Ichthyofauna as an indicator of biotic integrity in a port region of the Amazon Coast of Maranhense, Brazil

https://doi.org/10.56238/sevened2024.007-018

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ABSTRACT

The objective of this study was to evaluate the environmental quality of an estuarine region located in the port area of the Amazon Coast of Maranhão, based on the calculation of a biological integrity index (IIB) that uses ichthyofauna data as parameters. Fish were collected from May 2011 to November 2015 at 4 points (P1, P2, P3 and P4) with the aid of gillnets, with meshes ranging from 18 mm to 60 mm between opposite nodes. To calculate the IIB, attributes inherent to the local ichthyofauna were chosen and categories of biotic integrity (Excellent, Good, Fair, Poor, Very Poor and No Fish) were defined. A total of 56 fish species belonging to 15 orders were recorded. The family Sciaenidae had the largest number of species, the other families recorded were Ariidae, Carangidae, Engraulidae and Mugilidae. Carnivorous species were the most abundant with 51.79%, detritivorous totaled 32.14% and omnivorous 16.07%. The temporal and spatial analyses of the IIB indicated that the integrity classes were classified as "Poor", where the score ranged between 28 and 36. The use of the Biotic Integrity Index classified the environmental quality of São Marcos Bay as Poor, suggesting that the estuarine system has undergone environmental modifications. On the other hand, the study indicated that in the last five years the region has been showing stability, about the variation of biotic indexes.

Keywords: Estuary, Fish, Environmental quality, Ecology.

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INTRODUCTION

Estuaries are highly complex coastal ecosystems that form an interface between marine and continental water environments, being used as nurseries or refuges for fish, birds, molluscs and crustaceans (Pinto *et al*., 2009). However, the increasing human occupation without adequate planning has caused changes in water quality and the integrity of aquatic organisms in estuarine systems (BREINE et al., 2004; Jackson et al., 2001).

The anthropogenic modifications imposed on the estuarine environment have as an immediate consequence the alteration of the pattern of variation of faunal diversity (CASTRO, 2001). As an effect of the development in estuarine areas, there has been an increase in the interest in identifying indicators of ecosystem degradation that integrate structural and functional changes (BREINE et al., 2010). Over the past three decades, increased awareness and legislation around the world have led to the development of various methods to assess the ecological quality of aquatic ecosystems and the impacts of anthropogenic pressures (BORJA et al., 2008).

Decision-making related to management is based on physical and biological data, where the Biotic Integrity Indices (BII) condense biological information into quantitative data on the ecological condition of the environment (BRYCE; HUGHES; KAUFMANN, 2002).

The proposition of calculating a Biotic Integrity Index was initially applied to evaluate streams using the fish community by Karr (1981)). Subsequently, several fish-based assessment methods have been proposed to assess the ecological integrity of estuaries, both in Europe (BIRK et al., 2012; BORJA et al., 2004; BREINE et al., 2010; CABRAL et al., 2012; COATES 2007; DELPECH et al., 2010; PÉREZ-DOMÍNGUEZ et al., 2012). Likewise, several adaptations and modifications of the metrics (attributes) and scores proposed by Karr (1981) were used to evaluate estuaries in Brazil (FISCH et al., 2016; SOARES et al., 2011; SOUSA; CASTRO; SILVA, 2011; VIANA et al., 2010).

The Bay of São Marcos has entirely estuarine characteristics, is drained by several rivers and makes up the Maranhão Gulf which, in turn, is interconnected to the Atlantic Ocean. The environmental impacts on the estuarine complex have been worsening over the years, with the main causes being sewage discharge, nutrient runoff and changes in the landscape from the maritime terminals (Itaqui and ALUMAR / ALCOA) installed in the port region. Therefore, these activities have led to an increased threat to the health of aquatic organisms.

Several studies have shown that the degradation of aquatic ecosystems exposed to industrial waste discharges can lead to a reduction in the abundance of commercially important species, resulting in social and economic problems for local communities (BLABER, 2000; KENNISH, 2010). Fausch et al. (1990), consider that the biotic integrity of a fish community is a sensitive indicator of direct and indirect stress on the entire aquatic ecosystem, and has great application in biological monitoring to assess environmental degradation.

