Ecological aspects of the surf-zone ichthyofauna of Itamambuca Beach, Ubatuba, SP

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Abstract: Sandy beaches are among the most extensive environments in Brazil and are generally threatened by disorderly urban growth due to their location along the coast, where human populations tend to concentrate. This is especially true in southeastern Brazil, where the largest urban areas are located. Thus, better knowledge regarding these natural resources is of considerable importance. The surf zone of sandy beaches is inhabited by a number of fish species, including juveniles seeking both food and shelter from predators. An ecological survey was conducted in the surf zone of Itamambuca beach in the city of Ubatuba, São Paulo State, Brazil, in order to evaluate the composition, structure and dynamics of the fish fauna using community descriptors. Diurnal and nocturnal samples were taken with a beach seine at five oceanographic stations over a 12-month period. Water temperature and salinity were also recorded. A total of 2,147 individuals representing 34 species and 18 families were sampled. The main variation in fish fauna was detected on the diel level, followed by a spatial repartition possibly related to salinity. Seasonal variation was also observed. The five most important species in the overall context were *Atherinella brasiliensis*, *Eucinostomus melanopterus*, *Mugil* sp., *Trachinotus goodei* and *Atherinella blackburni*.
Keywords: *marine fish, sandy beach, community, West Atlantic, seasonal, diel cycle*

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Resumo: Praias arenosas estão entre os ecossistemas mais extensos do Brasil e, por serem próximas aos locais onde o Homem tende a se concentrar, são suscetíveis aos impactos negativos decorrentes do crescimento populacional desordenado. Isso é especialmente crítico na Região Sudeste do Brasil, onde uma das maiores populações humanas está instalada. Neste contexto, pesquisas no sentido de melhorar o conhecimento sobre os recursos naturais da região têm importante valor. A zona de arrebentação das praias arenosas é habitada por várias espécies de peixes, freqüentemente representadas por jovens, que buscam alimento e abrigo de predadores. Foi realizado levantamento ictiológico da zona de arrebentação da praia de Itamambuca, Ubatuba, São Paulo, com o intuito de se avaliar a composição, estrutura e dinâmica da fauna de peixes através de descritores da comunidade. Amostras foram coletadas com rede de picaré durante 12 meses, nos períodos diurno e noturno, ao longo de cinco estações oceanográficas na praia. Temperatura da água e salinidade também foram registradas. Foram amostrados 2.147 indivíduos de 34 espécies e 18 famílias. A variação mais marcante da ictiofauna foi a circadiana, seguida por repartição espacial relacionada principalmente à salinidade. Variação sazonal da assembléia também foi observada. As cinco espécies mais importantes no contexto geral foram *Atherinella brasiliensis*, *Eucinostomus melanopterus*, *Mugil* sp., *Trachinotus goodei* e *Atherinella blackburni*.
Palavras-chave: *peixe marinho, praia arenosa, assembléia, Atlântico Ocidental, sazonal, ciclo diário.*

Introduction

The continental shelf accounts for over 30% of the fishery production worldwide and the southern and southeastern regions of Brazil account for more than 50% of the national marine production (Knoppers et al. 2002). Moreover, 45% of fish species are found along coastal zones (Vazzoler 1996). Tropical and temperate shorelines have long extensions of beach that, along with estuaries and adjoining areas, are the first environments to suffer the impacts of human occupation, as two-thirds of the world population inhabits coastal regions (McLachlan & Erasmus 1983, Hoefel 1998).

Sandy beaches are productive ecosystems that sustain a diversified community. These environments are open, highly dynamic and sensitive systems that adjust to fluctuations in wind, water and biological processes under direct influence of turbulence and wave forces (Carter 1988, Brown & McLachlan 1990, Hoefel 1998). Waves and turbidity provide protection to fish, but can also cause physiological stress, which is compensated by the large amount of available food (Paes 2002).

The surf-zone ichthyofauna of sandy beaches is not a discrete entity and is in constant change (McLachlan & Erasmus 1983, Lasiak & McLachlan 1987). Abiotic variables such as tides, wind direction and speed, salinity, lunar phases and temperature influence the abundance and composition of the community (Kingsford & Finn 1997, Soares-Gomes & Figueiredo 2002), among which temperature is considered the most important (Lowe-McConnell 1999). It is important to know what factors directly influence the structure and dynamics of a given fish assemblage (Lowe-McConnell 1999).

The surf zone serves as a refuge from predators and a nursery for many species of fish, as evidenced by the large amount of juveniles found in this zone (Gillanders et al. 2003). According to Beyst et al. (2002), this zone also acts as a foraging place for some species, such as planktivores, insectivores, piscivores and opportunists, the latter of which accounts for the majority of species (McLachlan & Erasmus 1983, Lasiak & McLachlan 1987, Layman 2000). Fish assemblages in the surf zone are generally composed of species that live only part of their life cycles in this area and only a few species are considered residents (McLachlan & Erasmus 1983, Ramos & Vieira 2001). These assemblages are generally dominated by relatively few species (Vanderklift & Jacoby 2003). There are records of temporal alterations in the descriptors of the community, evidencing differences in diel rhythms in some cases and seasonal differences in others (Lasiak 1984a, b, Saul & Cunningham 1995, Godefroid et al. 1997, Nash & Santos 1998, Lazzari et al. 1999, Nagelkerken & Van der Velde 2004).

The aim of the present study was to carry out an ecological survey of the surf-zone ichthyofauna of Itamambuca beach in the city of Ubatuba, São Paulo State, Brazil, analyzing the composition and structure of the fish assemblage as well as temporal and spatial variations. A description of environmental factors that influence the dynamics of this assemblage is also offered.

