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Resposta da biocenoce e da tafocenose de foraminíferos e tecamebas a hidrodinâmica no Delta do Rio Paraíba do Sul – Rio de Janeiro

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RESPOSTA DA BIOCENOCE E DA TAFOCENOSE DE FORAMINÍFEROS E TECAMEBAS A HIDRODINÂMICA NO DELTA DO RIO PARAÍBA DO SUL – RIO DE JANEIRO

Monografia do Trabalho de Conclusão de Curso apresentada ao Instituto de Biociências da Universidade Federal do Estado do Rio de Janeiro, como parte dos requisitos à obtenção do título de Bacharel em Ciências Ambientais.

Orientador: Prof. Dr. Lazaro Luiz Mattos Laut

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“O homem quando está em paz não quer guerra com ninguém.”

Charlie Brown Jr.

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RESUMO

O Rio Paraíba do Sul (RPS) compõe um dos principais sistemas deltaicos do Brasil, percorre centros urbanos de São Paulo, Minas Gerais e Rio de Janeiro e tem sido severamente afetado por impactos antrópicos como construção de barragens e exploração irregular de areia, o que intensifica a ocorrência de processos erosivos costeiros. A fim de diagnosticar os impactos ambientais, foraminíferos e tecamebas foram utilizados como ferramenta para este estudo, objetivando a caracterização e distribuição da biocenose e da tafocenose destes microrganismos no delta do RPS, visando a identificação dos setores ambientais e condições hidrodinâmicas, com base nos parâmetros físico-químicos, sedimentológicos e biológicos. Ao longo de 24 estações foram identificadas 22 espécies de foraminíferos vivos e 63 mortos, além de 8 espécies de tecamebas vivas e 10 mortas. Os microrganismos dominantes no RPS foram os foraminíferos *Ammonia tepida*, *Cribroelphidium excavatum*, *Haplophragmoides wilberti* e *Trochamminita salsa*. Utilizando a análise de DCA foi possível determinar dois setores dentro do sistema deltaico. O primeiro foi influenciado por maiores valores de silte, argila, matéria orgânica e carbonato tendo como bioindicadores de regiões estuarinas as espécies *A. tepida* e *C. excavatum*, e o segundo foi influenciado por maiores valores de areia, temperatura e potencial de oxirredução, tendo como bioindicadores de regiões fluviais as espécies *H. wilberti* e *T. salsa*. Através da análise de agrupamento foi possível determinar similaridades entre as assembleias vivas e mortas apenas nas regiões norte e central do delta. Assim, este estudo foi eficiente na caracterização ambiental do RPS, respondendo a hidrodinâmica e aos impactos antropogênicos, e foi capaz de indicar as melhores regiões para a realização de futuros estudos paleoambientais.

Palavras-chave: foraminíferos e tecamebas bentônicos, biocenose e tafocenose, sistemas deltaicos, condições de hidrodinâmica.

ABSTRACT

The Paraiba do Sul River (PSR) crosses great urban areas of São Paulo, Minas Gerais and Rio de Janeiro and has been severely affected by anthropic impacts, such as dam construction and irregular exploration of sand, which intensify the occurrence of erosive coastal processes. In way to diagnose the environmental impacts in the region, the distribution of biocenosis and taphocenosis of foraminifera and thecamoebians were used to characterize the PSR delta, focusing on the identification of the environmental sectors and hydrodynamic conditions, analyzing the physical-chemical and sedimentological. Throughout the 24 stations there were identified 22 species of living foraminifera and 63 dead, as well as 8 species of living thecamoebians and 10 dead. The dominant microorganisms recorded in the PSR were the foraminifera *Ammonia tepida*, *Cribroelphidium excavatum*, *Haplophragmoides wilberti* e *Trochamminita salsa*. Using the DCA analysis, it was possible to determine two sectors in the deltaic system. The first was influenced by higher values of silt, clay, organic matter and carbonate and presented as bioindicators of estuarine regions the species *A. tepida* and *C. excavatum*, while the second was influenced by higher values of sand, temperature and oxi-reduction potential, presenting as bioindicators of fluvial regions the species *H. wilberti* and *T. salsa*. Through the cluster analysis, it was possible to determine similarities between the living and dead assemblages only in the north and central areas of the delta. Thus, this study was efficient on the environmental characterization of the PSR, responding to hydrodynamics and to anthropic impacts, and was capable to indicate the best regions for future paleoenvironmental studies.

Keywords: benthic foraminifera and thecamoebians, biocenosis and taphocenosis, deltaic systems, hydrodynamical conditions.

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1. INTRODUÇÃO

Deltas fluviais tem sido intensivamente estudados pois estão entre os ambientes de maior riqueza biológica no mundo (Costanza et al., 1997). Eles caracterizam-se como a parte final de uma bacia hidrográfica, podendo constituir um ambiente transicional entre o rio e o mar. Estes ambientes transicionais possuem um forte dinamismo e diversos gradientes ambientais (e.g. salinidade, nutrientes, pH, níveis de oxigênio dissolvido, tipos de sedimentos) (LePage, 2011), além da capacidade de sustentar uma grande biodiversidade e de disponibilizar áreas para uso agrícola e urbano (Matiatios et al., 2018).

Estas regiões fornecem recursos minerais e orgânicos, abrigam redes turísticas e portuárias, oferecem proteção contra tempestades ao longo de sua costa e são fundamentais para a viabilização de serviços relacionados a conservação ecológica e abastecimento de água (Evans, 2012). Tais características favoreceram a ocupação humana em grande escala, levando ao desenvolvimento de grandes cidades em regiões deltaicas (Seto, 2011; Syvitski and Saito, 2007; Syvitski et al., 2009).

Nesse sentido, sistemas deltaicos podem ser afetados por intervenção antropogênica através de práticas como intensa urbanização, construção de barragens dedicadas a irrigação e instalação de hidrelétricas, mudanças no uso da terra, extração irregular de sedimentos e dragagens para a navegação (Evans, 2012; Kondolf et al., 2014; Day et al., 2016; Besset et al., 2017; Best, 2018; Hagenlocher et al., 2018). Essas atividades intensificam a redução da vazão do rio e, consequentemente, do aporte de sedimento na foz do delta, tornando o ambiente passível a ocorrência de processos erosivos no litoral (Anthony, 2014), com impactos significativos sobre as populações que habitam a beira mar. Contudo, os processos erosivos costeiros não são exclusivamente provocados por ação antrópica, uma vez que a variação no regime de chuvas e o ângulo de incidências sobre as ondas no litoral podem alterar o balanço de carga sedimentar na foz do delta.

A associação entre a diminuição do aporte de sedimento e erosão de deltas afeta grandes sistemas deltaicos ao redor do mundo, tais como Rio Nilo (Stanley, 1996), Rio Mississippi (Blum & Roberts, 2009), Rio Ebro (Sanchez-Arcilla et al., 1998; Benito et al. 2015), Rio Mekong (Anthony et al., 2015) e Rio Amarelo (Chu et al., 2006; Wang et al., 2007). O delta do Ebro, por exemplo, foi afetado pela construção de aproximadamente 200 barragens ao longo do curso do rio (Ibáñez et al., 1996), influenciando negativamente seu potencial hidrodinâmico. Já o delta do Rio Mississipi foi impactado por atividades destinadas a produção de hidrocarbonetos e construções de canais, o que provocou uma contenção de sedimentos ao longo do curso do rio (Day et al., 2000, 2007; Paola et al., 2011; Blum & Roberts, 2012; Twilley et al., 2016) e corroborou para a perda de aproximadamente 5000 km² de área por conta da erosão costeira, com uma taxa de aproximadamente 100 km² por ano (Gagliano et al., 1981; Britsch & Dunbar, 1993; Boesch et al., 1994; Day et al., 2000; Couvillion et al., 2017). Por fim, o delta do Rio Nilo já não pode mais ser considerado um delta ativo segundo Stanley & Warne (1998), devido a intensa erosão e perda de porções significativas de terra.

Do mesmo modo, ações antropogênicas também impactam os deltas fluviais brasileiros ao longo de suas bacias (Dias et al., 2016; Angeli et al., 2018; Oliveira et al., 2016). Os principais deltas do Brasil são dos rios Amazonas, Jaguaribe, Parnaíba, São Francisco, Jequitinhonha, Caravelas, Doce e Paraíba do Sul. Nesse cenário, o Rio Paraíba do Sul (RPS), situado próximo aos grandes centros urbanos de São Paulo, Rio de Janeiro e Minas Gerais, possui importante papel na manutenção de atividades destinadas a subsistência de moradores locais, além de ser importante para a produção de eletricidade (por possuir barragens de hidrelétricas no seu curso) e de sistemas de irrigação industriais (Vasquez & Rezende, 2016).

De modo geral, o RPS tem sofrido intensamente com a diminuição do seu potencial hidrodinâmico e a alteração do fornecimento de sedimentos e nutrientes ao delta e com o desenvolvimento de um processo erosivo em seu sistema deltaico (Dias, 1981; Dominguez et al., 1981; Dias et al., 1984 a/b; Martin et al., 1984; Flexor et al., 1984; Dominguez et al., 1987). Em decorrência disso, o distrito de Atafona na cidade de São João da Barra, localizado na margem sul do delta, perdeu uma área equivalente a 40 campos de futebol por conta da ação do mar (Santos, 2006) e tende a continuar a ser impactado pela erosão costeira.

A fim de a caracterizar os impactos causados pelas atividades antrópicas em ambientes costeiros e marinhos, tais como deltas fluviais, os estudos com base nas assembleias bentônicas de foraminíferos e tecamebas tem demonstrado excelente potencial. Segundo a classificação de Cavalier-Smith (1997) e Jones (2014) os foraminíferos estão inseridos no Filo Foraminifera e as tecamebas estão inseridas no Filo Rhizopoda. Estes microrganismos podem ser bentônicos (quando vivem no sedimento) ou plantônicos (quando vivem flutuando na zona fótica) e sua distribuição é muito influenciada por variáveis ambientais da água e do sedimento, tais como temperatura, pH, salinidade e oxigênio dissolvido (Murray, 1991) e granulometria. Além disso, os foraminíferos possuem uma carapaça que pode ser classificada como “calcária”, formada por carbonato de cálcio, ou “aglutinante”, formada através da agregação de partículas do meio, como grãos de areia, argila e fragmentos calcários (Boltovskoy, 1965).

Resig (1960) e Watkins (1961) foram os pioneiros a caracterizar foraminíferos bentônicos como bioindicadores de ambientes costeiros e marinhos. A partir de então, muitos outros estudos foram realizados com o intuito de avaliar e monitorar possíveis impactos ambientais devido à disposição de esgotos domésticos, agrícolas e industriais, aportes de metais pesados, construções de portos e derramamento de petróleo em ambientes estuarinos e marinhos (Yanko et al., 1994; Alve, 1995; Armynot du Châtelet et al., 2004; Burone et al., 2006; Romano et al., 2008).

Os foraminíferos e as tecamebas apresentam vantagens como bioindicadores em relação a outros grupos pois são encontrados em abundância nos ambientes aquáticos (foraminíferos em zonas salinas e tecamebas em zonas fluviais), vivem na superfície do sedimento, possuem curto ciclo reprodutivo e grande diversidade taxonômica e são sensíveis a variações ambientais (Frontalini & Coccioni, 2011; Aloulou et al., 2012). Sendo assim, muitos estudos baseados na comunidade bentônica destes microrganismos tem sido conduzidos sob condições de hidrodinâmica em sistemas estuarinos e deltaicos no mundo (Sarita et al., 2014; Benito et al., 2015, 2016; Franzo et al., 2019) e no Brasil (Semensato & Brito, 2004; Laut et al., 2007, 2011, 2016; Dias et al., 2016; Angeli et al., 2018).

Contudo, muitos desses estudos utilizaram a assembleia total para análise (Semensato & Brito, 2004; Laut et al., 2011), sem realizar uma distinção entre assembleias vivas e mortas. Tal metodologia pode resultar em interpretações ambientais imprecisas pois, após a morte, as testas dos organismos são expostas a processos tafonômicos, tais como transporte, quebra e dissolução de carbonatos (Jorissen & Wittling, 1999; Belart et al., 2018).

2. OBJETIVOS

2.1 Objetivo Geral

O presente estudo teve como objetivo caracterizar a distribuição da biocenose e da tafocenose de foraminíferos e tecamebas da porção deltaica do Rio Paraíba do Sul visando a identificação dos setores ambientais e de diferentes condições hidrodinâmicas. O reconhecimento de compartimentos ambientais no delta, com base nos parâmetros físico-químicos, sedimentológicos e biológicos, contribuirá para o monitoramento das mudanças ambientais e para os estudos de evolução paleoambiental da região.

2.2 Objetivos Específicos

- Analisar taxonomicamente a biocenose e a tafocenose de foraminíferos e tecamebas no delta do Rio Paraíba do Sul;
- Caracterizar a distribuição desses microrganismos a partir da interação dos mesmos com os parâmetros físico-químicos da água e do sedimento locais;
- Identificar semelhanças e diferenças entre a biocenose e a tafocenose das assembleias desses microrganismos com base nas condições de hidrodinâmica do delta;

Capítulo 1 “*Response of biocenosis and taphocenosis of foraminifera and thecamoebians to hydrodynamics in Paraiba do Sul River Delta – Rio de Janeiro*”

RESPONSE OF BIOCENOSIS AND TAPHOCENOSIS OF FORAMINIFERA AND THECAMOEBIANS TO HYDRODYNAMICS IN PARAIBA DO SUL RIVER DELTA – RIO DE JANEIRO

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ABSTRACT

The Paraiba do Sul River (PSR) crosses great urban areas of São Paulo, Minas Gerais and Rio de Janeiro and has been severely affected by anthropic impacts, such as dam construction and irregular exploration of sand, which intensify the occurrence of erosive coastal processes. In way to diagnose the environmental impacts in the region, the distribution of biocenosis and taphocenosis of foraminifera and thecamoebians were used to characterize the PSR delta, focusing on the identification of the environmental sectors and hydrodynamic conditions, analyzing the physical-chemical and sedimentological. Throughout the 24 stations there were identified 22 species of living foraminifera and 63 dead, as well as 8 species of living thecamoebians and 10 dead. The dominant microorganisms recorded in the PSR were the foraminifera *Ammonia tepida*, *Cribroelphidium excavatum*, *Haplophragmoides wilberti* e *Trochamminita salsa*. Using the DCA analysis, it was possible to determine two sectors in the deltaic system. The first was influenced by higher values of silt, clay, organic matter and carbonate and presented as bioindicators of estuarine regions the species *A. tepida* and *C. excavatum*, while the second was influenced by higher values of sand, temperature and oxi-reduction potential, presenting as bioindicators of fluvial regions the species *H. wilberti* and *T. salsa*. Through the cluster analysis, it was possible to determine similarities between the living and dead assemblages only in the north and central areas of the delta. Thus, this study was efficient on the environmental characterization of the PSR, responding to hydrodynamics and to anthropic impacts, and was capable to indicate the best regions for future paleoenvironmental studies.

