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## Population structure of Gobiidae in a tropical urban estuary

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### ABSTRACT

As spatiotemporal variations in estuaries affect the population structure of species, the study aimed to analyze the distribution of species of the family Gobiidae in the Capibaribe River's estuary city of Recife (northeastern Brazil). Sampling was performed bi-monthly from February 2009 to December 2012 at two sampling stations. The weight-length relationship of the species was determined using potential regression analysis. Density and biomass values were determined for each species per sampling station and season. The Mann-Whitney test was used to compare spatial and seasonal differences in abundance. A non-metric multidimensional scaling ordination was used to assess changes in species composition. Seven hundred eighty-eight individuals were caught. The most representative species of Gobiidae was *Ctenogobius boleosoma*, followed by *Evorthodus lyricus* and *Gobionellus oceanicus*. The relationship between total weight (TW) and standard length (SL) was potential and significant for both *C. boleosoma* ( $TW = 0.04SL^{2.1815}$ ) and *E. lyricus* ( $TW = 0.0272SL^{2.795}$ ), and both exhibited negative allometric growth. The analysis of the main species' spatial variation demonstrated a significant difference in the number of individuals for *C. boleosoma* ( $U = 528$ ;  $p = 0.000005$ ) and *E. lyricus* ( $U = 312$ ;  $p = 0.000000$ ). No significant difference in abundance was found between the dry and rainy season for either *C. boleosoma* ( $U = 1052.2$ ;  $p = 0.4659$ ) or *E. lyricus* ( $U = 1054$ ;  $p = 0.4726$ ). The two most abundant species have similar habits and customarily inhabit stressful environments. *Ctenogobius boleosoma* and *E. lyricus* are residents of the Capibaribe River's estuary, and both move to regions near the outfall of the river in the rainy season.

**Keywords:** Fishes, gobies, seasonal and spatial abundance, impacted estuary Northeast Brazil.

### Introduction

The nutritional richness of estuaries and the typical geomorphological features that serve as an area for feeding and growth for juveniles attract large biomass of fishes (Haedrich & Hall, 1976; Beck et al., 2001; Allen et al., 2006). The properties and services made available by estuaries compensate for the high physiological-adaptive cost of living in an environment with such abrupt changes (Haedrich & Hall, 1976). However, estuarine environments' stressful conditions, such as salinity and temperature, limit diversity and individual abundance (Andrade-Tubino et al., 2008). Besides abiotic conditions, biological interactions, such as competition and predation,

and the influence of human activities regulate organisms' distribution (Costa de Azevedo et al., 2007).

Approximately 99% of nektonic fauna in estuaries is formed by fishes, playing a fundamental role in the flow of energy inside and outside the ecosystem (Andrade-Tubino et al., 2008). Fishes of the family Gobiidae have residents habits in many estuaries found in northeastern Brazil (Andrade-Tubino et al., 2008), as well as along the coast of Brazil (Paiva et al., 2013; Borgo et al., 2015; Gonçalves & Pérez-Mayorga, 2016; Bolzan et al., 2019). These species are important food items for commercially and recreationally important fishes (Darcy, 1980; Carpenter, 2002).

Gobies are small, benthic, or demersal fishes that occupy a wide variety of freshwater and marine habitats. They are among the most successful marine fishes concerning the colonization of waters with lower salinity (Darcy, 1980), commonly found in shallow and estuarine waters in sub-temperate and tropical regions (Fitzhugh & Fleeger, 1985; Yañez-Arancibia, 1986).

The Capibaribe River is important to the state of Pernambuco (northeastern Brazil). It is wholly contained within the territory of the state and passes through approximately 40 municipalities. The river's estuary is located in Recife's state capital, which is a highly urbanized area. Despite this, the river has diverse ichthyofauna (Lins et al., 2007).

As spatiotemporal variations in estuaries affect species' population structure, the important study aimed to analyze the distribution of species of the family Gobiidae in the Capibaribe River's estuary contribute knowledge that can be used for fish management and environmental conservation.

