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Research Article

The Occurrences of Harmful Algal Blooms (HABs) Species and Trophic Status Update in Kedung Ombo Reservoir

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Abstract

Anthropogenic inputs affect the quality of freshwater ecosystems which causes ecological and health problems to aquatic ecosystems. Harmful algal blooms (HABs) associated with cyanotoxins often occur in nutrient-rich or eutrophic freshwater ecosystems. Kedung Ombo Reservoir in Indonesia has been previously classified as eutrophic to hypertrophic. Therefore, this study aimed to identify the occurrences of potential HABs species, measure the bio-physico-chemical water quality parameters, and update the trophic status of Kedung Ombo Reservoir. Sampling was done thrice during the dry season in 2022 from 5 stations. Twenty-two species of phytoplankton were observed in Kedung Ombo Reservoir. *Anabaenopsis* sp., *Aphanizomenon* sp., *Ceratium* sp., *Mougeotia* sp., *Pandorina* sp., and *Ulothrix* sp. were identified as potentially harmful species. Among those, the potentially HABs species, *Aphanizomenon* sp. was the most abundant (179,344 cells/L) and Cyanophyceae (205,539 cells/L) was the dominant group of phytoplankton. Kedung Ombo Reservoir had a water temperature of 29.49±0.41°C, phosphate of 0.27±0.25 mg/L, and alkaline pH of 7.90±0.39. Kedung Ombo Reservoir also had low transparency coupled with low dissolved oxygen concentration. The occurrences of HABs species were correlated with transparency and dissolved inorganic nutrients, especially phosphate concentrations. Kedung Ombo Reservoir showed eutrophic conditions based on Secchi depth, chlorophyll-a, total phosphorus, and TSI. Based on research findings, control and mitigation efforts are needed to overcome the eutrophication problems which disrupt the balance of the aquatic ecosystem in the Kedung Ombo Reservoir.

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1. Introduction

Anthropogenic nutrient inputs affect the quality of freshwater aquatic systems causing ecological and health problems (Simanjuntak and Muhammad, 2018). Anthropogenic activities including irrigation, aquaculture, sewage waste disposal, contribute to nutrient enrichment which causes eutrophication (Álvarez *et al*., 2017; Liu *et al*., 2023; Malone and Newton, 2020; Minakova *et al*., 2019; Zhou *et al*., 2020).

Some forms of aquaculture, for example fish cages and ponds, can provide significant nutrient inputs to the environment (Du *et al*., 2022; Tabrett *et al*., 2024). The dynamics of nutrient input and eutrophication influence the growth of harmful algae in an ecosystem (Boivin-Rioux *et al*., 2022; Glibert, 2020). Eutrophication has caused an increase in phytoplankton biomass (Weigelhofer *et al*., 2018). For example, the blooms of nuisance cyanobacteria generally occur in lentic waters, such as lakes, and causes degradation of aquatic ecosystems (Gao *et al*., 2022; Sulastri *et al*., 2023). First algae bloom disaster in Indonesia was documented from 1991 in Lampung Bay. Harmful algal blooms (HABs) are common in Jakarta Bay, Ambon Bay, and Lampung Bay (Sidabutar *et al*., 2024).

The Kedung Ombo Reservoir is an example of an anthropogenically influenced aquatic ecosystem that experienced a decline in water quality and aquaculture carrying capacity between 1989 and 2012 (Legono *et al*., 2022). Simanjuntak and Muhammad (2018) found that in 2017 net cages aquaculture had exceeded the carrying capacity of the reservoir with a total of 3,781 net cages (185,269 m^2). Hidayah *et al*. (2014) found that the number of phytoplankton in the Kedung Ombo Reservoir was 195,988 cells/L, which indicates the trophic status of eutrophic waters. Therefore, it is necessary to carry out further research on plankton which shows the trophic status of the Kedung Ombo Reservoir. In addition to the influence of nutrient availability, physical factors also play an important role in phytoplankton variation (Park *et al*., 2023).

Determining trophic status based on multifactor can provide comprehensive information and assessments. Thus, this study focuses on identifying the occurrences of potentially harmful algal blooms (HABs) species, the biophysical-chemical water quality parameters responsible for algal occurrence, and the current trophic status of Kedung Ombo Reservoir.

2. Materials and Methods

2.1 Materials

The materials used were water samples, Lugol's solution, and 90% acetone. The tools used were Water Quality Checker LAQUA PD-220, Van Dorn Bottle, Secchi disc, plankton net with a mesh size of 25 µm, HDPE bottles, cold box, DRT-15CE turbidimeter, Sedgewick Rafter counting cells, cover glass, Olympus CX23 binocular microscope, and spectrophotometer Optima SP-3000 plus.

2.1.1 Ethical approval

This study does not require approval because it does not use experimental animals.

2.2 Methods

2.2.1 Study area

Kedung Ombo Reservoir, with an area of 4,800 ha, is located in Central Java province, Indonesia. The Kedung Ombo Reservoir is one of the large reservoirs in Indonesia over the borders of three regions, namely Sragen, Grobogan, and Boyolali (Purwana *et al*., 2019). The main water source of the reservoir consists of the Jrabung, Tuntang, Serang, Lusi, and Juara rivers. The reservoir has a volume of 0.72 km^3. Kedung Ombo Reservoir is used for rice field irrigation, tourism, power generation, drinking water sources, aquaculture in the form of floating net cages, and capture fisheries (Simanjuntak and Muhammad, 2018).

