FORAMINIFERA BIODIVERSITY COUPLED WITH ENVIRONMENTAL QUALITY IN PIUM RIVER ESTUARY AND PIRANGI CORAL REEF (RN, BRAZIL)

Patrícia Pinheiro Beck Eichler[1,2], Cristiane Leão Cordeiro de Farias[2], Diogo Santos[2], Audrey Amorim[1], Alison Mendonça[1], Helenice Vital[2] , Moab Praxedes Gomes[2].

[1]Programa de Pós-Graduação em Ciência Ambiental, Departamento de Engenharia Sanitária e Ambiental, Universidade do Sul de Santa Catarina (UNISUL). Cidade Universitária, Av. Pedra Branca, 25, Palhoça, SC, 88137-270, Brazil

[2]Programa de Pós Graduação em Geofísica e Geodinâmica (PPGG), Laboratório de Geologia e Geofísica Marinha e Monitoramento Ambiental, Centro de Ciências Exatas e da Terra da Universidade Federal do Rio Grande do Norte (GGEMMA, CCET, UFRN, Brazil), Campus Universitário, Lagoa Nova, 59072-970 - Natal, RN, Brazil

*corresponding author: email: patriciaeichler@gmail.com

ABSTRACT

The quality assessment of coastal and estuarine zone of Pium River Estuary and Pirangi coral reef area (inner shelf of Rio Grande do Norte) in recent and past environments is studied by organisms capable of: synthesizing the environmental characteristics (oceanographic and geological), highlighting the environmental variations of short periods and reacting sensitively to seasonal variations and anthropogenic effects. This work relates the ecological indices of the foraminifers' indicators species and the dominance of *Ammonia tepida*, *Bolivina striatula*, *Discorbis peruvianus*, *Elphidium articulatum*, *E. discoidale*, *Quinqueloculina lamarckiana*, *Q. intricata*, *Q. patagonica*, *Textularia gramen* and *T. earlandi* to characterize ecologically different environments as means of salinity, temperature and sediment characteristics, as well as levels of industrial pollution and organic contamination in the last 25 years. The three shallow sediment cores analyzed have showed higher species diversity and evenness about 18-20 years ago followed by recent periods with greater dominance and environmental instability. We observed inter annual fluctuations but there is a trend of decreasing foraminifera diversity and evenness, with greater dominance of less foraminifera species nowadays very close to fragile environments, the coral reef area and the estuary of the Pium river in a carbonate shelf. Our results indicate a decrease in biodiversity in the whole ecosystem towards today.

Key words: diversity, evenness, dominance, assessment, coastal, industrial pollution, organic contamination

a) INTRODUCTION

The use of biological indicators fossils (foraminifera), a simple handling and low cost tool is a good alternative for environmental studies in biodiversity, oceanography and environmental monitoring, as they are plentiful and easy to collect, present in all aquatic environments. Assessment and diagnosis of the carbonate inner shelf of Pium River Estuary and adjacent reef area in Pirangi (Rio Grande do Norte) in recent and past environmental is being accomplished through these organisms capable of synthesizing the general characteristics of the environment (oceanographic and geological), highlighting the environmental changes in short periods and react sensitively to seasonal variations and anthropogenic effects. The works that deal with the distribution of these fossils indicators aim to characterize different environments as salinity, temperature and sediment characteristics, as well as levels of industrial pollution, organic pollution (Alve, 1995 Yanko et al., 1994, 1998, 1999, Yanko 1997, Eichler et al. 2007, 2008, 2010 and 2012). Their potential for fossilization provides data to understand the current environmental quality of the region. Our objectives are to evaluate if there is a shift of biodiversity due to anthropogenic stress, and to verify if the there is interannual changes in the in the past 25 years.

b) Methodology

Three (3) shallow cores (about 25cm) were collected along the coral reef southward. Core 1 was closest to the river Pium and the other two were collected at 500m away, as shown in Figure 1.

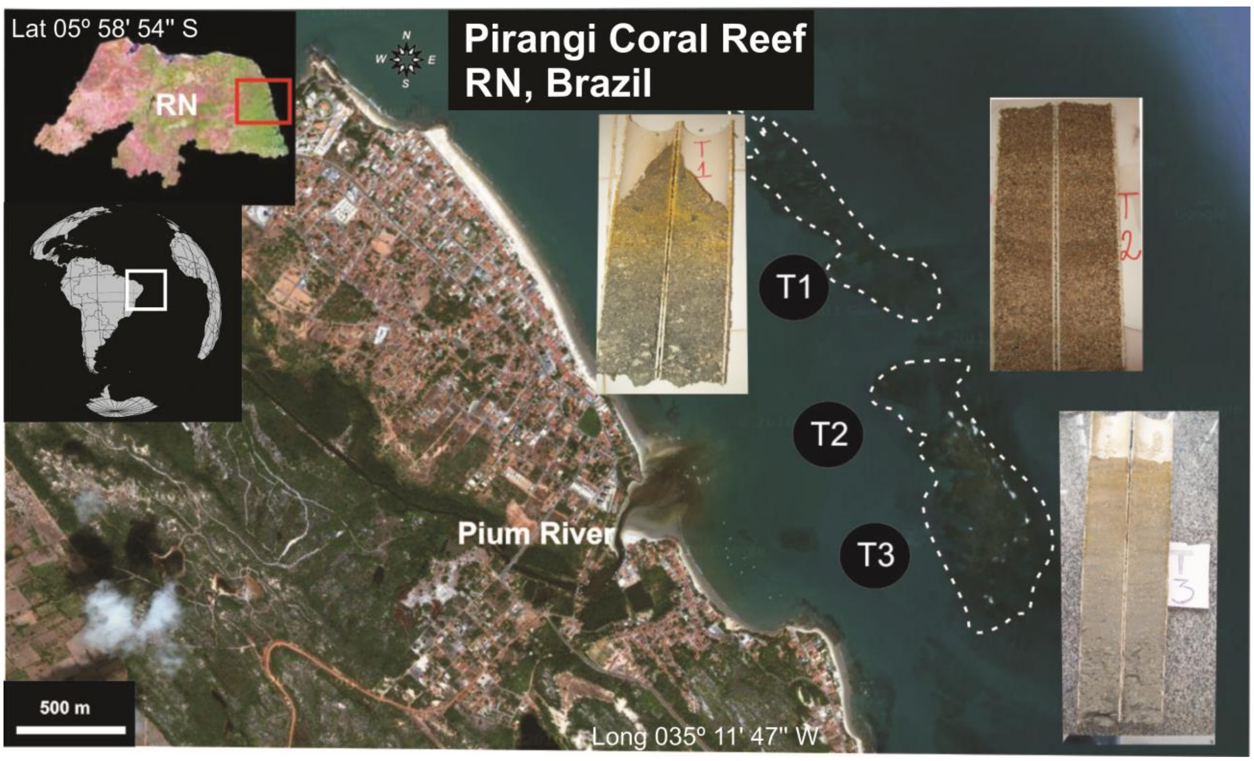


Figure 1: Location and photograph of open cores (T1, T2 and T3) collected along the reef area.