## Material and Methods

### *Study area*

The spring of the Capibaribe River is in the Jacarará Hills between the municipalities of Jataúna and Poção in the state of Pernambuco, Brazil. The river basin has 7454.88 km<sup>2</sup> and corresponds to approximately 7.5% of the state (APAC, 2018). The river's course to the estuary runs 270 km (APAC, 2018), passing through two distinct climatic sub-regions. The upper and middle courses of the river pass through the Agreste, which is predominantly hot and semi-arid (Köppen classification: BSh), and the lower course passes through the coastal zone of the state, which is predominantly humid tropical (Köppen classification: As') and has two distinct seasons: dry (spring and summer) and rainy (autumn and winter). Annual rainfall in the lower course of the river ranges from 1000 to 2000 mm. The Capibaribe River is only perennial in the coastal zone downstream from the municipality of Limoeiro as a result of the runoff from the main tributaries on the right margin of the lower Capibaribe (Cotunguba, Goitá, and Tapacurá Rivers) (Condepe, 1978).

Few of the municipalities along the Capibaribe have sewage treatment. Thus, the river receives a large amount of untreated domestic sewage either directly or from its tributaries. The

river also has problems with chemical pollution caused by the textile industry in the municipality of Santa Cruz do Capibaribe and many deforestation events along its course, especially in the coastal zone, due mainly to the informal land occupation.

The Capibaribe River's estuary is located entirely on the coastal plain of the Recife city, with a narrow, elongated shape in the west-east direction that follows an area of mild relief, forming a vast floodplain of quaternary deposition (Camaragibe) (Condepe, 1978). The mouth is formed by naturally floodable areas and numerous canals (Prefeitura da Cidade do Recife, 1999).

### *Data collection and analysis*

Two sampling stations were determined on the bank of the estuary of the Capibaribe River: Station 1 (S1) in the neighborhood of Torre (08°02'750'' S; 34°54'181'' W) and Station 2 (S2) near the mouth in the neighborhood of Ilha do Retiro (08°03'769'' S; 34°54'074'' W), which has a greater influence of salinity (Figure 1).

Sampling was performed bimonthly during daylight hours at low spring tide between February 2009 and December 2012, with two sampling station repetitions. Specimens were caught using a gill net measuring 20 m in length and 1.5 m in height with a 5 mm mesh. Captured individuals were preserved with a 10% aqueous solution of formol. The specimens were sorted, identified, measured (0.1 cm), and weighed (0.01 g) in the laboratory. Salinity was measured (PSU) using a multi-parameter probe.

The dry season (September to February) and the rainy season (March to August) were considered for seasonality analyses. Frequency of occurrence (FO%) of the species was calculated based on Dajoz (1983), using the formula  $FO\% = (N_{mi} \times 100) / N_{tm}$ , in which  $N_{mi}$  is the number of months in which species "i" was observed and  $N_{tm}$  is the total number of sampling months. Species with  $FO \geq 50\%$  were considered constant; those with  $25\% \leq FO < 50\%$  were considered an accessory, and those with  $FO < 25\%$  were considered occasional (Sarmiento-Soares & Martins-Pinheiro, 2013). Density ( $d = n / A$ ), in which  $n$  is the number of individuals and  $A$  is the sampling area (m<sup>2</sup>), and biomass ( $b = TW / A$ ), in which  $TW$  is total weight (g), and  $A$  is the area sampled (m<sup>2</sup>), were determined for each species per sampling station and season. The data were standardized by the collection area (30 m<sup>2</sup>).

