Spatiotemporal Variation in Fish Assemblage in a Coastal Lagoon without Direct Contact with the Sea (Southeastern Brazil)

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ABSTRACT

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The Cabiúnas Lagoon is a narrow water body that is perpendicular to the sea and isolated from it by a sandbank. Before 1991, the sandbank was sometimes opened for a few days by local residents, but at present seawater only enters by limited groundwater seepage or by overtopping the sea barrier in storms. In 1998 the Restinga de Jurubatiba National Park was established, including the Cabiúnas Lagoon. Studies on the structure and spatial distribution of the fish assemblage were performed between 1991 and 1994; we carried out one year (2001–2002) of monthly monitoring of the lagoon to identify spatiotemporal variations in the lagoon fish assemblage. The closed sandbank altered salinity content, and favoured oligohaline conditions and the increase of the aquatic macrophyte abundance, promoting freshwater species dominance and reduction of the marine dependent and some coastal lagoon resident species of fish adapted to paralic ecosystems. Two freshwater, two coastal lagoon resident, and five marine dependent fish species, which had been registered in the first studies (1991 and 1994), were not captured in the subsequent samplings. The mean number of individuals (N m^{-2}) decreased significantly (Kruskal-Wallis [KW] = 9.977; p = 0.0068); the decrease in biomass was found to be 80%. Species richness and diversity were also significantly reduced. Differences in the current conditions regarding specific composition along the longitudinal axis of the lagoon were observed. Temperature, salinity, and macrophyte coverage were important variables that influenced fish spatial distribution, abundance, and biomass.

ADDITIONAL INDEX WORDS: *Disturbance, fish assemblage, South Atlantic, Brazil.*

INTRODUCTION

Fish assemblages of coastal lagoons are exposed to constant stress conditions because of sporadic or permanent contacts with the adjacent marine and freshwater environments, which influence their structure and dynamics (DAY and YAÑEZ-ARANCIBIA, 1982; GORDO and CABRAL, 2001; POLLARD, 1994; WINEMILLER and LESLIE, 1992). The Brazilian coastal region in the northeast of the Rio de Janeiro state presents strong waves that constantly throw sand on the coast, developing a sandbank with the fluvial sediments associated with the coastal lagoons (MIRANDA, CASTRO, and KJERFVE, 2002; PANOSSO, ATTAYDE, and MUEHE, 1998). The Cabiúnas coastal lagoon is subject to a continuous marine influence through a percolation process or when the sea barrier is overtopped during storms. According to ESTEVES (1998), this type of coastal environment is defined as an "isolated lagoon."

The absence of direct contact between the Cabiúnas lagoon and the sea should be considered a disturbance to system stability. In fact, studies carried out in the Cabiúnas lagoon in the last 10 years indicated that the loss of contact with the adjacent sea led to physical, chemical, and biological variations, thus favouring the settlement of communities that require freshwater conditions (BRANCO, 1998; ENRICH-PRAST et al., 2004; ESTEVES, 1998; MELO and SUZUKI, 1998; PETRUCIO, 1998; REIS, AGUIARO, and CARAMASCHI, 1998). The lagoon variables are also modulated by the action of other local and continental variables. Aquatic macrophyte communities, arboreal species from the floodable forests established in the aggradation areas and on the sides of the lagoon, including the beach vegetation, vary their coverage area, which is influenced by local climate factors and major storm sea waves as well as by other factors (SCARANO and ESTEVES, 2004). The influence of these factors was evident in the variation of the structure of fish assemblages in the study carried out by REIS, AGUIARO, and CARAMASCHI (1998), in contrast to the previous study carried out by AGUIARO (1994), where the group of coastal lagoon residents and marine dependent fish species were dominant. More recently isotopic

analyses has demonstrated the influence of autotrophic carbon sources in the lagoon's internal part, while marine influence was verified in the sand barrier region, suggesting that variations in the energetic flows are due to the saline gradient (AGUIARO, 1999). The "loss of contact with the sea" may change the imbalance of Cabiúnas lagoon dynamics in a spatial-temporal scale. In other coastal lagoons and estuaries from tropical and temperate regions, the ichthyofauna distribution patterns observed were dependent on the influence of biotic and abiotic variables (BOUCHEREAU et al., 2000; HANNAN AND WILLIAMS, 1998; MARIANI, 2001; WHITFIELD, 1999; YAÑEZ-ARANCIBIA et al., 1985), and the spatial or temporal distribution was a result of the integration of these variables.

The functional guilds of fish were obtained from the literature for a better understanding of the life history and the structure and functioning of these assemblages in this coastal lagoon, following the procedures indicated by the studies of ELLIOTT and DEWAILLY (1995), GORDO and CABRAL (2001), LOBRY et al. (2003), and MATHIESON et al. (2000) for fish assemblages in temperate coastal environments in Europe. So, the aims of this study were to investigate spatial variation and the influence of temperature, salinity, and macrophyte coverage on the fish assemblage from Cabiúnas lagoon, and compare the temporal variation of the composition, biomass, and abundance of fishes.

MATERIAL AND METHODS

Studied Area

The Cabiúnas lagoon, located in Parque Nacional da Restinga de Jurubatiba RJ/Brasil (22°05'–22°20' S and 41°15'–41°45' W), presents an elongated profile perpendicular to the coast with a sandbank that separates it from the adjacent sea; it also has "arms" transverse to the main axis (Figure 1). An artificial canal, which was built in 1843, connects the cities of Macaé and Campos and crosses the lagoon and connects two of these "arms" (AGUIARO, 1999). This lagoon has an area of 0.35 km², with a maximum length of 0.9 km and a width of 0.2 km and gets a constant fluvial flow from a drainage basin of 45 km² (PANOSSO, ATTAYDE, and MUEHE, 1998). The Cabiúnas lagoon has an average depth of 2.5 m with a pH of about 7.0, and has been classified as oligohaline. The values of conductivity are affected by a continuous marine influence resulting from a percolating process or occasionally when the sandbank is torn apart or the sea barrier is overtopped as occurs in storms. The dissolved oxygen values are considered normoxical (mean 7.18 mg L^{-1}), and the low nitrogen and phosphorus concentrations (total and dissolved) allow this system to be classified as oligotrophic (ENRICH-PRAST et al., 2004; FARJALLA et al., 2001; PETRUCIO and FARIA, 1998). A high density and richness of aquatic macrophytes (15 taxa) can be found in the coastal region (ESTEVES, 1998; HENRIQUES et al., 1988). The climate is hot and humid, with rainy seasons in summer and spring, and dry periods in winter (HENRIQUES et al., 1988).

Characterization of Fish into Ecotrophic Guilds

The fish species frequently sampled in Cabiúnas lagoon were segregated into different groups according to their life

Figure 1. Regions of sampling (R1, sand barrier; R2, middle; and R3, far end) to Cabiúnas Lagoon (Google Earth, 2007).

history in relation to coastal lagoons. We obtained the functional guilds of fishes from the literature (AGUIARO, 1994; AGUIARO et al., 2003; ARANHA, 1991; ARAÚJO, 1983; CARAMASCHI, CARVALHO, and CARAMASCHI, 2001; CARAMASCHI et al., 2004; CARVALHO FILHO, 1999; FISHER, PEREIRA, and VIEIRA, 2004; FROESEN and PAULY, 2004; OLIVEIRA, 1989; SAAD, 1997; SOARES, 1998; VIEIRA and SCALABRIN, 1991). Each species was assigned to an ecological guild, vertical distribution guild, feeding preference guild, and reproductive strategies guild.

