Spatial, temporal and diel variations of fish assemblages at two sandy beaches in the Sepetiba Bay, Rio de Janeiro, Brazil

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Abstract

Fish assemblages from two beaches, one in the inner and the other in the outer Sepetiba Bay (latitude: 22°54′–23°04′S; longitude: 43°34′–44°10′W), Southeast Brazil, were sampled by beach seine net, simultaneously, on both seasonal and diel scales, between August 1998 and June 1999. Sites were selected to encompass different environmental conditions which reflect the two bay zones, thus providing a comprehensive assessment of the factors influencing surf zone fish assemblages, and their spatial, seasonal and diel variations. A total of 55 fish species was recorded, mostly young-of-the-year. *Anchoa tricolor*, *Micropogonias furnieri*, *Gerres aprion*, *Diapterus rhombeus*, *Harengula clupeola*, *Atherinella brasiliensis* and *Mugil liza* were numerically dominant and contributed to 95.2% of the total fish catches. Strong differences in fish assemblages were observed between the two areas, with higher number of species in the outer bay. Increases in fish numbers occurred in winter, while the highest biomass occurred in winter and summer. Transparency, followed by salinity, was responsible for most of the spatial variability and played an important role in structuring fish assemblages. Overall, diel patterns did not reveal any significant trends; however, if we consider each season separately, an increase in fish numbers during the day with peak at sunset was observed in winter, and a higher biomass occurred at night in winter and summer. Species preferences for various combinations of environmental variables are responsible for shifts in the structure and overall abundance of assemblages and dictated some patterns. The sciaenid *M. furnieri*, the second most abundant species, occurred only in the inner zone, being more abundant in winter. The species of Engraulidae were more abundant in the outer zone in winter/ spring during the day. The gerreids *G. aprion* and *D. rhombeus* occurred mainly in summer. Overall, temporal fluctuations act more at a specific level than at a structural one, and may be linked to some particular stages of the fish life cycle, but do not significantly influence the spatial organization.
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1. Introduction

Surf zones are physically dynamic environments, with little habitat complexity. They are dominated by a small number of fish species, mostly juveniles that use these areas for feeding and protection from predation (Blaber & Blaber, 1980; Lasiak, 1984a; Whitfield, 1996). The high proportion of juvenile fish suggests that sandy beaches provide an important alternative nursery habitat to estuaries for many species (Brown & McLachlan,

1990). The utilization of the surf zones by large numbers of juvenile fish is almost certainly due to the presence of rich food resources in the form of zooplankton and the protection from predation provided by the shallowness, turbidity and turbulence of these areas (Lasiak, 1986). However, the spatial and temporal instability of surf zones, which results from variable physical features such as wind and wave exposure, produces a dynamic fish assemblage (Romer, 1990). Furthermore, habitats themselves do not remain constant but vary regularly on a daily and seasonal basis. Species inhabiting shoreline regions employ numerous strategies, mainly associated with feeding and the avoidance of adverse physiochemical conditions and predators, leading to complex tidal

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and diel movements (Burrows, Gibson, Robb, & Commely, 1994).

Studies on the use of beaches by fish communities in the tropics are rather scarce, and little attention has been devoted to spatial, seasonal and daily environmental cycle influences. However, some studies of these environments included those in Terminos Lagoon, Mexico (Yáñez-Arancibia & Lara-Dominguez, 1983), where diel variations in fish density and biomass are probably related to specific trophic behavior (night or day feeding activity), reflecting a daily and seasonal succession of dominant fish. Lasiak (1984b) has found in the Algoa Bay (South Africa) that the lack of seasonality in the community parameters may reflect short-term variability masking seasonal perturbations, and that high variation of dominant component of the fish assemblage indicated instability in the community structure. Quinn and Kojis (1987) have reported that more species were caught per trawl at night than during the day in the Labu Estuary (Papua New Guinea) and that the greatest number of species, individual and biomass were caught just after dusk.

In Brazil only a few works have focused on this theme. Godefroid, Hofstaetter, and Spach (1998) found that eight fish species in the Pontal do Sul beach were influenced singly or in combination by factors such as moonlight, day/night period and tide. The succession of the days and nights produces oscillation in most of the environmental factors and determines strong influences on the relative abundance of most species, altering composition and dynamics of the fish assemblages (Clark, Bennett, & Lamberth, 1996). Blaber, Brewer, and Salini (1995) reported that water turbidity, tidal range, wind and day versus night were the only abiotic factors that correlated with the relative abundances of some fish species and that inshore zone acts as the first nursery ground for at least 11 species whose adults live mainly offshore.

Bays normally present a variety of habitats at shoreline, which define the type of fish assemblages that inhabit these areas, and variations among sites inside a bay are greater than variations among different bays in tropical zones. The changing features of these habitats and the mobility of juvenile fish greatly influence the composition of the fish assemblages. Changes in certain physical variables such as the degree of wave exposure, sediment particle size and turbidity have a strong influence on the relative abundance of certain species and may alter the composition and species richness of surf zone fish assemblages (Hillman, Davis, & Wennemer, 1977).

Sepetiba Bay (latitude: 22°54′–23°04′S; longitude: 43°34′–44°10′W) is a 520 km² sedimentary embayment in the southeastern Brazilian coast, with a wide opening to the sea in Rio de Janeiro State, Brazil (Fiszman, Pfeifer, & Lacerda, 1984), which plays an important role in the ecology of nearby coastal fish populations. Its 55 beaches along the continental margin provide shelter to several marine species that use these areas in the early life cycle (Araújo, Cruz-Filho, Azevedo, Santos, & Fernandes, 1997). In the last decades, the bay has been suffering an increasing degradation process due to industrial outflows and municipal effluents brought into the bay by rivers and drainage channels in the outskirts of Rio de Janeiro city. Its shoreline is characterized by several small beaches and a few estuarine zones (Fig. 1).

The bay can be divided into two zones according to environmental characteristics. The inner zone suffers more influences of human activities due to the proximity of very populated area. It is also influenced by discharges from perennial small rivers that contribute to decrease in water quality, showing increased turbidity and temperature, and decreased salinity. Substrate is mainly muddy, with depth mostly lower than 5 m, and salinity averaging 28 (Cruz Filho, Araújo, Azevedo, Santos, & de, 2000). The outer zone, nearer to the sea, presents an opposite situation for these environmental conditions, showing substrate mainly sandy, and comparatively lower temperature and higher salinity and transparency. Maximum depth in the outer bay is approximately 28 m, and salinity average is 33 (Cruz Filho et al., 2000). Furthermore, the outer zone is bounded by several islands in the west part of the bay. Tidal currents in the area are generally insignificant; predominantly currents northeasterly and southwesterly winds activate thermal currents between the bay and the ocean (Araújo et al., 1997). Two beaches were chosen to be compared in this study, due to differences in environmental conditions: Itacuruçá Beach located in outer zone and Sepetiba Beach located in inner zone. These two beaches were not intended to represent the full range of habitats available within the bay, but to provide comparable inner and outer zones.

