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Use of Harmful Algae Presence to Assess Water Quality in Lake Ranu Grati, Indonesia

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ABSTRACT

The evaluation of water quality is commonly conducted by measuring physicochemical parameters. However, to enable identification of water quality changes of aquatic ecosystems, such as lakes, requires long time series data sampling. In this study, we performed water quality assessments by utilising the presence of potential harmful algae presence in Lake Ranu Grati, Indonesia. We conducted water sampling to evaluate 13 water quality parameters (in-situ and ex-situ) and identified the phytoplankton community structure of the lake at seven sampling sites from December 2018 to February 2019. To assess the water quality of the lake, we used two approaches. First, calculated the classical water quality index using the STORET method. Second, identified the potential harmful algae from the phytoplankton community structure of Lake Ranu Grati, and then determined the water quality factors related to its occurrence using canonical correspondence analysis. The results showed that water quality condition of Lake Ranu Grati was optimum except for COD, BOD and ammonia. The STORET index also classified the seven sites in Lake Ranu Grati as lightly polluted and moderately polluted. Considering the presence of potentially harmful algae from the Cyanophyta and Euglenophyta divisions, it was suggested that Sites 6 and 7 were the most polluted areas of Lake Ranu Grati, which corresponded to the high concentration of COD and BOD. This finding indicates that agricultural and aquaculture activities around the lake need to be controlled to maintain the sustainability of the water quality condition of Lake Ranu Grati.

Keywords: freshwater ecosystem, harmful algae, phytoplankton, STORET index, water quality.

INTRODUCTION

A lake is a body of water that occupies a basin and is surrounded by land [Yapiyev et al., 2017; Barath, 2019]. Although some people claim that lakes are part of a river, there is a very substantial distinction between a river and a lake [Wurtsbaugh et al., 2014]. If a river is a body of water that flows relatively fast (lotic), then a lake is a body of water with sluggish or relatively calm water motions (lentic) [Hof et al., 2006]. Lake are an important source of water for a community [Rolston et al., 2017] as well as habitat for the aquatic living organisms [Schofield et al., 2018]. However, the rise of global population, industrialisation, and other anthropogenic practices have led to changes in land use, input of nutrient and hazardous material and alteration of water quality properties of an aquatic ecosystem [Xin et al., 2015]. These may cause many environmental problems such as drinking water scarcity, emergence of endemic diseases, as well as degradation of the aquatic ecosystem [Bao et al., 2012]. Since environmental pollution become an urgent issue, the public and governments are seriously focused on the issue of water quality [Olsen et al., 2012].

Physicochemical parameters of water, such as nutrients (nitrate and phosphate), dissolved oxygen (DO), turbidity, and total suspended solids (TSS) are commonly measured directly by performing water sampling and subsequent analyses or via remote sensing tools [Rahmanian et al., 2015]. However, the issue is that this method needs long series data sampling to detect any shift or change in water quality. Thus, many researches have suggested the use of biological organisms to assess the water quality condition of aquatic ecosystem [McQuatters-Gollop et al., 2009]. Phytoplankton or microalgae are some of the most common organisms used as a bioindicator [Parmar et al., 2016]. They are the main fundamental aquatic organism constituting as the primary producer in the food web [Chapman, 2013]. Phytoplankton were suggested as favourable bioindicators to evaluate long-run shifts in aquatic systems, especially those associated with eutrophication, climate changes and water management [Gökçe, 2016]. In this respect, the organism can quickly respond to ecosystem alteration, and thus result in faster water quality evaluation [Parmar et al., 2016]. Input of pollutant substances to the water and degradation of aquatic systems can shift the community structure of phytoplankton [Parmar et al., 2016]. For example, sewage discharges raise nutrients that can encourage a bottom-up effect [Davis et al., 2010] and configure the community structure of the aquatic ecosystem to sustain harmful algae blooms (HABs) [Berdalet et al., 2015].

