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ICHTHYOFAUNA IN THE INNER CONTINENTAL SHELF NEXT TO THE PARANAGUÁ ESTUARINE COMPLEX, SOUTHERN BRAZIL

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ABSTRACT

The composition and structure of fish assemblages in the inner continental shelf of the Paraná State are affected by cold fronts and the rainfall regime. Data from fishing activities in this region, as well as the analysis of environmental characteristics, are the main tools available for understanding fish dynamics, under influence of increasing human activities. In order to better understand patterns and temporal variations in fish assemblages in the inner continental shelf of the Paraná State, a total of 24 double trawls were performed with an otter trawl between August 2000 and July 2001, in two sampling areas, the North area in front of the northern mouth of the Paranaguá Estuary Complex, and the South area, in front of the Leste beach. A total of 45,277 fish specimens belonging to 35 families and 97 species were caught. Sciaenidae was the most abundant family, with 37.1% of the total number of individuals caught, and with the highest richness (18 species). Statistical analyses evidenced significant differences in environmental characteristics and in fish fauna, and that both areas disturbances were observed in the fish assemblages during the dry and wet season, being more intense in the Southern area, disturbances that would be related to the shrimp fishing present in the two areas sampled in this study.

Keywords: assemblages; coastal zone; seasonality; abiotic factors.

FAUNA DE PEIXES DA PLATAFORMA CONTINENTAL INTERNA PRÓXIMA DO COMPLEXO ESTUARINO DE PARANAGUÁ, SUL DO BRASIL

RESUMO

A composição e estrutura das assembleias de peixes na plataforma continental interna do Paraná são afetadas pelas frentes meteorológicas frias e pelo regime de chuvas. Os dados das atividades pesqueiras da região, bem como a análise das características ambientais, são a principal ferramenta disponível para o entendimento da dinâmica dos peixes, sob a influência de atividades antropogênicas crescentes. Para melhor entender os padrões de assembleia de peixes e suas variações temporais na plataforma continental interna do Estado do Paraná, foram realizados 24 arrastos duplos com rede de arrasto de porta entre agosto de 2000 e julho de 2001, em duas áreas de amostragem, a área norte em frente da entrada norte do complexo estuarino de Paranaguá e a área sul em frente a praia de Leste. Um total de 45.277 indivíduos de peixes foram capturados, pertencentes a 35 famílias e 97 espécies. Sciaenidae foi a família mais abundante, com 37,1% do número total de indivíduos capturados e com a maior riqueza (18 espécies). As análises estatísticas evidenciaram diferenças significativas nas características ambientais e na fauna de peixes, e em ambas as áreas foram evidenciadas perturbações nas assembleias de peixes durante a estação seca e chuvosa, sendo mais intenso na região sul, perturbações que estariam relacionados com a pesca do camarão presente nas duas áreas amostradas neste estudo.

Palavras-chave: assembleias; zona costeira; sazonalidade; fatores abióticos.

INTRODUCTION

The dynamics of fish populations are governed by both the biological needs of the individuals and by abiotic factors, especially those related to long-term changes and to the recurrent climatic and oceanographic processes in the region (Zacharias and Roff, 2001; Tu et al., 2015). There are a number of factors that have been identified for the prediction of the composition and structure of fish fauna in marine environments, such as the continental shelf width, depth, type of substrate and hydrography (Farré et al., 2016; Páez et al., 2018). In addition, studies on the biological and ecological characteristics, such as fish interspecific relationships (e.g., predation and competition) and food availability are necessary (Hixon and Jones, 2005; Tableau et al., 2016). The definition of the structure, diversity and stability of fish assemblages is related to the interactions between species of fish and between them and the physical environment (Francisa et al., 2002).

An important issue for understanding and managing coastal areas is to identify spatio-temporal changes in the structure of the demersal assembly and its relationship with oceanographic variation. In this sense, the objective of this study was to provide information on demersal fish assemblages from two continental shelf areas of the Paraná State, southern Brazil. It was hypothesized that if two areas are affected by different oceanographic factors, such as substrate, waves and tidal currents, it is expected to find differences in abundance, richness and composition in the fish assemblages.

This comparative approach between hydrography and fish is the first on the shallow continental shelf adjacent to the Paranaguá estuarine complex, the results of which can serve as a basis for current assessments.

MATERIAL AND METHODS

Study area

The study area encompasses two portions of the continental shelf of the Paraná State with a distance of 12 km between them, the North area, between Mel Island and Superaguí Island, in front of the northern mouth of the Paranaguá Estuary Complex (PEC) (48º10'W/25º36'S), and the South area, in front of the Leste beach (48º25'W/25º44'S) to the south of the PEC (Figure 1). Although both areas are located in the same isobath (10 m), there are marked differences mainly regarding the sediments that constitute the substrate; when compared to the South area, the North area presents coarser sediments, due to the higher energy waves and tidal currents in this region (Noernberg, 2001; Veiga et al., 2004; Sielski et al., 2017).

The inner continental shelf of the Paraná State is characterized by a smooth relief with a width of approximately 50 km, where the most striking features are related to the mouth of the PEC (tidal delta) (Veiga et al., 2004; Veiga, 2005). The bottom sediment has a predominance of fine sands, with occasional occurrences of medium to coarse sand from 10 m deep (Veiga et al., 2004; Lamour, 2007). The coast of the Paraná State has a hydrography characterized by large seasonal variations caused by the Brazil Current and the Malvinas Current (Brandini, 1990). The shallow currents are directly related to the tidal influence on the estuarine system, presenting speeds close to the bottom between 2 cm s^{-1} and 3 cm s^{-1} (Mesquita and Harari, 2003). The tide is classified as semi-diurnal, with a mean amplitude of ~2 m (Marone and Jamiyanaa, 1997).

