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Fish assemblage in shallow areas of Baía da Babitonga, southern Brazil: structure, spatial and temporal patterns

CIRO C. VILAR[1, 2], HENRY L. SPACH[3] & JOSÉ M. SOUZA-CONCEIÇÃO[4]

[1]*Núcleo de Atividades Ambientais, NATIVA, Avenida Hugo Musso, 1333, Apto 1106, 29101-280 Vila Velha, ES, Brazil. E-mail: cirovilar@nativa.org.br*
[2]*Universidade Federal do Paraná, Programa de Pós-Graduação em Ecologia e Conservação, Caixa Postal 19031, 81531-980 Curitiba, PR, Brazil.*
[3]*Universidade Federal do Paraná, Centro de Estudos do Mar, Avenida Beira Mar s/n, Pontal do Sul, Caixa Postal 50002, 83255-000 Pontal do Paraná, PR, Brazil.*
[4]*Universidade da Região de Joinville, Campus Universitário s/n, Bom Retiro, Caixa Postal 246, 89201-972 Joinville, SC, Brazil.*

Abstract. Fish assemblage structure and physical-chemical characteristics were analyzed in shallow areas of Baía da Babitonga, southern Brazil, by seasonal sampling at 13 sites distributed along the bay's shoreline. Two sectors (outer and inner) were defined within the bay according to salinity. In total, 71,085 fishes belonging to 70 taxa and 30 families were collected. The majority of collected taxa (45) were exclusively represented by juvenile fishes. Unidentified engraulids, *Eucinostomus* spp., *Mugil* spp., *Atherinella brasiliensis*, *Anchoa januaria*, *Harengula clupeola*, *Anchoa tricolor*, *Oligoplites saliens* and *Sphoeroides greeleyi* were numerically dominant, contributing 93.8% of captured fishes. Taxa exclusive of one or the other sector showed low abundance, but several species clearly tended to occupy specific regions of the estuary. Spatial variations in body size were indicated for the nine dominant taxa. The number of species, individuals and equitability varied significantly among months but not sectors. However, a high turnover in species composition occurred among sampling sites, with the average number of taxa per site (30.8) corresponding to less than half of the total number of registered taxa (70).

Key words: fish community, Santa Catarina, estuary, southwestern Atlantic

Resumo. Assembléia de peixes das áreas rasas da Baía da Babitonga, sul do Brasil: estrutura, padrões espaciais e temporais. A estrutura da assembléia de peixes e as características físicas e químicas das áreas rasas da Baía da Babitonga, sul do Brasil, foram analisadas por amostragens sazonais em 13 pontos distribuídos ao longo do estuário. Dois setores (externo e interno) foram caracterizados de acordo com a salinidade. No total, 71.085 peixes pertencentes a 70 taxa e 30 famílias foram coletados. A maioria dos taxa capturados (45) foram representados exclusivamente por indivíduos juvenis. Engraulideos não identificados, *Eucinostomus* spp., *Mugil* spp., *Atherinella brasiliensis*, *Anchoa januaria*, *Harengula clupeola*, *Anchoa tricolor*, *Oligoplites saliens* e *Sphoeroides greeleyi* dominaram numericamente, contribuindo com 93,8% do total capturado. Taxa exclusivos de um único setor foram pouco abundantes, entretanto, várias espécies tenderam a ocupar regiões específicas do estuário. Mudanças espaciais em função do tamanho do corpo foram indicadas para os nove taxa dominantes. O número de espécies, indivíduos e a equitabilidade variou significativamente entre os meses, mas não entre os setores. Porém, ocorreu uma alta substituição na composição de espécies entre os locais de amostragem, com o número médio de espécies por ponto (30,8) sendo menos da metade do número total de espécies registrado (70).

Palavras chave: comunidade de peixes, Santa Catarina, estuário, Atlântico sul-oeste

Introduction

The establishment of large cities and the economic development in coastal areas worldwide place estuaries among the aquatic ecosystems most vulnerable to changes in their natural conditions (Halpern *et al*. 2007). As a result of process of occupation and 'development', estuaries have always been subjected to anthropic pressures (*e.g.* over-exploitation, sewage and industrial effluents), which usually lead to biological changes (Blaber 2000, Costa *et al*. 2007). The conservation of the estuarine ichthyofauna necessitates the establishment of a reference condition of the abundance of species and the acquisition of knowledge about the relationship of their life histories with the estuarine ecosystem. This information is fundamental to the development of efficient management strategies for the sustainable use of resources (Vasconcelos *et al*. 2007).

In shallow areas of Brazilian subtropical estuaries, there is a great diversity of habitats, such as mangroves, salt marshes, tidal channels, tidal flats and sandy beaches, that are inhabited by fish assemblages numerically dominated by young individuals (Vieira & Musick 1994, Ramos & Vieira 2001, Spach *et al*. 2004, Félix *et al*. 2007). These environments play an important role for some species at the beginning of their life cycles, offering protection against predators and abundant food, which provide improved survival odds for juvenile individuals and faster growth (Blaber 2000, Layman 2000). Species that are adapted to the biotic and abiotic variability present in the estuaries possess a considerable advantage over species that cannot tolerate such variability, allowing for the occupation of an environment that is rich in food and from which many potential competitors are excluded (Whitfield 1999). As elsewhere, many fish species appear to make use of these benefits in the Baía da Babitonga estuary, inhabiting its shallow areas only during larval and juvenile phases (Souza-Conceição 2008, Araujo 2009).

The abundance and composition of fish species within estuaries are highly variable in space and time and are closely related to environmental conditions. Salinity has often been reported as the main environmental factor determining the composition and richness of species along the horizontal axis of estuaries, while temperature has been reported to affect mainly the seasonal variation (see Attrill 2002, Barletta *et al*. 2005, McLusky & Elliott 2006). Among the known effects of salinity, a progressive decrease in species richness from marine to freshwater reaches of estuaries has been proposed (McLusky & Elliott 2006), although hydrological differences among systems and in the taxa inhabiting them can make this trend inapplicable to all estuaries and organisms. Typically, the abundance of fish assemblages in subtropical and temperate estuaries shows a seasonal pattern associated with the reproductive activity of species in the region and with the arrival of larvae and juveniles at nursery areas within estuaries, both of which normally peak in warmer periods of the year (spring and summer) (Ramos & Vieira 2001, Spach *et al*. 2004, Whitfield 1999).

Although Baia da Babitonga has been specified as a priority site for conservation on the Brazilian coast (MMA 2007), knowledge concerning the importance of its shallow areas for fish fauna comes from just a few studies (*e.g*. Souza-Conceição 2008, Araujo 2009). The main objectives of the present study were to (1) describe the structure of the fish assemblage in shallow areas of Baía da Babitonga and (2) test whether the number of species, the number of individuals and the equitability vary among the months of the year and along the longitudinal axis of the estuary. We also tested the relationship between the environmental variables and the changes in the assemblage's attributes (*i.e.* number of individuals, number of species and equitability) and between the body size and the spatial distribution of the most abundant taxa. Specifically, the fish assemblage structure was analyzed by considering the abundance of each taxon by sampling site and month, stage of development, body length and economic value for fisheries.

Materials and Methods

Study area

Baía da Babitonga (26^{o}02'- 26^{o}28' S; 48^{o}28'- 48^{o}50' W) is a subtropical estuary located on the northern Santa Catarina State coast in southern Brazil (Figure 1). It occupies an area of 130 km^2, with a maximum depth of 28 m and an approximate volume of 7.8 x 10^8 m^3 (IBAMA 1998). The main channel of access to the Atlantic Ocean has a length of 20 km and a width between 1.5 and 5 km. The sediment of the bay is composed mainly of sand varying between the very coarse and very fine subclasses, with a predominance of very fine texture. According to the Köppen-Geiger classification, the climate of the region is of the humid subtropical type, with well-distributed rains during the year and a drier winter (Peel *et al*. 2007). The estuary is subjected to a microtidal system with an amplitude of 1.30 m.

The margins of the bay contain an area of 6,200 ha of mangroves, representing 75% of the total mangrove area in the state. The south side is extensively urbanized, where the cities of São Francisco do Sul and Joinville, which have the second largest port and the largest industrial complex in Santa Catarina, respectively, are located. Contrastingly, the population along the northern margin is small, and there is a great diversity of environments, such as tidal flats, sandy beaches, salt marsh banks (*Spartina densiflora*), and mangrove forests (*Laguncularia racemosa, Avicennia schaueriana* and *Rhizophora mangle*) interspersed with tidal channels and with the outfall of small perennial rivers. Approximately 33 fishing communities survive or supplement their income through catching crabs (*Callinectes* spp.), shrimp (*Litopenaeus schmitti*, *Farfantepenaeus paulensis* and *Xiphopenaeus kroyeri*), shellfish (*Mytella charruana* and *Crassostrea* spp.) and fishes (*e.g*. *Centropomus* spp., *Mugil* spp. and *Oligoplites* spp.) from the bay (IBAMA 1998). However, present activities, such as the building of new ports, the expansion of real estate, predatory fishing and poaching have threatened the environmental integrity of the remaining natural areas.

