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Space–Time Distribution of the Ichthyofauna from Saco da Fazenda Estuary, Itajaí, Santa Catarina, Brazil

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ABSTRACT

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From July 2003 to June 2004, the physiographic characteristics of the ichthyofauna of the estuary of Saco da Fazenda were studied in four defined areas representative of the estuary. A total of 4502 individuals were captured, with 42 species, 35 genera, and 21 families. Engraulidae were the most abundant fish, and *Cetengraulis edentulus* dominated the captures. The species of occasional occurrence prevailed in the samplings and were represented mainly by juvenile individuals. The highest abundances occurred during the months of summer and autumn, in contrast with high biomasses in the spring and autumn; area IV contributed the largest captures. The richness indexes, diversity, and equitability presented similar flotation patterns, with high values in spring and summer. The Jaccard index revealed a greater similarity in the composition of the ichthyofauna in areas II and IV, while the lowest happened between I and IV, which is probably due to the different sizes of these areas.

This paper clearly shows the relevance of this estuary, albeit strongly impacted, for recruitment of small fish mainly during summer and autumn months.

ADDITIONAL INDEX WORDS: *Abundance, diversity, richness, seasonal fluctuations.*

INTRODUCTION

The distribution of fish assemblages is closely related to environmental parameters such as salinity, temperature, turbidity, and dissolved oxygen (Ansari *et al.,* 1995; Barletta *et al.,* 2005; Garcia and Vieira, 1997; Marshal and Elliott, 1997; Vivier and Cyrus, 2002). In tropical environments, salinity mostly acts on the number of species while in temperate estuaries, temperature is normally regarded as the key factor that causes a reduced richness (Vieira and Musick, 1993).

In Brazil, most studies dealing with estuarine fish assemblages were made in Rio de Janeiro (Andreata *et al.,* 1990, 2002; Araújo *et al.,* 1998, 2001; Brum *et al.,* 1994; Costa, 1984; Pessanha *et al.,* 2000), Paraná (Chaves and Bouchereau, 1999a, 1999b; Chaves and Corrêa, 1998; Neto *et al.,* 2004; Santos *et al.,* 2002; Spach, Santos, and Godefroid, 2003; Spach *et al.,* 2004; Vendel *et al.,* 2002), Rio Grande do Sul (Chao *et al.,* 1982; Garcia and Vieira, 1997, 2001; Godefroid *et al.,* 2004; Pereira, 1994; Silva, 1982) and in some areas of the north states (Araújo, Teixeira, and Oliveira, 2000; Camargo and Isaac, 2001; Castro, 2001; Lopes, Oliveira-Silva, and Ferreira-Melo, 1998; Vasconcelos-Filho and Oliveira, 1999). Although Santa Catarina's coast has a fair number of important estuaries, their fish assemblages have been seldom studied (Hostim-Silva *et al.,* 2002). Nevertheless, work was done on the lagoon complex of Laguna (Monteiro-Neto *et al.,* 1990), the mangroves of Itacorubi (Florianópolis) (Clezar, Hostim-Silva, and Ribeiro, 1998), the Camboriú river estuary (Balneário Camboriú) (Rodrigues *et al.,* 1994), Babitonga Bay (São Francisco do Sul) (Hostim-Silva *et al.,* 1998), and the mouth of the Itajaí-Açú river (Itajaí) (Hostim-Silva *et al.,* 2002).

Because of the importance of Saco da Fazenda's estuary and the lack of both qualitative and quantitative data on this ecosystem and its fish assemblage (no studies published on fish ecology), we projected and developed the present work to obtain a primary analysis of spatial and temporal variations of its ichthyofauna. The region is highly threatened by several development processes, such as industrial ports and factories, which also imply increased pollution. This estuary is probably also important for larval and postlarval development.

