



## Fish assemblage dynamics in the Ratoles River Mangrove, State of Santa Catarina, Brazil

ANDRÉ PEREIRA CATTANI<sup>1\*</sup>, GISELA COSTA RIBEIRO<sup>2</sup>, EDUARDO MARCON<sup>2</sup>, MARCELO SOETH<sup>1</sup>, MAURICIO HOSTIM-SILVA<sup>3</sup>, LEANDRO CLEZAR<sup>2</sup> & HENRY LOUIS SPACH<sup>1</sup>

<sup>1</sup>Centro de Estudos do Mar, Universidade Federal do Paraná. Caixa Postal 50002, 83255-000, Pontal do Paraná, Paraná, Brasil. E-mail: [cattani.andre@gmail.com](mailto:cattani.andre@gmail.com);

<sup>2</sup>Universidade Federal de Santa Catarina. Núcleo de Estudos do Mar. Campus Universitário, Trindade, Florianópolis, Brasil. CEP. 88040-900.

<sup>3</sup>Universidade Federal do Espírito Santo, Pós-graduação em Biodiversidade Tropical, São Mateus – ES, Brasil

\*Corresponding author: [cattani.andre@gmail.com](mailto:cattani.andre@gmail.com)

**Abstract:** Estuarine fish assemblages are highly dynamic due to intra and interspecific interactions, physiological limitations and life strategy. Understanding this ichthyofauna dynamic will support conservation and species preservation strategies. Thereby, we investigated the composition, structure and the habitat use over time and space in fish assemblages of the Ratoles River estuary, Santa Catarina State. Sampling was conducted monthly from January to December 1998 at five areas of the Ratoles River using three cast nets with the same diameter and different mesh sizes. Salinity and temperature were significantly different between seasons, but were not different between the sampling sites. Likewise, environmental variables did not significantly explain the pattern of the 18 families and 30 fishes species sampled in this study. Although physical and chemical parameters play a key role on the species distribution patterns, it is likely that the major cause of variability in the abundance of fish in these areas relates to the reproductive patterns, associated with spawning and juvenile recruitment period, such as observed to *Mugil liza*, the second most abundant species in this study. Despite Ratoles River to be surrounded by anthropogenic activities of Florianópolis city, its mangroves seem help the development of juvenile fishes.

**Key words:** juvenile fishes, marine migrants, estuary, Brazilian southern mangroves

**Resumo:** Dinâmica da assembleia de peixes no mangue do Rio Ratoles, SC, Brasil. A assembleia de peixes estuarinos apresenta elevada dinâmica devido suas interações intra e interespecífica, limitações fisiológicas e estratégias de vida. Compreender esta dinâmica da ictiofauna suporta medidas estratégicas para preservação e conservação das espécies. Deste modo, nós investigamos espaço-temporalmente a composição, estrutura e o uso de habitat da ictiofauna do estuário do Rio Ratoles, ilha de Santa Catarina. Amostras foram conduzidas mensalmente entre janeiro e dezembro de 1998 em cinco áreas do Rio Ratoles usando três tarrafas com o mesmo diâmetro e diferentes malhas. Salinidade e temperatura foram significativamente diferentes entre as estações do ano, mas não foram diferentes entre os sites amostrados. Do mesmo modo, as variáveis ambientais não explicaram significativamente o padrão das 18 famílias e 30 espécies de peixes amostradas neste estudo. Embora os parâmetros físico-químicos exerçam papel chave nos padrões de distribuição, parece que a maior causa de variabilidade na abundância dos peixes nestas áreas se relacionam aos padrões reprodutivos, associados com o período de desova e recrutamento de juvenis, como observado para *Mugil liza*, a segunda

espécie mais abundante neste estudo. Apesar do Rio Ratores estar rodeado por atividades antrópicas da cidade de Florianópolis, seus manguezais parecem ajudar no desenvolvimento de peixes juvenis.

**Palavras-chave:** peixes juvenis, migrantes marinhos, estuário, mangues do sul do Brasil

## Introduction

In tropical, subtropical and temperate regions of the northern and southern hemispheres, coastal and estuarine areas act as a nursery for many species of aquatic biota, especially for the fish fauna (Blaber & Blaber 1980; Lenanton & Potter 1987; Laegdsgaard & Johnson 2001; Elliot & McLusky 2002; Barletta *et al.* 2005, 2008).

In general, when fish reach maturity, they migrate to deeper areas and away from the coast to complete the life cycle (Blaber & Blaber 1980; Hyndes *et al.* 1999). The largest group of fish from South America estuaries is of marine migrants, whose distribution and occurrence is conditioned, on the one hand, by the tidal regimes and, secondly, by seasonal fluctuations in freshwater discharge from rivers (Barletta *et al.* 2010).

The high primary and secondary productivity of estuaries has great influence on the density, richness and biomass of fish (Day Jr. *et al.* 1989; Whitfield 1999). Besides providing food resources, these areas provide breeding sites and protection from predation for juveniles (Kjerfve 1994).

In these environments, the fauna is highly dynamic due to intra- and interspecific interactions and physiological limitations and life strategy (Kennish 1990). Spatial and temporal variations of abiotic parameters, such as salinity and temperature, directly affect the aquatic biota of these environments. For fish, such variations play an important role in assemblage structure, changing the fish composition according to these environment parameters (Greenwood & Hill 2003; Akin *et al.* 2005;). This could be found in some of the most important estuaries from South America, where salinity is an important factor structuring the spatial structure of fish assemblages (Jaureguizar *et al.* 2004; Barletta *et al.* 2005, 2008, 2010).

The analysis of the fish assemblage biodiversity and its variation over spatial and temporal scales allow to evaluate the environmental quality, understanding of the ecosystem functioning and to support conservation and preservation strategies. This study investigated the composition, structure and the habitat use over time and space in fish assemblages sampled in the Ratores River estuary.

