Chapter 5
“Sediment’s Quality Responders”: Water Renovation, Sewage and Industrial Pollution Stress on Benthic Fauna

Abstract Analyses of living foraminiferal and environmental parameters near an outfall at Mar Grosso Beach (Laguna, SC, Brazil) demonstrate its usefulness as indicators of domestic sewage pollution. The low species diversity may be due to sand accumulation in the surf zone of the central part that prevents settlement on or in the substrate. Silt and clay content correlates well with the total coliforms higher diversity of foraminiferal species, reduced salinity, and higher temperatures closer to the mouth of Laguna estuarine system indicate freshwater influence, suggesting relationship between increased diversity and greater availability of terrestrial food, even if the salinity decreases. Higher Forams diversity and average coliform values are closer to the mouth of the estuarine system and under the influence of the outfall. The estuary mouth is under the influence of the outfall and exhibits higher foraminiferal diversity and higher mean values of total coliforms and silt-clay content. Due to the effect of local hydrodynamics, the particulate organic waste derived from the outfall settle down locally, accumulating nearby on the southwestern and northwestern parts of the beach. We confirm our hypothesis that the fine material derived from the outfall is accumulating in shallow parts of the beach. In general, the characteristics of the foraminiferal assemblages show that the environment is in the initial stages of eutrophication. Apparently, the nutrient enrichment of the water by the organic waste has induced changes in the benthic foraminiferal community through an increase in species richness. Due to the high energy of the marine environment, however, the particulate organic waste derived from the outfall does not settle down on the seabed; but it supports the hypothesis that the fine material derived from the 12-m deep outfall is accumulated on the southwest part of the beach.

The fluctuations in salinity and temperature in Todos os Santos Bay established different tolerance limits for certain species, which indicates that species distribution was subject to natural environmental seasonal changes and excellent water renovation. In the present study, many marine species were observed, indicating a strong influence due to intrusion of marine waters from the adjacent continental shelf. Given that, opportunistic-tolerant species directly benefit from certain kinds of contamination of organic substances, or indirectly, through the reduction of competition and predation, increasing their local occurrence; this chapter reveals this bay as an environment where organic matter is easily deposited, the excess of nutrients results in a low diverse fauna dominated by Ammonia spp. closer to freshwater sources.
The occurrence of *Elphidium* spp. and *Quinqueloculina* spp. is limited to the eastern part of the TSB. *Pseudononion atlanticum* and *Bolivina* spp. presented their occurrence limit in the area under continental runoff influence. A decrease in diversity indicates less stability close to Mataripe River and RLAM area, and an increase in diversity in central and east parts of Todos os Santos Bay. Some areas present aliphatic accumulation, and silt and clay accumulation. *Ammonia tepida*, *Bolivina* spp., and *Fursenkoina pontoni* tolerate sediment with aliphatic and unresolved complex mixture, while *Elphidium* spp. decreases in areas under the influence of pollutants. *Ammonia* spp., *Bolivina* spp., and *Fursenkoina pontoni* are known organic matter and low oxygen-tolerant foraminifers, and in the bay, they are tolerant to petroleum derived pollutants.

**Keywords** Diversity · Dominance · Hydrodynamics · Water renovation · Sewage · Outfall · Salinity · Coliforms · Estuarine system

**Introduction**

Scenic beauty and recreational opportunities attract people to the coastal zone which eventually leads to marine pollution. Using modern foraminiferal analyses coupled with oceanographic and geological proxies, we can understand the “water renovation” concept and its applicability in marine pollution.

Distribution of salinity, temperature, diversity, dominance of opportunist species, and organic matter helps us reach an understanding of the ecosystem and its function, showing natural, disturbed, or “optimum state” climax where diversity is so high that it is able to send biodiverse propagules to other less pristine nearby environments increasing their local biodiversity.

In long-term environmental monitoring of ecosystems, the use of benthic organisms as indicators of rate of change in pollution-prone areas is reliable, because the close dependence of benthic organisms on the composition of the marine sediment in which contaminating substances settle and accumulate. Due to slow moving or sessile way of life, benthic communities are used in the monitoring of effects of marine pollution, which render them more susceptibility to local disturbances integrating effects of pollutants over time. They comprise a large number of species, and because of specific sensitivity of species, it is possible to pinpoint subtle impacts reflected in changes in community structure.

