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# The role of estuarine beaches as habitats for fishes in a Brazilian subtropical environment

## O papel de praias estuarinas como habitats para peixes em um ambiente subtropical brasileiro

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## Abstract

Little information exists about the dynamics of the use of estuarine beaches by fishes. The present study describes the spatial and temporal changes in the fish assemblage of the estuarine beaches of Babitonga Bay, Santa Catarina State (Brazil). A total of 13 collections were conducted at seven estuarine beaches of Babitonga Bay from August 2005 to August 2006. At each sampling site, beach seine tows parallel to the coast were made, each with a different seine net. A total of 45,874 individuals (76 taxa) (>99% juveniles) was caught in 273 samplings. Paralichthyidae and Sciaenidae had the largest number of species, followed by Carangidae, Gobiidae, Gerreidae, Engraulidae, Mugilidae and Tetraodontidae. The following taxa were the most abundant: *Lycengraulis grossidens*, *Mugil* sp., *Atherinella brasiliensis*, *Eucinostomus* sp., *Harengula clupeola*, *Sphoeroides greeleyi*, *Eucinostomus argenteus* and *Sphoeroides testudineus*, comprising 93.34% of the total catch. There were significant differences among months regarding the mean number of individuals, number of species, diversity and evenness. Considering that the conservation of the studied beaches is under constant threat, the data surveyed in this work show the necessity of conservation and management plans for these environments, important as nurseries for fishes.

**Key words:** juvenile fish, shallow waters, diversity, nursery, Babitonga Bay.

## Resumo

Existem poucas informações sobre a dinâmica do uso de praias estuarinas por peixes. Este trabalho descreveu as mudanças temporais e espaciais na assembléia de peixes de praias estuarinas na baía da Babitonga, Santa Catarina, Brasil. De agosto de 2005 a agosto de 2006, foram realizadas treze coletas em sete praias estuarinas do setor polihalino da baía da Babitonga. Na margem de cada ponto amostral, foram realizados três arrastos paralelos à linha de costa com redes tipo picaré. Nas 273 amostras obtidas foram capturados 45.874 indivíduos (76 táxons), predominantemente juvenis (>99%). Maior número de espécies foi observado em Paralichthyidae e Sciaenidae, seguidas por Carangidae, Gobiidae, Gerreidae, Engraulidae, Mugilidae e Tetraodontidae. Os seguintes táxons foram os mais abundantes na área: *Lycengraulis grossidens*, *Mugil* sp., *Atherinella brasiliensis*, *Eucinostomus* sp., *Harengula clupeola*, *Sphoeroides greeleyi*, *Eucinostomus argenteus* e *Sphoeroides testudineus*, os quais constituíram 93,34% da captura total. Diferenças significativas mensais ocorreram entre o número médio de indivíduos, número de espécies, diversidade e equitabilidade. Considerando que a conservação das praias estudadas está sob constante ameaça, os dados coletados nesse trabalho mostram a necessidade de elaboração de planos de conservação e manejo dessas importantes áreas de criação para peixes.

**Palavras-chave:** peixes juvenis, águas rasas, diversidade, criadouro, baía da Babitonga.

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## Introduction

Seasonal and spatial changes of temperature, salinity, dissolved oxygen and turbidity influence composition, structure, the spatial and temporal distribution of the ichthyofauna in estuaries (Blaber and Blaber, 1980; Loneragan and Potter, 1990; Whitfield, 1999). Biological aspects such as reproduction of the species and patterns of recruitment and/or migration (Akin *et al*., 2003) as well as abundance of predators and availability of prey (Taylor and Rand, 2003) also influence the use of shallow estuarine areas by fishes.

Fish may spend all or part of their life cycles (including migration, feeding and reproduction) in an estuarine habitat (Costello *et al*., 2002; Elliott and Hemingway, 2002). Therefore, estuaries may be regarded as very important areas for the growth of many fish species (Moyle and Cech Jr., 1996; Rozas and Minello, 1997). The high levels of food availability, as well as protection against predators, favor the permanence of fish in estuaries (Weisberg *et al*., 1996; Rönnbäck, 1999).

In estuaries, several intertidal and subtidal environments offer abundant and diverse food resources, protection against predation, and other favorable environmental conditions for the growth and survival of fish (Patterson and Whitfield, 200). Matić-Skoko *et al*. (2005) cite salt marshes and mangroves as examples of these estuarine environments. Elliott and Hemingway (2002) included the interface with fresh water, reed beds, beds of macroalgae, bottoms rich in biogenic structures and intertidal substrata (tidal flat) (including estuarine beaches).

Studies of Brazilian beach fish assemblages have evaluated specific composition, spatio-temporal variation and comparison of areas (Giannini and Paiva-Filho, 1995; Teixeira and Almeida, 1998; Lopes *et al*., 1999; Gomes *et al*., 2003; Godefroid *et al*., 2004). Other authors have investigated the daily patterns of variation of the ichthyofauna and the influence of the morphodynamic gradient on fishes in a beach environment (Pessanha and Araújo, 2003; Gaelzer and Zalmon, 2003; Félix *et al*., 2007a, 2007b; Félix-Hackradt *et al*., 2010).

Estuarine beaches, unique environments that differ from beaches by presenting a stable substrate (allowing the fixation of fauna and flora) (Nordstrom, 1992) have been studied less (Godefroid *et al*., 1997; Hackradt *et al.*, 2009; Hackradt *et al*., 2011). Little information exists about the dynamics of the use of this environment by fishes. In this context, this study of estuarine beaches of the southern coast of Brazil aims to describe: (i) the composition and the structure of the ichthyofauna; (ii) the spatial and monthly variations of fish assemblages; (iii) the correlation between environmental factors such as temperature, salinity and transparency, and fish abundance.