## Materials and Methods

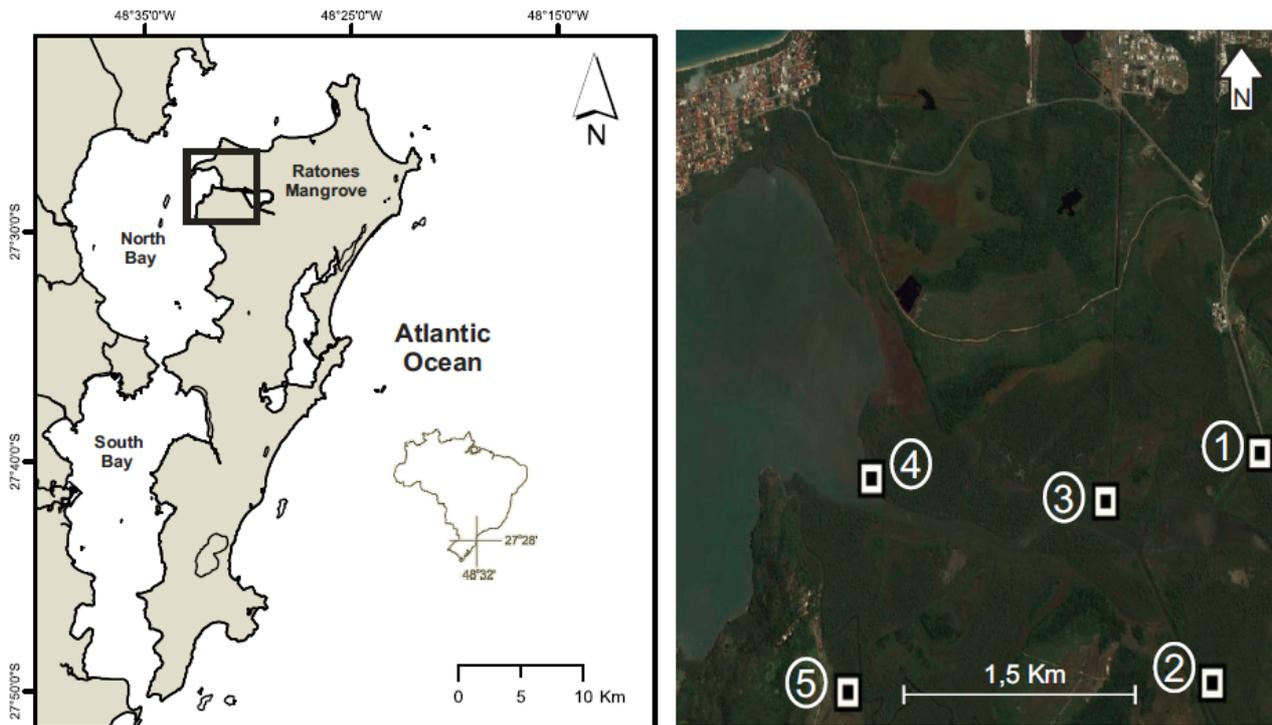
**Study area:** The island of Santa Catarina (28°37'S; 48°27'W), located parallel and adjacent to the continental margin, is elongated-shaped and oriented towards N-NE/S-SW (Fig. 1); it occupies an area of 431 km<sup>2</sup>, surrounded by 180 km coast, on the edge of the subtropical region (Sierra de Ledo 1997). The Ratores mangrove (27°27'30"/27°30'00"S; 48°28'12"/48°31'43"W) is located to the Northwest of the island of Santa Catarina on the Norte Bay, occupying an area reduced to 7.30 Km<sup>2</sup> in the estuarine part of the Ratores River (Simonassi *et al.* 1997). Its catchment area is drained by several rivers and streams, and the Ratores River is the main river of the basin. The vegetation is typical of mangroves, dominated by *Avicennia schaueriana*, *Laguncularia racemosa* and *Rhizophora mangle*, and formation of salt marsh banks with predominance of *Spartina alterniflora* (Simonassi *et al.* 1997). The tidal regime is semidiurnal, with an average amplitude of 0.52 m (Soriano-Sierra and Sierra de Ledo, 1998). The physicochemical variations respond mainly to continental input, and the environment is usually mesotrophic (Simonassi *et al.*, 2010).

**Sampling:** Sampling was conducted from January to December (except for February) 1998. Monthly samples were taken in five areas of the Ratores mangrove (Fig. 1). Three cast nets with the same diameter and different mesh sizes (45, 60 and 65 mm between opposite knots, respectively) were thrown 30 times in each area and month. Each cast net was thrown 10 times. A dipnet (10 mm mesh size) was also used on the margins. The specimens were weighed (g), measured [total length (TL) and standard length (SL)] and identified following Figueiredo and Menezes (1978, 1980, 2000), Menezes and Figueiredo (1980, 1985) and Marceniuk (2005).

Data of temperature and surface water salinity were monthly determined using thermometer and refractometer, respectively.

**Statistical analysis:** In order to test the temporal and spatial differences, we used a linear model:

$$X = \mu + Es + Po + Es * Po + e$$



**Figure 1.** Map of the Island of Santa Catarina detailing the five sampling areas in the Ratonés River mangrove.

where  $X$ =dependent variable;  $\mu$ =mean;  $Es$ =season,  $Po$ =point;  $e$ =error. The factors seasons (summer, fall, spring and winter) and points (1, 2, 3, 4 and 5) were considered fixed and orthogonal.

Temporal and spatial variations in fish abundance were tested by a Permutational multivariate analysis of variance (PERMANOVA) using PRIMER software (Anderson *et al.* 2008). When the null hypothesis was rejected by PERMANOVA, a posteriori comparisons between factors that showed significant differences ( $p < 0.05$ ) were performed by a pairwise PERMANOVA, with graphic display of differences through a canonical analysis of principal coordinates (CAP), which generates the graphic groups through permutation (Anderson *et al.* 2008). In the CAP analysis, Spearman correlation of 0.5 was used to determine which species (vectors) were responsible for the groupings.

The size structure of the two most abundant species was also tested for differences in space and time, using the PERANOVA. Unlike PERMANOVA, which analyzes the significance of the factors by means of a multivariate matrix (abundances of all species), PERANOVA is a univariate analysis. Therefore, to test any differences between the sizes of these most abundant species, we used the values of total length (TL) as the

dependent variable.

Spatial and temporal variations in temperature and salinity were tested by PERANOVA run on the Euclidean distance similarity matrix, and using the Akaike's information criterion (AIC), it was evaluated the influence of temperature and salinity on the pattern of fish occurrence by DISTLM (Distance Based Linear Model) (Anderson *et al.* 2008). Despite of the output analysis provides AIC values and  $p$ -values, the last were considered to choose which environment parameter was responsible for fish abundance variability. Through permutations of independent variables (normalized by the Primer routine), it was tested, through the stepwise procedure, which of these variables were responsible ( $p < 0.05$ ) for the variability in fish abundance (dependent variable, square root transformed) (Clark & Warwick, 1994). The distance-based redundancy analysis (dbRDA) (Anderson *et al.* 2008) illustrated the influence of predictor variables on the spatial distribution of the samples. For all analyses, 9999 permutations were used, biotic data were square root transformed and the similarity index used in the analysis of abundance data was the Bray-Curtis.

Using presence/absence matrices, we calculated indices of Average Taxonomic Distinctness (Delta+ or AvTD) and Variation of

Taxonomic Distinctness (Lambda+ or VarTD) for assessing the taxonomic differences between the seasons and to determine which seasons have greater taxonomic complexity (Clark & Warwick 1994). Both indices were calculated according to these formulas:

$$AvTD = [\sum_{i < j} \omega_{ij}] / [S(S - 1)]$$

$$VarTD = [\sum_{i < j} (\omega_{ij} - AvTD)] / [S(S - 1)]$$

where  $\omega_{ij}$  ( $i = 1, 2, \dots, S$ ) is the number of species ( $S$ ) in each sample analyzed for each location;  $\omega_{ij}$  is the degree of distinction between species given by the distance taxonomic between  $i$  and  $j$  species, based on the phylogenetic tree constructed by a kind of list drawn up in class levels, order, family, genus and species for each site analyzed.

