

Research Article

Spatio-temporal variation in surf zone fish communities at Ilha do Cardoso State Park, São Paulo, Brazil

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ABSTRACT. In order to analyze the time-space variation of the fish fauna in the surf zone fish communities at Ilha do Cardoso State Park, São Paulo, Brazil, four consecutive hauls were done over a year on three beaches with different degrees of exposure, at low and high tide. To evaluate the influence of each abiotic variable over the fish community, a Canonical Correspondence Analysis was conducted. We identified 7,286 individuals belonging to 20 families and 47 species, most specimens collected were juveniles. At low tide, the highest diversity and richness values were calculated while the highest dominance was obtained at high tide. As for the number of species collected at the three beaches, stood out for the lower values the cooler months, between June and September. Abiotic variables explained 41.3% of the variability of biological data, where 11.4% corresponds to the spatial variation. Meanwhile the temporal variables accounted for 31.9% of the variation in abundance, where 26.3% of the variance explained nycthemeral variation. Additionally two groups were clearly observed between months with low and high temperature. However in this variable, the tidal variation, excluding the seasonal effect, explained 6.2%, while seasonality, excluding tide effect, explained 26.3%. Although the main measurable seasonal changes were related to temperature, water temperature showed a low percentage of explanation in the fish fauna variability (2.7%). Finally, it is emphasized that the seasonal changes in surf zone fish community primarily reflect patterns of recruitment determined by the reproductive activity and coastal circulation.

Keywords: ichthyofauna, surf zone, seasonality, environmental variability, southeastern Brazil.

Variación espacio temporal de la ictiofauna del Parque Estatal Ilha do Cardoso, São Paulo, Brasil

RESUMEN. Para analizar la variación espacio-temporal de la ictiofauna en las playas del Parque Estatal Ilha do Cardoso São Paulo-Brasil; se realizaron, durante un año, cuatro muestreos en tres playas con diferentes grados de exposición. Para evaluar la influencia de cada variable abiótica sobre la comunidad íctica, se efectuó un Análisis de Correspondencia Canónica. Se identificaron 7.286 individuos pertenecientes a 20 familias y 47 especies, la mayoría de especímenes colectados fueron juveniles. Durante la marea baja se encontraron los mayores valores de diversidad y riqueza, y durante la marea alta los valores altos fueron los de dominancia. En cuanto al número de especies colectadas en las tres playas, se destacaron por presentar los menores valores los meses más fríos, entre junio y septiembre. Las variables abióticas evaluadas explicaron el 41,3% de la variabilidad de los datos biológicos, donde el 11,4% correspondió a la variación espacial. Por su parte las variables temporales explicaron 31,9% de la variación de la abundancia, donde 26,3% explicó la variación nictimeral. Adicionalmente, se observaron claramente dos grupos entre los meses con temperatura baja y alta. Sin embargo, la temperatura, a pesar de ser significativa, registró un bajo porcentaje de influencia en la variación de la ictiofauna (2,7%). Finalmente, cabe resaltar que los cambios estacionales en la comunidad de peces fueron causados principalmente por los patrones de reclutamiento determinados por las actividades reproductivas y de circulación costera.

Palabras clave: ictiofauna, zona de surf, estacionalidad, variabilidad ambiental, sudeste de Brasil.

INTRODUCTION

Beach surf zones are considered feeding and growth areas for a large number of fish species at juvenile and larval stage due to the turbidity, turbulence and shallowness that characterized this habitat. These same characteristics also inhibit use by large-sized fish, thus offering the young fish protection against predators (Lasiak, 1981; McLachlan *et al.*, 1981; Gaelzer & Zalmon, 2003). Although the primary production “*in situ*” is not high, the tidal effect distributes the nutrients and minerals through the surf zone community (Carter, 1988), favoring the phyto and zooplankton bloom in the surf zone (Spring & Woodbum, 1960; Ferreira *et al.*, 2010). This can be used as food resources for many fish species. Beaches adjacent to estuaries also serve as migration routes for various fish at larval or juvenile stage, that spend one or more stages of their life cycle within estuaries (Cowley *et al.*, 2001; Watt-Pringle & Strydom, 2003).

Various environmental factors influence the surf zone fish community structure. Low diversity and high dominance of a few fish species are explained mainly by the extreme beach hydrodynamics (Clark *et al.*, 1996a, 1997). Most fish species present in such environments are classified as non-resident, and occur in the surf zone only at certain times of the year (Brown & McLachlan, 1990; Félix *et al.*, 2007a), or stages of their life cycle (Modde, 1980; Layman, 2000).

Several fish communities have been described mainly based on the spatio-temporal variations, indicating some patterns: as the level of the beach exposure increases it is observed an increase in dominance and decrease in the fish abundance and richness (Romer, 1990; Teixeira & Almeida, 1998; Félix *et al.*, 2007b; Vasconcellos *et al.*, 2007); and a greater fish diversity and richness during the warmer months (Bennett, 1989; Giannini & Paiva-Filho, 1995; Clark, 1996b; Godefroid *et al.*, 2003; Araújo *et al.*, 2008; Lima & Vieira, 2009).

Studies in Brazilian beaches have mainly examined the structure and spatio-temporal variation on fish communities (Paiva-Filho & Toscano, 1987; Giannini & Paiva-Filho, 1995; Saul & Cunningham, 1995; Gaelzer & Zalmon, 2003; Gomes *et al.*, 2003; Araújo *et al.*, 2008; Oliveira-Silva *et al.*, 2008; Lima & Vieira, 2009), the day and night fish composition and structure variability (Pessanha & Araújo, 2003; Gaelzer & Zalmon, 2008a), the beach dynamics and morphology influence upon fish communities (Félix *et al.*, 2007a; Vasconcellos *et al.*, 2007), the tidal influence (Godefroid *et al.*, 1998; Gaelzer & Zalmon,

2008b; Félix *et al.*, 2010), and the trophic aspects (Stefanoni, 2008).