Sampling

Between August 2000 and July 2001, sampling period where the capture license was not required, two simultaneous double tows, lasting 30 minutes each, totaling four samples per area and month were performed with a trawling vessel (15-m length and 125-kW engine power), at a 2-knot speed using an otter trawl (lead-head opening of 1.8 m; mouth with 1.95 m wide in the lead line and 2.14 m in the float line; net wings with 4.26 m lead length and

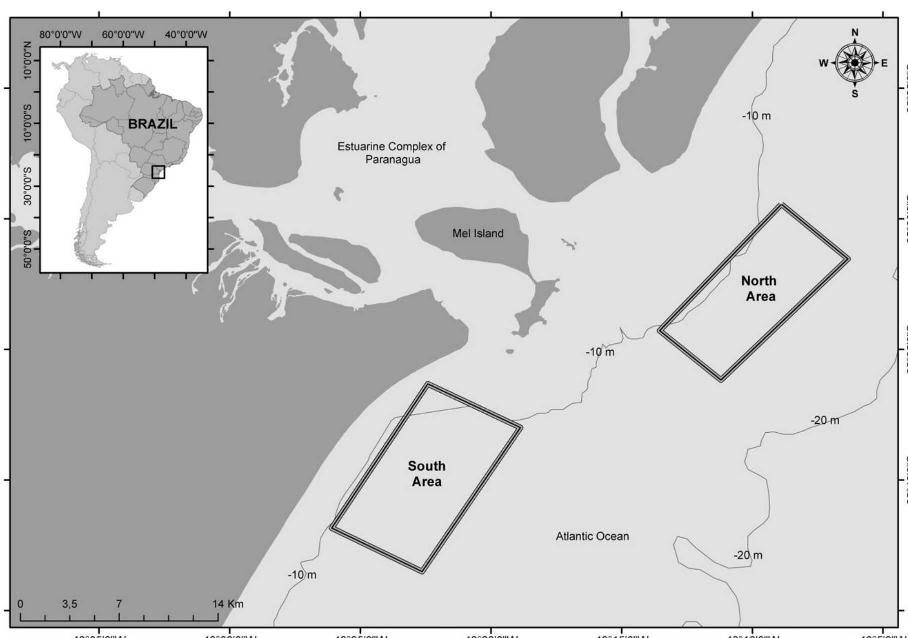

Figure 1. Sampling locations (North area and South area) in the inner continental shelf adjacent to the Paranaguá Estuarine Complex, Paraná, southern Brazil.

3.81 m float length; mesh with 3.0 cm in the lead and 4.0 cm in the float; and two flat rectangular otter boards 1.10 x 0.50 m and 75 Kg each). Prior to each 30-min tow, bottom temperature (°C) and salinity values were measured with a CTD probe and the water transparency (m) was determined using a Secchi disk. At the end of each deployment, the fish was placed in plastic bags and kept on ice for transport to the laboratory. The collected teleosts were identified to the highest possible taxonomic separation (Figueiredo, 1977; Figueiredo and Menezes, 1978, 1980, 2000; Barletta and Corrêa, 1992), before being weigted with an eletronic scale accurate to 0.01 gram.

Data analysis

For the analyses, the sampling months were pooled in relation to the seasons of higher and lower rainfall in the region, classified as follows: EW-early wet (October, November and December); LW-late wet (January, February and March); ED- early dry (April, May and June) and LD- late dry (July, August and September) (Figure 2).

Variations in temperature, salinity, transparency, number of individuals, biomass and number of species were tested by permutational multivariate analysis of variance (PERMANOVA) (Anderson et al., 2008). Dissimilarity matrices were based on Euclidean and Bray-Curtis distances for abiotic and biotic variables, respectively. The analysis was bifactorial and the factors are area and season, both fixed and orthogonal. The terms that presented significant differences were followed by a permutational pairwise comparisons (pseudo-F statistics) between all pairs of levels. A Canonical Analysis of Principal Coordinates (CAP) was applied to visualize spatial and temporal differences in fish assemblage (Anderson et al., 2008).

To evaluate the species dominance between the two areas, the K-dominance curve was plotted. In the graph corresponding to these analyses, a higher curve indicates a sector with lower species

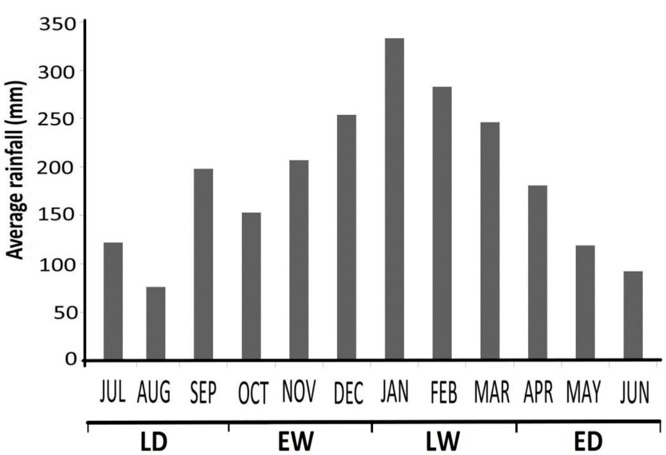

Figure 2. Average monthly rainfall (mm) between 2000 and 2007 in the inner continental shelf adjacent to the Paranaguá Estuarine Complex, Paraná, southern Brazil. LD (late dry); EW (early wet); LW (late wet) and ED (early dry).

diversity (Clarke and Warwick, 2001). The Abundance-Biomass Comparison (ABC) curve was also plotted. This analysis assumes that in an undisturbed community there is a predominance of conservative species (with large body size, usually dominant in terms of biomass). When this environment begins to be impacted, these species, move away from this area, remaining opportunistic species. Opportunistic species are generally dominant in number and thus recolonize this environment. That is, an environment not impacted has an ABC curve with biomass greater than abundance and impacted environments have an ABC curve with abundance greater than biomass (Clarke and Warwick, 2001).

To check for taxonomic differences between the two areas, the Average Taxonomic Distinctness (AvTD, Δ+) and the Variation in Taxonomic Distinctness (VarTD, Λ+) were calculated. These indices are useful because they allow comparing data with different sampling efforts; and are calculated based on the absence and presence of species and the taxonomic distance between them. The data collected are compared with a list of all species already found in the region. These data are plotted on a graph with 95% confidence interval; samples outside this interval indicate a change in community composition (Clarke and Warwick, 2001). All analyzes were performed using Primer 7 v.7.0.13.