There were five stations in this research (Figure 1), which were determined based on water use and fish cultivation density. Station 1 was in the floating restaurant tourism area, Station 2 was in the waters with a low density of floating net cages aquaculture, Station 3 was in the waters with a high density of floating net cages aquaculture, Station 4 was in the waters with a medium density of floating net cages aquaculture, and Station 5 was located at the outlet of the reservoir

2.2.2 Sample collection and analysis

The samples were collected three times at each sampling site during the dry season in the southeast monsoon in June, July, and August 2022, considering anthropogenic activities and the absence of nutrient degradation by rainwater. Samples were taken from the surface of the water.

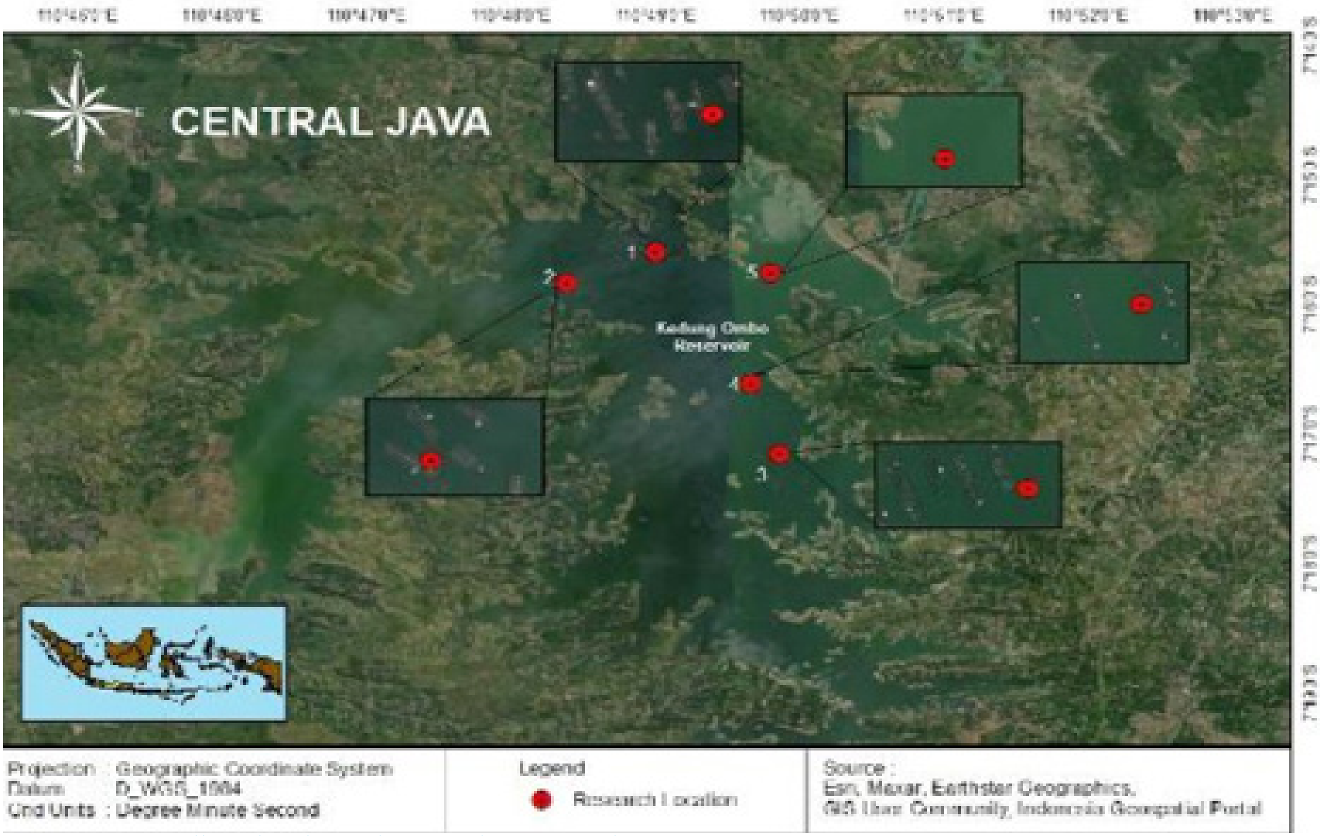

Figure 1. Sampling sites in Kedung Ombo Reservoir.

Water quality variables such as temperature, dissolved oxygen (DO), and pH were measured on-site using LAQUA PD-220. The turbidity was measured using a turbidimeter. Water transparency or Secchi depth was measured using a Secchi disc. Surface water samples were collected at each station using Van Dorn Bottle. Dissolved nutrients (ammonia, nitrate, and phosphate) and chlorophyll-a were analyzed using the spectrophotometric method. Measurement of ammonia, nitrate, and phosphate was done using a spectrophotometer with the phenate, ascorbic acid, and brucin sulfate methods, respectively. Unfiltered water was collected for chlorophyll-a from all stations. The chlorophyll pigment was extracted with 90% acetone. The extracted chlorophyll was measured using a spectrophotometer at 630, 647, 664, and 750 nm wavelengths following APHA (American Public Health Association, 2005).

Water samples for phytoplankton analysis were filtered with a plankton net (mesh size = 25 µm). Furthermore, the samples were put into HDPE bottles and preserved with Lugol 1% solution. Water and phytoplankton samples were stored in a cold box containing blue ice for further analysis in the laboratory. The phytoplankton samples were put into the Sedgewick Rafter counting cells and covered with a covered glass. Observation and identification were performed using an Olympus CX23 binocular microscope at 100x magnification. Phytoplankton identification was observed morphologically using the phytoplankton identification book (van Vuuren *et al*., 2006; Bellinger and Sigee, 2010; Sulastri, 2018).

