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Effects of a nuclear power plant thermal discharge on habitat complexity and fish community structure in Ilha Grande Bay, Brazil

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ABSTRACT

Fish communities and habitat structures were evaluated by underwater visual censuses a rocky location impacted by thermal discharge (I) and at two control locations, one in a *Sargassum* bed (C1) and the other in a rocky shore with higher structural complexity (C2). Habitat indicators and fish communities exhibited significant differences between the impacted and control locations, with the impacted one showing a significant decrease in fish species richness and diversity, as well as a decrease in benthic cover. At the I location, only 13 fish species were described, and the average water temperature was 32 ± 0.4 °C, compared with 44 species at C1 (25.9 ± 0.3 °C) and 33 species at C2 (24.6 ± 0.2 °C). Significant differences in fish communities among locations were found by ANOSIM with *Eucinostomus argenteus*, *Mugil* sp. and *Haemulon steindachneri* typical of location I, while *Abudefduf saxatilis*, *Stegastes fuscus* and *Malacoctenus delalandi* were typical of the control locations. Our study shows that thermal pollution alters benthic cover and influences fish assemblages by altering composition and decreasing richness.

1. Introduction

Fish assemblages are widely used in applied ecology to detect human impact on marine environments (Warwick and Clarke, 1993; Contador, 2005). Some variations in species assemblages can allow early detection and monitoring of human impacts on natural ecosystems.

Temperature is a crucial environmental factor affecting marine organisms and ecosystems. It affects the distribution of populations on both small and large geographical scales (Wilson, 1981), and determines the structure of communities and ecosystems (Glynn, 1988) by affecting the physiological processes and behavior of fish species (Dembski et al., 2006). Reefs and marine ecosystems around the world are exposed to the effects of thermal phenomena such as global warming, El Niño and localized thermal pollutants (Forchhammer et al., 2000). Heated effluents introduced on the marine environment may induce dramatic and unpredictable effects, depending on the amount and temperature of discharged material, as well as the climatic, hydrological and biological features of the local environment (Lardicci et al., 1999). Fish are mobile, and most can migrate to safe areas when chronic low levels of heat pollution. However, many of their food sources (i.e. corals, sponges, macroalgae, etc.) are sessile, and may be adversely affected. Apart from simply leaving an area, reef fish may be indirectly affected by the decreasing quality of food resources. Given the intensity and frequency of human disturbance and the ecological importance of coastal areas, it is critically important to understand the different aspects of the thermal effect on tropical rock shore organisms. Although there have been numerous studies performed on the impacts of heat pollution on coral reef environments (Roberts and Ormond, 1987; Chabanet et al., 1997; Öhman and Rajasuriya, 1998), little is known about the impact of thermal modification on tropical rocky shores.

Changes in water temperature caused by power station thermal discharge affect fish assemblages by decreasing species richness (Rong-Quen et al., 2001). Furthermore, rocky shores have a variety of microhabitats, which increase fish diversity (Luckhurst and Luckhurst, 1978). Thermally polluted rocky substrate may be unable to support sessile invertebrates or microalgae vegetation and will have a negative impact on fish using the habitat for shelter, food, nesting and juvenile settlement. A decrease in habitat complexity can also decrease species richness.

The southeastern coast of Brazil does not support any true coral reefs and rocky shores are the main habitat for reef fish and reef-associated biota (Floeter et al., 2007). The Ilha Grande Bay, a relatively well-preserved coastal system, is exposed to the thermal discharge of the Brazilian Nuclear Power Plant (BNPP), and provides a unique opportunity to evaluate thermal effects on the fish community. The current study will contribute to an early assessment of the global warming and some specific changes in the rocky habitat structure.

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In the present study, tropical rock reef fish were sampled in a location exposed to thermal discharge and at two controls areas of natural thermal conditions in order to evaluate the effect of thermal pollution on habitat structure of local fish assemblages. All sites have similar dimensions, type of substrate and depth. It was hypothesized that thermal pollution alters habitat structure changing fish assemblages. We focused on two specific research goals: to find out whether the cooling power station alters the habitat structure, and whether fish assemblages in this location shift in composition and richness, due to the thermal effect. In addition, we determined whether both control locations varied in structural complexity and, consequently, in fish assemblage composition.

2. Material and methods

2.1. Study area

The study was conducted at a rocky shore in Ilha Grande Bay, close to the discharge water of the Brazilian Nuclear Power Plant (BNPP), the only one in Brazil. The plant began commercial operation in 1985 and consists of two sections, producing 600 and 1300 MW, respectively, and the cooling water flow discharge into the sea is 40 and 80 $m^3 s^{-1}$, respectively, from each of the sections. Three study locations were chosen for sampling near BNPP (Fig. 1).