RESULTS

Values (mean ± SD) of water temperature varied between 17°C and 28°C, with a well-marked seasonal pattern, with significant lower temperatures in the late dry season (20.37 ± 2.57°C), medium temperatures in the early wet (22.5 ± 1.22°C) and early dry (22.33 ± 1.97°C), and higher temperatures in the late wet (27.08 ± 0.28°C). There were no significant differences in water temperature between the North and South areas nor the interaction between season and area (Table 1). Water salinity ranged from 32 to 36. Statistical differences were detected between seasons with higher salinity in the early dry season (36.08 ± 1.21) compared to late dry (34.25 ± 1.45), early wet (34.58 ± 0.88) and late wet (34.42 ± 1.35) and between areas, being on average higher in the South (35.17 ± 1.29) compared to the North area (34.5 ± 1.49). On the other hand, there was no significant interaction between season and area (Table 1). The transparency varied from 1 to 7 m. On average, the transparency was significantly different (p <0.05) between the north and south areas, with higher transparency in the south (4.54 ± 1.43 m) compared to the north (3.66 ± 1.42 m) and in the interaction between area and season in the early wet. On average, the transparency was significantly lower in the late dry (3.58 ± 1.69 m) and early dry (3.75 ± 0.85 m) than in the early wet (4.25 ± 1.63 m) and late wet 4.83 ± 1.37 m) (Table 1).

A total of 45,277 individuals belonging to 39 fish families and 97 species was sampled (Table 2). The families with the highest richness accounted for 41.24% of the species caught, being Sciaenidae, with 18 species, followed by Carangidae and Engraulidae (8 species each) and Paralichthyidae (6 species). The family Sciaenidae was also responsible for the highest number of individuals (37.2% total), followed by Carangidae (18.8%), Pristigasteridae (14.1%) and Haemulidae (12.9%). These families represented 38,798 individuals captured, comprising 85.7% of the

Table 1. Sumary of (PERMANOVA) results for the analysis of differences on temperature, salinity and transparency in the north and south areas during the wet and dry seasons, in the inner continental shelf adjacent to the Paranaguá Estuarine Complex (df = degrees of freedom, p >0.05 not significant).

	Temperature		
Source	**df**	**Pseudo-F**	**P(perm)**
Season	1	26.93	0.0001
Area	1	0.08	0.8712
Season x Area	1	0.06	0.9804
Residual	88		
	Salinity		
Source	**df**	**Pseudo-F**	**P(perm)**
Season	1	11.52	0.0001
Area	1	7.18	0.0096
Season x Area	1	0.15	0.9297
Residual	88		
	Transparency		
Source	**df**	**Pseudo-F**	**P(perm)**
Season	1	4.76	0.0038
Area	1	11.52	0.0007
Season x Area	1	5.74	0.0013
Residual	88		

catches. Species with the greatest abundance were *C. chrysurus* (17.2%), *H. corvinaeformis* (12.5%), *C. bleekerianus* (9.5%), *C. gracilicirrhus* (8.7%), *P. brasiliensis* (7.3%) and *M. americanus* (6.3%), which represented a total of 28,314 individuals (62.5%) (Table 2).

In economic terms, the great majority of the species is used for human consumption, animal food and as ornamental fish (Table 2). Of the 97 species sampled in this study, 84 appear on the Red List of the International Union for Conservation of Nature (IUCN, 2018). Of these, one species is classified as data deficient (*N. brasiliensis*), 75 as least concern, one near threatened (*P. percellens*), four vulnerable (*G. altavela*, *P. saltatrix*, *Z. brevirostris* and *H. erectus*) and one critically endangered (*S. lewini*) (Table 2).

Through PERMANOVA, no statistically significant differences (p <0.05) were detected in mean number of individuals, mean biomass and mean number of species between the seasons, between the North and South areas, and in the interaction between them (Table 3).

PERMANOVA identified significant differences for the fish assemblage structure between the wet and dry seasons, areas and interaction between these factors, except for the early dry season (Tables 4 and 5). The canonical analysis of principal coordinates (CAP) showed the differences in the fish fauna identified by PERMANOVA (Figure 3, canonical correlation of the axis δ_1= 0.9245 and δ_2= 0.852). Along the first axis, there was a clear separation between seasons, and along axis 2, between the areas in the late wet, early wet and late dry seasons. The higher number of individuals of *C. spixii*, *C. arenaceus*, *C. chrysurus* in the north area during the late wet season, *H. corvinaeformis* and *T. microphtalmus* in the south area during the early dry season and *P. brasiliensis*, *T. lepturus* and *U. brasiliensis* in the south area during the late dry season, were partially responsible for such differences (Figure 3).

The result of the AvTD, D + showed that both the southern and northern area samples were outside the 95% confidence interval. The South area presented 11 samples outside this range, being seven samples from the dry season and four from the wet season. The northern area showed seven samples, four samples in the dry season and three samples in the wet season. Thus, totaling 11 samples in the dry season and seven samples in the wet season (Figure 4).

Results of VarTD, Λ + presented three samples outside the confidence interval, one from the South area and two from the North area; both in the dry season (Figure 4). This analysis evidenced the capture of a greater number of species in the dry season, with occurrence of more than 20 species in 22 samples, while in the wet season, 15 samples presented more than 20 species. In the ellipse, there was no sample outside the 95% confidence interval (Figure 4).

The k-dominance plot shows the North and South lines close to each other and intersecting, indicating the absence of species dominance of one area over other, which points to similarity in species diversity in both areas (Figure 5). The ABC comparison curves show the biomass and abundance lines very close to each other and sometimes crossing, indicating a moderate impact for both North and South areas; a result confirmed by W-statistics that presented a value close to 0. The partial dominance analysis showed that even when the dominant species is removed, the trend of moderate impact remains, with the lines close to each other and overlapping (Figure 6).

DISCUSSION

Statistical analyzes did show significant differences in environmental characteristics and in fish fauna, and in both areas disturbances in fish assemblages were observed during the dry and wet season, being more intense in the southern region. Disturbances that would be related to the shrimp fishing present in the two areas sampled in this study.

Variations in environmental factors were more influenced by seasonality than by areas. Although relatively not far from each other, the areas sampled were heterogeneous in terms of temperature, salinity and transparency. In the shallow continental shelf of Paraná State, the environmental characteristics are ruled, mainly, by the rainfall regime and the entry of cold fronts, these in turn control the hydrodynamics in the region. Environmental factors, or abiotic factors, such as temperature, salinity, and transparency, are important in the influence of the permanence or not of individuals at certain places, being these factors governed by hydrodynamics (Jones et al., 2002).

Temperature variations were similar between the North and South areas, following the expected seasonal pattern for the area,

Table 2. Total and relative abundance (%), total and relative biomass (%), minimum and maximum total length (TL), economic importance (Spier et al., 2018) and conservation status by IUCN for species listed in alphabetical order of family in the inner continental shelf adjacent to the Paranaguá Estuarine Complex. food = human consumption, No = without any identified commercial purpose. IUCN status: NE = not evaluated, LC = least concern, NT = near threatened, DD = deficient data, VU = vulnerable, EN = endangered and CR = critically endangered.

