Search for Bioindicators of Pollution in the Guanabara Bay: Integrations of Ecologic Patterns

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Abstract

Guanabara Bay, since its discovery, has largely changed with the human occupation causing large amounts of deposited sediment and waste, as well as domestic and industry sewage. Surface sediment was analysed for foraminifera and ostracoda distribution, diversity and dominance studies. These results were compared with TOC analyses aiming the determination of pollution bioindicators.

In general, foraminifera dominant species were *Ammonia tepida, Buliminella elegantissima* and *Quinqueloculina seminulum*. The foraminifera assemblages presented distinct abundance and diversity values in different regions of the bay. The diversity was higher in the entrance (south) and in the central region than in the north region of the bay. The dominant species, that are characteristic of stressed environments, presented higher values of abundance in the north region.

The TOC values increased from south to north regions, and were inversely proportional to foraminifera diversity. The very high TOC values in very polluted areas suggest sediment deposition in anoxic-dysoxic environment.

The ostracoda Gen. *Cyprideis* was dominant and its occurrence increased from south to north region. Occurrence of *Callistocythere sigmocostata, Xestoleberis* sp., *Aurila* sp., and *Paracypris* sp. were restricted to the entrance and central area, indicating a preference for less restricted conditions, like marine conditions.

Foraminifera and ostracoda characteristic responses to the environment conditions related high TOC values showed their importance as bioindicators of stressed environments caused by anthropogenic pollution, in the Guanabara Bay.

Key-words: pollution, bioindicators, geochemistry, Guanabara Bay

Resumo

A Baía de Guanabara, desde o seu descobrimento, tem sido bastante modificada pela ocupação humana, causando o acúmulo de grande quantidade de sedimento depositado e lixo, bem como lançamento de esgotos domésticos e industriais. Sedimentos superficiais foram analisados visando o estudo da distribuição, diversidade e dominância de foraminíferos e ostracodes. Estes estudos foram comparados com análises de COT objetivando a determinação de bioindicadores de poluição.

Em geral as espécies dominantes de foraminíferos foram *Ammonia tepida*, *Buliminella elegantissima* and *Quinqueloculina seminulum*. As associações de foraminíferos apresentam distintos valores de abundância e diversidade em diferentes regiões da Baía. A diversidade foi mais elevada na entrada (sul) e na região central do que na região norte da Baía. As espécies dominantes, que são características de ambientes sob estresse, apresentaram valores altos de abundância na região norte.

Os valores de COT aumentaram da região sul para o norte e foram inversamente proporcionais à diversidade de foraminíferos. O elevados valores de COT em áreas muito poluídas sugerem deposição sedimentar em ambiente anóxico-desóxico.

O Gen. *Cyprideis*, de ostracode, foi dominante e sua ocorrência aumentou da região sul para o norte. A ocorrência de *Callistocythere sigmocostata*, *Xestoleberis* sp., *Aurila* sp. e *Paracypris* sp. foi estrita à entrada e região central, indicando uma preferência por condições menos restritas, como condições marinhas.

As respostas características dos foraminíferos e ostracodes às condições ambientais relacionadas aos elevados valores de COT mostraram sua importância como bioindicadores de ambientes sob estresse causado por poluição antropogênica na Baía de Guanabara.
Palavras-chave: poluição, bioindicadores, geoquímica, Baía de Guanabara

1 Introduction

Guanabara Bay, in Rio de Janeiro, is an important tourist and economic center in the southeast Brasil and, despite its beauty, is one of the most polluted regions in the Brazilian coast. Its margins include districts of the big cities of Rio de Janeiro and Niterói as well as Duque de Caxias, São Gonçalo and Magé cities, which form the Grande Rio megalopolis. It serves as recipient of untreated domestic and industry sewage, including two harbours, two oil refineries and thousands of industries contributing for its eutrophication. It is considered an estuarine environment that has been changed by the human activities since 1500. Much of its area including several mangroves and beaches was destroyed or reduced by empoldering.

