Temporal variation of fish community richness in coastal lagoons of the Restinga de Jurubatiba National Park, Rio de Janeiro, Brazil.

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ABSTRACT: Temporal variation of fish community richness in coastal lagoons of the Restinga de Jurubatiba National Park, Rio de Janeiro, Brazil. Fish species were sampled in August/2001 (dry season) and February/2002 (rainy season) from seven coastal lagoons of the Restinga de Jurubatiba National Park, located in a "restinga" (sandy coastal plain vegetation) of the State of Rio de Janeiro. Water samples were collected from each lagoon in both seasons for analysis of pH, total phosphorous, water colour and salinity. Data about lagoon area, connected to sea or rivers, and presence of aquatic macrophytes were obtained from literature and by fieldwork trips. We registered 21 fish species belonging to 13 families and six orders: 7 Characiforms species (33%), 5 Perciforms (24%), 4 Cyprinodontiforms (19%) and 5 species of Clupeiforms, Siluriforms and Atheriniforms orders (24%). Cabiúnas and Carapebus lagoons presented highest richness values (16 and 13 species, respectively), followed by Paulista (10 species), Comprida (5), Preta and Piripiri (3), and Garças (none). The similarity index values showed seasonal influence in species composition. The groups of lagoons generated by PCA were the same for both sampling periods and their spatial projection influenced by changes in salinity, pH and total phosphorus. Species richness of fishes were positively correlated to the richness of aquatic macrophytes and connection with other ecosystems. The main factors involved in the predominant freshwater fish fauna of the lagoons are the scarce and eventual link to the sea and the seasonal regime of rains.

Key-words: temporal variation, fish community, coastal lagoons, Restinga de Jurubatiba National Park.

RESUMO: Variação temporal na riqueza ictíica de lagoas costeiras do Parque Nacional da Restinga de Jurubatiba, Rio de Janeiro, Brasil. Coletas de peixes em agosto/2001 (período de seca) e fevereiro/2002 (período de chuva) foram realizadas em sete lagoas costeiras do Parque Nacional da Restinga de Jurubatiba. Para cada lagoa, em cada período foram registrados: pH, fósforo total, cor da água e salinidade. Dados da área das lagoas, de contatos com mar e rios, e de riqueza de espécies de macrófitas aquáticas foram obtidos em literatura e durante os trabalhos de campo. Foram capturadas 21 espécies de peixes, pertencentes a 13 famílias e seis ordens: 7 espécies de Characiformes (33%), 5 espécies de Perciformes (24%), 4 espécies de Cyprinodontiformes (19%) e 5 espécies das ordens Clupeiformes, Siluriformes e Atheriniformes (24%). As Lagoas Cabiúnas e Carapebus apresentaram as maiores riquezas ictíicas (16 e 13 espécies, respectivamente), seguidas por Paulista (10 espécies), Comprida (5 espécies), Preta e Piripiri (3 espécies), e Garças (0 espécie). A similaridade na fauna de peixes entre as lagoas mostrou variação sazonal na composição de espécies. Na análise de componentes principais, os agrupamentos das lagoas foram semelhantes para ambos os períodos, com suas projeções espaciais influenciadas pelas mudanças de salinidade, pH e fósforo total. A riqueza de peixes foi correlacionada positivamente com a riqueza de espécies de macrófitas aquáticas e com os contatos com ambientes adjacentes. O contato com o oceano, limitado a eventuais ressacas (barra arenosa permanentemente fechada) e o regime de chuvas, determinante para o contato

das lagoas com ambientes dulcícolas adjacentes, foram os principais fatores de influência na composição predominantemente dulcícola da fauna de peixes.
Palavras-chave: variação temporal, peixes, lagoas costeiras, Parque Nacional da Restinga de Jurubatiba.

