Marine Environmental Research 120 (2016) 44–54

Contents lists available at ScienceDirect

Marine Environmental Research

journal homepage: www.elsevier.com/locate/marenvrev

Increased anthropogenic pressure decreases species richness in tropical intertidal reefs

Adriana Brizon Portugal [a, *], Fabrício Lopes Carvalho [b], Pedro Bastos de Macedo Carneiro [a], Sergio Rossi [c], Marcelo de Oliveira Soares [a, c]

[a] Universidade Federal do Ceará, Instituto de Ciências do Mar (Labomar), Fortaleza, Ceará, Brazil
[b] Universidade Federal do Sul da Bahia, Grupo de Pesquisa em Carcinologia e Biodiversidade Aquática (UFSB/GPCBio), Itabuna, Bahia, Brazil
[c] Universitat Autònoma de Barcelona, Institut de Ciència i Tecnologia Ambientals (ICTA), Barcelona, Spain

ARTICLE INFO

Article history:
Received 23 April 2016
Received in revised form
26 June 2016
Accepted 4 July 2016
Available online 7 July 2016

Keywords:
Marine ecology
Biodiversity
Bioindicators
Community composition
Intertidal sandstone reef
Relative environmental pressure index
Anthropogenic pressure

ABSTRACT

Multiple human stressors affect tropical intertidal sandstone reefs, but little is known about their biodiversity and the environmental impacts of these stressors. In the present study, multiple anthropogenic pressures were integrated using the relative environmental pressure index (REPI) and related to benthic community structure across an intertidal gradient in five sandstone reefs in the tropical South Atlantic coast. Greater species richness and diversity were noted in the low intertidal zones. There was a negative relationship between REPI and species richness, suggesting that increasing anthropogenic pressure has decreased benthic richness. The factors associated with the loss of richness were jetties built to control erosion, urban areas, beachfront kiosks and restaurants, fish markets, and storm sewers with illegal sewage connections. Our results highlight the need for better infrastructure planning and rigorous monitoring of coastal urban areas, since the large influence of multiple human pressures in these reefs leads to biodiversity losses.

1. Introduction

The assessment of reef communities and anthropogenic pressure is considered a worldwide priority, with the aim to formulate effective conservation policies (Halpern et al., 2012); however, this remains an unsolved problem (Johnston and Roberts, 2009). Tropical reefs have high biodiversity and productivity, and provide diverse environmental services (Tittensor et al., 2010). Despite their importance, these ecosystems are among the most threatened in the world (Halpern et al., 2007; Mora et al., 2013; Palumbi et al., 2014).

Studies on anthropogenic pressure commonly relate changes in biological communities with a single factor such as human population density or the percentage of urbanized land (Alberti et al., 2007). However, this approach does not provide a broad view of multiple anthropogenic pressures. For example, Oigman-Pszczol and Creed (2011) pointed out that only a few studies have simultaneously evaluated multiple biological descriptors and anthropogenic pressures. For this reason, these authors proposed a method that combines heterogeneous pressure factors within a single index, the relative environmental pressure index (REPI). This index can be useful when analyzing impacts in the structure of benthic assemblages.

The influence of anthropogenic pressure is typically assessed using biological indicators (Goodsell et al., 2009). Sessile benthic organisms respond directly and quickly to changing environmental factors (Orfanidis et al., 2001, 2003), and thus are considered excellent indicators of anthropogenic modifications (Gall et al., 2016; Orfanidis et al., 2001, 2003). Use of the anthropogenic pressure index (an aggregation of multiple factors) and its association with benthic communities is important, but such knowledge remains scarce for the Tropical Southwestern Atlantic coast. Moreover, relatively few studies related to anthropogenic influences have been conducted in tropical and temperate environments in general (Martins et al., 2012; Oigman-Pszczol and Creed, 2011; Oliveira et al., 2014).

The Tropical Southwestern Atlantic coast contains diverse habitats, including coral reefs, intertidal sandstone reefs, sand beaches,

* Corresponding author.
E-mail addresses: adrianabrizonportugal@gmail.com (A.B. Portugal), flcarvalho@ufsb.edu.br (F.L. Carvalho), pedrocarneiro@ufc.br (P.B. de Macedo Carneiro), sergio.rossi@uab.cat (S. Rossi), marcelosoares@pq.cnpq.br (M. de Oliveira Soares).

http://dx.doi.org/10.1016/j.marenvres.2016.07.005
0141-1136/

and dunes. The area has a tropical wet and dry climate in the east, and a semi-arid climate on the northern coast, with a very stable annual seawater temperature ranging from 27 °C to 29 °C (Dias et al., 2013). Intertidal sandstone reefs differ from typical rocky shores and tropical coral reefs mainly by their gentle slope and sandstone composition. Substantial research has been conducted on coral reefs and rocky shores, but little is known about the benthic communities of tropical intertidal sandstone reefs (Leão et al., 2003, 2010; Rabelo et al., 2015).

