



ORIGINAL ARTICLE

Patterns of fish and crustacean community structure in a coastal lagoon system, Rio de Janeiro, Brazil

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Abstract

Coastal lagoons are feeding and nursery habitats for fish and crustaceans and fishing grounds for some of these species. This work describes the fish and crustacean community structure of the Piratininga–Itaipu lagoon system (Niterói, Rio de Janeiro, Brazil), evaluating the importance of environmental factors in structuring spatial and temporal changes. Sampling was conducted using gill-nets, cast-nets, hoop-nets and fish traps during summer and winter of 2006. A total of 50 fish and 9 crustacean species were collected, amounting to 17,143 specimens. Few species dominated in abundance, frequency and biomass. The marine–estuarine species *Atherinella brasiliensis* and *Cetengraulis edentulus* were most abundant in Piratininga and Itaipu, respectively. Analysis of Similarity, nMDS and Canonical Correspondence Analysis indicated a strong spacial segregation between Piratininga and Itaipu and to a lesser extent a seasonal component. Salinity was the main factor influencing species distribution, followed by water depth, water temperature and, to a lesser extent, organic matter in the sediment and bottom vegetation. A large number of occasional species occurring at sampling sites near the Itaipu channel, which connects the lagoon to the sea, suggests a high degree of communication between this lagoon and the adjacent marine coastal environment, unlike Piratininga lagoon, which has an indirect communication with the sea.

Key words: *spatial distribution, environmental factors, salinity, southeastern Brazil*

Introduction

Coastal lagoons provide essential goods and services for human populations, including shoreline protection, fisheries resources, habitat and food for migratory and resident animals. These highly productive ecosystems sustain a great diversity and high densities of organisms, with fish, crustacean and benthic assemblages playing an important role as biological indicators of human-induced changes (Ribeiro et al. 2008). The conservation of biodiversity and natural processes in coastal lagoons has become a challenge in recent decades due to increasing human pressures, including fisheries, recreational activities, tourism, demographic expansion and global climate change (Edgar et al. 2010).

Many studies have shown the role of lagoons as nurseries and feeding areas (Maci & Basset 2009;

Vasconcelos et al. 2010). Estuarine-resident, estuarine-dependent, opportunistic marine and occasional marine and freshwater fishes (Castro et al. 2009), as well as several shrimp (Pérez-Castañeda et al. 2010) and crab (Monteiro-Neto et al. 2003) species use coastal lagoons for food, shelter and reproduction.

Salinity (Martino & Able 2003; Sosa-Lopez et al. 2007; Castro et al. 2009; Maci & Basset 2009), water temperature, dissolved oxygen and pH often regulate community structure in coastal lagoons, following seasonal dynamic and tidal variations (Maes et al. 2004; Pombo et al. 2005; Murphy & Secor 2006; Sosa Lopez et al. 2007).

Estuaries and lagoons are especially affected by anthropogenic pressures, resulting in water quality impairment and loss of aquatic biota (Pérez-Domínguez et al. 2012). Human impacts on coastal lagoons include eutrophication through wastewater,

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modifications in the shoreline (landfills) and bottom dredging, often changing water circulation and exchange within the lagoon system (Carneiro et al. 1993), community composition (Murphy & Secor 2006) and structure. Studies conducted in coastal lagoons at the northern end of the State of Rio de Janeiro have shown that fish communities may undergo severe changes under salinity stress due to disturbances by sandbank opening (Sánchez-Botero et al. 2008, 2009).

Piratininga and Itaipu lagoons, Rio de Janeiro, southeastern Brazil, have undergone great changes due to urban real estate development in the last 30 years, with decreasing water quality of both systems (Knoppers et al. 1991, Wasserman et al. 1999). Nevertheless, baseline studies to determine distribution, abundance and diversity of fishes and crustaceans inhabiting the system are limited and outdated in the literature. Also, correlations with environmental variables as structuring components of this community are lacking. This study aims to characterize the fish and crustacean assemblages of the Piratininga–Itaipu lagoon system and to investigate the influence of environmental variables in structuring these communities. Furthermore, we propose to provide updated information on fish and crustacean biodiversity and community organization of the system for future monitoring programmes.

Material and methods

The Piratininga–Itaipu lagoon system – PILS (22°57'S, 43°04'W) is located in the metropolitan area of Niterói, Rio de Janeiro, Brazil. Piratininga lagoon has an area of 2.9 km² and an average depth of 0.6 m. The water cycle is influenced mainly by freshwater inflow and sewage discharge, maintaining low salinities and a flushing half-life of 16 days (Knoppers et al. 1991). The lagoon develops a great biomass of benthic algae, mostly *Chara hornemannii* J. Wallman, 1853 (Wasserman et al. 1999), and is connected with the Itaipu lagoon through the Camboatá canal. This lagoon has an area of 1.0 km², an average depth of less than 1 m, and is permanently connected with the sea through the Itaipu canal (Figure 1). Its water regime is greatly influenced by the adjacent sea and has a flushing half-life of one day (Knoppers et al. 1991). The lagoon is surrounded by mangrove trees, concentrating high values of organic matter in the sediment. The climate is classified as AW, hot and humid (Köppen 1948), with a summer (December–March) rainy season, with an average monthly rainfall greater than 100 mm, and a winter (June–September) dry season, with an average monthly rainfall around 50 mm (UFF 2012).

Samples were taken twice in summer (January and February) and winter (July and August) of 2006,

respectively. Sampling was conducted during day-time (8:00 a.m.–5:00 p.m.) following a design that divided each system into six different areas (Piratininga: P1–P6; Itaipu: I1–I6), covering both lagoons (Figure 1).

Underwater vegetation (mostly *Chara hornemannii*, but also *Ruppia maritima* Linnaeus, 1753 and *Ulothrix* sp) covers parts of the bottom of sampled areas P2, P4 and P6. Area P1 is mostly affected by the Camboatá canal and the densely vegetated shoreline of Modesto Island. P2, near the mouth of Jacaré River, has an extensive mud deposit. The shoreline at P3 is not populated by urban development and has marginal vegetation dominated by *Typha domingensis* Pers. P4 is less influenced by marine waters and P5 shows *Acrostichum* sp. throughout the margins. Both P4 and P5 are highly populated areas. P6 is the central deepest area of Piratininga lagoon.

Itaipu lagoon is less populated than Piratininga lagoon and parts of the marginal vegetation are represented by mangroves (*Laguncularia racemosa* (L.) C.F. Gaertn., *Avicennia schaueriana* Stapf & Leechman ex Moldenke and *Rhizophora mangle* L.), mostly in I2, I3, I4 and I5. I1 comprises the Itaipu canal and the mouth of Itaipu lagoon. I2 has an artificial rocky boulder shoreline covered with algae. I3 is influenced by the runoff of the Vala River, whereas I4 is influenced by the Camboatá canal and João Mendes River. I6 is the central deepest area of Itaipu lagoon (Figure 1).

The following types of fishing gear were used to collect fishes and crustaceans: (a) gill-nets made up of three 2.0 m × 50.0 m panels, of 12-, 20- and 35-mm mesh size between knots, respectively, and set tied to each other (150 m total) with mesh sequence randomly assigned; (b) two cast-nets of 32.1 m², with 12 and 20 mm mesh sizes, respectively; (c) hoop-net of 1 mm mesh; and (d) seven fish traps made of 2-litre PET bottles set together, equally spaced, on a 10 m line.