Microfauna present in the sediments such as foraminifera and ostracoda were used to evaluate the anthropogenic pollution in that region. A detailed study of foraminifera content in the samples as well as ostracoda preliminary results were carried out aiming the search for bioindicators of pollution.

Foraminifera and ostracoda are small organisms living in marine sediments, and their studies have large use for ecology and paleoecology, in old environment reconstructions. The use of those organisms as bioindicators in polluted regions has many advantages, like: their small size, hard tests that preserve in sediments after death, high diversity and abundance, short life histories that respond quickly to environmental changes, and species characteristic responses to ecologic conditions (Alve, 1995; Culver & Buzas, 1995; Schafer *et al.*,1995; Eagar, 1997; Melis *et al.*, 1997; Yanko *et al.*, 1998; Eagar, 2000; Samir, 2000). Ecologic parameters of foraminifera and ostracoda including species occurrence and abundance, characteristic assemblages, and diversity indexes integrated to TOC (total organic carbon) analyses allow to good interpretations of the pollution levels.

2 Methods

In November 1999, surface sediment samples were collected in all the Guanabara Bay area comprising: the entrance of the bay, the middle area, and the northern area that includes the Duque de Caxias oil refinery zone (REDUC) at the northwest and the APA de Guapimirim (Environment Protection Area) at the northeast. The treatment of samples for microfauna studies consisted of washing, wet sieving, drying, and heavy liquid concentration. After the treatment, the specimens were picked, counted and classified in species.

The microfauna occurrence was evaluated considering the characteristic distribution per area. A minimum counting of 100 specimens per sample was used for statistical data. Species with 10% or higher abundance values in the samples were considered dominant. For foraminiferal results, the Shannon-Wiener (H) diversity index was used, taking into account the number of species and their relative abundance in the assemblage (Sen Gupta & Kilbourne, 1974).

The geochemical methods consisted of pulverization, acidification, washing and drying of the samples. The samples were then put in an oven for burning with O_2, and the organic carbon amount was evaluated. The TOC analyses expressed the percentage of the organic carbon in the samples.

3 Regions of the Guanabara Bay

In general low values for abundance of foraminifera were encountered in the samples, with small and abraded tests.

The foraminiferal assemblages had distinct diversity patterns related to the different regions of the Guanabara Bay. Normal saline values were observed in bottom waters, except for the areas close to the coast. Figure 1 presents Program Surfer

The distinct values of Shannon-Wiener diversity and TOC can be observed in Table 1.

Samples	H(S)	TOC (%)	Samples	H(S)	TOC (%)	Samples	H(S)	TOC (%)
ENTRANCE			CENTRAL AREA			NORTHERN AREA		
			MAIN CHANNEL			APA (northeast)		
58	2,94	0,55	37	3,33	3,32	3	2,09	3,94
60	4,88	0,08	38	2,51	3,89	4	1,77	3,99
65	3,69	0,16	44	2,77	1,9	5	1,57	3,93
70	3,21	0,06				7	1,08	3,78
73	0,18	0,05	RIO CITY (west)			8	0,91	3,83
74	2,87	0,07	48	1,47	0,31	9	1,71	4
75	2,84	0,11	50	2,47	4,68	12	2,64	3,7
79	1,51	0,04	52	2,59	2,83	14	1,37	3,83
81	0,72	0,05	53	0,35	6,13	15	1,85	3,8
82	1,95	4,14	55	2,97	4,1			
						REDUC (northwest)		
			NITERÓI CITY (east)			17	1,69	4,8
			31	2,07	4,2	18	1,31	3,65
			33	3,42	3,23	20	1,87	3,79
			40	1,81	3,28	22	2,15	4,32
			41	2,44	3,25	24	2,72	3,09
						27	3,57	4,29
						29	2,79	3,72
						86	0,05	4,47
						88	2,82	3,27
						90	2,1	3,57
						92	3,19	4,81