Keywords: benthic foraminifera and thecamoebians, biocenosis and taphocenosis, deltaic systems, hydrodynamical conditions.

1. INTRODUCTION

The river deltas are among the most biologically productive and valuable environments and have been extensively studied in the world (Costanza et al., 1997). They establish a connection between the marine and the freshwater ecosystems, that characterizes it as a transitional region. Due to their location at the land–sea interface, these transitional waters have a strong dynamism and distinct environmental gradients (e.g. salinity, oxygen levels, nutrients, sediment) (LePage, 2011). Some of these natural gradients, however, can be modified by natural dynamics in deltaic systems, such as the variance of the rainfall regime, or by human activities (Syvitski et al., 2009).

Modern deltas around the world are impacted by human interference in the river's drainage basin, intensifying the erosion processes in their coastal areas (Luan, 2018) by the sediment trapping in the river's course (Syvitski et al., 2009). The association between the decrease of the sediment loads and erosion of the delta were presented in several studies on large deltas, including the Nile (Stanley, 1996), Mississippi (Blum & Roberts, 2009), Ebro (Sanchez-Arcilla et al., 1998; Benito et al. 2015), Mekong (Anthony et al., 2015), and Yellow River (Chu et al., 2006; Wang et al., 2007).

The Ebro delta was affected by the construction of nearly 200 dams along the river's course (Ibáñez et al., 1996), decreasing its hydrodynamical potential, and suffers with the effects of irrigation in the river's amount of water (Benito et al., 2015). The Mississipi River Delta is suffering from the intensive hydrocarbon activities (Morton et al., 2005) and showed erosion in the delta after the construction of a barrier in the river's flow. In way to respond the human interventions, the distributary channels of the river created a new delta surface, as occurred in the deltas of the Yellow River, Colorado River and Po River (Syvitski & Saito, 2007).

The main Brazilian deltas are the Amazon River, Jaguaribe River, Parnaiba River, São Francisco River, Jequitinhonha River, Caravelas River, Doce River and Paraiba do Sul River (PSR) and they are also impacted by anthropogenic activities (Dias et al., 2016; Angeli et al., 2018; Oliveira et al., 2016). The Paraiba do Sul River basin crosses great urban areas of São Paulo, Minas Gerais and Rio de Janeiro, making it more vulnerable to human impacts. The river has been intensively impacted by the construction of dams, responsible for changing the supply of sediment and nutrients (Laut et al. 2011), requiring the maintenance of the river to many households for drinking water systems, fishery and irrigation of agricultural crops and to the economic sectors by the production of electricity, manufacturing and industrial irrigation systems (Vasquez & Rezende, 2016).

In parallel with these anthropic impacts, the PSR also suffers with natural actions such as the variance of the rainfall regime and the angle of incidence of waves on the coast. Therefore, the natural and anthropic impacts are intensifying the erosive process in the deltaic system by the reduced discharge of freshwater and sediment loads (Dias, 1981; Dominguez et al., 1981; Dias et al., 1984 a/b; Martin et al., 1984; Flexor et al., 1984; Dominguez et al., 1987). The district of Atafona in São João da Barra city, located in the south margin of the deltaic system, has been intensively impacted by the coastal erosion. Until 2006, an area equivalent to 40 soccer fields were destroyed by the sea (Santos, 2006).

In way to diagnose the environment settings of coastal systems, the foraminifera and thecamoebians were used as a tool to respond to anthropic impacts and the hydrodynamics. These microorganisms have great potential since they are found in great abundance in all the aquatic environments (foraminifera in the marine zones and thecamoebians in the freshwater), live on the superficial layer of the sediment, have great taxonomic diversity, short reproductive cycle and are very sensitive to environmental variations (Aloulou et al., 2012; Frontalini & Coccioni, 2011).

Many studies based on the benthic communities of foraminifera and thecamoebians have been conducted to identify the environmental impacts and hydrodynamical conditions in estuaries and deltas around the world (Sarita et al., 2014; Benito et al., 2015, 2016; Franzo et al., 2019) and in Brazil (Semensato & Brito, 2004; Laut et al., 2007, 2011, 2016; Dias et al., 2016; Angeli et al., 2018). However, many of them were carried out with the total assemblage (Semensato & Brito, 2004; Laut et al., 2011), without distinction between living organisms (biocenosis) and dead (taphocenosis). These studies may lead to uncertain conclusions, since community dynamics and biological differences may cause divergences between living and dead assemblages, as the taphonomic processes, such as dissolution and transport of the shell (Jorissen & Wittling, 1999; Belart et al., 2018).

Therefore, objecting more accuracy in the results, it was considered the analysis of benthic foraminifera and thecamoebians focusing on the distinction between the biocenosis and the taphocenosis and its distribution along the deltaic system of Paraiba do Sul River. The study intends to sectorize this delta under influence of local hydrodynamics and physical-chemical and sedimentological parameters, in way to suggest these microorganisms as potential environmental bioindicators of the region.

2. ENVIRONMENTAL SETTINGS

The PSR belongs to drainage basin of same name that has an area equivalent to 56,500 km² crossing three states of Brazil (São Paulo, Minas Gerais and Rio de Janeiro) until it reaches the ocean, in the north of Rio de Janeiro. The entire deltaic area extends from the coast of Macaé to São Francisco do Itabapoana, but the Holocene portion of the delta, as the focus of this study, is located between the coordinates 41°15'14"W - 21°30'37"S and 40°49'18"W - 21°42'50"S, extending from Campos dos Goytacazes to São Francisco do Itabapoana (Fig 1).

The region is considered the emergent portion of the Campos Sedimentary Basin. The lithological substrate of the onshore portion includes a Precambrian basement (Silva and Cunha, 2001; Heilbron et al., 2004), the formation of Goytacás, Emborê and Barreiras in the sedimentary succession (Rangel et al., 1994; Winter et al., 2007; Lana, 2011; Vilela, 2015, Vilela et al., 2016) and Quaternary deposits (Martin et al., 1984; Silva, 1987; Martin et al., 1997; Rocha et al., 2013; Gatto, 2016; Plantz, 2017).

According to Dominguez et al. (1983); Dias et al. (1984); Martin et al. (1984); Martin & Flexor (1987); Dominguez (1990); Murillo et al. (2009); Vasconcelos et al. (2016), the PSR is one example of dominant wave delta, which the main characteristic is the formation of sandy barriers in the coast related to the strong contribution of fluvial sediments. The PSR delta has a geomorphological contrast between the plains located to the south and north of the river, resulting from a dynamic and distinct sedimentary evolution between the two sides of the river mouth. To the south, the coastline is linear, with its interior characterized by a long plain, with

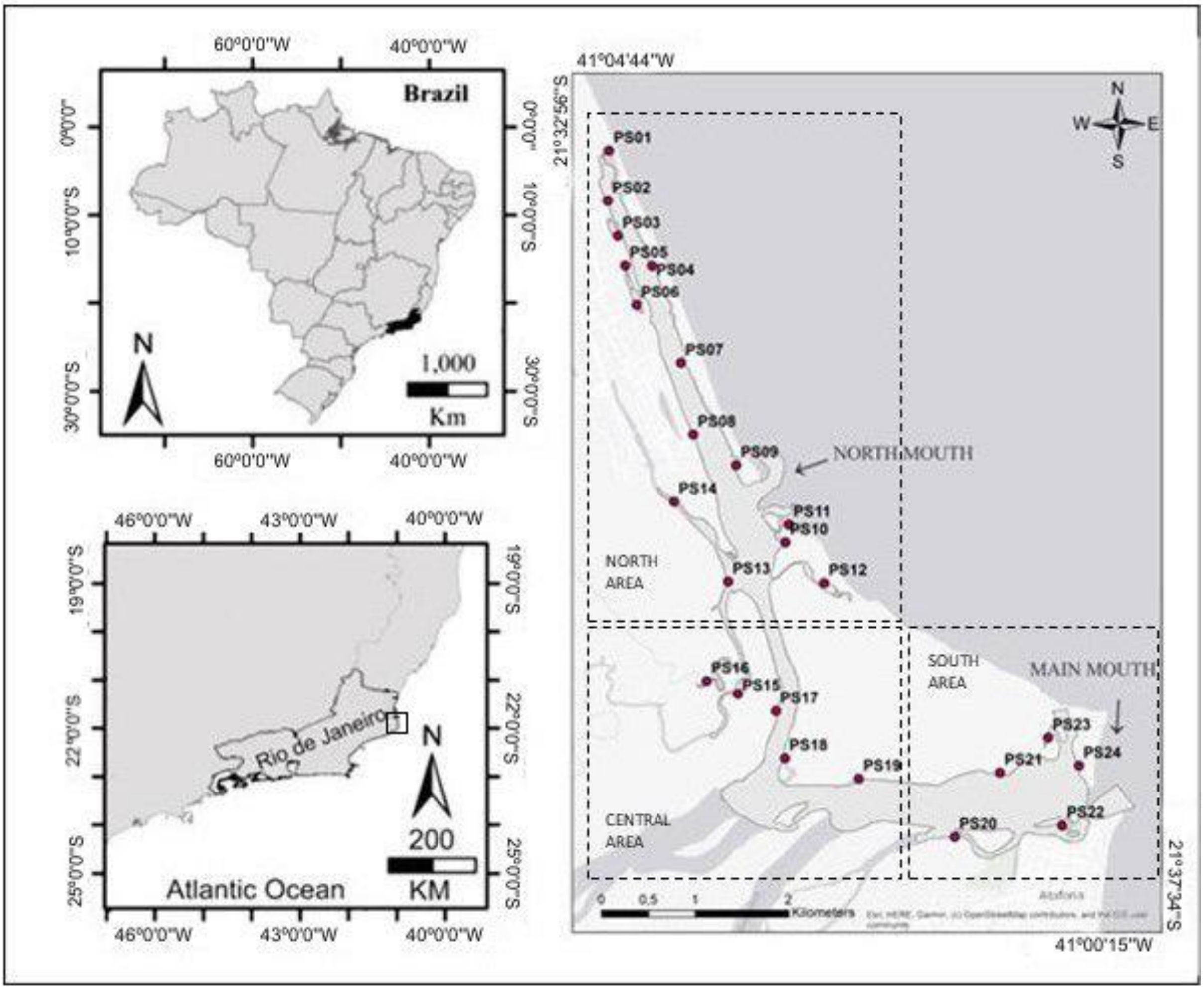

Fig 1. Study area and sampling locations in the Paraiba do Sul River Delta (Rio de Janeiro State, Brazil).

successive sandy ridges and long depressions, indicative of old coastline positions, as described by Dias (1981), Dominguez et al. (1981), Dias et al. (1984a, b), Martin et al. (1984) and Flexor et al. (1984). On the other hand, the north region of the PSR shows a development behavior associated with the presence of sandy barriers formed underwater causing changes in the mouths of the delta, locating one in the north channel and the other in the south responsible for the river's hydrodynamics.

Besides this sedimentary development of the delta, it presents two mouths in connection with the ocean. The main mouth follows the river's course, directed to Atafona district, while the north mouth is located to the north of the delta, inside the Grande River channel (Fig.1). The area is influenced by the moist tropical climate, with an average temperature of 22 °C, with a maximum variation of 40 °C and a minimum of 8 °C (Nimer, 1989). The rainfall regime has an annual average of 1300 mm with its peak in December with records of precipitation of 150 mm (BERNARDES, 1957), where winds of the N-NE quadrant predominate with average speeds around 25 km/h. Although they are dominant, the S-SE winds are related to the arrival of cold fronts and SW (in a less expressive way), according to Pinho (2003). The region is considered of micro tidal regime, ranging between 0,712 m a 1,538 m (Costa, 1994).

The PSR delta has the second largest mangrove area of Rio de Janeiro with approximately 725 ha of extension (Bernini and Rezende, 2011). It was highly affected by the large urbanization, erosion, dredging, draining to create pastures, deforestation and many degrading activities and, as a result, the mangrove forest lost 20% of its coverage between 1986 and 2001 (Bernini and Rezende, 2011). The mangroves vegetation has an important role for the preservation and nutrition of the environment providing plenty of ecological services, including supporting fisheries for households from neighboring communities, a biogeochemical barrier against pollution (Lacerda et al., 1998), shoreline's protection from erosion, sediment trapping, nutrient recycling, carbon sequestrations and organic matter for marine invertebrates and vertebrates (Rezende et al., 2007). Otherwise, mangrove areas are becoming highly stressed forests with a global reduction of approximately 25% (FAO, 2007; Ahmed and Glaser, 2016), declining due to the increased human activities (Barbier et al., 2011).

The PSR provides the primary water source for human consumption and other economic activities to the areas that surrounds it. As many rivers in Brazil, it is continuously polluted by the discharge of untreated residential wastewater and other effluents. According to National

Sanitation Ranking (2016), only 47% of the wastewater are treated in the southeast region of Brazil. On average, the 100 largest Brazilian cities only treat 50% of their effluents, and only 10 of those cities treat up to 80% of the wastewater (Instituto Trata Brasil, 2016).