All fishing gear was used in the six areas, respectively, during each sampling event, maintaining a constant fishing effort as follows: (a) gill-nets – one cast of approximately 3:30 h in the deepest parts of each area; (b) cast-nets – 12 casts with the 12- and the 20-mm mesh net, respectively, thrown randomly throughout the entire area; (c) hoop-net – 15 casts randomly distributed in the shallower waters of the area; (d) fish traps – one cast (one line with 7 bottles) of approximately 3:30 h in the shallower waters of the area. The sum of all catches within an area, regardless of the sampling gear, constitutes one sample. Species abundance and biomass were determined for each sample. Nine environmental variables were monitored in four randomly distributed stations within each area: (a) salinity and (b)

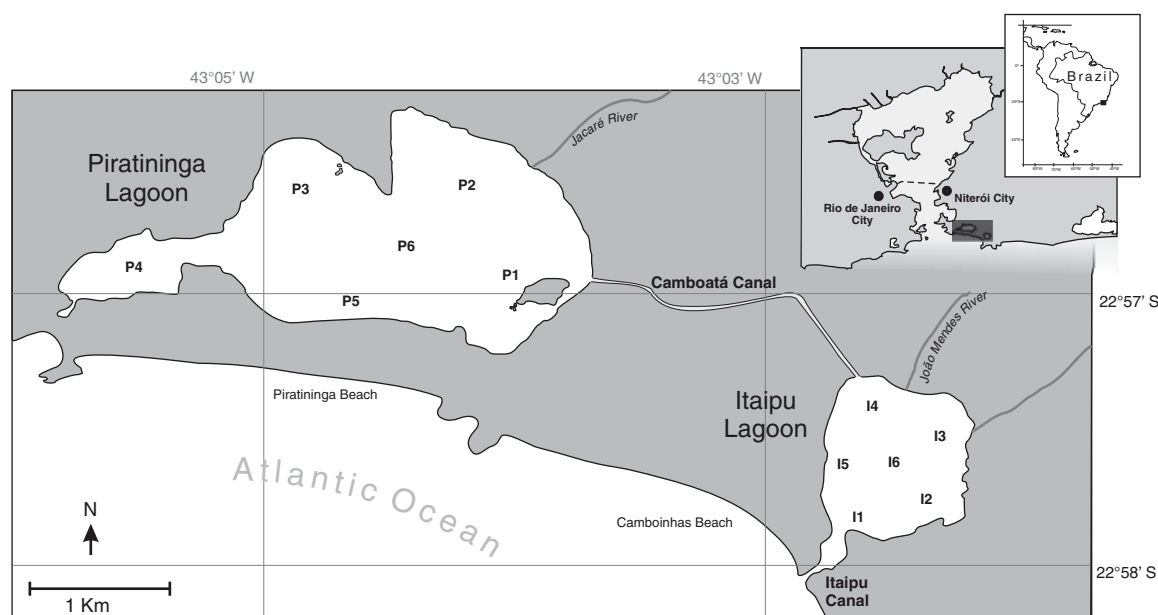


Figure 1. Map of the study area, showing sampling points established for the Piratininga–Itaipu lagoon system.

water temperature ($^{\circ}\text{C}$) using a Digital Handheld Conductivity YSI 30, (c) dissolved oxygen (mg l^{-1}) (WTW Oxi315i), and (d) pH (PH-206 LUTRON) measured at the surface, (e) transparency (cm, Secchi disc) and (f) water depth (cm, measured cable) of the water column, (g) organic matter (%) (mass balance difference), (h) grain size (%) of the upper sediment layer (CILAS 1026) and (i) under-water vegetation (presence/absence).

Fish and crustacean samples were tagged, cooled on ice or fixed in a 10% formalin solution in the field. In the laboratory all individuals were identified (Figueiredo & Menezes 1978, 1980; Menezes & Figueiredo 1980, 1985, 2000; Melo 1996; Young 1998; Carvalho-Filho 1999; Costa et al. 2003; Nelson 2006; Froese & Pauly 2008) and measured (total length of fish, carapace width of crabs and cephalothorax length of shrimps), using an ichthyometer and a precision calliper. Logarithmic transformations [$\log_{10}(x+1)$] of data were performed to reduce contagion (Legendre & Legendre 1998; Monteiro-Neto et al. 2003). Species that represented less than 0.1% of total abundance were discarded from the analysis to reduce bias (Boesch 1977).

The relationship between species and sample distribution patterns in a simplified two-dimensional space were assessed by non-Metric Multidimensional Scaling (nMDS). Analysis of Similarity (ANOSIM) was used to determine whether the composition of fish and crustaceans differed among lagoons and between seasons. A similarity percentage (SIMPER) was used (cut-off level at 60%) to determine which species contributed most to similarities within and dissimilarities between groups

(Clarke 1993). A resemblance matrix was calculated using the Bray–Curtis distance. All analyses were conducted using PRIMER 5.0 software (Clarke & Warwick 2001). Associations between fish and crustacean abundance, samples and environmental variables were analysed with Canonical Correspondence Analysis (CCA) using CANOCO 4.5 for Windows software (Leps & Smilauer 2003). All environmental variables were tested for significance tested ($p < 0.05$) through Monte Carlo permutation methods before entering the model.

Results

Table I shows the average values of environmental variables monitored during this study at Piratininga and Itaipu. The bottom sediments of both lagoons were characterized by a predominant mud fraction (around 90%). Piratininga lagoon showed the lowest salinities as compared with Itaipu lagoon. Water depth at Piratininga does not exceed 0.7 m, whereas the deepest parts of Itaipu lagoon are around 1.8 m. Patches of underwater vegetation cover parts of areas P2, P4 and P6 in Piratininga, whereas in Itaipu lagoon bottom vegetation occurs only in area I2. Average temperature was usually higher in Piratininga when compared with Itaipu. Top temperatures and pH values occurred in the summer and lowest in the winter in both lagoons. Average salinity was slightly higher in the winter for both lagoons due to low rainfall. Itaipu showed higher salinities than Piratininga, regardless of the season, due to its close contact with the adjacent sea. Dissolved oxygen was

Table I. Mean $\pm$ standard deviation of environmental variables measured in the Piratininga-Itaipu lagoon system by lagoon and season. Underwater vegetation: vegetation occurrence/total number of samples.

	Itaipu		Piratininga	
	Summer	Winter	Summer	Winter
Water temperature, °C	27.4 $\pm$ 2.1	23.9 $\pm$ 0.8	30.4 $\pm$ 2.1	23.6 $\pm$ 1.7
Salinity	30.1 $\pm$ 3.0	32.2 $\pm$ 1.1	4.4 $\pm$ 0.6	17.8 $\pm$ 1.4
pH	8.5 $\pm$ 0.2	6.8 $\pm$ 0.8	9.2 $\pm$ 0.4	6.9 $\pm$ 2.0
Dissolved oxygen, mg/l	6.9 $\pm$ 1.8	6.3 $\pm$ 0.8	7.5 $\pm$ 1.3	6.9 $\pm$ 2.0
Water transparency, cm	62.8 $\pm$ 17.5	66.1 $\pm$ 23.0	87.8 $\pm$ 11.1	65.7 $\pm$ 12.4
Water depth, m	0.9 $\pm$ 0.5	0.9 $\pm$ 0.5	0.5 $\pm$ 0.1	0.5 $\pm$ 0.1
Organic matter, %	11.4 $\pm$ 5.9	15.7 $\pm$ 10.6	16.6 $\pm$ 6.4	18.6 $\pm$ 6.7
Sand, %	8.4 $\pm$ 13.4	8.4 $\pm$ 13.4	7.6 $\pm$ 10.6	6.9 $\pm$ 9.1
Mud, %	91.6 $\pm$ 13.4	91.6 $\pm$ 13.4	92.4 $\pm$ 10.6	93.2 $\pm$ 9.1
Underwater vegetation	1/12	2/12	4/12	6/12
Precipitation rate, mm	179.6 $\pm$ 49.1	46.8 $\pm$ 9.6	179.6 $\pm$ 49.1	43.7 $\pm$ 9.2

slightly higher in Piratininga lagoon and top values occurred in summer in both lagoons.

A total of 48 samples were collected (12 summer and 12 winter from both Piratininga and Itaipu lagoons), which yielded 17,143 specimens of which 86.8% were fishes, from 10 orders, 26 families and 50 species. The remaining 13.2% individuals were crustaceans (Malacostraca, Decapoda) including 4 families and 9 species (Table II).

