Spatial distribution of phytoplankton in Jatigede Reservoir, Indonesia

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Abstract. Spatial distribution of phytoplankton at specific locations can present patterns. The distribution pattern of phytoplankton is strongly influenced by the physical and chemical parameters of the aquatic environment. This research aimed to determine the spatial distribution of phytoplankton and the environmental factors that will affect the abundance of phytoplankton in the Jatigede reservoir. The research was conducted in the period September 2020-February 2021. The survey method was performed at six sampling stations, selected based on the inlet of the rivers, BOD value and reservoir zonation. The results revealed that the highest abundance was 57,596 ind L^{-1} and the lowest abundance was 13,968 ind L^{-1}. The Simpson Diversity Index ranged from 0.46 to 0.79 and the Simpson Dominance Index ranged from 0.21 to 0.54. The Canonical Correspondence Analysis (CCA) of the water quality parameters indicated that pH, nitrate and ammonia were the most influent factors on the distribution of phytoplankton in Jatigede reservoir.

Key Words: CCA, aquatic environment, abundance, water quality, Cimanuk river.

Introduction. Jatigede reservoir is one of the manmade aquatic ecosystems in mainland of West Java, its main function being to of increase rice production by optimizing the existing irrigation network and fisheries capture activities (Balai Besar DAS Cimanuk-Cisanggarung 2009). The Jatigede reservoir water sources are the Cimanuk River as the main river, Cialing River and the Cinambo River. Those rivers affected the physical, chemical, and biological condition of the Jatigede reservoir. Previously inundated areas were settlements and plantations rich in nutrients contributing to the reservoir's water quality degradation, due to a high organic matter content. At the initial phase of the inundation, the trophic status of the Jatigede Reservoir was oligotrophic to mesotrophic (Faishal et al 2019), în spite of thepresence of waste inputs from the Cimanuk River watershed and the development of community activities alongside the Cimanuk River.

Phytoplankton, playing an important role in aquatic ecosystems, serve as primary producers in the food chain, generating oxygen through photosynthesis (Odum 1993). The distribution of phytoplankton can be seen temporally and spatially. Phytoplankton spatial distribution was observed to collect data based on specific locations, either vertically or horizontally, at the water surface area and in the water column depth. The distribution of phytoplankton was influenced by the interactions of physical-chemical factors, such as light intensity, dissolved oxygen, temperature stratification, and availability of nitrogen and phosphorus nutrients, while the biological aspects were the predation (food chain), natural mortality, and decomposition (Goldman & Horne 1994; Sim et al 2020).

The current research aimed to determine the spatial distribution of phytoplankton and the environmental factors which affected the abundance of phytoplankton in the Jatigede Reservoir. The relationship of physical-chemical parameters of water affects the life of the organisms in the aquatic ecosystem linkage, which is reflected by the typical distribution pattern of a biota, at specific location of the habitat (Takarina et al 2019). The Canonical Correspondence Analysis (CCA) is a largely used method for determining the water quality parameters which affect the distribution of phytoplankton (Yan et al 2012; Wang & Yu 2017), supporting the sustainability management of resources.

Material and Method

Description of the sampling sites. The research period was from September 2020 to February 2021. The purposive sampling was used, the determination of sampling points and sampling stations referred to the input of the river into the Jatigede Reservoir, the value of biochemical oxygen demand (BOD), and to the zoning of the reservoir, divided into 6 stations following its characteristics (Figure 1).

Station 1. Inlet of Cimanuk River into the Jatigede Reservoir; being the main river of Jatigede Reservoir, it is also supplied by the Cibuntu River and the Cialing River (6°55'52.59 "S and 108°05'46.87" E). Station 1 is a river zone and according to its high BOD concentration (14.6 mg L^{-1}), it is considered as moderately polluted.

Station 2. Riverine Zone of the main stream Cimanuk river, connected to Cimuja and Cijajaway (6°55'19,54"S 108°05'45,07"E), considered as non-polluted (BOD 4.9 mg L^{-1}).

Station 3. Transition Zone (6°54'40.1"S 108°05'46.4"E), interconnecting the lake and Cimanuk and Cihonje rivers, considered as highly polluted (BOD 16.2 mg L^{-1}), potentially from aquaculture activities with floating net cages.

