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Composition of the fish fauna in a tropical estuary: the ecological guild approach

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Summary: Ecological guilds have been widely applied for understanding the structure and functioning of aquatic ecosystems. This study describes the composition and the spatio-temporal changes in the structure of the fish fauna and the movements between the estuary and the coast of a tropical estuary, the Itapissuma/Itamaracá Complex (IIC) in northeastern Brazil. Fish specimens were collected during the dry and rainy seasons in 2013 and 2014. A total of 141 species of 34 families were recorded. Almost half of the species (66 species, 47%) were exclusive to the estuary and 50 species (35%) to the coast; 25 (18%) were common to both environments. Marine species were dominant in both richness and biomass as they explore the environment during part of their life cycle, whereas estuarine species were dominant in abundance. Marine stragglers displayed a higher richness, abundance and biomass in the coastal waters. The estuarine environment was dominated by zoobenthivores in terms of richness, while detritivores prevailed in abundance and biomass. Zoobenthivores had the highest richness and abundance in coastal waters, while piscivores had the highest biomass. The IIC supports a rich fauna with a diverse trophic structure and is an important feeding and development area for migratory species.

Keywords: fish; functional attribute; habitat; Pernambuco; spatial-temporal distribution.

Composición de la fauna de peces de un estuario tropical: el enfoque del grupo ecológico

Resumen: Los grupos ecológicos se han aplicado ampliamente para comprender la estructura y el funcionamiento de los ecosistemas acuáticos. Este estudio describe la composición y los cambios espaciotemporales en la estructura de la fauna de peces y los movimientos entre el estuario y la costa de un estuario tropical (Complejo Itapissuma/Itamaracá - CII) en el noreste de Brasil. Los especímenes de peces fueron recolectados durante la estación seca y lluviosa del 2013 y 2014. Se registraron un total de 141 especies de 34 familias. Casi la mitad de las especies (66 especies, 47%) eran exclusivas del estuario y 50 especies (35%) de la costa; 25 (18%) fueron comunes a ambos ambientes. Las especies marinas fueron dominantes tanto en riqueza como en biomasa, ya que exploraron el medio ambiente durante parte de su ciclo de vida, mientras que las especies estuarinas dominaron considerando la abundancia. Las especies marino-dependientes mostraron una mayor riqueza, abundancia y biomasa en las aguas costeras. El ambiente estuarino fue dominado por zoobentívoros en términos de riqueza, mientras que los detritívoros prevalecieron en abundancia y biomasa. Los zoobentívoros tuvieron la mayor riqueza y abundancia en las aguas costeras, mientras que los piscívoros mostraron la mayor biomasa. El CII sostiene una rica fauna con una estructura trófica diversa y es un área relevante de alimentación y desarrollo para las especies migratorias.

Palabras clave: peces; atributo funcional; hábitat; Pernambuco; distribución espaciotemporal.

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INTRODUCTION

The ichthyofauna can be described and classified through the functional attributes of organisms, mainly based on the trophic level, reproductive strategy or use of the environment (Elliott et al. 2007). The functional attributes divide the species into guilds, defined as groups of species that exploit the same class of environmental resources in a similar way (Root 1967). The guild approach allows a better understanding of the ecology and role of the biota in the ecosystem (Elliott et al. 2007). It may help identify overexploited resources through changes in the composition of the food web (Garrison and Link 2000) and of the energy flows in the system (Harrison and Whitfield 2008). The guild approach also helps to understand the effects of climate changes on the structure and composition of fish fauna (Feyrer et al. 2015).

Trophic and estuarine use guilds have been widely applied to understand the structure and functioning of aquatic ecosystems, the movement pattern between environments and their use as feeding, breeding or development grounds (Elliott et al. 2007). Estuarine use guilds reflect migratory patterns and physiological adaptations of species that explore the area throughout their life cycle or part of it (Elliott et al. 2007). Trophic guilds are useful in the comprehension of the feeding habits of a species (Elliott et al. 2007). Its ecological relationships and the energy flows (Paiva et al. 2008) may reflect the possible strategies for avoiding competition or for optimizing the consumption of available resources (Angel and Ojeda 2001).

Estuaries are important transitional environments for the movement of the ichthyofauna between the continental basins and the ocean (Ray 2005). As an ecotone, estuaries link marine and freshwater ecosystems (Gray and Elliott 2009), and persistent environmental fluctuations place considerable physiological demands on the species inhabiting the area (Elliott and Quintino 2007). Many species are dependent on estuarine environments; several marine species are considered visitors and explore estuarine habitats during their ontogenetic development, evidencing the relationship with coastal environments (Able 2005). Therefore, defining the relationships between species and their functional roles within communities is critical for understanding the dynamics of the ecosystem and fundamental for the implementation of ecosystem-based fisheries management (Buchheister and Latour 2015).

The Brazilian coast hosts large estuarine complexes along the 187 km of the coast of Pernambuco, and several areas are considered of great environmental importance (CPRH 2010). The variety of habitats, along with the complexity of interactions within the fish community and the migratory nature of many species, hampers the assessment of the overall condition of the area (Vasconcelos Filho et al. 2003).

Using the ecological guilds approach, this study describes the composition and structure of the fish fauna along a tropical estuarine complex in order to identify and explain the main patterns of seasonal and spatial variations in assemblage composition. The study also discusses the importance of the use of the ecological guilds approach to assess the effects of multiple anthropogenic pressures on the structure and functioning of fish communities in tropical estuaries.

MATERIALS AND METHODS

Study area

The Itapissuma/Itamaracá Complex (IIC), located in Pernambuco, northeastern Brazil, within the Santa Cruz Environmental Preservation Area (APA Santa Cruz), is considered highly productive (Macêdo et al. 2000), hosting the largest fishery port in the state. Fishery is a very important socio-economical activity in the IIC, generating income and proteins for the local communities (CPRH 2010). Conversely, this ecosystem is exposed to multiple pressures from industrial pollution, domestic sewage discharge, urban expansion, land reclamation and fisheries (Medeiros et al. 2001). In addition, it has a large variety of connecting habitats favouring the development of the ichtyofauna (Vasconcelos Filho et al. 2009). The IIC is composed of the estuarine area, the Santa Cruz Channel and the adjacent sea, locally named the "Inner Sea" (Fig. 1). The Santa Cruz channel has a length of 22 km, a width ranging from 0.6 to 1.5 km and a depth ranging from 2 to 5 m in the central part of the channel, reaching 10 m at the northern and southern bars that connect the channel to the sea (Vasconcelos Filho and Oliveira 1999). The channel bottom consists of quartz sand banks and dark, reductive and dense mud patches. The muddy banks are dominated by *Rhyzophora mangle*, *Laguncularia racemosa*, *Avicennia* sp. and *Conocarpus erectus*, and by meadows of the marine phanerogam, *Halodule wrightii*. Surface water temperature varies between 25°C and 31°C and salinity between 18 and 34. The Inner Sea, corresponding to the coastal area hereafter, with a depth of 2 to 5 m, is characterized by a reef barrier parallel to the coast, located 4 km from the beach (Kempf 1970), which functions as a barrier between nearshore and shelf waters. The substrate is formed by terrigenous sediments from the mouth of the Jaguaribe River and the Santa Cruz Channel, and carbonates from the reef barrier (Almeida and Manso 2011), partially covered by large banks of phanerogams (Kempf 1970). The carbonaceous material is the result of the decomposition of rocks and quartz, sand, mollusc shells, foraminifera and calcareous algal fragments. In the Inner Sea, water temperature varies between 27°C and 30.8°C and the average annual salinity is 34.

