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Sandy Beach Macrobenthos Assemblages at an Hypersaline Coastal Lagoon, Lagoa De Araruama, RJ, Brazil

Edson da Silva†, Abilio Soares-Gomes†, Flavio Fernandes‡ and Carlos Magno de Abreu†

†Departamento de Biologia Marinha
Instituto de Biologia
Universidade Federal Fluminense
Niterói, Rio de Janeiro, Brazil

‡Instituto de Estudos do Mar
Almirante Paulo Moreira
Arraial do Cabo,
Rio de Janeiro, Brazil

ABSTRACT

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Lagoa de Araruama (22° 49′ & 22° 57′ S and 42° & 42° 23′ W) is one of the largest lagoons in Brazil. It is a rare example of a high salinity environment with a gradient ranging from 35 to 80. Benthic samples were collected at 26 different beaches along the Lagoon and abiotic analyses were performed for salinity, carbonate content and granulometry. Relative richness and occurrence indices were used for the qualitative description of the macrobenthic community. Nineteen of the one hundred and nine taxa found at Lagoa de Araruama were restricted to the two first sampling stations closer to the ocean. Highest relative richness indices were obtained for the sites near the sea, decreasing gradually to the inner of the lagoon, probably due to the increasing of salinity. The highest relative occurrence was for the bivalve mollusc *Anomalocardia brasiliana.* Cluster analysis showed one group correspondent to those sampling points located near the sea, and another that corresponded to the inner lagoon and its stable high salinity conditions. The Canonical Correspondence Analysis showed that the biotic distribution can be related significantly with water salinity and carbonate content of sediments. Thus, the data suggest a strong importance of salinity in structuring the macrobenthos community of the Lagoa de Araruama.

ADDITIONAL INDEX WORDS: *Estuary,* Anomalocardia brasiliana, *biodiversity, salinity gradient, canonical correspondence analysis, soft-bottom.*

INTRODUCTION

Coastal lagoons are important habitats as they are directly related to major fisheries due to their importance as "nurseries" for crustaceans, molluscs and fishes (DAY *et al.,* 1989). The environment of coastal lagoons ranges from freshwater to hypersaline. Hypersaline habitats occurs where evaporation exceeds precipitation or freshwater inputs, and where there is a restrict connection to the sea (FRIEDMAN *et al.,* 1985). The pelagic primary productivity tends to be low in this ecosystems and the metabolism is rather based on benthos. The biocenoses of the hypersaline habitats are marine-like (SOUZA *et al.,* 2003), although it is expected an impoverished fauna due to physiological constraints (DAY *et al.,* 1989).

Lagoa de Araruama (22° 49′ & 22° 57′ S and 42° & 42° 23′ W) is one of the largest lagoon in Brazil and the largest one in Rio de Janeiro State, with an extension of 35 km (1). According to KJERFVE (1986) it is one of the largest permanent hypersaline lagoon in the world, and this hypersalinity condition is at least 4–5 thousand years old (MARTIN *et al.,* 1992). The local salinity range from 35 to 80 g L^{-1} (mean of 52 g L^{-1}), been a result of a semi-arid climate and a negative water balance in the eastern part of this coast (KJERFVE *et al.,* 1996). Its economic importance and biological role (salt extraction, alkalis industry, fisheries, tourism, biological production, etc.) is fully recognised by the local community and government.

Like other coastal marine environments, Lagoa de Araruama has been suffering with severe pollution problems, which are a threat to this rare environment and its marine biodiversity (SILVA and FERNANDES, 1994; COUTINHO *et al.,* 1999). However, due to the phosphorus retention in the sediment and the hypersaline condition of the lagoon, changes in autotrophic communities are not observed as well as an eutrophization is prevented (SOUZA *et al.,* 2003). In contrast with others lagoons from Rio de Janeiro coast, which suffer with cultural eutrophization, Lagoa de Araruama is slightly mesotrophic (MOREIRA-TURCQ, 2000).

The aim of this study was to know the sandy beach macrobenthic species association and their relation with sediment abiotic factors, as well as to use the singular mesotrophic condition of the lagoon to verify the solely influence of water salinity on species richness at Lagoa de Araruama.