There are few studies about surf zone fish communities in the São Paulo State coast (Paiva-Filho & Toscano, 1987; Giannini & Paiva-Filho, 1995; Saul & Cunningham, 1995), and none in the State Park. Thus, the objective of this study is to analyze the spatio-temporal variation in abundance and structure of fish communities at Ilha do Cardoso State Park, São Paulo State, Brazil.

MATERIALS AND METHODS

Sampling methods

The beaches studied are located in the Ilha do Cardoso State Park, south of São Paulo coast, Brazil (Fig. 1). They were named as “Sheltered”, “Moderate” and “Exposed”, according to their exposure level. The beach exposure was classified based mainly on their geographical location. Although no studies were found that characterize the morphology of these beaches, it could be observed, during the surveys, that the more into the channel, smaller wave heights and more silty sediments. The slope of the beaches can be used as an index of exposure level, and was calculated from a transect perpendicular to the shore down to 5 m isobath, using the nautical chart number 175.

Fishes were sampled monthly over one year, from February 2009 to January 2010. On each beach and tide, four consecutive hauls, of approximately 30 m each, were made using a beach seine net, 9 m long and 1.5 m height, with a stretched mesh size of 5 mm, totaling 24 fish samples per month. All samples were collected at low and high spring tide. Low tide was sampled at its morning peak while the high tide was usually sampled at the beginning of the afternoon, at a time close to its peak. At the start of the first haul and at the end of the last one, on each beach, the water temperature was measured with a mercury thermometer and the water salinity with a refractometer.

All fish collected were identified following Figueiredo & Menezes (1978, 1980, 2000); Menezes & Figueiredo (1980, 1985) and Richards (2006). Due to the difficulty in identifying juvenile Mugilidae and the lack of adequate bibliography for the specific distinction within this family in Brazilian southeast coast, all mugilids collected were separated based on Vieira (1991). The following nomenclatures were used: *Mugil hospes* (previously *Mugil gaimardianus*), *Mugil liza* (previously *Mugil platanus*) according to Menezes *et al.* (2010), *Mugil* 1 for mugilids that were identified by their anal fin having 13 elements (two

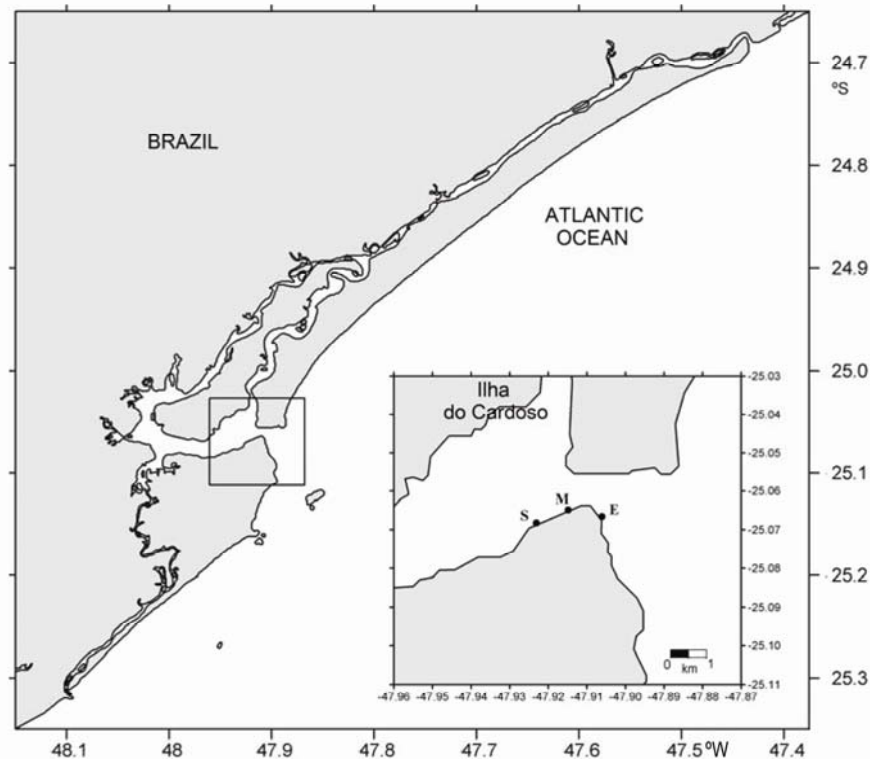


Figure 1. Location of the three sample beaches (S: Sheltered, M: Moderate, E: Exposed) at Ilha do Cardoso State Park, southeast Brazil.

spines and 11 rays) and *Mugil* 2 with two spines and eight rays on the anal fin.

These fish were then measured to the nearest 1 mm (standard length) and weighted (g), except when samples were too large. In these occasions, measurements were restricted to a subsample of 50 individuals per species, done at random. 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 subsample through direct observation, according to Vazzoler (1996) and Dias *et al.* (1998). Juvenile fish were separated from larvae by the presence of scales.

Data analysis

Analysis of variance (one way ANOVA) was used to test the significance differences between the abiotic data of water temperature and salinity, when calculated monthly, per beach and per tide. Tukey post-hoc tests were conducted to evaluate between-mean differences. The analysis of non-metric multidimensional scaling (nMDS) was used to identify possible patterns among samples, in terms of water temperature and salinity. Groupings found were tested by the analysis of similarity (ANOSIM). The abiotic

data was transformed by $\log(x+1)$, and Euclidean distance was used.

