Variations in physico-chemical parameters and Chl-a concentration in Setiu Wetlands lagoon during the northeast and inter-monsoon seasons 2018.

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Abstract: This study presents the seasonal changes of physico-chemical parameters and chlorophyll-a (Chl-a) concentration in Setiu Wetlands lagoon during the NEM (February 2018) and inter-monsoon (April 2018) seasons. The Chl-a and physico-chemical parameters of water temperature, dissolved oxygen (DO), pH and salinity were investigated for both surface and bottom waters at 3 sampling sites that are located in the upstream and downstream of the lagoon. There was a strong seasonal signal and spatial gradient in physico-chemical parameters within the Setiu lagoon. In February, when the strong northeast monsoon (NEM) prevailed, the surface and bottom waters of the lagoon were dominated by high pH and low water temperature, DO and salinity. As the weaker inter-monsoon dominated in April, the study area was characterized by low pH and high water temperature, DO and salinity. While the seasonal variation in physico-chemical properties of Setiu lagoon is well described, Chl-a concentrations varied between seasons and sampling locations. Chl-a showed an increased or only a slight change in the downstream stations but recorded a significant decreased in concentrations in the upstream station from the NEM to inter-monsoon season. Analysis of seasonal relationships clearly indicated the interchangeable negative and positive correlations of Chl, DO and salinity. These results suggest the influence of other environmental factors of the lagoon (e.g., nutrient enrichment, tidal and freshwater influx) that vary with seasons which require more detailed investigation.

1. Introduction

Coastal lagoons are ecologically and economically importance aquatic ecosystems since they provide a range of natural services such as fisheries productivity, tourism, biological filter against anthropogenic pollution as well as essential areas for biota [1]. Despite their importance, the lagoons have been subjected to increasing anthropogenic influence, aquaculture activities, sewage outfall and domestic wastes. Especially from the excessive nutrient loads and discharge of organic pollution, the lagoon can be affected by eutrophication problems and this may contribute significantly to the decrease in water quality and overall ecological status of the area within the lagoon system. Although the increased input of nutrients into the lagoon waters could increase Chl-a concentration and hence, level of primary production, elevated Chl-a is not necessarily predictive of good ecosystem health. High levels of Chl-a can also be an important indicator of eutrophication level or poor water quality, especially when algal biomass increases at higher nutrient concentrations [2]. Setiu Wetland is located in Setiu District, Terengganu, which is part of the Setiu River basin, and also of the larger Setiu-Chalok-Bari-Merang basin wetland complex. With the size of 23,000 hectares, Setiu Wetlands is the largest natural wetlands in the east coast region of Peninsular Malaysia, combining various ecosystems including freshwater, seawater, brackish water and a 14 km lagoon. It is the only wetland in Malaysia with nine interconnected ecosystems - the sea, beach, mudflat, lagoon, estuary, river, islands, coastal forest and mangrove forest. Setiu Wetland is known as one of the tourist eco-center in the east coast region due to its beautiful natural
habitat and recreational fishing [3]. Despite the ecological and economical importance, this area has been subjected to massive anthropogenic activities [4]. Over the last decades, numerous studies have been carried out in Setiu Wetland to assess the status of water quality and the effect of pollutants on ecosystem of the region.

Considering the rapid growth of aquaculture activities in Setiu Wetlands lagoon that could result in degradation of water quality and its natural resources, monitoring the status of physico-chemical and biological properties of water is essential to improve understanding of this lagoon ecosystem. In this study, physico-chemical parameters and Chl-a concentration are presented from 3 stations within the Setiu Wetlands lagoon. The aim of this study was to investigate the seasonal changes in physico-chemical parameters of water temperature, DO, pH and salinity; and Ch concentration during the NEM (Feb 2018) and inter-monsoon seasons (Apr 2018)

2. Materials and Methods

2.1 Study Area
The study area of this research is located in Setiu district at coordinates 5° 41’ 50.4”N, 102° 41’ 42.2”E for Station A, 5° 40.774’N, 102° 42.843’E for Station B and 5° 39.428’N, 102° 44.345’E for Station C (Fig 1). There are several cage and fish pond culture along the area. This area is influenced by the monsoon climate.
2.2 Sampling Data
Data collection were performed in NEM (February) and Spring IM (April) 2018. Water samples were collected at 3 sampling stations on 14th February 2018 and 11th April 2018, representing the pre-monsoon and monsoon, respectively. The water samples were filtered in the laboratory through MG/F filter paper (47 mm, 0.7 μm, Sartorius) with a vacuum pump. Chlorophyll pigment was extracted by 90% acetone, and the filters were then kept frozen in the dark. The samples were centrifuged at 3000 rpm for 10 min, and the absorbance of the extracted samples was recorded at 630, 647, 664, and 750 nm by a spectro-photometer (Shimadzu). Concentration was measured using the equation below (Jeffrey & Humphrey, 1975).

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\text{Chl } a (\text{mg/m}^3) = [11.85 \times (E_{664} - E_{750})] - [1.54 \times (E_{647} - E_{750})] - [0.08 \times (E_{630} - E_{750})] \times \frac{v}{L} \times \frac{V_f}{1}
\]

v - volume of acetone
L - Cell (cuvette) length
V_f - volume of filtered water.

