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MARINE QUALITY ASSESSEMENT OF AMAZON MANGROVES USING BENTHIC AND DIVERSITY INDICES BASED ON POLYCHAETE FAUNA

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ABSTRACT

The aim of this study was to evaluate the environmental quality of two mangroves in the Gulf of Maranhão, Brazil, based on polychaete composition. Samples were collected in two areas: Buenos Aires stream, located near to the Itaqui Port, and Quebra Pote. Biotic (AMBI, M-AMBI, BENTIX) and diversity indices (SHANNON-WEAVER) were used to assess disturbance levels. A total of 732 specimens of polychaetes belonging to 11 families were found. The most abundant polychaetes in the Buenos Aires stream were *Exogone* sp. and *Paradoneis* sp. In Quebra Pote mangroves, *Nephtys simoni* and *Notomastus* sp. were the most abundant species. According to AMBI, both areas were classified as slightly polluted. According to M-AMBI and BENTIX, both areas were considered unpolluted, and according to Shannon-Weaver, both areas were classified as moderately polluted. Based on this study, it is recommended the constant monitoring of those mangrove areas, thus ensuring the survival and health of benthic communities.
Keywords: annelids, ambi, bentix, m-ambi, shannon.

Abstract

Avaliação da qualidade marinha dos manguezais da Amazônia utilizando índices bênticos e de diversidade com base na fauna de poliquetas

O objetivo do presente trabalho foi avaliar a qualidade ambiental de duas áreas de manguezal do Golfão Maranhense, Brasil, com base na composição de poliquetas. As coletas foram realizadas em duas áreas: igarapé Buenos Aires, localizado no entorno da Região Portuária do Itaqui, e Quebra Pote. Foram usados índices bióticos (AMBI, M-AMBI e BENTIX) e o índice de diversidade (SHANNON-WEAVER) para verificar o grau de perturbação ambiental em cada área de estudo e em cada zona (P1, P2 e P3). Foram coletados 732 espécimes de poliquetas pertencendo a 11 famílias. As espécies mais abundantes para o igarapé Buenos Aires foram *Exogone* sp. e *Paradoneis* sp. e para o manguezal de Quebra Pote *Nephtys simoni e Notomastus* sp. De acordo com o AMBI, ambas as áreas estudadas foram classificadas como levemente poluídas. Enquanto para o M-AMBI e BENTIX foram consideradas como não poluídas e Shannon-Weaver classificou como moderadamente poluídas. O acompanhamento rigoroso dessas florestas de mangue é imprescindível para a sobrevivência e saúde das comunidades bentônicas.
Palavras-chave: anelídeos, ambi, bentix, m-ambi, shannon.

INTRODUCTION

Polychaetes comprise one of the most abundant and diverse groups of benthic macrofauna. They inhabit a range of environments, including estuaries, mangrove swamps, and deep sea, performing important ecological functions in marine food chains (Amaral & Migotto 1980, Paiva 2006). One of these functions is nutrient cycling, since many species of polychaetes incorporate organic debris and transform them into animal biomass (Amaral *et al*. 2005). They can also ease the recovery of organic debris that would otherwise be trapped in the sediment, as some species of polychaetes dwell in burrows.

Polychaetes are useful indicators of environmental disturbances due to their sensitivity to abiotic variations. Such particularities can be easily measured in quantitative and qualitative terms, especially when compared to other benthic fauna (Feres *et al*. 2008). For example, many polychaetes are extremely resistant to marine pollution, particularly to organic enrichment (Amaral & Nonato 1981, Reish & Gerlinger 1997, Sola & Paiva 2001, Muniz 2005).

In recent years, the monitoring of aquatic ecosystems has been intensified, particularly in European countries. This is likely due to initiatives for the development of good environmental status through evaluation of aquatic organisms and its application to unravel the environmental disturbances (Bigot *et al*. 2008). The characterization of marine ecosystem quality is commonly performed through the assessment of physicochemical parameters; however, such methodology can only quantify isolated substances (Callisto *et al*. 2001).

