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The Variability of Surface Chlorophyll-a in Lake Rawa Pening within Five-Month Observations

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ABSTRACT
Lake Rawa Pening is a natural lake in the Semarang Regency of Central Java Province, Indonesia, and its existence is pivotal to the surrounding communities as it provides ecological, economic, and social benefits. The ecosystem health of Rawa Pening can be represented by chlorophyll-a concentration because it indicates phytoplankton biomass, nutrient availability, and fish resources. Hence, the present study aims to disentangle the monthly variability of surface chlorophyll-a in Rawa Pening Lake by analyzing water samples that were collected once a month from nine stations within five-month observations (September 2020 to January 2021). The samples were analyzed using spectrophotometric method. Results showed that the highest surface chlorophyll-a concentration (23.33 mg/m^3) took place in December, while the lowest concentration (12.64 mg/m^3) occurred in October. The monthly variability of surface chlorophyll-a was likely controlled by variation of rainfall, with the highest (18.72 mm) and the lowest (12.33 mm) rainfall happened in December and October, respectively. The present study also indicates the anthropogenic activities such as agricultural activities, floating food stands, aquaculture, and tourist boats may contribute to surface chlorophyll-a variability in Rawa Pening Lake.

Keywords: chlorophyll-a, rainfall, anthropogenic activity, Rawa Pening Lake.

INTRODUCTION

Rawa Pening Lake is a freshwater lake in Central Java Province with a surface area of 2770 ha (Zulfa and Umar, 2009). It is one of fifteen lakes prioritized for protection from eutrophication damage by the Ministry of Environment, the Republic of Indonesia (Sulastri et al., 2016). The majority of Rawa Pening's Lake water comes from springs and several rivers that empty into the lake, including the Galeh, Torong, Panjang, Muncul, Parat, Legi, Pitung, Praginan, and Rengas Rivers (Aida et al., 2016). These rivers contribute approximately 60% of the water mass in Rawa Pening Lake, with the Muncul River contributing approximately 20% (Putra et al., 2013).

Rawa Pening Lake is used for aquaculture, agricultural irrigation, transportation, and tourism by local people (Zulfia and Umar, 2009). Moreover, the lake provides a variety of consumption fish to local residents who have been engaged in fish farming since 2007 (Sulastri et al., 2016). There are a total of 26 fish species, both endemic and introduced in Rawa Pening Lake. Endemic fish contribute to ecosystem balance but have a low economic value, whereas introduced fish are purposefully introduced into the lake ecosystem and have a higher economic value (Wibowo et al., 2013; Arthington et al., 2016; Weri and Sucahyo, 2017). Among the endemic species frequently encountered in Rawa Pening Lake are the green wader fish (*Osteochilus hasselti*) and cork (*Channa striata*). A key fishery commodity in Rawa Pening Lake is giant prawns (*Macrobrachium idea*) and it is a guardian of the ecological balance due to it has a fundamental role as algae eater as well as food for fish and other freshwater shrimp (Seftyono, 2014). The red claw crayfish (*Cherax quadricarinatus*) is an introduced species with a high economic value in Rawa Pening Lake (Putri et al., 2014).

Rawa Pening Lake has experienced siltation and eutrophication. This condition deteriorates into a major issue when sedimentation and eutrophication result in water pollution. Siltation occurs in Rawa Pening Lake because of material accumulation, reaching 778.93 tons/year (Aida and Utomo, 2016). It is believed that nutrients entering the lake come from household, agricultural, and fishery waste, which altered the water quality of Rawa Pening Lake, as indicated by rapid and abundant growth of aquatic plants. The abundance of aquatic plants may have a detrimental effect on the functioning of aquatic ecosystems, the economy, and public health.