The objective of this study is to investigate the influences of abiotic factors on species composition and to assess the importance of Sepetiba Bay as a nursery area. Fish were sampled from two beaches throughout the 24-h period in four seasons, using the same fishing effort were analyzed. Diel, spatial and seasonal fish assemblages were compared. The aims are to test the null hypotheses that no significant differences in fish assemblages exist between: (1) inner/outer bay zones, (2) seasons and (3) day/night period.

2. Materials and methods

2.1. Field sampling

The surveys were carried out in August 1998, November 1998, February 1999 and June 1999 to ensure that samples were obtained in each season, e.g.
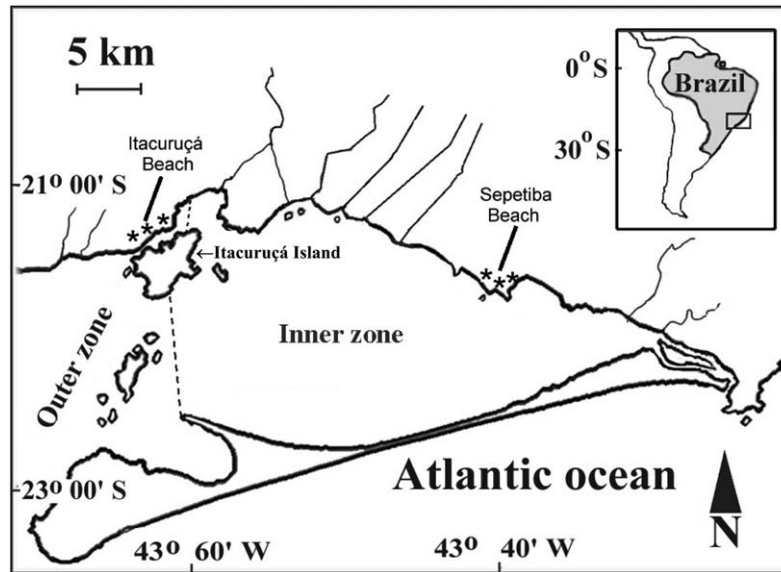
Fig. 1. Sepetiba Bay, Rio de Janeiro, Brazil, with indications of the two sampling sites: 1, Itacuruçá Beach (outer zone) and 2, Sepetiba Beach (inner zone).

winter, spring, summer and autumn. The soft-bottom fish assemblages were sampled using a beach seine net (10 m × 2.5 m; 7 mm mesh size). Seine hauls were 30 m long, parallel to and closing to shore, and were taken out to approximately 1 m depth. This procedure was replicated three times at each 3-h interval throughout the 24-h period. Samples were taken simultaneously at the two sites, Itacuruçá (outer bay) and Sepetiba (inner bay) Beaches, in the following period: 8, 11, 14 and 17 h (day period); and 20, 23, 2 and 5 h (night period). This design resulted in a total of 192 samples: two sites, 8 h-period, three replicates and four seasons. Water temperature, salinity and transparency were taken at every sampling occasion at approximately 0.5 m below surface water. Temperature and salinity were measured with a Horiba U-10 internally recording temperature–salinity recorder. A Sechi disc was used to measure water transparency. Tidal height was determined for each sampling occasion from tidal tables published by Brazilian Navy Hydrographer. Fish were fixed in 10% formalin, identified to species, counted, measured (total length in millimeters) and weighed in grams.

2.2. Data analysis

Logarithmic transformations ($\log_{10}(x + 1)$) of both environmental variables and fish abundance (number and weight) data were performed to meet assumptions of normality and homocedasticity for statistical tests and to reduce the bias of abundant species. Analyses of variance (ANOVA) were used for spatial, seasonal and diel comparisons among fish abundance and environmental variables. An a posteriori comparison of means was performed using the Tukey test. Principal compo-

nents analysis (PCA) was applied on environmental parameters and species abundance. A bi-plot of components' scores and factor loads was performed to detect patterns. Canonical correspondence analysis (CCA) was used to assess environmental influences on fish assemblages. Rare species, e.g. those that constituted a low percentage of the fish assemblage (<0.1% of the total number) were not considered in the multivariate analyses. Rare species increase noise and only affect the total variation expressed by the eigenvalues, but also did not change the interpretation (Araújo, Bailey, & Williams, 1999).

3. Results

3.1. Environmental parameters

3.1.1. Temperature

Seasonal average values ranged from 21.2 to 30.3 °C. Sepetiba Beach (inner zone) presented higher temperatures ($F = 6.21$; $P = 0.013512$) compared to Itacuruçá Beach (outer zone). Significant differences were also detected for each beach among seasons ($F = 111.41$; $P = 0.000001$), with highest values being recorded in spring/summer and lowest values in autumn (Table 1). Lowest averages were shown before dawn (2–5 h), and peaks in the first hours after noon (14 h), then decreasing throughout twilight and during the night, but no significant differences ($F = 9.49$; $P = 0.236798$) were shown.

3.1.2. Salinity

Seasonal average values ranged from 22.5 to 35.7. Itacuruçá Beach (outer zone) showed higher salinity

Table 1
Mean ± 1 standard error for environmental variables at the two sites in Sepetiba Bay

	Itacuruçá Beach				Sepetiba Beach			
	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut
Temperature (°C)								
Day	23.6 ± 0.1	25.5 ± 0.4	30.3 ± 0.1	21.7 ± 0.1	26.4 ± 0.63	30.0 ± 1.3	27.9 ± 0.4	23.7 ± 0.2
Night	22.8 ± 0.1	24.9 ± 0.1	29.4 ± 0.1	21.2 ± 0.1	22.6 ± 0.32	28.0 ± 0.6	27.8 ± 0.1	22.3 ± 0.3
Salinity								
Day	33.5 ± 0.5	31.8 ± 0.2	29.6 ± 0.2	27.5 ± 0.9	22.5 ± 0.9	25.5 ± 0.5	24.5 ± 0.4	28.7 ± 0.5
Night	35.7 ± 0.3	30.7 ± 0.3	29.8 ± 0.2	27.5 ± 0.15	27 ± 0.3	24.2 ± 0.7	25 ± 0.0	28.7 ± 0.6
Transparency (m)								
Day	0.6 ± 0.21	0.9 ± 0.2	0.9 ± 0.1	0.75 ± 0.25	0.1 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	0.1 ± 0.1

Seasons: Win, winter; Spr, spring; Sum, summer; Aut, autumn.

($F = 148.54$; $P = 0.000001$) compared to Sepetiba Beach (inner zone). No significant differences were shown among seasons ($F = 2.34$; $P = 0.074509$), although some trends could be discernible for each site; the highest values occurred in winter and the lowest in autumn at Itacuruçá, while the highest values were recorded in autumn and lowest in winter at Sepetiba (Table 1). Salinity was stable over the diel cycle and no significant differences were shown ($F = 0.231$; $P = 0.630988$).