Materials and Methods

1. Study area

Itamambuca beach (23° 24' S, 45° 00' W) is located on the northern coast of the state of São Paulo, Brazil, a few kilometers north of the town of Ubatuba (Figure 1). The region is characterized by rocky shores on steep beaches with wave action, alternating with bays of predominantly flat sandy beaches and calmer waters. The internal continental shelf is under the influence of the South Atlantic Central Waters (SACW) at the end of spring and in summer, when a thermocline is evident. The water column is more homogeneous in winter due to the input of Coastal Waters (CW) and

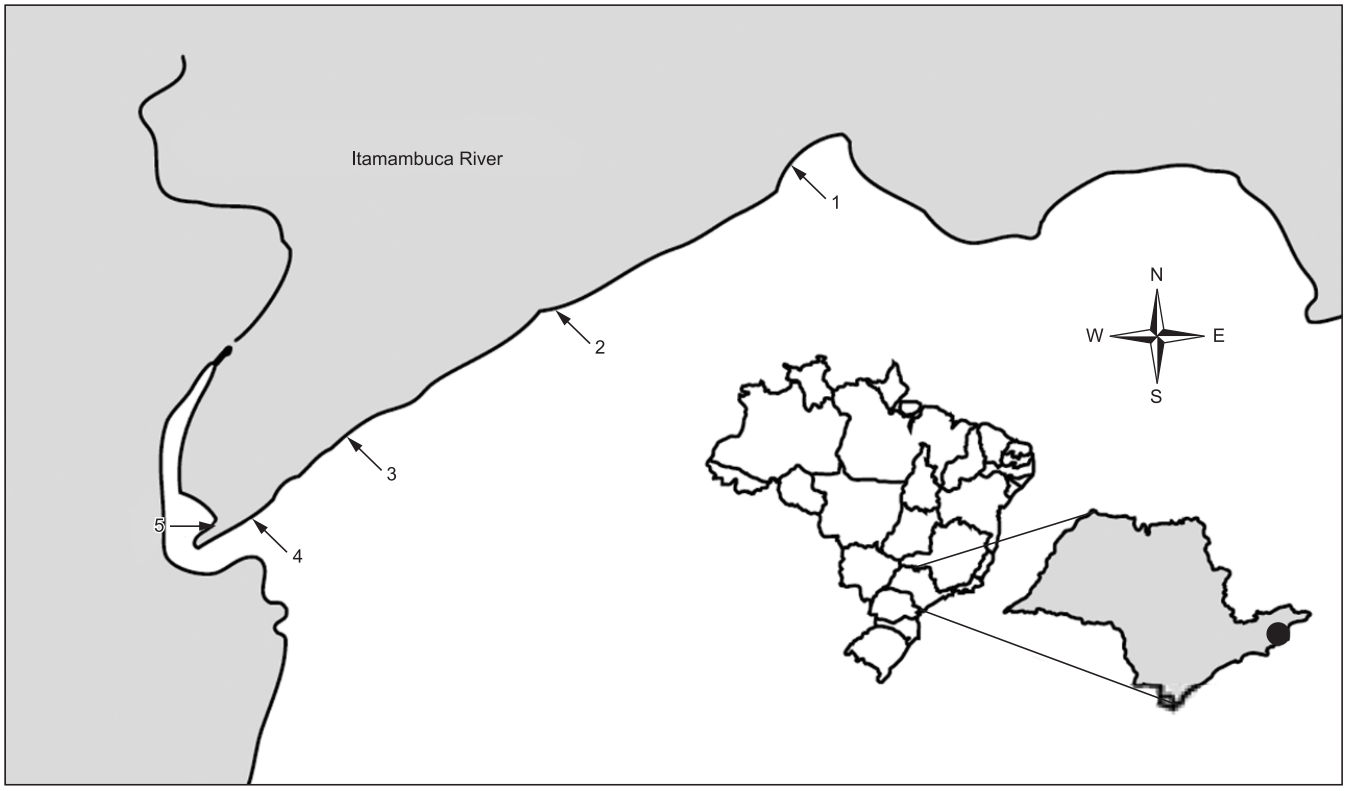

Figure 1. Map of oceanographic stations (numbered 1 to 5) at Itamambuca beach, Ubatuba, SP, Brazil (23° 24' S and 45° 00' W); beach length approximately 1800 m.

the retreat of the SACW to the margin of the continental shelf, which diminishes the thermocline (Castro Filho et al. 1987). Itamambuca is the most exposed among all beaches of Ubatuba. It is approximately 1800 m long, has a NE-SW direction turned toward SE, variable slope and medium coarse sands (Barros 1997). A small amount of freshwater input is found at both ends, with larger flows at the southern end due to the Itamambuca river draining from the Atlantic rainforest.

The shore along southeastern Brazil has a large human population that has occupied the different coastal environments in a disorderly fashion, especially due to real estate speculation. As a result, the region is compromised by sewage and solid waste discharge, waste from ships and waste transported by the fluvial systems, mining activities, disorderly tourism, a lack of water treatment, pollution, among others.

2. Sampling

Fish were sampled using a beach seine 9 m in length and 1.5 m in height, with a 3 m central mesh of 5 mm and the lateral 3 m meshes of 15 mm. One unit of sampling effort was represented by three consecutive 50 m trawls in the same area less than 1 m meter in depth. Trawls were performed parallel to the shoreline. Sampling was carried out monthly from October 2003 to September 2004, always during the period of the full moon. Diurnal sampling started one hour after sunrise and nocturnal sampling started one hour after sunset. The collections were authorized by permit number 42 (August 15th, 2003) granted by the Brazilian environmental protection agency IBAMA (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis).