The identification of potentially harmful phytoplankton was based on Watson et al. (2015). The occurrences of HABs were explained descriptively from the total abundance of harmful algae species that were found in Kedung Ombo Reservoir. Phytoplankton per liter expressed in cells/L was counted based on equation 1 (APHA, 2005):

$$N = n \times \frac{A_{cg}}{A_a} \times \frac{V_t}{V_s} \times \frac{1}{A_s} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where:
N = Phytoplankton abundance (cells/L)
n = Number of observed cells (cells)
Acg = Sedgewick-Rafter surface area (mm2)
Aa = Observation area (mm2)
Vt = Filtered volume (mL)
Vs = Volume of filtered water sample (L)
As = Volume of water in Sedgewick-Rafter (mL)

2.2.3 Analysis Data

The TSI method was one of the parameters used to determine the trophic status in Kedung Ombo Reservoir. The TSI method is calculated based on three variables that greatly affect the trophic status of the reservoir, which are Secchi depth (SD), chlorophyll-a (Chl), and total phosphorus (TP). The value of TSI is determined from each parameter (TSISD, TSIChl, and TSITP). The formula for calculating the TSI is as follows (Carlson, 1977):

$$TSI_{SD} = 10\left(6 - \frac{\ln SD}{\ln 2}\right) \tag{2}$$

$$TSI_{Chl} = 10\left(6 - \frac{2{,}04 - 0{,}68 \ln Chl}{\ln 2}\right) \tag{3}$$

$$TSI_{TP} = 10\left(6 - \frac{\ln\left(\frac{48}{TP}\right)}{\ln 2}\right) \tag{4}$$

$$TSI = \frac{(TSI_{SD} + TSI_{Chl} + TSI_{TP})}{3} \tag{5}$$

Where:

TSI = Trophic state index
SD = Secchi depth (m)
Chl = Chlorophyll-a (µg/L)
TP = Total phosphorus (µg/L)
TSISD = Trophic status index for Secchi depth
TSIChl = Trophic status index for chlorophyll-a
TSITP = Trophic status index for total phosphorus

TSI values, Secchi depth, chlorophyll-a, and total phosphorus were used to determine the trophic states of Kedung Ombo Reservoir based on predefined categories in Table 2. Statistical analysis methods such as the one-way ANOVA was used to determine the influence of stations on the water quality variables and canonical correspondence analysis (CCA) was used to identify the relationship between water quality variables and HABs abundance in the Kedung Ombo Reservoir.

3. Results and Discussion

3.1 Result

3.1.1 Water quality variables

The water quality variables measured in the Kedung Ombo Reservoir consist of temperature, transparency, turbidity, dissolved oxygen, pH, ammonia, nitrate, phosphate, and chlorophyll-a (Table 1). Kedung Ombo Reservoir had a water temperature of 28.90-30.50°C, transparency of 60.00-100.50 cm, and turbidity of 3.17-20.18 NTU. The DO concentration was low, between 2.04-3.92 mg/L. The pH of Kedung Ombo Reservoir is classified as alkaline, between 7.10-8.53. The phosphate concentration was 0.10-0.88 mg/L. High phosphate concentration and transparency are associated with the abundance of HABs (Figure 2).

Table 1. Water quality variables in Kedung Ombo Reservoir.

Variables	Station 1	Station 2	Station 3	Station 4	Station 5	Min	Max	p[1]	Standard*
Temperature (^{o}C)	29.37±0.29	29.47±0.45	29.4±0.44	29.37±0.31	29.87±0.60	28.9	30.5	0.845	Deviation 3
Transparency (cm)	81.17±9.70	90.50±13.61	75.00±8.66	80.83±12.83	77.50±15.21	60	100.5	0.727	250
Turbidity (NTU)	4.66±1.26	4.31±1.02	4.11±0.51	4.39±0.51	9.61±9.18	3.17	20.18	0.858	-
Dissolved Oxygen (mg/L)	2.92±0.27	3.26±0.62	2.88±0.46	2.71±0.63	3.19±0.42	2.04	3.92	0.804	3
pH	7.86±0.72	8.06±0.34	7.76±0.20	7.71±0.26	8.1±0.38	7.1	8.53	0.626	6-9
Ammonia (mg/L)	0.21±0.14	0.09±0.07	0.14±0.03	0.23±0.18	0.16±0.21	0.01	0.43	0.709	-
Nitrate (mg/L)	0.3±0.10	0.27±0.06	0.33±0.06	0.3±0.10	0.43±0.25	0.2	0.7	0.739	-
Phosphate (mg/L)	0.14±0.03	0.48±0.37	0.4±0.41	0.15±0.04	0.21±0.02	0.1	0.88	0.140	0.1
Chlorophyll-a (µg/L)	7.66±1.61	7.51±0.16	9.01±0.55	9.68±0.25	7.58±0.68	6.73	9.82	0.036	100
TSI	57.46±7.00	50.95±3.66	51.93±2.56	54.94±3.74	55.44±5.80	48.79	63.98	0.002	-

Note:
[1] ANOVA with p<0.05 was classified as statistically significant.
[2] Water quality standards based on government regulation number 22 of 2021 concerning the Implementation of Environmental Protection and Management.