Funnel plots of AvTD and VarTD demonstrated that the values of Average Taxonomic Distinctness and Variation of Taxonomic Distinctness of the seasons are within the taxonomic range expected for the area. A biplot graph was made with both indices on each axis, overlapping an ellipse of 95% probability of species occurrence to the point cloud of this plot.

Taxonomic differences between the seasons were tested by univariate PERANOVA, having as dependent variables the species richness, and values of AvTD and VarTD, and as fixed factor, the seasons.

## Results

**Environmental variables:** In relation to salinity, significant differences were found only between the seasons (Pseudo-F=3.8854,  $p=0.0182$ ). In paired comparison, significant differences were detected between summer and winter ( $t=2.749$ ,  $p=0.0189$ ) and summer and spring ( $t=2.4797$ ,  $p=0.0287$ ). Significant differences were also verified between fall and winter ( $t=2.2808$ ,  $p=0.036$ ). In descending order, highest mean values were observed in summer (mean±SD, 26.89±2.89), fall (24.93±4.53), spring (22.13±4.72) and winter (19.93±6.14) (Fig. 2a).

For temperature, similarly to salinity, significant differences were detected only between the seasons (Pseudo-F=8.9132,  $p=0.0002$ ). In paired comparison, significant differences were found between summer and winter ( $t=5.799$ ,  $p=0.0002$ ), fall and spring ( $t=2.7959$ ,  $p=0.0127$ ) and winter and spring ( $t=5.8845$ ,  $p=0.0001$ ). In descending order, highest mean values were registered in spring (22.27±2.46°C), summer (21.22±0.67°C), fall

(18.43±3.92°C) and winter (16.79±1.81°C) (Fig. 2b).

**Fish assemblage:** We collected 763 individuals of 18 families and 30 species (Table I). The families with the highest number of species were Sciaenidae and Gerreidae (4 each); Engraulidae (3), Ariidae, Gobiidae, Mugilidae and Paralichthyidae (2 each) (Table I). The other families had only one species. The families with the highest catches in number (ten families most abundant) were Gerreidae (168 individuals), Engraulidae (148), Mugilidae (114), Ariidae (98), Sciaenidae (79), Cichlidae (35), Atherinopsidae (28), Centropomidae (23), Paralichthyidae (21) and Tetraodontidae (19) (Table I). As for weight, the greatest catches (ten families) were verified for Mugilidae (10106.68 g), Gerreidae (2529.58 g), Sciaenidae (1979.78 g), Tetraodontidae (1959.07 g), Ariidae (1740.38 g), Engraulidae (1213.77 g), Cichlidae (1079.47 g), Centropomidae (666.69 g), Sparidae (334.07 g) and Atherinopsidae (277.89 g).

In descending order, *Cetengraulis edentulus*, *Mugil liza*, *Micropogonias furnieri*, *Eucinostomus melanopterus*, *Eucinostomus argenteus*, *Genidens barbatus*, *Genidens genidens*, *Mugil curema*, *Diapterus rhombeus*, *Geophagus brasiliensis* were dominant in number of individuals with a total catch above 75%, and the catches of *Cetengraulis edentulus* and *Mugil liza* corresponded to approximately 30% of the total. *Bathygobius soporator*, *Menticirrhus americanus*, *Parablennius pilicornis* and *Trichiurus lepturus* were caught only once (Table I).

The total catch in weight was 22632.94 g (Table I). *Mugil liza*, *Mugil curema*, *Sphoeroides testudineus*, *Micropogonias furnieri*, *Geophagus brasiliensis*, *Eucinostomus melanopterus*, *Cetengraulis edentulus*, *Diapterus rhombeus* and *Genidens genidens* corresponded, in descending order, to approximately 80% of the total weight. *Mugil liza* and *Mugil curema* totaled approximately 40% total catch weight.

On the occurrence of species in seasons, 12 species were caught in all seasons and seven species in only one of the seasons. There was a higher richness in the fall (24 species), followed by winter (22), spring (20) and summer (16) (Table I). Regarding the sites, nine species occurred in the five sites and eight species were exclusive to only one site. The greatest number of species occurred in the sites 3 and 5 (23 species), followed by the sites 4 (20), 2 (17), and 1 (14) (Table I).

**Table I.** List of species, number of individuals (n), weight (w), mean, minimum and maximum total length (TL), season and sites (higher abundances to the left) of fish caught in the Ratonos mangrove, Island of Santa Catarina, in 1998.

Families/Species	n	w (g)	mean TL (mm)	TL min	TL max	Season	Site
<b>ACHIRIDAE</b>							
<i>Achirus lineatus</i>	3	30,75	71,33	58	92	P>O	4>5
<b>ARIIDAE</b>							
<i>Genidens barbatus</i>	49	838,9	117,36	69	208	O>P>V=I	4>3>2>5>1
<i>Genidens genidens</i>	49	901,48	113,02	66	296	O>V>P>I	4>2>3>5>1
<b>ATHERINOPSIDAE</b>							
<i>Atherinella brasiliensis</i>	28	277,89	109,82	90	127	I>P>O	3>5>2>1>4
<b>BLENNIIDAE</b>							
<i>Parablennius pilicornis</i>	1	0,72	40	40	40	P	3
<b>CARANGIDAE</b>							
<i>Oligoplites palometa</i>	9	68,79	92,22	65	130	O>I	1>3=5>2
<b>CENTROPOMIDAE</b>							
<i>Centropomus parallelus</i>	23	666,69	143,65	111	195	O>P>V=I	4>3>2>1
<b>CICHLIDAE</b>							
<i>Geophagus brasiliensis</i>	35	1079,47	111,37	76	172	P>O>I>V	3>2=4>5
<b>CLUPEIDAE</b>							
<i>Harengula clupeola</i>	4	50,22	104,25	100	112	O>V	1>5
<b>CYNOGLOSSIDAE</b>							
<i>Symphurus tessellatus</i>	7	70,04	93,43	13	124	O>I>P	5>2=3=4
<b>ENGRAULIDAE</b>							
<i>Anchoviella lepidostole</i>	5	19,81	77,4	58	108	O>V=I	5>1=3
<i>Cetengraulis edentulus</i>	139	993,91	61,27	20	161	O>V	2>4>5>3
<i>Lycengraulis grossidens</i>	4	200,05	188,75	164	210	O>I=P	4>1=5
<b>GERREIDAE</b>							
<i>Diapterus rhombeus</i>	36	907,47	106,25	57	170	I=P>O>V	3>1>2>5>4
<i>Eucinostomus argenteus</i>	56	409,93	81,70	63	129	O>I>P>V	5>3>4>2
<i>Eucinostomus gula</i>	12	133,64	96,20	72	113	P>I>O	2=4>3=5
<i>Eucinostomus melanopterus</i>	64	1078,54	112,60	76	192	P>I>V=O	2>3>5>1>4
<b>GOBIIDAE</b>							
<i>Bathygobius soporator</i>	1	15,57	101	101	101	O	3
<i>Gobionellus oceanicus</i>	2	77,44	224,50	203	246	V=I	3=4
<b>MUGILIDAE</b>							
<i>Mugil curema</i>	44	2221,85	149,73	105	343	V>P>I>O	5>3>2>4
<i>Mugil liza</i>	70	7884,83	210,46	89	430	O>P>I>V	3>5>2>4>1
<b>PARALICHTHYIDAE</b>							
<i>Citharichthys spilopterus</i>	4	46,09	100,25	79	156	P	5
<i>Etropus crossotus</i>	17	216,72	99,12	59	165	O>P>V>I	2>4>1=5>3
<b>SCIAENIDAE</b>							
<i>Cynoscion jamaicensis</i>	3	90,95	144	134	160	I	5
<i>Cynoscion microlepidotus</i>	6	103,36	114	91	134	O	3
<i>Menticirrhus americanus</i>	1	339,62	309	309	309	P	4
<i>Micropogonias furnieri</i>	69	1445,85	125,29	95	186	O>V>P>I	3>2>4>1>5
<b>SPARIDAE</b>							
<i>Archosargus rhomboidalis</i>	2	334,07	214	203	225	O=I	5
<b>TETRAODONTIDAE</b>							
<i>Spherooides testudineus</i>	19	1959,07	159,79	67	200	P>I>V>O	5>3>2>1>4
<b>TRICHIURIDAE</b>							
<i>Trichiurus lepturus</i>	1	169,22	655	655	655	I	5
<b>TOTAL</b>	<b>763</b>	<b>22632,94</b>				<b>O&gt;V&gt;P&gt;I</b>	<b>3&gt;2&gt;5&gt;4&gt;1</b>

