THE IMPACT OF A NUCLEAR POWER PLANT DISCHARGE ON THE SPONGE COMMUNITY OF A TROPICAL BAY (SE BRAZIL)

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ABSTRACT

The CNAAA is the only Brazilian Nuclear Power Plant. Discharge from the cooling water system flows into the Ilha Grande Bay (SE, Brazil). Water temperature at the surface, chlorine level and current velocity were higher at the discharge than at the intake area. Diversity, evenness, richness and density were higher in control sites than in discharge site, mainly in the surface transect. *Mycale microsigmatosa* was considered a negative bioindicator and *Haliclona* sp.1 was considered a positive bioindicator for the discharge impact. The impact of the discharge of the CNAAA cooling system on the sponge community of Ilha Grande Bay was great, mainly due to high temperature. However, this impact is stronger at the surface than on the bottom and restricted to the vicinity of the discharge area.

KEY WORDS

Sponge ecology, bioindicators, thermal impact, Ilha Grande Bay, Rio de Janeiro.

INTRODUCTION

Many coastal industries and nuclear power plants use seawater in their cooling systems and discharge this heated wastewater into the sea. Deleterious effects of these discharges are already known, firstly, due to the high temperature of the discharges, and particularly in tropical areas during the summer, when the increase of few degrees of seawater temperature can create lethal conditions for the biota (LAWS, 1993). Other effects, often less important or local, are the biocides released in the cooling pipes in order to prevent the fouling development, with undesirable environmental consequences in the receiving water (JENNER *et al.,* 1997). Besides temperature and chlorine, the cooling water system produces high flow regimes and turbulence in the vicinity of the discharge, that can interfere with the settlement of many invertebrate larvae (ABELSON & DENNY, 1997).

The CNAAA (Almirante Álvaro Alberto Nuclear Central), is the only Brazilian Nuclear Power Plant. Nowadays, the CNAAA has two ^{135}U pressurised water reactors, producing 1966 MW and demanding 120 $m^{3}\cdot s^{-1}$ of seawater for the cooling system (Fig. 1). Chlorine is added in concentrations of 1 $mg\cdot l^{-1}$ at the heat exchangers.

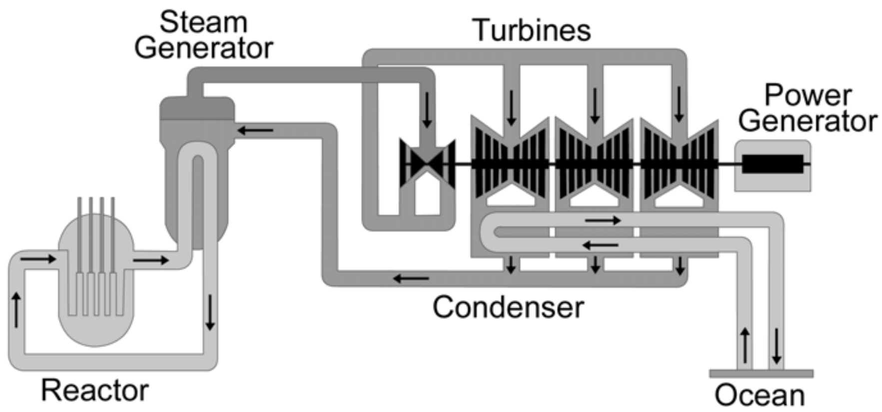

Fig. 1. Schematic view of the cooling system of CNAAA.

The effects of cooling water discharges are generally detected by changes in the composition of biological communities in the areas affected by the temperature increase (GRIMES, 1975). Sponges distribution is strongly influenced by abiotic factors, therefore these organisms are useful tools for environmental monitoring (ALCOLADO & HERRERA-MORENO, 1987; MURICY, 1989, 1991; CARBALLO *et al.,* 1996). In order to evaluate the impact of the cooling system discharge of CNAAA at Ilha Grande Bay the sponge community was sampled in the vicinity of the discharge area and in two control sites, as well as the water quality in the intake and discharge areas of the cooling system.

MATERIAL AND METHODS

The CNAAA is located at Ilha Grande Bay, on the southern coast of Rio de Janeiro state, SE Brazil (Fig. 2). This bay is classified as a non polluted and oligotrophic ecosystem, with clean water and low phytoplanktonic biomass (SILVA *et al.,* 1989).