When biological indicators are used in environmental monitoring, bottom-up and top-down methods are applied. Bottom-up method consists in the exposure of organisms to pre-determined stress agents or specific analysis of a compound present in the organism. On the other hand, top-down methods analyze impacts at the macro level, measuring the structural and functional organization of biological communities (Cairns *et al*. 1993). Several metrics can be used in the top-down method, such as diversity and biotic indices (e.g., Shannon-Weaver (1949), Simpson (1949), Margalef (1956) and Pielou (1966), that evaluate the structure of the community and its relation to species abundance, richness, and evenness (Metcalfe 1989). The present study used the diversity index of Shannon-Weaver, once it is one of the oldest and most used for environmental quality assessment (Equbal *et al*. 2017, Hutton *et al*. 2015, Leshno *et al*. 2016, Borja *et al*. 2012). Comparisons between reference areas and potentially impacted areas are frequently used (Buss *et al*. 2003).

Biotic indexes consist of attributing a score to the collected taxa according to its sensibility tolerance in relation to the environment. Among the biotic indexes are the Marine biotic index (AMBI) (Borja et al. 2000), Multivariable AMBI (M-AMBI) (Muxika et al. 2007) and BENTIX (Simboura & Zenetos 2002). Studies performed by Borja et al. (2000), Chainho et al. (2007), Pieper (2010), Pino et al. (2015), Brauko et al. (2015) and Basatnia et al. (2015) suggest that these indexes are efficient as indicators of environmental quality.

There is a huge knowledge gap regarding benthic invertebrates in Northern Brazil (Amaral & Jablonski 2005, Lana *et al*. 2009, Ribeiro & Almeida 2014), which includes the coast of Maranhão, where few environmental quality studies have been published and to date, no studies using benthic organisms have been carried out. Several studies proved the efficiency of using benthic fauna as indicators of environmental disturbance through the use of biotic indexes for estuarine areas (e.g. Omena *et al*. 2012, Brauko *et al*. 2015). Since estuaries and well-developed mangroves are very abundant on the coast of Maranhão, the use of biotic indexes can assist with the identification of impacted areas.

In this study, biotic and diversity indexes were applied to determine the level of environmental disturbance at pre-selected areas. Indexes based on polychaete communities were applied, aiming to compare the impacts in two mangroves located in Gulf of Maranhão, more specifically, in São Marcos Bay and São José Bay, respectively.

MATERIAL AND METHODS

Study Area

The coast of Maranhão has 640 km of extension, with a large continental shelf and shallow waters under the constant influence of river discharge (Almeida *et al*. 2010). The Gulf of Maranhão is located at the northern end of the state, comprising the bays of São Marcos and São José, which are separated by the island of São Luís (Teixeira & Sousa- Filho 2009). In São Marcos Bay, the sampling was carried out in the mangrove area of the Buenos Aires stream, located near the Itaqui Port (2°35′57,7″S 44°21′09,4’’W). Whereas in São José Bay, the sampling was performed in Quebra Pote mangroves, located on the east coast of the Island of São Luís (02°41’344’’S 044°12’604’’W) (Figure 1).

The Buenos Aires stream is located in the vicinity of the Itaqui Port, on the western coast of São Luís island. The Itaqui Port is considered one of the largest ports on the Brazilian coast, and it is the second largest port complex in Latin America. (Amaral & Alfredini 2010). Several studies conducted in São Marcos Bay have suggested that this area is potentially contaminated (Carvalho-Neta & Abreu-Silva 2010, Carvalho-Neta *et al*. 2012).