3.1.3. Transparency

Seasonal average values ranged from 0.1 to 0.9 m (Table 1). Itacuruçá Beach (outer zone) showed higher transparency ($F = 157.64$; $P = 0.000001$) compared to Sepetiba Beach (inner zone). No significant difference was detected among seasons.

3.1.4. Tide

Tide in Sepetiba Bay is semi-diurnal, ranging from 0.2 to 1.4 m during the study period. There are not detectable differences in the tide position between the two sites due to its proximity (25 km far apart) along the coastline.

PCA revealed two components obtained by the analysis of the five environmental variables (day/night, temperature, salinity, transparency and tide position), with eigenvalues exceeding 1.0 and explaining 63.8% of the total variance. Component I (Env I) presented high positive weight for salinity and transparency, and high negative weight for day/night period, explaining 38.4% of the total variance. Component II (Env II) presented high positive weight for day/night period, and high negative weight for salinity and temperature, explaining 25.4% of the total variance. The resulting diagram from Components I and II (Fig. 2) separated the two sites along the axis I, with Itacuruçá Beach (outer zone) samples on the right side, presenting higher transparency and salinity, while Sepetiba Beach (inner zone) samples on the left side, presenting the opposite situation (Fig. 2).

3.2. Spatial and temporal variation

A total of 48,768 fish from 55 species representing 26 families were collected in 192 beach-seine hauls made at Itacuruçá and Sepetiba Beaches, during the quarterly 24-h sampling program carried out between August 1998 and June 1999 (Table 2). Most fish were juveniles, mainly young-of-the-year, amounting a total weight of 21,500 g. *Anchoa tricolor*, *Micropogonias furnieri*, *Gerres aprion*, *Diapterus rhombeus*, *Harengula clupeola*, *Atherinella brasiliensis* and *Mugil liza* were the seven most abundant species accounting for 95.2% of the total number (Table 2).

Species composition varied spatially with the most abundant species shifting in rank depending on the site: *A. tricolor*, *G. aprion*, *H. clupeola*, *A. brasilliensis*, *M. liza* and *D. rhombeus* were the most numerically abundant fish at Itacuruçá Beach; *M. furnieri* occurred only at Sepetiba Beach, and was also the most abundant species at that site. *M. furnieri*, *D. rhombeus*, *G. aprion*, *H. clupeola*, *M. liza*, *A. tricolor* and *A. brasiliensis* were the most numerically abundant species
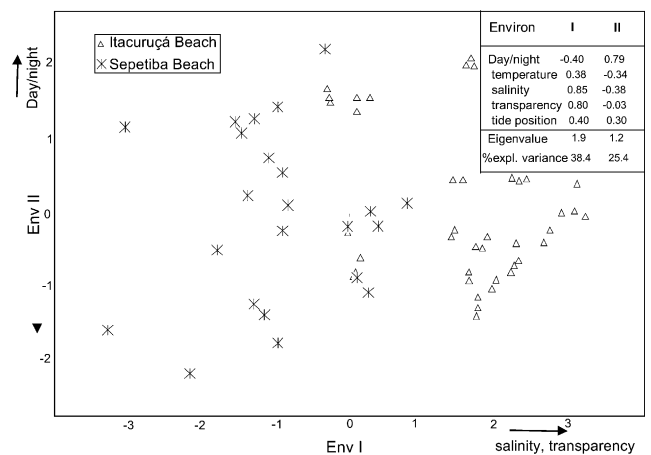

Fig. 2. Ordination diagram for the two first principal components on environmental variables (Env I and Env II), coded by sampling sites in the Sepetiba Bay.

Table 2
Total length, total number (N), biomass (g) and frequency of occurrence (FO) of fish species at Itacuruçá (IT) and Sepetiba (SE) Beaches—Sepetiba Bay, Rio de Janiero

Species	Total length (mm)		Abundance relative (N)			Biomass (g)			FO
	Max	Min	Itacuruçá	Sepetiba	%N (IT + SE)	Itacuruçá	Sepetiba	%g (IT + SE)	%
Anchoa tricolor	110	11	15,721	688	33.64	1211.58	48.24	5.86	26.04
Micropogonias furnieri	69	14	0	13,083	26.79	0	6135.15	28.49	23.96
Gerres aprion	134	8	3830	2427	12.85	3324.19	633.49	18.46	54.16
Diapterus rhombeus	137	15	500	4282	9.81	502.65	1441.09	9.04	20.83
Harengula clupeola	88	18	2281	1680	8.12	1485.83	266.98	8.15	23.43
Mugil liza	108	15	529	1004	3.10	387.21	567.85	4.44	37.50
Atherinella brasiliensis	129	18	710	190	1.80	1164.70	47.40	5.63	31.25
Anchoa januaria	79	26	249	173	0.86	119.24	149.45	1.24	6.77
Sphoeroides testudineus	140	10	308	4	0.64	853.76	4.20	3.99	22.91
Citharichthys spilopterus	162	13	257	7	0.54	961.71	2.40	4.48	28.64
Sphoeroides greeleyi	83	18	154	0	0.31	363.19	0	1.69	17.71
Monacanthus ciliatus	60	12	131	4	0.27	111.74	1.16	0.52	22.92
Mugil platanus	107	26	16	78	0.19	128.79	33.12	0.75	6.77
Orthopristis ruber	215	34	2	51	0.11	30.6	148.66	0.83	5.21
Citharichthys arenaceus	137	17	46	0	<0.1	210.33	0	0.97	9.37
Cynoscion leiarchus	145	15	0	40	<0.1	0	181.60	0.18	8.85
Menticirrhus americanus	71	21	0	34	<0.1	0	21.59	0.10	8.85
Synodus foetens	85	48	33	0	<0.1	80.44	0	0.37	10.93
Trachinotus carolinus	33	20	10	20	<0.1	3	3.40	<0.1	5.20
Oligoplites saurus	83	24	15	13	<0.1	24.55	9.91	0.16	8.40
Anchoa lyolepis	72	32	22	4	<0.1	8.15	11.8	<0.1	2.61
Gobionellus boleosoma	45	15	15	5	<0.1	2.77	2.0	<0.1	8.85
Prionotus punctatus	215	45	15	0	<0.1	258.18	0	1.20	6.25
Trachinotus falcatus	69	21	10	3	<0.1	26.14	0.56	0.12	4.17
Achirus lineatus	56	21	12	1	<0.1	19.80	0.20	<0.1	5.20
Fistularia petimba	415	210	11	0	<0.1	83.54	0	0.39	4.68
Cetengraulis edentulus	68	27	1	9	<0.1	0.18	4.80	<0.1	2.10
Elops saurus	32	15	0	9	<0.1	0	0.33	<0.1	1.56
Bathygobius soporator	128	60	6	2	<0.1	60.7	0.90	0.29	3.65
Chaetodipterus faber	62	22	8	0	<0.1	18.92	0	<0.1	3.65
Chloroscombrus chrysurus	55	12	2	5	<0.1	0.10	8.40	<0.1	2.08
Gerres gula	113	72	5	0	<0.1	45.80	0	0.21	2.08
Lutjanus synagris	66	49	5	0	<0.1	10	0	<0.1	2.08
Syngnathus folletti	180	92	5	0	<0.1	6.88	0	<0.1	2.08
Diplectrum radiale	113	51	2	2	<0.1	29.80	4.45	0.10	2.08
Strongylura timucu	214	160	4	0	<0.1	26.90	0	0.12	1.56
Gerres melanopterus	49	47	3	1	<0.1	2.30	0.21	<0.1	2.08
Genidens genidens	247	71	0	3	<0.1	0	181.60	0.80	1.04
Symphurus tessellatus	172	33	2	1	<0.1	36.70	0.20	0.17	1.56
Oligoplites palometa	40	26	1	2	<0.1	0.50	2.11	<0.1	1.50
Haemulon steindachneri	125	105	2	0	<0.1	35.46	0	0.16	0.50
Paralichthys brasiliensis	111	20	2	30	<0.1	12.51	0	<0.1	1.04
Hemiramphus brasiliensis	142	131	0	2	<0.1	0	10.90	<0.1	0.50
Menticirrhus littoralis	43	40	1	1	<0.1	0.50	2.40	<0.1	1.04
Gobionellus stigmaticus	43	28	2	0	<0.1	0.45	0	<0.1	1.04
Gerres lefroyi	24	20	2	0	<0.1	0.40	0	<0.1	0.50
Paralonchurus brasiliensis	24	19	0	2	<0.1	0	0.10	<0.1	0.50
Fistularia tabacaria	453	–	1	0	<0.1	36.0	0	0.16	0.50
Etropus crossotus	115	–	1	0	<0.1	15.90	0	<0.1	0.50
Acanthistius brasilianus	56	–	1	0	<0.1	2.50	0	<0.1	0.50
Paralichthys orbignyanus	84	–	1	0	<0.1	6.50	0	<0.1	0.50
Selene setapinnis	15	–	0	1	<0.1	0	1.80	<0.1	0.50
Lycengraulis grossidens	69	–	0	1	<0.1	0	1.69	<0.1	0.50
Syacium papillosum	16	–	1	0	<0.1	0.10	0	<0.1	0.50
Dactyloscopus crossotus	29	–	1	0	<0.1	0.06	0	<0.1	0.50
Total			48,768			21,500.38			

