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Research Article

Comparison of the temporal and taxonomic patterns of ichthyofauna captured with a fyke net in two sheltered environments in southern Brazil

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ABSTRACT. We use two taxonomic indexes to assess the variability of the taxonomic structure and diversity of the ichthyofauna of two low-energy environments in southern Brazil and to compare the temporal patterns of these two ichthyofaunas. Sampling was conducted in the infralittoral zones of Maciel (Paranaguá Bay, PR) and Indio Beach (Norte Bay of Florianópolis, SC). A fyke net was set up at a depth of 0.5 to 2.0 m and left in place for 48 h for each of the samplings. A total of two diurnal and two nocturnal samplings were conducted monthly per one year. The ichthyofaunas at the two sites exhibited similar temporal dynamics, with their abundance and biomass presenting a tendency to increase with increasing temperature during the spring and summer months. A total of 113 species were captured, of which 47 were present at both sites. *Harengula clupeola*, *Sphoeroides testudineus* and *S. greeleyi* were especially abundant at both sites. The co-occurring species displayed similar day and night occupancy trends. In all seasons, the obtained values for the average taxonomic distinctness and variation in taxonomic distinctness were within the confidence intervals. The seasonal reproduction and recruitment patterns led to slight changes in taxonomic distinctness during the year, which were within the expected intervals.

Keywords: ichthyofauna, taxonomic distinctness, nycthemeral dynamics, sheltered beach, southern Brazil.

Comparación de los patrones taxonómicos y temporales de la ictiofauna capturada con red fyke en dos ambientes protegidos en el sur de Brasil

RESUMEN. Se utilizaron dos índices taxonómicos para evaluar la variabilidad de la estructura taxonómica y diversidad de la ictiofauna en dos ambientes de baja energía en el sur de Brasil, así como para comparar sus patrones temporales. Los muestreos se realizaron en las zonas infralitoral de Maciel (Bahía de Paranaguá, PR) e Indio Beach (Bahía Norte, SC). Se instaló una "fyke net" a una profundidad de 0,5 a 2 m, durante 48 h, para cada uno de los muestreos. Durante un año se realizó un total de dos muestreos diurnos y dos nocturnos. La ictiofauna en los dos sitios mostró dinámicas temporales similares, con su abundancia y biomasa presentando una tendencia a aumentar con el incremento de la temperatura durante los meses de primavera y verano. Un total de 113 especies fueron capturadas, de los cuales 47 estuvieron presentes en ambos sitios. *Harengula clupeola*, *Sphoeroides testudineus* y *S. greeleyi* fueron especialmente abundantes en ambos sitios. Las especies coexistentes mostraron tendencias similares de ocupación tanto de día como de noche. En todas las estaciones, los valores obtenidos para la distinción taxonómica media y para la variación en la distinción taxonómica estuvieron dentro de los intervalos de confianza. Los patrones de reproducción y reclutamiento estacionales llevaron a ligeros cambios en la distinción taxonómica durante el año, que estuvieron dentro de los intervalos esperados.

Palabras clave: ictiofauna, distinción taxonómica, dinámica nictimeral, playa protegida, sur de Brasil.

INTRODUCTION

Ecological approaches that are sensitive to temporal and spatial changes in biodiversity are indispensable for the monitoring of ecosystems (Clarke & Warwick, 1999). The ecological integrity of coastal environments remains vulnerable at present as these areas suffer from intensive human occupation and over-exploitation of

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fishing resources (Coccosis, 1985; Hoefel, 1998; FAO, 2012). The use of tools that allow ongoing ecological changes to be interpreted is essential because the consequences of anthropogenic environmental impacts on ichthyofauna are still poorly understood.

Research in this area of study should represent the diversity, composition and taxonomic structure of a given area with the greatest possible accuracy. In shallow environments, the use of relatively small trawls and low sampling speeds is common (Pessanha *et al*., 2003; Gaelzer & Zalmon, 2008; Félix-Hackdart *et al*., 2010; Vasconcellos *et al*., 2010). However, this equipment is apparently not very effective in capturing individuals that respond rapidly to the net's visual and mechanical stimuli (Glass & Wardle, 1989; Methven *et al*., 2001; Gell & Whittington, 2002), generally resulting in an underestimation of the richness of the local ichthyofauna which can have greater or lesser importance for future handling and management decisions. Performing nocturnal sampling is also essential for the correct evaluation of fish diversity as such a sampling pattern increases the chances of capturing species that are rarely sampled during the day, resulting in a better representation of the true community structure (Rountree & Able, 1993; Morrison *et al*., 2002).

Studies examining the natural variations in fish assemblages suggest that the daily movements of the ichthyofauna primarily follow their physiological and ecological needs, such as foraging, protection against predators and decreasing interspecific competition for food and space (Thijssen *et al*., 1974; Piet & Guruge, 1997; Suda *et al*., 2002; Pessanha *et al*., 2003; Gaelzer & Zalmon, 2008). The daily movements of the ichthyofauna within an assemblage have been described for several environments (Wright, 1989; Piet & Guruge, 1997; Rooker & Dennis, 1991; Nagelkerken *et al*., 2000; Pessanha *et al*., 2003; Galzer & Zalmon, 2008; Félix-Hackradt *et al*., 2010). These descriptions indicate a pronounced dynamic of the ichthyofauna, with the structure of the community being affected primarily by food availability and the provision of shelter. Regardless of the scale of these studies, the applicability of the formulated hypotheses at a global scale appears uncertain (Unsworth *et al*., 2007) as the structural parameters of fish communities vary both spatially and temporally. Studies at a regional scale are therefore essential to support handling and management decisions.

The use of tools associated with ecological approaches that are sensitive to changes in taxonomic structure, such as phylogenetic and taxonomic diversity indexes addressing the phylogenetic relationships between species (Magurran, 2004), could be adopted in programs of environmental monitoring and coastal management in Brazil. The application of such indexes has been shown to be promising for the evaluation and monitoring of fish diversity (Cheal *et al*., 2008; Campbell *et al*., 2011), and they are seemingly more robust than traditional measurements based on the number of species (Clarke & Warwick, 1999).

In the present study, we tested two taxonomic indexes, the Average Taxonomic Distinctness (AvTD, Δ^+) and the Variation in Taxonomic Distinctness (VarTD, Λ^+), to evaluate the structural and taxonomic variability of the ichthyofauna of two sheltered environments. The use of these indexes is still restricted in the marine environment. To date, they have essentially been employed in environmental impact assessments (Bevilacqua *et al*., 2009), with the assumption that disturbed assemblages are taxonomically poorer than undisturbed assemblages (Warwick & Clarke, 1995). The application of the combination of AvTD and VarTD may enable a robust summary of the patterns of taxonomic relatedness within the assemblage to be obtained (Clarke & Warwick, 2001) based on the uniformity of the taxon distribution within a hierarchical taxonomic tree (Xiujuan *et al*., 2010). VarTD may, for example, identify differences in the taxonomic structure of an assemblage where a few genera are represented by a number of different species, whereas other superior taxa are represented by only one or a few species. In this case, AvTD may not indicate changes, whereas VarTD may increase significantly (Clarke & Warwick, 2001). In contrast, AvTD enables the evaluation of environmental stresses through simulations using an expected interval of AvTD values, calculated by resampling from a list of species that could inhabit the sampling region (Xiujuan *et al*., 2010). However, the viability of these indexes should be tested within each biological context. For example, it should be possible to distinguish the natural seasonal movements of the ichthyofauna related to their recruitment and reproduction patterns (Gibson *et al*., 1993; Pessanha *et al*., 2003; Félix *et al*., 2007; Félix-Hackdart *et al*., 2010) from other fluctuations resulting from stochastic variations or anthropogenic impacts, in addition to how the indexes respond to these changes.

The tendency toward an increase in the numbers of genera and families is naturally accompanied by a matching tendency toward an increase in the number of species, *e.g.*, over a latitudinal gradient (Vieira & Musick, 1994). We expect that the fish assemblage will respond in a similar manner temporally, *i.e.*, that even the displacement of fish species within a given area leads to losses of richness over time, the taxonomic structure will retain an equitable distribution.

