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Taxonomic sufficiency for soft-bottom sublittoral mollusks assemblages in a tropical estuary, Guanabara Bay, Southeast Brazil

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Abstract

Guanabara Bay (GB) is considered to be one of the most polluted environments of the southern Brazilian coastline. This typical estuarine system is impacted by the heavy discharge of both industrial and domestic waste from the Rio de Janeiro metropolitan area. The mollusc community structure and distribution was investigated between 2000 and 2001, using a three month sampling design of 38 stations, according to austral seasons. Species abundance was aggregated into progressively higher taxa matrices (genus, family, order) and were analysed using multivariate techniques. Mollusc distribution in GB varied significantly in space and time and was probably ruled by the organic enrichment effects of hypoxia and altered redox conditions coupled with prevailing patterns of circulation. Within the sectors of GB an increasing gradient in mollusc diversity and occurrence was observed, ranging from the azoic and impoverished stations in the inner sector to a well-structured community in terms of species composition and abundance inhabiting the outer sector. The non-metric multidimensional scaling (nMDS) and cluster analysis showed similar results when species were aggregated into genera and families, while greater difference occurred at coarser taxonomic identification (order). The literature about taxonomic sufficiency has demonstrated that faunal patterns at different taxonomic levels tend to become similar with increased pollution. In Guanabara Bay, an analysis carried out solely at family level is perfectly adequate to describe the ecophysiological stress. Further aggregation to order level changed the perceived patterns of differences. However, a different taxonomic resolution can be chosen depending on the type of ecological patterns investigated.

Keywords: Taxonomic sufficiency; Macrobenthos; Pollution monitoring; Tropical estuary

1. Introduction

Benthic communities are key indicators of estuarine environmental status, responding predictably to many kinds of natural and human-induced disturbances (Thompson et al., 2003; Venturini et al., 2004). However, as benthic community monitoring has been criticised as being time-consuming and expensive, both in terms of sampling effort in the field and laboratory analysis, there has been interest in examining ways of improving the cost-effectiveness of these studies. Therefore, a special focus has been given on the use of coarser levels of taxonomic resolution, if the loss of information is acceptable (Warwick, 1988; Ferraro and Cole, 1990; Gray et al., 1990; Thompson et al., 2003; De Biasi et al., 2003).

Taxonomic identification to species or to the lowest possible level is a common but labour intensive practice in monitoring programs (Ferraro and Cole, 1990). The sorting, identification and quantification stages, necessary to compile species abundances arrays, require a considerable degree of taxonomic expertise and familiarity with the local fauna. In addition to these time-consuming tasks, when several species within the genus are similar, the identification can be more error prone due to inaccuracy and imprecision (Warwick, 1988).

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Indeed, Gray et al. (1988) pointed out that there is a considerable degree of redundancy in species data and concluded that aggregation into higher taxonomic levels would reduce this problem, preventing natural variables from masking the effects of pollution. Accordingly, Warwick (1988) suggested that pollution effects are detectable at coarser taxonomic groups as natural variability affects community structure mainly by species replacement. Many other studies provided the best evidence to date for the taxonomic resolution of higher taxa in pollution studies, specially regarding the family-level identification (Somerfield and Clarke, 1995; Olsgard et al., 1997; Olsgard et al., 1998; Ferraro and Cole, 1990; Thompson et al., 2003; Gesteira et al., 2003; Dauvin et al., 2003). These studies demonstrated the equivalency of pollution assessments at the species to family level for several macrobenthic data sets, suggesting that identification to the level of family may be satisfactory in many routine monitoring surveys.

Therefore, to increase the cost-effectiveness of a monitoring survey all components must be optimised while maintaining the ability to reliably detect an impact. Consideration of taxonomic resolution and also the sieve-mesh-size should be made in conjunction with other sampling design variables such as number of replicates, sampler size, and sample unit size (Thompson et al., 2003) when seeking a statistically rigorous, cost-effective study design sufficient to meet pollution assessment objectives.