The nitrate concentration was 0.20-0.70 mg/L, while the ammonia concentration was 0.01-0.43 mg/L. The concentration of chlorophyll-a in the surface water of Kedung Ombo Reservoir varied between 6.73-9.82 µg/L. The lowest chlorophyll-a concentration was at station 2, which was in the lowest density of floating net cages aquaculture, and the highest chlorophyll-a concentration was at stations 3 and 4, which were in the high and medium density of floating net cages aquaculture.

3.1.2 Trophic state

The trophic state in Kedung Ombo Reservoir was determined based on chlorophyll-a, total phosphorus, Secchi depth, and TSI. The eutrophic conditions based on chlorophyll-a and TSI were found at all stations (Figure 3). The correlation between phytoplankton abundance and TSI was moderate (r=0.43) but not significant, and the coefficient of determination explained 16.2%. The dominant phytoplankton group in this study was Cyanophyceae (blue-green algae). Eutrophic and hypertrophic states were found at all stations. The hypertrophic state was determined based on the Secchi depth.

Table 2. Trophic states categories based on TSI values (Prasad and Siddaraju, 2012), Secchi depth (Vundo *et al.*, 2019), chlorophyll-a (Håkanson and Blenckner, 2014), and total phosphorus (Vollenweider, 1968).

Trophic States	TSI Values	Secchi Depth (cm)	Chlorophyll-a (µg/L)	Total Phosphorus (µg/L)
Oligotrophic	<30-40	600-1200	<2	<10
Mesotrophic	40-50	300-600	2-6	10-30
Eutrophic	>50	150-300	6-20	30-100
Hypertrophic	-	<150	>20	>100

3.1.3 Potential HABs species occurrences

There are six species included in potentially harmful algae, namely *Aphanizomenon* sp., *Anabaenopsis* sp., *Ceratium* sp., *Mougeotia* sp., *Pandorina* sp., and *Ulothrix* sp. (Table 3). Aphanizomenon sp. and *Anabaenopsis* sp. were from blue-green algae (Cyanophyceae). *Ceratium* sp. from dinoflagellates (Dinophyceae). Green algae (Cholorophyceae) that are potentially harmful in Kedung Ombo Reservoir were *Mougeotia* sp., *Pandorina* sp., and *Ulothrix* sp.

3.1.4 Phytoplankton abundance

There were twenty-two species of phytoplankton observed, consisting of three diatom species (Bacillariophyceae), twelve species of green algae (Chlorophyceae), four species of blue-green algae (Cyanophyceae), one species of dinoflagellates (Dinophyceae), and two species of Euglenophyceae (Figure 4). The highest phytoplankton abundance was found at station 2 (71,054 cells/L), while station 3 was the lowest (48,249 cells/L) (Figure 5). The dominant phytoplankton group in this study was Cyanophyceae (205,539 cells/L or 73.56%) (Figure 6). The abundance of *Aphanizomenon sp.* from Cyanophyceae amounted to 179,344 cells/L or 64.19% of the total phytoplankton abundance at all stations.

3.2 Discussion

The water temperature in the Kedung Ombo Reservoir was 28.90-30.50°C. Water temperature influences the chemical and/or physical factors of the water, so it becomes an important factor in the life of aquatic organisms. Temperature affects phytoplankton species (Vidyarathna *et al.*, 2020). Cyanophyceae grow optimally at temperatures of more than 25°C, while dinoflagellates at 10-25°C, and diatoms at 25-35°C (Briddon *et al.*, 2022). Kedung Ombo Reservoir has low transparency (average <150 cm), which is classified as hypertrophic (Table 2). The transparency value is inversely correlated with the turbidity value. The level of turbidity was fairly turbid (Azis *et al.*, 2015). The turbidity standard for lakes and reservoirs is <25 NTU (Sahoo and Anandhi, 2023).

The DO concentration was 2.04-3.92 mg/L. The low DO concentration is caused by low solubility in water at high temperatures. Low DO concentrations indicate an unhealthy aquatic ecosystem (Baleta and Bolaños, 2016). The pH of Kedung Ombo Reservoir is classified as alkaline, between 7.10-8.53. In other studies, alkaline conditions were caused by Cyanophyceae activity. Cyanophyceae have a very wide range of optimal pH conditions, from neutral to very alkaline levels (Fang *et al.*, 2018). pH fluctuations of 1.60 or more cause many negative impacts and serious problems for phytoplankton communities in freshwater ecosystems (Chakraborty *et al.*, 2021).

An important variable of the phytoplankton limiting factor was phosphate. The phosphate concentration in Kedung Ombo Reservoir was 0.10-0.88 mg/L. High phosphate concentration and transparency are associated with the abundance of HABs (Figure

2). Phosphate concentrations between 0.2-2.8 mg/L are preferred for the growth of Cyanophyceae and Bacillariophyceae in aquatic ecosystems (Baleta and Bolaños, 2016). Nitrate and ammonia are important nitrogen sources for phytoplankton growth. Nitrate and ammonia in waters are often influenced by anthropogenic activities. Ammonia can inhibit nitrate uptake by phytoplankton. Nitrates come from the production and use of fertilizers. Nitrates are usually less dangerous than ammonia (Wang *et al.*, 2023). Nutrient enrichment must be controlled because it can trigger algae blooms and eutrophication. Eutrophication in waters is associated with increased inputs of dissolved inorganic nitrogen and phosphate, which stimulates the growth of primary organisms in aquatic ecosystems (Smyth *et al.*, 2022).

