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The impact of coastal urbanization on the structure of phytobenthic communities in southern Brazil

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ABSTRACT

The anthropogenic pressures on coastal areas represent important factors affecting local, regional, and even global patterns of distribution and abundance of benthic organisms. This report undertakes a comparative analysis of the community structure of rocky shore intertidal phytobenthos in both pristine like environments (PLE) and urbanized environments (UBE) in southern Brazil, characterizing variations on different spatial scales. Multivariate analysis of variance indicated that the PLE is characterized by a larger number of taxa and an increased occurrence of Rhodophyta species in relation to UBE. In contrast, UBE were dominated by opportunistic algae, such as *Cladophora* and *Ulva* spp. Significance tests further indicated higher species richness and Shannon–Wiener diversity on the PLE in relation to UBE. Here we provide data showing the magnitude of seaweed biodiversity loss and discuss direct and indirect consequences of unplanned urbanization on these communities.

1. Introduction

Although the patterns of distribution and abundance of marine biota are known and reasonably foreseeable at different scales (Lüning, 1990), the increasing human ecological footprint on coastal ecosystems may profoundly change the local, regional, and even global structure of these communities. Such pressures were highlighted recently with the decline of phytoplankton on a global scale, mainly in tropical and subtropical regions, which, among other reasons, were attributed to coastal processes such as the input of continental effluents (Boyce et al., 2010). At the end of the last century, coastal population was approximately 3.6 billion people living no more than 100 km from the coastline (Vitousek et al., 1997). This has resulted in a pattern of irregular and disordered occupation which exerts even greater stresses on the coastal ecosystem. In the developing and underdeveloped countries this reality is even more striking, with occupancy rates larger than those observed in developed countries. Since most of these impacted regions are located in the southern hemisphere, this scenario is particularly worrisome because survival of the local population depends, either directly or indirectly, on the services and products provided by these ecosystems. This is aggravated by deforestation, combined with the release of domestic sewage *in natura*, which increases the degradation potential on coastal environments. Organic and inorganic pollutants, nutrients, turbidity, suspended solids in excess, and habitat changes, including hydrological regime, are examples of stressors that may impact the biota, singly or in combination, including synergistic effects (Adams, 2005).

Anthropogenic stressors promote a particular impact on benthic communities, which are often structured by sessile organisms such as seaweeds. As seen in other regions, such impacts can result in the reduction of species number and abundance of primary producers, with consequent simplification of community structure. This, in turn, leads to an eventual increase in the abundance of opportunistic taxa with high reproductive capacity and tolerance against pollution. By integrating the effects of prolonged exposure to adverse conditions, the rocky shore seaweeds can be considered good indicators of environmental changes caused by different types of disturbances (Gorostiaga and Díez, 1996). The potential application of these organisms as bioindicators is even greater because they are widely and easily found in intertidal regions, which frequently represent the entry point of continental effluents. Studies using seaweeds as a means of diagnosing the degradation of coastal environments have been conducted mostly in the northern

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hemisphere, as in Asia (Reopanichkul et al., 2009), Mediterranean (Ballesteros et al., 2007; Orfanidis et al., 2001, 2007; Terlizzi et al., 2002), Ireland, Scotland and England (Wells et al., 2007; Wilkinson et al., 2007), Spain (Juanes et al., 2008), Red Sea (Bahartan et al., 2010) and Caribbean (Littler et al., 2010). On the other hand, few studies have been reported on the subtropical southern Atlantic Ocean. Furthermore, these studies have not presented an adequate sampling design or large enough scale, most treating only single bays or cities (Amado Filho et al., 2003; Oliveira and Qi, 2003).

Based on accumulated evidence, human impact is putting the composition and structure of seaweed communities at risk. Therefore, the current challenge is to understand the conditions and mechanisms that cause the loss of habitats, with particular emphasis on lesser known areas of the world, especially those located in the southern hemisphere, in order to prevent future declines in biodiversity (Connell et al., 2008). These conditions imply an urgent need to provide subsidies for the development of tools that contribute to the management of human activities that impact the marine environment, especially in regions still under-developed, providing indicators that measure the extent of the impact at different scales (Rogers and Greenaway, 2005). To address this need, the present study aimed to compare both structure and composition of rocky shore intertidal phytobenthic communities in pristine like and urbanized environments in southern Brazil, where urban areas have experienced a sharp growth process in the past few decades. In so doing, this study not only shows the magnitude of the qualitative and quantitative macroalgae biodiversity loss, but also discusses the direct and indirect consequences of rapid and unplanned urbanization on such seaweed communities.

2. Materials and methods

2.1. Study area and sampling design

The study area is located on the southern Brazilian continental shelf, with relatively homogeneous oceanographic characteristics (Pereira et al., 2009), in an area subjected to the action of the convergence of Brazil and Falklands currents. According to Sanderson et al. (2003), the human footprint of the southwestern Atlantic, based on the Global Human Influence Index (GHII) is considered moderate to high (Fig. 1).