The five most abundant species – *Atherinella brasiliensis* Quoy & Gaimard, 1825, *Cetengraulis edentulus* Cuvier, 1829, *Poecilia vivipara* Bloch & Schneider, 1801, *Elops saurus* Linnaeus, 1766 and *Diapterus rhombeus* Cuvier, 1829 – together represented more than 50% of the total numerical abundance, whereas 42 species with individual numerical abundances of less than 1% accounted for 6.3% of the total catch (Table II). Nine species occurred in more than 50% of the samples. *Elops saurus*, *A. brasiliensis* and *Eucinostomus argenteus* Baird & Girard, 1855 were the most frequently found species. Twenty-five species were present in less than 10% of the samples in the entire study (Table II).

Thirty-three species of fishes and crustaceans were caught in Piratininga lagoon and 54 in Itaipu lagoon. *Atherinella brasiliensis* and *P. vivipara* were the most abundant species in Piratininga regardless of the season and occurred with low abundance in Itaipu. *Cetengraulis edentulus* and *Mugil curema* Valenciennes, 1836 were the most abundant in the winter and *D. rhombeus* and *C. edentulus* in the summer at Itaipu, all occurring at low abundances in Piratininga (Table II).

Non-Metric Multidimensional Scaling revealed four different groups, reflecting both spatial (Piratininga-P vs. Itaipu-I) and temporal (summer-S vs. winter-W) patterns (Figure 2). ANOSIM indicated that the composition between lagoons and between seasons differed significantly (global $R=0.868$, $p=0.001$ and global $R=0.261$, $p=0.001$, respectively).

SIMPER average similarity within P-W group was 58%, and *A. brasiliensis*, *E. saurus*, *Oreochromis niloticus* Linnaeus, 1758, *Callinectes danae* Smith, 1869 (Malacostraca, Portunidae), *Farfantepenaeus brasiliensis* Latreille, 1817 (Malacostraca, Penaeidae), *Micropogonias furnieri* Desmarest, 1823 and *Callinectes bocourti* A. Milne-Edwards, 1879 (Malacostraca, Portunidae) totalled above 60% for similarity within group. The P-S group showed an average similarity of 64% with greatest contributions by *A. brasiliensis*, *E. saurus*, *P. vivipara* and *O. niloticus*. The I-W group similarity was 57% and the most contributing species were *D. rhombeus*, *C. danae*, *Litopenaeus schmitti* Burkenroad, 1936 (Malacostraca, Portunidae), *Callinectes ornatus* Ordway, 1863 (Malacostraca, Portunidae), *C. edentulus* and *M. curema*. The I-S group showed 58% similarity with *D. rhombeus*, *E. argenteus*, *M. curema*, *E. saurus* and *Eucinostomus gula* Quoy & Gaimard, 1824 as the most contributing species.

Table III shows the species that contributed most to dissimilarities between groups. Ten to 12 species contributed to an average dissimilarity between groups varying from 52% to 83%. Lowest dissimilarities occurred between seasons within lagoons and higher dissimilarities occurred between lagoons during summer.

The total amount of variation explained by CCA was 46.2%. The first axis explained 29.6% of the variance and was responsible for discriminating Piratininga (right side) and Itaipu (left side) samples, whereas the second axis explained 8.1% and separated summer from winter sampling periods (Figure 3). Salinity had most influence on the distribution of species and samples along the first canonical axis, reflecting the predominantly freshwater regime of Piratininga against the tidal saltwater regime of Itaipu. Surface water temperature was predominantly associated with the second canonical axis and high summer temperatures. Depth contributed to

Table II. Percent abundance (number of individuals, N%) and percent frequency of occurrence (F%) of crustaceans (Malacostraca) and fish (Actinopterygii) species captured in Piratininga and Itaipu lagoons during Winter and Summer samplings. Species are listed by their percentage abundance rank from high to low. MS, marine stragglers; MM, marine migrants; ER, estuarine residents; EM, estuarine migrants; AN, anadromous; SC, semi-catadromous; AM, amphidromous; FM, freshwater migrants (Elliot et al. 2007). Note: table continues on next page.

Species	Anagram	Guild	Piratininga				Itaipu				Total	
			Summer		Winter		Summer		Winter			
			N%	F%	N%	F%	N%	F%	N%	F%	N%	F%
Class Malacostraca												
<i>Litopenaeus schmitti</i>	LITSCH	MM			1.2	67	0.4	33	11.9	92	3.2	48
<i>Palaemon northropi</i>	PALNOR	MM	7.1	50	0.5	42			0.2	42	3.0	33
<i>Callinectes danae</i>	CALDAN	EM			5.4	100	3.1	75	5.4	100	2.9	69
<i>Farfantepenaeus brasiliensis</i>	FARBRA	MM			3.3	92			2.3	83	1.3	44
<i>Callinectes ornatus</i>	CALORN	MM			1.8	75	0.4	25	2.9	92	1.2	48
<i>Callinectes bocourti</i>	CALBOC	SC	1.0	67	2.0	83			0.2	42	0.9	48
<i>Farfantepenaeus paulensis</i>	FARPAU	MM			1.0	75			1.5	75	0.6	38
<i>Callinectes sapidus</i>	CALSAP	SC	0.1	42	0.7	75					0.2	29
<i>Uca rapax</i>	UCARAP	ER					0.1	8			<0.1	2
Class Actinopterygii												
<i>Atherinella brasiliensis</i>	ATHBRA	ER	30.6	100	30.9	100	3.8	58	2.4	67	20.1	81
<i>Cetengraulis edentulus</i>	CETEDE	MM	<0.1	8	0.5	8	24.1	58	39.2	50	12.9	31
<i>Poecilia vivipara</i>	POEVIV	ER	19.6	100	12.0	75			0.1	8	10.4	46
<i>Elops saurus</i>	ELOSAU	MM	10.0	100	6.0	100	4.6	83	2.8	75	6.6	90
<i>Diapterus rhombeus</i>	DIARHO	MM	<0.1	8	0.6	33	30.8	100	8.1	100	6.5	60
<i>Jenynsia multidentata</i>	JENMUL	ER	13.6	75	1.6	42	<0.1	8			5.7	31
<i>Mugil curema</i>	MUGCUR	MM	0.1	33	0.9	58	10.6	92	13.7	75	5.1	65
<i>Oreochromis niloticus</i>	ORENIL	FM	7.6	100	7.5	100			0.3	58	4.7	65
<i>Phalloptychus januarius</i>	PHAJAN	ER	8.3	83	5.2	58					4.5	35
<i>Eucinostomus argenteus</i>	EUCARG	MM	0.2	42	9.3	75	4.2	100	2.6	83	3.4	75
<i>Micropogonias furnieri</i>	MICFUR	MM			4.8	75	0.8	58	0.5	17	1.3	38
<i>Eucinostomus gula</i>	EUCGUL	MM	0.1	17	0.7	50	3.3	83	1.5	83	1.0	58
<i>Harengula clupeiola</i>	HARCLU	MS					5.0	50			0.7	13
<i>Gobionella oceanicus</i>	GOBOCE	AM	<0.1	8	<0.1	8	2.9	75	0.8	83	0.6	44
<i>Mugil liza</i>	MUGLIZ	MM	0.4	67	0.7	75	1.3	83	0.2	50	0.6	69
<i>Brevoortia aurea</i>	BREAUR	MM			1.9	83	0.5	33	0.2	33	0.5	38
<i>Anchoviella lepidentostole</i>	ANCLEP	AN			1.1	50			0.9	58	0.5	27
<i>Centropomus undecimalis</i>	CENUND	AM	0.7	92			<0.1	8	<0.1	8	0.3	27
<i>Citharichthys spilopterus</i>	CITSPI	ER			0.1	8	0.4	67	0.7	83	0.2	40
<i>Centropomus parallelus</i>	CENPAR	AM	0.3	42	0.2	25	0.2	25	0.1	17	0.2	27
<i>Sardinella brasiliensis</i>	SARBRA	MS					1.2	33	<0.1	8	0.2	10
<i>Diapterus auratus</i>	DIAAUR	MM	<0.1	17	<0.1	8	0.6	58	0.3	58	0.2	35
<i>Pogonias cromis</i>	POGCRO	MM	0.3	50							0.1	13
<i>Ulaema lefroyi</i>	ULALEF	MM							0.3	33	0.1	8
<i>Pomatomus saltatrix</i>	POMSAL	MM					0.4	42			0.1	10
<i>Achirus lineatus</i>	ACHLIN	ER					<0.1	8	0.1	33	<0.1	10
<i>Opisthonema oglinum</i>	OPIOGL	MS			0.1	17	0.1	17	<0.1	8	<0.1	10
<i>Selene vomer</i>	SELVOM	MS					0.2	33			<0.1	8
<i>Anchoa tricolor</i>	ANCTRI	MM							0.1	25	<0.1	6
<i>Bathygobius soporator</i>	BATSOP	AM					0.2	17			<0.1	4
<i>Diplectrum formosum</i>	DIPFOR	MS					0.2	25			<0.1	6
<i>Diplectrum radiale</i>	DIPRAD	MS					0.2	25			<0.1	6
<i>Symphurus plagusia</i>	SYMPLA	MM							0.1	25	<0.1	6
<i>Eucinostomus melanopterus</i>	EUCMEL	MM					<0.1	8	<0.1	17	<0.1	6
<i>Prionotus punctatus</i>	PRIPUN	MS							0.1	25	<0.1	6
<i>Ctenogobius shufeldti</i>	CTESHU	AM							0.1	17	<0.1	4
<i>Chilomycterus spinosus</i>	CHISPI	MS							<0.1	17	<0.1	4
<i>Gobionella stomatus</i>	GOBSTO	ER	<0.1	8			<0.1	8			<0.1	4
<i>Synodus foetens</i>	SYNFOE	MS							<0.1	17	<0.1	4
<i>Sphoeroides testudineus</i>	SPHTES	MS					0.1	17			<0.1	4
<i>Caranx latus</i>	CARLAT	MS					0.1	8			<0.1	2
<i>Cynoscion acoupa</i>	CYNACO	MM							<0.1	8	<0.1	2
<i>Anchovia clupeioides</i>	ANCCLU	AM					<0.1	8			<0.1	2
<i>Archosargus rhomboidalis</i>	ARCRHO	MS					<0.1	8			<0.1	2