In the present study, for the first time, we tested the use of two taxonomic diversity indexes in two shallow sites in southern Brazil and compared the temporal patterns and the primary species inhabiting these two environments, as determined by following a sampling plan that is more robust than those that are usually applied in studies of the region's ichthyofauna.

MATERIALS AND METHODS

Shallow infralittoral environment of Maciel-Paranaguá Bay

The Paranaguá Bay (PR) is part of the Estuarine Complex of Paranaguá, which is the largest such complex on the southern coast of Brazil. It is situated 210 km north of Florianópolis. The annual average rainfall in the area is 2,500 mm, with increased rainfall being observed between October and March (Lana *et al.*, 2001) and no well-defined dry season (Ângulo, 1992). The tidal regime is semidiurnal, presenting a 2.2 m mean tidal range and a 5.4 m average depth (Lana *et al.*, 2001). There are several villages and hamlets in its surroundings as well as the largest city on the Paraná coast, Paranaguá, which has 116,000 inhabitants (Kolm *et al.*, 2002).

The shallow infralittoral zone of Maciel (25°33' 14"S, 48°24'06"W) is located in the euryhaline sector of Paranaguá Bay. The average salinity in this area is 30, and the sediments are essentially well-sorted fine sands with a low organic content due to the high energy of the sector (Lana *et al.*, 2001). However, these conditions may vary at the margins of Paranaguá Bay, where fine sediment can accumulate in the proximity of small subestuaries formed by rivers and tidal creeks. Maciel is located 3 km from the mouth of Paranaguá Bay, which is connected to the sea by a deep channel approximately 2.6 km wide. There is an important meandering tidal creek nearby that is approximately 10.6 km long, in addition to other significant rivers that are more distant and also empty into Paranaguá Bay, *i.e.*, the Guaraguaçu, Nhundiaquara and Itiberê rivers (Siqueira & Kolm, 2005).

Shallow infralittoral environment of Indio Beach-Norte Bay, Florianópolis

The Norte Bay of Florianópolis (SC), consists of a long canal with a 4 km-wide opening towards the Atlantic Ocean on the north end and a narrow canal, 370 m wide, connecting it to the Sul Bay of Florianópolis (Fig. 1). On both the island and the continent, the rivers flow along a short plane of tidal sediments, opening into small estuaries, with a large area of marshes and mangroves (Pagliosa & Barbosa, 2006). Most of the Norte Bay is composed of flat, shallow areas with an average depth of 3.3 m (Bonetti-Filho *et al.*, 1998). The system is dominated by wind-generated waves with limited capacity for reworking coarse sediments, except during high-energy events, which can create reflective beaches associated with mudflats (Silveira *et al.*, 2011). The high proportion of fine sediments (clay and silt) in the Norte Bay suggests a low-energy environment with a predominance of deposition processes. The region is densely populated, and the Norte Bay is surrounded by four municipalities with a total population of 702,249 inhabitants (IBGE, 2010).

Indio Beach (27°28'33.90"S, 48°32'0.75"W) is sheltered from waves (Jackson *et al.*, 2002) and faces northwest. The most important fluvial discharges in the vicinity come from the joint estuaries of the Ratones and Veríssimo rivers, which are located approximately 1.7 km from the collection site (Fig. 1). The tidal regime is semidiurnal, with a 0.52 m mean tidal range (Soriano-Sierra & Sierra De Ledo, 1998). The physical and chemical variations in the Norte Bay respond primarily to continental inputs, and the environment is mostly mesotrophic. The DIN:P (dissolved inorganic nitrogen:phosphate) and Si:DIN (silicate:DIN) ratios indicate that DIN is limiting for primary productivity, which is a situation that is often encountered in marine systems (Simonassi *et al.*, 2010). The area presents a prevalence of high salinities, generally above 30, and a temperature range of 16 to 28°C (Maciel *et al.*, 2010; Simonassi *et al.*, 2010). The Florianópolis region exhibits a humid subtropical climate (Cruz, 1998), with rains that are evenly distributed throughout the year, increasing slightly in the hotter seasons, and with relative rainfalls of 34% in summer, 21% in fall, 19% in winter and 26% in spring (Silva *et al.*, 2004).

Data collection

Monthly collections were performed between July 2006 and June 2007 in the shallow infralittoral zone of Maciel and from December 2010 to November 2011 in the shallow infralittoral zone of Indio Beach, always during the first neap tide of each month. At both sites, sampling was conducted using a fyke net designed to operate at depths between 0.5 and 2.0 m, composed of a fence net (20 m long, 2.0 m high, 13.0 mm mesh size) and three hoop nets with mesh sizes of 13.0 to 6.0 mm. The net was placed at the same locations for all collections, at depths of 0.5 to 2 m, and left in place for 48 h for each sampling. Collections were performed at dawn and nightfall, and a total of two diurnal and two nocturnal samplings were conducted, totaling four monthly samplings per site. The obtained specimens were identified and weighed (g).

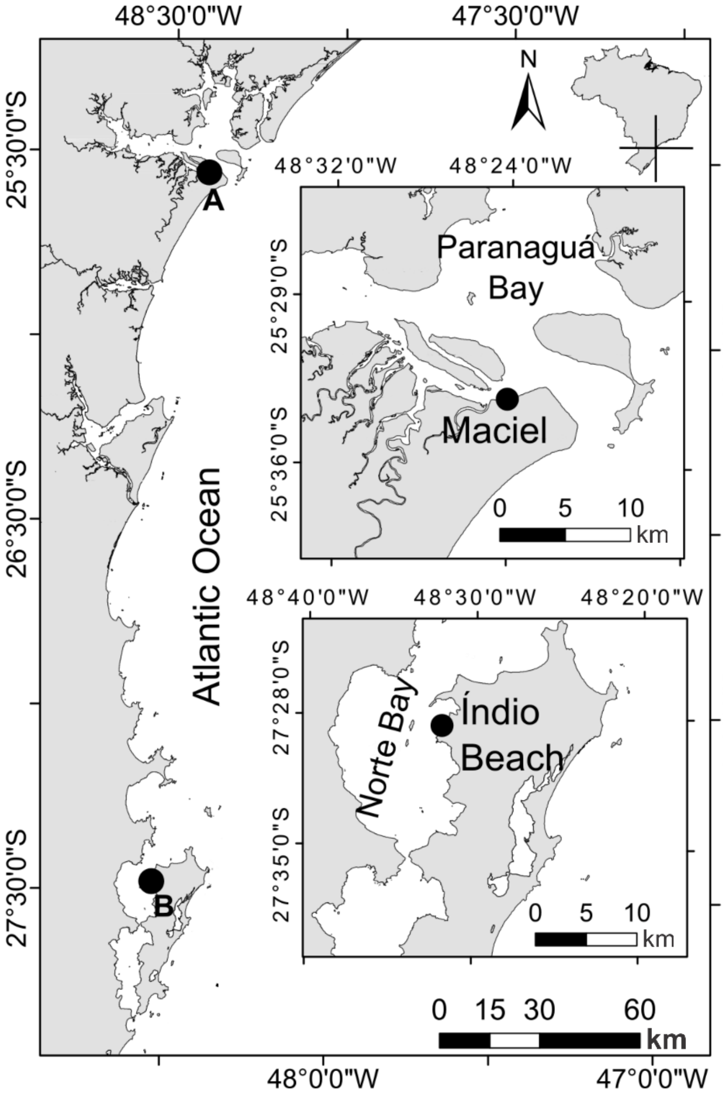

Figure 1. Paranaguá Bay (A), highlighting Maciel (25°33’14”S, 48°24’06”W), and the location of the Norte Bay of Florianópolis (B), highlighting Indio Beach (27°28'33.90"S, 48°32'0.75"W) in southern Brazil.

In situ measurements of the surface water temperature using an *Incotherm* Mercury thermometer (0.1ºC accuracy) and of the salinity using an RTS/101 ATC portable refractometer were performed every 12 h for a total of four monthly measurements of each variable at each site.