3. METHODS

3.1. Sample collection

In January of 2017, twenty-four stations were selected with a Garmin GPSMAP 64s to collect the samples in PSR delta (Fig. 1). The samples were collected in three replicates using a little box corer. To the sedimentological analysis, 100 ml of the bottom sediments were collected in the same sample stations. For the foraminifera and tecamoebians analysis 50 ml of the first centimeter was taken and, to identify the living organisms, a solution of 2 g of Rose Bengal dye in 1000 ml of alcohol 70% was added to all samples. The physical-chemical parameters of the water (temperature, salinity, dissolved oxygen ─ DO, pH and oxiredution potential ─ Eh) were measured in each station with the multiparametric probe YSI 6600v2 model. The deltaic zone was divided in three areas for better understanding: north area (PS01, PS02, PS03, PS04, PS05, PS06, PS07, PS08, PS09, PS10. PS11, PS12, PS13 and PS14), central area (PS15, PS16, PS18 and PS19) and south area (PS20, PS21, PS22, PS23 and PS24).

3.2.Foraminiferal and thecamoebians analyses

The sediment for microorganisms' analysis followed the methodology of Boltovskoy (1965) and Schönfeld et al. (2012). The sediment (50 ml) was washed through sieves of 500 µm and 62 µm. The fractions greater than 500 µm and smaller than 62 µm were discarded. After drying, the sedimentary particles with low density, including foraminifera and thecamoebians of each sample, were separated by flotation on trichloroethylene (C_2HCl_3).

With a microscope with increase of 80x, all the specimens of dead and living assemblage were picked per replicate. The values of relative abundance of the stations were determined by averaging the number of specimens in the three replicates. The assemblages' index such as species richness (S=number of species), diversity of Shannon ($H'=\Sigma p\ ilnp\ i$) and the equitability [$J'=H' / \ln(S)$], were calculated using the software MVSP 3.1, and the constancy demonstrated the relation between the species' occurrence and the sample stations (Tinoco, 1989). The species were identified according to Boltovskoy et al. (1980), Loeblich and Tappan (1987) and Laut et al. (2011, 2012, 2017). The nomenclature was standardized according to WoRMS (World Register of Marine Species; Hayward et al., 2019), Microworld (World of Amoeboid Organisms), Atlas of Living Australia and Rosa et al. (2017) (Appendix 1).

3.3.Sedimentological analyses

The granulometric analysis was performed using ~80 g of the dry sediment. Each sample had the organic matter (OM) removed using 30% Hydrogen Peroxide (H_2O_2) and CO_3 by 30% Hydrochloric Acid (HCl). At each stage the samples were dried and weighed to calculate the percentage of OM and Carbonate. Aliquots were placed to react on Sodium Hexametaphosphate $(NaPO_3)_6$ and analyzed on the CILAS 1064 equipment, according to Sales & Cardoso (2012). The data were processed in Microsoft Excel® through Gradistat, which was proposed by Blott & Pye (2001) to calculate the particle size for mesh or laser granulometric data.

3.4.Interpolation maps

The maps were shaped with ArcMap 10.5 using the Spline with Barriers (SWB) tool and were configured with cell size 15 and 0 of a smooth factor in accordance to Dias et al. (2017) and Belart et al. (2018, 2019). The interpolation shows the spatial distribution of the abiotic parameters concentration along the delta and spatial distribution of ecological indexes and foraminifera species. Coordinates are provided in WGS84 datum.

3.5.Statistical analyses

The biotic results were obtained by the values of relative abundance. The species that were found only in one station and the samples with less than 50 specimens were discarded from further analyses. Fatela & Taborda (2002) proposes the analysis with at least 100 specimens, but this method was not followed in this study due to the low abundance of organisms.

Using the software PCord 5.0, a two-way cluster analyses (Q and R- mode) was performed to identify the differences and the similarities between the sectors in the delta system, according to the relative abundance of the foraminifera and thecamoebians assemblages (living and dead). The Q-mode was analyzed using the Euclidean distance, which is recommended for measure ordering in space, and Ward linkage method, and the R-mode used r-Pearson’s linear correlation coefficient and Ward linkage method.

A Detrended Correspondence Analysis (DCA) was performed to calculate the relation between the living organisms and the abiotic parameters to understand which parameter conduct each species. Before both DCA and cluster analyses, the abiotic data were normalized by square root of 0.5.

4. RESULTS

4.1.Abiotic results

4.1.1. Physical and chemical variables of the water

The water parameters were very heterogeneous in the delta (Appendix 2). The temperature ranged from 31.8 °C in PS11 to 26.7 °C in PS01, both stations in the north area of the delta (Fig. 2). The salinity had a significative difference between the highest and the lowest values, with the average of 1.2 ─ the highest value was 26.1 in PS05, in the north area, and the lowest one was 0 from PS17 to PS24, in the central and south areas (Fig.2). The DO lowest value recorded was 2.96 mg/L at PS21, in the main mouth of the delta. Over it, the values varied from 7.89 mg/L at PS11 and 4.62 mg/L at PS16 (Fig.2). The pH values varied between 9 in PS11 and 7.57 in PS17, with the mean of 8.3 (Fig. 2). All the Eh values were positive, ranging from 222.3 (PS19) to 118.1 (PS03), with mean of 168.4 (Fig.2).

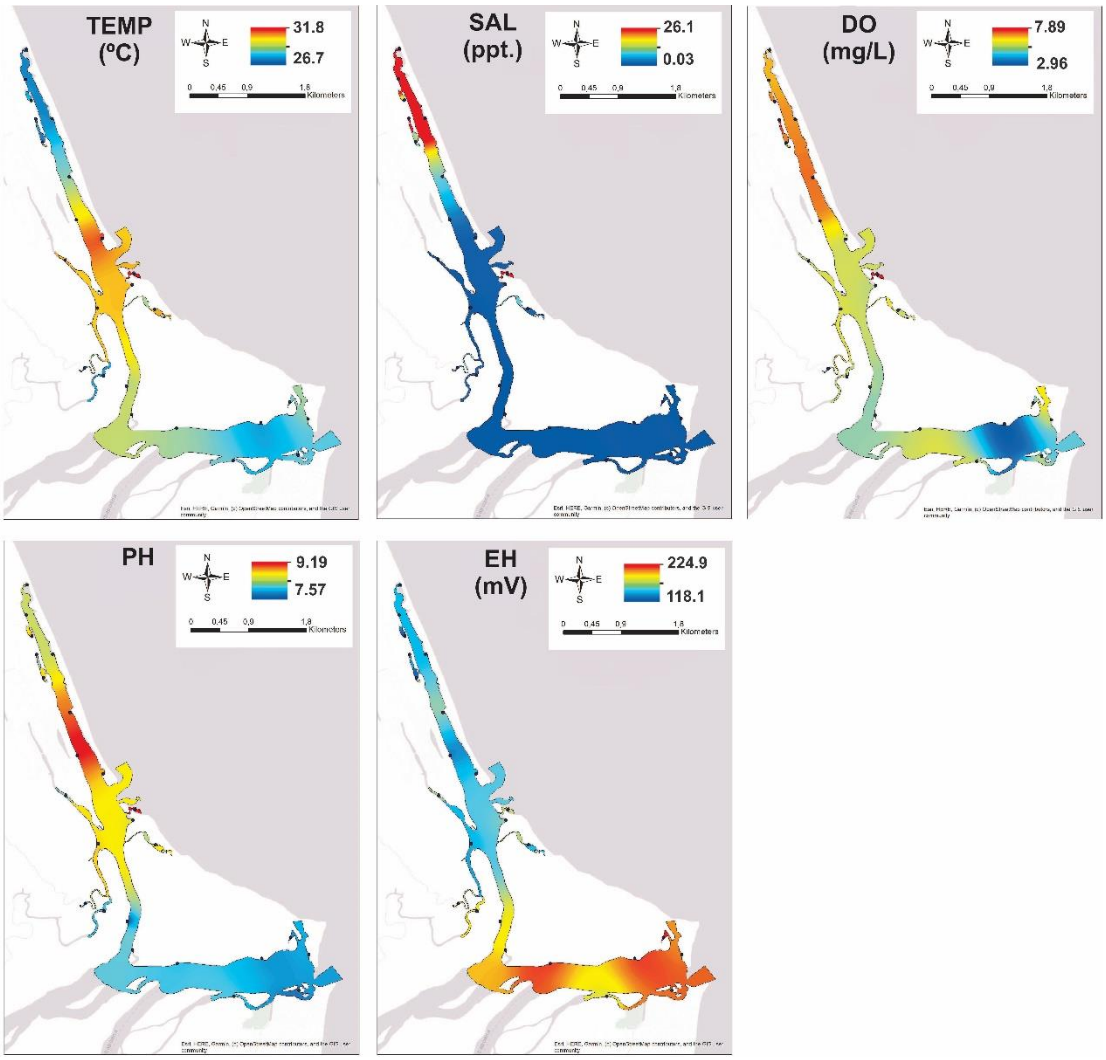

Fig 2. Interpolation maps of physical-chemical variables of the water (Temp. – temperature; Sal. – salinity; DO – dissolved oxygen; pH; Eh – oxi-reduction potential).

4.1.2. Grain size analysis

The values of sedimentological analysis were also demonstrated in Appendix 2. The OM values ranged from 23% (PS13) to 0.3% (PS03), with an outlier of 35% in PS05, and the mean was 6% (Fig. 3). The mean values of CO_3 was 4%, with its highest value of 26% (PS09) and the lowest value of 0% (PS02), both stations in the north area of the delta (Fig. 3).

There were 11 stations (PS01, PS02, PS03, PS07, PS11, PS12, PS14, PS16, PS22, PS23 and PS24) with more than 60% of sand and 13 stations with predominance of fine sediments – silt and clay (PS04, PS05, PS06, PS08, PS09, PS10, PS13, PS15, PS17, PS18, PS19, PS20 and PS21) (Fig. 3). The stations with fine sediments varied between 1% in PS03, in the north area, and 100% in PS20, in the south area (Fig. 3).

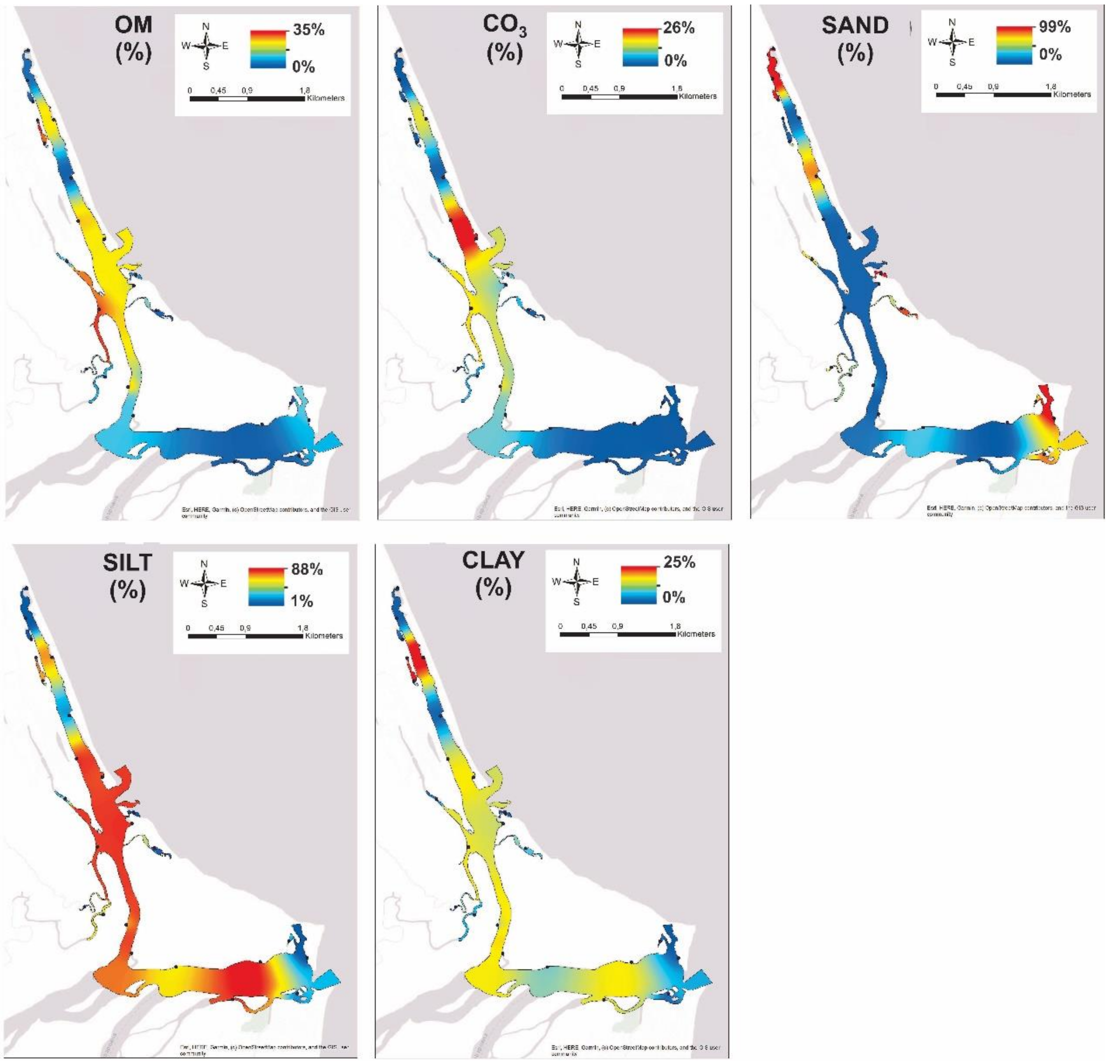

Fig 3. Interpolation maps of the OM, CO_3 and grain size analysis.

4.2.Biotic results

4.2.1. Living assemblages

Along 23 stations were found living 24 species of foraminifera and 8 species of thecamoebians (Appendix 3). The S ranged from 2 (PS08 and PS17) to 9 (PS18) species along all the stations whereas the H’ ranged from 0,4 (PS11) to 1,9 (PS22) and the J’ varied from 0,4 (PS11) to 1 (PS24) (Fig. 4).

The most dominant living species in the PSR delta were the foraminifera *Ammonia tepida*, *Cribroelphidium excavatum*, *Haplophragmoides wilberti* and *Trochamminita salsa*, and the thecamoebians were *Difflugia corona* and *Difflugia oblonga*.