Water temperature (surface and bottom, °C), chlorine levels ($mg{\cdot}l^{-1}$) and current velocity (knots) were measured weekly for three months (February to April of 2002) at two sites: the intake (A) and the discharge (B) areas of the CNAAA cooling system (Fig. 2).

The sponge community sampling was carried out in May 2002 at three rocky shore sites. One, at the discharge area, where the water from the cooling system flows (discharge site) and two control areas (control 1 and control 2 - Fig. 2). The sampling sites have the same depth (≅ 4 m), wave exposure and slope (35° - 45°). The samplings were taken by SCUBA diving along two horizontal transects (10 squares of 1 m^2, randomly), one at 1.5 m depth (surface) and the other at 3.5 m depth (bottom), at each site. The number of individuals of each species was estimated *in situ* for each transect. Based on these data the relative abundance of each species was calculated. Density of individuals ($ind{\cdot}m^{-2}$), Shannon's Diversity (H', log_2) and Pielou's Evenness (J, Log_2) were also calculated (PIELOU, 1975).

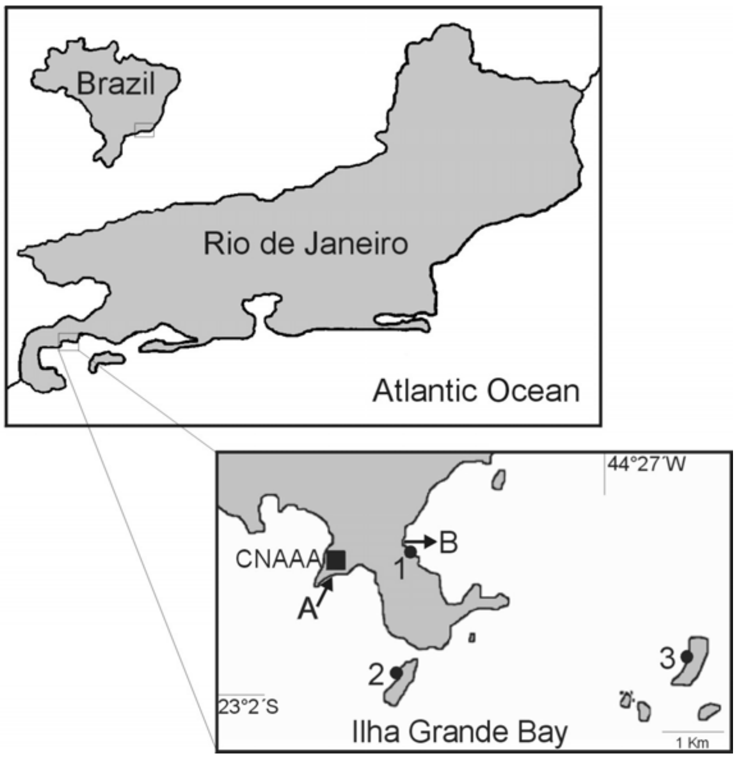

Fig. 2. Map showing the location of the intake and discharge areas and the sampling sites. **A,** Intake area. **B,** Discharge area. **1,** Discharge site. **2,** Control 1 site. **3,** Control 2 site.

The t-test was used to compare the water temperature between the sites (A and B). The non-parametric analysis of variance (Kruskal-Wallis test) was used to compare the density of *Mycale microsigmatosa* among transects (ZAR, 1996). Cluster analysis was made using Bray Curtis index with UPGMA aggregation algorithm using MVSP (MultiVariate Statistical Package) software, version 3.1 (http://www.kovcorp.com).

RESULTS

The superficial water temperature was significantly higher (t=5.02, p=0.01) at the discharge than at the intake site, while the mean bottom temperature was very similar in both areas. Mean chlorine level and current velocity were also higher at the discharge site (Tab. I).

Tab. I. Abiotic variables measured weekly (February to April of 2002) at Intake and Discharge areas of CNAAA water cooling system (mean and standard error).

	Intake	**Discharge**
Surface Temperature (°C)	26.56 ± 1.86	31.96 ± 2.47
Bottom Temperature (°C)	26.71 ± 2.10	26.14 ± 2.23
Chlorine Levels ($mg{\cdot}l^{-1}$)	>0.005	0.04 ± 0.005
Current velocity (Knots)	0.18	0.24

A total of 22 species were recorded in this study. Only two species were found at surface and six at bottom in discharge site, whereas more than 12 species were found at the control sites (surface and bottom transects). Diversity, evenness and density of individuals were also higher at control transects (Table II).