Species	Anagram	Guild	Piratininga				Itaipu				Total	
			Summer		Winter		Summer		Winter			
			N%	F%	N%	F%	N%	F%	N%	F%	N%	F%
<i>Haemulon plumieri</i>	HAEPLU	MS							<0.1	8	<0.1	2
<i>Microgobius meeki</i>	MICMEE	MM			<0.1	8					<0.1	2
<i>Chloroscombrus chrysurus</i>	CHLCHR	MS			<0.1	8					<0.1	2
<i>Sphoeroides greeleyi</i>	SPHGRE	MS					<0.1	8			<0.1	2
<i>Sphyraena tome</i>	SPHTOM	MS					<0.1	8			<0.1	2
<i>Stephanolepis setifer</i>	STESET	MS					<0.1	8			<0.1	2
Number of individuals			6784		3815		2455		4089		17143	
Number of species			21		30		38		38		59	
Number of samples				12		12		12		12		48

with Itaipu, regardless of the season (Figure 3). Dissolved oxygen, water transparency, pH and sediment grain size were not significant variables ($p > 0.05$) and were not included in the CCA diagram.

The present study provides the current baseline of fish and crustacean distribution, abundance, and diversity within the Piratininga–Itaipu lagoon system (PILS). The 50 fish species recorded is within the range of values obtained in similar ecosystems along the coast of Rio de Janeiro. Aguiaro & Caramaschi (1995) recorded a total of 53 fish species in 3 lagoons in the Macaé region, whereas Andreata et al. (1990, 1992) recorded 49 and 15 species in Tijuca and Jacarepaguá lagoons, respectively. Furthermore, Andreata et al. (2002) reached a maximum of 59 species after a 9-year study in Rodrigo de Freitas lagoon. Macrocrustaceans found in the present study included species of crabs (*Callinectes* spp.) and shrimps (*Farfantepenaeus* spp. and *Litopenaeus schmitti*) which are common in lagoons (Monteiro-Neto et al. 2000), bays (Lavrado et al. 2000; Keunecke et al. 2008) and estuaries (Garcia et al. 1996), and often subjected to fisheries.

Pérez-Ruzafa et al. (2006) indicated that lagoon size, substratum diversity, environmental heterogeneity and its degree of communication with the open

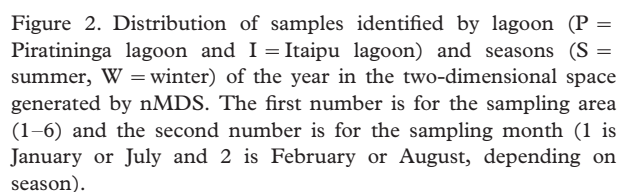


Table III. Results of SIMPER analysis showing fish and crustacean (*) taxa that contributed most (cut-off level = 60%) to the dissimilarity between the four groups: It-Wi, Itaipu-Winter; It-Su, Itaipu-Summer; Pi-Wi, Piratininga-Winter; Pi-Su, Piratininga Summer. AVAB, average abundance within group; PDC, percent dissimilarity contribution. Grey boxes indicate highest AVAB per species between each pairwise comparison.

Species	AVAB			AVAB			AVAB			AVAB			AVAB			AVAB		
	It-Wi	Pi-Wi	PDC	It-Wi	It-Su	PDC	Pi-Wi	It-Su	PDC	It-Wi	Pi-Su	PDC	Pi-Wi	Pi-Su	PDC	It-Su	Pi-Su	PDC
<i>Atherinella brasiliensis</i>	8.3	98.1	7.5	8.3	7.8	4.5	98.1	7.8	7.2	8.3	173.1	8.0	98.1	173.1	4.9	7.8	173.1	9.0
<i>Brevoortia aurea</i>	0.6	6.4	3.6				6.4	0.0	4.0				6.1	0.0	4.8			
(*) <i>Callinectes bocourti</i>					6.4	4.9							6.4	5.4	3.9			
(*) <i>Callinectes danae</i>				18.3	6.4	6.2				18.3	0.0	5.7	17.3	0.0	7.4			
(*) <i>Callinectes ornatus</i>				10.0	0.8	6.2				10.0	0.0	4.3						
<i>Cetengraulis edentulus</i>	133.4	1.7	6.3	133.4	49.3	9.1	1.7	49.3	4.6	133.4	0.2	5.3				49.3	0.2	4.4
<i>Diapterus rhombeus</i>	27.7	1.9	7.1				1.9	62.9	8.9	27.7	0.2	6.7				62.9	0.2	9.6
<i>Elops saurus</i>	9.7	19.1	4.3	9.7	9.3	5.1				9.7	56.6	5.0	19.1	56.6	3.9	9.3	56.6	4.7
<i>Eucinostomus argenteus</i>	8.9	29.4	4.2				29.4	8.6	4.0				29.4	1.3	5.4	8.6	1.3	4.0
<i>Eucinostomus gula</i>				5.2	6.8	3.9												
(*) <i>Farfantepenaeus brasiliensis</i>				8.0	0.0	5.3	10.4	0.0	4.4				10.4	0.0	5.5			
(*) <i>Farfantepenaeus paulseni</i>				5.1	0.0	4.4												
<i>Gobionellus oceanicus</i>				2.8	5.8	3.8	0.1	5.8	3.6									
<i>Jenynsia multidentata</i>										0.0	76.7	4.0	5.0	76.7	5.7	0.1	76.7	4.5
(*) <i>Liopenaeus schmitti</i>	40.6	3.9	5.2	40.6	0.8	8.4				40.6	0.0	5.7						
<i>Micropogonias furnieri</i>	1.7	15.3	4.7				15.3	1.6	4.2									
<i>Mugil curema</i>	46.8	2.9	4.6	46.8	21.8	6.7	2.9	21.8	4.3				15.3	0.0	5.9	21.8	0.8	4.6
<i>Oreochromis niloticus</i>	1.1	23.8	5.1				23.8	0.0	6.3	1.1	42.8	4.8				0.0	42.8	6.7
<i>Phallopterychus januarius</i>	0.0	16.7	4.4				16.7	0.0	4.2	0.0	46.9	5.8				0.0	46.9	6.6
<i>Poecilia vivipara</i>	0.3	38.1	4.9				38.1	0.0	4.8	0.3	110.7	7.3	16.7	110.7	6.7	0.0	110.7	8.5
Cumulative PDC			61.8			62.2			60.4			62.4			60.4			62.6
Average dissimilarity		61			53			70			83			54		82		

