Ichthyofauna as an environmental quality indicator of the Bertioga Channel, São Paulo (Brazil)

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Abstract

The aim of this study was to investigate the ichthyofauna structure in the region of the north outfall of the Bertioga Channel (São Paulo, Brazil) and the possible effects of the environmental quality loss. The samples were collected in a monthly basis, from September to December 2005, at two oceanographic stations with an otter-trawl. The fish fauna structure was evaluated by ecological indicators and the environmental quality evaluated by the ABC analysis and the Estuarine Fish Communities Index (EFCI). A total of 1553 individuals from 50 species were sampled. Ariidae and Sciaenidae amounted to 60 % and *Cathorops spixii* represented 36 % of all specimens collected. The highest richness and ecological diversity were recorded in December, while the highest numerical abundance was found in October. The majority of the species were represented by juveniles. The cluster analysis and canonical correspondence analysis showed a consistent and clear difference between the sampling stations, and the abiotic factors analyzed (temperature, depth and salinity) do not seem to have influence on the community structure. The ABC analysis suggested a moderate disturbed environment and the EFCI allowed classifying the area as "poor", due to the 12 metrics analyzed, concerning the reduction of the species diversity, composition and abundance, and modifications in the nursery function and trophic integrity of the area. Future studies should focus on jointly analyze chemical indicators of water and sediment with the biological indicators, to confirm the ichthyofaunal condition of the north outfall of the Bertioga Channel.

Descriptors: Fish fauna, Environmental integrity, Bertioga Channel, Southeastern Brazilian coast.

Resumo

O objetivo deste estudo foi investigar a estrutura da ictiofauna na região da desembocadura norte do Canal de Bertioga (São Paulo, Brasil) e os possíveis efeitos da perda da qualidade ambiental. As amostras foram coletadas mensalmente de setembro a dezembro de 2005, em duas estações oceanográficas, com rede de arrasto. A estrutura da fauna de peixes foi avaliada por indicadores ecológicos e a qualidade ambiental por curvas ABC e um índice de comunidades de peixes estuarinos (EFCI). Um total de 1553 indivíduos em 50 espécies foi amostrado. Ariidae e Sciaenidae totalizaram 60% e *Cathorops spixii* representou 36% de todos os espécimes coletados. Maior riqueza e diversidade ecológica foram registradas em dezembro, enquanto a maior abundância numérica foi encontrada em outubro. A maioria das espécies foi representada por juvenis. As análises de agrupamento e de correspondência canônica mostraram uma diferença consistente e clara entre as estações de amostragem, e os fatores abióticos analisados (temperatura, profundidade e salinidade) parecem não ter influência sobre a estrutura da comunidade. A curva ABC sugeriu um ambiente moderadamente perturbado e o EFCI permitiu classificar a área como "pobre", a partir das 12 métricas analisadas, que consideraram a redução da diversidade específica, a composição e a abundância, bem como a modificação na função de berçário/infantário e a integridade trófica da área. Futuros estudos devem se concentrar em analisar conjuntamente os indicadores químicos da água, do sedimento e os indicadores biológicos, para confirmar a condição da ictiofauna da desembocadura norte do Canal de Bertioga.

Descritores: Fauna de peixes, Integridade ambiental, Canal de Bertioga, Costa sudeste do Brasil.

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INTRODUCTION

Marine and estuarine ecosystems have important characteristics and functions in coastal water environments. Among the most notable features are the high primary and secondary productivity of estuaries, associated with high richness, abundance, biomass and diversity of fish and invertebrates (BECK et al., 2001; BARLETTA et al., 2008; BARLETTA; COSTA, 2009). In estuaries also occur fundamental biological processes, such as spawning, recruitment, migration and connectivity between the terrestrial and aquatic environments. Estuaries are important sites used as growth areas for juveniles of many fish species that leave the area when they reach maturity (VASCONCELOS et al., 2008).

Several indices have been used to assess the ecological quality of coastal ecosystems using fish as indicators, based on ecological guilds. MARTINHO et al. (2008) describe and compare 6 indices and verified that all of them gave consistent results, but diagnosed as the most adequate the EDI (Estuarine Demersal Indicators) (BORJA et al., 2004) and the TFCI (Transitional Fish Classification Index) (COATES et al., 2007). However, some metrics used in these two indices are not available for Brazilian coastal areas and in particular to the Bertioga Channel, as pollution indicator species, introduced species, fish health and indicator species.

In the Brazilian coast, ecological quality assessment using indices were applied to estuarine environments such as the Paranaguá Estuarine Complex – Paraná (FALCÃO et al., 2008; OTERO et al., 2006), and the Todos os Santos Bay – Bahia (DIAS et al., 2011).

The ichthyofauna of Brazilian estuaries have been studied under various aspects, such as its composition and abundance (FELIX et al., 2006, DIAS et al., 2011), diversity (CASTRO, 2001; CARVALHO NETO; CASTRO, 2008; BARLETTA et al., 2003), assemblages (CONTENTE et al., 2010; ARAÚJO et al., 2013; HOSTIM-SILVA et al., 2013; PASSOS et al., 2013), resource exploitation (BARLETTA; COSTA, 2009), structure and seasonal dynamics of ichthyoplankton (BARLETTA-BERGAN et al., 2002; PORCARO et al., 2014), influence of environmental variables on fish distribution (BARLETTA et al., 2005; BARLETTA et al., 2008), recruitment (BOLZAN et al., 2014), biological and socioeconomic aspects of fisheries exploitation (CHAVES et al., 2003), and also as indicator of environmental quality (VIANA; LUCENA FRÉDOU, 2014). The main hydrographic characteristics of estuaries that influence the fish distribution are salinity, temperature, turbidity and dissolved oxygen (BLABER; BLABER, 1980; BARLETTA et al., 2008).

An ichthyofauna inventory of the Bertioga Channel was recently published, presenting 78 species, 67 genera and 39 families, caught by 10 different fishing techniques (BARBANTI et al., 2013). To the same area, ROCHA and DIAS (2015), using only otter-trawling samples, added fifteen species to the inventory of BARBANTI et al., (2013). On the other hand, PORCARO et al. (2014) described the distribution of the sciaenid larvae in the estuarine system and adjacent continental shelf off Santos, highlighting the region as a Sciaenidae spawning area.