Quebra Pote is located in the east coast of São Luís Island, and it is influenced by the Tibiri River. This river carries out large quantities of nutrients, turning the water turbid, especially in the rainy season (Silva & Almeida 2002). Urbanization seems to be the main cause of environmental degradation, as indiscriminate dumping of garbage and domestic

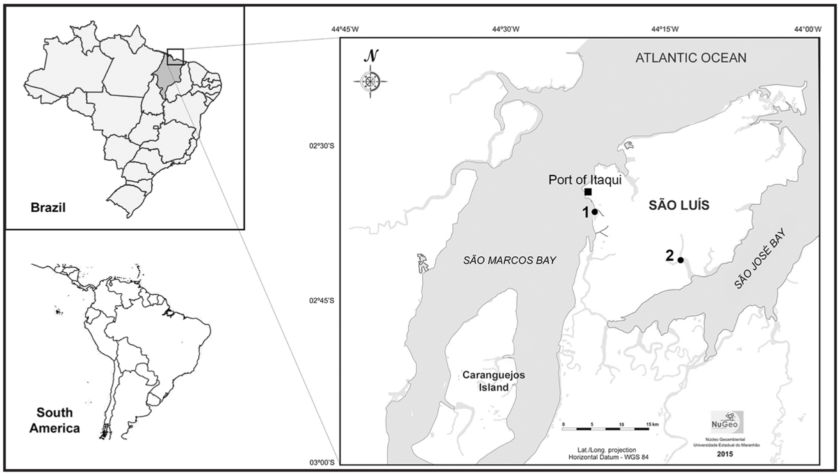

Figure 1. Geographical location of the sampling areas: 1) Buenos Aires stream, Itaqui Port, São Marcos Bay and 2) Quebra Pote mangrove, São José Bay, Maranhão.

sewage has been observed. In both study sites, the mangrove forests are predominantly composed of *Avicennia schaueriana* and *Rhizophora mangle* species.

Faunal sampling

In Buenos Aires stream, the sampling was performed between September 2012 and January 2014, while in Quebra Pote the sapling was carried out between November 2013 and July 2014. In both sites, the samplings were performed during low tide. Samples were collected with a 100 m transect, placed perpendicular to the waterline at each mangrove site.

Three points within the transect were defined: P1, below the eulittoral zone (water), P2, intermediate eulittoral zone, and P3, upper eulittoral region (continent). Three subsamples were taken at each point (10 meters to the left, center and right of the transect). A total of 18 samples were collected per sampling period, totaling 72 sub-samples in each area studied.

Sediment samples were also collected using a corer (10 cm in diameter, 20 cm depth). The material was then fixed in 4% formaldehyde and transported to the Laboratory of Fisheries and Aquatic Ecology, at the State University of Maranhão. All samples were washed in sieves (0.5 mm in diameter) and preserved in 70% ethyl alcohol. The material was screened, and the specimens were identified with the aid of a stereomicroscope and optical microscope. All specimens were identified to the lowest possible taxonomic level.

Along with the sediment sampling for analysis of biological material, it was also collected sediment samples for grain size characterization and organic material quantification in each study site. The samples were sent to the Laboratory of Soil Physics at the State University of Maranhão. The proportions of gravel, sand, silt, and clay were determined by sieving (> 0.062 mm in diameter) and pipetting (> 0.062 mm in diameter) according to Suguio (1973).

The organic matter content was determined through the calcination weight loss method. The samples were dried in an oven at 60º C for at least 48 hours to obtain the constant weight (dry weight). Then, they were incinerated in a muffle at 550 °C for 4 hours and then weighed. The organic matter content that volatilized was determined from the initial and final weight difference (Walkley & Black 1934).

The water abiotic parameters (temperature, salinity, and dissolved oxygen) were measured using a Hanna multiparameter probe. However, abiotic parameters of water were not assessed on September 12 and February 13 at Buenos Aires stream.

Data processing

Several indexes were used to evaluate the ecological quality of each mangrove: AMBI, M-AMBI, BENTIX. SHANNON was used to assess the current environmental status of each mangrove sampled. The indexes were also applied to verify the variability between zones in each location.

The indexes AMBI and M-AMBI classified the macrobenthic species into five ecological groups (EG) according to their sensitivity level, ranging from sensitive to disturbances (EG I) to tolerant (EG V). For each ecological group, a score was calculated through the formula $CB = \{(0 \times \%GI) + (1.5 \times \%GII) + (3 \times \%GIII) + (4.5 \times \%GIV) + (6 \times \%GV)\}/100$.