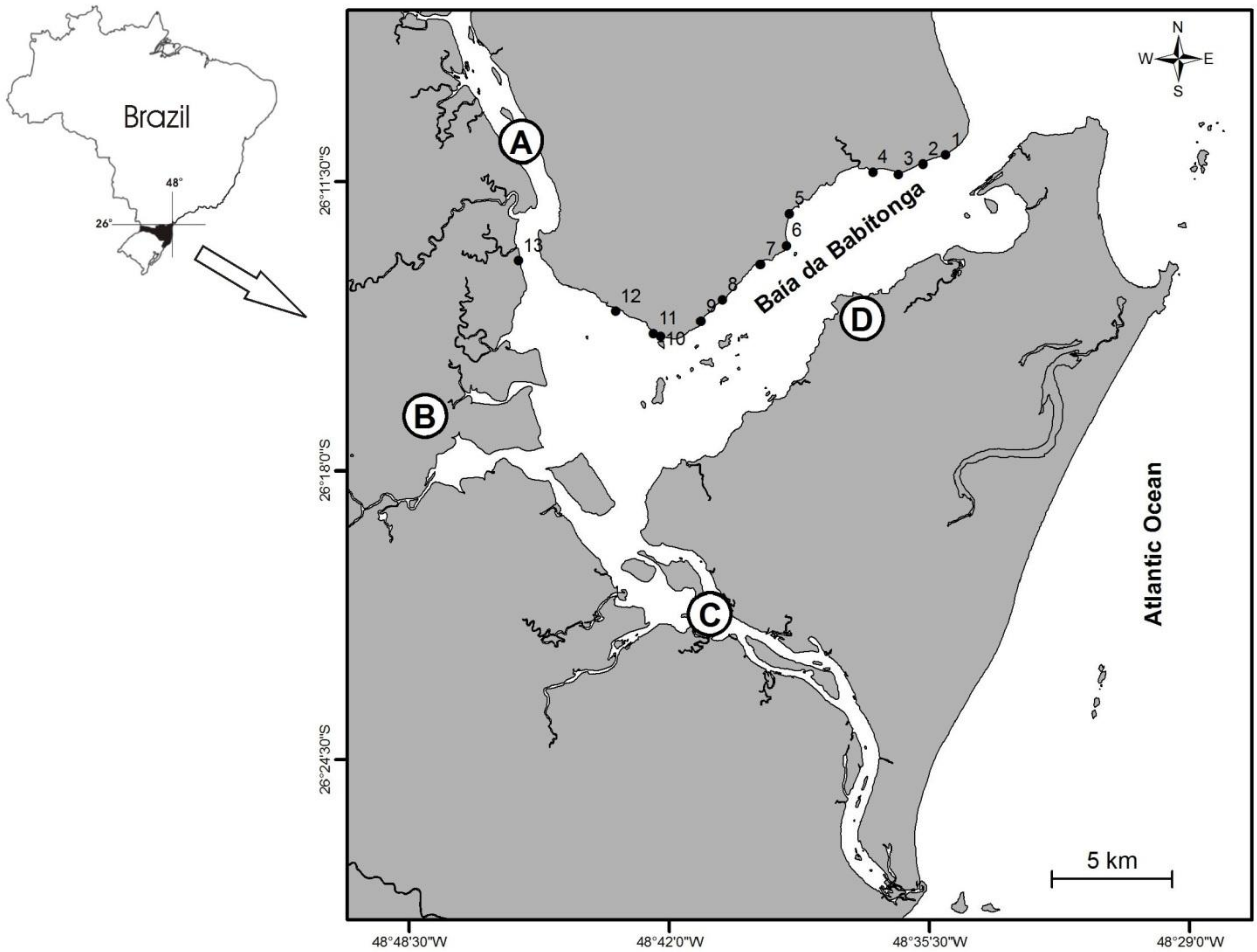

Figure 1. Map of Baía da Babitonga, southern Brazil, showing the Palmital river (A), the city of Joinville (B), the Linguado channel (C), the international harbor of São Francisco do Sul (D), and the sampling sites (1 to 13).

Field and laboratory procedures

A sampling program was conducted for eight months (October and November 2007; January, February, April, May, July and August 2008) at 13 sites along the bay's shoreline. Sampling sites were located on sand beaches distributed along an estuarine gradient for approximately 21 km. Every month, one haul per site was made parallel to the coast, with an extension of 30 m, up to roughly 1.5 m depth. A beach seine net 15 m long and 2 m high with a 2.5-mm mesh size (between adjacent knots) was used for the hauls, which were pulled by two local fishermen. Each 30-m haul was considered one unit of effort (N_{total} = 104; $N_{per\ site}$ = 8). The sampling always occurred during daylight hours.

The fishing gear was chosen based on former samplings performed in the bay's shallow areas using different kinds of nets (1-, 2.5- and 5-mm mesh sizes), when the 2.5-mm mesh size was found to have the lowest size selectivity (Souza-Conceição 2008). For that reason, the same equipment was utilized in the present study. The spatial arrangement of the sampling sites and the number of replicates at each site were defined in accordance with the physical limitations in the area. Thus, only the areas that could be trawled along the margin of the estuary were sampled.

All fishes captured in each haul were placed in plastic bags and conserved in ice until subsequent transfer to the freezer in the laboratory. Individuals were identified (following Figueiredo & Menezes 1978, 1980, 2000, Menezes & Figueiredo 1980, 1985), measured for their total length (precision of 1 mm) and analyzed for their stage of development. In samples for which the number of individuals of a taxon exceeded 30, a random subsample of 30 individuals was measured and analyzed to the stage of development, and the rest was counted. The number of individuals caught per unit of effort (CPUE) was used for estimating species-specific abundance. Determination of stage of development was done according to the macroscopic scale of gonadal maturation proposed by Vazzoler (1996): A, immature; B, maturation; C, mature; D, spent; and E, recovering. These stages were grouped into juveniles (A and B) and adults (C – E) for general comparison purposes. Voucher specimens were deposited in the fish collection of the Museu de História Natural Capão da Imbuia, Paraná, Brazil (MHNCI 12330-12390).

Each site was characterized during all samplings for salinity (refractometer), temperature (^{o}C; mercury thermometer), pH (PH-206 portable digital pH meter), transparency (cm; Secchi disc) and depth (cm; measured at the end of the net farthest from the margin using a ruler). Non-replicated collections of the sediment were made at each site using a PVC tube of 15-cm length and 5-cm diameter. The granulometric analysis of the sediment followed the methodology of pipetting and screening described by Suguio (1973). Four categories of sediments were determined according to Folk & Ward (1957): gravel (>2 mm), sand (1-0.062 mm), silt (0.061-0.004 mm) and clay (<0.004 mm). Monthly precipitation data were obtained from the meteorological station of Universidade da Região de Joinville - UNIVILLE, located next to the estuary (26^{o}15'19" S - 48^{o}51'36" W; 20 m altitude).

Fish classification

The fish taxa were classified into three categories of economic importance based on fishery landing in Santa Catarina State: highly commercial, species landed in the main ports by the industrial and artisanal fleet (IBAMA 2007, UNIVALI/CTTMar 2007); commercial, species landed by the artisanal fleet in small fishing communities (IBAMA 1998, Martins & Perez 2008); and non-commercial, species not included in landing data. If a taxon was landed both in the main ports and in small fishing communities, it was classified in the 'highly commercial' category.

Data analysis

Sectors were defined based on salinity data collected at 13 sites in the bay during 8 field campaigns using a similarity matrix calculated from the Euclidean distance among the samples (*Q-mode*; Legendre & Legendre 1998). This matrix was submitted to cluster analysis to generate a graphical representation and enable identification of groups of sites (sectors) of collection. Differences in physical and chemical characteristics (salinity, temperature, pH, transparency and depth) among the months and the sectors of the estuary identified in the cluster analysis were tested using permutational multivariate analysis of variance (PERMANOVA), where months and sectors were the factors. In that analysis, the Euclidean distance among the samples, calculated from the matrix of the environmental variables, was used (Anderson *et al*. 2008). To test each environmental variable individually in relation to the same factors included in PERMANOVA, a randomization analysis of variance (RANOVA) was applied, utilizing the Euclidean distance data.

The number of individuals, number of species and Pielou equitability index (Pielou 1969) were calculated for each sample. To test whether the fish assemblage attributes varied among months and the estuary sectors (outer and inner), a two-way RANOVA was applied to the number of individuals, number of species and equitability as dependent variables. When the null hypothesis was rejected, paired comparisons among the months were made using the permutation Student's t-test. The RANOVAs and the Student's t-tests were made with matrices with the Euclidean distance among the samples, calculated from biotic data (Anderson *et al*. 2008). In all permutation analyses, 5,000 residual permutations under a reduced model were utilized.