Fish numerical abundance was used to calculate ecological indexes: dominance, Shannon diversity, Margalef richness, and evenness according to Begon *et al.* (2006). Only the occurrence constancy (C) was calculated according to Dajoz (1983), who classifies the species as: constant $C \geq 50$, accessory $50 < C > 25$ and accidental $C \leq 25$. The differences among indexes were tested using the Bootstrap method, with 95% confidence.

The influence of each abiotic variable upon the fish community was assessed by Canonic Correspondence Analysis (CCA) (Legendre & Legendre, 1998), and the distribution of the species in relation to the significant abiotic variables was determined by CANOCO. Rare species, those with less than 0.2% relative abundance, were eliminated from the biotic matrix that contained the species numerical abundance in each sample. The abiotic data, after a first analysis using a single matrix, were divided into three matrices: environmental (salinity and temperature), temporal (high tide, low tide and months) and spatio (sheltered, moderate and exposed beach). In all

analyses the biological data were transformed by log (x+1), and low weight was given to rare species. The percentage of explanation of each abiotic variable, their interaction and the non-explainable, was calculated according to Borcard *et al.* (1992).

RESULTS

Environmental data

Water temperature varied over the sampling period following a seasonal pattern. Lowest values occurred between May-October and highest from November to April (Fig. 2a). Water temperature did not change among beaches (Fig. 3a), and among different tides (Fig. 4a). The maximum temperature was 30°C in April and the minimum was 18°C in August.

There was no significant difference among the water salinity over the months (Fig. 2b). The highest water salinity was obtained on the Exposed beach (maximum 36) followed by the moderate and then by the sheltered one (minimum 10) (Fig. 3b). Highest water salinity was measured at high tide (Fig. 4b).

The nMDS analysis enabled the visualization of two abiotic sample groups, being the cooler months correlated positively with the second axis, while those with greater salinity correlated negatively with the first axis (Fig. 5). The ANOSIM routine separated the two groups ($R = 0.63$, $P < 0.0001$).

The beach slope was higher at sheltered (8.2%), than at moderate (5.4%), and exposed (1.9%).

Species composition

A total of 7,286 fish from 20 families and 47 species was collected. The families Mugilidae (37.0%), Carangidae (23.0%), Gerreidae (15.1%), Atherinopsidae (9.3%), Engraulidae (8.3%), Sciaenidae (3.6%) and Clupeidae (2.3%) contributed with 98.6% of total catch. *Mugil curema* (17.6%), Gerreidae larvae (16.7%), *Mugil hospes* (15.7%), *Trachinotus carolinus* (15.5%), *Atherinella brasiliensis* (9.2%) and *Anchoa tricolor* (4.6%) were the six most representative species. A predominance of accidental species occurrence was observed, only *T. carolinus* and *Trachinotus goodei* were classified as constant, and *A. brasiliensis*, *Oligoplites saliens*, *M. hospes*, *Mugil liza*, *M. curema*, *Menticirrhus littoralis*, Engraulidae and Gerreidae larvae were considered as accessory (Table 1).

Total catch weight was 14,727.11 g. Atherinopsidae (35.5%) and Carangidae (32.2%) equaled 67.6% of biomass. *A. brasiliensis* (35.3%), *T. goodei* (11.6%), *O. saliens* (9.5%) and *T. carolinus* (9.1%) were the species with greatest abundance in terms of

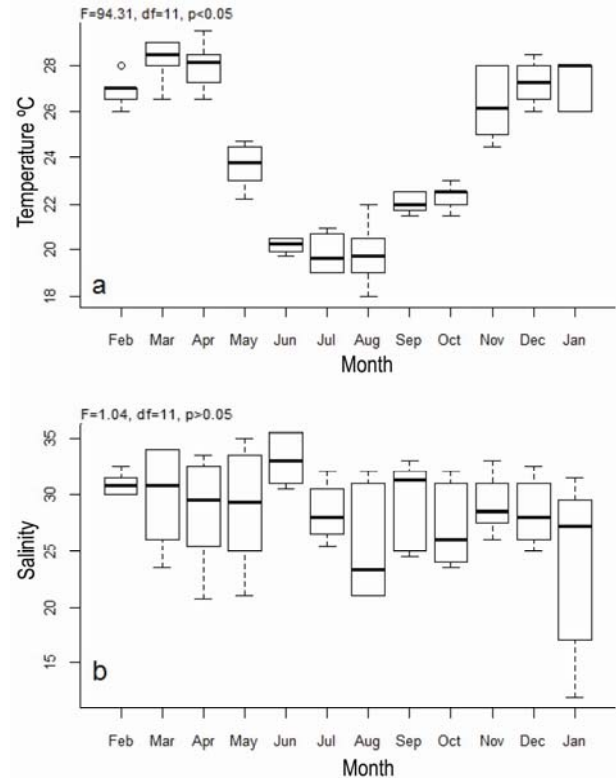


Figure 2. a) Monthly variation of water temperature, and b) water salinity, recorded in the surf zone of Ilha do Cardoso State Park, from February 2009 to January 2010 (Horizontal line: median; box: standard deviation; I: standard error).

biomass. *Strongylura timucu*, *Paralichthys orbignyanus* and *Sphoeroides testudineus* represented the species with greatest standard length. The smaller individuals belonged to *T. carolinus*, *Oligoplites* sp., *M. littoralis* and Gerreidae larvae. Among the specimens with greater range in standard length, more than 100 mm, were *S. timucu*, *T. goodei*, *M. littoralis*, *O. saliens* and *A. brasiliensis*. 78% of the specimens measured between 4 and 60 mm, and the standard length modal class predominance was 21 to 40 mm, totaling 34%.