The mean temperature of the seawater surface ranged from 29.5 °C in winter to 36.5 °C in summer at a distance of approximately 100 m from the outfall in the impacted location (I). The thermal effluent produced a mean increase of 8 °C in the discharge area (Bandeira et al., 2003). Two control locations (C1 and C2) with similar depth (1–2.5 m) were chosen at approximately 10 km (C1) and 9 km (C2) from the impacted location (I), following the coastline. Surface temperature was measured to be 23 °C in winter to 28 °C in summer. Salinity was found to be 34.5 (±1.2 SE) in all locations, consistent throughout the year.

2.2. Sampling design and methods

Our sampling methods allowed an in-depth comparison of the rock reef fish community features, and their relationship with local habitat structures, both at a location close to the BNPP effluent outlet, and at two undisturbed control locations. Monthly surveys were conducted between October 2005 and July 2006. The impacted location was chosen on the basis of high temperature (a mean value of 7 °C higher than the control locations).

2.3. Habitat structure

The study area is characterized by rocky shores covered by granitic boulders and a sandy bottom. All three study locations (C1, C2 and I) are typically rocky shores. The first area is characterized by *Sargassum* beds (C1), the second exhibits a comparatively more complex habitat structure (C2), and the third is impacted by heated effluent discharge (I), with the presence of rock rubble in some places.

Quadrants of 2 m^2 were used to quantify the variables describing physical structure. The crevices in each quadrant were counted and pooled into three size classes ($Ca \leqslant 30$ cm; Cb = 30 cm–1 m; $Cc \geqslant 1$ m), as well as the rocks, which were also counted and pooled into four size classes ($Ra \leqslant 30$ cm; Rb = 30 cm–1 m; Rc = 1 m–3 m; $Rd \geqslant 3$ m). In each area, a visual census estimated the percent benthic cover of the *Sargassum* (Phaeophyta, Fucales), other Phaeophyta algae, *Palythoa* (a genus of colonial cnidarians, Order Zoanthidea), encrusting calcareous algae, branched calcareous algae, sponges, barnacles, vermetids (genus *Petaloconchus*), bare rocks, sand and shell-sand patches.

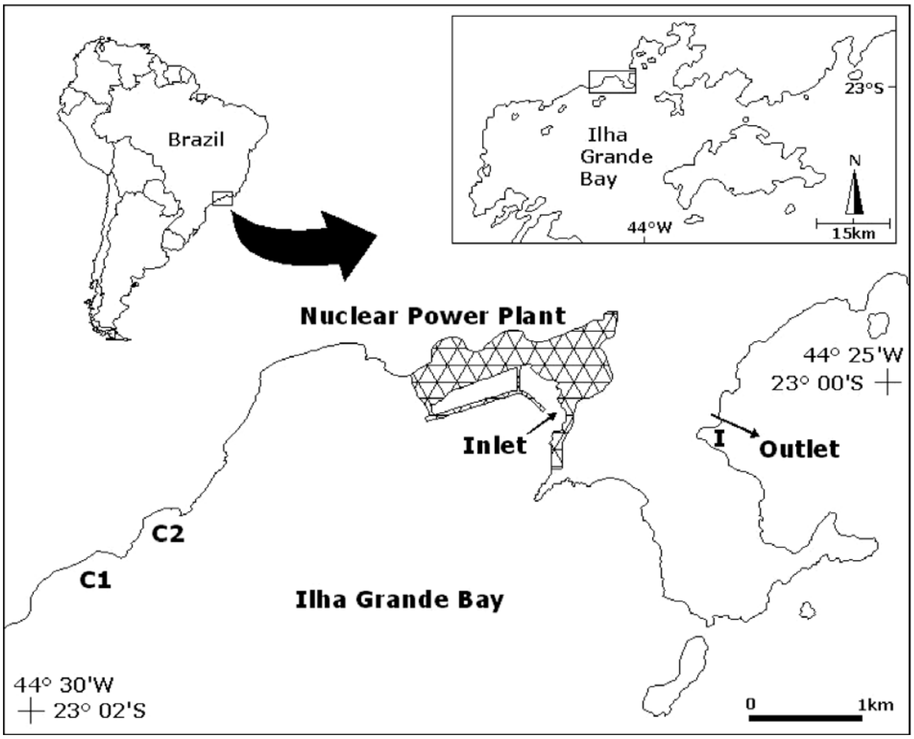

Fig. 1. Map of the study area in Ilha Grande Bay, Brazil: thermal impacted site (I) and controls (C1 and C2) locations.