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BACTERIA IN WATER AND SEDIMENTS OF GUARATUBA BAY, PARANÁ, BRAZIL

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RESUMO

Estudou-se, na Baía de Guaratuba, a variabilidade temporal e espacial do bacterioplâncton em relação à variação da maré, e a variação espacial do bactériobentos. Foram analisadas a variabilidade de bactérias heterotróficas totais, biomassa bacteriana, bactérias heterotróficas cultiváveis halófilas e halófobas, coliformes totais e *Escherichia coli*. Os parâmetros bióticos foram correlacionados com a salinidade, temperatura, pH, seston, transparência da água, oxigênio dissolvido, granulometria e clorofila. Os resultados mostraram que na água, nos dois períodos de maré, os valores de salinidade, pH e oxigênio dissolvido foram mais elevados nas estações externas da baía. Os demais parâmetros foram mais elevados nas regiões abrigadas e nas estações internas. No sedimento observou-se uma correlação positiva entre as heterotróficas totais, a biomassa bacteriana, as halófobas, a matéria orgânica e o carbonato de cálcio nas estações internas. Nas estações localizadas na entrada da baía puderam ser observados valores elevados de silte, argila e bactérias halófilas. Na parte mais interna da baia foram registrados valores extremamente altos de areia e *E. coli*. Os resultados mostraram que na água, apesar da inversão da maré, e no sedimento, os valores mais elevados de bactérias foram encontrados nas estações internas ou abrigadas da baía.

Palavras chave: bactérias; água; sedimento; Baía de Guaratuba; coliformes.

ABSTRACT

Spatial and temporal variability of bacterioplankton in relation to tide variation and spatial variation of bacteriobentos were studied in Guaratuba Bay. Total heterotrophic bacteria, bacteria biomass, cultivable heterotrophic

halophilic and halophobic bacteria, total coliform and *Escherichia coli* were estimated. These estimates were tested for their correlations with salinity, temperature, pH, seston, water transparency, dissolved oxygen, grain size and chlorophyll. The results showed that in the water column, at both tidal stages, salinity, pH and dissolved oxygen were higher at the sampling stations near the mouth of the bay. The remaining variables were higher in the sheltered areas and at sampling stations inside the bay. Total heterotrophic bacteria, bacteria biomass, halophobic bacteria, organic material and calcium carbonate in the sediments within the bay were all positively correlated. Silt, clay and halophilic bacteria were higher at the bay's entrance. Sand and *E. coli* had extremely large values at the innermost part of the bay. The results, in spite of the inversion of the tide, water and sediment, had elevated values of bacteria at inner or sheltered stations of the bay.

Key-words: bacteria; water; sediment; Guaratuba Bay; coliforms.

INTRODUCTION

In marine environments bacteria at the water column may be free-living or stay adhered to particles, in the superficial layer of the sediments, living and dead plant or animal tissues. Fundamental differences exist between free-living and adhered bacteria, such as cell size and rates of assimilation of organic substrates (KENNISH, 1990). In sediments, bacteria participate in the remineralization of organic compounds and in the nutrition of the benthic fauna (RHEINHEIMER, 1984). In general, bacteria are more common in the first few centimeters of the sediments due to the accumulation of organic matter, after which their abundance declines rapidly (RHEINHEIMER, 1987).

Bacteria are more abundant in coastal areas, especially in rivers, estuaries and bays, due to the availability of organic matter from terrestrial (GOCKE, 1977, RHEINHEIMER, 1984) and anthropogenic sources (KOLM; ANDRETTA, 2003). These sources are also potentially important to influence coliform bacteria, such as *Escherichia coli*, due to the large amount of sewage discharges that enter directly or indirectly into the sea (KOLM et al., 2002).

There are few ecological studies that include marine and estuarine heterotrophic bacteria along the Brazilian coast. However, in Paranaguá Estuary Complex and nearby regions a variety of studies with bacteria ware developed (KOLM et al., 2002, KOLM; ANDRETTA, 2003 with others). Here is present the first study on bacteria in surface and bottom waters and sediments of Guaratuba Bay, a nearby ecosystem. The objective of the present study was to measure, in surface and bottom waters, the variability of total bacteria, bacterial biomass, cultivable heterotrophic holophilic and halophobic bacteria, total coliforms and *E. coli* with the inversion of spring tides, as well as the relationships between these and other biotic and abiotic variables Spatial variability of bacteria in sediments was also measured.

STUDY AREA

Guaratuba Bay (25° 50' and 25° 55' S, 48° 30' and 48° 45' W) is relatively shallow, east-west oriented on the littoral of Paraná State (South Brazil) (Fig. 1). The bay is approximately 16 km long and 3 to 10 km wide, depending on the tide, with an drainage basin of approximately 1,886 km^2. It includes many canals and islands with extensive mangroves along the shore (MAACK, 1981; SOARES et al., 1997). Many rivers flow into the bay, with the Cubatão River being one of the most important. This river drains Curitiba City watershed and flows into the extreme west of the bay, forming an estuarine delta (Fig. 1).

The inner shores of the estuary and rivers, are bordered by mangrove forests (*Rhizophora mangle*, *Laguncularia racemosa* and *Avicennia schaueriana*) in areas less impacted by human activities. Banks of *Spartina alterniflora* are common in the sheltered regions of the estuary, and are replaced by *Crinum salsum* in the more internal areas. It is important to note that in some side channels of the bay (the proximities of stations 3 and 4) there were, at the time of the sampling campaings of the present work, small oysters farms.