Data analysis

Seasons were considered by the months of December, January and February (summer); March, April and May (autumn); June, July and August (winter); and September, October and November (spring).

A bifactorial PERMANOVA (*permutational multivariate analysis of variance*) was applied to test the effects of the factors time and site. PERMANOVA is a univariate or multivariate type of analysis of variance that uses permutation to obtain *P*-values based on similarity measurements. The analysis also returns pseudo-*F* values, which are analogous to the ANOVA *F*-statistic (Anderson *et al*., 2008). In addition, it enables multiple *a posteriori* comparisons to be made between factor levels in the case of significant interactions (Anderson *et al*., 2008). PERMANOVA is similar to ANOSIM (analysis of similarities), but it allows the user to check for the occurrence of space x time interactions (Anderson, 2001).

PERMANOVA was performed using PRIMER v.6.1.12 software (Clarke & Gorley, 2006) with the

Table 1. The abundance, biomass and index of relative importance (IRI%) for each species, time of day and site, in addition to the presence/absence by season and life stage for each species and site (the seasons of the year shown in the table are in accord with the average abundance values, from lowest to highest). Su: summer, A: autumn, W: winter, Sp: spring.

Family	Species	Indio							Maciel						
		Day			Night			Presense	Day			Night			Presense
			Biomass	IRI		Biomass	IRI	Season		Biomass	IRI		Biomass	IRI	Season
		n	(g)	(%)	n	(g)	(%)	N increases→	n	(g)	(%)	n	(g)	(%)	N increases→
Achiridae	*Achirus declivis*											6	174.9	0.017	Su,A,Sp
	Achirus lineatus	2	57.3	0.006	2	24.1	0.003	Su,A,W,Sp				4	93.1	0.007	Su,A
Ariidae	*Cathorops spixii*	58	969.0	0.409	222	3603.4	1.865	A,Sp,Su	2	96.2	0.005	89	4648.4	1.208	Sp,A,W,Su
	Genidens barbus	252	7272.5	7.273	849	31822.3	26.076	W,Sp,A,Su							
	Genidens genidens	92	3756.1	3.098	461	15351.9	13.531	A,W,Sp,Su				33	1975.1	0.339	W,Su,Sp,A
	Genidens machadoi	2	155.0	0.006	10	511.0	0.034	Sp							
Atherinopsidae	*Atherinella brasiliensis*	29	292.0	0.246	29	276.6	0.203		643	4711.3	4.178	452	4010	2.740	A,Su,W,Sp
	Odontesthes argentinensis				2	407.8	0.023	Sp							
Batrachoididae	*Opsanus beta*											2	365.5	0.008	W,Su
	Porichthys porosissimus				1	80.7	0.002	W							
Belonidae	*Strongylura marina*	2	70.7	0.007				A,W	1	49.1	0.001	6	323.8	0.018	Su,A,Sp
	Strongylura timucu								3	62.3	0.004	2	59.4	0.002	W,A,Su
Carangidae	*Chloroscombrus chrysurus*	42	778.0	0.496	31	180.3	0.120	W,A,Sp,Su	2	3	0.001	10	92.4	0.014	Sp,A,Su
	Hemicaranxam amblyrhynchus				1	2.7	0.000	Su							
	Oligoplites palometa	4	82.4	0.005				A							
	Oligoplites saliens	11	186.9	0.034				A,Su	1	4.7	0.000	2	53.2	0.002	Sp,Su,A
	Oligoplites saurus	31	512.4	0.342	5	50.0	0.012	W,A,Sp,Su	10	247.1	0.043				Su,A,Sp
	Selene vomer	64	886.4	1.044	17	285.2	0.106	Sp,A,W,Su	1	9.5	0.000	6	120.1	0.014	A,Su
	Trachinotus carolinus	14	140.0	0.065	3	22.4	0.005	W,A,Su	9	79.8	0.009	3	16.4	0.001	A,Su
	Trachinotus falcatus	3	181.4	0.023			0.000	Su,A	11	89.6	0.024	3	6.7	0.002	Sp,W,A,Su
	Uraspis secunda											1	7.8	0.000	Sp
Centropomidae	*Centropomus parallelus*				5	203.5	0.028	Sp,A,Su	3	111.5	0.009	8	652.9	0.049	W,Sp,Su
	Centropomus undecimalis								5	272.9	0.029	12	1044.1	0.090	A,Sp,Su
Clupeidae	*Harengula clupeola*	1776	6211.9	9.525	5050	7839.6	18.635	W,Sp,A,Su	9081	31241	36.337	3097	26848.5	20.329	W,Sp,A,Su
	Opisthonema oglinum	40	92.7	0.079	34	107.7	0.056	A	638	678.2	0.724	286	936.7	0.376	A,Su
	Platanichthys platana								2	1.6	0.000	2	2.8	0.000	Su
	Sardinella brasiliensis	271	1612.4	1.015	27	270.8	0.081	Su,W,Sp,A	398	1559.8	0.590	479	4089.2	0.782	W,A,Su,Sp
Cynoglossidae	*Symphurus tessellatus*	2	25.8	0.002	3	45.4	0.007	Sp,A							
Dactylopteridae	*Dactylopterus volitans*	9	111.0	0.038	1	19.2	0.001	W,A							
Diodontidae	*Chilomycterus spinosus*	3	410.4	0.048	6	107.9	0.024	W,A,Su	8	11.1	0.005	3	1027.9	0.022	Su,A,W,Sp
Eleotridae	*Guavina guavina*											1	13.4	0.000	Su
Elopidae	*Elops saurus*	1	28.7	0.001				W							
Engraulidae	*Anchoa januaria*	123	483.6	0.339	15	47.4	0.031	A,W,Sp							
	Anchoa marinii	3	69.0	0.004				A							W,A,Su
	Anchoa parva								65	99.7	0.020	247	262.3	0.049	Su
	Anchoa sp.								*4*	*62.2*	0.006	*4*	*563*	0.013	A,Su
	Anchoa spinifer	8	61.9	0.006	4	19.6	0.004	Sp							
	Anchoa tricolor	35	24.8	0.031	4	4.3	0.001	Su,W,Sp,A	242	360	0.074	5	9.9	0.005	A,Su