Station 4. Transition Zone (6°55'16,06"S 108°6'50,69"E), interconnecting in the lake and Cimanuk and Cacaban rivers, considered as moderately polluted (BOD 11.4 mg L^{-1}), affected by floating net cages and settlements.

Station 5. Centre of Jatigede reservoir, affected by Cimanuk and Cisitu rivers, and Cinambo and Cibayawak subrivers (6°53'20,64"S 108°06'18,77"E), considered as moderate polluted (BOD 6.5 mg L^{-1}).

Station 6. Outlet of Jatigede reservoir (6°51'45,96"S 108°06'10,9"E), considered as moderate polluted (BOD 6.5 mg L^{-1}).

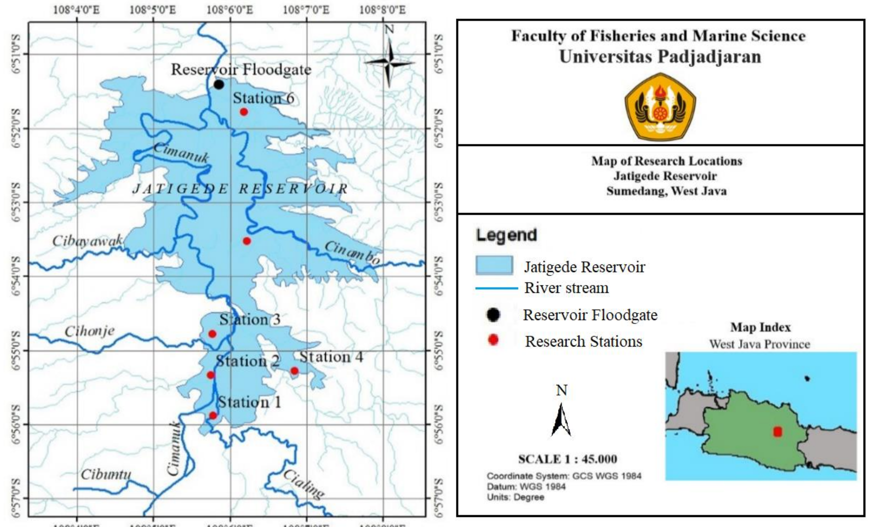

Figure 1. Sampling station in Jatigede Reservoir.

Sampling and measurement. The samples collection was performed at six sampling stations in three different depths 1) water surface; 2) half compensation depth; and 3) compensation depth. Plankton was collected using a plankton net (mesh size of 20 μm), then preserved using 1% lugol in the bottle. The analysis and identification was carried out at the Laboratory of Aquatic Resources, Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran, using a binocular microscope. The physical-chemical parameters of water transparency, temperature, flow velocity, pH, CO_2, biological oxygen demand test has been run for 5 days (BOD_5), dissolved oxygen (DO), nitrate, phosphate, total suspended solid (TSS) and total dissolved solid (TDS) were measured as water quality references of phytoplankton diversity.

Data analysis. Collected data analysed using comparative descriptive methods. Plankton abundance was expressed in individuals per unit of volume (ind L^{-1}). Diversity index was obtained from calculations based on the Shannon-Wiener Index and the dominance from the Simpson Dominance Index (Hossain et al 2017; Hedayati et al 2017; Miao et al 2019; Takarina et al 2020). Dominance Index illustrated the species that dominate the plankton community. The dominance index ranges from 0 to 1, high values indicating a dominant species presence (Odum 1993).

Shannon diversity index. The Shannon diversity index is widely used in aquatic and environment studies (Spellerberg & Fedor 2003; Hossain et al 2017; Miao et al 2019). It was calculated using the following formula (Shannon & Weaver 1964):

$$H = \sum - (Pi * \ln Pi) \quad i=1$$

Where:
H - the Shannon diversity index;
Pi - fraction of the entire population made up of species i;
S - numbers of species encountered;
∑ - sum from species 1 to species S.

Simpson dominance index (D). The dominance index is used to measure the domination of phytoplankton. It was adapted from the formula developed by Simpson (Simpson 1949) and used in several phytoplankton researches (Thukral et al 2019; Palupi et al 2022).

$$H = \sum (ni/n)2 \qquad i=1$$

Where:
ni - number of individuals of species i;
n - total number of individuals.

The correlation of the physical-chemical parameters and phytoplankton was calculated using Canonical Correspondence Analysis (CCA) analysis. The CCA was largerly used to analyze the correlation of several water quality parameters (Sevindik & Celik 2014; Drira et al 2016) and their link with the phytoplankton abundancein the Jatigede Reservoir.