Data collection

Fish specimens were collected during the dry season (January, February, March, November) and the rainy season (May, July, August) in 2013 and 2014 in the Santa Cruz Channel and the Inner Sea. In order to minimize biases due to gear selectivity, different fishing gears were combined for accessing and sampling different habitats and maximizing the collection of fish individuals (Table S1, Supplementary material). In the estuary, three 25-minute sets with a seine net and one

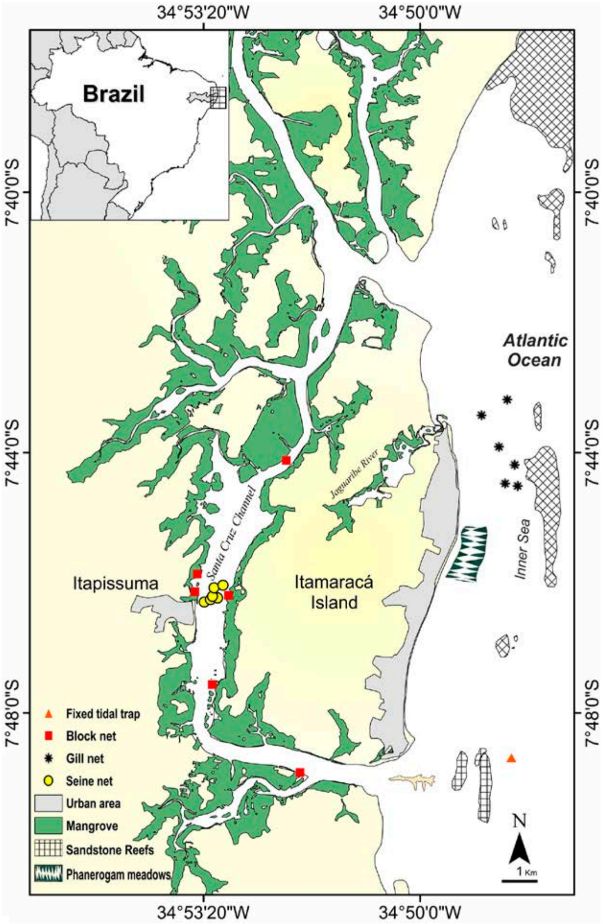

Fig. 1. – The study area of the Itapissuma/Itamaracá Complex, Pernambuco, Brazil and location of fish sampling points.

6-hour set with a block net were carried out quarterly. The seine net was 67.5 m long and had a mesh size of 10 mm. The block net was 348 m long and had a mesh size of 60, 70 and 80 mm. On the coast, samples were obtained quarterly with a gillnet (3 sets of two hours each) and with a fixed tidal trap (6 fishing days). The gill net had mesh sizes of 50, 70 and 80 mm, and was 690 m long, and the fixed tidal trap had a diameter of 27 m and a mesh size of 70 mm.

In the field, the fish fauna was conserved in thermal boxes with ice, and samples were frozen in the laboratory to be identified. Taxonomic classification followed Nelson et al. (2016).

Data analysis

Firstly, we computed a species accumulation curve with the non-parametric Bootstrap method (Smith and van Belle 1984) to assess whether the fish community was exhaustively sampled. This method assumes that all species occur randomly without taking into account species abundance, i.e. the method does not distinguish rare and abundant species (Smith and van Belle 1984). The index and standard deviations of the estimates were obtained through the analytical equation of Colwell et al. (2004) using the EstimateS software v. 9 9.1.0 (Colwell 2013).

The composition of the fish fauna was reported in terms of absolute species richness (S) and, for each species, frequency of occurrence (%FO) and relative abundance in number (%N) and biomass (%B). Species were considered to be abundant according to the Garcia and Vieira (2001) classification when %N was greater than 100/S, where S is the number of species recorded in the area. A species was defined as frequent when its %FO value for a given area was greater than 50%. The combination of these parameters allowed the species to be classified into four categories: abundant and frequent (%N>100/S and %FO≥50%); abundant but infrequent (%N>100/S and %FO<50%); less abundant but frequent (%N<100/S and %FO≥50%) and less abundant and infrequent (%N<100/S and %FO<50%).

Each species was assigned to an estuarine use functional group: marine stragglers, marine migrants and estuarine species, according to the classification proposed by Elliott et al. (2007). This classification is based on the type, frequency and period of use of the estuarine environment, and the abundance of the species in the estuary. In addition, each species was assigned to a trophic functional group based on local information about feeding preferences and strategies, according to the categories proposed by Elliott et al. (2007). The trophic functional groups were zooplanktivores, detritivores, piscivores, zoobenthivores, herbivores and omnivores. Information on trophic guilds were obtained in studies carried out in the IIC, in the scientific literature or, when not available, based on the WoRMS Editorial Board (2019) and FishBase project (Froese and Pauly 2007) (Table S2, Supplementary material). For each environment (estuary and coast) and season (dry and rainy), the estuarine use guild and the trophic guild were reported in terms of richness (%S), abundance (%N) and biomass (%B).

We computed multivariate analyses to investigate the spatial and temporal variations in the structure of the fish community, considering the absolute richness of estuarine use guild and the richness of trophic guild by environment and by season. To analyse the guild composition, a principal coordinate analysis (PCO) based on Bray-Curtis distances was applied. The differences of the contribution of guilds between environments and seasons was tested by permutational multivariate analysis (PERMANOVA) (Anderson 2001) performed with a Bray-Curtis distance matrix built on square-root-transformed data. Multivariate analyses were performed with the R software (R Core Team 2018).

RESULTS

Fish assemblage

A total of 140 species (135 Actinopterygii and 5 Elasmobranchii) of 34 families were recorded in the IIC (Table 1). For both coastal and estuarine areas, the species accumulation curve did not stabilize towards asymptotic values (Fig. S1, Supplementary material). However, a large portion of the estimated richness was

Table 1. – Composition of the ichthyofauna captured in the Itapissuma/Itamaracá Complex. D, dry; R, rainy; EUFG, estuarine use functional group; ES, estuarine species; MM, marine migrants; MS, marine stragglers; FMFG, feeding mode functional group; HV, herbivore; DV, detritivore; OV, omnivore; PV, piscivore; ZB, zoobenthivore; ZP, zooplanktivore; E, estuary; C, coast; N, abundance; B, biomass; FO, occurrence frequency; E, estuary; C, coast; IR, relative importance: 1, abundant and frequent; 2, abundant and infrequent; 4, less abundant and infrequent; (*) Species present in all the studied environments. Sea = Season. ** biomass (%) <0.01.

