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VARIABILIDADE ESPAÇO-TEMPORAL DAS ASSEMBLEIAS MACROBENTÔNICAS NO ESTUARIO DO RIO JAGUARIPE, BAÍA DE TODOS OS SANTOS – BA

Salvador

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Temporal and spatial variability on macrobenthic assemblages in the estuary of Jaguaripe river, Todos os Santos Bay – BA, Brazil.

Monografia apresentada ao curso de Oceanografia, Instituto de Geociências, Universidade Federal da Bahia, como requisito parcial para a obtençãodo grau de Bacharel em Oceanografia.

Orientador : Prof. Dr. FRANCISCO C. R. DE BARROS JR.

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“We know too well that what we are doing is nothing more than

a drop in the ocean. But if the drop were not there,

the ocean would be missing something.”

— Mother Teresa

Sumário

RESUMO

Estudos de longo-período são essenciais para o entendimento de fontes de variabilidade naturais e antrópicas nos estuários. Porém poucos estudos são feitos em estuários com baixa eutrofização, o que dificulta a detecção das variações temporais não-naturais (ex. mudanças climáticas, poluição, espécies exóticas, atividades exploratórias). O principal objetivo deste trabalho foi descrever a variabilidade espacial e temporal na distribuição da macrofauna bentônica. Amostras foram coletadas ao longo de um estuário tropical em quatro campanhas (2006, 2007, 2010 e 2014) em todo o gradiente de salinidade. Os resultados demonstraram um aumento de riqueza, abundância e mudanças de dominância temporalmente. O padrão espacial de riqueza mostrou um decaimento da diversidade da área marinha para a de água doce. As assembléias bentônicas de diferentes zonas de acordo com o sistema de Venice demonstraram diferenças significativas em sua estrutura. Variações granulométricas ao longo dos anos foram observadas, com uma redução das frações finas. O aumento dos indivíduos da família de Nereididae foi considerado como importante alteração e pode estar associada com variações granulométricas.

Palavras-chaves: Padrão estuarino, Sistema de Venice, Estrutura das assembleias e Sedimento.

O trabalho de graduação foi escrito em forma de artigo na língua inglesa, pois o mesmo tem como intuito uma publicação na revista internacional. Sendo assim a banca examinadora contribuirá para que o produto dessa monografia seja submetido. Porém foi exigido pelo colegiado do curso que a mesma apresentasse resumo, introdução e conclusão na língua portuguesa.

INTRODUÇÃO

Estuários são considerados um ecossistema muito importante tanto ecologicamente com alta produtividade, ciclagem de nutrientes e fluxo energético (Day, 1989; Kaiser et al., 2005; Schelske and Odum, 1961) como fonte marinha de serviços ecossistêmicos (Costanza et al., 2014). Estes apresentam uma alta variabilidade, resiliência e a maioria dos estuários do mundo são impactados antropicamente (Elliott and Whitfield, 2011).

O sistema de Venice veio como uma forma de classificar em zonas os estuários com base em salinidade, este define seis zonas: Limetica (0 – 0.5), Oligohalina (>0.5 – 5), Mesohalina (>5 – 18), Polihalina (>18 – 30), Euhalina (>30 – 40) e Hiperhalina (>40) (Limnology and Sciences, 1959). Este sistema vem sendo usado pela WFD (European Water Framework Directive), porém é questionado por alguns autores (Chainho et al., 2006; Taupp and Wetzel, 2014; Wolf et al., 2009).

Underwood (2000) questionou em seu estudo a diminuição dos estudos sobre padrão, sendo que estes servem de base cientifica para modelos de processos e estudo chave para monitoramento (Levin, 1992). O estudo de padrão mais utilizado em estuários é o modelo de Remane que analisa as variações de espécies marinhas, dulcícolas e salobras e sugere uma zona de diversidade mínima chamada de *artenminimum* (Kaiser et al., 2005). Estudos feitos no Brasil, França e Estados Unidos já contradizem esse modelo e propõem que ocorreria apenas uma diminuição de diversidade da área marinha para a dulcícola (Barros et al., 2014, 2012).

Os estudos de longo-prazo são mais indicados para entender a dinâmica populacional e seus fatores (Franke and Gutow, 2004), além de necessários para compreender a variabilidade natural e distinguir esta de impactos antrópicos (Borja and Rodriguez, 2010; Chainho et al., 2010; Elliott and Quintino, 2007; Hardman-Mountford et al., 2005; Magurran et al., 2010), porém esses estudos ainda são raros no Brasil (Bernardino et al., in press). Essas variações são causadas por quatro principais razões: mudanças climáticas, pesca e atividades exploratórias, espécies exóticas e poluição (Franke and Gutow, 2004). Dentre as mudanças climáticas podem ser citados efeitos como entrada de água doce, aumento da temperatura e maior ocorrência de tornados e furacões, sendo que a entrada de água doce é critica nos sistemas estuarinos (Day et al., 2008), pois pode ter bastante impacto nas zonas de salinidade afetando principalmente as espécies mais restritas a salinidades especificas (Attrill, 2002; Whitfield et al., 2012)

A menor mobilidade é um dos fatores que sugerem os organismos bentônicos como indicados para analises de variações temporais (Franke and Gutow, 2004; Pearson and Barnett, 1987). Alguns estudos já vêm sendo feitos utilizando esse grupo com períodos de 6 a 53 anos e todos salientam sua importância e a carência de mais estudos (Barry et al., 1995; Chainho et al., 2010; Dauer and Alden, 1995; de Juan and Hewitt, 2014; Frid et al., 2000; Grémare et al., 1998; Kolbe and Michaelis, 2001; Pollack et al., 2009). Varias consequências nos organismos bentônicos são associadas ao impacto humano como redução da densidade total, biomassa e riqueza, decaimento da relação predador/presa, redução do tamanho de espécies chave (de Boer and Prins, 2002). As mudanças climáticas já vêm sendo apontadas como causa de mudanças na comunidade bentônica (Barry et al., 1995; de Juan and Hewitt, 2014; Kim and Montagna, 2009). Por exemplo já foi relatado que mudanças de entrada de água e temperatura possam estar associadas ao aumento de comedores de depósito e à diminuição de suspensívoros (Kim and Montagna, 2009; Kolbe and Michaelis, 2001). Variações granulométricas e enriquecimento orgânico são outras possíveis causas dessas mudanças temporais (Dauer and Alden, 1995; Grémare et al., 1998; Kolbe and Michaelis, 2001).

