ICHTHYOFAUNA COMPOSITION ACROSS A WAVE - ENERGY GRADIENT ON SOUTHERN BRAZIL BEACHES

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ABSTRACT

Wave action in sandy beach surf zones and its influence on species composition were evaluated at three sites at Pontal do Paraná, Paraná State, between June/2004 and May/2005. At each sampling site, five hauls were performed monthly using a 15 m long, 2.6 m height beach seine with a 5 mm mesh-size. Samplings were carried out at low water spring tides during daylight. A total of 26,866 fishes were collected, amounting to a total weight of 84,838 kg, which were distributed amongst 28 families and 63 *taxa*. Multi- and univariated methods used indicated that sheltered and moderately exposed beach samples had similar ichthyofaunal composition, being clupeids and engraulids the most abundant at these beaches. Although abiotic factors differed significantly between beaches, depth appears to exert the major influence on ichthyofauna structure by providing less turbulent waters which might have permitted shoals maintenance. Conversely, exposed beach samples differed largely from the other beaches and were influenced primarily by wave height and salinity variables. These were displayed at CCA diagram and through the occurrence of *P. virginicus, M. littoralis* and *T. goodei*.

RESUMO

A ação das ondas em zonas de arrebentação de praias arenosas e sua influência na composição de espécies foram avaliadas em três praias em Pontal do Paraná, Paraná, entre junho/2004 e maio/2005. Cinco arrastos mensais foram realizados em cada local amostral durante maré de sizígia em período diurno, usando uma rede de arrasto de 15 m de comprimento, 2,6 m de altura e malha de 5 mm. Um total de 26.866 peixes foram coletados pesando aproximadamente 84 kg e distribuídos em 28 famílias e 63 *taxa*. Métodos multi- e univariados utilizados indicaram que as amostras das praias protegidas e moderadas foram semelhantes em composição da ictiofauna, sendo os clupeídeos e engraulídeos os mais abundantes nestas praias. Por mais que os fatores abióticos sejam diferentes entre as praias, a profundidade parece exercer maior influência na estruturação da ictiofauna provendo águas menos turbulentas, o que pode ter permitido a manutenção de cardumes. Em tendência oposta, as amostras da praia exposta diferem em grande parte das outras sendo influenciada principalmente pelas variáveis altura de onda e salinidade mostradas no diagrama CCA e pela ocorrência de *P. virginicus, M. littoralis* e *T. goodei*.

Descriptors: Beach slope, Energy gradient, Depth, Wave height, Shoals, Pontal do Paraná.
Descritores: Perfil praial, Gradiente energético, Profundidade, Altura de onda, Cardumes, Pontal do Paraná.

Introduction

Sand beach surf zones represent narrow, though expansive, transitional habitat lying between sea and land (ROMER, 1990). These zones are important areas for feeding, growing and reproduction of many marine species (GIBSON, 1973; LASIAK, 1984a, 1986; CLARK et al., 1996) and economically important fish such as many species of carangid, scianid and clupeid families (GAELZER; ZALMON, 2003). Although frequented by a wide variety of species, these shallow habitats are characterized by few numerically dominant species (McFARLAND, 1963; LASIAK, 1984b; BENNET, 1989) that are small in size and predominantly juveniles (MODDE, 1980; ROBERTSON; LENANTON, 1984; SANTOS; NASH, 1995).

Ichthyofaunal assemblages are expected to change locally in response to many environmental parameters such as temperature, salinity and wave exposure (ROMER, 1990). According to Clark (1997), wave exposure is one of the main factors affecting the community structure of fish and invertebrates of sandy beach environments. Previous studies have indicated that increase in levels of exposure are generally followed by reduction of abundance and diversity index, whilst improving in dominance (DYE et al., 1981; DEXTER, 1984; CLARK, 1997; WATT-PRINGLE ; STRYDOM, 2003).

The objective of this study is to compare the ichthyofauna composition, abundance and community descriptors (diversity, richness and evenness) in three different sites at Pontal do Sul, Paraná State, Brazil, which have distinct wave exposure gradients (sheltered, moderately and exposed). In addition, the influence of the environmental variables on the local fish community structure throughout the year was also verified. To investigate these questions the following hypotheses were formulated: Are there any changes in community structure between the beaches studied and amongst the months? Are there any relationships between changes in community structure and environmental variables?

Materials and Methods

Study Site

Paraná coast consists of 98 km of uninterrupted sandy beaches limited at north and south by two important estuaries: Paranaguá Bay, and Guaratuba Bay, respectively. The studied beaches are located next to the entrance of Paranaguá Bay, across a wave energy gradient conferred by submerged bars and channels formed by tidal currents and drainage of the harbor channel.

The sheltered beach, Estuarina, is the closest to the bay entrance and located southwesterly of Mel Island (Fig. 1), which acts as a barrier from north and east winds. Village Beach is not influenced by neither Mel Island nor submerged troughs and ridges, and therefore, is an exposed beach. Pontal Beach, on the other hand, has moderate levels of wave energy owing to its intermediate position (Fig. 1). Approximately 1 km separates adjacent beaches from one another and according to Godefroid et al. (1997), the beaches are classified as dissipative in accordance to the morphodynamic scale of Wright and Short (1984). Mean sediment grain size increases southward (BIGARELLA et al*.*, 1969) toward the most exposed beaches, but at the studied sites it remains homogeneous (GODEFROID et al., 1997). The beaches are microtidal (tidal range < 1.5 m) with two ebb tides per day.

