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Effects of nutrients and zooplankton on the phytoplankton community structure in Marudu Bay

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ABSTRACT

Current study was carried out to provide a better understanding on spatial and temporal variations in the phytoplankton community structure in Marudu Bay, an important nursery ground for fishery resources within the Tun Mustapha Marine Park and Coral Triangle Initiative, and their relationship with environmental variables. Samplings were conducted monthly from April 2014 to April 2015 in Marudu Bay, Malaysia. Water samples were collected for nutrients analysis, zooplankton and phytoplankton counting. Moreover, the *in situ* environmental parameters were also examined. The field study showed a total of forty seven phytoplankton genera, representative of 33 families were identified. The nutrient concentrations in Marudu Bay was low (mesotrophic) throughout the year, where the phytoplankton community was often dominated by *Chaetoceros* spp. and *Bacteriastrum* spp. In general, increase in nitrate concentration triggered the bloom of centric diatom, *Chaetoceros* spp. and *Bacteriastrum* spp. in Marudu Bay. However, the bloom of these phytoplankton taxa did not occur in the presence of high ammonia concentration. In addition, high abundance of zooplankton also a limiting factor of the phytoplankton blooms particularly at end of southwest monsoon. High silica concentration promoted the growth of pennate diatoms, *Proboscia* spp. and *Thallassionema* spp., but the depletion of silica quickly terminated the bloom. Interestingly, our study showed that *Chaetoceros* spp., tolerated silica depletion condition, but the average cell size of this taxon reduced significantly. In summary, the phytoplankton community structure in mesotrophic environment is more sensitive to the changes in zooplankton abundance, nutrient concentration and its ratio than that in nutrient rich environments. This study also recommends that bivalve farming at industrial scale is not recommended in Marudu Bay because it potentially depletes the primary productivity hence jeopardizing the availability of live food for larvae of many natural fishery resources in the bay.

1. Introduction

Marudu Bay is part of the largest marine protected areas in South East Asia, the proposed Tun Mustapha Marine Park and included within the priority conservation area of Coral Triangle Initiative Marudu Bay is rich in biodiversity and has been identified as one of the important nursery grounds of many commercially important marine species in South East Asia (Zakaria and Rajpar, 2015). The hydrodynamic of the bay is mainly affected by the seasonal monsoons (Malaysian Meteorological Department, 2014). In general, Asian tropical monsoon can be divided into three monsoons, the Northeast monsoon (NEM) from November to March, the Southwest monsoon (SWM) from May to September, and Intermonsoon (April and October). Monsoons have been suggested to play an important role in the fluctuation of nutrient concentration in Malaysian waters by the process of up-welling, down-welling, and nutrients run-offs through rivers and lands (Mohammad-Noor et al., 2012; Adam et al., 2011). The water of Marudu Bay is characterized by low to moderate nutrient concentrations and typical environmental conditions throughout the year (Tan and Ransangan, 2016). The multi-use demands of the bay for navigation, traditional fishing, recreation, green mussel and finfish mariculture, dictate that more attention should be given to this kind of water body, both for a better understanding of functionality and for ecological management purposes.

Phytoplankton plays a key role in marine ecology by providing first link in nearly all marine food chains (Tan and Ransangan, 2015a; Anderson, 2009). Phytoplankton provides food for

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zooplankton, bivalve molluscan and some fishes particularly anchovies and sardines (Tan and Ransangan, 2016; Smith et al., 1998). These animals, in turn, provide food for other marine animals in higher trophic levels. Therefore, without phytoplankton, the diversity and abundance of marine life would be impossible.

Generally, marine phytoplankton communities are strongly influenced by zooplankton grazing (Gislason and Silva, 2012), concentrations of nutrients (Tan and Ransangan, 2015a; Anderson, 2009; Cermeno et al., 2006) and environmental variables (Mohammad-Noor et al., 2012; Finkel et al., 2007). In general, grazing can reduce the abundance of small phytoplankton that is more vulnerable to zooplankton, favouring the survival of large phytoplankton species (Yoshida et al., 2012; Rezai et al., 2004; Othman et al., 1990). Therefore, grazing by zooplankton can significantly alter the phytoplankton species composition and influence the phytoplankton community structure (Gislason and Silva, 2012).

Strong positive correlation between nutrient loads and phytoplankton abundance has been well documented in many aquatic systems throughout the world (Sany et al., 2014; Rabalais and Nixon, 2002). Under eutrophic conditions, some phytoplankton species particularly the harmful algal bloom species, *Cochlodinium polykrikoides* (Anton et al., 2008), *Gymnodium catenatum* (Oshima et al., 1993), *Pyrodinium bahamense* Var. *compressum* (Lim et al., 2005; Usup et al., 2002) and *Alexandrium* spp. (Lefebvre et al., 2008) have shown to overwhelm other species and alter the overall phytoplankton composition. Moreover, high nutrient environment has also been suggested to shift the phytoplankton community structure from diatom dominance to dinoflagellate dominance (Tan and Ransangan, 2015a; Anderson, 2009).