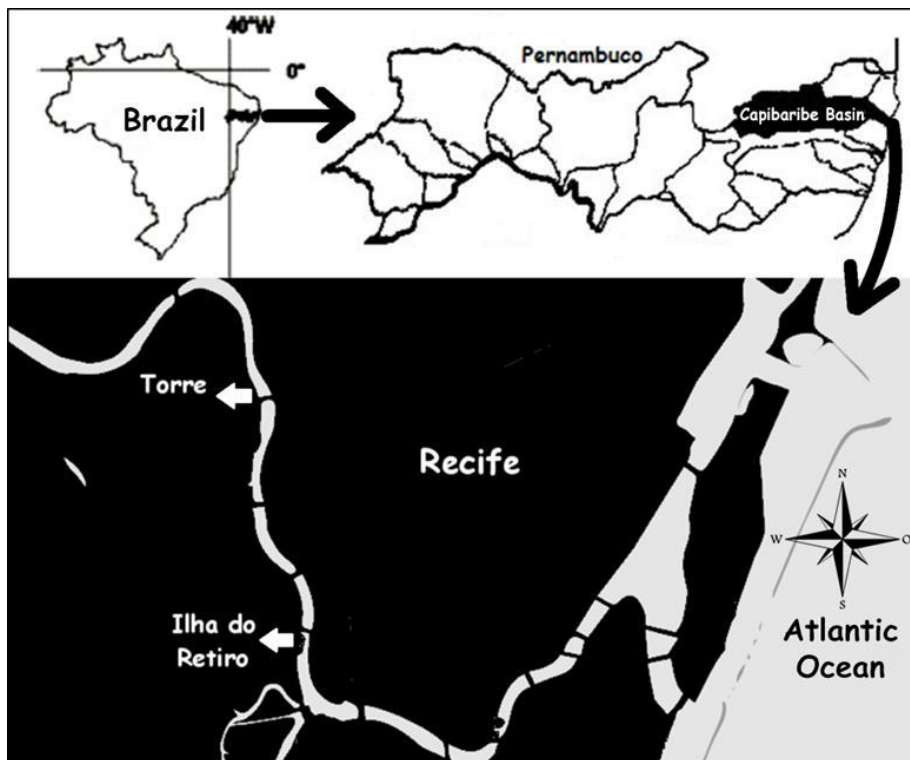


Figure 1. Location of sampling stations (S1 - Torre and S2 – Ilha do Retiro) in estuary of Capibaribe River, Recife, PE, Brazil. Font: Andrade (2016).

The Shapiro-Wilk and Bartlett tests were used to test the normality and homoscedasticity of the data, respectively. The Mann-Whitney test was used to compare spatial and seasonal differences in the individuals ( $p < 0.05$ ). Potential regression analysis was used for the determination of the weight-length relationship ( $p < 0.05$ ), using the equation  $TW = a SL^b$ , in which TW is total weight (g), SL is standard length (cm), and b is the angular coefficient. A non-metric multidimensional scaling ordination (NMDS) analysis was performed in R (R Core Team, 2017) to assess Gobiidae changes in species composition in the samples obtained from the two sampling sites. *Gobionellus oceanicus* was not included in the frequency distribution analysis and the weight-length

relationship due to the small number of individuals sampled. Data on mean salinity were analyzed by sampling station and season.

## Results

### *Composition and frequency of occurrence of species*

Seven hundred eighty-eight individuals of Gobiidae were caught, the most representative species was *Ctenogobius boleosoma* (Jordan & Gilbert, 1882) ( $n = 593$ ; 75.25%), followed by *Evorthodus lyricus* (Girard, 1858) ( $n = 192$ ; 24.37%) and *Gobionellus oceanicus* (Pallas, 1770) ( $n = 3$ ; 0.38%). Table 1 displays the numeric frequencies and frequencies of occurrence per station and season.

Table 1. Numeric frequency (NF%) and frequency of occurrence (FO%) of Gobiidae species sampled in the estuary of Capibaribe River, Recife, Brazil, per station, and season. Font: Andrade (2016).

Species	NF%		NF%		FO%		FO%	
	E1	E2	Es	Ch	E1	E2	Es	Ch
<i>Ctenogobius boleosoma</i> (Jordan & Gilbert, 1882)	61.43	80.70	75.37	75.08	41.66	58.33	66.66	50
<i>Evorthodus lyricus</i> (Girard, 1858)	37.67	19.12	24.21	24.60	54.16	83.33	83.33	83.33
<i>Gobionellus oceanicus</i> (Pallas, 1770)	0.90	0.18	0.42	0.32	8.33	4.16	16.66	8.33

E1 = station 1 – Torre; E2 = station 2 – Ilha do Retiro; Es = dry season; Ch = rainy season.

*Ctenogobius boleosoma* was considered accessory at S1 and constant at S2 throughout the entire sampling period. *E. lyricus* was constant, and

*G. oceanicus* was occasional at both sampling stations in both seasons (Table 1).

**Weight and length**

*Ctenogobius boleosoma* had the broadest range of SL (0.90 to 5.60 cm) and the lowest mean

SL ( $2.70 \pm 0.61$  cm). *E. lyricus* had the broadest range of TW (0.05 to 2.86 g), and *G. oceanicus* had the largest mean TW ( $3.53 \pm 3.97$  g) (Table 2).

Table 2. Standard length (SL) and total weight (TW) of Gobiidae species sampled in the estuary of Capibaribe River, Recife, Brazil. Font: Andrade (2016).