Introduction

Coastal lagoons are water bodies on the coast, isolated or semi-isolated from the ocean by a sand barrier and can be found in all continents; they are quite common in South America and occupy 12.2% of its coast (Barnes, 1980). In Brazil they can be found along all the coast (Esteves, 1998), particularly in the states of Rio Grande do Sul, as lagoa dos Patos, the greatest lagoon in the Brazilian South Atlantic coast with 10360 km² (Chao et al., 1982), and Rio de Janeiro with 111 registered lagoons (SEMADS, 2001). Coastal lagoons of Rio de Janeiro State present differentiated features regarding area, form, connection to the sea, freshwater inflow and anthropic influence. These factors can exert strong influence on the ichthyofauna structure and composition in those environments. Within this context, some lagoons and their fish communities and populations have been studied in the last years (Oliveira, 1955; Oliveira et al, 1955; Andreata et al., 1990a, b; Barbieri et al., 1991; Moraes & Andreata, 1994; Andreata et al., 1997). Lagoons located in the northeast region of Rio de Janeiro State were studied in Macaé and Carapebus (Aguiaro & Caramaschi, 1995, 1998; Frota & Caramaschi, 1998; Reis et al., 1998; Saad et al., 2002) and São João da Barra municipalities (Lima et al., 2001). The Restinga de Jurubatiba National Park, created in 1998, is located in a sandy coastal plain vegetation ("restinga") and comprehends at least 18 coastal lagoons. The National Park is the main research focus for ecological studies in that region and was selected as one of the twelve Brazilian localities for a long term ecological research program.

Having freshwater origin and being totally separated from the sea by a sand barrier, the lagoons vary in size, morphology, physical and chemical characteristics, anthropic impacts and resident communities (Esteves, 1998). All of them pertain to the "restinga plain lagoons", one of the three groups of Rio de Janeiro coastal lagoons proposed by Sofiatti (1998). Some of these are economically important for the population settled in that region, and constitute leisure and subsistence fishery areas. This region has a seasonal climatic regime and the alternation of dry and rainy seasons probably affects abiotic conditions and communities of the lagoons. In the present study we analyse the fish community composition in some lagoons and the effect of local features on species richness, during two seasonal periods.

Material and methods

This study was carried out in seven coastal lagoons of the Restinga de Jurubatiba National Park, located in the northeast of Rio de Janeiro state, between 22°05' - 22°20' S and 41°15' - 41°45' W including Macaé, Carapebus and Quissamã municipalities (Fig. 1). A tropical climate is the main characteristic of this region ("AW" in Köppen classification), with rainy periods in summer and dry periods in winter (Henriques et al., 1988) (Fig. 2).

In August/2001 (dry season) and February/2002 (rainy season), fishes were collected and biotic and abiotic variables were obtained in the Cabiúnas, Comprida, Carapebus, Paulista, Garças, Piripiri and Preta lagoons. Sampling was carried out by means of gill nets (15 m long, 1.5 m high and 15, 20, 25 and 30 mm of mesh size and seine nets (10 m long, 1 m high and 10mm of adjacent knots; and 2 m long, 1.5 m high and 5 mm of mesh size). Sampling effort was standardised between seasons and optimised for each lagoon in order to capture as many species as possible. Sampled fishes were fixed in 10% formalin and then preserved in alcohol at 70%. They were identified through specialised bibliography, 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).

