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SHORT-TIMESCALE VARIATION OF PHYTOPLANKTON ABUNDANCE AND DIVERSITY AT REDANG ISLAND

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ABSTRACT A short-timescale sampling of phytoplankton abundance and diversity was carried out at Redang Island waters, South China Sea. Physico-chemical variables measured at four intervals over a day were relatively stable (temperature = 29 ± 0.6°C ; salinity = 27 ± 2 ppt, pH = 7.8 ± 0.1; total alkalinity = 2025 ± 33 µeq l^{-1}) whereas inorganic nutrient concentrations (NH_4 = 1.36 ± 0.51 µM; NO_2 = 0.06 ± 0.03 µM; PO_4 = 0.08 ± 0.03 µM; and SiO_4 = 9.98 ± 0.54 µM) were low and reflected oligotrophic conditions. The oligotrophic nature of Redang Island waters supported relatively lower biomass i.e. bacterial abundance = 6.6 ± 0.5 × 10^5 cell ml^{-1}; picoplankton abundance = 9.3 ± 0.8 × 10^4 cell ml^{-1}; phytoplankton abundance = 4.8 ± 2.2 × 10^3 cell ml^{-1} and zooplankton abundance = 1.18 ± 0.57 × 10^3 cell l^{-1}. Phytoplankton community was made up of ten genera (*Asteramphalus* sp., *Bacteriastrum* sp., *Chaetoceros* sp., *Cosinodiscus* sp., *Diploneis* sp., *Hemialus* sp., *Leptocylindricus* sp., *Navicula* sp., *Nitzschia* sp., and *Rhizosolenia* sp.), and significantly different from near-shore waters. Redang Island waters exhibited a simpler phytoplankton community which is probably more susceptible to climate change.

ABSTRAK *Penyampelan cara skala masa pendek mengkaji kelimpahan dan kepelbagaian fitoplankton telah dijalankan di perairan Pulau Redang, Laut China Selatan. Pembolehubah fiziko-kimia yang diukur empat kali dalam sehari adalah agak stabil (suhu = 29 ± 0.6 ° C; kemasinan = 27 ± 2 ppt, pH = 7.8 ± 0.1; jumlah kealkalian = 2025 ± 33 µeq l^{-1}) manakala kepekatan nutrien tak organik (NH_4 = 1.36 ± 0.51 µM; NO_2 = 0.06 ± 0.03 µM; PO_4 = 0.08 ± 0.03 pM; dan SiO_4 = 9.98 ± 0.54 µM) adalah rendah dan mencerminkan keadaan oligotrofik. Sifat oligotrofik perairan Pulau Redang pula menyokong biojisim yang rendah iaitu kelimpahan bakteria = 6.6 ± 0.5 × 10^5 sel ml^{-1}; kelimpahan pikoplankton = 9.3 ± 0.8 × 10^4 sel ml^{-1}; kelimpahan fitoplankton = 4.8 ± 2.2 × 10^3 sel ml^{-1} dan kelimpahan zooplankton = 1.18 ± 0.57 × 10^3 sel l^{-1}. Komuniti fitoplankton terdiri daripada sepuluh genus (Asteramphalus sp., Bacteriastrum sp., Chaetoceros sp., Cosinodiscus sp., Diploneis sp., Hemialus sp., Leptocylindricus sp., Navicula sp., Nitzschia sp., dan Rhizosolenia sp.) , dan secara bererti berbeza dari perairan dekat pantai. Perairan Pulau Redang mempamerkan komuniti fitoplankton yang lebih ringkas, dan yang lebih mudah dipengaruhi oleh perubahan iklim.*

(**Keywords**: coral reef, Redang Island, phytoplankton abundance, phytoplankton diversity, Sunda Shelf)

INTRODUCTION

Phytoplankton plays an important role functioning at the base of the food web through photosynthesis, incorporating dissolved carbon dioxide (CO2) as biomass [5,23]. In recent years, anthropogenic activities have greatly affected the global carbon (C) cycle where an increasing amount of CO2 being released into the atmosphere is identified as the main cause of global warming [9,11]. This has accelerated research on ocean primary producers (e.g. phytoplankton) as primary production is responsible for removing 30 – 60% of the CO2 emissions [5,17]. Phytoplankton is usually classified as > 2 µm fraction, and consists mainly of diatoms and dinoflagellates [18]. Variability in phytoplankton biomass is attributed to light intensity, seawater temperature and inorganic nutrient concentrations [3,26,30] whereas phytoplankton diversity reflects the resilience of the phytoplankton community to environmental stresses [12,28].