MATERIALS AND METHODS

Collections were made on a monthly basis between June 2003 and June 2004 in Saco da Fazenda's estuary, Itajaí, SC, Brazil (26°53′33″–26°55′06″ S, 48°38′30″–48°39′14″ W), in four previously chosen areas that are physiographically representative of the whole ecosystem (Figure 1). Our study area is strongly affected by several human activities, namely long

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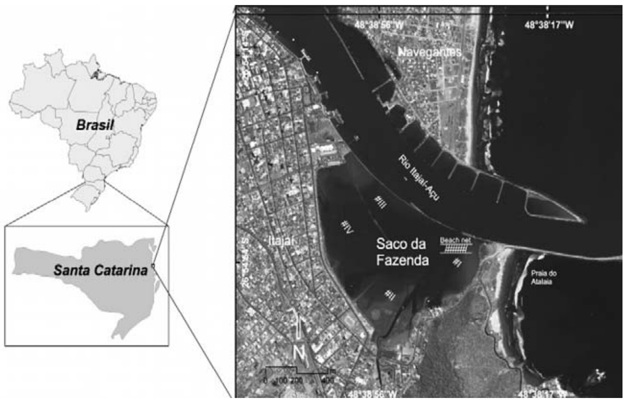

Figure 1. Satellite photograph of the study area. Saco da Fazenda, Itajaí, SC, Brazil. (Source: Google Earth.)

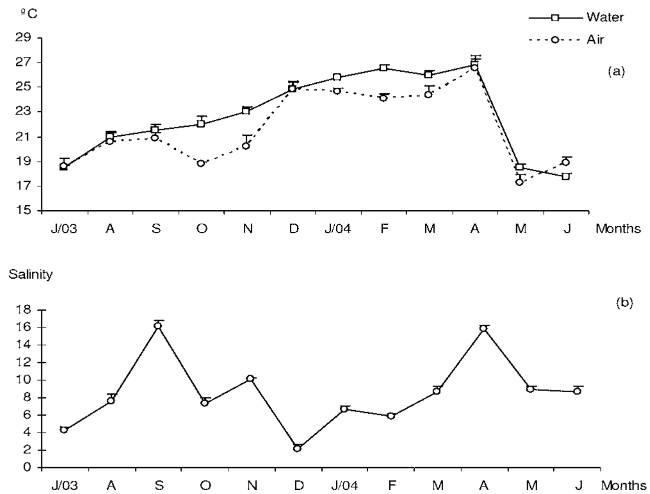

Figure 2. (a), (b) Average temporal variation of physicochemical parameters in the Saco da Fazenda estuary, Itajaí, SC, Brazil, between July 2003 and July 2004. (Vertical bar = median error.)

piers that advance the Itajaí-Açú river canal toward the ocean. This has resulted in the isolation of an ancient river meander. Water renewal is thus strongly restricted; the bottom substrate is typically composed of silt clay and the maximum depth is 2.0 m (while in the canals that connect it to the river the depth reaches 9.0 m). Tidal amplitude is lower than 1.4 m, and the average annual rainfall varies between 1250 to 1500 mm (Branco, 2000).

Fish were collected with a purse seine net (25-mm mesh) and a beach net (30 m long, with a central part made of 40-mm mesh and two lateral parts made of 400-mm mesh) trawled by a rowboat. In each area 20 throws were made with the seine net while the beach net was kept underwater near the connection canal for periods of 4 hours followed by a 2-hour interval. Collected material was placed in identified plastic bags and kept in isothermal boxes with ice. In the laboratory, specimens were separated by species (Barletta and Corrêa, 1992; Figueiredo and Menezes, 1978, 1980, 2000; Menezes and Figueiredo, 1980, 1985); and grouped by families following Nelson (2006). The number of specimens and biomass per species were noted. Air and water temperatures as well as salinity were measured in every sampling trip, thus obtaining relevant data for later ecological analyses.

Eventual significant differences in environmental parameters, richness, number of individuals, biomass, diversity, and evenness between collection areas were tested by ANOVA (Zar, 1999) with complementary tests for variance homogeneity (Bartlett test) and normality of distribution (Kolmogorov-Smirnov). When significant differences appeared, the median contrast (Tukey–Kramer test) was applied to show which were significantly different.

Fish species were grouped in the following categories (Chaves and Bouchereau, 1999a; Felix *et al.,* 2007) according to their percentage of occurrence: 0%–50% = occasional; 51%–75% = frequent, and 76%–100% common.

Indices of specific richness (Margalef, D), diversity (Shannon, H') and evenness (Pielou, J') were calculated monthly using the number of specimens per collection trip (Ludwig and Reynolds, 1988). Similarity between the study areas was estimated through the Jaccard index (Southwood, 1968). Total biomass, total abundance, richness, diversity, and evenness were correlated (Spearman rank correlation, Statistica for Windows, v. 6.0) with air temperature, water temperature, and salinity.