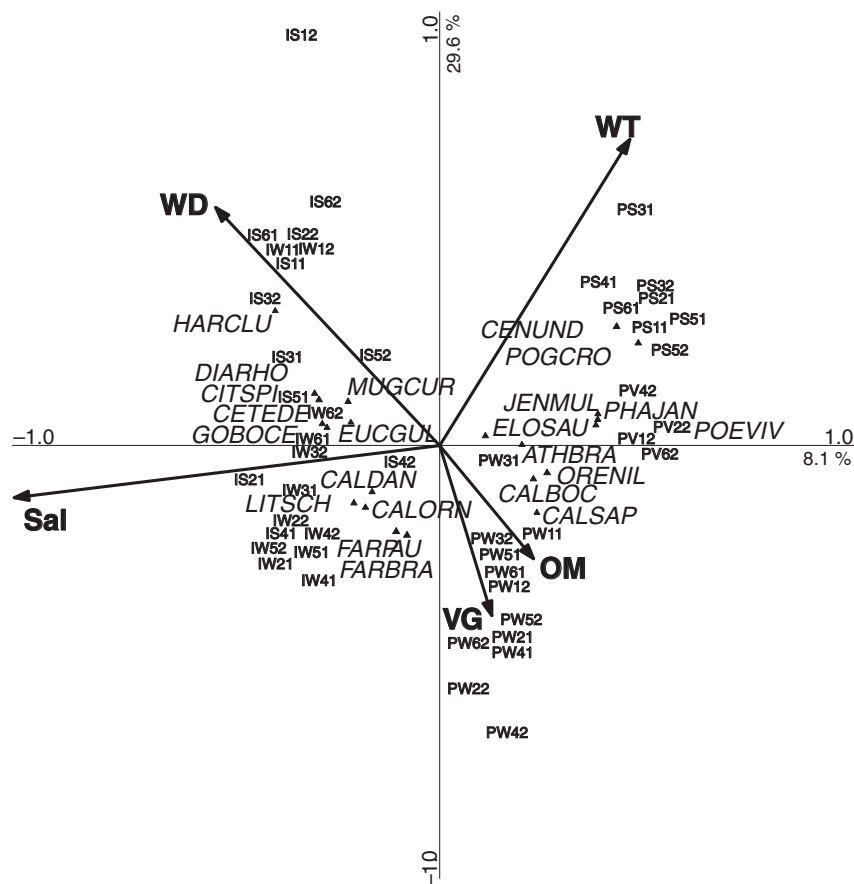


Figure 3. CCA between samples, species and significant environmental variables in the canonical space. P, Piratininga lagoon; I, Itaipu lagoon; S, summer; W, winter; the first number is for the sampling area (1–6) and the second number is for the sampling month (1 is January or July and 2 is February or August, depending on season). Environmental variables: OM, organic matter; Sal, salinity; VG, underwater vegetation; WD, water depth; WT, water temperature. For six-letter abbreviations, see Table II.

sea are important factors influencing diversity in the studied lagoon. Araújo & Azevedo (2001) suggested that the width of the mouth and surface areas of estuaries and lagoons are the main factors predicting the number of species, by allowing access to diversified habitats. This may be the case for Piratininga in comparison with Itaipu. Piratininga is almost three times the size of Itaipu, but showed the lowest species richness. The lagoon connectivity with the adjacent sea is limited and dependent upon the water circulation, which has a predominant unidirectional drainage flow from Piratininga to Itaipu through the Camboatá canal. These physiographical and dynamic features of the system may have limited species access to this confined habitat, restraining most marine stragglers and some marine migrants to Itaipu (Wasserman et al. 1999; Perez-Ruzafa et al. 2006).

Few dominant species in the community is a common pattern in shallow coastal lagoons and estuaries, either in tropical (Aguiaro & Caramaschi 1995; Andreatta et al. 1990, 1992, 2002) or temperate systems (Murphy & Secor 2006; Castro et al. 2009;

Maci & Basset 2009). A similar dominant distribution was observed in PILS, where 14 out of 59 species together represented 90.3% of total abundance.

Araújo & Azevedo (2001), studying coastal fish assemblages of south-southeastern Brazil, noted that several families and species were recurrent in estuaries and lagoons. Vieira & Musick (1994), studying the fish composition in temperate and tropical estuaries of the Western Atlantic, reached similar conclusions, denoting that latitudinal differences are present only at generic and specific levels. The taxonomic composition of the ichthyofauna of PILS has notable similarities, even at the species level, to other Brazilian systems. Nevertheless, species such as *Cetengraulis edentulus*, *Diapterus rhombeus* and *Oreochromis niloticus* were particularly important components in the PILS, but are often less important in other lagoon systems of southeastern Brazil (Araújo & Azevedo 2001). For instance, the exotic *O. niloticus* was incidentally introduced into the system a few years ago, due to an overflow of fish culture ponds. Once in the system, this freshwater migrant species (Elliot et al. 2007) found the

appropriate low salinity conditions and few local competitors in Piratininga lagoon, efficiently taking over the niche from native species such as *Geophagus brasiliensis* Quoy & Gaimard, 1824, previously recorded in the area (Sergipense & Pinto 1995), but absent in our survey. Monteiro-Neto et al. (1990) documented a similar case in the Laguna lagoon system in Santa Catarina State, in which young *O. niloticus* were recorded in less-saline areas, possibly due to bioinvasion. *Tilapia rendalli* Boulenger, 1897, a similar invasive species, was reported in lagoons of the northernmost part of the State of Rio de Janeiro (Sánchez-Botero et al. 2008, 2009).

The amount of variance explained by CCA in this study may be considered high. According to Ter Braak & Verdonschot (1995), eigenvalues greater than 30% indicate a strong explanation in the analysis. Also, the fact that only statistically significant (Monte Carlo permutation test) environmental variables are included in the ordination plot further enhances an explanation of the environment–community distribution (Ter Braak & Verdonschot 1995).

CCA showed that salinity was the most important environmental factor affecting fish and crustacean distribution. Several authors (e.g. Marshall & Elliott 1998; Martino & Able 2003; Rueda & Defeo 2003; Akin et al. 2005) found similar results, emphasizing the importance of salinity in these ecosystems. In addition to salinity, other environmental variables such as depth, temperature and substrate type were also indicated as main determinants of ecological discontinuities and species distribution in other coastal lagoons and estuaries (Yáñez-Arancibia et al. 1985; Nybakken & Bertness 2004; Pérez-Ruzafa 2006; Verdiell-Cubedo et al. 2012). In our study, salinity and water depth were the main factors discriminating both lagoons. In PILS these variables reflect the open communication with the adjacent sea at Itaipu, and the fact that this lagoon was dredged some 30 years ago, creating deeper channels in some areas (Correa et al. 1993). Both factors created a gradient from high salinity–deep water (Itaipu) to low salinity–shallow water (Piratininga) between lagoons. Furthermore, average water temperature was higher in summer and represented the seasonal component between sampling periods (summer–winter).

The type of substrate had little impact on community structuring in PILS, probably due to predominance of muddy sediments in both lagoons. CCA shows vegetation cover, organic matter and water depth percentage are more important factors; however, they were not clearly associated with only lagoon or season distinction and may also be attributed to heterogeneity between sampling areas.

