Nitrate and phosphate levels affect phytoplankton distribution in Jatigede Reservoir, Sumedang, West Java

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Abstract. Capture fishing is a key economic activity conducted within the Jatigede Reservoir, serving as a vital source of income for the local people. In order to enhance the productivity of capture fisheries, it is imperative to uphold the preservation of water quality and the availability of natural food sources for fish within aquatic environments. The presence of organic waste and dissolved sediments in water has a tendency to facilitate decomposition processes and increase the content of nitrogen and phosphorus. Nevertheless, in instances where the quantity of nitrates and phosphates exceeds the established threshold for optimal quality, it may result in an overabundance of phytoplankton, commonly referred to as blooming, or eutrophication, hence leading to a decline in the overall quality of the water. Hence, the active monitoring of nitrate and phosphate distribution can serve as a proactive measure to prevent the decline in water quality, aid in the selection of fishing grounds, and facilitate the establishment of conservation zones. The findings of the study indicate that the Jatigede Reservoir presents mean nitrate and phosphate concentrations within the range of 0.013 to 0.044 mg L^{-1} and 0.054 to 0.122 mg L^{-1}, respectively. Additionally, the reservoir has a substantial presence of phytoplankton, with abundance levels ranging from 20,134 to 59,817 individuals per liter (ind L^{-1}). The research findings indicate a significant association between nitrate and phosphate levels and the number of phytoplankton.
Key Words: capture fishing, fishing grounds, nutrient decomposition, water quality.

Introduction. A reservoir is one of the inland water ecosystems and has the multipurpose function to support the various activities of the community. The multipurpose reservoir is expected to improve the economics of the locals. However, a lack of monitoring of the reservoir's water quality causes several deteriorations, leading to higher water pollution and degrading the quality of the reservoir environment. Jatigede Reservoir is located in Sumedang Regency, West Java Province. One of the purposes of the Jatigede Reservoir is fisheries activity, focused on capture fisheries. Referring to Sumedang Regency regulation Number 4 of 2018 on Sumedang Spatial Planning, it is stated that the aquaculture activities in floating fish net cages in the Jatigede Reservoir is prohibited. However, the floating fish net cage aquaculture activities on several locations in the Jatigede Reservoir are already set up. To support capture fisheries and to gain high production yields, it is necessary to maintain the water quality and the availability of primary food in the waters. Excess waste input from cultivation activities, household, and agricultural containing nitrogen and phosphorus elements contributes to water pollution and reduces its quality and leads to eutrophication (Kennish & de Jonge 2011; Simanjuntak 2012; Dal'Olio Gomes et al 2021).

Organic pollutants and dissolved solids in waters will be decomposed thus increasing the biochemical oxygen demand (BOD) and the concentration of nitrogen and phosphorus, nurturing the growth of phytoplankton (Vasistha & Ganguly 2020). Phytoplankton is the primary producer in the aquatic ecosystems, its abundance naturally increasing the fish production in the reservoir. However, on the contrary, when the concentration of nitrogen and phosphorus is very high, it can result in the massive phytoplankton growth (blooming) or eutrophication and water pollution (Zaghloul et al 2020; Bartosiewicz et al 2021). These circumstances can decrease water quality, making the reservoir environment to be less suitable for its purpose, decreasing its carrying capacity for various aquatic organisms including fishes, and may affect the sustainability of fishing activities (Vasistha & Ganguly 2020).

Eutrophication is a process of enrichment of nutrients and organic matter in water or water pollution caused by the emergence of excessive nutrients into aquatic ecosystems (Dal'Olio Gomes et al 2021; Sun et al 2022). Eutrophication leads to severe problems in reservoir management, like physical, chemical, and biological disturbances in the waters. Low transparency, reduced dissolved oxygen levels, and increased growth of aquatic plants and phytoplankton are consequences of eutrophication (Irianto 2015). Therefore, as preventive measures in maintaining water quality and phytoplankton abundance, the research on the relationship between nitrate and phosphate distribution and their effect on phytoplankton abundance is needed to observe the correlation and the distribution pattern of nitrate, phosphate, and phytoplankton. The results can be used as a reference on the distribution pattern, and a guide for conservation areas on reservoir.

