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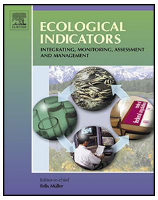

Structural and functional losses in macroalgal assemblages in a southeastern Brazilian bay over more than a decade

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ABSTRACT

Changes in macroalgae assemblages over more than a decade are described for Sepetiba Bay, Brazil. Variations in macroalgae abundances and functional diversity were compared with older data to test the hypothesis that their diversity decreases following anthropogenic stress that negatively impact environmental characteristics. Four field sampling excursions were undertaken at two different sites from December/2012 to May/2014. Destructive sampling per effort used six box cores (25 × 25 cm) distributed randomly along a shallow sublittoral rocky shore. Biomass was used to quantify macroalgae assemblages identified to the species level. Multivariate analyses demonstrated decreases in total biomass at both sites as well as changes in community physiognomies. The predominant corticated algae found were classified as Ecological Status Group IIA, characteristic of sites in the process of degradation and indicating that anthropogenic stress had negatively affected the macroalgae communities as evaluated by the Ecological Evaluation Index.

1. Introduction

Most Brazilian bays are now areas of intense human occupation due to the littoralization of human populations. Sepetiba Bay is a semi-enclosed estuary surrounded by the city of Rio de Janeiro (Lacerda et al., 2001) – the second largest metropolitan area in Brazil, with more than twelve million people (IBGE, 2014). Itaguaí Harbor, within that bay, is a principal harbor in that country and one of the largest industrial centers in Rio de Janeiro State, with many steel mills, petrochemical plants, and similar installations (INEA, 2014). The bay has consequently experienced strong environmental impacts due to discharges of urban sewage and industrial effluents with high metal concentrations (Pfeiffer et al., 1985; Lima Junior et al., 2002; Amado-Filho et al., 2003; Gomes et al., 2009). Other anthropogenic disturbances include constant dredging to maintain channel access to the harbor, which causes siltation along the channel margin and the resuspension of metal-contaminated sediments (Amado-Filho and Pfeiffer, 1998; Wasserman, 2005). There is clearly a need to evaluate the environmental quality of this region.

Evaluating changes in the compositions and functional diversities of macroalgae assemblages have been used to evaluate impacts on aquatic ecosystems (Orfanidis et al., 2001, 2011, 2014; Guinda et al., 2008; Juanes et al., 2008; Junshum et al., 2008; Reis 2009; Wong et al., 2010; Veiga et al., 2013; Becherucci et al., 2014). Macroalgae are often used in monitoring marine communities as they are key organisms for determining water quality, and macroalgae surveys have been undertaken in conservation and management programs in Europe (European Water Framework Directive) and USA (National Environmental Policy Act) to subsidize public policy decisions (Orfanidis et al., 2001, 2003, 2011, 2014; Ballesteros et al., 2007; Pinedo et al., 2007, 2013; Wells et al., 2007; Orlando-Bonaca et al., 2008; Guinda et al., 2008; Gaspar et al., 2012; Veiga et al., 2013; Foley et al., 2013).

The classification of macroalgae Ecological Status Groups (ESG) was developed in Europe as part of the Ecological Evaluation Index (EEI) to assess the Ecological Status Classes (ESC) of coastal and transitional waters. The EEI is based on ESG mean absolute coverage within a matrix of ecological classifications. It has been used for evaluating sustainable water policies framed by the European Water Framework Directive designed to protect transitional and coastal waters using biological communities as proxies for quality elements (Orfanidis et al., 2001, 2003, 2011, 2014; Orfanidis, 2007).

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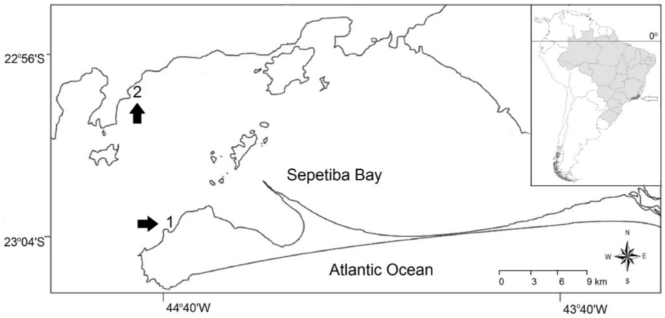

Fig. 1. Map of Brazil (gray). The white arrow indicates Rio de Janeiro State; the black arrows indicate sites 1 and 2 in Sepetiba Bay.

Another model used to identify environmental changes was developed by Steneck and Dethier (1994) and considers macroalgae communities as assemblages of algal functional groups with anatomical and morphological characteristics directly related to their environment. These authors established seven functional groups and found that their diversity decreases as the intensities and frequencies of disturbances increase.

Several studies have tested the effectiveness of the EEI classification developed by Orfanidis et al. (2001, 2003, 2011, 2014) based on the abundance of macroalgae assemblages. Dencheva (2008) assessed the ESC of coastal areas in the Black Sea, and noted that models estimating the ESC on the basis of functional grouping were more reliable and sensitive than those using the structural characteristics of those communities. Panayotidis et al. (2004) compared four different indices and concluded that the ESC was efficient for indicating disruption patterns in their study area. Neto et al. (2012) used the ESG with other environmental assessment indices to develop the MAR-Mat (Marine Macroalgae Assessment Tool) that proved to be an effective tool for evaluating coastal environments in Portugal. Gabriel et al. (2014) used the ESC and two European indices at six Azorean islands to evaluate the environmental qualities of their coastal waters, and classified them as having good or excellent ecological status.