The AZTI Marine Biotic Index (AMBI) developed by Borja *et al*. (2000) was used to assess the ecosystem quality and to analyze how substrate communities are responding to natural or anthropogenic changes (Borja & Muxika 2005).

The multivariate AMBI (M-AMBI) was calculated using factor analysis along with the AMBI, and the diversity and species richness structural indexes to assess the ecological quality of the ecosystem (high, good, moderate, poor, and bad) (Bolta 2013).

The species were classified into three ecological groups, according to BENTIX: sensitive to disturbance (GI), tolerant to disturbance (GII) and first order opportunistic species (GIII). This index was calculated using the following formula: *BENTIX= {6 X %GI + 2 X (% GII + % GIII)}/100*.

The SHANNON index was used to evaluate the composition and abundance of the species, and it was calculated using Primer 6.0 software (Clarke & Warwick 2001, Clarke & Gorley 2006). The ecological status of the study areas compiled by Chainho *et al*. (2007) (Table 1) was used in this study. A matrix with all the results was generated, and these data were analyzed by one-way ANOVA to verify significant differences between the sites P1, P2, and P3. This test was performed using the statistical package IBM SPSS version 20.0.

Table 1. Ecological status according to biotic indices (Chainho *et al*. 2007).

ECOLOGICAL	H'	AMBI	M- AMBI	BENTIX
Unpolluted	0<H≤'1	0<AMBI≤1.2	0.82<M-AMBI≤1.00	4.5<BENTIX≤6.0
Slightly polluted	1<H'≤2	1,2<AMBI≤3.3	0.61< M-AMBI≤0.82	3.5<BENTIX≤4.5
Moderately polluted	2<H'≤3	3,3<AMBI≤4.3	0.40< M-AMBI≤0.61	2.5<BENTIX≤3.5
Polluted	3<H'≤4	4,3<AMBI≤5.5	0.20<M-AMBI≤0.40	2.0<BENTIX≤2.5
Extremely polluted	4<H'≤5	5,5<AMBI≤6.0	0<M-AMBI≤0.20	0<BENTIX≤2.0

RESULTS

Environmental parameters

Water parameters (temperature, salinity and dissolved oxygen), grain size and organic material of the study sites were obtained and compiled with previous studies (2012-2014). According to the data obtained, water temperature in Buenos Aires stream ranged from 25ºC to 30.6 ºC, dissolved oxygen ranged from 1.35 mg/L to 5.42 mg/L, and salinity ranged from 23.2 to 33.8. In Quebra Pote, water temperature ranged from 25.5°C to 27.8ºC, dissolved oxygen ranged from 3.2 mg/L to 7.5 mg/L and salinity ranged from 11.3 from 30 (Table 2). The sediments of Buenos Aires stream exhibited a silt percentage of 42% and a clay percentage of 54%, and the organic matter content was 28%. In Quebra Pote the percentages of silt and clay were 38% and 55%, respectively, with organic matter content of 36% (Table 3).

Table 2. Water parameters in Buenos Aires stream and Quebra Pote mangroves. Temperature (°C), Dissolved Oxygen (D.O) (mg/L) and Salinity.

Abiotic variables	Buenos Aires				Quebra Pote			
	Mar/12	Jun/12	Nov/13	Jan/14	Nov/13	Jan/14	Mar/14	Jul/14
Temp./ºC	29.06	30.6	25	28	25.7	27.5	27.8	25.8
D.O	1.35	1.5	4.07	5.42	3.2	6.05	5.4	7.5
Salinity	23.2	26.9	33.8	31.9	27.5	30	11.3	26.3

Table 3. Grain size composition and organic matter content in the sediment from Buenos Aires stream and Quebra Pote mangroves.

Classes	Buenos Aires	Quebra Pote
Fine sand (%)	3	6
Coarse sand (%)	1	1
Silt (%)	42	38
Clay (%)	54	55
Organic matter (%)	28	36

Polychaetes composition

It was found a total of 732 polychaetes belonging to 11 families. In Buenos Aires stream 18 species were identified, with *Exogone* sp. and *Paradoneis* sp. being the most abundant. Whereas in Quebra Pote, 15 species were identified, with a higher abundance of *Nephtys simoni* (Perkins, 1980), *Notomastus* sp., and *Paraonis* sp.