Tab. II. Sponge community parameters: Diversity (H'); Evenness (J); Species Richness (S); Density ($Ind{\cdot}m^{-2}$, mean and standard error). Transect codes: DS = Discharge Surface; DB = Discharge Bottom; C1S = Control 1 Surface; C1B = Control 1 Bottom; C2S = Control 2 Surface; C2B = Control 2 Bottom.

Transect	**H'**	**J**	**S**	**$Ind{\cdot}m^{-2}$**
DS	0.358	0.358	2	5.90 ± 1.43
DB	1.727	0.668	6	10.40 ± 1.77
C1S	3.023	0.817	13	37.30 ± 6.19
C1B	2.893	0.782	13	42.20 ± 6.19
C2S	2.859	0.751	14	29.10 ± 5.97
C2B	2.745	0.766	12	22.10 ± 3.46

The most abundant species, *Tedania ignis* (Duchassaing & Michelotti, 1864), *Mycale americana* van Soest, 1984, *Amphimedon viridis* Duchassaing & Michelotti, 1864 and *Haliclona melana* Muricy & Ribeiro, 1999, were found in all transects except at discharge surface (Tab. III). *Mycale microsigmatosa* Arndt, 1927 was also abundant and it was the only species that occurred in all transects. However, its abundance was significantly lower (KW = 22.72, $p < 0.0004$) in discharge surface transect (Fig. 3). *Haliclona* sp. 1, occurred only at the discharge surface transect with relative abundance of 93.2 % (Tab. III).

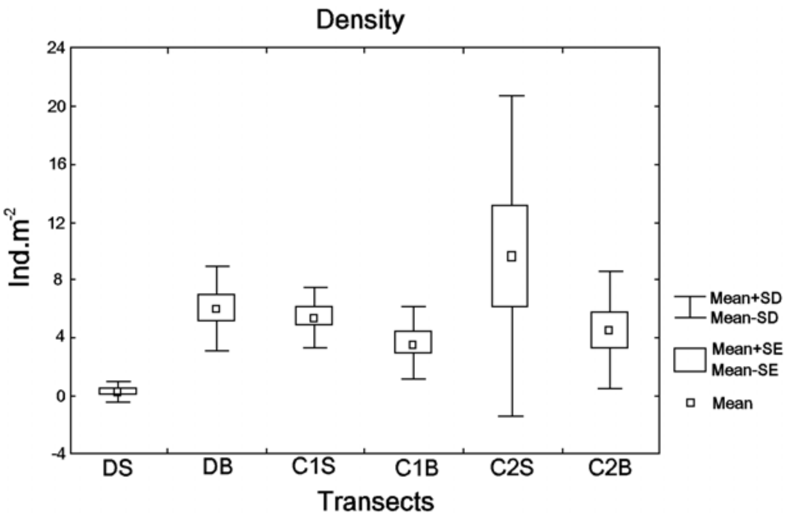

Fig. 3. Mean density of *M. microsigmatosa* in transects, Transect codes: DS = Discharge Surface; DB = Discharge Bottom; C1S = Control 1 Surface; C1B = Control 1 Bottom; C2S = Control 2 Surface; C2B = Control 2 Bottom.

Tab. III. Distribution and Relative Abundance (%) of species among the transects. Transects codes: DS = Discharge Surface; DB = Discharge Bottom; C1S = Control 1 Surface; C1B = Control 1 Bottom; C2S = Control 2 Surface; C2B = Control 2 Bottom.

	DS	DB	C1S	C1B	C2S	C2B
Clathrina aurea				0.47		
Chondrilla nucula			0.80	4.50	3.09	0.90
Terpios fugax			11.53			1.81
Laxosuberites aurantiaca				0.47		
Scopalina ruetzleri			4.83	14.22	1.72	5.88
Hymeniacidon heliophila			0.54		3.44	
Dragmacidon reticulatus						0.90
Mycale angulosa			0.54		3.09	1.81
Mycale microsigmatosa	6.78	58.65	14.75	8.77	34.02	20.81
Mycale americana		2.88	18.23	16.35	15.12	29.41
Mycale magnirafidiphera					0.34	
Desmapsamma anchorata			20.11		0.69	
Tedania ignis		17.31	8.85	0.95	16.15	7.69
Haliclona sp.1	93.22					
Haliclona sp.2		15.38	0.54		1.03	
Haliclona melana		4.81	13.40	28.20	5.50	6.79
Amphimedon viridis		0.96	5.63	14.69	13.40	21.27
Pachychalina sp.						2.26
Callyspongia pallida			0.27	0.47	0.69	
Aplysina fulva				8.06		
Dysidea etheria				2.13	1.72	0.45
Chaelonaplysilla erecta				0.71		

Cluster analysis showed low similarity among the discharge and control transects. Discharge surface showed 2 % of similarity with other transects while discharge bottom had less than 40 % of similarity with control transects. Control transects showed, approximately, 50 % of similarity among themselves (Fig. 4).