The innermost beach, Estuarina (25º33'979''S 48º21'119''W), has the narrowest surf zone wherein tides are the principal source of power, and is classified as a estuarine beach (BORZONE et al., 2003). Moreover, a steep slope profile created by deep navigable channels is present. Pontal Beach (25º34'769''S 48º21'018''W) is located outside the protection provided by the Mel Island, however, troughs and ridges formed by tidal currents have a great influence at the surf zone dynamics. As waves encounter these submerged obstacles, their energy is lost and they are broken several times up to the beach face. At low water of spring tides, extensive pools are formed parallel to the beach line, separated from one another by ridges, but with lateral communication to the sea. From the three existing troughs, the first is the shallowest (approximately 0.5–0.9 m), with depth increasing gradually seaward. The second trough location where most seine hauls took place, has an average depth of 1.5m, and the third through was not assessed. Finally, the largest wave heights and consequently the highest exposure were found in Village (25º35'354''S-48º22'025''W), the most external beach. This surf zone is longer than that at Estuarina but no longer when compared to that in Pontal, which is characterized by multiple breaking waves formed by the submarine profile, as described above.

Sampling Methods

Fish assemblage at the 3 locations were sampled during daylight hours, between 6.00 and 10.00 h from June 2004 to May 2005 using a beach seine net, 15 m long and 2.6 m height with a stretched mesh size of 5 mm. Five hauls 30 m apart ,separated each other by 5 m to minimize the influence on the next haul, were made at each site. All samples were collected at low water spring tides. The hauls were conducted by two people, one on each end of the net. The net was taken in the direction of the surf zone by one of them to a depth of 1.5 m, approximately between 10 and 30 m in the sea, and were pulled up simultaneously and parallel to the beach face.

All fish collected were identified to species following Fischer, 1978; Figueiredo and Menezes, 1978; Figueiredo and Menezes, 1980; Menezes and Figueiredo, 1980; Menezes and Figueiredo, 1985; Barletta and Corrêa, 1992; Figueiredo and Menezes, 2000. These were then weighted (g) and measured to the nearest 1 mm (total length and standard length), except when samples were very large. In these occasions, measurements were restricted to a sub sample of 30 individuals per species. The excess was weighted, counted and incorporated as weight and number counts. In addition, sex (male, female or non identified) and maturity stages were documented for the sub- sample trough direct observation, according to macroscopic scale of gonadal maturation of Vazzoler (1981).

To verify the environmental influence on the faunal composition and structure, surf zone water temperature (°C), salinity (Practical Salinity Scale – PSS), wave height (m) and period (s) were measured at each site monthly (since no differences between successive hauls were observed). Wave height was taken with a 2 m ruler and obtained from the metric difference between crest and sea level of the largest waves breaking on the surf zone. Wave period was measured from the duration (in sec) of 11 successive breaking waves and dividing it by 10 to obtain the period of a single wave. This procedure was applied twice to produce an average.

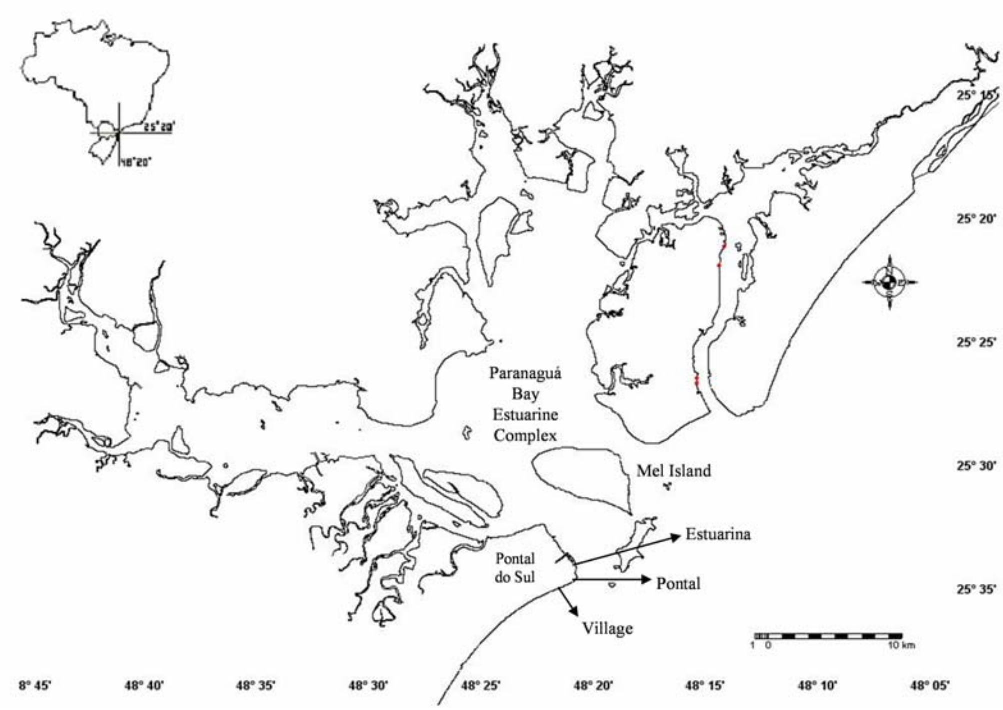

Fig. 1. Location of the three sampling sites (1-Estuarina, 2-Pontal and 3-Village) next to Paranaguá Bay Estuarine Complex, Paraná, South Brazil.