2.3 In Situ Parameters
Physical parameters (temperature, DO, pH and salinity) were measured in-situ using a YSI multi probe that have been calibrated.

3.0 RESULTS AND DISCUSSION

3.1 Physico-chemical parameters

| Station | Temp (°C) | DO (mg/L) | pH | Salinity (ppt) |
|---------|-----------|-----------|----|----------------|
|         | 14/2/18   | 11/4/18   | 14/2/18 | 11/4/18 | 14/2/18 | 11/4/18 |
| A Surface | 28.32 | 28.67 | 3.86 | 4.21 | 7.28 | 7.19 | 12.93 | 17.16 |
| Bottom | 28.34 | 28.50 | 3.07 | 3.59 | 7.41 | 7.16 | 13.07 | 17.16 |
| B Surface | 28.29 | 29.40 | 0.07 | 3.96 | 7.50 | 7.16 | 17.76 | 19.69 |
| Bottom | 28.28 | 29.10 | 0.09 | 3.52 | 7.56 | 7.17 | 18.66 | 20.33 |
| C Surface | 28.67 | 30.00 | 0.08 | 4.46 | 7.11 | 7.03 | 18.56 | 15.32 |
| Bottom | 28.57 | 29.40 | 0.85 | 2.51 | 7.54 | 7.11 | 23.38 | 23.18 |

Table 1 summarizes the mean concentration of physico-chemical parameters collected at all sampling stations during the study period. In general, all measured parameters varied either between stations or between sampling periods. The surface and bottom water temperatures showed higher values during the NEM season (Feb 2018) than in the spring inter-monsoon (Apr 2018) at all sampling stations. During the NEM season, water temperature did not change much among stations, ranging between 28.3 and 28.7°C. As the inter-monsoon conditions prevailed in April, water temperature increased slightly at all sampling stations, ranging between 28.5 and 30.0°C for both surface and bottom waters.

A similar decreasing trend was also observed for DO concentrations. DO ranged from 0.08 mg/L...
to 3.86 mg/L during the NEM season but was significantly increased during the inter-monsoon period (2.51 – 4.21 mg/L) especially at stations A and B. During the NEM, the maximum value was recorded at station A and minimum values were obtained at stations B and C. The higher biological activity may have reduced the DO content concentration [5] at these stations. These 2 stations are located very near to cage and fish ponds (Figure 1). Especially during the NEM, strong terrestrial runoff may significantly increase the amount of nutrients entering the lagoon, consequently increased the algal growth thus reducing DO in the water. Station A that is located in the upstream of the lagoon and far from the aquaculture activities (Figure 1) did not show any significant changes in DO values in both surface and bottom waters.

Despite showing a slight decrease from NEM to inter-monsoon period, the neutral pH values were recorded during both sampling periods. The pH ranged between 7.11 and 7.56 during the NEM with the lowest and highest values were observed at station C and B, respectively. During the inter-monsoon, the pH value was decreased slightly at all stations, ranging between 7.03 and 7.19. During this season, the lowest value of pH was obtained at station C. High values during the NEM season could be either due to the uptake of CO2 by the photosynthesizing organisms, increased in organic material and non-point pollution. For example, an increased in nutrients favour algal blooms, this will increase primary productivity causing a decrease in CO2 and a higher pH [6]. The influence of these factors at stations B and C is also confirmed by the parallelism between the high concentrations of pH and low DO values. In contrast, relatively low pH values at all stations during the inter-monsoon season could be due to several factors such as low primary productivity, decreased in organic matter and dilution of seawater.

In general, the salinity in the study shows a typical lower surface values and high bottom salinity waters. The salinity ranged between 12.9 and 23.4 psu during the NEM season and from 15.3 to 23.2 psu during the inter-monsoon period. Except for station C, the salinity showed an increasing trend from the NEM to inter-monsoon season, likely due to the influence of strong freshwater influx during the NEM season. In the tropical region, the NEM is the season with the highest rainfall intensity that contributes to large river discharge and surface water cooling. Due to intense freshwater influx and water column mixing, this season is generally characterized by high increase in nutrient supply and primary production in the surface layer [7] [8]. High salinity values in both seasons were always observed at stations B and C due to their location that are very close to the mouth of the lagoon (Figure 1), where the influence of seawater and the tidal influx are strongest in the downstream part of the study area.

In situ parameters (pH and temperature) measured at the three stations. Several factors influence water temperature, which included location and time of sampling. Higher water temperature recorded at Station C were influenced by sampling time, was conducted during afternoon. The values of pH were found acidic (13.07 to 23.38). Salinity also affects chemical conditions within the estuary, particularly levels of dissolved oxygen in the water. The amount of oxygen that can dissolve in water, or solubility, decreases as salinity increases. The results revealed that chlorophyll a was more susceptible to thermal degradation in acidic conditions.