Species	Sea	EUFG	FMFG	N (%)		B (%)		FO (%)		IR	
				E	C	E	C	E	C	E	C
Carcharhinidae											
Rhizoprionodon porosus (Poey, 1861)	D	MS	PV		0.11		0.06		1.9		4
Rhizoprionodon lalandii (Valenciennes, 1839)	D	MS	PV		0.11		0.04		1.9		4
Dasyatidae											
Hypanus guttatus (Bloch and Schneider, 1801) *	D/R	MS	ZB	0.01	0.11	0.07	2.57	3.4	1.9	4	4
Hypanus marianae Gomes Rosa and Gadig, 2000	D/R	MS	ZB		0.22		0.14		3.8		4
Elopidae											
Elops saurus (Linnaeus, 1766)	D	MS	PV	0.01		0.07		3.4		4	
Muraenidae											
Gymnothorax funebris Ranzani, 1839	R	MS	ZB		0.43		1.53		5.8		4
Gymnothorax ocellatus Agassiz, 1831*	D/R	MS	ZB	0.01	0.33	0.04	0.55	3.4	1.9	4	4
Muraenidae sp.	R				0.33		1.98		1.9		4
Engraulidae											
Anchoa lyolepis (Evermann and Marsh, 1900)	D	MS	ZP	0.02				3.4		4	
Anchoa marinii Hildebrand, 1943	D	MS	ZP	0.04		0.01		3.4		4	
Anchoa sp.	R			0.06		0.01		3.4		4	
Anchoa spinifer (Valenciennes, 1848)	D	MM	PV	0.21		0.04		17.2		4	
Anchoa tricolor (Spix and Agassiz, 1829)	D/R	MM	ZB	0.12		0.03		10.3		4	
Anchovia clupeoides (Swainson, 1839)	D	MM	ZP	0.91		1.06		3.4		4	
Cetengraulis edentulus (Cuvier, 1829)	D/R	MM	ZP	4.63		6.55		41.4		2	
Engraulis anchoita Hubbs and Marini, 1935	R	MS	ZP	0.25		0.1		3.4		4	
Lycengraulis grossidens (Spix and Agassiz, 1829)	D/R	ES	PV	0.2		0.05		13.8		4	
Clupeidae											
Harengula clupeola (Cuvier, 1829)	D/R	MS	ZP	0.24		0.44		6.9		4	
Opisthonema oglinum (Lesueur, 1818)*	D/R	MS	ZP	0.21	1.84	0.10	0.22	17.2	15.4	4	2
Rhinosardinia bahiensis (Steindachner, 1879)	D/R	ES	ZP	0.07		0.02		17.2		4	
Sardinella brasiliensis (Steindachner, 1879)	D/R	MS	ZP	0.06		0.05		6.9		4	
Chaetodontidae											
Chaetodon ocellatus Bloch, 1787	D	MS	ZB	0.01				3.4		4	
Ariidae											
Ariidae sp.	D				0.22		0.27		1.9		4
Aspistor luniscutis (Valenciennes, 1840)	D/R	MS	OV		5.31		2.15		15.4		2
Aspistor quadriscutis (Valenciennes, 1840)	D/R	MS	ZB		0.87		0.4		9.6		4
Aspistor sp.	R				0.33		0.13		1.9		4
Bagre marinus (Mitchill, 1815)	D/R	MM	ZB		1.52		0.92		9.6		2
Cathorops agassizii (Eigenmann and Eigenmann, 1888)	R	ES	ZB	0.01		0.04		3.4		4	
Cathorops spixii (Agassiz, 1829)	R	ES	ZB		0.43		0.11		3.8		4
Sciades herzbergii (Bloch, 1794)	D/R	ES	ZB	0.07		1.11		10.3		4	
Sciades proops (Valenciennes, 1840)	D/R	ES	ZB		1.84		2.29		7.7		2
Synodontidae											
Synodus foetens (Linnaeus, 1766)	D/R	MS	PV	0.02		0.02		6.9		4	
Batrachoididae											
Batrachoides surinamensis (Bloch and Schneider, 1801)	D/R	MS	ZB	0.04		0.21		13.8		4	
Thalassophryne nattereri Steindachner, 1876	D/R	MS	ZB	0.08		0.17		20.7		4	
Mugilidae											
Mugil curema Valenciennes, 1836 *	D/R	MM	DV	10.4	0.65	41.8	0.4	17.2	9.6	2	4
Atherinopsidae											
Atherinella brasiliensis (Quoy and Gaimard, 1825)	D/R	ES	OV	0.01		**		6.9		4	
Belonidae											
Tylosurus acus acus (Lacepède, 1803)	D	MS	PV	0.02		0.03		10.3		4	
Hemiramphidae											
Hemiramphus brasiliensis (Linnaeus, 1758)	R	MS	HV	0.10		0.06		13.8		4	
Hyporhamphus unifasciatus (Ranzani, 1841)	D/R	MM	OV	0.10		0.07		20.7		4	
Syngnathidae											
Syngnathus sp.	D			0.01		**		3.4		4	
Triglidae											
Prionotus punctatus (Bloch, 1793)	D	MS	ZB	0.01		**		3.4		4	
Centropomidae											
Centropomus parallelus Poey, 1860	D/R	MM	PV	0.46		1.25		20.7		4	
Centropomus pectinatus Poey, 1860	D/R	MM	PV	0.03		0.09		6.9		4	
Centropomus sp.	D				0.11		0.5		1.9		4
Centropomus undecimalis (Bloch, 1792)*	D/R	MM	PV	0.26	0.76	2.41	2.26	17.2	11.5	4	4
Serranidae											
Epinephelus adscensionis (Osbeck, 1765) *	D/R	MS	ZB	0.01	0.11	**	0.01	3.4	1.9	4	4
Epinephelus marginatus (Lowe, 1834)	R	MS	OP	0.01		0.18		3.4		4	
Mycteroperca bonaci (Poey, 1860) *	D	MS	PV	0.01	0.11	**	0.02	3.4	1.9	4	4
Carangidae											
Carangoides bartholomaei (Cuvier, 1833)	D/R	MS	PV		3.9		1.51		19.2		2
Caranx crysos (Mitchill, 1815) *	D	MS	PV	0.01	0.11	**	0.03	3.4	1.9	4	4
Caranx hippos (Linnaeus, 1766)*	D/R	MS	PV	0.4	6.39	0.24	40.5	17.2	32.7	4	2
Caranx latus Agassiz, 1831*	D/R	MS	ZB	0.21	0.98	0.33	3.63	17.2	9.6	4	4
Caranx ruber (Bloch, 1793)	D	MM	ZB		3.25		0.54		1.9		2

Table 1 (Cont.). – Composition of the ichthyofauna captured in the Itapissuma/Itamaracá Complex. D, dry; R, rainy; EUFG, estuarine use functional group; ES, estuarine species; MM, marine migrants; MS, marine stragglers; FMFG, feeding mode functional group; HV, herbivore; DV, detritivore; OV, omnivore; PV, piscivore; ZB, zoobenthivore; ZP, zooplanktivore; E, estuary; C, coast; N, abundance; B, biomass; FO, occurrence frequency; E, estuary; C, coast; IR, relative importance: 1, abundant and frequent; 2, abundant and infrequent; 4, less abundant and infrequent; (*) Species present in all the studied environments. Sea = Season. ** biomass (%) <0.01.