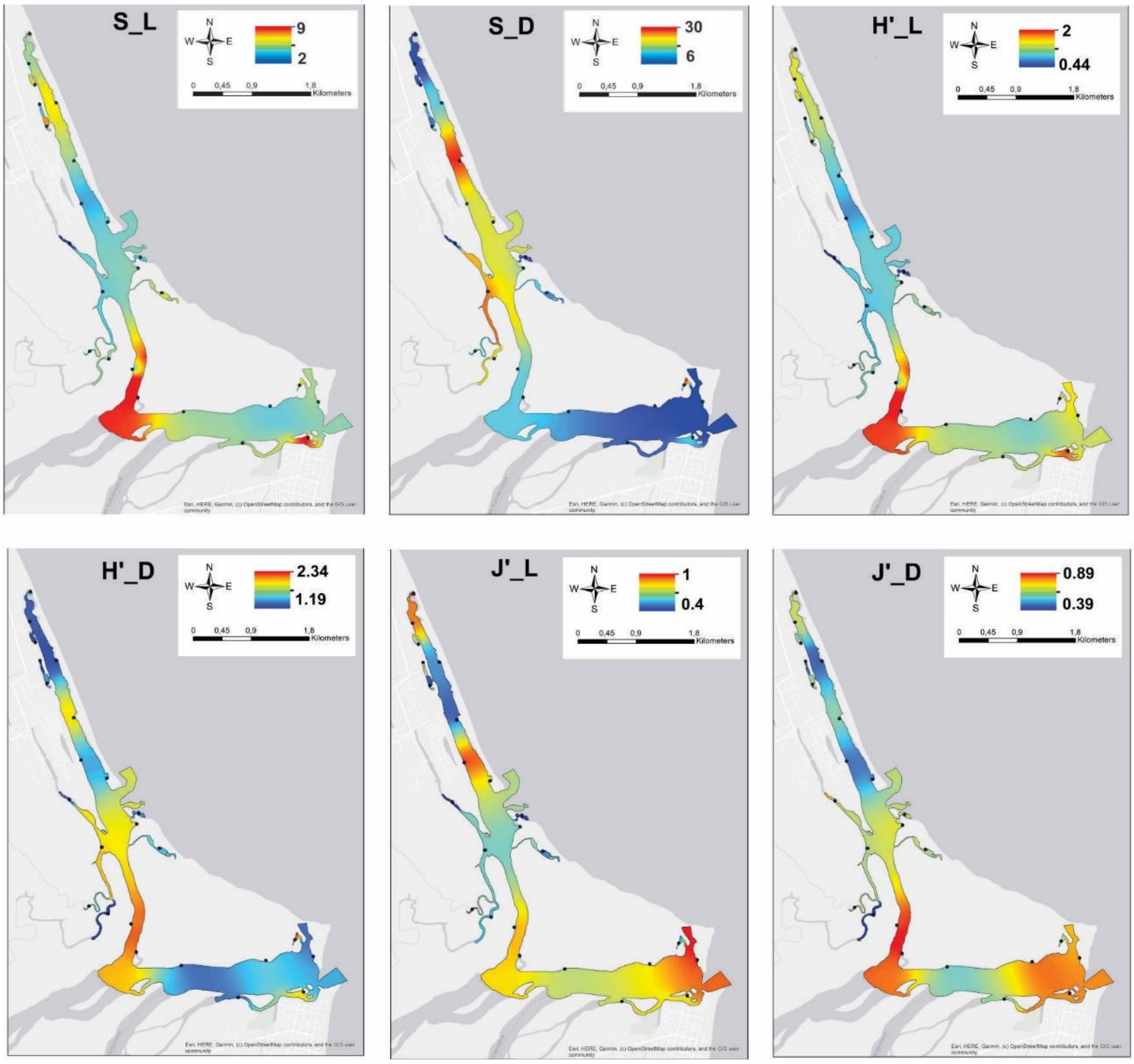

Fig 4. Interpolation maps of the biotic indexes: S – species richness, H' – species diversity, J' – species equitability. The living assemblages were represented by "_L" and the dead ones were "_D".

Ammonia tepida was constant in 66.7% of the stations in the living assemblages and it had the highest relative abundance over the delta. It represented 31.8% of the living species, with the specimens ranging from 8% (PS11) to 94.1% (PS07), with mean of 49.7% organisms. *Cribroelphidium excavatum* was constant in 33.3% of the stations and this species represented 10.7% of the living assemblages, with its abundance ranging from 3.1% (PS12) to 56% (PS08) and mean of 35%. *Haplophragmoides wilberti* was constant in 45.8% of the stations and this species represented 11.1% of the living assemblages, with its abundance varying from 5.2 (PS05) to 37.5 (PS21 and PS22) and mean of 23%. *Trochamminita salsa* was constant in 41.7% of the stations and showed 12.2% of the living assemblage of organisms. This species abundance ranges from 1.7% (PS04) to 66.7% (PS19), with mean of 29.2%. *Difflugia corona* was constant in 25% of the stations and presented 5% above the living assemblages. The species abundance ranges from 3.1% (PS12) to 61.5% (PS10), with mean of 13.4%. *Difflugia oblonga* was constant in 20.8% of the stations and presented 3.8% of the living organisms. This species abundance ranges from 2.7% (PS22) to 31.8 (PS18), with mean of 25% (Appendix 3).

4.2.2. Dead assemblages

Along the 24 stations analyzed, 63 species of foraminifera and 12 species of thecamoebians were recorded (Appendix 4). The S ranged from 6 (PS14 and PS24) to 30 (PS07), the H' varied from 1,2 (PS05) to 2,3 (PS18) and the J' values varied from 0,4 (PS15) to 0,9 (PS18) (Fig. 4).

The species *A. tepida* was also the main one in the dead assemblages with 23,4% of representative above the total. This species presented the highest relative abundance of the delta, ranging between 2.8% (PS22) and 64.3% (PS05) with constancy of 75% in the stations and mean of 34.2%. *Trochamminita salsa* was the second most dominant species with 13.3% of representative above the dead assemblages. This species also had 75% of constancy in the stations, with abundance ranging from 0.2 (PS04) to 49.5 (PS03), with mean of 8.8%. *Haploghragmoides wilberti* had 11.7% of representative above the dead assemblages and a constancy of 83.3% in the stations. The abundance ranges from 0.3% (PS07) to 41.5% (PS01), with mean of 6.4%. *Cribroelphidium excavatum* had 10.5% of representative above the total of the dead assemblages, with a constancy of 54.2%. The abundance ranges from 1.5% (PS02) to 56.6% (PS09), with mean of 8.5% (Appendix 4).

Other species were also frequent in the delta, such as the foraminifera species *Polyssaccamina ipohalina* (constancy of 54.2%, mean relative abundance of 9.7%) and *Arenoparrella mexicana* (constancy of 50%, mean relative abundance of 5.3%), and the thecamoebians *Difflugia corona* (constancy of 37.5%, mean relative of 4,5%), *Difflugia oblonga* (constancy of 33.3%, mean relative of 3.4%), *Lagenodifflugia vas* (constancy of 25%, mean relative abundance of 4,6%) and *Pontigulassia compressa* (constancy of 33.3%, mean relative abundance of 5,4%) (Appendix 4).

4.2.3. Statistical analysis

Eighteen stations of the living assemblages were discarded from the statistics because they contain less than 50 specimens of foraminifera and thecamoebians (PS01, PS02, PS07, PS08, PS10, PS11, PS12, PS13, PS15, PS16, PS17, PS18, PS19, PS20, PS21, PS22, PS23 and PS24) and one station (PS14) had no living organisms' abundance. Thus, only eleven species of foraminifera were considered to the statistical analysis (*Ammonia parkinsoniana*, *Ammonia tepida*, *Arenoparrella mexicana*, *Cribroelphidium excavatum*, *Cribroelphidium gunteri*, *Entzia macrescens*, *Haploghragmoides wilberti*, *Miliolinella subrotunda*, *Polyssaccamina ipohalina*, *Quinqueloculina seminula* and *Trochamminita salsa*) and five of thecamoebians (*Centropyxis constricta*, *Difflugia corona*, *Difflugia oblonga*, *Difflugia urceolata* and *Lagenodifflugia vas*).

Regarding the dead assemblages, five stations were discarded due to the low abundance of foraminifera and thecamoebians (PS01, PS17, PS20, PS21 and PS24). The statistics were performed using 42 species of foraminifera and 9 species of thecamoebians. The species of foraminifera that were identified but not considered to the statistics were: *Adelosina milletti, Ammotium morenoi, Ataxophragmium variabile, Bolivina inflata, Bolivina* sp., *Bulimina patagonica*, *Cancris* sp., *Entzia* sp., *Eponides repandus*, *Favolagena digitalis*, *Fissurina globosocaudata*, *Fissurina* sp., *Lagena hispidula*, *Lagena* sp., *Lepidodeuterammina ochracea*, *Oolina* sp., *Paratrochammina guaratibaensis*, *Quinqueloculina poyeana*, *Textularia agglutinans, Triloculina oblonga* and *Uvigerina peregrina,* and the thecamoebian species was *Difflugia protaeiformis* (Appendix 4). These species were identified in every areas of the deltaic system.

The axes of the DCA for the living assemblages accounted for 57% of the total variance in the samples and species dispersion (Axis 1=47%, Axis 2=10%). The analysis allowed the distribution of two groups according to the axis 1. The calcareous species *A. parkinsoniana*, *C. gunteri*, *C. excavatum*, *M. subrotunda* and *A. tepida* responded positively to OM, CO_3, DO and fine sediments (silt and clay). The other foraminifera species *A. mexicana*, *P. ipohalina, E. macrenscens*, *H. wilberti* and *Q. seminula* as thecamoebians species *D. corona*, *D. urceolata*, *D. oblonga*, *L. vas* and *C. constricta* responded positively to sandy sediments, temperature and Eh values (Fig. 5).

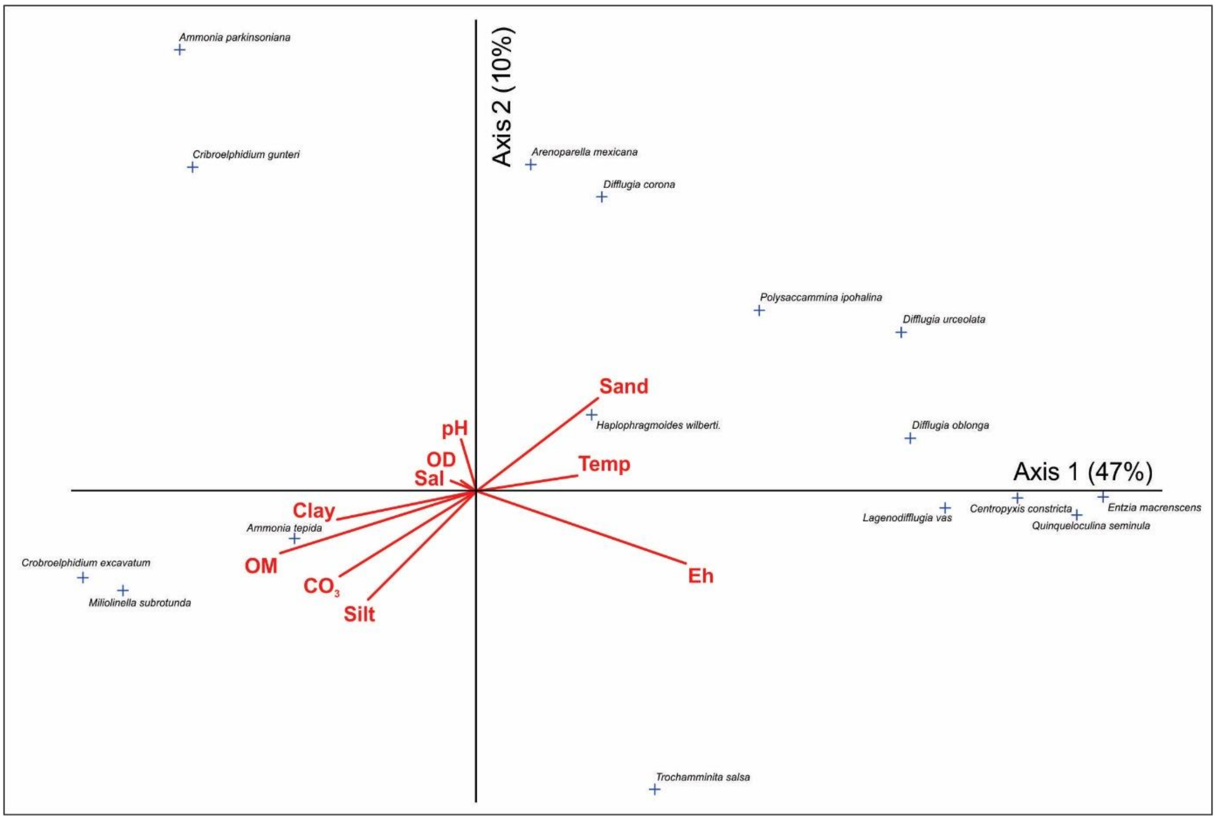

Fig 5. DCA analysis of the living assemblages and the abiotic variables (Temp. – temperature (ºC); Sal. – salinity (ppt.); pH; Eh – oxireduction potential (mV); DO – dissolved oxygen (mg/L)); sediment parameters (%) (sand, silt and clay fractions; OM - organic matter; CO_3 – carbonate).

The Q-mode (Fig. 6) cluster analysis identified five groups of stations in the delta considering 75% of similarity. The group I was divided in Ia' and Ib' to characterize different environmental conditions. Ia' is composed by the stations PS02, PS12, PS16, PS18 and L_PS03 (living organisms) and Ib' is composed only by stations (L_PS04, L_PS05, L_PS06 and L_PS09). The group II contains the stations PS03, PS10, PS14, PS19 and PS22; group III contains PS05, PS07, PS11, PS13 and PS23; group IV is only composed by PS06; group V contains PS04, PS08, PS09 and PS15.