The beach was divided into five areas representing oceanographic stations (stations 1 to 5, Figure 1). Stations 1 to 3 were located equidistant along the beach; station 4 was at the mouth of the Itamambuca river; and Station 5 was located in the internal area of the estuary, approximately 100 m from the river mouth. One unit of sampling effort was performed in the morning and one at night at each station. The sampling order in each period and each month was independently randomized in order to avoid data bias, using a random numbers table (Zar 1996).

Abiotic factors (salinity, water temperature, atmospheric temperature and wind direction) were recorded prior to each sampling at each station. At station 5, two determinations of salinity and temperature were made – one near the surface and one close to the bottom. Salinity was determined with aid of an optical refractometer and temperature was determined with thermometers. Wind direction was determined with the aid of a compass.

After each trawl, the fish were sacrificed, placed in plastic bags and refrigerated. At the laboratory, the specimens were identified to the lowest possible taxonomic level, based on Figueiredo & Menezes (1978, 1980, 2000) and Menezes & Figueiredo (1980, 1985). Following identification, the total length and total weight of each specimen were determined using an ichthyometer and a scale with a precision of 0.01 g, respectively. Most specimens were then fixed in 4% formalin, transferred to 70% alcohol and deposited as vouchers in the Fish Collection of *Museu de Zoologia da Universidade de São Paulo* (MZUSP).

The list of fish families follows the systematic order presented by Menezes et al. (2003) and Nelson (2006), with species names listed in alphabetical order. The Relative Importance Index (RII) was calculated for each station, each month, each diel period and the total sample (Pinkas et al. 1971). Indices of richness, dominance and diversity were calculated to better describe the community structure (Magurran 1996). Richness was determined using the Margalef Index. Dominance was determined using the Simpson Index and its inverse was used to represent the community diversity.

Results

1. Environmental variables

Water temperature ranged from 17.6 to 26.5 °C throughout the year, with extremes in the nocturnal periods. Diurnal periods had a slightly narrower range (17.9 to 26 °C). Station 5 exhibited the lowest water temperature values in both the diurnal and nocturnal periods (Table 1). A thermocline was detected in some samples at this station, with a maximal temperature range of 4,2 °C between the surface and bottom.

The highest salinity was 34 and was recorded at most stations in winter. A salinity value of 0 was recorded several times throughout the year, predominantly at Station 5 (Table 2). A halo-thermocline was also detected at Station 5 based on salinity values, with the most discrepant differences between surface and bottom salinities recorded in September during the diurnal sampling.

2. Biotic variables

2.1. General analysis

A total of 34 species belonging to 18 families were recorded at Itamambuca beach (Table 3). Two taxa were only identified to the genus level and one was only identified to the subfamily level. The fish totaled 2147 individuals, weighing a total of 5475.29 g, with a mean weight of 2.55 g per individual. The collector's curve (Figure 2) was stabilized by April, which was the seventh month of sampling.

The most specious families were the Carangidae and the Gerreidae (five species each), followed by the Sciaenidae (three), Achiridae, Atherinopsidae, Engraulidae, Mugilidae, Paralichthyidae and Tetraodontidae (two each), while each of the remaining nine families were represented by a single species (Table 3).

Among the species, *Eucinostomus melanopterus* (Bleeker, 1863) exhibited the greatest relative abundance (37.54%), followed by *Atherinella brasiliensis* (Quoy & Gaimard, 1824) (14.86%) (Figure 3a). With regard to weight, *A. brasiliensis* had the greatest overall biomass (36.88%), followed by *E. melanopterus* (11.51%) (Figure 3b). These two species occurred in all months sampled, as did *Trachinotus goodei* Jordan and Evermann, 1896, whereas *Atherinella blackburni* (Schultz, 1949), *Bathygobius soporator* (Valenciennes, 1837) and *Mugil* sp. occurred in 11 of the 12 sampling months (Table 3).

2.2. Temporal analysis

A total of 33 species occurred at night and 19 occurred during the day, 18 species were common to both periods, while 15 were exclusive of the nocturnal period (Table 3). None of the families were exclusive of the diurnal period, but five were represented only at night. With few exceptions, the nocturnal period was more diverse than the diurnal period (Table 4).

October 2003 and February 2004 were the months with the highest number of species, with 18 species recorded in each, while December 2003 and September 2004 were the months with the lowest number of species, with only eight species each. Approximately 20% of the total number of individuals occurred in October 2003 and the highest value of relative total weight (approximately 30%) was recorded in the same month. Considering both periods, mean weight ranged from 0.93 g per individual in June 2004 to 4.70 g per individual in October 2003 (Table 4).

The diurnal period yielded a slightly larger number of individuals (55.99%), but 70.70% of the total weight was caught at night, when individuals weighed a mean of 4.10 g vs. 1.33 g per individual in the diurnal period (Table 4).

Table 1. Water temperature (°C) recorded in each diel period among five oceanographic stations throughout the year at Itamambuca Beach, Ubatuba, SP, Brazil.