Guaratuba Bay has a straight, direct opening to the ocean, with rocky outcrops at the entrance of the bay. In estuarine areas such as this the constriction of the interface with the open ocean causes the increase of tidal currents favoring their penetration up to the innermost zones of the estuary, and consequently favours its erosive power (EMERY; STEVENSON, 1957).

Guaratuba is the major city of the region, with 30,565 inhabitants (IBGE, 2007). At the time of this research Guaratuba had only 30% of its water runoff and sewage needs installed, and waters from these sources were routed directly or indirectly into the bay. Caiobá is a small balneary on the opposite side of the bay. Ferryboats carry passengers between Caioba and Guaratuba. Also, during the summer, the number of small boats increases in the bay.

The Guaratuba Environmental Protection Area was created in 1992 and comprises approximately 200,000 ha, including total or partially five municipalities. This area includes a mosaic of environmental characteristics from the first high plains of Paraná, to the estuarine-lagunar complex of Guaratuba Bay. Numerous kinds of human activities occur within this mosaic, including deforestation, questionable agricultural practices, use of unapproved agrochemicals and clandestine extraction of forest resources. Another strong pressure on the environment occurs in the summer, when the population triples in the area (INSTITUTO AMBIENTAL DO PARANÁ, 2003).

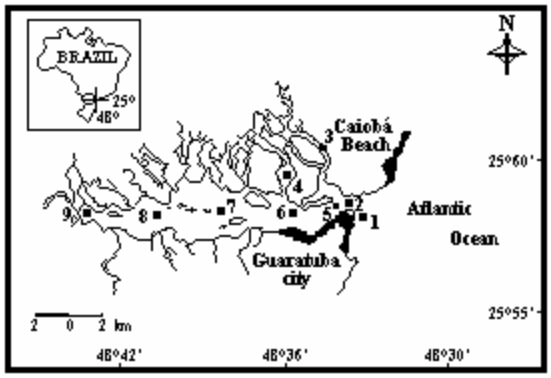


Figure 1 – Map of Guaratuba Bay and sampling stations.

MATERIAL AND METHODS

Samples of surface and bottom waters and sediments were collected at nine stations in July and August 2002. Seven sampling stations were located along the east-west axis and two in the arms of Guaratuba Bay. In the first sampling period (July/2002), samples of surface and bottom waters were collected between peaks of high (station 1) and low (station 9) spring tides. At this time surface sediments were also collected. During the second sampling period (August/2002), water samples were collected in the reverse order (low to high tide). Tide (Laboratory of Marine Physics, Center for Studies of the Sea, Federal University of Paraná), salinity (Atago refractometer), temperature (standard thermometer), dissolved oxygen (Winkler technique), seston (Whatmann filters GF/F), transparency (Secchi disk), pH (Digimed pH-meter) and chlorophyll *a* (STRICKLAND; PARSONS, 1972) were measured at all stations in all water samples. For sediment analysis (grain size, calcium carbonate and organic matter) a surface sample was taken (≈2 cm) (SUGUIO, 1973).

To measure total heterotrophic bacteria and bacterial biomass, 15 ml of water were preserved in formaldehyde (final concentration 5%) on site. For other analyses, sub samples were collected in the field, conditioned in sterile Erlenmeyer flasks and preserved on ice until examined in the laboratory.

Surface sediment samples were collected in the first trip with a sediment trap (Petite-Ponar) and conditioned in the field in sterile Petri dishes. In the laboratory, 15 cm^3 of each sample were mixed with 135 ml distilled water (1:10), stirred for 10 minutes at 80 rpm and decanted for 10 (sandy sediments) to 15 (muddy sediments) minutes. Immediately, 15 ml of the supernatant were set aside (in formaldehyde 5%) for total heterotrophic bacteria counts. At that time, aliquots were collected for heterotrophic halophilic and halophobic bacteria, as well as for total coliform bacteria and *Escherichia coli*. Total heterotrophic bacteria were counted by epifluorescence microscopy with acridine orange stain (PARSONS et al., 1984). Bacterial biomass was calculated following Kolm et al. (2002), with a conversion factor of 0.4 $pgC.\mu m^{-3}$ (BJØRNSEN; KUPARINEN apud DELILE et al., 1996). Aerobic

heterotrophic bacteria (halophilic and halophobic) were counted following Kolm and Corrêa (1994) and Kolm and Absher (1995). Coliform bacteria and *E. coli* were analyzed using a chromogenic substrate (Colilert, Idexx Laboratories, Inc.) following Kolm et al. (2002).

For statistical analyses, coliform bacteria and *E. coli* values greater than 2,419.2 MPN.ml^{-1} in water and 24,192 MPN.cm^{-3} in sediments were adjusted to that value. All variables were examined together by Principal Component Analysis (BOUROCHE; SAPORTA; 1982; LEGENDRE; LEGENDRE; 1983; CLARK; WARWICK; 1994).

RESULTS

Water Column

Abiotic variables and chlorophyll *a* in surface and bottom waters can be seen in table 1 at the end of this paper.

The highest values of total heterotrophic bacteria and bacterial biomass (186 x 10^5 cel.ml^{-1} and 781.116 µg.C.l^{-1}, respectively) were obtained from bottom water at station 9, while the lowest values (0.710 x 10^5 cel.ml^{-1} and 0.673 µg.C.l^{-1}) were from surface waters at station 5 in the first sampling period (Figs. 2 and 3).