The study area is located in the coastal zone of the Estuary Pium and inner shelf adjacent to the reef area Pirangi. The cores were collected in April 2012 in a depth of 6 meters. After drying for a few weeks they were cut in half and photographed. Then sub sampling was performed for the fauna of foraminifera every two centimeters. The cores had recovered the following sizes: 20 cm with T1, T2 and T3 with 24 cm each. Based on the rate of sedimentation in coastal internal platforms (Patchineelam & Smoak, 1999) we can approach that 1 cm is equals to about one year in coastal cores.

b.1. Processing of samples:

Each sample was washed and sieved into two sieves of 0.500 mm and 0.062 mm. The material retained on the sieves was dried on filter paper and then placed in an oven at 50 degrees for 72 hours. The material of the 0.062 mm sieve went through the process of splitting for later sorting, identification, counted and classification of species of benthic foraminifera in stereoscope. During the separation of each sample, the specimens are transferred with the aid of special brush to slides with black background. Absolute frequency tables of foraminiferal species were made. Univariate (diversity indices, evenness and dominance) and multivariate (Cluster and MDS) analysis were applied using Primer 6 program.

C. Results

Core 1

In core 1, we can observe the presence of 57 species and the occurrence of *Ammonia tepida*, *Discorbis peruvianus*, *Elphidium articulatum*, *Quinqueloculina lamarckiana*, *Q. intricata*, *Q. patagonica*, and *Textularia gramen* in all periods (Table 1).

Species/Stations	1 (top)	2	3	4	5	6	7	8	9	10 (bottom)
Ammonia rolshauseni	0	0	200	180	45	0	0	560	100	420
Ammonia tepida	4130	4725	920	1215	405	3255	1320	5800	380	7080
Amphisorus sp.	0	0	0	0	0	0	0	0	0	30
Amphistegina sp.	0	0	0	0	0	0	0	0	20	30
Arenoparrella mexicana	35	175	40	90	0	0	0	0	0	180
Bolivina difformis	210	140	0	45	0	0	0	80	0	180
Bolivina striatula	700	665	0	0	90	560	0	400	80	1080
Bolivina sp.	0	0	0	45	0	0	0	80	0	0
Bolivina tortuosa	0	175	0	135	0	0	0	40	20	150
Bolivina translucens	245	210	0	0	45	0	120	0	0	0
Bulimina patagonica	0	0	0	0	0	35	0	40	20	120
Bulimina sp.	0	0	0	0	0	0	0	0	0	30
Buccella peruviana	0	385	320	45	315	140	160	360	120	480
Bulimina marginata	0	70	0	0	0	0	0	0	0	30
Buliminella elegantissima	140	140	0	0	0	0	0	0	0	120
Cassidulina subglobosa	140	70	0	0	0	0	0	80	0	60
Cibicides dispars	70	0	0	0	45	0	0	0	0	0
Cibicides fletcheri	35	0	0	0	90	0	0	80	0	120
Cibicides variabilis	0	70	0	0	45	0	0	0	0	30
Cornuspira involvens	665	210	0	45	45	175	40	40	20	450
Discorbis peruvianus	560	630	80	315	225	385	80	840	100	1620
Discorbis valvulatus	0	0	200	135	0	0	40	200	240	120
Discorbis williamsoni	70	175	600	135	0	0	80	560	0	300
Elphidium articulatum	70	175	40	225	225	210	200	240	140	60
Elphidium discoidale	280	105	0	0	135	315	160	120	0	180
Elphidium galvestonense	0	0	120	90	0	0	0	200	20	150
Elphidium magellanicum	70	0	0	0	0	0	0	120	20	90
Elphidium sp.	35	35	0	0	0	0	0	0	0	30
Fissurina laevigata	35	0	0	0	0	0	0	0	0	30
Fissurina lucida	70	70	0	0	0	0	0	0	0	30
Hanzawaia boueana	70	70	80	90	45	35	80	160	0	270
Hopkinsina pacifica	0	105	0	45	0	35	40	40	0	0
Miliolinella subrotunda	0	0	1000	1125	135	0	40	840	160	161
Orthomorphina sp.	0	0	40	0	0	35	40	160	60	120
Patellina corrugata	0	0	0	0	0	0	0	0	0	60
Poroeponides lateralis	280	210	80	90	0	35	200	120	40	360
Pseudononium atlanticum	105	70	0	90	45	70	0	80	40	240
Pyrgo nasuta	35	35	80	45	0	35	0	40	0	30
Pyrgo ringens	0	70	400	270	270	70	40	120	20	90
Pyrgo subsphaerica	0	0	0	0	45	0	40	0	0	0
Quinqueloculina gregaria	35	35	0	135	0	35	0	200	0	0
Quinqueloculina intricata	105	280	280	225	225	35	80	360	40	420
Quinqueloculina lamarckiana	2835	2730	3160	2295	990	1505	1000	4360	620	3930
Quinqueloculina patagonica	2170	2240	560	1305	1620	1715	960	1560	160	1650
Quinqueloculina seminulum	0	0	0	270	0	0	0	0	40	120
Quinqueloculina sp.	70	0	40	0	360	35	40	0	20	120
Textularia earlandi	0	0	80	45	90	70	120	80	40	120
Textularia gramen	35	525	560	585	675	420	400	840	240	720
Triloculina baldai	70	420	0	0	135	70	40	80	20	30
Trochammina inflata	0	35	120	0	0	0	0	80	0	0
Trochammina ochracea	70	35	40	0	0	0	0	0	0	30
Trochammina plana discorbis	70	35	80	45	0	0	120	160	40	0
Trochammina sp.	0	0	0	45	0	0	0	0	0	30
Trochammina squamata	35	35	0	45	0	35	0	160	0	60
Uvigerina peregrina	35	35	0	0	0	0	0	0	0	60
Uvigerina striata	0	70	0	45	0	0	0	120	0	330
Wiesnerella sp.	0	35	0	45	0	210	0	0	0	90

Table 1: Absolute frequency of species of foraminifera identified in Core 1.

It is observed that the stations 9 and 10 show higher diversity and evenness followed by stations 4 and 5.

Interval 6 and 1 (top) show the highest values of dominance and lower diversity and evenness.

