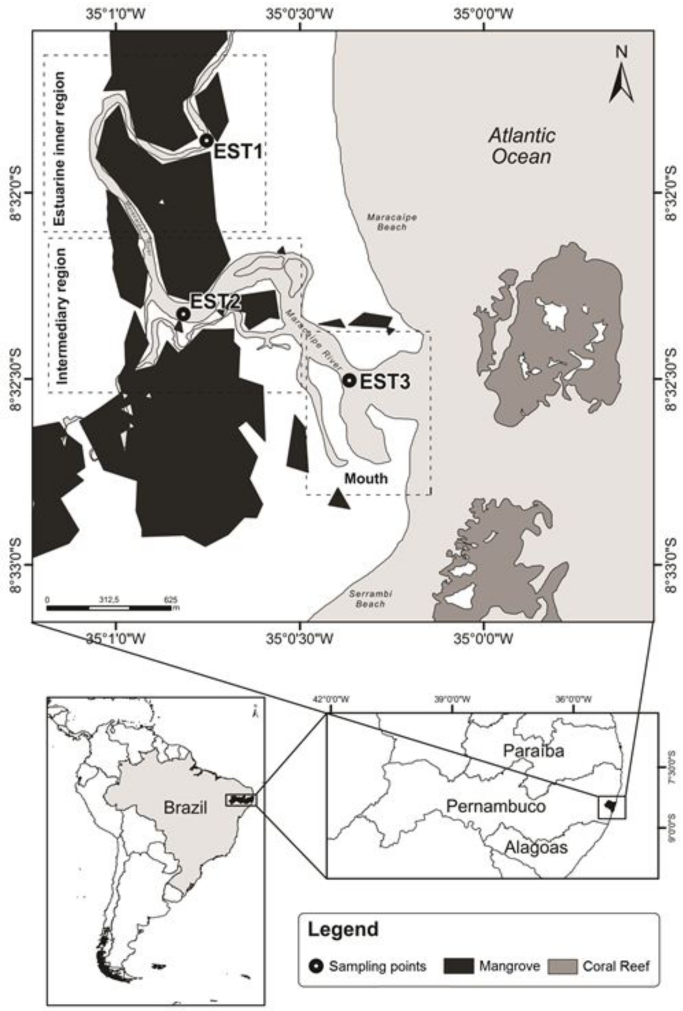

Figure 1. Map of the Maracaípe River estuary, with the location of the three sampling points: EST 1 - estuarine upper region; EST 2 - intermediary region; and EST 3 – lower region (river mouth).

dissolved oxygen and pH were measured with a portable field meter, and surface water samples were collected for analysis of turbidity and chlorophyll-a (Nusch, 1980).

The captured specimens were kept in identified plastic bags separated according to the collection point (EST 1, EST 2 or EST 3), period of day (day or night) and month of sampling, immersed in ice and subsequently fixed in 4% formaldehyde. The collections were carried out through the authorization 33383-2/SISBIO/ICMBio, and the methodological procedures were approved by the ethic license CEUA/UFRPE N º 056/2013.

Laboratory procedure

In the laboratory, samples were transferred to 70% ethanol, and the taxonomic identification was done using appropriate literature (Figueiredo, 1977; Figueiredo and Menezes, 1980, 2000; Menezes and Figueiredo, 1980, 1985; Whitehead, 1985; Whitehead et al., 1988; Carpenter, 2002; Marceniuk, 2005).

After the taxonomic identification, each specimen was weighed (TW – total weight in grams) with a precision scale (0.001 g) and measured (L – total length in mm) with a digital caliper (0.01 mm), and all data were typed into an electronic spreadsheet.

The fish species were classified into occupational guilds, according to the functional use guilds of Elliott et al. (2007), as marine estuarine-opportunist (MMO), marine species that enter the estuary frequently, in large groups, usually when juveniles, making use of distinct forms and/or as an optional habitat; marine estuarine-dependent (MMD), those who enjoy the abundant food and shelter offered by the estuary, especially when young; and estuarine specie (ES), species that complete their entire life cycle in the estuary.

For the grouping of species into trophic guilds, the food habits categories were adapted from Bouchon-Navarro et al. (1992), characterized as: herbivores (H), fish feeding from algae to higher aquatic vegetables; planktivores (P), including species that favors phytoplankton and zooplankton as food; omnivores (O), fish that ingest from invertebrates to algae, depending on the availability of the food; 1st order carnivores (C-I), representatives who ingest primarily benthic invertebrates; 2nd order carnivores (C-II), basically consume invertebrates and fish; and 3rd order carnivores (C-III), species whose diet is composed of more than 80% of fish. It was also considered the trophic category of detritivores (D), including species that feed on organic remains (Elliott et al., 2007).

The classification of species into trophic and use guilds was based on information available at the virtual database Fishbase (Froese and Pauly, 2018), and publications related to the topic (e.g. Bouchon-Navarro et al., 1992; Barletta and Blaber, 2007; De Paiva et al., 2009; Reis Filho, 2013).

Length at first maturity (L_{mat}) of the most abundant and frequent species was estimated using the formula $L_{mat} = 0.64\ L_{\infty}^{0.95}$, according to Gislason et al. (2008), for individuals' classification into juvenile phase. Maximum size (L_{max}) was used instead of L_{∞}, since there is insufficient data to model growth for all species (Le Quesne and Jennings, 2012), and L_{max} data are more readily available and can be accessed directly from data sets, such as Froese and Pauly (2018).

Vulnerable species that occurred in the study area were classified, according to the RedList of the International Union for the Conservation of Nature (the IUCN Red List), and the list of threatened species from the Brazilian Ministry of the Environment (MMA, 2016).

The sum of the three trawls taken at each collection point per daily period was considered as a single sample. These data were used to obtain the abundance and biomass of the captured species, and for the analysis of the structure of the fish assemblage, based on species richness (S), and Brillouin diversity (H) and evenness (J). The twenty species with relative abundance exceeding 2% in each sampling point and occurrence ≥50% in all sampling months were considered for the comparative analysis of the assemblage structure, using the Bray-Curtis similarity index (S_{bc}) based on an abundance matrix. The analyses were performed with the application Primer 6.0 (Anderson et al., 2008).

Environmental variables and fish abundance data were analyzed for normality and homoscedasticity, and further compared for differences between sampling points, periods of the day (day and night) and seasons (dry and rainy) with Kruskal-Wallis and Mann-Whitney tests, as assumptions of normality were not met, using Statistica 8.0 (StatSoft Inc., 2007).

RESULTS

Environmental variables

The median values of water temperature, pH, chlorophyll-a, turbidity, salinity and dissolved oxygen from each collection point of the estuary of the Maracaípe River are presented in Table 1. No significant difference between the collection points in relation to the abiotic variables studied were observed, except for dissolved oxygen. This variable presented significantly higher values in EST 3 (6.6 $mg.L^{-1}$), relative to EST 1 and EST 2 (4.9-5.5 $mg.L^{-1}$). Altogether, abiotic variables did also not differ between periods of day ($p>0.07$ for all variables) but presented significant differences between seasons for all variables, except for chlorophyll-a.

Assemblage structure

The ichthyofauna of the Maracaípe River estuary is composed of 91 species, belonging to 38 families and 15 orders, based on a total catch of 11,513 individuals (Tables 2, 3 and 4).

For analysis of the data, the species were classified according to their occurrence in the sampling points, being 29 species with occurrence at all points (Table 2); 25 species occurring in two points (Table 3), and 37 species with occurrence at only one of the sampling points (Table 4).