Chlorophyll-a plays a vital role in food webs of aquatic ecosystems (Scheinin and Asmala, 2020). It can increase the growth of phytoplankton by synthesizing essential components such as amino acids, lipids, proteins, polysaccharides, pigments, and nucleic acids (Kyewalyanga, 2016; Filstrup and Downing, 2017). In general, an increase or decrease in chlorophyll-a concentration can affect the availability of nutrients and fish resource in aquatic ecosystems (Dutta et al., 2016; Filstrup and Downing, 2017; Kärcher et al., 2020; Yu et al., 2021). Studies on variations of chlorophyll-a concentration in Rawa Pening Lake have never been conducted. Given the vital role of chlorophyll-a as an indicator of water fertility, the present study investigated the temporal variation of chlorophyll-a concentration in Rawa Pening Lake within five-month observations (September 2020 to January 2021), which covered transitional monsoon and wet monsoon seasons.

MATERIAL AND METHOD

The monthly water samples collection was conducted at nine stations in Rawa Pening Lake (Figure 1). Chlorophyll-a measurement was performed using the trichromatic method (APHA, 1992) by filtering 1 L of water samples using a cellulose filter paper (millipore, 0.45 μm). The chlorophyll-a

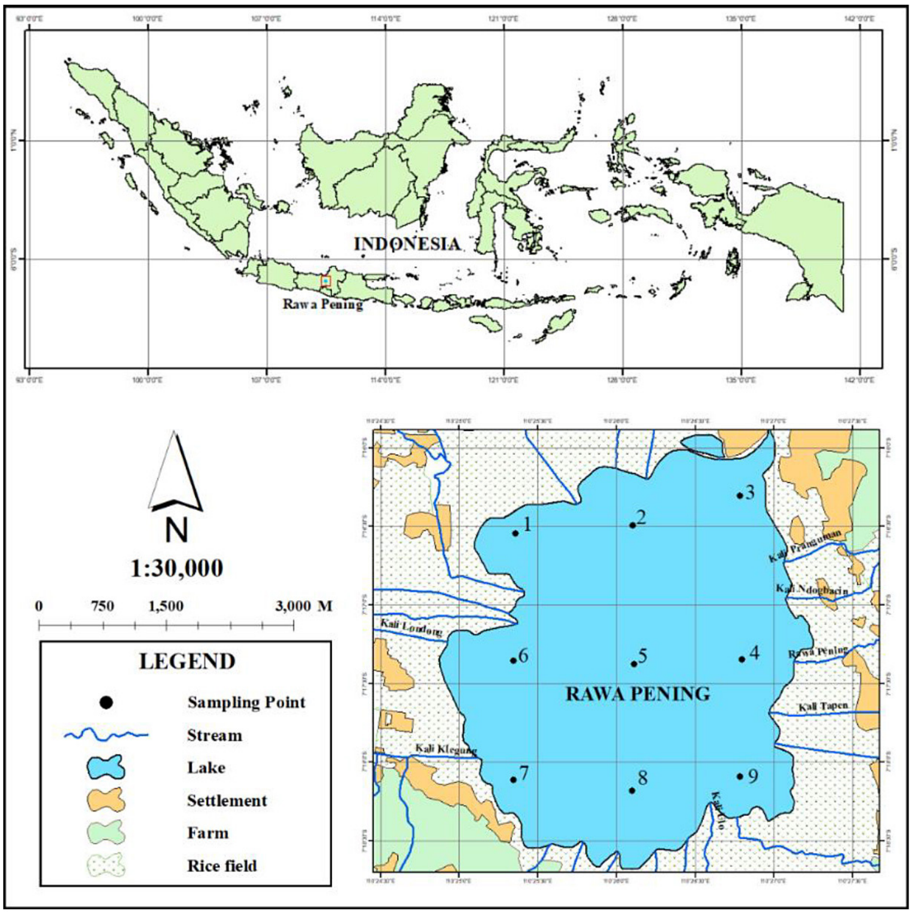

Figure 1. Map of sampling stations in Rawa Pening Lake

samples were extracted using 10 ml of 90% acetone and then incubated in refrigerator for 16 hours.