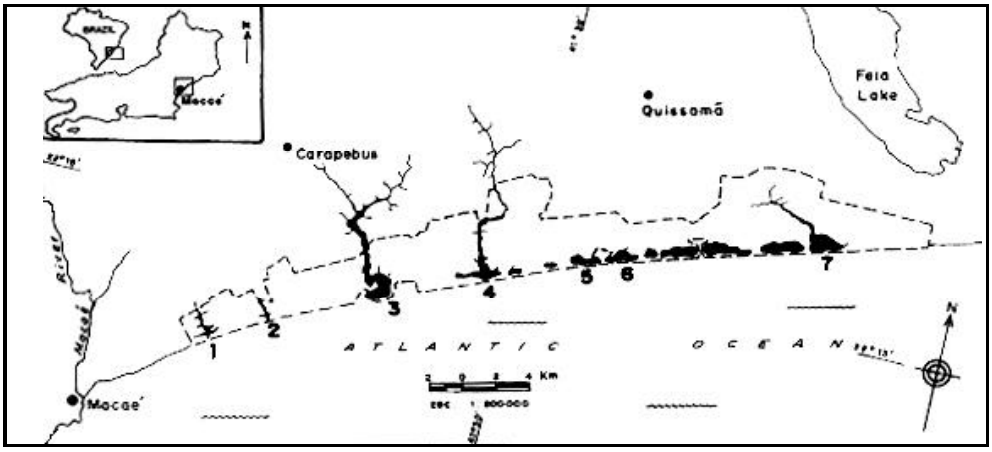

Figure 1: Sampled lagoons of the Restinga de Jurubatiba National Park 1. Cabiúnas Lagoon; 2. Comprida Lagoon; 3. Carapebus Lagoon; 4. Paulista Lagoon; 5. Garças Lagoon; 6. Piripiri Lagoon; 7. Preta Lagoon. (——) Limits of the Restinga de Jurubatiba National Park. (Modifield from map produced by IBAMA/UFRJ/Macaé, Carapebus, Quissamã Municipalities).

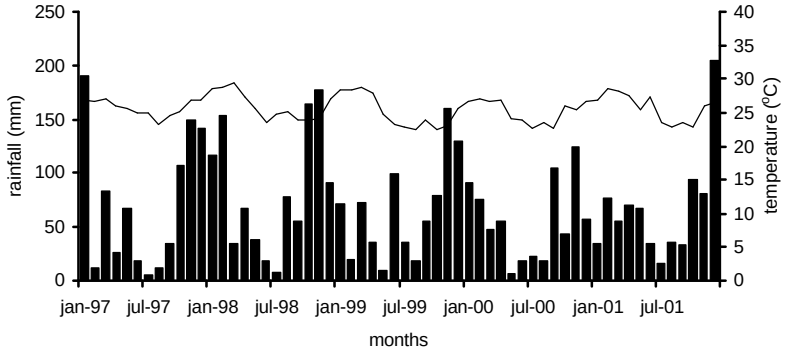

Figure 2: Precipitation (bars; $\overline{X}$ 68.4; VC= 74.1%) and temperature (lines; $\overline{X}$ =25.6; VC=7.6%) in the region of the Restinga de Jurubatiba National Park. (Source: Climatologic station, São Lázaro Farm, Macaé, RJ, Brazil).

In each sampling, colour of the water (Abs_{430nm}) was obtained by means of a spectrophotometer as well as aquatic macrophyte richness (number of species) by comparing morphotypes. Through a profile carried out in the water column of each lagoon, we obtained mean values (‰) of salinity (field thermosalinometer YSI); pH (pHmeter Analion PM 608) and total phosphorus (mmol/l), determined in laboratory following Golterman et al. (1978).

The lagoons area (km²) were obtained in SEMADS (2001). Connections with rivers were identified and estimated with satellite images and field observations, where: 0 – without connection to river; 50 – connection to river that had a small drainage basin; 100 – connection to river that had a large drainage basin. Estimations of connections to the sea (by high tides and waves) were directly related to the distance between the lagoons and the ocean, varying from 60 to 100 m ($\overline{X}$= 78m, VC= 20.5%) (Tab. I).

Similarity dendrograms of fish richness between the lagoons for each sampling period were generated from the Sorensen coefficient, using single linkage as clustering method. Clustering analyses were carried out with the abiotic and biotic variables obtained in each lagoon for each sampling period through Principal Component Analysis (PCA). In order to verify possible associations between variables and fish richness, linear correlations (Pearson index) between species richness and abiotic and biotic variables were calculated.

Table I: Biotic and abiotic variables of the coastal lagoons from the Restinga de Jurubatiba National Park in August/2001 (A) and February/2002 (F) (SC = sea connection; RC = river connecttion).

