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Tissue nitrogen and phosphorus in seaweeds in a tropical eutrophic environment: What a long-term study tells us

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Abstract

Percentages of nitrogen and phosphorus in 10 species of seaweeds (6 green and 4 red algae) were monitored from 1997 to 2004 by seasonal sampling in Guanabara Bay, South-eastern Brazil. The species did not show consistent variations in tissue *N*, *P* and *N*:*P* that related to annual cycles. Throughout this study, higher percentages of tissue *N* and *P* were found in *Bostrychia radicans* and *Grateloupia doryphora* (red algae) and lower in *Cladophora rupestris* and *Codium decorticatum* (green algae). In November 1999, the Icaraí Submarine Sewage Outfall became operational, resulting in a reduction of visual pollution in the area and an improvement in the local quality of seawater for recreational use. Measurements of dissolved nutrients at the sampling site did not indicate significant changes in concentrations after the commissioning of the submarine sewage outfall; however, tissue *P* and *N*:*P* ratio of most of species were significantly lower than in the first two years of this survey. Variations in tissue nitrogen throughout this study were not significant, except for *G. doryphora* in some comparisons. Results show that seaweeds function very well as monitors of environmental changes in Guanabara Bay. Experimental data are needed to identify possible environmental processes which are promoting changes in chemical composition of the local seaweed populations.

Introduction

Anthropogenic inputs of nutrients have had remarkable impacts on marine organisms in coastal areas (Clark, 2001). Increased abundance of opportunistic seaweeds is among the general consequences of nutrient loading in coastal areas (Rivers & Peckol, 1995). Macroalgae respond to nutrient enrichment by taking up nutrients, growing, and storing "excess" nutrients for future growth (Fujita, 1985; Björnsäter & Wheeler, 1990). The proliferation of opportunistic seaweeds affects local biodiversity and may promote a decrease in concentrations of dissolved nutrients in the water column (Rivers & Peckol, 1995; Valiela et al., 1997).

Concentrations of tissue nutrients reflect the environmental conditions of the site, providing a useful indicator of local nutrient status (Fong et al., 1994). In addition, total nutrient concentration in the algal tissue provides an integrated measurement of nutrient regime over time (Wheeler & Björnsäter, 1992; Villares & Carballeira, 2003). Monitoring of tissue nutrients to detect enrichment can be undertaken at less frequent intervals than monitoring of the water-column nutrients, and allows a more accurate evaluation of the nutrient status of the macroalgae. Studies on tissue *N* and *P* content of macroalgae predominantly in temperate coastal environments (Wheeler & Björnsäter, 1992; Peckol et al., 1994) reveal wide fluctuations in the tissue content of *N* and *P* related to seasonal changes and nutrient availability. By comparison, information on tissue *N* and *P* of algae from tropical environments is relatively scarce (Schaffelke, 1999; Fong et al., 2001), and more data are needed from those regions.

Guanabara Bay, Brazil, is a eutrophic coastal environment connected to the sea by a narrow mouth, which partially restricts water exchange. The Bay receives substantial river runoff relative to the total water volume, making it similar to a large estuary in its inner parts (Kjerfve et al., 1997). The Bay is located in a very populated urban area, and long-term cultural eutrophication has generated an environment with permanent high concentrations of dissolved nutrients due to output of both domestic and industrial wastewater (Mayr et al., 1989). Considering these characteristics, we hypothesised that the seaweeds of Guanabara Bay would present permanently high concentrations of tissue *N* and *P* and show no significant variations in their tissue nutrients throughout the year and no inter-annual changes in tissue nutrients.

In this study we report on the seasonal variations of tissue *N*, *P* and *N*:*P* atomic ratio of ten abundant macroalgal species of Guanabara Bay. Comparisons were made between algal *N* and *P* contents and the concentrations of dissolved nutrients in the system in this 7-year assessment. In addition, during this study a submarine sewage outfall was built in the study area and its possible effects on the tissue composition of the macroalgal flora was evaluated.

Materials and methods

Study area

The sampling site is located at Boa Viagem Beach (23°04′S, 43°08′W), in Guanabara Bay. The site is in the urban area of Niterói City, and it is located near the entrance of the Bay (Figure 1), which promotes a local dilution in the typical high levels of pollution of the Bay. The Bay shows a low water exchange rate (Mayr et al., 1989) due to geomorphological features and human occupation of coastal areas. Guanabara Bay comprises an area of 381 km^2 and an estimated 2 billion m^3 of water. The catchment area (4000 km^2) includes 35 rivers that contribute substantially to the freshwater input. The mean depth is 7.7 m, varying from 50 m (main channel) to less than 1 m in the inners parts close to the internal margins. The area of Guanabara Bay comprises 15 municipalities, with a population of ca. 7.6-milion inhabitants (FEEMA, 1999). According to Paranhos et al. (2001), ca. 470 t of BOD and 150 t of industrial sewage are disposed of daily into the Bay. CIBG (2004) indicates that in 1994 ca. 8 t of oil derivatives and 55 kg of heavy metals were disposed of daily

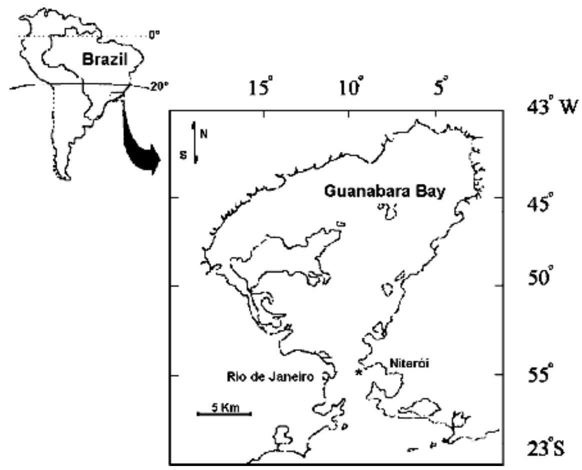

Figure 1. Sampling site in Guanabara Bay. * = Sampling site.

into the Bay by the 55 main industrial plants in the area. An ongoing program has been reducing many sources of pollution into the Bay, but the total amount of pollutants that enters the system daily is still high (CIBG, 2004).

Taouil and Yoneshigue-Valentin (2002) classified the sampling site as moderately affected by wave action, with an unusual abundance of pebbles and large-grain sand in the intertidal area.

Algae studied

In this study ten macroalgal species were analysed. The identification of the macroalgae was carried out following the checklist of Wynne (1998). Experts were consulted to confirm our identifications.

Chlorophyta: *Chaetomorpha antennina* (Bory) Kützing, *Cladophora rupestris* (L.) Kützing, *Codium decorticatum* (Woodw.) M. Howe, *Enteromorpha flexuosa* (Wulfen) J. Agardh, *Ulva fasciata* Delile, and *Ulva lactuca L.*

Rhodophyta: *Bostrychia radicans* (Mont.) in Orbigny, *Chondracanthus teedii* (Mertens ex Roth) Fredericq, *Grateloupia doryphora* (Montagne) M. Howe, and *Gymnogongrus griffthsiae* (Turner) Mart.

The species are found attached to the rocks and pebbles of the sampling site (water column between 0.4 to 0.8 m). Samples of two species (*B. radicans* and *C. anteninna*) were collected at Itapuca Stone, a site located 400 m from Boa Viagem Beach, where they were more abundant (attached to vertical rock surfaces). We assume that both sampling sites have virtually the same environmental characteristics (temperature,