The ten species with the highest total lengths (mean TL) were *Trichiurus lepturus* (655 mm), *Menticirrhus americanus* (309 mm), *Gobionellus oceanicus* (mean±SD; 224,5±30.41 mm), *Archosargus rhomboidalis* (214±15.56 mm), *Mugil liza* (210.46±61.75 mm), *Lycengraulis grossidens* (188.75±22.73 mm), *Spherooides testudineus* (159.79±36.4 mm), *Mugil curema* (149.72±52.45

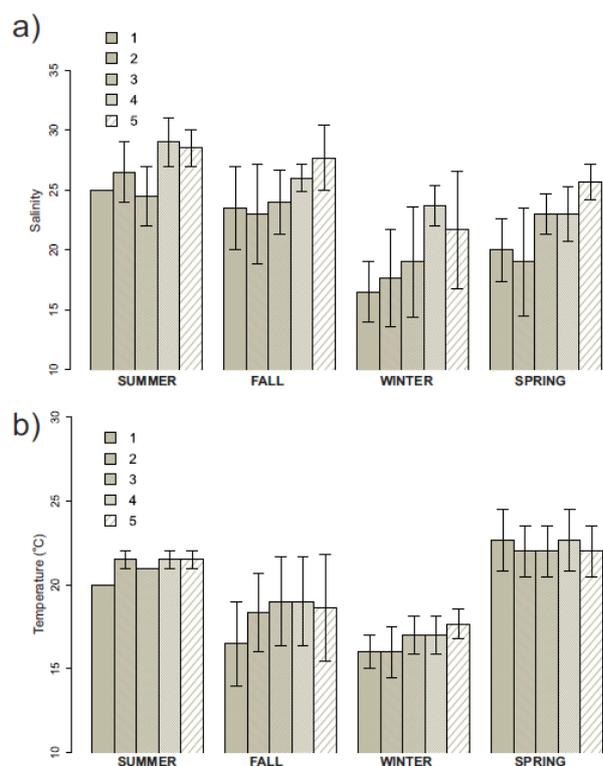
mm), *Cynoscion jamaicensis* (144±14 mm) and *Centropomus parallelus* (143.65±22.46 mm).

When comparing the mean values of total length, the PERANOVA detected significant differences between seasons and sites for *Eucinostomus melanopterus*, but found no difference for *Mugil liza* in relation to these factors (Table II). In relation to the differences between sites, in each

**Table II.** PERANOVA on the Bray-Curtis similarity of the total length (square root transformed) of *Eucinostomus melanopterus* and *Mugil liza*. Factors: season = (Es) and site = (Po). df = degrees of freedom; MS = mean square sum.

Source	<i>Eucinostomus melanopterus</i>				<i>Mugil liza</i>			
	df	MS	Pseudo-F	p(perm)	df	MS	Pseudo-F	p(perm)
Es	3	44,379	49,338	0,0046	3	43,545	0,82284	0,4998
Po	4	70,836	7,875	0,0001	4	34,834	0,15197	0,6344
EsxPo	8	25,172	27,985	0,0138	9	94,393	17,837	0,0908
Res	48	89,951			53	52,921		

season, for *Eucinostomus melanopterus*, significant differences were detected between sites 2 and 3 in the summer, sites 2 and 5, and sites 4 and 5 in the winter, and sites 2 and 3, in the spring.

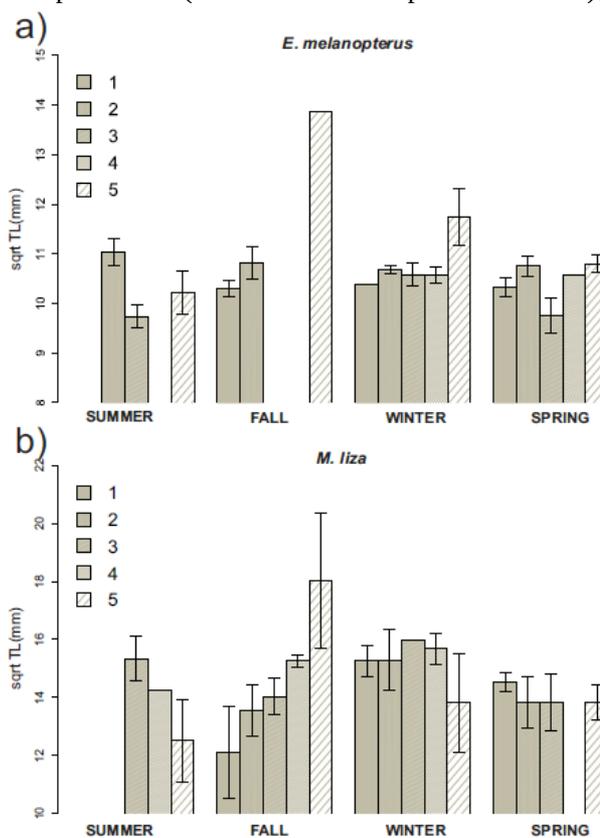


**Figure 2.** Mean values and standard errors (in bars) of Salinity (a) and Temperature (b) in the four seasons of 1998 and in each sampling site (1, 2, 3, 4 and 5) in the Ratones mangrove, Island of Santa Catarina.

Higher mean values were recorded in the summer in sites 1 (192 mm), 2 (138.67±23.71mm), 3 (122±10.15 mm), 4 (117.57±18.69mm) and 5 (116.8±7.98 mm) and lower mean values in the spring in site 1 (95±8.52 mm), and in the winter in sites 5 (96.14±18.57 mm), 4 (105.25±18.43 mm) and 3 (106±6 mm) (Fig. 3).