Species	Sea	EUFG	FMFG	N (%)		B (%)		FO (%)		IR	
				E	C	E	C	E	C	E	C
Chloroscombrus chrysurus (Linnaeus, 1766)*	D/R	MS	ZB	0.15	0.54	0.01	0.07	13.8	9.6	4	4
Oligoplites palometa (Cuvier, 1832) *	D/R	MM	PV	0.01	1.3	**	1.14	3.4	17.3	4	4
Oligoplites saliens (Bloch, 1793)	D	MM	PV	0.01		0.01		3.4		4	
Oligoplites saurus (Bloch and Schneider, 1801)*	D/R	MM	PV	0.02	0.87	0.01	0.25	10.3	11.5	4	4
Selene brownii (Cuvier, 1816)	D/R	MS	ZB		19.5		6.18		48.1		2
Selene spixii (Castelnau, 1855)	R	MS	ZB		0.76		0.41		3.8		4
Selene vômer (Linnaeus, 1758)	D/R	MS	PV		8.99		5.36		57.7		1
Trachinotus carolinus (Linnaeus, 1766)	D/R	MM	ZB		0.98		3.03		11.5		4
Trachinotus falcatus (Linnaeus, 1758)	D/R	MS	ZB		0.98		3.6		13.5		4
Trachinotus goodei Jordan and Evermann, 1896	D/R	MS	ZB		0.76		0.53		7.7		4
Lutjanidae											
Lutjanus alexandrei Moura and Lindeman, 2007	D/R	MS	ZB	0.28		0.85		17.2		4	
Lutjanus analis (Cuvier, 1828)*	D/R	MS	ZB	0.41	1.08	0.13	0.45	41.4	13.5	4	4
Lutjanus jocu (Bloch and Schneider, 1801) *	D/R	MS	ZB	0.24	0.22	0.19	0.05	31	1.9	4	4
Lutjanus synagris (Linnaeus, 1758)	D/R	MS	ZB	0.33		0.03		17.2		4	
Gerreidae											
Diapterus auratus Ranzani, 1842 *	D/R	MM	ZB	1.44	2.17	4.08	0.79	20.7	21.2	2	2
Diapterus rhombeus (Cuvier, 1829) *	D/R	MM	ZP	1.11	0.43	0.55	0.28	41.4	3.8	2	4
Diapterus sp.	R			0.06		0.01		6.9		4	
Eucinostomus argenteus Baird and Girard, 1855 *	D/R	MM	ZB	4.69	0.33	5.75	0.07	75.9	5.8	1	4
Eucinostomus gula (Quoy and Gaimard, 1824)	D/R	MM	ZB	2.84		1.99		55.2		1	
Eucinostomus havana (Nichols, 1912)	D/R	MM	ZB	0.18		0.25		17.2		4	
Eucinostomus melanopterus (Bleeker, 1863)	R	MM	ZB	0.07		0.12		3.4		4	
Eucinostomus sp.	D/R			0.52		0.05		20.7		4	
Eugerres brasilianus (Cuvier, 1830)	D/R	MM	OV	0.03		0.01		6.9		4	
Haemulidae											
Anisotremus moricandi (Ranzani, 1842)	D/R	MS	OV		0.43		0.06		7.7		4
Anisotremus virginicus (Linnaeus, 1758)	R	MS	OV		0.43		0.08		1.9		4
Conodon nobilis (Linnaeus, 1758)	D	MM	ZB		0.22		0.02		1.9		4
Genyatremus luteus (Bloch, 1790)	R	MS	OP	0.02		0.11		3.4		4	
Haemulon aurolineatum Cuvier, 1830	D	MS	ZB		0.22		0.06		1.9		4
Haemulon parra (Desmarest, 1823)	D/R	MS	ZB		1.3		0.53		9.6		4
Haemulon plumierii (Lacepède, 1801)	D	MS	ZB		6.18		0.89		11.5		2
Haemulon steindachneri (Jordan and Gilbert, 1882)	D/R	MS	ZB		0.43		0.19		5.8		4
Pomadasys corvinaeformis (Steindachner, 1868)	D/R	MS	ZB		2.93		0.45		11.5		2
Pomadasys crocro (Cuvier, 1830)	D/R	MS	ZB	0.01		0.07		6.9		4	
Sparidae											
Archosargus probatocephalus (Walbaum, 1792)	D	MS	OV	0.03		**		6.9		4	
Archosargus rhomboidalis (Linnaeus, 1758) *	D/R	MS	ZB	0.81	0.54	0.19	0.32	27.6	7.7	2	4
Polynemidae											
Polydactylus virginicus (Linnaeus, 1758) *	D/R	MM	ZB	0.02	3.14	0.05	1.01	6.9	3.8	4	2
Sciaenidae											
Bairdiella ronchus (Cuvier, 1830)	D/R	MM	ZB	0.18		0.62		13.8		4	
Cynoscion sp.	D			0.03		**		3.4		4	
Cynoscion virescens (Cuvier, 1830)	D	MM	ZB	0.06		0.01		10.3		4	
Isopisthus parvipinnis (Cuvier, 1830)	R	MM	PV		0.43		0.39		3.8		4
Larimus breviceps Cuvier, 1830	R	MM	ZB		0.33		0.06		1.9		4
Menticirrhus americanus (Linnaeus, 1758)	D/R	MM	ZB		0.43		0.23		5.8		4
Ophioscion sp.	D			0.01		0.03		3.4		4	
Paralonchurus brasiliensis (Steindachner, 1875)	D	MM	ZB		0.33		0.04		1.9		4
Stellifer stellifer (Bloch, 1790)	D	ES	ZB	0.02		0.03		3.4		4	
Mullidae											
Pseudupeneus maculatus (Bloch, 1793)	D	MS	ZB		0.11		0.02		1.9		4
Labridae											
Halichoeres radiatus (Linnaeus, 1758)	D	MS	ZB		0.11		0.02		1.9		4
Scaridae											
Sparisoma radians (Valenciennes, 1840)	R	MS	HV	0.65		0.14		1.9		4	
Sparisoma axillare (Steindachner, 1878) *	D/R	MS	HV	0.23	0.65	0.04	0.09	10.3	7.7	4	4
Sparisoma cf *amplum*	R	MS	HV		0.33		0.11		3.8		4
Ephippidae											
Chaetodipterus faber (Broussonet, 1782) *	D/R	MM	OV	0.1	1.52	1.26	1.38	6.9	17.3	4	2
Pomacanthidae											
Pomacanthus paru (Bloch, 1787)	R	MS	ZP		0.11		0.01		1.9		4
Eleotridae											
Guavina guavina (Valenciennes, 1837)	D	ES	ZB	0.01		**		3.4		4	
Gobiidae											
Ctenogobius boleosoma (Jordan and Gilbert, 1882)	D	ES	DV	0.13		0.01		3.4		4	
Ctenogobius shufeldti (Jordan and Eigenmann, 1887)	D/R	ES	OV	0.17		0.03		20.7		4	
Ctenogobius smaragdus (Valenciennes, 1837)	D/R	ES	DV	0.48		0.08		44.8		4	
Ctenogobius stigmaticus (Poey, 1860)	D/R	ES	DV	3.83		0.35		48.3		2	
Evorthodus lyricus (Girard, 1858)	D	MS	DV	0.01		**		3.4		4	
Gobionellus oceanicus (Pallas, 1770)	D/R	ES	DV	2.44		4.01		58.6		1	

Table 1 (Cont.). – Composition of the ichthyofauna captured in the Itapissuma/Itamaracá Complex. D, dry; R, rainy; EUFG, estuarine use functional group; ES, estuarine species; MM, marine migrants; MS, marine stragglers; FMFG, feeding mode functional group; HV, herbivore; DV, detritivore; OV, omnivore; PV, piscivore; ZB, zoobenthivore; ZP, zooplanktivore; E, estuary; C, coast; N, abundance; B, biomass; FO, occurrence frequency; E, estuary; C, coast; IR, relative importance: 1, abundant and frequent; 2, abundant and infrequent; 4, less abundant and infrequent; (*) Species present in all the studied environments. Sea = Season. ** biomass (%) < 0.01.

Species	Sea	EUFG	FMFG	N (%)		B (%)		FO (%)		IR	
				E	C	E	C	E	C	E	C
Gobionellus stomatus Starks, 1913	D/R	ES	DV	53.5		18.5		58.6		1	
Microgobius meeki Evermann and Marsh, 1899	D	MS	ZB	0.11				6.9		4	
Trichiuridae											
Trichiurus lepturus Linnaeus, 1758	D/R	MS	PV		7.8		7.43		44.2		2
Acanthuridae											
Acanthurus bahianus Castelnau, 1855	D/R	MS	HV		0.43		0.07		5.8		4
Acanthurus chirurgus (Bloch, 1787) *	D/R	MS	HV	0.01	0.33		0.03	6.9	3.8	4	4
Acanthurus coeruleus Bloch and Schneider, 1801	D	MS	HV		0.11		0.01		1.9		4
Sphyraenidae											
Sphyraena barracuda (Edwards, 1771)	D/R	MM	PV	0.05		0.38		6.9		4	
Sphyraena guachancho Cuvier, 1829 *	D	MS	PV	0.02	0.22	0.19	0.18	6.9	1.9	4	4
Sphyraena viridensis Cuvier, 1829	D	MS	PV		0.11		0.12		1.9		4
Scombridae											
Scomberomorus brasiliensis Collette, Russo and Zavala-Camin, 1978	D	MS	PV		0.22		0.13		1.9		4
Paralichthyidae											
Citharichthys sp.	D/R			0.11		0.02		10.3		4	
Citharichthys spilopterus Günther, 1862	D/R	MM	ZB	0.79		0.26		48.3		4	
Etropus crossotus Jordan and Gilbert, 1882	R	MM	ZB	0.5		0.06		6.9		4	
Paralichthys brasiliensis (Ranzani, 1842)*	D/R	MM	ZB	0.01	0.11	0.02	0.01	6.9	1.9	4	4
Syacium micrurum Ranzani, 1842	D	MM	ZB		0.11		0.01		1.9		4
Syacium papillosum (Linnaeus, 1758)	D	MS	ZB		0.11		0.01		1.9		4
Bothidae											
Bothus ocellatus (Agassiz, 1831)	R	MM	ZB		0.11		**		1.9		4
Achiridae											
Achirus declivis Chabanaud, 1940	D	ES	ZB	0.03		**		10.3		4	
Achirus lineatus (Linnaeus, 1758)	D/R	ES	ZB	1.48		0.08		48.3		2	
Achirus sp.	D/R			0.68		0.03		13.8		4	
Trinectes paulistanus (Miranda Ribeiro, 1915)	D	MM	ZB	0.21		0.01		3.4		4	
Cynoglossidae											
Symphurus tessellatus (Quoy and Gaimard, 1824)	D/R	MM	ZB	0.04		0.04		17.2		4	
Ostraciidae											
Lactophrys trigonus (Linnaeus, 1758)	D	MS	ZB		0.11		0.28		1.9		4
Tetraodontidae											
Colomesus psittacus (Bloch and Schneider, 1801)	D/R	MS	ZB	0.03		1.43		6.9		4	
Sphoeroides greeleyi Gilbert, 1900	D/R	ES	ZB	0.2		0.05		27.6		2	
Sphoeroides testudineus (Linnaeus, 1758)	D/R	ES	ZB	2.13		2.01		79.3		1	
Diodontidae											
Chilomycterus spinosus spinosus (Linnaeus, 1758)	R	MS	ZB		0.11		0.05		1.9		4

effectively sampled: 88 species (88% of the estimated richness) were observed in the estuary and 75 species (85% of the estimated richness) on the coast. A total of 25 species (18%) were common to both the estuary and the coast, 65 species (47%) were exclusive to the estuary and 50 species (35%) occurred only on the coast (Table 1).