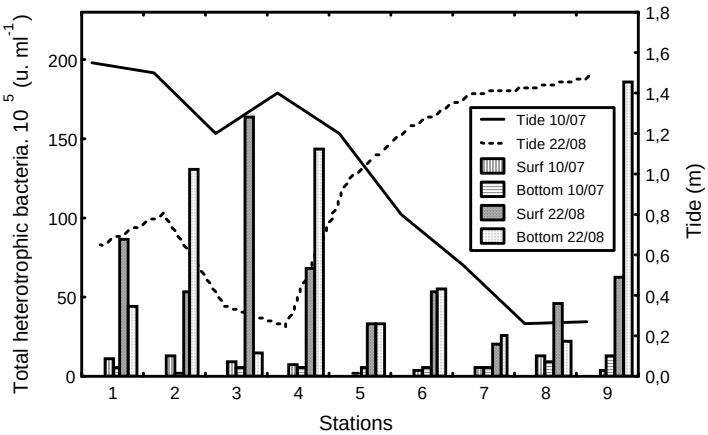


Figure 2 – Frequency of total heterotrophic bacteria in surface and bottom waters.

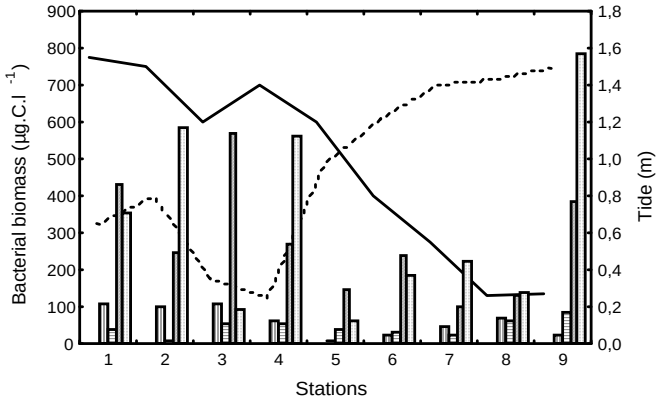


Figure 3 – Frequency of bacterial biomass in surface and bottom waters.

Heterotrophic halophilic bacteria with a peak of 28 x 10^4 CFU. ml^{-1} were highest in stations 2, 3 and 4 on August/02. The lowest values of the same bacteria (41 CFU. ml^{-1}), were found in surface waters at station 1 on July/02 (Fig. 4).

The highest values of heterotrophic halophobic bacteria (3.7 x 10^4 CFU. ml^{-1}) were found in bottom waters at station 9, and the lowest values (38 CFU. ml^{-1}) in surface waters at station 1, both in the first sampling period (Fig. 5).

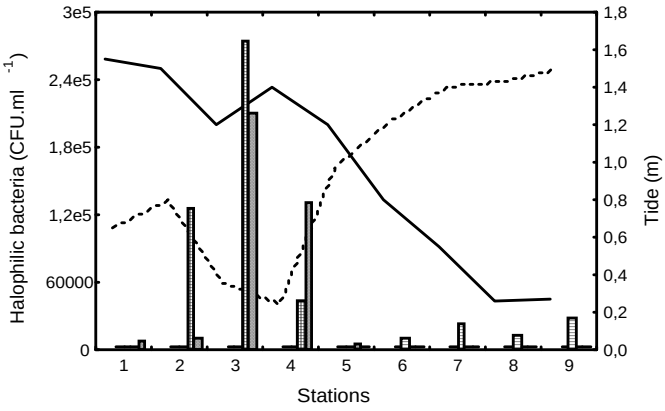


Figure 4 – Frequency of heterotrophic halophilic bacteria in surface and bottom waters.

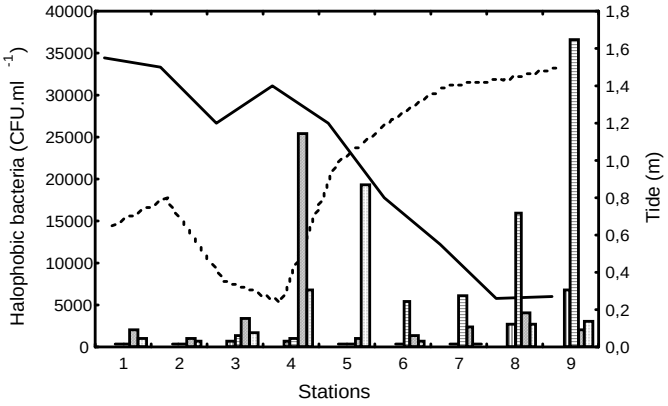


Figure 5 – Frequency of heterotrophic halophobic bacteria in surface and bottom waters.

An extremely large concentration of total coliform bacteria (> 2419.2 MPN.100ml^{-1}) was found in the internal stations (3, 4, 8 and 9) in surface and bottom waters. The lowest values of the same (98.2 MPN.100 ml^{-1}) were observed at the external stations (Fig. 6).

Highest values for *E. coli* (> 2419.2 MPN.100ml^{-1}) were those from stations 3 (surface waters in the first sample period), 6 and 8 (bottom waters of the first sample period). The lowest values (64.50 MPN. 100ml^{-1}) were found at station 2 (surface waters in the first sample period) (Fig. 7).