In spite of its ecological importance, urban development in the region associated to fisheries, mariculture and tourism have brought the contribution of waste influx, generating deposits and contaminating surface sediments along the Bertioga Channel, with environmental degradation of the region in the last decades (EICHELER et al., 2007; GONÇALVES et al., 2013).

Among the studies regarding contamination in the Bertioga Channel are LAMPARELLI et al. (2001) that found levels of mercury between TEL and PEL in the sediment of the Bertioga Channel, next to the Santos Channel; ABESSA et al. (2008) that ranked the Bertioga Channel as the third most contaminated area in Santos Estuarine System based on integrative approach of both environmental factors and contaminants; SILVA et al. (2011) that found high values of zinc and arsenic in the region of the Santos Estuarine System; BORDON et al. (2011) that foud mercury concentrations above TEL limit levels in sediment of the north outfall of the Bertioga Channel and other metal contamination confirmed for the bentic ecosystem of the Santos Estuarine System; GONÇALVES et al. (2013) that found no significant levels of contaminants in the channel but arsenic; and SOUSA et al. (2014), who performed the most recent survey in the channel, found cadmium in concentration levels above TEL as well as LABs (linear alkylbenzene sulfonates), which indicates the presence of household sewage and aromatic cyclic hydrocarbons.

The aim of this study was to investigate the viability of the ichthyofauna structure as an indicator of the environmental quality of the Bertioga Channel, Brazil.

MATERIAL AND METHODS

Study area

The Santos region, central coast of São Paulo State (Brazil), has the port of Santos and the Cubatão industrial park. The introduction of effluents in the estuarine system and the dredging of the port channel, due to the intensification of human activities, can be associated with the environmental quality loss (LAMPARELLI et al., 2001).

The Bertioga Channel is located at the eastern end of the Santos region and is considered a secondary connection to the ocean of the estuarine system of Santos - São Vicente. The Channel is 25 km long with an average depth between 3-6 m with a width ranging from 200 to 700 m.

The North Channel opening presents greater depths and receives the influence of the continental shelf waters (MIRANDA et al., 1998; EICHLER et al., 2004). The salinity varies from 24-33 to 20-33 during the winter and summer (EICHLER et al., 2004). It presents micro-tidal regime and mixed tides are predominantly semi-diurnal, with amplitude ranging from 0.7 m to 1.5 m. The sediments from the river inflow are deposited by the action of tidal currents, which also remobilizes sediment into the channel (FÚLFARO; PONÇANO, 1976), but sandy sediment dominates the areas of the Channel adjacent to the Atlantic Ocean (EICHLER et al., 2007). The Bertioga Channel is classified as a partially mixed estuary type, due to its geomorphological characteristics and the variability of its physical properties (MIRANDA et al., 1998).

Sampling and data processing

The samples were collected monthly from September to December 2005 in the north outfall of the Bertioga Channel at two oceanographic stations, displaced 3.5 to 4 km from each other (Figure 1). An otter-trawl, with 40 mm of mesh size in the arms, 30 mm in the bagger, and 11 m length, was used for fish sampling. The effort unit used was a 10 minutes trawl at two knots. Trawling depths varied between 3 and 6 m depending on the local depth. Temperature and salinity data from the water column were obtained with a CTD (Conductivity, Temperature and Depth probe).

In the laboratory, the collected specimens were identified with taxonomic identification keys (FIGUEIREDO; MENEZES, 1978, 1980, 2000; MENEZES; FIGUEIREDO, 1980, 1985; CARPENTER, 2002a, b; MARCENIUK, 2005; GOMES et al., 2010) and the CATALOG OF FISHES (CAS, 2015), FROESE and PAULY (2015), WORLD REGISTER OF MARINE SPECIES (WorMS, 2015), MARCENIUK and MENEZES (2007) and MENEZES et al. (2015) to update the nomenclature. After identification, individual data were obtained: total length (TL) (in mm) with ichthyometer, total weight (TW) and gonad weight (GW) (g) with a semi-analytical scale. Sex identification was based on the gonad description, according with VAZZOLER (1996). The identification of female maturity stages followed the scale described by DIAS et al. (1998), with the group of stages B (in maturation), C (mature), D (hydrated/spawning) and E (spawned) characterized as adults. Males were classified as juvenile or adults, based in VAZZOLER (1996). Sex ratio was evaluated by χ^2 test with 1 degree of freedom and 0.05 significance (χ^2<3.84), to check for possible differences between the number of males and females sampled. When possible, the length of first maturation (L_{50}) was estimated according to KING (1995) for females, to separate juveniles from adults.

Data analysis

The Whitfield index (WHITFIELD, 1994) was used to quantify synthetically the assemblies (WI=number of fish species/number of fish families). The structure of fish fauna was described using the following indicators: Simpson dominance index (λ); diversity of Shannon and Weaver (H'); Margalef richness (R) and Pielou evenness (J) (BEGON et al., 2006). These indicators were applied monthly and spatially. The frequency of occurrence was calculated, based on the following classification: constant species (C ≥ 50), accessory species (25> C <50) and incidental species (C ≤ 25) (DAJOZ, 1973).