Material and Method

Sampling points*.* The selection and division of research stations into six sampling points were based on their characteristics and their location within the river basin, taking into consideration inputs from the surrounding Jatigede Reservoir. The field sampling periods spanned from September 2020 to February 2021. The geographic layout of the research stations is displayed in Figure 1. Station 1 operates as the designated inlet zone for the Jatigede Reservoir. Station 2 represents the point of convergence across the Cimuja and Cijajaway rivers. Stations 1 and 2 are characteristic of the riverine zone. Floating net cage locations have been identified as stations 3 and 4. These stations also serve as indicators of the transition zone. Stations 5 and 6 are representative of the lacustrine zone, with the additional feature that station 6 has a location at the reservoir outlet (Figure 1).

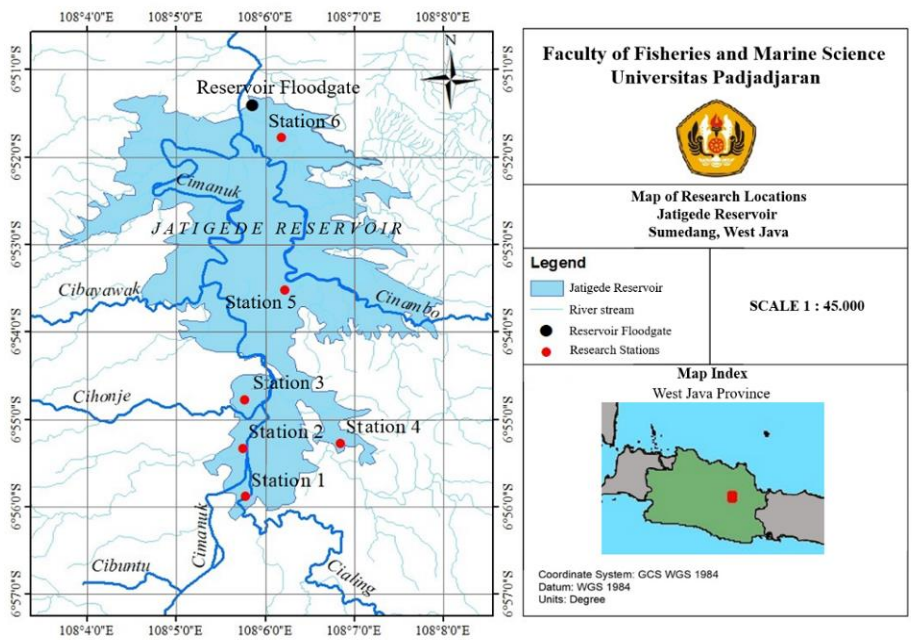

Figure 1. Research locations.

Observation parameters. The observational parameters considered in this study encompass a range of physical-chemical and biological characteristics of water. These parameters consist of temperature, transparency, total suspended solids (TSS), total dissolved solids (TDS), biochemical oxygen demand (BOD), dissolved oxygen (DO), nitrate, phosphate, ammonia, carbon dioxide (CO_2), current velocity, and acidity (measured as pH) (Table 1). The sampling procedure was conducted on six occasions, with a monthly interval. Sampling was conducted on the superficial stratum of the aquatic environment. To conduct phytoplankton analysis, a volume of 5 liters of the surface water sample was collected and subsequently treated with Lugol's iodine solution for preservation purposes. The specimens were stored for a duration of 48 hours to allow for settling, with the solid components being readily distinguishable by visual observation. The phytoplankton specimens were observed and analyzed using a ZEISSJ-902984 microscope. The identification process involved determining the taxonomic classification of the specimens to the most specific level possible, utilizing identification keys. The species abundance was calculated using the following formula:

$$N = n \times \frac{Vr}{Vo} \times \frac{1}{Vs}$$

where: N is abundance (ind L^{-1}), n is identified plankton, Vr is filtered plankton volume, Vo is observed volume of plankton, and Vs is filtered water volume.