Month	Period	1	2	3	4	5 Surface	5 Bottom
Oct 2003	Day	21.0	21.5	22.5	22.0	20.8	23.0
	Night	20.0	21.0	19.0	17.8	17.6	18.2
Nov 2003	Day	24.0	24.5	19.5	19.0	19.0	19.9
	Night	23.5	19.0	23.5	22.0	22.0	21.9
Dec 2003	Day	24.5	24.5	24.5	24.0	22.5	23.8
	Night	25.5	25.0	25.5	25.0	25.0	25.8
Jan 2004	Day	24.0	24.0	24.0	22.5	22.5	21.5
	Night	25.0	25.0	24.0	24.0	23.0	23.5
Feb 2004	Day	26.0	25.5	24.5	23.5	22.0	22.8
	Night	25.0	25.0	24.0	22.5	22.0	22.0
Mar 2004	Day	25.5	25.0	23.5	22.0	21.5	21.0
	Night	25.0	25.0	24.5	22.5	22.0	22.0
Apr 2004	Day	26.0	26.0	24.0	25.0	22.0	26.2
	Night	26.0	26.5	26.0	26.0	24.0	24.0
May 2004	Day	24.0	24.5	24.0	22.0	20.5	21.8
	Night	24.0	24.0	24.0	23.0	21.5	22.5
Jun 2004	Day	21.0	22.0	22.0	21.5	18.0	19.5
	Night	21.5	22.0	21.5	21.0	18.0	18.0
Jul 2004	Day	22.0	22.0	21.0	20.5	20.0	23.5
	Night	23.0	22.5	23.0	22.0	21.5	23.0
Aug 2004	Day	21.0	21.0	18.0	18.2	17.9	20.2
	Night	22.0	22.0	21.5	20.5	20.0	21.5
Sep 2004	Day	22.0	23.0	22.0	21.0	19.5	22.2
	Night	23.0	23.0	22.0	22.0	21.5	21.5

Table 2. Salinity recorded in each diel period among five oceanographic stations throughout the year at Itamambuca Beach, Ubatuba, SP, Brazil.

Month	Period	1	2	3	4	5 Surface	5 Bottom
Oct 2003	Day	2.0	30.0	32.0	17.0	2.0	24.0
	Night	12.0	19.5	1.8	0.3	0.0	0.0
Nov 2003	Day	32.0	32.5	2.5	1.0	0.0	0.0
	Night	31.0	32.5	31.0	2.5	0.0	0.0
Dec 2003	Day	32.0	33.0	31.0	32.0	2.0	16.0
	Night	32.0	31.0	30.0	10.0	1.0	16.0
Jan 2004	Day	33.0	33.0	24.0	12.0	0.0	0.0
	Night	27.5	32.0	5.0	6.0	0.5	2.0
Feb 2004	Day	33.0	31.0	25.0	16.0	0.0	0.0
	Night	32.0	30.0	20.0	6.0	2.0	2.0
Mar 2004	Day	32.0	32.0	20.0	3.0	0.0	1.0
	Night	28.0	31.0	26.0	3.0	0.0	0.0
Apr 2004	Day	32.0	32.0	14.0	24.0	0.0	15.0
	Night	31.0	33.0	25.0	23.0	2.0	19.0
May 2004	Day	30.0	32.0	26.0	6.0	0.0	0.0
	Night	31.0	32.0	32.0	17.0	0.0	6.0
Jun 2004	Day	18.0	30.0	27.0	26.0	0.0	0.0
	Night	32.0	31.0	29.0	29.0	0.0	0.0
Jul 2004	Day	33.0	33.0	18.0	10.0	0.0	22.0
	Night	33.0	33.0	28.0	20.0	0.0	21.0
Aug 2004	Day	34.0	34.0	4.0	2.0	0.0	22.0
	Night	25.0	34.0	17.0	10.0	0.0	19.0
Sep 2004	Day	32.0	34.0	23.0	10.0	2.0	25.0
	Night	34.0	34.0	12.0	10.0	1.0	27.0

Table 3. List of species recorded in the surf zone of Itamambuca Beach, Ubatuba, SP, Brazil, throughout the year (second column) during day and at night (third column) and at the five oceanographic stations along the beach (fourth column).

Taxon	Month												Period		Station				
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Day.	Night	1	2	3	4	5
Engraulidae																			
Anchoa lyolepis	-	-	-	-	-	-	X	-	X	-	-	-	X	X	-	X	X	-	-
Anchoviella lepidentostole	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	X
Characidae																			
Astyanax bimaculatus	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	X	-	-
Ariidae																			
Genidens genidens	X	-	-	-	-	-	-	-	X	-	-	-	-	X	-	-	-	X	X
Mugilidae																			
Mugil curema	-	-	-	-	-	-	X	-	-	-	-	-	-	X	-	-	-	-	X
Mugil sp.	X	X	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X
Atherinopsidae																			
Atherinella blackburni	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-
Atherinella brasiliensis	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Belonidae																			
Strongylura marina	-	-	X	-	X	-	-	-	-	X	-	-	X	X	X	-	-	X	X
Hemiramphidae																			
Hyporhamphus unifasciatus	-	X	-	-	-	-	-	-	-	X	-	-	-	X	-	-	-	X	-
Syngnathidae																			
Bryx dunckeri	-	X	-	-	-	X	-	-	X	-	-	-	X	X	-	-	-	-	X
Centropomidae																			
Centropomus parallelus	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	X
Serranidae																			
Epinephilinae sp.	-	X	-	-	X	-	-	-	-	-	-	-	X	X	-	-	X	-	X
Carangidae																			
Caranx latus	X	-	-	-	X	X	X	-	-	-	-	-	X	X	-	X	X	-	X
Oligoplites saurus	-	-	-	-	-	X	-	-	-	-	-	-	X	-	X	-	-	-	-
Trachinotus carolinus	-	X	X	X	X	X	X	X	X	-	X	X	X	X	X	X	X	X	-
Trachinotus falcatus	-	-	-	-	X	X	-	-	-	-	-	-	X	X	X	-	-	X	-
Trachinotus goodei	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Gerreidae																			
Diapterus rhombeus	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X
Eucinostomus argenteus	X	-	-	-	X	-	-	-	-	-	-	-	X	X	-	-	-	-	X
Eucinostomus gula	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X
Eucinostomus melanopterus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	X	-	X
Eugerres brasilianus	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X
Polynemidae																			
Polydactylus virginicus	-	-	-	X	X	X	X	X	-	-	-	-	-	X	X	X	X	-	-
Sciaenidae																			
Menticirrhus americanus	-	X	-	-	-	X	-	-	-	X	-	-	X	X	X	X	X	-	-
Menticirrhus littoralis	-	-	-	X	X	X	X	X	X	-	X	-	-	X	X	X	X	-	-
Micropogonias furnieri	X	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	-
Gobiidae																			
Bathygobius soporator	X	X	X	X	X	X	X	X	-	X	X	X	X	X	-	-	-	X	X
Paralichthyidae																			
Citharichthys arenaceus	X	X	X	-	X	X	X	X	-	X	X	X	X	X	-	-	-	X	X
Citharichthys macrops	-	-	-	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X
Achiridae																			
Achirus lineatus	X	-	-	-	X	X	-	-	-	-	-	-	X	X	-	-	-	-	X
Trinectes paulistanus	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X
Tetraodontidae																			
Sphoeroides testudineus	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	X
Sphoeroides sp.	-	X	-	-	-	-	X	-	-	-	-	-	X	X	X	-	-	-	X