Em resposta a essas modificações físicas a comunidade bentônica vem demonstrado algumas alterações como variações de abundância, riqueza e biomassa (Dauer and Alden, 1995; Grémare et al., 1998; Pollack et al., 2011) geralmente associada à substituição de espécies (Barry et al., 1995; de Juan and Hewitt, 2014; Frid et al., 2000; Kim and Montagna, 2009). Então os objetivos desse estudo são analisar a estrutura das assembléias bentônicas em um estuário tropical descrevendo padrões espaciais e temporais e testar se a estrutura das assembléias bentônicas serão diferentes em diferentes zonas do sistema de Venice.

Title

Temporal and spatial variability on macrobenthic assemblages in the estuary of Jaguaripe river, Todos os Santos Bay – BA, Brazil.

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1. ABSTRACT

Long-term monitoring are essential to understand natural and anthropogenic sources of variability in estuaries. Very few studies were done in pristine estuaries to detect long-temporal causes (e.g. climate change). The main goal of this study was to describe spatial and temporal variability of benthic macroinfaunal assemblages. Samples along a tropical estuary were collected in four years (2006, 2007, 2010 and 2014) along the entire salinity gradient. Results showed an increase of diversity, abundance and changes in dominance among years. Benthic macrofauna values of richness decreased from marine to freshwater portions. Benthic assemblages of the different zones, according to the Venice system, showed significantly different structure. Changes in sediment fraction along years were observed, with reduction of fine grains. Increase of individuals from Nereididae family was notice as an important change and could be associated with changes in sediment.

Keywords: Estuarine patterns, Venice system, assemblage structure, sediment.

2. INTRODUCTION

Estuaries can be regulated by geological, physical and biological variables (Day, 1989) and, especially the latter, have a great importance in energy flux and nutrients recycle (Day, 1989; Kaiser et al., 2005). Furthermore, estuaries are among the most valuable marine ecosystems (Costanza et al., 2014), are well known as highly variable and resilient systems and almost all estuaries in the world are affected by anthropogenic activities (Elliott and Whitfield, 2011).

The Venice System is the most widespread classification of estuarine salinity zones and classifies estuarine gradients in Limnetic [0 - 0.5), Oligohaline (>0.5 – 5), Mesohaline (>5 – 18), Polyhaline (>18 – 30), Euhaline (>30 – 40) and Hyperhaline zones (>40) (Limnology and Sciences, 1959). The European Water Framework Directive (WFD) adopts this system to characterize transitional and coastal waters. Some studies have suggested that this system can be applicable without modifications in regions without marked seasons, because less changes in freshwater input would be observed in estuaries at these regions (Chainho et al., 2006; Reiss and Kröncke, 2005) and in comparison with others system of classification, only Limnetic and Polyhaline zones coincide with the zones created by fauna similarity (Taupp and Wetzel, 2014).

Estuaries are naturally stressful environments therefore, to find general spatial patterns to build solid theoretical models are not an easy task. Fifteen years ago, Underwood (2000) questioned about the necessity of understanding patterns before processes, he found a large number of articles about processes and a decreasing number of studies describing patterns. The understanding of a pattern is essential as scientific basis to extrapolate to process models and key for the development of principles for management (Levin, 1992).

The Remane model, which introduces the variation in marine, freshwater and brackish species and suggests a diversity minimum zone called arteminimum is the most popular estuarine model (e.g. Whitefield et al., 2012; Kaiser et al., 2005). Nevertheless, in some parts of the world such in tropical estuaries of the Brazilian coast it has been suggested that estuaries only showed gradual decrease of diversity from marine to freshwater zones (Barros et al., 2012) . More recently, it was also suggested for some temperate estuaries (Barros et al., 2014) and for intertidal assemblages (Mariano and Barros, 2014).

Estuarine spatial variability is more studied than temporal variability and, when temporal variability is studied, they are mostly restricted to seasonal variations (Rhoads and Germano, 1986).It’s already suggested that annual changes play a more important role than seasonal changes (Chainho et al., 2010) and long-term studies are more indicated to understand population dynamics and the factors that influence those (Franke and Gutow, 2004). Temporal studies are very important, although they are still rare in Brazilian estuaries (Bernardino et al., in press), they are essential to understand the natural variability avoiding confounded interpretations of anthropic impacts (Borja and Rodriguez, 2010; Chainho et al., 2010; Elliott and Quintino, 2007; Hardman-Mountford et al., 2005; Magurran et al., 2010), even though very few studies are done in areas that may not show eutrofization, which can difficult the detection of other annual factors of change such climate changes (Dauer and Alden, 1995; Patrício et al., 2009).

For instance, several reasons can cause long-term ecological changes: climate changes, fishing and other exploratory activities, introduction of exotic species and organic and inorganic pollution (Franke and Gutow, 2004). Estuarine monitoring is crucial to evaluate impacts due to climate changes such as changes in the input of freshwater, rise of seawater level and higher frequencies of extreme events (e.g. hurricanes and tornados). Changes in the inflow of freshwater is critical for estuarine systems, it can also cause the increase or decrease inputs of sediment and nutrients (Day et al., 2008).

Benthic fauna are indicated to long-term studies, they are less mobile insuring detailed and precise observations in time (Franke and Gutow, 2004; Pearson and Barnett, 1987). Some studies have described long-term changes in the benthic community in periods of 6 (Dauer and Alden, 1995) to 53 years (Frid et al., 2000), and all salient that few studies are done; even so, they are very important (Barry et al., 1995; Chainho et al., 2010; Dauer and Alden, 1995; de Juan and Hewitt, 2014; Frid et al., 2000; Grémare et al., 1998; Kolbe and Michaelis, 2001; Pollack et al., 2011).

Human impacts are a well documented cause of changes in benthic fauna that can occur in different ways such as reducing total density, biomass and richness, decreasing predator/prey ratios and reducing the size of keys species (de Boer and Prins, 2002). Climate changes has been pointed as cause of modifications in the benthic fauna and it can produce habitat fragmentation (de Juan and Hewitt, 2014), changes in the input and output of water (Kim and Montagna, 2009)and increase of the global temperature (Barry et al., 1995; de Juan and Hewitt, 2014). Changes in water input as increase of temperature can increment salinity and this has been correlated with the increase of deposit feeders and the decrease of suspension feeders (Kim and Montagna, 2009; Kolbe and Michaelis, 2001). Other possible explanation of this modifications are grain sizes variations, especially when occur changes in estuarine hydrodynamic (Grémare et al., 1998; Kolbe and Michaelis, 2001). Organic enrichment is pointed as another explanation of long-term variations and usually drive to an increase of opportunistic species (Dauer and Alden, 1995; Grémare et al., 1998).