Results and Discussion

Phytoplankton community structure. The phytoplankton of 6 phyla, consisting of 10 classes and 36 genera, were identified from the Jatigede Reservoirs. The abundance of phytoplankton in the Jatigede Reservoir ranged from 13,968 to 57,596 ind L^{-1} with the Dinophyceae having the highest abundance at the surface, at half the compensation depth and at the compensation depth. Based on the abundance value, the waters of Jatigede Reservoir were categorized into eutrophic waters, considering the abundance of phytoplankton >15,000 ind L^{-1} (Landner 1978; Suryanto & Hermawati 2019). The dominating genus, through the research period, was Peridinium, from the class Dinophyceae, phylum Pyrrophyta. Peridinium has the ability to dominate and prevent other phytoplankton growth in freshwater ecosystems (Rengefors & Legrand 2001). The detailed information on the average abundance of phytoplankton at the time of research can be seen in Figure 2.

The abundace of phytoplankton were varying in Jatigede Reservoir (Figure 2), the highest level was found on the surface, at Station 1 (57,596 ind L^{-1}) and the lowest at Station 4, in the compensation depth (13,968 ind L^{-1}). The phytoplankton identified in this research consists of 37 genera and 6 phyla: Chlorophyta, Cyanophyta, Chrysophyta, Pyrrophyta, Bacillariphyta, and Euglenophyta. Pyrrophyta emerges as the most abundant

(19,718 ind L^{-1}), at Station 1. The great abundance of phytoplankton at Station 1 (an inlet of the Jatigede) as results of the high nutrients input into Cimanuk River. Due to the high prevalence of the phylum Pyrrophyta at Station 1, this phytoplankton has the capacity for rapid reproduction and successions and is well adapted to environmental changes (Arum et al 2017).

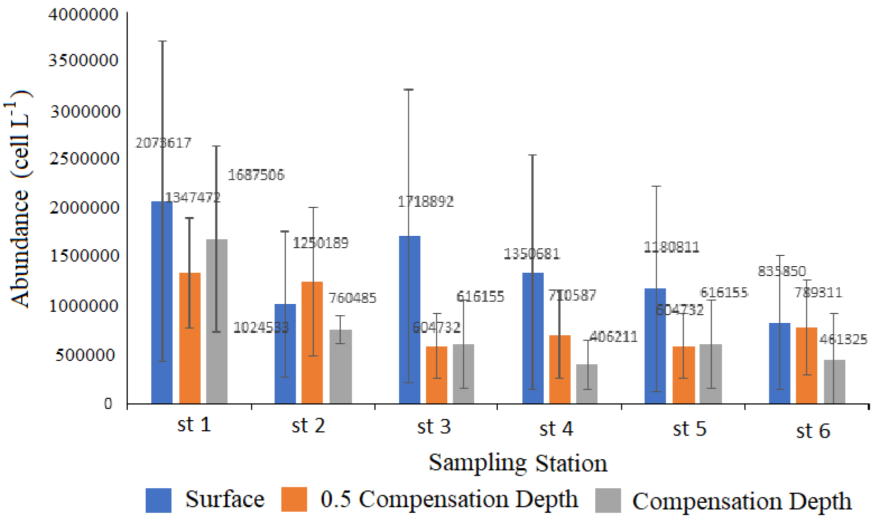

Figure 2. Average abundance of phytoplankton in the Jatigede Reservoir.

The varying abundance of phytoplankton is influenced by several physical and chemical factors which affect the growth of phytoplankton in a very complex way, being interconnected; the main factors are: dissolved oxygen, temperature, brightness (transparency), and the availability of nitrogen and phosphorus (Goldman & Horne 1994). The phytoplankton abundance fluctuates in response to physical, chemical and biological changes (Reynolds 2006).

The stability of plankton communities and the level of pollution can be explained by the Diversity Index (Figueredo & Giani 2001; Sagala 2012; Meng et al 2020). The higher the quality of water ecosystem, the higher the phytoplankton species diversity. Diversity Index value of phytoplankton in Jatigede Reservoir revealed the lowest diversity at Station 2 (0.46), at the water surface, while the highest was found at Station 6 (0.79), at half compensation depth (Figure 3). Overall, the diversity index in Jatigede Reservoir shown that the water ecosystem presented a low diversity of phytoplankton.