Multiple regressions were used to test for the relationship between the numbers of individuals and species and environmental variables, with the correlation between each dependent and independent variable being analyzed separately through semipartial correlation. Before being submitted to regressions, the biotic data were transformed [$\log_{10}(x+1)$] to reduce heterogeneity in variances (Sokal & Rohlf 1995).

The existence of a relationship between body length and spatial distribution of the assemblage's nine most abundant taxa (≥ 1.6% of the total catch) was analyzed separately in each season utilizing the Pearson correlation (Sokal & Rohlf 1995). Samples were grouped by seasons as follows: spring (Oct. and Nov.), summer (Jan. and Feb.), autumn (Apr. and May), and winter (Jul. and Aug.).

Cluster and permutation analyses were performed with the PRIMER 6 statistical software (Clarke & Gorley 2006), and the other analyses using the SYSTAT 12 program (Wilkinson 1990).

Results

Physical and chemical characteristics of the environment

The bay was dominated by marine waters with high salinity (mean and range = 27.3, 9.0-36.0), moderate temperature (22.0 ^{o}C, 17.0-29.0), low transparency (90.0 cm, 20.0-220.0) and basic pH (7.8, 7.1-8.5). The depth at the sampling sites was shallow (65.0 cm, 24.0-130.0), and the sediment was mainly composed of sand (95.0%, 87.0-100).

The months of January and February showed the highest average temperature (mean ±SD = 25.2 ±1.4 ^{o}C) and the lowest salinity (16.7 ±5.0) and transparency (62.4 ±18.4 cm), respectively. The lowest temperature (17.6 ±0.8 ^{o}C) and the highest salinity (33.4 ±2.7) occurred in August, and the highest transparency (144.7 ±53.9 cm) occurred in May (Figure 2). Environmental variables were significantly different among the months (PERMANOVA: pseudo-$F_{7,\,87}$ = 2.3, $P < 0.001$). In the individual analyses, all environmental parameters differed among months ($P < 0.05$) except for depth ($P = 0.791$).

Two sectors were determined within the bay from the cluster analysis based on the salinity of the collection locations: the outer sector (sites 1-6) and the inner sector (sites 7-13) (Figure 3). Site 13, subject to a higher influence of continental drainage, had lower salinities; consequently, it was separated from the other sites of the inner sector. However,

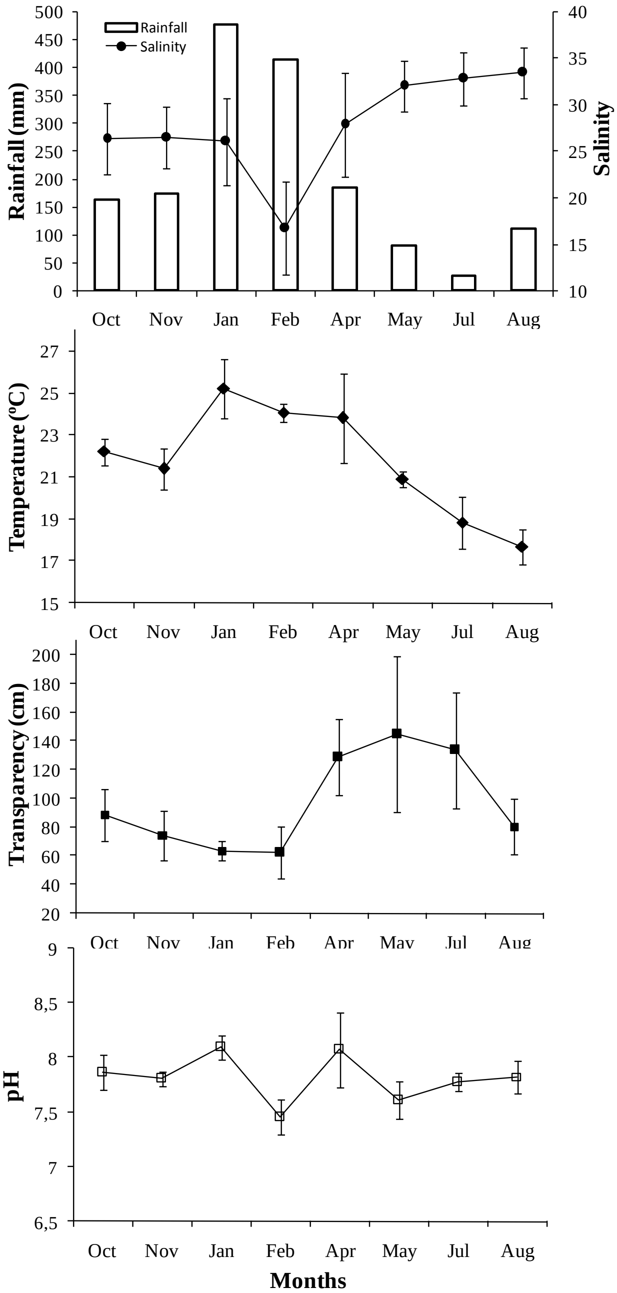

Figure 2. Total rainfall (mm) and mean monthly values (±SD) of salinity, temperature (^{o}C), transparency (cm) and pH sampled between October 2007 and August 2008 in Baía da Babitonga.

due to geographical proximity, it was considered to belong to the inner sector. Salinity was on average highest at site 1 (mean ±SD = 32.2 ±1.8) and lowest at site 13 (15.0 ±6.1) (Table I). Temperature had only small spatial variations, with the lowest average at site 5 (21.1 ±1.7 ^{o}C) and the highest at site 7 (27.6 ±2.9 ^{o}C). Sites 1 (102.2 ±65.1 cm) and 6 (45.6 ±34.4 cm) had the highest and the lowest transparency values, respectively. Average depth was highest at site 1 (126.1 ±9.4) and lowest at site 8 (39.5 ±6.9), and pH was similar at all the sites (Table I).

Environmental characteristics differed among sectors (PERMANOVA: pseudo-$F_{1, 98}$ = 30.2, P < 0.001). In the individual analyses, significant differences were found for salinity (30.8 ±3.6 outer; 24.3 ±5.8 inner; P < 0.001), transparency (102.0 ±41.8 cm, outer; 79.1 ±25.0 cm, inner; P < 0.001), temperature (21.2 ±2.6 °C, outer; 22.7 ±2.7 °C, inner; P < 0.001) and depth (85.0 ±31.0 cm, outer; 48.0 ±20.0 cm, inner; P < 0.001).

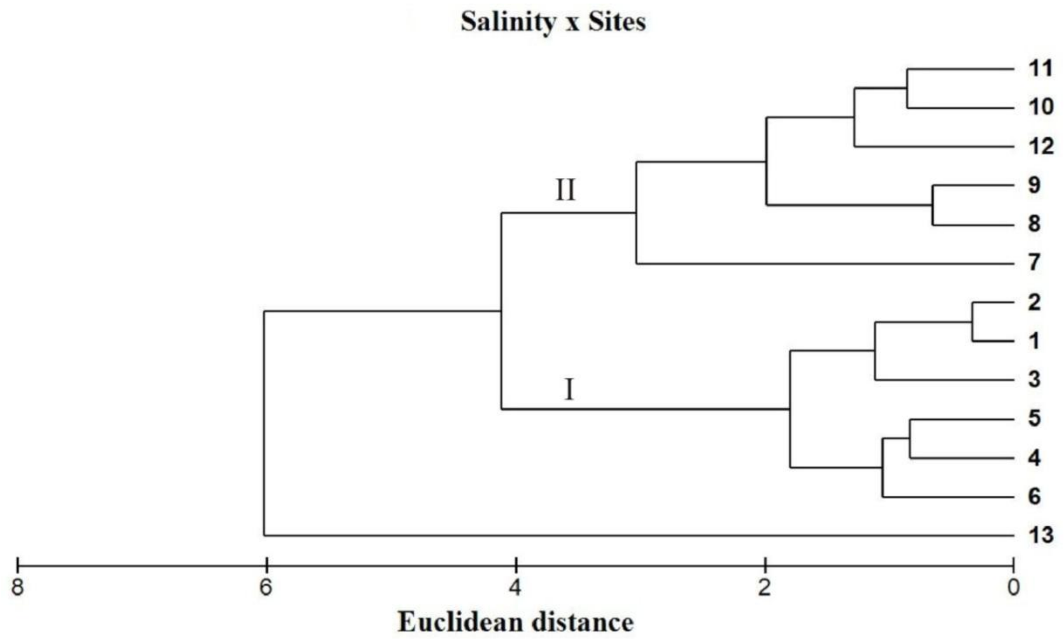

Figure 3. Dendrogram using the Euclidean distance based on salinity values at the thirteen sampling sites (I, outer sector and II, inner sector).