The analysis of diurnal samples revealed that the highest diversity was registered in March 2004 (12 species), while the highest abundancy was registered in June 2004 (11.77% of individuals). October 2003 presented the highest total weight (7.88%) as well as the largest mean weight per individual (8.09 g.ind^{-1}) (Table 4). The analysis of nocturnal samples revealed that the highest diversity was registered in February 2004 (17 species). October 2003 had the highest relative number of individuals (21.01%) as well as the largest relative total weight (22.74%). May 2004 exhibited the largest mean weight per individual in the nocturnal samples (5.97 g.ind^{-1}) (Table 4).

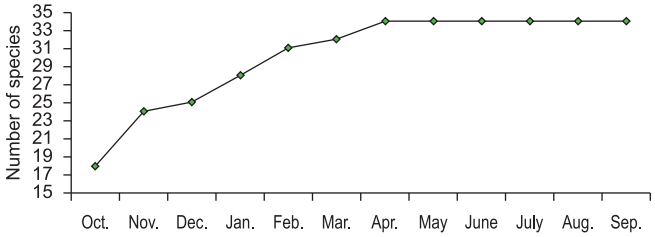

Figure 2. Collector curve of accumulated number of species of fish sampled at Itamambuca beach, Ubatuba, SP, Brazil, throughout year.

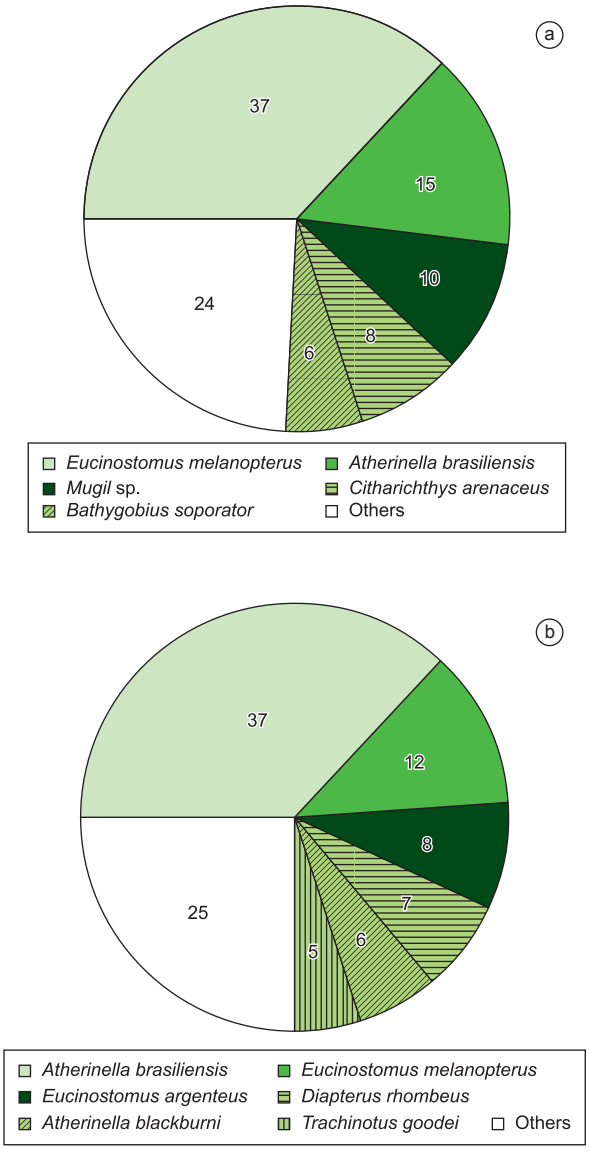

Figure 3. a) Relative abundance; and b) relative weight of the most important species sampled at Itamambuca beach, Ubatuba, SP, Brazil.

2.3. Spatial analysis

The spatial distribution of the species revealed that station 5 was the richest, with 23 species (Table 5), eleven of which were exclusive to this station (Table 3). *Atherinella brasiliensis* and *Mugil* sp. occurred at all stations, while *Trachinotus carolinus* (Linneaus, 1766) and *T. goodei* occurred in all but station 5. Considering both day and night, the largest relative number of individuals and relative weight were recorded at station 5, but the large relative weight recorded for this station was due to the night sampling. Mean weight was greatest at station 4 in both the diurnal and nocturnal samples, whereas the lowest mean weight was recorded at station 5, especially in the daytime samples (Table 5).