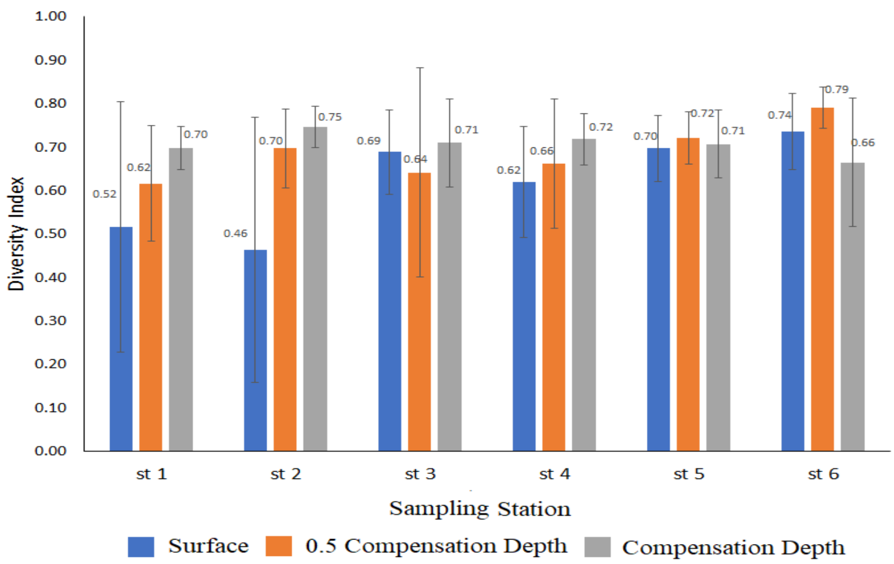

Figure 3. Diversity index of phytoplankton in Jatigede Reservoir.

The phytoplankton dominance index in Jatigede Reservoir ranged from 0.21 (Station 6) at a half compensation depth, to 0.54 (Station 2), showing a relatively low dominance or no dominant species (Figure 4). The dominance index was in line with previous studies, where the phytoplankton and zooplankton dominance indices in Jatigede Reservoir ranged from 0.258 to 0.681 (Dahlan et al 2020). These values indicated that the level of dominance in Jatigede Reservoir is low, suggesting a less intense competition in the use of resources and a balanced condition of the aquatic environment.

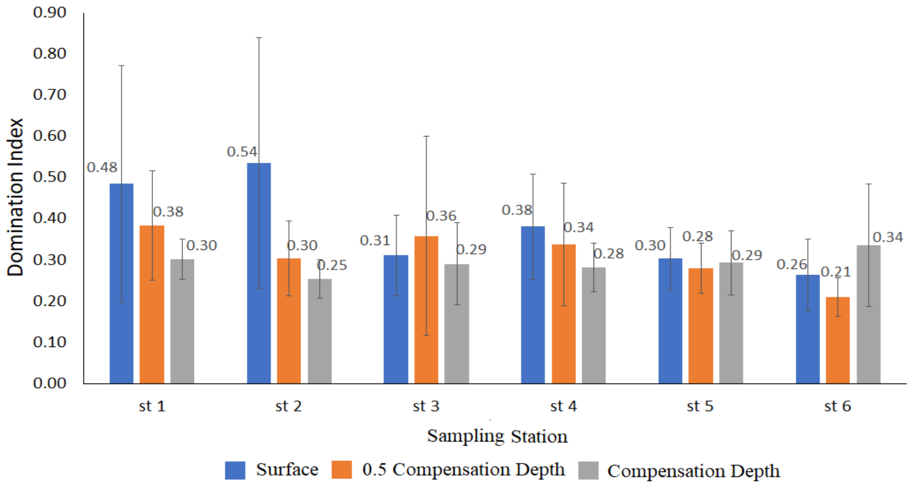

Figure 4. Domination index of phytoplankton in Jatigede Reservoir.

Physical and chemical parameters of the Jatigede Reservoir. The physical and chemical conditions of water is favorable to the presence of phytoplankton in the waters. In general, the water quality parameters at each observation station (Table 1 and 2) fluctuate due to a data collection over two seasons (dry season and rainy season). The results of the water quality measurements at six stations refer to the Indonesian regulation Water Quality Management and Control of Water Pollution. The ater quality category shows that all physical and chemical parameters of water are within the tolerance limits of class III, the designation for recreation water (facilities or infrastructure, freshwater for livestock and fish farming, for irrigating landscapes and for other purposes requiring the same water quality.

