

Geoecology of Sublittoral Benthic Communities in Todos os Santos Bay (Bahia, Brazil): Biotic and Sedimentological Diversity

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ABSTRACT

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Studies on marine ecosystems of tropical regions are still relatively few. In general, knowledge of marine biodiversity lags behind. This work aims to analyze the structural features of macrobenthic communities in unconsolidated substrates in Todos os Santos Bay (TSB) in relation to the environment. TSB is 1086 km² in area, and is located between 12°35' to 13°07' S and 38°29' to 38°48' W. Thirty-two stations were sampled in 1997 using a van Veen grab and a dredge to sample sediments, and bottles to sample near-bottom water. The sediment was highly heterogeneous, with 12 textural types. Three faunistic associations were defined using Twinspan cluster and discriminant analyses of abundance data for the families of Polychaeta, Mollusca Bivalvia and Echinodermata. However, faunal distribution was shown by DCA to be continuous. The first association, occurring in siliciclastic sandy sediments and located in the bay mouth, showed intermediate richness. The second and richest association occurred in mixed sands with higher carbonate content, the preferred habitat of 24% of the families collected. The third association, occurring in muddy sediments from the northern to the central portion of TSB (47% of the stations), showed the lowest richness and abundance values, with some families not recorded. Biodiversity, in terms of richness and abundance, was proportional to carbonate content, median grain size, and the percentage of the coarse sediment fraction; and inversely proportional to the percentage of mud. Richness and abundance showed linear and logarithmic patterns respectively.

ADDITIONAL INDEX WORDS: *Echinodermata, Mollusca, Polychaeta.*

INTRODUCTION

Studies on fauna and characterization of marine benthic communities have intensified in recent years, mainly reflecting greater awareness of environmental issues. Nevertheless, in many parts of the tropics even the taxonomy of the benthic fauna is poorly known (AGARD *et al.*, 1993, NORSE, 1993 and ORMOND *et al.*, 1997).

LANA *et al.* (1996, p. 12), in an evaluation of knowledge of the benthos along the Brazilian coast, stated that "there are no biogeographic analyses of the Brazilian Atlantic fauna or flora treated as a whole. This is because of the traditional restriction of studies on shelf fauna taxonomy to isolated groups, still present in the Brazilian scientific community". According to these authors, the benthic fauna in the region between Salvador and Vitória, including TSB, is the least known of the faunas of both coastal and shelf environments of Brazil.

TROLL (in: GUERRA *et al.*, 1996, p. 122) created the term Geoecology, defining it as "the science of the interrelations among the organisms or biocenosis and their environmental factors". Although in theory the disciplines of ecology and geoecology have similar definitions and common objects of study, in practice they differ in their approach to biotic-abiotic relationships, the former highlighting living environments, the latter attempting to give equal attention to living and non-living environments.

This work is a summary of a doctoral thesis (ALVES, 2002), which aimed to analyze features of the structure of the infralittoral benthic communities of unconsolidated substrates of TSB and their relationships to sediment characteristics, in a geoecological approach.

STUDY AREA

TSB is the second-largest Brazilian bay, having an area of 1.086 km² and width of 32 km. Located between the

geographical coordinates 12°35'30" - 13° 07'30" S and 38° 29'00" - 38° 48'00" W, it has several entrances, nearly 200 km of coastline, and bights, capes, peninsulas and beaches compounding its environmental richness. Surrounding the bay are important cities of the so-called "Recôncavo Baiano", among them Salvador, the capital of the state of Bahia (GERMEN *et al.*, 1997, LESSA *et al.*, 2001 and SILVA *et al.*, 1996).

LESSA *et al.* (2000) identified five quaternary sedimentary facies within the bay. LESSA *et al.* (2001) described the tides and tidal circulation within the bay, characterizing tsb as a typical marine environment.

There have been few published studies of TSB, and particularly in the area of ecology and biodiversity the number of studies is even fewer. LOPES *et al.* (1998), analyzing the ichthyofaunal composition of the Cacha Pregos mangrove (on Itaparica Island), found 85 species belonging to 46 families, and observed that the mangrove environment is important for many species which spend part of their life cycles there. PESO-AGUIAR *et al.* (2000) found a significant negative spatial relationship between impacts of oil exploitation and diversity indexes in the intertidal ecosystem in northern TSB.

METHODS

The study region was divided according to its morphology into six large areas, so that different sediment environments were represented, in order better to characterize their biodiversity (Figure 1).