The sediment was composed of four categories in the inner sector (gravel, sand, silt and clay) and three in the outer sector (gravel, sand and silt). Sand was the predominant category at all collection sites. The proportions of silt (5.1%) and clay (6.1%) were highest at site 9, and silt was absent at sites 2 and 3 (Table I).

Fish assemblage structure

A total of 71,085 individuals from 70 taxa belonging to 30 families were captured (Table II). The assemblage was dominated by the taxa engraulids not identified (n.i.), *Eucinostomus* spp. and *Mugil* spp., which together contributed 62.0% of the total abundance. The most representative species, in terms of numerical abundance, were *Atherinella brasiliensis* (12.9%), *Anchoa januaria* (8.9%), *Harengula clupeola* (3.2%), *Anchoa tricolor* (2.8%), *Oligoplites saliens* (2.2%) and *Sphoeroides greeleyi* (1.6%), accounting for 31.8% of the total number of individuals. The remaining species represented individually less than 1.0% of the fishes captured. The families Carangidae (eight species), Gobiidae (six), Engraulidae and Sciaenidae (five each) showed the highest number of species (Table II).

Most fishes analyzed for stage of development were juveniles (93.1%, 8354 individuals), with adults accounting for a relatively small portion (6.8%, 616 individuals). Among the taxa captured, 45 were represented exclusively by juveniles, 22 by both juveniles and adults and 3 only by adults.

Regarding economic importance for fisheries, the highly commercial fishes dominated in abundance and number of taxa (84% of total abundance and 41 taxa), followed by non-commercial (15.3% and 24) and commercial (0.05% and 6). The economic importance of each species is shown in Table III.

The mean length and the range differed among the taxa, with *Strongylura marina* featuring the largest average length (204 mm) and *Eucinostomus* spp. and *Oligoplites palometa* the smallest (16.5 mm). As for range, the taxa with the greatest variations in length were *Myrophis* *punctatus* (100-343 mm) and *Sphoeroides testudineus* (15-194 mm), and those with the smallest variations were *Eucinostomus gula* (70-73 mm) and *Mycteroperca* sp. (23-26 mm) (Table III).

Table I. Mean values (±SD) of the physical and chemical variables and percentage of sediment categories per sampling site and sector in Baía da Babitonga.

Sites (Sectors)	Salinity	Temperature (°C)	pH	Transparency (cm)	Depth (cm)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
1	32.2 ± 1.8	22.2 ± 1.4	8.0 ± 0.4	120.2 ± 65.1	126.1 ± 9.4	0.2	98.8	1.0	0.0
2	31.0 ± 2.5	22.4 ± 1.2	7.9 ± 0.1	89.1 ± 29.9	123.3 ± 2.3	0.0	100.0	0.0	0.0
3	31.0 ± 1.6	23.7 ± 1.4	8.1 ± 0.1	73.7 ± 15.5	106.1 ± 11.2	0.0	100.0	0.0	0.0
4	28.5 ± 2.8	22.8 ± 2.8	7.8 ± 0.2	89.8 ± 16.5	63.9 ± 18.8	1.3	96.7	2.0	0.0
5	28.6 ± 1.8	21.1 ± 1.7	7.8 ± 0.1	63.1 ± 12.6	64.8 ± 15.5	0.0	95.6	4.4	0.0
6	25.9 ± 3.7	23.2 ± 2.0	7.7 ± 0.3	45.6 ± 34.4	75.8 ± 10.8	6.1	89.8	4.2	0.0
(Outer)	30.8 ± 3.6	21.2 ± 2.6	7.8 ± 0.2	102.0 ± 41.8	85.0 ± 31.0	1.3 ± 2.4	96.8 ± 3.8	1.9 ± 1.9	0.0 ± 0.0
7	22.8 ± 4.3	23.3 ± 2.7	7.8 ± 0.3	57.5 ± 10.6	42.1 ± 22.0	5.3	91.7	3.0	0.0
8	23.8 ± 3.1	26.9 ± 2.9	8.1 ± 0.3	76.4 ± 22.8	39.5 ± 6.9	2.6	96.4	1.0	0.0
9	24.5 ± 2.2	27.6 ± 2.9	8.2 ± 0.3	73.6 ± 10.8	40.1 ± 11.6	2.2	86.6	5.1	6.1
10	20.7 ± 3.4	25.3 ± 1.3	7.9 ± 0.3	62.4 ± 9.2	45.5 ± 12.1	0.6	95.3	2.1	2.1
11	23.6 ± 2.5	24.9 ± 1.9	7.9 ± 0.2	70.8 ± 17.6	49.2 ± 1.2	2.8	94.1	3.1	0.0
12	20.5 ± 5.4	24.1 ± 2.4	7.8 ± 0.4	85.6 ± 24.8	55.9 ± 11.3	0.6	95.3	4.1	0.0
13	15.0 ± 6.1	23.8 ± 1.3	7.4 ± 0.2	71.1 ± 41.2	70.5 ± 21.1	0.8	92.2	5.0	2.0
(Inner)	24.3 ± 5.8	22.7 ± 2.7	7.7 ± 0.3	79.1 ± 25.0	48.0 ± 20.0	2.1 ± 1.6	93.1 ± 3.3	3.3 ± 1.5	1.5 ± 2.2

Spatial and temporal patterns

The taxa *Eucinostomus* spp., *Mugil* spp., engraulids n.i., *A. brasiliensis*, *H. clupeola*, *O. saliens* and *A. tricolor* were the most abundant in the outer sector, while engraulids n.i., *A. brasiliensis*, *A. januaria*, *Mugil* spp., *Eucinostomus* spp., *S. greeleyi* and *A. tricolor* dominated in the inner sector (Table II). Ten taxa occurred exclusively in the outer sector, and nine occurred exclusively in the inner sector of the bay; however, none contributed very much to the total abundance, corresponding individually to < 0.1% (except *Anchoviella lepidentostole*, 0.2%). The number of individuals, number of species and equitability did not differ significantly between the inner (mean ±SD = 700.6 ±2,354.5 individuals; 9.5 ±4.5 species; 0.5 ±0.2 equitability) and the outer sector (663.5 ±2,328.1 individuals; 8.9 ±5.3 species; 0.6 ±0.2 equitability; Figure 4a, Table IV). Similarly, no relationship between the number of individuals and species and collection sites occurred within the bay (r^2 = 0.002, P = 0.681; r^2 = 0.017, P = 0.186, respectively), indicating an absence of spatial trends for these parameters. Temporally, changes in abundance occurred in the assemblage's most numerous taxa.

Mean CPUE of the engraulids n.i., *Eucinostomus* spp., *Mugil* spp., *Harengula clupeola* and *Oligoplites saliens* was highest in January (Table III). Capture of *Atherinella brasiliensis* peaked in November and January. *Anchoa januaria* was more abundant in the summer months (January and February), while *Anchoa tricolor* was more abundant in the early summer and early autumn months (January and April). *Sphoeroides greeleyi* was abundant from late summer to late autumn (February – May; Table III). The number of individuals and species differed significantly among months (Table IV), with higher averages in January (mean ±SD = 3,503.7 ±5,820.0 individuals; 17.3 ±4.0 species) and lower averages in October (38.0 ±22.6 individuals) and July (4.4 ±2.1 species; Figure 4b). Equitability also varied significantly, and it showed a pattern opposite to that of the number of individuals, with the highest averages in October (0.7 ±0.1) and the lowest in January (0.4 ±0.1; Figure 4b).

Table II. Mean number of individuals caught per unit of effort by site and sector and relative contribution (%) in total number of individuals for fish taxa sampled between October 2007 and August 2008 in Baía da Babitonga. Species are organized by alphabetic order of the families.

