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The effects of thermal effluent on marine diatoms and bacteria

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ABSTRACT. In this study, the effects of thermal effluent on the abundance and diversity of microbes (diatoms and bacteria) are investigated. The abundance of diatoms ($5.3 – 16 \times 10^5$ cells l^{-1}) and bacteria (110 – 2500 cfu ml^{-1}) showed reduction near the thermal effluent outfall (–56 and –96%, respectively). However, the effects of thermal effluent are limited to < 200 m from the outfall.

ABSTRAK. Di dalam kajian ini, kesan efluen panas pada kelimpahan dan kepelbagaian mikrob (diatom dan bakteria) diselidiki. Kelimpahan diatom ($5.3 – 16 \times 10^5$ cells l^{-1}) dan bakteria (110 – 2500 cfu ml^{-1}) menunjukkan penurunan berdekatan dengan punca efluen panas ini (–56 dan –96% masing-masing). Bagaimanapun, kesan efluen panas terhad pada < 200 m dari puncanya.

(near-field, diversity, power station, Port Dickson)

INTRODUCTION

The earliest investigations on the effects of thermal discharges on aquatic life was done in 1957 [1]. Thermal effluent from a power plant includes heated water, antifouling biocides and leached metals [2] has been shown to affect aquatic life [3,4]. One method of evaluating the effect of thermal pollution is to monitor the kinds and numbers of organisms living in the environment [5,6].

The Tuanku Ja'afar Power Station (TJPS) is located at the coastal town of Port Dickson, Malaysia, and its thermal effluent is discharged directly into the sea. In Malaysia, there are few biological studies on the effects of thermal effluent [7]. In this study, carried out in 1996, sampling was done in the immediate thermal discharge area [2].

I used the synecological method where the disturbed site is compared with control sites [8]. I sampled along a transect projecting away from the outfall until ambient temperature was obtained. The marine microbes examined are the diatoms and bacteria. Diatoms are often used as indicators of environmental change [9]. Diatoms have a rapid doubling time and respond quickly to changes in environmental conditions. As a result, diatom assemblages can provide a model to illustrate the effects of environmental change or ecosystem stress [10,11].

METHODS

There were five sampling stations (Stn 1 until Stn 5) along a transect projecting from the TJPS outfall (Figure 1). The farthest station (Stn 5) was located 240 m from the outfall. Sampling was carried out during low tides, and both *in-situ* measurements and samples were taken at 1 m depth. Samplings were also done in the thermal outfall of the Sultan Salahuddin Abdul Aziz Power Station (SSAAPS) located at Kapar, Selangor and a control site at Batu 10, Port Dickson (Batu 10). *In-situ* temperature measurements of seawater was carried out with a thermocouple (Fluke 51K/J, USA) and dissolved oxygen (DO) was measured with a DO membrane electrode (YSI, USA).

I used the Zobell 2216E medium [12] to isolate for marine bacteria, and identification was done to generic level [13]. Seawater samples for diatom analyses were preserved with Lugol's Iodine, and observed using an inverted microscope (Olympus CK2, Japan). The diatoms were identified based on taxonomic descriptions available [14,15]. Diversity indices are useful in monitoring changes and detecting shifts in water quality [6], hence the Shannon-Weiner Diversity Index, $H = -\sum p_i \log p_I$, (H) [16] was calculated for each site where p_i is the proportion of each species.

Benthic diatom community structure in sediments at mangrove forests near each site were also compared. Samples of benthic diatoms were collected by scraping the surface sediment layer with a cleaned metal scraper. The samples were then placed in a glass vial, and preserved with Lugol's iodine. Sediment classification at each site was based on particle size and sediment organic matter was the weight loss after ignition at 500˚C for 3 hrs.