## Material and methods

### Study area

Babitonga Bay, southern Brazil, is a homogeneous microtidal and semidiurnal estuary that has an area of 130 km², an average depth of 6 meters and an approximate volume of 7.8 x $10^8$ $m^3$ (IBAMA, 1998), with a tide amplitude of 1.30 m (Cremer *et al.*, 2006). The length of the bay is 20 km; its width varies from 1.5 km (at the outlet to the sea) to 5 km (inner portion). It is part of the largest estuarine complex of the Santa Catarina State coast, being surrounded by the Atlantic Forest, mangroves, and salt marsh banks (mainly *Spartina alterniflora*), as well as sandy beaches, rocky formations and extensive tidal flats (Knie, 2002).

Around Babitonga Bay, the nearby municipalities of Joinville, Araquari, São Francisco do Sul, Itapoá and Garuva are home to more than 500,000 inhabitants, and form the largest industrial area of the state. Thus, the area suffers from increasing water pollution from industrial and domestic wastes. In addition, there is illegal deforestation, predatory fishing, concealed hunting, illegal occupation of public areas, badly-dimensioned constructions and landfill of mangrove forests (IBAMA, 1998). There is still lack of information about the area, which makes it more vulnerable to anthropogenic pressures.

### Environmental variables

The water temperature (°C) and salinity were recorded *in situ* using a HORIBA multi-parameter probe (model U-10) at the subsurface. The water transparency was determined in centimeters (Secchi disc) at a maximum distance of 50 m offshore.

### Fish collections

During the day monthly sampling was performed from August 2005 to August 2006 (during the neap high tide) at seven estuarine beaches distributed on the shoreline along a 7-km stretch in the polyhaline sector of Babitonga Bay (Figure 1). All seven stations were always sampled on the same sample day following the tidal wave at each sampling station. Three single tows parallel to the coast (maximum depth 1.5 m) were carried out in the margin of each sampling site using seine nets. One tow used a 15m x 1.6m (5mm mesh) net, one a 15m x 1.6m (2.5mm mesh) net and one a 6m x 1.6m (1mm mesh) net. The tow distance was standardized at 20 meters for nets with the 2.5-mm and 5.0-mm meshes, and at 6 meters for the 1.0-mm mesh. The 6-m tow was adopted to minimize mesh clogging.

The 2.5-mm and 5.0-mm mesh samples were collected and stored in plastic bags and kept on ice in a thermal box for transport; whereas the 1.0-mm mesh samples were stored in containers with 4% buffered formaldehyde solution. Fishes were counted (abundance) and identified to the lowest possible taxonomic level (Figueiredo and Menezes, 1978, 1980, 2000; Menezes and Figueiredo, 1980, 1985; Fahay, 1983; Moser, 1996; Ré, 1999; Richards, 2006). Inference about juveniles in the catches was carried out based on available maturity information for each species (Froese and Pauly, 2012).

### Statistical analysis

Considering months as replicates for each beach and beaches as pseudo-replicates for each month, a separate one way ANOVA, with degree of freedom 12 for the temporal and 6 for the spatial analysis, was applied to identify spatio-temporal variations in the temperature, salinity and water transparency, and in the number of specimens, number of species (S), Shannon-Wiener diversity (H') and Pielou evenness (J). All data were tested as regards the homogeneity of the variance (Bartlett's test) and normality (Kolmogorov-Smirnov test). Log (x+1) transformation was used in the analysis of the number of specimens to carry out the presuppositions of the ANOVA. The test of Tukey was applied *a posteriori* where significant differences occurred ($p < 0.05$) (Sokal and Rohlf, 1995).

Hierarchical Cluster grouping analysis was used to study time and space variations in the fish assemblage composition. The similarity matrix was generated through the Bray-Curtis index of similarity, and the unweighted pair group method with averages (UPGMA) used to generate groups. Analysis of Similarity (ANOSIM) was applied to evaluate the significance of differences between groups of months and beaches. Percent Similarity analysis (SIMPER) was used to identify which species were mainly responsible for similarities within each group defined by Cluster Analysis (normal mode) and for dissimilarities between those groups (discriminant species) (Clarke and Warwick, 1994).

The BIOENV routine allowed the examination of the environmental variables or group of environmental variables that explained the observed biological patterns (Clarke and Warwick, 1994).

## Results

### Environmental data

The water temperature varied between 19 and 29.9ºC. The mean temperatures were significantly different between months (ANOVA, $F = 336.00$; $p < 0.01$) and collection sites (ANOVA, $F = 3.42$; $p = 0.005$), with the lowest occurring in June, July, August and September and the highest in January, February and March (Figure 2). As regards the beaches, the mean temperature was significantly higher at beach 1 than at beaches 6 and 7 (Figure 2).

The salinity varied between 23.3 and 36 at the collection site. Although statistically different, the mean salinities did not indicate any seasonal pattern in the sampling area (ANOVA, $F = 24.14$; $p < 0.01$) (Figure 2). The mean salinities were higher at beaches 4, 5, 6 and 7 than at beach 3, with no differences between the other beaches (ANOVA, $F = 5.96$; $p < 0.01$ (Figure 2).

Transparencies between 23.5 and 92.3 cm were observed. As regards the collection months, the mean transparency was only statistically different between May and August 2006 (ANOVA, $F = 2.25$; $p = 0.018$) (Figure 2). The lowest mean transparency was observed at beach 3, with similar means between the other beaches (ANOVA, $F = 11.89$; $p < 0.01$) (Figure 2).