A diversity of responses in the benthic fauna are related in long-term monitoring and showing increase in richness, abundance and biomass associated to increase in water quality after longs period of human impact (Dauer and Alden, 1995), increase in richness and abundance but a decrease in biomass because of change in the local grain texture with increase of fine material (Grémare et al., 1998), decrease of richness, abundance and biomass related to decline of mean salinity (Pollack et al., 2011) and in a lot of these studies was found changes in the benthic community structure by turnover (Barry et al., 1995; de Juan and Hewitt, 2014; Frid et al., 2000; Kim and Montagna, 2009).

So the aims of this study were to analyze the structure of benthic assemblages in a tropical estuary describing general spatial and temporal patterns and to test if benthic assemblages structure would be different at different zones accordingly to the Venice System. Two main hypothesis was tested: 1- The spatial pattern are a decrease of diversity to marine to freshwater areas without the *artemninimum* zone and this pattern remain along the years, 2 – Stations of same Venice’s zone shows high fauna similarity.

3. MATERIALS AND METHODS

3.1. Study area

Todos os Santos Bay (TSB) is a large Brazilian bay, with 1233 km^2,with a high ecological, economical and social values with a great variety of environments like estuaries, reefs and mangroves. The water column is well mixed with well-marked estuaries in the output of rivers (Hatje and de Andrade, 2009). The three largest tributaries in this bay are Paraguaçu, Subaé and Jaguaripe rivers. The estuary of the Jaguaripe River has unique characteristics as its position, it localizes in the most external part of the bay, close to the Itaparica channel with a great connection with the open sea (Fig. 1). The Jaguaripe estuary was suggested as reference area for TSB because there was not found evidences of metal contamination and the benthic macrofauna distribution might be more correlated with natural stressful conditions (Krull et al., 2014). Previous studies at Jaguaripe estuary focused on intertidal benthic fauna (Mariano and Barros, 2014), β-diversity of subtidal benthis assemblages (Barros et al., 2014), polychaeta fuctional groups (Magalhães and Barros, 2011) and also compare spatial patterns with the other estuaries in the region (Barros et al., 2012).

3.2. Macrofauna

The samples were taken in four occasions, May 2006, August 2007, July 2010 and August 2014. Ten sampling stations were distributed along the estuary (Fig. 1) and each station had two sites that were 50 meters apart and four replicates were sampled at each site (N= 80 per sampling date. All the samples were collected by scuba divers with PVC corers (10cm of diameter and 15cm depth) and were carried to the Benthic Ecology Laboratory (LEB). Macrofauna samples were collected in two sites in each station. All samples were washed in the field with 0,5mm mesh, kept in labeled plastic bags, fixed with 70% alcohol and frozen. In the lab, samples were washed with 0,5mm mesh and sorted with a stereoscopic microscope. Invertebrates were identified to family level using this list of books: Amaral et al., 2006; Beesley et al., 2000; Buckup and Bond-Buckup, 1999; Melo, 1999, 1996; Rios, 1985, as suggest by Souza and Barros (2014) for another estuary in the region and by Guzmán-alvis (2005) and Chainho (2007) elsewhere.

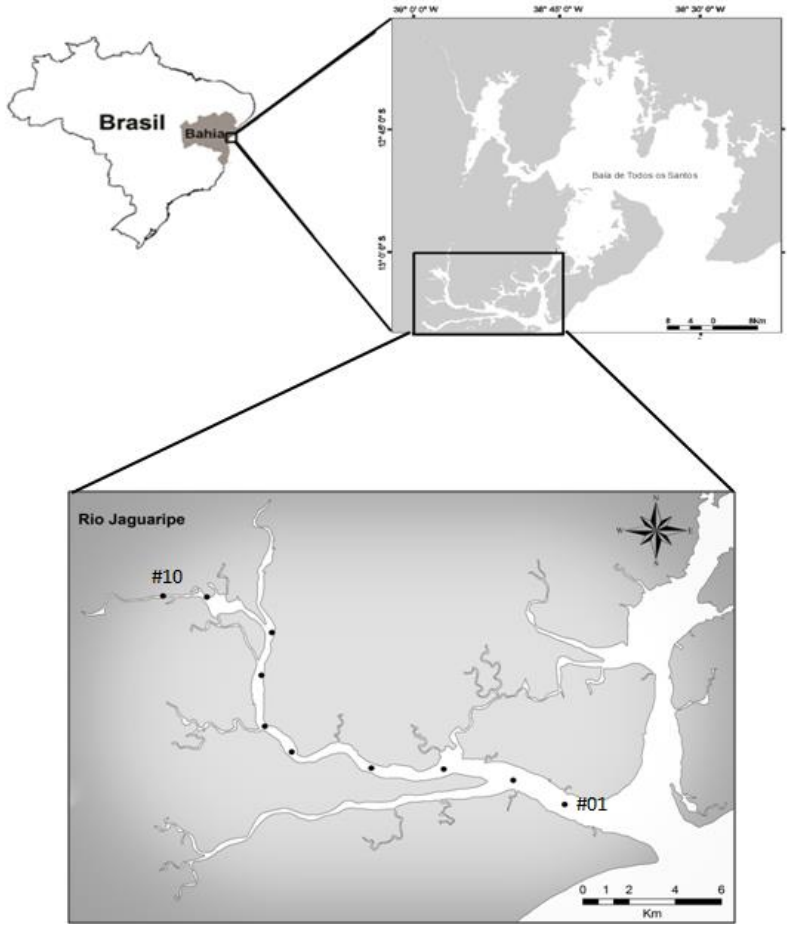

Fig. 1. The location map of the studied with the samples position in Jaguaripe estuary.

3.3. Data analysis

Spatial and Temporal variations were analyzed using multivariate statistical techniques with the PRIMER software package. Similarity percentage breakdown procedure (SIMPER) was used to determine the contribution of samples towards the dissimilarity between and similarity within the Venice's zones, the years and combination of both. Densities of the dominant species were plotted for each family (View complementary material). Similarity matrix was calculated using the Bray-Curtis coefficient and was used to a non-parametric multidimensional scaling (n-MDS) ordination to each years and all years together, the Venice's zones was used as labels to compare similarity. Two-way crossed analysis of similarity (ANOSIM) procedure were used to determine if there was a significant difference between zones and years with respect to species composition and to assign stations to areas. To analyze if the benthic fauna would show replacement in the years and between the years was used the Relate Routine with Spearman correlation.