In addition, benthos, unlike the plankton or nekton, adapt and reflect local sedimentary conditions over a period of years, instead of just a snapshot of the conditions prevailing at the moment of sediment sampling. Benthic Foraminifera is used in hazard assessment at specific discharge sites, and monitoring of the effectiveness of remedial actions because their short life cycle and quick reaction to environmen-
tal shifts. These “fast first-community” responders to disturbing, impacting and distressing agents are used as an early warning of human-induced environmental change, as defined by Kramer and Botterweg (1991).

Variability of salinity, temperature, sediment type, amount of organic carbon, pH, and tidal energy unraveled Benthic Foraminifera as bio indicators of coastal pollution (Boltovskoy et al. 1991; Alve 1991, 1995; Yanko et al. 1999; Scott et al. 2001) revealing that the common effect of increasing concentration of contaminants is reduction in species diversity, until only opportunistic species remain. Such opportunists react favorably to pollution dominating impacted areas of marshes (Schafer et al. 1995; Collins et al. 1995), being tolerant or resistant to the pollutants or contaminants. However, on the other hand, species that are sensitive to specific impact often express that sensitivity through their absence (Yanko et al. 1999). The foraminiferal assemblages impose themselves as a means of assessing the quality of waters and aquatic ecosystems, for the biological variables, associated with salinity, temperature, dissolved oxygen content, pH, sediment characteristics, and heavy metal concentrations provide data indicative of depositional and erosional patterns, pollution, contamination, and eutrophication levels as well.

Distribution patterns of benthic Forams species in shallow, enclosed marine environments, contaminated by organic and industrial wastes have demonstrate that they are sensitive and inexpensive biomarkers capable of indicating sediment quality and water renovation potential.

This chapter talks about these findings illustrating two examples in Brazil, one in the south, and other one located in the northeast. One is a Beach in Mar Grosso Beach, downtown Laguna (Santa Catarina State), where this beach is under the influence of a domestic submarine outfall discharge, and the other one, the Todos os Santos Bay, Bahia state is influenced by refinery wastes. This chapter intend to enlighten the reader in the wonders of the hydrodynamics capacity of increase local biodiversity, and we are here to explain how we are able to say these things.

The Popular Mar Grosso Beach!!

Here we show how foraminiferal species dynamics, and total coliform bacteria, responds to physiochemical (salinity, temperature, dissolved oxygen, pH) and to geological proxies (percentage of sand, silt, and clay) helping us to evaluate the ecological conditions resulting from the outfall discharge in the sampling setting of Fig. 5.1. Summer sampling was carried out on the Mar Grosso Beach, a very important tourist destination in the south of Brazil, close to where the effluents from the submarine outfall are released.

Sampling was done on the beach adjacent to the lagoon’s entrance where the submarine outfall is located (Mar Grosso Beach). The area receives contribution from freshwater and marine water masses, being highly dynamic with coarse grains dominating in most parts, and some exceptions where silt and clay predominate.
Our hypothesis is that the fine material derived from the outfall is accumulating on the southwestern and northwestern parts of the beach.

**Water Renovation and Domestic Sewage**

All over the world, domestic sewage is an inevitable consequence of human settlement and activity, the coastal zone is affected by alterations introduced to the water, and it has been increasing in recent decades. This growth of coastal urban centers have resulted in an increase of the amount of nutrients and other harmful material in the sewage, including organisms, which are not welcome at all, such as pathogens. This continued growth calls for the establishment of adequate strategies to manage, reduce, or eliminate the impact that sewage wastes have on the environment and on human health. The water renovation is the probability that the ocean provides a cleaning effect on the waters, and especially bottom waters, giving the environment the capacity to auto regenerate.

The restrict environments like bays are prone to be totally polluted or contaminated and it is directly related to the ocean intrusion in the environment. However, open sea can also be contaminated by sewage being transported by wind, surface circulation, or along the ocean bed from polluted coastal zones to other zones (Castro and Miranda 1998). Bottom waters bathe marine sediments and therefore
benthic habitat has the ability to tell the quality of conditions. A healthy bottom habitat is necessary to maintain the organisms that live in the water column as a whole. Clean water with potential periodic natural renovation is of “high ecological status” and, successful environmental implementation and management requires a thorough understanding of ecosystem structure and functioning under pre-impacted conditions in order to set realistic restoration goals for the problems of sewage and industrial pollution challenges like sediment settlement of urban wastes in specific situations.