Family/Specie	Total Abundance	%	Total Biomass (kg)	%	TL (mm)	Economic Importance	IUCN
Achiridae							
Achirus declivis Chabanaud, 1940	33	0.07	1.51	0.04	82-170	animal food	LC
Achirus lineatus (Linnaeus, 1758)	3	0.006	0.06	0.008	85-113	fishkeeping	LC
Trinectes microphthalmus (Chabanaud, 1928)	605	1.31	6.06	0.8	41-163	animal food	LC
Trinectes paulistanus (Miranda Ribeiro, 1915)	73	0.16	0.13	0.17	68-164	animal food	LC
Ariidae							
Bagre bagre (Linnaeus, 1766)	4	0.008	0.08	0.011	107-190	food	LC
Cathorops spixii (Agassiz, 1829)	369	0.8	22.56	2.99	72-265	food	NE
Genidens barbus (Lacepéde, 1803)	59	0.13	6.38	0.85	170-330	food	NE
Genidens genidens (Cuvier, 1829)	1	0.002	0.15	0.02	252	food	LC
Batrachoididae							
Porichthys porosissimus (Cuvier,1829)	3	0.006	0.09	0.01	86-175	fishkeeping	NE
Carangidae							
Caranx crysos (Mitchill, 1815)	3	0.006	0.29	0.038	185-218	food	LC
Caranx latus Agassiz, 1831	18	0.04	0.74	0.1	125-180	food	LC
Chloroscombrus chrysurus (Linnaeus,1766)	7946	**17.23**	78.21	10.37	63-147	food	LC
Oligoplites palometa (Cuvier, 1832)	2	0.004	0.09	0.01	110-220	food	LC
Oligoplites saliens (Bloch, 1793)	41	0.09	1.07	014	113-185	fiskeeping	LC
Selene setapinnis (Mitchill, 1815)	462	1	5.10	0.68	31-142	food	LC
Selene vomer (Linnaeus, 1758)	35	0.08	0.25	0.03	44-111	fishkeeping	LC
Seriola dumerili (Risso, 1810)	1	0.002	0.16		230	food	LC
Clupeidae							
Harengula clupeola (Cuvier, 1829)	332	0.72	4.12	0.55	85-166	animal food	LC
Sardinella brasiliensis (Steindachner, 1879)	764	1.66	11.24	1.49	45-235	food	NE
Cynoglossidae							
Symphurus tesselatus (Quoy & Gaimard,1824)	74	0.16	2.32	0.3	89-211	animal food	LC
Dactylopteridae							
Dactylopterus volitans (Linnaeus, 1758)	20	0.04	0.13	0.017	76-123	fishkeeping	LC
Diodontidae							
Chilomycterus spinosus (Linnaeus, 1758)	37	0.08	15.134	2.01	80-326	fishkeeping	LC
Engraulidae							
Anchoa lyolepis (Fowler, 1915)	772	1.68	4.20	0.65	70-183	food	LC
Anchoa spinifer (Valenciennes, 1848)	19	0.04	0.33	0.04	10-163	food	LC
Anchoa tricolor (Spix & Agassiz, 1829)	41	0.09	0.28	0.037	63-120	food	NE
Anchovia clupeoides (Swainson, 1839)	2	0.004	0.03	0.004	122-134	No	LC
Anchoviella lepidentostole (Fowler, 1911)	3	0.006	0.02	0.003	82-109	food	LC
Cetengraulis edentulus (Cuvier, 1829)	375	0.81	7.73	1.02	114-153	animal food	LC

Table 2. Continued...

Family/Specie	Total Abundance	%	Total Biomass (kg)	%	TL (mm)	Economic Importance	IUCN
Engraulidae							
Engraulis anchoita Hubbs & Marini, 1935	4	0.008	0.005	0.006	64-70	food	NE
Lycengraulis grossidens (Spix & Agassiz, 1829)	27	0.06	0.59	0.08	109-200	food	LC
Epinephelidae							
Hyporthodus nigritus (Holbrook, 1855)	2	0.004	0.36	0.048	208-230	food	NT
Mycteroperca acutirostris (Valenciennes, 1828)	1	0.002	0.05	0.007	155	food	LC
Rypticus randalli Courtenay, 1967	26	0.06	0.58	0.08	97-173	No	LC
Ephippidae							
Chaetodipterus faber (Broussonet,1782)	22	0.05	0.46	0.06	50-136	fishkeeping/ food	LC
Gerreidae							
Diapterus rhombeus (Cuvier, 1829)	18	0.04	0.68	0.09	120-181	food	LC
Eucinostomus argenteus Baird & Girard, 1855	509	1.1	6.75	0.89	59-144	food	LC
Eucinostomus gula (Quoy & Gaimard, 1824)	9	0.02	0.28	0.038	109-143	food	LC
Eucinostomus sp.	2	0.004	0.02	0.003	87-97		
Gobiidae							
Microgobius meeki Evermann & Marsh, 1899	1	0.002	0.02	0.003	97	No	LC
Gymnuridae							
Gymnura altavela (Linnaeus, 1758)	1	0.002	10.50	1.39	683	food	VU
Haemulidae							
Conodon nobilis (Linnaeus, 1758)	75	0.16	0.68	0.009	62-131	fishkeeping	LC
Orthopristis ruber (Cuvier, 1830)	15	0.03	0.76	0.1	63-269	fishkeeping	LC
Pomadasys corvinaeformis (Steindachner, 1868)	5750	12.49	68.59	9.09	30-185	fishkeeping	LC
Monacanthidae							
Stephanolepis hispidus (Linnaeus, 1766)	22	0.05	0.30	0.04	46-224	fishkeeping	LC
Mullidae							
Mullus argentinae Hubbs & Marini, 1933	1176	2.55	7.50	0.99	51-144	fishkeeping	NE
Muraenidae							
Gymnothorax ocellatus Agassiz in Spix and Agassiz, 1831	2	0.004	0.18	0.02	365-445	fishkeeping	LC
Narcinidae							
Narcine brasiliensis (Olfers, 1831)	23	0.05	3.44	0.46	86-381	No	DD
Ogcocephalidae							
Ogcocephalus vespertilio (Linnaeus,1758)	1	0.002	0.08	0.01	160	fishkeeping	NE
Ophichthidae							
Ophichthus gomesii (Castelnau, 1855)	2	0.004	0.18	0.02	484-529	No	LC
Paralichthyidae							
Citharichthys arenaceus Evermann & Marsh, 1900	142	0.31	2.83	0.37	48-180	animal food	LC
Citharichthys macrops Dresel,1885	230	0.5	1.33	0.18	46-199	animal food	LC

Table 2. Continued...