Intervals	Species number	Specimens number	Evenness	Diversity	Dominance
1 (top)	33	13580	0.65	2.29	0.17
2	39	15365	0.67	2.47	0.15
3	25	9520	0.76	2.44	0.14
4	34	9720	0.76	2.68	0.11
5	25	6840	0.81	2.63	0.10
6	26	9765	0.68	2.23	0.17
7	25	5760	0.77	2.50	0.12
8	39	19920	0.69	2.55	0.14
9	28	3060	0.83	2.79	0.08
10 base)	52	22931	0,67	2,68	0,14

Table 2: Number of species (S), number of specimens (N), Evenness, Diversity and Dominance in core 1.

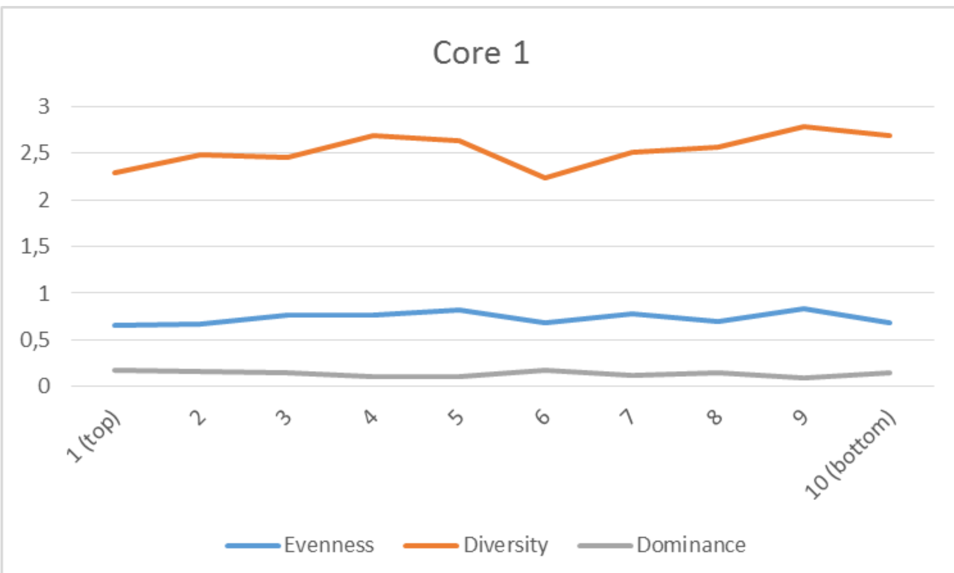
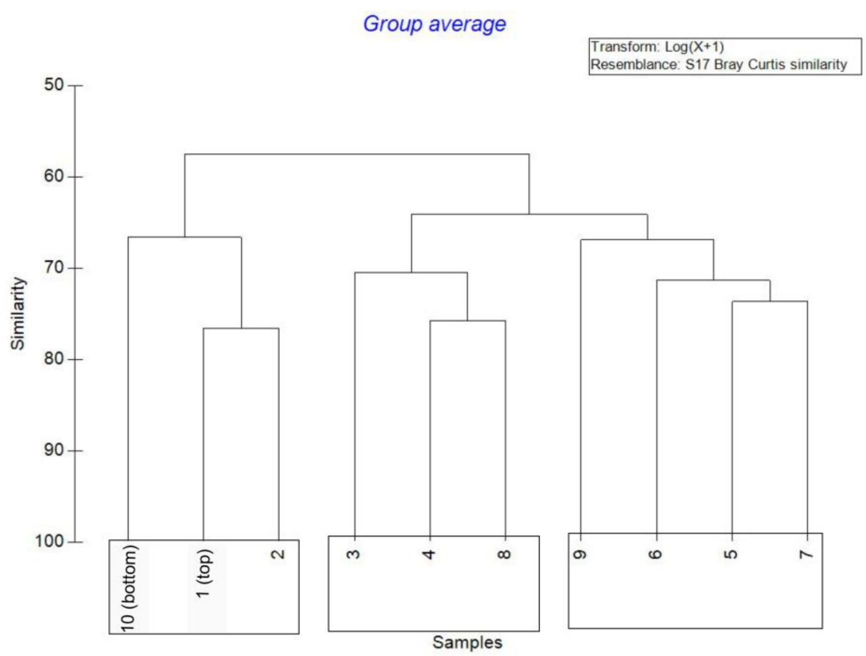


Figure 2: Evenness, Diversity and Dominance Core 1.

The groups formed by the cluster analysis and the definition of MDS showed 3 main groups (10, 1 & 2), (3, 4, and 8) (5, 6, 7, and 9) (Figure 3). Group 1 formed by the most recent to oldest stations (1 and 2) and the interval 10. This group may have been formed by high dominance of a few species such as: *Ammonia tepida*, *Cornuspira involvens*, and the appearance of rare species like *Buliminella elegantissima*, *Fissurina lucida*, *F. laevigata*, *Uvigerina peregrina*, and *Elphidium* sp. The other two groups formed are not clear about the group. This core by being closer to the estuary of the River Pium may be showing an influence of seasonal freshwater discharge.



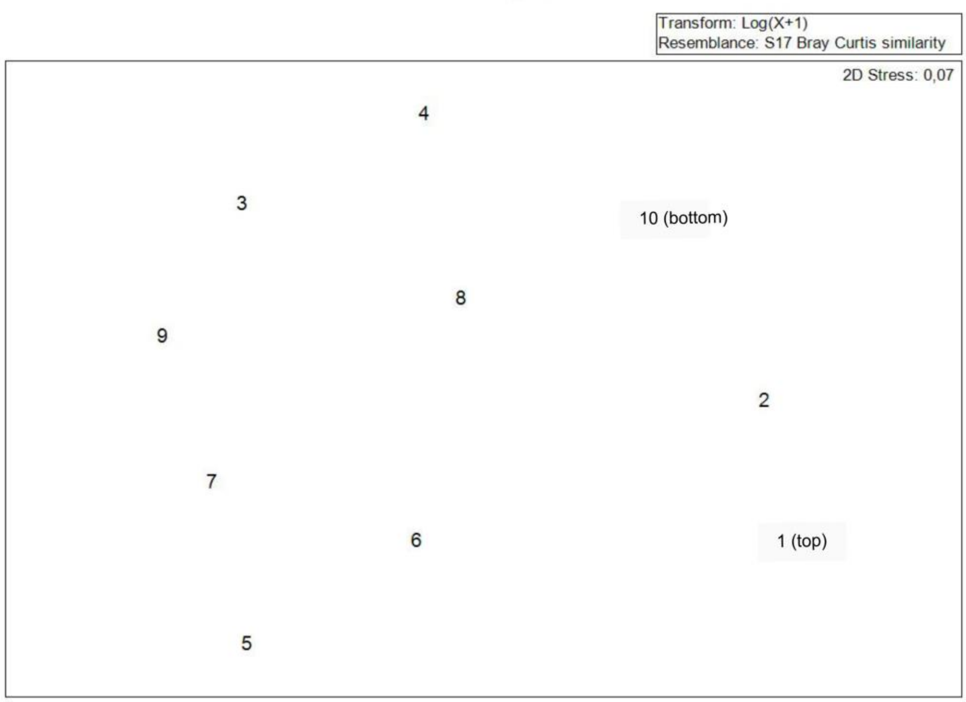


Figure 3: Cluster analysis and MDS in Core 1.