In the estuary, Engraulidae (9 species), Gerreidae (9 species) and Gobiidae (8 species) were dominant in richness (S). The Gobiidae family had the highest abundance (%N) in the dry (7694 individuals, 62%) and rainy (3776 individuals, 58%) seasons. In terms of biomass, Mugilidae were dominant during the dry season (114.34 kg, 51.74%) and Gobiidae during the rainy season (22.20 kg, 28%). The gobiid *Gobionelus stomatus* Starks, 1913 showed the highest abundance in both seasons (dry season 6582 individuals, 53%; rainy season 3532 individuals, 54%), while for biomass, *Mugil curema* Valenciennes, 1836 (114.39 kg, 52%) and *Cetengraulis edentulus* (Spix and Agassiz, 1829) (18 kg, 22.42%) were dominant during the dry and the rainy seasons, respectively (Table 1).

On the coast, Carangidae were dominant in richness (14 species); in abundance, with 288 individuals (49%) and 166 individuals (50%) during the dry and rainy seasons, respectively; and in biomass, with 115 kg (57%) and 203 kg (74%) in the dry and rainy seasons, respectively. In terms of species, *Selene brownii* (Cuvier, 1816) was dominant with the highest abundance d,uring the dry season (138 individuals; 23%) and *Selene vomer* (Linnaeus, 1758) during the rainy season (45 individuals, 14%), while *Trichiurus lepturus* Linnaeus, 1758 (26 kg, 13%) and *Caranx hippos* (Linnaeus, 1766) (151.59 kg, 55%) dominated in terms of biomass during the dry and the rainy seasons, respectively (Table 1).

Less abundant and infrequent species were dominant in the estuary (85%) and on the coast (77%) (Table 1). *Eucinostomus argenteus* Baird and Girard, 1855, *Eucinostomus gula* (Quoy and Gaimard, 1824), *Ctenogobius smaragdus* (Valenciennes, 1837), *Ctenogobius stigmaticus* (Poey, 1860), *Gobionellus oceanicus* (Pallas, 1770), *G. stomatus* and *Sphoeroides testudineus* (Linnaeus, 1758) were considered abundant and frequent in the estuary, and *S. vomer* in the coastal area.

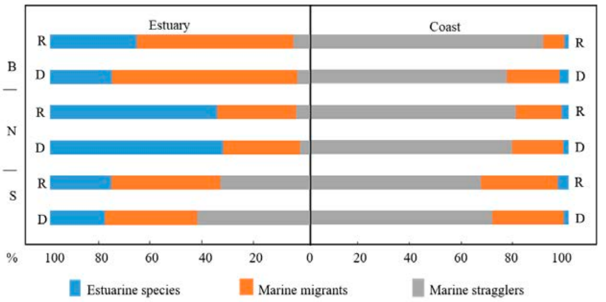

Fig. 2. – Percentage participation (%) of richness (S), abundance (N) and biomass (B) of estuarine use guilds by season (D, dry; R, rainy) and location in the Itapissuma/Itamaracá Complex, northeastern Brazil.

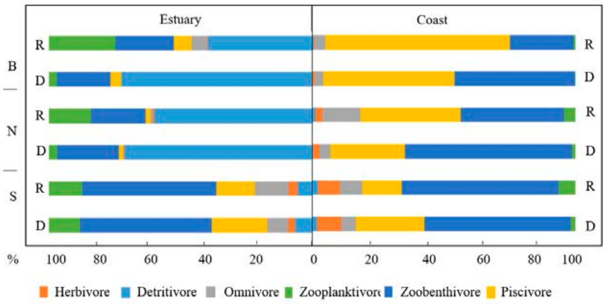

Fig. 4. – Percentage participation (%) of richness (S), abundance (N) and biomass (B) of trophics guilds by season (D, dry; R, rainy) and location in the Itapissuma/Itamaracá Complex, northeastern Brazil.

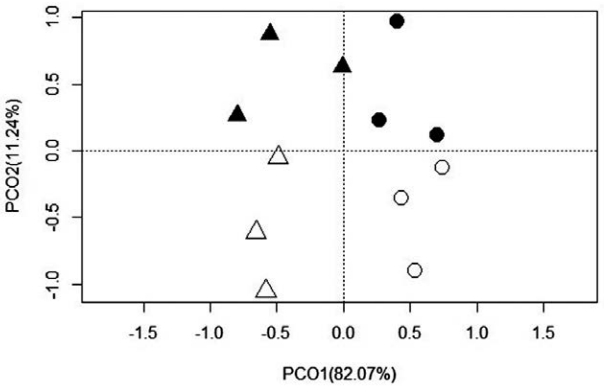

Fig. 3. – Principal coordinates ordination analysis of the richness of estuarine use guilds in the estuary (circle) and coast (triangle) during the dry (empty) and rainy (full) seasons in the Itapissuma/Itamaracá Complex.

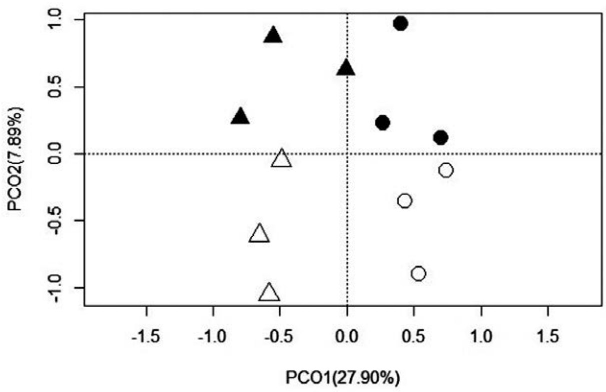

Fig. 5. – Principal coordinates ordination analysis of the richness of trophic guilds in the estuary (circle) and coast (triangle) during the dry (empty) and rainy (full) seasons in the Itapissuma/Itamaracá Complex.

Estuarine use structure

Richness, abundance and biomass of the estuarine use guilds did not vary by season, but differences were observed between the estuary and the coast. In the estuary, marine stragglers and marine migrants dominated in richness during the dry season (33 species, 43%) and the rainy (23 species, 41%). Estuarine species showed the highest abundance in the dry season (8150 individuals, 66%) and the rainy season (4099 individuals, 64%), but in terms of biomass, marine migrants dominated throughout the year (Fig. 2). On the coast, marine stragglers were dominant in richness (38 species, 70%; 31 species, 65%), in abundance (458 individuals, 78%; 259 individuals, 79%) and in biomass (147 kg, 76%; 238 kg, 90%) in the dry and rainy seasons, respectively (Fig. 2).

The PCO analysis based on the estuarine use guilds revealed that the main effect along the first axis (82.07 %) was spatial as it discriminated the samples from the coast and the estuary. Estuarine samples were very similar between seasons, whereas coastal samples showed a more heterogeneous pattern (Fig. 3). The patterns were tested through PERMANOVA and confirmed the location (estuary and coast) effect ($p<0.05$). No seasonal effect was observed (Table 2, $p=0.01$).

Table 2. – PERMANOVA test results for the effects of environment and season on the richness of estuarine use guilds in the Itapissuma/Itamaracá Complex, northeastern Brazil.

	d.f	SS	MS	Pseudo-F	p
Environment	1	0.153	0.153	32.348	**0.001**
Season	1	0.017	0.017	3.592	0.069
Environment *vs.* Season	1	0.000	0.000	0.063	0.892
Residuals	8	0.037	0.004		
Total	11	0.208			

Trophic structure

Zoobenthivores were the richest trophic guild in the estuary: 38 species (41%) and 28 species (30%) in the dry and rainy seasons, respectively. The detritivores showed the highest abundance (15452 individuals, 62%; 10176 individuals, 53) and biomass (203 kg, 70; 82 kg, 47%) in the dry and rainy seasons, respectively (Fig. 4). On the coast, zoobenthivores also dominated in richness (30 species, 55.5%; 34 species, 60.1%) and abundance (372 individuals, 63.3%; 229 individuals, 50%), and piscivores had the greatest biomass (96 kg, 49%; 188 kg, 66.9%) in the dry and rainy seasons, respectively (Fig. 4).