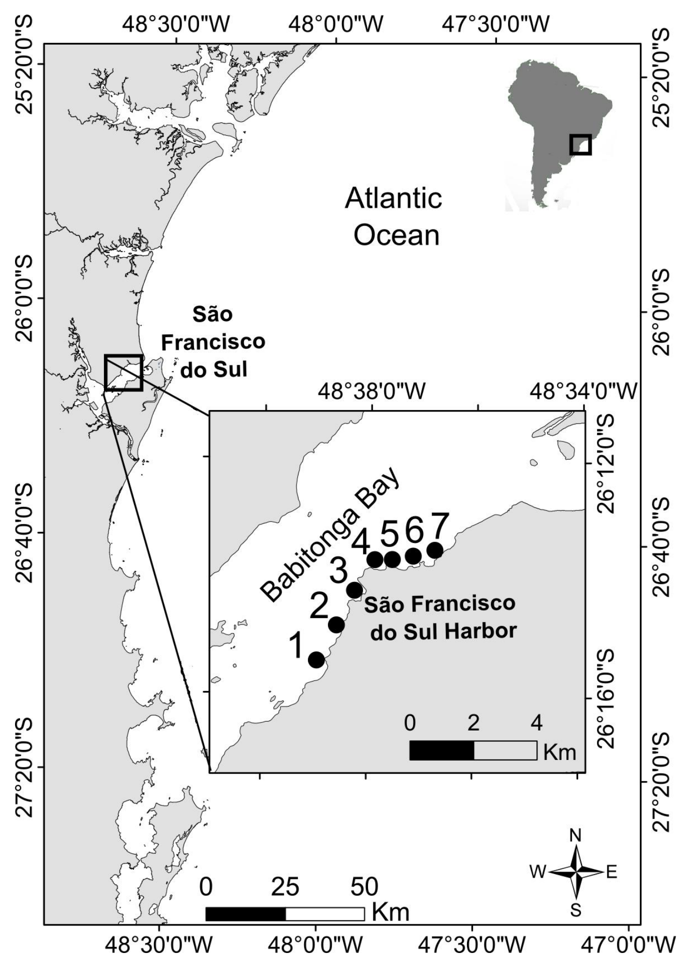


**Figure 1.** Location of the study area on the coast of Brazil and the seven estuarine beaches in Babitonga Bay, Santa Catarina State.

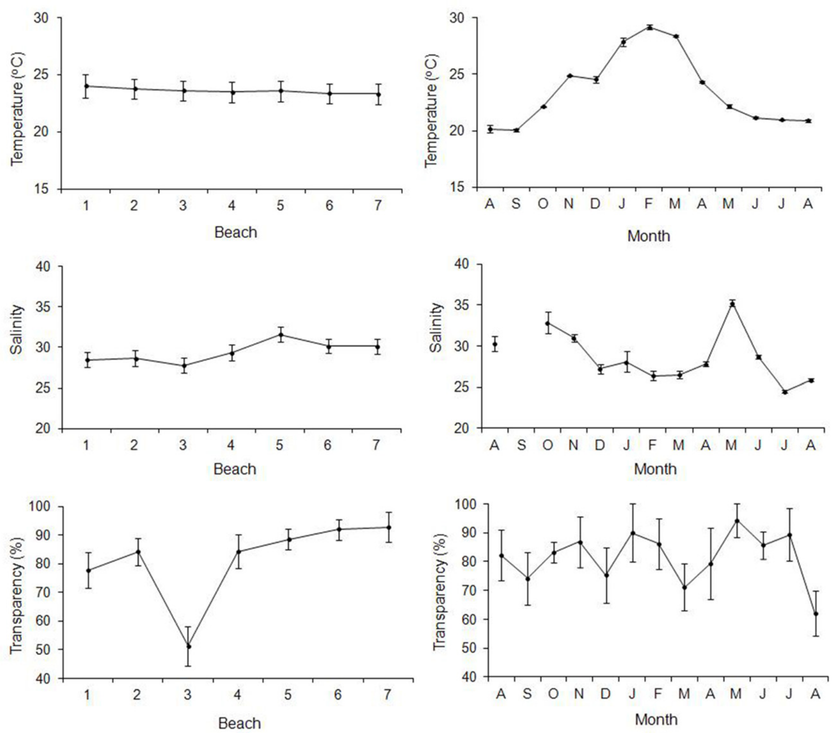


**Figure 2.** Spatial and temporal variation of mean values (±standard error) of the water temperature, water salinity and water transparency in Babitonga Bay, southern Brazil.

## Species assemblage

A total of 273 samples resulted in the capture of 45,874 fish, distributed among 76 taxa. The sampled fish assemblage was predominantly juvenile (> 99%), usually dominant in estuarine shallow waters. The largest number of species was observed in Sciaenidae and Paralichthyidae (7 species each), Carangidae and Gobiidae (6 species each), Gerreidae and Mugilidae (5 species each), Engraulidae and Tetraodontidae (4 species each). In decreasing order the families Engraulidae, Mugilidae Atherinopsidae, Gerreidae, Tetraodontidae, and Clupeidae contributed to 95.54% of the total number of captured individuals (Table 1).

The taxa *Atherinella brasiliensis*, *Eucinostomus argenteus, Eucinostomus* sp., *Harengula clupeola*, *Lycengraulis grossidens*, *Mugil* sp., *Sphoeroides greeleyi* and *Sphoeroides testudineus* were the most abundant and constituted 93.34% of the total catch. Most of the other taxa contributed individually with less than 1% of the total abundance. The taxa *A. brasiliensis*, *Citharichthys spilopterus*, *Ctenogobius shufeldti*, *E. argenteus*, *Eucinostomus gula*, *Eucinostomus* sp., *H. clupeola*, *L. grossidens*, *Micropogonias furnieri*, *Mugil* sp., *S. greeleyi*, *S. testudineus*, *Strongylura timucu*, *Synodus foetens* and *Trachinotus carolinus* were the most frequent in the samples, with most of the other species present in less than 10% of the samples (Table 1).

## Temporal changes

There were significant differences between the monthly mean number of captured individuals (ANOVA, F = 4.86; p < 0.01). There was a tendency towards an increasing mean value between August and December 2005, followed by a decrease in the subsequent months (Figure 3). The mean for December 2005 was statistically higher than the mean for August 2005 and May, June, July and August 2006; however, January 2006 presented a higher mean than the ones observed in July and August 2006 (Figure 3).