RESULTS AND DISCUSSION

At TJPS, seawater temperatures decreased (39 – 29ºC) whereas DO increased (160 – 210 µM) away from the outfall (Figure 2a). DO showed inverse relation to seawater temperature, as solubility of DO decreases with temperature [17]. Relative to the Stn 5, seawater temperature at the outfall was elevated > 10°C. Thermal dispersion was limited due to the small volume of water available during low tides. However at Stn 5, temperatures decreased substantially, possibly due to the dilution by longshore tidal currents.

Both diatom and bacteria increased with greater distance from the outfall ($5.3 - 12 \times 10^5$ cells ml^{-1} and 110 – 2550 cfu ml^{-1}, respectively) (Figure 2b). The diatoms commonly found here included *Coscinodiscus*, *Navicula*, *Pleurosigma* and *Rhizosolenia*. *Vibrio* (relative abundance of 28%), *Achromobacter* (22%), *Pseudomonas* (16%) and *Corynebacterium* (12%) are the most abundant of bacteria isolated.

Diversity decreases either through a reduction in the total number of species present (decreased species richness) or when the number of those species that can survive the stress increased (decreased evenness) [6]. In this study, diatom diversity increased with distance from the outfall (0.56 – 1.52) (Figure 2c), in response to thermal effluent factor [2].

However the diversity for bacteria fluctuated between 1.0 to 1.6 (see Figure 2c). This could be due to the limitation of the technique used. The plate culture technique detects only a small fraction of total bacteria that are present in the environment [18]. In this study, bacterial diversity might not be an appropriate assessment of community structure as the bacteria isolated are based by their ability to grow on the medium used.

Using diatoms as indicators, I observed that the diatom abundance in samples nearest the outfall at both TJPS (5.3×10^5 cells l^{-1}) and SSAAPS (4.0×10^5 cells l^{-1}) are one order less than at Batu 10 (3.0×10^6 cells l^{-1}) while diatom diversity at both TJPS and SSAAPS were lower than at Batu 10. The thermal effluent at both TJPS and SSAAPS could have been the causal factor for the reduction of both diatom abundance and diversity, relative to the control site Batu 10.

Further away from the thermal outfall at nearby mangrove forests, benthic diatom community structure in sediments were also studied. At TJPS, sediment samples both outside and inside the mangrove boundary were observed. The mangrove trees and sediment classification at TJPS is *Rhizophora apiculata* – sandy silt whereas at SSAAPS (*Sonneratia alba*, *R. apiculata* and *Avicienna alba*, silt), and at Batu 10, (*S. alba*, medium sand).

Benthic diatom abundance was 2.9×10^4 cells cm^{-3} (TJPS in – inside the mangrove boundary), 3.1×10^4 cells cm^{-3} (TJPS out – outside the mangrove boundary), 2.5×10^4 cells cm^{-3} (SSAAPS) and 4.5×10^4 cells cm^{-3} (Batu 10), respectively. Benthic diatom diversity was 1.0 (TJPS in), 2.1 (TJPS out), 1.9 (SSAAPS) and 1.5 (Batu 10) (Table 1). Unlike the observations near the thermal outfall, both the abundance and diversity of benthic diatom in mangroves were not affected by the presence of a power station at the site. The mangroves are probably outside the zone of thermal stress as the mangroves were > 200 m away from the outfall.

In this study, I found that the effects of thermal effluent towards marine microbes are limited to an area < 200 m away from the outfall. The effects are near-field in nature, and future studies on thermal effluent studies should take this into consideration. Diatoms are better indicators of thermal pollution than bacteria.