Ecological fish guilds indicate the use and importance of a coastal lagoon for different species: coastal lagoon residents (CLR) complete their entire life cycle in a coastal lagoon; marine dependent (MD) species spawn in the sea and use the coastal lagoons as a nursery for larvae and juveniles, or for adult permanence for long periods; freshwater (FW) species have no apparent saline requirements, even though they may inhabit paralic waters; and potadromous species experience displacement between lotic and lentic environments (FWp).

Vertical distribution guilds were differentiated according to the place occupied by the species on the water column: pelagic (P), demersal (D), benthic (B), benthic pelagic (BP), or demersal benthic (DB).

Feeding preference guilds for each species were considered: strictly invertebrate (IS), strictly fish (FS), nekton (N), detritus (D), omnivorous (OV), planktivorous (P), other than invertebrates and fish (IF), and planktivorous and invertebrates (PI).

Reproductive guilds were grouped by the mode of reproduction used by the species: ovoviviparous (W), oviparous (O), oviparous with pelagic eggs (Op), eggs guarded by parents (Og), or eggs deposited in substratum (Os).

Spatial Variation of Fish

Different fish capture methods had to be implemented because of the heterogeneity of the Cabiúnas lagoon; thus, spe-

cial devices were used for the sandy environments as well as for the aquatic macrophyte and limnetic ones. However, to identify the possible differences in the lagoon longitudinal profile, fish sampling was carried out in three regions: R1, located between the sandy strip that separates it from the sea and the first lagoon arms; R2, central region of the lagoon with arms dominant; and R3, region where the "sand barrier" region cannot be visualized. This region lies between the aggradation arms of the Macaé-Campos canal and stretches up to the beginning of the lagoon drainage area (Figure 1).

Monthly samplings were carried out during one year (October 2001–September 2002) in the different Cabiúnas lagoon environments. Seine nets were used monthly in a standardized way: (1) seine net of 11.5 × 1.8 m and 15 mm between adjacent knots in the sand barrier (two drags with 15 m distance separating them on the right (R1r) and left (R1l) sides of the barrier) between 1700 and 1800 hours; (2) seine nets of 1.50 × 1.20 m and 5 mm between adjacent knots ("picaré") for captures in aquatic macrophyte stands (eight drags per region: R1, R2, and R3) between 1600 and 1800 hours; and (3) gill nets 15 m long, 1.5 m tall, and 15, 20, 25, 30, 40, and 45 mm between the adjacent knots were used for each region (R1, R2, and R3) of the lagoon in limnetic and exposed areas between 1600 and 2200 hours. The sampling license number was 006/2003 (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis—IBAMA). Sampled fishes were fixed in 10% formalin and then preserved in alcohol at 70%. They were identified through specialized literature at the Fish Ecology Laboratory of the Federal University of Rio de Janeiro. Voucher specimens were registered in the fish collection of the National Museum of Rio de Janeiro (MNRJ).

Measurements of the standard length (centimeters) and total weight of each individual (grams) were taken. Temperature and salinity profiles were obtained with a thermosalinometer (YSI-30SET model), on the surface, middle, and bottom of the water column within the specific fish sampling region (R1, R2, and R3) and schedule. Estimation of the percentage of aquatic macrophyte coverage was carried out with photographs; the regions (R1, R2, and R3) were divided into quadrants of the same size for later calculation of the total emergent macrophyte coverage as well as of the limnetic zones.

The standard length of each fish was obtained to classify them into juveniles or adults. The minimum (centimeter) size at sexual maturity was determined by the macroscopic examination of the ovary, considering the smallest individual of each species. To obtain the smallest sexual maturity size of *Poecilia vivipara*, the smallest individual without developed gonopodium was considered as indicated by ROSEN and BAYLEY (1963). Considering these criterion, young individuals were classified and counted with a standard length less than 1.7 cm.

Variance analysis (ANOVA) was used to compare the mean values of the individuals' data as well as the biomass and standard length of the ichthyofauna between regions (R1, R2, and R3), in limnetic zones, and in aquatic macrophyte stands. To do so, the collection effort was standardized, and limnetic zones or macrophyte stands were independently analyzed. The total area of the gill net set in the limnetic zone was

84.46 m², and it was left in the water for 6 h. Posteriorly, the abundances were converted to square meters per hour using the simple rule of three. Collections made with aid of "picaré" (1.50 × 1.20 m and 5 mm between opposite knots) in macrophyte stands were performed in eight throws, in a total area of 14.4 m², and then the abundances were converted to square meters, also using the simple rule of three. The following criteria were considered when choosing this analysis (ANOVA): The standard deviation of the samplings did not show significant differences when tested (Bartlett or Conchran test); the samples had normal distribution (Kolmogorov and Smirnov $p > 0.05$ test) (LILLIEFORS, 1967). The data were transformed to $\ln(n + 1)$ before the analysis because of the heterogeneity in the variances. The Tukey post hoc test was used to determine the differences between pairs of regions when significant differences were identified through the ANOVA test (ZAR, 1984).

The Mann-Whitney analyses (ZAR, 1984) were carried out to compare the number of individuals, biomass, and standard length of the ichthyofauna, which were sampled between the right (R1r) and left (R1l) sides of the sand barrier in the Cabiúnas lagoon. In this case, the mean data already transformed to $\ln(n+1)$ presented significant differences (Bartlett $p < 0.05$ test), and the samplings did not show normal distribution (Kolmogorov and Smirnov $p < 0.05$ test) (LILLIEFORS, 1967).

The Sorensen similarity index (WOLDA, 1981) and the UPGMA ("Arithmetic Average Clustering") (SNEATH and SOKAL, 1973) grouping method were used to assess ichthyofauna spatial distribution between the regions of the lagoon (R1, R2, and R3), keeping the same fishing effort in the limnetic zone, as well as in the aquatic macrophyte stands were independently analyzed. As a second step, principal component analysis (PCA) (HOTELLING, 1933) was carried out to identify the influence of physical (temperature), chemical (salinity), and environmental (aquatic macrophyte coverage percentage) variables on fish spatial distribution. The species *Centropomus undecimalis, Mugil curema,* and *Micropogonias furnieri* considered rare (less than four individuals found) were retired from the PCA analysis, which included the sum from the abundances of the fish species collected in R1, R2, and R3 regions, limnetic zones, and aquatic macrophytes stands. The significance of the relation between the variables and the axis was estimated accordingly to LEGENDRE and LEGENDRE (1983), where the relation is considered significant whether $d \geq (2/m)^{1/2}$, d being the distance of the variables measured from the origin (zero in both axis) to the point of variable in the axis and m is the number of variables included in the PCA analyses. Pearson linear correlations were carried out to verify possible associations between the assessed variables and abundance, biomass, richness, and diversity of fishes between regions (R1, R2, and R3) of the lagoon.