When comparing the mean values of abundance between seasons and sites, the PERMANOVA evidenced significant differences (p

<0.05) only between seasons (Table III). In paired comparisons (PERMANOVA pairwise test),



**Figure 3.** Mean values and standard errors (in bars) of the square root total length (TL) of *Eucinostomus melanopterus* and *Mugil liza* caught in the four seasons of 1998 and in each sampling site (1, 2, 3, 4 and 5) in the Ratones mangrove, Island of Santa Catarina.

significant differences occurred between summer and winter, summer and spring, fall and winter and fall and spring (Table IV).

Highest mean values of abundance were found in the summer in site 2 (mean±SD, 47±43.84); fall, in sites 3 (33±8.88) and 4 (26±28.58); summer, in site 5 (18.5±20.5) and spring, in sites 3 (16±10.58) and 5 (15.67±14.22) and lower mean values were observed in the winter, in sites 1

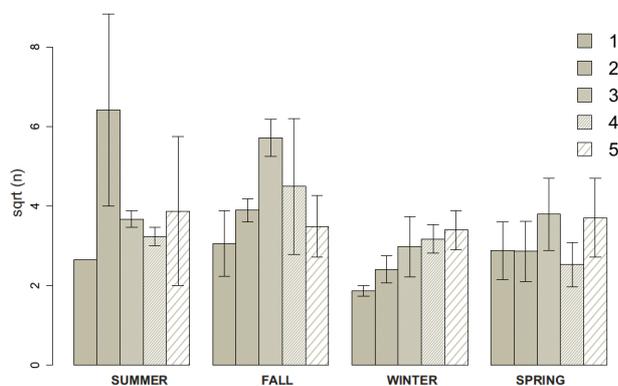
(3.5±0.7) and 2 (6±2.6); spring, in site 4 (7±4.3); summer, in site 1 (7) and spring, in sites 2 (9.33±7.02) and 1 (9.33±6.35) (Fig. 4).

**Table III.** PERMANOVA based on the Bray-Curtis similarity of abundance (square root transformed). Factors: season = (Es) and site = (Po). df = degrees of freedom; MS = mean square sum.

Source	df	MS	Pseudo-F	p(perm)
Es	3	6047,2	21,566	0,0029
Po	4	3516,9	12,543	0,1674
EsxPo	12	2630,2	0,93802	0,6466
Res	22	2804		

**Table IV.** Pairwise PERMANOVA based on the Bray-Curtis similarity of abundance (square root transformed) comparing the seasons.

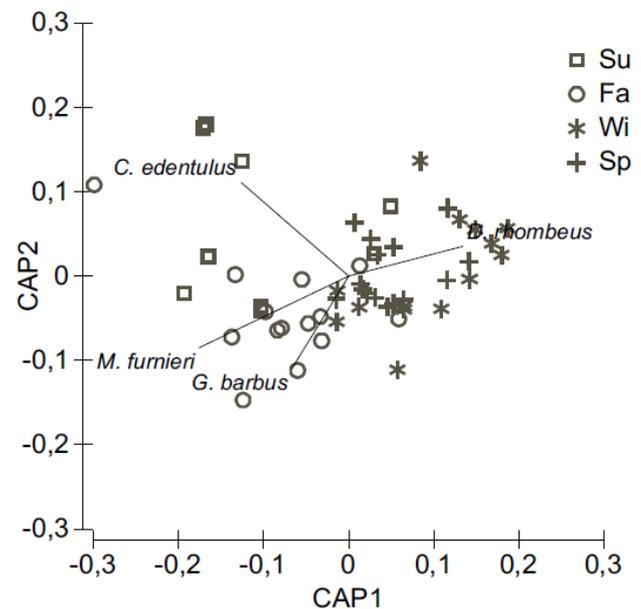
Grups	t	p(perm)
Summer x Fall	11,751	0,2171
Summer x Winter	16,708	0,0198
Summer x Spring	15,008	0,0273
Fall x Winter	18,841	0,0051
Fall x Spring	15,844	0,0094
Winter x Spring	0,74449	0,7777



**Figure 4.** Mean values and standard errors (in bars) of the square root abundance of fish caught in the four seasons of 1998 and in each sampling site (1, 2, 3, 4 and 5) in the Ratones mangrove, Island of Santa Catarina.

Regarding the species responsible for the clusters in the plots of the canonical analysis of principal coordinates (CAP), *C. edentulus* was mainly correlated with summer samples; *D. rhombeus*, with winter samples and *M. furnieri* and *G. barbuis*, with fall samples (Fig. 5). There was a separation of the samples of fall and summer to the left and samples of winter and spring over the

right, following a gradient associated with the axis 1 (Fig. 5).



**Figure 5.** Result of the canonical analysis of principal coordinates (CAP), with species that contributed most to the differences between the seasons (summer = Su; fall = Fa; winter = Wi and spring = Sp). Vector of species based on the Spearman correlation above 0.5 ( $p > 0.5$ ). The canonical correlation of the two axes obtained by the analysis was  $\delta_1 = 0.7680$  and  $\delta_2 = 0.4907$ .

In the linear model developed by DISTLM, no predictor variable significantly explained the clustering of samples (Table V). The dbRDA showed a separation of samples of each season, with a positive correlation of temperature with spring samples and salinity with fall and summer samples (Fig. 6). However this relationship is weak, due to the low axis explanation (Fig. 6).

**Table V.** Result of the DISTLM test with p-value of permutation and the proportion of explanation of the variables for the selected model.

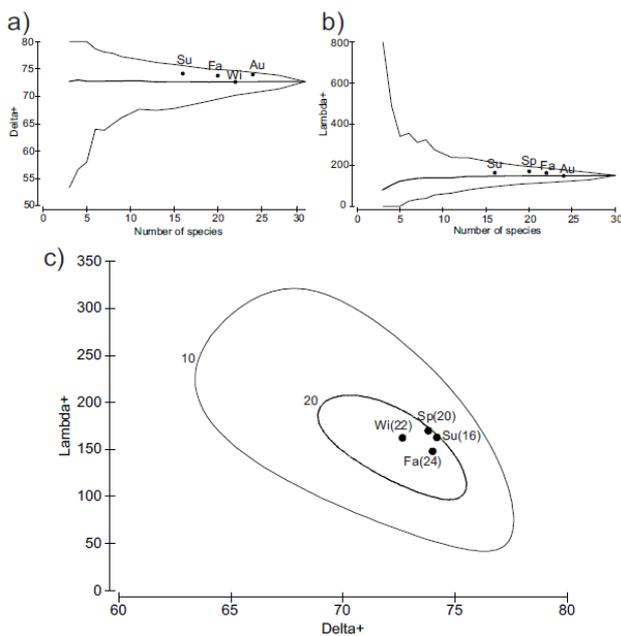
Variable	p(perm)	proportion
Temperature	0,1491	2.89E-02
Salinity	0,052	3.60E-02

Regarding the average taxonomic distinctness (Delta+) and variation of taxonomic distinctness (Lambda+) associated with the species richness, the PERMANOVA evidenced no significant differences for any of the variables between the seasons (Table VI). For Delta+ and Lambda+, values for each season were within the confidence interval

**Table VI.** Result of the PERANOVA for richness, average taxonomic distinctness (AvTD) and variation of taxonomic distinctness (VarTD) for the Ratonés mangrove, with the season as the factor. df = degrees of freedom; MS = mean square sum.