Family/ Taxa	Outer sector							Inner sector								Total (%)
	1	2	3	4	5	6	Total	7	8	9	10	11	12	13	Total	
Achiridae																
Achirus lineatus									0.25	0.13					0.05	< 0.01
Ariidae																
Genidens barbus					2.25	0.25	0.42	0.63	0.88						0.21	0.05
Genidens genidens					12.13	1.13	2.21	16.75	2.38	0.13					2.75	0.37
Atherinopsidae																
Atherinella brasiliensis	0.88	12.00	22.88	11.00	282.38	1.38	55.08	20.63	16.00	16.63	443.38	233.25	66.00	24.13	117.14	12.95
Odontesthes bonariensis	3.00	3.13	0.25	0.13	0.13	0.13	1.13			0.50	0.13		0.75	2.38	0.54	0.12
Belonidae																
Strongylura marina	0.25		1.13	0.25			0.27	0.13			0.88		0.25	0.13	0.20	0.03
Strongylura sp.	0.25	1.38	2.00	0.38	3.75		1.29	1.00	0.50	0.63	0.13			0.25	0.36	0.12
Carangidae																
Caranx hippos								0.25		0.25					0.07	0.01
Chloroscombrus chrysurus	0.13		1.25				0.23	0.13				0.13			0.04	0.02
Oligoplites palometa		1.75	10.38				2.02				1.13			0.13	0.18	0.15
Oligoplites saliens	5.88	27.25	142.63	4.50	1.38	0.63	30.38	6.75	5.25	4.63	0.50	0.38	0.38	1.13	2.71	2.26
Oligoplites saurus	0.38	2.13	6.38				1.48				0.38				0.05	0.1
Selene vomer				0.13		0.13	0.04		0.38			0.13			0.07	0.01
Trachinotus carolinus	12.38	8.75	10.00	0.13	17.00	5.25	8.92	0.50	2.38	2.50					0.77	0.66
Trachinotus falcatus	6.13	3.13	19.38	3.25	0.63		5.42	0.50	0.25						0.11	0.37
Centropomidae																
Centropomus undecimalis									0.13	0.13					0.04	< 0.01
Clupeidae																
Harengula clupeola	9.75	191.13	62.75	0.13			43.96	0.88			1.00	9.88	8.38	0.13	2.89	3.2
Opisthonema oglinum	2.75						0.46									0.03
Sardinella brasiliensis	0.13		5.88				1.00				2.00				0.29	0.09
Cynoglossidae																
Symphurus tesselatus						0.13	0.02	1.38	0.13	1.13				0.25	0.41	0.03
Dactylopteridae																
Dactylopterus volitans														0.13	0.02	< 0.01
Diodontidae																
Chilomycterus spinosus spinosus		0.13	0.38				0.08				0.13	0.13		0.25	0.07	0.01
Engraulidae																
Anchoa januaria	15.00	5.50	4.75	0.88	4.00	16.13	7.71	21.25	59.88	45.25	513.88	15.25	18.38	73.38	106.75	8.93
Anchoa tricolor	39.75	123.00	7.50	0.88		0.25	28.56	0.38	0.75	0.13	10.25	66.25	5.88	0.13	11.96	2.87
Anchoviella lepidentostole												24.38			3.48	0.27
Cetengraulis edentulus	1.13		11.00			0.38	2.08	3.00		0.25	0.50	2.00	0.13	0.88	0.96	0.22
Lycengraulis grossidens		0.63	9.00	0.13	1.00	1.38	2.02	0.38	0.88	2.13	0.25	0.63	0.38	1.25	0.84	0.2
Not identified (n.i.)	87.00	112.38	11.25	8.38	145.75	3.75	61.42	109.50	70.88	95.75	1392.38	485.50	38.25	118.13	330.05	30.15
Ephippidae																
Chaetodipterus faber	0.13		0.13	0.38	0.50	0.38	0.25	0.50	0.13						0.09	0.02
Fistulariidae																
Fistularia petimba								0.38		0.25					0.09	0.01
Gerreidae																
Diapterus rhombeus					0.25		0.04	0.25	0.25		5.13	1.13	2.38	5.38	2.07	0.17
Eucinostomus argenteus				0.25	0.25	1.00	0.25	0.13	0.50	0.63	6.13	4.25	1.50	0.38	1.93	0.17
Eucinostomus gula					0.13		0.02				0.13				0.02	< 0.01
Eucinostomus melanopterus		0.13					0.02				3.63	0.63	0.25	0.75	0.75	0.06
Eucinostomus spp.	1.88	33.50	1334.88	29.25	17.50	2.00	236.50	0.13	9.25	2.50	119.75	22.13	11.25		23.57	17.83
Gobiidae																
Bathygobius soporator				0.13			0.02	0.13		0.38		0.25	0.13	0.38	0.18	0.02
Ctenogobius boleosoma					0.13		0.02	0.63		0.38	1.75	1.00	1.63	1.13	0.93	0.07
Ctenogobius stigmaticus											3.38				0.48	0.04
Gobionellus oceanicus														0.13	0.02	< 0.01
Gobionellus stomatus											0.13				0.02	< 0.01
Microgobius meeki									0.13		0.13				0.04	< 0.01
Haemulidae																
Pomadasys corvinaeformis	0.13	13.25	40.63	9.75	0.50	1.63	10.98	2.75	1.75	0.13					0.66	0.79
Hemiramphidae																
Hyporhamphus unifasciatus		0.25	0.25			0.13	0.10							2.75	0.39	0.04
Monacanthidae																
Monacanthus ciliatus			0.13				0.02									< 0.01
Mugilidae																
Mugil curema	0.13		0.13	1.00			0.21		0.13		0.50	0.25	0.25	0.75	0.27	0.04
Mugil sp.	0.25	1.38	1.38	0.13	0.13	0.38	0.60	0.13	0.63	0.25	3.25		2.25		0.93	0.11
Mugil spp.	259.88	84.25	457.25	1.50	12.88	6.75	137.08	43.38	39.25	13.50	325.38	1.63	1.88	1.50	60.93	14.06
Ophichthidae																
Myrophis punctatus						0.50	0.08									0.01
Paralichthyidae																
Citharichthys arenaceus		0.25	1.75				0.33									0.02
Citharichthys spilopterus			0.88	0.38	0.25	0.25	0.29	1.13	1.50	1.00	1.25	2.63	1.75	2.50	1.68	0.15
Etropus crossotus	0.25	0.25	0.88		0.38	1.38	0.52		2.38	0.13		0.25	0.38	1.25	0.63	0.08
Paralichthys orbignyanus	0.25						0.04									< 0.01

Table II (*Cont.*)

Polynemidae																
Polydactylus virginicus	0.50				0.13	0.13	0.13									0.01
Pomatomidae																
Pomatomus saltatrix		6.00	2.50				1.42									0.1
Sciaenidae																
Cynoscion leiarchus					0.13		0.02		0.38					0.13	0.07	0.01
Menticirrhus americanus	0.63	0.13	0.38		0.25	0.25	0.27	0.63	1.13					0.25	0.29	0.04
Menticirrhus littoralis	12.88	4.63	1.00				3.08		0.38						0.05	0.21
Micropogonias furnieri	0.38				2.75	1.63	0.79	7.38	5.88	1.75		0.13	0.13	0.63	2.27	0.23
Stellifer rastrifer					0.25	44.50	7.46	1.00							0.14	0.51
Serranidae																
Diplectrum radiale			0.13				0.02									< 0.01
Mycteroperca sp.				0.13			0.02				0.13	0.13			0.04	< 0.01
Syngnathidae																
Cosmocampus elucens					0.13	0.25	0.06	0.25	0.25						0.07	0.01
Syngnathus folletti		0.50	1.00	0.25	0.63		0.40	0.13	0.25			0.13			0.07	0.03
Syngnathus pelagicus						0.25	0.04									< 0.01
Synodontidae																
Synodus foetens		1.00	0.63				0.27					0.38			0.05	0.02
Tetraodontidae																
Lagocephalus laevigatus			0.13			0.13	0.04						0.13		0.02	< 0.01
Sphoeroides greeleyi			0.63	11.38	5.13	11.38	4.75	17.00	35.00	6.00	18.00	20.00	11.50	9.88	16.77	1.64
Sphoeroides testudineus			0.13	5.00	0.75	0.13	1.00	1.00	1.88	4.38	2.25	1.38	2.75	0.50	2.02	0.23
Triglidae																
Prionotus punctatus			0.13			0.13	0.04		0.13			0.13		0.5	0.11	0.01
Uranoscopidae																
Astrocopus y-graecum		0.5	0.25				0.13									0.01
Mean CPUE	462.00	638.25	2173.88	89.63	513.38	104.00	663.52	260.88	262.00	201.38	2857.75	894.25	176.88	251.38	700.64	683.51
Number of individuals	3,696	5,106	17,391	717	4,107	832	31,849	2,087	2,096	1,611	22,862	7,154	1,415	2,011	39,236	71,085
Number of taxa	28	28	40	26	31	33	60	35	35	28	31	29	25	32	60	70
Mean equitability	0.45	0.60	0.35	0.66	0.39	0.59	0.60	0.56	0.59	0.52	0.42	0.41	0.62	0.45	0.57	0.58

Multiple regressions indicated that the numbers of individuals and species were significantly related to environmental variables (R^2 = 0,272, $F_{5, 98}$ = 7,334, $P < 0.001$; R^2 = 0.466, $F_{5, 98}$ = 17,108, $P < 0.001$, respectively). Considering each environmental variable individually, significant positive correlations were found for the number of individuals and species with temperature (semipartial correlations: $r^2 = 0.317$, $P < 0.001$; $r^2 = 0.320$, $P < 0.001$, respectively) and depth ($r^2 = 0.190$, $P = 0.029$; $r^2 = 0.202$, $P = 0.007$, respectively), and a significant negative correlation was found between the numbers of species and transparency ($r^2 = -0.246$, $P = 0.001$). No significant correlations were found between fish assemblage attributes and salinity (for the number of individuals, $r^2 = 0.036$, $P = 0.674$; for the number of species, $r^2 = -0.021$, $P = 0.768$) or pH ($r^2 = -0.086$, $P = 0.319$; $r^2 = -0.062$, $P = 0.401$).