The blooming of harmful algae can destruct other organisms and affect human health [Landsberg, 2002]. There are different consequences of high and low abundance of HABs [Mahmudi et al., 2020]. High abundance may cause oxygen depletion [Anderson et al., 2012]; in addition, the fish may also die as a result of excessive mucus secretion of the algae [Gobler, 2020]. Meanwhile, small abundance of some HAB species tends to be noxious (mostly from divisions Cyanophyta and Dinophyta), which may be consumed via a filter feeder and later ingested by humans [Davidson et al., 2014]. HABs are usually found in marine waters; however, the issue has been increasingly frequent in freshwater ecosystems [Ho and Michalak, 2015]. The evidence from Lake Erie [Michalak et al., 2013], Lake Taihu [Qin et al., 2010] Lake Victoria [Sitoki et al., 2012], the Korean reservoir [Cha et al., 2014], and Arcos reservoir [Quesada et al., 2006] have all reported the presence of HABs, demonstrating examples of a disturbing pattern in freshwater environments around the world [Ho and Michalak, 2015].

In Indonesia, especially Java Island, many natural lakes have been formed as results of volcanic activity (maar lakes) [Sudarmadji et al., 2019]. The area around the volcanic lakes contain pyroclastic material, and is close to fresh water sources, and therefore a fertile grounds for agriculture. Hence, these areas have been favoured as settlement sites [Ako et al., 2012]. For example, Lake Ranu Grati, located East Java, Indonesia – the lake is used for clean water, irrigating agricultural land, socio-cultural activities, fishing and freshwater fish cultivation [Mahmudi et al., 2019; Lusiana et al., 2020]. Previous studies have mentioned that the lake has encountered several problems, such as eutrophication, mainly caused by aquaculture (floating net cages) byproducts in the lakes that increase nutrients (N and P), and lake silting due to high sedimentation [Mahmudi et al., 2019]. In addition, the floating net cages in these areas were also facing difficulties because the productivity had declined due to massive fish deaths [Kurniawan et al., 2016]. Thus, the assessment of water quality condition in Lake Ranu Grati is urgent. However, such investigations that incorporate harmful algae occurrence at the area into the study have not been performed yet.

MATERIAL AND METHOD

Study area

The research was conducted in Lake Ranu Grati, Indonesia, beginning from December 2018 until February 2019, with three replications. Ranu Grati is a volcanic lake formed by a volcanic eruption and is the only lake located in the south of the Pasuruan Regency, East Java. It is not far from the main north coast road of the Pasuruan-Probolinggo road and is surrounded by three villages, namely Sumberdawesari, Ranuklindungan, and Gratitunon. Ranu Grati has an area of ± 1084 ha, the location of which can be seen in Figure 1.

There are seven sampling sites which were determined purposively. They represent the (1) inlet from Kali Kedung river, (2) the outlet, (3) to (5) the floating net cages area, (6) the centre of the lake, and (7) the southern part of the lake near the agricultural land and plantations. The cultivation of floating net cages, with tilapia as the main commodity, is a cultivation sector that is of interest to residents around Lake Ranu Grati. The development of floating net cage units have increased in recent years, due to the large demand for fish by the market, resulting in its uncontrolled development in the cultivation area.