Family/Specie	Total Abundance	%	Total Biomass (kg)	%	TL (mm)	Economic Importance	IUCN
Paralichthyidae							
Citharichthys spilopterus Günter, 1862	1	0.002	0.02	0.003	147	animal food	LC
Etropus crossotus Jordan & Gilbert, 1882	509	1.1	5.50	0.73	43-166	animal food	LC
Paralichthys patagonicus Jordan, 1889	7	0.01	0.08	0.01	90-144	food	NE
Syacium papillosum (Linnaeus, 1758)	16	0.03	1.48	0.19	112-258	animal food	LC
Phycidae							
Urophycis brasiliensis (Kaup, 1858)	515	1.12	5.73	0.76	53-196	food	LC
Pleuronectidae							
Oncopterus darwinii Steindachner,1874	2	0.004	0.05	0.007	100-154	animal food	NE
Pomatomidae							
Pomatomus saltatrix (Linnaeus,1766)	27	0.06	1.09	0.14	85-290	food	VU
Pristigasteridae							
Chirocentrodon bleekerianus (Poey, 1867)	4357	9.47	21.07	2.79	51-134	animal food	LC
Pellona harroweri (Fowler, 1917)	2026	4.4	10.66	1.41	40-161	animal food	LC
Rhinobatidae							
Pseudobatos percellens (Walbaum, 1792)	25	0.05	21.79	2.89	135-906	food	NT
Zapteryx brevirostris (Muller & Henle, 1841)	106	0.23	78.91	10.46	410-527	food	VU
Sciaenidae							
Bairdiella ronchus (Cuvier, 1830)	11	0.02	0.04	0.005	54-92	animal food	LC
Ctenosciaena gracilicirrhus (Metzelaar, 1919)	3999	8.69	34.50	4.57	41-160	animal food	LC
Cynoscion acoupa (Lacepède, 1801)	14	0.03	0.05	0.006	50-117	food	LC
Cynoscion jamaicensis (Vaillant & Bocourt, 1883)	325	0.71	6.47	0.86	55-200	food	LC
Cynoscion leiarchus (Cuvier, 1830)	42	0.09	2.76	0.36	60-282	food	LC
Cynoscion microlepidotus (Cuvier, 1830)	364	0.79	2.82	0.37	36-179	food	LC
Cynoscion sp.	64	0.14	0.16	0.02	30-113		
Cynoscion virescens (Cuvier, 1830)	6	0.01	0.60	0.08	73-310	food	LC
Isopisthus parvipinnis Cuvier, 1830	2157	4.69	39.30	5.21	26-203	food	LC
Larimus breviceps Cuvier, 1830	1383	3	15.80	2.09	45-185	food	LC
Macrodon ancylodon (Bloch & Schneider, 1801)	25	0.05	0.76	0.1	100-184	food	LC
Menticirrhus americanos (Linnaeus, 1758)	2897	6.29	84.18	11.16	47-315	fishkeeping/ food	LC
Menticirrhus littoralis (Holbrook, 1847)	15	0.03	0.58	0.08	86-223	food	LC
Micropogonias furnieri (Desmarest, 1823)	163	0.35	3.37	0.45	60-233	food	LC
Nebris microps (Cuvier. 1830)	4	0.009	0.08	0.01	75-155	food	LC
Paralonchurus brasiliensis (Steindachner, 1875)	3365	7.31	89.95	11.92	59-237	fishkeeping	LC
Pogonias cromis (Linnaeus, 1766)	1	0.002	2.67	0.35	620	food	LC
Stellifer brasiliensis (Schultz, 1945)	764	1.66	11.24	1.49	45-235	food	NE
Stellifer rastrifer (Jordan, 1889)	1225	2.66	9.53	1.26	41-180	animal food	LC

Table 2. Continued...

Family/Specie	Total Abundance	%	Total Biomass (kg)	%	TL (mm)	Economic Importance	IUCN
Scorpaenidae							
Scorpaena isthmensis Meek & Hildebrand, 1928	4	0.009	0.006	0.007	64-106	fishkeeping	LC
Serranidae							
Diplectrum radiale (Quoy & Gaimard, 1824)	102	0.22	6.55	0.87	57-203	fishkeeping	LC
Diplectrum formosum (Linnaeus, 1766)	6	0.01	0.09	0.013	82-145	fishkeeping	LC
Dules auriga Cuvier, 1829	2	0.004	0.11	0.015	140-150	fishkeeping	LC
Sphyraenidae							
Sphyraena guachancho Cuvier, 1829	144	0.31	5.89	0.79	140-272	food	LC
Sphyraena tome Fowler, 1903	2	0.004	0.09	0.01	122-253	food	NE
Sphyrnidae							
Sphyrna lewini (Griffith & Smith, 1834)	1	0.002	0.46	0.06	474	food	CR
Stromateidae							
Peprilus paru (Linnaeus, 1758)	329	0.71	2.47	0.33	31-155	fishkeeping	LC
Syngnathidae							
Hippocampus erectus Perry, 1810	1	0.002	0.002	0.002	80	fishkeeping	VU
Synodontidae							
Synodus foetens (Linnaeus, 1766)	6	0.01	0.13	0.018	71-192	fishkeeping	LC
Tetraodontidade							
Lagocephalus laevigatus (Linnaeus, 1766)	56	0.12	1.48	0.2	49-187	fishkeeping	LC
Sphoeroides greeleyi Gilbert, 1900	18	0.04	0.09	0.01	34-112	fishkeeping	LC
Sphoeroides spengleri (Bloch, 1785)	2	0.004	0.00 7	0.009	55	fishkeeping	LC
Sphoeroides testudineus (Linnaeus, 1758)	1	0.002	0.12	0.02	180	fishkeeping/ food	LC
Trichiuridae							
Trichiurus lepturus Linnaeus, 1758	372	0.81	7.29	0.97	173-1070	food	LC
Triglidae							
Prionotus nudigula Ginsburg, 1950	120	0.26	0.45	0.06	30-140	fishkeeping	NE
Prionotus punctatus (Bloch, 1793)	288	0.63	1.99	0.26	41-181	food	LC
Uranoscopidae							
Astroscopus y-graecum (Cuvier, 1829)	1	0.002	0.02	0.001	119	food	LC

showing no differences that could influence the distribution of the species between the areas. Variations in salinity also appear to have not influenced the preference of individuals for the areas, also with similar variation between seasons in the North and South areas. Among the variables, transparency presented greater heterogeneity in the monthly mean values, with larger variations in the dry season between the two areas, and lower values in the Northern area; the lowest values can be related to the presence of barrier coast that facilitate the resuspension of sediments towards the interior of the Paranaguá Bay in periods of high frequency of cold fronts, in addition to the continental water inflow that contains high concentrations of suspended matter (Veiga et al., 2004).