Data Analysis

All environmental and biological data were tested for normality (normal probability plot and Kolmogorov-Smirnov test) and homogeneity of variances (Bartlett Chi-square test) (SOKAL; ROHLF, 1995). Number of individuals and weight were log-transformed, while number of species was square root transformed in order to meet the assumptions of ANOVA. Two-way ANOVA's were carried out to test the effects of factors "month" and "site" on the following variables: the community parameters (Shannon-Wiener diversity and Pielou evenness indexes), abundance, weight and species richness. For the significant results ($p < 0.05$), Tukey post-hoc tests were conducted to evaluate which means differred from each other. As the results of post-hoc tests are difficult to visualize, due to high level interactions, these are not displayed. Interpretation of ANOVA results were focused on general differences observed at the interactions and on the main differences found in the analyses performed on isolated factors.

The weight abundance data (square root transformed) were converted into a matrix of similarities between all months and sites, using the Bray-Curtis similarity coefficient. Results are displayed on a dendrogram using group average linking (Cluster), and an ordination plot, generated by a non-metric multidimensional scaling (MDS) procedure (CLARKE; WARWICK, 1994). To evaluate the level of correlation to which environmental variables interferred in the samples grouping, a Canonical Correspondence Analysis (CCA) was performed. The matrix included weight abundance of all species collected at each site during the 12 months (log transformed) as well as environmental values of temperature, salinity, and wave height and period.

For operational purposes some abbreviations were adopted to distinguished between two different species: *Mugil* sp.1 is a species of *Mugil* genus that cannot be identified since scales were absent on individuals analyzed; *Mugil* sp.2 is the code to *Mugil gaimardianus* species name that no longer exists; and *S. brasiliensis* 1 is *Sardinella brasiliensis* to be distinguished from *Scomberomorus brasiliensis* abbreviation, *S. brasiliensis* 2 (ICZN, 2000).

Results

Environmental Data

While salinity was lowest at Estuarina beach, the variation was also the largest recorded during the study period. On the remainder of the beaches, salinity values showed similar fluctuation pattern along the year (Fig. 2a). Water temperature did not change among sites but varied along the months, following a seasonal pattern. Highest values occurred between December/04-February/05 and lowest in June and August/04 (Fig. 2b). Morphodynamic parameters did not display any seasonal pattern. Highest and lowest wave period values oscillated across sampling sites, but nearly always, minimum values were recorded in Estuarina or Pontal Beach (Fig. 2c). Moreover, wave height was spatially distinct, with smallest values at Estuarina, intermediate at Pontal, and highest at Village (Fig. 2d).

Species Composition

A total of 26,866 fish from 63 *taxa* and 28 families was collected in the 180 seine net hauls carried out throughout the year. *Harengula clupeola* (42.10%), *Sardinella brasiliensis* (14.52%), *Trachinotus carolinus* (11.76%), *Anchoa lyolepis* (10.85%) and *Odontesthes bonariensis* (8.47%) dominated numerically the catches; overall, accounting for nearly 90% of the total catch. With regard to biomass, *H. clupeola* (41%), *T. carolinus* and *O. bonariensis* remained the most important species captured, representing 54.5% of the 84,838 kg of fish collected.

Species composition, abundance and structure of fish in seine net hauls at the three sampling sites are presented in Table 1. The trend in total abundance recorded per site displayed a clear convex profile, where more individuals were caught at the moderately exposed site than at the sheltered and exposed ones (Tab. 1). However, in terms of species richness and weight a linear increase occurred from Village (28 species and 11 kg) to Pontal (40 species and 35 kg) and finally to Estuarina (52 species and 37 kg) (Table 1).

Spatial Variation

The beaches studied presented 19 *taxa* in common. Exclusively from Estuarina 17 species were found, whilst at Pontal and Village, only 5 and 3 exclusive species were observed, respectively (Table 1). Some species have shown distinct occupation patterns across the sites sampled. Following the abundance trends of higher fish catches at moderate wave-energy levels, were *O. bonariensis, H. clupeola, S. brasiliensis* and *A. lyolepis*, usually found in shoals. Furthermore, *T. carolinus,* Engraulidae juveniles*, E. lefroyi* and *Mugil* sp. 1, also commonly found in aggregates, showed higher total catches at low energy levels; and *T. goodei, P. virginicus* and *M. littoralis* were more abundant at the most exposed site (Table 1).