Species	SL (cm)	TW (g)
	Mean $\pm$ SP (min – max)	Mean $\pm$ SP (min – max)
<i>Ctenogobius boleosoma</i>	$2.70 \pm 0.61$ (0.90 – 5.60)	$0.38 \pm 0.22$ (0.03 – 2.19)
<i>Evorthodus lyricus</i>	$3.32 \pm 0.79$ (1.50 – 5.40)	$0.91 \pm 0.58$ (0.05 – 2.86)
<i>Gobionellus oceanicus</i>	$5.97 \pm 1.93$ (4.70 – 8.20)	$3.53 \pm 3.87$ (1.10 – 8.00)

The distribution per length class showed a greater abundance of *C. boleosoma* in the 2.0 to 3.0 cm (53.12%) and 3.0 to 4.0 cm (34.91%). A greater

abundance of *E. lyricus* was found in the 3.0 to 4.0 cm (39.06%) class (Figure 2).

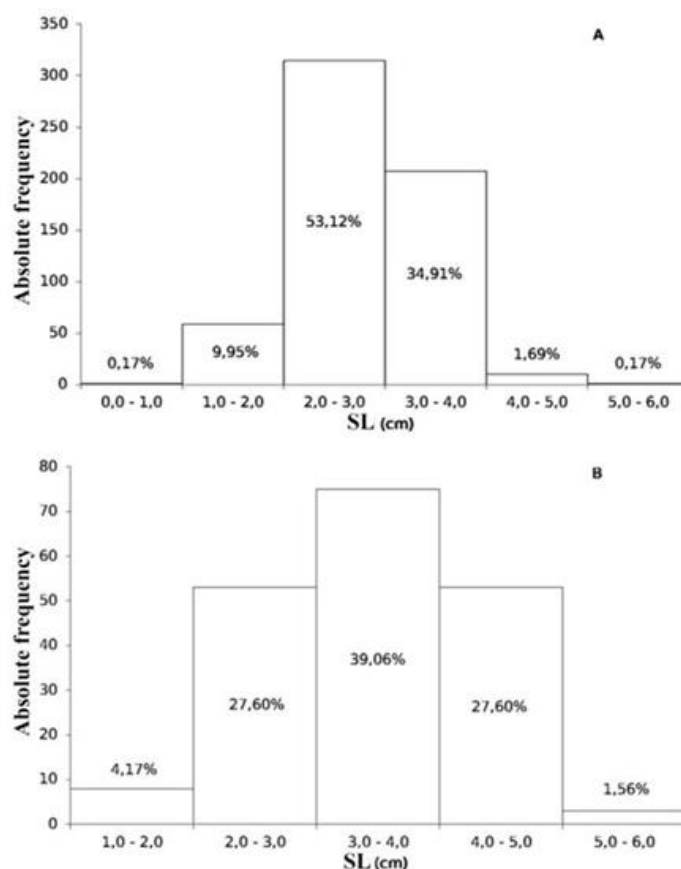


Figure 2. Frequency distribution of *Ctenogobius boleosoma* (A) and *Evorthodus lyricus* (B) per length class in the estuary of Capibaribe River in Recife, Brazil. Font: Andrade (2016).

Total biomass (b) of the individuals sampled was  $13.94 \text{ g} / 30 \text{ m}^2$ , with  $4.36 \text{ g} / 30 \text{ m}^2$  (31.27%) at S1 and  $9.57 \text{ g} / 30 \text{ m}^2$  (68.65%) at S2. Regarding seasonality, total biomass was  $10.03 \text{ g} / 30 \text{ m}^2$  (71.95%) in the dry season and  $3.90 \text{ g} / 30 \text{ m}^2$  (27.97%) in the rainy season. Higher mean biomass values were found for *C. boleosoma* and *E. lyricus* at S2 ( $5.88 \text{ g} / 30 \text{ m}^2$  and  $3.42 \text{ g} / 30 \text{ m}^2$ ,

respectively). *Ctenogobius boleosoma* had higher biomass values in both the dry and rainy seasons ( $5.52 \text{ g} / 30 \text{ m}^2$  and  $2.19 \text{ g} / 30 \text{ m}^2$ , respectively). When considering the sampling stations, the lowest biomass was found at S1 in the rainy season (0.50 g), and the highest was found at S2 in the dry season (6.17 g) (Table 3).

Table 3. Total biomass (g) at sampling stations in dry and rainy seasons of Gobiidae species in the estuary of Capibaribe River, Recife, Brazil. Font: Andrade (2016).