Lagoon	Periods	Salinity (‰)	Colour (Abs430 nm)	pH	Total Phosphorus (µmol/l)	Area (km^2)	SC	RC	Macrophyte richness
Cabiúnas	A	2.50	0.012	7.25	0.150	0.34	100	50	20
	F	0.50	0.061	7.10	0.458				
Comprida	A	1.10	0.053	6.11	0.120	0.13	100	0	14
	F	0.20	0.149	4.87	0.328				
Carapebus	A	5.70	0.048	8.50	0.295	6.70	100	100	7
	F	3.30	0.022	6.96	0.625				
Paulista	A	3.80	0.031	7.60	0.125	1.22	0	50	7
	F	1.50	0.002	4.00	0.428				
Garças	A	0.80	0.365	3.53	2.350	0.70	0	0	2
	F	0.30	0.394	3.45	1,064.000				
Piripiri	A	39.64	0.059	8.22	0.430	1.92	0	0	0
	F	36.70	0.098	8.15	0.669				
Preta	A	64.60	0.052	7.95	1.370	5.30	0	50	3
	F	50.00	0.018	8.43	0.971				

Results

In the sampled lagoons 21 fish species were captured, belonging to 13 families and six orders. From this total 33% (seven species) belong to the Characiforms order, followed by 24% Perciforms (five species) and 19% Cyprinodontiforms (four species). The Clupeiforms, Siluriforms and Atheriniforms orders represent 24% of the total species. Fish richness from marine (five) and freshwater (16) origin represented 24% and 76% respectively from the ichthyofauna collected (Tab. II).

Cabiúnas and Carapebus lagoons presented the greatest fish richness, 16 and 13 species respectively, followed by Paulista Lagoon with 10 species, Comprida Lagoon with five species, and Preta and Piripiri lagoons, with three species each. In the Garças Lagoon we did not capture fish in either of the collecting periods (Tab. II). Comparison of fish richness among the lagoons in dry season (August/2001) showed a three-group formation: the first formed by Cabiúnas and Carapebus lagoons, with 14 and 11 species respectively; the second one by Paulista Lagoon (four species), Piripiri (two species) and Preta Lagoon (three species); the third one by Comprida Lagoon, with four species. For rainy season (February/2002) three groups were formed: the first one was composed by Cabiúnas Lagoon with 13 species, and Carapebus, with 12 species; the second one by Comprida Lagoon with five species, and Paulista Lagoon, with seven species; and the third one by Piripiri and Preta lagoons, with three species each (Fig. 3 a and b).

The most commonly captured species were: Poecilia vivipara (five lagoons), Atherinella brasiliensis, Geophagus brasiliensis, Cichlasoma facetum, Hoplias malabaricus and Hyphessobrycon bifasciatus (four lagoons). The other species occurred in three or less than three lagoons (Tab. II).

In PCA based on lagoons biotic and abiotic characteristics, axis 1 and 2 accounted for 77% in August/2001 and for 78% in February/2002 of total data variability (Fig. 4 a and b). During dry and rainy seasons the same groupings were formed, but with different spatial patterns. These variations occurred mainly due to salinity and pH increase in all the lagoons and due to total phosphorous decrease in five lagoons, during the dry season (August).

The main component analysis in the dry season demonstrated that the two first components explained 77% of total variability of the sampled data (51% and 26%, respectively). In the first axis Garças Lagoon presented high values of colour and total phosphorus; in the opposite quadrant, the position of Carapebus Lagoon was influenced by pH values, size and drainage basin area. The second axis evidenced high richness of

Table II: Fish species captured in the sampled lagoons of the Restinga de Jurubatiba in August/2001 (A) and February/2002 (F).