The Sunda Shelf region is important in terms of marine biodiversity and yet studies on phytoplankton in this region have mainly focused on near-shore coastal waters e.g. Klang and Port Dickson [13]. This present study was an attempt to complement our understanding of phytoplankton distribution by studying waters with less anthropogenic influence. We chose Redang Island waters located on the east side of Peninsular Malaysia. Redang Island is a popular tourist spot with teeming coral reefs. As phytoplankton exhibits relatively short reaction time to environmental change, we adopted a short-timescale sampling strategy to observe for any temporal variation. Although we only captured 'snapshots' of the environment in this study, short-term changes can drive long-term patterns [29], and results from this study could give us a lead on possible long-term research strategies.

MATERIALS AND METHODS

Sampling and Physiochemical Characteristics

Short-timescale sampling was carried out at Redang Island (N5º46', E103º02'), east coast of Malaysia (Figure 1). Four samplings were carried out over a one-day period (8:00 am, 11:00 am, 14:30 pm and 17:30 pm), and about 12 l of water sample was collected each time. Physical parameters such as temperature, salinity (YSI–30, USA) and pH (Mi 106, USA) were measured in-situ. For inorganic nutrient analyses [ammonium (NH4), phosphate (PO4), nitrite (NO2) and silicate (SiO4)] [19] and total alkalinity measurements [7], seawater sample was preserved with mercury chloride (HgCl2) (1% final concentration). Although nitrate (NO3) predominates in island or offshore waters in this region [13], it was not measured here as the preservation method was not suitable for NO3 analysis [8]. Additionally, 10 ml of the seawater sample was preserved with glutaraldehyde (4% final concentration) for bacteria and phototrophic picoplankton enumeration. The remaining water sample (≈ 5.5 l) was concentrated via plankton nets with mesh sizes of 140 µm and 20 µm for zooplankton and phytoplankton, respectively. These samples were then preserved with 4% Lugol's iodine [27]. All preserved samples were kept cold until further analyses in the laboratory.

Plankton Enumeration

Bacterial abundance was determined via epifluorescence microscopy (Olympus BX60, Japan) on samples stained with 4',6-diamidino-2-phenylindole (DAPI) [21] whereas unstained samples were viewed for autofluorescing phototrophic picoplankton (Ppico). For phytoplankton and zooplankton enumeration, samples were placed in a sedimentation chamber and observed via an inverted microscope (Olympus IX51, Japan) whereas phytoplankton identification was carried out according to Salleh & Tajuddin [24].

Statistical Analyses

All values were reported as mean ± standard deviation (S.D.) unless otherwise stated. Shannon-Wiener diversity index (H') [25] was used to express phytoplankton species richness in the community, taking into account the proportion of each genus relative to their abundance whereas correlation analysis was used to show the relationship among the different parameters measured. Comparison of the phytoplankton community was carried out via Analysis of Similarity (ANOSIM). All tests were carried out with the software PAST [10].

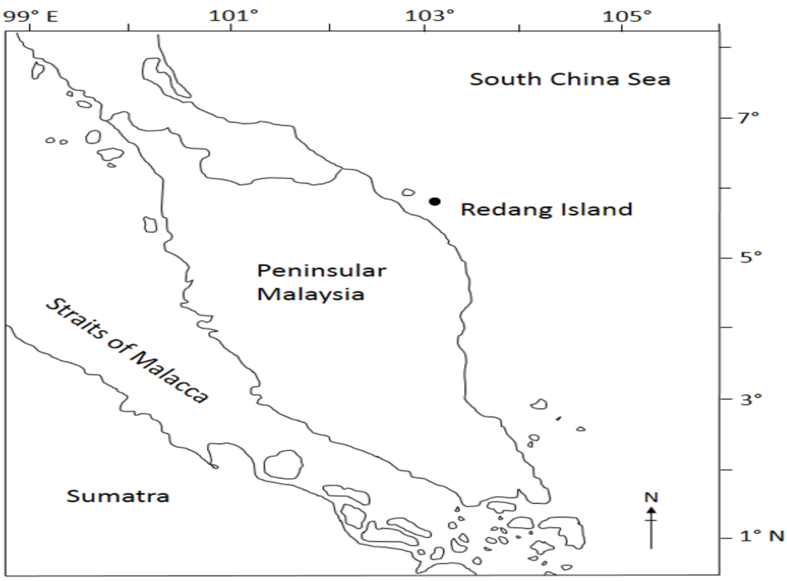

Figure 1. Location of Redang Island sampling site (N 5º46', E 103º02').