3. Community descriptors

The results of the Relative Importance Index (RII) reveal that *Atherinella brasiliensis* had the highest value among all samples (Figure 4a). This species was also the most important in eight out of the 12 months sampled. *Eucinostomus melanopterus*, *A. blackburni*, *Citharichthys arenaceus* Evermann & Marsh, 1900 and *Mugil* sp. were the most important species in October 2003, January, February and August 2004, respectively.

Considering the diurnal and nocturnal samples separately, *Atherinella brasiliensis* was also the most important species in both periods (Figures 4b-c). Seasonally, *Mugil* sp. was the most important species in the nocturnal period in August and September 2004, while *A. brasiliensis* had the highest RII values in the remaining months. In the diurnal period, *A. brasiliensis* was the most important in seven months, while *Eucinostomus melanopterus* was the most important species in December 2003, *A. blackburni* was the most important in January and April 2004, *Trachinotus goodei* was the most important in February 2004 and *Mugil* sp. was the most important in August 2004.

In terms of spatial distribution, *Atherinella blackburni* and *A. brasiliensis* were the most important species at stations 2 and 4, respectively, considering both periods of the day (Figures 4e-g). The most important species at stations 1, 3 and 5 were *Trachinotus goodei*, *A. brasiliensis* and *Eucinostomus melanopterus*, respectively, in both the diurnal period and total sample. *Menticirrhus littoralis* (Holbrook, 1847), *T. goodei* and *A. brasiliensis* were the most important species at stations 1, 3 and 5, respectively, in the nocturnal period (Figure 4d-f-h).

Simpson Dominance was 0.19 for the community as a whole and, consequently, Simpson Diversity (DS) was 0.81. Shannon Diversity (H') was 0.94 and Margalef Richness (R) was 9.90. DS, H' and R values were higher in the nocturnal period, with the respective values of 0.88, 1.08 and 10.75 vs. DS = 0.71, H' = 0.73 and R = 6.48 in the diurnal period. Seasonally, the highest Simpson Dominance (0.65) and lowest Shannon Diversity (0.38) values occurred in August 2004. The lowest Dominance and highest Shannon Diversity values were recorded in March 2004 (0.18 and 0.93, respectively). Richness values ranged from 3.50 to 7.94 in August and February 2004, respectively (Figure 5). In the spatial context, the highest Simpson and Shannon Diversity values were recorded at Station 1, but this area had the lowest richness value. Station 4 had the lowest Simpson and Shannon Diversity values (0.56 and 0.60, respectively). The highest Margalef Richness value occurred at station 5 (Figure 6).

Discussion

Itamambuca is a typical sandy beach under peculiar influences from wave action, wind, air temperature, water temperature and other physical factors. Low water temperatures were usually related

to freshwater inputs found regularly at the surface at station 5, demonstrating the influence of the Itamambuca river in the system. Furthermore, different temperature and salinity values were recorded between the surface and bottom at station 5 in different months, which indicates different masses of water at the mouth of the Itamambuca river. Stations 1 and 2 generally exhibited the highest temperature and salinity values, most likely due to their distance from the Itamambuca river and the overall current pattern. However, a small intermittent stream occasionally reached station 1. A broad variation in values was recorded at station 4, especially with regard to salinity, due to the fact that this station is under the influence of the freshwater input from the Itamambuca river during the low tides and from the ocean during the high tides. The same occurred at station 3, but with lesser intensity, as this station was located farther from the mouth of the river. It is worth mentioning, however, that one specimen of *Astyanax bimaculatus* (Linnaeus, 1758) was collected in the night sample from October 2003; this is a primary freshwater fish belonging to the Characiformes, an exclusive continental water order.

Comparisons regarding composition, structure, diversity and spatial-temporal patterns between different communities are very complex due to the heterogeneity of habitats and abiotic factors, as well as different sampling methods and approaches employed by different researchers (Stoner 1986). According to Lasiak (1984a) and Lasiak & McLachlan (1987), the composition of species is variable, with changes in the number and identity of dominant species; moreover, the surf zone is in constant flux. Nevertheless, some common patterns are found when comparing different communities assessed by different researchers.

The surf-zone ichthyofauna is generally characterized by low richness and a high degree of dominance in comparison to deeper regions (Saul & Cunningham 1995, Andreata et al. 2002). As evidenced herein at Itamambuca beach, fish assemblages studied on other Brazilian beaches in the states of Rio Grande do Sul (Monteiro-Neto & Musick 1994, Monteiro-Neto et al. 2003), Paraná (Spach et al. 2004), São Paulo (Paiva-Filho & Toscano 1987, Giannini 1994, Saul & Cunningham 1995) and Rio de Janeiro (Gomes et al. 2003) as well as in other countries, such as South Africa (Strydom & D'hotman 2005), the United States (Layman 2000, Ross & Lancaster 2002) and Japan (Inoue et al. 2005), are characterized by a low number of species. The majority of species in these environments also occur at low

Table 4. Number of species, relative abundance of individuals, relative total weight and average total weight of individuals throughout the year at Itamambuca Beach, Ubatuba, SP, Brazil, including diurnal, nocturnal and both periods combined.