To access the distribution patterns, the cluster analysis using Bray-Curtis similarity was applied to the overall fish composition by months and stations. The canonical correspondence analysis (CCA) was used to identify the most important environmental variable which influences the structure of the fish community. The CCA was used for abundance data for the most important species (about 96% of total registered). The environmental variables analyzed were depth, temperature and salinity. The data were log(x+1) transformed. The canonical correspondence analysis was also applied to investigate the distribution patterns of fish community compared to the month and station. The Spearman correlation coefficient was used

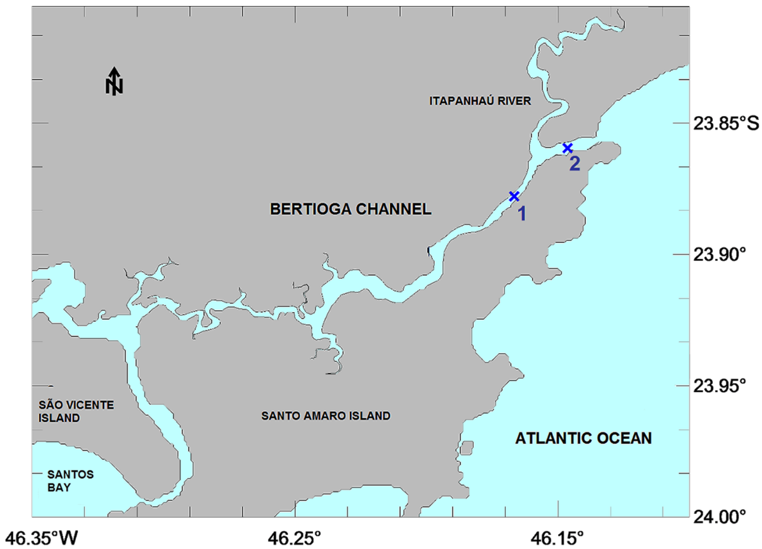

Figure 1. Study area showing the oceanographic stations in the North end of the Bertioga Channel.

to determine if there were differences between fish abundance and environmental variables (ZAR, 1999).

The comparison between the collection sites concerning species was carried out by a non-metric ordering technique (nMDS) with data transformed by $\log_{10}(x+1)$ withdrawing the rare species, and the Bray-Curtis similarity coefficient. The significance of differences was tested by Similarity Analysis (ANOSIM). The species with the greatest dissimilarity between sampling stations were tested for similarity percentages (SIMPER) (CLARKE; WARWICK, 2001).

The ABC analysis, or curves of cumulative percentage abundance and biomass by species ordered, was calculated for the total area to verify the environmental integrity. This ratio relates the overlap of the abundance and biomass curves and allows an interpretation of the environmental condition based on the fauna (WARWICK et al., 1987; OTERO, 2006; GONÇALVES; BRAGA, 2008). This is a method for assessing the status of polluted areas based in local populations, without the need for reference of the temporal or spatial series of controlled samples (WARWICK, 1986). The value of W statistical, that measures the difference between the abundance and biomass lines on an ABC plots, was also provided.

To assess the ecological quality status of the Bertioga Channel, a modified Estuarine Fish Community Index (EFCI) was applied. The EFCI was developed by HARRISON and WHITFIELD (2004) and is described in MARTINHO et al. (2008). This index is conceptually simple and is based on the idea that attributes of fishes, over time, are good indicators of ecosystem health such as the reduction of the species diversity, composition and abundance, and modifications in the nursery function and trophic integrity of the ecosystem. Species from all Families were included. The list of endangered species of the Brazilian fauna (MMA-445, published in December 17, 2014), was referred to check the threatened species. The feeding mode and estuarine use were based on descriptions of ELLIOT et al. (2007), and the data about diet to classify the species in trophic function groups were accessed in Fishbase (FROESE; PAULY, 2015). The species were not classified in subcategories as proposed by (ELLLIOT et al. 2007), in order to generalize the aspects of the trophic guilds or use of the area by the species. Due to the absence of reference data, metric related to a reference communities were not applied.

The EFCI is calculated as the sum of the scores (MARTINHO et al., 2008) and in this study the maximum value was reduced from the original 70 to 60, due to the lack of two metrics. So, the five thresholds were recalculated in order to better compare values: Very Poor (EFCI $<$ 17), Poor (19 $\geq$ EFCI $\leq$ 33), Moderate (35 $\geq$ EFCI $\leq$ 39), Good (41 $\geq$ EFCI $\leq$ 54) and Very Good (54 $\geq$ EFCI $\leq$ 60).

RESULTS

In the Bertioga Channel, the mean salinity per station ranged from 26.2 to 33.7, whereas mean temperature from 21.5 to 25.8°C (Figure 2). Two patterns in the distribution

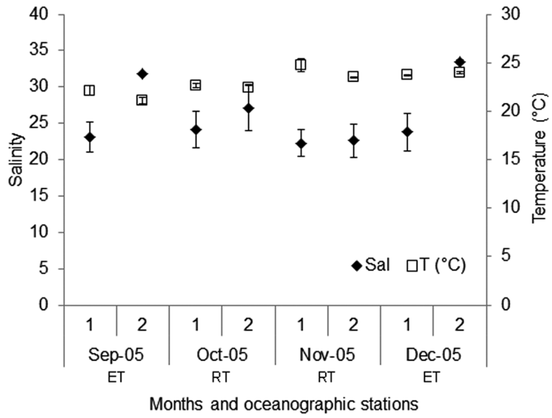

Figure 2. Mean and standard deviation values of temperature (T °C) and salinity from September to December 2005 in each oceanographic station (1 and 2) and by month, in the Bertioga Channel. ET=ebb tide; RT=rising tide.

of salinity could be found, with lower values at inner station (#1) and the higher values associated with outer station (#2). Over the months, the salinity showed two peaks, one in September and another in December, both in station 2, related to the ebb tides. Regarding salinity in the water column, station 1 and two months of station 2 presented a pattern, with the stratified halocline between the surface less saline water (21.5) and the bottom layer (26.5), even in a channel as shallow as Bertioga Channel (Figure 3). This pattern with a sharp boundary that separates an upper less salty layer from an intruding wedge-shaped salty bottom layer characterizes a salt wedge estuary. Moreover, in September and December at station 2 the water column was homogeneous, with high salinity, indicating higher influence of coastal adjacent waters at the Channel's outfall during ebb tides.

The mean temperature showed small variation, with the highest values recorded in November and December (Figure 2). There is a general trend of a gradual increase at the temperature of the water column over the months in the two stations, where September had cooler temperatures and December had the warmest (Figure 3). The bottom layer, less saline, it is also colder.