Nutrient assimilation by phytoplankton is strongly influenced by environmental variables (Mohammad-Noor et al., 2012; Finkel et al., 2007; Anderson et al., 2002; Dahl and Tangen, 1993). Therefore, in addition to nutrient concentration, the abundance and composition of phytoplankton community in an area are also affected by the surrounding environments (Maso and Garces, 2006). Moderate changes in a day length (Romdhane et al., 1998), light intensities (Parkhill and Cembella, 1999), water salinity (Tan and Ransangan, 2015a) and/or temperature (Lim and Ogata, 2005) have been shown to significantly increase or decrease the abundance of certain taxa of phytoplankton.

Most recent efforts to understand the effects of grazing, nutrients concentrations and environmental variables on the dynamic of phytoplankton community structure have focused on eutrophic waters (Sany et al., 2014; Mohammad-Noor et al., 2012; Adam et al., 2011; Sidik et al., 2008). However, very little is known about these effects in the mesotrophic and oligotrophic water bodies (Sany et al., 2014; Redfield, 1958). There is insufficient *in situ* data to reveal the dynamic of phytoplankton community structure in response to nutrients and environmental condition in the nutrient depleted environments.

To understand the dynamic of phytoplankton community structure in nutrient depleted environment, we carried out a one year field observation to elucidate the effects of grazing pressure from zooplankton, nutrients and environmental conditions on the dynamic of phytoplankton community structure in ecological important habitat, Marudu Bay.

2. Materials and methods

2.1. Study area

Marudu bay is situated on the north part of Sabah (6°35′ to 7° N and 116°45' to 117° E) (Fig. 1). It has a tropical climate with uniform temperature, high humidity and abundant rainfall due to its proximity to the equator (Malaysian Meteorological Department, 2014). Ten sampling stations were positioned in Marudu Bay along the depth gradient and human activities. Stations 1, 2, 3 and 10 represent sites with water depth less than 5 m, stations 4, 5, 7 and 9 represent sites with water depth between 5 and 10 m, and stations 8 and 6 represent sites with water depth of 13 and 26 m, respectively. Stations 1, 2 and 10 were adjacent to highly populated coastal areas, with station 1 located near the green mussel farm. Station 3 was located in front of the Marudu river mouth and also the main artisanal fishing ground, while stations 7 and 8 were positioned nearby the anchovy fishing platforms.

2.2. Sampling schedule

Samplings were conducted once per month during full moon (spring tide) and approximately the same time at 8.00–8.30 a.m. during high tide, from April 2014 until April 2015. Similar tidal condition was selected each month to minimize the tidal effect on the phytoplankton composition.

2.3. Sample collection

At each station, *In situ* environmental parameters including temperature, salinity, pH and dissolved oxygen at 0.5 m below the water surface were measured using a multi-function environmental sensor (YSI; Loveland, CO, USA). Water current was measured using current meter (Stanley, USA) and water transparency was measured with Secchi disc.

One liter (1 L) of water samples were collected at 0.5 m depth below the water surface and filtered through the 0.45 μm cellulose ester membrane filters (Whatman; diameter 47 mm) for chlorophyll-*a* determination (Parsons et al., 1984). The filtrates were stored at 4 °C until analysis. Dissolved inorganic phosphorus (DIP), nitrate (NO_3-N), nitrite (NO_2-N), ammonia (NH_3-N) and dissolved silica (DSi) were measured following methods described in Parsons et al. (1984). Total dissolved inorganic nitrogen (DIN) was then calculated from the sum of NO_3-N, NO_2-N and NH_3-N.

Qualitative samples of phytoplankton were collected by vertical tow of plankton net (mesh size 20 μm) to cover 0.5 m above the sea floor to the surface of water. The net was towed several times until the water in the sample collector becomes unclear or coloured by the concentrated algae (on average 200 ± 50 L of sea water was filtered for each sample). Samples were then immediately preserved with Lugol's solution (Saraceni and Ruggiu, 1974). Species identification was performed using a Carl Zeiss light microscope at 400× and 1000× magnification according to Hartley (1996).

Approximately 1 L water samples were collected at 0.5 m depth using a 1-L Van Don water sampler for phytoplankton quantitative study. All samples were immediately preserved with Lugol's solution (Saraceni and Ruggiu, 1974). In laboratory, samples were concentrated following the Utermöhl sedimentation method into 50 mL samples. The phytoplankton cell density was then counted as cells/mL using a Sedgwick Rafter chamber at 400× magnification (Aktan et al., 2005).

Zooplankton at 0.5 m below the water surface was collected by towing a 50 μm (140 μm is recommended) plankton net (Mouth area = 3.142 m^2) at speed about 45 m min^{-1}. The tow duration ranged between 3 and 10 min depending on the net clogging (about 500 to 1200 L of sea water on average was filtered for each sample). The samples were then preserved in 70% ethanol. In the laboratory, samples were filtered through a 50 μm mesh Endecott sieve and quickly washed with running tap water to remove fine debris. The zooplankton were immediately resuspended in 70% ethanol. The abundance (ind m^{-3}) of zooplankton was counted using a Sedgwick- Rafter counting cell under a Carl Zeiss light microscope using