The physical condition of Jatigede Reservoir (Table 1) was characterized by: a temperature range of 26.6-29.76°C, with the highest average temperature value at Station 3 (29.07±0.28°C), a transparency ranging from 38 to 150 cm, with the highest average transparency value at Station 6 (105.25±22.64 cm), a current velocity ranging from 0.5 to 1.4 m s^{-1}, with the highest average velocity at Station 2 (0.44±0.66 m s^{-1}), a TSS value ranging from 4 to 17 mg L^{-1}, with the highest average value of TSS at Station 4 (7.17 mg L^{-1}), and the TDS value ranging from 110 to 142 mg L^{-1}, with the highest average value at Station 3 (124.83 mg L^{-1}).

The water temperature was declining with the water depth, since light transparency affected the water temperature (Zahidah 2020). The solar intensity has a direct effect on temperature and on its suitability for the growth of phytoplankton (Zohary & Flaim 2021). The optimum temperature for phytoplankton growth in waters ranges 20-30°C (Effendi 2003). Transparency values of 30-50 cm are considered optimal to support plankton life (Boyd 1990) and also indicate low levels of turbidity and dissolved materials, supported by low TSS and TDS values. According to the Indonesian regulation 82 of 2001, values from 400 to 1,000 mg L^{-1}, indicated that the water in Jatigede Reservoir was suitable for the 3rd class. However, the large concentration of suspended solids in several stations can cause a low value of transparency and affects the photosynthesis process in waters (Rinawati et al 2016). Even though the water current velocity in the reservoir ecosystem was relatively low in the riverine zone (Station 2), the influence of the main river, Cimanuk, and of the Cimuja and Cijajaway sub-rivers contributes to the current velocity.

Table 1

Physical parameters in the Jatigede reservoir

Parameters	*Depth*		*Sampling station* 1	2	3	4	5	6
Temperature (°C)	S	r	27.2-29.7	26.7-29.6	28.1-29.3	27.8-29.2	27.4-29.3	26.8-29.3
		a	28.5±1.04	28±1.02	28.82±0.47	28.5±0.57	28.55±0.66	28.26±0.98
	0.5 C	r	27.2-29.4	25-29.6	27.5-29	27.3-29	26.9-28.8	27.4-29.2
		a	28.46±1.07	27.44±1.7	28.46±0.59	28.15±0.68	28.12±0.78	28.48±0.78
	C	r	27.9-29.8	27.1-29.7	27.4-29.2	27-29	26.6-28.9	27.2-28.7
		a	28.55±0.69	27.95±0.93	28.44±0.65	28.18±0.73	27.98±0.88	28.1±0.62
Transparency (cm)		r	44.5-108	38-94	61.5-150	67-120	72.5-125	74-138
		a	68.33±22.73	66.83±21.44	92.75±30.37	87.67±19.7	94.83±18.74	105.25±22.64
Water current ($m\ s^{-1}$)		r	0.13-0.83	0.1-1.42	0.05-0.2	0.08-0.2	0.2-0.35	0.14-0.4
		a	0.4±0.31	0.44±0.66	0.14±0.06	0.15±0.05	0.3±0.07	0.25±0.13
TDS ($mg\ L^{-1}$)		r	110-136	110-142	110-135	110-131	111-126	111-125
		a	122.67±10.73	124.83±13.59	123±10.2	119.17±9.17	119.5±6.35	119.17±5.6
TSS ($mg\ L^{-1}$)		r	7-17	5-12	4-9	5-9	4-8	4-8
		a	12±4	8.33±2.5	6.33±1.97	7.17±1.33	6.17±1.72	6±1.41

S-Surface; C-Compensation; r-range value; a-average value.