Continuation

Family	Species	Indio							Maciel						
		Day			Night			Presense	Day			Night			Presense
			Biomass	IRI		Biomass	IRI	Season		Biomass	IRI		Biomass	IRI	Season
		n	(g)	(%)	n	(g)	(%)	N increases→	n	(g)	(%)	n	(g)	(%)	N increases→
	Anchovia clupeoides	2	4.7	0.001	12	45.8	0.005	Sp							
	Anchoviella lepidentostole	3380	4011.6	18.403	2146	5662.8	5.982	Sp,W,Su,A							
	Cetengraulis edentulus	151	2563.5	1.384	641	16721.2	9.893	W,A,Sp,Su	18	108.4	0.024	16	317	0.043	A,Su,Sp
	Engraulis anchoita	31	26.4	0.027	5	3.5	0.003	A	35	42.8	0.015	4	13.7	0.002	Su,Sp
	Lycengraulis grossidens	31	436.4	0.284				A,Sp,W				3	98.9	0.003	W
Ephippidae	*Chaetodipterus faber*	7	127.1	0.045	13	260.1	0.090	Sp,W,A,Su	5	231.1	0.012	12	490.2	0.043	Su,Sp,A
Fistulariidae	*Fistularia petimba*								1	0.8	0.000	0	0	0.000	Su
Gerreidae	*Diapterus auratus*	3	121.0	0.017	3	129.8	0.013	W,A,Su	20	1028.6	0.110	73	4195	0.728	W,Sp,Su,A
	Diapterus rhombeus	16	1026.9	0.346	6	313.0	0.062	W,A,Sp,Su	239	7775.4	3.273	696	20633.4	8.113	W,Su,A,Sp
	Eucinostomus argenteus	9	167.6	0.058	6	131.0	0.011	W,Sp,A,Su	319	4041.7	3.127	446	8929.4	3.637	A,Su,W,Sp
	Eucinostomus gula	17	284.2	0.137	4	108.2	0.013	A,Sp,W,Su	24	559.9	0.148	78	1965.4	0.412	Su,A,Sp
	Eucinostomus melanopterus	46	1304.0	1.114	21	728.2	0.291	W,A,Sp,Su	66	2415.1	0.601	40	1334.7	0.188	W,A,Su
Gobiidae	*Bathygobius soporator*								9	63.1	0.013	2	65.5	0.002	W,Sp,Su
	Gobionellus oceanicus	1	20.4	0.001				W							
Haemulidae	*Anisotremus surinamensis*				2	69.57	0.005	Su							
	Orthopristis ruber	10	670.3	0.225	28	2299.67	0.710	A,W,Sp,Su				33	1595.2	0.178	A,Su,W,Sp
	Pomadasys corvinaeformis	6	71.4	0.015	8	169.90	0.036	A,Sp,W	382	6506.9	1.018	5332	95075.4	42.954	Su,A,W,Sp
Hemiramphidae	*Hemiramphus brasiliensis*								1	6.5	0.000	5	94.1	0.006	
	Hyporhamphus unifasciatus	3	97.4	0.014	6	234.11	0.033	A,W,Su							
Lobotidae	*Lobotes surinamensis*											6	23.4	0.004	Su,A
Lutjanidae	*Lutjanus analis*	2	296.6	0.023	1	173.33	0.005	Su							
Monacanthidae	*Stephanolepis hispidus*	1	4.2	0.001	2	14.27	0.002	Su	1	0.2	0.000				Sp
Mugilidae	*Mugil curema*	605	9989.7	6.060	53	3564.25	1.585	Sp,Su,W,A				6	240.2	0.018	W,Sp,Su,A
	Mugil liza	2	232.2	0.018	1	31.73	0.001	W,Sp							
	Mugil sp.	47	11.6	0.079				Sp,W,Su	15	15.1	0.004	14	244.5	0.041	Sp,A,W,Su
Muraenidae	*Gymnothorax ocellatus*	1	122.3	0.005	1	141.46	0.004	Su							
Ophichthidae	*Ophichthus gomesii*				7	532.28	0.083	Sp,A,Su				5	202.9	0.006	Sp
Paralichthyidae	*Citharichthys arenaceus*								10	178.6	0.022	5	60.5	0.003	W,Sp,A,Su
	Citharichthys macrops	40	542.3	0.358	11	176.90	0.050	W,A,Sp							
	Citharichthys spilopterus	78	1654.4	1.551	26	592.86	0.293	A,Sp,W,Su	32	633.2	0.211	47	823	0.205	W,A,Su,Sp
	Etropus crossotus	7	72.9	0.022	6	63.18	0.018	A,W,Sp,Su							
	Paralichthys patagonicus	1	68.3	0.003				A							
Polynemidae	*Polydactylus virginicus*	7	518.8	0.129	23	2182.73	0.927	Sp,W,Su,A	1	128.2	0.003	10	624.4	0.025	A
Pomatomidae	*Pomatomus saltatrix*	1	58.4	0.002				A							
Pristigasteridae	*Pellona harroweri*	1	21.7	0.001	8	190.77	0.039	Su,Sp,W							
Sciaenidae	*Bairdiella ronchus*				1	180.94	0.005	Su	11	376.1	0.042	671	24234.7	7.766	W,A,Sp,Su
	Ctenosciaena gracilicirrhus											52	1248	0.178	Sp,Su,A
	Cynoscion jamaicensis	2	12.5	0.003	5	55.59	0.009	Sp, A							

Continuation

Family	Species	Indio							Maciel						
		Day			Night			Presense	Day			Night			Presense
			Biomass	IRI		Biomass	IRI	Season		Biomass	IRI		Biomass	IRI	Season
		n	(g)	(%)	n	(g)	(%)	N increases→	n	(g)	(%)	n	(g)	(%)	N increases→
	Cynoscion leiarchus											3	166.2	0.004	Su
	Cynoscion microlepidotus	6	32.2	0.007	4	24.78	0.004	Su,A							
	Cynoscion sp.											1	263.5	0.003	Sp
	Cynoscion striatus											3	215.5	0.005	Sp,Su
	Isopisthus parvipinnis	8	135.3	0.049	40	1416.56	0.819	Su,Sp,W,A	1	2.4	0.000				Sp
	Larimus breviceps	7	237.2	0.023	7	332.96	0.067	Su,A,W							
	Macrodon atricauda				1	4.07	0.000	Su							
	Menticirrhus americanus	1	38.1	0.002	13	722.23	0.213	W,A,Su	1	78.8	0.002	6	399.2	0.015	Su,Sp
	Menticirrhus littoralis	5	242.7	0.054	4	208.99	0.021	Su,A,W,Sp				1	60.2	0.001	Su
	Micropogonias furnieri	32	1286.9	0.769	71	4601.40	2.793	W,A,Sp,Su				2	287.5	0.007	Su,A
	Paralonchurus brasiliensis	1	108.2	0.004	5	731.37	0.085	Sp,Su							
	Pogonias cromis				1	101.00	0.003	Su							
	Stellifer rastrifer	176	9085.5	5.561	232	10748.68	6.936	A,W,Su,Sp	16	417.9	0.012	115	2741.5	0.147	W,Sp,Su
	Stellifer stellifer	1	95.6	0.004	11	458.89	0.048	W,Sp,Su							
	Umbrina coroides											1	214	0.002	Sp
Scombridae	*Scomberomorus brasiliensis*	2	104.0	0.005				A	3	170	0.014	1	7.4	0.000	W,Su
Serranidae	*Diplectrum radiale*	8	140.3	0.050	1	3.28	0.000	Sp,A,Su,W							
	Rypticus randalli											119	3468.8	0.858	W,Su,A,Sp
Sparidae	*Archosargus rhomboidalis*	11	1408.7	0.494	7	536.08	0.084	Sp,W,A,Su	3	1202.8	0.060	16	1914.2	0.179	Su,A,Sp
	Diplodus argenteus				4	263.18	0.034	Su,A,W,Sp							
Sphyraenidae	*Sphyraena guachancho*	8	91.6	0.020				A							
	Sphyraena sp.								4	2.9	0.001				Su
Stromateidae	*Peprilus paru*	1	122.9	0.005				Su							
Synodontidae	*Synodus foetens*	1	28.7	0.001				W	2	65.1	0.004				A
Tetraodontidae	*Lagocephalus laevigatus*	1	55.6	0.002	1	44.25	0.002	Su							
	Sphoeroides greeleyi	379	5094.5	7.099	90	1104.49	0.887	W,A,Su,Sp	1051	15062.7	11.779	307	4471.9	2.250	A,Su,W,Sp
	Sphoeroides spengleri	111	2470.2	1.474	22	246.11	0.083	Su,W,Sp							
	Sphoeroides testudineus	547	29981.1	29.829	193	9840.02	6.556	A,W,Sp,Su	842	38631	25.060	349	18849.5	5.877	W,A,Sp,Su
	Sphoeroides tyleri	9	155.7	0.019	18	191.68	0.022	W							
Trichiuridae	*Trichiurus lepturus*	5	134.3	0.027	21	930.00	0.287	Sp,W,Su,A				1	477.5	0.005	A
Triglidae	*Prionotus nudigula*				2	1.50	0.001	Su,A							
	Prionotus punctatus	5	142.1	0.036	10	89.42	0.034	W,A,Su				7	95.4	0.005	Sp
Uranoscopidae	*Astroscopus ygraecum*	1	0.5	0.000				A							

additional add-on package PERMANOVA+ v.1.0.2 (Anderson *et al*., 2008). The significance of the variations in and interactions between abundance, biomass, richness and the AvTD and VarTD indexes was tested through 9,999 randomizations, considering the site and season as fixed factors and the season and time of day for each of the sites separately. The differences between temperature and salinity at both sites were tested using a PERANOVA. The routine analysis is the same as PERMANOVA. However, only one dependent variable were considered (temperature and salinity separated). To decrease the weights of very abundant species in the analysis, all data were fourth-root transformed. Similarity matrices were calculated for the abundance values based on the Bray-Curtis similarity measure, whereas the similarity matrices for the biomass, richness and taxonomic indexes were based on Euclidean distance (Clarke & Gorley, 2006).