In the following step, the filter papers containing chlorophyll were centrifuged at 4000 rpm for 20 minutes. The supernatant was measured using spectrophotometer (Thermo Scientific™ GENESYS 10S UV-Vis) with wavelengths (λ) of 630 nm, 647 nm, 664 nm, and 750 nm. The absorbance at λ750 was used as a correction for turbidity because there is no absorption caused by chlorophyll-a (Johan et al., 2018). The following equations were used to calculate chlorophyll-a concentration:

$$\text{Ca}=11.85(\lambda 664)-1.54(\lambda 647)-0.008(\lambda 630) \quad (1)$$

$$\text{Chlorophyll-a concentration (mg/m}^3\text{)} = \text{Ca} \times v/V \quad (2)$$

where: λ630 is the value of absorbance at wavelength 630 nm, λ645 is the value of absorbance at wavelength 645 nm, λ664 is the value of absorbance at wavelength 664 nm, v is the extraction volume (liter), and V is the sample volume (m^3).

The turbidity and temperature of surface waters were measured using a logger of INFINITY-CLW (ACLW2-USB). Furthermore, we used rainfall data from the Indonesian Agency of Meteorology, Climatology, and Geophysics (BMKG), and the NASA Global Precipitation Measurement (GPM) Integrated Multi-satellitE Retrievals for GPM (Huffman, 2019). All data obtained from the nine stations (Table 1) were averaged into a single data (Figure 2) and we will refer to this data when discussing the results.

RESULT AND DISCUSSION

During the study period, the lake surface temperature ranged from 27.27 to 31.31°C, with the highest temperature (31.31°C) and the lowest temperature (27.27°C) happened in November 2020 and January 2021, respectively (Table 1). The highest surface chlorophyll-a concentration (32.3 mg/m^3) occurred in December 2020,

Table 1. Chlorophyll-a concentration, water temperature, and turbidity in Rawa Pening Lake

Station	Parameter	Month				
		September	October	November	December	January
1	Chlorophyll-a (mg/m^3)	13.36	8.88	15.49	19.74	18,09
	Turbidity (FTU)	24.56	29.51	26.17	30.9	31.25
	Temperature (ºC)	29.56	27.93	30.2	27.59	27.54
2	Chlorophyll-a (mg/m^3)	28	22.03	14.98	20.29	21.51
	Turbidity (FTU)	23.78	30.48	31.50	30.21	31.74
	Temperature (ºC)	29.86	28.64	30.05	28.01	27.43
3	Chlorophyll-a (mg/m^3)	19.94	11.15	13.68	19.32	17.81
	Turbidity (FTU)	27.14	29.74	25.84	24.91	57.19
	Temperature (ºC)	28.8	28.9	30.3	27.76	28.12
4	Chlorophyll-a (mg/m^3)	28	9.9	13.12	23.2	26.18
	Turbidity (FTU)	25.97	27.52	22.11	12.2	30.76
	Temperature (ºC)	27.96	27.89	30.97	27.42	27.68
5	Chlorophyll-a (mg/m^3)	21.28	13.4	26.65	32.3	27.71
	Turbidity (FTU)	28.54	26.12	26.42	24.98	26.79
	Temperature (ºC)	28.6	28.21	29.14	27.51	27.21
6	Chlorophyll-a (mg/m^3)	17.11	3.48	15.63	17.45	17.3
	Turbidity (FTU)	23.09	54.87	34.08	28.71	29.43
	Temperature (ºC)	28.46	27.25	29.82	27.77	28.33
7	Chlorophyll-a (mg/m^3)	24.48	9.69	22.95	21.81	16.55
	Turbidity (FTU)	23.91	24.92	31.15	30.61	32.69
	Temperature (ºC)	29.07	28.89	31.31	28	28.98
8	Chlorophyll-a (mg/m^3)	-	22.5	19.83	32.26	26.77
	Turbidity (FTU)	-	98.87	34.76	24.97	23.89
	Temperature (ºC)	-	28.97	30.55	28.3	28.26
9	Chlorophyll-a (mg/m^3)	-	-	1.67	23.61	20.1
	Turbidity (FTU)	-	-	29.87	27.41	30.53
	Temperature (ºC)	-	-	27.33	27.54	27.44

whereas the lowest concentration (1.67 mg/m^3) occurred in November 2020. Meanwhile, the highest turbidity (98.87 FTU) took place in October 2020, whereas the lowest turbidity (12.2 FTU) appeared in December 2020.