Table 3. – PERMANOVA test results on the richness of trophic guilds, testing for the effects of factors environment and season in the Itapissuma/Itamaracá Complex, northeastern Brazil.

	d.f	SS	MS	Pseudo-F	p
Environment	1	0.077	0.077	6.919	**0.004**
Season	1	0.016	0.016	1.450	0.273
Environment *vs.* Season	1	0.001	0.001	0.168	0.925
Residuals	8	0.089	0.011		
Total	11	0.184			

The PCO based on trophic guilds discriminated samples from the estuary and from the coast along axis 1 (69.64%). In the estuary, differences were observed between the dry and rainy seasons (Fig. 5).

According to the PERMANOVA, the environments (estuary and coast) significantly influenced the abundance of the trophic guilds in the IIC (Table 3, p=0.004), confirming the groups formed by PCO (Fig. 5).

DISCUSSION

Overall, species composition of the IIC was similar to that of the fish fauna typically found in other tropical estuaries (Paiva et al. 2008, Mourão et al. 2014). The observed species richness was close to the estimated richness, indicating that sampling was satisfactory, thanks to the concomitant implementation of active and passive fishing gear. Sampling is known to affect catch composition, especially its diversity (Magurran and McGill 2011), but the use of different gears provides the best estimate of structure (Kwak and Peterson 2007, Mourão et al. 2014) and diversity of fish assemblages (Mérigot et al. 2016). Different gears use different capture processes, mainly based on fish behaviour (Huse et al. 1999). In this study, the use of multiple gears was necessary, considering the differential characteristics of each environment sampled and the fact that fish species explore different habitats of a given environment differently. By exploring multiple gears in different habitats, we improved the estimation of biodiversity, thus providing as wide a variety of guilds as possible.

PCO analysis and PERMANOVA showed spatial differences in the estuarine use functional group between the estuarine and coastal areas, but temporal variations were not evidenced. Spatial segregation processes were observed in other tropical estuaries (Mourão et al. 2014, Loureiro et al. 2016) and may be related to differences in the life cycle and in species tolerance to diverse environmental stresses. Temporal changes in the composition of estuarine fish communities were not observed in the IIC, as reported in other tropical estuaries (Castillo-Rivera et al. 2002, Mendoza et al. 2009).

In the estuary, migrant species predominated in richness and biomass, and estuarine species in abundance. The high richness and biomass of marine species in the estuary can be attributed to the permanent connection between the estuarine area and the Atlantic Ocean throughout the year (Medeiros and Kjerfve 1993), allowing an uninterrupted connectivity with the marine ecosystem (Vasconcelos et al. 2015). Migratory species are of great importance in connected systems, such as estuaries and the adjacent marine area (Harrison and Whitfield 2008). In addition, the IIC is considered a system with high biodiversity and primary and secondary productivity (Vasconcelos Filho et al. 2010, Mérigot et al. 2016). The positive effect of primary productivity on species richness allows larger populations to persist, thereby reducing extinction risk and supporting a higher diversity of niche specialists (Tittensor et al. 2010). According to Vasconcelos Filho and Oliveira (1999), marine species of the IIC are mostly juveniles, some of which are of commercial value. The high abundance of estuarine species within the estuary of the IIC was mainly due to gobiids. Mérigot et al. (2016) analysed the diversity of fish communities in estuarine complexes in Brazil and revealed differences between assemblages from Itapissuma, especially due to the relatively high abundance of some species of Gobiidae. The high abundance of gobiids in tropical estuaries may be partly due to their prolonged larval duration (Shen and Tzeng 2008), closely linked to the mainly muddy substrate and thus restricting their migrations to the sea (Vasconcelos Filho and Oliveira 1999).

In the coastal environment of the IIC, the marine stragglers predominated in richness, abundance and biomass in all periods. However, the percentages of resident (estuarine) and dependent (marine migrant) species were also high, thus confirming the dependence between the estuary and coast of the IIC. The connection between continental and marine environments is an essential characteristic, as marine species are important exporters of energy to the adjacent coastal areas (Vasconcelos Filho et al. 2009). Also, the coast of the IIC offers favourable conditions for the development of the marine fish fauna as protection and food resource (Medeiros et al. 2001).

In relation to the feeding guild approach, our findings emphasized that the substrate of the IIC is of extreme importance for the high productivity in the system (CPRH 2010), contributing to the high occurrence of species with feeding habits associated with the substrate (i.e. zoobenthivores and detritivores). The high availability of organic rich detritus in mangroves may increase the feeding opportunities for detritivores (Kuo et al. 1999), and can be considered the main trophic contribution factor for the estuarine fish fauna (Paiva et al. 2008). In north Brazil, Loureiro et al. (2016) observed that fish assemblage was strongly associated with substrates composed of organic matter. The high richness of zoobenthivores in the estuarine area of the IIC can be attributed to the great abundance of available benthic fauna (Silva 2013). Benthos is one of the structuring elements of the food web and plays an important role in the system dynamics (Herman et al. 1999), transferring energy to fishes in estuarine environments (Buchheister and Latour 2015). Detrivores dominated in abundance and biomass mainly due to large supply of organic matter and detritus in the IIC (Vasconcelos Filho et al. 2009, 2010), which support estuarine trophic webs (Hoffman et al. 2008). The estuarine organic material of the IIC originates from various rivers (Eskinazi-Lessa et al. 1999). The river discharge, sediment resuspension, mangrove litter, waste input, terrestrial runoff and atmospheric input are sources of nutrients in the IIC estuary (Medeiros 1991). The highest proportion of detritus usually occurs in environments with great amounts of organic matter. Detritus is consumed, constituting a link between organic production and animal nutrition, and increasing the efficiency of the energy transfer between the trophic levels (Qasim and Sankaranarayanan 1972).

The large supply of zoobenthic fauna (Silva 2013) and the sandy substrate along the coast (Almeida and Manso 2011) favour the high species richness and abundance of zoobenthivores in the IIC coastal area. Benthophagous fish are highly associated with sandy substrates (Loureiro et al. 2016). The dominance of piscivores in biomass is mainly due to large carangids, which benefit from a high supply of food in the coastal area. Carangids are visual, active predators that spend a great part of their time on the reef searching for prey (Cervigón 1972): they feed on fish and also consume benthic prey to complement their diets (Moreno-Sánchez et al. 2016).

Estuaries are dynamic ecosystems subject to notable variability of environmental conditions, and their fish assemblages show within-estuary seasonal and spatial variations, so taking into account this variability should further clarify trait patterns and drivers of estuarine fish (Henriques et al. 2017). The IIC is an important ecosystem for several species that inhabit or visit the area, mainly associated with the substrate. However, coastal areas are exposed to multiple anthropogenic pressures (Blaber and Barletta 2016) that can alter the structure and function of the fish community (Baptista et al. 2015). The anthropogenic stresses and climate changes may facilitate or inhibite the processing of detritus and consequently cause dramatic shifts in species composition, which are often long-lasting and difficult to reverse (Ooi and Chong 2011). The increase in human impacts could significantly affect the topology and functioning of the food web by altering stabilizing elements of the network and decreasing the diversity of trophic flows that ensures the resilience of the trophic structure (Lobry et al. 2008). From the point of view of ecosystem management, it is necessary to identify and understand the biotic and abiotic effects on the distribution of fish fauna as a precursor for the management and monitoring of coastal environments (Pichler et al. 2017).

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SUPPLEMENTARY MATERIAL

The following supplementary material is available through the online version of this article and at the following link:
http://scimar.icm.csic.es/scimar/supplm/sm04855esm.pdf

Fig. S1. – Species accumulation curve of the estuary (A) and coast (B), computed by a random method without replacement. Mean species richness value ± SD.
Table S1. – Data collection dates according to the environmental and type of fishing gear utilised in the Itapissuma/Itamaracá Complex, northeastern Brazil.
Table S2. – Literature utilised for classication of the ecologic guilds of the ichthyofauna captured in the Itapissuma/Itamaracá Complex, northeastern Brazil. EUFG-Estuarine Use Functional Groups; FMFG-Feeding Mode Functional Groups, basead Elliott et al. (2007).