Core 2

Analyzing Table 3 absolute frequency of core 2 shows the presence of 39 species and the occurrence of *Ammonia tepida, Bolivina striatula, Discorbis peruvianus, Elphidium discoidale, Quinqueloculina Lamarckian, Q. patagonica,* and *Textularia earlandi* in all periods since the most recent to the most current. Compared to core 1, it is observed that the core 2 shows a much smaller number of specimens. One can note a few species at the top (1) with a predominance of *Quinqueloculina lamarckiana*. (2) The interval features three dominant species: *Ammonia tepida, Quinqueloculina lamarckiana* and *Q. patagonica.* In Sample 3 besides these three species the interval 2 also present *Bolivina striatula* and *Discorbis peruvianus* with relatively high frequency. In interval 4, *Discorbis wiliamsoni* also appears in representative number. Intervals 5 and 6 show a predominance of *A. tepida*. Sample 7 shows the same in the other abundant species, and contain *Textularia earlandi* and *Milionella subrotunda* in significant numbers. Highlighting the large number of specimens found in this season. Samples 9 and 10 retain the same characteristics of the other, with no major highlights. Already the 11 sample stands out as the most diverse when compared with others, as well as the large amount of specimens. The base (12) shows a small number of specimens of *A. tepida*.

Species/Stations	1 (top)	2	3	4	5	6	7	8	9	10	11	12 (bottom)
Ammonia rolshauseni	0	0	1	0	0	0	0	0	1	0	0	2
Ammonia tepida	8	23	44	57	88	87	111	74	37	57	121	13
Amphicoryna scalaris	0	0	1	2	1	2	0	0	2	2	0	0
Bolivina striatula	2	4	11	18	15	28	28	30	15	24	60	28
Bolivina tortuosa	0	0	0	0	5	5	2	1	0	0	1	1
Buccella peruviana	0	2	0	0	1	6	4	6	9	20	24	26
Bulimina marginata	0	1	3	0	0	0	0	0	0	1	3	0
Cassidulina subglobosa	1	0	0	2	0	3	5	5	1	1	4	1
Cibicides fletcheri	0	3	1	0	1	0	0	0	0	0	3	0
Cibicides variabilis	2	0	0	0	1	1	1	0	0	2	1	3
Cornuspira envolvens	1	1	1	2	2	3	1	5	9	3	12	1
Discorbis peruvianus	1	1	4	15	13	28	33	17	11	15	29	22
Discorbis valvulatus	0	1	4	2	7	1	0	2	0	0	1	3
Discorbis williamsoni	1	1	1	10	0	1	2	5	0	1	1	0
Elphidium discoidale	1	3	1	4	6	1	4	4	0	1	1	3
Elphidium poeyanum	0	0	1	0	0	0	0	2	2	0	0	0
Fissurina laevigata	0	0	1	0	2	0	3	1	1	0	0	1
Gaudryna exilis	0	0	0	1	0	2	0	0	0	0	0	0
Hanzawaia boueana	1	2	0	4	0	2	4	6	0	0	1	0
Hopkinsina pacifica	0	0	0	0	0	0	1	2	0	0	1	0
Lagena striata	0	0	0	0	0	0	0	1	0	0	1	0
Milliolinella subrotunda	0	0	2	0	1	0	7	2	2	1	2	7
Patellina corrugata	0	1	0	5	5	12	4	3	1	0	12	8
Planorbilina mediterranensis	0	0	0	0	0	1	1	0	0	0	0	0
Poroeponides lateralis	1	0	4	1	2	0	0	0	1	0	1	3
Pseudononium atlanticum	0	0	0	4	2	2	3	1	0	1	3	5
Pyrgo nasuta	1	0	0	0	1	2	0	1	0	0	3	0
Quinqueloculina angulata	0	0	0	0	0	0	2	1	1	0	0	0
Quinqueloculina intricata	0	1	0	0	2	1	3	0	2	0	3	1
Quinqueloculina lamarckiana	34	21	54	43	48	38	44	32	17	12	63	69
Quinqueloculina patagonica	9	23	16	21	22	43	37	22	18	19	58	23
Quinqueloculina sp	0	3	0	0	1	3	2	2	2	2	2	3
Robalus rotulatus	1	0	3	0	0	0	0	0	0	0	0	0
Spiriloculina planulata	0	0	1	0	0	1	0	0	0	0	0	0
Textularia earlandi	3	0	3	8	5	7	10	4	9	2	13	6
Triloculina baldai	0	0	4	1	2	9	1	1	0	0	0	0
Trochammina ochracea	0	1	1	3	1	3	1	5	1	0	4	2
Trochammina squamata	0	0	0	0	0	13	4	0	0	0	0	0
Uvigerina peregrina	1	0	0	1	0	2	0	0	0	1	1	0

Table 3: Absolute frequency of species of foraminifera identified in Core 2.

Table 4 shows the number of species varied between 16 and 29 and the number of species varied between 68 and 430 individuals. Evenness showed a lower value (0.66) in the interval 3 and higher value (0.79145) in the interval 9. Diversity was lower in the interval 1 (1.83) and highest in the interval 6 (2.43). The dominance showed the lowest value (0.12) in the interval 9 and the highest value in the interval 1 (0.28).

Intervals	Species number	Specimens number	Evenness	Diversity	Dominance
1	16	68	0.66	1.83	0.28
2	17	92	0.72	2.06	0.18
3	22	162	0.67	2.08	0.20
4	20	204	0.75	2.20	0.15
5	24	234	0.66	2.12	0.20
6	28	307	0.72	2.43	0.13
7	26	318	0.68	2.24	0.17
8	26	235	0.73	2.38	0.15
9	20	142	0.79	2.37	0.12
10	18	165	0.71	2.06	0.18
11	29	430	0.68	2.29	0.14
12	22	231	0.76	2.36	0.13

Table 4: Number of species, individuals, evenness, diversity and dominance.