In most individuals, the sex could not be identified due to their small standard length, or the gonads were not located or were very small, disabling macroscopic classification. These individuals totaled 88.2% of the total sampled, with only 7.8% and 4.0% of females and males, respectively. Among females, there was little presence of mature and spent gonads (5.5% and 1.3% respectively). No hydrated gonad was observed. The immature (39.7%) and maturing (53.4%) stages were the most abundant. Individuals that could not be classified due to their small standard length were considered as immature and/or juvenile.

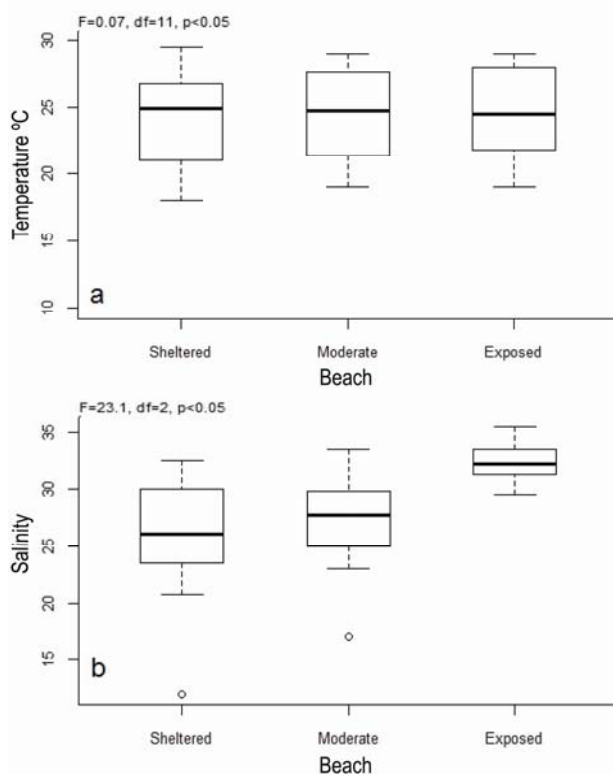


Figure 3. a) Water temperature, and b) water salinity recorded in the surf zone of three different beaches in Ilha do Cardoso State Park (Horizontal line: median; box: standard deviation; I: standard error).

Atherinella brasiliensis was the only species represented by adult (N = 176), juvenile (N = 497) and larvae stage (N = 1). *S. testudineus* and *S. timucu* were represented by adults (N=2) and juveniles (N=9). *P. orbignyana* was represented by a single adult individual. *M. littoralis*, *M. americanus* and the Engraulidae were sampled in their juvenile and larvae stages, while *Porichthys porosissimus*, *Elops saurus*, *Micropogonias furnieri* and all the Gerreidae were collected only in larval stage.

Spatio-temporal variation

Although the greater quantity of specimens was collected on the Exposed beach, it presented the least richness among the beaches (Table 2). There was no significant difference in richness values between the Sheltered and Moderate beaches, but the latter presented the smallest number of individuals obtained. The Moderate beach was more diverse than the Sheltered followed by the Exposed one, which in turn showed the highest dominant values (Table 2). The dominant species at Exposed beach were *M. hospes* and *T. carolinus*. The Gerreidae larvae and *A. brasiliensis* were abundant at the Sheltered beach,

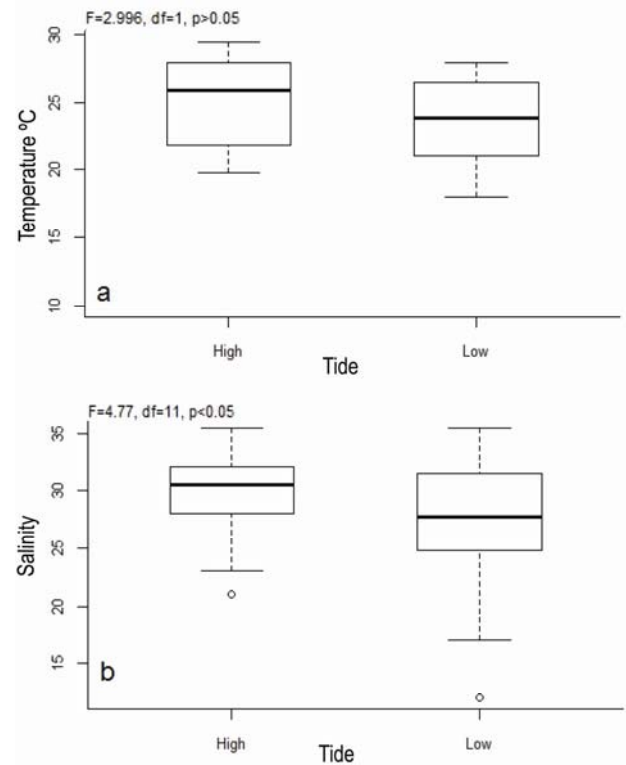


Figure 4. a) Water temperature, and b) water salinity recorded in the surf zone during High and Low tide (Horizontal line: median; box: standard deviation; I: standard error).

while *M. curema* and *T. carolinus* were abundant at the Moderate beach.

Highest diversity and richness values were obtained at low tide, in addition to a greater quantity of individuals. There was no significant difference in the evenness value, and at high tide dominance was greater than at low tide (Table 2). The Gerreidae larvae and *T. carolinus* dominated the sampling during high tide.