Temporal Variation of Fish

Gill nets were used to obtain standardized data: the number of individuals captured per square meter (N m⁻²), grams per hour (g h⁻¹), and grams per square meter (g m⁻²) could be compared between this study and those carried out by

Table 1. *Orders, families, and species captured in Cabiúnas lagoon by Aguiaro (1994); Reis, Aguiaro, and Caramaschi (1998); and during the present study, with percentage of each species percentage constancy (C, constant; A, accessory; Ac, accidental), functional guild classifications for the species (/: preference not classified; for guild codes see Material and Methods section), number of individuals per area, and biomass per area and time.*

Orders Families Species	Code	Aguiaro (1994)	Reis et al. (1998)	Present Study	Ecological Guild	Vertical Distribution Guilds	Feeding Guilds	Reproductive Guilds
Clupeiformes								
Cupleidae								
Platanichthys platana	*Pp*	C		A	CLR	P	PI	Op
Engraulididae								
Anchovia clupeoides	*Ac*	A	A	Ac	MD	BP	P	Op
Lycengraulis grossidens	*Lg*	C	A	Ac	MD	P	N	Op
Characiformes								
Characidae								
Astyanax bimaculatus	*Ab*	C	C	C	FWp	BP	OV	Op
Hyphessobrycon bifasciatus	*Hb*	C		C	FWp	BP	OV	Os
Hyphessobrycon luetkenii	*Hl*	C		C	FWp	BP	OV	Os
Oligosarcus hepsetus	*Oh*	C	C	C	FW	BP	IF	Op
Curimatidae								
Cyphocharax gilbert	*Cg*	C	C	C	FW	BP	D	Op
Erythrinidae								
Hoplias malabaricus	*Hm*	C	C	C	FWp	BP	IF	O
Hoplerythrinus unitaeniatus	*Hu*	A	Ac		FW	P	IF	/
Siluriformes								
Heptapteridae								
Rhamdia sp.	*Rs*	C	Ac		FW	BP	IF	Op
Auchenipteridae								
Trachelyopterus striatulus	*Ts*	C	A	C	FW	BP	OV	W
Ariidae								
Genidens genidens	*Gg*	Ac	Ac	C	CLR	B	PI	Og
Atheriniformes								
Atherinopsidae								
Atherinella brasiliensis	*Abr*	C		C	CLR	BP	PI	O
Beloniformes								
Belonidae								
Strongylura timucu	*St*	Ac	Ac		MD	P	FS	Op
Cyprinodontiformes								
Poeciliidae								
Poecilia vivipara	*Pv*	C		C	FW	BP	OV	W
Perciformes								
Centropomidae								
Centropomus paralellus	*Cp*	C	A	A	MD	D	IF	Op
Centropomus undecimalis	*Cu*			Ac	MD	D	IF	Op
Cichlidae								
Geophagus brasiliensis	*Gb*	C	A	C	FWp	BP	OV	Os
Cichlasoma facetum	*Cf*	C	A	C	FW	BP	OV	Os
Gobiidae								
Awaous tajasica	*At*	A		Ac	CLR	D	/	Op
Mugilidae								
Mugil curema	*Mc*	Ac		Ac	MD	D	D	Op
Haemulidae								
Conodon nobilis	*Cn*	Ac			CLR	D	N	/

Table 1. *Continued.*

Orders Families Species	Code	Aguiaro (1994)	Reis *et al.* (1998)	Present Study	Ecological Guild	Vertical Distribution Guilds	Feeding Guilds	Reproductive Guilds
Gerreidae								
Eugerres brasilanus	Eb	Ac			MD	D	N	/
Eucinostomus argenteus	Ea	C	A	Ac	MD	D	PI	O
Diapterus rhombeus	Dr	Ac			CLR	D	PI	O
Ulaema lefroyi	Ul	Ac			MD	BP	/	Os
Sciaenidae								
Micropogonias furnieri	Mf		A	Ac	MD	D	IF	O
Pleuronectiformes								
Achiridae								
Trinectes paulistanus	Tp	Ac			MD	DB	IS	/
Paralichthyidae								
Citharichthys spilopterus	Cs	A	Ac		MD	DB	P	/
No of species		28	17	21				
Abundance (N m^{-2})—CPUE$_1$		0.52	0.15	0.075				
Biomass (g h^{-1})—CPUE$_2$		40.5	—	41				
Biomass (g m^{-2})—CPUE$_3$		29.63	—	6.01				

AGUIARO (1994) and REIS, AGUIARO, and CARAMASCHI (1998). AGUIARO (1994) performed quarterly collections between July 1991 and January 1993, in a total of seven campaigns, whereas REIS, AGUIARO, and CARAMASCHI (1998) made trimonthly collections between May 1994 and April 1995. Samplings were made using 12 gill nets in both studies (three of 15 mm, four of 20 mm, two of 25 mm, two of 30 mm, one of 45 mm between neighboring knots), in a total of 387.12 and 579.23 m² of collecting area, respectively. During our monthly collections from October 2001 to September 2002, the same gill net set previously described was used, but the collection area per campaign was 274 m².

The catch per unit effort (CPUE) for each study was calculated as follows:

$$CPUE_1 = N.m^{-2}$$
$$CPUE_2 = g.h^{-1}$$
$$CPUE_3 = g.m^{-2}$$

where N is the total number of individuals collected; g is the sum of the mass of all individuals collected; m² is the total area of each gill net; and h is the time, in hours, that each net was left in the water.

The Kruskal-Wallis test was used to compare the mean of the number of individuals (N·m^{-2}) between the different studies. Standardized captures with gill and seine nets [except seine net for the study of REIS, AGUIARO, and CARAMASCHI (1998) because they did not employ the cited gear] were used to obtain species constancy (C) using the same number of collections, and CPUE (N·m^{-2}) was compared in the three studies using the DAJOZ (1978) classification, where $C \geq 50\%$ was considered constant, $\geq 25\%$ and $<50\%$ was considered accessorial, and $<25\%$ accidental. Shannon-Wiener diversity (log$_2$) (PEET, 1974) and species richness data (taxa number) obtained in this study and by AGUIARO (1994) were compared using the Mann-Whitney test (ZAR, 1984).

RESULTS

Ecotrophic Guilds

The relative proportions of each guild varied between species of fishes: a high percentage of marine dependent (40%) and freshwater (40%), and a small percentage (20%) of coastal lagoon residents (Table 1). Freshwater fish dominated pelagic and benthic (37%) communities in vertical distribution whereas the other ecological guilds (CLR and MD) varied widely in the water column. The relative proportion of feeding preference guilds varied greatly between species of fishes, with a high percentage of the omnivorous guild (25%) in freshwater, and invertebrates and fish (25%) consumed by freshwater and marine dependent species. The other species of fishes with different ecological guilds presented wide variation and low percentage in the feeding preference guilds. The most abundant reproductive guilds of fishes were oviparous (92%), with 48% with pelagic eggs.

Spatial Variation of Fish

A total of 2745 fish individuals were collected and identified, belonging to 21 species, 14 families, and 7 orders, with a total weight of 23,607 g.

The aquatic macrophyte stands, where fish captures had been carried out, were mainly composed of the species *Typha domingensis* and *Potamogeton stenostachys* in the R1; *Eleocharis interstincta* and *P. stenostachys* in the R2, and *Salvinia auriculata* and *Eichhornia* spp. in the R3 regions of the lagoon. A total of 1596 individuals were sampled in these macrophytes stands; they belonged to 10 species, 7 families, and 5 fish orders. The most abundant fish species, which summed to 97.3% of the total number of individuals, were *Hyphessobrycon bifasciatus* with 607, *P. vivipara* with 469, *H. luetkenii* with 342, and *Cichlasoma facetum facetum* with 135 individuals. The six remaining species showed an abundance of less

Table 2. *Estimated length of the first sexual maturity, number of individuals (N), relative quantity of juvenile and adult individuals of the icthyofauna, collected in the Cabiúnas lagoon, in aquatic macrophyte, limnetic, and sand barrier zones.*