Species	Total	Sampling stations		Seasons		Seasons (sampling stations)			
		E1	E2	Es	Ch	Es		Ch	
						(E1)	(E2)	(E1)	(E2)
<i>Ctenogobius boleosoma</i>	7.71	1.82	5.88	5.52	2.19	1.67	3.83	0.14	2.04
<i>Evorthodus lyricus</i>	5.88	2.45	3.42	4.19	1.68	2.12	2.06	0.32	1.35
<i>Gobionellus oceanicus</i>	0.35	0.09	0.26	0.32	0.03	0.05	0.26	0.03	0.00
<b>Total</b>	13.94	4.36	9.57	10.03	3.90	3.86	6.17	0.50	3.40

E1 = station 1 – Torre; E2 = station 2 – Ilha do Retiro; Es = dry season; Ch = rainy season.

The weight-length relationship was potential and significant for both *C. boleosoma* (TW = 0.04 SL<sup>2.1815</sup>) and *E. lyricus* (TW = 0.0272

SL<sup>2.795</sup>). Both species exhibited negative allometric growth (b < 3) (Figure 3).

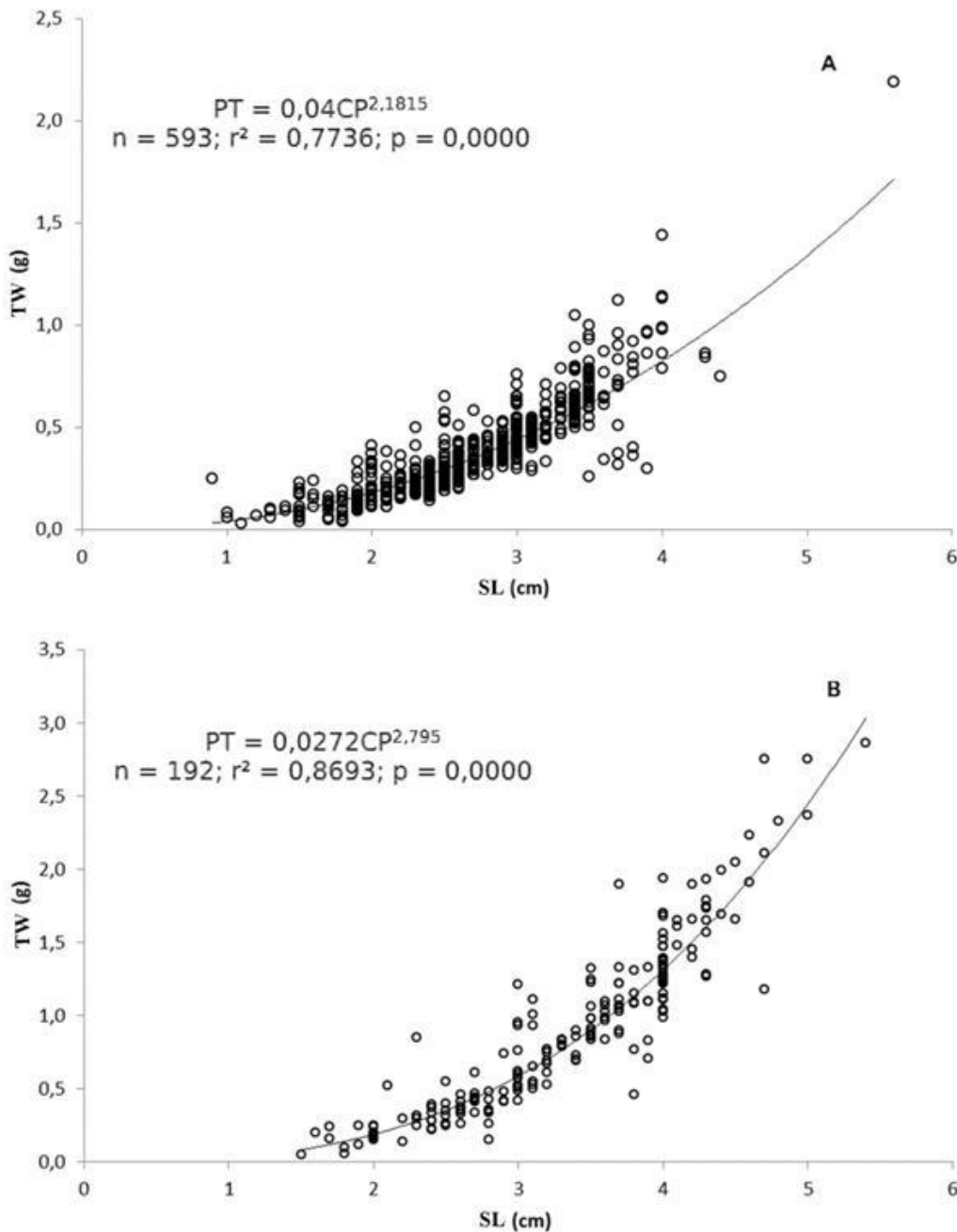


Figure 3. Relationship between total weight (TW) and standard length (SL) of *Ctenogobius boleosoma* (A) and *Evorthodus lyricus* (B) in the estuary of Capibaribe River, Recife, Brazil. Font: Andrade (2016).