A total of 1553 individuals represented by 50 species and 22 families were collected, totalizing 56017.52 g. The most abundant families were Ariidae (32.7%), Sciaenidae (26.5%), Trichiuridae (7.7%) and Carangidae (6.7%) (Table 1). Ten species represented approximately 75% of the catch in number: *Cathorops spixii, Stellifer rastrifer, Genidens genidens, Trichiurus lepturus, Chloroscombrus chrysurus, Achirus lineatus, Micropogonias furnieri, Aspistor luniscutis, Stellifer stellifer* and *Etropus crossotus*. *C. spixii* showed the highest numerical abundance, with 508 (or 32.7 %) specimens collected.

Catfishes and sciaenids, except *M. americanus*, had the highest abundance in station 1, while *T. lepturus* and *C. chrysurus* were the most abundant species in station 2. *Achirus lineatus* and *Lagocephalus laevigatus* were captured on both stations, but with different abundances.

Regarding the population dynamics, five species showed significant differences in the overall sex ratio: *M. furnieri*, *A. luniscutis*, *S. stellifer*, *C. spilopterus*, *B. ronchus* (Table 2). Proportion of males was higher in three species analyzed (*G. genidens*, *B. ronchus* and *M. americanus*). The majority of the species were represented by juveniles, which have not reached the length and/ or maturity to discriminate the gender. *C. chrysurus*, *P. corvinaeformis*, *L. laevigatus*, *O. oglinum*, *S. tessellatus* and *L. lagocephalus* presented only juveniles specimens.

It was possible to estimate the first maturation average length of catfishes *C. spixii* (L_{50}=121.2 mm), *G. genidens* (L_{50}=180.2 mm) and *A. luniscutis* (L_{50}=111.9 mm), and sciaenids *S. rastrifer* (L_{50}=89 mm) and *S. stellifer* (L_{50}=106.2 mm) (Table 2).

The Whitfield index for total samples was 2.27, whereas in the inner station (#1) was 2.22 and in the outer station (#2) was 1.60. Results from station 2 reflects the lower number of species and higher of families in the outfall of the Channel.

Highest number of species, ecological diversity and richness were recorded in December, while the highest numerical abundance was found in October (Table 3). Between oceanographic stations, the highest richness, abundance, dominance and evenness were recorded at station 1 (inner station), which also presents about 70% of fish sampled in this study. In spite of being close to each other, station 2 is in the channel outfall, and presents estuarine and marine representative species.

The results of cluster analysis, nMDS and canonical correspondence analysis showed a consistent and clear difference between the sampling stations, despite they are only 3.5 km from each other (Figures 4 and 5). The station groups were formed by combining the number of stations separately (1 and 2) within four months. The canonical correspondence analysis of species distribution between the oceanographic stations showed a pattern which ten species are correlated mainly with the inner station (station 1), especially for the catfish species (*C. spixii*, *G. genidens, A. luniscutis* and *G. barbus*) and sciaenids (*S. rastrifer, M. furnieri, S. stellifer* and *B. ronchus*), and ten

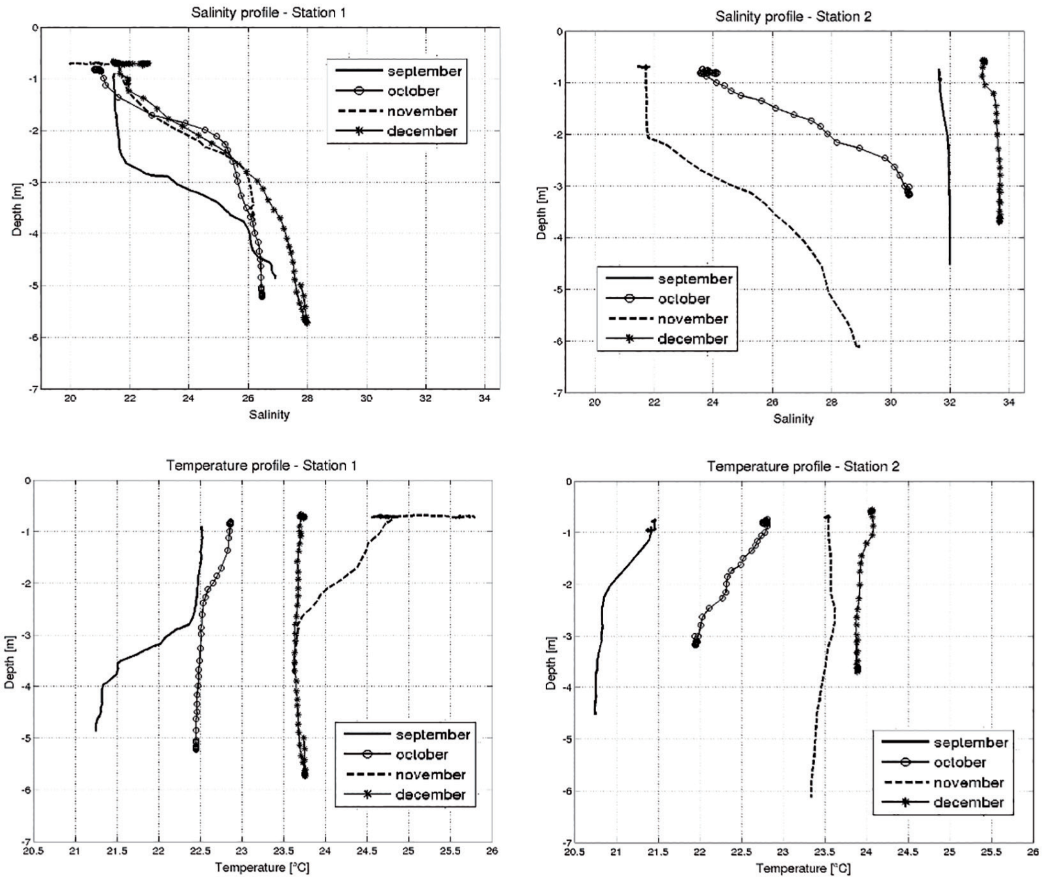

Figure 3. Temperature (a and b) and salinity (c and d) profiles from oceanographic stations 1 and 2 in the Bertioga Chanel, from September to December 2005.

species correlated with station 2, including the pelagic *C. chrysurus*, *H. clupeola*, *L. laevigatus*, *A. lepidentostole*, two flatfishes - *C. spilopterus* and *E. crossotus*, and the demersal species *M americanus*, *P. pruntatus* and *P. corvinaeformis*, essentially marine migrants. The Similarity Percentage Analysis (SIMPER) identified the contribution of each fish species between oceanographic stations, and also determined its contribution to dissimilarity within groups. Catfishes *C. spixii*, *G. genidens*, *A. luniscutis* and the sciaenid *S. rastrifer* were the most contributed to the dissimilarity between the groups, since occurring almost exclusively in the inner station.