3.4. Granulometry

For sediment size analyses, in 2006, 2007, 2010 2014 one sample was collected at each station (Fig. 1) and frozen, but 2010 samples were lost. They were washed with 0,063mm mesh, dried until constant weight, sieved with an electromagnetic agitator with different mesh sizes (4 mm; 2mm; 1mm; 0,5mm; 0,25mm; 0,125mm and 0,063mm) and weighted.

3.6. Venice's zones

The stations was grouped in zones based in early study of Krull (2014). Based on mean salinity of 2004 to 2013, stations #1 and #2 was considered as Euhaline, #3, #4 and #5 was Polyhaline, #6 and #7 was Mesohaline and #08, #09 and #10 was Oligohaline (Fig. 2).

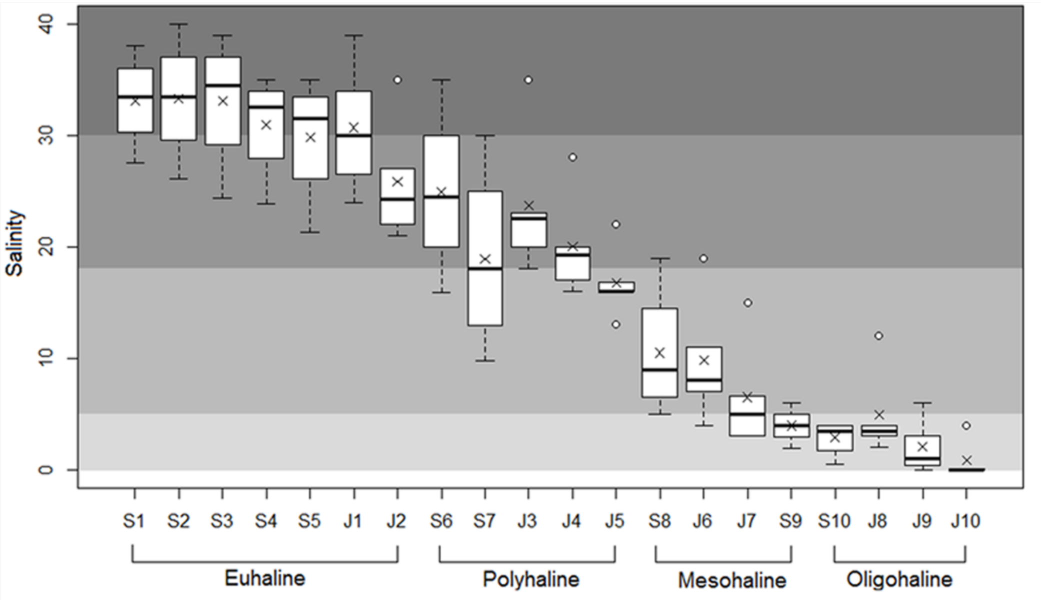

Fig. 2. Venice's zones of Jaguaripe and Subaé estuaries (adapted from Krull et al., 2014).

4. RESULTS

4.1. Spatial patterns in benthic community

A total of 3.442 invertebrate specimens was collected, and 69 different taxa were identified during the study period and the major group was polychaetes (84%). The number of families showed a relative increase from 2006 to 2014 and abundance had a large increase in the latest sampling occasion (Table 1), mainly due to high values of Nereididae in station #10.

Table 1. Number of organisms, families and individuals of polychaete, crustacean and mollusk in 2006, 2007, 2010 and 2014 on Jaguaripe River.

	Jaguaripe River			
	2006	2007	2010	2014
Number of organisms	553	698	617	1574
Number of families	23	35	39	45
Number of polychaetes	415	633	520	1234
Number of crustaceans	43	14	18	56
Number of mollusks	75	40	36	69

The number of individuals and families (Fig. 3) showed a general decline in richness from marine to freshwater zones. The abundance didn't show a clear pattern but was observed a increase of abundance in the station 10 that was associated to increase one family of polychate (Nereididae). In 2014 the Nereididae family correspond 50% of organisms found in that year.

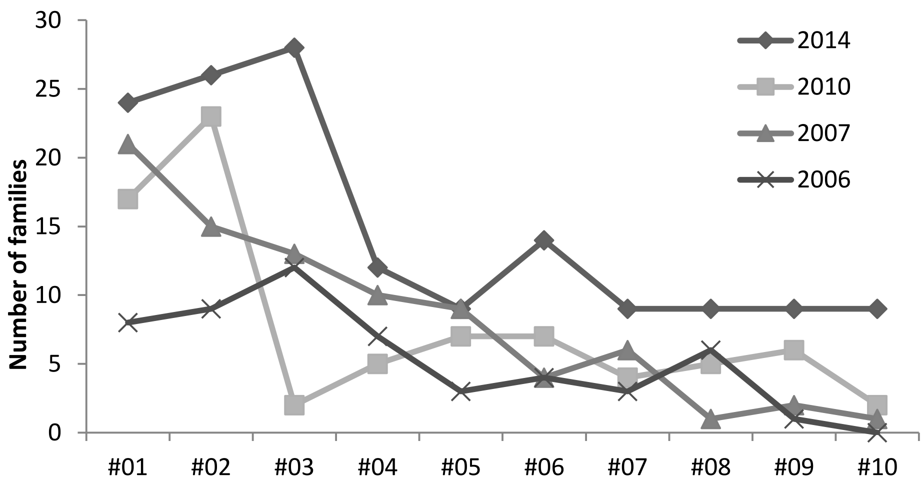

Fig. 3. Number of families along Jaguaripe estuary in 2006, 2007, 2010 and 2014.

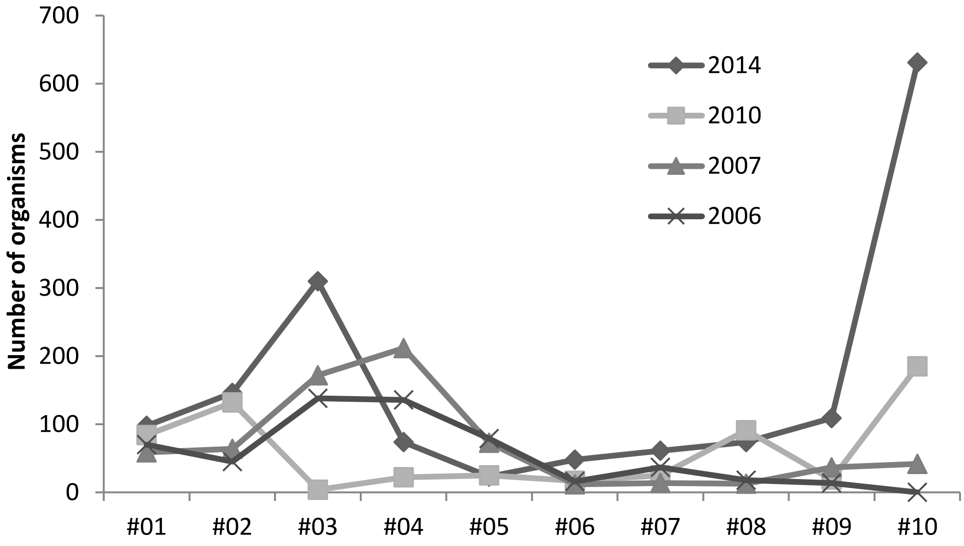

Fig. 4. Abundance along Jagauripe estuary in 2006, 2007, 2010 and 2014.