The greatest quantity of individuals was collected in months with higher water temperatures. The Margalef richness, Shannon diversity and Pielou's evenness indexes varied similarly, with October being the month with the highest values of the three indexes, in spite of the small quantity of specimens collected at that time. After October, March and January presented high diversity and richness values, while the evenness was followed by May and March. The least rich and diverse months were August, September and November, and the latter had, in addition, the least evenness. November and September showed high dominance due to the large capture of gerreids and *A. brasiliensis*, respectively (Fig. 6).

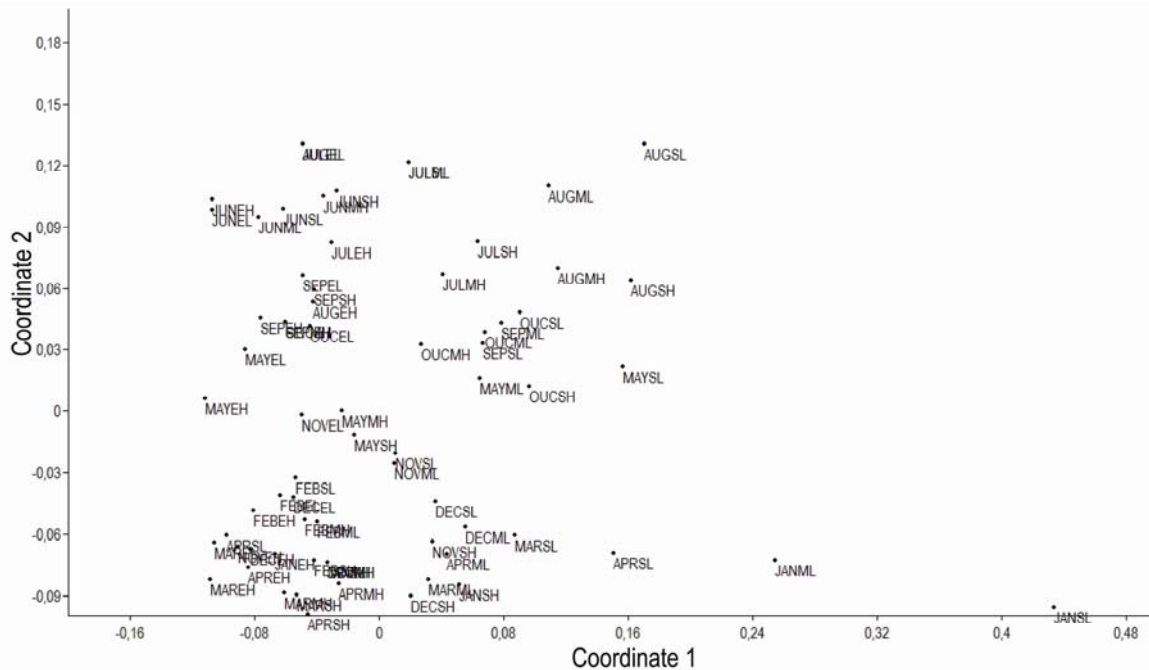


Figure 5. Non-metric multidimensional scaling (MDS) of abiotic samples using the water temperature and water salinity values as attributes. Labels = month + beach (S: Sheltered, M: Moderate, E: Exposed) + tide (H: high, L: Low).

T. carolinus, *T. goodei* and *A. brasiliensis* were collected during the entire year. *O. saliens* only did not occur in August, and *M. littoralis* in February. The Gerreidae larvae and *M. hospes* did not occur during low water temperatures months. Nineteen and nine species occurred, respectively, in only one or two months during the year (Table 1).

The abiotic variables explained 41.3% of the variability on biological data, being only water salinity not significant ($P < 0.05$), by Monte Carlo permutation test. The first two axes were responsible for 54.5% of the biological data variation. The axis 1 was positively correlated with Exposed beach and high tide, and negatively correlated with the sheltered beach. The axis 2 was negatively correlated with water temperature. The species-environment correlation presented high values with the first (0.84) and second (0.82) axis (Table 3). The canonic axes were significantly different by the Monte Carlo permutation test ($F = 3.16$; $P = 0.0001$). Figure 7 represents the distribution of the species in relation to the significant abiotic variables. Water temperature explained 13.93% of biological data variation (sum of all canonic eigenvalues = 0.321). Excluding water temperature influence from the spatio-temporal interaction, the explanation percentage decreased to 2.70%. Gerreidae larvae, *T. carolinus* and *M. hospes* showed preference for warmer waters, while *M. liza* and *A. brasiliensis* preferred cooler waters (Fig. 7).

The different beach types explained 11.41% of biological data variation (sum of all canonic eigenvalues = 0.263). Removing the interaction with temporal variables, the percentage of explanation decreased approximately 1%. The following species were abundant on the most sheltered beach *A. brasiliensis*, *A. tricolor*, *S. timucu*, *A. lepidentostole* and Engraulidae larvae, while *M. hospes*, *T. carolinus*, *T. goodei* and *M. littoralis* were abundant on the most exposed one (Fig. 7).

The temporal variables explained 31.9% of biological data variation (sum of all canonic eigenvalues = 0.734). Two influences were observed on this variable, one related to the different tide amplitudes and the other with the months sampled. Only tidal variation, excluding the seasonal effect, explained 6.1%, while seasonality, without the tidal effect, explained 26.3%. At high tide *T. carolinus* and *M. littoralis* were sampled in abundance, while at low tide *A. tricolor*, *A. brasiliensis* and *S. timucu* were abundant.

DISCUSSION

The fish community studied was characterized by the dominance of few species, a pattern described in several studies on surf zone fish communities (Brown & McLachlan, 1990; Godefroid *et al.*, 2003; Pessanha & Araújo, 2003; Félix *et al.*, 2007b; Stefanoni, 2008).