% Is the percentage of the total abundance at Itacuruçá and Sepetiba Beaches pooled.

at Sepetiba Beach. Itacuruçá Beach showed greater abundance and species richness than Sepetiba Beach, with 46 species, from which 19 were recorded only at this site. Sepetiba Beach had 36 species, with only nine species being recorded only at this site. The species recorded only at one site, with exception of *M. furnieri*, showed minor contribution to the total number of fish.

Spatial comparisons revealed that overall number of individuals ($F = 0.36$; $P = 0.547956$) did not change between the two sites, but the number of species ($F = 9.02$; $P = 0.000278$) and biomass ($F = 10.64$; $P = 0.000061$) were significantly higher at Itacuruçá than at Sepetiba Beach, although some shifts in this pattern can be shown depending on the season (Fig. 3). Significant differences were recorded for the number of individuals ($F = 5.65$; $P = 0.000025$), number of species ($F = 5.46$; $P = 0.000006$) and biomass ($F = 5.10$; $P = 0.000001$) among seasons. Number of individuals was higher in winter at both sites, and lowest in autumn at Itacuruçá and in spring at Sepetiba. Number of species increased from winter to summer reaching peaks in this latter season and lowering in autumn at Itacuruçá; no seasonal change was detected at Sepetiba. Biomass was higher in winter at Itacuruçá, and in summer at Sepetiba; both sites showed lowest biomass in spring and autumn.

3.3. Diurnal variation

No clear diel pattern for the number of individuals was detected according to ANOVA, but some trends were observed for a particular season. In winter and spring, higher average values were recorded during the day than at night for Itacuruçá; the highest number of individuals at Itacuruçá and Sepetiba occurred late afternoon (17 h) in winter. In summer and autumn, when overall abundance decreased, no diel variation in fish density was recorded for both sites ($F = 3.12$; $P = 0.078774$). Higher fish density occurred during the night in summer at Sepetiba (Fig. 4).

The number of species did not show a diel pattern for both sites during the study period, although some changes could be shown depending on the season. The number of species was relatively stable over the seasons but decreased in autumn ($F = 0.42$; $P = 0.514958$), and did not vary daily at Itacuruçá. Highest number of species was recorded during the day in winter and spring at Sepetiba (Fig. 5) decreasing at dusk and reaching the lowest values at 23 h. Twelve species were recorded only during the day: *Fistularia tabacaria*, *Strongylura timucu*, *Lutjanus synagris*, *Gerres lefroyi*, *Dactyloscopus crossotus*, *Paralichthys orbignyanus*, *Gerres melanopterus*, *Oligoplites palometa*, *Paralonchurus brasiliensis*, *Hemiramphus brasiliensis*, *Paralichthys brasiliensis*, *Lycengraulis grossidens* and *Selene setapinnis*; and four species were captured only at night: *Acanthistius brasilianus*, *Haemulon steindachneri*, *Etropus crossotus* and *Syacium papillosum*.
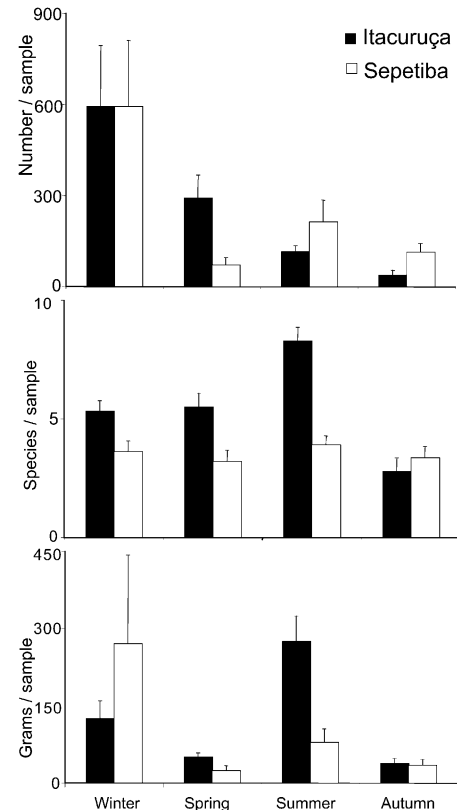

Fig. 3. Seasonal and spatial variation of number of individuals, number of species and biomass (means + 1 standard error) at Itacuruçá and Sepetiba beaches—Sepetiba Bay.