Few evaluations of environmental changes have been undertaken to subsidize mitigation processes for marine conservation in Brazil. We therefore evaluated macroalgae assemblages at a site with high continental influences as well as in another site with stronger marine influences in Sepetiba Bay to test the hypothesis that diversity decreases in response to anthropogenic stress negatively altering environmental characteristics. The results were compared with data obtained nearly two decades ago. The representative species were classified into functional groups (Steneck and Dethier, 1994) and ESG (Orfanidis et al., 2001), and the environmental qualities of the two sites were evaluated using ESC techniques (Orfanidis et al., 2011, 2014).

2. Materials and methods

Four field excursions were undertaken between December/2012 and May/2014 to two sites in Sepetiba Bay, Rio de Janeiro State, Brazil. Site 1 (Kutuca Beach, 43°59′35″W–23°04′00″S), near the entrance to the bay, has a rocky shoreline (±45°), formed by boulders that have gradually become silted over (Reis, 2009). The area currently has a maximum water depth at high tide of two meters. Site 2 (Ibicuí Beach, 44°01′34″W × 22°57′46″S) experiences greater continental influence and has a lower and smaller rock slope with boulders up to two meters in diameter distant from the rocky shore. The water depth does not exceed two meters during high tides (Fig. 1).

Destructive sampling was employed (De Wreede, 1985; Reis and Yoneshige-Valentin, 1998) using six box cores (25 × 25 cm) that were laid out randomly along a 20 m line parallel to the rocky shore, approximately 1 m below the water surface at low tide (0.0). The means of field samples collected during two dry seasons and two wet seasons at each site were used. Data from site 1 for the years 1999 (T1) and 2003 (T2) were compared with those of 2013 (T3), and data from site 2 for 1994 (T1) and 1995 (T2) were compared with those of 2013 (T3). After identifying the macroalgae (using a stereoscopic microscope), the samples were dried in an oven (60 °C) to a constant weight. Algae with calcium carbonate deposits were decalcified with 10% hydrochloric acid.

Algal classifications followed Guiry and Guiry (2016); voucher material was deposited in the herbarium at the Federal University of Rio de Janeiro State (Huni).

The Relative Abundance of an algal taxon (RA) was defined as the percentage of its biomass in relation to the total biomass of the organisms encountered in the box score, using the formula: RA (%) = (mean dry mass of each specie/mean total mass of all algae at a given sampling time) × 100 (Reis and Yoneshige-Valentin, 1998; Amado-Filho et al., 2003; Reis, 2009). Species with RA <5% were considered “other algae”. Species richness and RA were compared with the data cited by Reis and Yoneshige-Valentin (1998), Amado-Filho et al. (2003), and Reis (2009).

The species were grouped in functional groups, as proposed by Steneck and Dethier (1994), and according to their ESG as proposed by Orfanidis et al. (2014). Macroalgae classified as ESG I (slow-growing, late-successional species), and those classified as ESG II (fast-growing, opportunistic species) were divided into subgroups, namely: ESG IA = slow-growing, sun-adapted, perennial, with high adaptive plasticity, forming late-successional communities under pristine and/or moderately degraded conditions; ESG IB slow-growing, sun-adapted, perennial to annual, forming late-successional communities under pristine and/or moderately degraded conditions.; ESG IC = shade-adapted, slow-growing red algal with calcareous crusts, living mainly as epiphytes on macroalgae thalli or angiosperm leaves; ESG IIA = fast-growing, sun-adapted, coarsely branched species growing in all environments, but highly abundant in degraded environments, ESG IIB = fast-growing, sun-adapted filamentous and sheet-like taxa with high reproductive capacities and short life spans that grow in essentially all environments, but often form blooms in degraded environments.

The macroalgae assemblages at each sampling site and in each sampling period (T1, T2, T3) were evaluated using their ESC based on the Ecological Evaluation Indices (EEI-c) and by their Ecological Quality Ratios (EEIeqr) proposed by Orfanidis et al. (2001, 2003, 2011, 2014).

The environmental integrative index (EnII) was based on Orfanidis et al. (2014). The degree of anthropogenic stress was classified in four classes (absence to very low = 0; low = 1; moderate = 2; high = 3) in each sampling site as the sum of partial component metrics.

The differences between the macroalgae assemblages (considering their biomasses, g m^{-2} mass) at both sites during the three sampling periods in the seasonal period (dry and rainy seasons) were analyzed using Permutational Multivariate Analysis of Variance – PERMANOVA (Anderson, 2005). The factors (site, time, and seasonal period) were treated as fixed factors, using 4999 permutations. Post-hoc pairwise tests were performed (also using 4999 permutations) to detect any differences between means (conditions). The data were represented by box plots grouped by sampling years.

Similarity and Principal Coordinates (PCO) analyses used the mean log 10(x + 1) transformed biomass (g m^{-2}) and the Bray-Curtis dissimilarity, expressed as 1-D, clustered by the UPGMA