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Composition of the fish fauna in a tropical estuary: the ecological guild approach

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Flávia L. Frédou

Supplementary material

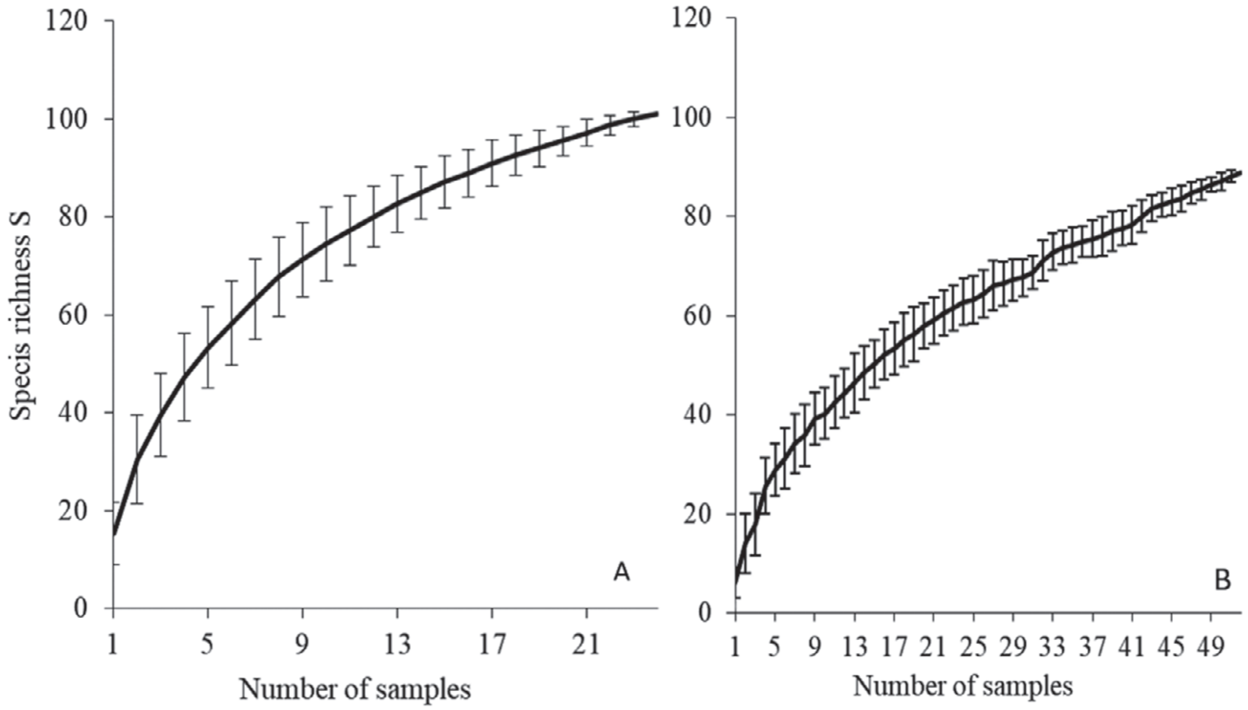

Fig. S1. – Species accumulation curve of the estuary (A) and coast (B), computed by a random method without replacement. Mean species richness value ± SD.

Table S1. – Data collection dates according to the environmental and type of fishing gear utilised in the Itapissuma/Itamaracá Complex, northeastern Brazil.

Environmental	Season	Fishing gear	Date	Set
Estuary	Dry	Block net	January-13	1
			November-13	1
			March-14	1
		Seine net	January-13	3
			November-13	3
			March-14	3
	Rainy	Block net	May-13	1
			August-13	1
			May-14	1
		Seine net	May-13	3
			August-13	3
			May-14	3
Coast	Dry	Gill net	February-13	3
			November-13	3
			March-14	3
		Tidal fixed trap	February-13	6
			November-13	6
			February-14	6
	Rainy	Gill net	May-13	3
			August-13	3
			June-14	3

Table S2. –≠ Literature utilised for classication of the ecologic guilds of the ichthyofauna captured in the Itapissuma/Itamaracá Complex, northeastern Brazil. EUFG-Estuarine Use Functional Groups; FMFG-Feeding Mode Functional Groups, basead Elliott et al. (2007).

Species	Reference	
	EUFG	FMFG
Rhizoprionodon porosus	Lessa and Almeida 1997	Lessa and Almeida 1997
Rhizoprionodon lalandii	Silva and Almeida 2001	Bornatowski et al. 2014
Hypanus guttatus	Vasconcelos Filho and Oliveira 1999	Gianeti 2011
Hypanus marianae	Shibuya and Rosa 2011	Shibuya and Rosa 2011
Elops saurus	Vasconcelos Filho and Oliveira 1999	Froese and Pauly 2019
Gymnothorax funebris	Vasconcelos Filho and Oliveira 1999	Froese and Pauly 2019
Gymnothorax ocellatus	Froese and Pauly 2019	Santos and Castro 2003
Anchoa lyolepis	Froese and Pauly 2019	Froese and Pauly 2019
Anchoa marinii	Froese and Pauly 2019	Froese and Pauly 2019
Anchoa spinifer	Vasconcelos Filho and Oliveira 1999	Nizinski and Munroe 2002
Anchoa tricolor	Araújo et al. 2008	Araújo et al. 2008
Anchovia clupeoides	Vasconcelos Filho and Oliveira 1999	Paiva et al. 2008
Cetengraulis edentulus	Vasconcelos Filho and Oliveira 1999	Paiva et al. 2008
Engraulis anchoita	Froese and Pauly 2019	Vasconcellos et al. 1998
Lycengraulis grossidens	Mai and Vieira 2013	Bortoluzzi et al. 2006
Harengula clupeola	Vasconcelos Filho and Oliveira 1999	Paiva et al. 2008
Opisthonema oglinum	Vasconcelos Filho and Oliveira 1999	Vasconcelos Filho 1979
Rhinosardinia bahiensis	Clark and Pessanha 2015	Clark and Pessanha 2015
Sardinella brasiliensis	Castello 2007	Castello 2007
Chaetodon ocellatus	Froese and Pauly 2019	Froese and Pauly 2019
Aspistor luniscutis	Denadai et al. 2012	Denadai et al. 2012
Aspistor quadriscutis	Denadai et al. 2012	Denadai et al. 2012
Bagre marinus	Segura-Berttolini and Mendoza-Carranza 2013	Mendonza-Carranza 2003
Cathorops agassizii	Dantas 2012	Dantas 2012
Cathorops spixii	Vasconcelos Filho and Oliveira 1999	Possato 2010
Sciades herzbergii	Vasconcelos Filho and Oliveira 1999	Possato 2010
Sciades proops	Vasconcelos Filho and Oliveira 1999	Guedes and Vasconcelos Filho 1980
Synodus foetens	Vasconcelos Filho and Oliveira 1999	Cruz-Escalona et al. 2005
Batrachoides surinamensis	Froese and Pauly 2019	Collette 2010
Thalassophryne nattereri	Vasconcelos Filho and Oliveira 1999	Sampaio and Nottingham 2008
Guavina guavina	Vasconcelos Filho and Oliveira 1999	Teixeira 1994
Ctenogobius boleosoma	Vasconcelos Filho and Oliveira 1999	Vasconcelos Filho et al. 2009
Ctenogobius shufeldti	Wyanski and Targett 2000	Contente et al. 2012
Ctenogobius smaragdus	Vasconcelos Filho and Oliveira 1999	Lima 2015
Ctenogobius stigmaticus	Vasconcelos Filho and Oliveira 1999	Lima 2015
Evorthodus lyricus	Vasconcelos Filho and Oliveira 1999	STRI 2017
Gobionellus oceanicus	Vasconcelos Filho and Oliveira 1999	Vasconcelos Filho et al. 2009
Gobionellus stomatus	Vasconcelos Filho and Oliveira 1999	Lima 2015
Microgobius meeki	WoRMS Editorial Board 2019	Froese and Pauly 2019
Mugil curema	Vasconcelos Filho and Oliveira 1999	Medeiros 2013
Atherinella brasiliensis	Vasconcelos Filho and Oliveira 1999	Paiva et al. 2008
Tylosurus acus acus	WoRMS Editorial Board 2019	Froese and Pauly 2019
Hemiramphus brasiliensis	Vasconcelos Filho and Oliveira 1999	Schwamborn 2004
Hyporhamphus unifasciatus	Vasconcelos Filho and Oliveira 1999	Trigueiro 2013
Carangoides bartholomaei	Froese and Pauly 2019	Paiva et al. 2008
Caranx crysos	Froese and Pauly 2019	Sley et al. 2009
Caranx hippos	Vasconcelos Filho and Oliveira 1999	Temóteo et al. 2015
Caranx latus	Vasconcelos Filho and Oliveira 1999	Temóteo et al. 2015
Caranx ruber	Froese and Pauly 2019	Froese and Pauly 2019
Chloroscombrus chrysurus	Vasconcelos Filho and Oliveira 1999	Silva and Lopes 2002
Oligoplites palometa	Vasconcelos Filho and Oliveira 1999	Vasconcelos Filho et al. 2010
Oligoplites saliens	Vasconcelos Filho and Oliveira 1999	Winik et al. 2007
Oligoplites saurus	Vasconcelos Filho and Oliveira 1999	Vasconcelos Filho et al. 2010
Selene brownii	WoRMS Editorial Board 2019	Bomfim 2014
Selene spixii	WoRMS Editorial Board 2019	Froese and Pauly 2019
Selene vômer	Vasconcelos Filho and Oliveira 1999	Daros 2014
Trachinotus carolinus	Denadai et al. 2013	Stefanoni 2008
Trachinotus falcatus	Vasconcelos Filho and Oliveira 1999	Höflin et al. 1998
Trachinotus goodei	WoRMS Editorial Board 2019	Stefanoni 2008
Sphyraena barracuda	Vasconcelos Filho and Oliveira 1999	Akadje et al. 2013
Sphyraena guachancho	Bonecker et al. 2014	Froese and Pauly 2019
Sphyraena viridensis	Barreiros et al. 2002	Barreiros et al. 2002
Citharichthys spilopterus	Vasconcelos Filho and Oliveira 1999	Vasconcelos Filho et al. 2010
Etropus crossotus	Oliveira and Favarro 2011	Paiva et al. 2008
Paralichthys brasiliensis	Vasconcelos Filho and Oliveira 1999	Froese and Pauly 2019
Syacium micrurum	Vasconcelos Filho and Oliveira 1999	Lucato 1997
Syacium papillosum	Lucato 1997	Lucato 1997
Lutjanus alexandrei	Fernandes et al. 2012	Moraes 2012
Lutjanus analis	Vasconcelos Filho and Oliveira 1999	Freitas et al. 2011
Lutjanus jocu	Vasconcelos Filho and Oliveira 1999	Monteiro et al. 2009
Lutjanus synagris	Vasconcelos Filho and Oliveira 1999	Froese and Pauly 2019
Diapterus auratus	Vasconcelos Filho and Oliveira 1999	Temóteo 2015
Diapterus rhombeus	Vasconcelos Filho and Oliveira 1999	Temóteo 2015
Eucinostomus argenteus	Vasconcelos Filho and Oliveira 1999	Leão 2016
Eucinostomus gula	Vasconcelos Filho and Oliveira 1999	Zahorcsak et al. 2000