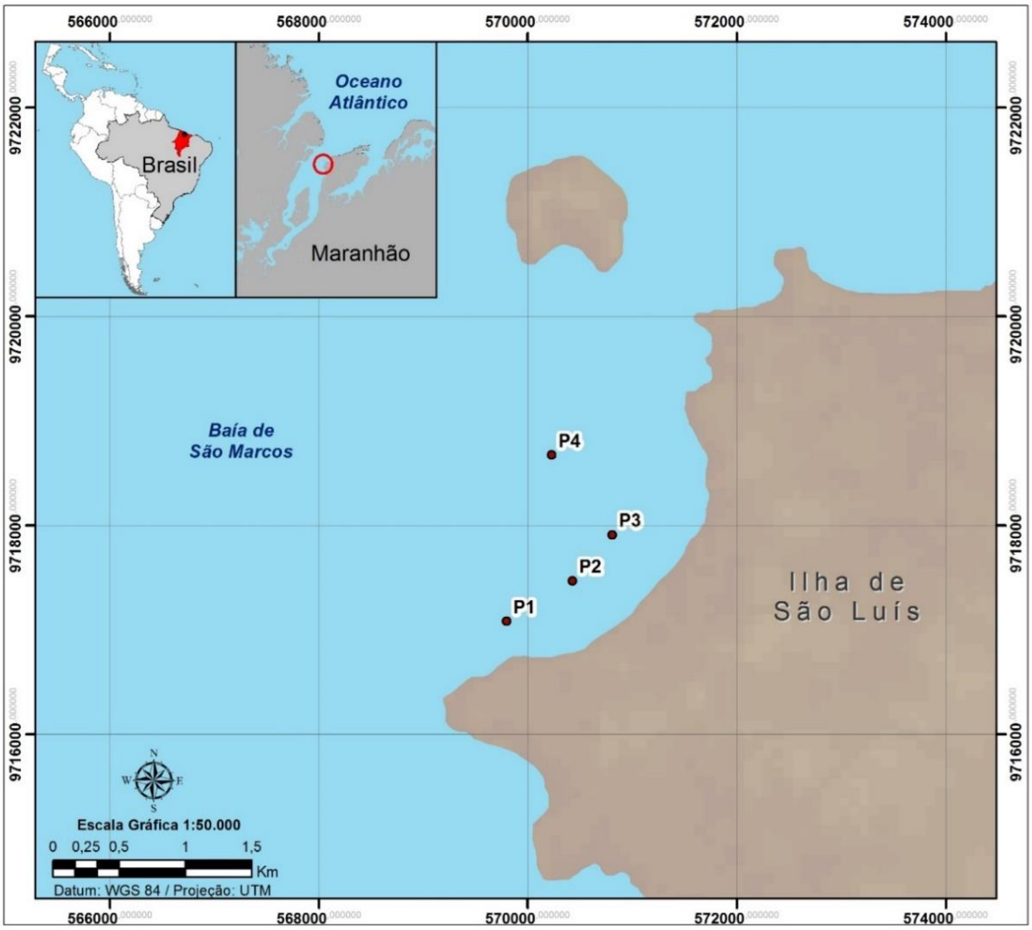
In this context, the use of indices that evaluate the environmental integrity of areas affected by anthropic inference become important tools to aid possible decision-making. It is worth mentioning that fish can be effective bioindicators and have been successfully used to assess the quality of many aquatic environments (VIANA et al., 2010). Therefore, the present study aims to to evaluate the ichthyofauna as an indicator of biotic integrity of the port region of the estuarine complex of São Marcos Bay.

MATERIAL AND METHODS

FIELD OF STUDY

The fish were caught in the Bay of São Marcos located on the Island of São Luís, State of Maranhão, at the following collection sites: Point 1 (44° 22' 19.745" W and 2° 33' 34.062" S); Point 2 (44° 21' 59.359" W and 2° 33' 21.469" S) and Point 3 (44° 21' 47.033" W and 2° 33' 7.150" S); Point 4 (44° 22' 5.857" and W 2° 32' 42.265" S) (Figure 1).

Figure 1. Location of St. Mark's Bay. Fish catch points, Maranhão, Brazil.