In this study, *Exogone* sp., *Laeonereis culveri* (Webster, 1879), *Lumbrineriopsis* sp. and *Abyssoninoe* sp. were exclusively found in Buenos Aires stream, while *Alitta succinea* Leuckart, 1847 were exclusively found in Quebra Pote mangroves. *Phyllodoce* sp. and *Streblospio benedicti* showed the lowest abundance at both study sites (Table 4).

Biotic and diversity indexes

The biotic indexes for Buenos Aires stream were: AMBI = 2.46, M-AMBI = 1.00, BENTIX = 5.45 e SHANNON= 2,3. In Quebra Pote, the indexes values were: AMBI = 2.65, M-AMBI = 0.90, BENTIX = 5.11 e SHANNON= 2.1 (Figure 2). According to AMBI, both areas are slightly polluted. The M-AMBI and BENTIX indexes, classify the study areas as unpolluted, and according to the SHANNON index, both areas are classified as moderately polluted.

According to the AMBI index, groups II and III were predominant ecological groups in both mangroves (Figure 3A). According to BENTIX, two ecological groups were detected: sensitive species and tolerant species, with the former presenting a higher percentage (Figure 3B).

Table 4. Absolute abundance and ecological group of specimens collected in Buenos Aires stream and in Quebra Pote mangroves. (BA)= Buenos Aires, (QP)= Quebra Pote and (EG)= Ecological group according to AMBI and BENTIX.

Family/ species	Abundance BA	Abundance QP	(EG) AMBI	(EG) BENTIX	Total Abundance
Ampharetidae					
Isolda pulchella Müller in Grube*, 1858*	7	1	III	I	8
Capitellidae					
Capitella sp.	9	30	V	I	39
Heteromastus sp.	6	12	IV	I	18
Notomastus sp.	23	118	III	II	141
Lumbrineridae					
Lumbrineriopsis sp.	4	0	II	I	4
Abyssoninoe sp.	5	0	II	I	5
Nephtyidae					
Nephtys simoni Perkins*, 1980*	1	109	II	I	110
Nereididae					
Alitta succinea (Leuckart, 1847)	0	13	III	I	13
Nereis sp.	11	7	III	II	18
Perinereis andersoni Kinberg, 1866	2	4	III	I	6
Laeonereis culveri (Webster, 1879)	3	0	III	I	3
Orbiniidae					
Scoloplos texana (Maciolek & Holland, 1978)	7	19	III	I	26
Paraonidae					
Paradoneis sp.	25	16	III	I	41
Paraonis sp.	15	98	III	I	113
Phyllodocidae					
Phyllodoce sp.	1	1	II	I	2
Pilargidae					
Sigambra grubei Müller in Grube, 1858	5	13	IV	I	18
Spionidae					
Streblospio benedicti Webster, 1879	1	1	II	II	2
Syllidae					
Exogone sp.	70	0	II	I	70
Syllis sp.	16	79	II	I	95
Total	**211**	**521**			**732**

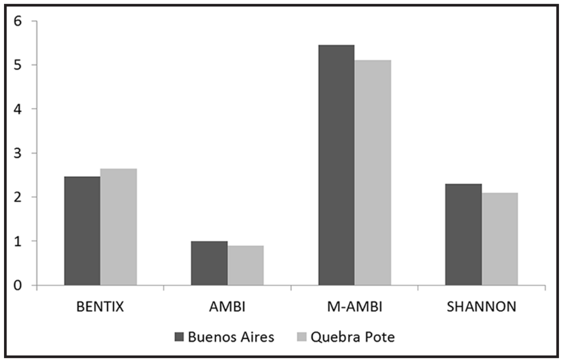

Figure 2. Biotic indexes (AMBI, M-AMBI, BENTIX) and diversity index (SHANNON-WEAVER) for Buenos Aires and Quebra Pote mangroves.