RESULTS

Seawater temperature measured varied within a narrow range throughout the day, from 28 to 29°C (29 ± 0.6°C) whereas salinity varied from 25 to 28 ppt (27 ± 2 ppt) (Figure 2). There was also minimal change in pH i.e. from 7.8 to 7.9 (7.8 ± 0.1) throughout the day. Similarly, total alkalinity ranged from 1990 to 2060 µeq l^{-1} (2025 ± 33 µeq l^{-1}). As for inorganic nutrient concentrations, NH_4 and NO_2 fluctuated from 0.92 to 2.06 µM (1.36 ± 0.51 µM) and 0.02 to 0.09 µM (0.06 ± 0.03 µM), respectively. On the other hand, PO_4 and SiO_4 fluctuated from 0.04 to 0.10 µM (0.08 ± 0.03 µM) and 9.20 to 10.33 µM (9.98 ± 0.54 µM), respectively.

In terms of the biology, bacterial abundance varied from 5.8 to 7.2 × 10^5 cell ml^{-1} (6.6 ± 0.5 × 10^5 cell ml^{-1}) whereas Ppico abundance was about two–orders of magnitude lower, from 0.8 to 1.0 × 10^4 cell ml^{-1} (9.3 ± 0.8 × 10^4 cell ml^{-1}). Both bacterial and Ppico abundance were relatively stable (Coefficient of Variation, CV = 13%). In contrast, phytoplankton and zooplankton abundance varied over two-fold. Phytoplankton abundance fluctuated from 2.6 to 7.7 × 10^3 cell ml^{-1} (4.8 ± 2.2 × 10^3 cell ml^{-1}) (Figure 2) and the genera observed were *Asteramphalus* sp., *Bacteriastrum* sp., *Chaetoceros* sp., *Cosinodiscus* sp., *Diploneis* sp., *Hemialus* sp., *Leptocylindricus* sp., *Navicula* sp., *Nitzschia* sp., and *Rhizosolenia* sp. (Figure 3). The predominant genus observed here was *Chaetoceros* sp. which accounted for >58% of the phytoplankton abundance. Phytoplankton diversity in terms of Shannon-Wiener diversity index (H') ranged from 0.439 to 1.076 (0.822 ± 0.303). Zooplankton abundance fluctuated in tandem with phytoplankton abundance and varied more than two-fold from 0.54 to 1.82 × 10^3 cell l^{-1} (1.18 ± 0.57 × 10^3 cell l^{-1}). Both phytoplankton and zooplankton abundance were highest at around noon (11:00 am).

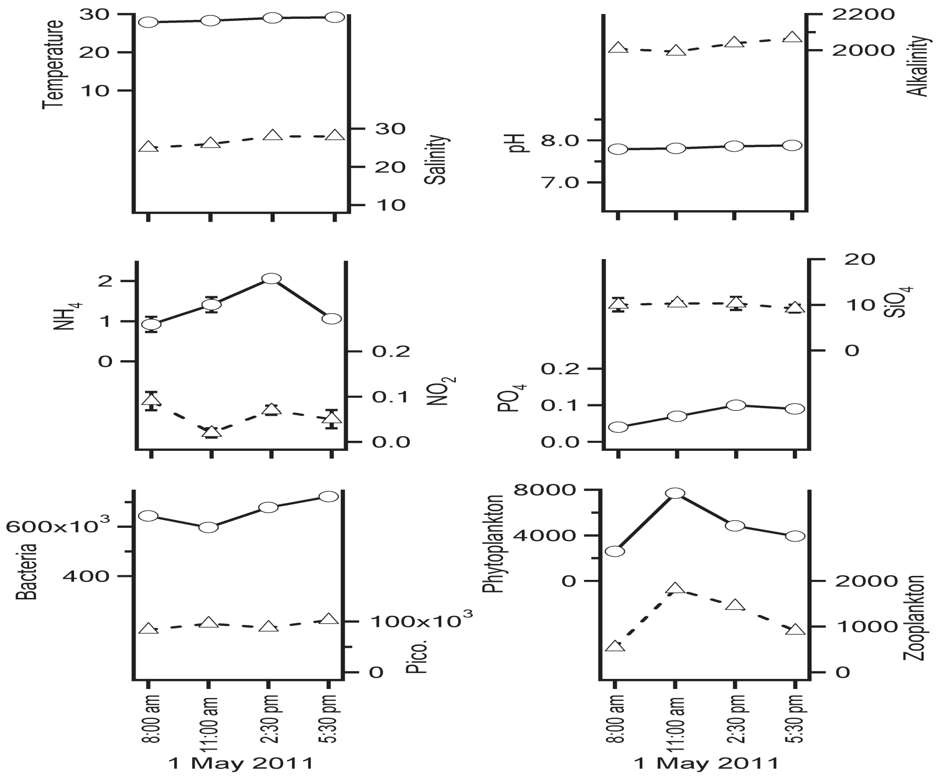

Figure 2. Short-timescale variation of temperature (°C), salinity (ppt), pH, alkalinity (µeq l^{-1}), ammonium (NH4, µM), nitrite (NO2, µM), phosphate (PO4, µM), silicate (SiO4, µM), bacterial abundance (cell ml^{-1}), phototrophic picoplankton abundance (Pico., cell ml^{-1}), phytoplankton abundance (cell ml^{-1}) and zooplankton abundance (cell l^{-1}) measured at Redang Island.