From the species occurring in only one of the sampling points (Table 4), eight were found in EST 3 (21.6%), nine in EST 1 (24.3%) and twenty in EST 2 (54.0%), including two species of sea-horses (*Hippocampus erectus* and *H. reidi*). Species richness, diversity and evenness were higher in EST 1 and EST 2, and evenness values (>0.5) indicate that the fish species are well distributed in the assemblages (Table 5).

Abundance

The higher abundance was recorded at the middle sampling point (EST 2), with 4,789 specimens captured (39.9% of the total number of fish collected in all points), followed by the upper point (EST 1), with 3,912 individuals (32.6%), and the lower point (EST 3), with 3,289 individuals (27.4%). Fish were more abundant during the day (59.0%), from which 7,228 individuals (60.3%) were collected in the dry season and 4,762 fish (39.7%) in the rainy season.

The Bray-Curtis quantitative similarity between the sampling points was 64.1% between EST 1 and EST 3, and 52.3% between these and EST 2. The median values of fish abundance in each sampling point did not differ significantly between the periods of the day or seasons (Table 6).

The abundance of the fish assemblages in the estuary of the Maracaípe River was dominated by *Atherinella brasiliensis* (26.4%), *Ulaema lefroyi* (16.5%), *Lile piquitinga* (16.4%), *Ctenogobius boleosoma* (8.7%), *Eucinostomus argenteus* (8.3%), *Hyporhamphus unifasciatus* (4.3%) and *Eucinostomus melanopterus* (2.5%), representing altogether 82.9% of total abundance. Considering the species with relative abundance ≥2% in any sampling point and occurrence ≥50% in sampling months, other thirteen species represented together almost 95% of total abundance: *Achirus lineatus, Anchoa tricolor, Anchovia clupeoides, Centropomus undecimalis, Diapterus auratus, D. rhombeus, Eucinostomus gula, E. havana, Haemulon aurolineatum, Mugil curema, Sphoeroides greeleyi, S. testudineus* and *Strongylura timucu*.

The similarity analysis based on the twenty more-abundant species showed the formation of three groups: group A consisted of less-abundant or absent species at any sampling point, group B formed by those with average abundances, and group C for the more-abundant ones (Figure 2, Table 7).

Biomass

The total biomass obtained was 51,792.64g (17,634.85g in EST 1; 17,010.58g in EST 2 and 17,147.21g in EST 3), and the twenty species that contributed most corresponded to the more-abundant ones. These species represented 81-93% of the total biomass of

Table 1. Median values of water temperature, pH, turbidity, salinity, dissolved oxygen and chlorophyll–a in each sampling point, season and period of day of the Maracaípe River estuary, between March 2012 and February 2013.

Abiotic variables	Sampling point			p
	EST 1	EST 2	EST 3	
Dissolved oxygen ($mg.L^{-1}$)	4.87	5.50	5.62	0.003*
Salinity	33.97	34.53	34.53	0.917
pH	7.71	7.71	7.69	0.978
Chlorophyll-a (µg/L)	2.23	1.40	1.95	0.099
Turbidity (NTU)	3.00	3.00	3.00	0.807
Temperature (°C)	27.25	27.47	27.61	0.930

*Significant values ($p<0.05$).

Table 2. Species with occurrence at all sampling points of the Maracaípe River estuary (EST 1, EST 2 and EST 3), with respective total abundance (N), total biomass (TB), use (UG) and trophic (TG) guild classification.

Species	N	TB (g)	UG#	TG‡
Anchoa tricolor (Spix & Agassiz, 1829)**	143	871.75	ES	C-II
Anchovia clupeoides (Swainson, 1839)**	205	1917.40	ES	P
Lile piquitinga (Scheiner & Miranda Ribeiro, 1903)**	1963	7931.70	ES	P
Mugil curema Valenciennes, 1836**	106	1604.07	MMD	O
Mugil curvidens Valenciennes, 1836	9	297.25	MMO	D
Mugil liza Valenciennes, 1836	19	337.28	MMO	O
Mugil sp. Linnaeus, 1758	16	9.10	MMD	D
Atherinella brasiliensis (Quoy & Gaimard, 1824)**	3162	9479.16	ES	O
Hyporhamphus unifasciatus (Ranzani, 1841)**	517	3234,.41	MMO	H
Strongylura timucu (Walbaum, 1792)**	56	1097.89	MMO	C-II
Bathygobius soporator (Valenciennes, 1837)	15	97.21	MMO	O
Caranx hippos (Linnaeus, 1776)	11	94.85	MMD	C-II
Caranx latus Agassiz, 1831	49	375.81	MMD	C-II
Centropomus parallelus Poey, 1860	12	258.32	MMD	C-II
Ctenogobius boleosoma (Jordan & Gilbert, 1882)**	562	135.60	ES	C-I
Diapterus auratus Ranzani, 1842**	46	370.91	MMD	O
Eucinostomus argenteus Baird & Girard, 1855**	993	7733.47	MMD	C-II
Eucinostomus gula (Quoy & Gaimard, 1824)**	52	256.95	MMO	O
Eucinostomus havana (Nichols, 1912)**	41	209.75	MMD	C-I
Ulaema lefroyi (Goode, 1874)**	1976	545.76	MMD	C-I
Eucinostomus melanopterus (Bleeker,1863)**	301	644.25	MMD	O
Eugerres brasilianus (Cuvier, 1830)	19	0.16	MMO	O
Achirus lineatus (Linnaeus,1758)**	233	2618.80	MMO	C-II
Bothus ocellatus (Agassiz, 1831)	42	113.49	MMD	C-II
Citharichthys arenaceus Evermann & Marsh, 1900	84	252.57	MMO	C-II
Citharichthys macrops Dresel, 1885	86	223.75	MMO	C-II
Citharichthys spilopterus Günther, 1862	41	208.26	MMO	C-I
Sphoeroides greeleyi Gilbert, 1900**	265	2362.32	ES	C-I
Sphoeroides testudineus (Linnaeus, 1758)**	114	2680.48	MMD	C-I
Total	11138	46167.92	-	-

#Use guilds: MMO – marine estuarine-opportunist; MMD-estuarine-dependent and ES- estuarine resident; ‡ Trophic guilds: C-I – 1st order carnivore; C-II – 2nd order carnivore; C-III – 3rd order carnivore; D – detritivore; H – herbivore; O – omnivore; P – planktivore; ** Species with relative abundance higher than 2% at any sampling point and occurrence ≥50% in the sampling months.

Table 3. Species with occurrence in two sampling points of the Maracaípe River estuary (EST) with respective total abundance (N), total biomass (TB), use (UG) and trophic (TG) guild classification.

Species	N	TB (g)	UG*	TG*	EST
Albula vulpes (Linnaeus,1758)	7	93.44	MMO	C-II	2,3
Myrophis punctatus Lütken, 1852	2	26.64	MMD	C-II	1,2
Anchoviella lepidentostole (Fowler, 1911)	2	10.78	MMD	C-I	2,3
Harengula clupeola (Cuvier, 1829)	16	157.91	MMD	P	1,2
Synodus foetens (Linnaeus, 1766)	19	645.98	MMO	C-II	2,3
Mugil incilis Hancock, 1830	4	334.61	MMD	D	1,2
Atherinella cf. *blackburni* (Schultz, 1949)	2	0.29	MMO	C-I	1,3

*The description of the acronyms of the use and trophic guilds is stated in the footnote of Table 2. ** Species with relative abundance higher than 2% at any sampling point and occurrence ≥50% in the sampling months. ***Species classified as vulnerable (VU) according to IUCN and MMA.

Table 3. Continued...