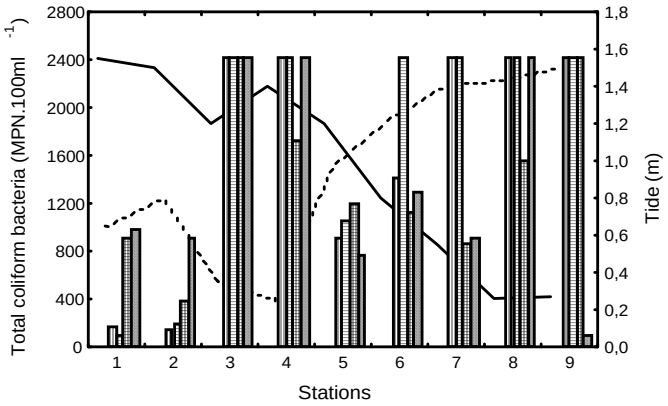


Figure 6 – Frequency of total coliform bacteria in surface and bottom waters.

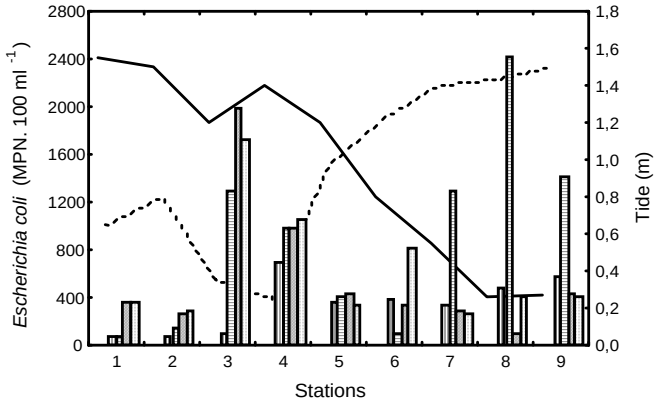
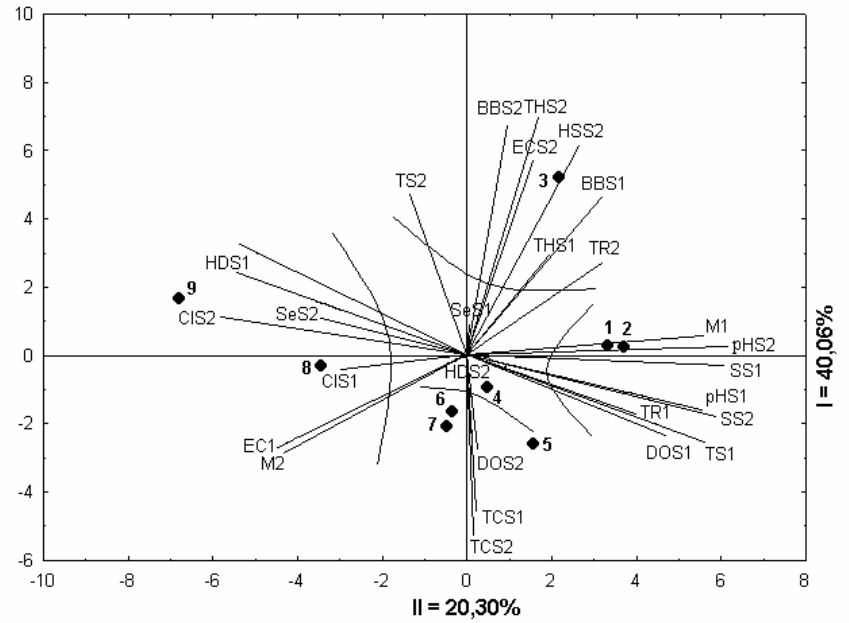


Figure 7 – Frequency of *Escherichia coli* in surface and bottom waters.

The results from Principal Component Analysis of biotic and abiotic parameters observed in surface waters is shown on Fig 8. The first component explained 40,06% of the total variability and showed positive correlation with salinity and pH in both sampling periods (July and August). Also, it showed positive correlation with tide, temperature, transparency and dissolved oxygen in the first sampling period (July) within stations 1 and 2. It showes still negative correlation of these parameters within the stations 8 and 9. The last ones, on the contrary, showed positive correlation with chlorophyll in both sampling periods (July and August), halophilic and halophobic cultivable heterothrofic bacteria, and *E. coli* in the first sampling period (July) and, tide and seston in the second sampling period (August).

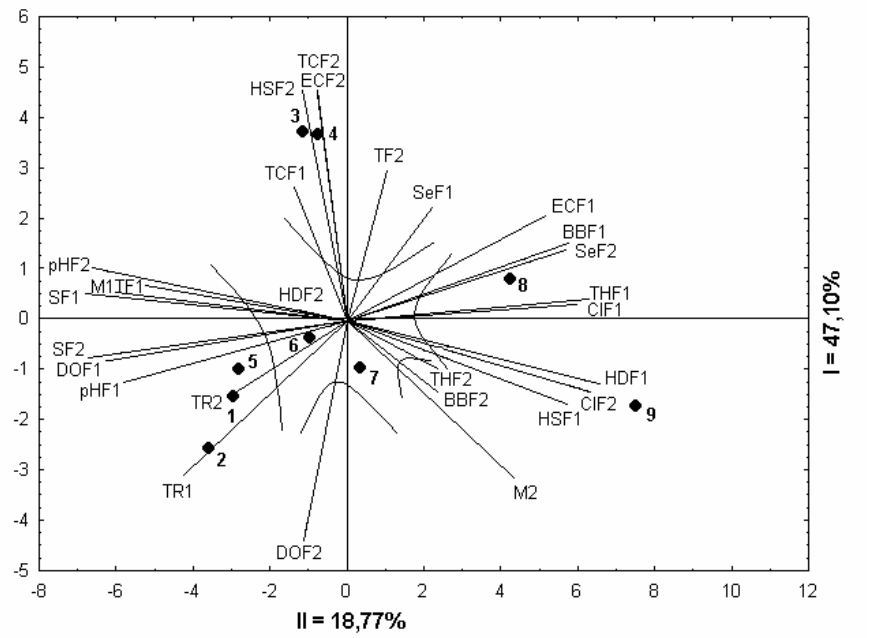
The second component explained 20,30% of the total variability and indicated positive correlation of total coliforms in both sampling periods (July and August), and dissolved oxygen in the second period (August) within stations 5, 6 and 7. These stations presented negative correlation with total heterotrophic bacteria and bacterial biomass in both sampling periods (July and August), and transparency, temperature, halofilas cultivable bacteria and to *E. coli* in the second period (August), all were higher at station 3. The halophobic cultivable heterotrophic bacteria of the second period (August) and station 4 did not interfere in the analysis.