*Spatiotemporal variation*

Mean density (*d*) of the individuals sampled was 26.26 / 30 m<sup>2</sup>, with 7.43 ind. / 30 m<sup>2</sup> (28.30%) at S1 and 18.83 ind. / 30 m<sup>2</sup> (71.70%) at

S2. Seasonally, density values were 15.83 ind. / 30 m<sup>2</sup> in the dry season (60.28%) and 10.43 ind. / 30 m<sup>2</sup> (39.71%) in the rainy season (Table 4).

Table 4. Total density (m<sup>2</sup>) as sampling stations in dry and rainy seasons of Gobiidae species in the estuary of Capibaribe River, Recife, Brazil. Font: Andrade (2016).

Species	Total	Sampling stations		Seasons		Seasons (sampling stations)			
		E1	E2	Es	Ch	Es		Ch	
						(E1)	(E2)	(E1)	(E2)
<i>Ctenogobius boleosoma</i>	19.76	4.56	15.20	11.93	7.83	4.13	7.80	0.43	7.40
<i>Evorthodus lyricus</i>	6.40	2.80	3.60	3.83	2.56	2.10	1.73	0.70	1.86
<i>Gobionellus oceanicus</i>	0.10	0.06	0.03	0.06	0.03	0.03	0.03	0.03	0.00
<b>Total</b>	<b>26.26</b>	<b>7.43</b>	<b>18.83</b>	<b>15.83</b>	<b>10.43</b>	<b>6.26</b>	<b>9.56</b>	<b>1.16</b>	<b>9.26</b>

E1 = station 1 – Torre; E2 = station 2 – Ilha do Retiro; Es = dry season; Ch = rainy season.

Compared to *E. lyricus*, *C. boleosoma* exhibited greater mean density at both S1 (4.56 ind. / 30 m<sup>2</sup>) and S2 (15.20 ind. / 30 m<sup>2</sup>) as well as in the dry season (11.93 ind. / 30 m<sup>2</sup>) and the rainy season (7.83 ind. / 30 m<sup>2</sup>). However, *E. lyricus* (0.70 ind. / 30 m<sup>2</sup>) was more abundant than *C. boleosoma* (0.43 ind. / 30 m<sup>2</sup>) at S1 in the rainy season (Table 4). The spatial variation analysis demonstrated a significant difference in the number of *C. boleosoma* (U = 528; p = 0.000005) and *E. lyricus* (U = 312; p = 0.000000), with the greater abundance of both species at S2. No significant

difference in abundance was found between the dry and rainy seasons for either *C. boleosoma* (U = 1052.2; p = 0.4659) or *E. lyricus* (U = 1054; p = 0.4726).

Mean salinity was higher at S2 (1.72 ± 1.94). The highest mean salinity was found at S2 in the dry season (2.62 ± 2.17), and the lowest mean salinity was found at S1 in the rainy season (0.65 ± 0.91). A non-metric multidimensional scaling revealed that the overall community composition in the rain season was more homogeneous than the dry season (Figure 4).