Table 1

Measuring methods, of physical and chemical parameters, type and manufacturer of the devices

Parameters	*Unit*	*Method*	*Device (type and manufacturer)*
Temperature	^oC	Potentiometry, using a thermometer	Digital thermometer Krisbow 50-1300^oC
Transparency	cm	Visual, using a Secchi disk	Nobile SD-15, Plate stainless diameter 200 mm x 15 mm
TSS	mg L^{-1}	Gravimetric method	-
TDS	mg L^{-1}	Cyberscan PC 300 series	Cyberscan PC 300 series
BOD_5	mg L^{-1}	Winkler modification	Winkler bottle 250 ml
DO	mg L^{-1}	Potentiometry, using a DO meter	Digital Lutron DO-5510
Nitrate	mg L^{-1}	Spectrophotometry	UV-visible thermo scientific spectrophotometer
Phosphate	mg L^{-1}	Spectrophotometry	UV-visible thermo scientific spectrophotometer
Ammonia	mg L^{-1}	Spectrophotometry	UV-visible thermo scientific spectrophotometer
CO_2	mg L^{-1}	Titration	-

Results and Discussion

Physico-chemical water parameters. The water quality at the six observation stations revealed that the physical and chemical characteristics of the water remain within the acceptable thresholds outlined in class II of the standards. This classification follows the Indonesian Government Regulation No. 22 of 2021, which pertains to various applications such as infrastructure, water recreation, freshwater fish farming, animal husbandry, and irrigation of agricultural areas. Therefore, this outcome is consistent with the intended objectives of the Jatigede Reservoir, which include the provision of hydropower, as well as the promotion of fisheries and agricultural productivity.

The water's transparency varied within the range of 38 to 150 cm. The water temperature ranged from 27.2 to 29.7^oC, while the water current velocity ranged from 0.08 to 1.42 m s^{-1}. Additionally, the concentration of TDS was found to be within the range of 110 to 149 mg L^{-1}, and the concentration of TSS ranged from 4 to 17 mg L^{-1} (Table 2). According to Jewlaika et al (2014), a decrease in the concentration of suspended solids in water indicated increased turbidity, resulting in reduced light penetration. This phenomenon may create favorable conditions for the growth of phytoplankton. The temperature in Jatigede has a significant impact on the growth of phytoplankton. Specifically, the temperature range of 27.2-29.7°C observed in this area falls within the optimal range of 25-40°C for photosynthesis, as stated by Effendi (2003). According to Siagian & Simarmata (2015), the presence of elevated levels of DO in water can be attributed to the processes of air diffusion and photosynthesis. The process of photosynthesis is subject to the influence of CO_2 concentration within the aqueous environment. The presence of elevated concentrations of CO_2 and the prevailing velocity of water currents contribute to the facilitation of both the dissemination and the promotion of robust photosynthetic processes in surface waters.

Table 2

Physical parameters of Jatigede Reservoir

Parameter	*Sampling station*					
	1	*2*	*3*	*4*	*5*	*6*
Temperature (°C)	28.2-29.7	27.2-29.6	28.6-29.3	27.8-29.2	27.4-29.3	27.3-29.4
Transparency (cm)	44.5-108	38-94	61.5-150	67-120	72.5-133	74-138
TDS (mg L^{-1})	110-149	110-149	110-147	110-148	111-148	111-148
TSS (mg L^{-1})	5-17	5-12	4-9	5-9	4-8	4-8
Current velocity (m s^{-1})	0.13-0.83	0.1-1.42	0.05-0.2	0.080-0.2	0.2-0.35	0.14-0.4

The water samples were analyzed for various chemical parameters and their concentrations. The DO levels ranged from 4.3 to 6.8 mg L^{-1}, BOD levels ranged from 3.2 to 16.2 mg L^{-1}, CO_2 levels ranged from 0.5 to 1.9 mg L^{-1}, pH levels ranged from 6.84 to 7.72, ammonia levels ranged from 0.0002 to 0.0456 mg L^{-1}, nitrate levels ranged from 0.009 to 0.044 mg L^{-1}, and phosphate levels ranged from 0.054 to 0.122 mg L^{-1} (Table 3). Zonneveld et al (1991) posit that a concentration of dissolved CO_2 exceeding 2 mg L^{-1} can create an optimal environment conducive to the sustenance and proliferation of phytoplankton. The pH range of 6-8 is considered to be neutral, and within this range, photosynthesis is optimized. In the case of Jatigede, pH levels of 6.84 to 7.72 have been observed, indicating a favorable environment for phytoplankton, as reported by Effendi (2003).