Table 1 Shannon-Wiener diversity index (H) and Total Organic Carbon (TOC) values, per sample

contour graphics of diversity H(S) and TOC values. Graphics in Figure 2 show diversity and TOC values for samples at the entrance, central and REDUC area. We can observe that diversity and TOC values are inversely proportional. In the entrance there is a channel that enters the bay transporting coarse (sandy) sediments from the marine shelf. The water circulation and salinity are controlled by tides, in an almost normal marine condition with higher diversity of foraminifera and lower TOC values. High TOC values in sample 82 can be explained by the proximity of domestic and industry sewages inside the Jurujuba Sound (Figure 2). In the central area, TOC values are increased in the shallow depths near Rio and Niterói coast, and the foraminiferal abundance is very low. Sample 53, located close to the Rio de Janeiro harbour, has very poor contents of foraminifera as a response for the high level of pollution. The northern area includes the APA de Guapimirim, that is a highly degraded mangrove and the Duque de Caxias industrial area, with the REDUC (oil refinery) and many other industries. TOC values are very high suggesting deposition under anoxic-dysoxic environment, and foraminiferal diversity is low in both the REDUC and APA areas. The proximity of the oil refinery pipes and industry sewages in those areas caused high levels of organic carbon, hydrocarbon contaminations in the sediments and consequent microfauna damage.

4 Foraminifera Results

Occurrences of characteristic dominant species confirmed the different regions of the bay. The dominant species of foraminifera were *Ammonia tepida, Buliminella elegantissima* and *Quinqueloculina seminulum* (Figura 3). These species were cited in the literature like opportunistic in coastal regions under stressed environmental conditions caused by anthropogenic pollution (Alve, 1995; Culver & Buzas, 1995; Collins *et al*., 1995; Yanko *et al*., 1999).

In the northern area, the diversity was very low but dominant species abundances were higher. There is a trend of the *A. tepida* and *B. elegantissima* abundances towards the northern and eastern most polluted and confined areas. Distributions of characteristic species were evaluated, like an increasing abundance of *Textularia earlandi* and *Bolivina lowmani* into the main channel and the north direction. Otherwise, species like *Bulimina marginata, Bucella peruviana, Pseudononion cuevanensis* and *Bolivina striatula* were found in samples collected in the entrance and the main channel, that are influenced by continental shelf marine conditions. These species are common in the Brazilian and Argentinean continental shelves (Tinoco, 1971; Boltovskoy, 1980; Closs & Barberena, 1962; Vilela, 1995).

5 Ostracoda Results

The ostracoda microfauna included 29 species with dominance of *Cyprideis salebrosa, Cyprideis* sp., *Xestoleberis* sp., *Aurila* sp., *Paracypris* sp. and *Callistocythere sigmocostata*. Gen. *Cyprideis* comprises more than 90% of the total assemblage, with a tendency of distribution into the northern region. That genera and rare occurrences of