Table 1. Relative frequency (%), total contribution and occurrence constancy (C) and standard length (SL) of fish sampled in the surf zone of Ilha do Cardoso State Park. *larvae, **larvae and juveniles, ***larvae, juveniles and adults.

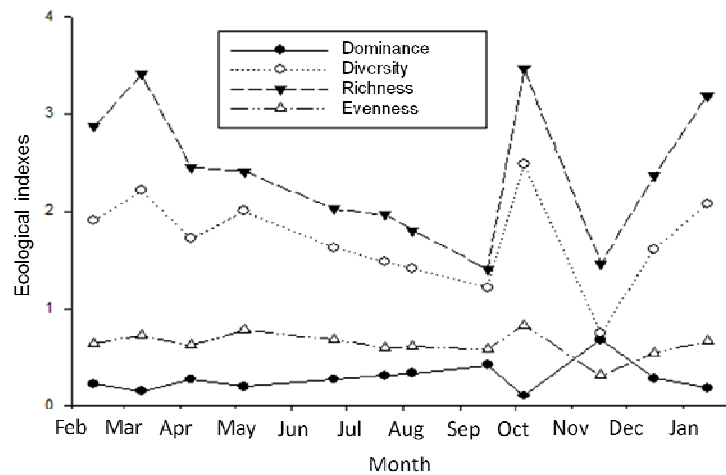
Family/Species	Relative frequency (%)													SL (mm)		
	2009						2010						Total	C	Min	Max
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan				
<i>Elops saurus</i> *	4.1	0.8							3.3	0.3		0.1	0.5	19.7	20	39
<i>Anchoa januaria</i>				0.7						0.2		5.3	0.6	4.2	25	85
<i>Anchoa lyolepis</i>		1.1											0.1	2.8	33	46
<i>Anchoa tricolor</i>	9.3	11.1	0.4		1.4					0.2		31.6	4.6	14.1	26	73
<i>Anchoviella lepidentostole</i>	0.2	1.1		7.7		0.7						2.5	0.3	9.9	23	53
<i>Cetengraulis edentulus</i>												0.7	0.5	4.2	33	73
Non identified larvae	3.7	2.5	4.6	4.8	23.4	1.8	1.4		6.6	3.9		1.0	2.2	36.6	15	53
<i>Lycengraulis grossidens</i>	0.2	0.3											<0.1	2.8	53	74
<i>Clupeidae</i>																
<i>Harengula clupeola</i>	2.4	9.5	2.6	4.1		2.9	24.3	26.5	1.2			1.4	2.2	23.9	25	80
<i>Opisthonema oglinum</i>												0.1	<0.1	2.8	52	54
<i>Platanichthys platana</i>													<0.1	1.4	26	26
<i>Sardinella brasiliensis</i>												0.2	0.1	1.4	40	50
<i>Synodontidae</i>																
<i>Synodus foetens</i>													<0.1	1.4	83	83
<i>Belonidae</i>																
<i>Strongylura marina</i>													<0.1	1.4	119	119
<i>Strongylura timucu</i>	1.1	1.1	0.7							0.4		0.5	0.2	12.7	18.5	460
<i>Batrachoididae</i>																
<i>Porichthys porosissimus</i> *									0.4				<0.1	1.4	16	16

Family/Species	Relative frequency (%)												SL (mm)						
	2009						2010						C	Min	Max				
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan				Total			
Mugilidae																			
<i>Mugil curema</i>	0.7	0.8		2.7	0.7		2.0	7.8	0.2	39.2	1.1	17.6	29.6	14	76				
<i>Mugil hospes</i>	2.2	0.3	1.1	6.8	3.5			0.4		33.1	8.7	15.7	33.8	17	69				
<i>Mugil liza</i>	0.4			0.7	1.4	32.6	8.8	1.4	11.5	1.2	0.1	2.4	32.4	18	26				
<i>Mugil 1</i>	0.2				1.4			0.8		2.5	0.3	1.2	8.5	17	54				
<i>Mugil 2</i>						0.4	0.7					<0.1	2.8	21	22				
Atherinopsidae																			
<i>Atherinella brasiliensis</i> **	3.7	21.4	5.5	8.2	15.6	43.2	50.7	58.5	19.3	1.6	0.3	22.9	9.3	42.3	25	125			
<i>Odontesthes argentinensis</i>				0.2															
Hemiramphidae																			
<i>Hemiramphus</i> spp.	0.2																		
Carangidae																			
<i>Caranx latus</i>		0.8								1.2		0.6	2.8	33	86				
<i>Choloroscombrus chrysurus</i>										5.3		2.3	1.4	22	40				
<i>Oligoplites saliens</i>	2.6	3.3	1.1	4.8	2.8	1.1	2.0	0.4	0.4	2.1	5.0	2.1	33.8	11	127				
<i>Oligoplites</i> spp.		0.3																	
<i>Selene vomer</i>		0.6																	
<i>Trachinotus carolinus</i>	38.2	24.2	24.0	38.1	43.3	4.4	1.4	4.1	13.6	9.9	11.8	13.1	15.5	77.5	4	64			
<i>Trachinotus falcatus</i>	0.6	0.3																	
<i>Trachinotus goodiei</i>	5.4	6.1	5.5	17.7	5.7	1.5	1.4	2.7	10.3	0.4	0.6	0.4	2.3	56.3	16	134			
Syngnathidae																			
<i>Syngnathus folletti</i>											0.1								
Lobotidae																			
<i>Lobotes surinamensis</i>	0.2																		
Gerreidae																			
Non-identified larvae	25.5	13.1	44.7	6.8						1.2	81.6	1.1	16.7	38.0	8	15			