Studies developed on the continental shelf of the Paraná State indicate that fish community structure is characterized by the presence of key species, with remarkable dominance in number and weight of species of the family Sciaenidae (Cattani et al., 2011; Santos et al., 2016). Key species are those that make up the community base and, when absent, result in a substantially different community (Mahon and Smith, 1989). The concept of key species can be applied in this study, where 37.2% of the total catch of individuals was from the family Sciaenidae; the high

Table 3. Summary of PERMANOVA results for the analysis of differences on fish abundance, biomass and number of species in the north and south areas during the rainy and dry seasons, in the inner continental shelf adjacent to the Paranaguá Estuarine Complex (df = degrees of freedom, *p* >0.05 not significant).

Abundance			
Source	**df**	**Pseudo-F**	**P(perm)**
Season	1	12.29	0.0702
Area	1	5.20	0.3337
Season x Area	1	6.04	0.0786
Residual	88		
Biomass			
Source	**df**	**Pseudo-F**	**P(perm)**
Season	1	10.87	0.0721
Area	1	6.662	0.3318
Season x Area	1	4.96	0.0834
Residual	88		
Number of species			
Source	**df**	**Pseudo-F**	**P(perm)**
Season	1	20.46	0.0781
Area	1	0.625	0.6652
Season x Area	1	7.43	0.1104
Residual	88		

Table 4. Summary of PERMANOVA results for the analysis of differences on fish assemblages in the north and south areas during the wet and dry seasons, in the inner continental shelf adjacent to the Paranaguá Estuarine Complex (df = degrees of freedom, *p* >0.05 not significant).

Source	df	Pseudo-F	P(perm)
Season	3	8.15	**0.0001**
Area	1	3.49	**0.0004**
Season x Area	3	2.74	**0.0001**
Residual	88		

Table 5. Summary of pairwise PERMANOVA results for the analysis of differences on fish assemblages in the north and south areas during the wet and dry seasons, in the inner continental shelf adjacent to the Paranaguá Estuarine Complex (LD = late dry, ED = early dry, LW = late wet, EW = early wet, N = north, S = south, t = values of the Student`s t-test and *p* >0.05 not significant).

Groups	t	P(perm)	Area/Season	t	P(perm)
LD x EW	2.178	**0.0001**	(NxS) LD	1.905	**0.0074**
LD x LW	3.844	**0.0001**	(NxS) ED	1.208	0.1365
LD x ED	2.347	**0.0001**	(NxS) LW	1.747	**0.0177**
EW x LW	3.360	**0.0001**	(NxS) EW	1.998	**0.0011**
EW x ED	2.145	**0.0001**			
LW x ED	3.033	**0.0001**			

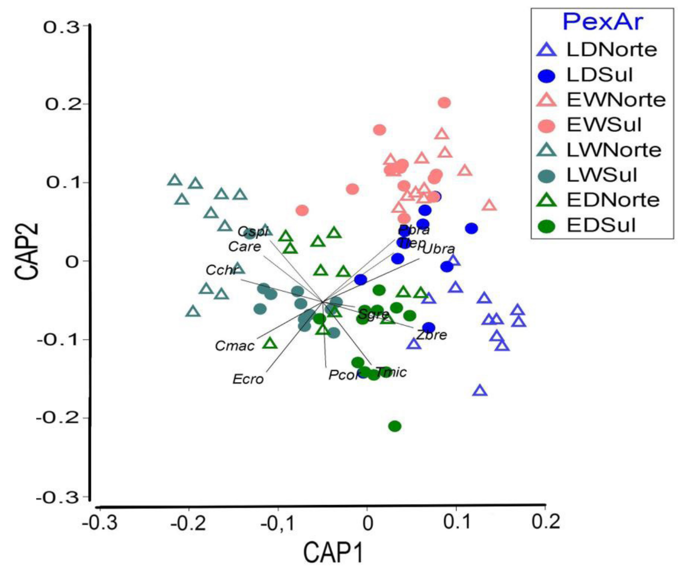

Figure 3. Result of the Canonical analysis of principal coordinates (CAP), with species (*Cspi* = *Cathorops spixii*, Care = *Citharichthys arenaceus*, Cchr = *Chloroscombrus chrysurus*, Pcor = *Pomadasys corvinaeformis*, Tmic = *Trinectes microphthalmus*, Pbra = *Paralonchurus brasiliensis*, Tlep = *Trichiurus lepturus*, Ubra = *Urophycis brasiliensis*) that contributed most to the differences between the seasons and areas (LD = late dry, ED = early dry, LW = late wet, EW = early wet, N = north, S = south). Vector of species based on the Spearman correlation above 0.4. The canonical correlation of the two axes obtained by the analysis was $\delta_1 = 0.9245$ and $\delta_2 = 0.852$.

representativeness of this family seems to be a common pattern in the sand-muddy bottom areas of the brazilian coast (Muto et al., 2000; Moraes et al., 2009; Silva Junior et al., 2013; Nóbrega et al., 2019). This predominance is common in other estuaries of the world and is due to the fact that this transition between marine/euryhaline environments occurred several times throughout the evolutionary history of the family. This reflects the ease of the family species in adapting to salinity changes, which allowed its permanence in regions of estuarine influence (Lo et al., 2015).