Table 2

Chemical parameters in the Jatigede reservoir

Parameters	*Depth*		*Sampling station* 1	2	3	4	5	6
pH	S	r	6.86-7.3	6.94-7.53	6.96-7.59	6.93-7.15	6.96-7.72	6.84-7.22
		a	7.04±0.2	7.2±0.2	7.13±0.2	7.02±0.1	7.13±0.3	7.03±0.1
	0.5 C	r	6.69-7.09	6.75-7.36	6.92-7.7	6.73-7.31	6.96-7.36	6.6-7.36
		a	6.9±0.2	7.1±0.2	7.13±0.3	7.01±0.2	7.07±0.2	7.06±0.3
	C	r	6.9-7.11	6.9-7.13	6.97-7.63	6.77-7.1	6.97-7.09	6.9-7.1
		a	7.01±0.1	7.04±0.1	7.19±0.3	6.97±0.1	7.03±0.05	7.03±0.1
CO_2 ($mg\ L^{-1}$)	S	r	0.5-1.9	1.4-1.9	1-1.4	0.5-1	0.5-1.4	0.5-1.4
		a	0.95±0.52	1.59±0.25	1.11±0.25	0.95±0.52	0.87±0.36	1.03±0.36
	0.5 C	r	4.4-17.6	8.8-17.6	8.8-13.2	4.4-17.6	4.4-13.2	4.4-17.6
		a	8.07±5.14	13.93±3.31	10.27±2.27	8.8±4.82	8.07±3.31	8.07±5.14

Parameters	Depth		Sampling station					
			1	2	3	4	5	6
	C	r	4.4-13.2	8.8-13.2	4.4-17.6	4.4-22	4.4-13.2	4.4-13.2
		a	9.53±4.33	11±2.41	11±4.61	11.73±7.19	9.53±3.31	9.53±4.33
	S	r	4.4-13.2	8.8-17.6	8.8-13.2	4.4-22	4.4-17.6	4.4-13.2
		a	9.53±3.31	11±3.68	10.27±2.27	12.47±6.48	9.53±4.33	9.53±3.31
BOD ($mg\ L^{-1}$)	0.5 C	r	6.49-14.59	3.24-12.97	6.49-12.97	4.86-11.35	4.86-9.73	3.24-12.98
		a	10.05±3.52	7.46±3.91	10.05±2.9	8.11±2.51	6.81±1.78	6.16±3.87
	C	r	4.86-9.3	1.62-11.35	6.49-12.97	3.24-9.73	3.24-16.22	3.24-8.11
		a	7.03±1.96	5.68±3.36	9.73±2.29	7.03±2.44	6.16±5.66	5.51±1.85
	S	r	4.5-5.9	4.4-5.6	4.3-5.4	4.6-6.2	4.5-6.6	4.5-6.8
		a	5.3±0.56	5.15±0.48	4.9±0.46	5.48±0.64	5.78±0.97	5.68±0.95
DO ($mg\ L^{-1}$)	0.5 C	r	4.2-5.3	4.2-5.5	4-4.8	4.1-5.6	4.4-5.8	4.1-6.6
		a	4.66±0.4	4.92±0.5	4.44±0.34	4.97±0.57	5.14±0.68	5.12±0.93
	C	r	3.4-5.3	4-5.4	3-4.6	3.2-5.6	4-5.6	4-4.8
		a	4.47±0.73	4.72±0.47	3.82±0.63	4.22±0.97	4.84±0.71	4.34±0.32
	S	r	0.017-0.027	0.023-0.044	0.014-0.035	0.015-0.044	0.013-0.039	0.008-0.03
		a	0.022±0.004	0.029±0.008	0.025±0.008	0.023±0.011	0.024±0.01	0.017±0.009
Nitrate ($mg\ L^{-1}$)	0.5 C	r	0.013-0.035	0.021-0.035	0.027-0.034	0.015-0.032	0.007-0.038	0.007-0.04
		a	0.021±0.009	0.027±0.007	0.028±0.003	0.022±0.007	0.021±0.014	0.02±0.014
	C	r	0.018-0.028	0.017-0.04	0.022-0.032	0.008-0.025	0.016-0.035	0.012-0.04
		a	0.023±0.004	0.029±0.007	0.029±0.004	0.017±0.008	0.022±0.008	0.022±0.011
	S	r	0.063-0.111	0.078-0.122	0.061-0.121	0.063-0.116	0.074-0.112	0.054-0.119
		a	0.09±0.022	0.095±0.015	0.094±0.02	0.089±0.022	0.09±0.014	0.094±0.026
Phosphate ($mg\ L^{-1}$)	0.5 C	r	0.085-0.108	0.079-0.137	0.079-0.122	0.06-0.117	0.062-0.107	0.065-0.116
		a	0.092±0.01	0.105±0.023	0.098 ± 0.018	0.092±0.021	0.09±0.019	0.088±0.021
	C	r	0.076-0.114	0.076-0.119	0.063-0.107	0.074-0.106	0.079-0.117	0.062-0.12
		a	0.091±0.017	0.097±0.016	0.088±0.019	0.089±0.012	0.099±0.016	0.089±0.022
	S	r	0.001-0.0043	0.0013-0.0044	0.0012-0.0033	0.001-0.0032	0.0011-0.0036	0.0011-0.004
		a	0.0022±0.0011	0.0028±0.0011	0.0021±0.0009	0.0021±0.0009	0.0021±0.0009	0.0021±0.0012
Ammonia ($mg\ L^{-1}$)	0.5 C	r	0.001-0.0032	0.0008-0.0032	0.0014-0.0029	0.0011-0.0036	0.0012-0.0036	0.001-0.0037
		a	0.0018±0.0008	0.0022±0.0011	0.0023±0.0006	0.0021±0.0009	0.0024±0.0009	0.0022±0.001
	C	r	0.001-0.0035	0.0014-0.0032	0.0015-0.0031	0.001-0.0039	0.0015-0.003	0.0015-0.003
		a	0.0023±0.0009	0.0023±0.0007	0.0025±0.0006	0.0022±0.0011	0.0023±0.0007	0.0024±0.0006