The abiotic factors analyzed (temperature, depth and salinity) seem to have no influence on the species distribution, as showed by the canonical correspondence analysis and the correlation coefficient of Spearman; however, it was possible to observe a pattern of species distribution related to abiotic factors, *i.e.*, the species *P. punctatus* was related to temperature. *H. clupeola, M. furnieri* and *P. harroweri* were related to salinity, and *C. spixii* and *A. lineatus* with depth (Figure 6).

The ABC analysis for the whole area presented curves of cumulative abundance and biomass very close and parallel, with some parts of the biomass curve falling below the number curve suggesting a moderate disturbed environment (Figure 7), same pattern of the inner station. Station 1 also presented the lowest value of W-statistic.

The Bertioga Channel is dominated by three species of estuarine resident catfishes, mainly *C. spixii,* and by the sciaenid *S. rastrifer*. The values of the metrics calculated and the classification in the score thresholds presented (see Material and Methods section) regarding the species diversity, composition and abundance, the nursery function and the trophic integrity of the area allowed to classify the quality of the area as “Poor”, due to the values

Table 1. List of species collected at the Bertioga Channel between September and December 2005, with species code and abundances at station #1 and #2.

Family	Species	Species Code	# 1 (%)	# 2 (%)
ENGRAULIDAE	*Anchoa januaria* (Hildebrand, 1943)	ANJA	<0.5	0
	Anchoviella lepidentostole (Fowler, 1941)	ANLE	0.6	3.3
	Centegraulis edentulus (Cuvier, 1829)	CEED	<0.5	2
	Lycengraulis grossidens (Agassiz, 1829)	LYGR	<0.5	<0.5
PRISTIGASTERIDAE	*Pellona harroweri* (Fowler, 1919)	PEHA	2.5	<0.5
CLUPEIDAE	*Harengula clupeola* (Cuvier, 1829)	HACL	0.5	3.3
	Opisthonema oglinum (Lesueur, 1818)	OPOG	0	2.2
ARIIDAE	*Aspistor luniscutis* (Valenciennes, 1840)	ASLU	5.8	0
	Cathorops spixii (Agassiz, 1829)	CASP	22.3	0
	Genidens barbus (Lacepède, 1803)	GEBA	2.5	0
	Genidens genidens (Valenciennes, 1840)	GEGE	15.6	0
SYNODONTIDAE	*Synodon foetens* (Linnaeusm 1766)	SYFO	0	<0.5
MUGILIDAE	*Mugil curvidens* (Valenciennes, 1836)	MUCU	0	<0.5
FISTULARIA	*Fistularia tabacaria* (Linnaeus, 1758)	FITA	0	<0.5
TRIGLIDAE	*Prionotus punctatus* (Bloch, 1793)	PRPU	<0.5	4.2
CENTROPOMIDAE	*Centropomus parallelus* (Poey, 1860)	CEPA	<0.5	<0.5
	Centropomus undecimalis (Bloch, 1796)	CEUN	<0.5	<0.5
SERRANIDAE	*Diplectrum radiale* (Quoy & Gaimard, 1824)	DIRA	0	1.1
	Rypticus sp. (Cuvier & Valenciennes, 1829)	RYSP	<0.5	0
CARANGIDAE	*Chloroscombrus chrysurus* (Linnaeus, 1766)	CHCH	0.8	20.1
	Selene vomer (Linnaeus, 1758)	SEVO	<0.5	<0.5
GERREIDAE	*Diapterus auratus* (Ranzani, 1842)	DIOL	0	<0.5
	Diapterus rhombeus (Valenciennes, 1830)	DIRH	0	<0.5
	Eucinostomus gula (Quoy & Gaimard, 1824)	EUGU	<0.5	0
HAEMULIDAE	*Pomadasys corvinaeformis* (Steindachner, 1868)	POCO	0	7.1
SCIAENIDAE	*Bairdiella ronchus* (Cuvier, 1830)	BARO	2.6	0
	Isopisthus parvipinnis (Cuvier, 1830)	ISPA	<0.5	<0.5
	Larimus breviceps (Cuvier, 1830)	LABR	<0.5	0
	Menticirrhus americanus (Linnaeus, 1758)	MEAM	<0.5	4.6
	Micropogonias furnieri (Desmarest, 1823)	MIFU	6.7	<0.5
	Ophioscion punctatissimus (Meek & Hildebrand, 1925)	OPPU	<0.5	0
	Paralonchurus brasiliensis (Steindachner, 1875)	PABR	<0.5	0
	Stellifer rastrifer (Jordan, 1889)	STRA	20.6	<0.5
	Stellifer stellifer (Bloch, 1790)	STST	4.7	0
EPHIPPIDIDAE	*Chaetodipterus faber* (Broussonet, 1782)	CHFA	2.0	1.3
TRICHIURIDAE	*Trichiurus lepturus* (Linnaeus, 1758)	TRLE	0.8	24.3
PARALICHTHYIDAE	*Citharichthys spilopterus* (Günther, 1880)	CISP	1.5	3.1
	Etropus crossotus (Jordan & Gilbert, 1882)	ETCR	<0.5	6.9
ACHIRIDAE	*Achirus declives* (Chabanaud, 1940)	ACDE	<0.5	0
	Achirus lineatus (Linnaeus, 1758)	ACLI	5.4	5.1
	Trinectes paulistanus (Miranda Ribeiro, 1915)	TRPA	<0.5	0
CYNOGLOSSIDAE	*Symphurus tesselatus* (Quoy & Gaimard, 1824)	SYTE	0.5	0.7
MONACANTHIDAE	*Stephanolepis hispidus* (Linnaeus, 1766)	STHI	0	<0.5
TETRAODONTIDAE	*Lagocephalus laevigatus* (Linnaeus, 1766)	LALA	1.1	3.3
	Lagocephalus lagocephalus (Linnaeus, 1758)	LALAg	0.7	0
	Sphoeroides greeleyi (Gilbert, 1900)	SPGR	0.4	2,2
	Sphoeroides spengleri (Bloch, 1785)	SPSP	<0.5	0
	Sphoeroides testudineus (Linnaeus, 1758)	SPTE	<0.5	<0.5
	Sphoeroides tyleri (Shipp, 1974)	SPTY	0	<0.5
DIODONTIDAE	*Chilomycterus spinosus* (Linnaeus, 1758)	CYSP	<0.5	<0.5