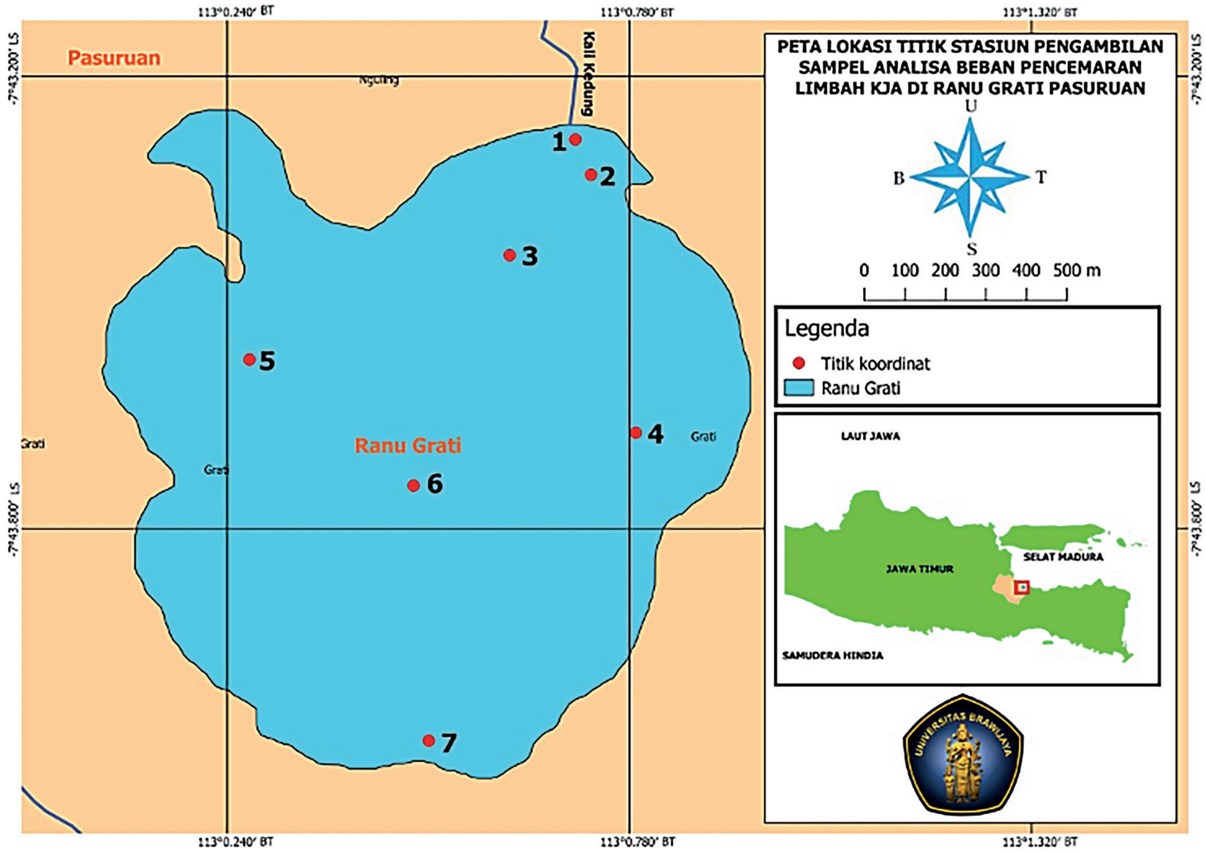

Figure 1. Research location of Lake Ranu Grati and sampling site points

Water quality measurement

Water sampling is carried out at the surface layer of the lake, which is euphotic. The euphotic layer, which is the epilimnion layer, is considered the most productive layer because it gets an adequate supply of sunlight, so that photosynthesis takes place optimally. In addition, the availability of oxygen from photosynthesis and diffusion from the air is also sufficient. For water quality measurement purposes, we collected about 5 L of water from each sampling site. In this research, we observed 13 water quality variables as described in Table 1.

The ex-situ measurement of this research was conducted in the Hydrobiology Laboratory of Brawijaya University, except for total coliform which was analysed at Perum Jasa Tirta 1

Table 1. The measurement method of water quality parameters observed at Lake Ranu Grati

No	Parameter	Unit	Method	Measurement
1	Temperature	°C	APHA 2550 B 2012	In-situ
2	Transparency	m	[Yahuli et al. 2014]	In-situ
3	pH	-	SNI 06-6989.11-2004	In-situ
4	DO	$mg \cdot L^{-1}$	SNI 06-6989.14-2004	Ex-situ
5	COD	$mg \cdot L^{-1}$	APHA 5220 B 2017	Ex-situ
6	BOD	$mg \cdot L^{-1}$	APHA 5210 B 2012	Ex-situ
7	Nitrate	$mg \cdot L^{-1}$	SNI 19-6964.7-2003	Ex-situ
8	Nitrite	$mg \cdot L^{-1}$	SNI 06-6989.9:2004	Ex-situ
9	Ammonia	$mg \cdot L^{-1}$	SNI 06-6989.30-2005	Ex-situ
10	Total phosphate	$mg \cdot L^{-1}$	SNI 06-2483-1991	Ex-situ
11	TSS	$mg \cdot L^{-1}$	SNI 6989.3:2019	Ex-situ
12	TDS	$mg \cdot L^{-1}$	SNI 6989.27:2019	Ex-situ
13	Total coliform	$Ind \cdot 100\ cm^{-3}$	SNI 06-4158-1996	Ex-situ

laboratory. Furthermore, we also observed the structure of phytoplankton community in Lake Ranu Grati's water as well as its abundance by using the Lackey's drop method.