Table S2 (Cont.). – Literature utilised for classication of the ecologic guilds of the ichthyofauna captured in the Itapissuma/Itamaracá Complex, northeastern Brazil. EUFG-Estuarine Use Functional Groups; FMFG-Feeding Mode Functional Groups, basead Elliott et al. (2007).

Species	Reference	
	EUFG	FMFG
Eucinostomus havana	Vasconcelos Filho and Oliveira 1999	Froese and Pauly 2019
Eucinostomus melanopterus	Chaves and Bouchereau 2000	Araújo et al. 2016
Eugerres brasilianus	Vasconcelos Filho and Oliveira 1999	Vasconcelos Filho et al. 2009
Anisotremus moricandi	Dias 2007	Dias 2007
Anisotremus virginicus	Vasconcelos Filho and Oliveira 1999	Dias 2007
Conodon nobilis	Vasconcelos Filho and Oliveira 1999	Lira et al. 2013a
Genyatremus luteus	Vasconcelos Filho and Oliveira 1999	Almeida et al. 2005
Haemulon aurolineatum	Vasconcelos Filho and Oliveira 1999	Dantas 2012
Haemulon parra	Vasconcelos Filho and Oliveira 1999	Paiva et al. 2008
Haemulon plumierii	Shinozaki-Mendes et al. 2013	Costa e Silva 2015
Haemulon steindachneri	Daros 2014	Daros 2014
Pomadasys corvinaeformis	Vasconcelos Filho and Oliveira 1999	Denadai et al. 2013
Pomadasys crocro	Froese and Pauly 2019	Froese and Pauly 2019
Polydactylus virginicus	Vasconcelos Filho and Oliveira 1999	Lopes and Oliveira-Silva 1998
Bairdiella ronchus	Vasconcelos Filho and Oliveira 1999	Pina et al. 2015
Cynoscion virescens	Froese and Pauly 2019	Froese and Pauly 2019
Isopisthus parvipinnis	Silva Junior et al. 2015	Lira et al. 2013b
Larimus breviceps	Bessa et al. 2014	Bessa et al. 2014
Menticirrhus americanus	Haluch et al. 2011	Lira et al. 2013c
Paralonchurus brasiliensis	Silva Junior et al. 2015	Lira et al. 2013d
Stellifer stellifer	Dantas 2012	Pombo et al. 2013
Pseudupeneus maculatus	Vasconcelos Filho and Oliveira 1999	Dantas 2012
Halichoeres radiatus	Froese and Pauly 2019	Froese and Pauly 2019
Sparisoma radians	Vasconcelos Filho and Oliveira 1999	Paiva et al. 2008
Sparisoma axillare	Feitosa and Ferreira 2014	Feitosa and Ferreira 2014
Sparisoma aff. *amplum*	Francini-Filho et al. 2008	Francini-Filho et al. 2008
Chaetodipterus faber	Froese and Pauly 2019	Vasconcelos Filho et al. 2009
Pomacanthus paru	Vasconcelos Filho and Oliveira 1999	Cerqueira and Haimovici 1990
Prionotus punctatus	Vasconcelos Filho and Oliveira 1999	Longo et al. 2015
Centropomus parallelus	Vasconcelos Filho and Oliveira 1999	Lira et al. 2016
Centropomus pectinatus	Jackson and Bockelmann-lobello 2006	Lira et al. 2016
Centropomus undecimalis	Vasconcelos Filho and Oliveira 1999	Lira et al. 2016
Epinephelus adscensionis	Nelson 2006	Medeiros et al. 2017
Epinephelus marginatus	Andrade et al. 2003	Machado et al. 2008
Mycteroperca bonaci	Daros 2014	Daros 2014
Trichiurus lepturus	Vasconcelos Filho and Oliveira 1999	Vasconcelos Filho et al. 2010
Scomberomorus brasiliensis	Vasconcelos Filho and Oliveira 1999	Menezes 1970
Bothus ocellatus	Vasconcelos Filho and Oliveira 1999	Hostim-Silva et al. 2005
Achirus declivis	Vasconcelos Filho and Oliveira 1999	Couto and Farias 2001
Achirus lineatus	Vasconcelos Filho and Oliveira 1999	Vasconcelos Filho et al. 2003
Trinectes paulistanus	Vasconcelos Filho and Oliveira 1999	Contente et al. 2009
Symphurus tessellatus	Pina 2009	Lima 2012
Acanthurus bahianus	Vasconcelos Filho and Oliveira 1999	Pimentel 2012
Acanthurus chirurgus	Vasconcelos Filho and Oliveira 1999	Longo et al. 2015
Acanthurus coeruleus	Longo et al. 2015	Longo et al. 2015
Archosargus probatocephalus	Castillo-Rivera et al. 2007	Castillo-Rivera et al. 2007
Archosargus rhomboidalis	Vasconcelos Filho and Oliveira 1999	Yáñez-Arancibia et al. 1986
Lactophrys trigonus	Paiva et al. 2008	Froese and Pauly 2019
Colomesus psittacus	Vasconcelos Filho and Oliveira 1999	Araújo 2012
Sphoeroides greeleyi	Schultz 2002	Lima 2014
Sphoeroides testudineus	Vasconcelos Filho and Oliveira 1999	Vasconcellos et al. 1998
Chilomycterus spinosus	Vasconcelos Filho and Oliveira 1999	Almeida-Silva et al. 2015

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