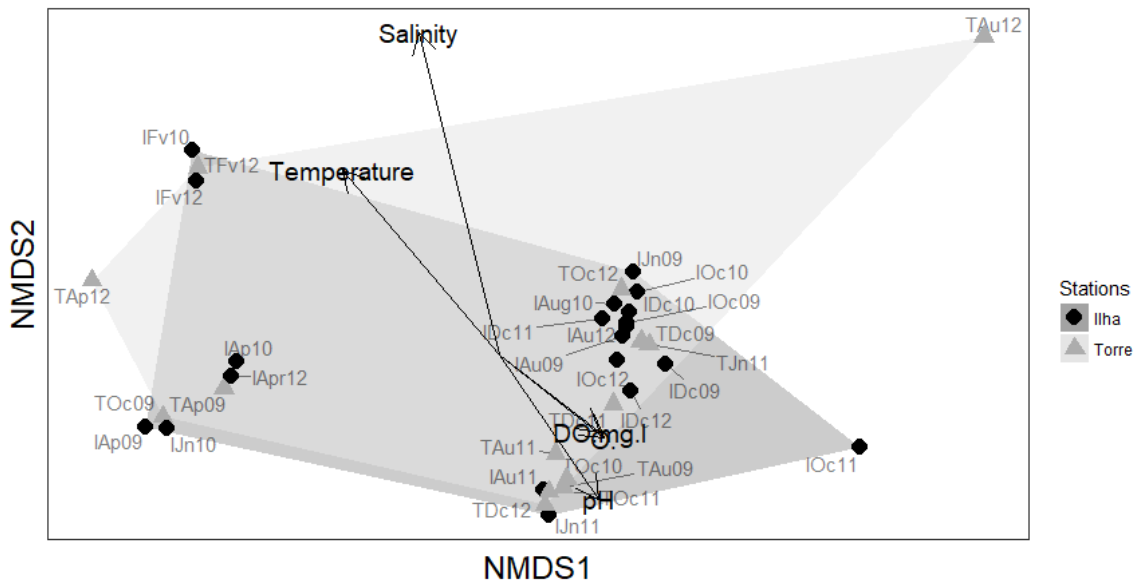


Figure 4. Graphic representation of the first two axes of ordination by Non-Metric Multidimensional Scaling (NMDS) representing the Gobiidae species composition in the estuary of Capibaribe River, Recife, Brazil. Black and gray symbols represent samples sites. Font: Andrade (2016).

**Discussion**

*Ctenogobius boleosoma* and *E.lyricus* were the most abundant species of Gobiidae in the estuary of the Capibaribe River. These species were recorded in a previous study on the

ichthyofauna of the lower course of the river, with *C. boleosoma* cited as one of the most abundant, corresponding to 35.90% of the sample (Lins et al., 2007). Andrade-Tubino et al. (2008) documented the occurrence of these two species among the most

frequent demersal fishes in estuaries of northeastern Brazil, and both were found in the Santa Cruz Channel of Itamaracá Island on the northern coast of the state of Pernambuco (Vasconcelos Filho & Oliveira, 1999). The occurrence of these species is not restricted to northeastern Brazil, as both compose the fish fauna in the estuarine region of Maciço da Pedra Branca in the state of Rio de Janeiro (Gomes, 2006).

*Ctenogobius boleosoma* has broad distribution throughout the coast of Brazil. It has been found in Bahia, considered a species of intermediate occurrence on Cabuçu Beach (Sarmiento-Soares et al., 2007; Oliveira-Silva et al., 2008). The southernmost record of *C. boleosoma* in Brazil was the Saí Guaçu River's outfall on the border between Paraná and Santa Catarina (Spach et al., 2010).

*Evorthodus lyricus* is the only species of the genus *Evorthodus* to occur in the Atlantic Ocean (Wyanski & Targett, 1985). It is distributed throughout practically the entire western coast of the Atlantic, from the Chesapeake Bay in the United States to Pontal da Barra in southern Brazil (Cheffe et al., 2010). The occurrence of this typically tropical species in subtropical waters may be related to the Brazil Current, which carries warm surface water to subtropical regions (Cheffe et al., 2010).

*Ctenogobius boleosoma* and *E. lyricus* have similar habits, and both juveniles and adults of this species customarily occupy shallow estuarine habitats, mostly plains with muddy substrates (Foster & Fuiman, 1987; Falcão et al., 2006; Oliveira-Silva et al., 2008; Spach et al., 2010; Cheffe et al., 2010), such as the sampling stations in the Capibaribe River used in the present investigation. The larvae of *C. boleosoma* and *E. lyricus* also share many similarities regarding habits and morphology and are found in the plankton community of tropical estuaries (Wyanski & Targett, 1985).

*Ctenogobius boleosoma* larvae generally pass to the juvenile phase when reaching 0.7 to 1.3 cm SL, and individuals up to 2.0 cm SL are considered juveniles (Wyanski & Targett, 2000). Adults can reach a maximum total length of 7.5 cm (Robins & Ray, 1986). *Evorthodus lyricus* has a similar lifecycle, with larvae reaching the juvenile phase at around 1.0 cm SL. Juveniles generally reach about 3.0 cm SL (Wyanski & Targett, 1985). The species displays sexual dimorphism, with males usually smaller than females. Adult males reach 3.0 to 4.0 cm SL, whereas adult females can reach a length of around 7.0 cm SL (Foster & Fuiman, 1987). In the present study, 89.89% of the population of *C. boleosoma* was formed by adults,

whereas the population of *E. lyricus* was more varied, with adults accounting for 68.23% of the specimens sampled and juveniles accounting for 31.77%. These findings demonstrate the permanence of these species in the estuary.