Family/Species	Relative frequency (%)													SL (mm)				
	2009						2010						Total	C	Min	Max		
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan						
Haemulidae														<0.1	1.4	45	46	
<i>Pomadasys corvinaeformis</i>		0.6																
Polynemidae																		
<i>Polydactylus oligodon</i>								0.4										
Sciaenidae																		
<i>Menticirrhus americanus</i> **			0.2					6.2							0.2	4.2	10	16
<i>Menticirrhus littoralis</i> **		0.6	0.4	4.1	0.7	11.0	10.1	2.7	4.9	1.1	0.9	2.3		1.8	26.8	9	126	
<i>Micropogonias furnieri</i> *						0.4									<0.1	1.4	11	11
<i>Umbrina coroides</i>						0.4									<0.1	1.4	32	32
Pomatomidae																		
<i>Pomatomus saltatrix</i>											<0.1				<0.1	1.4	72	72
Paralichthyidae																		
<i>Etropus crossotus</i>	0.2								7.4					0.3	2.8	31	59	
<i>Paralichthys orbignyanus</i>									0.4						<0.1	1.4	242	242
Tetraodontidae																		
<i>Sphoeroides greeleyi</i>									2.9			0.7		0.2	9.9	29	71	
<i>Sphoeroides testudineus</i>			0.2						0.8		<0.1			0.1	5.6	171	199	
Diodontidae																		
<i>Chilomycterus</i> spp.										0.1					<0.1	1.4	25	25
Individuals number	537	359	454	147	141	273	148	147	243	940	3163	734	7286					
Species number	19	21	16	13	11	12	10	8	20	11	20	22	47					
Family number	11	9	9	8	5	7	7	5	12	9	10	11	20					

Table 2. Ecological indexes calculated using fish data collected at different beaches and tides. In indicated the significant differences.

	Beach			Tide	
	Sheltered	Moderate	Exposed	High	Low
Species number	33	34	21	26	43
Individuals number	2036	1985	3265	1245	6041
Dominance	0.22	0.12	0.24	0.20	0.14
Diversity	2.08	2.48	1.69	2.12	2.32
Richness	4.20	4.35	2.47	3.51	4.82
Equitability	0.60	0.70	0.55	0.65	0.62

**Figure 6.** Monthly variation of ecological indexes calculated using the fish data collected in the surf zone of Ilha do Cardoso State Park from February 2009 to January 2010.

Species of *Trachinotus*, *Mugil*, *Atherinella* and *Anchoa* genera were the most abundant. Several studies carried out in the Paranaguá Coastal System at Paraná coast, an ecosystem contiguous to the area of this study, indicated the importance of these genera in structuring the surf zone fish community, even when sampled at different beaches and years (Godefroid *et al.*, 1998, 2003; Spach *et al.*, 2004; Félix *et al.*, 2006, 2007b, Stefanoni, 2008). These genera are also representative on south Brazilian beaches, except for *Anchoa* (Lima & Vieira, 2009). At Rio de Janeiro state coast, it was observed that the relative abundance of Mugilidae decreased (Gaelzer & Zalmon, 2003; Gomes *et al.*, 2003; Pessanha & Araújo, 2003; Vasconcellos, 2007). In a beach in Espírito Santo state, mugilids were not observed and the most abundant species were *Lutjanus synagris*, *Achosargus romboidalis*, *Eucinostomus lefroyi*, *Paralonchurus brasiliensis* (Araújo *et al.*, 2008). On beaches at Todos os Santos Bay, Bahia State, *L. synagris*, *Larimus*

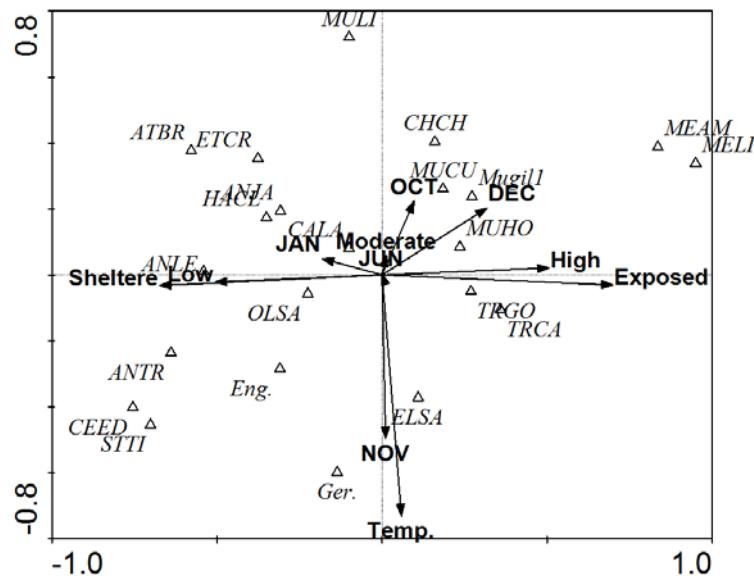
breviceps, *Chaetodipterus faber*, *Polydactylus virginicus*, *Ophioscion punctatissimus* and *Conodon nobilis* were dominant (Oliveira-Silva, 2008). In Pernambuco state, approximately 40% of the total species were represented by *O. punctatissimus* (Lira & Teixeira, 2008).

Thus, it is possible to observe a greater difference in the species composition of the studied beaches than in the ones in Espírito Santo state along the northeast. It is known that the southeast and southern Brazilian coast have subtropical characteristics, and is commonly considered as transition area to a temperate fauna. (Floeter *et al.*, 2006). This fact probably explains the difference of the surf zone ichthyofauna observed in the southeast and southern Brazilian coast compared to the northeast, which has tropical characteristics.