MATERIAL AND METHODS

Samples were collected in the intertidal zone at 26 different beaches along side the Lagoa de Araruama (1). A sediment volume of 250 ml was taken at each beach to perform carbonate (inorganic carbon) and granulometric analysis. Salin-

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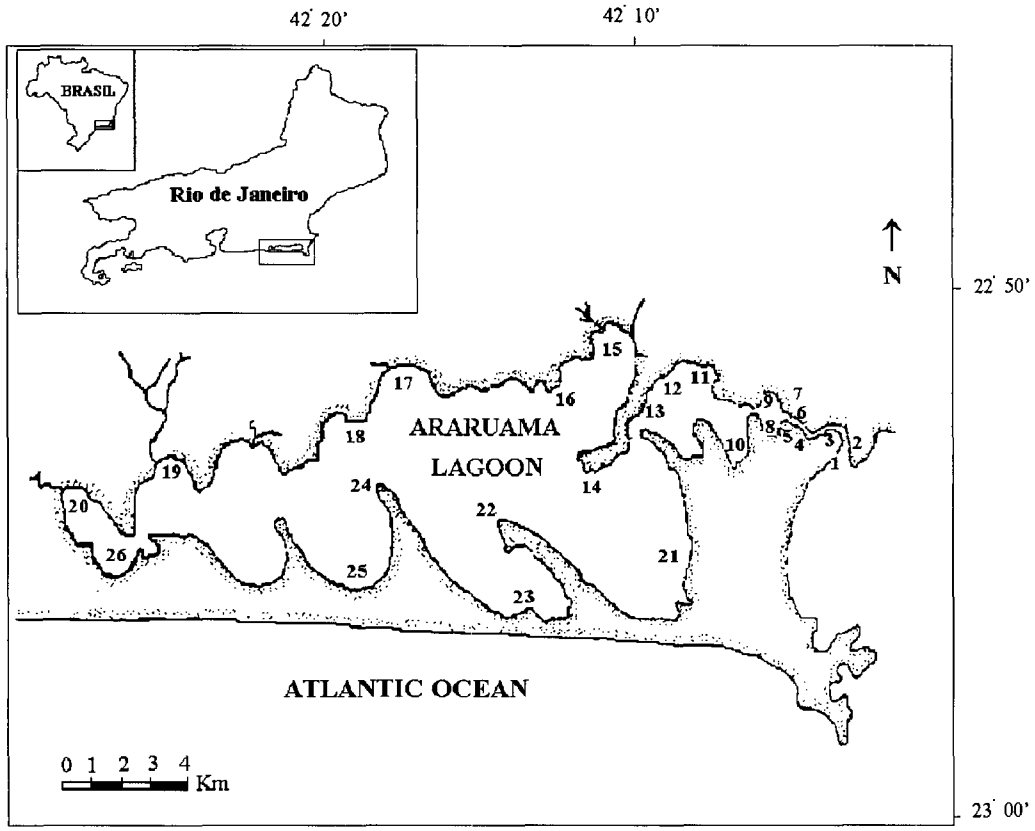

Figure 1. Sampling station locations at Lagoa de Araruama.

ity values were obtained from daily measurements performed by tritation in several different points over many years in Lagoa de Araruama. Carbonate content was determined by ignition and the granulometric fractions were obtained by mechanical sieving and the sedimentation method.

Organisms were identified at the best possible taxonomic level, and relative richness (R = n/N; where: n = number of taxa find by station e N = total number of taxa find on all stations), and occurrence (O = st/ST; where: st = number of stations where the taxa were find e ST = total number of stations) indices were used for the qualitative description of the biological variables.

The Unweighted Pair Group Method of clustering was performed on biotic variables using the Jaccard coefficient (PODANI, 1994). Canonical Correspondence Analysis (CCA) was used on both, abiotic and biotic matrix, to analyse the relation between them (TER BRAAK, 1987).