The results of ANOSIM tests showed a significant difference overall between the zones in all years: 2006 (R=0.528, P=0.001), 2007 (R=0.7, P=0.001), 2010 (R= 0.342, P=0.001) and 2014 (R= 0.233, P=0.018). The SIMPER analysis indicated dissimilarity of more than 80% between the zones in 2006, 2007 and 2010 but in 2014 the dissimilarity was between 68% and 88% between the zones. In 2006 less than three families (Magelonidae, Orbiinidae e Tellinidae) contributed with more than 50% of this dissimilarity and the same was observed in 2007 and 2010. Even though in 2014 were necessary more than five families to explain the zones difference. All the most contributed are families abundant dominant (Complementary material). All the years had a significant patterns of seriation and had significance level of 0.001 with a different rho values, 2006 (rho=0,506), 2007 (rho=0,529), 2010 (rho=0, 29) and 2014 (rho=0,434). In all years, no values of permutations were greater or equal to the rho observed.

Multivariate ordination (nMDS) showed a clear separation between the Venice's zones in all years even though 2014 (Fig. 8) did not demonstrate the perfect distinction than the others years. Closer zones demonstrated more similarity as Polyhaline and Euhaline with each other than with Mesohaline and Oligohaline that had more similarity with each other too. The contrast of the graphics of 2006 (Fig. 5) and 2007 (Fig. 6) with 2010 (Fig. 7) and 2014 (Fig.8) suggested that the zones are less marked in more recent years.

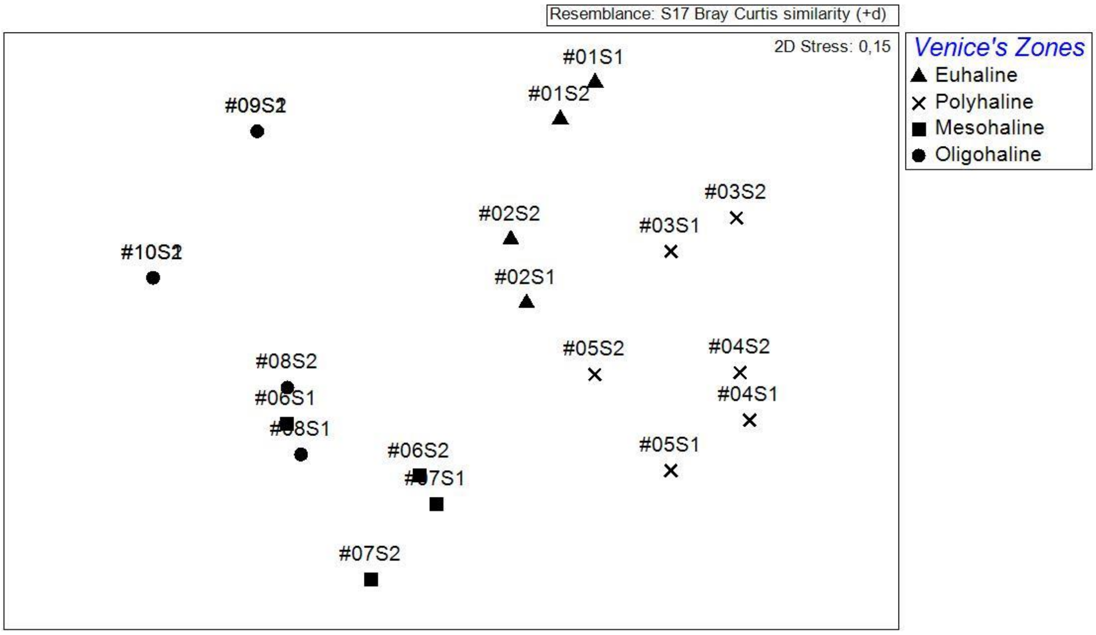

Fig. 5. MDS ordination of species abundances of 2006. Variously shaped symbols refer to zones.

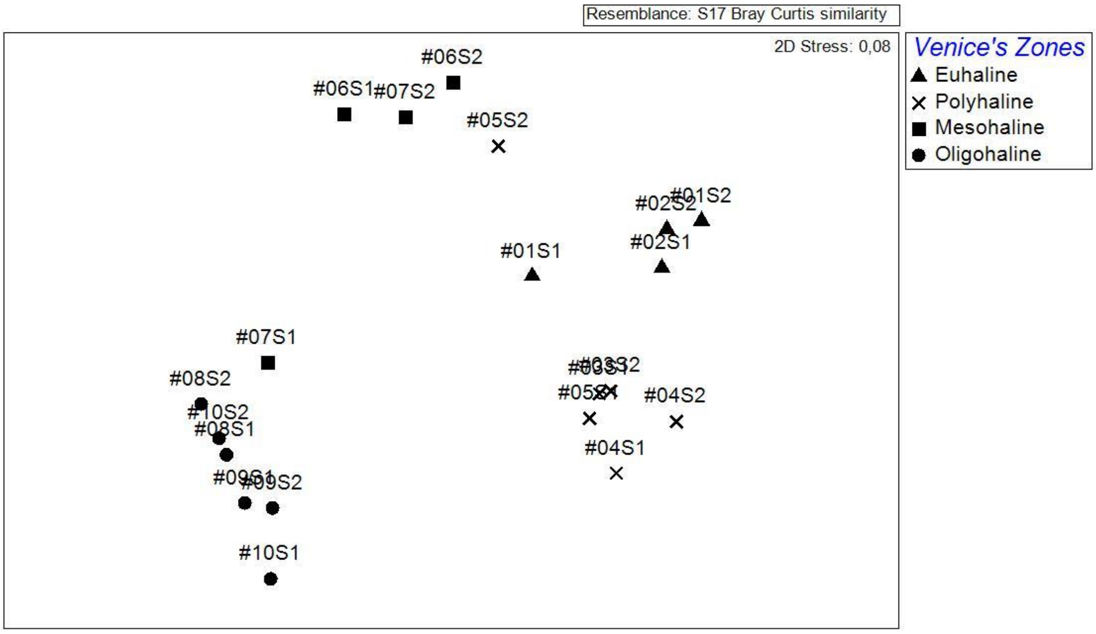

Fig. 6. MDS ordination of species abundances of 2007. Variously shaped symbols refer to zones.