SAMPLING

Fish samples were collected from May 2011 to November 2015, totaling 18 collections. The species were captured at 4 points (P1, P2, P3 and P4) with the aid of gillnets, with meshes ranging from 18 mm to 60 mm between opposite nodes.

All the fish collected were packed in plastic bags, preserved on ice and transported to the Ichthyology Laboratory of the Federal University of Maranhão. In the next step, the biological material was identified down to the species level, using the Cervigón et al., (1992); Figueiredo; Menezes, (2000); Fischer, (1978). The nomenclature of the species was standardized according to information from Fishbase (FROESE; PAULY., 2011). For each specimen collected, biometric measurements (total length (cm) and weight (g) were determined, as well as aspects of its external anatomy were observed for possible detection of anomalies, tumors, deformities or other diseases for use in the Biotic Integrity Index (IIB).

DATA ANALYSIS

To evaluate the possible changes in the structure of the community that would indicate environmental impacts, the Biotic Integrity Index (IIB) was used (KARR, 1981) to assess the effects of possible environmental changes. The system aims to describe the environment in six classes of water quality (Excellent, Good, Fair, Poor, Very Poor and No Fish) (Table 1).

Table 1. Biotic Integrity Score, classes, and attributes.

Integrity Classes (Scoring)	**Attributes**
Excellent (57-60)	Comparable to the best situations without the influence of man; all regional species expected for the habitat and size of the watercourse present, including the most intolerant forms, in all age and sex groups; Balanced trophic structure.
Good (48-52)	Species richness somewhat below expectations, especially due to the loss of the most intolerant forms; some species with an abundance distribution or of less than optimal size; Trophic structure shows some signs of stress.
Regular (39-44)	Additional signs of deterioration with fewer intolerant forms, more altered trophic structure (e.g., increased frequency of omnivores); Adult classes of predators may be rare.
Poor (28-35)	Dominated by omnivores, pollution-tolerant species and generalists in habitat; few carnivores; growth rates and diminished condition factor; hybrid and/or diseased species always present.
Very poor (< 24)	Few fish present, mostly introduced or very tolerant species; frequent hybrids; common diseases, parasites, fin wounds and other abnormalities.
No fish (0)	Repeated fishing without catching any fish.

This index was based on various attributes of the fish community to assess the effects of environmental change. These attributes cover a range of ecological levels from individuals to population, communities, and ecosystems, and were grouped into three categories: species composition and richness, trophic composition and fish abundance, and conditions (Table 2) (ARAÚJO, 1998). Each attribute was given a score ranging from 5 (good), 3 (fair) and 1 (poor), to accommodate the ecological and evolutionary variations of each attribute. The final value of the index was represented by the sum of the scores of each measure. The IIB was calculated for each place and month in which the samples were collected, based on the methods outlined by Karr et al. (1986).

Table 2. Scores used in the determination of Biotic Integrity for the fish community of São Marcos Bay.

Category/Score	**Punctuation**		
	5	**3**	**1**
Species composition and richness			
1. Number of species	> 80	40 - 80	< 40
2. Presence of intolerant species	> 5	3 - 5	< 3
3. Number of Clupeiformes	> 6	3 - 6	< 3
4. Number of Siluriformes	> 10	5 - 10	< 5
5. Number of Perciformes	> 36	18 - 36	< 18
6. Proportion of very tolerant species	< 2%	2 - 4%	> 4%
Trophic composition			
7. Proportion of omnivores	< 20%	20 - 45%	> 45%
8. Proportion of detritivores	< 3%	3 - 5%	> 5%
9. Proportion of carnivores	> 8%	4 - 8%	< 4%
Fish abundance and conditions			
10. Number of individuals	> 95	48 – 95	< 48
11. Ratio of estuarine fish – opportunists	> 24%	12 – 24%	< 12%
12. Proportion of fish with anomalies, diseases, etc.	< 1%	1 – 3%	> 3%

These categories should be compared to expected values in a relatively degradation-free estuary of similar size and in the same ecological region. However, in the study area it is impossible to find sites with unchanged fish community. In view of this, it was necessary to adopt its own criteria both in the composition of the attributes and in the score ranges, according to the methodology modified and adapted by Sousa et al. 2011, which carried out such modifications to assess the effects of environmental changes on estuarine environments on the island of São Luís. The authors adapted the IIB to the ecological conditions of the island's estuaries and its adaptation was taken as a basis for the application of this methodology in the study area. The relationship between the 12 attributes that characterize the IIB and the final value of the index of each campaign was quantified by means of simple linear correlation.