The nitrate concentration at the reservoir exhibits a range of 0.009 to 0.044 mg L^{-1}. The nitrate concentration at station 2 (0.021-0.044 mg L^{-1}) (Table 3; Figure 2) is the highest among the observed values. This finding suggests that the elevated nitrate concentration at station 2 is likely attributed to the biodegradation process of ammonia. This inference is supported by the fact that the highest concentration of ammonia is observed at station 2, which aligns with the known process of ammonia oxidation leading to nitrate production (Seitzinger 1988). The geographical aspect of the station may potentially influence these conditions. Station 2 is situated close to the settlement and confluence of the Cimuja River and the Cijajaway River, rendering it susceptible to potential impacts stemming from human activities occurring along both river systems.

According to previous studies conducted by Macketum (1969) and Sari et al (2016), it has been observed that the concentration of nitrate in the Jatigede Reservoir exceeds the threshold necessary for the optimal growth of phytoplankton under specific conditions of the reservoir water environment. To achieve maximum growth, the phytoplankton needs to have nitrate concentrations within the range of 0.9-3.5 mg L^{-1} (Beruat et al 2018). However, nitrate concentration at a minimum of 0.144 mg L^{-1} is considered a limiting factor for phytoplankton growth. Nitrate is an essential component in the process of photosynthesis for phytoplankton, as it can enhance the growth and development of these organisms. Additionally, phytoplankton rely on nitrogen for the synthesis of proteins (Mustofa 2015).

Table 3

Chemical parameters of Jatigede Reservoirs

Parameter	*Sampling station*					
	1	*2*	*3*	*4*	*5*	*6*
BOD (mg L^{-1})	6.5-9.7	3.2-16.2	6.5-16.2	8.1-13.0	4.9-9.7	3.2-6.5
DO (mg L^{-1})	4.5-5.9	4.4-5.6	4.3-5.4	4.6-6.2	4.5-6.6	4.5-6.8
Nitrate (mg L^{-1})	0.017-0.027	0.021-0.044	0.015-0.035	0.015-0.044	0.013-0.039	0.009-0.030
Phosphate (mg L^{-1})	0.063-0.111	0.078-0.122	0.061-0.121	0.063-0.116	0.074-0.112	0.054-0.119
Ammonia (mg L^{-1})	0.0006-0.0225	0.0007-0.0301	0.0003-0.0299	0.0003-0.0083	0.0002-0.0456	0.0003-0.0056
CO_2 (mg L^{-1})	0.5-1.9	1.0-1.9	1.0-1.4	0.5-1.9	0.5-1.4	0.5-1.4
pH	6.86-7.30	6.94-7.53	6.96-7.59	6.93-7.15	6.96-7.72	6.84-7.22

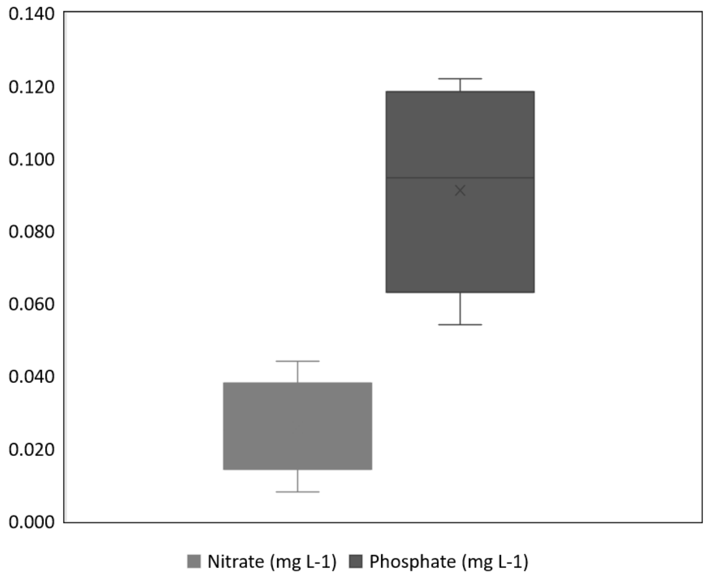

Figure 2. Nitrate and phosphate concentration (mg L^{-1}) in the Jatigede Reservoir.