The concentration of chlorophyll-a in the surface water of Kedung Ombo Reservoir was varied. Chlorophyll-a concentrations were related to high concentrations of total phosphorus and ammonia (Figure 2). It was indicated that the chlorophyll-a concentration pattern was correlated with the nutrient distribution pattern. The same pattern was found in Benoa Bay, Bali (Rahayu *et al.*, 2018). Another study also found that phytoplankton abundance has a strong correlation with chlorophyll-a concentration (Ridho *et al.*, 2020).

This study found that chlorophyll-a concentration had a moderate correlation with phytoplankton abundance. This shows that chlorophyll-a concentration has no significant effect on phytoplankton abundance ($p > 0.05$). A similar result was found in Benoa Bay, Bali (Suteja *et al.*, 2021),

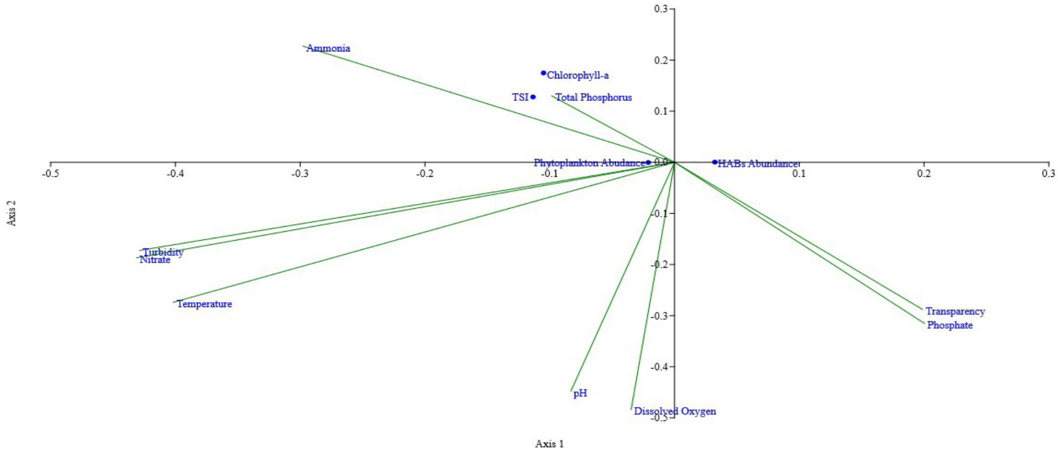

Figure 2. CCA plot showing the relationship between water quality variables and HABs abundance.

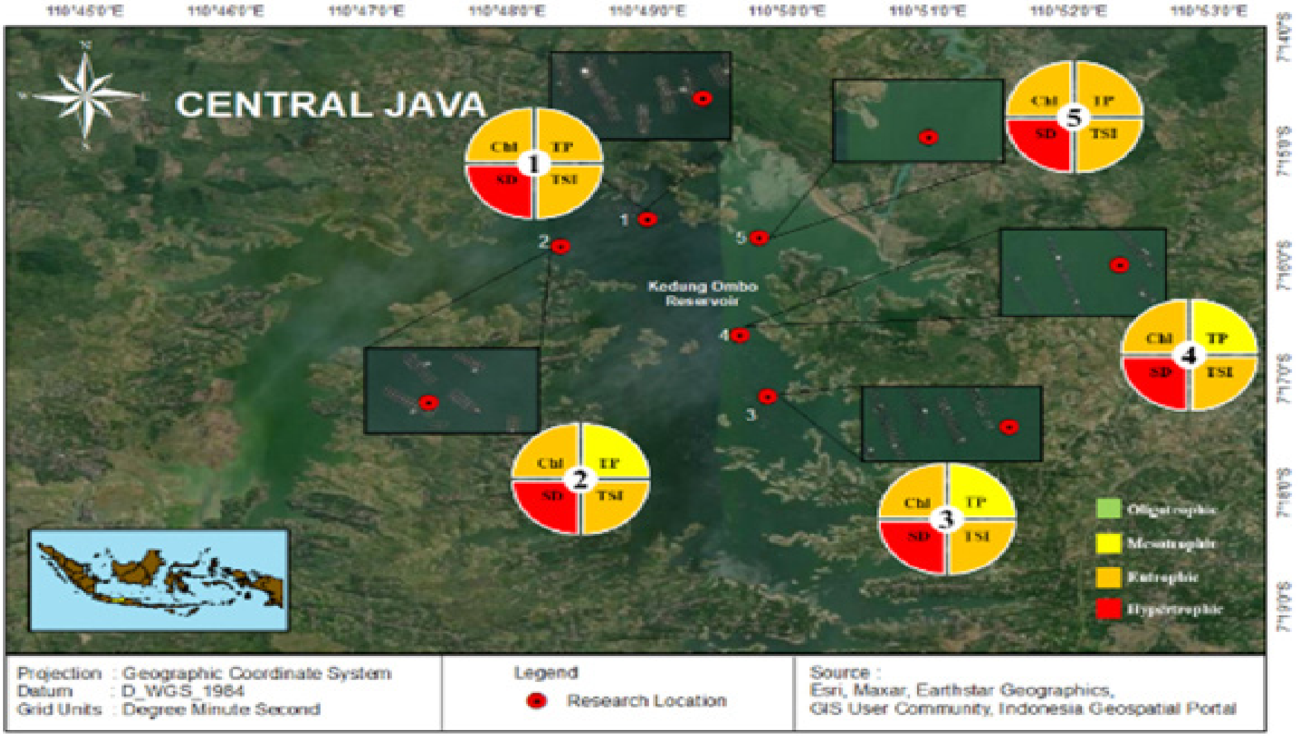

Figure 3. Trophic states based on chlorophyll-a (Chl), total phosphorus (TP), Secchi depth (SD), and TSI.

and Bintan, Riau Island Province, Indonesia (Syakti *et al*., 2019). However, several other conditions can influence chlorophyll-a concentration, such as the average phytoplankton cell volume, dominant plankton species, water conditions, season, and tides (Suteja *et al*., 2021). Chlorophyll-a estimation has the potential to be used as an indicator of HABs (Kimambo *et al*., 2019; Na *et al*., 2022). Further research is needed to determine the dynamics of chlorophyll-a concentration.