Taxonomic Distinctness Analysis shows that both areas disturbances were observed in the fish communities both in the dry and in the rainy season, being more intense in the South area. According to Clarke and Warwick (2001), the samples outside the 95% interval indicate disturbance in community composition. The results of the ABC method, for the North and South areas, showed a moderate degree of impact where abundance and biomass are relatively similar. Nevertheless, a difference can be noticed at the top of the graph: for the South area, the abundance curve shows a greater distance from the biomass curve when compared to the North area, this difference may indicate a greater imbalance in the South area.

The impacts of the fishing activity are classified into physical and biological. The main consequences of the physical impacts fall on the benthic habitat, with immediate effect on the topography

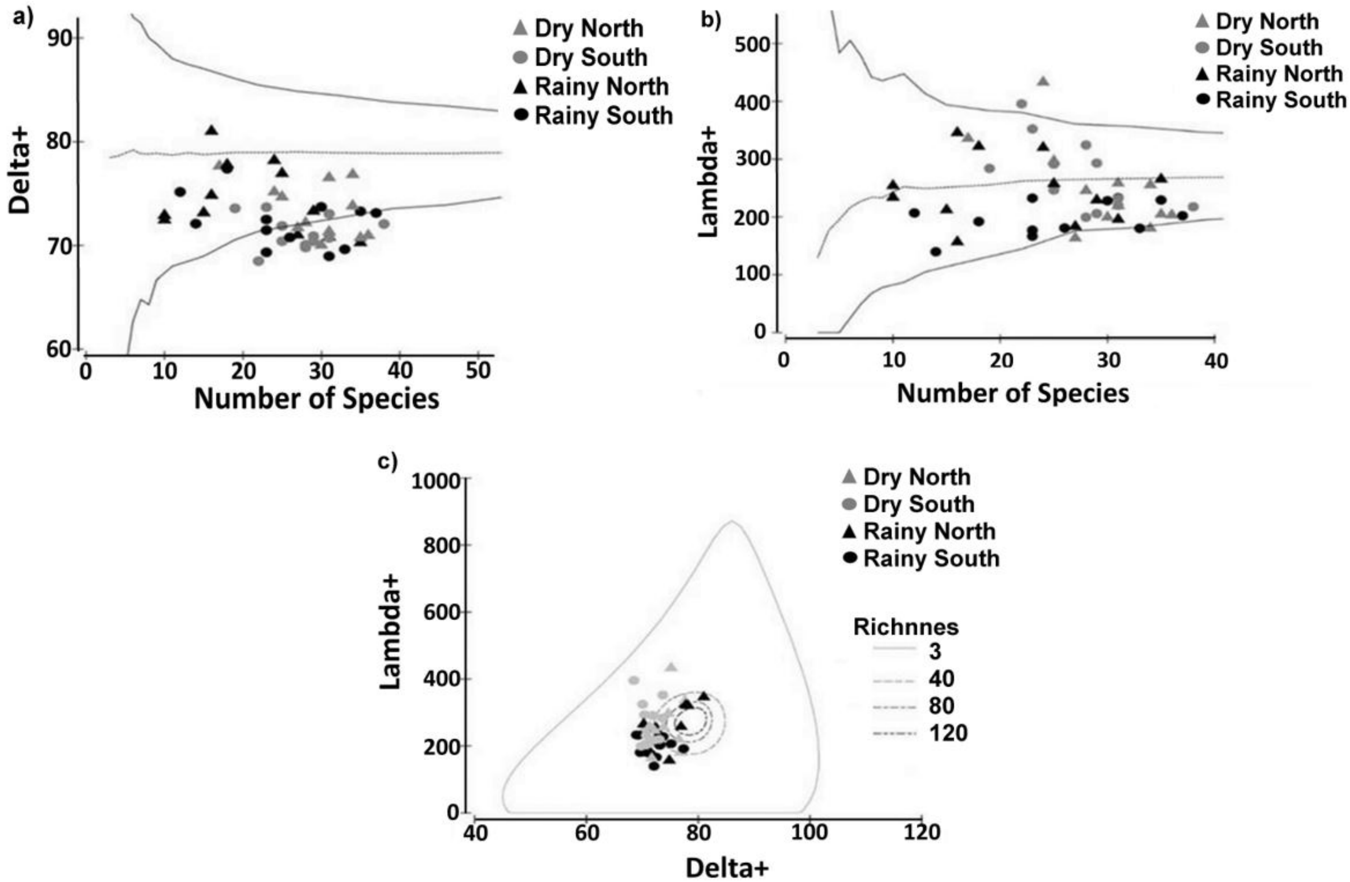

Figure 4. (a) Average taxonomic distinctness (AvTD, Delta+); (b) variation in taxonomic distinctness (VARTD, Lambda+) calculated for the northern and southern areas and the dry and wet seasons; (c) for both indices, the expected average is represented by the center line and the 90% confidence interval by the funnel-shaped line. The ellipse represents the value of 95% of the confidence interval of the probability of finding between 3 and 120 species.

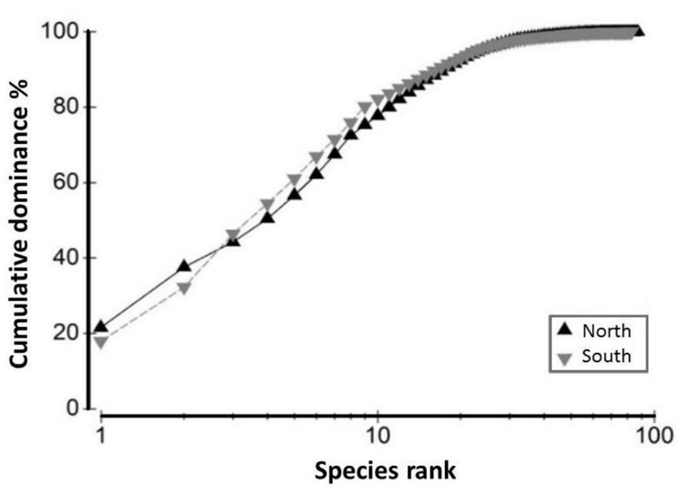

Figure 5. Cumulative K-dominance curves for the north and south areas during the wet and dry seasons, in the inner continental shelf adjacent to the Paranaguá Estuarine Complex.

of the sedimentary surface. According to Lokkeborg (2005), the average recovery time of these habitats was calculated at one year. Areas under intense trawling activity tend to change the surface roughness and decrease the hardness of the substrate (Schwinghamer et al., 1998; Lokkeborg, 2005). One of the biological effects of trawling also falls directly on the benthic fauna, with a reduction in total biomass (Lokkeborg, 2005) and the decrease in diversity and abundance of these species (Kenchington et al., 2001) being the most observed effects. Another known effect is the result of bycatch activities. Trawling generates the capture and disposal of thousands of immature individuals that have not yet reached their reproductive stage or ideal size for economic exploitation (Suuronen, 2005).