Results of the Principal Component Analysis of biotic and abiotic parameters analyzed in the bottom water is shown in Fig 9. The first component explained 47,10% of the variability and indicated a positive correlation between pH and salinity in both sampling periods (July and August) and with tide, transparency, temperature and dissolved oxygen in the first sampling period (July). On the contrary, a negative correlation in these stations was observed with chlorophyll in both sampling periods, total heterotrophic bacteria, bacterial biomass, halophylic cultivable heterotrofic bacteria and halophobic and *E. coli* in the first period (July) and seston in the second sampling period (August). These parameters were directly correlated to stations 8 and 9.



The numbers 1 and 2 with letters indicate samples 1 (July) and 2 (August). Letters indicate T - Temperature; S – Salinity; DO – Dissolved Oxygen; TR - Transparency; SE - Seston; pH – Hydrogen ionic potential; CL - Chlorophyll; TH – Total Heterotrophic Bacteria; BB – Bacteria Biomass; HD – Halophobic Bacteria; HS – Halophilic Bacteria; TC – Total Coliform; EC - *Escherichia coli*. The numbers besides solid circles denotes sampling points.

Figure 8 – Principal Component Analysis of the physico-chemical and biological variables in surface waters of Guaratuba Bay in 2002.



The numbers 1 and 2 with letters indicate samples 1 (July) and 2 (August). Letters indicate T - Temperature; S – Salinity; DO – Dissolved Oxygen; TR - Transparency; SE - Seston; pH – Hydrogen ionic potential; CL - Chlorophyll; TH – Total Heterotrophic Bacteria; BB – Bacteria Biomass; HD – Halophobic Bacteria; HS – Halophilic Bacteria; TC – Total Coliform; EC - *Escherichia coli*. The numbers besides solid circles denotes sampling points.

Figure 9 – Principal Component Analysis of the physico-chemical and biological variables in bottom waters of Guaratuba Bay in 2002.

The second component explained 18,77% of the variability and showed direct correlation of the total coliforms in both sampling periods (July and August), seston in the first (July), temperature, halofitas cultivable heterotrofic bacteria and to *E. coli* in the second period (August) and an inverse relation with dissolved oxygen of the second sampling period (August) with stations 3 and 4. This last one presented direct correlation with station 7. The halophobic cultivable heterotrophic bacteria and station 6, had no effect in the analysis.

Sediments

Grain size analysis, biodetritic calcium carbonate and organic material in the sediments are presented in Table 2.

Total heterotrophic bacteria and bacterial biomass (maximum of 24.47 x 10^6 cells. cm^{-3} and 1,462.29µC. cm^{-3} respectively) increased from the bay entrance to the middle of the bay, and decreased toward the interior of the bay (Figs. 10A and B).

Table 2 – Average percentages of the abiotic variables in the sediments by stations.

Station	Sand	Silt	Clay	$CaCO_3$	Organic Matter
1	95,50	3,002	1,501	3,360	1,29
2	57,33	37,150	5,522	2,880	2,59
3	90,48	8,018	1,503	5,280	4,25
4	87,45	10,040	2,509	4,900	4,62
5	95,50	2,001	2,501	5,380	1,48
6	94,49	3,006	2,505	5,190	2,03
7	74,62	21,890	3,483	5,570	6,66
8	60,38	37,110	2,507	8,260	9,07
9	98,50	1,000	0,500	2,980	1,29

Maximum counts of heterotrophic halophilic bacteria (4.2 x 10^5 CFU.cm^{-3}) were found at station 4. In the remaining stations, these values were relatively low, with their minima at stations 1 (2.19 x 10^4 CFU.cm^{-3}) and 9 (1.18 x 10^4 CFU.cm^{-3}) (Fig. 11A).

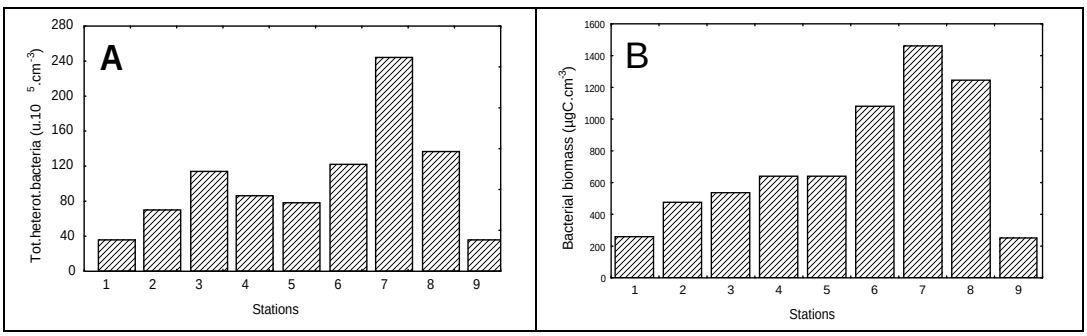


Figure 10 – Frequency, in sediments of: A) Total heterotrophic bacteria; B) Bacterial biomass.