Variable	Source	df	MS	Pseudo-F	p(perm)
Richness	Season	3	223,47	1,3205	0,2752
	Res	48	169,23		
AvTD	Season	3	0,510	1,9664	0,0897
	Res	46	0,259		
VarTD	Season	3	37,319	1,5327	0,2215
	Res	36	24,348		

calculated through 1,000 simulations for each index (Fig. 7a-7b). Delta+ values for summer, spring and fall were above average, while the winter was on average (Fig. 7a). Except for the fall, all Lambda+ values were above average (Fig. 7b). The biplot graph of both indices demonstrated a grouping of all the seasons within the ellipse of 95% probability of



**Figure 7.** Average taxonomic distinctness (AvTD-Delta+) (a) and variation of taxonomic distinctness (VarTD - Lambda+) (b) calculated for the Ratonés mangrove according to the season (summer = Su; fall = Fa; winter = Wi and spring = Sp). For both indices, the expected mean value is represented by the central dotted line and the 95% confidence interval limit is given by the solid line of the funnel-shaped surrounding. Biplot graphic Lambda+ and Delta+ (c). The ellipse represents the value of the 95% confidence interval of the probability of finding 10 and 20 species, respectively.

occurrence of 20 species, with the winter value most distant from the other, with the lowest value of Delta+ (Fig. 7c).

## Discussion

In the Ratonés mangrove, salinity and temperature were significantly different between seasons, but were not different between the sampling sites. However, the environmental variables (predictor) did not significantly explain the fish fauna pattern, despite the marginally significant p-value (0.052) of temperature. In dbRDA, the temperature was more correlated with spring samples and salinity with the summer and fall samples. Considering the low tide range we could hypothesize that the continental runoff could be one of the most important environmental factor to influence the fauna. These influences are reflected in the salinity values which are directly related to the Rainfall patterns.

With regard to fish fauna, high dominance of fish of the families Engraulidae and Mugilidae found in the Ratonés mangrove seems to be a recurring pattern in estuarine shallow areas of southern and southeastern Brazil (Chao *et al.* 1982; IBAMA 1994; Clezar *et al.* 1994; Chaves & Boucherau 2000; Garcia *et al.* 2001; Ramos & Vieira *et al.* 2001; Pessanha & Araújo 2003; Falcão *et al.* 2006; Spach *et al.* 2006; Ignácio & Spach 2009; Oliveira-Neto *et al.* 2010; Spach *et al.* 2010; Contente *et al.* 2011; Vilar *et al.* 2011; Moura *et al.* 2012; Ribeiro *et al.* 2014). However, the absence of fish of the family Atherinopsidae, often caught in these shallow areas, was probably because samplings were conducted in the mangroves, and fish were collected using cast nets and dip nets. The occurrence of fish in this family is associated with tidal flats environments of estuarine systems in the south and southeast regions (Ramos & Vieira 2001). In this environment, the most used method consists of beach trawling with beach seines. Despite the differences between samplings, the fish fauna structure was very similar, even in studies conducted in the estuarine shallow areas devoid of mangrove vegetation, such as the coast of the State of Rio Grande do Sul (Chao *et al.* 1982, Garcia *et al.* 2001; Ramos & Vieira 2001; Moura *et al.* 2012). It is worth noting the high abundance of Mugilids in these environments, which was also verified in the Ratonés mangrove.

Moreover, considering the seasonality, as well as observed with demersal fish fauna, in the estuarine regions of southern and southeastern Brazil, there are differences in the abundance and

richness of fish species in shallow areas between the seasons (IBAMA 1994; Chaves & Bouchereau 2000; Garcia *et al.* 2001; Ramos & Vieira 2001; Pessanha & Araújo 2003; Falcão *et al.* 2006; Ignácio & Spach 2009; Oliveira-Neto *et al.* 2010; Spach *et al.* 2010; Contente *et al.* 2011; Vilar *et al.* 2011; Ribeiro *et al.* 2014). Many species use these environments at different stages of life, but in general, juveniles predominate. In the specific case of mangroves, some species use these areas during the breeding season (Chaves & Bouchereau 2000). Thus, although the physical and chemical parameters play a key role on the species distribution patterns, it is likely that the major cause of variability in the abundance of fish in these areas relates to the reproductive patterns, associated with spawning and recruitment (Whitfield & Elliot 2002).

Unlike the pattern expected of higher abundances in warmer seasons, such as spring and summer, higher abundances were found in fall in the Ratonés mangrove. A similar pattern occurred in the shallow areas of the Sepetiba Bay, due to the high abundance of juvenile fish of the family Engraulidae (Pessanha & Araújo 2003). In a gamboa in the Pinheiros Bay, it was also found a high abundance of engraulids in the fall (Oliveira-Neto *et al.* 2010). According to these authors, in addition to the reproductive aspects, Engraulidae fish seek shallower areas to get protection from predators, which are also abundant this time of year.

In relation to the most abundant species, this study showed high occurrences of *C. edentulus* and *M. liza*. *G. genidens* and *M. furnieri* were equally abundant, but in smaller numbers. As for *C. edentulus*, greater abundance values were observed in summer in the Ratonés, but in that site, there was no record of this species in winter and spring. It is a species showing preference for periods with higher salinities (Souza-Conceição *et al.* 2005). This preference for more saline environments was confirmed herein, because in the Ratonés mangrove, the greatest abundance coincided with the highest salinity values observed in the summer. As to reproduction, a study conducted in the Saco dos Limões on the reproductive aspects of *C. edentulus* reported that the total length (TL) at first reproduction is 118 mm for grouped sexes, and also noticed the existence of two reproductive peaks in spawning season, in the spring and summer, the first being the most significant (Souza-Conceição *et al.* 2005). Higher abundances in the summer in the Ratonés were made up of immature individuals with length smaller to those of the first maturity. They

possibly are individuals spawned in the summer. Larger sizes were observed in the spring and fall in the Ratonés.

On the comparison of occurrence of *C. edentulus* in other parts of the coast of the State of Santa Catarina, higher abundances were found in summer and fall in the Camburiú River mangrove (IBAMA 1994), summer and spring, coinciding with larger sizes, at Índio Beach, on the banks of the Norte Bay (Ribeiro *et al.* 2014), and in warm and dry seasons in the Babitonga Bay (Villar *et al.* 2011). On the coast of the State of Paraná, despite the lower importance, engraulids were recorded with higher abundances in hot months in the shallow infralittoral of the Maciel River (Ignácio & Spach 2009). Nevertheless, in gamboas, higher abundances were verified in the fall (Oliveira-Neto *et al.* 2010). A different pattern was found in Sepetiba Bay, with higher abundances in winter (Pessanha & Araújo 2003).