The phosphate concentration in the Jatigede area exhibits a range of 0.054 to 0.122 mg L^{-1}. Notably, the highest concentration of 0.078-0.122 mg L^{-1} was observed at station 2, as indicated in Table 3. The subject of discussion pertains to the Indonesian regulatory framework, specifically the Government Regulation No. 22 of the year 2021, which addresses the permissible levels of phosphate concentration within the Jatigede Reservoir, as evaluated against the established water quality standards for class II classification. Nevertheless, it is also classified as eutrophic waters, denoting concentrations ranging from 0.03 to 0.1 mg L^{-1} or above. Phosphate is employed by phytoplankton and serves a crucial function in the cellular energy transfer process. According to Sidaningrat et al (2018), the ideal concentration range of phosphate for promoting the growth of phytoplankton is 0.09-1.80 mg L^{-1}.

According to Yang et al (2020), the primary sources of phosphate in aquatic environments are derived from the wastewater industry, agricultural activities, and domestic waste discharged from human settlements. However, the presence of floating net cages (aquaculture) at the Jatigede Reservoir site has the potential to contribute to the accumulation of phosphate. One of the materials used in the floating net cages is the pellet feed which is composed of certain materials, including phosphate. According to Chatvijitkul et al (2018), the composition of phosphate used in the pellet feed varies from 0.3 to 2% of the total weight, depending on the formulation used by the factories. Nevertheless, the implementation of the manual fish-feeding system is expected to result in a direct release of approximately 10-15% into the aquatic environment.

Fish farming significantly impacts phosphorus dynamics in aquatic ecosystems. Phosphorus from fish feed dissolves in water or accumulates in sediment layers, releasing phosphate into the water and enhancing biochemical activity and biodegradation (Rustadi 2009). This process alters sedimentary phosphorus forms, shifting from organic to residual phosphorus primarily derived from fish feed. The resulting changes increase sedimentation rates and promote long-term phosphorus accumulation in the reservoir. Furthermore, the elevated presence of readily mobilizable phosphorus from fish feed heightens the risk of eutrophication, potentially disrupting the ecosystem balance.

The phytoplankton distribution and nitrate and phosphate relation. The phytoplankton present in the Jatigede reservoir were classified into six distinct phyla, namely Chlorophyta, Chrysophyta, Cyanophyta, Pyrrophyta, Bacillariophyta, and Euglenophyta. The eight classes of categories encompass Chlorophyceae, Zygnematophyceae, Coscinodiscophyceae, Cyanophyceae, Dinophyceae, Bacillariophyceae, Mediophyceae, and Euglenophyceae. The overall abundance of phytoplankton based on the sampling station varies between 20,134 and 59,817 ind L^{-1} (Figure 3), while the abundance based on the phyllum ranged from 750 to 25,000 ind L^{-1} (Figure 4). Physical and chemical parameters significantly influence the distribution and abundance of phytoplankton in water. The abundance and diversity of phytoplankton are subject to the influence of multiple intricate and interconnected factors that interact with physical and chemical parameters, including DO, temperature, turbidity, transparency, and the availability of nitrogen and phosphorus nutrients in aquatic environments (Horne & Goldman 1994).

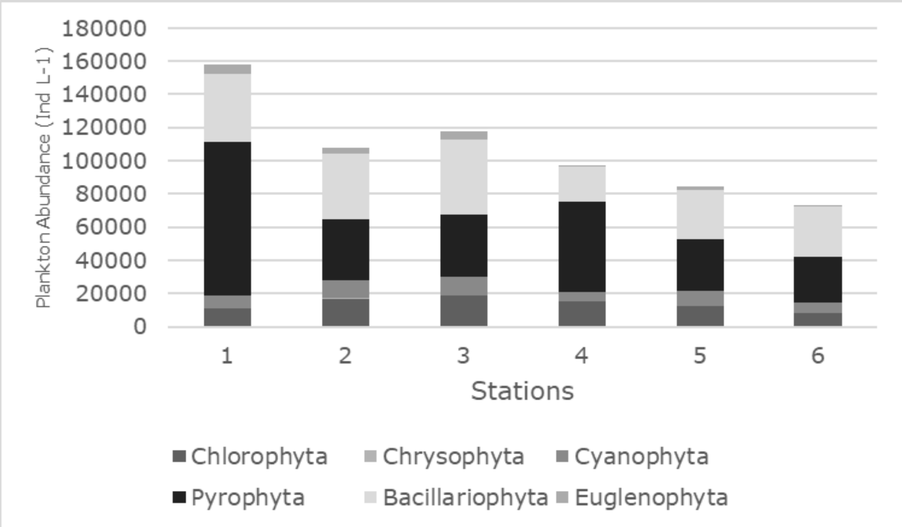

Figure 3. Plankton distribution in the Jatigede Reservoir.