RESULTS

The mean grain size of sediment at the stations ranged from 1.5 (medium sand) to 0.23 phi (coarse sand), and the sorting coefficient (graphical standard deviation) from 2.49 (very poorly sorted) to 0.27 phi (very well sorted). Carbonate content of the sediments was low, ranging from 9.73 to 0.10%. Salinity followed a distance gradient from the mouth to the inner parts of the lagoon, ranging from 35 to 67 g L^{-1} (Table 1).

One hundred and nine taxa were found in the 26 sandy beaches sampling stations at Lagoa de Araruama. From these, nineteen are restricted to the two first stations (1 and 2). The relative richness showed a decrease as stations gradually depart from the Itajuru Channel, the lagoon link with the sea. The highest relative occurrence indices was obtained for the bivalve *Anomalocardia brasiliana* (0,77). The maximum number of species at one site was 32 at station 2. By contrast, in the 17 and 21 stations was only observed the presence of Acarina taxa. These results are summarised at Table 2.

Cluster analysis revealed two groups of stations (2). The first one corresponded to those stations located near the sea. All these stations are influenced by tides and, therefore, are subject to higher salinity variability. The other group corresponded to the inner lagoon, where the tide influence is low or do not exist at all, producing a stable high salinity condition.

CCA analysis (3, Table 3) showed that water salinity and carbonate content of sediments are the main gradient influencing the stations. Figure 4 showed the variation of richness along the same gradient of the two first CCA axes. The was an inverse relation between richness and salinity gradient.

Table 1. *Values of mean grain size (mean ϕ), sorting coefficient (φ_i), carbonate content ($CaCO_3$), and salinity (S). (ms = missing value).*

Sampling Stations	Mean ϕ	φ_i	$CaCO_3$	S
1	ms	ms	ms	35
2	1.5	0.97	0.10	35
3	1.0	1.78	0.49	35
4	1.09	0.51	1.28	37
5	1.18	0.46	0.94	37
6	0.96	0.69	0.99	37
7	1.11	0.49	1.95	37
8	0.04	1.71	4.35	42
9	0.05	1.78	6.78	42
10	0.42	1.26	8.07	54
11	0.78	0.87	4.24	53
12	0.16	2.48	3.09	53
13	0.40	1.06	6.11	53
14	0.27	0.76	8.00	67
15	0.41	0.54	4.45	67
16	0.07	0.66	9.73	67
17	0.14	0.53	3.11	65
18	0.52	0.64	0.57	65
19	0.42	0.46	2.55	52
20	0.01	1.02	8.34	52
21	0.28	1.15	13.82	63
22	0.32	0.79	4.25	60
23	0.92	0.32	1.11	61
24	0.93	0.27	1.50	63
25	0.44	0.32	1.06	63
26	0.23	1.31	3.12	52

Table 2. *Relative richness of all sampling stations and the 26 species (out of a total of 109) of higher occurrence at Lagoa de Araruama.*

Sampling Stations	Relative Richness	Species	Occurrence
1	0.08	Acantophora spicifera	0.15
2	0.29	Amphora turgida	0.08
3	0.20	Anomalocardia brasiliana	0.77
4	0.22	Bulla striata	0.08
5	0.24	Capitella capitata	0.35
6	0.14	Cladophora vagabunda	0.12
7	0.13	Clibanarius sclopetarius	0.08
8	0.09	Cymadusa filosa	0.12
9	0.08	Hypnea cervicorlis	0.15
10	0.10	Jania adhaerens	0.08
11	0.19	Laponereis culveri	0.12
12	0.14	Licmophora abreviata	0.08
13	0.10	Littoridina australis	0.12
14	0.03	Lygia exotica	0.12
15	0.06	Nereis (Neanthes) succinea	0.08
16	0.03	Neritina virginea	0.23
17	0.01	Nitzchia angularis	0.08
18	0.03	Nitzchia closterium	0.08
19	0.02	Orchestia darwini	0.08
20	0.04	Pagurus creniticornis	0.23
21	0.00	Petrolisthes armatus	0.08
22	0.02	Tellina lineata	0.12
23	0.03	Uca (Celuca) leptodactila	0.08
24	0.03	Ulva fasciata	0.15
25	0.06	Ulva lactuca	0.08
26	0.04	Zoobotrium pellucidum	0.12