Table 2. Maximum (TL max) and minimum (TL min) total lengths, mean length of first maturity, sex ratios and percentage of juveniles of fourteen species collected in the Bertioga Channel in 2005.

Species	TL min	TL max	L_{50}	M : F	% of Juveniles
Aspistor luniscutis	109	370	111.92	0.37 : 1*	-
Genidens genidens	110	294	180.2	1.35 : 1	20.2%
Micropogonias furnieri	70	243	-	0.28 : 1*	14.8%
Cathorops spixii	80	240	121.16	0.71 : 1	13.9%
Bairdiella ronchus	138	216	-	3.3 : 1*	-
Menticirrhus americanus	70	193	-	3 : 1	-
Harengula clupeola	56	187	-	-	36.8%
Anchoviella lepidentostole	70	180	-	0.86 : 1	-
Pomadasys corvinaeformis	90	159	-	1 : 1	100%
Citharichthys spilopterus	73	157	-	0.08 : 1*	26.7%
Stellifer stelifer	76	143	106.18	0.21 : 1*	-
Achirus lineatus	68	135	111,7	-	-
Pellona harroweri	54	134	-	0.6 : 1	-
Stellifer rastrifer	68	133	88.99	0.79 : 1	5.7%

Table 3. Calculated indices of fish community structure at the different sampling months and sites at the Bertioga Channel.

Dates/ Oceanographic stations	Species Richness	N	Simpson Dominance (λ)	Shannon Diversity (H')	Margalef Richness	Pielou Evenness (J)
Sep 30 2005	30	238	0.078	2.83	5.30	0.832
Oct 21 2005	32	651	0.196	2.16	4.79	0.623
Nov 17 2005	32	380	0.129	2.63	5.22	0.760
Dec 16 2005	35	284	0.098	2.84	6.02	0.799
#1	40	1101	0.132	2.45	5.57	0.633
#2	34	452	0.122	2.59	5.40	0.735

of the 12 metrics analyzed (Table 4). It agrees with ABC analysis and dominance of few species.

DISCUSSION

Estuaries are some of the most heavily used and threatened natural coastal systems. Their ecosystem services as the noncollapsed fisheries, the nursery ground function and the filtering and detoxification function suffer deterioration due to the increasing of the human activities (BARBIER et al., 2011).

The typical fish fauna from estuarine regions is characterized by a high abundance but few dominant species (BLABER et al., 1989). The Bertioga Channel fish community presented 50 species and was dominated by 10 species of Ariidae, Sciaenidae and a Trichiuridae in abundance and biomass. In tropical estuaries the marine catfish species (Ariidae) can be considered the most important fish group in terms of number of species, density and biomass (ARAÚJO et al., 1998; LOWE-MCCONNELL, 1999; BARLETTA; BLABER, 2007; BARLETTA et al., 2008; BARLETTA et al., 2010). In this study, Ariidae was represented by four species, and *C. spixii* was the most abundant. This is a similar pattern of other estuarine regions in the Brazilian coast (ARAÚJO et al., 1998; AZEVEDO et al., 1999; SCHWARZ JR. et al., 2006; SCHWARZ, JR. et al., 2007; CARVALHO-NETO; CASTRO, 2008; SCHMIDT et al., 2008), as in other tropical regions, such as Mexico (RUEDA; DEFEO, 2003).

The estuaries act as a reproduction or breeding area for the development of eggs and larvae of many organisms, including fish. Some species use the estuary throughout their life cycle, while others spend the early part of his life there, where there are abundant food and protection from predators, thus increasing their survival, and others use them as escape routes and migration (CHAO et al., 1985; ELLIOTT et al., 2007). In this study, all species in the Bertioga Channel showed overall length below the maximum recorded in the literature (FIGUEIREDO;

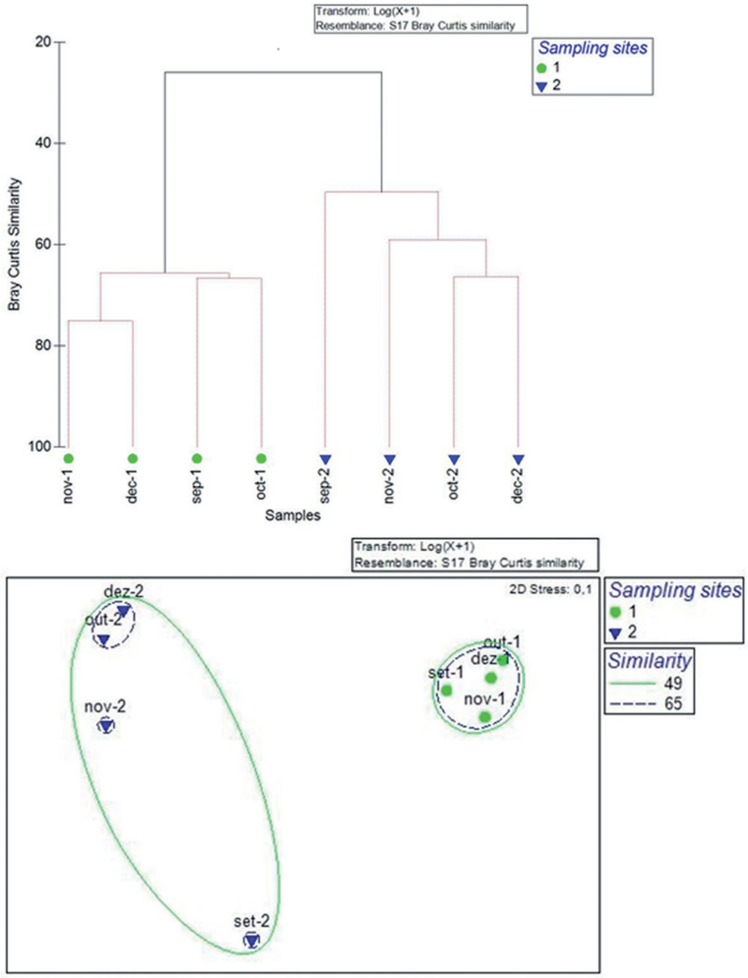

Figure 4. Spatial and temporal cluster of fish assemblages and nMDS plot of the groups from stations 1 and 2 from the Bertioga Channel based on Bray–Curtis similarity.