In turn, *M. liza* was the second most abundant species in this study, with the greatest abundance occurring in winter. The longer lengths were also found in winter. It is a species that migrates to the sea to reproduce, from the coast of Argentina (38°S) to the southeastern Brazilian coast (24-26°S) in the months from April to June with peak spawning between the northern coast of the states of Santa Catarina and Paraná (Lemos *et al.* 2014). According to these authors, the size at first maturity is 408.3 mm for grouped sexes. On average, all specimens collected in the Ratonés were not in reproductive activity; only one individual was recorded at reproductive age in April.

Compared to other studies, the occurrence pattern of *M. liza* was similar, with higher values of abundance and size in winter (Sierra De Ledo *et al.* 1997; IBAMA 1994; Ramos & Vieira 2001; Ignácio & Spach 2009; Contente *et al.* 2011). However, for Mugillids, a recurring pattern is the alternation of abundance peaks between *M. liza* and *M. curema*. While in spring and summer there is a peak of *M. curema* and low occurrence of *M. liza*, in fall and winter, such pattern is reversed. This has been observed in the Ratonés mangrove, as well as in the Camburiú River (IBAMA 1994) and in the shallow areas of the State of Rio Grande do Sul (Ramos & Vieira 2001). In recent studies, it was not possible to notice this pattern due to the low catch of *M. liza*. Because it is an important fishing resource, its population may have been overfished, given the low catches at Índio Beach, located a hundred meters from the mouth of the Ratonés River.

In general, the patterns observed, as well as the most abundant species, are consistent with the patterns observed in other regions of the southeastern and southern Brazil. Despite the greater importance of reproductive aspects in explaining the occurrence patterns of fish fauna of the Ratonas mangrove, in the studies that have used longer time scales, it was shown that environmental parameters are of utmost importance (Garcia *et al.* 2001; Ramos & Vieira 2001; Contente *et al.* 2011). Among these parameters, both for demersal fauna and for the fauna of shallow areas, salinity seems to be a major factor in the structuring of the assemblages (Jaureguizar *et al.* 2004, Barletta *et al.* 2008; Contente *et al.* 2011).

## References

- Akin, S., Buhar, E., Winemiller, K. O., 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: 671–684.
- Anderson M. J., Gorley R. N., Clarke K. R. 2008. **PERMANOVA + for PRIMER: guide to software and statistical methods**. PRIMER-E, Plymouth, 214 p.
- Barletta, M., Barletta-Bergan, A., Saint-Paul, U., Hubold, G. 2005. The role of salinity in structuring the fish assemblages in a tropical estuary. **Journal of Fish Biology**, 66: 45–72.
- Barletta, M., Amaral, C. S., Corrêa, M. F. M., Guebert, F., Dantas, D. V., Lorenzi, L., Saint-Paul, U. 2008. Factors affecting seasonal variations in demersal fish assemblages at an ecocline in a tropical–subtropical estuary. **Journal of Fish Biology**, 73: 1314–1336.
- Barletta, M., Jaureguizar, A. J., Baigun, C., Fontoura, N. F., Agostinho, A. A., Almeida-Val, V. M. F., Val, A. L., Torres, R. A., Jimenes-Segura, L. F., Giarrizzo, T., Fabré, N. N., Batista, V. S., Lasso, C., Taphorn, D. C., Costa, M. F., Chaves, P. T., Vieira, J. P., Corrêa, M. F. M. 2010. Fish and aquatic habitat conservation in South America: a continental overview with emphasis on neotropical systems. **Journal of Fish Biology**, 76: 2118–2176.
- Blaber, S. J. M., Blaber, T. G. 1980. Factors affecting the distribution of juvenile estuarine and inshore Fish. **Journal of Fish Biology**, 17: 143–162.
- Chao, L. N., Pereira, L. E., Vieira, J. P., Benvenuti, M. A. E., Cunha, L. P. R. 1982. Relação preliminar dos peixes estuarinos e marinhos da Lagoa dos Patos e região costeira adjacente, Rio Grande do Sul, Brasil. **Atlântica**, 5: 67–75.
- Chaves, P., Bouchereau, J. L. 2000. Use of mangrove habitat for reproductive activity by the fish assemblage in the Guaratuba Bay, Brazil. **Oceanologica Acta**, 23(3): 273–280.
- Clarke, K. R., Warwick, R. W. 1994. **Change in marine communities: an approach to statistical analysis and interpretation**. Plymouth Marine Laboratory, Plymouth, 144 p.
- Clezar, L., Ribeiro, G. C., Hostim-Silva, M. 1994. Relação Peso total/comprimento total e Fator de Condição da Manjuba *Cetengraulis edentulus* (Cuvier, 1828) (Clupeiformes, Engraulidae) no Manguezal do Itacorubi, SC, Brasil. **Arquivos de Biologia e Tecnologia**, 37(3): 685–691.
- Contente, R. F., Stefanoni, M. F., Spach, H. L. 2011. Feeding ecology of the Brazilian silverside *Atherinella brasiliensis* (Atherinopsidae) in a sub-tropical estuarine ecosystem. **Journal of the Marine Biological Association of the United Kingdom**, 91: 1197–1205.
- Day Jr., J. W., Hall, C. A. S., Kemp, W. M., Yáñez-Arancibia, A. 1989. **Estuarine Ecology**. Wiley, New York, 558 p.
- Elliott, M., Mcluskay, D. S. 2002. The need for definitions in understanding estuaries. **Estuarine, Coastal and Shelf Science**, 55: 815–827.
- Falcão, M. C., Sarpédonti, V., Spach, H. L., Otero, M. E. B., De Queiroz, G. M. N., Santos, C. 2006. A ictiofauna em planícies de maré das Baías das Laranjeiras e de Paranaguá, Paraná, Brasil. **Revista Brasileira de Zootecias**, 8(2): 125–138.
- Figueiredo, J. L., Menezes, N. 1978. **Manual de Peixes Marinhos do Sudeste do Brasil – II. Teleostei (1)**. Museu de Zoologia, Universidade de São Paulo, São Paulo, 110 p.
- Figueiredo, J. L., Menezes, N. 1980. **Manual de Peixes Marinhos do Sudeste do Brasil – III. Teleostei (2)**. Museu de Zoologia, Universidade de São Paulo, São Paulo, 90 p.
- Figueiredo, J. L., Menezes, N. 2000. **Manual de Peixes Marinhos do Sudeste do Brasil – VI. Teleostei (5)**. Museu de Zoologia, Universidade de São Paulo, São Paulo, 116 p.
- Garcia, A. M., Vieira, J. P., Winemiller, K. 2001. Dynamics of the shallow-water fish