Since Forams geo habitats are fossilized and allow tracking of periodically natural and environmental changes due to human impacts over the last hundreds of years, ecological studies employ different multi-variate statistical techniques for interpreting modern foraminiferal environment relationships. Benthic foraminiferal communities living in marine and coastal environments respond to a broad range of biotic and abiotic factors that result in complex interactions in space and time. The first case of this chapter deals with quantitative analyses of living foraminiferal as indicators of domestic sewage and environmental parameters near a submarine outfall at Mar Grosso Beach (Laguna, Santa Catarina, Brazil).

In this stretch of Mar Grosso beach where the submarine outfall is situated, we evaluated the response of the foraminiferal microfauna and fecal coliforms to physical, geological and chemical gradients, and point out the area most affected by the sewage plume. Mar Grosso beach, a humid temperate, with an average annual temperature of 19.7 °C is situated in Tubarão city region, about 118 km south from Florianópolis, the Santa Catarina State Capital. This coastline of 208.706 km is subjected to micro tides, with the wind playing an important role on the ocean dynamics. The outflow of this estuarine system is in the southeastern part of Mar Grosso Beach.

**The Submarine Outfall: The Eww of Sewage Making the Gross of Mar Grosso Beach!!**

The domestic sewage on the coast of Laguna discharges effluent residues and wastes into the open sea from a submarine outfall, about 1400 m long, at a depth of about 12 m off the Mar Grosso beach, one of the most popular beaches in the southern region of Brazil.

The effluent shows obvious increases in summer, causing biological, chemical, physical and geological alterations in the marine environment, because the introduced fresh water and excessive nutrients disturbs the basic conditions of the ecosystem thus interfering with the ecological chain. Salinity changes affect the water-mass stratification; nekton and benthos, the consumers, take advantage of the extraordinary increase in food availability (Eichler et al. 2003).

Besides Eichler et al. (2012a) samplings which are illustrating part of this chapter, no other studies or assessments of ecological consequences and fauna responses
due to the installation (in 1986) of the submarine sewage outfall, and the extent of its influence on the sediment quality of the Mar Grosso beach and surroundings have been done. Will this gross negligence and subsequent contamination continue to accumulate indefinitely? There are impact questions needing immediate address that remain unanswered.

Domestic sewage directly released into the sea is a problem worldwide, whether in terms of the volume of substances or in terms of practical problems of public health. Pathogenic organisms contained in fecal material transmit diseases specially this new coronavirus, so we should also consider the potential of water renovation from nature to help fight pandemics. Nitrogen and organic phosphorus from human fecal material, together with other organics that flow into the sea and can cause diseases, are normally recycled into their inorganic forms. If this amount of material is too much, it will promote an increase of planktonic algae (eutrophication), which in turn will drastically reduce dissolved oxygen, causing fish death from low oxygen. Other impacts, such as the accumulation of sand, silt, clay, and organic material, and a reduction of water transparency from suspended particulate matter, produce negative visual effects. These features will worsen as time passes and become unbearable for local and touristic alike.

**Hydrographical Parameters**

Increasing from West to East, depth of sampling varied between 4 and 20 m, with shallowest areas in the south part of the beach. Higher salinity in the eastern and southeastern sectors of the study area, and lower at the mouth of the estuarine system and near the outfall. It is possible to see zonation of this variable, where lower salinity occurs in the south most part. Higher temperatures occur near the mouth of the estuarine system. Oxygen content remains constant above 7 mg/l, pH did not show significant variation, and the lowest value occurred in between the outfall and the mouth of the estuarine system. High salinity and oxygen peaks with low temperature occurred in the southwestern part of the beach. Figure 5.2 illustrates these conditions.

**Geological Parameters**

Sediment pH shows lower values in two different areas of the beach. One is closer to the outfall and the other one is in the central part of the beach. Higher amounts of silt and clay were noted in the southern sector adjacent to the mouth of the estuarine system, and in the northwestern sector. The distribution of silt and clay shows the influence of the plume from the outfall and the Laguna estuarine system, suggesting that clay does not settle in the central sector because of the turbulence generated by the confluence of continental waters into the ocean.
Accumulation of “natural” origin due to the influence of the estuarine system occurs rather adjacent to its mouth, whereas in the southeastern and northwestern sectors its provenance seems to be from the effluents discharged by the submarine outfall and thus of anthropogenic origin. No accumulation of silt or clay in the central sector, however, there is a sand bank formation starting at the entrance of the outfall, in the western sector of the beach. The sand accumulation seems to have occurred because the circulation generated by the balance between northeasterly and southerly winds. Sand, however, is being accumulated at the outfall. Due to the effect of local hydrodynamics, the particulate organic waste derived from the outfall does settle down locally accumulating nearby the southern part of the beach and the entrance of the outfall (Fig. 5.3).