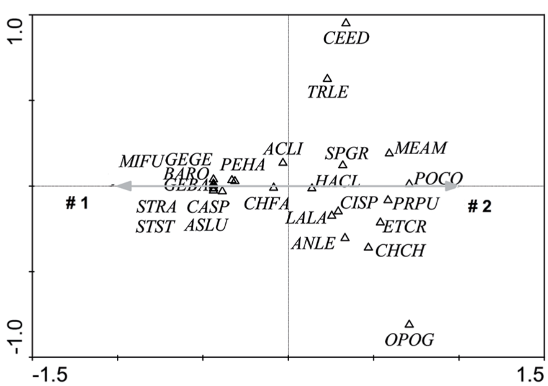

Figure 5. Canonical Correspondence Analysis diagram for oceanografic stations and fish species from the Bertioga Channel in 2005. Codes for fish names are presented in Table 1.

MENEZES, 1978, 1980, 2000; MENEZES; FIGUEIREDO, 1980, 1985; FROESE; PAULY, 2015) suggesting that the region studied is used by most of the species as a growth area. This information is reinforced by the fact that many species captured in this study were characterized only by juveniles such as *C. chrysurus*, *P. corvinaeformis*, *L. laevigatus*, *O. oglinum*, *S. tessellatus* and *L. lagocephalus*.

For only three species of catfish and two *Stellifer* species was possible to estimate the average length of first maturation (L_{50}). According to VAZZOLER (1996), the length of first maturation (L_{50}) is a reproductive tactic highly biased by place and sample season, dependent on the growth of individuals, and correlated with environmental conditions prevailing in the area of its occurrence. Its estimate is crucial for understanding the dynamics and

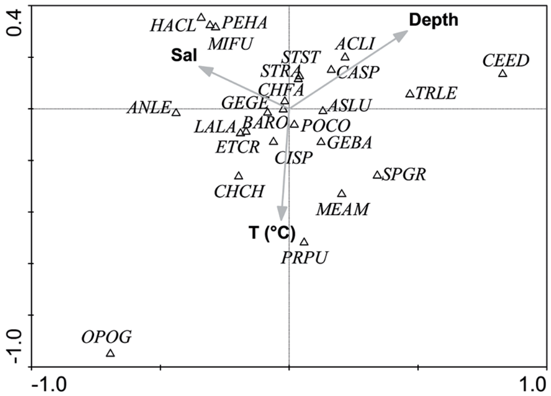

Figure 6. Canonical Correspondence Analysis diagram for environmental factors and the most abundant fish species from the Bertioga Channel. Codes for fish species names are in Table 1.

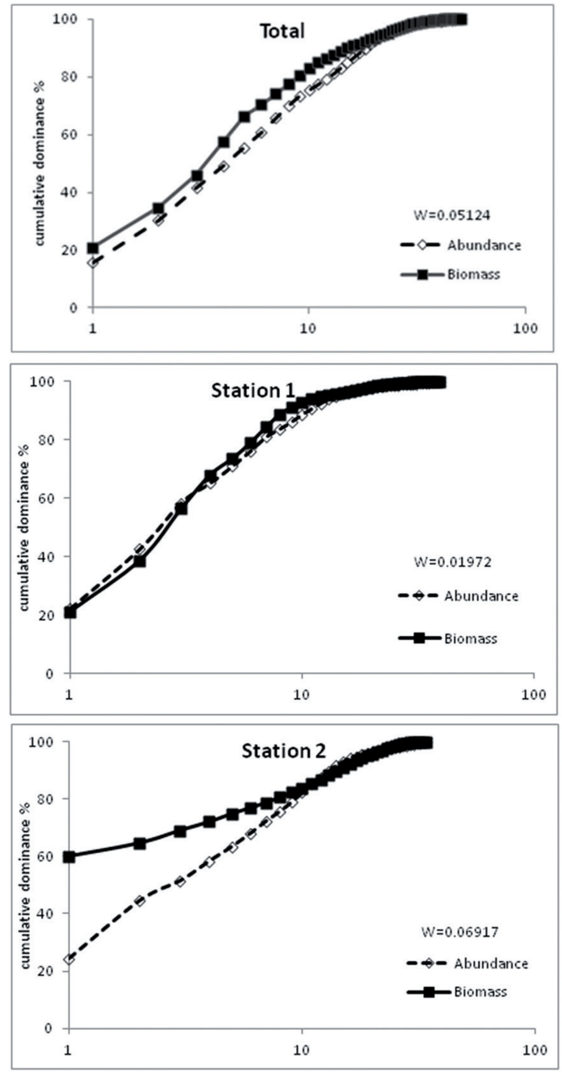

Figure 7. ABC curves of cumulative dominance for the total area (a) and to stations 1 (b) and 2 (c) for fish species caught in the Bertioga Channel.

reproductive growth of both species populations, for economic as well as ecological importance (VAZZOLER, 1996).