Species	N	TB (g)	UG*	TG*	EST
Strongylura marina (Walbaum, 1792)	6	128.35	MMO	C-II	1,2
Strongylura sp. van Hasselt, 1823	2	1.21	MMO	C-II	1,2
Tylosurus acus acus (Lacepède, 1803)	14	377.21	MMD	C-II	1,2
Carangoides bartholomaei (Cuvier, 1833)	7	119.13	MMD	C-III	1,2
Centropomus pectinatus Poey, 1860	2	16.75	MMD	C-II	1,2
Centropomus undecimalis (Bloch, 1792)**	60	1270.17	MMD	C-II	1,2
Chaetodipterus faber (Broussonet, 1782)	2	67.85	MMO	C-I	1,2
Diapterus rhombeus (Cuvier, 1829)**	21	57.79	MMD	C-II	1,2
Haemulon aurolineatum Cuvier, 1830**	80	336.60	MMO	C-I	2,3
Haemulon steindachneri (Jordan & Gilbert, 1882)	8	28.77	MMO	C-I	2,3
Haemulopsis corvinaeformis (Steindachner, 1868)	3	86.55	MMO	O	2,3
Lutjanus alexandrei Moura & Lindeman, 2007	5	105.11	MMO	C-II	1,2
Lutjanus cyanopterus (Cuvier, 1828)***	3	34.40	MMO	C-II	1,3
Lutjanus jocu (Bloch & Schneider, 1801)	6	223.30	MMO	C-II	1,2
Oligoplites saurus (Bloch & Schneider, 1801)	3	18.58	MMO	C-II	2,3
Polydactylus virginicus (Linnaeus, 1758)	3	31.02	MMD	C-I	2,3
Sphyraena barracuda (Edwards, 1771)	9	531.10	MMO	C- III	1,2
Symphurus tessellatus (Quoy & Gaimard, 1824)	9	65.96	MMO	C-II	1,2
Total	295	4769.5	-	-	-

*The description of the acronyms of the use and trophic guilds is stated in the footnote of Table 2. ** Species with relative abundance higher than 2% at any sampling point and occurrence ≥50% in the sampling months. ***Species classified as vulnerable (VU) according to IUCN and MMA.

Table 4. Species with occurrence in one of the sampling points of the Maracaípe River estuary (EST), with respective total abundance (TN), total biomass, use (UG) and trophic (TG) guild classification.

Species	TN	TB (g)	UG*	TG*	EST
Ophichthus cylindroideus (Ranzani, 1839)	1	10.73	MMO	C-II	1
Ophichthys ophis (Linnaeus, 1758)	1	18.92	MMO	C-II	2
Anchoa spinifera (Valenciennes, 1848)	9	59.20	MMO	C-II	1
Cetengraulis edentulus (Cuvier, 1829)	2	11.88	MMD	P	3
Cathorops spixii (Agassiz, 1829)	1	0.80	MMD	C-I	2
Talassophryne nattereri Steindachner, 1876	1	0.18	MMD	C-II	2
Antennarius striatus (Shaw, 1794)	1	2.29	MMO	C-III	3
Ablennes hians (Valenciennes, 1846)	1	12.85	MMO	C-II	2
Tylosurus crocodilus (Péron & Lesueur, 1821)	3	27.08	MMD	C-III	2
Bryx dunckeri (Metzelaar, 1919)	1	0.20	MMO	C-I	2
Hippocampus erectus Perry, 1810**	1	2.75	MMO	C-I	2
Hippocampus reidi Ginsburg, 1933**	1	0.51	ES	C-I	2
Syngnathus pelagicus Linnaeus, 1758	1	0.23	MMO	C-I	2
Dactylopterus volitans (Linnaeus, 1758)	3	32.54	MMO	C-II	3
Acanthurus bahianus Castelnau, 1855	1	1.15	MMO	H	2
Archosargus rhomboidalis (Linnaeus, 1758)	1	108.21	MMO	C-I	2

*The description of the acronyms of the use and trophic guilds is stated in the footnote of Table 2. **Species classified as vulnerable (VU) according to IUCN and MMA.

Table 4. Continued...

Species	TN	TB (g)	UG*	TG*	EST
Astroscopus y-graecum (Cuvier, 1829)	1	13.87	MMO	C-III	3
Bairdella ronchus (Cuvier, 1830)	4	37,.24	MMD	C-II	1
Dactyloscopus crossotus Starks, 1913	1	0.20	MMO	O	3
Epinephelus adscensionis (Osbeck, 1765)	1	0.57	MMO	C-II	2
Gobioides broussonnetii Lacepède, 1800	1	0.40	MMD	O	1
Gobionellus oceanicus (Pallas, 1770)	8	0.67	ES	O	2
Pomacanthus paru (Bloch, 1787)	2	1.27	MMO	C-I	3
Pomadasys crocro (Cuvier, 1830)	2	8.34	MMO	O	1
Pseudupeneus maculatus (Bloch, 1793)	1	1.30	MMO	C-I	2
Rypticus saponaceus (Bloch & Schneider, 1801)	1	39.30	MMO	C-II	2
Sparisoma radians (Valenciennes, 1840)	1	0.25	MMO	H	2
Sphyraena guachancho Cuvier, 1829	1	27.06	MMO	C-III	2
Achirus declives Chabanaud, 1940	7	75.21	MMO	C-III	1
Bothus robinsi Topp & Hoff, 1972	3	3.14	MMD	C-I	1
Citharichthys sp. Günther, 1862	3	0.11	MMO	C-II	2
Etropus crossotus Jordan & Gilbert, 1882	2	2.04	MMD	O	3
Paralichthys brasiliensis (Ranzani, 1842)	2	113.12	MMO	C-II	3
Symphurus plagusia (Bloch & Schneider, 1801)	3	11.56	MMD	C-I	1
Trinectes paulistanus (Miranda Ribeiro, 1915)	4	37.52	MMD	C-II	1
Balistes vetula Linnaeus, 1758**	1	3.22	MMO	C-I	2
Sphoeroides spengleri (Bloch, 1785)	1	9.18	MMO	C-I	2
Total	79	657.09	-	-	-

*The description of the acronyms of the use and trophic guilds is stated in the footnote of Table 2. **Species classified as vulnerable (VU) according to IUCN and MMA.

Table 5. Result of species richness and Brillouin diversity and evenness indexes of the fish assemblages at the sampling points of the Maracaípe River estuary.

Indexes	Sampling points		
	EST 1	EST 2	EST 3
Species richness (S)	55	72	47
Diversity (H)	2.39	2.24	1.86
Evenness (J)	0.60	0.56	0.51

Table 6. Median values of fish abundance according to daily period (day and night) and season (dry and rainy) at the sampling points of the Maracaípe River estuary.

	Sampling point				p
	EST 1	EST 2	EST 3		
Period	Day	168.0	145.0	99.0	0.1812
	Night	70.5	201.0	120.5	0.1160
Season	Dry	113.5	189.5	186.0	0.7664
	Rainy	87.0	101.5	71.5	0.4368
	Total	106.5	178.0	104.5	0.4675

Table 7. Fish species with frequency of occurrence ≥50% along the period of study and total abundance ≥2% at any sampling point of the Maracaípe River estuary, grouped according to the quantitative similarity of Bray-Curtis, and respective use and trophic guilds.