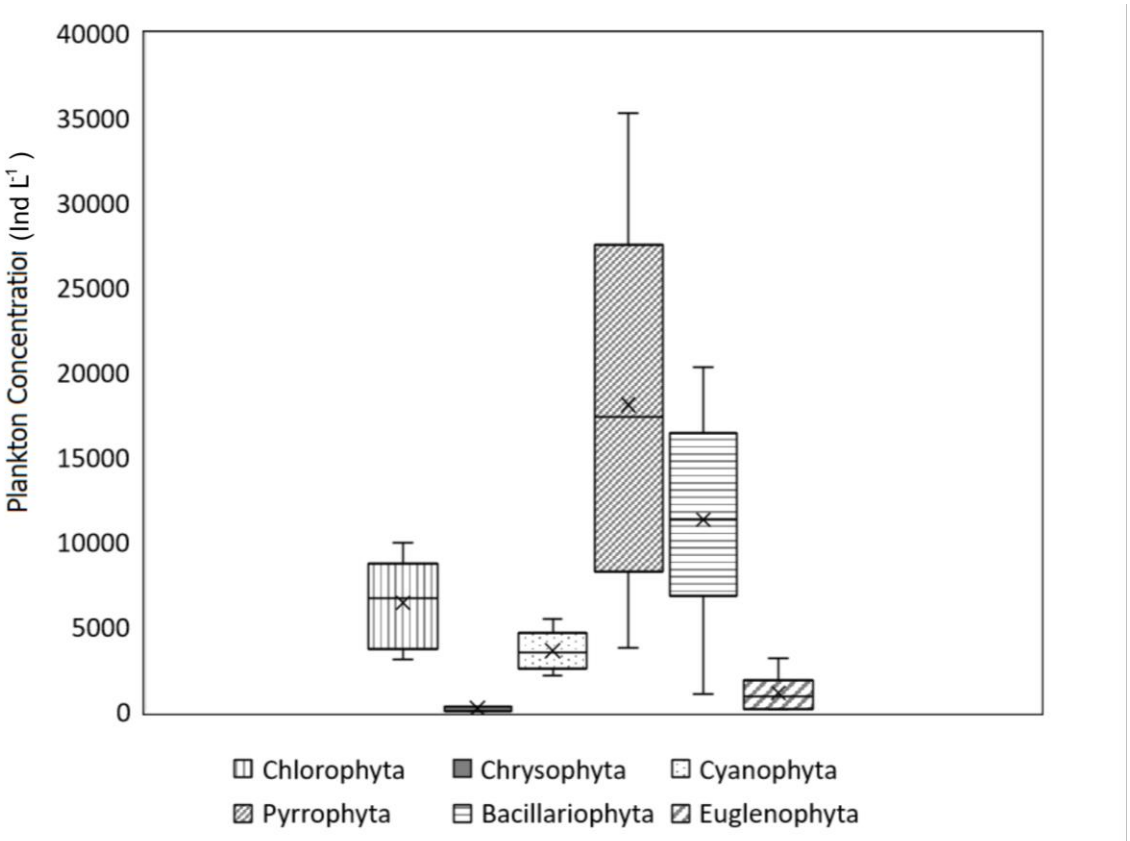

Figure 4. Plankton concentration in the Jatigede Reservoir.