**Biological Parameters**

Small numbers of living foraminiferal species in the area, and some sterile samples with no organisms at all. These barren ones were located in the surf zone, where strong water dynamics hinder growth of foraminiferal communities. Fecal coliforms were absent at the majority of sampling stations, however, two stations located in the southwest part of the beach were exceptions, having high coliform abundance. These sites where silt and clay also accumulate, seemed to be one of the
worst sites in regards to the health of the ecosystem. As for total coliforms, we note that the samples with very high values of total coliforms and those with high clay and silt content were barren of Foraminifera, and low concentrations of total coliforms were found related to the higher salinity.

The spatial distributions of dominant foraminiferal species *Pseudononion atlanticum*, *Elphidium* spp., *Buccella peruviana*, and total coliforms are shown in Fig. 5.4. *Buccella peruviana* had reduced abundance at sites where the values for total coliforms were higher. Higher values of coliforms are closer to the mouth of the estuarine system and under the influence of the outfall. The abundance peaks of *Pseudononion atlanticum* and *Elphidium* spp. were at stations with highest water temperatures. The fecal coliform group consists of a variety of bacteria, including the genera *Klebsiella*, *Escherichia*, *Serratia*, *Erwenia*, and *Enterobacteria*. The use of fecal coliform bacteria as indicators of sanitary pollution is regarded as more significant than the use of “total” coliform bacteria, because fecal bacteria are restricted to the intestinal tract of warm-blooded animals. Overall, the concentration of coliforms is an important parameter that may indicate the existence of pathogenic organisms, including those responsible for the transmission of water-borne diseases such as typhoid, fever, paratyphoid fever, bacillary dysentery, cholera, and proliferation of already mentioned coronavirus. A sterile zone for Foraminifera linked to a lack of silt and clay and consequently of organic material and food for the species, is present with low numbers of total coliforms.
A plume of lower diversity follows until the middle of the beach being more pronounced closer to the mouth of the estuarine system. Higher diversity is observed in the submarine outfall. Higher values of foraminiferal dominance closer to the mouth of the estuarine system and under the influence of the outfall the dominance is lower (Fig. 5.5).

Based on foraminiferal diversity and average coliform count, higher values are closer to the mouth of the estuarine system, and under the influence of the outfall. There is accumulation of fine particles of silt and clay and high correlation with total coliforms in the southern part of the beach. In addition, due to the effect of local hydrodynamics, the particulate organic waste derived from the outfall does
settle down locally, and thus accumulates nearby in the south part of the beach where there is dominance.

**Concluding Remarks of the Submarine Outfall**

Low diversity of foraminifera and the presence of barren zone near the outfall may be partly related to the surf zone, where hydrodynamics hinders benthic foraminiferal colonization. However, the sand accumulation and lack of clay and silt deposition in this sector severely reduce the food supply, and also prevent the development of a foraminiferal community.

The accumulation of silt and clay in the deepest parts of the inner continental shelf of Mar Grosso Beach suggests that their origin may be either of “natural” origin, under the influence of the estuarine system, or of anthropogenic origin, from the sewage outfall. This accumulation of fine-grained sediment has promoted local increases in foraminiferal diversity. The deposition of total coliforms in the central part of the beach probably was facilitated by a circulation associated with the northeasterly and southerly winds that prevail in the region.

Higher dissolved oxygen all over was not a limiting factor that negatively impact any foraminiferal species, on the other hand, the temperature increase observed at the mouth of the Laguna estuarine system favored the proliferation of *Elphidium* spp. and *Pseudononion atlanticum*. The distribution of *Buccella peruviana*, also representative of other foraminifera species (*Ammonia tepida, Bulimina marginata, Buliminella elegantissima Elphidium* spp., *Orbulina* spp.) are responding to temperature, depth, salinity, and percentage of sand rather than percentage of clay and total coliforms.

In the present study, fecal coliforms were recorded at only two stations. However, other bacteria of the coliform group were present at all stations, demonstrating the contamination of the region although foraminifera species are showing a better correlation with temperature, depth, salinity, and percentage of sand.