Biomass was slightly higher during the night in winter and summer for both sites (Fig. 6). The higher number of individuals in winter during the day at Itacuruçá (Fig. 4) does not match biomass because the fish assemblage in winter was dominated by anchovies, which do not contribute much to weight (Fig. 6; Table 2). On the other hand, the highest weight at night in winter and summer ($F = 0.05$; $P = 0.821663$) was due to higher contribution of *G. aprion* and *D. rhombeus* (Fig. 6; Table 2).

3.4. Fish assemblages

PCA on abundance of the 14 most numerous species yielded five axes with eigenvalues exceeding 1.0, and explaining 55% of the total variance. Component I (SP I) explained 18% of the variance and was significantly correlated with *G. aprion*, *Sphoeroides testudineus*, *Monacanthus ciliatus* and *Sphoeroides greeleyi*. Component II (SP II) accounted for 10% of the total variance and was negatively correlated with *Mugil platanus*, *M. furnieri* and *Orthopristis ruber*. A spatial separation in the sample sites resulted from ordination diagram, which separated on the right side samples from Itacuruçá, in opposition to samples from Sepetiba on the left side (Fig. 7). Species which were characteristic of
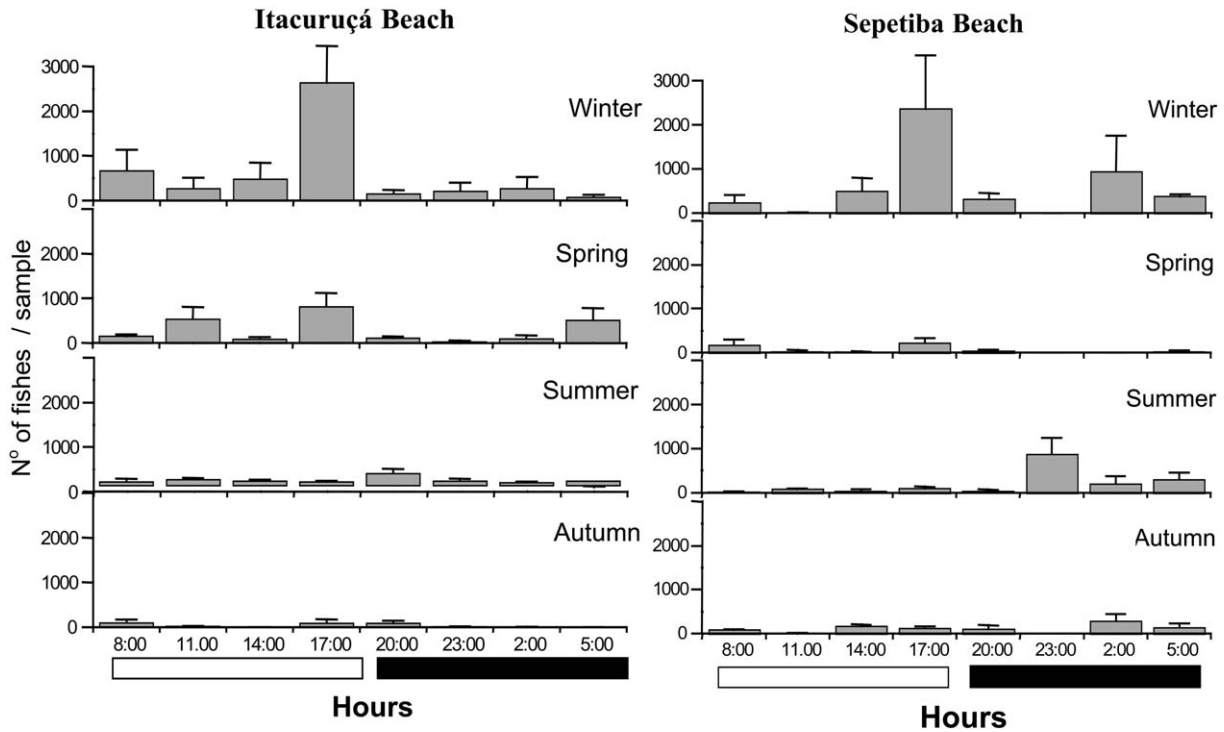
Fig. 4. Diel variation in the number of individuals (means ± 1 standard error) at Itacuruçá and Sepetiba Beaches—Sepetiba Bay. □ Daylight hours, ■ darkness hours.

the inner zone (Sepetiba) included *M. furnieri*, *O. ruber*, *M. liza*, *D. rhombeus* and *M. platanus*, while species characteristic of the outer zone (Itacuruçá) included *A. tricolor*, *H. clupeola*, *A. brasiliensis*. *Citharichthys spilopterus*, *Anchoa januaria*, *M. ciliatus*, *S. greeleyi*, *S. testudineus* and *G. aprion* (Table 2).

3.5. Influence of environmental variables on fish abundance

The CCA revealed that the most significant environmental variables related to fish abundance were transparency and salinity. Correlations between species and
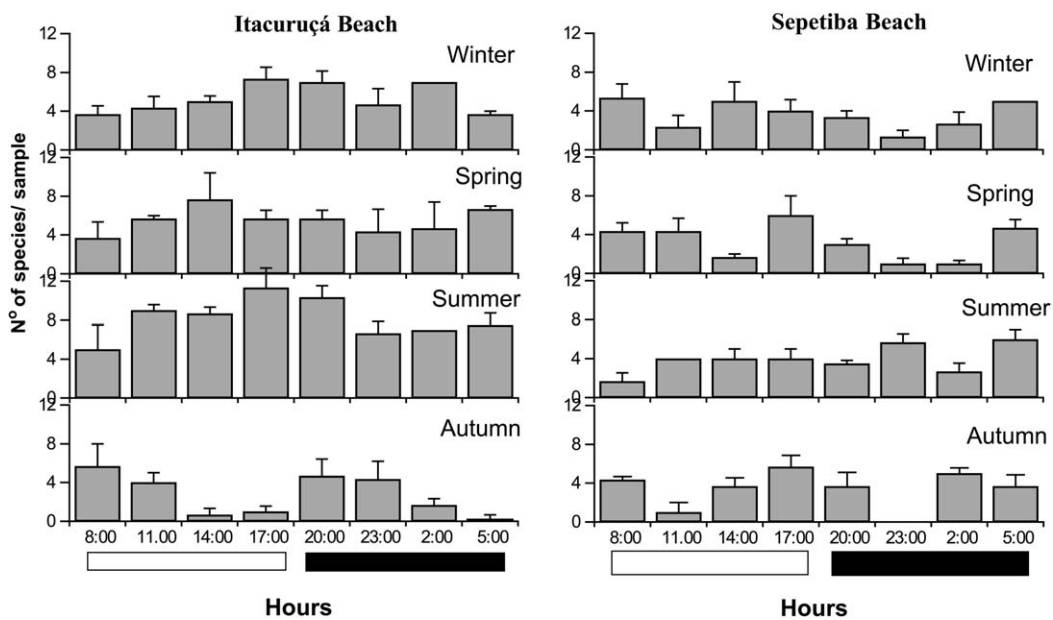