From the analysis of Figure 4 can be noted the interval 1 (top) because of lower diversity and higher dominance. The interval 6 shows the greatest diversity of core. Stations 4 and 9 show the highest indices of evenness which shows no species dominating over another exists. One can also notice low levels of dominance.

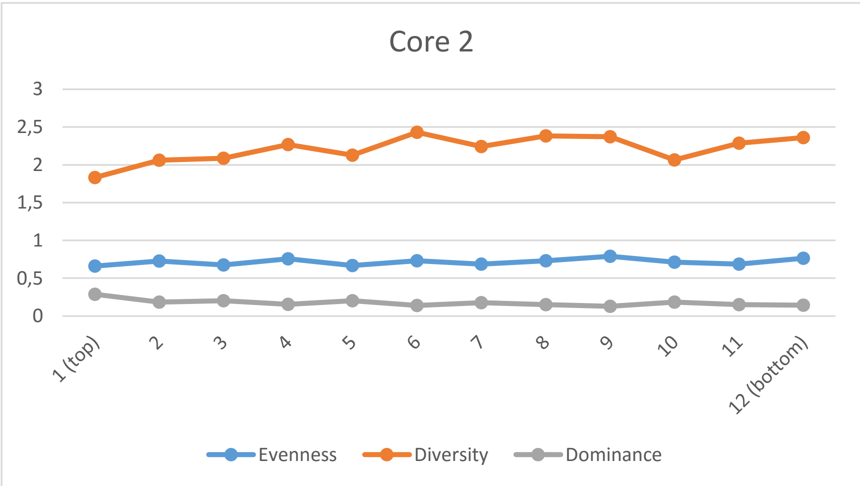


Figure 4: Data diversity, dominance and evenness of Core 2.

According to the number of species (Figure 5) it can be seen that several stations were the number 6 and 11 opposed, leaving the top station as less diverse

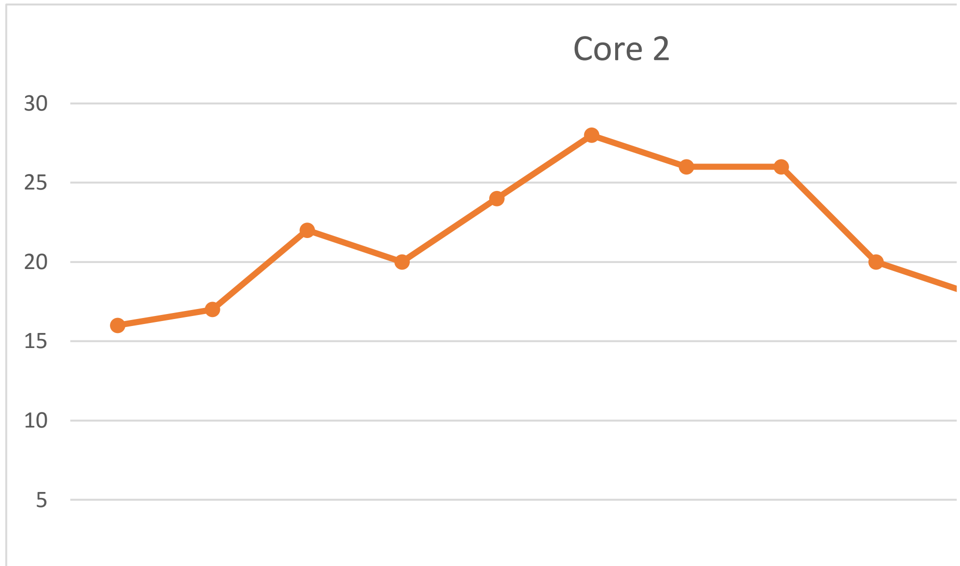


Figure 5: Number of species of foraminífera Core 2.

Figure 6 shows the number of individuals found at each station, revealing that the sample 11 has the largest number of subjects followed by the stations 6 and 7. Again, the sample is revealed as the top with a lower number of specimens.

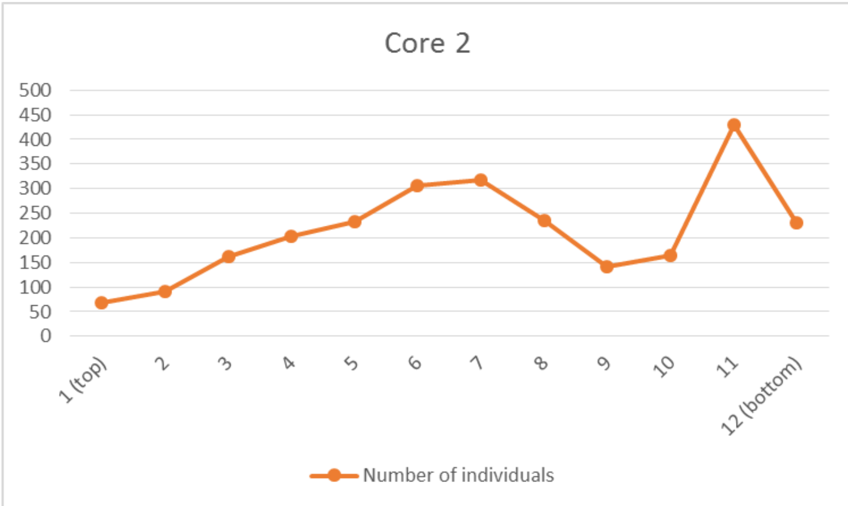


Figure 6: Number of individuals per station.

From figure 7a observed the formation of two major groups excluding the interval 5. From figure 7b we find that the interval 1 (top) was less diverse, followed by samples 2, 3, 4, 5. Intervals 9, 10, 11 and 12 had the highest diversity.