The index of relative importance (IRI%) (Pinkas et al., 1971) was used to evaluate the importance of each species in the fish assemblage as follows: [(N% + W%)*FO%]*100, where N% = the percentage of the number of individuals of each species relative to the total number of individuals, W% = the percentage of the weight of each species relative to the total weight, and FO% = n/N*100, where n = the number of samples in which the species was present and N = the total number of samples.

From all of the species collected at the two sites, 18 species were selected based on the IRI%. A canonical analysis (CA) was performed for this subset of data using log(x+1) transformed abundance values to evaluate the affinity of this subset between the sites, seasons and times of day. CA provides an absolute value of the obtained canonical coefficients, and this value is higher when there is differentiation between groups.

The existence of differences in taxonomic structure between sites and seasons of the year was tested by calculating the Average Taxonomic Distinctness (AvTD, Δ^+) and the variation in taxonomic distinctness (VarTD, Λ^+) (Clarke & Warwick, 1999).

RESULTS

Environmental variables

The PERANOVA showed not significant differences in temperature (*DF* = 95; Res = 94; MS = 0.4481; pseudo-*F* = 3.5507; *P* = 0.0688) between shallow infralittoral zones of Maciel and Indio Beach. Both sites presented well-defined seasonal patterns, with average temperatures increasing in the spring. The temperatures at Maciel were between 28.1°C (maximum) and 18.2°C (minimum) and the average seasonal were 22°C in spring (Sp), 27.5°C in summer (Su), 25.4°C in autumn (A) and 19°C in winter (W). In the Indio Beach the temperatures were between 27.5°C (maximum) and 16°C (minimum) and the average seasonal were 21.5°C (Sp), 25°C (Su), 22°C (A) and 17°C (W). The PERMANOVA showed significant differences in the salinity (*DF* = 95; Res = 94; MS = 3.7467; pseudo-*F* = 20.197; *P* = 0.0001) between shallow infralittoral zones of Maciel and Indio Beach. The salinity at Maciel varied from 20 to 34, and the average salinity decreased with increasing rainfall. The average seasonal salinity values recorded at Maciel were 30 (Sp), 26 (Su), 25 (A) and 33 (W). At Indio Beach, the salinity levels varied from 28 to 36, and the salinity tended to increase in the period of lower rainfall (winter). The average salinities at Indio Beach were 31 (Sp), 31 (Su), 33 (A) and 35 (W). At both sites, a narrow band with higher sand concentrations could be observed, located in a shallow area associated with a shallow mudflat. Rocky outcrops were present in the vicinity of Indio Beach. At Maciel, salt marshes and mangroves were present, and rocky outcrops were absent.

Ichthyofauna

The PERMANOVA revealed significant differences in the abundance (*DF* = 95; Res = 94; MS = 59074; pseudo-*F* = 34.05; *P* = 0.0001) and biomass (*DF* = 1; Res = 9 4; MS = 67517; pseudo-*F* = 19.224; *P* = 0.0001) between the shallow infralittoral zones of Maciel and Indio Beach. At Maciel, a total of 39,714 individuals belonging to 69 species and 32 families were captured, and a total biomass of 368.515 g was recorded. At Indio Beach, 19,302 individuals belonging to 89 species and 39 families were captured, showing a total biomass of 229.066 g.

Among the identified families, 30 were present at both sites. At Maciel, the families showing the greatest species richness were Sciaenidae (11), Carangidae (7), Engraulidae (7), Gerreidae (5) and Clupeidae (4). High species richness was also observed at Indio Beach for the families Sciaenidae (13 species), Engraulidae (9), Carangidae (8), Gerreidae and Tetradontidae (5 each). Among all of the captured species, 47 were present at both sites, while 21 were exclusive to the Maciel shallow infralittoral zone, with *Anchoa lyolepis* being highlighted, and 42 were exclusive to Indio Beach, with *Genidens barbus* and *Anchoviella lepidentostole* showing particularly high abundance. The number of species that were present exclusively at a single time of the day was 26 at Maciel (5 diurnal and 21 nocturnal) and 28 at Indio Beach (16 diurnal and 12 nocturnal) (Table 1).

In the Maciel shallow infralittoral zone, eight species were responsible for 92% of the IRI%, considering the averages obtained during day and night. These species were *Harengula clupeola*, *Pomadasys corvinaeformis*, *Sphoeroides testudineus*, *S. greeleyi*, *Anchoa lyolepis*, *Diapterus rhombeus*, *Bardiella ronchus* and *Atherinella brasiliensis*. At Indio Beach, eight species were responsible for 85% of the total IRI%, which were *S. testudineus*, *Genidens barbus*, *G. genidens*, *H. clupeola*, *Anchoviella lepidentostole*, *Stellifer rastrifer*, *Cetengraulis edentulus* and *S. greeleyi* (Table 1).

PERMANOVA indicated significant variations in abundance between the different times of day and seasons for both of the studied sites as well as a significant interaction of these factors (Table 2). At Maciel, the average abundance was higher during the day in the summer and during the night in the spring (Fig. 2). Regarding the seasonal variations observed at this site, only the summer and the autumn did not differ significantly during the night (pairwise test: P = 0.1329), whereas there were significant differences between all seasons during the day. At Indio Beach, the average abundances were higher during the night in summer and during the day in autumn (Fig. 2). In the remaining seasons, the average abundances were higher during the day (pairwise test: $P < 0.05$). At Indio Beach, all of the differences observed between seasons were statistically significant, for both day and night (pairwise test: $P < 0.05$), except for the difference between winter and spring during the day (pairwise test: P = 0.1439). The total accumulated variation in fish abundance at Maciel was 52.3% for the period of the day, 37.3% for the season and 10.4% as a result of the interaction. The Indio Beach showed a similar pattern, with most of the accumulated variation for the season (48.2%), followed by period of the day (34.9%) and the interaction (16.9%).

At Maciel, the seasonal variation in biomass was significant (Table 2). There were significant differences between all seasons in both the day and night, with the exception of autumn and summer, between which there were no significant differences (pairwise test: $P > 0.05$). The biomass was also significantly different between the day and night for all seasons (pairwise test: $P < 0.05$). In contrast to Indio Beach, the nocturnal biomass at Maciel exhibited lower variation between seasons than the diurnal biomass, with significant differences being observed between spring and winter (pairwise test: P = 0.004) and between summer and winter (pairwise test: P = 0.041) during the night. At Indio Beach, the biomass was higher on average during the night and during the summer (Fig. 2), and it was significantly different between seasons and times of day (Table 2). Additionally, there was a significant interaction between the seasons and times of day. The biomass was significantly different between all seasons during the night and during the day, with the exception of the comparison between spring and summer (pairwise test: P = 0.0675). Furthermore, the differences in biomass between the day and night were significant in all seasons (pairwise test: $P > 0.05$). The accumulated total variance of the fish biomass at Maciel was 42.5% for the diel period, 36% for the season and 21.5% as a result of the interaction. On the other hand, in the Indio Beach, season accounted 54% of the total biomass variation, whereas the period of the day and the interaction amounted to 39.5% and 6.5% of the total variation, respectively.