### 3.2 Chlorophyll-a concentration

Table 2 depicts the concentrations of Chl-a at all sampling stations during the study periods. Chl-a concentrations during the sampling periods varied from 3.7 to 14.8 mg m⁻³ with the lowest value was observed at station C during the inter-monsoon and the highest concentration was recorded at station A during NEM season. Although the mean value for this parameter was comparatively similar (8.5 mg m⁻³) for both seasons, Chl-a values did not show a consistent seasonal trend between the sampling periods. By comparison of the in-situ data, we notice a significant increase in Chl-a at station B, from 5.88 mg m⁻³ during the NEM season to 12.81 mg m⁻³ during the inter-monsoon season. At station A, high phytoplankton biomass (14.76 mg m⁻³) was developed during the NEM season and decreased significantly (8.98 mg m⁻³) during the inter-monsoon period. In a similar fashion, although only a
slightly change, Chl-a decreased from ~ 5.0 mg m$^{-3}$ during the NEM to 3.67 mg m$^{-3}$ in the inter-
monsoon period at station C. Results during the NEM season showed a clear pattern of high
phytoplankton biomass in the upstream station (Station A) as compared to the downstream
stations (Stations B and C), which is most probably due to less dilution from the open ocean along the upstream
lagoon during this season.

| Table 2: Concentrations of chl-a |
|----------------------------------|
| Station   | Chl-a     | Chl-a     |
|           | 14 Feb 2018 | 11 April 2018 |
| A         | 14.759    | 8.971     |
| B         | 5.876     | 12.807    |
| C         | 4.974     | 3.664     |

The increasing trend in Chl-a at station B is in contrast with the general knowledge about the
nutrient enrichment and high primary production during the NEM season in this region. Although this
contrasting trend was only observed at only one sampling station, several studies have suggested that
estuaries can be more resilient to the nutrient enrichment during the strong winter monsoon. For
example, [9] found that concentrations of nutrient and phytoplankton biomass in the Pearl River estuary
were significantly higher during the weak SWM monsoon than during the strong NEM season. Similar
findings were also reported by Cloern [2001] in the San Francisco Bay during the winter season and this
behaviour has been related to the susceptibility of the estuarine ecosystem to nutrient enrichment. One
of the important factors is the exchange of water with open ocean [11] [12] that flush the entire coastal
and estuary waters thus, reducing the long-term accumulation of nutrients in the bottom waters and
sediments. Since nutrient measurements were not made in this study, no definitive conclusion can be
drawn as to the effect of nutrient enrichment during both sampling periods.

In order to determine the association between physico-chemical parameters and Chl
concentration, the correlation analysis was conducted for both parameters. Table 3 shows that no
significant correlations (p > 0.05) were found between physico-chemical parameters and Chl
concentration during both seasons. The analysis of data for each season, however revealed significant
 correlations (p < 0.05) between DO and salinity with Chl-a concentration. We must bear in mind that
the statistical results involved only a small number of data (3 stations for each season) and we would
expect a different result if large dataset is used. Dissolved oxygen (DO) was strongly positively
correlated with Chl (r = 0.99, p < 0.05) during the NEM but showed a negative correlation (r = -0.99, p
< 0.05) during the inter-monsoon season. In contrast, a strong negative association was recorded
between Chl-a and salinity (r = -0.99, p < 0.05) during the NEM season but showed a positive correlation
during the inter-monsoon season. The interchangeable positive and negative correlations for both
parameters during different sampling periods suggest that Chl-a in the study area varies with the degree
of environmental factors (e.g. dilution of water, tidal and freshwater influx) that change with seasons.
Table 3: Pearson correlation between Chl-a and physico-chemical parameters. Star sign (*) indicates p < 0.05

| Parameter | NEM | Inter-monsoon | All seasons |
|-----------|-----|---------------|-------------|
| Temperature | -0.52 | 0.65 | -0.09 | 0.94 | -0.14 | 0.79 |
| DO | 0.99 | 0.05* | -0.99 | 0.05* | 0.45 | 0.37 |
| pH | 0.02 | 0.99 | 0.82 | 0.39 | 0.19 | 0.72 |
| Salinity | -0.99 | 0.03* | 0.98 | 0.02* | -0.24 | 0.64 |

4. Conclusions
The present study highlights the seasonal changes in physico-chemical parameters and Chl-a concentration of the Setiu lagoon estuary, which is under the stress of anthropogenic activities associated with aquaculture and agriculture activities. The results reveal a typical seasonal trend of higher pH and lower water temperature, DO and salinity during the NEM (Feb 2018) than that observed in the inter-monsoon season (Apr 2018). This trend could be related to the run-off of nutrients and organic material, and resuspension of sediment caused by river discharge and water column mixing which are stronger during the NEM and weaker during the inter-monsoon season. While the physico-chemical parameters showed a clear seasonal signal, Chl-a concentrations varied between seasons and sampling locations. Stations located along the downstream river/lagoon showed an increased or a slight change in Chl-a concentrations while the upstream station presented a significant decreased in concentration from the NEM to inter-monsoon season. An extension of this complex variation may account for the interchangeable negative and positive covariations of Chl, DO and salinity during both sampling periods. It is possible that variations in Chl-a concentrations in the study area were determined by the environmental characteristics of the lagoon which vary seasonally that warrant further investigation.

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