To evaluate the adequacy of the sample size, we used the pooled quadrat method (Pielou, 1966) where the cumulative numbers of randomly pooled samples were plotted against the cumulative diversity. The Shannon Index (Magurran, 1988) was employed to measure the diversity as

$$H' = -\sum_{i=1}^{n} Pi(\log_e Pi),$$

where Pi is the proportion of individuals of the ith species. Because the cumulative diversity curves are based on random orders of quadrats, 1000 random orders of samples were calculated. The mean curve for each sample was then estimated and plotted. Each diversity curve was considered asymptotic if at least two previous values of the total sample diversity (H') were in the range $H' \pm 0.05H'$.

RESULTS

Abiotic Factors

Air and water average temperatures showed a typical seasonal pattern and did not significantly differ between collection sites ($F_{3-40} = 0.083$, $p \geq 0.05$ and $F_{3-40} = 0.052$, $p \geq 0.05$, respectively). Average water temperatures were highest in January and April (24.6°C and 26.6°C respectively) and lowest in May (17.3°C) and June (17.8°C) (Figure 2a). Water temperature showed a highly significant positive correlation with total fish abundance ($p = 0.01$) and a significant correlation with total biomass ($p = 0.04$).

Salinity was also not different between sampling areas ($F_{3-40} = 0.161$; $p \geq 0.05$). Nevertheless, the highest average values occurred in September (16.1) and April (15.9), and the lowest ones in December (2.1) (Figure 2b), showing a positive

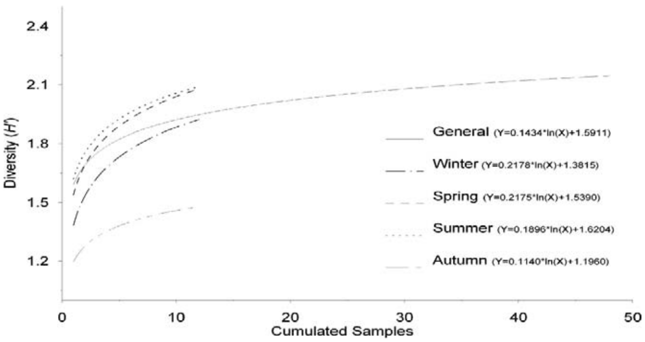

Figure 3. Cumulative diversity curves from all samples in the Saco da Fazenda estuary, Itajaí, SC, Brazil.

significant correlation with total fish abundance ($r_s = 0.4153$; $p < 0.01$).

Ichthyofauna Description

The total number of unit samples analyzed to describe the ichthyofauna of Saco da Fazenda appears to be sufficient because all samples reached an asymptote (at least two values of total sample H' were in the range $H' \pm 0.05$) (Figure 3).

During the sampling period, 4502 fish were collected belonging to 21 families, 35 genera, and 42 species (Table 1). Of these, 15 species occurred in all sampling sites. Eight families corresponded to the highest abundances (96.96% of total fish). The most common families were: Engraulidae (37.72%), Mugilidae (34.01%), Gerreidae (16.84%), and Clupeidae (7.44%) (Table 1). *Cetengraulis edentulus* (Cuvier, 1829) was the dominant species representing 30.96% of the total abundance, followed by *Mugil curema* (Valenciennes, 1836) (27.57%), *Eucinostomus melanopterus* (Bleeker, 1863) (7.71%), *Diapterus rhombeus* (Cuvier, 1829) (7.37%), *Harengula clupeola* (Cuvier, 1829) (7.00%), *Mugil platanus* (Günther, 1880) (6.26%), and *Lycengraulis grossidens* (Agassiz, 1834) (2.75%) (Table 1).

Occasional species dominated all sampled sites with the highest frequencies in site I (88.00%), followed by sites III (84.00%), IV (76.00%), and II (73.00%) (Table 1), while frequent species predominated in site III (12.00%) and common species in site II (19.00%) (Table 1).

Area IV produced the highest abundance of fish (2033), followed by areas I (1022), II (939), and III (508) (Table 1). In spite of some oscillations, the number of species per sample was not significantly different between sampling areas ($F_{3-44} = 1.826$; $p \geq 0.05$), with greater occurrences in spring–summer and fewer in fall–winter (Figure 4), where area I contributes 32 species, followed by areas II (26), III (25), and IV (25) (Table 1).