Vieira & Musick (1994) described a shallow water ‘Atherinidae–Jenynsiidae–Poeciliidae assemblage’ in

warm-temperate estuaries of the southern Atlantic. Monteiro-Neto et al. (2003) observed *Atherinella brasiliensis* and *Jenynsia multidentata* in the surf-zone of Cassino Beach, next to the estuary of Patos Lagoon, but regarded these species as shallow water estuarine residents straying into the marine surf zone occasionally. In our study we observed this assemblage, composed of *A. brasiliensis*, *Poecilia vivipara*, *J. multidentata* and *Phallopterychus januaris*. Jenynsiidae and Poeciliidae were mostly captured in shallow nearshore areas of both lagoons. Nevertheless, their predominance in lower salinity sites indicated a stronger association with Piratininga lagoon. Similar findings were reported by Mendonça & Andreato (2001) for *P. vivipara* in Rodrigo de Freitas lagoon (RJ).

The association of fishes and underwater vegetation was previously noted by Monteiro-Neto et al. (1990) and Griffiths (2001), who found young individuals using stretches of the eelgrass (*Zostera* spp.) as natural nurseries, but also adults as feeding habitats. Pérez-Ruzafa (2006) studied the Mar Menor lagoon and found that species were distributed into distinct lagoon communities depending on the nature of the substratum and vegetation cover. Sergipense & Vieira (1999) observed a seasonal pattern of occurrence for *A. brasiliensis* in Piratininga lagoon, with higher frequencies in the summer when the abundant underwater vegetation offered food and protection from predators. In our data this pattern was not clear, probably due to limited patches of underwater vegetation observed in this study based on presence/absence rather than abundance. Anecdotal information from fishermen suggested that Piratininga lagoon’s vegetation has been highly reduced due to human intervention. Other studies emphasized that human activities like dredging, aquaculture, fishing and increasing urban population have major effects in lagoons and estuaries by changing habitat variability and the relative abundance of several fish species (Pérez-Ruzafa et al. 2006; França et al. 2012; Verdiell-Cubedo et al. 2012).

Several species found in PILS were marine migrant species, common in coastal waters of the Western South Atlantic, with juveniles often recruiting into bays and estuaries (Chaves & Bouchereau 2000; Monteiro-Neto et al. 2003; Elliot et al. 2007). Juvenile *Mugil curema* (5.3 cm mean total length) was one of the most abundant species in Itaipu in the present study. Sergipense & Pinto (1995) found similar results, with young *M. curema* concentrating in more saline waters and sandbars near the Itaipu canal. Young individuals from other marine migrant species were also captured (Table II), reinforcing the importance of Itaipu lagoon as a nursery area for young teleost fishes (Monteiro-Neto et al. 2008).

Some species (*D. rhombeus*, *C. edentulus*, *M. curema*, *Eucinostomus gula*) occurred in high-salinity sites associated with Itaipu lagoon, but showed no clear distinction between sampling periods. These species are frequent in coastal habitats, including bays, beaches, estuaries and mangroves (Carvalho-Filho 1999). Furthermore, a large number of occasional species (including *Harengula clupeiola*) occurring at sampling sites near the Itaipu channel, which connects the lagoon to the sea, suggests a high communication between this lagoon and the adjacent marine coastal environment, unlike Piratininga lagoon, which lacks a direct communication with the sea.

The CCA analysis showed that crustaceans at PILS were distributed on the negative side of the II-axis in the canonical space, associated with low temperatures. High abundances of crustaceans in winter seem related to the development period of juveniles within the estuaries, with drastic abundance reduction in summer. In southern regions of Brazil, where water temperatures in estuaries are generally low (below 20°C), high abundances for *Litopenaeus schmitti*, *Farfantepenaeus paulensis*, *F. brasiliensis*, *Callinectes sapidus* and *C. danae* are observed around summer, when water temperature is about 25°C (Monterio-Neto et al. 2000; Lückmann et al. 2008; Santos et al. 2008). In PILS similar mean water temperatures occur in winter (24°C), becoming warmer in summer (29°C). This temporal pattern of variation occurs north of PILS, where *C. ornatus* was also more abundant in estuaries during winter (Carvalho & Couto 2011; Ceuta & Boehs, 2012). Laboratory experiments showed that the optimum temperature for *F. paulensis* postlarvae survival is 25°C (Tsuzuki & Cavalli, 2000) and this may be the explanation for the high abundances observed in different seasons in the south as compared with southeast–northeast regions of Brazil.

The distribution of *Callinectes* spp. showed differences between Piratininga and Itaipu lagoons. *Callinectes sapidus* and *C. bocourti* were clearly associated with Piratininga, occurring in both seasons, whereas *C. danae* and *C. bocourti* were associated with Itaipu. *C. bocourti* and *C. sapidus* prefers low-salinity environments and adults are frequently found in freshwater (Almeida et al. 2008). The association between these species in estuaries has already been reported by Williams (1974). Monteiro-Neto et al. (2000), studying the Laguna estuarine system in Santa Catarina, Brazil, found *C. danae* positively and *C. sapidus* negatively related to high-salinity waters. Our findings corroborated these previous results.

Callinectes danae occurred in both lagoons in winter but only in Itaipu during summer, whereas *C. ornatus* occurred in PILS only in winter, with high abun-

dances in Itaipu. In the Rio Cachoeira estuary, where water temperatures are usually above 27°C, *C. danae* was found over the year in all areas of the estuary, at salinities varying between 17 and 34. Nevertheless, *C. ornatus* was restricted to the outer areas with high salinities and occurred only in the winter (Carvalho & Couto 2011). Although salinity was an important factor influencing the distribution of these crabs, in our study *C. ornatus* occurred in Piratininga in the winter (mean salinity = 18), but not in Itaipu during the summer (mean temperature = 27°C) and temperature seems to be the main factor influencing this pattern.

Seasonal variations in the environmental parameters apparently have a relevant influence on the distribution and occurrence of fish and crustacean species. The environmental factors monitored in Piratininga and Itaipu lagoons were found to be dynamic, but had most notable significant differences between lagoons, and to a lesser extent between sampling periods, at least for the monitored period. A continued monitoring programme may provide further evidence of this seasonal pattern.

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References

- Aguiaro T, Caramaschi EP. 1995. Ichthyofauna composition of three coastal lagoons in the north of state of Rio de Janeiro (Brazil). *Arquivo Biológico e Tecnológico* 38(4):1181–89.
- Akin S, Buhar E, Winemiller WO, Yilmaz H. 2005. Fish assemblage structure of Koycegiz Lagoon–Estuary, Turkey: Spatial and temporal distribution patterns in relation to environmental variation. *Estuarine, Coastal and Shelf Science* 64:671–84.
- Almeida AO, Coelho PC, Luz JR, Santos JTA, Ferraz NR. 2008. Decapod crustaceans in fresh waters of southeastern Bahia.