The canonical analysis based on the abundance of 18 species showing high IRI% values in the shallow infralittoral zones of Maciel and Indio Beach clearly separated the samples according to the sampling sites, which were associated with the analyzed species to a lesser or greater degree (Fig. 3). The analysis grouped the samples from Indio Beach on the right side of the graph and the samples from Maciel on the left. The species *S. testudineus* and *S. greeleyi*, which were abundant at both sites, were situated in the center of the grouping, with the remaining species being placed closer to the sites where they were more abundant. The analysis did not result in the formation of groups according to the seasons. Some species were correlated with nighttime samplings, such as *G. barbus*, *Bairdiella ronchus* and *Pomadays corvinaeformis*, indicating that they are preferentially nocturnal, and others were correlated with daytime samplings, such as *Anchoa lyolepis* and *Opisthonema oglinum*, indicating diurnal behavior (Fig. 3). The species that contributed the most to explaining axis 1 were *G. barbus*, *Stellifer rastrifer*, *G. genidens* and *Anchoviella lepidentostole*, whereas axis 2 was mostly explained by *A. lyolepis* and *O. oglinum*, in addition to *Sardinella brasiliensis*, *A. lepidentostole* and *B. ronchus* to a lesser extent (Table 3). The placement of *Sphoeroides testudineus* at the center of the grouping (Fig. 3) was confirmed by PERMANOVA. This species did not differ in terms of abundance between the sites (pseudo-F = 2.1238; P = 0.1148), and no significant site x season interaction was indicated for *S. testudineus* (pseudo-F = 0.9438; P = 0.1148).

The average taxonomic richness in the shallow infralittoral zones of Maciel and Indio Beach was visually observed to be equal over the course of the seasons (Fig. 4). A decrease in richness followed decreases in the numbers of genera and families at both sites. However, the number of orders was apparently more constant over time, and the differences in species,

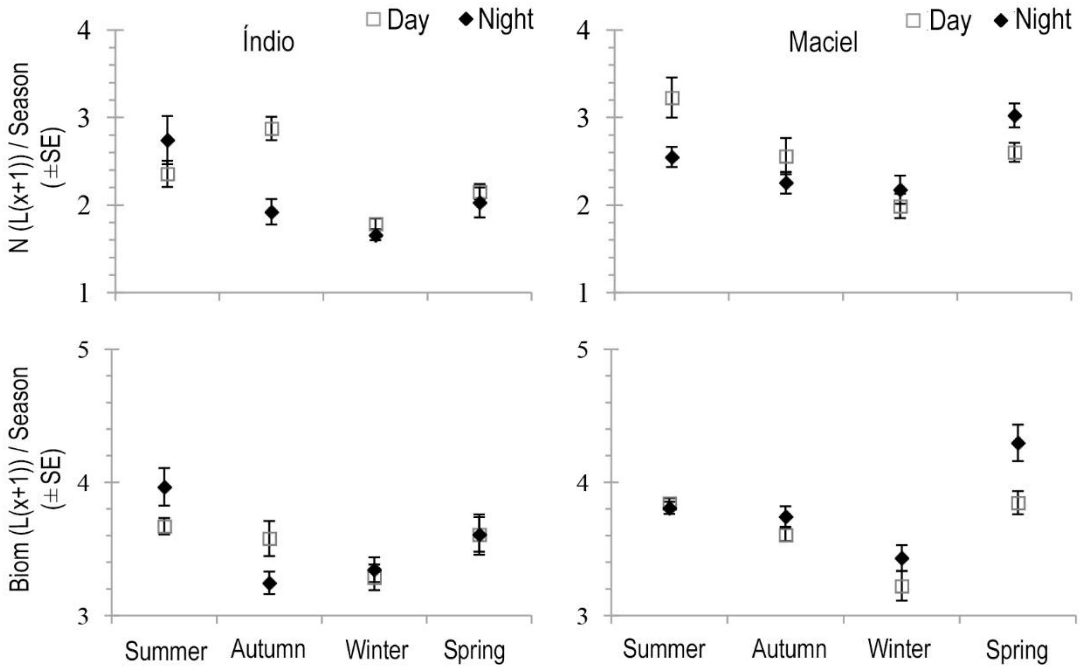

Figure 2. Seasonal variation of the average abundance log(x+1) and average biomass (g) log(x+1) recorded at Indio Beach (left) and Maciel (right).

Table 2. PERMANOVA based on the Bray-Curtis similarity of abundance data and the Euclidean distance of biomass data (both fourth-root transformed) for 89 species of fish from Indio Beach and 69 species of fish from Maciel, in response to the period of the day, the season of the year and the interaction between the seasons and period of the day. Significant values are shown in bold.

Variation resource		Indio				Maciel			
		df	MS	*pseudo-F*	*P*(perm)	*df*	MS	*pseudo-F*	*P(perm)*
Abundance	Period	1	11725	7.1662	**0.0001**	1	13952	15.766	**0.0001**
	Season	3	8611.1	5.263	**0.0001**	3	5546.1	6.2671	**0.0001**
	Per x Sea	3	2858.6	1.7472	**0.0058**	3	1531.2	1.7303	**0.0174**
	Residue	40	1636.2			40	884.95		
	Total	47				47			
Biomass	Period	1	12686	6.2141	**0.0001**	1	33514	13.312	**0.0001**
	Season	3	9280.6	4.5459	**0.0001**	3	15649	6.2158	**0.0001**
	Per x Sea	3	2472.8	1.2113	0.1852	3	6456.3	2.5645	**0.0013**
	Residue	40	2041.5			40	2517.5		
	Total	47				47			

genera and family richness appeared to decrease during the winter at Maciel (Fig. 4).

The results of the PERMANOVA indicated that the species richness was significantly different between the sites and seasons of the year, with no significant interaction between the sites and seasons being detected (Table 4). The average richness was higher at Indio Beach in all seasons (Fig. 5). The species richness was only significantly different between Indio Beach and Maciel during winter (pairwise test: P = 0.0003). At Indio Beach, there were significant differences in species richness between the summer and winter (pairwise test: P = 0.0006) and between the autumn and winter (pairwise test: P = 0.0023). At Maciel, there were significant differences between the summer and winter (pairwise test: P = 0.0001), autumn and winter (pairwise test: P = 0.0031) and spring and winter (pairwise test: P = 0.0014).

For both Maciel and Indio Beach and for all seasons, the average taxonomic distinctness Δ+ (AvTD) and the

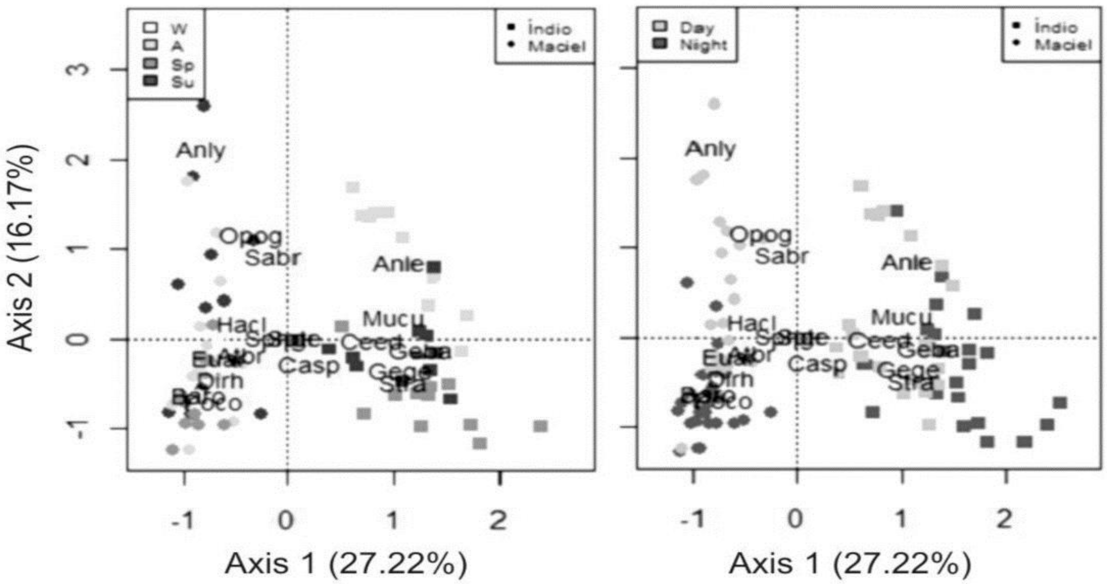

Figure 3. Groupings obtained through correspondence analysis by the season of the year and site (left) and by the time of day and site (right), based on the abundance log(x+1) of 18 species selected according to their IRI% values in the shallow infralittoral zones of Maciel and of Indio Beach. Codes for the species: Anly: *Anchoa lyolepis*; Anle: *Anchoviella lepidentostole*; Atbr: *Atherinella brasiliensis*; Baro: *Bairdiella ronchus*; Casp: *Cathorops spixii*; Ceed: *Cetengraulis edentulus;* Dirh: *Diapterus rhombeus*; Euar: *Eucinostomus argenteus*; Geba: *Genidens barbus*; Gege: *Genidens genidens*; Hacl: *Harengula clupeola*; Mucu: *Mugil curema*; Opog: *Ophisthonema oglinum*; Poco: *Pomadasys corvinaeformis*; Sabr: *Sardinella brasiliensis*; Spgr: *Sphoeroides greeleyi*; Spte: *Sphoeroeides testudineus*; Stra: *Stellifer rastrifer*.