Data analysis

To assess the water quality status of Lake Ranu Grati, we used two approaches: (1) Calculated the classical water quality index using the STORET method, and (2) identified the potential harmful algae from the phytoplankton community structure of Lake Ranu Grati and its associated risks. Furthermore, we also analysed the relationship between the observed water quality parameters with phytoplankton abundance via the Canonical Correspondence Analysis (CCA) [Greenacre, 2010], which was performed using the statistical software PAST version 4.0.

RESULTS AND DISCUSSION

Water quality measurement results

The following Table 2 shows that water quality parameter measurement results of Lake Ranu Grati which mostly met the expected standards of the Indonesia Ministry of Environment Article No. 82 of 2001. However, several parameters that exceed the standard were COD, BOD, and ammonia. Laku Ranu Grati's temperature was around 30 °C with small variations across sites, and the value of DO was greater than 10 mg·L^{-1}. Water temperature is one of the most important measurement criteria for eutrophication [Bouraï et al., 2020]. As water temperature rises, it decreases the DO and leads to nutrients escalation, which aids the development and reproduction of algae and speeds up the eutrophication process [Li et al., 2013]. The pH ranged within 7.05 to 7.26, meaning the water was quite neutral to a little alkaline. Extremely values of pH are unfavourable for an aquatic ecosystem. A high pH may retain the growth of phytoplankton [Hansen, 2002], and a low pH creates the lowest degree of organism diversity [Spyra, 2017]. The water transparency of Lake Ranu Grati was greater than 1 m, except for site 7. A reduction of water transparency may impact aquatic organisms that rely on vision for foraging, breeding or intra-specific communication [Bartels et al., 2012].

On the other hand, total phosphate content of the lake was less than 0.2 mg·L^{-1}, as well as TSS and TDS concentration, which were below 50 mg·L^{-1}and 1000 mg·L^{-1}, respectively. TSS raises a waterbody's turbidity which limits light exposure, and in turn impairs aquatic plants' photosynthetic processes, possibly leading to oxygen depletion [Bilotta and Brazier, 2008]. TDS is an integrated indicator of a waterbody's quantity of soluble components. Ecotoxicological effects can be caused by the particular ions and their concentrations belonging to TDS [Weber-Scannell and Duffy, 2007]. In addition, the biological parameter (total coliform) provided satisfying results, being less than 30 ind·100 cm^{-3}. This parameter is key to water quality in freshwater systems because it can decide whether the water available is for recreation or drinking purposes [Seo et al., 2019].

On the other hand, COD observation was mostly over 13 mg.L^{-1}which surpassed the

Table 2. The water quality parameters of Lake Ranu Grati

Parameter	RG1	RG2	RG3	RG4	RG5	RG6	RG7	Standard
Temperature (°C)	30.11	29.78	29.89	30.56	30.67	30.22	30.56	Deviation 3
Transparency (m)	1.48	1.42	1.14	1.25	1.20	1.42	0.99	not specified
pH	7.10	7.10	7.18	7.22	7.26	7.05	7.17	6-9
DO (mg·L^{-1})	11.81	11.92	10.83	11.12	11.73	11.36	11.37	6
COD (mg·L^{-1})	8.60	13.30	21.00	18.00	13.87	11.63	15.90	10
BOD (mg·L^{-1})	1.93	3.23	4.10	4.10	2.30	2.00	2.00	3
Nitrate (mg·L^{-1})	1.35	1.93	2.23	2.12	1.77	1.43	1.82	10
Nitrite (mg·L^{-1})	0.01	0.02	0.02	0.01	0.04	0.03	0.04	0.06
Ammonia (mg·L^{-1})	0.40	0.48	0.39	0.42	0.42	0.60	0.61	0.05
Total Phosphate (mg·L^{-1})	0.14	0.11	0.18	0.15	0.14	0.14	0.16	0.2
TSS (mg·L^{-1})	14.67	21.67	21.67	15.67	24.00	26.00	23.33	50
TDS (mg·L^{-1})	13.33	17.00	15.33	11.33	17.67	16.00	19.67	1000
Total Coliform (ind·100 cm^{-3})	20.67	15.00	5.33	4.67	9.00	11.00	4.67	5000