		Species	Guilds	
			Use	Trophic
Groups*	A	*Haemulon aurolineatum* (1)	MMO	C-I
		Diapterus rhombeus (2)	MMD	C-II
		Centropomus undecimalis (3)	MMD	C-II
		Diapterus auratus (4)	MMD	O
		Strongylura timucu (5)	MMO	C-II
		Eucinostomus gula (6)	MMO	O
		Eucinostomus havana (7)	MMD	C-I
	B	*Sphoeroides testudineus* (8)	MMD	C-I
		Anchovia clupeoides (9)	ES	P
		Achirus lineatus (10)	MMO	C-II
		Eucinostomus melanopterus (11)	MMD	O
		Hyporhamphus unifasciatus (12)	MMO	H
		Sphoeroides greeleyi (13)	ES	C-I
		Anchoa tricolor (14)	ES	C-II
		Mugil curema (15)	MMD	O
	C	*Atherinella brasiliensis* (16)	ES	O
		Lile piquitinga (17)	ES	P
		Ctenogobius boleosoma (18)	ES	C- I
		Ulaema lefroyi (19)	MMD	C-I
		Eucinostomus argenteus (20)	MMD	C- II

* Group A – less-abundant species or absent at any sampling point; Group B – Species with average abundance, and group C – more-abundant species; with their respective functional (MMO – marine estuarine-opportunist; MMD – marine estuarine-dependent and ES – estuarine resident) and trophic (C-I-1st order carnivore; C-II – 2nd. order carnivore; H – herbivore, O – omnivore, and P – planktivore) guilds.

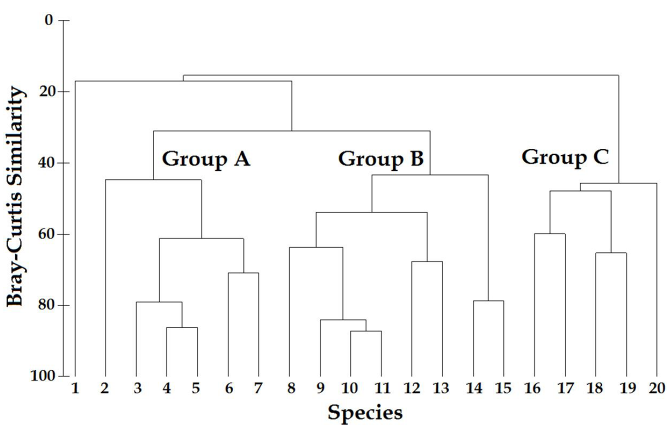

Figure 2. Dendrogram of the Bray-Curtis similarity based on fish biomass of the most frequent (>50%) and abundant (≥2%) species at any sampling point of the Maracaípe River estuary. Species numbers correspond to fish species as presented in Table 7.

each sampling point, and 87.8% of the total biomass collected in the estuary. The other 71 species presented reduced individual participation in total biomass, 42 of them having contributed with less than 0.1%. The individual weight of the specimens varied from 0,01 to 98 g (mean 4,3 g), and the largest number of them belonged to Atherinopsidae, Engraulidae, Clupeidae and Gobiidae (46.1% of total biomass), families whose species were small-sized fish (mean SL<54 mm).

The most frequent and abundant fish species collected in the Maracaípe estuary were mainly juveniles (Table 8), and those whose maximum sizes (L_{max}) exceeded the estimated size at maturity (L_{mat}) were in low numbers (<16%), except for *Anchoa tricolor*, whose individuals were mostly adults (>90%).

Functional guilds

Among the species common to all sampling points (Table 2), 55.2% are carnivorous (C-I – 20.7% and C-II – 34.5%) and 79.4% represented by marine species (dependent – 41.4% and opportunistic – 38.0%). Many of them are of economic importance, such as *Anchoa tricolor*, *Mugil* sp., *Hyporhamphus unifasciatus*, S*trongylura timucu* and *Centropomus parallelus*.

Regarding the species found in two of the sampling points (Table 3), 17 were captured in EST 1, 23 in EST 2 and 10 in EST 3, mostly represented by marine opportunistic (60%) and 2nd order carnivorous species (56%), without occurrence of resident and herbivorous ones.

Only eight resident species were found in the Maracaípe River estuary (Table 9), including *Hippocampus reidi*, *Gobionellus oceanicus*, *Lile piquitinga, Anchoa tricolor, Sphoeroides greeleyi, Anchovia clupeoides, Atherinella brasiliensis* and *Ctenogobius boleosoma*, but only the latter six of them are among the twenty most abundant species, and with greater participation in total biomass (groups B and C, Table 7 and Figure 2). Despite their small number, resident species comprised 56.6% of total abundance and 44.3% of total biomass.

As for the Maracaípe estuary as a whole, more than 90% of the species fall into the marine estuarine-opportunist and marine estuarine-dependent use guilds, and 73.9% of them presented carnivorous habits (Table 9). The largest abundance was represented by carnivores (45.9% of total biomass) and omnivores (31.2%), *Atherinella brasiliensis* being the most abundant omnivore species (26.37%) in the estuary of the Maracaípe River (Table 2).

Table 8. Size range (L_{min}-L_{max}), average size (L_m), recorded maximum size (RL_{max}) and estimated size at maturity (L_{mat}) of the most abundant and frequent fish species recorded at the Maracaípe estuary. Species with $L_{max} > L_{mat}$ are indicated in percentage of total number.

Species	L_{min}-L_{max} (mm)	L_m (mm)	RL_{max}* (mm)	L_{mat}** (mm)	L_{max}>L_{mat} (%)
Achirus lineatus	14-101	60.1	331.0	158.5	-
Atherinella brasiliensis	13-108	59.8	160.0	79.4	16.1
Strongylura timucu	106-378	230.7	610.0	283.3	1.5
Centropomus undecimalis	59-168	114.2	1400.0	623.7	-
Lile piquitinga	15-100	59.6	150.0	74.7	15.3
Anchovia clupeoides	33-130	96.0	300.0	144.4	-
Anchoa tricolor	25-123	81.6	118.0	59.5	90.2
Diapterus auratus	42-83	64.7	340.0	162.6	-
Diapterus rhombeus	19.4-89.8	38.7	400.0	189.7	-
Eucinostomus argenteus	13-102.1	59.6	210.0	102.9	-
Eucinostomus gula	17-101.5	47.5	255.0	123.7	-
Eucinostomus havana	36.2-83.9	59.1	180.0	88.8	-
Eucinostomus melanopterus	15.4-90	42.5	300.0	144.4	-
Ulaema lefroyi	8.4-91	21.0	230.0	112.2	-
Ctenogobius boleosoma	11-41	23.9	75.0	38.7	0.4
Haemulon aurolineatum	21-74	42.7	250.0	121.4	-
Hyporhamphus unifasciatus	40-150	97.3	300.0	144.4	1.0
Mugil curema	26-191	79.2	910.0	414.2	-
Sphoeroides greeleyi	11-133	47.7	180.0	88.8	1.5
Sphoeroides testudineus	10-183	60.6	388.0	184.3	-

*RL_{max} according to Froese and Pauly (2018). **L_{mat} estimated according to Gislason et al. (2008) and Le Quesne and Jennings (2012).

Table 9. Richness, abundance (n) and biomass (g) of fish species belonging to the different use and trophic guilds of the Maracaípe River estuary.

Guilds	Richness (%)	Abundance (%)	Biomass (%)
Use			
Marine estuarine-opportunist	52 (56.5)	1341 (11.2)	11534.1 (22.4)
Marine estuarine-dependent	32 (34.8)	3862 (32.2)	17174.1 (33.3)
Estuarine resident	8 (8.7)	6787 (56.6)	22800.51 (44.3)
Trophic			
1st. order carnivore	24 (26.1)	3591 (29.9)	6861.2 (13.3)
2nd. order carnivore	37 (40.2)	1899 (15.8)	17067.9 (33.1)
3rd. order carnivore	7 (7.6)	29 (0.2)	795.7 (1.5)
Detritivore	3 (3.3)	29 (0.2)	641 (1.2)
Herbivore	3 (3.3)	519 (4.3)	3235.8 (6.3)
Omnivore	14 (15.2)	3737 (31.2)	12888.2 (25.0)
Planktivore	4 (4.3)	2186 (18.2)	10018.9 (19.5)

The dominance of 2nd. order carnivores (33.1%) in relation to biomass, derived from the largest size of carnivorous species, and the contribution of omnivorous species (25%), may be attributed to their occurrence in shoals, in spite of their smaller individual weight.