Spatial Variations and Temporal Changes of Abundance and Biomass

The average monthly abundance of fish collected within the estuary remained relatively low during winter, spring, and early summer, increasing from March 2004 onward and peaking in April (212 ± 85.91), followed by a fall in May (119 ± 56.42) and another increase in June (165.25 ± 79.23) (Figure 5). Significant differences ($F_{3-44} = 4.291$; $p < 0.05$) were registered between the number of fish and sampling areas throughout the year and are due, according to Tukey–Kramer's test, to lower captures in site III when compared with higher ones from site IV (Table 1).

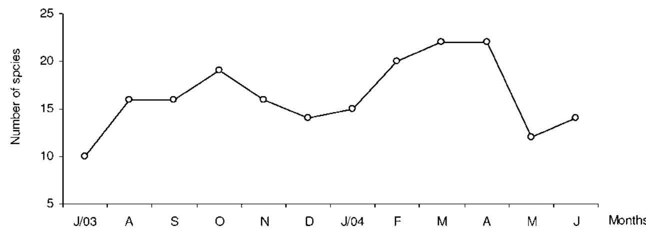

Figure 4. Variation in the number of species throughout the study period in the Saco da Fazenda estuary, Itajaí, SC, Brazil.

According to Figure 6, the highest average monthly biomass levels occurred during the spring–fall months, with annual peaks alternating between November 2003 (2.57 ± 0.92 kg), April 2004 (2.15 ± 0.69 kg), and June (2.18 ± 0.84 kg). Significant differences ($F_{3-44} = 6.687$; $p < 0.001$) were observed between average biomass from the sampling sites. We attribute these differences to higher collections registered in site IV.

Richness, Diversity, and Evenness

Margalef's richness index (D) showed higher values in site I (4.47), followed by sites III (3.85), II (3.65), and IV (3.15) (Table 1). No significant differences ($F_{3-44} = 0.951$; $p \geq 0.05$) were detected between monthly values of D and sampling sites. Thus, higher average richness occurred in spring–summer months and lesser ones in fall–winter months (Figure 7).

Shannon–Wiener's diversity index (H') did not differ significantly ($F_{3-44} = 1.078$; $p \geq 0.05$) between sampling sites, and the highest H' value was detected in site III (2.26), followed by sites II (2.09), I (1.99), and IV (1.68) (Table 1). When analyzing the average monthly changes in H' one may verify that higher values occurred also during spring–summer months, with peaks in October (1.74 ± 0.30) and March (1.83 ± 0.25), and lesser values in the fall (May—0.90 ± 0.20) (Figure 8).

Pielou's evenness index (J'), although moderately fluctuating between sampling sites, stayed statistically similar ($F_{3-44} = 2.117$; $p \geq 0.05$), with the higher annual value in site III (0.70), followed by sites II (0.64), I (0.57), and IV (0.52) (Table 1). Generally speaking, evenness followed the same tendency shown by D and H' with higher values during spring–summer (peaking in October, February, and March—all 0.76) while lower ones occurred in winter (May = 0.50 ± 0.12) (Figure 9).

Similarity

Results achieved with Jaccard's index showed a relatively low level of similarity between our sampling sites. Values

Table 1. *Check list of fish species and their abundances between July 2003 to July 2004 in Saco da Fazenda's estuary, Itajaí, SC, Brazil. (Species occurrence is represented by: > = common; + = frequent; < = occasional) (Nelson, 2006).*