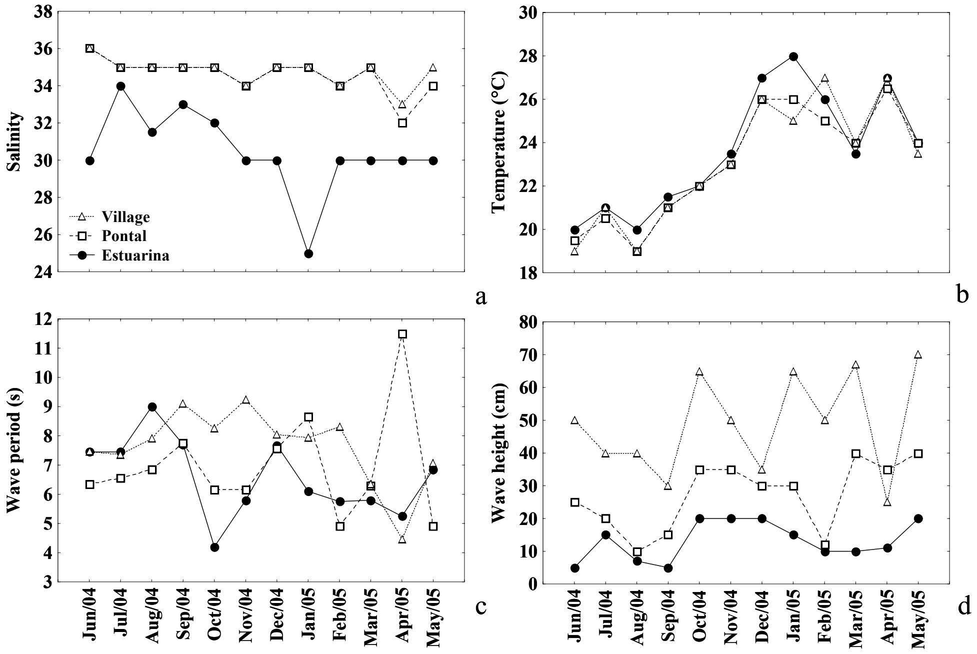

Fig. 2. Monthly variation of environmental variables recorded at sampling sites Estuarina (sheltered), Pontal (moderated) and Village (exposed) in Pontal do Paraná, Paraná, South Brazil. a) salinity, b) temperature, c) wave height and d) wave period.

These differences were also observed at the results from the two-way ANOVA. All community descriptors used were statistically different among months (n=12), sites (n=3) and in the interaction of these factors (n=36), except for evenness and diversity indexes which were only significant ($p < 0.05$) among months and sites, and among months, respectively (Fig. 3).

Abundance (month: F = 19.97, df = 11, $p < 0.05$; site: F = 12.54, df = 2, $p < 0.05$), weight (month: F = 9.59, df = 11, $p < 0.05$; site: F = 15.19, df = 2, $p < 0.05$) and species richness (month: F = 11.97, df = 11, $p < 0.05$; site: F = 15.47, df = 2, $p < 0.05$) presented strong seasonal influence with significant differences found in September and March when highest and lowest values occurred, respectively. However, spatial differences were registered only for Village Beach (Fig. 3a-c). Regarding to the evenness index, July was significantly different from the other months (F = 5.4, df = 11, $p < 0.05$) due to great catches of shoals and also, spatially (F = 10.23, df = 2, $p < 0.05$) different at Village, where higher values observed for evenness could be attributed to homogeneous species distribution and lower shoals capture (Fig. 3d). Diversity index only suffered influence of seasonal fluctuation (F = 5.14, df = 11, $p < 0.05$), and high values of abundance and species richness were responsible for the statistical difference occurring in March (Fig. 3e).

Similarities among sites could be seen at ordination and dendrogram plots (Fig. 4). Although masked by seasonal influence, the studied beaches revealed a distinct faunal composition. Almost all samples taken from Village Beach were under higher degree of similarity (>40%) than the other samples, which varied at 20-30% similarity level (Fig. 4). Results of Simper (Table 2) analysis between these 2 groups (1 – Estuarina + Pontal and 2 – Village) indicated that *H. clupeola* (33.27%), *M. littoralis* (23.49%), *T. carolinus* (19.53%) and *T. goodei* (11.74%) provided the greatest contribution (~89%) to similarity levels in the samples from Village. *H. clupeola* (55.78%) and *T. carolinus* (22.05%) were the major contributors for grouping the remainder of the samples, while most (66.36%) of the dissimilarity between the two groups was attributed to seven species. These are, in order of importance: *H. clupeola* (22.27%), *T. carolinus* (9.30%), *M. littoralis* (8.21%), *O. bonariensis* (8.04%), *S. brasiliensis* (6.98%), *T. goodei* (5.85%) and *P. saltatrix* (4.49%).

Table 1. Number (ind.), Weight (g) and Size (mm; standard length) of species caught at the sampling sites in Paraná, South Brazil.