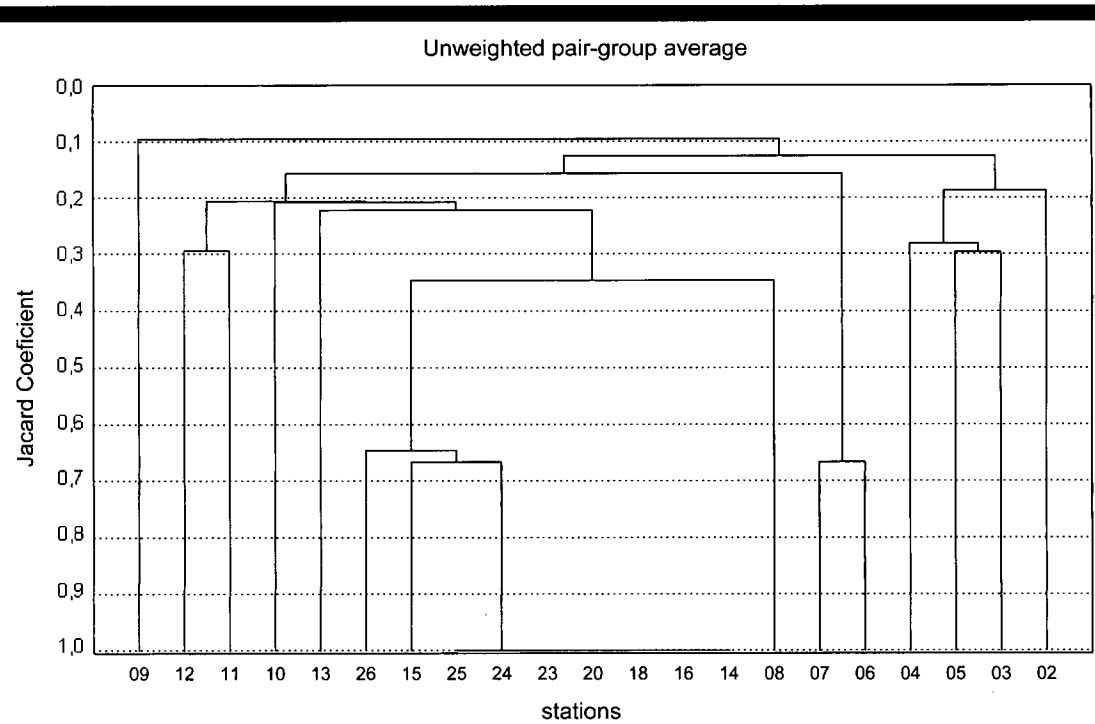

Figure 2. Q-mode dendrogram based on biotic variables.