S-Surface; C-Compensation; r-range value; a-average value.

The pH of the water in Jatigede reveals ranged from 6.6 to 7.7, with the highest average at Station 3 (7.2) of the compensation depth and the lowest at Station 1 (6.9) in the half compensation depth. It is related to the concentration of free CO_2 and organic matter in waters. The low pH value at the half compensation depth (Station 1) is followed by a high value of CO_2. Increasing the concentration of CO_2 can result in a decrease in the pH value and the waters become acidic, so that the availability of calcium carbonate ($CaCO_3$) needed by phytoplankton as a supply of calcium for the survival of phytoplankton also decreases (Sahabuddin et al 2014). The CO_2 value in Jatigede Reservoir ranged from 4.4 to 22.0 mg L^{-1}; the highest average value of CO_2 was found at Station 2 (13.93 mg L^{-1}), at the water surface, and the lowest was found at Station 5 (8.07 mg L^{-1}), at the water surface. The high value of CO_2 at the water surface at Station 2 was the result of the water and air diffusion process in the inlet which connected the reservoir with the Cimuja and Cijajaway rivers. In the photosynthesis process, phytoplankton absorbs sunlight and carbon dioxide as a raw material for photosynthesis, which produces oxygen (Heriyanto et al 2018).

Biological Oxygen Demand (BOD) values in Jatigede Reservoir ranged from 1.62 to 16.22 mg L^{-1}. Its vertical distribution indicated a decrease in BOD with the depth increase (Table 2). The highest average BOD value was found at the water surface at Station 3 (13.51 mg L^{-1}), and the lowest was at the water surface at Station 6 (5.41 mg L^{-1}). BOD value indicated the amount of oxygen needed by organisms while decomposing organic matter, under aerobic conditions (Salmin 2005). The large BOD value at Station 3 was the effect of the floating net cages activities, which increased the content of organic matter in the waters.

The dissolved oxygen (DO) measurement results ranged from 3.7 to 6.8 mg L^{-1}. Its highest average value was found at half the compensation depth at Station 6 (5.68 mg L^{-1}) and the lowest at the compensation depth at Station 4 (4.22 mg L^{-1}). Oxygen in the waters is the result of the photosynthesis of chlorophyll organisms and of the diffusion of oxygen from the atmosphere. The high value of dissolved oxygen at the half compensation depth at Station 1 is due to the photoinhibition at the surface, resulting in an optimal photosynthesis occuring at a half compensation depth. The value of dissolved oxygen also affects the density of phytoplankton.

The nitrate concentration in the Jatigede Reservoir ranged from 0.007 to 0.044 mg L^{-1}. The highest nitrate concentration was found at the surface at Station 2 (0.029 mg L^{-1}). The high nitrate concentration was likely caused by the rate of dissolved oxygen and by the pH, which leads to nitrification. In addition, the high concentration of nitrate at Station 2 was the result of domestic waste and agricultural waste from the Cimanuk River, as the main river, and of the Cimuja and Cijajaway sub-rivers. Domestic waste and agricultural waste are the main sources of enrichment with nitrate nutrients (Ramadhan & Yusanti 2020). Nitrate concentration qualifies the waters of Jatigede Reservoir for Class II (<10 mg L^{-1}), and class III (<20 mg L^{-1}), according to the water quality standard.