		Estuarina					Pontal					Village				
				Size (mm)					Size (mm)					Size (mm)		
Family	**Species**	**Number**	**Weight (g)**	**Mean**	**Min**	**Max**	**Number**	**Weight (g)**	**Mean**	**Min**	**Max**	**Number**	**Weight (g)**	**Mean**	**Min**	**Max**
Albulidae	*Albula vulpes*	14	35.24	59.3	23.0	128.0	2	6.29	74.5	74.0	75.0	--	--	--	--	--
Atherinopsidae	*Odontesthes bonariensis*	--	--	--	--	--	1406	2865.64	57.3	42.0	153.0	871	2426.51	62.9	43.0	150.0
Belonidae	*Strongylura marina*	23	343.79	327.0	230.0	437.0	4	47.86	286.3	202.0	322.0	--	--	--	--	--
	Strongylura timucu	14	176.47	290.1	162.0	395.0	--	--	--	--	--	--	--	--	--	--
	Strongylura sp.	1	0.95	57.0	57.0	57.0	--	--	--	--	--	--	--	--	--	--
Carangidae	*Chloroscombrus chrysurus*	1	0.06	15.0	15.0	15.0	3	10.95	54.0	40.0	70.0	4	2.91	28.8	18.0	39.0
	Oligoplites saliens	16	802.66	113.7	30.0	385.0	118	95.05	119.4	60.0	139.0	23	23.23	55.1	13.0	134.0
	Selene vomer	2	2.25	32.0	30.0	34.0	--	--	--	--	--	--	--	--	--	--
	Trachinotus carolinus	1856	3940.58	40.6	12.0	76.0	770	1220.87	36.4	11.0	95.0	536	805.29	31.6	12.0	106.0
	Trachinotus falcatus	17	10.52	23.2	18.0	26.0	7	3.33	24.4	21.0	34.0	25	20.04	27.5	15.0	43.0
	Trachinotus goodei	30	108.08	48.6	35.0	73.0	10	183.03	84.4	57.0	104.0	132	526.99	46.0	22.0	97.0
	Trachinotus marginatus	--	--	--	--	--	--	--	--	--	--	3	19.18	63.3	33.0	81.0
	Trachinotus sp.	1	0.080	14.0	14.0	14.0	1	0.09	15.0	15.0	15.0	1	0.06	13.0	13.0	13.0
Centropomidae	*Centropomus parallelus*	1	148.18	198.0	198.0	198.0	--	--	--	--	--	--	--	--	--	--
Clupeidae	Clupeidae juveniles	4	0.13	20.8	19.0	22.0	--	--	--	--	--	--	--	--	--	--
	Harengula clupeola	3754	11558.27	56.9	38.0	109.0	6354	19630.67	57.3	34.0	131.0	1205	4412.36	56.2	32.0	102.0
	Ophisthonema oglinum	7	6.09	55.0	50.0	63.0	75	12.85	61.1	45.0	76.0	4	2.80	51.0	37.0	61.0
	Platanychthys platana	3	0.207	26.7	26.0	27.0	1	0.15	24.0	24.0	24.0	--	--	--	--	--
	Sardinella brasiliensis	1629	15345.95	70.2	32.0	108.0	2263	5440.07	61.9	29.0	92.0	10	28.30	52.2	25.0	85.0
Dactylopteridae	*Dactylopterus volitans*	1	75.94	166.0	166.0	166.0	--	--	--	--	--	--	--	--	--	--
Diodontidae	*Cyclichthys spinosus*	1	0.15	12.0	12.0	12.0	--	--	--	--	--	--	--	--	--	--
Engraulidae	*Anchoa lyolepis*	374	0.89	43.6	35.0	57.0	2534	3.39	42.3	34.0	55.0	9	13.93	49.6	40.0	70.0
	Anchoa parva	50	60.54	46.9	33.0	57.0	45	77.54	50.4	31.0	67.0	4	5.53	47.0	43.0	51.0
	Anchoa tricolor	39	14.89	46.4	34.0	97.0	106	16.74	48.9	31.0	103.0	2	2.11	44.5	40.0	49.0
	Cetengraulis edentulus	11	51.54	71.8	57.0	84.0	4	18.49	69.8	67.0	75.0	--	--	--	--	--
	Engraulidae juveniles	401	0.55	23.1	14.0	41.0	14	0.68	26.9	22.0	32.0	--	--	--	--	--
	Lycengraulis grossidens	1	1.17	49.0	49.0	49.0	--	--	--	--	--	--	--	--	--	--
Ephippidae	*Chaetodipterus faber*	3	0.95	25.0	23.0	27.0	3	7.62	37.7	32.0	43.0	--	--	--	--	--
Gerreidae	*Diapterus rhombeus*	--	--	--	--	--	3	48.12	106.7	101.0	112.0	--	--	--	--	--
	Eucinostomus argenteus	11	24.20	67.0	58.0	81.0	1	23.14	97.0	97.0	97.0	--	--	--	--	--
	Eucinostomus lefroyi	639	0.20	14.0	8.0	56.0	13	0.05	13.3	10.0	15.0	2	0.33	23.5	15.0	32.0
	Eucinostomus melanopterus	1	49.29	127.0	127.0	127.0	--	--	--	--	--	--	--	--	--	--
Haemulidae	*Conodon nobilis*	--	--	--	--	--	2	1.37	32.5	26.0	39.0	6	6.93	36.7	35.0	39.0
Haemulidae	*Pomadasys corvinaeformis*	11	16.10	59.5	53.0	76.0	10	1.33	38.2	34.0	42.0	--	--	--	--	--

Table 1. Continued.