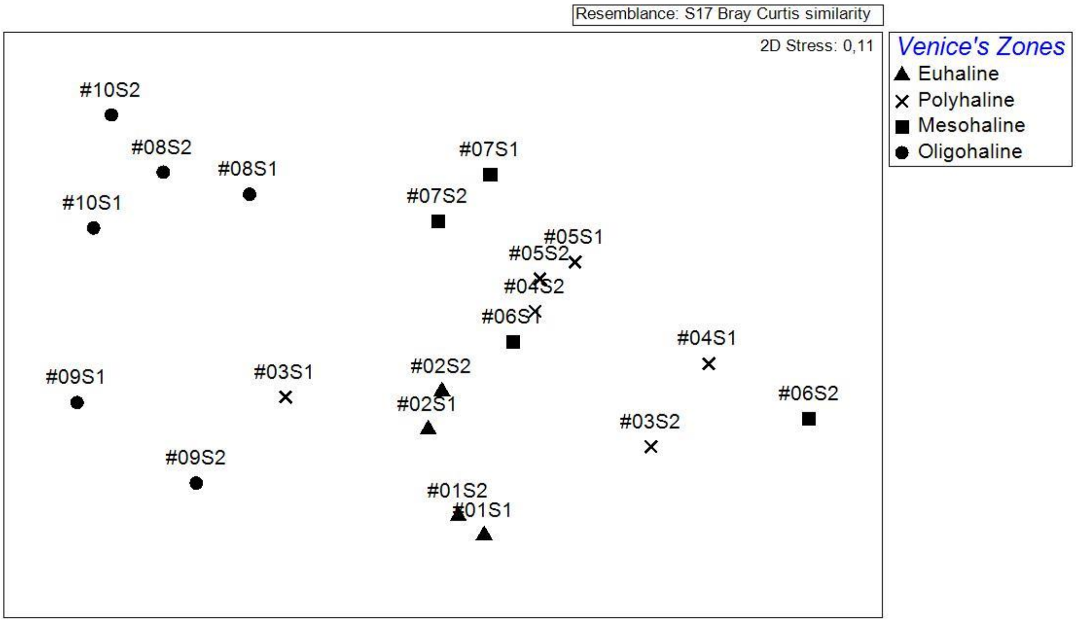

Fig. 7. MDS ordination of species abundances of 2010. Variously shaped symbols refer to zones.

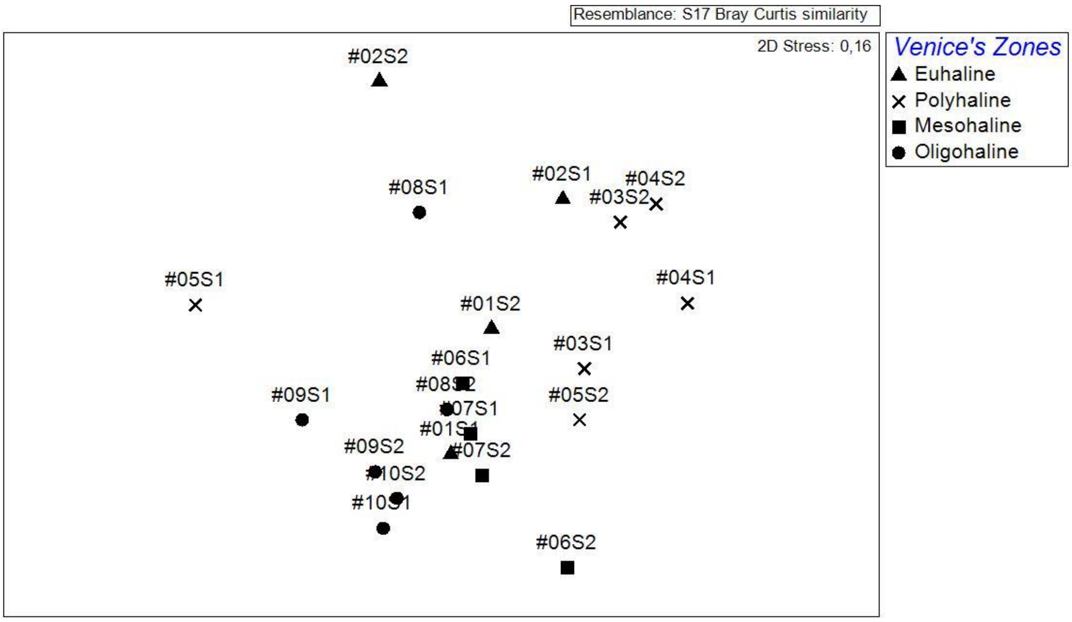

Fig. 8. MDS ordination of species abundances of 2014. Variously shaped symbols refer to zones.

4.2. Temporal variation in benthic communities

Two-way ANOSIM crossed with nested showed significant difference (R=0,567, P=0.001). The results of SIMPER of years demonstrated an average dissimilarity of 90% and Nereididae was the taxa that contributed the most. SIMPER for the zones showed dissimilarities of 90% too but the most contributors were Nereididae, Magelonidae e Orbiinidae. Two-way SIMPER (Zones and years) showed that the similarity between zones increase 20% than only year or zone as factor. Pattern of seriation was considered significant with rho value of 0.11, significance level of 0.001 and no permuted values was greater than or equal to the observed rho.

nMDS analysis (Fig. 9) indicated that zones are as important as years and can be observed that samples of 2014 are closer to 2010 than 2006.