Heterotrophic halophobic bacteria were consistently lower than halophilic bacteria, with exceptions at stations 1 and 9. At station 4 was registered the maximum (5.8 x 10^4 CFU.cm^{-3}) and at station 5 the minimum (2.03 x 10^4 CFU.cm^{-3}) values (Fig. 11B).

Total coliform bacteria, with maxima greater than 24,192 MPN.cm^{-3} at stations 6 and 9, were registered in the inner regions of the bay, with a minimum at station 2 (434 MPN.cm^{-3}) (Fig. 11C).

High values of *E. coli* with a maximum above 24,192 MPN.cm^{-3}, was observed between stations 6 and 9. The lowest value was 25 MPN.cm^{-3} at station 4 (Fig. 11D).

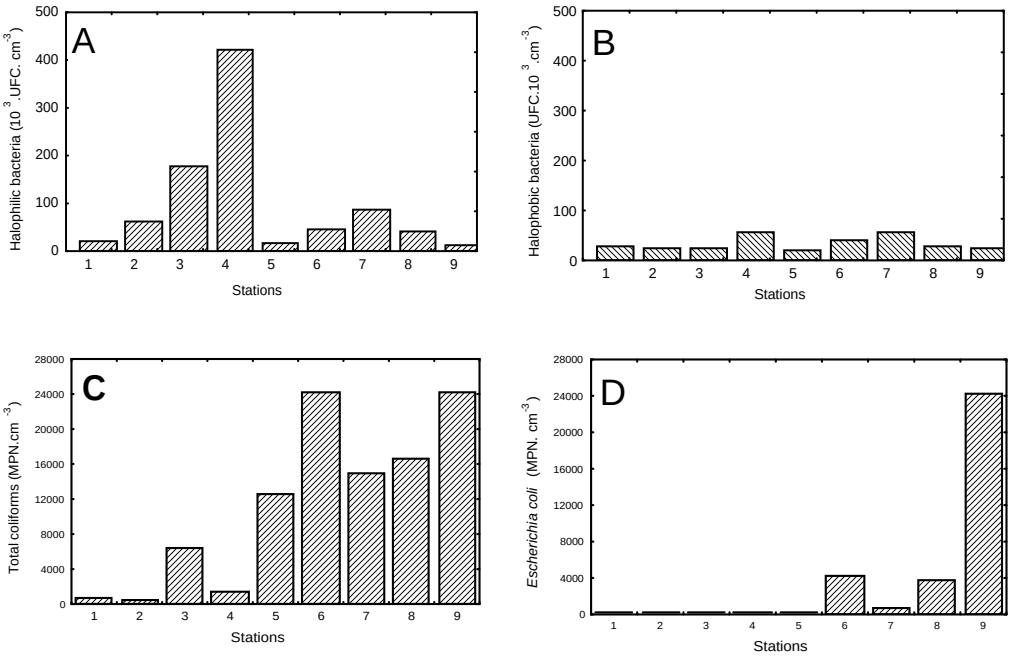
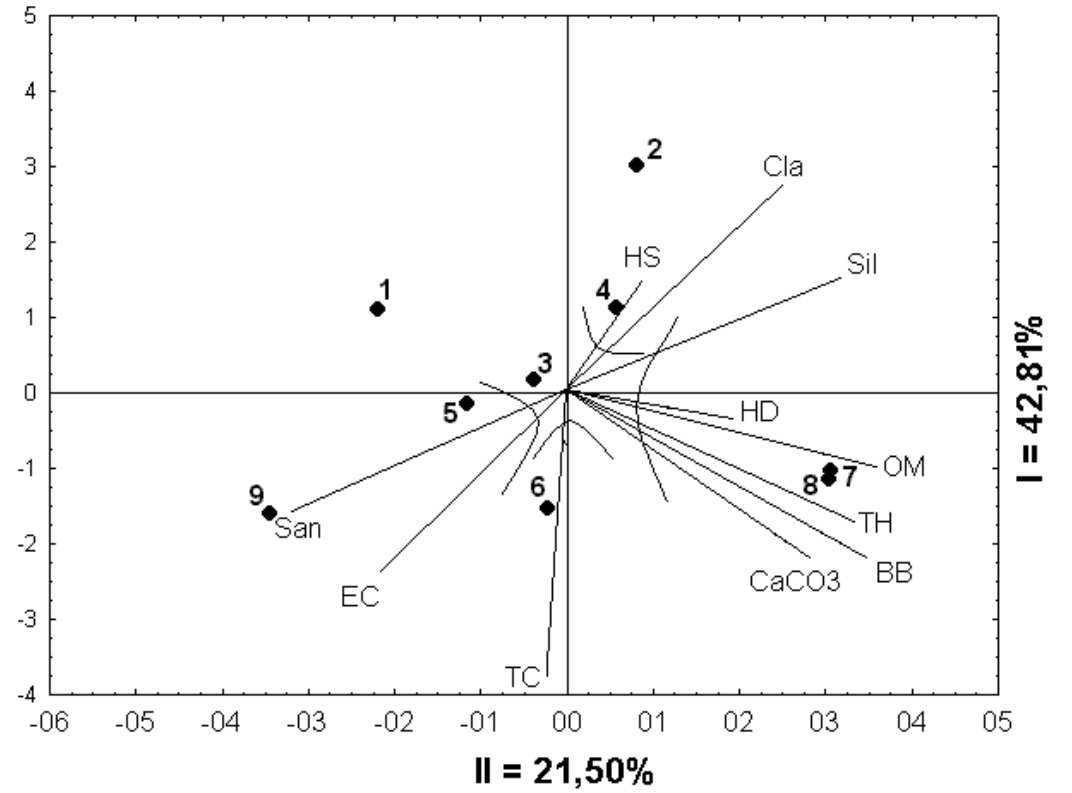


Figure 11 – Frequency, in sediments of: A) Heterotrophic halophilic bacteria;B) Heterotrophic halophobic bacteria; C) Total coliform bacteria; D) *Escherichia coli*.