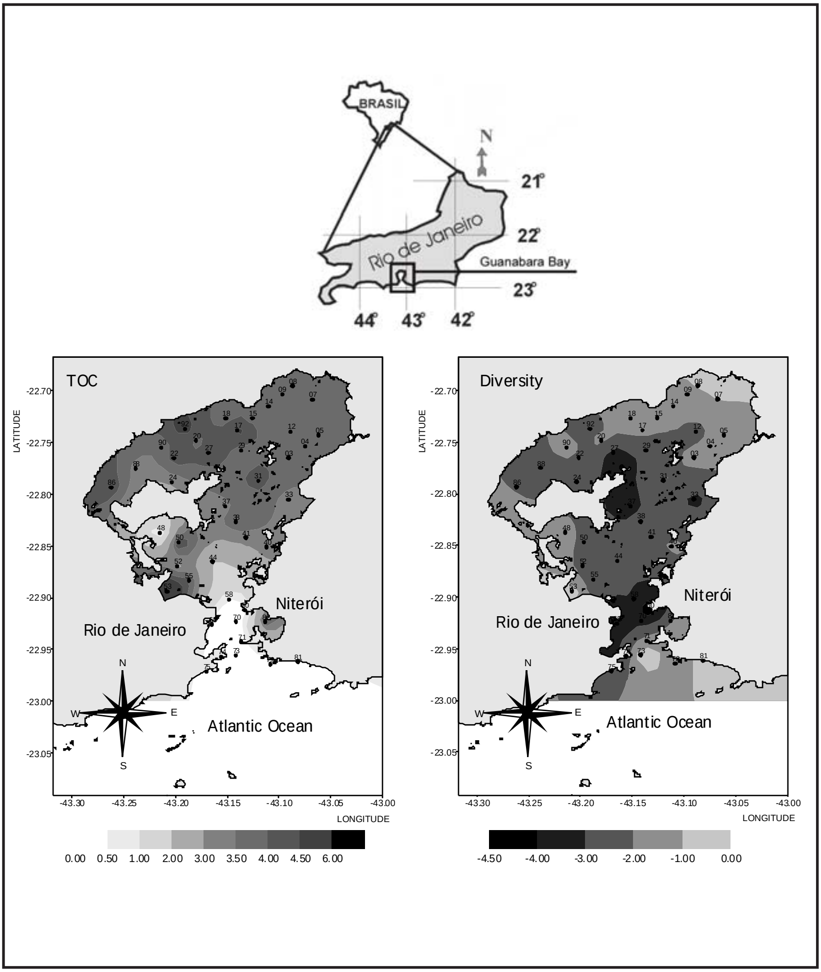

Figure 1 Location map of the samples in the Guanabara Bay with contour graphics of TOC and foraminifera diversity.

other species suggest stressed conditions in those samples. Species like *Xestoleberis* sp., *Aurila* sp., *Paracypris* sp. and *Callistocythere sigmocostata* are present in the samples indicating preferences for marine conditions. *Xestoleberis* sp. and *Aurila* sp. are distributed into the main channel, and *C. sigmocostata* has a distribution pattern in the entrance of the bay (Figure 4).