Figure 4 shows, in individuals per liter, the concentrations of different plankton phylla found in the Jatigede reservoir. Cyanophyta has the highest concentration and variability of these, with a median of about 25,000 ind L^{-1} and an interquartile range (IQR) of roughly 15,000 to 30,000 ind L^{-1}. The fact that the whiskers reach about 40,000 ind L^{-1} emphasizes how dominant it is in the environment. Chrysophyta, on the other hand, exhibits the lowest concentration, with values near 0 ind L^{-1} and no variability, suggesting modest ecological importance. With an IQR of 5,000 to 15,000 ind L^{-1}, a median of roughly 10,000 ind L^{-1}, and whiskers reaching 20,000 ind L^{-1}, Bacillariophyta has a moderate concentration. Chlorophyta, on the other hand, has comparatively low concentrations with minimal variability, with an IQR of 4,000 to 6,000 ind L^{-1} and a median close to 5,000 ind L^{-1}. The concentration of Euglenophyta is likewise modest, with a skewed distribution and values centered around 1,000 ind L^{-1}. Last but not least, Pyrrhophyta has the second-lowest concentrations, 500-1,000 ind L^{-1}, which is indicative of its small ecological importance. Overall, the statistics highlight Cyanophyta's ecological dominance and the other plankton groups' very small contributions.

According to their location, the phytoplankton distribution and abundance in Jatigede indicate that the highest abundance was observed at station 1, the inlet, with a recorded value of 59,817 ind L^{-1} (Figure 3). Conversely, the lowest abundance was observed at station 6, the outlet, with a recorded value of 20,134 ind L^{-1}. The abundance and distribution of phytoplankton at station 1, the reservoir inlet, are significantly impacted by the flow of the Cimanuk River. The Cimanuk River serves as the main river in the area and consistently transports nutrients from the upper side of Jatigede, which is known for its high level of anthropogenic activities, including cultivation and residential areas. In contrast, the reservoir outlet at station 6 is less influenced by river flow and primarily impacted by nutrients derived from natural processes, leading to comparatively lower levels when compared to the other stations. According to Nurruhwati et al (2017), the concentration of nutrients at the outlet of the reservoir tends to be lower due to their utilization and sedimentation before reaching the outlet. The concentration of nutrients obtained exhibits fluctuations that align with the abundance of phytoplankton. These nutrients are effectively utilized to support the growth of phytoplankton. Prescott (1970) posited a significant correlation between the abundance of phytoplankton communities and the concentration of essential nutrients, including phosphate, nitrate, silicate, and other nutrients.

Table 4 represents the multiple linear regression results, the correlation coefficient of 0.787 obtained from the linear regression analysis suggests a strong relationship between the concentrations of nitrate and phosphate and the abundance of phytoplankton. This finding aligns with the research conducted by Hasan (2003), which indicates that variables with correlation coefficients ranging from 0.60 to 0.799 are considered to have a strong correlation. Moreover, the R^2 coefficient of determination, with a value of 0.62, suggests that 62% of the variation in phytoplankton presence in the Jatigede Reservoir can be attributed to the influence of nitrate and phosphate. The observed distribution pattern of these key parameters is found to be instrumental in elucidating the relationship between nitrate and phosphate concentrations and their impact on phytoplankton abundance within the context of this study. The spatial distribution of nitrate, phosphate, and phytoplankton revealed that station 2 exhibited the highest concentration of nitrate (0.021-0.044 mg L^{-1}), the highest concentration of phosphate (0.078-0.122mg L^{-1}), and a substantial abundance of phytoplankton. The variability in the ratio of phosphate to biomass in aquatic organisms, particularly phytoplankton, is more pronounced compared to the ratio of nitrogen, including ammonia and nitrate, on biomass (Horne & Goldman 1994).

Table 4

Multiple linear regression result

Equality	*R*	*R^2*
$Y = -215.681+250.828X_1+2.261.400X_2$	0.787	0.620

The spatial distribution and abundance of phytoplankton in the Jatigede Reservoir are affected by the water currents originating from the Cimanuk River. Station 1 and station 2, which serve as the reservoir inlet (riverine zone), exhibit higher nutrient levels compared to other stations. Consequently, these nutrients disperse throughout the water and eventually reach the outlet at station 6. The lower abundance of phytoplankton observed at the outlet appears to be influenced by the outflows and the rate of water current close to the outlet (Priambodo 2015). The computation results were analyzed using the interpolation approach to visualize the distribution of nitrates, phosphates, and phytoplankton in the Jatigede reservoir (Figure 5).