- International Journal of Tropical Biology and Conservation 56:1225–54.
- Andreata JV, Saad AM, Bizerril CRS, Bockmann FA. 1990. Alguns aspectos da ecologia das espécies de peixes da Laguna da Tijuca, período de março de 1987 e fevereiro de 1989. *Acta Biológica Leopoldensia* 12:247–68.
- Andreata JV, Saad AM, Moraes L, Soares CL, Marca AG. 1992. Associação, similaridade e abundância relativa dos peixes da laguna de Jacarepaguá Rio de Janeiro, Brazil. *Boletim do Museu Nacional* 355:1–25.
- Andreata JV, Manzano FV, Baptista MGS, Teixeira DE, Oliveira LOV, Longo MM, et al. 2002. Assembléia de peixes da Lagoa Rodrigo de Freitas, Rio de Janeiro. PUC-Campinas, Bioikos 16:19–28.
- Araújo FG, Azevedo MCC. 2001. Assemblages of southeast-south Brazilian coastal systems based on the distribution of fish. *Estuarine, Coastal and Shelf Science* 52:729–38.
- Boesch DF. 1977. Application of numerical classification in ecological investigations of water pollution. *Ecological Research Series*, EPA-600/3-77-033. Corvallis, OR: United States Environment Protection Agency. 115 pages.
- Carneiro MER, Barroso IV, Ramalho NM, Azevedo C, Knoppers BA, Kjerfve B, et al. 1993. Diagnóstico ambiental do sistema lagunar Piratininga-Itaipu, Niterói, RJ. Parte II. III Simpósio de Ecossistemas da Costa Brasileira, p 196–203.
- Carvalho FL, Couto ECG. 2011. Environmental variables influencing the *Callinectes* (Crustacea: Brachyura: Portunidae) species distribution in a tropical estuary – Cachoeira River (Bahia, Brazil). *Journal of the Marine Biological Association of the United Kingdom* 91:793–800.
- Carvalho-Filho A. 1999. Peixes: Costa Brasileira. 3th edition. São Paulo: Melro. 320 pages.
- Castro MG, Astarloa JMD, Cousseau MB, Figueroa DE, Delpiani SM, Bruno DO, et al. 2009. Fish composition in a south-western Atlantic temperate coastal lagoon: Spatial-temporal variation and relationships with environmental variables. *Journal of the Marine Biological Association of the United Kingdom* 89:593–604.
- Ceuta LO, Boehs G. 2012. Reproductive cycle of *Tagelus plebeius* (Mollusca: Bivalvia) in the estuary of the Cachoeira River, Ilhéus, Bahia, Brazil. *Brazilian Journal of Biology* 72:569–76.
- Chaves P, Bouchereau JL. 2000. Use of mangrove habitat for reproductive activity by the fish assemblage in the Guaratuba Bay, Brazil. *Oceanologica Acta* 23:273–80.
- Clarke KR. 1993. Non-parametric multivariate analysis of changes in community structure. *Australian Journal of Ecology* 18:117–43.
- Clarke KR, Warwick RM. 2001. Changes in Marine Communities: An Approach to Statistical Analysis and Interpretation. 2nd edition. Plymouth: PRIMER-E. 172 pages.
- Correa KS, Marcolini S, Silva TT, Sanmartin PA, Barroso LV. 1993. Gerenciamento ambiental do Sistema Lagunar de Piratininga-Itaipu, Niterói, RJ. *Anais do X Simpósio de Recursos Hídricos e I Simpósio de Recursos Hídricos do Cone Sul* 1:452–61.
- Costa RC, Fransozo A, Melo GAS, Freire FAM. 2003. Chave ilustrada para identificação dos camarões Dendrobranchiata do litoral Norte do Estado de São Paulo, Brazil. *Biota Neotropica* 3:1–12.
- Edgar GJ, Last PR, Barrett NS, Gowlett-Holmes K, Driessen M, Mooney P. 2010. Conservation of natural wilderness values in the Port Davey marine and estuarine protected area, south-western Tasmania. *Aquatic Conservation: Marine and Freshwater Ecosystems* 20:297–311.
- Elliott M, Whitfield AK, Potter IC, Blaber SJM, Cyrus DP, Nordlie FG, et al. 2007. The guild approach to categorizing estuarine fish assemblages: A global review. *Fish and Fisheries* 8:241–68.
- Figueiredo JL, Menezes NA. 1978. Manual de Peixes Marinhos do Sudeste do Brasil: II Teleostei (1). São Paulo: Museu de Zoologia, USP. 110 pages.
- Figueiredo JL, Menezes NA. 1980. Manual de Peixes Marinhos do Sudeste do Brasil: III Teleostei (2). São Paulo: Museu de Zoologia, USP. 90 pages.
- França S, Vasconcelos RP, Reis-Santos P, Fonseca VF, Costa MJ, Cabral HN. 2012. Vulnerability of Portuguese estuarine habitats to human impacts and relationship with structural and functional properties of the fish community. *Ecological Indicators* 18:11–19.
- Froese R, Pauly D. 2008. FishBase. World Wide Web electronic publication. www.fishbase.org, version 01/2007. (accessed XX Xxx 2013).
- Garcia AM, Vieira JP, Bemvenuti CE, Geraldi RM. 1996. Abundância e diversidade da assembléia de crustáceos decápodos dentro e fora de uma pradaria de *Rupia Maritima* no estuário da Lagoa dos Patos (RS-Brasil). *Nauplius* 4:113–28.
- Gray CA, Jones MV, Rotherham D, Broadhurst MK, Johnson MK, Barnes LM. 2005. Utility and efficiency of multi-mesh gill nets and trammel nets for sampling assemblages and populations of estuarine fish. *Marine and Freshwater Research* 56:1077–88.
- Griffiths SP. 2001. Factors influencing fish composition in an Australian intermittently open estuary. Is stability salinity-dependent? *Estuarine, Coastal and Shelf Science* 52:739–51.
- Keunecke KA, D'Incao F, Moreira FN, Silva-Jr DR, Verani JR. 2008. Idade e crescimento de *Callinectes danae* e *C. ornatus* (Crustacea, Decapoda) na Baía de Guanabara, Rio de Janeiro, Brasil. *Iheringia, Série Zoologia* 98:231–35.
- Knoppers B, Kjerfve B, Carmouze JP. 1991. Trophic state and water turn-over time in Six choked lagoons in Brazil. *Biogeochemistry* 16:149–66.
- Köppen W. 1948. *Climatologia*. Buenos Aires: Fondo de Cultura Económica. 478 pages.
- Lavrado HP, Falcão APC, Carvalho-Cunha P, Silva SHG. 2000. Composition and distribution of Decapoda from Guanabara Bay, RJ. *Nauplius* 8:15–23.
- Legendre P, Legendre L. 1998. *Numerical Ecology*. 2nd edition. Amsterdam: Elsevier. 853 pages.
- Leps J, Smilauer P. 2003. *Multivariate Analysis of Ecological Data using CANOCO*. New York: Cambridge University Press. 269 pages.
- Lüchmann KA, Freire AS, Ferreira NC, Daura-Jorge FG, Marques MRF. 2008. Spatial and temporal variations in abundance and biomass of penaeid shrimps in the subtropical Conceição Lagoon, southern Brazil. *Journal of the Marine Biological Association of the United Kingdom* 88:293–99.
- Maci S, Basset A. 2009. Composition, structural characteristics and temporal patterns of fish assemblages in non-tidal Mediterranean lagoons: A case study. *Estuarine, Coastal and Shelf Science* 83:602–12.
- Maes J, Van Damme S, Meire P, Ollevier F. 2004. Statistical modeling of seasonal and environmental influences on the population dynamics of an estuarine fish community. *Marine Biology* 145:1033–42.
- Marshall S, Elliott M. 1998. Environmental influences on the fish assemblages of the Humber Estuary, U.K. *Estuarine, Coastal and Shelf Science* 46:175–84.
- Martino EJ, Able KW. 2003. Fish assemblages across the marine to low salinity transition zone of a temperate estuary. *Estuarine, Coastal and Shelf Science* 56:969–87.
- Melo GAS. 1996. Manual de Identificação dos Brachyura (Caranguejos e Siris) do Litoral Brasileiro. São Paulo: Plêiade. 604 pages.