Species	First Maturation	Macrophyte Aquatic		Limnetic		Sand Bar	
		N	Juveniles (%)	N	Juveniles (%)	N	Juveniles (%)
Platanichthys platana	3.1					34	50
Anchovia clupeoides	Nr*					1	
Lycengraulis grossidens	Nr			6	0	21	
Astyanax bimaculatus	Nr			14	0	3	
Hyphessobrycon bifasciatus	1.5	607	13			1	100
Hyphessobrycon luetkenii	1.7	342	15			12	
Oligosarcus hepsetus	5.4	9	66.5	22	0	22	
Cyphocharax gilbert	Nr	1		59	0	3	
Hoplias malabaricus	6.2	19	58	4	0	1	
Trachelyopterus striatulus	Nr	2	100	40	0		
Genidens genidens	Nr			7	0		
Atherinella brasiliensis	7.8	4	100			660	91
Poecilia vivipara	1.7	469	31.6			290	10.7
Centropomus paralellus	Nr			10	0		
Centropomus undecimalis	Nr			2	0		
Geophagus brasiliensis	4.3	8	62.5	6	0	22	
Cichlasoma facetum	3.8	135	87.5			2	100
Awaous tajasica	Nr					1	
Mugil curema	Nr			2	0		
Eucinostomus argenteus	Nr					2	
Micropogonias furnieri	Nr			2	0		

* Nr = non registered first maturation for captured individuals.

than 20 individuals. The smallest captured fish measured 0.7 cm (*P. vivipara*) and the largest measured 17.6 cm (*Hoplias malabaricus*). Adult individuals (73.4%) were dominant, presenting significant differences in relation to the juveniles (χ^2 = 166.61; p = 0.0001). Only 424 juvenile individuals (26.6%) from eight species were present in the macrophyte stands; *Oligosaurus hepsetus* with 66.5% (6 individuals), *Atherinella*

brasiliensis 100% (4 individuals), *Trachelyopterus striatulus* 100% (2 individuals), *C. facetum* 87.5% (118 individuals), and *Geophagus brasiliensis* with 62.5% (5 individuals) were considered the most important ones (Table 2).

A total of 174 individuals were sampled in the limnetic zones (captures with gill nets) of the R1, R2, and R3 regions of the lagoon. They belonged to 12 species, 9 families, and 4 fish orders, and 100% of the individuals were adults. The smallest fish measured 6.6 cm (*G. brasiliensis*) and the biggest one 38 cm (*Centropomus paralellus*). The most abundant species in this region was *Cyphocharax gilbert* (34.3% of the total of individuals), followed by *T. striatulus* (22%) and *O. hepsetus* (12.8%). The remaining species presented less than 8% of the total individuals (Table 2).

A total of 1075 individuals were sampled in the captures carried out with seine nets on the sand barrier region (R1r and R1l sides of the barrier). They belonged to 14 species, 10 families, and 5 fish orders; 59.6% of the individuals were adults and presented significant differences in relation to the juveniles (χ^2 = 856.64; p = 0.001). The smallest fish measured 1.1 cm (*A. brasiliensis*) and the biggest 19 cm (*Awaous tajasica*). The most abundant species in this region, with 51.2% of the total, was *P. vivipara* followed by *A. brasiliensis* with 40.5%; the latter represented 40.4% out of the total of sampled juveniles of the total of captured fishes. The remaining species presented an abundance of less than 2.3% of the total individuals (Table 2).

The number of individual fishes in the limnetic zone in the R3 region of the lagoon was significantly different when compared with the limnetic zones in the R1 and R2 regions. However, the mean values of the number of individuals for each sampling occasion were higher in R3. The ichthyological biomass was significantly different between the R1 and R3 regions in the limnetic zones; mean biomass per sampling occasion was higher in R3. In the aquatic macrophyte stands, the number of individuals of fishes presented higher values in R1 when compared with the R2 and R3. No significant differences, regarding ichthyological biomass were found between the aquatic macrophyte stands in the three regions of the lagoon (Table 3).

No significant differences were found between the number of individuals (p = 0.12; U' = 99.000), biomass (p = 0.26; U' = 92.000), and ichthyofauna standard length on the right (R1r) and left (R1l) regions of the sand barrier.

The similarity dendrogram, with 73% critical level, showed

Table 3. *Analysis of variance of the first number of individuals, ichthyofauna biomass, and standard length between the sand barrier (R1), middle (R2), and far end (R2) regions of the Cabiúnas lagoon.*

Regions	Abundance of Individuals in Limnetic Zones			Abundance of Individuals in Aquatic Macrophyte Stands			Biomass of Individuals in Limnetic Zones			Biomass of Individuals in Aquatic Macrophyte Stands			Standard Length of Individuals in Limnetic Zones			Standard Length of Individuals in Aquatic Macrophyte Stands		
	P	F	T	P	F	T	P	F	T	P	F	T	P	F	T	P	F	T
R1 and R2	0.605	2.908	NS	0.001*	1.073	*	0.070	3.248	NS	0.067	3.398	NS	0.105	2.970	NS	0.998	2.970	NS
R1 and R3	0.000*	6.511	*	0.000*	1.114	*	0.002*	5.352	*	0.942	0.468	NS	0.033*	3.731*	*	0.896	3.731	NS
R2 and R3	0.041*	3.603	*	0.983	0.041	NS	0.310	2.104	NS	0.124	2.930	NS	0.853	0.761	NS	0.867	0.761	NS

P: probability (Tukey post hoc test); F: Fisher test; T: Tukey post hoc test.
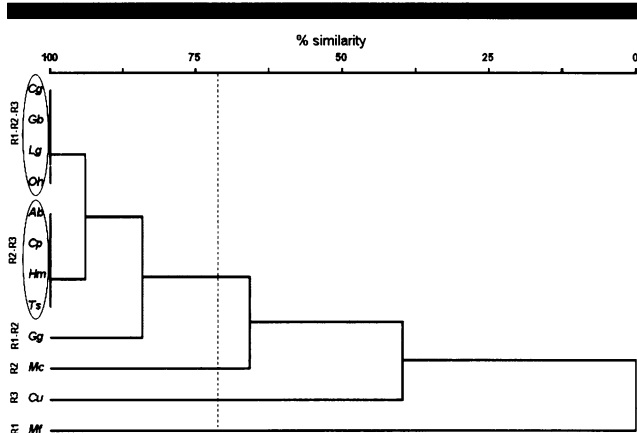* Significant difference.

Figure 2. Grouping dendrogram of the fish species in the R1, R2, and R3 regions in the limnetic zones of the Cabiúnas lagoon (Sorensen, single linkage); sampling in 2001 and 2002. The italic codes correspond to species of fish in Table 1.
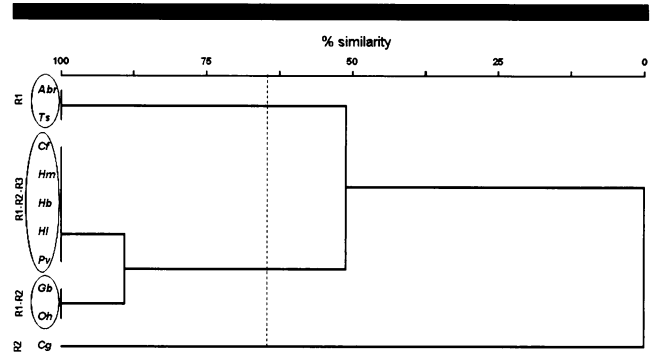

Figure 3. Grouping dendrogram of the fish species in the R1, R2, and R3 regions in the aquatic macrophyte stands of the Cabiúnas lagoon (Sorensen, single linkage) sampling in 2001 and 2002. The italic codes correspond to species of fish in Table 1.

that the spatial distribution of the ichthyofauna in limnetic zones revealed that *M. furnieri* (*Mf*) was constrained to the R1. *M. curema* (*Mc*) and *C. unidecimalis* (*Cu*), on the other hand, were constrained to R2 and the R3, respectively. *Genidens genidens* (*Gg*) were collected in the R1 and R2 regions of the lagoon. The species *C. gilbert* (*Cg*), *G. brasiliensis* (*Gb*), *Lycengraulis grossidens* (*Lg*), and *O. hepsetus* (*Oh*) were collected in all three regions. Constrained to R2 and R3 regions of the lagoon were *Astyanax bimaculatus* (*Ab*), *C. paralellus* (*Cp*), *H. malabaricus* (*Hm*), and *T. striatulus* (*Ts*) (Figure 2).