Water and sediment samples were collected at 32 stations from March to May of 1997. The water near the bottom was sampled using van Dorn collecting bottles, to measure temperature, salinity and dissolved oxygen. Three replicate sediment samples were obtained with a 0.1 m² van Veen grab, and a fourth sample was taken with a rectangular dredge.

Locality, water depth and water transparency data were recorded by GPS, echo sounder and Secchi disc, respectively.

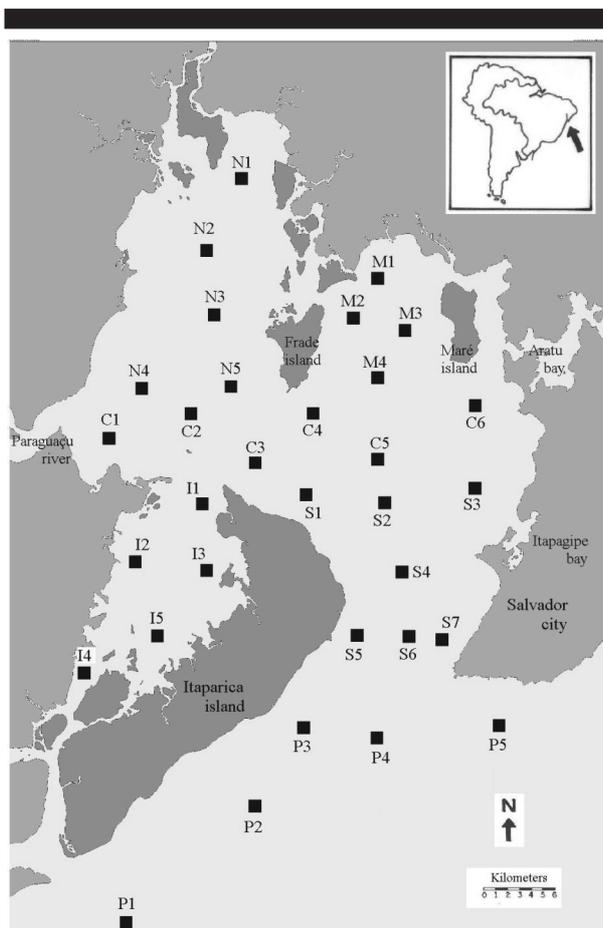


Figure 1. Map of the study area showing the 32 sampling stations.

The sediment samples for faunal evaluation were washed in 5.0 mm, 2.0 mm and 1.0 mm mesh sieves. The sediment samples were evaluated by sieving and pipette methods according to SUGUIO (1973). Carbonate content was measured by the method of digestion in hydrochloric acid. MENDES (1999) measured the organic content of the sediment.

Family abundance data for the groups Polychaeta, Mollusca Bivalvia and Echinodermata were used to evaluate communities. The data collected with the van Veen grab during the 1997 campaign were included. Multivariate analyses were performed using PC-Ord (McCUNE and MEFFORD, 1999). Twinspan (Two-Way Indicator Species Analysis), which classifies stations and families simultaneously, was used as the classification technique. DCA (Detrended Correspondence Analysis), an ordination technique, and Indicator Species Analyses were also performed. Richness, Shannon and Simpson diversity, and evenness indexes were obtained. The Statistica and SPSS (Statistical Package for Social Sciences) programs were used for running Pearson's correlation and discriminant analysis respectively.

RESULTS AND DISCUSSION

Abiotic Data

Depths ranged from 1.5 m to 62 m, the latter near Itaparica Island. Water transparency was between 1.5 m and 2.0 m at the

northern stations, reaching 10-14 m over the adjacent continental shelf (Area P). Salinities ranged from 27 o/oo to 36 o/oo, with lower values in Area N. Dissolved oxygen ranged from 5.4 mg/l to 10.4 mg/l, and was highest at the deepest stations (S1 and S4). Surface-water temperature ranged from 26°C to 29°C, while water near the bottom was slightly cooler (26°C to 28°C).

The total carbonate (sieve fractions ≥ 0.062 mm + mud fraction < 0.062 mm) ranged from 3.3% (northern TBS) to 99.9% (west of Maré Island). Eight stations (25%) had total carbonate above 50% (ALVES *et al.*, 2004).