- Mendonça JP, Andreatta JV. 2001. Aspectos reprodutivos de *Poecilia vivipara* (Bloch & Schneider) (Poeciliidae) da Lagoa Rodrigo de Freitas, Rio de Janeiro, Brasil. *Revista Brasileira de Zoologia* 18:1041–47.
- Menezes NA, Figueiredo JL. 1980. Manual de Peixes Marinhos do Sudeste do Brasil: IV Teleostei (3). São Paulo: Museu de Zoologia, USP. 96 pages.
- Menezes NA, Figueiredo JL. 1985. Manual de Peixes Marinhos do Sudeste do Brasil: V Teleostei (4). São Paulo: Museu de Zoologia, USP. 105 pages.
- Menezes NA, Figueiredo JL. 2000. Manual de Peixes Marinhos do Sudeste do Brasil: VI Teleostei (5). São Paulo: Museu de Zoologia, USP. 116 pages.
- Monteiro-Neto C, Musick JA. 1994. Effects of beach seine size on the assessment of surf-zone fish communities. *Atlantica*, Rio Grande 16:23–29.
- Monteiro-Neto C, Prestrelo, L. 2013. Comparing sampling strategies for surf zone fish communities. *Marine and Freshwater Research* 64:102–07.
- Monteiro-Neto C, Blacher C, Laurent AS, Snizek FN, Canozzi MB, Tabajara LLC. 1990. Estrutura da comunidade de peixes de águas rasas na região de Laguna, Santa Catarina, Brasil. *Atlântica*, Rio Grande 12:53–69.
- Monteiro-Neto C, Laurent AAS, Blacher C, Tabajara ILL, Canozzi MB. 2000. Distribuição de juvenis de siris do gênero *Callinectes* no sistema estuarino lagunar de Laguna, SC, Brasil. *Arquivos de Ciências do Mar* 33:57–64.
- Monteiro-Neto C, Cunha LPR, Musick JA. 2003. Community structure of surf-zone fishes at Cassino Beach, Rio Grande do Sul, Brazil. *Journal of Coastal Research* 35:492–501.
- Monteiro-Neto C, Tubino RA, Moraes LES, Neto JPM, Esteves GV, Fortes WL. 2008. Associações de peixes na região costeira de Itaipu, Niterói, RJ. *Iheringia, Série Zoologia* 98:50–59.
- Murphy RF, Secor DH. 2006. Fish and blue crab assemblage structure in a U.S. mid Atlantic coastal lagoon complex. *Estuaries and Coasts* 29(6B):1121–31.
- Nelson JS. 2006. *Fishes of the World*. 4th edition. New York: John Wiley and Sons, Inc. 601 pages.
- Nybakken JW, Bertness MD. 2004. *Marine Biology: An Ecological Approach*. 6th edition. San Francisco, CA: Benjamin Cummings. 579 pages.
- Pérez-Castañeda R, Blanco-Martínez Z, Sánchez-Martínez JG, Rábago-Castro JJ, Aguirre-Guzmán G, Vázquez-Sauceda ML. 2010. Distribution of *Farfantepenaeus aztecus* and *F. duorarum* on submerged aquatic vegetation habitats along a subtropical coastal lagoon (Laguna Madre, Mexico). *Journal of the Marine Biological Association of the United Kingdom* 90:445–52.
- Pérez-Domínguez R, Maci S, Courrat A, Lepage M, Borja A, Uriarte A, et al. 2012. Current developments on fish-based indices to assess ecological-quality status of estuaries and lagoons. *Ecological Indicators* 23:34–45.
- Pérez-Ruzafa A, García-Charton JA, Barcala E, Marcos C. 2006. Changes in benthic fish assemblages as a consequence of coastal works in a coastal lagoon: The Mar Menor (Spain, Western Mediterranean). *Marine Pollution Bulletin* 53:107–20.
- Pombo L, Elliott M, Rebelo JE. 2005. Environmental influences on fish assemblage distribution of an estuarine coastal lagoon, Ria de Aveiro (Portugal). *Scientia Marina* 69:143–59.
- Ribeiro J, Monteiro CC, Monteiro P, Bentes L, Coelho R, Gonçalves JMS, et al. 2008. Long-term changes in fish communities of the Ria Formosa coastal lagoon (southern Portugal) based on two studies made 20 years apart. *Estuarine, Coastal and Shelf Science* 76:57–68.
- Rueda M, Defeo O. 2003. Spatial structure of fish assemblages in a tropical estuarine lagoon: combining multivariate and geo-statistical techniques. *Journal of Experimental Marine Biology and Ecology* 296:93–112.
- Sánchez-Botero JJ, Caramaschi EP, Garcez DS. 2008. Spatio-temporal variation in fish assemblage in a coastal lagoon without direct contact with the sea (Southeastern Brazil). *Journal of Coastal Research* 24:225–38.
- Sánchez-Botero JJ, Garcez DS, Caramaschi EP, Saad AM. 2009. Indicators of influence of salinity in the resistance and resilience of fish community in a tropical coastal lagoon (Southeastern Brazil). *Boletín de Investigaciones Marinas y Costeras* 38:171–95.
- Santos JL, Severino-Rodrigues E, Vaz-Dos-Santos AM. 2008. Estrutura populacional do camarão-branco *Litopenaeus schmitti* nas regiões estuarina e marinha da baixada santista, São Paulo, Brasil. *Boletim do Instituto de Pesca* 34:375–89.
- Sergipense S, Pinto DG. 1995. Aspectos de ocorrência e distribuição espacial da ictiofauna da Lagoa de Itaipu–Niterói – Rio de Janeiro. *Boletim do Instituto Oceanográfico de São Paulo* 11:179–86.
- Sergipense S, Vieira AC. 1999. Aspectos sazonais de ocorrência e tamanho de *Xenomelaniris brasiliensis* (Quoy & Gaimard, 1924) (Teleostei, Atherinidae) na laguna de Piratininga, Niterói-RJ. *Oecologia Brasiliensis* 7:292–304.
- Sosa-Lopez A, Mouillot D, Ramos MJ, Flores HD, Do Chi T. 2007. Fish richness decreases with salinity in tropical coastal lagoons. *Journal of Biogeography* 34:52–61.
- Ter Braak CJE, Verdonschot PEM. 1995. Canonical correspondence analysis and related multivariate methods in aquatic ecology. *Aquatic Sciences* 57:255–89.
- Tsuzuki M, Cavalli R. 2000. The effects of temperature, age, and acclimation to salinity on the survival of *Farfantepenaeus paulensis* postlarvae. *Journal of the World Aquaculture Society* 31:459–68.
- UFF. 2012. Pluviometric station HIDROUFF. Universidade Federal Fluminense, São Domingos, Niterói – RJ, Brazil. Available from: <http://www.hidrouff.uff.br/> (accessed 26 March 2013).
- Vasconcelos RP, Reis-Santos P, Maia A, Fonseca V, França S, Wouters N, et al. 2010. Nursery use patterns of commercially important marine fish species in estuarine systems along the Portuguese coast. *Estuarine, Coastal and Shelf Science* 86:613–24.
- Verdiell-Cubedo D, Torralva M, Andreu-Soler A, Oliva-Paterna FJ. 2012. Effects of shoreline urban modification on habitat structure and fish community in littoral areas of a Mediterranean coastal lagoon (Mar Menor, Spain). *Wetlands* 32:631–41.
- Vieira JP, Musick JA. 1994. Faunal composition in warm-temperate and tropical estuaries of western Atlantic. *Atlantica* 16:31–53.
- Wasserman J, Cunha LC, Carneiro MEE, Knopper B. 1999. The impact of a canal lock upon the water balance and the trophic state of Piratininga lagoon, state of Rio De Janeiro, Brazil. *Environmental Geochemistry of Coastal Lagoon Systems* 6:169–77.
- Williams AB. 1974. The swimming crabs of the genus *Callinectes* (Decapoda, Portunidae). *Fishery Bulletin* 72:685–798.
- Yáñez-Arancibia A, Lara-Domínguez AL, Aguirre-León A, Díaz-Ruiz S, Amezcua-Linares F, Flores Hernández D, et al. 1985. Ecology of dominant fish populations in tropical estuaries: environmental factors regulating biological strategies and production. In: Yáñez-Arancibia A, editor. *Fish Community Ecology in Estuaries and Coastal Lagoons: Towards an Ecosystem Integration*. México City: Editora Universitaria Universidad Nacional Autónoma de México, p 311–66.
- Young PS. 1998. Catalogue of Crustacea of Brazil. Série Livros do Museu Nacional no. 6. Rio de Janeiro: Museu Nacional. 717 pages.