STATISTICAL ANALYSIS

The spatial and temporal patterns for the Biotic Integrity Index were initially evaluated by the Levene test, in order to verify the assumptions of homogeneity of the variances. When attended, the data were tested using One-Way Analysis of Variance (ANOVA). For cases in which the results indicated significant differences ($p<0.05$), the Tukey test was applied a posteriori to identify which means were different. In situations in which the ANOVA assumption was not met (heterogeneous variances), the non-parametric Kruskal-Wallis test was applied (Sokal & Rohlf, 1995). All analyses were performed using the PAST and STATISTICA 7.0 softwares.

RESULTS

A total of 56 species of fish belonging to 15 orders were recorded, where Siluriformes contributed with the highest richness, followed by Clupeiformes, Mugiliformes, Perciformes, Pleuronectiformes, Tetraodontiformes, Beloniformes, Rajiformes. The families Sciaenidae had the highest number of species, the other families recorded were Ariidae, Carangidae, Engraulidae and Mugilidae (Table 3). The most abundant species were *Genyatremus luteus*, *Sciades proops*, *Macrodon ancylodon*, *Bairdiella ronchus*, *Catfish catfish*, *Mugil gaimardianus*, *Sciades herzbergii* and *Sardinella janeiro*.

The available data on the trophic ecology of fish assemblages allowed the identification of seven trophic guilds: omnivorous, detritivorous, piscivorous, planktophagous, insectivorous, herbivorous and bentophagous, however, a more comprehensive classification was used following the adaptation of Sousa et al. (2011), where guilds were distributed into carnivores, omnivores, and detritivores. Carnivorous species were the most abundant with 51.79%, detritivorous totaled 32.14% and omnivorous 16.07%.

Table 3. List of species recorded during the sampling period.

Order	Species	Nome-popular	Eating habits	N
Batrachoidiformes	*Batrachoides surinamensis*	Pacuma toadfish	Dream-eater	15
Beloniformes	*Strongylura timucu*	Timicu	Carnivorous	6
	Symphurus plagusia	Duskycheek tonguefish	Detritivore	44
Carcharhiniformes	*Sardinella janeiro*	Brazilian Sardinella	Dream-eater	61
Clupeiformes	*Anchoa spinifer*	Spicule anchovy	Dream-eater	6
	Cetengraulis edentulus	Atlantic anchoveta	Detritivore	37
	Lile piquitinga	Atlantic piquitinga	Dream-eater	72
	Pellona castelnaeana	Amazon pellona	Carnivorous	17
	Rhinobatos horkelli	Brazilian guitarfish	Carnivorous	1
	Sciades herzbergii	Pemecou sea catfish	Detritivore	267
Elopiformes	*Elops saurus*	Ladyfish	Carnivorous	11
Lophhiiformes	*Ogcocephalus vespertilio*	Seadevil	Carnivorous	2
Mugiliformes	*Mugil curema*	White mullet	Detritivore	95
	Mugil gaimardianus	Redeye Mullet	Detritivore	191
	Mugil incilis	Parassi Mullet	Detritivore	33
Peciformes	*Cynoscion leiarchus*	Smooth weakfish	Carnivorous	10
	Cynoscion microlepidotus	Smallscale weakfish	Carnivorous	25