As for the distribution of the 70 taxa registered, 10 were widely distributed within the estuary (*A. brasiliensis*, *O. saliens*, *A. januaria*, *A. tricolor*, engraulids n.i., *Mugil* spp., *Citharichthys spilopterus*, *S. greeleyi*, *Sphoeroides testudineus* and *Eucinostomus* spp.), occurring at least 11 of the 13 sites sampled along the bay (Table II), and 10 were constant during the sampling months (*A. brasiliensis*, *O. saliens*, *Trachinotus carolinus*, *A. januaria*, engraulids n.i., *Mugil* spp., *Citharichthys spilopterus*, *Etropus crossotus*, *S. greeleyi* and *Sphoeroides testudineus*), occurring in at least 7 of the 8 months sampled (Table III). Most species occurred seasonally in restricted parts of the estuary.

The lengths of the 9 most abundant taxa changed spatially, with 23 statistically significant correlations out of the 26 tested (Table V). In 4 taxa (*A. brasiliensis*, *O. saliens*, *Mugil* spp., and *Eucinostomus* spp.), relationships between length and position within the estuary were influenced by seasonality, reversing the direction of the relationship among the variables temporally. The lengths of engraulids were negatively correlated with the distance from the estuary mouth in all analyses, indicating a body size increase toward the outer part of the bay. For *H. clupeola*, a positive correlation was observed. *Sphoeroides greeleyi* had significant negative correlations among variables in spring and autumn, with a predominance of smaller individuals within the estuary (Table V).

Table III. Mean number of individuals caught per unit of effort by month, total average length and range (in mm), stage of development (J, juvenile; A, adult) and commercial importance (HC, highly commercial; C, commercial; NC, non-commercial) for fish taxa sampled between October 2007 and August 2008 in Baía da Babitonga.

Taxa	Months								Mean Length	Life	Commercial
	Oct	Nov	Jan	Feb	Apr	May	Jul	Aug	(range)	Stage	Importance
Achirus lineatus				0.15		0.08			58.6 (55-61)	J	NC
Anchoa januaria	1.62	3.69	100.62	378.77	0.46	1.08		2.08	48.4 (25-185)	J, A	HC
Anchoa tricolor		0.08	47.77		90.85	9.38	0.08	8.85	48.9 (25-111)	J, A	HC
Anchoviella lepidentostole			15.00						40.3 (30-52)	J	HC
Astrocopus y-graecum	0.15	0.15			0.08			0.08	48.6 (32-106)	J	NC
Atherinella brasiliensis	9.08	408.38	216.54	22.69	26.00	11.92	4.92	8.46	57.7 (12-162)	J, A	NC
Bathygobius soporator		0.08	0.15	0.23	0.15	0.23			63.1 (19-102)	J, A	NC
Caranx hippos			0.15		0.08	0.08			57 (40-69)	J	HC
Centropomus undecimalis			0.15						170.5 (125-216)	J	HC
Cetengraulis edentulus			4.00	0.46	0.08	6.92	0.15	0.23	65.5 (27-122)	J	HC
Chaetodipterus faber		0.08	0.92	0.23		0.08			29.7 (11-45)	J	HC
Chilomycterus spinosus spinosus		0.08	0.08	0.08		0.08	0.23	0.08	40.7 (25-73)	J	NC
Chloroscombrus chrysurus		0.08	0.85		0.08				24.7 (15-34)	J	HC
Citharichthys arenaceus	0.23						0.15	0.85	106.3 (52-171)	J	HC
Citharichthys spilopterus	1.15	0.62	1.69	2.62	0.38	1.15	0.23	0.46	69.6 (18-142)	J, A	HC
Cosmocampus elucens						0.23	0.15	0.15	86.1 (49-113)	J, A	NC
Ctenogobius boleosoma				1.38	1.54	1.08		0.08	33.6 (16-47)	J, A	NC
Ctenogobius stigmaticus							2.08		36.9 (12-58)	J, A	NC
Cynoscion leiarchus			0.31				0.08		42 (20-111)	J	HC
Dactylopterus volitans								0.08	100	J	C
Diapterus rhombeus			5.31	1.92	0.69			1.15	48.6 (22-123)	J	HC
Diplectrum radiale								0.08	118	A	NC
Etropus crossotus	0.31	0.46	0.85	2.15	0.46	0.23	0.08	0.08	67 (12-120)	J, A	C
Eucinostomus argenteus			7.23	0.62	1.15	0.15		0.08	43 (20-92)	J, A	HC
Eucinostomus gula	0.08			0.08					71.5 (70-73)	J	HC
Eucinostomus melanopterus		0.08	0.08	2.85	0.15		0.15		38.6 (21-150)	J	HC
Eucinostomus spp.			919.69	38.85	14.54	1.69			16.5 (10-25)	J	HC
Fistularia petimba		0.15				0.23			177.4 (157-206)	J	C
Genidens barbus	0.31			2.15					76.9 (50-166)	J	C
Genidens genidens	0.08	0.08	0.31	19.54					67.6 (48-134)	J, A	C
Gobionellus oceanicus			0.08						166	J	NC
Gobionellus stomatus						0.08			115	A	NC
Harengula clupeola		1.85	158.46	9.69		4.54	0.15	0.08	55.3 (16-91)	J, A	HC
Hyporhamphus unifasciatus	0.31	1.15	0.31	0.15			0.08	0.08	147.1 (60-192)	J, A	C
Lagocephalus laevigatus		0.15	0.08						105.6 (80-151)	J	HC
Lycengraulis grossidens	0.46	1.46		0.77		2.31	4.92	1.15	96.4 (16-171)	J, A	HC
Menticirrhus americanus	0.15	0.23	0.38	1.38				0.08	79.5 (22-137)	J	HC
Menticirrhus littoralis			1.31		1.31	4.69	3.00	1.31	35.1 (11-144)	J	HC
Microgobius meeki				0.15					37 (32-42)	J, A	NC
Micropogonias furnieri	6.46	4.00	0.62				0.23	1.38	65.6 (15-180)	J	HC
Monacanthus ciliatus			0.08						19	J	NC
Mugil curema		0.62	0.15	0.92	0.23				86.7 (43-155)	J	HC
Mugil sp.			1.62	2.08	0.77	1.77			85.3 (71-133)	J	HC
Mugil spp.	0.77	23.62	638.92	2.00	76.38	4.69	3.85	18.38	26.9 (16-60)	J	HC
Mycteroperca sp.	0.23								24.6 (23-26)	J	HC
Myrophis punctatus		0.08		0.15				0.08	197.5 (100-343)	J, A	NC
Not identified (n.i.)	0.23	200.08	1215.46	58.77	101.69	72.23		0.08	27.5 (10-34)	J	
Odontesthes bonariensis	1.31	0.23	4.38	0.46		0.08			55.7 (26-89)	J, A	NC
Oligoplites palometa			8.08	0.15					16.5 (10-33)	J	HC
Oligoplites saliens	0.23	0.08	74.15	0.31	0.15		13.92	35.00	40.9 (11-145)	J	HC
Oligoplites saurus	0.08		5.38	0.23					19.9 (5-125)	J	HC
Opisthonema oglinum			1.69						66.4 (57-74)	J	HC
Paralichthys orbignyanus					0.08		0.08		203 (171-235)	J	HC
Polydactylus virginicus	0.08		0.38						44.6 (22-99)	J	NC
Pomadasys corvinaeformis			35.38	7.62		0.38			57.8 (34-75)	J	HC

Table III (*Cont.*)

Pomatomus saltatrix						4.00	0.62	0.62	84.4 (58-123)	J	HC
Prionotus punctatus		0.08	0.15	0.08		0.08	0.08	0.15	67.5 (48-96)	J	HC
Sardinella brasiliensis			4.85			0.08			28.9 (25-49)	J	HC
Selene vomer	0.08	0.31					0.08		58.6 (48-70)	J	HC
Sphoeroides greeleyi	7.08	6.46	6.92	16.85	16.31	19.62	7.85	8.69	76.3 (15-124)	J, A	NC
Sphoeroides testudineus	0.92	0.54	1.31	3.85	1.62	2.00	0.85	1.31	80.5 (15-194)	J, A	NC
Stellifer rastrifer	1.46	1.69		25.00					114 (65-156)	J, A	HC
Strongylura marina	0.31	0.46	0.08	0.31	0.46	0.23			204 (198-376)	J, A	NC
Strongylura sp.		3.08	2.77	0.31	0.15				55.6 (19-137)	J	NC
Symphurus tesselatus	0.69	0.38	0.08	0.62		0.08			86.3 (60-114)	J	NC
Syngnathus folletti		0.77	0.38		0.23	0.08	0.15	0.15	80.6 (43-148)	J, A	NC
Syngnathus pelagicus								0.15	122 (120-124)	A	NC
Synodus foetens	0.08	0.23	0.54	0.23	0.15				87.5 (41-135)	J	NC
Trachinotus carolinus	4.15	11.00	3.15	8.15	2.15	6.69	0.54	0.38	48.2 (16-107)	J	HC
Trachinotus falcatus		0.23	14.92	0.54	0.23	4.54			34 (17-62)	J	HC
Mean CPUE	38.08	672.77	3,503.77	615.54	338.62	162.77	44.69	91.85			
Number of individuals	495	8,746	45,549	8,002	4,402	2,116	581	1,194			
Number of species	28	37	49	42	30	35	26	32			
Mean equitability	0.71	0.30	0.46	0.43	0.51	0.60	0.66	0.57			