Despite the socioeconomic and ecological importance of tropical intertidal sandstone reefs, there is a knowledge gap in the scientific understanding of reef biodiversity and its response to multiple anthropogenic pressures. The aim of the present study was to incorporate different anthropogenic pressures using the REPI and relate them to species richness, Shannon's diversity, and Pielou's evenness in intertidal sandstone reefs located in coastal Ceará, Brazil (Tropical Southwestern Atlantic, *sensu* Spalding et al., 2007). The Tropical Southwestern Atlantic coast is rapidly transforming due to recent intense urbanization (Marchese, 2015; Selig et al., 2014) with a recent increase in cumulative human impact (Halpern et al., 2015).

The goal of the study was to address the following questions: (1) Are there differences in the structure of sessile benthic communities between different intertidal zones and between intertidal sandstone reefs? (2) Do species richness, evenness, and diversity decrease as REPI increases? (3) What anthropogenic pressures may influence the structure of sessile benthic communities?

2. Materials and methods

2.1. Study area

The study was conducted in five intertidal sandstone reefs distributed along the west coast of the state of Ceará, Brazil, in the Tropical Southwestern Atlantic (Fig. 1). The intertidal zones of this coast consist of sandstone reefs and beach rocks, which are rocky outcrops with flat surfaces that are tilted slightly seaward (Rabelo et al., 2015). The reefs were formed by the erosion of cliffs and belong to the Barreiras Stratigraphic Group (Maia, 1998). The Barreiras Group is a terrigenous sedimentary cover that formed during the Miocene to Early Pleistocene, and is widespread along the Brazilian coast (Vilas Boas et al., 2001).

The reefs are located west of Fortaleza, the capital of Ceará, located in northeastern Brazil. Fortaleza's population has increased in recent decades to approximately 2.55 million, with a population of over 3.5 million in the overall metropolitan region (Garmany, 2011; Zuquette et al., 2004).

All sandstone reefs studied are gently sloping (maximum slope value: 2°, measured in the field) and have similar exposure to waves and winds, accessibility and a semi-diurnal tidal regime.

2.2. Sampling procedures

Qualitative and quantitative sampling of sessile benthic communities in tropical intertidal reefs was conducted using a non-destructive photo-quadrat method. Five intertidal reefs were sampled during the dry season (late October and early December 2013) during low-water spring tide, an approach similar to that in Oigman-Pszczol and Creed (2011), which also collected over a period to assess the influence of anthropogenic stressors. All species were identified in the lower taxonomic levels genus and species. The identification of algal genus and species was carried out using an optical microscope with reference to a specialized bibliography, and was compared to material deposited in herbariums, with nomenclature following the guidelines of Guiry and Guiry (2016).

In each intertidal reef, a central region was georeferenced, delimiting a 100 m × 90 m area parallel and perpendicular (in length) to the coast. Subsequently, this length was divided into three intertidal sub-zones (Rabelo et al., 2015; Rosa-Filho et al., 2009): a high zone (90 m–60 m), mid zone (60 m–30 m), and low zone (30 m–0 m), measured from the low limit of the intertidal zone. In order to have 30 samples from each reef for quantitative analyses, each intertidal sub-zone was sampled with 10 photo-quadrats (Gotelli and Ellison, 2011) measuring 2500 cm^2 (50 cm × 50 cm) each, which were randomly positioned using a

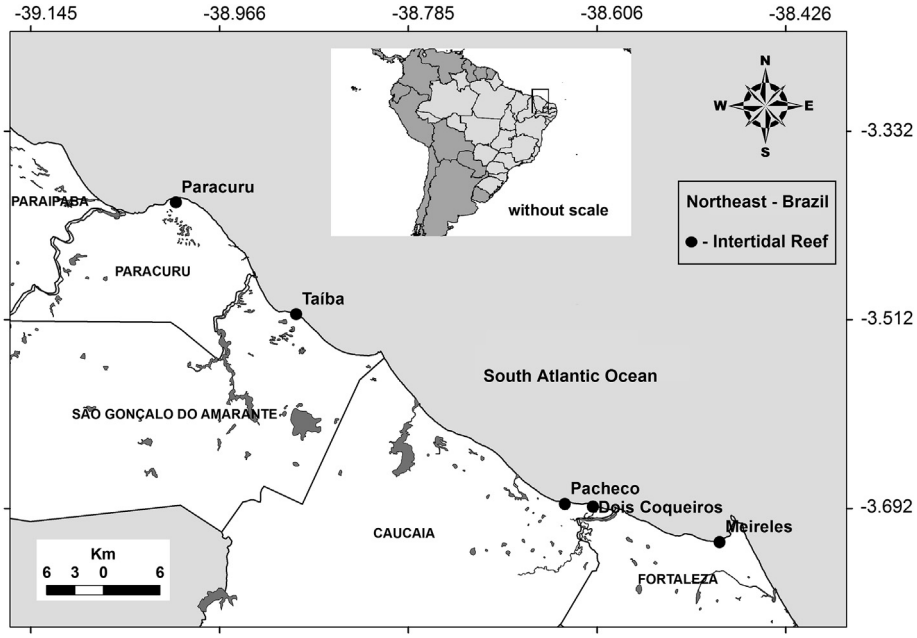

Fig. 1. Location of the reefs sampled distributed along the west coast of the state of Ceará, Brazil, in the Tropical Southwestern Atlantic.