Regarding the macrophyte stands, the similarity dendrogram (with 62.5% critical level) revealed that *A. brasiliensis* (*Abr*) and *T. striatulus* (*Ts*) were constrained to R1. *Cichlasoma facetum* (*Cf*), *H. malabaricus* (*Hm*), *H. bifasciatus* (*Hb*), *H. luetkenii* (*Hl*), and *P. vivipara* (*Pv*) were collected in all three regions of the lagoon. *Geophagus brasiliensis* (*Gb*) and *O. hepsetus* (*Oh*) were restricted to R1 and R2 regions. *Cyphocharax gilbert* (*Cg*) seemed to be restricted to R2 (Figure 3).

Extreme values varied between 0.23 (R3) to 3.33 (R1) for salinity; 20.87°C (R2) to 29.5°C (R2) for water temperature; and 10% (R1) to 85% (R3) for macrophyte coverage percentage. A decrease in salinity values as well as in water temperature was registered in R1 and toward the R3 region of the lagoon. On the other hand, the aquatic macrophyte coverage percentage presented higher values in R3, followed by R2, and with lower values in R1 (Table 4).

PCA based on the biotic and abiotic characteristics of the lagoon found that axis 1 and 2 were responsible for 86.626% of the total variation of data, equivalent to its eigenvalues of 27.345 and 3.84, respectively. The six values of the 10 generated axes were compared with the null model based on the Monte Carlo algorithm. Based on the values, the first two axes were chosen for interpretation because they presented values above randomization and were significant. Therefore, values higher than 0.82 presented for temperature, salinity, and macrophyte coverage (Table 5) were considered as having significant variability. However, because the objective was to

Table 4. *Values of temperature, salinity, and percentage of the aquatic macrophyte coverage obtained during a year of monthly samplings in the R1, R2 and R3 regions of the Cabiúnas lagoon.*

Months	Regions	Temperature (°C)	Salinity	Macrophyte Coverage (%)
October	R1	25.50	2.50	10
	R2	26.20	2.00	20
	R3	23.90	1.10	40
November	R1	28.88	1.43	15
	R2	29.50	1.35	25
	R3	28.93	1.01	45
December	R1	26.68	1.11	20
	R2	26.84	1.01	30
	R3	26.08	0.54	50
January	R1	27.09	0.51	25
	R2	28.20	0.50	35
	R3	28.11	0.44	55
February	R1	28.58	0.48	30
	R2	26.87	0.27	40
	R3	26.13	0.23	60
March	R1	26.17	0.40	40
	R2	26.23	0.40	50
	R3	25.60	0.30	70
April	R1	25.33	0.40	50
	R2	25.07	0.40	60
	R3	24.77	0.40	80
May	R1	21.87	1.17	55
	R2	21.35	0.30	65
	R3	22.60	0.40	85
June	R1	21.87	1.17	45
	R2	21.77	0.40	55
	R3	21.90	0.57	75
July	R1	23.27	3.33	35
	R2	23.03	1.10	45
	R3	23.03	0.53	65
August	R1	22.23	1.60	25
	R2	20.87	0.60	35
	R3	21.37	0.60	55
September	R1	27.13	1.60	15
	R2	27.20	1.27	25
	R3	25.90	0.60	45

Table 5. *Coordinates of the variables in the two first factors, extracted from the principal component analysis. The italic codes correspond to the species of fish in Table 1.*

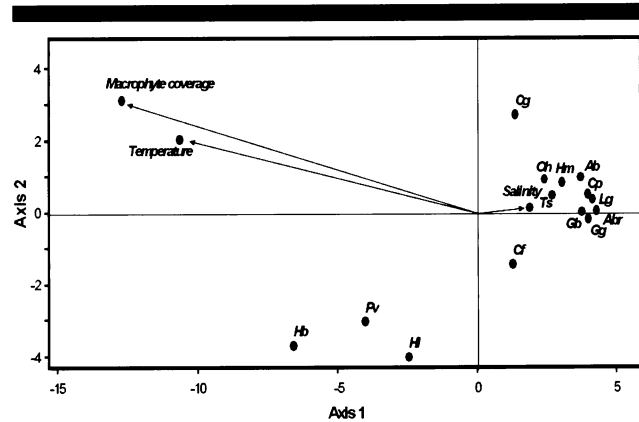|	Axis 1	Axis 2
Biotic and Abiotic Characteristics		
Temperature	−10.650	2.061
Salinity	1.870	0.135
Macrophyte percentage	−12.701	3.121
Abundance of Species		
Ab	3.709	0.974
Abr	4.294	0.068
Cf	1.262	−1.417
Cg	1.359	2.726
Cp	3.952	0.530
Gb	3.754	0.014
Gg	3.991	−0.167
Hb	−6.600	−3.682
Hl	−2.473	−3.993
Hm	3.043	0.832
Lg	4.134	0.377
Oh	2.397	0.931
Pv	−4.034	−3.017
Ts	2.689	0.505
Eigenvalues	27.345	3.840
% total of the variance	75.958	10.668

Figure 4. Variation of fish species in the Cabiúnas lagoon in relation to biotic and abiotic characteristics (macrophyte coverage: aquatic macrophyte coverage percentage, salinity, and temperature), according to principal component analysis. The italic codes correspond to species of fish in Table 1.

assess the strength of the variables in an exploratory way, it can be mentioned that in axis 1 (75.958% of variance), *H. bifasciatus* (*Hb*), *H. luetkenii* (*Hl*), and *P. vivipara* (*Pv*) species, the abundances were inversely influenced by macrophyte coverage and temperature. In the same axis, abundances of *O. hepsetus* (*Oh*), *H. malabaricus* (*Hm*), *G. genidens* (*Gg*), *A. bimaculatus* (*Ab*), *C. paralellus* (*Cp*), *C. facetum* (*Cf*), *G. brasiliensis* (*Gb*), *L. grossidens* (*Lg*), *T. striatulus* (*Ts*), and *A. brasiliensis* (*Abr*) species were mainly influenced by salinity. In axis 2 (10.668% of variance) the abundance of the species *C. gilbert* (*Cg*) was influenced by temperature and macrophyte coverage (Figure 4).

Pearson linear correlations showed significant associations between total abundance of fishes and the percentage of aquatic macrophyte coverage ($r = -0.40, p = 0.032$), and fish total abundance and salinity ($r = 0.40, p = 0.036$), and between fish biomass and percentage of aquatic macrophyte coverage ($r = 0.61, p < 0.0003$). Correlation analysis between fishes' richness and diversity and the assessed biotic and abiotic variables was not significant ($p > 0.05$).

Temporal Variation of Fish

Comparing the data from AGUIARO (1994) and REIS, AGUIARO, and CARAMASCHI (1998) and the present study indicates a current reduction in the percentage of the marine-dependent species constancy. During the present study, it was possible to observe differences between groups of fishes from marine and freshwater origin, which were greater than the groups formed by marine-dependent and coastal lagoon resident species (Table 1).

Nine fish species, two freshwater (*Hoplerythrinus unitaeniatus* and *Rhamdia* sp.), five marine dependent (*Strongylura*

timucu, Eugerres brasilanus, Ulaema lefroyi, Trinectes paulistanus, and *Citharichthys spilopterus*), and two coastal lagoon resident species (*Conodon nobilis* and *Diapterus rhombeus*), which were registered in the first studies as accidental species (AGUIARO, 1994; REIS, AGUIARO, and CARAMASCHI, 1998), were not captured in the present study (Table 1).