Fig. 5. Diel variation in the number of species (means ± 1 standard error) at Itacuruçá and Sepetiba Beaches—Sepetiba Bay. □ Daylight hours, ■ darkness hours.
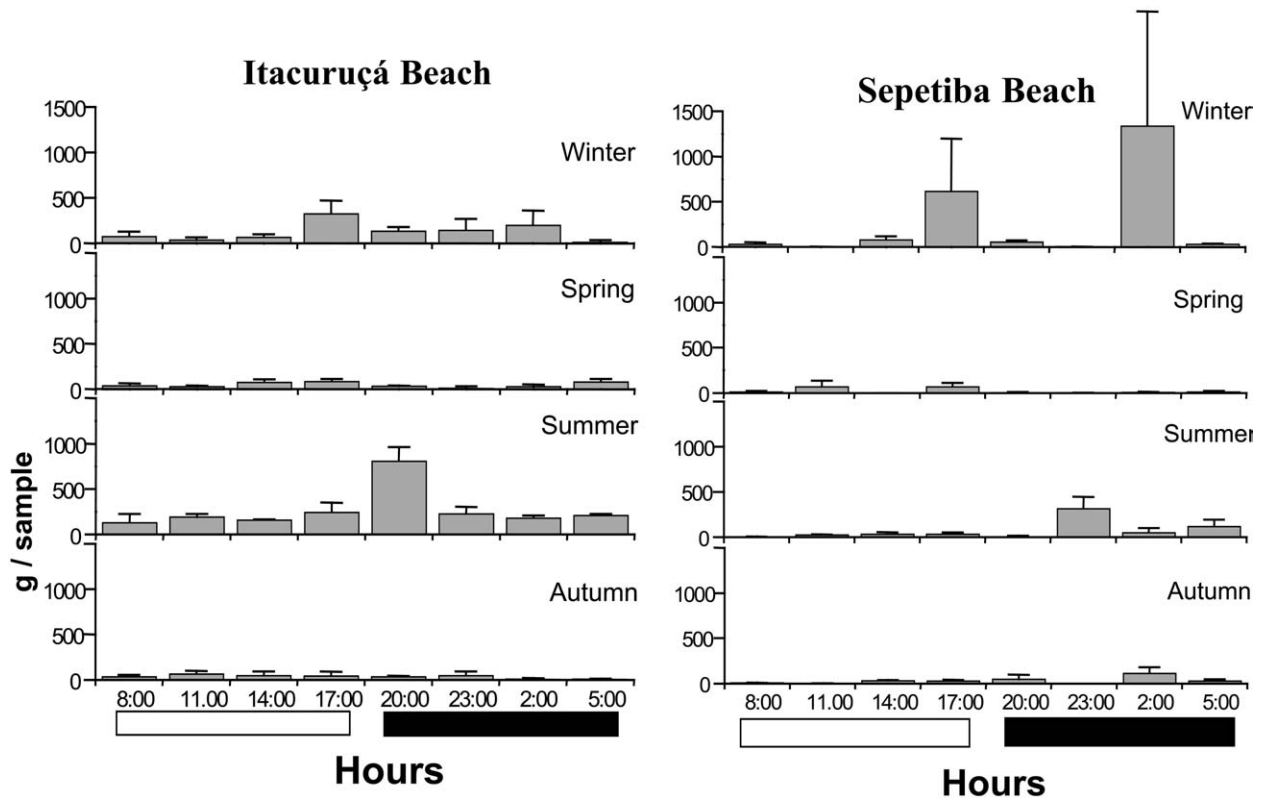
Fig. 6. Diel variation in the biomass (means ± 1 standard error) at Itacuruçá and Sepetiba Beaches—Sepetiba Bay. □ Daylight hours, ■ darkness hours.
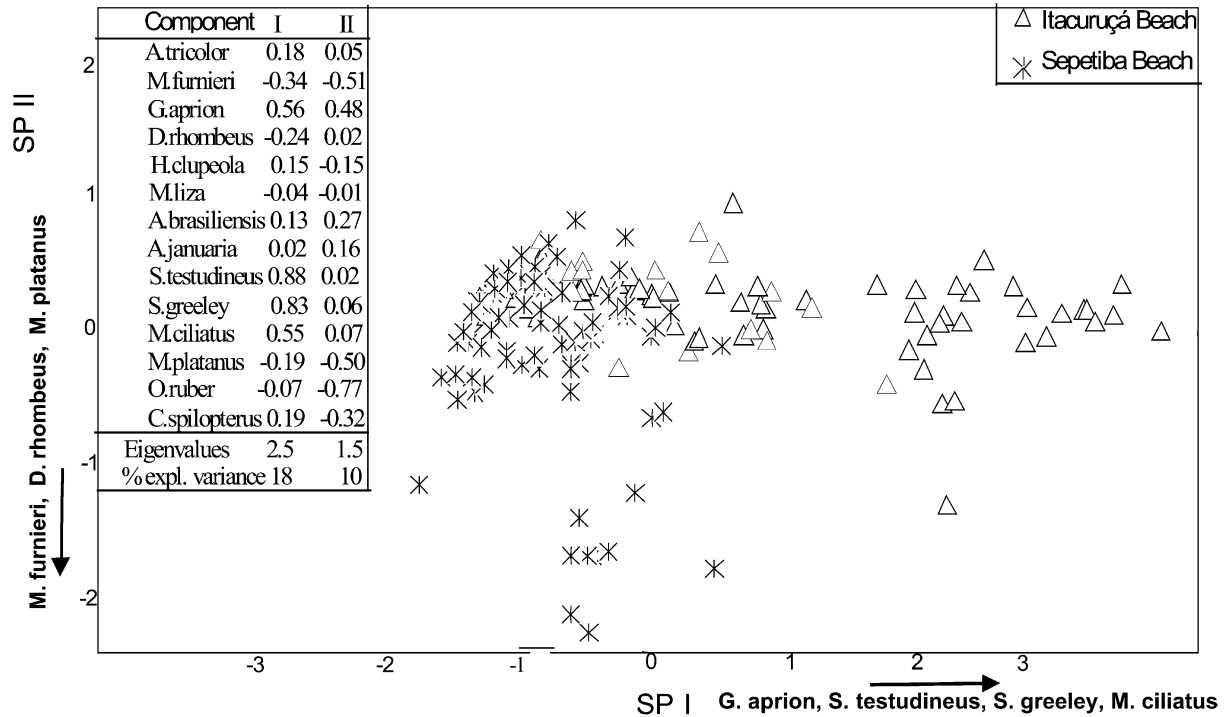

Fig. 7. Ordination diagram for the first two components from PCA on abundance of the 14 most numerous species, coded by sampling sites in the Sepetiba Bay.