Discussion

Fish assemblage structure

The taxonomic structure of Baía da Babitonga's fish fauna is similar to that of other subtropical estuaries in the southeastern Atlantic, being characterized by high numerical abundance of Atherinopsidae, Mugilidae and Engraulidae (Vieira & Musick 1994, Ramos & Vieira 2001). In places south of the bay, as in the estuaries of Laguna (28^{o}S) and Lagoa dos Patos (32^{o}S), the intertidal ichthyofauna is numerically dominated by the families Atherinopsidae (mainly *A. brasiliensis*) and Mugilidae (Monteiro-Neto *et al*. 1990, Vieira & Musick 1994, Ramos & Vieira 2001), while in northern regions, such as Baía de Guaratuba and Baía de Paranaguá (25^{o}S), besides the taxa mentioned above, Engraulidae make up a significant portion of the ichthyofauna (Spach *et al*. 2004, Chaves & Vendel 2008). Carangidae and Sciaenidae ranked among the four most species-rich families in this study and in Baía de Guaratuba (Chaves & Bouchereau 1999), Baía de Paranaguá (Félix *et al*. 2007) and Laguna estuary (Monteiro-Neto *et al*. 1990). The Baía da Babitonga location (26^{o}S) apparently contributed to fish fauna characteristics shared with estuaries on the two latitudinal extremes of the warm temperate southwestern Atlantic zoogeographical region (24^o to 32^{o}S; Vieira & Musick 1994). Other features, such as the great relative abundance of young-of-the-year of the taxa engraulids n.i., *Eucinostomus* spp. and *Mugil* spp. found here, strongly contrast with shallow fish assemblages in other southern Brazil estuaries (Monteiro-Neto *et al*. 1990, Spach *et al*. 2004). These differences might be an artifact of the fishing gear used in this study. The use of a net with a relatively small mesh (2.5 mm) was very effective in capturing young individuals with a reduced body size, suggesting that these taxa might have been underestimated in the studies mentioned previously, which were performed with meshes of larger sizes (≥5 mm).

In spite of some selectivity due to the fishing equipment, the predominance of juveniles found in the samples is consistent with results of studies on ichthyofauna of shallow estuarine areas around the world (Whitfield 1999, Blaber 2000, Elliott & Hemingway 2002, França *et al*. 2009). This may be considered an inherent characteristic of estuary shallow habitats, such as salt marshes, tidal channels, sand beaches, muddy plains and mangroves, which are often reported as important nursery areas for many fish species (Blaber 2000, Layman 2000, Ramos & Vieira 2001). Besides its ecological functions, Baía da Babitonga plays an important social and economic role because some of the fish species marketed or used as food by the region's coastal populations (*e.g*. *Micropogonias furnieri*, *Oligoplites saliens* and *Mugil* spp.) inhabit its margins during the beginning of their life cycles, although they are captured mainly next to the coast outside the bay (Chaves & Robert 2003). Some of these species are strongly targeted by artisanal and industrial fisheries in Santa Catarina State and elsewhere along the Brazilian coast (IBAMA 2007), making them vulnerable to overfishing. This fact is already established for four of the species found in this work (6.0% of all recorded species), which are categorized as overexploited on the Brazilian red list (MMA 2008).

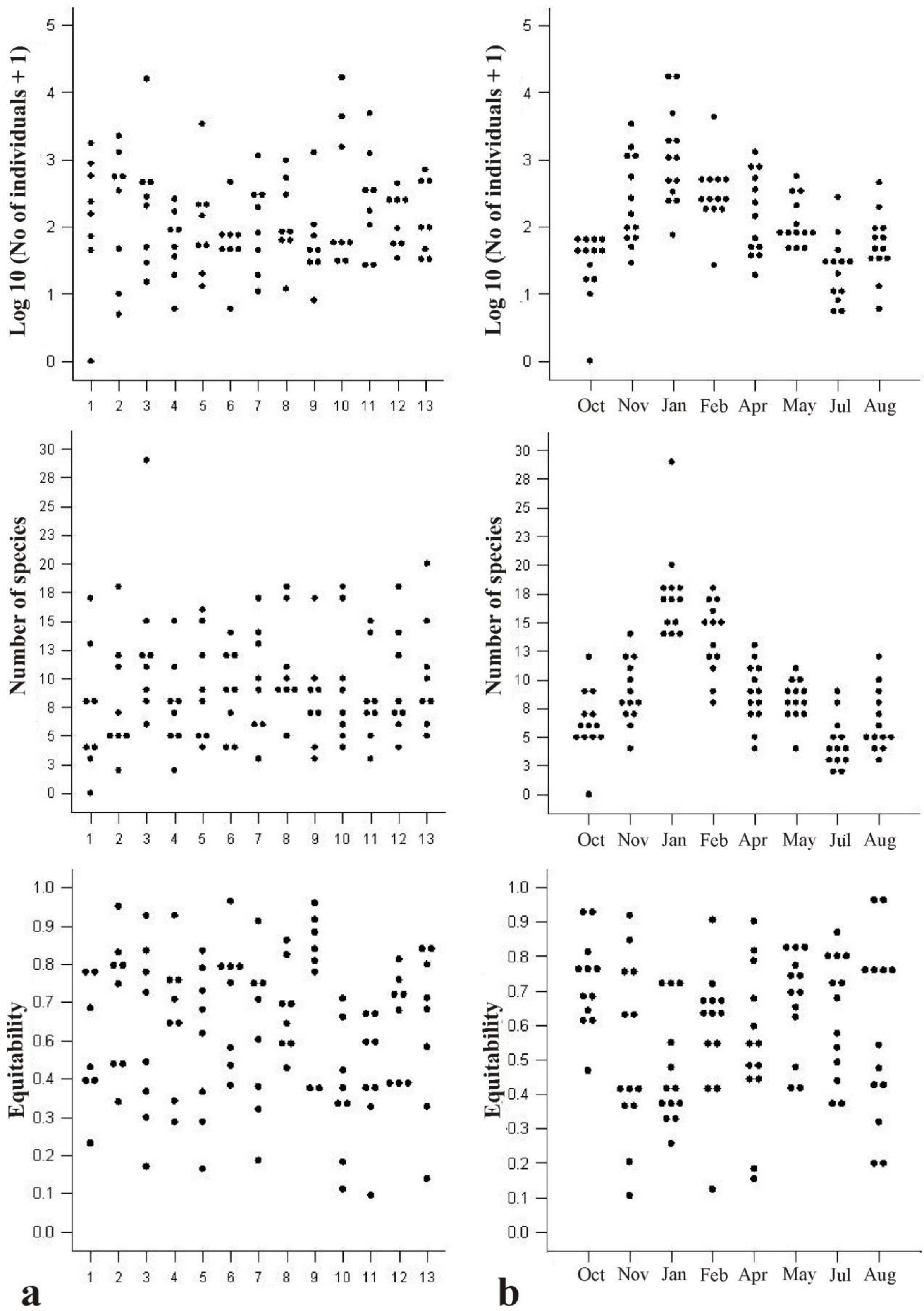

Figure 4. Catch per unit of effort of the number of individuals, number of species and equitability per site (a) and month (b) sampled between October 2007 and August 2008 in Baía da Babitonga. Each dot corresponds to a sample.

Table IV. Results of the Randomization Analysis of Variance made on the number of individuals, number of species and equitability as dependent variables and months and sectors as independent variables. Months codes (J, Jan.; F, Feb.; A, Apr.; M, May; JU, Jul.; AU, Aug.; O, Oct.; N, Nov.) not joined by underline in pair-wise tests were significantly different (P < 0.05; permutation Student's t-tests). Codes are ordered from those of higher means (left) to those of lower means (right).