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Table 1: Relative abundance and diversity of benthic diatoms in mangrove sediments. TJPS in – sampled inside mangroves, TJPS out – sampled outside the mangrove boundary. Key for abundance: a = absent; p = present (0.5 – 2.9%); c = common (3 – 24%); cc = very common (≥ 25%)

	TJPS in	**TJPS out**	**SSAAPS**	**Batu 12**
Navicula sp.	cc	c	cc	cc
Pleurosigma sp.	c	c	c	c
Nitzschia sp.	c	c	c	p
Amphora sp.	c	c	c	cc
Surirella sp.	a	p	c	c
Thalassiothrix sp.	p	a	a	a
Amphiprora sp.	a	a	a	c
Hantzschia sp.	a	a	a	p
Coconeis sp.	a	a	a	c
Gyrosigma sp.	a	a	p	a
Coscinodiscus sp.	c	c	c	p
Cyclotella sp.	a	c	c	p
Chaetacerous sp.	a	a	p	p
Rhizosolenia sp.	a	c	a	p
Bacteriastrum sp.	p	a	a	a
Fragilaria sp.	a	c	c	a
Diatom abundance (cells cm^{-3})	2.9×10^4	3.1×10^4	2.5×10^4	4.5×10^4
Shannon-Weiner Index	1.0	2.1	1.9	1.5

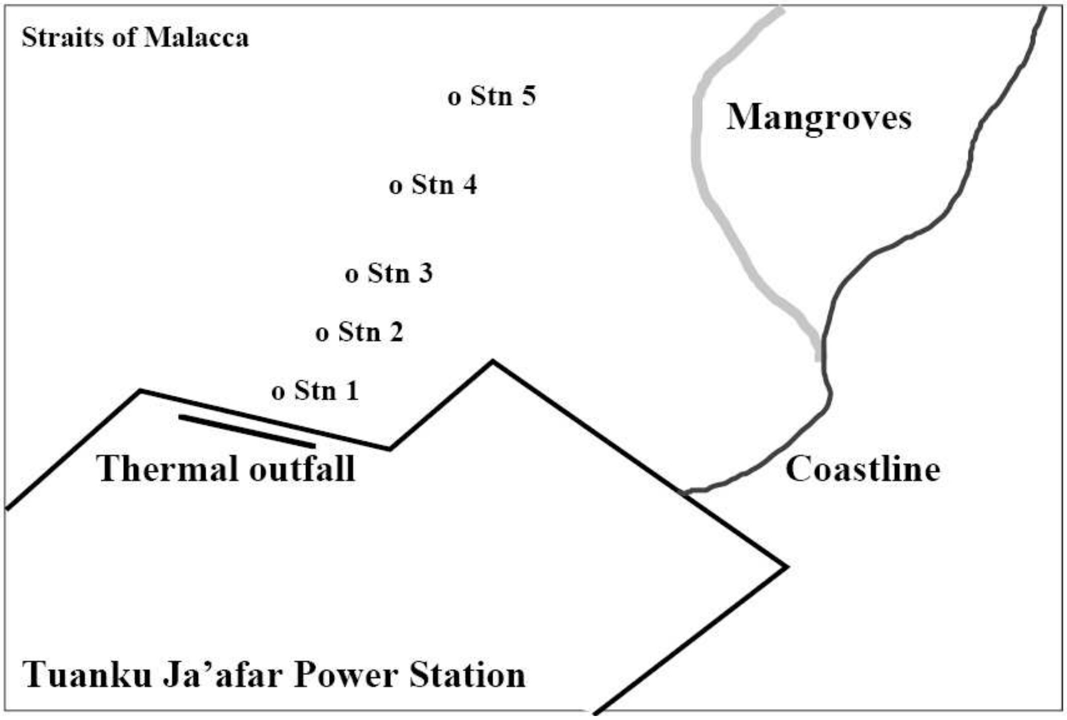

Figure 1. Map showing the relative locations of the sampling stations (Stns 1 – 5) at the TJPS (2º32'N, 101º47'E) (not to scale).