Family/Species	Area I	Occ.	Area II	Occ.	Area III	Occ.	Area IV	Occ.
Osteichthyes								
Engraulidae								
Cetengraulis edentulus (Cuvier, 1829)	479	<	172	>	37	<	706	+
Lycengraulis grossidens (Agassiz, 1834)	103	+	3	<	16	+	2	<
Clupeidae								
Opisthonema oglinum (Lesuer, 1818)	4	<			7	<	2	<
Harengula clupeola (Cuvier, 1829)	130	<	57	+	29	<	99	<
Sardinella brasiliensis (Steindachner, 1789)					5	<	2	<
Ariidae								
Genidens genidens (Valenciennes, 1848)	17	<	18	<			5	<
Mugilidae								
Mugil curema (Valenciennes, 1836)	57	+	284	>	205	>	695	>
M. gaimardianus (Desmarest, 1831)					7	<	1	<
M. platanus Günther, 1880	4	<	39	>	30	<	209	>
Atherinopsidae								
Atherinella brasiliensis (Quoy and Gaimard, 1825)	3	<	4	<	17	<	13	+
Belonidae								
Strongylura timucu (Walbaum, 1792)					1	<		
Centropomidae								
Centropomus parallelus Poey, 1860			4	<			4	<
Pomatomidae								
Pomatomus saltator (Linnaeus, 1758)	2	<	1	<	2	<		
Carangidae								
Caranx latus Agassiz, 1831	2	<	1	<				
Selene setapinnis (Mitchill, 1815)			1	<	1	<		
S. vomer (Linnaeus, 1758)	1	<					1	<
Chloroscombrus chrysurus (Linnaeus, 1766)	1	<			9	<		
Oligoplites saliens (Bloch, 1793)	25	<	11	<	28	<	3	<
Oligoplites saurus (Bloch and Schneider 1801)			1	<			2	<
Trachinotus falcatus (Linnaeus, 1766)							2	<
Gerreidae								
Eucinostomus argenteus (Baird and Girard, 1854)	22	<	8	<	14	<	14	<
E. melanopterus (Bleeker, 1863)	70	>	151	>	46	+	80	>
E. gula (Cuvier, 1830)	9	<	4	<	2	<	6	<
Diapterus rhombeus (Cuvier, 1829)	27	<	109	>	32	+	164	>
Haemulidae								
Conodon nobilis (Linnaeus, 1758)	6	<			7	<		
Sciaenidae								
Micropogonias furnieri (Desmarest, 1823)	18	+	6	<	5	<	4	<
Cynoscion leiarchus (Cuvier, 1830)	1	<						
Stellifer rastrifer (Jordan, 1889)	5	<						
S. stellifer (Bloch, 1790)	1	<						
Bairdiella ronchus (Cuvier, 1830)	15	<						
Cichlidae								
Geophagus brasiliensis (Quoy and Gaimard, 1824)	8	<	50	+	2	<	9	<
Oreochromis niloticus (Linnaeus, 1758)			2	<			3	<
Blenniidae								
Hypleurochilus fissicornis (Quoy and Gaimard, 1824)	1	<						
Gobiidae								
Gobioides braussonnetii Lacépède, 1800			1	<				
Bathygobius soporator (Valenciennes, 1837)	2	<	1	<				
Gobionellus oceanicus (Pallas, 1770)	2	<	2	<	1	<		
Scombridae								
Scomberomorus brasiliensis Collette, Russo, and Zavala-Camin, 1978	2	<			1	<		
Paralichthyidae								
Citharichthys spilopterus (Günther, 1862)	2	<	4	<	3	<	4	<
Achiridae								
Achirus lineatus (Linnaeus, 1758)	1	<	4	<	1	<	1	<
Cynoglossidae								
Symphurus tessellatus (Quoy and Gaimard, 1824)	1	<						
Tetraodontidae								
Lagocephalus laevigatus (Linnaeus, 1766)	1	<						
Diodontidae								
Chilomycterus spinosus spinosus (Linnaeus, 1758)			1	<			2	<
Total fish	1022		939		508		2033	
Total species	32		26		25		25	
No occasional species	28		19		21		19	
No frequent species	3		2		3		2	
No common species	1		5		1		4	
Richness D	4.47		3.65		3.85		3.15	
Shannon-Wiener's diversity H'	1.99		2.09		2.26		1.68	
Pielou's evenness J'	0.57		0.64		0.70		0.52	

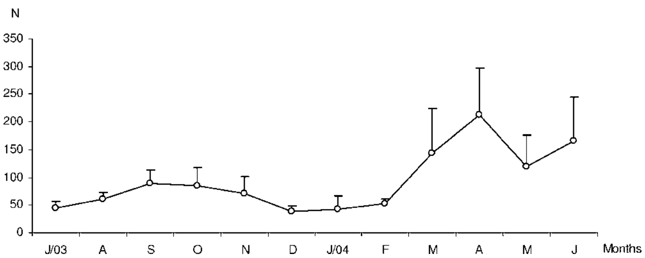

Figure 5. Monthly variation of the average number of fish collected in the Saco da Fazenda estuary, Itajaí, SC, Brazil, between July 2003 and July 2004. (Vertical bar = median error.)