The first principal component explains 43% of the variance, with a positive correlation between total heterotrophic bacteria, bacterial biomass, heterotrophic halophobic bacteria, organic matter, calcium carbonate and, to a lesser degree, silt at stations 8 and 9. At stations 5 and 9, sand was positively correlated with *E. coli*. The second component explained 22% of the variance and was positively correlated with clay and heterotrophic halophilic bacteria at stations 2 and 4. Total coliform bacteria were at their maximum at stations 6 (Fig. 12).



San – Sand; Sil – Silt; Cla – Clay; OM – Organic Matter; $CaCO_3$; TH – Total Heterotrophic Bacteria; BB- Bacteria Biomass; HD – Halophobic Bacteria; HS – Halophilic Bacteria; TC – Total Coliform; EC – *Escherichia coli.*

Figure 12 – First two principal component axes of variables and stations.

DISCUSSION

The knowledge of bacterial importance in natural waters and sediments on the decomposition of organic matter and the regeneration of nutrients, in addition to being ingested as food by many animals (WRIGHT, 1978), dates from a long time. Thus, the studies of bacteria in coastal regions like bays, estuaries and river outlets is very important.

In the two tidal cycles, the highest values for salinity, pH and water transparency, and the lowest for chlorophyll *a* were at stations 1 and 2. These stations should be considered as being characterized by water originating on the continental shelf. Similar characteristics were registered by KOLM et al. (2002) for the nearby bays of Paranaguá and Antonina.

The lack of nearby islands at the entrance of Guaratuba Bay, which could reduce the energetic impact of ocean waters, favors a high energy region at the external area of the bay. This is corroborated by the high values of sand at stations 1 and 5.

Station 9 is influenced by fresh water input coming from São João River, where salinity was very low (1‰ at low tide, and 8‰ at high tide). Low

salinity shows that this station has little tidal influence. Abundance of sand, and scarcity of calcium carbonate and organic matter, along with low counts of total heterotrophic bacteria in the sediment (similar to those at the bay entrance), suggesting that this is a high energy region, in part due to the rivers that drain here from the adjacent mountain range.

Sediments from station 1 were obtained inside the tidal channel and from station 2 outside the main channel, what could explain the lower sand and higher silt and clay values that were registered at station 1, 5 and 6.

Stations 3 and 4 were located in protected regions of the bays sounds, where fine sediments were expected. However, our results indicated the contrary, what could be easily explained since they were near cultivated areas with evidence of anthropogenic influence. Great abundance of *E. coli* at these stations are also evidence of anthropogenic influence. Additionally, high salinity values show the direct influence of waters from the continental shelf, poor in organic matter. It is known that organic matter is limiting for bacterial development in oceanic waters (SCHLEGEL, 1993). The results from stations 3 and 4 indicated the influence of oceanic waters that penetrate the sounds. When these waters join waters with high organic matter contents from the sound, total heterotrophic bacterial growth is favoured in the water column. Heterotrophic halophilic and halophobic bacteria were also elevated here, but only during flood tide. In periods of ebb tide, stations 8 and 9 had the highest counts of these bacteria. Also, sediments from stations 8 and 9 had the greatest total heterotrophic bacteria and bacterial biomass values. This result confirm that the cultivable bacteria (halophilic and halophobic) respond more rapidly to environmental variations than total heterotrophic bacteria (HOPPE, 1986).

The number of saprophytic (aerobicaly cultivable) bacteria has been suggested to be greater in the sediments than in the water column (WEYLAND, 1967). Except at station 9, in all other stations heterotrophic halophobic bacterial counts were higher in surface sediments. At station 9 the higher concentration of this bacteria group was in bottom waters during low tide. The heterotrophic halophilic bacteria counts were more elevated in sediments at stations 1, 4 and 8, but at station 2 this bacteria was higher in surface waters during flood tide. Station 3 had higher bacteria in surface and bottom waters also during flood tide, and at station 9 in bottom waters during ebb tide. This results show that saprophytic (aerobic cultivable) bacteria values are not always higher in sediments.

Many so-called heterotrophic halophilic bacterial colonies, even though cultivated in saline culture media, are halotolerant and survive for longer or lesser time in saline environments, while bacteria that grow in fresh water culture media are strictly halophobic (RHEINHEIMER, 1987). KOLM et al. (2002) encountered more halophilic (halotolerant) and halophobic bacteria in surface waters of the inner region of Antonina Bay (near Corisco Island), with low salinities, than near the entrance of Paranaguá Bay, with high salinities, leading to the conclusion that part of bacteria that grew in saline culture media were halotolerants. Similar results were found in the present study.