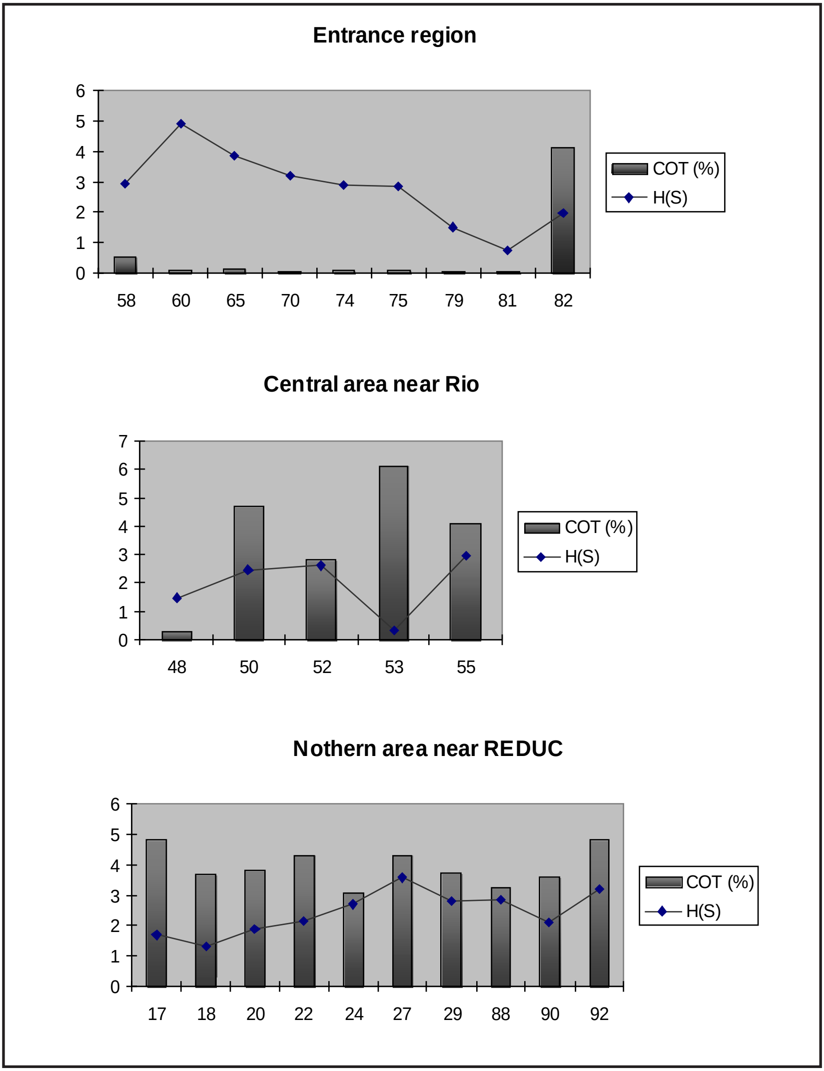

Figure 2 TOC and foraminifera diversity indexes for samples at the entrance, central and northern areas. Samples are plotted in the X axis.

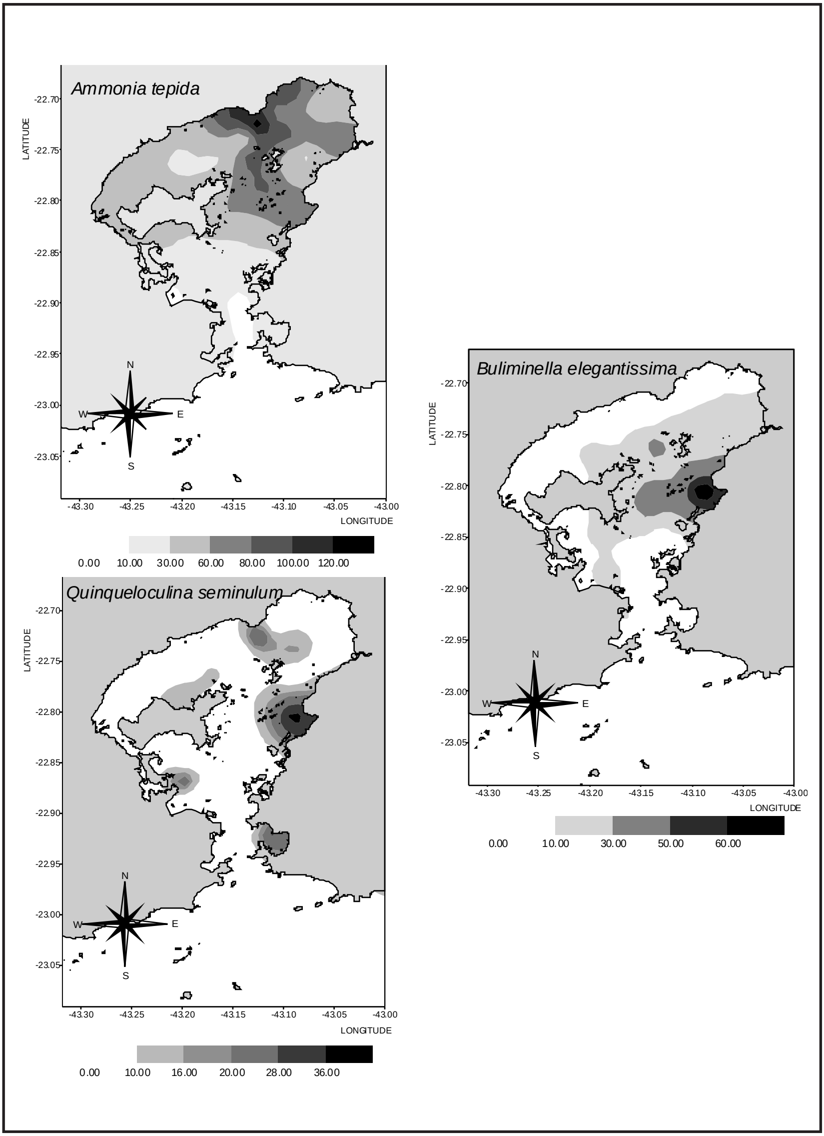

Figure 3 Occurrence of characteristic dominant foraminifera species in the Guanabara Bay.