DISCUSSION

Fishes inhabiting estuaries are subject to the variation of environmental physical and chemical factors, which determine the patterns of distribution, movement and occurrence in these environments (Blaber et al., 2000). However, in the estuary of the River Maracaípe, within the 3.8 km stretch between the innermost point and its mouth on the sea, there were no spatial differences of the abiotic variables analyzed, except for dissolved oxygen. A possible explanation for the lack of a spatial difference in salinity and temperature may be the low water discharge of Maracaípe River and predominant influence of sea tide on water renewal in the estuary (Bastos et al., 2011). On the other hand, most abiotic variables differed between seasons, with higher temperature, salinity and dissolved oxygen levels in the dry period, and lower pH and turbidity. This characteristic is similar to other estuaries of the coast of Pernambuco, where higher salinity, temperature, pH and dissolved oxygen values have been recorded in the dry season (Macêdo et al., 2000; Araújo et al., 2004; Paiva et al., 2008).

Dissolved oxygen was the only environmental variable that showed significant spatial difference within the estuary of the Maracaípe River, with lower values at the upper point (EST 1), which is subject to strong anthropic influence by being located near an urbanized area and receiving domestic effluents. This characteristic differs from other estuaries of nearby rivers, which usually present higher concentration of this gas in more distant locations from the mouth of the river (Macêdo et al., 2000; Paiva et al., 2008).

Higher organic matter and lead levels have been reported by Coimbra et al. (2015) for the same stretch of the Maracaípe river where EST 1 is located, and related it to the anthropic influence on the site. Despite being the point with lower concentration of dissolved oxygen, fish assemblage in EST 1 presented greater diversity and evenness, corroborating with Elliott et al. (2007), who stated that stress caused by moderate pollution may eliminate the dominant species (biomass), thereby contributing to greater equitability in terms of abundance and biomass, and that diversity can also increase temporarily through the flow of species more adapted to the environment. On the other hand, EST 1 and EST 2 are located on the more vegetated area of Maracaípe estuary mangrove, and the dominant tree species *Rhizophora mangle* has been recognized as the major contributor of organic matter in this environment (Nova et al., 2017).

There is a great difficulty in comparing the ichthyofauna between estuaries in any geographic region, mainly due to the environmental physical and chemical differences between them, and the different capture effort employed in different studies (Araújo et al., 1997). Species richness and abundance vary according to season, sampling point location within the estuary and selectivity of the fishing gear used (Villarroel, 1994). Despite such limitations, the Maracaípe River estuary houses a large number of species (91), as compared with other estuaries of tropical West Atlantic rivers in Brazil, for example, Formoso River, Pernambuco (78 species) (Paiva et al., 2008), Caeté River, Pará (49) (Barletta et al., 2003), Paciência River, Ceará (55) (Castro, 2001), Jaguaribe River, Ceará (75) (Alves and Soares-Filho, 1996) and Todos os Santos Bay, Bahia (45) (Lopes et al., 1998), where samplings were made with greater number of collections, and fishing gears of larger dimensions than in Maracaípe.

Gerreidae, Atherinopsidae, Clupeidae, Engraulidae, Gobiidae, Paralichthyidae, Tetraodontidae and Hemiramphidae were, in descending order, the families with greater abundance in Maracaípe, corresponding to those most commonly found in tropical and subtropical estuaries (Andrade-Tubino et al., 2008; Bot Neto et al., 2018), and also recorded as abundant in different estuaries of Pernambuco (Mérigot et al., 2017).

As noted in this study, individuals collected near estuary shorelines are usually young of species of commercial importance, belonging to Clupeidae, Mugilidae, Centropomidae, Carangidae, Lutjanidae, Gerreidae, Haemulidae and Sciaenidae (Silva-Falcão, 2007; Vasconcelos-Filho et al., 2007). The predominance of small-sized individuals for most abundant species recorded in this work indicates the prevalence of juveniles, as demonstrated by several authors for estuaries of different geographical regions (Lasiak, 1986; Clark, 1997). The high availability of food and protected microhabitat associated with low transparency and reduced water movement recorded in estuaries (Clark et al., 1994), make these environments important for the initial life cycle of many fish (Spach et al., 2004), highlighting the ecological importance of this ecosystem for coastal fish fauna.

A larger number of opportunistic (MMO) and dependent (MMD) visiting species than residents (ES) is a well-known and documented aspect in tropical (Andrade-Tubino et al., 2008) and temperate (Franco et al., 2008; Harrison and Whitfield, 2008) estuaries. Among the eight resident species in the Maracaípe River estuary, *Atherinella brasiliensis, Lile piquitinga* and *Ctenogobius boleosoma* are the most abundant, as has also been reported for the Canal of Santa Cruz (Eskinazi, 1972) and the Formoso River estuary (Paiva et al., 2008), respectively located in the north and south coast of the state of Pernambuco.

The predominance of marine estuarine-opportunistic species in Maracaípe is associated with a greater percentage of carnivorous species, whose high number corroborates the results of other estuaries along the Brazilian coast, such as Mamanguape River, Paraíba (Medeiros, 2016); Formoso River, Pernambuco (Paiva et al., 2008) and Conceição da Barra River and Barra Nova River, Espírito Santo (Hostim-Silva et al., 2013). According to Araújo et al. (2003), the presence of carnivorous species indicates a stable and diversified assemblage and suggests that their populations tend to decrease or disappear when environment quality declines. First and second order carnivores (zoobenthivores and invertivores) are represented by almost 70% of the species in Maracaípe. Small-sized benthic, epibenthic and hyperbenthic preys, mainly represented by mysids, shrimps, amphipods and fish larvae, are the predominant food of estuarine species. Also, marine migrants significantly feed on hyperbenthos, presenting an ontogenetic shift from smaller to larger preys and or fish (Franco et al., 2008). Since the individuals found in the Maracaípe River estuary are seemingly predominantly juveniles, for which the bottom meiofauna constitutes the main food item within estuaries (Blaber et al., 2000), might explain the proportionality of the carnivorous trophic guilds.

The knowledge about the taxonomic composition and the spatial and seasonal distribution of the species at different trophic levels in estuaries helps in environmental assessment (Elliott et al., 2007). In the estuary of the Maracaípe River, all trophic guilds are present along its extent, except for detritivores and herbivores not recorded at the estuary mouth (EST 3), as has also been recorded by De Paiva et al. (2009), in the estuary of the Formoso River. Such low occurrence of these trophic guilds at this site may be related to the predominance of fine sand and absence of marine seagrass or mangrove trees (Macêdo et al., 2012), thus limiting the local availability of organic matter or leaf debris on which such fish guilds usually feed or graze.

The availability of hard substrata colonized by encrusting algae and macrovegetation (seagrasses and saltmarshes) may influence the presence of herbivorous fish in estuaries, although their richness is usually higher at lower rather than higher latitudes (Franco et al., 2008). Low number of herbivorous in South African estuaries, mainly represented in warm-temperate ones, has been attributed to the low abundance of submerged plant communities in such environments. In turn, detritus is mainly autochthonous in rivers deprived from an adequate river flow, and derived from intertidal and subtidal plants (such as mangrove trees), and the biomass contribution of detritivores is lower in open estuaries (Harrison and Whitfield, 2012), such as the case of Maracaípe River.

The occurrence of juveniles of ecologically and economically important species in the estuarine waters of Maracaípe River, indicates its relevance to the life cycle of these species. These include four species considered vulnerable by the IUCN and MMA, among which *Hippocampus erectis* and *H. reide,* two out of the three seahorse species recorded for the Brazilian coast (Pereira et al., 2016).