		Estuarina					Pontal					Village				
				Size (mm)					Size (mm)					Size (mm)		
Family	Species	Number	Weight (g)	Mean	Min	Max	Number	Weight (g)	Mean	Min	Max	Number	Weight (g)	Mean	Min	Max
Hemirhamphidae	*Hyporhamphus unifasciatus*	75	48.18	133.6	100.0	222.0	8	61.50	134.4	94.0	205.0	2	5.13	120.5	112.0	129.0
Monacanthidae	*Stephanolepis hispidus*	4	3.15	29.8	20.0	35.0	--	--	--	--	--	--	--	--	--	--
Mugilidae	*Mugil* sp. 1	114	25.15	23.2	19.0	29.0	41	7.76	21.6	10.0	27.0	47	11.84	23.0	17.0	29.0
	Mugil sp. 2	4	30.03	92.8	80.0	97.0	--	--	--	--	--	2	39.88	107.0	106.0	108.0
Paralichthyidae	*Citharichthys arenaceus*	15	44.50	70.7	45.0	106.0	--	--	--	--	--	1	32.74	117.0	117.0	117.0
	Citharichthys macrops	1	2.59	7.0	57.0	57.0	--	--	--	--	--	--	--	--	--	--
	Etropus crossotus	36	96.00	49.3	24.0	68.0	2	13.01	65.0	53.0	77.0	2	19.57	66.0	40.0	92.0
	Scyacium papillosum	1	106.37	183.0	183.0	183.0	--	--	--	--	--	--	--	--	--	--
Pleuronectidae	*Oncopterus darwinii*	--	--	--	--	--	1	0.39	25.0	25.0	25.0	--	--	--	--	--
Polynemidae	*Polydactylus virginicus*	--	--	--	--	--	9	89.79	73.0	24.0	98.0	112	279.29	43.7	17.0	103.0
Pomatmidae	*Pomatomus saltatrix*	37	297.33	76.4	52.0	99.0	52	708.94	87.7	61.0	133.0	17	147.08	79.8	68.0	98.0
Sciaenidae	*Ctenosciaena gracilicirrhus*	2	0.20	17.5	15.0	20.0	3	0.36	20.7	20.0	21.0	--	--	--	--	--
	Larimus breviceps	2	0.09	15.5	13.0	18.0	1	7.89	70.0	70.0	70.0	--	--	--	--	--
	Menticirrhus americanus	4	10.22	47.5	27.0	73.0	6	4.11	33.2	23.0	46.0	4	8.61	37.5	21.0	67.0
	Menticirrhus littoralis	51	478.39	68.7	12.0	124.0	95	344.15	48.7	12.0	112.0	465	955.40	41.7	13.0	160.0
	Micropogonia furnieri	--	--	--	--	--	7	1.84	23.7	1.0	27.0	--	--	--	--	--
	Ophioscion punctatissimus	--	--	--	--	--	--	--	--	--	--	2	0.81	35.5	34.0	37.0
	Paralonchurus brasiliensis	1	1.26	39,0	39.0	39.0	--	--	--	--	--	--	--	--	--	--
	Stellifer rastrifer	--	--	--	--	--	3	1.03	30.7	24.0	38.0	--	--	--	--	--
	Umbrina coroides	3	0.83	33.3	31.0	38.0	24	2.42	33.5	22.0	46.0	--	--	--	--	--
Scombridae	*Scomberomorus brasiliensis*	--	--	--	--	--	1	36.74	156.0	156.0	156.0	--	--	--	--	--
Sphyraenidae	*Sphyraena tome*	1	1.62	73.0	73.0	73.0	--	--	--	--	--	--	--	--	--	--
Syngnathidae	*Syngnathus folletti*	6	6.20	130.2	110.0	147.0	--	--	--	--	--	1	0.16	85.0	85.0	85.0
Synodontidae	*Synodus foetens*	63	198.41	68.5	42.0	133.0	--	--	--	--	--	--	--	--	--	--
Tetraodontidae	*Sphoeroides testudineus*	6	230.71	111.3	89.0	122.0	1	115.47	150.0	150.0	150.0	--	--	--	--	--
Trichiuridae	*Trichiurus lepturus*	--	--	--	--	--	--	--	--	--	--	1	743.30	99.0	99.0	99.0
Triglidae	*Prionotus nudigula*	13	32.53	45.6	34.0	64.0	--	--	--	--	--	--	--	--	--	--
	Prionotus punctatus	5	20.42	53.0	43.0	72.0	1	4.56	58.0	58.0	58.0	--	--	--	--	--
Uranoscopidae	*Astroscopus y-graecum*	8	31.95	43.3	30.0	70.0	--	--	--	--	--	--	--	--	--	--
	Total	**9368**	**34441.32**				**14004**	**31115,31**				**3493**	**10540,13**			
	Species number	**52**					**40**					**28**				

The Canonical Correspondence Analysis - CCA explained 72.08% of data variance. The axis 1 was responsible for 47.80% of data variation. This axis shows the formation of two distinctive groups. One group directly related to highest values of salinity and wave height, which is comprised mostly by the samples from Village and Pontal Beaches. The second is influenced by wave period and temperature, and is formed almost entirely by samples from Estuarina. The axis 2 accounted for 24.28% of data variation. The group is formed by samples from all beaches studied which suffered a strong influence of temperature, and in lower proportion to wave period and height (Fig. 5).