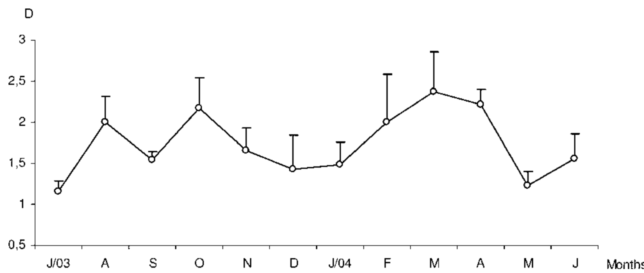

Figure 7. Monthly variation of average richness (*D*) in the Saco da Fazenda estuary, Itajaí, SC, Brazil, between July 2003 and July 2004. (Vertical bar = median error.)

varied between 46.15% and 64.25%. Highest faunistic similarity was found between sites II and IV (64.25%), followed by the groupings I and III (58.33%), III and IV (56.25%), III and II (54.55%), I and II (52.63%), and the lowest one between the groupings I and IV (46.15%).

DISCUSSION

Seasonal changes in the abundance of estuarine fish have been attributed to both water temperature and salinity (Hagan and Able, 2003; Pereira, 1994; Pessanha *et al.,* 2000; Santos *et al.,* 2002; Spach, Santos, and Godefroid, 2003; Vendel *et al.,* 2000, 2003). According to Marshall and Elliot (1997) and to Hagan and Able (2003), temperature was considered to be the main cause of variation in the number of species occurring in a given moment. Alternatively, Pessanha *et al.* (2000) and Vendel *et al.* (2003) attribute these variations to food availability inside estuaries (a fact that may well be directly dependent on the previously discussed abiotic factors). Laffaille, Feunteun, and Lefeuvre (2000) and Ikejima, Tongnunui, and Taniuchi (2002), also refer to factors such as reproductive periods, mortality rates, and species migration patterns as the main factors that are decisive in a community's species composition and abundance.

In Saco da Fazenda's estuary, the occurrence of larvae in summer, coming straight from the nearby oceanic environment and clearly associated with higher summer and early fall temperatures, together with higher food availability, may well have been a major contributor to our increasing abundances in spring–summer months. Biomass showed a similar pattern, albeit higher weights are obtained during spring–fall months.

The significant differences obtained in both abundance and biomass between the sampling sites may well be due to the presence of both macrophytes and mangrove vegetation in site IV. According to Garcia and Vieira (1997), estuaries with important densities of aquatic vegetation offer a highly suitable habitat for larval development and juvenile nurseries, minimizing predation and increasing food sources. Besides this well-known aspect, in our area considerable amounts of domestic sewage discharges do occur, thus increasing the nutrient input to plants and primary consumers, all important food items for Mugilidae (Araújo-Silva and Araújo, 2000), a group abundantly collected during our study.

Margaleff's index (*D*) of seasonal fluctuations was also verified by Vendel *et al.* (2002) in the fish community of Gamboa do Baguaçú (PR, Brazil). However, the greater richness of that region may be due to the size of the estuary, higher habitat diversity, and the nearness of adjacent coastal environments (Tongnunui *et al.,* 2002). Although not significantly different, higher *D* values shown in site I may be due to the number of occasional species that, according Vieira and Musick (1993), are highly responsible for specific richness variations in tropical estuaries.

In our study, H' varied between 0.90 and 1.83; the lagoon complex of Laguna was found to be between 0.60 and 2.40 (Monteiro-Neto *et al.,* 1990), Gamboa do Sucuri (Spach, San-

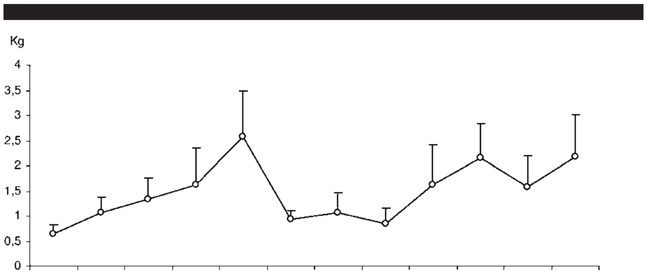

Figure 6. Monthly variation of the average biomass of fish collected in the Saco da Fazenda estuary, Itajaí, SC, Brazil, between July 2003 and July 2004. (Vertical bar = median error.)