The monthly mean number of species (ANOVA, F = 7.09; p < 0.01) was also different. The mean rate increased between August and September 2005, and between November 2005 and January 2006. A continuous reduction in the number of species occurred between January and May 2006, followed by an alternating sequence of increases and decreases in the mean species quantity between May and August 2006 (Figure 3). The mean for March 2006 was higher than the means for August 2005 and May 2006; however, the means for December 2005 and February 2006 were higher than the ones for August 2005, May 2006 and July 2006 (Figure 3).

Significant differences between the monthly mean Shannon-Wiener diversity index (ANOVA, F = 2.4; p = 0.01) were observed. However, the test of Tukey did not show differences between the mean rates (Figure 3). The mean was generally lower in 2005 than in 2006. Differences were observed between the monthly mean evenness (ANOVA, F = 2.43; p < 0.01). The Tukey test shows that the June and August 2006 means were higher than the December 2005. There were no differences between the other mean rates.

Three groups of months can be observed at the 55% level of similarity (all species) (Figure 4): Group I was formed at the 58% similarity level (August, September and October 2005) (60.43% internal similarity), with (mainly) *Mugil* sp.*, S. greeleyi, H. clupeola, A. brasiliensis* and *L. grossidens* contributing to the similarity of the group (Table 2). Group III was formed at the 67% similarity level (May, June and August 2006) (59.32% internal similarity), with *A. brasiliensis*, *L. grossidens*, *Mugil* sp., *S. greeleyi*, *Eucinostomus* sp. and *E. argenteus* contributing most (Table 2).

**Table 1.** List of taxa, frequency (percentage of the total number), occurrence (percentage of samples in which individuals occurred) and standard length (mm; mean ± standard deviation) of fishes collected in estuarine beaches of Babitonga Bay, southern Brazil.

| Taxa | Frequency (%) | Occurrence (%) | Standard Length (mm) |
|---|---|---|---|
| *Achirus lineatus* (Linnaeus, 1758) | 0.017 | 2.19 | 37.75 ± 14.58 |
| *Albula vulpes* (Linnaeus, 1758) | 0.013 | 1.83 | 41.33 ± 15.73 |
| *Albula* sp. | 0.002 | 0.36 | 25.00 |
| *Anchoa januaria* (Steindachner, 1879) | 0.002 | 0.36 | 27.00 |
| *Anchoviella* sp. | 0.002 | 0.36 | 33.00 |
| *Anisotremus* sp. | 0.002 | 0.36 | 11.00 |
| *Archosargus probatocephalus* (Walbaum, 1792) | 0.002 | 0.36 | 56.00 |
| *Atherinella brasiliensis* (Quoy and Gaimard, 1825) | 19.704 | 62.63 | 43.78 ± 21.62 |
| *Bairdiella ronchus* (Cuvier, 1830) | 0.004 | 0.36 | 69.50 ± 6.36 |
| *Bathygobius soporato*r (Valenciennes, 1837) | 0.020 | 2.56 | 60.44 ± 22.95 |
| Belonidae | 0.002 | 0.36 | 31.00 |
| *Cetengraulis edentulus* (Cuvier, 1829) | 0.050 | 2.19 | 45.00 ± 28.98 |
| *Chaetodipterus faber* (Broussonet, 1782) | 0.089 | 7.69 | 18.70 ± 4.91 |
| *Chilomycterus spinosus* (Linnaeus, 1758) | 0.065 | 6.95 | 40.24 ± 13.25 |
| *Citharichthys arenaceus* (Evermann and Marsh, 1900) | 0.050 | 4.76 | 46.39 ± 25.35 |
| *Citharichthys spilopterus* (Günther, 1862) | 0.240 | 19.41 | 60.45 ± 28.83 |
| *Citharichthys macrops* (Dresel, 1885) | 0.011 | 1.46 | 39.60 ± 6.18 |
| *Ctenogobius shufeldti* (Jordan and Eigenmann, 1887) | 0.937 | 30.76 | 25.79 ± 8.49 |
| *Ctenogobius boleosoma* (Jordan and Gilbert, 1882) | 0.013 | 0.73 | 37.66 ± 4.67 |
| *Cynoscion leiarchus* (Cuvier, 1830) | 0.002 | 0.36 | 108.00 |
| *Dactylopterus volitans* (Linnaeus, 1758) | 0.002 | 0.36 | 160.00 |
| *Diapterus rhombeus* (Cuvier, 1829) | 0.229 | 4.39 | 55.07 ± 15.13 |
| *Diplectrum radiale* (Quoy and Gaimard, 1824) | 0.009 | 1.09 | 48.75 ± 10.43 |
| *Elops saurus* (Linnaeus, 1766) | 0.052 | 4.39 | 35.83 ± 22.68 |
| Engraulidae | 0.002 | 0.36 | 35.00 |
| *Etropus crossotus* (Jordan and Gilbert, 1882) | 0.004 | 0.36 | 48.50 ± 6.36 |
| *Etropus longimanus* (Norman, 1933) | 0.009 | 0.36 | 22.25 ± 3.30 |
| *Eucinostomus argenteus* (Baird and Girard, 1855) | 2.882 | 32.39 | 40.52 ± 15.75 |
| *Eucinostomus gul*a (Quoy and Gaimard, 1824) | 0.423 | 13.55 | 44.54 ± 21.00 |
| *Eucinostomus* sp. | 5.615 | 16.84 | 14.58 ± 8.05 |
| Gerreidae | 0.841 | 1.83 | 8.95 ± 0.93 |
| *Gobiesox strumosus* (Cope, 1870) | 0.013 | 0.73 | 14.00 |
| *Gobionellus stomatus* (Starks, 1913) | 0.002 | 0.36 | 72.00 |
| *Gobionellus* sp. | 0.017 | 2.19 | 13.37 ± 9.31 |
| Haemulidae | 0.070 | 1.83 | 9.63 ± 1.37 |
| *Harengula clupeola* (Cuvier, 1829) | 5.301 | 10.62 | 38.68 ± 13.44 |
| *Hemiramphus brasiliensis* (Linnaeus, 1758) | 0.013 | 1.09 | 68.66 ± 28.23 |
| *Hippocampus reidi* (Ginsburg, 1933) | 0.015 | 1.46 | 103.33 ± 43.68 |
| *Hyporhamphus unifasciatus* (Ranzani, 1841) | 0.004 | 0.36 | 24.00 |
| *Lagocephalus laevigatus* (Linnaeus, 1766) | 0.004 | 0.73 | 76.50 ± 33.23 |
| *Lycengraulis grossidens* (Agassiz, 1829) | 29.812 | 45.05 | 31.76 ± 15.32 |
| *Menticirrhus americanus* (Linnaeus, 1758) | 0.009 | 0.73 | 65.00 ± 48.00 |
| *Menticirrhus littoralis* (Holbrook, 1847) | 0.004 | 0.73 | 52.50 ± 30.40 |
| *Microgobius meeki* (Evermann and Marsh, 1900) | 0.015 | 1.46 | 27.57 ± 7.63 |
| *Micropogonias furnieri* (Desmarest, 1823) | 0.196 | 10.25 | 26.85 ± 16.99 |
| *Mugil curema* (Valenciennes, 1836*)* | 0.020 | 0.73 | 52.33 ± 12.72 |
| *Mugil gaimardianus* (Desmarest, 1831) | 0.312 | 3.29 | 54.01 ± 13.82 |
| *Mugil liza* (Valenciennes 1836) | 0.007 | 0.36 | 63.66 ± 9.86 |
| *Mugil platanus* (Günther, 1880*)* | 0.007 | 0.36 | 82.00 ± 12.00 |
| *Mugil* sp. | 23.905 | 49.45 | 25.68 ± 7.97 |