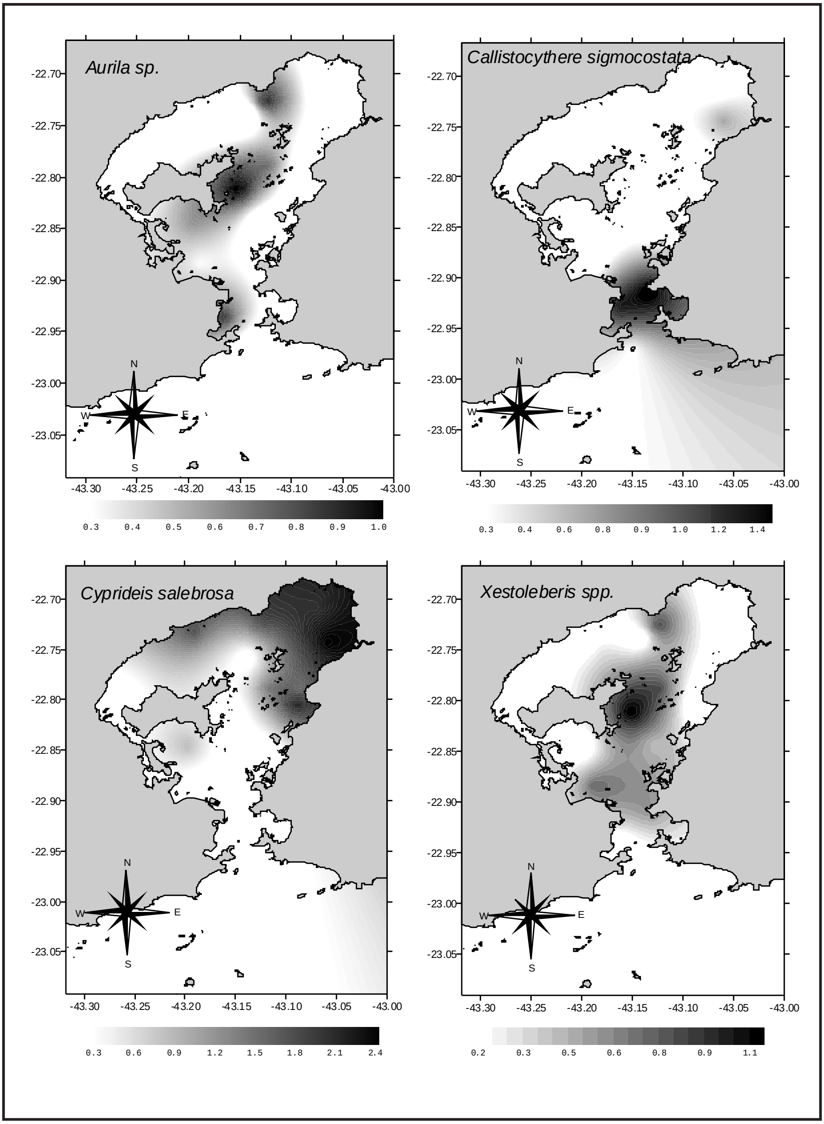

Figure 4 Occurrence of characteristic ostracoda in the Guanabara Bay

6 Conclusion

In the Guanabara Bay, foraminifera occurrence is related to distinct areas and show a response to marine influence and pollution levels. Diversity patterns of foraminifera are inversely proportional to TOC values. High TOC values suggested deposition in anoxic-dysoxic environment. Opportunistic species like *Ammonia tepida* and *Buliminella elegantissima* were dominant in confined areas under stressed conditions. Their occurrence and abundance values confirm their utility as bioindicators in future Guanabara Bay pollution monitoring. The abundance of the ostracoda Gen. *Cyprideis* and the characteristic distribution of other taxa corroborated the foraminifera results.

7 Acknowledgements

The authors thank LAGEMAR/UFF for the support during the collection trips.

This work was supported by FAPERJ (Fundação Carlos Chagas Filho de Amparo à Pesquisa do Rio de Janeiro).

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