Penaeid fishing may be one of the major contributors to this expected biomass reduction in relation to abundance due to the large amount of fish bycatch resulting from this activity (Vianna et al., 2004; Branco and Verani, 2006; Gomes and Chaves, 2006; Cattani et al., 2011; Santos et al., 2016). In this study, the overlap of the biomass curve on the abundance may be related to a possible plastic trajectory: according to Stearns and Crandall

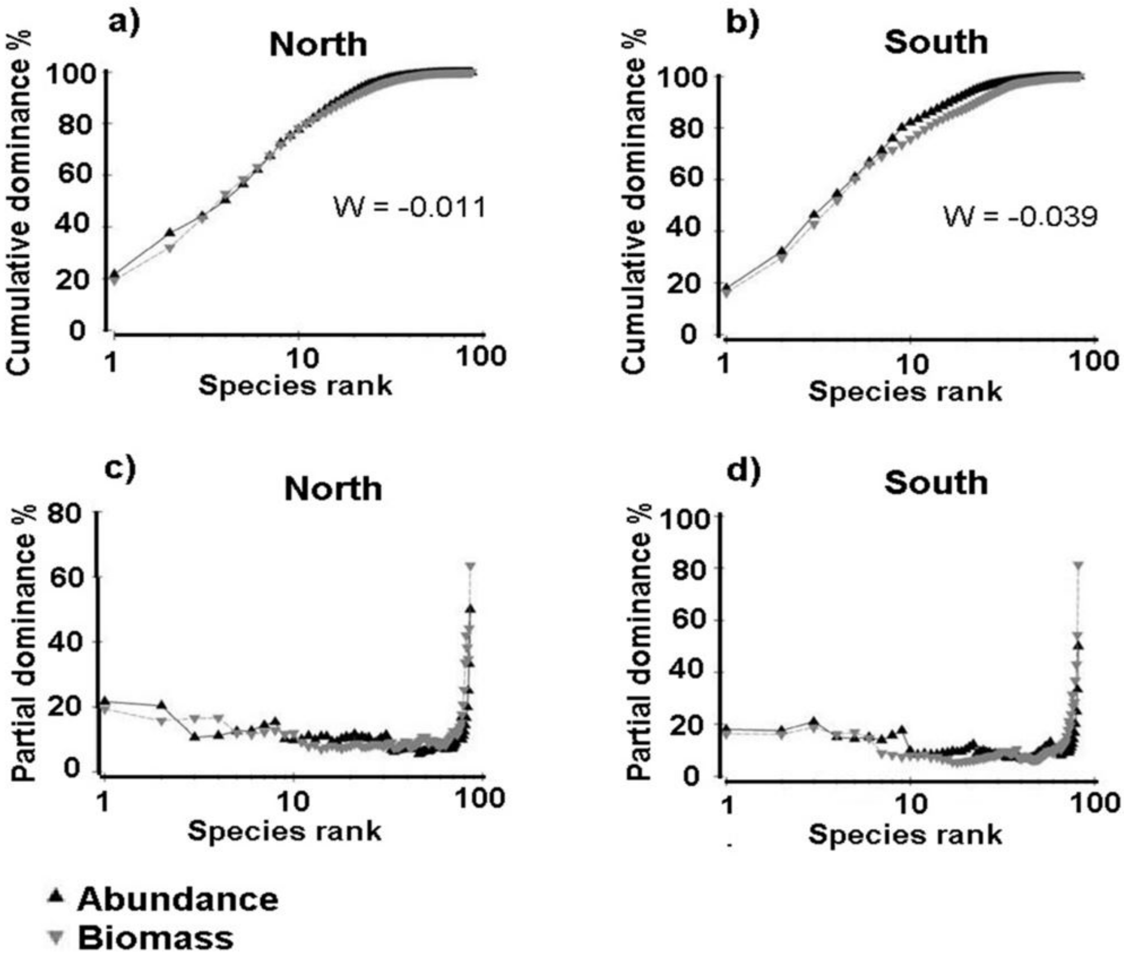

Figure 6. Abundance and biomass curves of the north (a) and south (b) areas, and partial dominance curves of the north (c) and south (d) areas, in the inner continental shelf adjacent to the Paranaguá Estuarine Complex.

(1984), with increasing stress to which the species is subjected to, the size at first maturity of the individuals changes, causing maturation of these individuals at smaller sizes to compensate for the impact effects; such changes, over time, are incorporated and evolve in each population, reflecting an adaptive component as response. This reduction in the average length at first maturity, when compared to other studies on the Brazilian coast, was observed in *M. americanus*, *P. brasiliensis*, *S. brasiliensis* and *S. rastrifer*, species collected in the present study (Santos, 2006).

The indication of disturbance in the North and South areas may be related to penaeid fishing, where immature fish, which have not reached their reproductive stage, are incidentally caught and returned to sea. The high discard rate in the fisheries worldwide affects the sustainability and the biodiversity of the marine environment; reducing this impact becomes one of the main objectives for fishing management. Large-scale environmental changes, as well as recurrent anthropogenic actions, are likely to lead to changes in the fish community in the region. In view of this, it is necessary to include historical data about fishing and its products for a better analysis of disturbances and changes in the structure and composition of the fish community on the shallow shelf of the Paraná State.

Several studies have been conducted to interpret and evaluate ecological and environmental changes in oceanic and estuarine areas using the fish community to guide local management (Whitfield and Elliott, 2002; Harrison and Whitfield, 2004), mainly in relation to fishing activities (Andriguetto Filho, 1999). In the coast of Paraná State, these studies have been mostly made in different sectors of estuarine regions. This study is the first approach that describes the possible impact on fish assemblage by trawling in the inner continental shelf of the State of Paraná. What was perceived by local fishermen themselves that fishing practices damage stocks (Andriguetto Filho, 1999).

CONCLUSION

Despite the proximity of the two sampled areas, significant differences were identified in the environmental characteristics and in the ichthyofauna. There was also the absence of dominant species from one area in relation to another and the indication of moderate disturbance in both areas, being greater in the south area. The disturbance would be related to shrimp fishing that occurs in the region.

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