Table 3
Summary of the CCA performed on abundance of 14 most numerous fish species

	Axes			
	1	2	3	4
Correlation of environmental variables				
Day/night	−0.35	0.16	0.58	0.61
Temperature	−0.38	0.72	−0.17	−0.53
Salinity	0.64	−0.18	−0.58	0.05
Transparency	0.79	0.38	−0.36	0.27
Tide	−0.13	−0.30	−0.73	0.58
Summary statistics for ordination axes				
Eigenvalues	0.352	0.224	0.088	0.042
Species-environment correlations	0.78	0.67	0.49	0.39
Cumulative percentage of variance				
Of species data	9.0	14.7	16.9	18.0
Of species-environmental correlations	48.5	79.4	91.5	97.2
Sum of all unconstrained eigenvalues				3.930
Sum of all canonical eigenvalues				0.727

Significant factors were selected by a stepwise procedure analogous to forward elimination in multiple regression analysis.

the four environmental axes were higher for the first and second axes, and lower for the third and fourth axes, and only 39.3% of the total inertia of the species matrix was explained by the five factors included in the analysis (Table 3). Fig. 8 represents the ordination plot showing the sampling sites and the distribution of the species in relation to the environmental variables, as determined by CANOCO. Although four axes were determined by the analysis, only the axes 1 and 2 were plotted because they accounted for 79.4% of the variability explained. Transparency, followed by salinity, was responsible for most of the spatial variability and played an important role in structuring fish assemblages, as indicated by axis 1 (Table 3).

The axes 1 and 2 separate the samples from Itacuruçá and Sepetiba Beaches. Itacuruçá samples are located on the right side of the ordination diagram, while Sepetiba samples showed a wider distribution, but were concentrated on the left side of the diagram (Fig. 8). *S. greeleyi* and *S. testudineus* were associated with high transparencies and low tides. *A. tricolor*, *M. ciliatus* and *C. spilopterus* were associated with high transparencies and salinities and low temperatures. Additionally, they showed high abundance at the day. *D. rhombeus*, *A. januaria* and *M. liza* were associated with high temperatures and low salinities, being captured in high abundance at the night. *M. furnieri*, *H. clupeola*, *M. platanus* and *O. ruber* were captured in high tides and low transparency waters. *G. aprion* and *A. brasiliensis* did not show a clear preference for any of these environmental variables, and were located near to the center of the ordination diagram (Fig. 8).

4. Discussion

The most noticeable changes in the fish assemblages in the Sepetiba Bay were the marked differences in
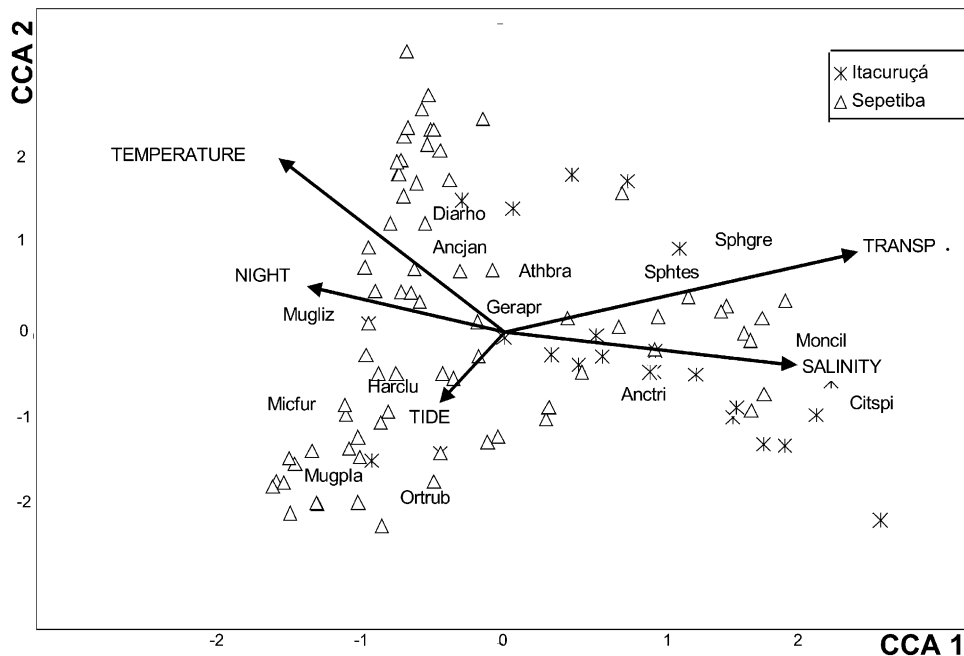

Fig. 8. Ordination diagram (triplot) from canonical correspondence analysis, including fish species, environmental variables (represented by vectors) and samples sites. Species coded by the three first words of the genus and species scientific names.

composition and relative abundance between the two beaches. In the inner zone, represented by Sepetiba Beach, the fish assemblage was dominated by a sciaenid *M. furnieri*, which was found only at that beach. In the outer zone, represented by Itacuruçá Beach, the fish assemblage was dominated by an engraulid *A. tricolor*. The Sepetiba Bay plays an important role as recruitment area and rearing ground for these two species that developed over their evolutionary history the capacity to use different areas in the bay. A long and continuous recruitment period for *M. furnieri* in the inner beaches of Sepetiba Bay is probably associated with organic loads brought into the bay by municipal drainage channels. This seems to favor increasing primary and secondary productivity in the area, since this species feeds on mainly on small benthic organisms (Costa & Araújo, 2002). Decreased water quality in this area does not seem to influence fish occurrence. This species also finds at that beach, protection against predators, favored by low transparencies. The absence of *M. furnieri* in the outer zone could be associated with the highest water transparency, common in outer bay zone that would favor action of predators. The more stable conditions in the outer zone, and the more transparent and saline water enable the recruitment in large numbers of *A. tricolor*, a planktophagous species well adapted to lower temperature due to the influence of oceanic waters. Engraulidae fish are well-adapted water column species, which probably feed visually so the high water transparency in the outer bay is necessary for suitable habitat. These species are more abundant during the day than at night and this could be linked to their visual feeding strategies. *A. tricolor* were also associated with lowest temperatures, which coincide with spawning peaks during late winter/early spring (Silva & Araújo, 2000), being more abundant at temperature $<28\,°C$ and salinity >25. Salinity was probably a major environmental parameter to contribute for spatial separation of the most abundant Engraulidae species in the Sepetiba Bay, with *A. tricolor* being more abundant in higher salinity, while the closed related *A. januaria* and *Cetengraulis edentulus* in lower salinity. Furthermore, this is probably an adaptative process that these species underwent in order to explore the available resources and to avoid competition (Silva & Araújo, 1999).