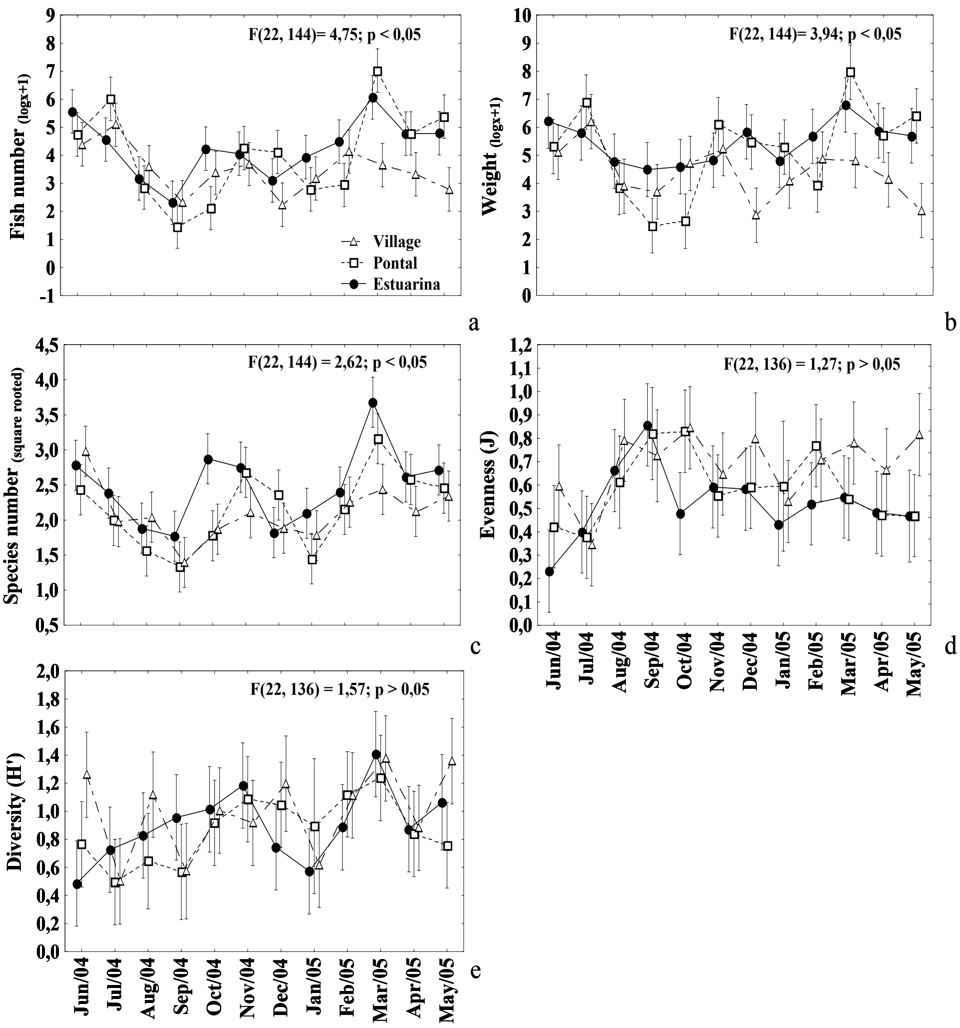

Fig. 3. Two-way ANOVA test of significance for: mean fish number (a), weight (b), species richness (c), Pielou evenness (d) and Shannon-Wiener diversity (e) indexes among months x sites. Standard deviation is represented by bars.

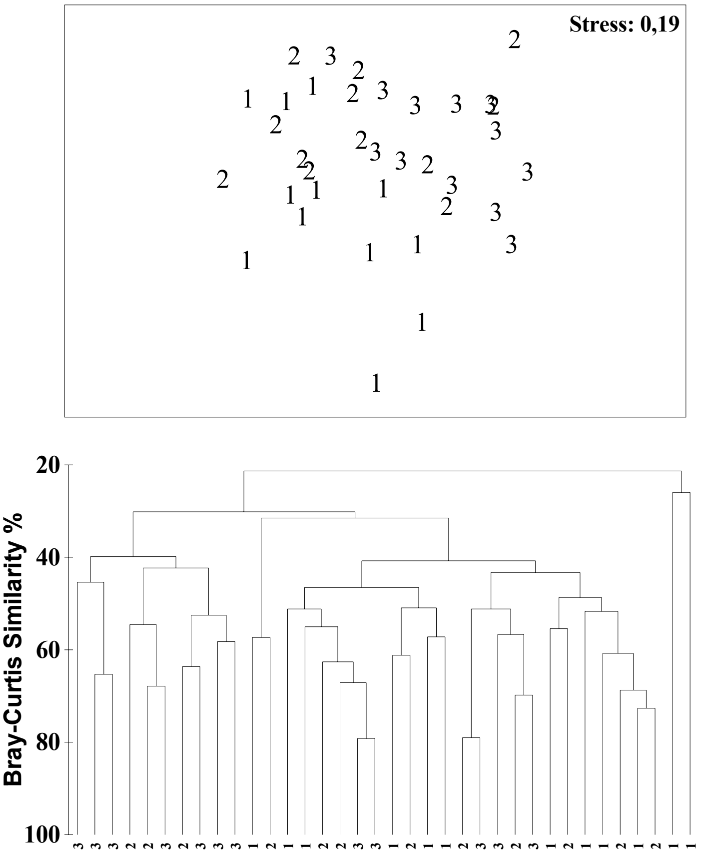

Fig. 4. Multidimensional scaling (MDS) of fish samples captured per site from June/04 to May/05, using the abundance of species caught as attributes. Hauls were pooled by month and labeled as 1-Estuarina (sheltered), 2- Pontal (moderated) and 3-Village (exposed).

Table 2. Simper results showing species contribution to similarities within, and dissimilarities between, groups of samples identified using Cluster and MDS analysis. (Group 1: Estuarina and Pontal samples; Group 2: Village samples).

Species	Mean Similarity %		Mean Dissimilarity %
	1	2	1 x 2
	35.95	45.40	66.36
H. clupeola	55.78	33.27	22.27
T. carolinus	22.05	19.53	9.3
P. saltatrix	3.46		4.49
M. littoralis	2.89	23.49	8.21
T. goodei		11.74	5.85
O. bonariensis			8.04
S. brasiliensis			6.98