The sediment analyses indicated wide variations in granulometry (ALVES, 2002 and ALVES *et al.*, 2004). In the northern part of the bay (Area N), the sediment was mainly composed of siliciclastic mud. A similar composition was found at two stations in Area M (M1 and M4). Stations M2 and M3 had heterogeneous sediments, high in carbonate. In the central part of the bay (Area C), siliciclastic mud composed most of the samples, while the sediments at Stations C3 and C4 were more heterogeneous in both size and composition. Carbonate was an important component of the sediment in the area between Itaparica and the western shore of the bay (Area I), reaching 100% in the composition of sieving fractions (pebble, gravel and sand) at Station I5. This area has very heterogeneous sediment. This varied sediment granulometry also appeared in Areas S and P, while carbonate also appeared in the composition of these sands. Station P1, located near the mouth of the Jaguaribe River, had mainly siliciclastic muddy sediment.

Overall, median grain size ranged from -1.17 (gravel) to 10.17 phi (clay). The majority of the stations (78%) showed a dispersion (standard deviation) greater than 1.0, characteristic of poorly sorted to extremely poorly sorted sediment. Skewness values ranged from -0.61 (very negatively skewed) to +0.84 (very positively skewed) and showed no defined spatial pattern. Kurtosis varied enormously, from 0.59 (very platykurtic) to 6.21 (extremely leptokurtic), and also showed no clear spatial distribution in the study area.

Sediment organic matter content ranged from 0.3 to 12.1%. The highest contents of organic carbon, organic nitrogen and organic matter were measured in the northern part of the bay and in the channel between Itaparica Island and the western shore of TSB. In those areas, the bottom is more stable, and fresh water enters from the Paraguaçu River; the highest ratios of organic carbon to organic nitrogen have been measured in the river mouth (MENDES, 1999).

Using the Shepard diagram sediment-texture classification, and including the total carbonate content of samples (more or less than 50%), 13 different texture types were characterized: 3 clay bottoms: clay, silty clay, and sand-silt-clay; 2 silt bottoms: clayey silt and sandy silt; and 8 types of sand: clayey sand (siliciclastic), clayey sand (carbonate), silt-clay-sand (siliciclastic), sand (siliciclastic), sand (carbonate), gravelly-muddy sand (carbonate), gravelly sand (siliciclastic) and gravelly sand (carbonate).

Biotic Data

A total of 80 families belonging to Polychaeta, Bivalvia and Echinodermata were recorded in the triplicate samples (0.3m²/station). For the statistical analyses, 13 families (16%) with abundance equal to 1 were excluded.

The groups obtained from the classification analyses are shown in Figure 2. From the biotic data, two groups (1a and 1b) were better defined and characterized in regard to their faunal composition. Moreover, according to the discriminant analysis,

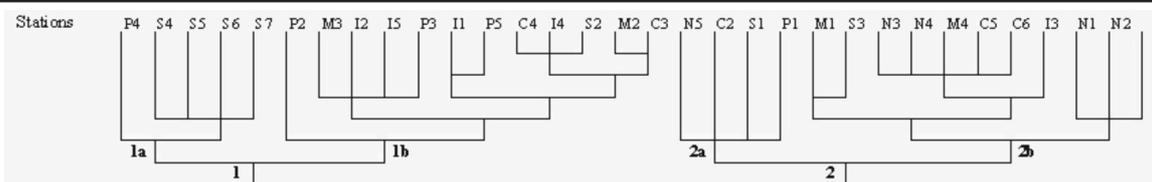


Figure 2. Dendrogram constructed from the results of Twinspan analyses.

Table 1. Correlations between data for richness and abundance, and the most important environmental variables (* indicates correlation not significant at $p < 0.05$).

Variable	Richness (family level)	Abundance (untransformed data)	Abundance (log-transformed)
% Carbonate (in Very Coarse Sand fraction)	0.84	0.53	0.77
% Carbonate (total)	0.76	0.13*	0.42
Median sediment (Md - phi)	-0.82	-0.52	-0.74
Mean sediment (M - phi)	-0.73	-0.47	-0.69
% Coarse fraction (total)	0.76	0.52	0.74
% Sand	0.69	0.56	0.74
% Mud	-0.76	-0.52	-0.74
% Clay	-0.74	-0.52	-0.73

Groups 2a and 2b were very close to each other in their biotic characteristics and did not show a well-defined faunal composition. Therefore, three faunal associations (1a, 1b and 2) were considered to characterize the study area. Contrariwise, DCA analysis revealed the continuous character of families and station distributions. This "continuum" pattern of fauna distribution is common in nature (RICKLEFS, 1993). The Indicator Species Analyses for the three associations showed 24 indicator families (to IV, indicator value, >50% and $p < 0.05$ significance).