The continuing increase of the sand bank would reduce water depth and may impede water circulation, especially in the deeper parts of the southwestern and northwestern sectors of the Mar Grosso beach; these sectors are currently seriously affected by silt and clay accumulation, and oceanic bottom waters are not capable of renewing the system. The foraminifera benthic fauna has undergone degradation in the central sector, because the accumulation of sand and the absence of fine material here are conducive to the development of a barren zone, preventing the proper flush of bottom waters.

Populations of coliform bacteria, however, exist all over; their development does not seem to be related to the amount of silt and clay in the sediment. The accumulation of silt and clay in the study area is linked to both a “natural” source, influenced by the estuarine system, and an anthropogenic source, i.e., the sewage outfall. The deposition of material of both origins is affected by water circulation associated with northeasterly and southerly winds, and the low species diversity may be due to
sand accumulation in the central part. By the other hand, higher diversity closer to the mouth of Laguna estuarine system, where reduced salinity and higher temperatures indicate freshwater influence, suggests a relationship between increased diversity and greater availability of terrestrial food. At present, fine particles such as silt and clay do not accumulate in the immediate neighborhood of the Mar Grosso submarine outfall, but the deposition of sand in the central near the mouth of the estuarine system may cause a stagnation problem in the future. There is accumulation of fine particles of silt and clay and high correlation with total coliforms in the southern part of the beach that are not being exported, being also a problem concern for the near future.

Todos os Santos Bay, the Oil Refineries in Bahia!!

For 2 consecutive years, from 2003 to 2005, the composition of Benthic Foraminifera organisms’ assemblages was used to assess the occurrence of different bio facies and to establish pollution and contamination bio indicators of the environmental quality of marine sediments in the ecologically differentiate environments of Todos os Santos Bay. This region holds the Landulpho Alves Refinery (RLAM) area from PETROBRAS, and this study shows the influence of the industrial pollution on the benthic communities using a hypoxia index.

Species Distribution

No anomalies in foraminiferal tests were detected. Year round, mangrove areas harbor less diversity areas than sites closer to the refinery. In summer there are more fragmented tests were than in winter. Ammonia spp. dominates in the region, followed by species characteristic of marine environments under little influence from continental runoff such as Elphidium spp., Pseudononion atlanticum spp. and Quinqueloculina spp. The presence of agglutinated forms (Gaudryina exilis, Ammotium spp., Haplophragmoides wilberti, Arenoparrella mexicana, Trochammina sp.) was also found, indicating high influence from continental runoff in some stations.

Hypoxia Index

To determine the degree of environmental pollution of marine sediment through the hypoxia (A-E index) we applied the index described by Sen Gupta et al. (1996), and it application was based on the absolute abundance of two common species (Elphidium excavatum and E. poyeannum). Species of Ammonia tepida are tolerant to hypoxia, although species of Elphidium are less resistant than those of Ammonia. The A-E index is calculated by the formula:
\[
\frac{A.B.\text{Ammonia}}{A.B.\text{Ammonia} + A.B.\text{Elphidium}} \times 100
\]

where: A.B. = absolute abundance (number of individuals/50 cm³).

Percentage of organic carbon and concentration of PAH values were correlated to A-E index and \textit{Ammonia tepida} in plots, and the analysis of tests fragmentation were observed in relation to the state of test preservation, due to acidity and transportation.

Positive correlation between distribution of \textit{Ammonia} spp. and PAH (polycyclic aromatic hydrocarbons) concentration in two seasons, and the A-E index was also correlated to organic carbon, and increases in the hypoxia index and in organic carbon content (Fig. 5.6).

**Concluding Remarks Regarding the Industrial Pollution**

The study of foraminifera in the bay shows occurrence of marine species in environments under low freshwater runoff influence such as \textit{Ammonia} spp., \textit{Elphidium} spp., \textit{Pseudononion atlanticum}, \textit{Buliminella elegantissima} and \textit{Quinqueloculina} spp., and of agglutinated forms. This kind of fauna in the Todos os Santos Bay (TSB) indicates that marine waters dominate the environment, however low diversity and strong dominance of a few species is characteristic of estuarine environments where
fresh water limits organism distribution, or yet of not very well preserved environments.