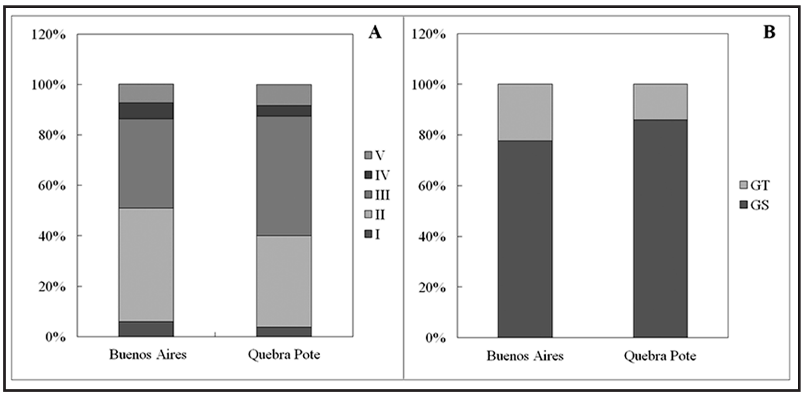

Figure 3. Percentage of Polychaete per group, according to (A) AMBI and (B) BENTIX in Buenos Aires and Quebra Pote mangroves. (*I= sensitive species, II= species indifferent to organic enrichment, III= tolerant species, IV= second-order opportunistic species, V= First-order opportunistic species); *(GT= tolerant group; GS= sensitive group).

The biotic indexes were also applied to verify the gradient of environmental disturbance in each mangrove. For Buenos Aires stream, the corresponding values were: BENTIX (P1=5,27, P2=5,43, P3=5,57), AMBI (P1=2,70, P2=2,39, P3=2,13), M-AMBI (P1=1,00, P2=1,00, P3=1,00) and SHANNON (P1=2,58, P2=2,3, P3=1,83) (Figure 4A). For Quebra Pote, the corresponding values were: BENTIX (P1=5,44, P2=4,43, P3=5,50), AMBI (P1=2,34, P2=2,85, P3=2,38), M-AMBI (P1=1,00, P2=1,00, P3=1,00) and SHANNON (P1=2,14, P2=2,04, P3= 2,0) (Figure 4B).

The BENTIX index for Buenos Aires stream classified all sites as unpolluted, while in Quebra Pote only site P2 was classified as slightly polluted. According to AMBI index, all sites in the study areas were classified as slightly polluted. The M-AMBI index, classified the study sites as unpolluted. On the other hand, the SHANNON index classified the sites P1 and P2 as moderately polluted and P3 slightly polluted, in Buenos Aires stream, while in Quebra Pote, all sites were classified as moderately polluted.

According to One-way ANOVA, there was no significant difference among the littoral zones regarding the indices (BENTIX, AMBI, M-AMBI and SHANNON) (Table 5).

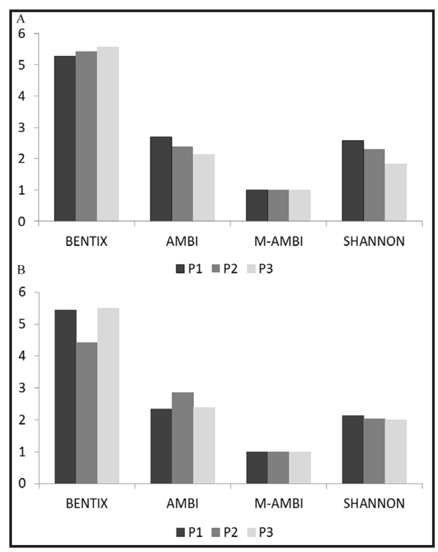

Figure 4. Biotic indices (AMBI, M-AMBI, BENTIX) and diversity index (SHANNON-WEAVER) for PI, P2 and P3 in (A) Buenos Aires and (B) Quebra Pote mangroves.

Table 5. Analysis of variance (One-way ANOVA) among zones according to BENTIX, AMBI, M-AMBI e SHANNON.