The length of first maturation (L_{50}) for females of *C. spixii* was 121.2 mm in the present study, however in the region of Cananéia was 96 mm (MISHIMA; TANJI, 1983). For *Genidens genidens* the value of L_{50} was 180 mm, higher than that found by BARBIERI et al. (1992) in a pond (RJ) as well as the 133 mm found in Sepetiba Bay by ARAÚJO et al. (1998). To *S. rastrifer* the L_{50} was estimated at 89 mm, far below that found in the literature (L_{50}=95 mm (COELHO et al., 1985, CAMARGO; ISAAC, 2005). The same pattern was observed for *S. stellifer*, with the length of first maturity estimated at 106 mm, while in the region of Santa Catarina, the L_{50} was estimated at 75 mm (ALMEIDA; BRANCO, 2002).

Segregation in species distribution was observed between stations, with greater richness, abundance and biomass in a more protected area of the estuary outfall (station 1), with little variation in the temperature and salinity. This preference for the inner region has been reported in other studies, such as ARAÚJO et al. (1998), AZEVEDO et al. (1999), SCHWARZ JR. et al. (2007). According to AZEVEDO et al. (1999) two demersal fish communities were evident, the inner area of the Sepetiba Bay and the other in the outer zone, with occurrence of *G. genidens* and *C. spixii* in the inner and middle area. SCHWARZ JR. et al. (2007) also recorded greater abundance of *C. spixii* in the inner Pinheiros Bay and high occurrence of *I. parvipinnis*, *S. rastrifer* and *S. brasiliensis* in the outermost area, differing from that found in the present study for Sciaenid species.

Estuaries are dynamic systems that exhibit wide fluctuations in environmental conditions (KUPSCHUS; TREMAIN, 2001). The main water quality parameters, such as salinity, temperature, turbidity and dissolved oxygen are known to influence the distribution of fish, although the temperature and salinity are not important for many juveniles (BLABER; BLABER, 1980). According BARLETTA et al. (2008) juveniles and adults of some species respond differently to seasonal fluctuations of environmental factors, and this behavior is seen as a strategy to avoid competition and predators. The Bertioga Channel was occupied mainly for juveniles from coastal and estuarine species.

Table 4. Metrics of the Estuarine Fish Community Index, respective values and scores to the Bertioga Channel. See text to EFCI classification thresholds.

Metric	Value	Score
Total number of taxa	50	1
Rare or threatened species	1	1
Exotic or introduced species	0	3
Number of species that make up 90% of the abundance	18	1
Number of estuarine resident taxa	3	3
Number of estuarine-dependent marine taxa	35	1
Relative abundance of estuarine resident taxa	6 %	5
Relative abundance of estuarine-dependent marine taxa	70 %	1
Number of benthic invertebrate feeding taxa	14	1
Number of piscivorous taxa	3	1
Relative abundance of benthic invertebrate feeding taxa	28 %	1
Relative abundance of piscivorous taxa	6 %	1
Classification		Poor

Several studies have described the influence of environmental factors on the distribution of fish species (MARSHALL; ELLIOTT, 1998; ARAÚJO et al., 2002; RUEDA; DEFEO, 2003). In this study, environmental factors measured did not affect the fish community, or distribution over the months. However, there was a correlation of environmental variables with the distribution of some species.

The ABC analysis compares the ranked distribution of abundance among species against the similar distribution of biomass among species. It is based in r-K strategy of life cycle, and considers that under stress condition, the diversity decreases and r-strategist species are dominant (BERVOETS et al., 2005). This method is considered a more useful than the univariate ones and is easily contrasted and interpreted (RICE, 2000). Under stress conditions, there is a competitive balance, the diversity decreases, and the dominant species are r -strategists, small size and with short life cycle.

In few months sampled, both stations #1 and #2 presented biomass curves below and/or overlapping the abundance curves, suggesting some degree of disturbance, mainly in station 1, despite of the inner station concentrates higher amount of species with K-strategy like catfishes. On the other hand, OTERO et al. (2006) discuss the relationship between abundance/biomass is shown to be directly related to the occurrence of juvenile fish in shallow areas, which is the case of the total area analyzed.

According to WARWICK (1986) the ABC analysis uses local populations to assess the status of an ecosystem, with no references to temporal or spatial series of controlled samples. This is important since pristine areas for comparison are absent in the vicinities. Several authors agree that the ABC analysis should be used in combination with other methods to access quality of aquatic environments, but this index was applied in Brazilian inland waters (PINTO et al., 2006; ROCHA; FREIRE, 2009; DIAS; TEJERINA-GARRO, 2010) as well as in coastal estuarine systems (FALCÃO et al., 2008, OTERO et al., 2006, DIAS et al., 2011). Other indices as the Index of Biotic Integrity - IBI (KARR, 1981) were applied in inland waters (PINTO et al., 2006a, b; PINTO; ARAÚJO, 2007; COSTA; SCHULZ, 2010). A combination of two indicators was preformed only by SOARES et al. (2011) in different impacted tidal creeks of an estuarine area in northern Brazil, and their results indicate that the ecological indices applied reflect the environmental quality and environmental changes in this coastal system.

In combination with the ABC analysis, the EFCI also classified the Bertioga Channel as poor concerning the integrity of fish community. The EFCI is an ecologically based method that combines both structural and functional attributes of fish communities, providing a robust and sensitive method for assessing the ecological condition of estuarine ecosystems. As explained above, it is not possible to compare our results with other studies.

The main component of fish based indicators is the functional guild. As the knowledge of fish fauna of estuarine and coastal water environments from Brazil is partial, mainly due to fragmented information, it is not possible to find a consensus concerning trophic and reproductive functional guilds, and classifications may vary, as discussed by MARTINHO et al. (2008).

The Bertioga Channel is a multi-use area, considered a secondary connection to the ocean of the estuarine system of Santos - São Vicente, which suffers intense pressure from pollution, habitat alteration and overfishing (ROCHA; DIAS, 2015). In spite of few months of sampling and a restricted area, the results are consistent and qualified the north outflow of the Bertioga Channel as moderately disturbed. Only a healthy ecosystem can provide good quality of the water and keep the ecosystem functions and ecosystem services.

In addition, the methods employed presented a diagnosis of the area, so that may be applied to other regions, to provide quick response on environmental conditions, using the fish fauna. Future studies should focus on jointly analyze the results available of chemical studies of water and sediment, with the biological studies of longer terms, to confirm the condition of the Bertioga Channel.

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