- assemblage of the Patos Lagoon estuary (Brazil) during cold and warm ENSO episodes. **Journal of Fish Biology**, 59: 1218-1238.
- Greenwood, M. F. D., Hill, A. S. 2003. Temporal, spatial and tidal influences on benthic and demersal fish abundance in the Forth estuary. **Estuarine Coastal and Shelf Science**, 58: 211-225.
- Hyndes, G. A., Potter, I. C., Platell, M. E., Lenanton, R. C. J. 1999. Does the composition of the demersal fish assemblages in temperate coastal waters change with depth and undergo consistent seasonal changes? **Marine Biology**, 134: 335-352.
- IBAMA. 1994. **Manguezal do Rio Camboriú: Preservação e Controle da Qualidade Ambiental**. Coleção Meio Ambiente, Série Estudos – pesca, n° 13. Itajaí: IBAMA, Cepsul.
- Ignácio, J. M., Spach, H. L. 2009. Variação entre o dia e a noite nas características da ictiofauna do infra-litoral raso do Maciel, Baía de Paranaguá, PR. **Revista Brasileira de Zootecias**, 11: 25-37.
- Jaureguizar, A. J., Menni, R., Guerrero, R., Mianzan, H., Lasta, C. 2004. Environmental factors structuring fish communities of the Rio de la Plata estuary. **Fisheries Research**, 66: 195-211.
- Kennish, M. J. 1990. **Ecology of estuaries: anthropogenic effects**. Boca Raton: FL: CRC Press, 494 p.
- Kjerfve, B. 1994. Coastal Lagoons. In: KJERFVE, B. (ed.), **Costal Lagoon Processes**, p. 1-8, Amsterdam: Elsevier Science, 576 p.
- Laegdsgaard, P., Johnson, C. R. 2001. Why do juvenile fish utilise mangrove habitats? **Journal of Experimental Marine Biology and Ecology**, 257: 229-253.
- Lemos, V. M., Varela, A. S., Schwingel, P. R., Muelbert, J. H., Vieira, J. P. 2014. Migration and reproductive biology of *Mugil liza* (Teleostei: Mugilidae) in south Brazil. **Journal of Fish Biology**, 85: 671-687.
- Lenanton, R. C., Potter, I. C. 1987. Contribution of estuaries to commercial fisheries in temperate western Australia and concept of estuarine dependence. **Estuaries**, 10: 367-382.
- Marceniuk, A. P. Chave de identificação das espécies de bagres marinhos (Siluriformes, Ariidae) da costa brasileira. **Boletim do Instituto de Pesca**, v. 31, n. 2, p. 89-101, 2005.
- Menezes, N., Figueiredo, J. L. **Manual de Peixes Marinhos do Sudeste do Brasil – IV. Teleostei (3)**. Museu de Zoologia, Universidade de São Paulo, São Paulo, 96 p., 1980.
- Menezes, N., Figueiredo, J. L. **Manual de Peixes Marinhos do Sudeste do Brasil – V. Teleostei (4)**. Museu de Zoologia, Universidade de São Paulo, São Paulo, 105 p., 1985.
- Moura, P. M., Vieira, J. P., Garcia, A. M. 2012. Fish abundance and species richness across an estuarine freshwater ecosystem in the Neotropics. **Hydrobiology**, 696: 107-122.
- Oliveira Neto, J. F., Spach, H. L., Schwarz Jr, R., Pichler, H. A. 2010. Fish communities of two tidal creeks in the Pinheiros Bay, state of Paraná, southern Brazil. **Brazilian Journal of Aquatic Science and Technology (Impresso)**, 14: 47-54.
- Pessanha, A. L. M., Araujo, F. G. 2003. Spatial, temporal and diel variations of fish assemblages at two sandy beaches in the Sepetiba Bay, Rio de Janeiro, Brazil. **Estuarine, Coastal and Shelf Science**, 57(5-6): 817-828.
- Ramos, L. A., Vieira, J. P. 2001. Composição específica e abundância de peixes de zonas rasas dos cinco estuários do Rio Grande do Sul, Brasil. **Boletim do Instituto de Pesca**, São Paulo, 27(1) 109-121.
- Ribeiro, G. C., Clezar, L., Hostim-Silva, M. 1999. Comunidade Ictíca, sua Variação espacial e sazonal na Lagoa da Conceição e Área Costeira, Ilha de Santa Catarina, SC, Brasil. O Ecossistema da Lagoa da Conceição. **Série Fepema**, 4: 261-273.
- Ribeiro, G. C., Soeth, M., Andrade, V. K., Spach, H. L., Cattani, A. P. 2014. Nycthemeral and Monthly Occupation of the Fish Assemblage on a Sheltered Beach of Baía Norte, Florianópolis, Santa Catarina State, Brazil. **Brazilian Journal of Oceanography (Online)**, 62: 209-223.
- Sierra De Ledo, B. 1997. Subsídios ecológicos para um plano de gestão integrada na zona costeira da Ilha de Santa Catarina, **Aquitaine Océan**, 1(3): 9-28.
- Sierra De Ledo, B., Ribeiro, G. C., Clezar, L., Hostim-Silva, M. 1997. Padrões de ocorrência espacial e temporal de peixes mugilídeos jovens na Lagoa da Conceição, Ilha de Santa

- Catarina, Brasil. **Biotemas**, 6(1): 133-146.
- Simonassi, J. C., De La Corte, F. S., Soriano-Sierra, E. J. 1997. Variação temporal das concentrações de matéria orgânica e inorgânica circulantes entre o manguezal de Ratonos e a Baía Norte, Ilha de Santa Catarina, Brasil. **Aquitaine Océan**, Florianópolis, 1(3): 229-234.
- Simonassi, J. C., Hennemann, M. C., Talgatti D., Marques Jr., A. N. 2010. Nutrient variations and coastal water quality of Santa Catarina Island, Brazil. **Biotemas**, 23: 211-223.
- Souza-Conceição, J. M., Ribeiro, M. R., Castro-Silva, M. A. 2005. Dinâmica populacional, biologia reprodutiva e o ictioplâncton de *Cetengraulis edentulus* Cuvier (Pisces, Clupeiformes, Engraulidae) na enseada do Saco dos Limões, Florianópolis, Santa Catarina, Brasil. **Revista Brasileira de Zoologia**, 22(4): 953-961.
- Spach, H. L., Félix, F. C., Hackrad, C. W., Laufer, D. C., Moro, P. S., Cattani, A. P. 2006. Utilização de ambientes rasos por peixes na Baía de Antonina, Paraná. **Biociências**, 14(2): 125-135.
- Spach, H. L., Silva, A. L. C., Bertolli, L., Cattani, A. P., Budel, B. R., Santos, L. O. 2010. Assembléias de peixes em diferentes ambientes da desembocadura do rio Saí Guaçu, sul do Brasil. **Pan-American Journal of Aquatic Sciences**, 5: 126-138.
- Vilar, C. C., Spach, H. L., Joyeux, J. C. 2011. Spatial and temporal changes in the fish assemblage of a subtropical estuary in Brazil: environmental effects. **Journal of the Marine Biological Association of the United Kingdom**, 91: 635-648.
- Whitfield, A. K. 1999. Ichthyofaunal assemblages in estuaries: A South African case study. **Reviews in Fish Biology and Fisheries**, 9: 151-186.
- Whitfield, A. K., Elliott, M. 2002. Fishes as indicators of environment and ecological changes within estuaries: a review of progress and some suggestions for the future. **Journal of Fish Biology**, 61: 229-250.

Received: February 2016

Accepted: September 2016

Published: January 2017