**Table 1.** Continuation

| Taxa | Frequency (%) | Occurrence (%) | Standard Length (mm) |
|---|---|---|---|
| *Oligoplites saliens* (Bloch, 1793) | 0.085 | 9.15 | 21.02 ± 12.92 |
| *Oligoplites saurus* (Bloch and Schneider, 1801) | 0.135 | 4.39 | 33.74 ± 24.98 |
| *Orthopristis ruber* (Cuvier, 1830) | 0.009 | 0.36 | 12.00 ± 1.82 |
| *Paralichthys brasiliensis* (Ranzani, 1842) | 0.013 | 1.83 | 142.80 ± 88.47 |
| *Paralichthys patagonicus* (Jordan, 1889) | 0.002 | 0.36 | 35.00 |
| *Poecilia vivípara* (Bloch and Schneider, 1801) | 0.002 | 0.36 | 11.00 |
| *Pomadasys corvinaeformis* (Steindachner, 1868) | 0.275 | 5.49 | 50.94 ± 11.50 |
| *Pomatomus saltatrix* (Linnaeus, 1766) | 0.004 | 0.36 | 16.50 ± 4.94 |
| *Prionotus punctatus* (Bloch, 1793) | 0.026 | 4.02 | 40.00 ± 12.24 |
| Sciaenidae | 0.007 | 0.36 | 10.50 ± 0.70 |
| *Selene vomer* (Linnaeus, 1758) | 0.004 | 0.36 | 39.00 ± 4.24 |
| *Sphoeroides greeleyi* (Gilbert, 1900) | 4.735 | 75.82 | 56.06 ± 22.36 |
| *Sphoeroides testudineus* (Linnaeus, 1758) | 1.389 | 47.25 | 50.03 ± 27.34 |
| *Sphoeroides* sp. | 0.070 | 3.29 | 11.15 ± 2.78 |
| *Stellifer stellifer* (Jordan and Snyder, 1902) | 0.002 | 0.73 | 31.00 |
| *Stephanolepis hispidus* (Linnaeus, 1766) | 0.007 | 1.09 | 30.66 ± 16.86 |
| *Strongylura* sp. | 0.002 | 0.36 | 54.00 |
| *Strongylura timucu* (Walbaum, 1792) | 0.255 | 15.01 | 88.95 ± 60.32 |
| *Syngnathus folletti* (Herald, 1942) | 0.004 | 0.73 | 148.00 ± 65.05 |
| *Syngnathus Rousseau* (Kaup, 1856) | 0.044 | 3.66 | 93.94 ± 21.66 |
| *Synodus foetens* (Linnaeus, 1766) | 0.617 | 17.94 | 58.16 ± 21.20 |
| *Trachinotus carolinus* (Linnaeus, 1766) | 0.813 | 19.78 | 26.75 ± 8.42 |
| *Trachinotus falcatus* (Linnaeus, 1758) | 0.218 | 8.79 | 21.02 ± 9.64 |
| *Trachinotus goodei* (Jordan and Evermann, 1896) | 0.007 | 0.36 | 12.33 ± 0.57 |
| *Ulaema lefroyi* (Goode, 1874) | 0.229 | 8.42 | 29.14 ± 13.91 |
| *Umbrina canosai* (Berg, 1895) | 0.022 | 1.09 | 38.80 ± 36.77 |