The two most abundant species of Gobiidae in the estuarine region of the Capibaribe River were classified as estuarine residents in several previous studies (Oliveira, 1972; Vasconcelos Filho & Oliveira, 1999; Joyeux et al., 2004; Falcão et al., 2006; Oliveira-Silva et al., 2008; Andrade-Tubino et al., 2008; Lasso et al., 2009; Neves et al., 2010). The results confirm that *C. boleosoma* and *E. lyricus* are resident species in the estuary.

*Ctenogobius boleosoma* and *E. lyricus* demonstrated significant variations in the weight-length relationship and negative allometric growth. These same findings have been described in other population studies involving the family Gobiidae (Wyanski & Targett, 1985; Abdoli et al., 2009). Variations in the weight-length relationship in fishes may be influenced by habitat, sexual maturity, metamorphosis, and feeding (Ilhan et al., 2012; Lizama & Ambrósio, 1999). Gobies generally exhibit allometric growth due to various shape changes during the life phases (Wyanski & Targett, 1985). Indeed, *C. boleosoma* and *E. lyricus* undergo many transformation events during their lifecycles (Ginsburg, 1931; Wyanski & Targett, 1985; Foster & Fuiman, 1987; Wyanski & Targett, 2000).

*Ctenogobius boleosoma* and *E. lyricus* both tolerate large variations in salinity and temperature and demonstrate territorial and cryptic behavior (Schwartz, 1999; Spach et al., 2010). These characteristics explain the greater occurrence at the Ilha do Retiro station (S2), which has higher mean salinity values and is located closer to the estuary's mouth, making it more subject to greater environmental variation and stress.

Lins et al. (2007) also found a high density of individuals near the Capibaribe River's mouth. The ichthyofauna of estuaries is formed mainly by marine species, with a progressive reduction in the number of species as the degree of salinity diminishes (Oliveira, 1972). Adult gobies tend to occupy environments with large environmental variations, and *C. boleosoma*, in particular, is abundant in stressful environments. This behavior has also been observed in reef pools on Castelhanos Beach in the state of Espírito Santo (Macieira, 2008) and at the mouth of the Saí Guaçu River in the state of Santa Catarina (Spach et al., 2010).

Salinity is the most significant environmental factor acting on species' dynamics

in brackish waters (Oliveira, 1972). Indeed, salinity explains the predominance of *C. boleosoma* and *E. lyricus* at Ilha do Retiro station (S2) and the lower biomass values in the rainy season, when salinity tends to diminish due to the greater influx of freshwater, making the species move to areas closer to the mouth of the estuary (Barletta et al., 2003).

*Evorthodus lyricus* is euryhaline, tolerating an extensive range of salinity, and can be found at more distant locations from rivers' mouths (Cheffe et al., 2010; Foster & Fuiman, 1987). Individuals have been found in entirely freshwater environments on Trinidad and Suriname (Foster & Fuiman, 1987). *Evorthodus lyricus* prefers habitats that are more protected from tidal dynamics (Wyanski & Targett, 1985) and customarily reproduce in the colder waters of the rainy season (Cheffe et al., 2010). These characteristics explain its frequency at both sampling stations in the present investigation and its slight predominance in the rainy season at the Torre station (S1), which is farther from the estuary's mouth.

Despite the slight variation between sampling periods, no significant seasonal difference in the abundance was found, as both species are residents. According to Neves et al. (2010), a lack of a significant difference in the seasonal distribution of species is a common finding due to the abundance in the community of resident species that are tolerant to a broad range of environmental variations, with long recruitment periods and multiple spawning throughout the year.

## Conclusion

*Ctenogobius boleosoma* and *Evorthodus lyricus* are resident species in the Capibaribe River estuary, found in all sizes throughout the year, even though inadequate human activities have made the river highly polluted.

The two species exhibit high relative abundance nearer to the river's outfall, which is under greater influence of the tide and has a more significant influx of marine water. This finding suggests the preference of these species for environments with greater salinity.

*Ctenogobius boleosoma* seems to be less tolerant of seasonal changes in salinity and needs to move closer to the river's mouth in the rainy season, unlike *Evorthodus lyricus* euryhaline species.

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