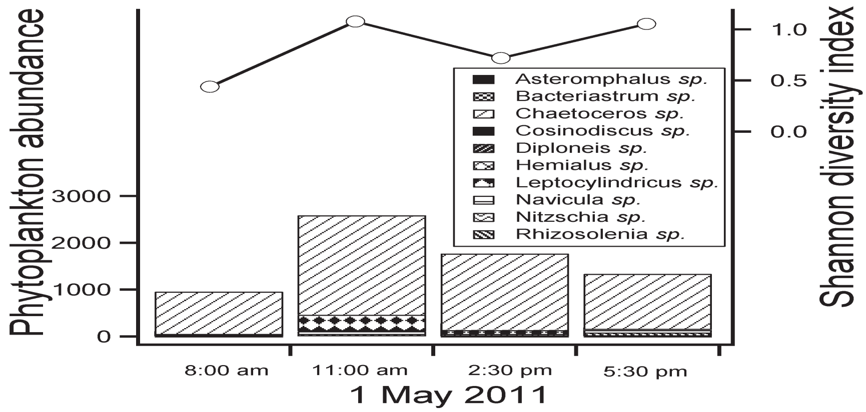

Figure 3. Composition of different phytoplankton based on abundance (cell ml^{-1}) and Shannon diversity index (H') observed at each interval.

DISCUSSION

Generally, the temperature observed at Redang Island is typical of tropical waters [13]. Average salinity and pH were relatively constant probably because there was no significant freshwater input at Redang Island. Total alkalinity was reported for the first time for coral reef waters in Malaysia, and was within the range measured at other coral reef systems e.g. Great Barrier Reef [2]. In general, inorganic nutrient concentrations (NH4, NO2, PO4, and SiO4) at Redang Island were low and reflected an oligotrophic state. This is typical of coral reef systems that are characterized by low nutrient inputs [16].

The oligotrophic nature of the Redang Island waters supported a strikingly lower amount of biomass compared to other coastal water systems in this region [13,14]. Both bacterial and Ppico abundance at Redang Island were about one order lower than near-shore coastal waters [13,15]. Ppico abundance in Redang Island waters also correlated significantly to phytoplankton abundance ($R = 0.87$, $p < 0.05$). This is in contrast to near-shore waters where Ppico abundance was independent of phytoplankton abundance (unpublished data). Our observations concurred with others who reported the co-dominance of Ppico and phytoplankton as typical in oligotrophic waters [1,22] due to the nutrient uptake efficiency of Ppico with their high surface-to-volume ratio [22].

In this study, phytoplankton abundance varied over two-fold, and peaked at around noon. This temporal pattern is probably the result from increased phytoplankton growth with day-light. From the phytoplankton community profile, we observed the predominance of *Chaetoceros* sp. in Redang Island waters throughout the day. Chaetoceros sp. employs the r-strategy, is small in size and could respond to the nutrient limiting conditions [20]. *Chaetoceros* sp. also correlated with zooplankton abundance ($R = 0.93$, $p < 0.01$). Although we did not measure zooplankton grazing rate, zooplankton grazing is an important process that accounts for 60 – 75% of daily phytoplankton production [4,6], and the correlation between zooplankton abundance and *Chaetoceros* sp. that we observed could be a result of predator-prey coupling.

In order to place our study here within a larger spatial context, we compared our study here with data from Port Dickson and Klang estuary (unpublished data), representing mesotrophic and eutrophic systems, respectively. Generally, phytoplankton abundance at Redang Island was similar to Port Dickson ($9.85 \pm 0.15 \times 10^3$ cell ml^{-1}) but lower compared to Klang ($1.39 \pm 0.99 \times 10^4$ cell ml^{-1}). Eutrophic systems have higher amounts of nutrients that support a higher phytoplankton biomass [13]. However in terms of phytoplankton community, we observed that the phytoplankton community from these three stations were significantly different (ANOSIM: $R= 0.85$, $P< 0.001$). The lower phytoplankton abundance and oligotrophic nature at Redang Island resulted in a simpler phytoplankton community (with 10 genera) compared to Klang (28 genera) and Port Dickson (28 genera). One of the perils of small phytoplankton community is the susceptibility to climate change due to the decreased variety of response from the community [12,28].

CONCLUSION

From this study, we reported the phytoplankton community from Redang Island waters which also represented coral reef waters. The oligotrophic nature of these waters supported a lower phytoplankton abundance and a simpler phytoplankton community, suggesting the susceptibility of these communities to climate change.

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