Fish distributions are determined by complex responses to environmental and biotic factors (Gibson, Robb, Burrows, & Ansell, 1996). Garcia and Vieira (1997) compared fish assemblages of juveniles in Patos Lagoon Estuary, Brazil, and verified that some species were more abundant in vegetated areas, while others in un-vegetated areas. Romer (1990) studied the fish community in three beaches in the Algoa Bay, South Africa, and reported that 16 species were common at all sites attributing variations in occurrence to abiotic variables,

mainly to waves exposure. In some systems, there is a strong tidal influence, with more species being present at low tide and higher abundance of dominant species at high tide (Gibson, Ansell, & Robb, 1993; Gibson et al., 1996; Lasiak, 1984b). The effect of tide position does not seem to be a very important environmental constraint for juvenile fish assemblages at the Sepetiba Beaches because tides are too small to have an affect on the fish distribution. The sea influence is more accentuated at Itacuruçá Beach, which receives denser and colder sea water. At Sepetiba Beach, seawater is mixed with continental drainage from rivers and artificial channels that carry into this area natural freshwater and wastewater. Current circulation in the Sepetiba Bay was studied by Signorini (1980) and Stevenson, Brito, Stech, and Kampel, 1998, who confirmed differences in water quality between these two zones.

Transparency, followed by salinity, were the parameters that varied most markedly between the two zones, and contributed to changes in fish assemblages at Sepetiba Bay. A number of species, as detected by CANOCO, were more associated with the inner zone, while others were more linked to the outer zone. According to Clark et al. (1996), transparency and the presence of emergent rock on the shore are good predictors of spatial variations in the surf zone fish community structure. It is also possible that transparency may be acting as a proxy for other factors that were not measured (e.g. food availability, etc.). The presence of calm waters (Blaber & Whitfield, 1977), turbidity, substratum type and depth (Blaber & Blaber, 1980) are probably the most important factors in the distribution of juvenile in nearshore areas. Itacuruçá Beach shows calmer and more transparent waters, favoring the development of juveniles fish. Additionally, it presents a comparatively higher microhabitat diversity provided by the Itacuruçá Island, which is located about 1 km away from the shoreline; this increases fish richness at this site compared to Sepetiba Beach. On the other hand, Sepetiba Beach with less habitat diversity, less transparent and shallower waters would favor the development of only a few juvenile fish species such as *M. furnieri* and *M. liza*. Abookire, Piatt, and Robards (2000) reported that spatial differences in the fish community at an Alaskan Estuary were due to oceanographic conditions, with the inner bay being characterized by higher temperature and lower salinity than the outer bay. Stratification and the input of river nutrients supporting high primary production could also explain the higher abundance of some fish species in inner bay habitats.

Temporal changes in fish assemblages indicated shifts in the abundance of some species, mainly due to reproduction pulses, since most individuals were young-of-the-year or juvenile in the first part of their life cycle. Temporal patterns in the abundance of fish were described by Ayvazian, Deegan, and Finn (1992) at

Waquoit Bay, and they reported higher values in the mean density, biomass and number of the species in summer. Gibson et al. (1993) reported that changes in abundance in summer are due to the recruitment of the young-of-the-year, while Lasiak (1984a) cited that the general seasonal pattern indicates a decline in the number of individuals and species during the winter, and peaks during spring/summer. In Sepetiba Bay, the relatively higher temperature when compared to the above areas, allows highest abundance in winter, caused mainly by recruitment of abundant species (*M. furnieri* at Sepetiba Beach and *A. tricolor* at Itacuruçá Beach), while high biomass in summer are due to contribution of larger sized individuals (e.g. mojarras *D. rhombeus* and *G. aprion*).

A slight tendency for higher abundance before sunrise in winter at both beaches, and higher biomass during darkness in winter and summer, suggest that some photic influences on the whole assemblage or in its major components occur. *A. tricolor* was more abundant during the day, and this certainly contributed to abundance peaks in Itacuruçá. Pelagic fish use the surface layers throughout the day while demersal fish remained on the bottom (Maes, Pas, Taillieu, Van Damme, & Ollevier, 1999). The results of the present work contrast with the findings of Gibson et al. (1996) that recorded highest abundance at night, indicating an onshore migration at dusk followed by an offshore migration at dawn, determined possibly by feeding activity and predator avoidance. Quinn and Kojis (1987) found more species, individuals and biomass immediately after dusk, probably due to changes in illumination, gear efficiency and/or behavior of the animals. Changes in the fish assemblages could occur due to migration of some species seeking shelter during the night, and reappearing at dawn, when the light level is suitable for them to begin feeding again (Potts, 1990). Lasiak (1984b) found a peak just after twilight, and thereafter a decline with some variation during daylight, while Godefroid et al. (1998) pointed out that maximum abundance occurs at the end of the day. In spite of diel changes in some species occurrence in Sepetiba Bay, no strong evidence for the existence of distinct day and/or night communities was detected. Changes in assemblage structure observed were caused by shifts in abundance of a particular species rather than by their presence and/or absence.

The fish assemblage in Sepetiba Bay is dominated by few abundant species which are common in tropical and subtropical bays according to Yáñez-Arancibia, Lara-Dominguez, and Pauly (1994). Previous works using beach seine, performed only during the day in five beaches of the Sepetiba Bay recorded 55 species between 1993 and 1994 (Araújo et al., 1997), while Pessanha, Araújo, Azevedo, and Gomes (2000) registered 80 species in 1983–1984. The species *G. aprion*, *A. januaria*,

Anchoviella lepidentostole, *A. brasiliensis* and *Netuma barba*, were more abundant in 1983–1984 (Pessanha et al., 2000), while *G. aprion*, *A. januaria*, *M. liza*, *M. furnieri*, *A. brasiliensis* and *D. rhombeus* were more abundant in 1993–1994 (Araújo et al., 1997). Differences in species rank between these two periods (1983–1984 and 1993–1994) suggest that changes in the community structure over the decade occurred. In this study, carried out in 1998–1999, the 55 recorded species coincided with the findings of Araújo et al. (1997), although minor shifts in rank of the most abundant species were shown. The decreased number of species, in the same sites, which were sampled using similar fishing effort, is probably related to pollution from increasing industrialization that took place in the area adjacent to the bay over the last decade. Given that we sampled in both day and night, one would expect a more diverse fish assemblage in this study. This reinforces the hypothesis of increased environmental deterioration since this study coincided with dredging of the access channel and the enhancement of the Sepetiba port, which increased pollution by re-suspended sediment. The spatial segregation on fish assemblages found in this work remained fairly stable, despite seasonal and diel fluctuation, which were noticeable for certain species. Our results suggest that temporal fluctuations act more at a specific level than at a structural one. Temporal variability may be linked to some particular stages of the fish life cycle, like juveniles in winter, which generate slight changes in species composition, but do not significantly influence the spatial organization.

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