Furthermore, results of this research demonstrate that the monthly mean variability of surface chlorophyll-a in Rawa Pening Lake is likely controlled by rainfall variation. Specifically, Figure 2 illustrates the trend of monthly surface chlorophyll-a variation is similar to the monthly rainfall variation, except during September-October 2020. Surface chlorophyll-a exhibited an increase in concentration during November-December 2020 and a decrease in January 2021. At the same time, the rainfall shows an enhancement during November-December 2020, then followed by a decline in January 2021 (Figure 2). It is likely that the increase of surface chlorophyll-a was due to the elevation of river flow volume and/or surface runoff that carried nutrients to the lake (Moura et al., 2017; Maslukah et al., 2021; 2022). There are 16 rivers that empty to Rawa Pening Lake and the dissolved nutrients and organic matter can be factors affecting the concentration of surface chlorophyll-a (Filstrup and Downing, 2017; Zhang et al., 2021). Moreover, the current result may imply that a small lake will typically respond more quickly to any disturbance in its vicinity than a large lake. A large lake has a buffering capacity and tends to exhibit a delayed response (Dearing and Jones, 2003).

The high surface chlorophyll-a concentration in September 2020 (21.74 mg/m^3) did not indicate a direct effect of rainfall. September is the end of dry season and there was no effect of surface runoff as well as river discharge in the research site. We postulate there were other factors that caused high surface chlorophyll-a in September 2020, possibly due to anthropogenic waste from agriculture, floating restaurant, fish farming, and tourist boat. Dubois et al. (2017) and Ferronato and Torretta (2019) suggest that anthropogenic impact can be caused by atmospheric transport, soil erosion, pollution, agricultural, and industry activity. As a consequence, those activities can alter characteristics of an aquatic ecosystem (Syawal et al., 2016) and increase ecosystem productivity, especially by the overflow of nitrogen and carbon (Perez-Ruzafa et al., 2019; Anderson et al., 2020). Generally, the number of tourists is high during dry season, resulting an increase in waste supply. Various nutrients that enter Rawa Pening Lake can affect the life of biota, especially phytoplankton. These factors are probably the cause of the relatively high concentration of surface chlorophyll-a in September 2020.

The lake surface turbidity showed a marked variation during investigation period (Figure 3). Low (high) turbidity values correspond to low (high) suspended and dissolved organic and inorganic materials (Alvado et al., 2021). We expected that the trend of turbidity will follow the trends of rainfall as well as surface chlorophyll-a, however, the turbidity pattern was opposite to both parameters. This discrepancy will be investigated in our future study.

The lake surface temperature variation was 2.19°C and it is expected not to exert impact on the variability of surface chlorophyll-a (Figure 4). In this temperature range, phytoplankton can grow and carry out chemical processes well so that the chlorophyll-a pigment contained in phytoplankton in aquatic ecosystems tends

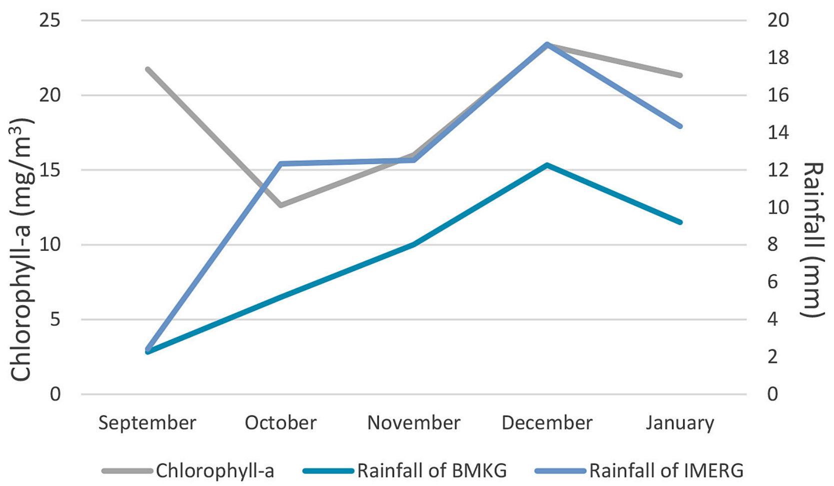

Figure 2. Monthly variations of surface chlorophyll-a (mg/m^3) and rainfall (mm)