standard value set at 10 mg·L^{-1}. Similarly, some BOD results were greater than the quality standard (3 mg·L^{-1}) found at sites 2, 3 and 4. Both parameters reflect the levels of organic pollutants in the waterbody that absorb oxygen, and thus represent an intense anthropogenic disturbance [Xu et al., 2020]. Furthermore, nitrate and nitrite values were 1.35 to 2.23 m mg·L^{-1} and 0.01 to 0.04 mg·L^{-1}, respectively. However, the ammonia concentration was 0.39 to 0.61 mg·L^{-1}, which was far higher than the standard (0.05 mg·L^{-1}). The contamination of nitrogen in water has become a serious global environmental problem [Leoni et al., 2018]. It induces eutrophication of water, promotes the development of dinoflagellates and cyanobacteria, affects the blooms of phytoplankton and poses a possible risk to human health [Zekker et al., 2012; Collos and Harrison, 2014]. Further analysis of water quality measurement results to produce the STORET Index (Table 3) showed that sites 1, 6 and 7 classified as moderately polluted, while the rest were lightly polluted. This is a consequence of the excessive values of COD, BOD, and ammonia in sites 1, 6 and 7 which were beyond the quality standard.

The abundance and community structure of phytoplankton

According to Figure 2, it can be seen that the phytoplankton abundance of Lake Ranu Grati ranges from 40000 ind·L^{-1} to 160000 ind·L^{-1}. The highest abundance was found at site 7, while the lowest was at site 1. Site 7 is an area located near an agricultural land and community plantations. Therefore, the site is susceptible to agricultural runoffs containing organic wastes that support nutrient enrichment in water [Wisha et al., 2018].

Table 3. Water quality STORET index

Site	Storet index	Category
RG1	-18	Moderately polluted
RG2	-10	Lightly polluted
RG3	-10	Lightly polluted
RG4	-10	Lightly polluted
RG5	-10	Lightly polluted
RG6	-20	Moderately polluted
RG7	-20	Moderately polluted

As the consequence, it led to rapid phytoplankton growth and induced water eutrophication [Lusiana et al., 2019]. Furthermore, the composition of phytoplankton in Lake Ranu Grati consisted of five divisions: Chlorophyta, Charophyta, Cyanophyta, Euglenophyta. The most dominant division was Chlorophyta, which comprised more than three-fourth of the overall phytoplankton divisions, followed by Charophyta and Cyanophyta. The specific genus composition of each division can be found in Table 4.

The Chlorophyta division was composed of genera *Chlorococcum, Coelastrum, Zoochlorella* and *Chlorochytrium*. All these genera can be found in each site, except *Chlorochytrium* which was absent in Site 2. Green algae species from genus *Chlorococcum* contain bioactive compounds with antimicrobial activity that are effective against microbial pathogens [Bhagavathy et al., 2011]. Meanwhile, genus *Coelastrum* is considered to largely emerge during spring or summer. The species belong to this genus are considered a "by-catch" food for juvenile fish due to its small size [Richter et al., 2013]. Meanwhile, *Zoochlorella* can be used as a wastewater treatment agent as it can reduce the concentration of

Table 4. Phytoplankton community structure

Division	Genus	RG1	RG2	RG3	RG4	RG5	RG6	RG7
Chlorophyta	*Chlorococcum*	+	+	+	+	+	+	+
	Coelastrum	+	+	+	+	+	+	+
	Zoochlorella	+	+	+	+	+	+	+
	Chlorochytrium	+	-	+	+	+	+	+
Charophyta	*Euastrum*	+	+	+	+	+	+	+
Cyanophyta	*Amphitrix*	+	+	+	+	+	-	+
	Chroococcus	+	+	+	+	+	+	+
	Coelosphaerium	-	-	-	-	+	+	+
Chrysophyta	*Goniochloris*	+	+	-	+	+	-	-
Euglenophyta	*Euglena*	+	+	+	+	+	+	+
	Trachelomonas	-	-	+	+	-	+	+