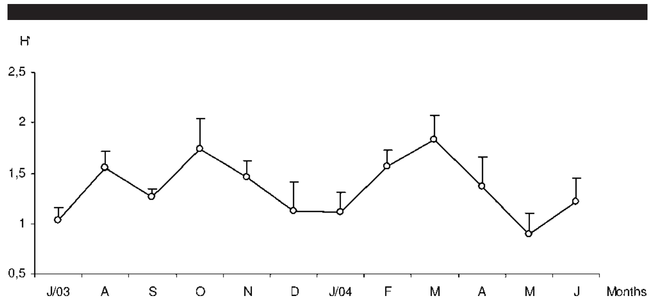

Figure 8. Monthly variation of average diversity (H') in the Saco da Fazenda estuary, Itajaí, SC, Brazil, between July 2003 and July 2004. (Vertical bar = median error.)

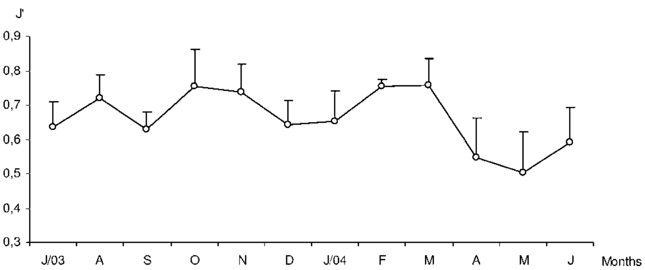

Figure 9. Monthly variation of average evenness (J') in the Saco da Fazenda estuary, Itajaí, SC, Brazil, between July 2003 and July 2004. (Vertical bar = median error.)

tos, and Godefroid, 2003) between 1.10 and 1.95, and Barra do estuário da Lagoa dos Patos between 1.20 and 2.27 (Pereira, 1994). Vieira and Musick (1993), state that these differences are probably related to temporal fluctuations in the abundance of resident species as well as the recruitment processes and opportunistic behavior of occasional species within each estuary.

Generally speaking, the higher diversity obtained during spring–summer months may be due to richness values and to a more proportional distribution of specimens during those periods. Using the same logic, we can attribute lesser diversities to a reduced number of species and to the strong dominance of both *Mugil curema* and *Cetengraulis edentulus.* This is something pointed out by Barreiros *et al.* (2004, 2005), while describing the ichthyofauna of adjacent oceanic waters about 60 km south of our study site. They especially note high increases of Engraulidae in spring–summer months. Although not significantly different, lower diversities in our site IV may reflect the region's instability caused by a low resistance by some species to high levels of domestic sewage inputs (see also Marshall and Elliot, 1997). This line of reasoning is also a probable explanation for the evenness variations detected.

Our fluctuations in H', J', and D follow similar patterns as to the system's structural evaluation referred to by Castro (1997) in a study of the fish community of Barra Bonita, and by Benedito-Cecílio *et al.* (1997) in the Itaipú reservoir and adjacent areas.

Measures of similarity between habitats have been widely used when analyzing ichthyofauna stability together with studies on environmental influences and species occurrence that identify an ecosystem's discontinuities (Castro, 1997). In our study, the higher similarities obtained for sites II and IV are probably related to the presence of common species in the areas that are favored by abundant sheltering vegetation. In contrast, the similarity detected between sites I and III may be explained by the occurrence of occasional species coming straight from the Itajaí-Açú river, here functioning as a species "corridor." The piers from the central estuary area probably also act as a barrier between fish from areas I and IV, which may explain the low similarities found. These may also be a reflection of the instability caused by organic pollution in site IV, a factor that might well be deterrent for less tolerant species.

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□ **Resumo** □

A Ictiofauna do estuário Saco da Fazenda foi estudada mensalmente entre julho de 2003 e junho de 2004 em quatro áreas definidas em função das características fisiográficas e da representatividade do estuário nesta região. Foram capturados 4502 exemplares, distribuídos em 42 espécies, 35 gêneros e 21 famílias. Engraulidae foram os peixes mais abundantes, onde *Cetengraulis edentulus* dominou nas capturas. As espécies de ocorrência ocasional, representadas, principalmente por indivíduos juvenis, predominaram nas amostragens. As maiores abundâncias ocorreram durante os meses de verão e outono, em contraste com as elevadas biomassas na primavera-outono; sendo que a área IV diferenciou-se das demais, por contribuir com as maiores capturas. Os índices de riqueza, diversidade e equitabilidade, apresentaram padrões semelhantes de flutuação, com valores elevados nos meses de primavera e verão. O índice de Jaccard revelou uma maior similaridade na composição da ictiofauna entre as áreas II e IV, enquanto que a menor ocorreu entre I e IV, provavelmente devido às diferentes áreas destes locais.