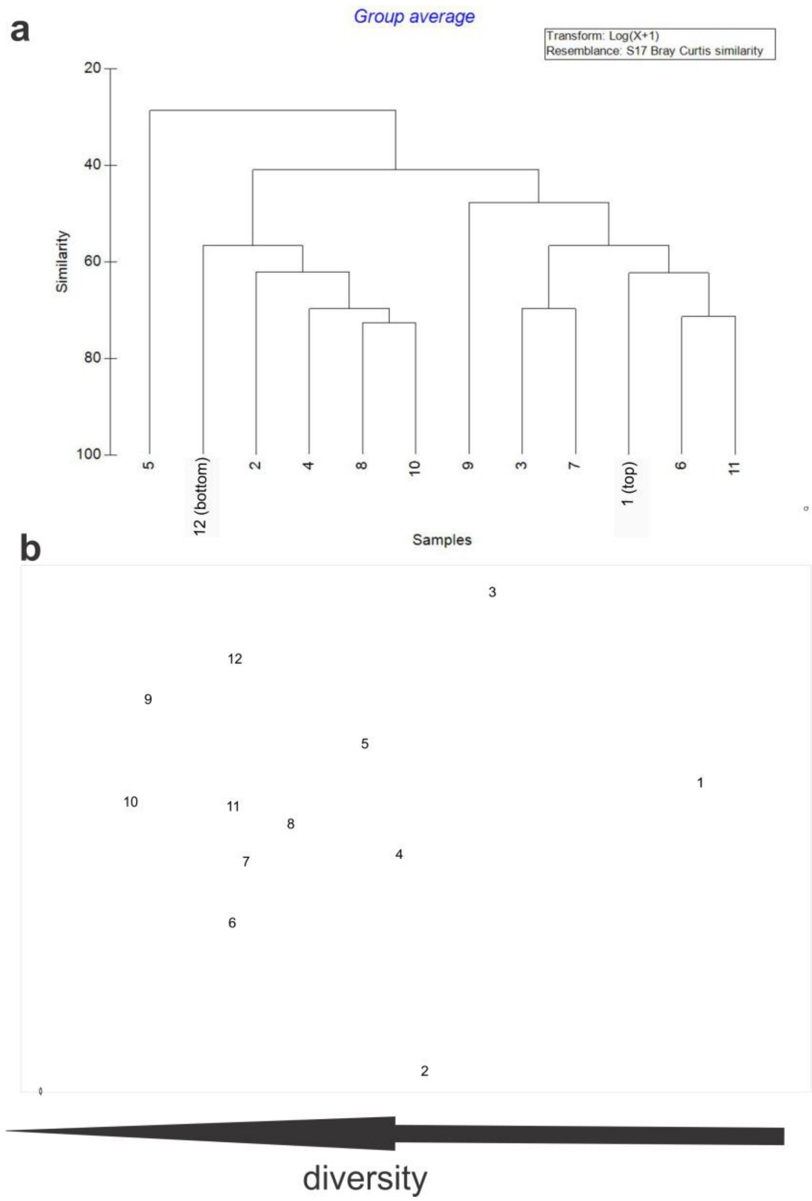


Figure 7a: Cluster analysis among species of foraminifera and Figure 7b: Analysis of MDS stations.

Core 3:

We can observe the presence of 70 species and the occurrence of *Ammonia tepida, Elphidium discoidale, Quinqueloculina lamarckiana,* and *Q. patagonica*, in all periods.

Species/Stations	1 (top)	2	3	4	5	6	7	8	9	10	11	12 (bottom)
Agglutinella agglutinans	0	0	0	120	0	0	0	60	0	100	0	0
Ammonia tepida	5370	6630	15500	26160	80	668	33540	15000	495	11050	598	5940
Arenoparrella mexicana	0	210	0	200	0	0	0	0	0	150	0	0
Bolivina sp.	0	0	0	0	0	0	0	60	0	100	0	0
Bolivina striatula	240	270	1175	1000	6	69	0	1080	90	600	26	360
Bolivina tortuosa	0	270	200	1040	0	0	120	420	0	600	0	45
Buccella peruviana	0	0	0	40	0	0	0	240	990	600	17	0
Bulimina marginata	0	120	0	440	0	5	0	300	0	0	0	45
Bulimina patagonica	0	120	425	360	0	9	600	240	0	300	0	45
Buliminella elegantissima	0	180	0	0	0	0	0	120	0	50	0	0
Cassidulina subglobosa	0	0	0	40	0	0	0	600	0	250	0	45
Cibicides fletcheri	0	180	0	320	0	0	0	300	0	400	0	0
Cibicides variabilis	0	30	0	0	0	0	0	0	0	500	0	135
Cornuloculina sp.	0	0	0	0	0	0	0	60	0	50	0	0
Cornuspira involvens	60	60	200	160	1	0	120	120	0	550	13	90
Discorbis peruvianus	0	450	75	2120	7	76	540	1920	45	1900	8	315
Discorbis valvulatus	0	0	0	0	0	0	0	60	0	50	0	0
Discorbis williansoni	0	90	0	80	0	0	360	120	0	50	0	45
Eplphidium articulatum	0	0	125	360	0	0	0	180	135	150	25	0
Elphidium discoidale	1110	120	900	400	17	125	1680	360	360	100	8	45
Elphidium excavatum	0	60	0	160	0	0	0	180	0	400	0	0
Elphidium galvestonense	0	0	0	680	0	0	0	60	0	100	0	0
Elphidium sp.	0	90	0	80	0	0	0	0	0	0	0	0
Falsagglutinella angularis	0	30	0	0	0	0	0	60	0	0	0	0
Fissurina laevigata	30	30	75	0	0	1	0	0	0	0	9	0
Fissurina lucida	0	0	0	40	0	0	120	0	0	0	0	0
Floresina spicata	30	0	0	0	0	0	0	0	0	50	0	0
Fursenkoina sp.	0	0	25	40	0	0	0	0	0	0	0	0
Hanzawaia boueana	0	0	0	560	0	0	0	300	0	250	0	180
Hopkinsina pacifica	0	30	0	0	0	0	0	180	0	100	0	0
Lagena laevis	0	0	0	0	0	0	0	0	0	150	1	0
Lagena striata	0	0	0	80	0	0	60	0	0	0	0	0
Lobatula lobatula	0	0	0	0	0	0	0	0	0	100	0	0
Loxostomina sp.	0	0	0	0	0	0	0	120	0	0	0	0
Massilina planata	0	0	0	0	0	0	0	60	0	100	0	0
Massilina timorensis	0	0	0	40	0	0	0	0	0	0	0	0
Miliolinella subrotunda	90	540	25	1600	0	16	480	1680	0	2950	36	1350
Patellina corrugata	0	0	0	0	0	0	0	0	0	150	0	45
Peneroplis jovem	0	0	25	0	0	0	0	60	0	0	0	0
Peneroplis pertusus	0	0	0	240	0	0	0	180	0	200	0	0
Poroeponides lateralis	0	90	25	160	0	0	0	60	0	50	0	0
Pseudononium atlanticum	30	30	175	80	0	3	240	360	0	550	33	45
Pseudotriloculina patagonica	0	0	0	0	0	0	0	0	0	150	0	405
Pyrgo nasuta	30	0	0	0	0	0	0	60	0	0	0	0
Pyrgo ringens	0	30	0	0	0	0	0	0	0	100	0	0
Pyrgo subsphaerica	60	30	0	0	0	0	0	0	225	0	0	0
Quinqueloculina intricata	0	60	0	80	0	0	0	180	0	200	0	90
Quinqueloculina lamarckiana	2250	1290	5175	5080	19	441	8820	5160	225	4800	371	1395
Quinqueloculina limbata	0	0	0	0	0	0	0	420	0	450	0	45
Quinqueloculina milletti	0	0	0	0	0	0	0	0	0	200	0	0
Quinqueloculina patagonica	1920	1680	3975	6040	22	247	11520	4620	225	2100	237	495
Quinqueloculina sp.	0	120	0	400	0	0	0	60	0	500	0	45
Quinqueloculina tubilocula	0	0	0	0	0	0	0	0	0	100	0	0
Quinqueloculina undulata	0	0	0	40	0	0	0	0	0	50	0	0
Reussella sp.	0	0	25	0	0	0	0	0	45	300	0	0
Rosalina sp.	0	30	0	0	0	0	0	0	1575	0	0	0
Siphogenerina raphana	0	0	0	40	0	0	120	0	0	0	0	0
Siphogenerina striatula	0	0	0	0	0	0	0	0	0	50	0	0
Siphonina bradyana	0	0	0	160	0	0	0	0	0	200	0	45
Spirilina vivipara	0	0	0	0	0	0	0	0	0	50	0	0
Spiroculina sp.	0	0	0	0	0	0	0	0	0	200	0	90
Spiroculina subimpressa	0	0	0	40	0	0	0	0	0	50	0	0
Textularia earlandii	0	150	50	560	0	17	1380	60	45	350	25	0
Textularia gramen	300	270	1000	1400	0	13	1560	420	0	750	66	270
Textularia sp.	0	0	0	280	0	0	0	60	0	100	0	0
Triloculina baldai	0	930	0	3600	0	0	0	2520	1035	2100	0	585
Uvigerina peregrina	0	0	25	0	0	12	780	60	0	50	0	0
Uvigerina striata	0	0	0	0	0	0	0	120	0	0	0	0
Wiesnerella sp.	0	30	0	200	0	0	0	240	0	150	0	0
Wiesnerella ujiiei	0	0	0	0	0	0	0	180	0	50	0	0