The R-mode (Fig. 6) cluster analysis identified five assemblages of species considering 37.5% of similarity. The A assemblage is represented by the foraminifera species *Ammonia parkinsoniana*, *Cribroelphidium gunteri*, *Ammonia rolshauseni*, *Lagena perlucida*, *Nonionella opima*, *Reusoolina laevis*, *Adelosina sp.*, *Bolivina spathulata*, *Lagena striata*, *Ammonia tepida*, *Cribroelphidium excavatum*, *Bolivina marginata*, *Cancris sagra*, *Nonionella auris*, *Haynesina germânica*, *Bolivinella translucens*, *Fissurina lucida*, *Cornuspira involvens*, *Buliminella elegantíssima*, *Miliolinella sp.*, *Quinqueloculina lamarckiana*, *Fissurina semimarginata*, *Pseudononion japonicum*, *Rosalina bradyi*, *Fissurina agassizi*, *Pyrgo* *williamsoni*, *Fursenkoina pontoni*. The B assemblage is represented by the foraminifera living species *Ammonia parkinsoniana*, *Cribroelphidium gunteri*, *Entzia macrescens, Ammonia tepida*, *Miliolinella subrotunda* and *Cribroelphidium excavatum*. The C assemblage is represented by the living foraminifera species *Arenoparrella mexicana*, *Trochamminita salsa* and *Haplophragmoides wilberti* and the dead species *Cribroelphidium poyeanum*, *Trochamminita squamata*, *Haplophragmoides manilaensis*, *Polysaccammina ipohalina*, *Entzia macrescens, Trochammina inflata*, *Quinqueloculina seminula*, *Miliolinella subrotunda* and *Siphotrochammina lobata*. The D assemblages is represented by *Arenoparrella mexicana*, *Miliammina fusca*, *Entzia polystoma*, *Haplophragmoides wilberti*, *Trochamminita salsa* and *Bullopora irregularis,* and the E assemblages is represented by the thecamoebians species *Centropyxis aculeata*, *Centropyxis constricta*, *Difflugia globularis*, *Difflugia corona*, *Pontigulassia compressa*, *Difflugia oblonga*, *Difflugia urceolata*, *Lagenodifflugia vas* and *Difflugia viscidula*

The combination between Q-mode and R-mode (Fig. 6) associated that the stations of: group 1a' is represented by the thecamoebians and the living and dead foraminifera species *H. wilberti*, *T. salsa*, *A. mexicana* (assemblages C, D and E), group 1b' is represented by the living *A. tepida* and *C. excavatum* (assemblage B), group II is represented by *P. ipohalina*, *A. mexicana*, *T. salsa* and *H. wilberti* (assemblages C and D), group III is characterized mostly by *A. tepida* (assemblage A), group IV is represented by *C. gunteri* (assemblage A) and group V is represented by *A. parkinsoniana*, *C. excavatum* and *M. subrotunda* (assemblage A).

5. DISCUSSION

5.1.Abiotic parameters

The temperature can range according to the water column depth, confined regions or even the sampling time as occur in others coastal areas (Dias et al., 2017). The stations in the north area (from PS01 to PS06) were the firsts to be collected and low temperatures were identified, which can be associated to the lack of sunny incidence. The parameter variations in the PSR were of 5.1ºC and was higher than Laut et al. (2011) identified, with a variation of 2ºC. This difference can be associated to the different sampling seasons, since the present study was collected in summer and Laut et al (2011) collected in winter.

The delta is very influenced by the fluvial discharge (Laut et al., 2011). On the other hand, the development of the deltaic system and the emergent sandbar in the north margin parallel to the coast causes complex conditions of tidal influence (Dias & Gorini, 1980; Vasconcelos, 2010), and provides the formation of coastal lagoons. Thus, the salinity tends to increase in these areas, as showed in stations PS01, PS02, PS04 and PS05. In addition, Mathers et al. (1999) and Laut et al. (2011) affirm the occurrence of overwash events in asymmetric deltas as the PBS, that provides the entrance of marine water into a frontal lagoon and increases the salinity values.

The stations in the south area of the delta, which are influenced by mangroves, present the lower alkaline values (7.8 pH average between PS21, PS22, PS23 and PS24). The decomposition process of organic matter provided by the mangrove forests decreases the pH value in these regions (Esteves, 1998). Similar results of lower pH associated to mangrove forests were identified in Paraíba do Sul River delta (Laut et al., 2011), in Itaipu Lagoon (Raposo et al., 2018) and in Saquarema Lagoon System (Belart et al., 2019).

The dissolved oxygen (DO) is a very important factor for the preservation of life in the aquatic environment, one of the main water quality indicators (Imhoff and Klaus, 1985; Leite, 2004). According to Nacional Water Agency (ANA), values of DO fewer than 5 mg/L can consider the area as no polluted when is associated to mangrove forests. Laut et al. (2011) identified lower values of DO in the entire delta (ranging between 3.9 and 5.2 mg/L), which can be explained by the widest distribution of the mangrove forests at the time. In this study, however, the DO values were not associated to the mangrove in the north area because they are still in development, explaining the higher values of this parameter in this region. The central and south areas of the delta, otherwise, are very influenced by the mangrove conditions, which corroborates to the vegetation representativity.

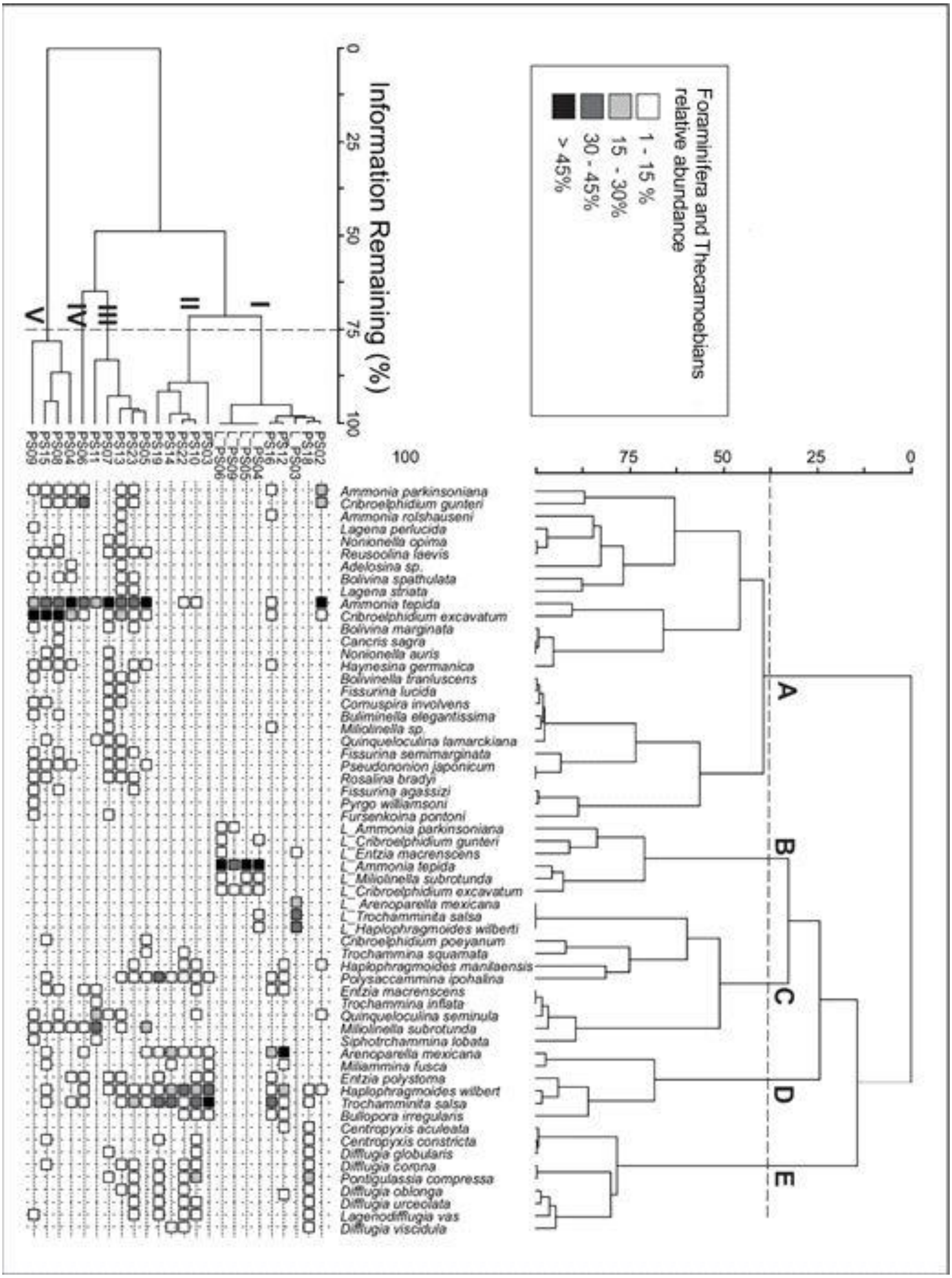

Fig. 6. Cluster analysis in Q-mode (from group I to V) and R-mode (from assemblage A to E) – "L_" represents the living species and stations.

The results of Eh were positive throughout the delta and it is associated to the high fluvial water current, providing high hydrodynamics. The lower values of the parameter are located in confined regions of the deltaic system, which also occurs in the study described by Laut et al. (2011).

The sandy sediments, presented in the north area of the delta, enter the system by overwash events and this sediment is accumulated in the extreme north of the channel probably due to the low hydrodynamic activity in the region to remobilize it. Vasconcelos (2016) also identified evidences of overwash events into the deltaic system by a stratigraphy analysis of the PSR and identified layers of sand inside the muddy sedimentation. Besides, the coastal development provides an inconsistent sandbar between the channel and the ocean (Dominguez et al., 1983; Martin & Flexor, 1984; Dias et al.,1984; Martin et al., 1984; Dominguez, 1990; Murillo et al., 2009), which provides the sediment transport into the water by the wind action.

The PSR presented OM values varying from 0.3 to 23%, and the higher values were located in stations in the north and in the central areas of the delta. The mangrove vegetation in the deltaic system affects the station PS17, which explains the OM value of 22% in this site. The urbanized area of Gargaú is connected to the deltaic system by a straight channel, which is marked by an intense boat traffic. These boat activities justify the few OM in the PS14 (8%) and provides an accumulation of OM in PS13 (23%) by the organic compounds carried by the channel. Furthermore, the stations PS04, PS05, PS06, PS08 and PS09 are probably impacted from human influence, since the north area of the delta is not well represented by the mangrove. The station PS05, although, stood out of the OM range of the delta presenting 35% of organic matter, which is probably associated to a high quantity of effluents discharge from the urbanized area of Gargaú city, stocked in a confined site.

Usually, the organic matter values in tropical coastal regions mainly range between 0 and 6%, according to Carreira et al. (2001), Baptista-Neto et al. (2000) and Laut et al (2007, 2016), in studies along the Brazilian’s coast, not exceeding 6% (Baptista-Neto et al., 2000; Vilela et al., 2002; Silva et al., 2005). In Itaipu Lagoon there were identified sites with 15% of OM, characterizing it as a very impacted area (Raposo et al., 2018), but the values identified in PSR were much higher. These results corroborate the conclusion of Miguens et al. (2016) in a previous study in the Paraiba do Sul River delta, affirming that this region has been considered very polluted.

In coastal environments, the higher carbonate values are associated to the presence of shells (Greiner, 1974) or to the sea water input into the system (Belart et al, 2019). In PSR, the higher values CO3 were identified in the north area, suggesting the most marine conditions in this region.

5.2. Characterization of assemblages in the delta

5.2.1. The living assemblages of foraminifera and thecamoebians

The richness and diversity results of the living assemblages found in this deltaic system can be related to the ones identified in the Guadiana Estuary, which presented the richness ranging from 1 to 21 and diversity ranging from 0 to 2.3 (Sarita, 2014). These values, therefore, were considered typical to estuarine environments according to Murray (2003) and were higher than the ones identified in the tropical delta of PSR, that presented the richness values ranging from 2 to 9 and the diversity values ranging from 0.7 to 2.

The estuarine conditions in the north area of the delta allowed the survival of calcareous foraminifera species (Sen Gupta and Kilbourne, 1974; Douglas, 1979) such as *A. parkinsoniana*, *C. gunteri* and *C. excavatum*. On the other hand, the high freshwater influence promotes good environment for thecamoebians and some agglutinants foraminifera (Moreno et al., 2005; Fatela et al., 2009), which are dominant in the south and central areas of the PSR. So, the diversity and the equitability are irregularly distributed, which characterizes the heterogeneity of this region.

According to the DCA analysis, these calcareous species were related to lagoon conditions in the environment provided by marine water entrance, due to the high salinity, DO, OM, CO_3 and fine sediments. The species *A. tepida*, *A. parkinsoniana* and *C. excavatum*, although, can be associated to regions with lower salinity values, which indicates a resistant character to live in diverse habitats and to accept a wide range of environmental settings (Hayward et al.,1996; Debenay et al., 2002; Laut et al. 2012, 2016a), becoming bioindicators of eurytropic conditions. The foraminifera species *C. excavatum* was recorded in other estuarine conditions as Potengi River (Souza et al., 2010), in many Brazil lagoons and around the world (Debenay et al., 2002; Vilela et al., 2003; Laut et al., 2012; Martins et al., 2015; Dias et al., 2017).

The abundance of the living foraminifera assemblages can be modified by the fresh water supply and the abiotic parameters (Laut et al., 2011). Besides, Nichols (1974) argues that a region with less than 50 tests of foraminifera can represent the low benthic productivity.

Therefore, the PSR delta can be associated to these characteristics since there are 18 stations of living assemblages with less than 50 specimens (PS01, PS02, PS07, PS08, PS10, PS11, PS12, PS13, PS15, PS16, PS17, PS18, PS19, PS20, PS21, PS22, PS23 and PS24).

Regarding the most dominant foraminifera species, *A. tepida* is frequently found along the paralic regions (Debenay & Guillou, 2002) associated with river mouths (Rossi and Vaiani, 2008; Frezza and Carboni, 2009; Goineau et al., 2011). The authors Frontalini et al. (2009); Debenay et al (2015) and Martins et al (2015) affirms that the *A. tepida* dominates coastal environments around the world and demonstrated a high resistance to different physical-chemical or sedimentological parameters. In the PSR, this species is found throughout the deltaic system, including the stations with freshwater influence, which corroborate to this resistance character. The DCA analysis associates this species to the estuarine influence in this delta.