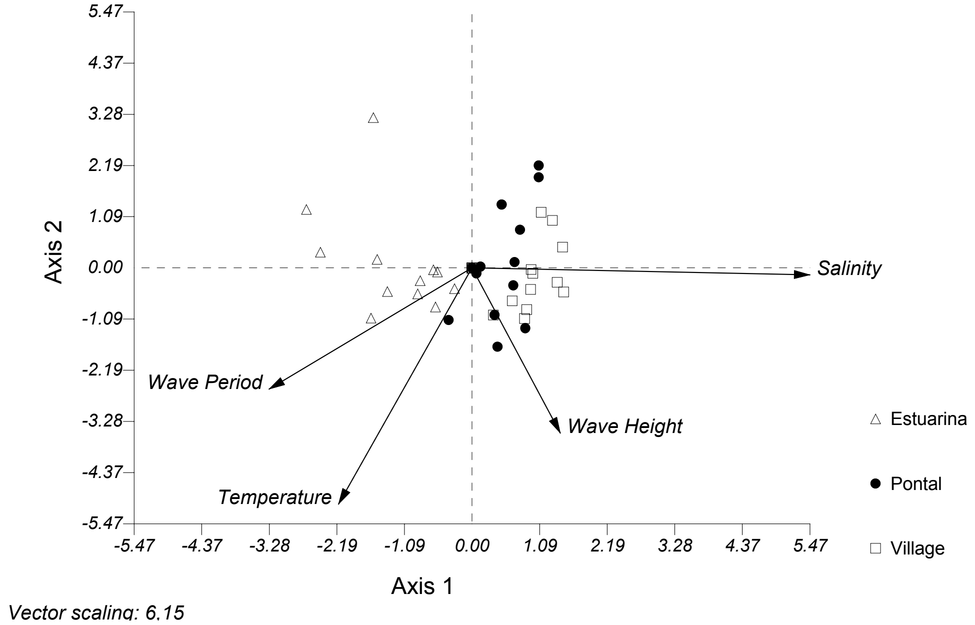

Fig. 5. Factorial diagram from the Canonical Correspondence Analysis showing the distribution of samples and their relationship to environmental variables. Samples are labeled as 1-Estuarina (sheltered), 2- Pontal (moderately) and 3-Village (exposed).

Discussion

Two general trends were evident in the composition of catches across the sites studied: 1) overall species and family numbers, and weight decreased as wave exposure increased, and 2) high abundance values were recorded at intermediate level of exposure. Both findings contrast with some morphodynamic studies where higher species richness and diversity occurred at intermediate levels of energy and abundance generally decreases when exposure increases (HILMAN et al., 1977; DYE et al., 1981; ROMER, 1990; CLARK et al. 1994, 1996; CLARK, 1997).

Bottom morphology not only made comparisons between beaches impossible but could have also exerted major influence on the catches composition. According to Naughton and Saloman's (1978) work at nearshore zones in Florida, USA, deeper areas are associated with larger captures and higher diversity values. Thus, the elevated fish number encountered at Pontal beach may be directly related to trough presence, since less turbulent waters due to high depths could have facilitated the permanence of these fish. The fact that only the number and not fish weight was higher in this beach indicates that contributing species were made up basically by small size fish, such as *H. clupeola, S. brasiliensis* and *A. lyolepis*. These are usually found in shoals which may explain the elevated catch in number, despite the low biomass. Moreover, trough depth may also have contributed to their aggregation. High larval occurrence in surf zones with ridge and runnel system has been investigated by Watt-Pringle and Strydom (2003). They suggested that aggregation behavior would serve as a temporary refugee next to the coast, in which fish would use long shore currents to move without swimming effort and consequently, wasting little energy. This behavior does not occur in the same intensity in high energy surf zones due to the water column agitation, which would result in high energy consumption (BROWN; McLACHLAN, 1990).

The location next to the entrance of Paranaguá Bay estuary may have contributed to the highest value of species and family number, and also the highest catch in weight registered in Estuarina Beach. Besides allowing shoals to remain in calm waters, at Pontal Beach for instance, the steeper submerged profile of Estuarina Beach, conditioned by

Paranaguá Bay drainage channel, could have also permitted the approximation of large species. Fishes such as *C. parallelus, O. saliens, S. timucu* and the heavy *S. testudineus* could raise the total amount of catches in weight at this beach as a consequence.

Robertson and Lenanton (1984) believed that exposed beaches are structurally more homogeneous environment to nektonic organisms. At this study, the segregation of exposed beach samples at MDS and Cluster plots and the significant spatial differences displayed in the ANOVA results pointed to the uniqueness of this beach in relation to ichthyofaunal composition and structure. In addition, a major contributor for that was the great abundances of *M. littoralis* and *T. goodei* when comparing to other beaches, and to a minor proportion of *P. virginicus*. Despite seasonal fluctuations, Village was nearly always the beach with the highest values of evenness index, which shows its structural homogeneity and equalitarian species distribution among the months.

Dexter (1984) found higher faunal similarity coefficients amongst protected beaches when 4 of them, with distinct exposure degree, were studied in Australian sandy beaches. In our work, according to the univariate and multivariate techniques discussed above, a mixture between Pontal and Estuarina samples was observed, probably, reflection of the similar occupation patterns of fishes in response to the similar submerged profiles of high depths. This is in contrast to patterns expected to occur on beaches of distinct energetic features such as the two mentioned above. In agreement with CCA results, there is an environmental alteration across the three studied beaches. Although Pontal and Village were more similar due to their salinity and wave height measurements, the former is closest to axis 2, and thus, less explicable by the factors analyzed. Estuarina, on the other hand, was in an opposite trend and was more related to temperature and wave period. Samples altogether revealed a gradual change related to environmental variables, like an energy gradient. Although wave-energy influence was not tested properly, data variance can largely be explained by the measured variables, demonstrating its susceptibility to short-term changes.

In summary, beach morphodynamic state are reflex of many interacting environmental parameters such as sediment, submerged profile, winds, and tidal regime among others, but only few were analyzed in this work. Possibly depth more than energy accounted for most differences found between these beaches, particularly, to shoaling behavior of certain species. Probably the existence of troughs in Pontal Beach made it more similar to Estuarina. Although these beaches are considered to have completely distinct energy levels, they provided temporary refugees to transient fish species. Integrated studies (planktologic, trophic, behavioral, geomorphologic and chemical studies) are now necessary to understand spatial and temporal species segregation and the many distinct behaviors presented by these species.

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