variation in taxonomic distinctness $\Lambda+$ (VarTD) were within the confidence interval calculated from 1000 simulations for each index (Fig. 5). In general, the seasonal values of $\Delta+$ and $\Lambda+$ obtained for Maciel and Indio Beach showed very similar values, with the main difference being observed in the number of species corresponding to the x axis (Fig. 5). Although the $\Delta+$ and $\Lambda+$ values were within the confidence interval, they varied within this interval. During summer, $\Delta+$ was below the average at Indio Beach, displaying a value close to the limit of the confidence interval. During winter, at both sites, the $\Lambda+$ values were below the average. The bivariate simulations for $\Delta+$ and $\Lambda+$ also showed that Indio Beach and Maciel both exhibited values within the 95% confidence interval in all seasons (Fig. 6). The shape of the ellipse and that of the distribution of objects indicated a negative correlation between $\Delta+$ and $\Lambda+$.

According to the PERMANOVA, AvTD was not significantly different between the two sites (Table 4). However, AvTD was significantly different between different seasons, with a significant interaction being detected between the site and season (Table 4). PERMANOVA pairwise comparisons between the two sites per season showed that AvTD was significantly different between the sites in the summer (pairwise test: *P* = 0.0074) and autumn (pairwise test: *P* = 0.002). At Maciel, the differences between seasons were significant, except between summer and autumn (pairwise test: *P* = 0.3924) and between winter and spring (pairwise test: *P* = 0.5847). At Indio Beach, AvTD was not significantly different between seasons. According to the PERMANOVA, VarTD varied significantly between different sites but not between different seasons, and the interaction between the sites and seasons was significant (Table 4). The pairwise comparisons between the sites for each season revealed significant differences in VarTD in all seasons, except for winter (pairwise test: *P* = 0.2331). The pairwise comparisons by season at Maciel showed significant differences between summer and spring (pairwise test: *P* = 0.0001) and between autumn and winter (pairwise test: *P* = 0.0007). At Indio Beach, the differences were significant between summer and spring (pairwise test: *P* = 0.0079) and between autumn and spring (pairwise test: *P* = 0.0028).

DISCUSSION

The differences in ichthyofaunal abundance and biomass between the two studied sites (the shallow infralittoral zones of Indio Beach and Maciel) were much greater than the differences in abundance between different times of the day or seasons of the year

Table 3. Distribution of the absolute contribution of each species to the two first axes of the correspondence analysis, based on the abundance log(x+1) of the 18 main species indicated in the present study according to their IRI% values obtained at Maciel and Indio Beach. The codes for the species are the same as in Fig. 3. The higher contributions to each axis are shown in bold.

Species	Contribution		Species	Contribution		Species	Contribution	
	CA1	CA2		CA1	CA2		CA1	CA2
Hacl	-0.42439	0.178748	Sabr	-0.15140	**0.914852**	Euar	-0.66449	-0.195739
Anly	-0.82004	**2.111221**	Atbr	-0.44154	-0.152990	Baro	-0.84899	**-0.627708**
Poco	-0.71798	-0.701577	Geba	**125.684**	-0.124106	Mucu	0.98678	0.258967
Anle	**104.923**	**0.843327**	Opog	-0.34162	**1.146.843**	Gege	**107.142**	-0.366931
Spte	0.05668	0.013074	Dirh	-0.63756	-0.457756	Stra	**107.338**	-0.477772
Spgr	-0.08628	0.004918	Ceed	0.79113	-0.009477	Casp	0.20077	-0.303633

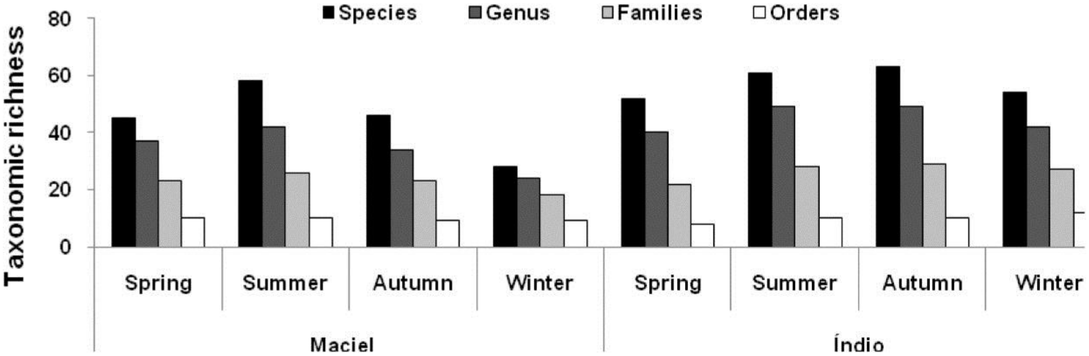

Figure 4. Average taxonomic richness according to the season at Indio Beach and Maciel during the study period.

Table 4. Bifactorial PERMANOVA based on the Euclidean distance of the species richness, average taxonomic distinctness (AvTD) and variation in taxonomic distinctness (VarTD), considering the site and the season of the year as random and fixed factors. Significant values are indicate in bold.

Variation resource		*df*	MS	*pseudo-F*	*P*(perm)
Richness	Local	1	337.5	14.429	**0.0006**
	Season	3	359.01	15.349	**0.0001**
	Lo x Sea	3	18.361	0.78499	0.5074
	Residue	88	23.39		
	Total	95			
AvTD	Local	1	11.158	2.8924	0.0867
	Season	3	18.882	4.8949	**0.0026**
	Lo x Sea	3	17.517	4.5409	**0.0052**
	Residue	88	3.8576		
	Total	95			
VarTD	Local	1	16285	4.5769	**0.0341**
	Season	3	3170.2	0.89098	0.4589
	Lo x Sea	3	27845	7.8258	**0.0002**
	Residue	88	3558.1		
	Total	95			

at each site (PERMANOVA). However, the significance of the seasonal variations in abundance and biomass at both sites reflected the high seasonal dynamics of the ichthyofauna. The ichthyofaunal abundance and biomass in the shallow infralittoral zones of Maciel and Indio Beach exhibited a tendency to increase with increasing temperature during the spring and summer months. Seasonally, the two sites presented fluctuations in their average salinities, as expected (Lana *et al*., 2001; Maciel *et al*., 2010), with the salinity at Indio Beach being more homogeneous over time, while Maciel presented more pronounced variations in salinity levels.