Group 1b showed the highest richness: the values ranged from 25 to 42 families, 16 of them (24% of the total) being indicators for this association. Analyzing the trophic structure of 39 polychaete families of TSB, BARROSO *et al.* (2002) found that deposit-feeders and carnivores were the most dominant groups, especially in Area I, reflecting the structural complexity of this part of the bay.

Biotic-Abiotic Relationships

The relationships between the diversity indexes (richness, Shannon and Simpson diversity, and evenness) and the environmental factors showed a statistically significant linear correlation (Pearson's, $p < 0.05$) between richness (number of families) and certain environmental variables (Table 1).

The abundance data also revealed significant correlations with the environmental parameters. This relationship was logarithmic rather than linear (Table 1). This pattern is characteristic of biotic communities, as shown by GAUCH (1982), LUDWIG and REYNOLDS (1988), MAGURRAN (1988) and CLARKE and WARWICK (1994).

The results obtained for TSB showed that the mean (or median) grain size, the percentage of the total coarse fraction or the % of mud (inversely), especially clay, and also the % of total carbonate (especially the very coarse sand fraction) are the most important environmental variables in the structure of diversity (richness) of unconsolidated bottoms in this bay. Nevertheless, the role of the granulometric parameters, such as the standard deviation, indicators of environmental heterogeneity, was not clear in this evaluation, as discussed in ABSALÃO *et al.* (1999). According to COOPER (1992) and GRAY (1997), the standard deviation (or sorting) of the sediment does not appear to be a good indicator of heterogeneity. CLARKE and CRAME (1997, p.123) noted that "an improved understanding of the role of spatial heterogeneity in regulation of diversity in the sea is urgently required".

GRAY (1997) pointed out that a research agenda for marine diversity should concentrate in the tropical and subtropical areas, where human impacts are greatest, and that the currently accepted paradigm of low coastal diversity and high deep-sea diversity needs to be re-examined. In the same paper, Gray emphasized the need for better documentation of marine diversity patterns in certain areas of the southern hemisphere, such as the African and American continents.

Preliminary results of this research and data from samples

collected in 1996 were presented by ALVES *et al.* (1999), who reported the loss of diversity in Aratu Bay.

CONCLUSIONS

Data on family abundance (Polychaeta, Mollusca Bivalvia and Echinodermata) allowed us to characterize three faunal associations, grouped by Twinspan and confirmed by the Discriminant Analyses.

The first association was found in the entrance of the bay (5 stations, 16%), between Salvador and Itaparica Island (Stations S4, S5, S6, S7 and P4), occurring in siliciclastic sands, with carbonate contents less than 30% and organic matter less than 1.3%. This association showed intermediate values of richness (between 15 and 26), with 8 families (12%) occurring preferentially in this association.

The second association united 12 stations (37%) where 16 families (24%) had a preference for these habitats. The stations had mixed sands, from gravelly sand to clayey sand, with carbonate values ranging from 25 to 100% (mean 53%), and organic matter content ranging from 0.3 to 5.6%. This association showed the highest values of richness (between 25 and 42), uniting most stations in Area I (1, 2, 4 and 5) and Area P (2, 3 and 5) and four stations in the center (C3 and C4) and Area M (2 and 3).

The third association, represented by 15 stations (47%), showed the lowest values of richness (between 5 and 17) and also of abundance (between 13 and 333). In this association were grouped all stations in Area N, two in Area M (1 and 4), most stations in the central area (C) and some in Areas S, P and I, occurring from the center of the bay to the innermost (northern) part. Muddy sediments predominated, carbonate contents were less than 36% and organic matter contents were the highest in the study area (from 2.6 to 12.1%). No families belonging to this association occurred preferentially in these environments.

The abundance data of faunal distribution in TSB indicated a continuous pattern, which was observed in the DCA ordination analyses.

The most important environmental variables in the characterization of biodiversity (especially richness and abundance) were: the percentage of carbonate (mainly carbonate from very coarse sand), the median grain size, the total coarse fraction of sediment (especially sand) and inversely the percentage of mud (mainly clay). The relationships of the indexes of evenness and diversity (Shannon and Simpson) with the environmental parameters were unclear. Richness showed a linear relationship with these parameters, while abundance showed a logarithmic relationship. The environment showed great heterogeneity, being that 13 different textural sediment types (5 muddy and 8 sandy) were found.

The methodology revealed that the combination of different techniques, for both collecting and data analysis, is fundamental in allowing better comprehension of the community structure.

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