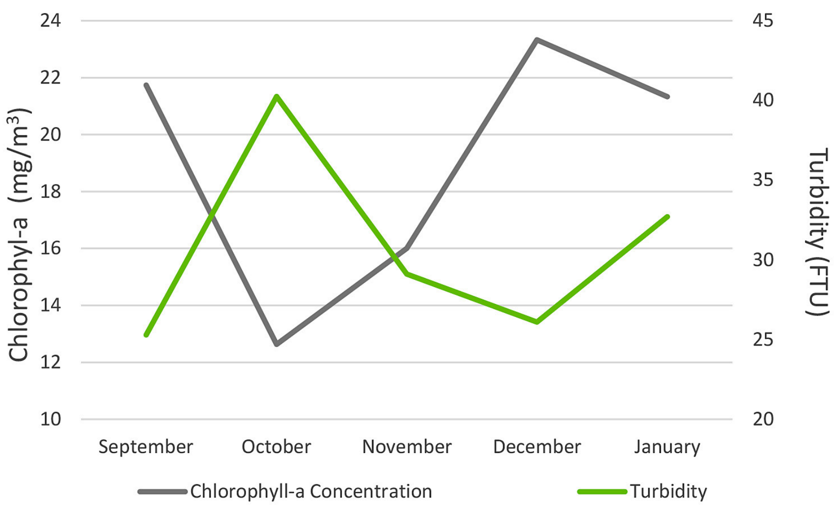

Figure 3. Monthly variations of surface chlorophyll-a (mg/m^3) and turbidity (FTU)

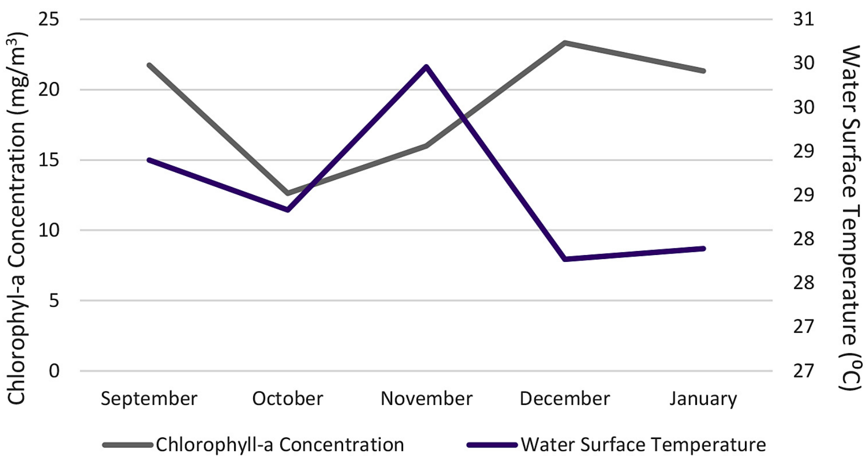

Figure 4. Monthly variations of surface chlorophyll-a (mg/m^3) and water temperature (ºC)

to have a relatively higher concentration than aquatic ecosystems with temperature values outside the range of 20–30°C (Faturohman et al., 2016). The variation of lake surface temperature perhaps induced by differences in sunlight penetration during data collection. For instance, the weather condition in November 2020 was sunny with few clouds, thus allowing the maximum intensity of solar insolation to penetrate water column. This condition may result higher lake surface temperature compared to other months. Overall, the variability of Rawa Pening Lake surface temperature can support the life of freshwater biota.

CONCLUSION

For the first time, the variability of surface chlorophyll-a concentration in Rawa Pening Lake within five-month observations was examined. Results suggest that rainfall may play a dominant role in affecting surface chlorophyll-a variation in the region of interest perhaps through surface runoff and river discharge. The higher the rainfall, the higher the surface chlorophyll-a concentration, except for September 2021. We postulate that the high surface chlorophyll-a in September presumably due to anthropogenic activities such as agricultural activities, floating restaurant, fish farming, and tourist boat.

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