Dependent variables	Independent variables						
	Sectors			Months			
	DF	F	P	DF	F	P	Pair-wise tests
Number of individuals	1	7.20	0.920	7	3.53	0.001	J, N, F, A, M, AU, JU, O
Number of species	1	1.07	0.320	7	29.36	< 0.001	J, F, N, A, M, AU, O, JU
Equitability	1	0.91	0.345	7	2.30	0.034	O, JU, M, AU, F, A, N, J

In contrast to the Laguna estuary in the south (Monteiro-Neto *et al*. 1990) and Caeté in the north (Barletta & Blaber 2007) of the Brazilian coast, Baía da Babitonga maintained marine characteristics most of the year. There was not a pronounced salinity gradient except during the summer (January and February), when there was an increase in rainfall and salinity dropped to 9‰ at the innermost sites, a value relatively high compared to those registered in these other estuaries, where typically limnic zones were defined. These hydrological features may explain the absence of strictly freshwater species in this study, whereas they are commonly found in the environments mentioned above. Nevertheless, this slight decrease in salinity toward the inner estuary apparently limited the use of the inner portion for some marine species, such as *T. carolinus* and *O. saliens*.

Spatial and temporal patterns

Declining species richness toward the inner estuary has been recognized as a general pattern for major groups of animals living within estuaries (McLusky & Elliott 2006), but the examples quoted are predominantly for benthic macroinvertebrate taxa. In the present study, no spatial trend was found for the number of species, the number of individuals or the equitability. Alternation in locations of occurrence of uncommon species (*e.g*. *Diplectrum radiale* and *Myrophis punctatus* in the outer sector; *Centropomus undecimalis* and *Achirus lineatus* in the inner sector) and in abundance of dominant species (*e.g*. *Eucinostomus* spp. in the outer sector; engraulids n.i. in the inner sector) may explain homogeneity in the assemblage's basic attributes within the bay. On the other hand, temporal changes in the assemblage structure were evident. Abundance increase and equitability decrease during the early summer (January) were caused mainly by the capture of juvenile shoals of the taxa engraulids n.i., *Mugil* spp., *Eucinostomus* spp. and *Oligoplites saliens*. Many of the species that inhabit Babitonga are recognized for reproducing primarily during austral spring and summer (Pichler 2005, Félix *et al*. 2007). This seems to have contributed to the temporal pattern of richness, abundance and equitability found, considering that most individuals captured were in a juvenile stage. In general, fish assemblage richness and abundance are higher during warmer periods and lower during colder times, which reflect recruitment patterns determined by reproductive activity and coastal circulation (Whitfield 1999, Elliott & Hemingway 2002, Spach *et al*. 2004, McLusky & Elliott 2006).

While the species richness was relatively constant along the estuary, the composition varied among the sectors, as did the water's physical characteristics and the environment's structural characteristics. For example, Gobiidae were exclusive or more abundant in the inner sector, where salinity and depth were significantly lower and higher proportions of silt and clay occurred in the substrate; on the other hand, Carangidae dominated in the outer portion of the estuary, composed of sandy beaches and under a larger influence of marine water masses. Then a turnover in the species composition is indicated to occur along the bay concomitant with environment changes. Factors associated with water quality and habitat structure, such as salinity, transparency, depth and sediment, were related to species composition but not to richness, indicating that these variables may limit the occurrence or abundance of some species.

Besides the seasonal influence on abundance, species diversity also showed a strong seasonal dependence. Only 28 taxa among the 70 registered were captured throughout the whole sampling period, with the assemblage's seasonal

Table V. Results of the Pearson correlation tests between total length and the collection sites for the nine most abundant taxa collected between October 2007 and August 2008 in Baía da Babitonga. The number of individuals and sites included in the analyses are listed (*a*, intersection of the line on the y axis; *b*, slope; *r*, correlation coefficient; *P*, probability; N/A, not applicable).

Taxa	N	No. of sites	Seasons	*a*	*b*	*r*	*P*
Engraulids n.i.	254	11	Spring	31.05	-0.24	-0.19	< 0.001
	472	13	Summer	28.38	-0.27	-0.31	< 0.001
	393	13	Autumn	30.86	-0.41	-0.41	< 0.001
	1	1	Winter	N/A	N/A	N/A	N/A
Eucinostomus spp.	0	0	Spring	N/A	N/A	N/A	N/A
	321	11	Summer	17.88	-0.21	-0.41	< 0.001
	107	10	Autumn	15.55	0.18	0.17	0.064
	0	0	Winter	N/A	N/A	N/A	N/A
Mugil spp.	163	12	Spring	29.36	-0.47	-0.37	< 0.001
	251	13	Summer	23.84	0.47	0.31	< 0.001
	159	9	Autumn	26.17	0.21	0.27	< 0.001
	108	9	Winter	26.82	0.12	0.33	< 0.001
Atherinella brasiliensis	393	12	Spring	35.06	1.79	0.17	< 0.001
	501	13	Summer	63.30	-0.84	-0.17	< 0.001
	261	11	Autumn	117.52	-6.13	-0.68	< 0.001
	132	10	Winter	114.72	-4.75	-0.49	< 0.001
Anchoa januaria	69	5	Spring	94.20	-1.50	-0.25	0.033
	604	13	Summer	52.24	-1.10	-0.35	< 0.001
	20	4	Autumn	74.63	-3.05	-0.58	0.006
	27	2	Winter	N/A	N/A	N/A	N/A
Harengula clupeola	24	1	Spring	N/A	N/A	N/A	N/A
	245	9	Summer	43.64	1.29	0.44	< 0.001
	33	2	Autumn	N/A	N/A	N/A	N/A
	3	1	Winter	N/A	N/A	N/A	N/A
Anchoa tricolor	1	1	Spring	N/A	N/A	N/A	N/A
	141	5	Summer	52.21	-1.56	-0.60	< 0.001
	153	10	Autumn	50.88	-1.47	-0.36	< 0.001
	80	8	Winter	76.91	-0.89	-0.27	0.012
Oligoplites saliens	4	2	Spring	N/A	N/A	N/A	N/A
	220	13	Summer	18	1.01	0.16	0.017
	2	1	Autumn	N/A	N/A	N/A	N/A
	100	4	Winter	84.21	-2.33	-0.24	0.012
Sphoeroides greeleyi	176	11	Spring	90.49	-1.14	-0.20	0.007
	282	11	Summer	67.54	0.46	0.07	0.216
	348	10	Autumn	81.63	-0.59	-0.10	0.053
	199	10	Winter	73.94	0.59	0.11	0.115

members being dominant. These observations coincide with those described for other fish communities in estuaries (Pessanha *et al*. 2003, Spach *et al*. 2004). Whitfield (1999) argues that estuaries are normally characterized by the low richness and great abundance of a few taxa tolerant of the fluctuating environmental conditions found in these systems. Few species were represented by juveniles and adults in the present study, suggesting that most use the margins of the bay for development during the beginning of the life cycle and later migrate to adjacent coastal areas or to deeper locations within the estuary. The negative relationship between body length and distance to the bay mouth found for Engraulidae (*A. tricolor*, *A. parva* and engraulids n.i.), *Eucinostomus* spp. and *A. brasiliensis* in this study corresponds to the pattern of distribution observed for these taxa in Baía de Paranaguá (Hackradt *et al*. 2009), suggesting the preference of the inner estuarine areas for recruitment. Changes in habitat use according to size are common in aquatic populations (Kneib 1987). Araujo & Santos (1999) suggest that gerreidae *D. rhombeus* and *Gerres aprion* recruit at the margins of Baía de Sepetiba, southeastern Brazil, as juveniles and later, as adults, move to deeper locations within the estuary or on the shallow shelf to reproduce. These spatial differences in distribution within the same species are probably related to the search of juvenile individuals for shallow habitats to avoid pressure from predators (Kneib 1987) or to ontogenetic segregation to avoid intraspecific competition (Ross 1986).

The capture of large shoals of young-of-the-year from the three most abundant taxa during the summer and a subsequent decrease during the rest of the year were the main causes of temporal changes in the number of individuals, while the restricted occurrence of species of low abundance in the same season resulted in an increased richness of species. Spatial changes in the physical characteristics of the habitat are suggested to be the main force governing the distribution of species, reflecting a richness per site (mean = 30.8) that is relatively low compared to the total number of taxa registered (N = 70). Additionally, the fact that phylogenetically related species segregated in space and time as coexistence strategies (Ross 1986) may have influenced the species distribution in the bay on a smaller scale. For example, *A. tricolor* dominated in the outer sector at the beginning of autumn (April), and *A. parva* dominated in the inner sector at the beginning of summer (January); *S. greeley* and *S. testudineus* were more abundant in the late summer and early autumn months (February – April) but at different locations (sites 8, 11 and 4, 9, respectively); *T. carolinus* occupied the outer sector mainly during the late spring (November) and late summer (February) months, and *O. saliens* occupied the outer sector in the early summer (January) and winter (July and August) months. Therefore, marine reserves currently implanted in the region should contemplate the whole area studied as well as the adjacent marine environments for conservation of fish fauna diversity. Based on the strong predominance of juveniles, including species that inhabit these environments transitionally, such initiatives would help maintain the nursery function of its habitats and consequently coastal fisheries in the region.

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