We selected four municipalities (sites) along the southern Brazilian coast, between the latitudes 26°58′19″S and 29°21′63″S, and in each one we selected two beaches with features of urban and non-urban or pristine like environments (treatments). Three rocky shores were randomly selected for sampling within each beach. Definition of urbanized (UBE) and pristine like (PLE) environments was based on the characterization of the density patterns of human occupation measured from data gathered by the Brazilian national census (IBGE, 2010) and high-resolution Digital Globe images, taken from 10 km in altitude (Google Earth®), for analysis of land use (size of urban area and percent of urban and vegetation cover) and the distance from the nearest discharge of sewage.

To complement the characterization, in each site we analyzed the concentration of dissolved inorganic nutrients and suspended particulate matter. These descriptors were selected because they are possible indicators of the presence of effluents and because they directly influence the ecophysiology of seaweeds. Triplicates of one liter of water, in each sampled station were passed through GF/F Whatman filters 0.45 um. Filters for determination of suspended particulate material (SPM) were prepared according to Strickland and Parsons (1972). Dissolved inorganic nutrients (NO_3^{-2}, NH_4^+, PO_4^{3-}) were determined by a colorimetric method, using a spectrophotometer (Pro-analysis, UV-1100), equipped with buckets with 5 cm optical step. Phosphate and nitrate were determined according to Grasshoff et al. (1983). Concentration of ammonia was determined according to Tréguer and Le Corre (1976).

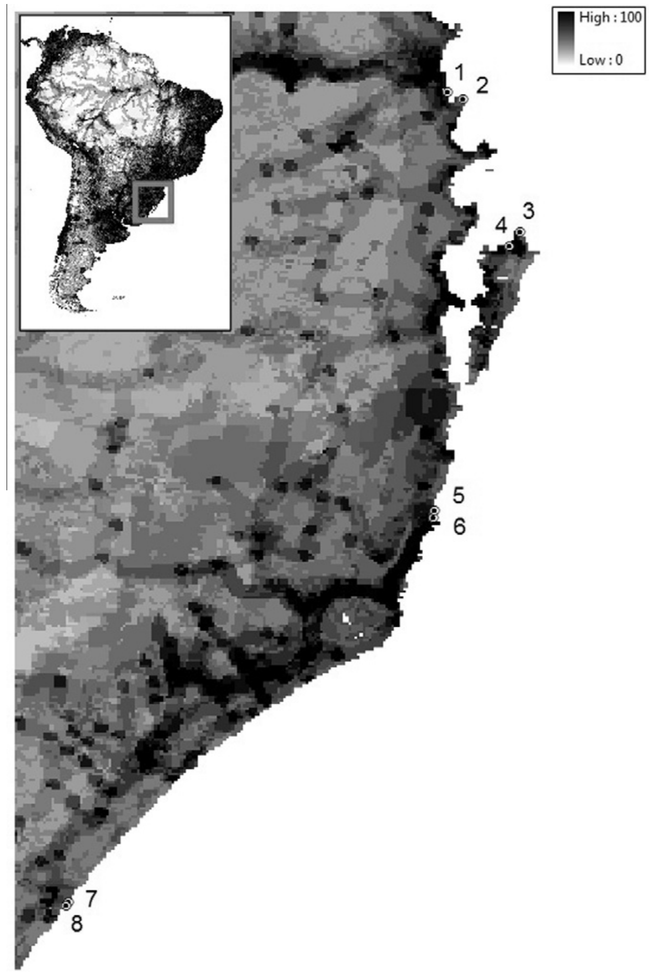

Fig. 1. Study area map based on human footprint showing sites sampled. The gray scales represent the relative density of human occupation. Modified from Sanderson et al. (2003).

2.2. Sampling procedures

For qualitative and quantitative phytobenthos analysis, three rocky shores were selected in each PLE and UBE. Only rocky substrate with similar slope, orientation and wave exposure were selected for comparison, in order to minimize the effects of other sources of variability. Seaweeds were manually collected during one sampling campaign, between February 10 and March 31, 2010. Qualitative samples were made in all selected rocky shores for identification and documentation. For quantitative analysis each selected rocky shore was characterized by 15 photo-quadrates (25 × 25 cm), randomly positioned following a Cartesian plot (10 × 2 m), with the longer side placed parallel to the coast line and with the lower limit adjacent to the water level, during low spring tides. In a pilot study we determined the minimum number of samples (around 10) that included more than 95% of species richness by plotting the cumulative number of species in relation to the number of samples, according to Murray et al. (2006). As the number of samples depends mainly on the spatial distribution and density of benthic populations and this is in the sampling area, 15 photo-quadrates can be considered representative for our purposes.