The constancy index indicated that freshwater species had remained constant or had increased their constancy during the assessed periods. On the other hand, 40% of the freshwater species had their constancy index reduced to accessories or accidental. Others coastal lagoon resident species, like *G. genidens,* changed from accidental to constant and *A. brasiliensis,* remained constant (Table 1).

A significant reduction was found for the mean number of individuals (N m^{-2}) between the study carried out by AGUIARO (1994) and the present one (KW = 9.977; $p = 0.0068$); the biomass means (g m^{-2}) between these two studies showed a reduction rate of 80%. Means in g h^{-1} did not show any differences (Table 1).

Fishes' diversity and richness values presented significant variations among drags carried out in the sand barrier region (Table 6). Values greater than these were obtained by AGUIARO (1994) with means of 1.64 ± 0.50 for diversity and of 6.57 ± 3.41 for richness, when compared with the present study: 1.07 ± 0.55 for diversity and 3.75 ± 1.29 for richness.

Table 6. *Mann-Whitney test comparing diversities, equitabilities, and ichthyological richness estimated by Aguiaro (1994) and by the present study in captures with gill and seine nets. p: probability; U': Mann-Whitney test.*

	Gill Nets		Seine Nets	
	p	U'	p	U'
Diversity	0.75	32.000	0.036*	67.000
Evenness	0.25	23.000	0.299	29.000
Richness	0.13	19.000	0.022*	15.500

* Significant difference.

DISCUSSION

Spatial Variation of Fish

The sand barrier that separates the Cabiúnas lagoon from the sea is permanently closed; this favoured the increase of oligohaline conditions in such an environment. In turn, it has favoured the increase and dominance of fishes whose reproductive cycles occur in the lenthic habitats of the inland waters. This same situation favoured the increase in abundance of aquatic macrophytes in the lagoon, providing a possible increase in refuge and feeding areas for smaller fishes (MANZANO and ANDREATA, 2001; SÁNCHEZ-BOTERO and ARAUJO-LIMA, 2001). In fact, H. bifasciatus (38%), P. vivipara (29.4%), H. luetkenii (21.5%), and C. facetum (8.5%) were considered the most important freshwater species, when 50% of the total of species collected in the aquatic macrophyte stands is considered. These results indicate that macrophyte stands can supply enough food for adult (73.4%) and juvenile (26.6%) freshwater fish species, which are highly dependent on these environments during their ontogeny. Indeed it was observed that species H. bifasciatus, H. luetkenii, G. brasiliensis, and C. facetum take care of eggs or carry out parental care in the complex, submerged aquatic macrophyte stands (LIMA et al., 2008).

Therefore, the presence of Chaoboridae and Palaemonidae larvae in aquatic macrophyte stands, as well as Copepoda Calanoida species in freshwater environments (BRANCO, 1998) confirm this fact because they were widely registered in nearly all the fish species' diets in the lagoon (AGUIARO, 1999). In fact, 14 types of benthic macroinvertebrates that colonize submerged structures of T. domingensis in the Cabiúnas lagoon (OLIVEIRA, 2002) were found in the stomach contents of fish analyzed by AGUIARO (1994); these same species of fish were captured in this study in banks of aquatic macrophytes. Therefore, LIMA et al. (2008) observed individuals of H. bifasciatus and H. luetkenii in the Cabiúnas lagoon foraging in stands dominated by the submerged macrophyte P. stenostachys and the emergent T. domingensis.

A lower proportion of other species collected in the aquatic macrophyte stands (abundance <20) show that these environments favour fish predation by the H. malabaricus and O. hepsetus species because fishes and fish remains were registered in the stomach contents of 33% of such species (LEITÃO et al., 2005). Young individuals of T. striatulus, A. brasiliensis (100%), and G. brasiliensis (62.5%) were captured in still lesser quantity, thus indicating their partial dependency upon these environments because the highest percentage of adults was captured in the limnetic zones. Capture of only one adult in the aquatic macrophyte stands belonging to the C. gilbert species was considered an accident because this kind of detritivorous habit (AGUIARO and CARAMASCHI, 1998) was found to be predominant in the limnetic zones of the R2 and R3 regions of the lagoon. That is because its potadromous species characteristic growth of younger individuals and reproduction probably occurs in the drainage basin next to the lagoon.

Dominance of organisms with omnivorous and carnivorous habits (99%) in aquatic macrophyte stands shows that these environments are favourable for species with high feeding plasticity. However, the inexpensive contribution of detritivorous species in these stands might indicate a reduced contribution of organic material in these coastal areas, which is the result of sandy substrate composition that builds up the proper sand barriers, where the Cabiúnas lagoon is located (ARAÚJO et al., 1998), or no palatable debris to fishes in this environment. Even though the literature indicates that stands of aquatic macrophytes are environments of high detritus output (HICKENBICK, FERRO, and ABREU, 2004), the results of this study presented only two individuals of detritivorous species. In this specific case and for this environment it is possible that these plants do not supply the quantities or nutritional qualities demanded by detritivorous species. Although in estuarine environments the biomass of detritus can be consumed by many species of fish (DAY et al., 1989), it is possible that the detritus originated from the decomposition of macrophytes because the high level of cellulose and lignin that these plants possess would not be palatable or are of low digestibility for the detritivorous species that inhabit in the Cabiúnas lagoon.

The significant difference between the number of individuals in the macrophyte stands in the R1 region, in relation to the R2 and R3 regions of the lagoon, might be directly related to the macrophyte coverage percentage. Considering this, the highest capture rates in the R1 region might be related to a greater fish concentration in the lower coverage percentage of such plants (mean 30.4%). In contrast, in the R2 and R3 region, where macrophyte coverage percentages were higher (means 40.4% and 60.4%, respectively), fishes were more dispersed, thus influencing capture rates. On the other hand, differences in aquatic macrophyte composition might influence this abundance if the morphological characteristics of the submerged parts of such plants influence the community structure that inhabits those stands (CHICK and MCIVOR, 1997; SÁNCHEZ-BOTERO et al., 2003).

The information gathered on fishes from the limnetic zones in the Cabiúnas lagoon, which were 100% adults, showed a greater number of individuals, biomass, and length in the R3 region, which was dominated by an abundance of freshwater species (83.3%). The C. gilbert and T. striatulus species represent 57% of the captures and 52% of the biomass in this lagoon environment. REIS, AGUIARO, and CARAMASCHI (1998) stated that this fauna could be considered exclusive of areas influenced by vegetation in the Cabiúnas lagoon. In fact, a higher percentage of aquatic macrophyte coverage in the R3 region of the lagoon (mean 60.4%) and the proximity of the fluvial flow from the drainage basin favour the benthopelagics guilds, which might, consequently, influence these species' dominance. However, the high constancy (≥50%) of C. gilbert is due, among other issues, to the large consumption of the available periphytic algae. These algae belong to the Zignemaficeas and diatoms group (Bacillariophyceae); salinity reduction and consequent reduction of the pH values favour the growth of these algae (MELO and SUZUKI, 1998).

The limnetic zone is inhabited by fishes from different ecotrophic guilds (FW: 6; MD: 5; CLR: 1), which present wider vertical distribution and variable diet, showing this habitat

as favourable to the growth and reproduction for species from different origins.