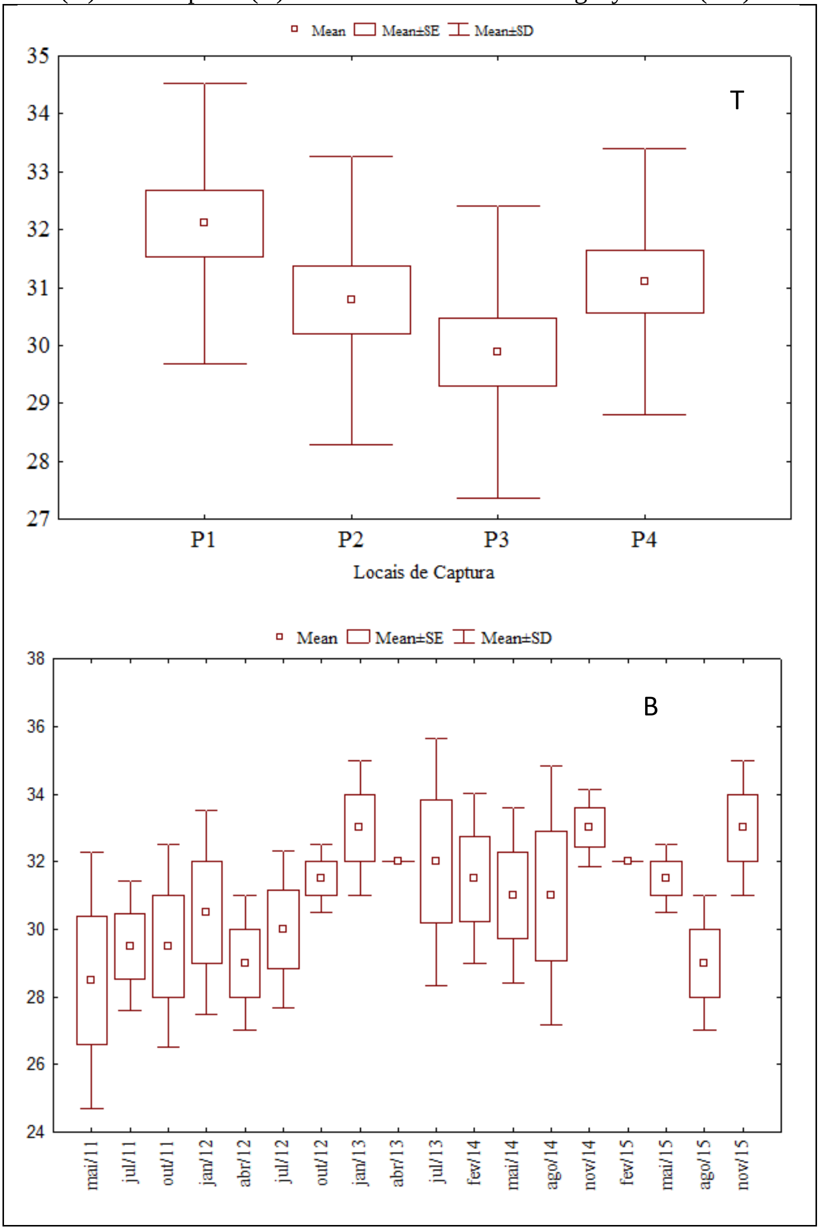
Order	Species	Nome-popular	Eating habits	N
	Polydactylus virginicus	Bargu	Dream-eater	28
	Bairdiella ronchus	Ground croaker	Detritivore	286
	Caranx latus	Horse-eye-jack	Detritivore	1
	Centropomus parallelus	Fat snook	Carnivorous	37
	Centropomus undecimalis	Commom snook	Carnivorous	76
	Chaetodipterus faber	Atlantic spadefish	Detritivore	12
	Cynoscion acoupa	Acoupa weakfish	Carnivorous	98
	Cynoscion jamaicensis	Jamaica weakfish	Carnivorous	11
	Diapterus rhombeus	Caitipa mojarra	Detritivore	3
	Genyatremus luteus	Toronto grunt	Detritivore	398
	Lobotes surinamensis	Tripletail	Carnivorous	1
	Lutjanus jocu	Dog snapper	Carnivorous	9
	Macrodon ancylodon	King weakfish	Carnivorous	317
	Menticirrhus americanus	Southern kingcroaker	Carnivorous	62
	Micropogonias furnieri	Whitemouth croaker	Detritivore	31
	Nebris microps	Smalleye croaker	Carnivorous	1
	Oligoplites palometa	Maracaibo leatherjacket	Carnivorous	6
	Pseudauchenipterus nodosus	Cocosoda catfish	Detritivore	32
	Stellifer rastrifer	Rake stardrum	Detritivore	70
	Stellifer stellifer	Little croaker	Carnivorous	6
	Strongylura marina	Atlantic needlefish	Carnivorous	25
	Trichiurus lepturus	Largehead hairtail	Carnivorous	88
Pleuronectiformes	*Achirus lineatus*	Lined sole	Carnivorous	128
	Pterengraulis atherinoides	Wingfin anchovy	Dream-eater	116
	Trachinotus falcatus	Permit	Carnivorous	2
Rajiformes	*Hypanus guttatus*	Longnose stingray	Detritivore	3
	Gymnura micrura	Smooth butterfly ray	Carnivorous	2
Rhinobatiformes	*Rhizoprionodon lalandii*	Brazilian sharpnose shark	Carnivorous	2
Siluriformes	*Amphiarius rugispinis*	Softhead sea catfish	Carnivorous	70
	Aspistor quadriscutis	Bressou sea catfish	Dream-eater	1
	Aspredinichthys tibicen	Tenbarbed banjo	Detritivore	2
	Bagre bagre	Sea catfish	Carnivorous	317
	Cathorops spixii	Madamango sea catfish	Dream-eater	38
	Cathorops agassizii	New granada sea catfish	Dream-eater	15
	Sciades proops	Crucifix sea catfish	Carnivorous	372
	Selene setapinnis	Atlantic moonfish	Carnivorous	1
Tetraodontiformes	*Aluterus monoceros*	Unicorn leatherjacket filefish	Carnivorous	1
	Colomesus psittacus	Banded puffer	Detritivore	7
	Stellifer naso	Black loggerhead (Brazil)	Detritivore	15