Order	Family	Species	Cabiúnas	Comprida	Carapebus	Paulista	Garças	Piripiri	Preta	Total
Clupeiformes	Clupeidae	Platanichthys platana	F		F					2
	Engraulidae	Lycengraulis grossidens	A F		A					2
Characiformes	Characidae	Astyanax gr. bimaculatus	A F		A F	F				3
		Hyphessobrycon luetkenii	A F							1
		Hyphessobrycon bifasciatus	A F	A F	A F	F				4
		Oligosarcus hepsetus	A F		A					2
	Curimatidae	Cyphocharax gilbert	A F							1
	Erythrinidae	Hoplerythrinus unitaeniatus				F				1
		Hoplias malabaricus	A F	F	A F	F				4
Siluriformes	Auchenipteridae	Parauchenipterus striatulus	A			F				2
	Ariidae	Genidens genidens	F							1
Atheriniformes	Atherinidae	Atherinella brasiliensis	A F		A F	A			A F	4
Cyprinodontiformes	Poeciliidae	Phalloceros caudimaculatus		A						1
		Poecilia vivipara	A F		A F	A		A F	A	5
		Phalloptycus januarius			A F	A		A F		3
	Anablepidae	Jenynsia multidentata			F			F	A F	3
Perciformes	Centropomidae	Centropomus parallelus	A							1
	Cichlidae	Tilapia rendalli			A F					1
		Cichlasoma facetum	A F	A F	A F	F				4
		Geophagus brasiliensis	A F	A F	A F	A F				4
	Gobiidae	Awaous tajasica	A							1
Total	**13**	**21**	**16**	**5**	**13**	**10**	**0**	**3**	**3**	

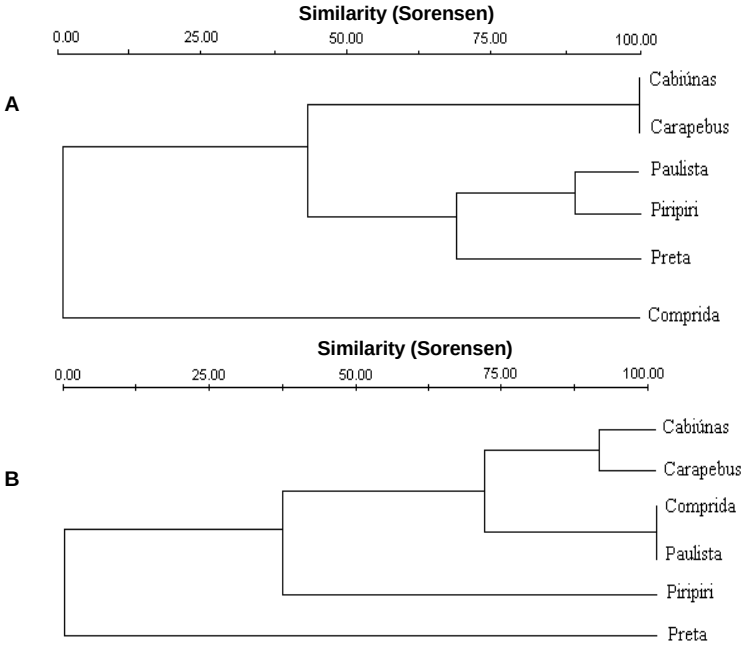

Figure 3: Similarity cluster of ichthyological richness between sampled lagoons in the dry season - August/2001 (A) and rainy season - February/2002 (B).