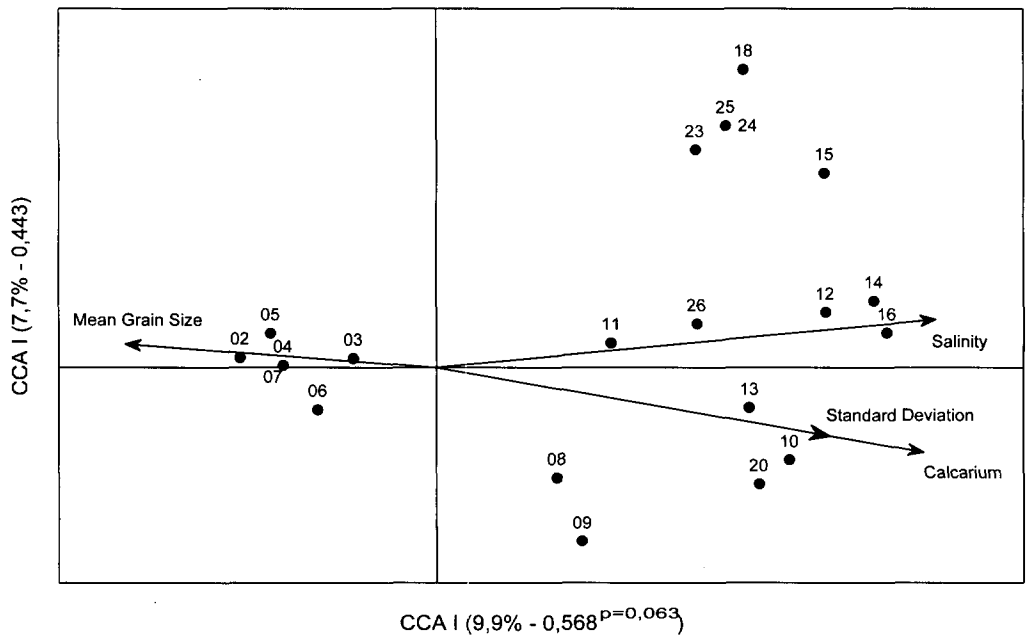

Figure 3. Ordination diagram of CCA showing the station plots and abiotic vectors.

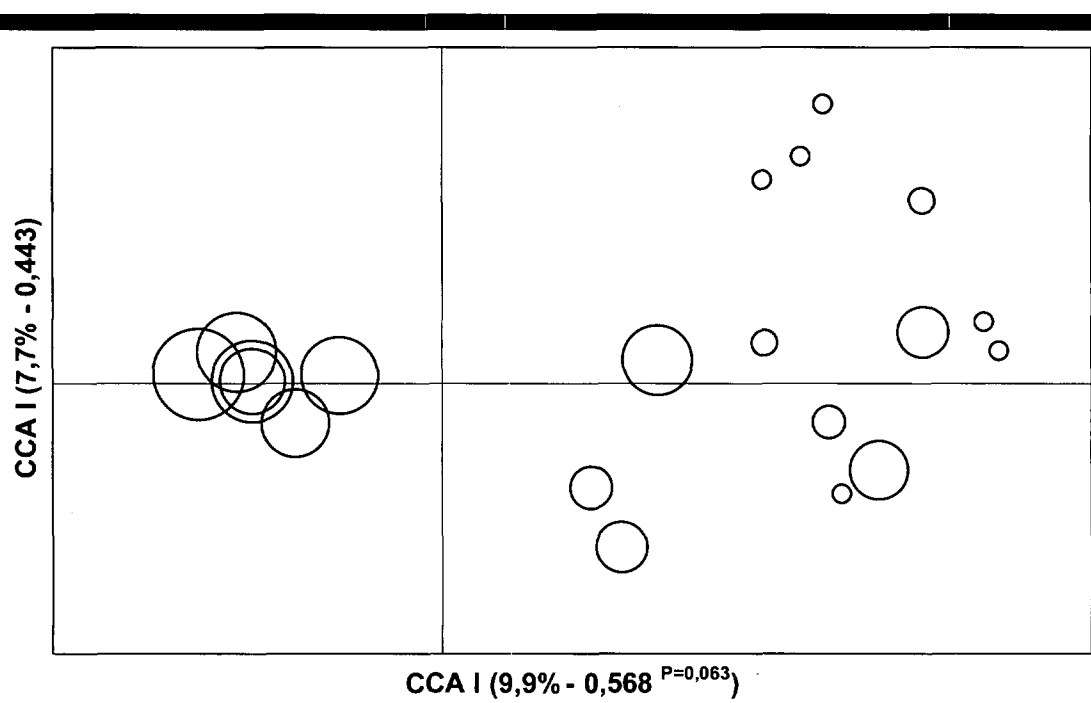

Figure 4. Ordination diagram of CCA showing variation of species richness along the same gradient of the two first CCA axes shown in Figure 3.