Table 3. Phytoplankton species in Kedung Ombo Reservoir. Potentially harmful species were text highlighted. (+) = cell abundance 1-10 cells/l; (++) = cell abundance 10-102 cells/l; (+++) = cell abundance 102-103 cells/l; (++++) = cell abundance 103-104 cells/l; (+++++) = >104 cells/l; (-) = not found.

Group	Species	Station 1	Station 2	Station 3	Station 4	Station 5
Bacillariophyceae	*Navicula sp.*	++++	++++	++++	++++	++++
	Nitzschia sp.	+++	+++	++++	++++	++++
	Synedra sp.	+++	++	++	++	++
Chlorophyceae	*Chlamydomonas sp.*	+++	+++	+++	+++	+++
	Cosmarium sp.	+++	++	+++	++	++
	Dictyosphaerium sp.	+++	+++	+++	+++	+++
	Monoraphidium sp.	+++	++++	+++	+++	+++
	Mougeotia sp.	-	++	++	++	-
	Oocystis sp.	+++	++++	++++	++++	++++
	Pandorina sp.	+++	+++	+++	+++	+++
	Pediastrum sp.	+++	+++	+++	+++	+++
	Scenedesmus sp.	++	+++	+++	-	+++
	Sphaerocystis sp.	++++	++++	++++	++++	++++
	Staurastrum sp.	+++	+++	+++	+++	+++
	Ulothrix sp.	-	++	-	-	++
Cyanophyceae	*Anabaenopsis sp.*	++	-	-	++	++
	Aphanizomenon sp.	+++++	+++++	+++++	+++++	+++++
	Chroococcus sp.	++++	++++	++++	++++	++++
	Merismopedia sp.	++++	++++	++++	++++	++++
Dinophyceae	*Ceratium sp.*	++	++	++	-	+++
Euglenophyceae	*Phacus sp.*	+++	++	++	++	++
	Trachelomonas sp.	+++	+++	+++	+++	+++

Most of the Kedung Ombo Reservoir stations were eutrophic (poor water quality). The total phytoplankton abundance at all stations (279,413 cells/L) was in an eutrophic state (Karydis, 2009). The dominant phytoplankton group in this study was Cyanophyceae (blue-green algae). Eutrophication in lakes and reservoirs is characterized by the dominance of blue-green algae (Igwaran *et al*., 2024). Cyanophyceae have buoyancy regulation to position themselves near the water surface (Burkholder *et al*., 1995). By exploiting this buoyancy regulation mechanism, Cyanophyceae can significantly reduce water transparency. High nutrient concentrations limit light penetration in the water column. The decrease in water transparency was exacerbated by the dominance of *Aphanizomenon* sp. as a harmful algal blooms species in Kedung Ombo Reservoir. *Aphanizomenon* sp. is one of the common bloom-forming Cyanophyceae species in waters (Igwaran *et al*., 2024).

Aphanizomenon sp. and *Anabaenopsis sp.* have heterocysts to fix nitrogen. Blooms of these species cause serious problems in reservoirs and lakes (Assmy and Smetacek, 2009). The presence of these species in the Kedung Ombo Reservoir can cause the death of fish around floating net cages or in their natural habitat and has the potential to endanger the life of the aquatic environment and humans. Blue-green algae can produce neurotoxin toxins that harm animals and humans during recreational activities and other water uses. Anatoxin-a, PSTs (paralytic shellfish toxins), and homoanatoxin-a, which are neurotoxins have been detected in *Aphanizomenon* sp. Fatal doses of these toxins cause paralysis of the respiratory muscles (Watson *et al.*, 2015). The neurotoxin of Cyanobacteria blooms causes cattle and wildlife deaths (Metcalf *et al.*, 2021; Turner *et al.*, 2022).