The aim of this study was to investigate the taxonomic resolution sufficiency for the sublittoral mollusk assemblage of Guanabara Bay, Rio de Janeiro State, southern Brazil. The present research is a contribution to what concerns the taxonomic sufficiency approach in tropical environments, once previous studies have been conducted mostly in temperate areas worldwide.

2. Study area

Guanabara Bay (GB), located at 23° 50′ S, 43° 08′ W, is a 384 Km^2 eutrophic coastal bay in southeast Brazil (Kjerfve et al., 1997). It is considered to be one of the most polluted environments of the southern Brazilian coastline (Carreira et al., 2002). Due to the rapid degradation of this ecosystem, the bay represents an important focus of environmental interest but little information is available about the local benthos. The ongoing socio-economic pressure upon GB requires updated knowledge of its ecosystems structure and function.

This typical estuarine system is impacted by the heavy discharge of both industrial and domestic waste from the Rio de Janeiro metropolitan area. Its drainage basin receives polluted effluents from 24 sub basins with about 6000 industries, two airports, two harbours and 15 oil terminals located in its vicinities (Kjerfve et al., 1997). Apart from the residues of this large industrial park, the sewage of an increasing population of 10 million inhabitants is also released into the bay's water through about 45 rivers, 6 of which are responsible for 85% of the total runoff (Kjerfve et al., 2001). As a result, 75% of the organic wastes originate from urban untreated sewage and 25% from industries. Further, high inputs of heavy metals, petroleum hydrocarbons, pesticides (Xavier et al., 2002) and other toxic chemical compounds (Ventura et al., 2002) enter the bay daily, especially in the inner portion, accumulating in the bottom sediments. However, these pollutants seems to be buried in anoxic sediments and are therefore, unavailable for biological uptake (Carvalho and Lacerda, 1992).

The bay experiences a large spatial and temporal variability of its water quality, mainly caused by circulation patterns and pollution foci (Kjerfve et al., 1997). Circulation is controlled by tides and winds, allowing water inflow from the ocean through the bottom layers. As described by Kjerfve et al. (2001), BG has a complex bathymetry with a 400 m wide central channel, which stretches from the mouth (1.6 m wide) more than 5 km into the bay, and is defined by the 30 m isobath. The channel rapidly becomes shallower further into the bay, reaching to a maximum 1 m depth in the inner portion. Because of the rapid mud sedimentation, the mean depth measures only 5.7 m.

According to Kjerfve et al. (2001), the worst water quality is indicated by average faecal coliform counts higher than 1000 ml^{-1} and by the average chlorophyll concentration exceeding 130 $\mu g\, l^{-1}$ in the inner bay, the most critical zone, in response to high nutrient loading. Sediments are not evenly distributed at the bottom, predominating mud at the inner areas and fine sand near the mouth (JICA, 1994). As a result of increase pollution levels and poor circulation towards the inner region, the sediments in this area presents reducing conditions, being considered anoxic during the wet season.

3. Material and methods

3.1. Sampling design

The sublittoral soft-bottom molluscs of GB were investigated through four oceanographic surveys conducted between the years of 2000 and 2001. It was performed at three month interval sampling design of 38 stations, according to austral seasons. The sampling stations were grouped into subsets and named as: inner sector (stations 1–14), intermediary sector (stations 15–26), and outer sector (stations 27–38) in relation to the sampling design of previous works in the area, natural hydrodynamic characteristics and pollution intensity (Fig. 1).

At each station a 0.1 m^2 van-Veen grab sample was taken in triplicate. Sediment samples were analysed for grain size distribution, organic matter, carbonate content and oxi-redox potential. The methods of mechanical dry sieving and decantation described by Suguio (1973) were used to determine the grain size fractions. The percentage of total organic matter was determined by loss of mass on ignition and sediments samples were oven-dried at 105 °C for 12 h and subsequently ashed at 500 °C for 2 h. Biodetritic carbonate ($CaCO_3$) was obtained by HCl 10%