Fifty percent of the coastal lagoon resident marine and freshwater species are dispersed throughout the water body in the limnetic zones, probably because of the reduced size of this lagoon or the dispersion capacity of such species. It is worth mentioning the saline gradient because this factor influences fish abundance in other coastal lagoons of Brazil and around the world (ALBARET and ECOUTIN, 1989; ANDREATA et al., 1997; ARAÚJO and AZEVEDO, 2001; GORDO and CABRAL, 2001; LIMA et al., 2001; MONTEIRO-NETO et al., 1990; SAAD, BEAUMORD, and CARAMASCHI, 2002; WINEMILLER and LESLIE, 1992). In fact, the capture of only five marine dependent species (24% of the total) in the R1 region of the Cabiúnas lagoon was probably influenced by the higher salinity values and their large variations (mean = 1.31; C_v = 68.3%), possibly caused by the major storm waves that overtake the sand barrier region of the lagoon (personal observation). This region of the lagoon is an "ecotonous," lying between the marine and freshwater environments, presenting the highest number of fish species in the lagoon. Four of these were coastal lagoon resident species, seven were freshwater species, and three marine dependent species. This was the most disturbed region in terms of diversity, as well as in ichthyological richness because of the permanent closure of the sand barrier and probably because of the *P. vivipara* freshwater species' (19.5%) greater dominance, and the *A. brasiliensis* (44.5%) coastal lagoon resident species. *Poecilia vivipara* is ovoviviparous with constant spawn during the year in coastal lagoons (ARANHA, 1991), young individuals of *A. brasiliensis* as well as adults with mature or spawned gonads in the Cabiúnas lagoon are present during all months of the year (TRIVÉRIO-CARDOSO, 2004), which indicates the success in the recruitment of this species and consequently dominance.

The dominance of *A. brasiliensis*, with 91% of the young individuals and more than 50% in the same stand of *Platanichthys platana* (17 individuals) indicates, on a preliminary basis, the effect of the major storm waves on the colonization of such individuals. However, this needs a more detailed reproductive study, as well as research on population ecology of fishes, which would only attempt to answer the issue on major storm waves and their effect on abundance and biomass in the Cabiúnas lagoon. On the other hand, the freshwater species, *P. vivipara,* seems to have no abundance variation when salinity is less than 10 (ANDREATA et al., 1997). Probably, variations caused by major storm waves of this variable do not potentially affect this population's dynamics.

Different morphological and physical characteristics did not influence abundance and biomass when the right region of the sand barrier, where water depth is lower (mean = 1.15 m in the dragging area) and has an adjacent arm, was compared with the R1l region, which has a greater water depth (mean = 1.75 m in the dragging area). This is probably because of the short distance between the two sampling sites (approximately 50 m) and the dispersion capacity of fish species that inhabit that region.

The greatest variation in salinity, temperature, and macrophyte coverage between regions influenced the ichthyofauna distribution. The R1 region, with the highest values of salinity and bigger limnetic available zone, favoured the presence of freshwater fish and coastal lagoon residents, with domains of benthic and pelagics guilds. The principal species captured in R1 were *A. brasiliensis, P. vivipara,* and *G. brasiliensis,* which together represented 61.3% of the total sampled community in this region, and 46.5% of the total in the lagoon. Temperatures registered in the R1, R2, and R3 regions of the lagoon were within the tolerance interval for neotropical fishes (BRETT, 1956; FRY, 1971; RANTIN and PETERSEN, 1985; RANTIN et al., 1985; RIETZLER, RANTIN, and GLENS, 1981). However, low variation frequencies affected, in minor proportion, the distribution of the ichthyofauna in the Cabiúnas lagoon.

Salinity influenced the abundance of coastal lagoon resident, marine dependent, and freshwater fish species that are adapted to oligohaline conditions. Capturability was mainly influenced by aquatic macrophyte coverage. The evaluated variables showed longitudinal differences between the different regions of the lagoon, and affected the biomass and abundance of fishes.

The existence of a distribution pattern in the longitudinal axis and between different regions of the Cabiúnas lagoon observed in this study corroborates the distribution pattern described by REIS, AGUIARO, and CARAMASCHI (1998). However, as these authors have mentioned, the reduced dimensions between the margin and the central part of the lagoon did not allow distinction of the ichthyofauna between coastal and limnetic zones. This seems to be related to the sampling design for assessing this particular distribution.

The great variety of species found in the Cabiúnas lagoon, with different origins, sizes, physiological needs, feeding, vertical distribution, and reproductive guilds has shown an environment with a wide variety of available sources. Similar characteristics were described in other coastal and marginal lagoons; this shows that such environments give support to a complex ichthyological structure (AGOSTINHO and VAZZOLER, 1995; ARAUJO-LIMA, AGOSTINHO, and FABRÉ, 1995; JUNK, SOARES, and SAINT-PAUL, 1997; MERONA and BITTENCOURT, 1993; WINEMILLER and LESLIE, 1992; YÁÑEZ-ARANCIBIA and NUGENT, 1997). This variety composed by freshwater (10), marine dependent (7), and coastal lagoon resident (4) fish species and distribution showing that the different longitudinal ichthyological zonation was mainly determined by the salinity and macrophyte coverage gradients in the Cabiúnas lagoon.

Temporal Variation of Fish

The decrease in the constancy of the coastal lagoon resident and some marine dependent fish species registered in the present study, when compared to the previous studies (AGUIARO, 1994; REIS, AGUIARO, and CARAMASCHI, 1998) in the Cabiúnas lagoon, probably is due to the oligohaline characteristics that dominate such an environment (ENRICH-PRAST et al., 2004; PETRUCIO, 1998; PETRUCIO and FARIA, 1998). In fact, the historical analysis of fish species occurring in the Cabiúnas lagoon indicated that *C. gilbert, A. bimaculatus, H. malabaricus, G. brasiliensis, C. facetum, O. hepsetus,*

and *T. striatulus* are the most constant ones in each period. The dominance of freshwater species is favoured by the environmental heterogeneity of the lagoon with its streams, large variety of food resource availability (AGUIARO, 1994; BRANCO, 1998; OLIVEIRA, 2002), and favourable conditions for the development of eggs and larvae (SOARES, 1998).

However, 100% of the species characterized as accidental or accessorial during the present study, some being coastal lagoon resident and all the marine dependent species, which were registered as constant or accessorial by AGUIARO (1994) and REIS, AGUIARO, and CARAMASCHI (1998), indicated a variation in the specific abundance, possibly due to the loss of contact with the sea. In fact, the absence of seven species from the same ecological guilds in the recent captures, which were considered accessorial or accidental, reinforced the idea that the isolation caused a reduction in species richness. In the same way, the not yet confirmed reproductive events of *A. brasiliensis* and *G. genidens,* coastal lagoon resident species inside the Cabiúnas lagoon, brings out questions on the reproductive capacity of these species in permanently closed environments (CERVIGÓN *et al.*, 1992; FIGUEIREDO and MENEZES, 1980). Considering *A. brasiliensis* in particular, young and sexually mature individuals were identified during 14 continuous months; this suggests that such species had partial spawning or that such individuals would be introduced when the sea barrier was overtopped (TRIVÉRIO-CARDOSO, 2004). For *G. genidens,* with seven adult individuals captured in the Cabiúnas lagoon (minimun standard length: 21.5 cm; maximum standard length: 24 cm), there is evidence of its spawn on other coastal lagoons in the region (Imboassica and Maricá Lagoons), which possess ephemeral contacts with the sea (OLIVEIRA, 1989; SAAD, 1997). The life cycle of *G. genidens* occurs in estuaries and coastal lagoons, and it is possible that its low rate of capture has been related to the nocturnal activity of the species (ARAÚJO, 1983). On the other hand, the registering of larvae of *P. platana* in a recent-eclosion stage in the Cabiúnas lagoon suggests that this species concludes its reproductive cycle in this environment (SOARES, 1998). However, the capture of this species during this study was low, and it is possible that other environmental factors or biological interactions might be influencing the abundance of this population in Cabiúnas lagoon. However, it is possible to affirm that the present environmental conditions of Cabiúnas lagoon favours the life cycle development of mainly freshwater species and some coastal lagoon resident species such as *A. brasiliensis* and *G. genidens.*

The absence of two freshwater species (*H. unitaeniatus* and *Rhamdia* sp.) during the present study possibly is explained by sampling circumstances or real population reduction, considering that both of the two species were considered accidental in the previous studies. It would be advisable to extend sampling to the evening hours in future; the drainage basin should also be included in future sampling areas, which is the preferred environment of *Rhamdia* (GALVIS, MOJICA, and CAMARGO, 1997); marshes and ponds next to the lagoon, where *H. unitaeniatus* is usually captured (HOLLANDA-CARVALHO, 2002), should also be considered.