Table 5: Absolute frequency of foraminifera species in core 3.

The groups shown by the cluster evident groups formed by the oldest (9 and 10), (6, 7, 8 and 11) (4, 5, and 12) most recent stations (1, 2, 3). The grouping is not clear, we still need further analysis (Figure 8).

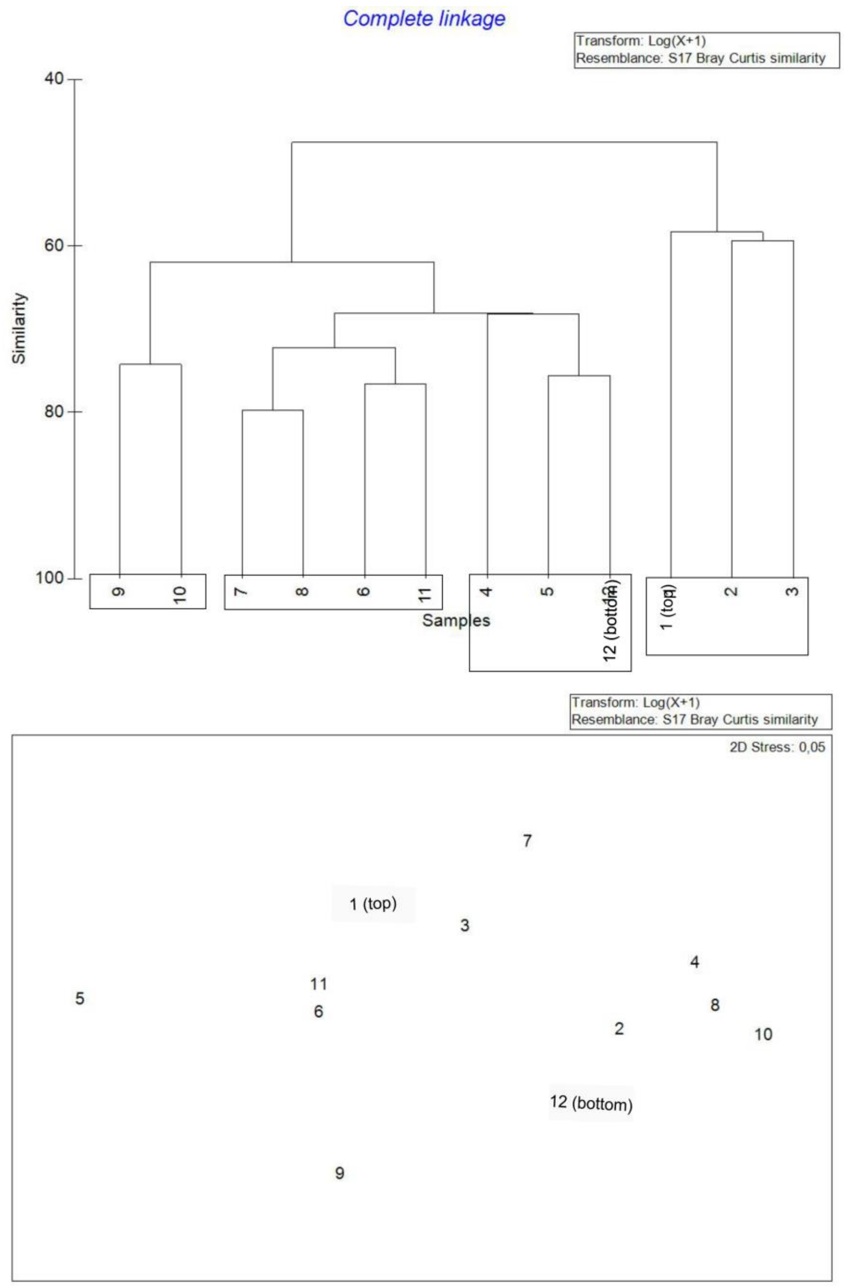
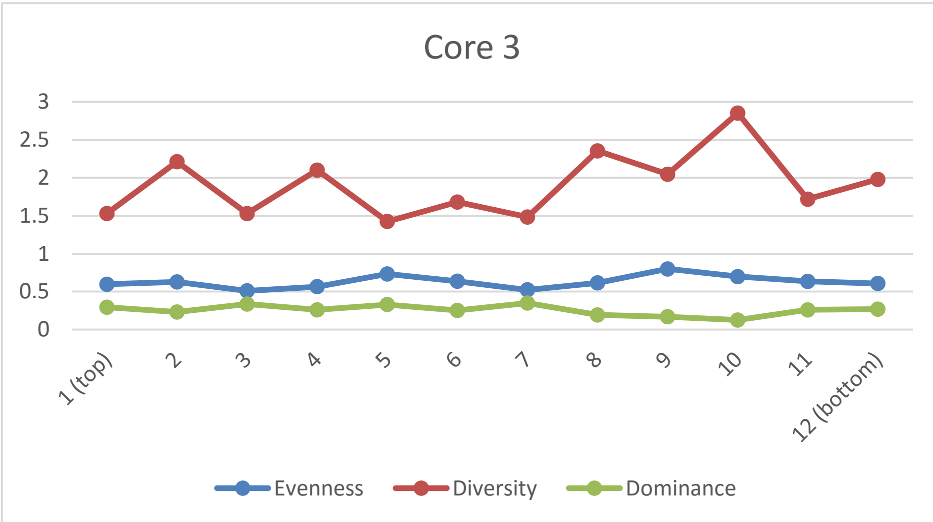


Figure 8: Cluster analysis among species of foraminifera and analysis of MDS in the intervals of core 3.