Some total coliform bacteria may be found at any time as part of the normal biota of soils and water (SCHLEGEL, 1993). Yet, the high abundance of

these bacterial groups and low of *E.coli* in the water column of stations 6 and 9 and in the sediments of station 6 suggest that they are constituted mainly by autochtonous bacteria. Similar results were observed by KOLM, et al. (2002) with higher values of total coliforms and low *E. coli* in surface waters near Antonina city (with low human population) and high total coliforms and *E. coli* near Paranaguá city (with high human population) (KOLM, et al., op.cit.).

Very high values of *E. coli* were found in the sediments at station 9, probably brought to this place by the São João and Cubatão rivers, from the Curitiba Metropolitan Area and other villages located at its margins. Therefore, we suggest that these rivers should receive greater attention as sources of pollution to the region.

While *E. coli* analysis was not intended to provide recommendations for monitoring bathing waters these results show that waters are excellent at stations 1 and 2, very good at stations 5 and 7, satisfactory at stations 4, 6 and 8, while at 3 and 9 the water quality is not adequate for bathing (CONAMA, 2000).

In conclusion, we found that, during the study period, at both tidal stages (flood and ebb) the highest values of total heterotrophic bacteria, bacterial biomass and heterotrophic halophilic and halophobic bacteria were found in the sheltered areas or sounds within the bay.

CONCLUSION

Compared to the water column, bacteria are not always most abundant in the sediments as expected. In the water column dissolved oxygen is not a limiting factor for bacterial development in this region. The abundance of bacteria in the sediment depends not only on grain size, but also on availability of organic matter. There was no increase in bacterial counts at locations where marine organisms were being cultivated.

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Table 1 – Absolute values for the abiotic parameters measured in surface and bottom waters.

Date	Stations	Locality	Tide (m)	Temp. (°C)	Salin (‰)	DO (%)	Transp (m)	Seston ($mg.L^{-1}$)	pH	Chloroph. *a* ($mg.L^{-1}$)
10.07.02	1	Surface	1.55	19	33	106.36	3.50	561.98	7.83	0.20
10.07.02	1	Bottom		19	33	112.81		876.68	7.82	0.11
10.07.02	2	Surface	1.5	19.2	33	105.97	4.00	183.64	7.82	0.24
10.07.02	2	Bottom		19.1	33	105.95		16.24	7.85	0.36
10.07.02	3	Surface	1.2	19.3	31	100.43	1.25	694.28	7.82	1.34
10.07.02	3	Bottom		19.3	31	99.59		678.98	7.33	1.53
10.07.02	4	Surface	1.4	19.4	27	100.36	2.00	728.65	7.53	1.16
10.07.02	4	Bottom		19.2	28	96.21		617.53	7.52	1.35
10.07.02	5	Surface	1.2	19.4	33	105.55	2.40	558.14	8.20	0.36
10.07.02	5	Bottom		19.2	33	105.53		102.33	8.07	0.49
10.07.02	6	Surface	0.8	19	23	104.90	1.45	422.00	7.67	2.57
10.07.02	6	Bottom		19.8	27	96.59		298.93	8.07	1.36
10.07.02	7	Surface	0.55	19.7	19	100.55	2.20	453.05	7.63	1.39
10.07.02	7	Bottom		19.5	23	92.79		402.65	7.63	0.78
10.07.02	8	Surface	0.26	18.8	13	96.68	1.40	756.83	7.16	2.30
10.07.02	8	Bottom		18	17	84.17		563.80	7.33	9.72
10.07.02	9	Surface	0.27	17.2	1	87.36	1.50	316.38	6.77	1.01
10.07.02	9	Bottom		18	8	81.33		602.36	6.78	6.68
22.08.02	1	Surface	0.65	20	30	102.59	1.40	209.15	7.79	1.53
22.08.02	1	Bottom		19.5	31	95.51		133.81	7.64	1.22
22.08.02	2	Surface	0.8	20	30	97.05	1.80	116.81	7.80	0.61
22.08.02	2	Bottom		20	31	98.79		14.96	7.59	1.54
22.08.02	3	Surface	0.35	21	26	81.94	1.60	535.22	7.60	0.65
22.08.02	3	Bottom		20	26	83.14		565.50	7.68	0.36
22.08.02	4	Surface	0.25	21	23	117.00	0.80	366.20	7.46	1.45

Table 1 – Absolute values for the abiotic parameters measured in surface and bottom waters. Continuation…

Date	Stations	Locality	Tide (m)	Temp. (°C)	Salin (‰)	DO (%)	Transp (m)	Seston ($mg.L^{-1}$)	pH	Chloroph. *a* ($mg.L^{-1}$)
22.08.02	4	Bottom		20.5	24	75.66		235.30	7.52	2.12
22.08.02	5	Surface	0.97	20	31	97.22	1.00	347.60	7.50	0.52
22.08.02	5	Bottom		20	30	96.65		36.89	7.58	0.71
22.08.02	6	Surface	1.22	20	26	93.58	1.40	426.70	7.29	1.94
22.08.02	6	Bottom		20	27	86.70		399.60	7.42	1.79
22.08.02	7	Surface	1.40	20	25	86.15	1.40	451.28	7.20	1.78
22.08.02	7	Bottom		20	26	83.52		393.35	7.31	2.58
22.08.02	8	Surface	1.43	20.5	18	94.73	1.20	757.68	6.95	5.70
22.08.02	8	Bottom		20	20	80.71		450.35	6.87	4.64
22.08.02	9	Surface	1.49	20.5	11	96.80	1.00	399.40	6.56	9.08
22.08.02	9	Bottom		20	13	96.05		748.53	6.69	11.44