		Months												
	Periods	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	
Number of Species														Total
	Day	6	7	5	6	10	12	7	7	8	6	7	6	19
	Night	15	12	7	8	17	11	11	8	7	9	4	6	33
	Both periods	18	13	8	10	18	16	13	10	10	10	9	8	34
Relative abundance	Day	1.3	4.0	2.6	2.7	2.1	5.5	2.2	2.6	11.8	7.0	7.3	1.0	
	Night	21.0	4.4	1.8	1.2	4.7	2.2	4.6	0.5	1.6	5.1	1.0	2.0	
Relative weight	Day	7.8	6.1	0.3	2.4	3.2	5.9	4.7	5.2	5.5	4.2	3.9	0.9	
	Night	22.7	4.9	2.6	0.7	4.1	2.6	4.8	0.8	1.5	3.6	0.5	1.3	
Average weight of individuals														Average
	Day	8.1	2.0	0.1	1.2	2.1	1.4	2.8	2.7	0.6	0.8	0.7	1.2	1.3
	Night	4.4	4.5	5.8	2.5	3.6	4.8	4.3	6.0	3.8	2.9	1.9	2.6	4.1
	Both periods	4.7	3.2	2.2	1.5	3.1	2.2	3.8	3.2	0.9	1.6	0.8	2.1	2.6

Table 5. Number of species, logarithmic relative frequency of individuals, relative total weight, average total weight of individuals among five oceanographic stations at Itamambuca Beach, Ubatuba, SP, Brazil, including diurnal, nocturnal and both periods combined.

		Oceanographic stations				
	Periods	**1**	**2**	**3**	**4**	**5**
Number of Species	Day	6	7	6	7	11
	Night	10	8	12	8	22
	Both periods	11	11	13	11	23
Relative abundance	Day	4.7	6.5	7.7	5.8	75.2
	Night	7.3	5.1	4.1	4.1	79.4
	Both periods	5.9	5.9	6.1	5.1	77.0
Relative weight	Day	11.7	14.2	31.1	29.7	13.3
	Night	5.9	6.4	1.3	12.2	74.2
	Both periods	7.6	8.7	10.0	17.4	56.3
Average weight of individuals	Day	3.3	2.9	5.4	6.8	0.2
	Night	3.3	5.1	1.3	12.1	3.8
	Both periods	3.3	3.8	4.2	8.7	1.9

frequencies. There is a high numerical dominance of one or few species and individuals are often small in size, represented mostly by juveniles.

The samples from October 2003 exhibited seven exclusive species, some of which with high frequencies, such as *Diapterus rhombeus* (Cuvier, 1829) and *Eucinostomus argenteus* Baird & Girard, 1855. This may be due to the heavy rains that occurred during that particular field trip, which may be responsible for a rather atypical condition with regard to the ichthyofauna in this period. This is further exemplified by the aforementioned occurrence of *Astyanax bimaculatus* in the surf zone in this sample.

Species of the family Atherinopsidae are known to be residents of surf zones worldwide, completing their life cycles in these environments (Monteiro-Neto et al. 2003). *Bathygobius soporator* also seems to be a resident, remaining close to estuarine regions, as this species occurred exclusively at stations 4 and 5, with a wide range of sizes, representing different stages in the life cycle of the species. Some species that were frequent throughout the year, such as *Trachinotus carolinus*, *T. goodei*, *Eucinostomus melanopterus*, *Citharichthys arenaceus* and *Mugil* sp., are cited in the literature as species whose juveniles inhabit the surf zone (Monteiro-Neto et al. 2003). Some species with relatively frequent occurrence were concentrated in the warmer months of summer and autumn, such as *Menticirrhus littoralis* and *Polydactylus virginicus* (Linnaeus, 1758), evidencing that some fish use the surf zone only during part of their life cycle (Monteiro-Neto et al. 2003).

Three groups of species were defined based on salinity and the oceanographic station at which they occurred. The first group was composed of *Atherinella brasiliensis* and *Mugil* sp., which occurred at all stations regardless of salinity and were therefore considered eurytopic with regard to salinity. The second group was made up of *Citharichthys arenaceus*, *Bathygobius soporator* and