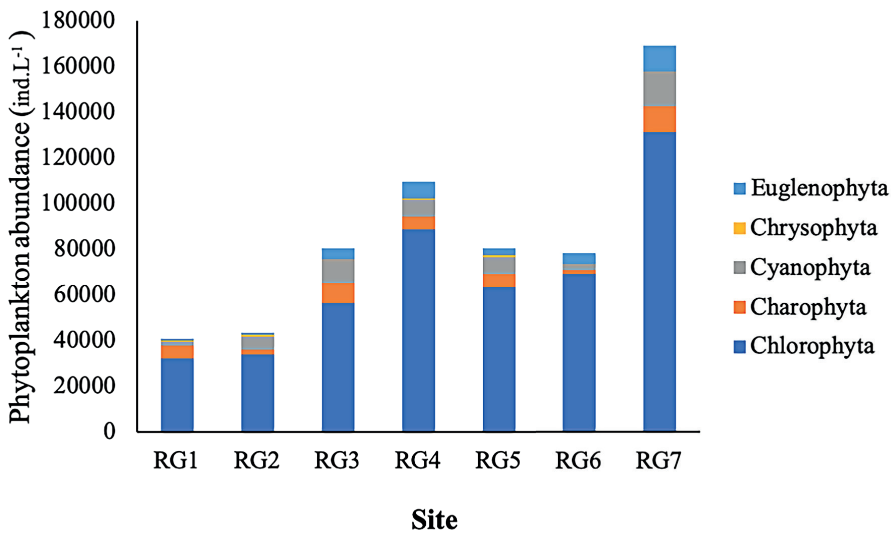

Figure 2. The abundance of phytoplankton

COD and BOD [Arsad et al., 2020]. Charophyta and Chrysophyta are both divisions that are represented by a single genus, which are *Euastrum* and *Goniochloris*, respectively. *Euastrum* is a genera that is mainly distributed in aquatic ecosystem located in the mountains and lowland areas [Lenarczyk et al., 2015], while a study reported species of *Goniochloris* being found in a subarctic lake [Forsström et al., 2005].

Cyanophyta and Euglenophyta or dinoflagellate are widely known as the main reasons behind HABs, around the world [Berdalet et al., 2015; Yunes, 2019]. From the three genera of Cyanophyta division, only genus *Coelosphaerium* has been previously reported to cause environmental degradation. A species of this genera was related to the geosmin that caused musty odour outbreaks in Lake Shinji, Japan [Godo et al., 2017]. An unpleasant taste and odour of aquatic ecosystems contribute to the reduction in the quality of drinking water and fisheries [Wurtsbaugh et al., 2019]. Genus *Coelosphaerium*, in this study, was only present at sites 5, 6 and 7. On the other hand, genera *Euglena* and *Trachelomonas* have been reported to be associated with harmful algae occurrences. *Euglena* produces an alkaloid euglenophycin toxin which is known to kill fish and hinder the development of mammalian tissue and microalgal production [Zimba et al., 2017]. Nevertheless, a *Trachelomonas* species population was formed during the development of *Planktothrix agardhii* bloom and contained extracellular microcystin [Grabowska and Wołowski, 2014]. It is an important attributor of cyanobacterial bloom in water bodies and the primary cause behind microcystins (MCs). MCs are cyclic secondary metabolites of heptapeptides that are extremely stable and toxic. Potential severe health issues such as liver cancer, pneumonia and gastroenteritis are caused by excessive doses or long-term exposure to MCs [Dong et al., 2016]. Genus *Euglena* was found at all sites, but *Trachelomonas* was absent from sites 1, 2 and 5. According to the results, it can be said that sites 6 and 7 are the most polluted areas of Lake Ranu Grati due to the presence of harmful algae from the Cyanophyta (*Coelosphaerium*) and Euglenophyta (*Euglena* and *Trachelomonas*) division. The results are in line with the STORET index of sites 6 and 7, which categorised them as moderately polluted as compared to other sites which were classified as lightly polluted.

Canonical corresponding analysis (CCA) – water quality parameter associated with potential harmful algae presence

From the previous section, it can be seen that the potential harmful algae in this study come from Cyanophyta and Euglenophyta division. We performed a CCA to analyse the water quality factors associated with their presence. The relationship was obtained by taking the shortest projection of the division point to the water quality parameter vector from the CCA triplot. According to Figure 3, the Cyanophyta species are likely to occur in high concentrations of TSS, TDS, COD, BOD, nitrite, nitrate, total phosphate, moderate ammonia, temperature, transparency, and low concentration of DO, pH and total coliform. Similarly, the appearance of Euglenophyta corresponds with high