Table 3. *Summary of Canonical Correspondence Analysis results.*

Axes	1	2	3	4
Total inertia				5.746
Eigenvalues	0.568	0.443	0.376	0.244
Species-environment correlations	0.988	0.848	0.901	0.785
Cumulative percentage variance				
of species data	9.9%	17.6%	24.1%	28.4%
of species-environment relation	34.9	62.0	85.1	100.0
Sum of all unconstrained eigenvalues				5.746
Sum of all canonical eigenvalues				1.631

DISCUSSION

The decreasing relative richness at Lagoa de Araruama system is directly associated with increasing salinity and sediment carbonate contents. Associations between salinity and low relative richness was already described for fouling communities in the Itajuru Channel (CORREIA, 1987), as well as for hard substratum macrobenthos (SILVA and FERNANDES, 1990a) and associated fauna at mangroves (SILVA and FERNANDES, 1990b). This pattern of reduced number of species related to extremes of salinity gradients is very common in an estuary (DAY *et al.,* 1989, LEVINTON, 1995), but is dramatic at Lagoa de Araruama (29,36 g L^{-1} at sampling station 1 to 0,00 g L^{-1} at sampling station 21), where salinities can reach levels as far as 80 g L^{-1}.

Anomalocardia brasiliana has the highest occurrence in the lagoon. This bivalve is an eurihaline organism that can bear salinities from 15 up to 70 g L^{-1} (LEONEL *et al.,* 1982, 1983). This species is exploited commercially in Brazil, and has a large geographical and ecological distribution in the Caribbean and along the Eastern coast of South America (RIOS, 1970).

As a result of the highly differentiated salinity regimes found at the Lagoa de Araruama extension, at least two different lagoon systems have been considered (INPH and PORTOBRAS, 1987; SOUZA, 1997). The first system begins at the Itajuru Channel and runs until the Boqueirão area, been submitted to intense tide influence, higher primary production and a salinity gradient ranging from 35 up to 57 g L^{-1}. The second system corresponds to central lagoon, which presents low tide influence, lower productivity and salinities from 57 up to 70 or 80 g L^{-1}. The cluster analysis revealed a similar pattern showing two different groups correspondent to stations located at one or another lagoon systems described. This result is very interesting, once it shows a correspondence between independent biotic and abiotic data from Lagoa de Araruama. A third system was also proposed for the last end of the lagoon based on river drainage influence (SOUZA *et al.,* 2003).

Besides salinity, sediment abiotic variables may also influence the distribution of macrobenthos. Among these variables, the habitat heterogeneity could influence the richness of macrobenthic communities. The sorting coefficient of sediment grain sizes, could be viewed as a measure of spatial heterogeneity. The higher phi values of this coefficient meaning a more heterogeneous environment. Thus, it is expected that more heterogeneous habitats harbour a richer macrobenthic fauna than homogeneous one (GRAY, 1974, 1982). Apparently, it was not the case at Lagoa de Araruama, where the lower richness values were observed at stations located inner in the lagoon, which show sediments, in general, more heterogeneous (poorly sorted). Possibly, the salinity is the variable that overshadows other abiotic variables influence in hypersaline ecosystems like the one found at Lagoa de Araruama.

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☐ SUMMARY ☐

A Lagoa de Araruama é uma das maiores lagunas costeira do Brasil, sendo um raro exemplo de ambiente hipersalino, apresentando salinidade entre 35 a 80 g L^{-1}. Amostras biológicas coletadas em 26 praias ao redor da laguna foram correlacionadas com medidas de salinidade da água, carbonato e granulometria do sedimento. Medidas de riqueza específica e índices de ocorrência das espécies foram utilizadas para uma descrição qualitativa das associações de macrobentos. Dentre os 109 taxa encontrados na lagoa, 19 foram restritos as 2 estações mais próximas ao oceano. Os maiores valores de riqueza relativa foram observados nas estações mais próximas ao oceano, decrescendo gradualmente para o interior da laguna. A espécie com maior ocorrência foi o molusco bivalve *Anomalocardia brasiliana.* A análise de agrupamento evidenciou um grupo de estações situado próximo a saída da laguna e um outro grupo de estações localizado no setor mais interno. A análise de correspondência canônica (CCA) indicou que a distribuição do macrobentos está significativamente relacionada com a salinidade da água e com o teor de carbonatos dos sedimentos.