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The development of a preliminary rock reef fish multimetric index for assessing thermal and urban impacts in a tropical bay

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ABSTRACT

We developed a multimetric index for assessing ecological conditions in rocky reefs areas to evaluate thermal and urban influences on fish community. Eight metrics were selected to assess thermal influence: (1) total number of species; (2) number of water column species; (3) number of transient species; (4) density of individuals with low resilience; (5) density of omnivores; (6) density of carnivores; (7) number of cryptic species; (8) density of herbivores. For urban influence, six metrics were selected: (1) total density; (2) ratio between the number of rare species and the total number of species; (3) density of individuals with heavy fishing pressure; (4) number of resident species; (5) number of cryptic species; (6) density of herbivores. This preliminary index succeed in discriminating control/impacted sites and proved to be an important tool to assess impacts that alter fish community and have potential to be used in tropical rock reef coastal areas.

1. Introduction

The human development with growth of urban centers and demand for natural resources is increasingly impacting coastal environments. Anthropogenic activities in coastal areas are directly or indirectly associated with tourism, oil and gas industries, fisheries and services that cater to the dynamic economy generated by these activities. Impacts of pollution on coastal ecosystems have the potential to alter the patterns of natural variability at various scales of organization within the community (Guidetti et al., 2002; Azzurro et al., 2010). Knowledge of these processes is an important step to establish an effective policy of management and conservation of the coastal biodiversity (Islam and Tanaka, 2004; Begossi et al., 2011). This is of special importance in tropical areas, where assessment and permanent monitoring programs are scarce.

The use of multimetric indices (MMI) for international agencies has been employed for monitoring and assessing the impacts in different ecosystems. MMIs use biological or ecological measurements of communities, compiled into metrics, to quantify the degree of human disturbance on biological communities (Coates et al., 2007; Delpech et al., 2010; Schoolmaster-Jr et al., 2013). In this sense, metrics are sensible indicators of a given type of environmental disturbance and are useful tools to be used in multimetric indices to assess the level of ecosystem integrity (Harrison and Whitfield, 2004; Henriques et al., 2008a).

The closest studies related to marine environments were developed for estuarine systems (e.g., Cooper et al., 1994; Deegan et al., 1997; Quinn et al., 1999; Harrison and Whitfield, 2004; Coates et al., 2007; Henriques et al., 2008b; Delpech et al., 2010; Cabral et al., 2012). To our knowledge, only Henriques et al. (2013) has selected metrics of rocky-shore fish assemblages to evaluate the impacts of different human disturbances (e.g. fishing, sewage discharges, port activities and thermal effluent). However, all these studies were developed for temperate regions and there is a lack of information for tropical rocky shores. Differences between temperate and tropical ecosystems in species richness, habitat diversity and ecological/biological characteristics such as growth rate, early age-at-maturity, r-selected species (Fromentin and Fonteneau, 2001), range of size (Fulton and Bellwood, 2004) may influence metric selections and index sensitivity.

In this study, we considered two types of impacts: 1) the influence of a nuclear power plant's cooling water (thermal influence), and, 2) the influence of coastal urban areas as diffuse impact; mainly the constant access of tourists, proximity of marinas, harbors, fishing activities (urban influence).

Temperature is a very important ecological parameter that affects almost every aspect of aquatic life (Krishnakumar et al., 1991; Rajadurai et al., 2005). Heated effluents introduced into the marine environment may induce dramatic and unpredictable effects such as temperature-induced changes in energy utilization (Finn et al., 2002), effects on sex determination (Brown et al., 2014), metabolic organization and scope for growth (Hanel et al., 1996). Heat from the cooling water of nuclear power plants changes environmental conditions and consequently ecological components of tropical coastal systems with influence on fish

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assemblage, reduction of benthic cover, thus limiting resources availability (see Teixeira et al., 2009, 2012). Thus, species more sensible to changes in temperature may be potentially used as indicators of thermal influences in coastal areas.

Indices can also be applied to evaluate urban pollution caused by different human activities (urban influence). The Ilha Grande Bay suffers from anthropogenic impacts such as recreational fisheries targeting rocky reef fishes, tourism, high population, many marinas, sewage discharges, port activities and thermal effluent. These impacts can change characteristics of fish community, such as diversity, biomass and abundance, and may cause massive fish death, reproductive inhibition or failure, and unbalanced trophic structure (Guidetti et al., 2002; Smith et al., 1999, Islam and Tanaka, 2004).

Teixeira et al. (2009), studying the effects of a nuclear power plant thermal discharge on fish community structure in Ilha Grande Bay found that thermal pollution alters benthic cover and influences fish assemblages by altering composition and decreasing richness. Moreover, Teixeira-Neves et al. (2015) found that coastal reef fish species richness in Ilha Grande Bay was positively associated with deeper areas and greater distance from the coast, thus being less accessible to human influence, and that richness and density increased with the physical complexity indicated by the physical structure index, suggesting that the presence of a variety of refuges enhances the availability of shelter. The main goals of this study were (1) select fish metrics that best distinguish impacted from control sites for both thermal and urban influences and, (2) develop a preliminary multimetric index to assess ecological condition based on the rocky reef fish assemblage.