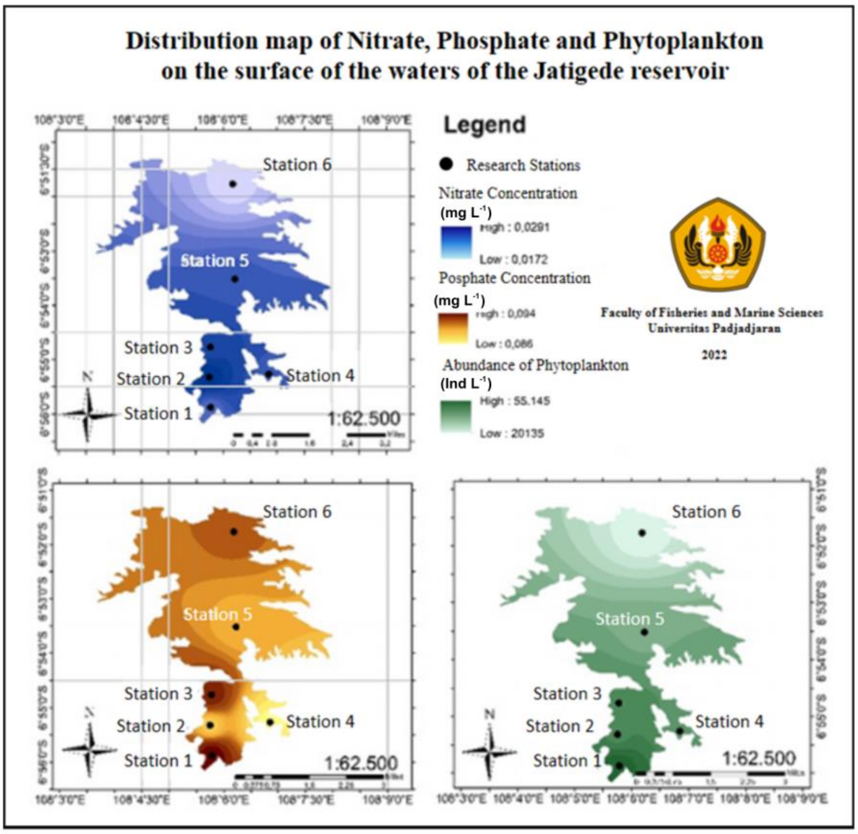

Figure 5. Distribution map of nitrate, phosphate, and phytoplankton on the surface of the waters of the Jatigede Reservoir.

The distribution of phytoplankton abundance is influenced by various factors, such as the physical and chemical characteristics of the water. These factors encompass temperature, light intensity, and DO levels (Nirmalasari 2018). Nevertheless, Zahidah (2020) argues that the correlation between transparency and primary productivity, particularly in relation to phytoplankton, does not consistently exhibit a linear pattern. In addition, the spatial arrangement of nitrate, phosphate, and phytoplankton can serve as a valuable indicator for the implementation of restocking or introduction initiatives, particularly in the context of sustainable fisheries practices. Additionally, it aids in facilitating the operation of the Jatigede Reservoir by serving as a valuable resource for the fisheries sector, providing valuable data on fishing locations.

Conclusions. Based on the findings of water quality assessments conducted at six sampling stations, overall, the water quality of Jatigede Reservoir can support the phytoplankton growth. However, the nitrate concentration of about 0.013-0.044 was not exhibit the minimum requirement, yet still has a strong relationship with the phytoplankton growth. The mean phosphate concentration varied between 0.054 and 0.122 mg L^{-1}, with the highest phosphate concentration observed at station 2, measuring 0.078-0.122 mg L^{-1}. The obtained correlation coefficient (r-value) between nitrate and phosphate concentrations and the abundance of phytoplankton in the Jatigede Reservoir is 0.787, indicating a strong positive correlation. This suggests a robust relationship between nitrate, phosphate, and phytoplankton in the reservoir's aquatic environment. The conducted R^2 test yielded a result of 0.62, suggesting that the presence of phytoplankton in the Jatigede Reservoir is influenced by nitrate and phosphate by 62%, while other factors contribute to 38% of the influence.

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Conflict of interest. The authors declare that there is no conflict of interest.

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