Table 6 shows the number of species varied between 7 and 60 and the number of species varied between 152 and 62040 individuals. Evenness showed a lower value (0.51) in the interval 3 and higher value (0.797951) in the interval 9. Diversity was lower in the interval 5 (1.42) and highest in the interval 10 (2.853171992). The dominance showed the lowest value (0.11) in the interval 9 and the highest value in the interval 7 (0.34).

Table 6: Number of species, specimens, evenness, diversity and dominance.

Intervals	Species number	Specimens number	Evenness	Diversity	Dominance
1 (topo)	13	11520	0.59	1.52	0.29
2	34	14790	0.62	2.21	0.23
3	20	29200	0.51	1.52	0.33
4	41	54640	0.56	2.10	0.25
5	7	152	0.73	1.42	0.32
6	14	1702	0.63	1.68	0.25
7	17	62040	0.52	1.48	0.34
8	46	38820	0.61	2.35	0.19
9	13	5490	0.79	2.04	0.16
10	60	37050	0.69	2.85	0.12
11	15	1473	0.63	1.71	0.25
12 (base)	26	12240	0.60	1.97	0.26



z

Figure 9: Diversity, dominance and evenness of core 3.

D. Discussion

This study investigated the ecologically fragile region of an inner shelf coral reef through foraminifers' species in the last 25 years approximately. Closer to River Pium we observe greater oscillation due to intrannual variations of drought and rain. A little southern the environment was more diverse and stable with lower dominances of species. We observed intrannual fluctuations in three different microenvironments, but there is a declining trend in diversity and evenness, with greater dominance of few species nowadays. Through the study of benthic foraminifera population dynamics, we have evidenced a decrease in the diversity and evenness, and increase in dominance today when compared with values of 25 years ago in 3 distinct regions in the reef area.

In a study of a coral reef supporting carbonate shelf, Almeida et al., (2013) has found three bio sedimentary units or functional groups (Hallock,2000): symbiotic-bearing foraminifers (*Amphistegina*, *Peneroplis* and *Archais*), other small taxa (*Miliolinella* and *Cornuspira*) and stress tolerant genera

(*Bolivina, Elphidium* and *Ammonia*). The reef degradation over time can be estimated by shifts in the Foram index (Hallock, 2000) that are based on grouping foraminifera into the above mentioned functional groups. Our study reveal that the absence of symbiotic-bearing foraminifers and the dominance of stress tolerant genera, which in according to Almeida et al., (2013) is due to the loss of favorable environmental conditions to support a healthy fauna even in the past. In according to Uthicke et al., (2010) studying benthic Foraminifera as ecological indicators for water quality on the Great Barrier Reef revealed that low light and higher nutrient conditions is acceptable for the stress tolerant heterotrophic Rotaliid but several large foraminifera symbiotic-bearing ones were identified as indicators for offshore, clear water conditions. Our study revealed that the loss of environmental quality is evident by the decrease of biodiversity towards today.

Bibliography

Almeida, C.M., Barbosa, C.F., Cordeiro, R.C., Seoane, J.C.S., Fermino, G.M., Silva, P.O. and Turcq, B.J., 2013. Palaeoecology of a 3-kyr biosedimentary record of a coral reef-supporting carbonate shelf. Continental Shelf Research, 70, pp.168-176.

Eichler PPB, Eichler BB, Miranda LB de, Rodrigues, AR (2007) Foraminiferal assemblages in a subtropical, mixohaline, estuarine channel, Bertioga (São Paulo). Braz J Res 37:45-58

Eichler PPB, Sen Gupta BK, Eichler BB, Braga ES, Campos EJ (2008) Benthic foraminiferal assemblages of the South Brazil: Relationship to water masses and nutrient distributions. Cont Shelf Res 28:1674-1686

Eichler PPB, Billups K Velez, CC (2010) Investigating faunal and geochemical methods for tracing salinity in an Atlantic Coastal lagoon, Delaware, USA. J For Res 40, 14-33

Eichler PPB, Eichler B.B, Sen Gupta B.K., Rodrigues, AR (2012) Foraminifera as indicators of marine pollutant contamination on the inner continental shelf of southern Brazil Marine Pollution Bulletin 64, 22-30

Uthicke, S., Nobes, K. (2008). Benthic Foraminifera as ecological indicators for water quality on the Great Barrier Reef, Estuarine, Coastal and Shelf Science, Volume 78, Issue 4, Pages 763-773, ISSN 0272-7714, http://dx.doi.org/10.1016/j.ecss.2008.02.014.

Yanko V., Kronfeld J, Flexer A (1994) Response of benthic foraminifera to various pollution sources: implications for pollution monitoring J For Res 24: 1-17

Yanko V. (1997) Benthic foraminifera as bioindicators of stress environment: anthropogenic problems - foraminiferal solution In: the first international conference application of micropaleontology in environmental sciences, Tel Aviv Program & Abstracts, Herzlia: Anamet Ltd, pp.117-119

Yanko V, Ahmad M, Kaminsky M (1998) Morphological deformities of benthic foraminiferal tests in response to pollution by heavy metals: implications for pollution monitoring. J For Res 28:177-200

Yanko V, Arnold AJ, Parker WC (1999) Effects of marine pollution on benthic Foraminifera In: Sen Gupta, BK (Ed), Modern Foraminifera, New York: Kluwer Acad Publ, pp 217-235

Sen Gupta BK. (2003) Modern Foraminifera. New York: Kluwer Academic Publishers;.

Sen Gupta BK, Platon E. (2006) Tracking past sedimentary records of oxygen depletion in coastal waters: Use of the Ammonia-Elphidium Foraminiferal Index. Journal of Coastal Research Special Issue.; 39(8–12):1351–1355.

Patchineelam, S.R. & Smoak, J.M. (1999). Sediment accumulation rates along the inner eastern Brazilian continental shelf. Geo-Marine Letters, 19, 196-201.