2. Materials and methods

2.1. Study area and sampling

This study was conducted along coastal and insulars rocky shores in the Ilha Grande Bay (23°02′-23°14′S, 44°07′-44°42′W), a tropical region in the Brazilian southeastern coast (Fig. 1). Ilha Grande Bay covers an area of about 650 km^2 and contains roughly 350 islands surrounded by shallow water (typically no more than 8 m in depth) (Ignacio et al., 2010). Physical structure of the study sites is characterized by rocky shores covered by granite boulders, ending in a sand bottom.

Sites to assess thermal influence (both impacts and controls) had predominant small boulders and slight slope, whereas the sites to assess urban impact had predominant larger boulders, and a more steep slope. The benthic cover in the control sites (for both impacts) was characterized by the dominance of fleshy algae, turf, soft coral and filamentous

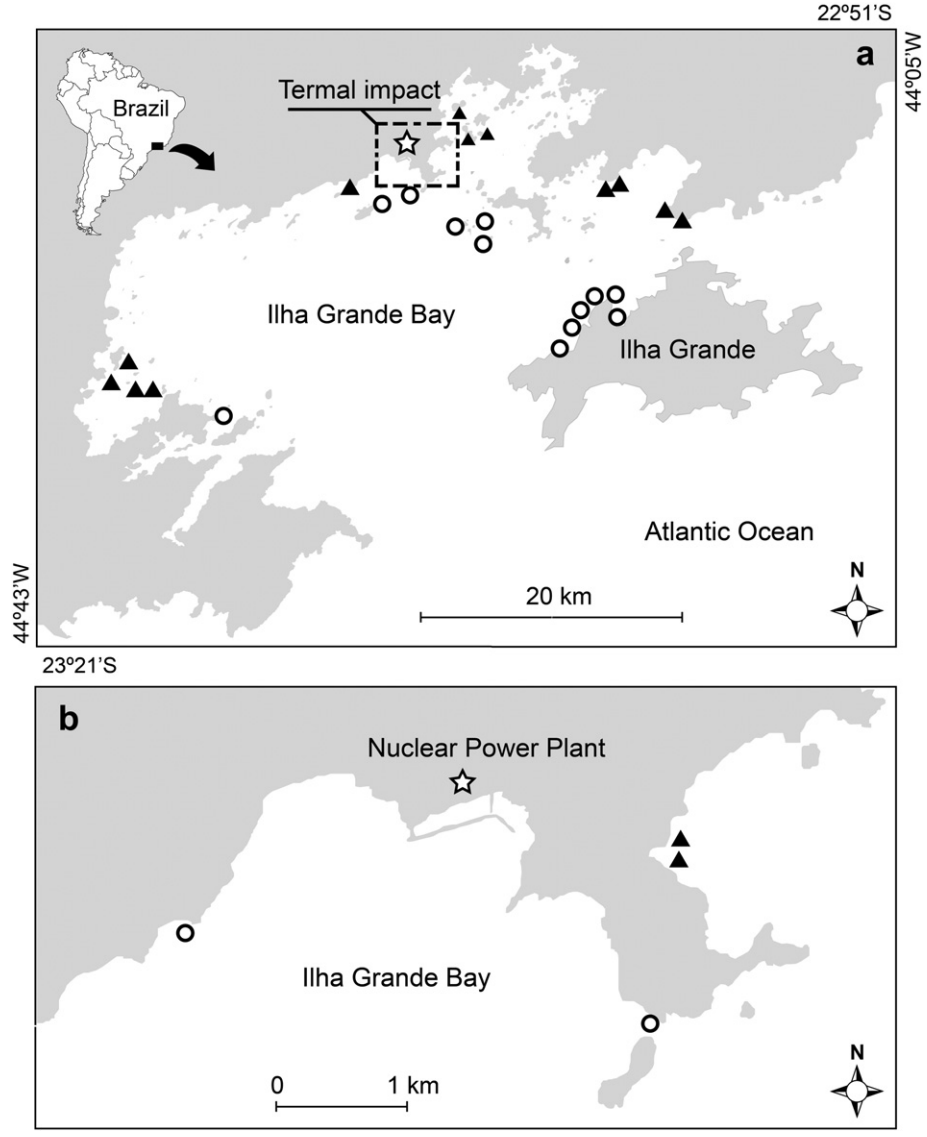

Fig. 1. a. Map of the study area with indications of the sampling sites. Circles indicate the control sites under urban influence and triangles the impacted sites (above). The inserted rectangle indicates the position of the thermal sites. b. Sites impacted by thermal influence, with circles corresponding to the control sites and triangles the impacted sites.