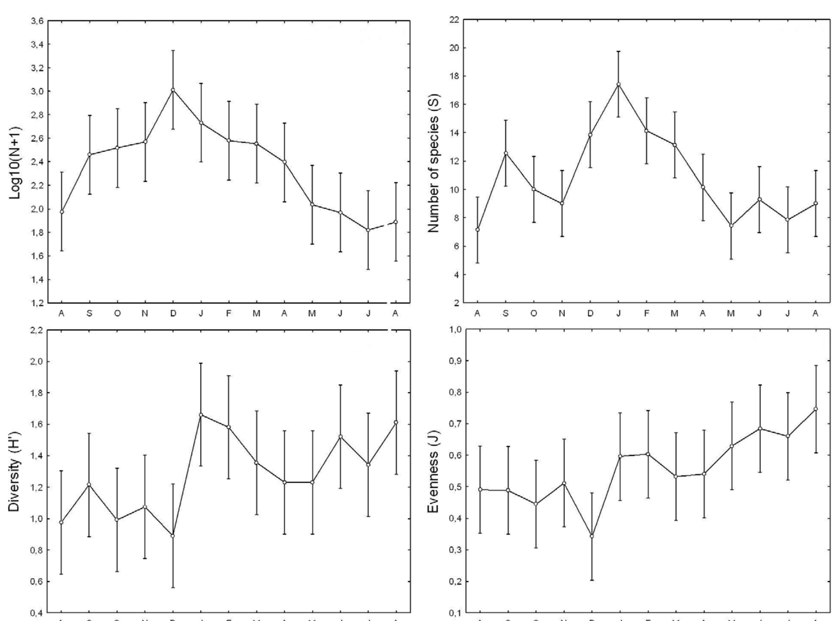


**Figure 3.** Temporal variation in the mean (± 95% confidence intervals) number of fish, number of species, Shannon–Wiener diversity index and Pielou evenness index at the estuarine beaches of Babitonga Bay, southern Brazil.

Group II was formed at the 58% level (November and December 2005 and January, February, March and April 2006) (70.48% internal similarity), with *A. brasiliensis*, *S. greeleyi*, *L. grossidens*, *Mugil* sp. and *S. testudineus* contributing most (Table 2).

Group I displayed a mean dissimilarity of 50.73% in relation to group II, due to the higher mean abundance of *L. grossidens*, *A. brasiliensis* and *Eucinostomus* sp. in group II and *Mugil* sp. and *H. clupeola* in group I (Table 2). The mean dissimilarity between groups I and III was 46.48%, due to higher occurrences of discriminant taxa *Mugil* sp., *H. clupeola* and *L. grossidens* in group I. The mean dissimilarity between groups II and III was 50.26%, with higher mean abundance of *L. grossidens*, *A. brasiliensis*, *Mugil* sp. and *Eucinostomus* sp. in group II (Table 2).

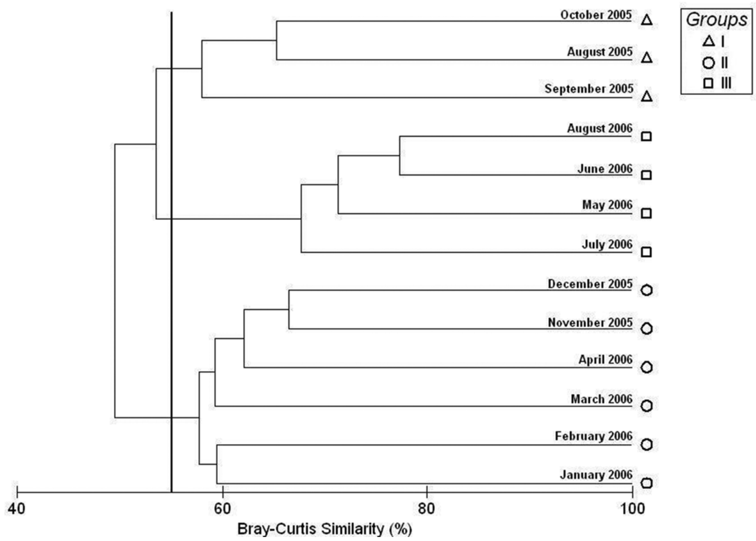


**Figure 4.** Dendrogram based on the abundance of all the species sampled monthly, showing similarities between the thirteen sampling months at the estuarine beaches of Babitonga Bay, southern Brazil (55% similarity level).

**Table 2.** SIMPER results showing species contribution to similarities within each group and dissimilarities between groups of sampling months in Babitonga Bay, southern Brazil, identified using Cluster analysis (I: September, October and August/05; II: May, June, July and August/06; III: November, December/05, January, February, March and April/06).

| Groups | Mean Similarity (%) | | | Mean Dissimilarity (%) | | |
|---|---|---|---|---|---|---|
| | I | II | III | I x II | I x III | II x III |
| | 60.43% | 59.32% | 70.48% | 50.73% | 46.48% | 50.26% |
| *Mugil* sp. | 30.46 | 14.51 | 9.26 | 12.01 | 29.47 | 10.80 |
| *Sphoeroides greeleyi* | 12.61 | 9.70 | 16.34 | | | |
| *Harengula clupeola* | 11.60 | | | 9.16 | 17.48 | |
| *Atherinella brasiliensis* | 7.42 | 17.28 | 18.72 | 11.38 | | 12.13 |
| *Lycengraulis grossidens* | 7.04 | 16.07 | 15.82 | 14.61 | 9.44 | 17.52 |
| *Sphoeroides testudineus* | | | 9.22 | | | |
| *Eucinostomus* sp. | | 8.12 | | 9.02 | | 10.43 |
| *Eucinostomus argenteus* | | 5.78 | | | | |

Analysis of Similarity (ANOSIM) showed that the formed month groups were significantly different (R = 0.759; p = 0.1%), indicating, through paired comparison, a higher difference between groups I and III (R = 0.870; p = 2.9%), followed by the comparison of groups I and II (R = 0.802; p = 1.2%), and the lowest difference between groups II and III (R = 0.758; p = 0.5%).

### Spatial differences

As regards grouped months, no statistical difference was observed between the beaches in the mean number of specimens (F = 1.16; p = 0.334), the mean number of species (F = 1.03; p = 0.41), the mean Shannon-Wiener diversity (F = 2.34; p = 0.96) and the mean Pielou evenness (F = 0.37; p = 0.89).

At the similarity level of 65%, three beach groups were formed (Figure 5): Group I - beaches 1 and 2 (75.35% internal similarity), with *A. brasiliensis*, *S. greeleyi*, *Mugil* sp. and *L. grossidens* (Table 3) strongly contributing to this similarity. The largest contribution to the internal similarity of group III (beaches 4 and 5) was, in decreasing order, *L. grossidens*, *A. brasiliensis*, *S. greeleyi*, *H. clupeola* and *Eucinostomus* sp. Group II was formed by beaches 3, 6, and 7, with an internal similarity of 66.51%, due especially to the numerical occurrence patterns of *L. grossidens*, *Mugil* sp., *A. brasiliensis*, *E. argenteus* and *H. clupeola* (Table 3).