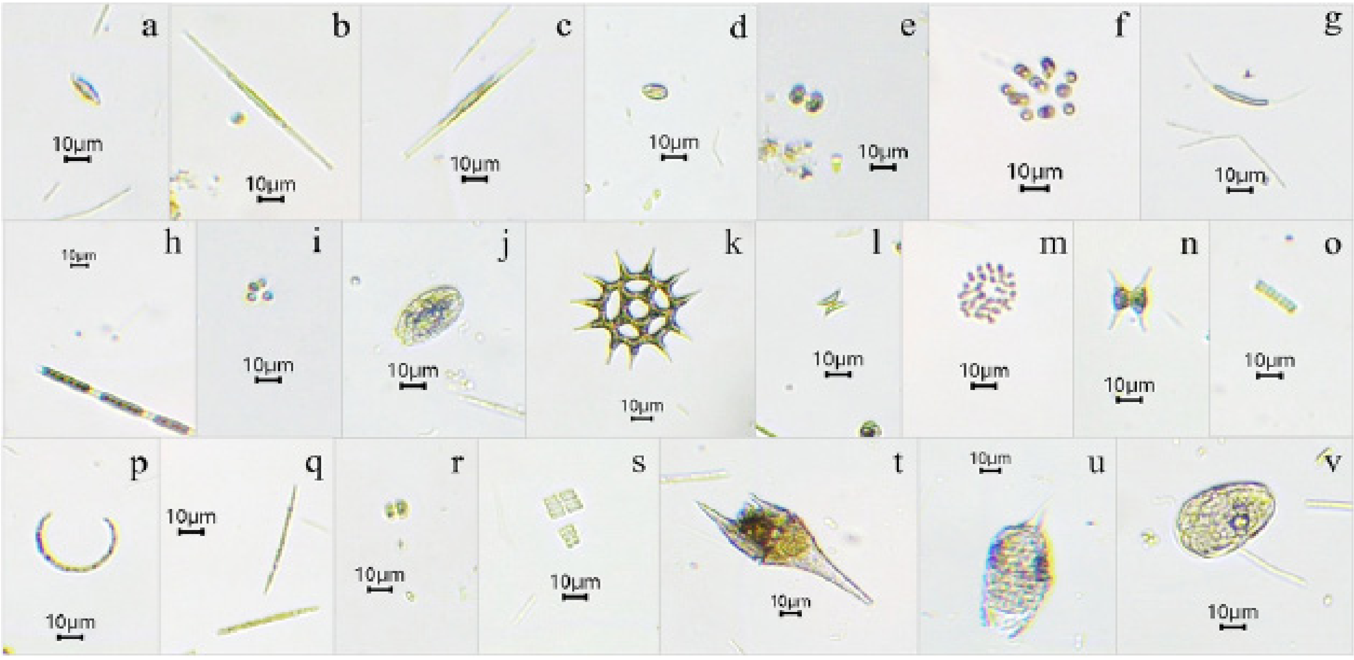

Figure 4. Phytoplankton species from Kedung Ombo Reservoir. Bacillariophyceae: a. *Navicula* sp., b. *Nitzschia* sp., c. *Synedra* sp. Chlorophyceae: d. *Chlamydomonas* sp., e. *Cosmarium* sp., f. *Dictyosphaerium* sp., g. *Monoraphidium* sp., h. *Mougeotia* sp., i. *Oocystis* sp., j. *Pandorina* sp., k. *Pediastrum* sp., l. *Scenedesmus* sp., m. *Sphaerocystis* sp., n. *Staurastrum* sp., o. *Ulothrix* sp. Cyanophyceae: p. *Anabaenopsis* sp., q. *Aphanizomenon* sp., r. *Chroococcus* sp., s. *Merismopedia* sp. Dinophyceae: t. *Ceratium* sp. *Euglenophyceae*: u. *Phacus* sp., v. *Trachelomonas* sp.

Mougeotia sp. is one of Zygnematales which is part of a mixed assemblage seen as floating mats of blooms forming filamentous chlorophytes (Watson *et al.*, 2015). *Mougeotia* sp. blooms in the littoral lakes zone occur in the early stages of acidification (Turner *et al.*, 1991). *Pandorina* sp. as Chlorophyceae with flagel is not commonly HABs species, while these blooms are associated with high inorganic nutrient supplies (Watson *et al.*, 2015). *Ulothrix* sp. was one of the filamentous Chlorophyceae. Blooms of filamentous Chlorophyceae will affect nutrient cycling, reduce water storage capacity, lead to flooding, and increase evaporative losses (Oberholster and Botha, 2011). The consequences of Chlorophyceae existence in Kedung Ombo Reservoir are potentially associated with high inorganic nutrient supplies. Chlorophyceae also cause disruption of the food web structure and anoxia during bloom decay (Watson *et al.*, 2015). *Ceratium* sp. found in the Kedung Ombo Reservoir is one of the potentially harmful algae. Odors of *Ceratium* sp. have not been identified as volatile organic compounds. It may be derived from saturated hydrocarbons (Watson *et al.*, 2015).

The phytoplankton abundance in Kedung Ombo Reservoir varies between stations. The lowest phytoplankton abundance was found at station 3, which had the highest density of floating net cage aquaculture, and vice versa in station 2. Phytoplankton biovolume and net cage aquaculture have small effects (Bartozek *et al.*, 2016). Phytoplankton abundance is influenced by nutrients, moreover, other influencing factors are light, temperature, variation, and stability of the water column (Becker *et al.*, 2010). The highest ammonia concentration in the Kedung Ombo Reservoir was at station 4 (0.23±0.18 mg/L), which has the lowest phytoplankton abundance. Ammonia could be the poison that inhibits phytoplankton growth (Suteja *et al.*, 2021).

The total phytoplankton abundance of Kedung Ombo Reservoir in this study differed from the previous study. The total phytoplankton abundance in this study was 279,413 cells/L, whereas in 2007, the highest phytoplankton abundance was reported at 163,978 cells/L (Krismono and Sugianti, 2007), and in 2014 it was 195,988 cells/L (Hidayah *et al.*, 2014). Environmental parameters such as nutrient input, season, rainfall, suspended solids, and habitat changes contribute to the differences in phytoplankton abundance. Phytoplankton abundance depends on the weather and water quality conditions in their habitat (Baleta and Bolaños, 2016).