The species *H. wilberti* and *T. salsa*, as the most abundant agglutinated species, responded positively to sandy sediments, high Eh and temperature. Previous studies described by Laut et al. (2012, 2016a, 2017) and Martins et al. (2015) related the occurrence of these agglutinant species to environments influenced by freshwater, fine sediments and mangroves, identifying an opposite sediment affinity as in PSR. These species were identified in many coastal environments, such as Godineau River Estuary (Laut et al., 2017), Itacorubí River (Laut et al., 2007), Paraiba do Sul River (Laut et al., 2011) and Caeté River (Laut et al., 2016).

Concerning the foraminifera species *T. salsa*, *A. mexicana* and *Q. seminula*, there was presented a negative relation with the OM, diverging from the results found by Cotano & Villate (2006). In addition, these species can respond to the abiotic parameters in a similar way that *P. ipohalina* does (Semensatto Jr. & Dias-Brito 2004, 2006; Laut et al., 2011), presenting affinity to sandy sediments, Eh and temperature according to the DCA analysis,

Regarding the thecamoebians species, the genus *Difflugia* was the most representative in the delta and it is frequently found in association with high organic matter (Kliza & Schröder-Adams, 1999.; Laut *et al.* 2010). However, this genus did not follow this association in Paraiba do Sul River delta, responding negatively to the OM. The species *Difflugia corona* and *Difflugia oblonga* were the most abundant species and they were also identified by Laut et al. (2011, 2016b) in the Paraiba do Sul River and in Caeté River and by Rosa et al. (2017) in many rivers of Mato Grosso do Sul state. The species *D. oblonga* was described as a common bioindicator of the internal estuarine zone (Kliza & Schröder-Adams, 1999; Laut et al., 2010), but in this delta the species presented an irregular distribution, being identified in every sectors of the delta. All the thecamoebians species (*D. corona*, *D. urceolata*, *D. oblonga*, *C. constricta*, *L. vas*) were associated to the fluvial dominance according to the DCA analysis, responding positively to sandy sediments, high Eh and temperature and low influence of OM.

5.2.2. Dead assemblages of foraminifera and thecamoebians in the delta

The richness of dead foraminifera assemblages had values ranging from 6 to 30 species. These values were higher than the ones found by Laut et al. (2011) in Paraiba do Sul River (ranging from 3 to 13) and by Semensatto Jr & Dias-Britto (2004) in São Francisco Delta (ranging from 2 to 22). The diversity values of the PSR ranged from 1.2 (PS05) to 2.3 (PS18), while Semensatto Jr & Dias-Britto (2004, 2006) recorded in São Francisco River delta diversity values ranging between 0.4 and 0.8, through the total assemblage analysis. The ranges determined by Semensatto Jr & Dias-Britto (2004) were considered typical for paralic regions, characterizing the PSR as a rich and diverse environment.

In the south area, the higher diversity values are related to the association between the foraminifera and thecamoebians species. This is provided by a transitional area in the delta, due to the different abiotic parameters beneficiating the assemblages, and to locate the allocation of the tests from external zones of the study area. This distribution of organisms shows a low dominance of species, which causes the increasing values of diversity and equitability.

The dead assemblages of foraminifera and thecamoebians are associated to the high hydrodynamics of the deltaic system. This dynamic allows the transport of the microorganisms' tests from external regions to different compartments in the delta, either by fluvial or marine influence. As an example, the species *Pseudononion japonicum*, *Reussoolina laevis* and *Bolivina spathulata* were located in the north and the central areas of the PSR and they were only identified in the dead assemblages, suggesting a transport of these species into the deltaic system.

In a previous study of Paraiba do Sul River, Laut et al. (2011) described more species of thecamoebians than it was identified in this study. Their results, although, identified a sector totally influenced by fluvial settings which corroborated to the higher diversity of thecamoebians. The species that were described in common between both studies were: *Centropyxis constricta*, *Difflugia oblonga*, *Difflugia urceolata*, *Difflugia viscidula*, *Lagenodifflugia vas* and *Pontigulassia compressa*, and, according to the authors, they were distributed throughout the entire delta, demonstrating the fluvial influence and the lower estuarine conditions into the system. In the present study, however, these species have a more restrict distribution being identified only in the central and south areas, suggesting a different hydrodynamics by the reduced influence of fluvial water. This different behavior of the delta may probably be intensified by the human interventions along the Paraiba do Sul River basin, decreasing the sediment discharge and resulting distinct abiotic and hydrodynamics in this delta.

5.3.Comparison between living and dead organisms' assemblages

The cluster analysis contributed to comprehend that the PSR delta demonstrates few similarities between the groups of stations and the biocenosis and the taphocenosis of foraminifera species, while the analysis did not present any comparison concerning the thecamoebians species due to the absence of their living assemblages. The foraminifera species *A. mexicana*, *A. parkinsoniana*, *A. tepida*, *C. gunteri*, *C. excavatum*, *E. macrescens*, *H. wilberti* and *T. salsa* were the only ones recorded in the living and in the dead assemblages, and their distribution was only represented in the group I of the cluster analysis.

Therefore, the deltaic system of PSR delta could be divided in five groups, which responded the relation between the microorganisms and its distribution. The group Ia' suggests an environment with mangrove influence due to the representativity of the living and dead foraminifera assemblages of *H. wilberti*, *T. salsa* and *A. mexicana*, plus the occurrence of every species of thecamoebians. The group Ib' is characterized by the estuarine conditions in the environment, which provides the survival of the foraminifera species *A. tepida* and *C. excavatum*. The group II represents an oligohaline environment with brackish and freshwater influence indicated by the dead assemblages of *T. salsa*, *H wilberti* and the thecamoebians species. The group III highlights the hydrodynamical conditions in the deltaic system since the dominant species is *A. tepida*, which was identified in every region of the delta, and is composed only by dead assemblages, supporting the intense taphonomic processes. The group IV represents coastal regions with estuarine conditions by the high abundance of *C. gunteri*. The group V is also influenced by estuarine conditions, indicated by the foraminifera species *A. parkinsoniana*, *C. excavatum* and *M. subrotunda*.

6. CONCLUSIONS

Based on a comparison with previous studies in the PSR, it was possible to identify differences in the hydrodynamics and in the abiotic parameters. These differences, thus, can be related to the human interference along the river's basin, intensifying the reduction of the sediment discharge and the fluvial influence in the delta.

The bioindicators that responded to organic matter, carbonate and fine sediments were the calcareous foraminifera *A. tepida*, *C. excavatum* e *M. subrotunda*, and the bioindicators of sandy sediments, temperature and oxireduction potencial were the agglutinant foraminifera *T. salsa*, *H. wilberti* e *P. ipohalina*. The thecamoebians responded negatively to the estuarine conditions, following the parameters related to the agglutinated foraminifera species.

Besides the high hydrodynamical conditions, the sectorization of the PSR delta through the biocenosis and the taphocenosis was possible to be realized. These results considered to the species the minimum of 50 specimens and more than one station of occurrence, presenting an adaptation to Fatela & Taborda (2002). So, the living calcareous foraminifera were located in the north area of the delta and the agglutinated species were recorded in the central and south areas, as well as the living and dead species of thecamoebians. The dead species of foraminifera were identified throughout the deltaic system because of the transport of the tests.

The analysis of the living and dead assemblages allowed the identification of few similarities between them by the species *A. mexicana*, *A. parkinsoniana*, *A. tepida*, *C. gunteri*, *C. excavatum*, *E. macrescens*, *H. wilberti* and *T. salsa*. Therefore, the analysis of the biocenosis and the taphocenosis of foraminifera and thecamoebians were efficient on the diagnose of the deltaic system, responding to the influence of the hydrodynamics. The obtained results are able to contribute to the monitoring of the environmental changes and to paleoenvironmental studies of evolution in the deltaic region.

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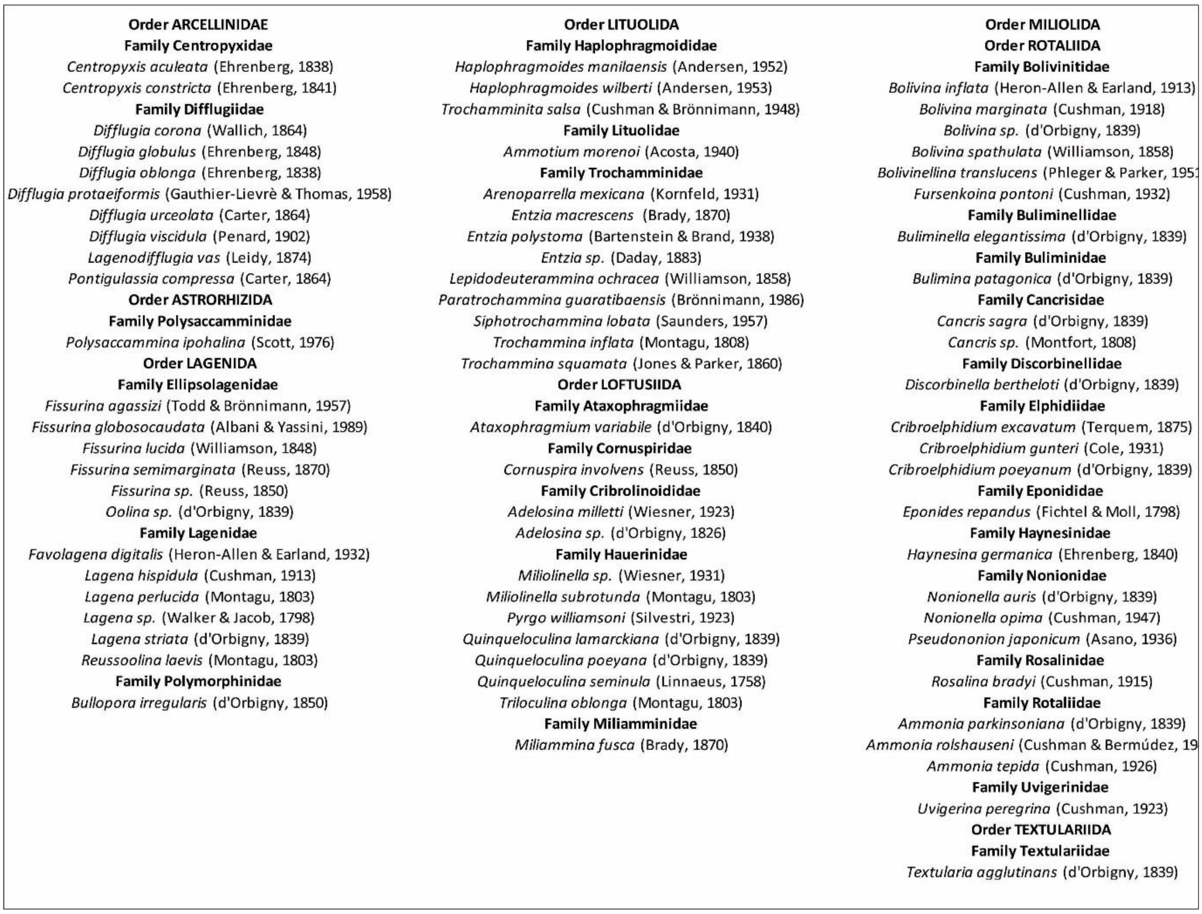
Appendix 1. Foraminifera and thecamoebians species identified on the Paraiba do Sul River.

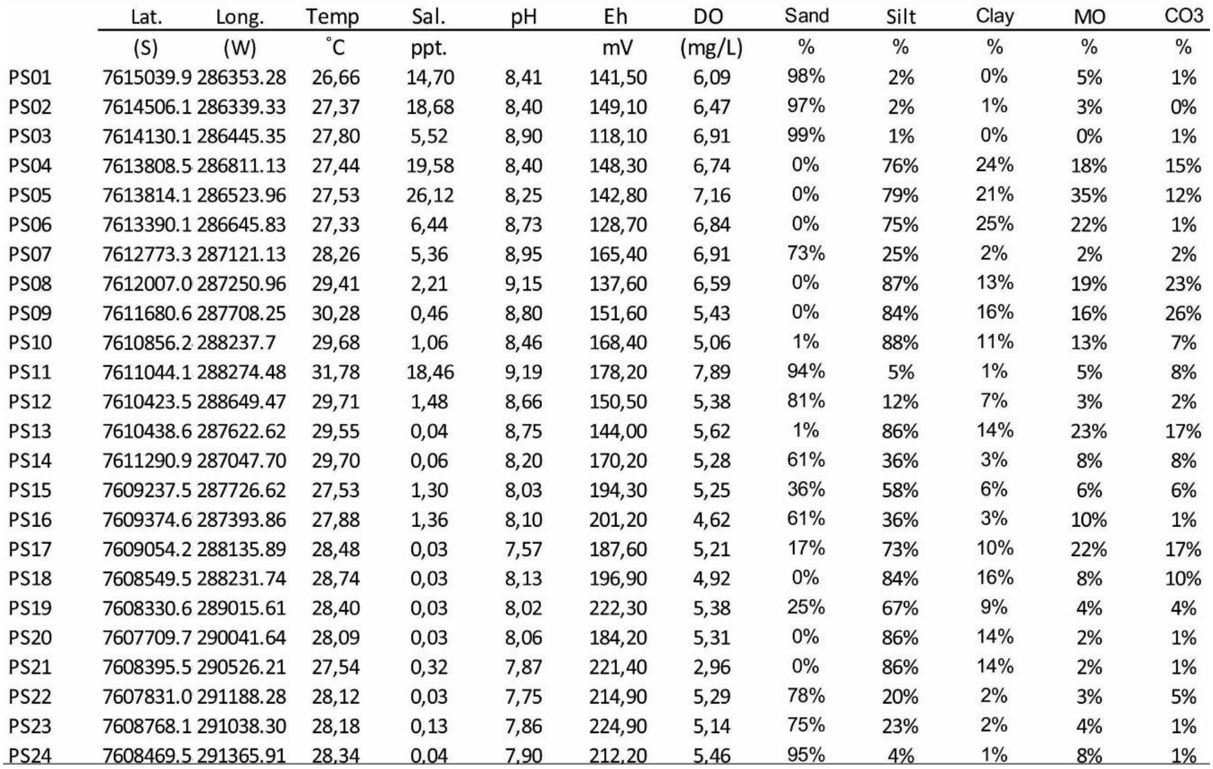


Order ARCELLINIDAE
Family Centropyxidae
Centropyxis aculeata (Ehrenberg, 1838)
Centropyxis constricta (Ehrenberg, 1841)
Family Difflugiidae
Difflugia corona (Wallich, 1864)
Difflugia globulus (Ehrenberg, 1848)
Difflugia oblonga (Ehrenberg, 1838)
Difflugia protaeiformis (Gauthier-Lievrè & Thomas, 1958)
Difflugia urceolata (Carter, 1864)
Difflugia viscidula (Penard, 1902)
Lagenodifflugia vas (Leidy, 1874)
Pontigulassia compressa (Carter, 1864)
Order ASTRORHIZIDA
Family Polysaccamminidae
Polysaccammina ipohalina (Scott, 1976)
Order LAGENIDA
Family Ellipsolagenidae
Fissurina agassizi (Todd & Brönnimann, 1957)
Fissurina globosocaudata (Albani & Yassini, 1989)
Fissurina lucida (Williamson, 1848)
Fissurina semimarginata (Reuss, 1870)
Fissurina sp. (Reuss, 1850)
Oolina sp. (d'Orbigny, 1839)
Family Lagenidae
Favolagena digitalis (Heron-Allen & Earland, 1932)
Lagena hispidula (Cushman, 1913)
Lagena perlucida (Montagu, 1803)
Lagena sp. (Walker & Jacob, 1798)
Lagena striata (d'Orbigny, 1839)
Reussoolina laevis (Montagu, 1803)
Family Polymorphinidae
Bullopora irregularis (d'Orbigny, 1850)