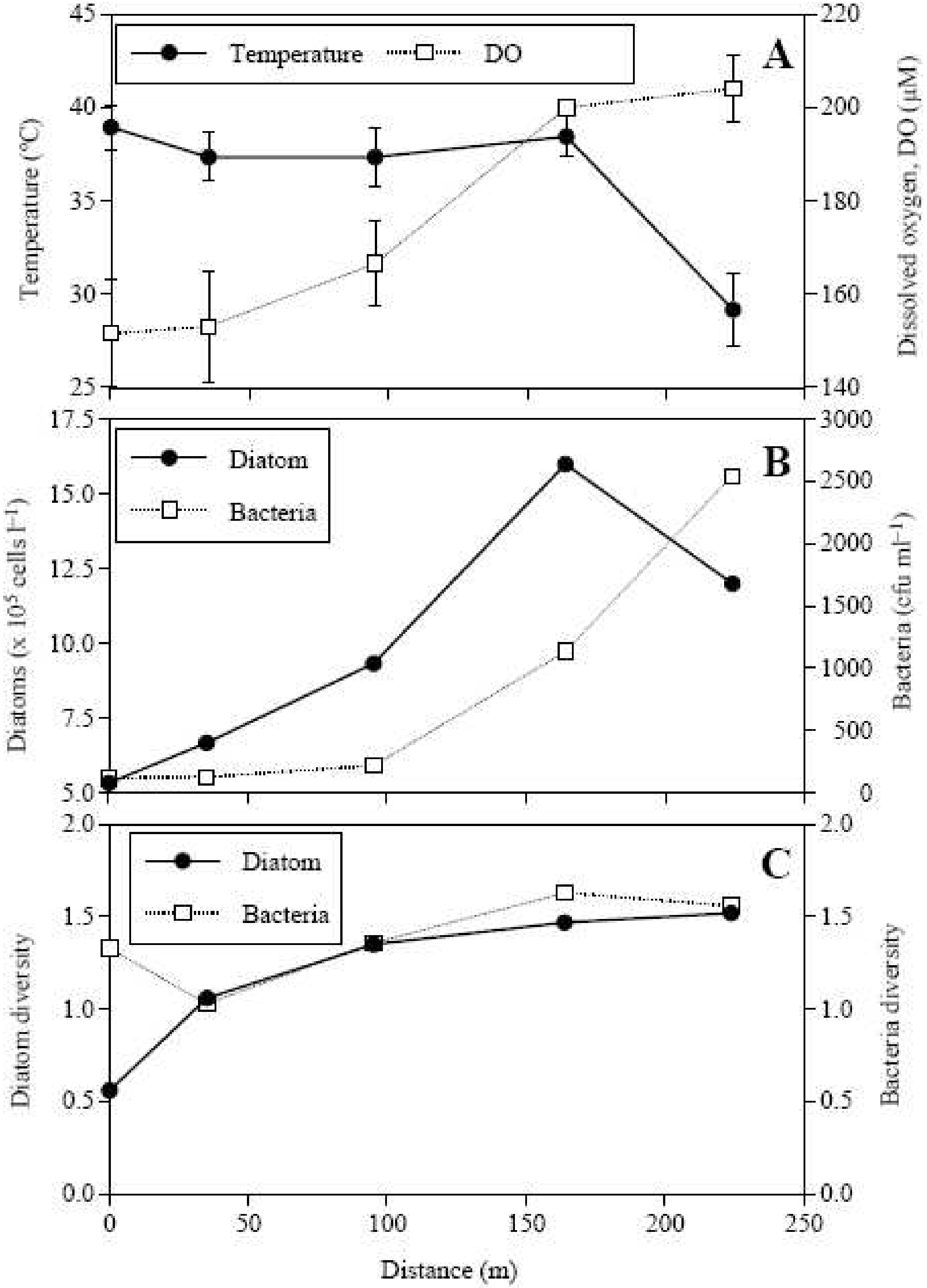

Figure 2. (a) Temperature (ºC) and dissolved oxygen (DO, µM) profiles with distance from the TJPS thermal outfall, (b) Diatom (× 10^5 cells l^{-1}) and bacterial (cfu ml^{-1}) abundance with distance from the TJPS thermal outfall, (c) Diversity of both diatom and bacteria with distance from the TJSP thermal outfal