	P1		P2		P3	
	F	p	F	p	F	P
BENTIX	2.72	0.11	0.48	0.49	0.41	0.66
AMBI	1.29	0.26	0.77	0.38	1.27	0.30
M-AMBI	0.43	0.51	1.90	0.18	1.87	0.17
SHANNON	0.07	0.78	0.008	0.92	1.56	0.23

DISCUSSION

Environmental parameters

In the present study, water temperature was similar to the expected values to tropical regions, with little variations throughout the year (Siqueira *et al*. 2003). Additionally, abiotic factors such as dissolved oxygen, salinity as well as water temperature, were similar to previous studies carried out in São Luís Port Complex and Quebra Pote mangrove (Siva & Almeida 2002; Carvalho- Neta *et al*. 2012).

Analysis of metals in the water and sediment was not performed in the present study. However, previous studies on metal contamination in the water column and on sediments in the study area showed significantly higher levels of mercury and chrome, indicating that the area exhibit high exposure risks to some contaminants (Cavalcante *et al.* 1990). Such high concentrations in the environment may lead to significant changes in local macrobenthic communities, modifying their structure and distribution (Linnik & Zubenko 2000).

Despite receiving effluents from the Industrial District of São Luís, the Quebra Pote mangroves do not have high levels of metals such as copper and zinc (Castro *et al*. 1999). However, the region has high concentrations of solid residues and domestic effluents released by the local community (Silva & Almeida 2002), which causes the accumulation of organic matter in sediments, leading to significant alterations in the trophic structure by increasing the biomass of benthic communities (Omena *et al*. 2012).

The grain size composition of the mangroves was characterized by elevated silt and clay content, and a large amount of organic matter. Such characteristics were also observed in mangroves on the coast of the state of Maranhão by Sousa et al. (2015) and, on the coast of the state of Pará (Barbosa et al. 2015). The large content of organic matter found in the sediment analyzed in this study might be due to the grain size composition (fine sediment), as well as the indirect action of tides, which normally facilitate retention and assimilation of organic matter (Siqueira and Aprile 2012). Fine particle composition is particularly adequate for the establishment of benthic populations, since there is a large amount of organic matter, besides facilitating their locomotion (McLachlan & Brown 2006).

Polychaetes composition

Nephtys simoni and *Exogone* sp. are carnivores with great motility, being able to cope with habitat instability or move away easily. *Notomastus* sp. and *Paradoneis* sp. are deposit feeders, and their abundance is directly related to food availability (Jumars *et al*. 2015). According to Pearson & Rosenberg (1978), areas with high organic matter are more prone to be colonized and exhibit a greater abundance of these polychaetes.

Alitta succinea was exclusively found in Quebra Pote mangroves. This species has a wide distribution and exhibit high plasticity, being found from rocky shores to intertidal regions, both in marine and brackish environments (Sene-Silva *et al*. 2011).

Phyllodoce sp. and *Streblospio benedicti* were the less abundant species in both study areas. Species of the Phyllodocidae family are characterized by being flexible and mainly associated with hard substrates (Oliveira 2013). Spionidae has widespread geographic distribution, and it is one of the most abundant and diverse taxa (Rocha *et al*. 2009).

The total number of polychaete species observed in Buenos Aires stream was lower when compared to Quebra Pote. This difference may be related to the local disturbances in Buenos Aires stream, once the region is located near the port complex and may be influenced by dredging activities that are carried out frequently. Such physical disturbances might explain why the abundance was lower, since constant removal prevent polychaetes from recolonizing the area (Cruz-Motta & Collins 2004; Powilleit *et al*. 2005; Witt *et al*. 2004; Palmer *et al*. 2008). Moreover, the recovery period after such activity can vary from weeks to years (Harvey *et al*. 1998; Bolam 2004) Despite the rapid expansion of the São Luís port complex, few studies on the local macrofauna were carried out (Ribeiro &

Almeida 2014). Therefore, there is a lack regarding the species resilience and invasion capacity. This situation is worrying since domestic and international maritime transport crosses natural barriers, which facilitates the entry of new species (*Paraonis* sp., *Phyllodoce* sp. and *Syllis* sp.) into environments previously inaccessible by natural means (Carlton 1987, Lodge 1993, Williamson & Fitter 1996).