The Maracaípe River estuary was classified by Braga (2000) as moderately degraded, although its degradation status has worsened since then due to the strong pressure of use arising from real estate speculation, tourism and uncontrolled fishing. In spite of this, our results indicate that the estuary still presents a considerably rich fish fauna and potential resilience.

CONCLUSIONS

The estuary of the Maracaípe River presents a rich ichthyofauna and high species diversity, most of them from marine origin, a large number of carnivorous and opportunistic species, predominantly composed of juvenile fish, thus emphasizing the importance of the estuary for their life cycle and the maintenance of coastal fish stocks.

Therefore, greater care and attention should be given to this coastal complex, with the establishment of public policies aimed at environmental education for the resident and visiting population, and an active supervision of the responsible agencies, to ensure the preservation of this environment so important for the regional fish fauna diversity.

ACKNOWLEDGEMENTS

The authors would like to thank Fundação de Amparo à Ciência e Tecnologia de Pernambuco (FACEPE) and Programa Institucional de Bolsas de Iniciação Científica (PIBIC/CNPq/UFRPE) for the scholarships provided respectively to IMSA and FLTF. Fundação Apolônio Salles de Desenvolvimento Educacional (FADURPE) is acknowledged for the financial support provided in field campaigns and laboratory infrastructure. Thanks are also extended to all interns of the Laboratory of Ichthyology/UFRPE who helped in field sampling and laboratory analyses.

REFERENCES

Able, K.W.; Wilber, D.H.; Muzeni-Corino, A.; Clarke, D.G. 2010. Spring and summer larval fish assemblages in the surf zone and nearshore off northern New Jersey, USA. Estuaries and Coasts, 33(1): 211-222. http://dx.doi.org/10.1007/s12237-009-9240-2.

Alves, M.I.M.; Soares-Filho, A.A. 1996. Peixes do estuário do rio Jaguaribe (Ceará- Brasil): aspectos fisioecológicos. Ciência Agronômica, 27(1/2): 5-16.

Anderson, M.J.; Gorley, R.N.; Clarke, K.R. 2008. PRIMER: Guide to software and statistical methods. Plymouth: PRIMER-E.

Andrade-Tubino, M.F.; Ribeiro, A.N.R.; Viana, M. 2008. Organização espaço-temporal das ictiocenoses demersais nos ecossistemas estuarinos brasileiros: uma síntese. Oecologia Brasiliensis, 12(4): 640-66.

Araújo, F.G.; Cruz-Filho, A.; Azevêdo, M.C.; Santos, A.C.A.; Fernandes, L.A.M. 1997. Estrutura da comunidade de peixes jovens da margem continental da Baía de Sepetiba, RJ. Acta Biologica Leopoldensia, 19(1): 61-83. Disponível em: < http://www.scielo.br/pdf/%0D/rbbio/v58n3/4569.pdf> Access on: 31 jul. 2018.

Araújo, F.G.; Fichberg, I.; Pinto, B.C.T.; Peixoto, M.G. 2003. A preliminary index of biotic integrity for monitoring the condition of the Rio Paraíba do Sul, southeast Brasil. Journal of Environmental Planning and Management, 32: 516-526. http://dx.doi.org/10.1007/s00267-003-3003-9.

Araújo, M.E.; Teixeira, J.M.C.; Oliveira, A.M.E. 2004. Peixes estuarinos marinhos do nordeste do Brasil: Guia ilustrado. Fortaleza: Editoras UFC e UFPE. 260p.

Barbieri, E.; Marques, H.L.A.; Bondioli, A.C.V.; Campolim, M.B.; Ferrarini, A.T. 2014. Concentrações do nitrogênio amoniacal, nitrito e nitrato em áreas de engorda de ostras no município de Cananeia-SP. O Mundo da Saúde, 38(1):105-115. http://dx.doi.org/10.15343/0104-7809.20143801105115

Barletta, M.; Barletta-Bergan, A.; Saint-Paul, U.; Hubold, G. 2003. Seasonal changes in density, biomass, and diversity of estuarine fishes in tidal mangrove creeks of the lower Caeté Estuary (northern Brazilian coast, east Amazon). Marine Ecology Progress Series, 256: 217-228. http://dx.doi.org/10.1111/j.1439-0426.2007.01043.x.

Barletta, M.; Blaber, S.J. 2007. Comparison of fish assemblages and guilds in tropical habitats of the Embley (Indo-West Pacific) and Caeté (Western Atlantic) estuaries. Bulletin of Marine Science, 80(3): 647-680. Disponível em: < https://www.ingentaconnect.com/contentone/umrsmas/bullmar/2007/00000080/00000003/art00015#> Access on: 31 jul. 2018.

Bastos, R.B.; Feitosa, F.A.N.; Koening, M.L.; Machado, R.C.A.; Muniz, K. 2011. Caracterização de uma zona costeira tropical (Ipojuca-Pernambuco-Brasil): produtividade fitoplanctônica e outras variáveis ambientais. Brazilian Journal of Aquatic Science and Technology, 15(1): 1-10. http://dx.doi.org/10.14210/bjast.v15n1.p1-10.

Blaber, S.J.M.; Cyrus, D.P.; Albaret, J.J.; Ching, C.V.; Day, J.W.; Elliott, M.; Silvert, W. 2000. Effects of fishing on the structure and functioning of estuarine and nearshore ecosystems. ICES Journal of Marine Science, 57(3): 590-602. http://dx.doi.org/10.1006/jmsc.2000.0723.

Bot Neto, R.L.; Passos, A.C.; Schwarz Junior, R.; Spach, H.L. 2018. Use of shallow areas by ichthyofauna (Teleostei) on the north-south axis of the Paranaguá Estuarine Complex, State of Paraná, Brazil. Pan-American Journal of Aquatic Sciences, 13(1): 64-78. Disponível em: http://www.panamjas.org/pdf_artigos/PANAMJAS_13(1)_64-78.pdf Access on: 31 jul. 2018

Bouchon-Navarro, Y.; Bouchon, C.; Louis, M. 1992. L'ichtyofaune des herbiers de phanérogames marines de la baie de Fort-de-France (Martinique, Antilles Françcaises). Cybium, 16(4): 307-330. Disponível em: <http://sfi-cybium.fr/fr/lichtyofaune-des-herbiers-de-phanérogames-marines-de-la-baie-de-fort-de-france-martinique-antilles> Access on: 31 jul. 2018

Braga, R.A.P. 2000. Caracterização das zonas estuarinas de Pernambuco. In: Seminário Internacional. Perspectivas e Implicações da Carcinicultura Estuarina no Estado de Pernambuco, 1, Recife. Anais… Recife: Projeto Prorenda. p. 13-20.

Brasil, 1986. Lei nº. 9.931, de 11 de dezembro de 1986. Define como áreas de proteção ambiental as reservas biológicas constituídas pelas áreas estuarinas do Estado de Pernambuco. Diário Oficial do Estado, Pernambuco, 12 de dezembro de 1986, nº 1016, p. 3.

Carpenter, K.E. 2002. The living marine resources of the Western Central Atlantic. 2. Bony fishes part 1 (Acipenseridae to Grammatidae). Rome: FAO. p. 1286-1293. Disponível em: < http://www.fao.org/docrep/009/y4160e/y4160e00.htm> Access on: 31 jul. 2018.

Castro, A.C.L. 2001. Diversidade da assembleia de peixes em igarapés do estuário do rio Paciência (MA - BRASIL). Atlântica, 23: 61-72.

Clark, B.M.; Bennet, B.A.; Lamberth, S.J. 1994. A comparison of the ichthyofauna of two estuaries and their adjacent surf-zones, with as assessment of the effects of beachseining on the nursery fuction on estuaries for fish. South African Journal of Marine Science, 14: 121-131. http://dx.doi.org/10.2989/025776194784286941.