Reductions in the number of individuals and biomass per area in the captures carried out with gill nets are probably due to scarcity of bigger fish that invade these kinds of environments in the northern part of the state during contacts with the sea (AGUIARO and CARAMASCHI, 1995; FROTA, 1998; LIMA *et al.*, 2001; SAAD, BEAUMORD, and CARAMASCHI, 2002). The increase of smaller freshwater species that in general are not caught with these nets may also be responsible for such reductions.

The permanently closed sand barrier favoured the increase of oligohaline conditions in the lagoon, which in turn favours the increase and dominance of fishes with reproductive cycles occurring in lentic habitats. Thus, diversity and richness of species in this lagoon are significantly reduced. This same situation favoured the increase in abundance of aquatic macrophytes in the lagoon, providing a possible increase in the refuge and feeding areas for smaller fishes (MANZANO and ANDREATA, 2001; SÁNCHEZ-BOTERO and ARAUJO-LIMA, 2001).

Fish assemblages of the Cabiúnas and other coastal lagoons in Rio de Janeiro state, such as Marapendi (ANDREATA, SAAD, and BARBIERI, 1989), Tijuca (ANDREATA *et al.*, 1990), Iquipari (LIMA *et al.*, 2001), Rodrigo de Freitas lagoons (ANDREATA *et al.*, 2002) and Imboassica (SAAD, BEAUMORD, and CARAMASCHI, 2002) have suffered reduction in diversity and species richness, especially because of the loss of contact with the sea or because of poor communication with the adjacent ocean. The lack of renewal of marine dependent species that temporarily colonize these lagoons favoured the dominance of an ichthyofauna with freshwater or coastal lagoon resident species characteristics, which are adapted to lentic environments and complete their entire life cycle in coastal lagoons. According to KREBS (1994), the diversity of a community depends on the addition of species per evolution and on the rates of loss from extinction and emigration, which are influenced by environmental heterogeneity. Thus, a greater number of habitats and niches to be explored by organisms favour the coexistence of various species and consequently, greater diversity.

However, with the segregation of this environment, the dominants' autotrophic carbon sources had turned out to be lagunar or terrestrial (AGUIARO, 1999), favouring the dominance of omnivorous fish species that are less selective about food or that have more feeding plasticity. In contrast, the coastal lagoon resident and marine dependent species (except *M. curema*) are dependent on feeding carnivore guilds composed of benthonic invertebrates and zooplanktonic or nekton organisms from freshwater or estuaries. These guilds present a variety of densities that is determined by biotic and abiotic factors and by environmental disturbances, depending on the amount of marine influence in the lagoon (AGUIARO, 1994; AGUIARO, 1999; BRANCO, 1998; CALLISTO *et al.*, 1998). These resources compromise those populations that depend on more selective food.

Contacts with the adjacent ocean in the Cabiúnas lagoon are ephemeral and thus influence some of the aspects of the ichthyofauna structural dynamics. However, it must be mentioned that the present autotrophic carbon sources, which are dominant in this environment, are lagunar and terrestrial (AGUIARO, 1999), suggesting the presence of energetic flows that favour the establishment of a continental ichthyofauna.

Considering that the coastal lagoons are marine systems, separated from the ocean by natural sand barriers and connected to the ocean by one or more channels (KJERFVE, 1994), the permanent closing of the sand barrier can be considered a disturbance for communities adapted to this flow. Dominant oligohaline conditions in the lagoon, in particular, may increase the water content in the marine species muscles, causing abnormal behaviour and death in most cases (WU and WOO, 1983). The permanent closing of the sand barrier in the Cabiúnas lagoon caused changes in the environmental characteristics (ENRICH-PRAST et al., 2004; PETRUCIO, 1998), affecting the dynamics, distribution, and structure of the communities that inhabit such places. This also may affect the density of the marine dependent species of fish, *Anchovia clupeoides, C. undecimalis, Eucinostomus argenteus,* and *M. curema,* and the coastal lagoon resident *A. tajasica,* which have no evidence of reproduction registered in this lagoon.

CONCLUSIONS

The permanent closing of the sand barrier favoured oligohaline conditions in the Cabiúnas lagoon, which in turn favoured the increase of aquatic macrophyte stands. Consequently, an ichthyofauna of minor size adapted to freshwater lenthic ecosystems was established. The absence of direct contact with the sea, considered as a disturbance to system stability, is responsible for the reduction of the marine dependent and some coastal lagoon resident species, thus altering the ichthyofauna diversity, richness, and biomass values. The longitudinal distribution pattern of the ichthyofauna in the Cabiúnas lagoon was influenced by the salinity, temperature, and percentage of aquatic macrophyte coverage. Salinity influenced the coastal lagoon resident, marine dependent, and freshwater species that are adapted to oligohaline conditions. On the other hand, abundance of fish was mainly influenced by the aquatic macrophyte coverage. Numeric dominance of *A. brasiliensis* and *P. vivipara* species, as well as their greater individual concentrations in the sand barrier region (R1, R1l, and R1r) of the Cabiúnas lagoon were relevant, indicating that these species are successfully adapted to this environment. The great variety of ecotrophic guilds of fish species found in the Cabiúnas lagoon shows an environment with a high availability of sources for this fauna.

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☐ RESUMO ☐

A lagoa Cabiúnas, localizada no Parque Nacional da Restinga de Jurubatiba, RJ/Brasil, apresenta um perfil alongado perpendicular ao litoral com uma barra arenosa que a separa do mar adjacente, sujeita, atualmente, à influência marinha por ressacas de curta duração. Entre 1991 e 1994 foram realizados estudos com o objetivo de caracterizar a estrutura e distribuição espacial da ictiofauna neste ambiente. Posteriormente, um monitoramento mensal na lagoa durante um ano (2001–2002), teve por objetivo identificar as mudanças na ictiofauna quando comparada com os estudos anteriores. A barra permanentemente fechada neste ambiente favoreceu condições oligohalinas e incremento da abundância de macrófitas aquáticas, promovendo aumento na abundância e dominância das espécies dulcícolas e diminuição na constância das especíés de peixes marinho dependentes e algumas residentes de lagoas costeiras adaptadas a ecossistemas salobros. Duas espécies de peixe de origem dulcícola, duas residentes de lagoas costeiras e cinco marinho dependentes, registradas nos primeiros estudos (1991 e 1994), não foram capturadas nas coletas posteriores. As médias do número de indivíduos ($N.m^{-2}$) diminuíram significativamente (Kruskal-Wallis KW = 9,977; p = 0,0068) e a biomassa diminuiu em 80%. Da mesma forma, valores de riqueza de espécies e diversidade foram significativamente diferentes. Também foram observadas diferenças quanto à composição específica ao longo do eixo longitudinal da lagoa. Variáveis que influenciaram a distribuição espacial, abundância e biomassa de peixes, foram temperatura, salinidade e cobertura de macrófitas.