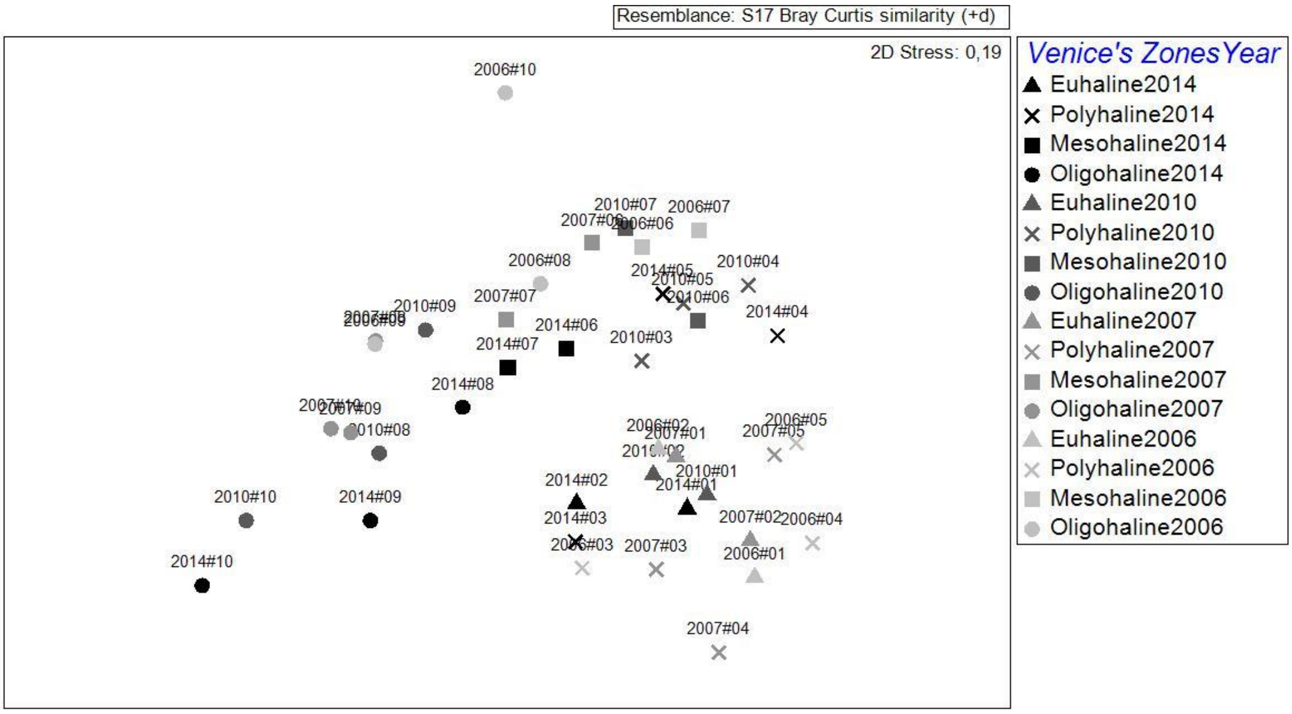

Fig. 9. MDS ordination of species abundances. Variously shaped symbols refer to zones and colours to years.

4.3. Granulometry

In all sampled years, sediments were mostly dominated by very fine sand with a clear pattern of finer fractions in stations #3, #4 and #5 (Fig. 10). In 2014, it was observed coarser fractions in freshwater stations than at the others years. In all the years the stations #3, #4, #5 and #8 were dominated by very fine sand, in the stations #1 and #2 was found a domination of very fine and fine sand, although fine sand was predominant in almost all years, the stations #6 and #7 had more fine sand and middle sand than the others fractions. In the stations #09 and #10

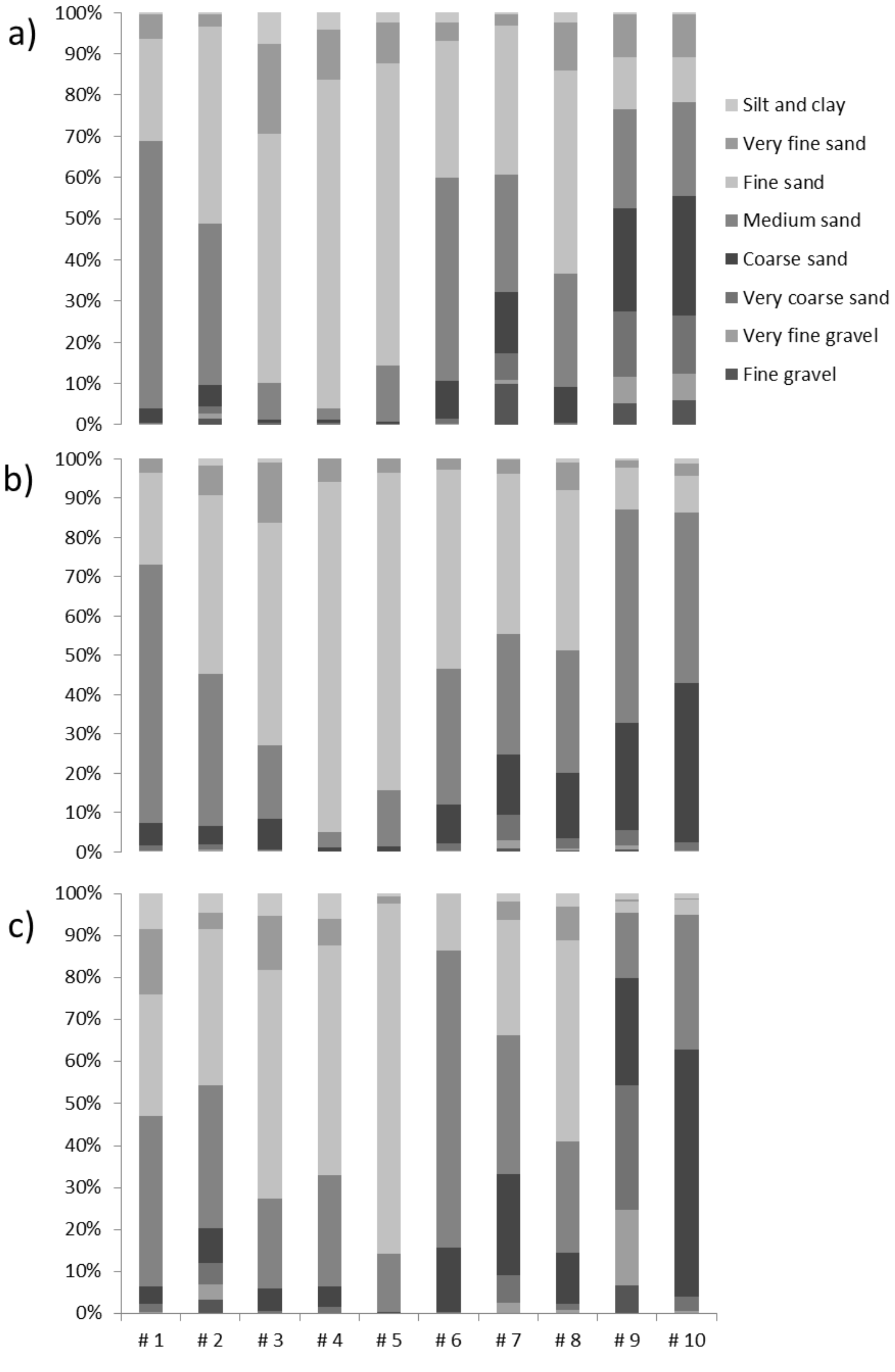

Fig. 10. Percentage of sediment fractions along the Jaguaripe estuary on 2006 (a), 2007(b) and 2014(c).