Clark, B.M. 1997. Variation in surf-zone fish community structure across a wave exposure gradient. Estuarine, Coastal and Shelf Science, 44: 659-674. http://dx.doi.org/10.1006/ecss.1996.0151.

Coimbra, C.D.; Carvalho, G.; Philippini, H.; Silva, M.F.M.; Neiva, E. 2015. Determinação da concentração de metais traço em sedimentos do estuário do rio Maracaípe – PE/Brasil. Brazilian Journal of Aquatic Science and Technology, 19(2): 58-75. http://dx.doi.org/10.14210/bjast.v19n2.4863.

Dolbeth, M.; Martinho, F.; Viegas, I.; Cabral, H.; Pardal, M.A. 2008. Estuarine production of resident and nursery fish species: Conditioning by drought events? Estuarine, Coastal and Shelf Science, 78(1): 51-60. http://dx.doi.org/10.1016/j.ecss.2007.11.021.

Elliott, M.; Quintino, V. 2007. The estuarine quality paradox, environmental homeostasis and the difficulty of detecting anthropogenic stress in naturally stressed areas. Marine Pollution Bulletin, 54: 640-645. http://dx.doi.org/10.1016/j.marpolbul.2007.02.003.

Elliott, M.; Whitfield, A.K.; Potter, I.C.; Blaber, S.J.; Cyrus, D.P.; Nordlie, F.G.; Harrison, T.D. 2007. The guild approach to categorizing estuarine fish assemblages: a global review. Fish and Fisheries, 8(3): 241-268. http://dx.doi.org/10.1111/j.1467-2679.2007.00253.x.

Eskinazi, A.M. 1972. Peixes do Canal de Santa Cruz-Pernambuco-Brasil. Trabalhos Oceanográficos da Universidade Federal de Pernambuco, 13(1): 283-302. http://dx.doi.org/10.5914/tropocean.v38i2.5166.

Figueiredo, J.L. 1977. Manual dos peixes marinhos do Sudeste do Brasil. I. Introdução. Cações e raias e quimeras. São Paulo: Museu de Zoologia da Universidade de São Paulo. 104p.

Figueiredo, J.L.; Menezes, N.A. 1980. Manual de peixes marinhos do Sudeste do Brasil. III. Teleostei (2). São Paulo: Museu de Zoologia da Universidade de São Paulo. 90p.

Figueiredo, J.L.; Menezes, N.A. 2000. Manual de peixes marinhos do sudeste do Brasil. VI Teleostei (5). São Paulo. useu de Zoologia da Universidade de São Paulo. 110p.

Franco, A.; Elliott, M.; Franzoi, P.; Torricelli, P. 2008. Life strategies of fishes in European estuaries: the functional guild approach. Marine Ecology Progress Series, 354: 219-228. http://dx.doi.org/10.3354/meps07203.

Froese, R.; Pauly, D. 2018. FishBase. World Wide Web electronic publication. Version 06/2018. [online] URL: < http://fishbase.org/>.

Garcia, A.M.; Raseira, M.B.; Vieira, J.P.; Winemiller, K.O.; Grimm, A.M. 2003. Spatiotemporal variation in shallow-water freshwater fish distribution and abundance in a large subtropical coastal lagoon. Environmental Biology of Fishes, 68(3): 215-228. Available from: https://link.springer.com/content/pdf/10.1023%2FA%3A1027366101945.pdf Access on: 31 jul. 2018

Giarrizzo, T.; Krumme, U. 2007. Spatial differences and seasonal cyclicity in the intertidal fish fauna from four mangrove creeks in a salinity zone of the Curuçá estuary, north Brazil. Bulletin of Marine Science, 80(3): 739-754.

Gislason, H.; Pope, J.G.; Rice, J.C.; Daan, N. 2008. Coexistence in North Sea fish communities: implications for growth and natural mortality. ICES Journal of Marine Science, 65(4): 514-530. http://dx.doi.org/10.1093/icesjms/fsn035.

Harrison, T.D.; Whitfield, A.K. 2008. Geographical and typological changes in fish guilds of South African estuaries. Journal of Fish Biology, 73(10): 2542-2570. http://dx.doi.org/10.1111/j.1095-8649.2008.02108.x.

Harrison, T.D.; Whitfield, A.K. 2012. Fish trophic structure in estuaries, with particular emphasis on estuarine typology and zoogeography. Journal of Fish Biology, 81(6): 2005-2029. http://dx.doi.org/10.1111/j.1095-8649.2012.03458.x.

Hostim-Silva, M.; Lima, A.C.; Damasceno, J.; Sciarretta, T.; Silva, J.V.; Bot Neto, R.L.; Carvalho, B.M.; Spach, H.L. 2013. As assembleias de peixes dos estuários de Conceição da Barra e Barra Nova, Espírito Santo. Tropical Oceanography, 41(1-2): 133-153. http://dx.doi.org/10.5914/tropocean.v41i1-2.5718.

Köppen, W. 1936. Handbuch der Klimatologie. In: Köppen, W.; Geiger, R. C-1–C-44. Berlin: Gebruder Borntraeger. Available from: http://koeppen-geiger.vu-wien.ac.at/pdf/Koppen_1936.pdf Access on: 31 jul. 2018.

Lasiak, T.A. 1986. Juveniles, food, and the surf zone habitat: implications for the teleost nursery areas. South African Journal of Zoology, 21: 51-55. http://dx.doi.org/10.1080/02541858.1986.11447956.

Le Quesne, W.J.F.; Jennings, S. 2012. Predicting species vulnerability with minimal data to support rapid risk assessment of fishing impacts on biodiversity. Journal of Applied Ecology, 49(1): 20-28. http://dx.doi.org/10.1111/j.1365-2664.2011.02087.x.

Lopes, P.R.D.; Oliveira-Silva, J.T.; Ferreira-Melo, A.S.A. 1998. Contribuição ao conhecimento da ictiofauna do manguezal de Cacha Pregos, Ilha de Itaparica, Baía de Todos os Santos, Bahia. Revista Brasileira de Zoologia, 15(2): 315-325. http://dx.doi.org/10.1590/S0101-81751998000200005.

Macêdo, R.J.A.; Barreto, E.P.; Santos, A.C.; Manso, V.D.A.V. 2010. Estudo geoambiental da Orla de Maracaípe–Ipojuca (PE), Brasil. Estudos Geológicos, 20(2): 93-111.

Macêdo, R.J.A.; Manso, V.A.V.; Pereira, N.S.; França, L.G. 2012. Transporte de sedimentos e variação da linha de costa em curto prazo na Praia de Maracaípe (PE), Brasil. Revista da Gestão Costeira Integrada, 12(3): 343-355. Available from: http://www.scielo.mec.pt/pdf/rgci/v12n3/v12n3a06.pdf.

Macêdo, S.D.; Montes, M.J.F.; Lins, I.C. 2000. Características abióticas da área. In: Barros, H.M.; Eskinazi-Leça, E.; Macedo, S.J.; Lima, T. Gerenciamento participativo de estuários e manguezais. Recife: Editora Universitária da Universidade Federal de Pernambuco, p. 7-25.

Marceniuk, A.P. 2005. Chave para identificação das espécies de bagres marinhos (Siluriformes, Ariidae) da costa brasileira. Boletim do Instituto de Pesca, 31(2): 89-101.

Mérigot, B.; Frédou, F.L.; Viana, A.P.; Ferreira, B.P.; Junior, E.D.N.C.; Silva Júnior, C.B.; Frédou, T. 2017. Fish assemblages in tropical estuaries of northeast Brazil: A multi-component diversity approach. Ocean and Coastal Management, 143: 175-183. http://dx.doi.org/10.1016/j.ocecoaman.2016.08.004.