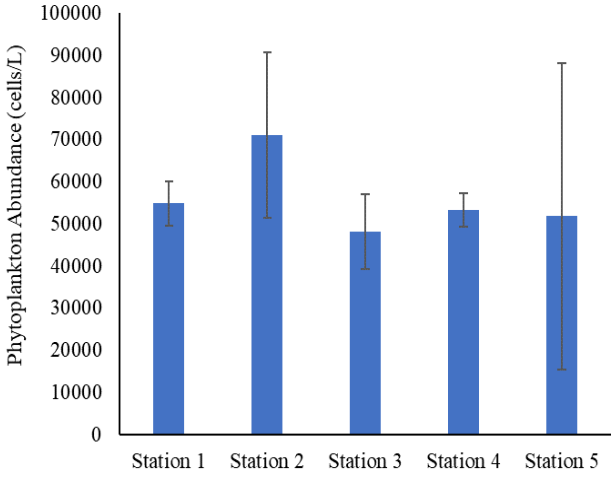

Figure 5. Phytoplankton abundance in Kedung Ombo Reservoir.

Station 2 has the highest Cyanophyceae abundance, followed by station 1 and then station 3. The possible cause is that Kedung Ombo Reservoir has *Aphanizomenon* sp. as the dominant phytoplankton, which is capable of N2-fixing (diazotrophic) like the Cyanophyceae (Watson *et al*., 2015). The dominance of Cyanophyceae is also associated with phosphate levels. Cyanophyceae blooms typically do not occur in water bodies with low phosphate levels (>0.005 mg/L) in oligotrophic conditions (Beaulieu *et al*., 2014). Meanwhile, hypertrophic conditions were observed at all stations based on phosphate in the Kedung Ombo Reservoir. This finding is supported by the dominance of the Cyanophyceae group as harmful algae in Kedung Ombo Reservoir because Cyanophyceae can survive and promote the mass proliferation of nuisance bloom-forming with luxury phosphate uptake and storage in polyphosphate bodies, and nitrogen fixation by vegetative cell compartmentalization or heterocytes mechanisms (Watson *et al*., 2015).

Cyanophyceae have been widely recorded, and their increase in the reservoir has caused environmental problems (Moraes *et al*., 2021; Thawabteh *et al*., 2023; Igwaran *et al*., 2024). Cyanophyceae were the dominant group in summer in Salto Caxias Reservoir, Brazil. Possible causes were the higher light availability and precipitation, which increased nutrient levels (Bartozek *et al*., 2016). *Aphanizomenon* sp. from Cyanophyceae, known as harmful algae species, was found to be the dominant phytoplankton in the Kedung Ombo Reservoir. The high abundance of harmful algae species in Kedung Ombo Reservoir can be a warning to the government and local communities, encouraging them to carry out control and mitigation efforts to reduce the impact of this problem. Biological strategies using biomanipulation and algicidal microorganisms produce sustainable solutions. However, monitoring and controlling HABs efficiently still needs further research and development (Xu *et al*., 2022; Anabtawi *et al*., 2024).

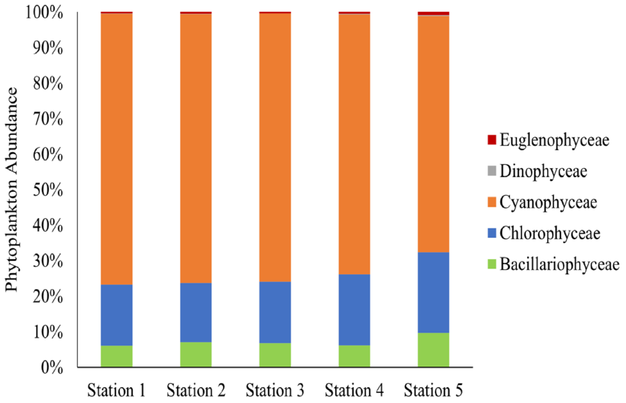

Figure 6. The dominant group of phytoplankton in Kedung Ombo Reservoir.

The highly certain responsible species during a bloom is a characteristic feature of a bloom. It is considered a bloom if the total cell number is 104 cells/L or lower, resulting from a background growth of 102 cells/L (Smayda, 1997). HABs virulence effects are not necessarily related to cell abundance. Harmful impacts are also not easily measured (Watson and Molot, 2013). Phytoplankton abundance cannot determine the level of toxin or harmful metabolites risk. In addition, organisms with toxin detection and harmful effects of HABs species in the Kedung Ombo Reservoir require further research.

4. Conclusion

The research investigated the water quality conditions in Kedung Ombo Reservoir. Kedung Ombo Reservoir has low transparency, a fairly turbid level, and a low DO concentration. The dominant phytoplankton in all stations and the highest phytoplankton abundance was *Aphanizomenon* sp. from Cyanophyceae. The phytoplankton abundance increases by the year. The present study revealed the occurrences of six potential HABs species (*Anabaenopsis* sp., *Aphanizomenon* sp., *Ceratium* sp., *Mougeotia* sp., *Pandorina* sp., and *Ulothrix* sp.). In general, Kedung Ombo Reservoir was in a eutrophic state.

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Authors' Contributions

All authors have contributed to the final manuscript. The contribution of each author is as follows, Haeruddin; devised the main conceptual ideas and critical revision of the article. Kukuh Prakoso; collected the data and data analysis. All authors discussed the results and contributed to the final manuscript.

Conflict of Interest

The authors declare that they have no competing interests.

Declaration of Artificial Intelligence (AI)

The author(s) affirm that no artificial intelligence (AI) tools, services, or technologies were employed in the creation, editing, or refinement of this manuscript. All content presented is the result of the independent intellectual efforts of the author(s), ensuring originality and integrity.

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