Comparing the surf zone fish composition with the fish species collected in hauls at Cananéia Estuary

Table 3. Summary of the CCA performed on abundance of 22 most numerous fish species.

	Axes			
	1	2	3	4
Correlation of environmental variables				
December	0.3179	0.203	0.6998	0.3057
January	-0.1815	0.0492	0.4429	-0.3217
June	-0.0015	0.0042	-0.0526	-0.0537
November	0.0109	-0.4957	-0.2619	0.3959
October	0.0971	0.2236	-0.254	0.3282
Sheltered beach	-0.6748	-0.0323	-0.1926	0.0562
Moderate beach	0.0129	0.0598	0.236	-0.3381
Exposed beach	0.6995	-0.0305	-0.0512	0.3058
High tide	0.5054	0.0211	-0.3216	-0.4958
Low tide	-0.5054	-0.0211	0.3216	0.4958
Water temperature	0.0583	-0.7298	0.5439	-0.1321
Summary statistics for ordination axes				
Eigenvalues	0.31	0.208	0.15	0.113
Species-environment correlations	0.839	0.822	0.861	0.79
Cumulative percentage variance:				
of species data	13.5	22.5	29	33.9
of species-environment relation	32.6	54.5	70.2	82.1
Sum of all eigenvalues				2.304
Sum of all canonical eigenvalues				0.952

**Figure 7.** Ordination diagram (biplot) from CCA including fish species and significant environmental variables (represented by vectors). Species coded by the first two letters of genus and the species scientific name (e.g. TRCA= *Trachinotus carolinus*).

Complex and in beaches at Bom Abrigo Island, located on the platform adjacent to the estuary (Zani-Teixeira, 1983; Saul & Cunningham, 1995; Maciel, 2001), it is possible to notice that a low number of species were exclusive to the studied beaches, indicating connectivity of the surf zone fish community with other habitats, both inside and outside the Cananéia-Iguape Coastal System.

The great abundance of sampled specimens at juvenile and larval stages corroborated the importance of the studied area for the initial ontogenetic stages. Godefroid *et al.* (2003), Félix *et al.* (2007a), Inoue *et al.* (2008) and Stefanoni (2008) also reported a high proportion of juvenile and/or larval individuals in surf zone fish communities.

The beach exposure is considered one of the main surf zone fish community structuring factors (Romer, 1990; Clark, 1996b; Gaelzer & Zalmon, 2003; Vasconcellos *et al.*, 2007). However, the beach exposure influence on fish community composition may be misunderstood, mainly due to the interconnection between this variable and others, such as macroalgae abundance and/or organic matter decomposing, water salinity and water transparency (Clark, 1997). In the present study, the beach exposure explained only 11.41% of biological data variation.

In several studies there was an increase in the species richness and diversity as the beach shelter increased, while the most exposed beaches were dominated by few species (Romer, 1990; Gaelzer & Zalmon, 2003; Vasconcellos *et al.*, 2007). This pattern was also observed in the present study, but, as in Stefanoni (2008), the study area may not have been appropriate to test this hypothesis because there were interactions with other variables related to the estuary presence. Beaches considered as Sheltered and Moderate in the present study were influenced by estuary waters, while the Exposed beach had marine waters influence. The greater species richness and fish diversity on sheltered beaches may be due to the greater food availability and accessibility compared to more exposed beaches. The turbulence generated by waves may reduce the food ingestion rate due to the continuous need to adjust the body position in the water column and a decrease of the visual field (Clark, 1997).

T. goodei and *M. littoralis* were associated with the high energy environments where the greatest salinity was registered as a reflex of greater exposure. This was also observed by Félix *et al.* (2007a), Vasconcellos *et al.* (2007) and Stefanoni (2008). Water salinity can be a structuring factor in estuaries (Barletta *et al.*, 2005), but at exposed beaches this factor does not satisfactorily explain the biological

data variability. The species that are correlated with the more protected beaches were also associated with estuary regions (Zani-Teixeira, 1983; Maciel, 2001; Peres-Rios, 2001; Ramos & Vieira, 2001).

The highest water salinity measured at high tide probably was due to the fact that, at low tide, the beaches suffered greater influence from inland waters.

Temporal variations had the greatest influence on fish community composition and structuring by approximately 30%. Within the temporal variations, a small relevance was due to tidal variation, with seasonal variation the most important variable. Although the main seasonal alterations measured were related to water temperature, this variable alone showed a low percentage of explained biological data variation. Thus, it is emphasized that, as already reported by Ross *et al.* (1987) and Félix *et al.* (2007a), seasonal changes in the surf zone fish community are mainly due to recruitment patterns determined by reproductive activity and coastal circulation. As in the present study, several studies as Bennett (1989), Giannini & Paiva-Filho (1995), Clark (1996b), Godefroid *et al.* (2003); Félix *et al.* (2006) and Araújo *et al.* (2008), reported the highest diversities and abundance values during warmer months, coinciding with the reproductive period of many fish species. High water temperatures also favor phytoplankton and zooplankton bloom, increasing the food available for larvae and juvenile fish, and consequently, their chances of survival (Nybakken & Bertness, 2004).

However, a problem concerning fish population studies on dynamic and fish reproductive aspects is the sampling frequency. Thus, relating warmer months (end of spring or summer) and capture of juvenile specimens in the same period is not very enlightening. The fish length and their growth rate should be investigated and related with the hatching period and not with the reproductive period. Studies on growth rates of the most abundant surf zone species were not available, and therefore might restrict interpretation of the results.

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