Mclusky, D.S.; Elliott, M. 2007. Transitional waters: A new approach, semantics or just muddying the waters? Estuarine, Coastal and Shelf Science, 71: 359-363. http://dx.doi.org/10.1016/j.ecss.2006.08.025.

Medeiros, A.P.M. 2016. Padrões de distribuição e organização trófica da assembleia de peixes no estuário do Rio Mamanguape, Paraíba, Brasil. 108f. (Dissertação de Mestrado. Universidade Federal da Paraíba, UFPB). Available from: <http://tede.biblioteca.ufpb.br:8080/handle/tede/8735> Access on: 17 ago. 2017.

Menezes, N.A.; Figueiredo, J.L. 1980. Manual de peixes marinhos do Sudeste do Brasil. IV. Teleostei (3). São Paulo: Museu de Zoologia, Univ. de São Paulo. 96p.

Menezes, N.A.; Figueiredo, J.L. 1985. Manual de peixes marinhos do Sudeste do Brasil. V. Teleostei (4). São Paulo: Museu de Zoologia, Univ. de São Paulo. 105p.

MMA – Ministério do Meio Ambiente. 2016. Lista da fauna brasileira ameaçada de extinção. Brasília: ICMBio. Available from: <http://www.icmbio.gov.br/portal/images/stories/comunicacao/ publicacoes/publicacoes-diversas/dcom_sumario_executivo_livro_vermelho_ed_2016.pdf> Access: 12 may 2018.

Nova, F.V.P.V.; Torres, M. 2012. Avaliação ambiental em unidades de conservação: estuário do Rio Maracaípe, Ipojuca-PE, Brasil. Revista de Geografia, 29(3): 199-224. Available from: https://periodicos.ufpe.br/revistas/revistageografia/article/view/229011/23413 Access on: 17 ago. 2017.

Nova, F.V.P.V.; Torres, M.F.A.; Coelho, M.P. 2017. Composição físico-química de solos em espécies arbóreas do ecossistema manguezal. ACTA Geográfica, 11(27): 1-19. http://dx.doi.org/10.5654/acta.v11i27.3034.

Nusch, E.A. 1980. Comparison of methods for chlorophyll and phaeopigment determination. Archiv für Hydrobiologie Beiheft Ergebnisse der Limnologie, 14(1): 14-36.

Paiva, A.C.; Chaves, P.T.; Araújo, M.E. 2008. Estrutura e organização trófica da ictiofauna de águas rasas em um estuário tropical. Revista Brasileira de Zoologia, 25(4): 647-661. http://dx.doi.org/10.1590/S0101-81752008000400010.

Paiva, A.C.; Lima, M.F.; De Souza, J.R.; Araújo, M.E.D. 2009. Spatial distribution of the estuarine ichthyofauna of the Formoso river (Pernambuco, Brazil), with emphasis on reef fish. Zoologia (Curitiba), 26(2): 266-278. http://dx.doi.org/10.1590/S1984-46702009000200009.

Pereira, L.F.; Silveira, R.B.; Abilhoa, V. 2016. New records of *Hippocampus patagonicus* Piacentino & Luzzatto, 2004 (Teleostei: Syngnathidae) from the coast of Paraná, southern Brazil. Check List, 12(1): 1-5. http://dx.doi.org/10.15560/12.1.1822.

Possamai, B.; Vieira, J.P.; Grimm, A.M.; Garcia, A.M. 2018. Temporal variability (1997-2015) of trophic fish guilds and its relationships with El Niño events in a subtropical estuary. Estuarine, Coastal and Shelf Science, 202: 145-154. http://dx.doi.org/10.1016/j.ecss.2017.12.019.

Potter, I.C.; Chuwen, B.M.; Hesp, S.A.; Hall, N.G.; Hoeksema, S.D.; Fairclough, D.V.; Rodwell, T.M. 2011. Implications of the divergent use of a suite of estuaries by two exploited marine fish species. Journal of Fish Biology, 79: 662-691. http://dx.doi.org/10.1111/j.1095-8649.2011.03051.x.

Potter, I.C.; Tweedley, J.R.; Elliott, M.; Whitfield, A.K. 2015. The Ways in which fish use estuaries: a refinement and expansion of the guild approach. Fish and Fisheries, 16(2): 230-239. http://dx.doi.org/10.1111/faf.12050.

Reis-Filho, J.A. 2013. Efeito da perda de habitat natural sobre a ictiofauna de áreas rasas em um estuário tropical. 73f. (Dissertação de Mestrado - Instituto de Biologia da Universidade Federal da Bahia). Available from: <http://repositorio.ufba.br/ri/handle/ri/12664> Access on: 13 apr 2017.

Silva-Falcão, E.C. 2007. Estrutura da comunidade de formas iniciais de peixes em uma gamboa do estuário do rio Catuama, Pernambuco, Brasil. 78f. (Dissertação de Mestrado - Universidade Federal de Pernambuco). Available from: <http://repositorio.ufpe.br/handle/123456789/8800> Access on: 02 feb 2017.

Spach, H.L.; Santos, C.; Godefroid, R.S.; Nardi, M.; Cunha, F. 2004. A study of the fish community structure in a tidal creek. Brazilian Journal of Biology = Revista Brasileira de Biologia, 64(2): 337-351. http://dx.doi.org/10.1590/S1519-69842004000200020.

StatSoft Inc. 2007. STATISTICA (data analysis software system), version 8. [online] URL: <www.statsoft.com>

The IUCN Red List of Threatened Species. 2018. Version 2017-1. [online] URL: <www.iucnredlist.org>. Access on: 30 may 2018.

Vasconcelos-Filho, A.L.; Neumann-Leitão, S.; Ramos-Porto, M.; Almeida, Z.S. 2007. Biologia alimentar de *Citharichthys spilopterus* (Paralichthyidae) em um estuário tropical, Pernambuco, Brasil. Revista Brasileira de Engenharia de Pesca, 2(2): 6-12.

Vasconcelos-Filho, A.L.; Oliveira, A.M.E. 1999. Composição e ecologia da ictiofauna do Canal de Santa Cruz (Itamaracá-PE, Brasil). Trabalhos Oceanográficos da UFPE, 27(1): 101-113. http://dx.doi.org/10.5914/tropocean.v27i1.2775.

Villarroel, P.R. 1994. Estrutura de las comunidades de peces de la Laguna de Raya, isla de Margrita, Venezuela. Ciencias Marinas, 20(1): 1-16. Available from: http://www.redalyc.org/articulo.oa?id=48020101 Access on: 30 may 2018.

Whitehead, P.J.P. 1985. FAO species catalogue. v. 7: Clupeoid fishes of the world (suborder Clupeoidei). An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. pt. 1: Chirocentridae, Clupeidae and Pristigasteridae. London: FAO Fisheries Synopsis (FAO). Available from: www.fao.org/docrep/009/ac482e/ac482e00.htm Access on: 30 may 2018.

Whitehead, P.J.P.; Nelson, G.J.; Wongratana, T. 1988. FAO species catalogue. Clupeoid fishes of the world (Suborder Clupeoidei). An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. pt. 2: Engraulididae. FAO Fisheries Synopsis, 125(7). Available from: <www.fao.org/docrep/009/ac482e/ac482e00.htm> Access on: 30 may 2018

Whitfield, A.; Elliott, M. 2011. Ecosystem and Biotic Classifications of Estuaries and Coasts. Treatise on Estuarine and Coastal Science, 1: 99-124. http://dx.doi.org/10.1016/B978-0-12-374711-2.00108-X.