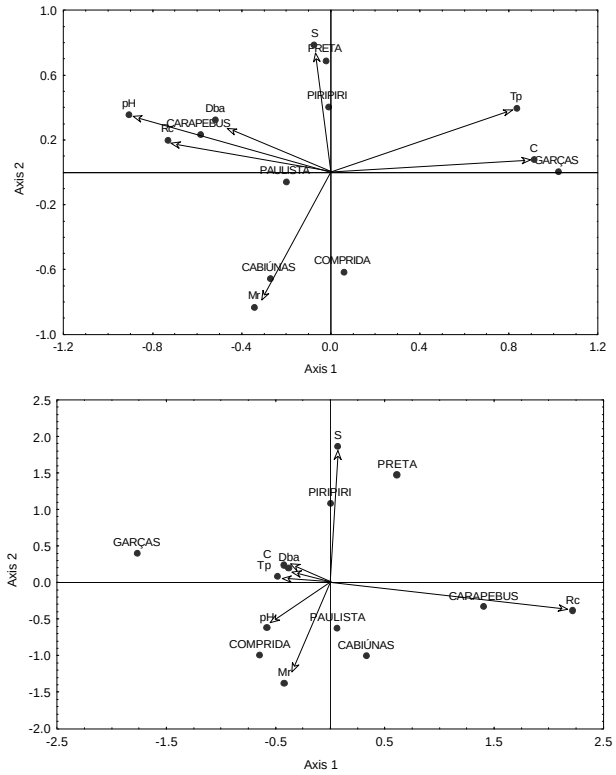

Figure 4: Ordination diagram (PCA) of sampled lagoons (CABIÚNAS, COMPRIDA, CARAPEBUS, PAULISTA, GARÇAS, PIRIPIRI and PRETA) by their biotic and abiotic features (Mr: Macrophyte richness; Rc: River connection Dba: Drainage basin area; S: Salinity; C: Colour; Tp: Total phosphorus and pH) in the dry season (A) and in the rainy season (B).

aquatic macrophytes influencing Cabiúnas and Comprida lagoons. In the opposite quadrant, Piripiri and Preta lagoons were related to high salinity values. Paulista Lagoon presented intermediate position to abiotic and biotic characteristics (Fig. 4a).

The main component analysis in the rainy season demonstrated that the two first components explained 78% of total variability of the sampled data (51% and 27%, respectively). Carapebus Lagoon evidenced the influence of the large area of the drainage basin. In the other quadrant Piripiri and Preta lagoons were influenced by high salinity values. Paulista, Cabiúnas and Comprida evidenced the influence of high richness of aquatic macrophytes. The position of Garças Lagoon is related to high total phosphorus and colour values (Fig. 4b).

Pearson linear analyses between fish richness in each sampling period and abiotic and biotic variables revealed positive correlation of connection with the river ($r=0.686$ in dry season and $r=0.741$ in rainy season; $p<0.05$) and aquatic macrophytes richness ($r=0.745$ in dry season and $r=0.691$ in rainy season; $p<0.05$). Fish richness and other variables presented no significant correlations ($p>0.05$).

Discussion

The fish composition of the Restinga de Jurubatiba National Park lagoons presented species belonging to Characiforms, Perciforms and Cyprinodontiforms orders, which are dominant groups in South American continental waters (Lowe-McConnel, 1969). This fact evidences the high influence of the regional freshwater ecosystems. On the other hand, most of Rio de Janeiro coastal lagoons presents predominantly a marine fish composition, mainly influenced by the frequency of connection to the sea (e.g.: Rodrigo de Freitas Lagoon; Andreata et al., 1997; Maricá Lagoon; Brum et al., 1994; Marapendi Lagoon; Andreata et al., 1989). Freshwater species of the secondary division (as proposed by Myers, 1937), such as Cyprinodontiforms and cichlids that tolerate salinity variations, are common in the environments which are frequently connected to the sea (Chao et al., 1982; Andreata et al., 1990 a, b; Brum et al., 1994; Aguiaro & Caramaschi, 1995; Andreata et al., 1997). Thus, the fish composition of the National Park coastal lagoons is affected by adjacent freshwater systems, and secondarily by sporadic connections with the sea due to high tides and waves or human opening of the sand bar.