5. DISCUSSION

The first aim of this study was to understand the general spatial pattern in Jaguaripe estuary. The richness pattern found contributed to the suggestion of Barros (2014) that benthic macrofauna diversity decreases from marine to freshwater, indicating that the decline of salinity is the main factor regulating it (Bleich et al., 2011). The pattern was different to the well-known pattern of Remane and the arteminimum zone was not found. Similar pattern was also described by others studies (Attrill, 2002; Barros et al., 2012). The Baltic Sea, to build Remane's diversity model, is a homoiohaline estuary, so does not present significant variations of salinity, and this may be relate to the increase of diversity observed in the oligohaline zone.

Temporal variations occurred even in dominance (Complementary material) and peaks of abundance. Changes in dominance occurred especially in 2014 compared to other years when the dominance was distributed between more taxa but in a less equitable way. This study detected small increases in richness and large increases of abundance in 2014, what was similar to others long-term studies (Dauer and Alden, 1995; de Paz et al., 2008; Grémare et al., 1998). Generally it has been attributed to three main factors: improvement of water quality (Dauer and Alden, 1995), proximity to oyster culture rack (de Paz et al., 2008) and decrease of fine grains (Grémare et al., 1998). The firsts are quite improbably and the most indicated are changes in granulometry what is already suggested as a very important role in log-term changes on community structure (Silva et al., 2006).

Granulometry pattern was as expected and similar to Hatje (2010) but in 2014 was observed that in the inner stations occurred coarser fractions than other years. As what was related in Grémare (1998), these long-term variations in sediment could be responsible for responses in benthic fauna. In 2014, there was an increase of abundance in freshwater stations and this may be associated to the reduction of fine sediment because proportion of fine particles was related as negatively correlated to macrobenthic fauna (de Paz et al., 2008). However, this needs formal tests. Some studies observed that changes in the input of sediments would be responsible for one species of polycheata increase and the same reason could be the answer to increase of Nereididade family in the present study (Grémare et al., 1998). Magalhães and Barros (2011) showed that species form this family ingests fine sand and detritus. Some studies made about Nereididae family found that some species are highly tolerant to heavy metals (Bryan and Hummerstone, 1973) and to low oxygen concentration (Henriksson, 1969). Other studies, have found that some species of Nereididae family would be negatively affected by pollution because it may affect their recruitment (Gillet et al. 2008).

However, as this estuary is considered as a low impacted system, human impacts as possible causes of changes were unlikely important.

Venice's system was considered an adequate way to group benthic assemblages in this estuary and assemblages of one zone were dissimilar to others zones. In the nMDS graphs it was observed that station from the same zone seems to be grouped. Therefore, there were high correlations between assemblage structure and salinity. Jaguaripe estuary are characterized as poikilohaline estuaries, estuaries that presents strong salinity fluctuations, and this kind of estuary was incompatible with the Venice System (Taupp and Wetzel, 2014). Nevertheless this estuary does not shows marked seasons (Barros et al., 2012) and this might be associated to a well applicability of this system (Chainho et al., 2006). Although this study suggests that these zones are affected by temporal variability since occurred years like 2014 that had less marked zones than early years. The SIMPER analysis contributed to this tot because when we group sample for the same year and the same zone occur an increase in the fauna similarity. So we suggested because of the fauna similarity, the Venice system could be applied as an ecological classification not only as a physical classification based in salinity.

This study contributed to understand the variability in a tropical estuary what could be used in monitoring systems to evaluate possible anthropic interferences and confirms the importance of long-term studies with adequate spatial and temporal understanding of ecological conditions of estuarine ecosystems.

6. CONCLUSION

Although Remane's model is widespread, the present study corroborated with the suggestions that spatial pattern in estuary is represented by a diversity decrease. Relevant conclusions can be taken from our study: (1) Abundance, dominance and richness detected temporal and spatial changes; (2) Sediment variability could be the main cause of these variations; (3) The increase of Nereididae family might be associated to a reduction of fine grains. Jaguaripe estuary showed an increase of diversity and this results suggests that more studies are require to analyze the dynamic behavior of richness, so is necessary more work on temporal scales that can contribute to this (White et al., 2006).

The Venice System can be applied in poikilohaline estuaries and it was not limited to homoiohaline estuaries as was suggested by Taupp (2014). The benthic fauna was welldescribed by this system, so we suggest as a reliable classification and we can imply that the Venice system could be apply as ecological categorization.

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CONCLUSÃO

Apesar do modelo de Remane ser bastante utilizado, este estudo contribui com a sugestão de que o padrão espacial em estuários se da com um decaimento da diversidade. As seguintes conclusões relevantes podem ser retiradas desse estudo: (1) Abundância, riqueza e dominância detectaram variações temporais e espaciais, (2) a variabilidade granulométrica pode ser considerada a causa principal das variações temporais e (3) o aumento de indivíduos da família de Nereididae pode estar associado com a redução de grãos finos. O estuário do Rio Jaguaripe apresentou um crescimento de riqueza e esse resultado sugere que mais estudos são necessários para analisar o comportamento dinâmico de diversidade, então são essências mais trabalhos de escala temporal que possam contribuir com isso (White et al., 2006).

O sistema de Venice pode ser aplicado em estuários poikilohalinos e não estão somente limitados a estuários homoiohalinos como sugerido por Taupp (2014). A fauna bentônica foi bem descrita por esse sistema, então o sugerimos como categorização confiável e acreditamos que o sistema de Venice pode ser usado como categorização ecológica.

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10. COMPLEMENTARY MATERIAL

Fig. 11. Abundance of dominant taxa in all years along Jaguaripe estuary in all years. Dominant families were in 2006 (Cirratulidae, Magelonidae, Orbiniidae and Tellinidae), 2007 and 2010 (Nereididae, Cirratulidae, Magelonidae and Orbiniidae) and 2014 (all taxa except Orbiinidae).