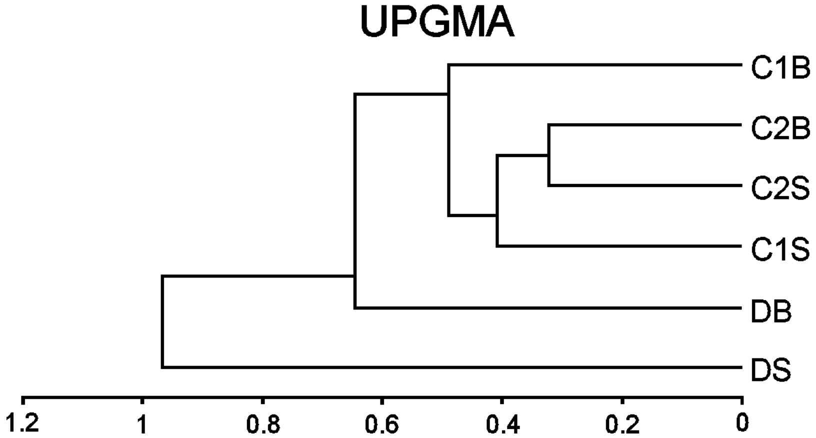

Fig. 4. Dendrogram (Bray-Curtis index) showing the similarity among the transects. Transect codes: DS = Discharge Surface; DB = Discharge Bottom; C1S = Control 1 Surface; C1B = Control 1 Bottom; C2S = Control 2 Surface; C2B = Control 2 Bottom

DISCUSSION AND CONCLUSIONS

Ilha Grande Bay has warm waters with temperature varying from 21° C to 30° C (SILVA *et al.,* 1989; SILVA, 1998). At the intake area of CNAAA cooling system the mean temperature was approximately 26° C both at the surface and at the bottom whereas at the discharge area was approximately 32° C at the surface. The surface water temperature in the discharge area can achieve 39.5° C (CURBELO-FERNANDEZ, 2002). Water temperature at the surface is higher because heated effluents have the tendency to rise stratifying at the surface (LAWS, 1993). This causes a thermocline separating two distinct zones, one close to the surface and the other close to the bottom.

Sessile benthic organisms are particularly susceptible to heated effluents. The incipient lethal temperature of most aquatic species lies within or below the 30 - 35° C range, so that in tropical climates where summer water temperatures may approach this limit naturally, a further increase of only a few degrees centigrade may prove lethal to many organisms (LAWS, 1993). Mortality of shallow water corals at Oahu, Hawaii (JOKIEL & COLES, 1974) and of almost the entire benthos over a large area of Biscayne Bay, Florida (ZIEMAN & WOOD, 1975) are two examples of thermal deleterious effects on benthic communities in tropical areas. Besides the thermal impact, the discharge site presented chlorine, a potent biocide (JENNER *et al.,* 1997) and a higher current velocity, that can interfere with the settlement of many invertebrate larvae (ABELSON & DENNY, 1997). The species richness, diversity, evenness and density of sponges in the discharge site, mainly at the surface transect, were lower than in control sites. The decrease of these parameters and the cluster analysis indicate a thermal impact, associated with the presence of chlorine and the high water flow, in the discharge site

M. microsigmatosa was the only species found in all transects. This species is considered tolerant to organic pollution (MURICY, 1989), and may be also considered as tolerant to thermal and chlorine impact. However, its lower abundance at the discharge surface transect suggests that it is a negative bioindicator for this impact. *Haliclona* sp.1 was dominant at the surface discharge transect, and was found only in this transect, suggesting that this species is opportunistic and tolerant, and can be considered a positive bioindicator for the impact approached in this work.

This study indicates a great impact of the discharge of the CNAAA cooling system on the sponge community of Ilha Grande Bay, mainly due to water temperature rising. However, this impact is stronger at the surface and restricted to the vicinity of the discharge area.

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