The analysis of the spatial variation of the IIB indicated that the integrity classes were classified as "Poor" in all sampling areas, where the score alternated between 28 and 36 (Figure 2A). Point 1 had the highest values, while point 3 had the lowest scores when compared to the other capture sites. Levene's test identified homogeneity of variances (p = 0.516), thus allowing the use of

ANOVA. However, the result of the parametric test detected a spatial difference between the collection points of the species (p>0.05), where point 3 showed a significant difference in relation to point 1.

The temporal IIB result also categorized the environmental quality of the study area as "Poor" throughout the sampling period. The months of July 2013, November 2014 and November 2105 had the highest averages, while the lowest values were observed in May 2011, April 2012 and August 2015 (Figure 2B). The application of Levene's test showed a difference between the temporal values (p= 0.2448), so the non-parametric Kruskal-Wallis test was used to verify the existence of a difference or not in the indices for the months of collection. The application of the test indicated temporal homogeneity among the indices.

Figure 6-2. Spatial (A) and temporal (B) variation of the Biotic Integrity Index (IIB) in São Marcos Bay.



DISCUSSION

The environmental condition of the Bay of São Marcos, demonstrated through the Biotic Integrity Index, indicated that the situation of the environmental quality of the estuarine system was classified as Poor, there was no spatial or temporal variation for the results. In studies carried out in estuaries of the island of Maranhão, which were influenced by an aluminum company, Sousa et al. (2011) found different results for the temporal (Very Poor to Poor) and spatial (Very Poor) analyses, where the increase in rainfall indices negatively interfered in the biotic integrity of the region.

Carnivorous and dentritivorous species accounted for 70% of the total, the results were similar to the study carried out by Soares et al. (2011), which recorded more than half of the species as detritivores and carnivores in the Maranhão Gulf. In a comparative study, Giarrizzo & Krumme (2008) found that the contribution of carnivorous species in the water bodies of Maranhão was approximately five times greater than that of the State of Pará.

The classification defined for the IIB of São Marcos Bay, which ranged from poor to regular, may be associated with the disorderly occupation of the surroundings, the discharge of effluents or repeated dredging (Schettini, 2002; Araújo et al., 2009; Schettini, 2009; Schettini and Truccolo, 2009; Silveira and Resgalla Jr., 2009). Studies carried out in three estuaries of the Paciência River (MA) found greater variations between the months (Very Poor, Poor and Regular) and no variation between the collection points (Poor) (SOARES et al., 2011).

When the influence of the seasonality of the hydrological periods on the distribution pattern of the species and its relationship with the environmental quality of the tidal channels was verified, the dry season showed a significantly better biotic integrity than the rainy season. Soares et al. (2011), associates this difference with the rainy season, which results in a greater contribution of waste directed to the estuary, and consequently, affects the occurrence of the ichthyofauna in the hydrological period, which decreases the IIB values.