Biotic and diversity indexes

The AMBI index classified the two mangrove areas classified as slightly polluted due to the predominance of the ecological groups II and III. Species in the ecological group II are indifferent to organic enrichment and species in the ecological group III are tolerant species that may occur under normal conditions, but are stimulated by organic enrichment (Borja *et al*. 2000).

The two areas were considered unpolluted according to the indexes M-AMBI and BENTIX. According to BENTIX, the species are classified into two ecological groups: sensitive species and tolerant species. In the present study, sensitive species were more abundant. However, tolerant or opportunistic species tend to dominate organically enriched environments, and less tolerant or sensitive species are likely to become increasingly rare or disappear altogether (Belan 2003). The SHANNON index overestimated the results compared to the other indexes since it classified the mangroves as moderately polluted. Regarding the littoral zones, no significant difference was observed among the sites P1, P2, and P3, which suggests that there is no gradient of pollution in the intertidal of the two study areas.

In the present study, the ecological status was not congruent according to the biotic indexes, except for M-AMBI and BENTIX that classified the environments as unpolluted. That is opposite to what was observed by Brauko *et al*. (2015) in a southern Brazilian estuary, in which BENTIX and M-AMBI presented a low congruence, and BENTIX and AMBI showed similar results. That was expected, since both of them are based only in the ecological groups and do not consider the global diversity. The M-AMBI index also presented good ecological status in the study carried out by Garaffo *et al*. (2016).

Most of the studies on these biotic indices show that BENTIX presents low levels of discrimination and sensitivity, due to the classification of the species in only three ecological groups (Dauvin et al. 2007, Muniz et al. 2012). Whereas for M-AMBI, overestimation has been observed due to a possible reflection of the incorporation of the SHANNON diversity index and species richness as metrics (Simboura & Argyrou 2010).

Seasonal changes also result in drastic alterations in species composition, affecting indices that include metrics as categories of sensitive pollution and indicative pollution (Chainho 2007). Studies carried out by Salas et al. (2006) and Reiss & Kroencke (2005), showed that diversity indices were more variable than the AMBI method, since the former depends on species composition and abundance, while the latter reflects the balance between indicative pollution and species-sensitive pollution. The incongruent responses among the indices may be due to inadequacy of species attributions in the list of ecological groups of each index, originally developed for European waters (Gillett *et al*. 2015).

It is important to note that changes in the environmental quality coupled with biotic indices are often confused with variability in the distribution of macrobenthic communities, once the indices may vary or respond to natural disturbances (Muniz *et al*. 2012). The community structure of benthic fauna is strongly influenced by environmental characteristics. The spatial and temporal variability of these organisms depends on their life cycle, physicochemical variables (e.g., temperature, salinity and substrate characteristics) and biological interactions, such as predation (Levinton 1995). Benthic organisms are usually widely distributed spatially and influenced by disturbances, biotic and abiotic factors, and the seasonal patterns are correlated with temporal variability of the water column. (Brauko *et al*. 2015). Due to environmental variations, estuarine ecosystems are characterized as naturally stressed, and the greater the degree of stress, the smaller the number of species able to inhabit these systems, leading the dominant species to exhibit opportunistic characteristics (Bemvenuti & Colling 2010).

The present study showed that coupled analyses of biotic indices are in fact useful for the assessment of the effects of environmental impacts on polychaete communities. Future studies should be performed to have a deep understanding of how polychaete distribution patterns in mangroves could be used to understand the impacts of environmental disturbances on local macrofauna. However, using benthic fauna to assess estuarine environments is difficult to interpret due to the high variability of the ecosystem natural conditions. Therefore, further studies are needed to understand the natural variability of the ecosystem and to understand how anthropic impacts on mangroves might affect the survival and health of benthic communities.

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