Order LITUOLIDA
Family Haplophragmoididae
Haplophragmoides manilaensis (Andersen, 1952)
Haplophragmoides wilberti (Andersen, 1953)
Trochamminita salsa (Cushman & Brönnimann, 1948)
Family Lituolidae
Ammotium morenoi (Acosta, 1940)
Family Trochamminidae
Arenoparrella mexicana (Kornfeld, 1931)
Entzia macrescens (Brady, 1870)
Entzia polystoma (Bartenstein & Brand, 1938)
Entzia sp. (Daday, 1883)
Lepidodeuterammina ochracea (Williamson, 1858)
Paratrochammina guaratibaensis (Brönnimann, 1986)
Siphotrochammina lobata (Saunders, 1957)
Trochammina inflata (Montagu, 1808)
Trochammina squamata (Jones & Parker, 1860)
Order LOFTUSIIDA
Family Ataxophragmiidae
Ataxophragmium variabile (d'Orbigny, 1840)
Family Cornuspiridae
Cornuspira involvens (Reuss, 1850)
Family Cribrolinoididae
Adelosina milletti (Wiesner, 1923)
Adelosina sp. (d'Orbigny, 1826)
Family Hauerinidae
Miliolinella sp. (Wiesner, 1931)
Miliolinella subrotunda (Montagu, 1803)
Pyrgo williamsoni (Silvestri, 1923)
Quinqueloculina lamarckiana (d'Orbigny, 1839)
Quinqueloculina poeyana (d'Orbigny, 1839)
Quinqueloculina seminula (Linnaeus, 1758)
Triloculina oblonga (Montagu, 1803)
Family Miliamminidae
Miliammina fusca (Brady, 1870)

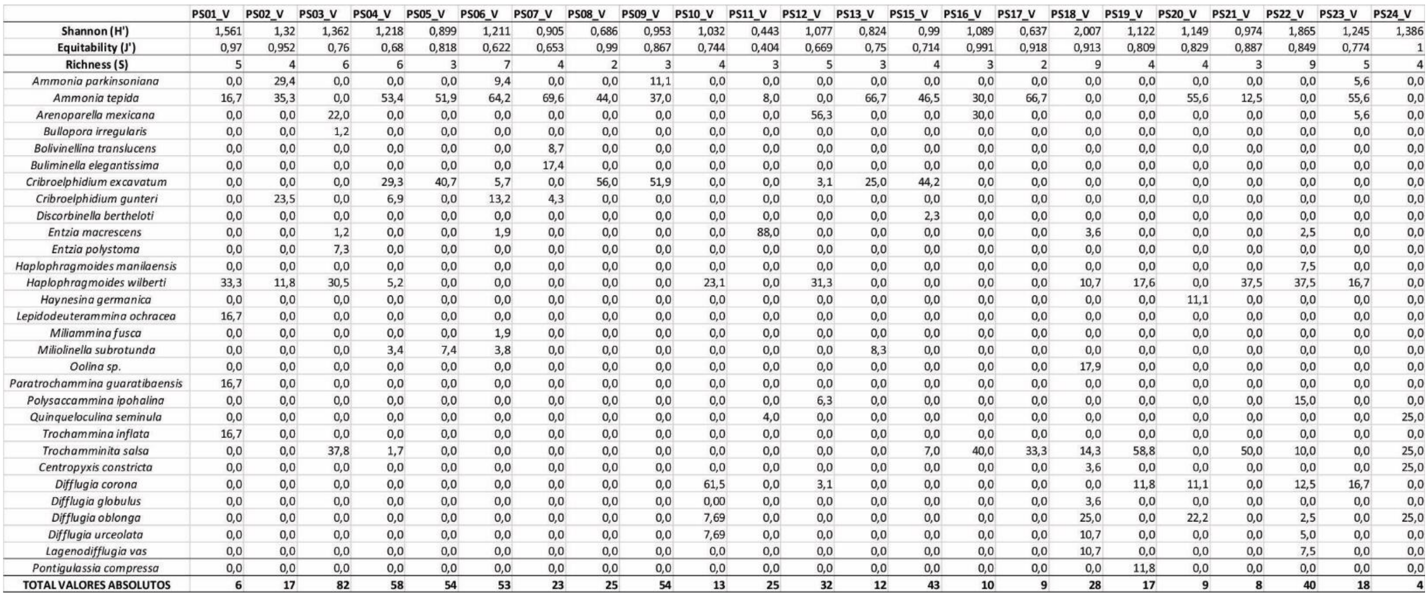
Order MILIOLIDA
Order ROTALIIDA
Family Bolivinitidae
Bolivina inflata (Heron-Allen & Earland, 1913)
Bolivina marginata (Cushman, 1918)
Bolivina sp. (d'Orbigny, 1839)
Bolivina spathulata (Williamson, 1858)
Bolivinellina translucens (Phleger & Parker, 195
Fursenkoina pontoni (Cushman, 1932)
Family Buliminellidae
Buliminella elegantissima (d'Orbigny, 1839)
Family Buliminidae
Bulimina patagonica (d'Orbigny, 1839)
Family Cancrisidae
Cancris sagra (d'Orbigny, 1839)
Cancris sp. (Montfort, 1808)
Family Discorbinellidae
Discorbinella bertheloti (d'Orbigny, 1839)
Family Elphidiidae
Cribroelphidium excavatum (Terquem, 1875)
Cribroelphidium gunteri (Cole, 1931)
Cribroelphidium poeyanum (d'Orbigny, 1839)
Family Eponididae
Eponides repandus (Fichtel & Moll, 1798)
Family Haynesinidae
Haynesina germanica (Ehrenberg, 1840)
Family Nonionidae
Nonionella auris (d'Orbigny, 1839)
Nonionella opima (Cushman, 1947)
Pseudononion japonicum (Asano, 1936)
Family Rosalinidae
Rosalina bradyi (Cushman, 1915)
Family Rotaliidae
Ammonia parkinsoniana (d'Orbigny, 1839)
Ammonia rolshauseni (Cushman & Bermúdez, 19
Ammonia tepida (Cushman, 1926)
Family Uvigerinidae
Uvigerina peregrina (Cushman, 1923)
Order TEXTULARIIDA
Family Textulariidae
Textularia agglutinans (d'Orbigny, 1839)

Appendix 2. Dataset of the Paraiba do Sul River: geographic coordinates; average values of water parameters (Temp. – temperature (ºC); Sal. – salinity (ppt.); pH; Eh – oxireduction potential (mV); DO – dissolved oxygen (mg/L)); sediment parameters (%) (sand, silt and clay fractions; OM - organic matter; CO_3 – carbonate).



	Lat.	Long.	Temp	Sal.	pH	Eh	DO	Sand	Silt	Clay	MO	CO3
	(S)	(W)	˚C	ppt.		mV	(mg/L)	%	%	%	%	%
PS01	7615039.9	286353.28	26,66	14,70	8,41	141,50	6,09	98%	2%	0%	5%	1%
PS02	7614506.1	286339.33	27,37	18,68	8,40	149,10	6,47	97%	2%	1%	3%	0%
PS03	7614130.1	286445.35	27,80	5,52	8,90	118,10	6,91	99%	1%	0%	0%	1%
PS04	7613808.5	286811.13	27,44	19,58	8,40	148,30	6,74	0%	76%	24%	18%	15%
PS05	7613814.1	286523.96	27,53	26,12	8,25	142,80	7,16	0%	79%	21%	35%	12%
PS06	7613390.1	286645.83	27,33	6,44	8,73	128,70	6,84	0%	75%	25%	22%	1%
PS07	7612773.3	287121.13	28,26	5,36	8,95	165,40	6,91	73%	25%	2%	2%	2%
PS08	7612007.0	287250.96	29,41	2,21	9,15	137,60	6,59	0%	87%	13%	19%	23%
PS09	7611680.6	287708.25	30,28	0,46	8,80	151,60	5,43	0%	84%	16%	16%	26%
PS10	7610856.2	288237.7	29,68	1,06	8,46	168,40	5,06	1%	88%	11%	13%	7%
PS11	7611044.1	288274.48	31,78	18,46	9,19	178,20	7,89	94%	5%	1%	5%	8%
PS12	7610423.5	288649.47	29,71	1,48	8,66	150,50	5,38	81%	12%	7%	3%	2%
PS13	7610438.6	287622.62	29,55	0,04	8,75	144,00	5,62	1%	86%	14%	23%	17%
PS14	7611290.9	287047.70	29,70	0,06	8,20	170,20	5,28	61%	36%	3%	8%	8%
PS15	7609237.5	287726.62	27,53	1,30	8,03	194,30	5,25	36%	58%	6%	6%	6%
PS16	7609374.6	287393.86	27,88	1,36	8,10	201,20	4,62	61%	36%	3%	10%	1%
PS17	7609054.2	288135.89	28,48	0,03	7,57	187,60	5,21	17%	73%	10%	22%	17%
PS18	7608549.5	288231.74	28,74	0,03	8,13	196,90	4,92	0%	84%	16%	8%	10%
PS19	7608330.6	289015.61	28,40	0,03	8,02	222,30	5,38	25%	67%	9%	4%	4%
PS20	7607709.7	290041.64	28,09	0,03	8,06	184,20	5,31	0%	86%	14%	2%	1%
PS21	7608395.5	290526.21	27,54	0,32	7,87	221,40	2,96	0%	86%	14%	2%	1%
PS22	7607831.0	291188.28	28,12	0,03	7,75	214,90	5,29	78%	20%	2%	3%	5%
PS23	7608768.1	291038.30	28,18	0,13	7,86	224,90	5,14	75%	23%	2%	4%	1%
PS24	7608469.5	291365.91	28,34	0,04	7,90	212,20	5,46	95%	4%	1%	8%	1%

Appendix 3. Abundance and ecological index of the living assemblages of foraminifera and thecamoebians from Paraiba do Sul River ("_L" represents the living assemblages).



	PS01_V	PS02_V	PS03_V	PS04_V	PS05_V	PS06_V	PS07_V	PS08_V	PS09_V	PS10_V	PS11_V	PS12_V	PS13_V	PS15_V	PS16_V	PS17_V	PS18_V	PS19_V	PS20_V	PS21_V	PS22_V	PS23_V	PS24_V
Shannon (H')	1,561	1,32	1,362	1,218	0,899	1,211	0,905	0,686	0,953	1,032	0,443	1,077	0,824	0,99	1,089	0,637	2,007	1,122	1,149	0,974	1,865	1,245	1,386
Equitability (J')	0,97	0,952	0,76	0,68	0,818	0,622	0,653	0,99	0,867	0,744	0,404	0,669	0,75	0,714	0,991	0,918	0,913	0,809	0,829	0,887	0,849	0,774	1
Richness (S)	5	4	6	6	3	7	4	2	3	4	3	5	3	4	3	2	9	4	4	3	9	5	4
Ammonia parkinsoniana	0,0	29,4	0,0	0,0	0,0	9,4	0,0	0,0	11,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	5,6	0,0
Ammonia tepida	16,7	35,3	0,0	53,4	51,9	64,2	69,6	44,0	37,0	0,0	8,0	0,0	66,7	46,5	30,0	66,7	0,0	0,0	55,6	12,5	0,0	55,6	0,0
Arenoparella mexicana	0,0	0,0	22,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	56,3	0,0	0,0	30,0	0,0	0,0	0,0	0,0	0,0	0,0	5,6	0,0
Bullopora irregularis	0,0	0,0	1,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Bolivinellina translucens	0,0	0,0	0,0	0,0	0,0	0,0	8,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Buliminella elegantissima	0,0	0,0	0,0	0,0	0,0	0,0	17,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Cribroelphidium excavatum	0,0	0,0	0,0	29,3	40,7	5,7	0,0	56,0	51,9	0,0	0,0	3,1	25,0	44,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Cribroelphidium gunteri	0,0	23,5	0,0	6,9	0,0	13,2	4,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Discorbinella bertheloti	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Entzia macrescens	0,0	0,0	1,2	0,0	0,0	1,9	0,0	0,0	0,0	0,0	88,0	0,0	0,0	0,0	0,0	0,0	3,6	0,0	0,0	0,0	2,5	0,0	0,0
Entzia polystoma	0,0	0,0	7,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Haplophragmoides manilaensis	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	7,5	0,0	0,0
Haplophragmoides wilberti	33,3	11,8	30,5	5,2	0,0	0,0	0,0	0,0	0,0	23,1	0,0	31,3	0,0	0,0	0,0	0,0	10,7	17,6	0,0	37,5	37,5	16,7	0,0
Haynesina germanica	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	11,1	0,0	0,0	0,0	0,0
Lepidodeuterammina ochracea	16,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Miliammina fusca	0,0	0,0	0,0	0,0	0,0	1,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Miliolinella subrotunda	0,0	0,0	0,0	3,4	7,4	3,8	0,0	0,0	0,0	0,0	0,0	0,0	8,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Oolina sp.	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	17,9	0,0	0,0	0,0	0,0	0,0	0,0
Paratrochammina guaratibaensis	16,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Polysaccammina ipohalina	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	6,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	15,0	0,0	0,0
Quinqueloculina seminula	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	4,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	25,0
Trochammina inflata	16,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Trochamminita salsa	0,0	0,0	37,8	1,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	7,0	40,0	33,3	14,3	58,8	0,0	50,0	10,0	0,0	25,0
Centropyxis constricta	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	3,6	0,0	0,0	0,0	0,0	0,0	25,0
Difflugia corona	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	61,5	0,0	3,1	0,0	0,0	0,0	0,0	0,0	11,8	11,1	0,0	12,5	16,7	0,0
Difflugia globulus	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,00	0,0	0,0	0,0	0,0	0,0	0,0	3,6	0,0	0,0	0,0	0,0	0,0	0,0
Difflugia oblonga	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	7,69	0,0	0,0	0,0	0,0	0,0	0,0	25,0	0,0	22,2	0,0	2,5	0,0	25,0
Difflugia urceolata	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	7,69	0,0	0,0	0,0	0,0	0,0	0,0	10,7	0,0	0,0	0,0	5,0	0,0	0,0
Lagenodifflugia vas	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	10,7	0,0	0,0	0,0	7,5	0,0	0,0
Pontigulassia compressa	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	11,8	0,0	0,0	0,0	0,0	0,0
TOTAL VALORES ABSOLUTOS	**6**	**17**	**82**	**58**	**54**	**53**	**23**	**25**	**54**	**13**	**25**	**32**	**12**	**43**	**10**	**9**	**28**	**17**	**9**	**8**	**40**	**18**	**4**

Appendix 4. Abundance and ecological index of the dead assemblages of foraminifera and thecamoebians from Paraiba do Sul River.