Of the 113 total captured species, only 47 were present at both sites. Among the eight species showing the highest relative importance (IRI%), three (*Harengula clupeola*, *Sphoeroides testudineus* and *S. greeleyi*) were present at both sites, displaying a high IRI% at both Indio Beach and Maciel. Additional similarities were observed in the structure of the captures. For example, *S. testudineus* was abundant in summer and spring during the day at both sites, showing equally distributed abundances among the

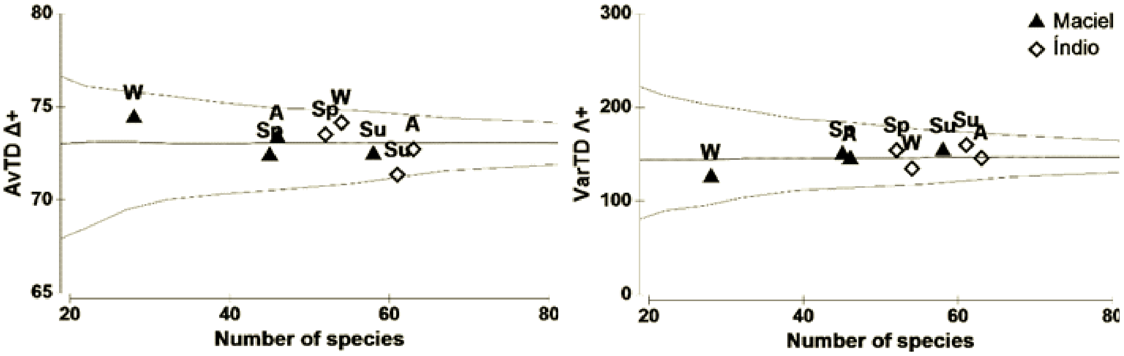

Figure 5. a) Average taxonomic distinctness and b) variation in taxonomic distinctness for the shallow infralittoral zones of Indio Beach and Maciel according to the season of the year. For both indexes, the expected average is represented by the central dotted line, and the limit of the 95% confidence interval is indicated by the surrounding funnel-shaped solid line.

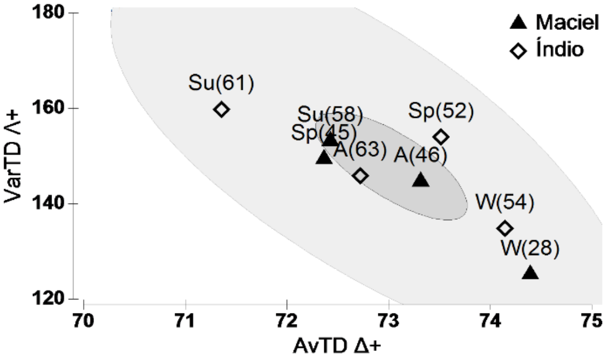

Figure 6. Average taxonomic distinctness values obtained in the shallow infralittoral zones of Indio Beach and Maciel plotted against the corresponding variation in the taxonomic distinctness values. The ellipse represents the 95% confidence interval of the paired values, obtained from 1000 independent simulations of random subsets. The total number of species for each site during each season is shown in brackets.

different size classes present, and the total number of captured individuals of this species was not significantly different between the two sites. *S. greeleyi* occurred in greater numbers in spring and during the day, with the distribution frequency of its size classes also being equal at the two sites, although a slightly higher abundance was observed at Maciel. In contrast, *H. clupeola*, which was one of the most abundant species at both sites, showed an opposite occupation trend, being more abundant during the day at Indio Beach and during the night at Maciel. *Harengula clupeola* was one of the most important species recorded by Pessanha *et al.* (2003) at Sepetiba Bay (Rio de Janeiro), exhibiting a tendency toward higher abundances during the night and during winter, but without a well-defined pattern being detected.

In general, the species that co-occurred at both sites presented similar occupancy tendencies during the day and night. These species included *Cathorops spixii* (nocturnal, N), *Oligoplites saurus* (diurnal, D), *Anchoa tricolor* (D), *Eucinostomus melanopterus* (D), *Stellifer rastrifer* (N), *S. greeleyi* (D), *S. testudineus* (D) and *Prionotus punctatus* (N). At both sites, *Ophichthus gomesii* was exclusively nocturnal, and *Synodus foetens* was exclusively diurnal. The species that were exclusive to a single time of the day were generally species showing a low abundance, although a few of these species were more abundant, such as *Ctenosciena gracilicirrhus* and *Rypticus randalli*.

The specific sampling conducted in two environmentally heterogeneous bays with wide habitat diversities restrict the comparison of ichthyofaunal similarity between the bays but enable comparisons between Indio Beach and Maciel. Among the species collected at Indio Beach, only five were not recorded in the Paranaguá Estuarine Complex (*checklist*, Passos *et al.* (2012)): *Genidens machadoi*, *Anchoa marinii*, *Heteropriacanthus cruentatus*, *Macrodon atricauda* and *Odontesthes argentinensis*. The distribution of the last species is restricted to the south of Brazil (Froese & Pauly, 2012). Nevertheless, *O. argentinensis* has been reported to occur at a sheltered beach in the Paranaguá Bay (Félix *et al.*, 2007). The observed ichthyofaunal compositions indicate that the two sites belong to the same biogeographical region, without natural borders. However, the slight environmental differences and the ecological contexts of the two sites favor the occurrence of different species at lower or higher abundances, resulting in different structural compositions of their assemblages (Yemane *et al.*, 2010).

Comparison of the two sites confirmed the efficiency of the net used to capture some of the species and families in the shallow infralittoral zone. For example, the low abundance of Gerreidae at Indio Beach was due to the low occurrence of this family at this site given that Gerreidae were captured in great numbers at Maciel using the same sampling method, thus verifying the efficacy of the fyke net employed for the capture of these demersal fishes. The same pattern was observed for the Ariidae and several other species (Table 1). However, the low abundance and richness of cryptic species showing limited displacement, such as Gobiidae (Ryan, 1992), indicates that a fixed net may be ineffective for the collection of these individuals. Gobiidae are apparently more abundant in the internal areas of estuaries (Spach *et al.*, 2006; Vilar *et al.*, 2011) and are generally among the families showing greater species richness in estuarine regions (Contente *et al.*, 2011), although this is not the case for sheltered beaches (Pessanha *et al.*, 2003; Félix-Hackradt *et al.*, 2010). It is important to know the limitations of fyke nets, similar to other methods, as poor sampling in ecological studies may result in false representations of fish assemblages and lead to underestimations of possible impacts (such as the impact of building marinas) on the existing ichthyofauna (Griffiths, 2001).

The natural variation of the observed taxonomic structure was within the confidence intervals for the expected AvTD and VarTD values and provides a more robust corroboration of the graphical representation of the taxonomic richness, which indicated little variation in richness within a given season.

The species present in the shallow infralittoral zones of Maciel and Indio Beach exhibited a high turnover of occupancy over time, with the majority of the species presenting seasonal peaks of abundance. These abundance peaks are not measurable using AvTD and VarTD, which only consider the presence/absence of species (Clarke & Warwick, 1998). At Indio Beach, lower values of AvTD and higher values of VarTD were obtained during summer. The decrease in AvTD at Indio Beach during summer may be partially associated with the absence of some superior taxa during that season, such as the orders Batrachoidiformes, Beloniformes, Elopiformes and Aulopiformes and the families Atherinopsidae, Gobiidae, Pomatomidae, Scombridae, Sphyraenidae and Uranoscopidae, which were represented by a small number of species in the present study. The decrease in the number of superior taxa represented by only a few species may have been reflected by the increase in the variation in taxonomic distinctness for the same period. The AvTD and VarTD indexes presented a negative correlation, *i.e.*, the lower the average taxonomic distinctness, the higher the variation in taxonomic distinctness. A slight tendency for a decrease in AvTD to occur with an increase in the number of species was also observed, while the opposite was observed for VarTD.

Despite being pseudo replicated, our results indicate that evaluation of the integrity of the fish assemblages at the studied sites, based on taxonomic distinctness indexes and a list of species that can occur in the studied area, can be performed from samplings carried out in any season using a fyke net. Computer simulations can be conducted to confirm the responses of AvTD and VarTD to a decrease in demersal or pelagic ichthyofaunal richness or in functional groups, among other simulations. However, it is clear that evaluation of the ecological integrity of a site based on taxonomic distinctness may not be very sensitive to slight changes in taxonomic structure. To achieve a better assessment, the interpretation of the taxonomic distinctness indexes should be corroborated with abundance and biomass data, in addition to data from other traditional ecological indexes that are less robust (Clarke & Warwick, 1999) but are sensitive to additional important components of the assemblage (Somerfield *et al.*, 1997). In turn, the use of these indexes may serve to support the choice of preferential sites for conservation, as sites with higher AvTD values exhibit higher ecological resilience.

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