The opportunistic species *Buliminella elegantissima*, known for its high tolerance to high organic matter content (Setty and Nigam 1982; Eichler et al. 1995; Sen Gupta 1999), had same distribution pattern throughout the year. Occurrence peaks for this species were found especially where PAH levels were high. The absence of *B. elegantissima* and of *Pseudononion atlanticum* in some stations suggests high influence of continental runoff in winter and summer. These estuarine species occur more associated with strong marine influence. The dominance of *Ammonia* spp., especially at stations where the highest organic phosphorus, PAH, UCM and aliphatic levels were found, reaffirms its status as an opportunistic species. On the other hand, *Elphidium* spp. dominated where a decrease in PAH, UCM and aliphatic was observed.

According to some authors, *Bolivina* spp is a species typical of environments rich in organic matter, which is mainly retained in muddy sediments, found practically in all regions of TSB. Environments with high organic contents have a direct relation to high mud concentrations (Tyson 1995), since in this type of sediment energy is quite low, contributing to the processes of organic matter deposition. In addition, fine sediments have a tendency to retain heavy metals and other pollutants (Kjerfve et al. 1997). Figure 5.7 shows that dominant species found in Todos os Santos Bay are *Ammonia tepida, Elphidium* spp., *Bolivina* spp., *Pseudononion atlanticum* and *Quinqueloculina* spp.

The number of species per sample increases when the environmental features are more typically marine (Phleger 1970). It was thus to be expected that this bay presented a higher diversity per sample level than more restricted estuarine environments. Although this bay is under the influence of continental runoff in the summer and winter, the foraminiferal assemblages indicate that this influence is quite small.

Comparison of the present study with data from less saline estuarine environments shows that number of species found is similar to this bay. This fact demonstrates that the pollution effects superimpose themselves onto the natural

---

**Fig. 5.7** Dominant species found in Todos os Santos Bay: *Ammonia tepida, Elphidium* spp., *Bolivina* spp., *Pseudononion atlanticum* and *Quinqueloculina* spp.

---
environmental factors, limiting the establishment of non-opportunistic species and facilitating the development of the opportunistic ones. Those species that are abundant in polluted areas are obviously tolerant to the pollutants to which they are subjected, whereas other species can manifest their sensitivity to the same pollutants by their absence (Yanko et al. 1994).

The accumulation of pollutants in coastal areas does not rely entirely on the supply of these materials by rivers, but also on the chemical interaction between those elements and the sediment constituents, and are therefore reflected by the carbon and fine sediment contents, which more easily adsorb these types of particles (Baptista-Neto et al. 2000).

Analysis of relative abundances suggests that the species *Gaudryina exillis*, *Textularia earlandi*, *Arenoparrella mexicana*, *Haplophragmoides wilberti*, *Trochammina* sp., *Ammotium* spp., *Ammoastuta inepta*, and *Miliammina fusca*, which occur in places more subjected to continental runoff, were grouped. The marine species *Globocassidulina subglobosa* and *Uvigerina* spp. are species rarely found in the study region, since they are usually associated to colder water masses. In the summer the influence of marine species was observed by the presence of *Discorbis* spp. Cardoso (2000), studying São Sebastião Channel (São Paulo State, Brazil), and Eichler et al. (2001), studying Bertioga Channel (São Paulo State, Brazil), suggest that the occurrence of this species was related to high-density marine currents penetrating via the bottom. Therefore, in the south region of the RLAM subtidal area, the penetration of the marine current was evidenced by the presence of *Discorbis* in that region, showing the potential to renew the water system of the bay.

High-diversity peaks were observed in the central and eastern regions of the RLAM subtidal area, while smaller values were found in the northern region close to the mouth of the Mataripe River and immediately offshore from the RLAM. That region displays a high dominance of *Ammonia* spp. Evenness is distributed along a gradient, where the smallest environmental stability values occur close to the RLAM and the Mataripe River continental runoff, indicating less environmental stability in those regions, and increase toward the region more subjected to ocean influence to the south. As environmental stress increases, species diversity falls, resulting in an increase of dominance (Odum 1988).

The north-to-south diversity increase probably reflects local hydrodynamic, where marine with high salinity waters are responsible for water renovation in the southern portion of the bay. The data obtained in the present study reveal that the northern sector, including the regions close to the RLAM, are low-circulation zones, and are thus less subject to water renovation. The analysis carried out over 2 consecutive years shows a relative environmental stability in terms of foraminifera. The higher diversity figures found in the second monitoring year reflected the inclusion of stations with more marked euhaline characteristics in the RLAM subtidal area and therefore do not have an apparent relation to eventual inter annual changes.