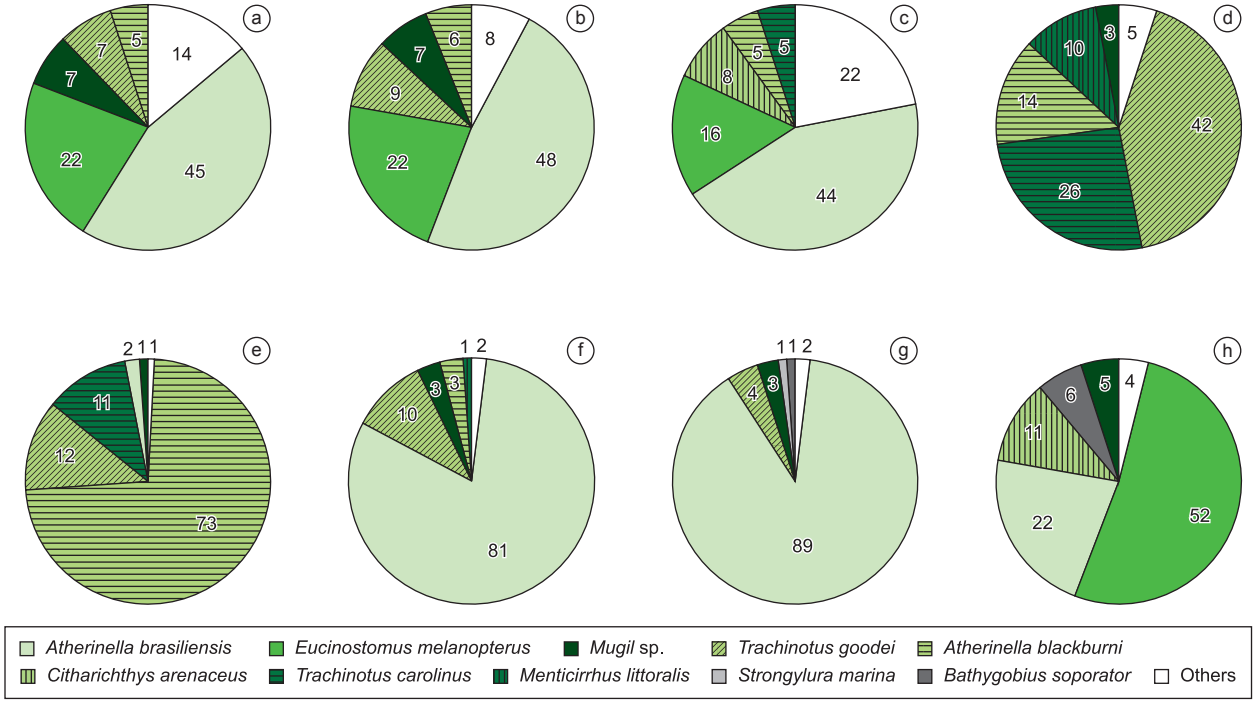

Figure 4. Relative Importance Index frequencies calculated for species at Itamambuca beach, Ubatuba, SP, Brazil, in relation to: a) whole sample; b) diurnal samples; c) nocturnal samples; d) oceanographic station 1; e) oceanographic station 2; f) oceanographic station 3; g) oceanographic station 4; and h) oceanographic station 5.

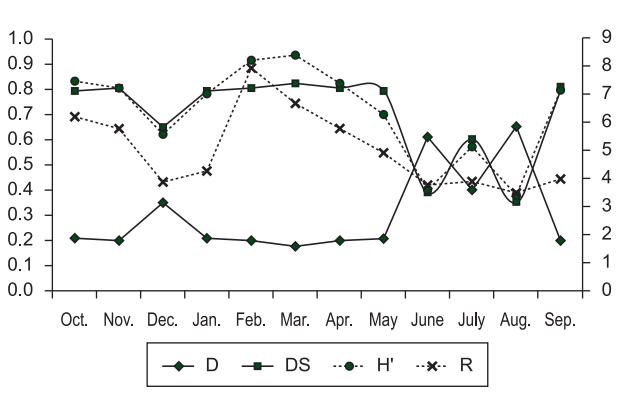

Figure 5. Seasonal distribution of Simpson Dominance (D), Simpson Diversity (DS), Shannon Diversity (H') and Margalef Richness (R) values calculated for fish community at Itamambuca beach, Ubatuba, SP, Brazil; richness values referred on secondary axis.

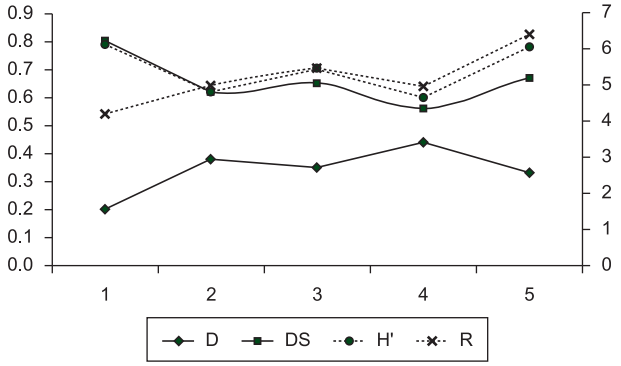

Figure 6. Spatial distribution of Simpson Dominance (D), Simpson Diversity (DS), Shannon Diversity (H') and Margalef Richness (R) values calculated for fish community at Itamambuca Beach, Ubatuba, SP, Brazil at five oceanographic stations along the beach; richness values referred on secondary axis.

Eucinostomus melanopterus, which were found nearly exclusively at station 5, which was located within the river and, more rarely, at stations 4 and 3 when salinity values were lower (during low tide). Station 5 also had the highest diversity and richness values, which could be due to the natural protection of the station against wave power and the greater availability of resources due to the proximity to the forest. Paiva-Filho & Toscano (1987) and Clark (1997) described a similar pattern. The third group united species that do not seem to tolerate low salinities and occurred mainly at stations 1, 2 and 3, with rarer occurrences at station 4 when salinity values were higher. This last group was composed of species of the genera *Trachinotus* and *Menticirrhus* as well as *Polydactylus virginicus* and *Atherinella balckburni*. The latter species is mentioned in the literature as a fish with a preference for waters with high salinity and temperature values (Lopes & Oliveira-Silva 2001, Mattox et al. 2008).

At Itamambuca beach, richness was greater in the nocturnal samples. This could be due to a predation pressure by piscivorous fish, which forces the prey towards shallow waters (Layman 2000). Furthermore, diel-activity patterns are plastic and reflect different factors, such as foraging habits and competition between species (Reebs 2002). Gaelzer & Zalmon (2008) added local characteristics, such as presence of macroalgae beds, wave stress and upwelling to the list of causes of diel variation. Diel variations have been described by a number of authors studying the surf-zone ichthyofauna, at times recording greater diversity, biomass or activity patterns in the nocturnal period, with fewer examples demonstrating greater values in diurnal samples (Lasiak 1984a, b, Nash & Santos 1998, Layman 2000, Pessanha & Araujo 2003, Gaelzer & Zalmon 2008).

The composition and structure of the ichthyofauna at Itamambuca beach varied on the diel, seasonal and spatial scales. For which, the most uneven distribution of composition was on the diel scale, followed by the spatial and seasonal scales. These results demonstrate that the fish assemblage is characterized by complex distribution patterns and that the maintenance of these patterns is essential to the conservation of the assemblage as a whole. Both Itamambuca beach and the Itamambuca river estuary are located in a region where human occupation has increased dramatically in recent decades. This scenario urges greater knowledge regarding the biodiversity of this region in order to propose conservation initiatives.

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