A dissimilarity of 38.39% was observed between groups I and II, due to a greater abundance of *A. brasiliensis* and *Mugil* sp. at beaches 1 and 2, respectively; whereas at beaches 4 and 5 it was due to *L. grossidens* and *H. clupeola* (Table 3). Between beaches of groups I and III, dissimilarity was 38.34%. *Mugil* sp., *L. grossidens* and *H. clupeola* in group III and *A. brasiliensis* in group I contributed most to the results. Between groups I and III, the mean dissimilarity was 37.37%, due, especially, to a more massive presence of *Mugil* sp., *L. grossidens*, *H. clupeola* and *E. argenteus* in group III (Table 3).

Although the Analysis of Similarity (ANOSIM) indicated significant differences between the beach groups (R = 0.900; p = 1.0%), such differences were not significant in paired comparisons between groups I and II (R = 0.833; p = 10.0%), groups I and III (R = 1.0; p = 33.3%) and groups II and III (R = 0.833; p = 10.0%).

Very low correlation values were observed in the analysis of the influence of the environmental parameters on the spatial and temporal structuration of the ichthyofauna (BIOENV) (Table 4), which indicated that the parameters considered in the distribution of the species had little influence.

## Discussion

Among the 76 recorded taxa, 9 occurred in every collection month and 17 at every beach. The results confirmed that the structure of the fish assemblage at the studied estuarine beaches is basically conditioned by the occurrence of large aggregates of a few

**Table 3.** SIMPER results showing species contribution to similarities within each group and dissimilarities between groups of beaches (I: 1 and 2; II: 4 and 5; III: 3, 6 and 7) in Babitonga Bay, southern Brazil, identified using Cluster analysis.

| Groups | Mean Similarity (%) | | | Mean Dissimilarity (%) | | |
|---|---|---|---|---|---|---|
| | I | II | III | I x II | I x III | II x III |
| | 75.35% | 67.79% | 78.92% | 38.39% | 38.34% | 37.27% |
| *Atherinella brasiliensis* | 26.54 | 11.74 | 14.56 | 12.97 | 8.93 | |
| *Sphoeroides greeleyi* | 13.26 | | 8.39 | | | |
| *Mugil* sp. | 11.38 | 15.03 | 5.66 | 8.16 | 14.91 | 21.11 |
| *Lycengraulis grossidens* | 11.09 | 15.81 | 16.95 | 7.82 | 14.59 | 11.50 |
| *Eucinostomus argenteus* | | 8.15 | | | | 6.25 |
| *Harengula clupeola* | | 7.73 | 6.71 | 6.65 | 10.79 | 6.55 |
| *Eucinostomus* sp. | | | 6.06 | | | |

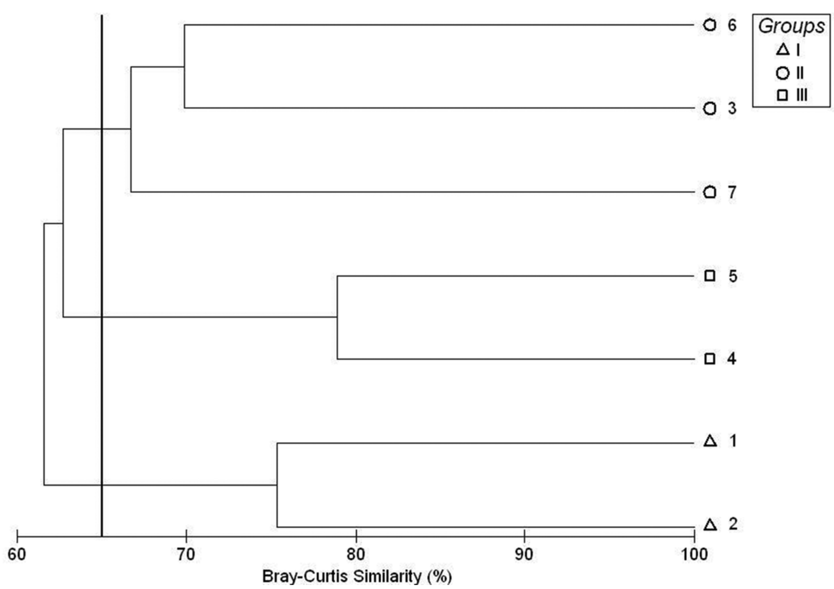


**Figure 5.** Dendrogram based on the abundance of all the species sampled monthly, showing similarities between the seven estuarine beaches of Babitonga Bay, southern Brazil (65% similarity level).

**Table 4.** Procedure BIOENV applied to find the best match among multivariate patterns in a fish assemblage sample, in Babitonga Bay, southern Brazil, and those from environmental variables associated with the samples (1: temperature; 2: salinity; 3: transparency).

| Number of Variables | *Spearman* correlation | Selections |
|---|---|---|
| 1 | 0,106 | 3 |
| 2 | 0069 | 1; 3 |
| 2 | 0,058 | 2; 3 |
| 3 | 0,045 | 1; 2; 3 |
| 1 | 0,016 | 1 |
| 2 | -0,006 | 1; 2 |
| 1 | -0,007 | 2 |

dominant species (generally 10% of the species total). There was a spatially stratified dominance of some species, which could indicate that some of the beaches were chosen due to the abiotic characteristics and location within the estuarine complex. A large number of fish species remain in an estuarine region for only a short period, while some complete their entire life cycle there (Garcia and Vieira, 2001). The beaches studied in Babitonga Bay also possess species that remain for a short time and others that complete their entire life cycle in this environment. Santos *et al.* (2002) report that a low number of species and families found in an estuary has their biological cycles being developed only there. Thus, few fish groups have evolved to remain exclusively in estuaries, because the physical and chemical changes in these environments are rapid and demand, in physiological terms, a lot of energy from the fish, which makes the survival of many species difficult (Elliot and Hemingway, 2002).