Habitat area and spatial heterogeneity are factors positively associated to the variations in species richness (Emery 1978; Rahel et al., 1984; Minns, 1989). Water exchange with adjacent environments and aquatic macrophytes abundance probably favoured the fish richness in Cabiúnas, Comprida, Carapebus and Paulista lagoons. The presence of Cyphocharax gilbert, Oligosarcus hepsetus and Parauchenipterus striatulus probably are due to the temporary connection in the past with the artificial Macaé-Campos channel as mentioned to Cabiúnas Lagoon by Aguiaro & Caramaschi (1995). The species that inhabit coastal lagoons are rather specialists: omnivorous, detritivorous and piscivorous, among others (Aguiaro & Caramaschi, 1998; Aguiaro, 1999). Also, they can use different habitats, such as the aquatic macrophyte areas that reduce predation pressure over small fishes (Dielh & Eklov 1995; Sánchez–Botero & Araújo-Lima, 2002). On the other hand, the lack of aquatic macrophyte species in the Preta and Piripiri lagoons and the high salinity and pH values are conditions for a limited fish fauna, favouring the presence of species with marine ancestrality (Poecilia vivipara, Phalloptychus januarius and Jenynsia multidentata) or of marine origin (Atherinella brasiliensis) with tolerance to high salinity values. These species were registered in freshwater environments and have already been captured in other coastal lagoons with salinity values reaching 35‰ (Andreata et al., 1990a). Probably they have wide salinity tolerance limits and are favoured by osmotic adaptations to hypertonic environments (Andreata et al., 1997).

Variation in the fish composition between rainy and dry seasons were probably caused by changes in the physical, chemical and biological conditions of the environment.

Lagoons connected to river basins exhibit high richness when compared to isolated and shallow ones. Annual variations in the intensity and duration of rainy and dry seasons lead to important modification in the relative abundance of fish species, favouring some and being restrictive to others (Merona & Gascuel, 1993; Agostinho, 1997). In the Restinga de Jurubatiba National Park lagoons, in the rainy season, salinity and pH decreased slightly, whereas the colour and total phosphorous increased. The connection of the lagoons with other adjacent freshwater ecosystems is indicated by the presence of species such as: Astyanax gr. bimaculatus, Hyphessobrycon bifasciatus, Hoplerythrinus unitaeniatus, Parauchenipterus striatulus, Jenynsia multidentata, Cichlasoma facetum and Hoplias malabaricus. Increasing fish richness in Comprida, Carapebus, Paulista and Piripiri lagoons occurred during this period. In fact, in Rodrigo de Freitas Lagoon, Jenynsia multidentata and Poecilia vivipara presented a density increase when salinity was below 10‰ (Andreata et al., 1997).

The capture of some species, such as Centropomus parallelus in Cabiúnas Lagoon and Phalloptychus januarius in Paulista Lagoon in the dry season, may have been influenced by salinity increase. This factor probably was also responsible for the displacement of freshwater species to connected no brackish environments. The sea influence can also be observed in the Lagoon species composition. There is scarce historical register of the exchanges between the sea and the lagoons. However, the short distances (sand barrier width average X= 78m, VC= 20.5%) between the freshwater bodies and the sea, suggest that during sporadic events, the marine species invasion is possible. In fact, lagoons have marine or estuarine species and offer conditions through time to their permanence. Long term studies are fundamental to evidence patterns in structural responses of the fish community related to environmental variations and their role in community theory. Variability in the habitat has a direct influence in biological functions of each species, generating structural changes in the community. Therefore, temporal variations in fish composition of coastal lagoons could be made more evident through periodical samplings of the different habitats. The characterisation of the National Park lagoons showed variation in the composition related to changes in the physical, chemical and biological conditions of these ecosystems, for dry and rainy seasons.

Garças Lagoon is shallow (average depth 25cm) and it is submitted to desiccation processes during the dry season. Six fish species have already been registered in the environment (Hollanda-Carvalho, 2002), however no fish was captured during the period of this study due to extremely low depth. Studies in floodplains showed that annual variations in the intensity and duration of wet and dry seasons led to significant fluctuations in the species relative abundance, modifying the community structure (Junk et al., 1997; Agostinho, 1997). In the coastal lagoons of the Restinga de Jurubatiba National Park, the closed sand barrier and the influence of rainy and dry seasons on the connection to adjacent freshwater bodies directly affect fish species richness.

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