	PS01	PS02	PS03	PS04	PS05	PS06	PS07	PS08	PS09	PS10	PS11	PS12	PS13	PS14	PS15	PS16	PS17	PS18	PS19	PS20	PS21	PS22	PS23	PS24
Shannon (H')	1,633	1,321	1,195	1,257	1,186	1,461	2,109	1,486	1,522	2,03	1,437	1,558	2,158	1,375	1,209	1,945	2,307	2,342	1,43	1,428	1,616	2,131	2,149	1,427
Equitability (J')	0,785	0,679	0,614	0,476	0,462	0,634	0,62	0,496	0,5	0,732	0,691	0,65	0,655	0,768	0,391	0,758	0,852	0,887	0,596	0,65	0,83	0,807	0,685	0,796
Richness (S)	8	7	7	14	13	10	30	20	21	16	8	11	27	6	22	13	15	14	11	9	7	14	23	6
Adelosina milletti	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Ammonia parkinsoniana	0,0	19,4	0,0	0,6	0,0	4,7	0,0	0,2	0,9	0,0	0,0	0,0	6,3	0,0	0,7	0,9	5,9	0,0	0,0	0,0	0,0	0,0	1,5	0,0
Ammonia rolshauseni	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	0,9	2,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Ammonia tepida	4,9	46,3	0,0	53,1	64,0	32,1	49,7	36,1	19,5	1,6	25,5	0,0	39,1	0,0	44,1	8,8	23,5	0,0	0,0	62,5	4,8	2,8	36,1	0,0
Ammotium morenoi	0,0	0,0	0,0	0,0	0,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Arenoparella mexicana	7,3	0,0	8,2	0,0	1,7	1,2	0,0	0,0	0,0	6,4	0,0	46,6	0,0	20,2	1,5	15,8	3,9	0,0	0,4	0,0	0,0	2,8	0,0	0,0
Ataxophragmium variabile	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	3,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Adelosina sp	0,0	0,0	0,0	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Bolivina inflata	0,0	0,0	0,0	0,0	0,0	0,0	0,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Bullopora irregularis	0,0	0,0	1,4	0,0	0,0	0,0	0,0	0,0	0,0	1,6	0,0	1,4	0,0	0,0	0,0	3,5	0,0	0,0	0,0	0,0	0,0	0,7	0,0	0,0
Bolivinellina translucens	0,0	0,0	0,0	0,0	0,0	0,0	5,0	0,6	1,5	0,0	0,0	0,0	2,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,8	0,0
Bolivina marginata	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,8	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,4	0,0
Bulimina patagonica	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Bolivina sp.	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Buliminella elegantissima	0,0	0,0	0,0	0,0	0,0	0,0	2,5	0,8	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Bolivina spathulata	0,0	0,0	0,0	0,4	0,0	0,0	0,0	1,6	1,2	0,0	0,0	0,0	2,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,3	0,0
Cancris sagra	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Cancris sp.	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,3	0,0
Cornuspira involvens	0,0	0,0	0,0	0,0	0,0	0,0	1,4	0,0	0,3	0,0	0,0	0,0	0,3	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Cribroelphidium excavatum	0,0	1,5	0,0	28,7	4,7	3,2	5,2	45,0	56,7	0,0	0,0	0,0	21,5	0,0	46,1	13,2	7,8	0,0	0,0	8,3	0,0	0,0	8,0	0,0
Cribroelphidium poyeanum	0,0	0,0	0,0	0,0	3,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Cribroelphidium gunteri	0,0	26,9	0,0	2,1	0,0	44,9	0,0	0,2	0,0	0,0	0,0	0,0	0,3	0,0	0,3	0,0	0,0	0,0	0,0	4,2	0,0	0,0	1,5	0,0
Entzia macrescens	26,8	0,0	0,0	0,0	0,0	0,5	0,0	0,4	0,0	0,5	7,2	1,4	0,0	0,0	0,2	0,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Entzia polystoma	4,9	0,0	2,4	0,2	0,0	0,5	0,3	0,0	0,0	0,5	0,0	0,0	0,3	0,0	0,0	2,6	0,0	0,0	0,4	0,0	0,0	0,0	0,0	0,0
Eponides repandus	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	3,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Entzia sp.	0,0	0,0	0,0	1,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Fissurina agassizi	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,4	0,0
Favolagena digitalis	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Fissurina globosocaudata	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Fissurina lucida	0,0	0,0	0,0	0,0	0,0	0,0	2,2	0,0	0,0	0,0	0,0	0,0	0,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Fissurina semimarginata	0,0	0,0	0,0	0,0	0,0	0,0	1,7	0,2	1,2	0,0	0,0	0,0	2,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,9	0,0
Fursenkoina pontoni	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Fissurina sp.	0,0	0,0	0,0	0,0	0,0	0,0	0,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Haplophragmoides manilaensis	0,0	3,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,0	2,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	4,2	0,0	3,5	0,4	0,0
Haplophragmoides wilberti	41,5	1,5	35,2	0,0	0,6	4,2	0,3	0,0	0,0	17,6	0,0	27,4	0,7	26,0	1,2	3,5	3,9	1,7	10,3	4,2	14,3	34,0	8,4	45,5
Haynesina germanica	0,0	0,0	0,0	0,4	0,6	0,0	1,1	1,2	0,6	0,0	0,0	0,0	0,0	0,0	0,3	0,9	5,9	0,0	0,0	4,2	0,0	0,0	0,4	0,0
Lagena perlucida	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	0,0	1,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Lagena striata	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,8	0,0
Lagena hispidula	0,0	0,0	0,0	0,0	0,0	0,0	5,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Lagena sp.	0,0	0,0	0,0	0,0	0,0	0,0	0,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Lepidodeuterammina ochracea	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Miliammina fusca	0,0	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	4,1	0,0	1,0	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Miliolinella subrotunda	0,0	0,0	0,0	11,5	21,5	1,0	0,0	3,9	9,3	0,0	38,6	0,0	0,3	0,0	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Miliolinella sp.	0,0	0,0	0,0	0,0	0,0	0,0	0,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Nonionella auris	0,0	0,0	0,0	0,0	0,0	0,0	0,3	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Nonionella opima	0,0	0,0	0,0	0,0	0,0	0,0	0,6	0,6	0,0	0,0	0,0	0,0	2,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Oolina sp.	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	3,5	0,0	0,0	0,0	0,0	0,0	0,0
Paratrochammina guaratibaensis	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,7	0,0	0,0	0,0	0,0	0,0	0,0
Polysaccammina ipohalina	0,0	0,0	3,1	0,0	0,6	0,0	0,0	0,0	0,0	5,3	0,0	9,6	0,7	13,0	1,5	13,2	0,0	0,0	43,3	0,0	19,0	13,2	4,2	22,7
Pseudononion japonicum	0,0	0,0	0,0	0,2	0,6	0,0	5,8	0,6	1,5	0,0	0,0	0,0	6,3	0,0	0,3	0,0	2,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Quinqueloculina lamarckiana	0,0	0,0	0,0	0,0	0,0	0,0	3,9	0,0	0,0	0,0	2,4	0,0	0,7	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Quinqueloculina poeyana	0,0	0,0	0,0	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Quinqueloculina seminula	0,0	1,5	0,0	0,0	0,0	0,0	6,9	5,1	2,8	0,5	24,1	0,0	4,6	0,0	0,0	0,0	2,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Reussoolina laevis	0,0	0,0	0,0	0,0	0,6	0,0	1,1	1,0	0,9	0,0	0,0	0,0	3,6	0,0	0,2	0,0	7,8	0,0	0,0	0,0	0,0	0,0	1,1	0,0
Rosalina bradyi	0,0	0,0	0,0	0,0	0,0	0,0	1,7	0,0	0,3	0,0	0,0	0,0	1,7	0,0	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,4	0,0
Pyrgo williamsoni	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	4,2	0,0	0,0	0,0	0,0
Siphotrochammina lobata	7,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Textularia agglutinans	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Trochammina inflata	2,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Triloculina oblonga	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Trochamminita salsa	0,0	0,0	49,5	0,2	0,6	7,8	0,0	0,0	0,0	32,1	0,0	2,7	1,0	39,4	0,8	35,1	23,5	6,1	34,3	4,2	42,9	9,7	22,1	4,5
Trochammina squamata	4,9	0,0	0,0	0,0	0,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,7	0,0	0,0
Uvigerina peregrina	0,0	0,0	0,0	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Centropyxis aculeata	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,4	0,0	0,0	0,0	0,0	0,0	2,6	0,0	0,0	0,0	0,0	0,0	0,0
Centropyxis constricta	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,0	0,0	0,0	0,0	0,2	0,0	0,0	10,4	0,9	0,0	4,8	0,0	0,0	0,0
Difflugia corona	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	7,5	0,0	0,0	0,7	0,0	0,2	0,0	0,0	10,4	0,9	0,0	4,8	5,6	1,5	4,5
Difflugia globulus	0,0	0,0	0,0	0,0	0,0	0,0	0,6	0,0	0,0	1,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	8,7	0,0	0,0	0,0	0,0	0,0	0,0
Difflugia oblonga	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,4	0,7	0,0	0,0	0,0	0,0	10,4	2,6	4,2	0,0	4,2	1,9	18,2
Difflugia protaeiformis	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,9	0,0	0,0	0,0	0,0	0,0	0,0
Difflugia urceolata	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	7,0	0,4	0,0	0,0	2,8	0,4	0,0
Difflugia viscidula	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,0	0,0	0,0	1,7	0,0	0,0	0,0	1,4	0,0	0,0
Lagenodifflugia vas	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	5,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	13,9	3,9	0,0	0,0	12,5	1,9	0,0
Pontigulassia compressa	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	17,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	20,9	2,6	0,0	9,5	6,3	1,5	4,5
TOTAL VALORES ABSOLUTOS	**41**	**67**	**293**	**471**	**172**	**408**	**362**	**509**	**323**	**187**	**290**	**73**	**302**	**208**	**590**	**114**	**51**	**115**	**233**	**24**	**21**	**144**	**263**	**22**

CONCLUSÕES GERAIS

A partir de uma comparação com estudos anteriores realizados no RPS foi possível identificar diferenças nas condições de hidrodinâmica e nos parâmetros ambientais. Essas diferenças, portanto, podem estar relacionadas a interferência humana ao longo da bacia do rio, intensificando a redução da descarga de sedimentos e da influência fluvial no delta.

As espécies bioindicadoras de matéria orgânica, carbonato e sedimentos finos foram os foraminíferos calcários *A. tepida*, *C. excavatum* e *M. subrotunda*, enquanto as espécies bioindicadoras de sedimentos arenosos, maior temperatura e potencial de oxirredução foram os foraminíferos aglutinantes *T. salsa*, *H. wilberti* e *P. ipohalina*. As tecamebas, por fim, responderam negativamente ao ambiente de condições estuarinas, acompanhando os parâmetros relacionados as espécies aglutinantes de foraminíferos.

Apesar da alta condição hidrodinâmica do RPS, a setorização do delta através da biocenose e da tafocenose foi possível de ser realizada. Os resultados estatísticos foram encontrados através da adaptação do método proposto por Fatela & Taborda (2002), considerando o mínimo de 50 indivíduos por espécie e a ocorrência da mesma em mais de uma estação. As espécies vivas de foraminíferos calcários foram localizadas na área norte do delta e os aglutinantes foram localizadas nas áreas central e sul, assim como as espécies vivas e mortas de tecamebas. Já os foraminíferos mortos foram encontrados ao longo do sistema deltaico devido a alocação das carapaças.

Desta forma, a análise da biocenose e da tafocenose permitiu a identificação de poucas similaridades entre as assembleias vivas e mortas, a partir das espécies *A. mexicana*, *A. parkinsoniana*, *A. tepida*, *C. gunteri*, *C. excavatum*, *E. macrescens*, *H. wilberti* and *T. salsa*, evidenciando o intenso transporte de carapaças entre os setores do delta. Sendo assim, a biocenose e a tafocenose de foraminíferos e tecamebas foram eficientes na diagnose do sistema deltaico do RPS, respondendo a condições de hidrodinâmica e identificando impactos causados por origem antropogênica. Os resultados obtidos contribuirão para o monitoramento das mudanças ambientais e para os estudos de evolução paleoambiental da região.

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