In this work, a period of 5 years for the Bay of São Marcos was analyzed, which made it possible to estimate possible temporal and spatial changes in the local integrity. Second Zhu & Chang (2008) A continuous sampling period of six years would be sufficient for the evaluation of a fish assemblage for impacted environments. The responses of ecosystems are usually related to immediate or past environmental changes. In addition, variations in the results of the attributes may also be related to physical and structural differences in the habitat, such as depth, type of substrate and salinity (Marciano et al., 2004), which were not considered for the validation of the indexes.

The Bay of São Marcos aggregates several port activities along its coast, despite this constant interference, 56 species were recorded in the study area. The region presented a relevant composition in the ichthyofauna, compared to other tropical estuaries (BASILIO et al., 2009; CASTRO, 2001; FISCH et al., 2016; MARTINS-JURAS; JURAS; MENEZES, 1987; SILVA JÚNIOR et al., 2013;

VIANA et al., 2010). Despite receiving external inputs and nutrients brought by rivers and tidal flows, estuaries have an enormous capacity for regeneration, thus accrediting them as breeding grounds for several species of fish, including those of commercial importance (BARLETTA-BERGAN; BARLETTA; SAINT-PAUL, 2002; IKEJIMA et al., 2003).

Other studies carried out in port areas of Maranhão show that the families with the highest number of species are Sciaenidae, Carangidae, Ariidae and Gerreidae. In number of individuals, Ariidae, Pomadasyidae, Mugilidae and Sciaenidae predominated, and in weight, Ariidae, Mugilidae, Sciaenidae and Tetraodontidae stand out. Pelagic species include those of the families Mugilidae and Carangidae. The present study also portrayed similar patterns.

According to Pessanha et al. (2000), the family Engraulidae in their adult stage are more abundant in coastal environments and migrate to the estuary for the purpose of spawning. However, individuals belonging to this family use the marine environment for recruitment and development. In this study, a good incidence of the species was observed *C. edentulus, P. atherinoides* and *S. janeiro*, all belonging to the Engraulidae family, both in adult and juvenile stages, especially at point 1 which, although it is a coastal environment, is also characterized by its proximity to mangrove areas and muddy tidal plain (washed), functioning as a feeding, reproduction and shelter area.

Still on the Engraulidae family, - Krumme & Saint-Paul (2010) , observed in the Caeté estuary an association between the increase in biomass and the increase in planktonic production towards the mouth of the Amazon River. Sampling in the area of the present study indicated a high presence of the family Haemulidae and Mugilidae. Second Giarrizzo & Krumme (2008), the abundance of this group may be associated with the strong marine influence that occurs on the island of São Luís.

With regard to the family Tetraodontidae, Giarrizzo & Krumme (2008) state that the strong marine influence and large tidal amplitude in São Marcos Bay may influence the proportion of species with low biomass on São Luís Island. This condition can be confirmed in this study, since the lowest levels of biomass were found for the species *C. psittacus*, which belongs to the family Cited.

Regarding the feeding habits of the species, carnivores dominated the sample (51.79%), followed by detritivores (32.14%) and omnivores (16.07%). In a study carried out in Pará, near mangrove areas, Krumme et al. (2004) found the dominance of detritivores in their samples.

Studies that address trophic guilds in the Maranhão Gulf indicate uniformity in the diet of fish species, mainly due to tropical species having specialized habits (ABELHA et al., 2001). Most species have generalist characteristics, however, always with some degree of preference in the use of the resources available in the environment (PEREIRA et al., 2007).

The Biotic Integrity Index classified the environmental quality of São Marcos Bay as Poor, suggesting that the estuarine system has undergone environmental changes. On the other hand, the study pointed out that in the last five years the region has been showing stability, with regard to the variation of the biotic index. The index makes it possible to understand the connections between the aquatic environment and the "activities" that can disturb its balance, being a useful tool for dialogue between managers, politicians and other groups of actors involved (FISCH et al., 2016).

The use of the Biotic Integrity Index was an important instrument for monitoring and evaluating the environmental quality of the environment studied, especially fish, which were good bioindicators for determining areas with probable anthropogenic impacts.

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