A numerical dominance of resident and marine-estuarine species was observed in studies about the fish fauna of Paraná State tidal plains (Spach *et al.*, 2006; Santos *et al.*, 2002). The shallow zones of the estuary presented a community dominated by small resident estuarine fish, e.g. *A. brasiliensis*, and dependent marine-estuarine species, such as *Mugil* spp. (Garcia and Vieira, 2001), which were observed at the beaches of Babitonga Bay. As in the present study, resident species *A. brasiliensis, S. greeleyi* and *S. testudineus* have been constant and abundant in the samples from Paranaguá Bay (Paraná state) (Félix *et al*., 2006). Occasional visitor marine species, like representatives of the tropical families Carangidae and Gerreidae, represented a numerous group that has appeared irregularly in the estuarine waters of Babitonga Bay. This has also been observed in estuaries of Rio Grande do Sul State (Fisher *et al.*, 2004).

The most abundant families in Laranjeiras and Paranaguá bays (Paraná State) were Atherinopsidae, Engraulidae and Mugilidae (Falcão *et al.*, 2006). These three families were the most abundant at the studied estuarine beaches (Babitonga Bay), with the inclusion of Gerreidae, Gobidae, Paralichthyidae and Tetraodontidae. A similar pattern was found by Ramos and Vieira (2001) in estuaries of Rio Grande do Sul State. In Barra do Saí (northern coast of Santa Catarina State), Vendel and Chaves (2006) (using beach tows) recorded Gerreidae, Atherinopsidae, Centropomidae, Tetraodontidae, Paralichthyidae and Gobidae in every collection in the lagoon. The predominance of other families was also reported at other sites (Felix *et al*., 2006; Paiva-Filho *et al.*, 1987). The composition of the fish communities in the shallow areas near the mouth of the main estuaries of southern Brazil seems to determine the composition of the estuary because families that dominate at one site are replaced by others at another site, or the dominant species is not the same in the different estuaries (Ramos and Vieira, 2001).

A larger number of specimens in the spring and in the summer was recorded at the estuarine beaches studied in Babitonga Bay, mainly due to a larger number of juveniles linked to periods after reproduction in the area (IBAMA, 1998; Cremer *et al*., 2006; Costa and Souza-Conceição, 2009). This has been corroborated by Paiva-Filho *et al.*, (1987) and Godefroid *et al.* (2003). On the other hand, the larger number of fish species in Babitonga Bay occurs during the summer and neighboring months, mainly at the beginning of autumn, as it is related to the reproductive period and the recruitment of juveniles in the area (IBAMA, 1998; Cremer *et al*., 2006). According to Johannes (1978), the reproductive activity of coastal marine fish generally extends over a considerable part of the year. There are certain periods in which a large number of species and individuals of these species reproduce (collective spawning). The specific composition of the estuarine fish community changes constantly and drastically due to the variability of the environmental conditions and the specific limits of tolerance of certain species as regards the environmental alterations (Kennish, 1990; Loebmann and Vieira, 2005). According to McLachlan (1983) and Elliot and Hemingway (2002), the structure and the distribution of the fish community change because of the influence of spatial factors like degree of exposure, wave energy and hydrographical factors like temperature and salinity, which vary at short distances. Although BIOENV had not indicated any significant influence of the environmental variables on the distribution pattern of the species, the location of the beaches in the Babitonga Bay estuarine complex and the environmental configuration of each were important in the structuration of the juvenile fish assemblage that was found. The most abundant taxon, *L. grossidens*, expressed a clear dominance at beaches 4 and 7, which possess more marine characteristics due to their being in the outermost sector of the bay. *Mugil* sp. was dominant at beaches 3 and 6, with the presence of a river plume and, even in the most external sector, a constant surface runoff, respectively, which, according to Menezes and Figueiredo (1985) and Santos (1992), attracts mullets in their initial phases. As *A. brasiliensis* prefers the inner areas of estuaries, it was dominant at beaches 1 and 2 (the innermost of this study). According to Oliveira-Neto *et al.* (2004), spatial stratification can reduce trophic competition between species and between phases that have a similar diet, and consequently favor growth along the estuary. Ikejima *et al*. (2003) and Félix *et al.* (2006) demonstrated significant differences in the composition of families and species of fish in nearby areas within a single estuary, which were probably associated with the different environmental configurations of each study site.

Economically important taxa appear in the study area samples (e.g.: *Menticirrhus americanus*, *M. littoralis*, *Micropogonias furnieri*, *Mugil platanus*, *M. gaimardianus*, *Oligoplites saliens*, *O. saurus*, *Paralichthys brasiliensis*, *Pomatomus saltatrix*, and *Trachinotus carolinus*). Some, although classified as with lower commercial importance, perform a fundamental role in family subsistence in study area fishing communities; whereas others represent regional fishery stocks exploited by industry. Godefroid *et al*. (2003) described that the Atami beach samples were dominated by a few commercially less important species, e.g. *M. littoralis*, *H. clupeola*, *Odonthestes bonariensis* (Cuvier & Valenciennes, 1835), *T. carolinus* and *Anisotremus surinamensis* (Block, 1791), the abundances of which varied over the year. According to Garcia and Vieira (1997), *M. furnieri*, very important in the fisheries of southern Brazil, is one of the most abundant species in the Laguna dos Patos estuary.

The Babitonga Bay estuary is ecologically, economically and socially very important; however, it is under strong anthropogenic pressure and has, consequently, suffered environmental degradation (IBAMA, 1998), with the studied beaches under a constant threat. This and the data surveyed in this work show the necessity of conservation and management plans for these beach environments (important as nurseries for fishes) and demonstrate that the establishment of an environmental reserve (e.g. fauna reserve) would be a key factor in the protection of species and their habitats in the estuarine complex of Babitonga Bay.

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