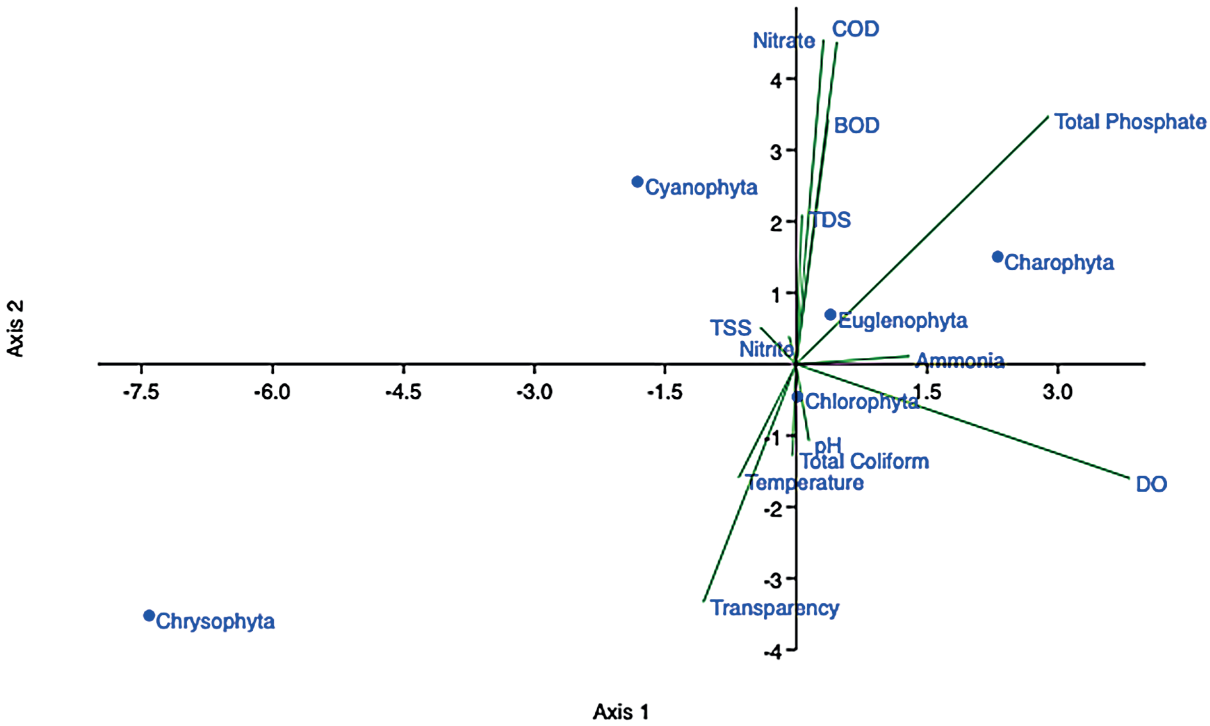

Figure 3. CCA results of this study

total phosphate, TDS, TSS, COD, BOD, nitrate, nitrite, DO, low temperature, transparency, total coliform, and moderate pH and DO.

In conforming to the results of the water quality measurement of Lake Ranu Grati (Table 2), the prime parameters for the water were determined as COD and BOD, also reflected in the potential harmful algae presence. This finding is in line with study conducted at the Mid-Cross river floodplain, Nigeria, that showed the association of elevated density of Cyanobacteria with a decline in dissolved oxygen and a rise in BOD values [Okogwu and Ugwumba, 2009]. In addition, research from Wuhan Lake, China, also reported that Cyanobacteria and Euglenophyta were positively correlated with COD and BOD [Lv et al., 2011]. The identification of COD and BOD factors are as important water quality parameters, indicating the urgency of controlling anthropogenic activities in the formation of aquaculture (site 6) and agriculture (site 7) around the lake as an attempt to maintain the water quality conditions of Lake Ranu Grati.

CONCLUSION

Generally, the water quality measurement results of Lake Ranu Grati showed optimum conditions because the values met the quality standard set by the government. Only three parameters (COD, BOD, ammonia) exceeded the standard value. Moreover, the STORET index classified the seven sites in Lake Ranu Grati as lightly polluted (sites 2, 3, 4 and 5) and moderately polluted (sites 1, 6 and 7). Furthermore, by considering the presence of potential harmful algae from the Cyanophyta (*Coelosphaerium*) and Euglenophyta (*Euglena* and *Trachelomonas*) divisions, it was suggested that sites 6 and 7 were the most polluted areas of Lake Ranu Grati, with corresponding high concentrations of COD and BOD. This finding indicates that agricultural and aquaculture activities around the lake need to be controlled to maintain the sustainability of the water quality condition of Lake Ranu Grati.

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