The concentration of phosphate values ranged from 0.054 to 0.137 mg L^{-1}, indicating that the phosphate concentration of Jatigede Reservoir waters is still in Class II (<0.2 mg L^{-1}) and Class III (<1 mg L^{-1}). The optimum orthophosphate content for the phytoplankton growth is 0.09-1.80 mg L^{-1} (Permatasari et al 2016). The concentration of ammonia ranges from 0.0011 to 0.0044 mg L^{-1}. Ammonia concentration with the highest average value was found at the water surface at Station 5 (0.0024 mg L^{-1}), while the lowest average value was found at half compensation depth at Station 1 (0.0018 mg L^{-1}). The overall ammonia concentration indicated that the Jatigede Reservoir water quality is still relatively good. The lowest limit of ammonia concentration for phytoplankton growth is 0.017 mg L^{-1} (Guildford & Hecky 2000). Some types of phytoplankton are only able to utilize nitrogen from simple elements, such as nitrate, and other types are able to absorb nitrogen from more complex elements, such as ammonia and urea (Patey et al 2008).

Correlations of water quality and phytoplankton. The CCA triplot ordination diagram shows the effect of different physical-chemical parameters on each phytoplankton order. As the water quality affected the abundance and distribution of phytoplankton, there are 8 orders that correlate with pH, nitrate, and ammonia parameters in the same ordinate

(Table 3). Phosphate, depth, and transparency correlated with 3 orders: Aulacoseirales, Melosirales, and Stephanodiscales. The order Chlorellales, Peridiniales, and Synechococcales are at an ordinate point nearby to the triplot line parameters of carbon dioxide, DO and temperature, therefore the changes in these parameters will affect the presence of this order in waters.

There are 7 orders that do not have a strong correlation with certain environmental parameters, so the phytoplankton groups in this order are tolerant to changes and to various environments (Figure 5). It is indicated that 7 orders will relatively not be affected by the environmental parameter changes in waters.

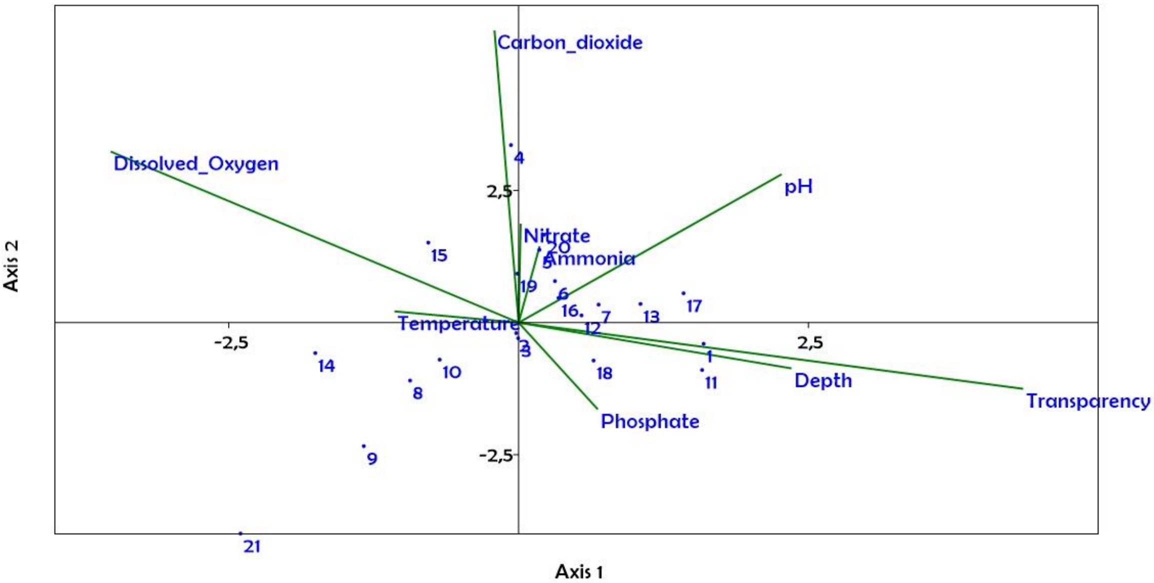

Figure 5. Diagram CCA phyitoplankton order correlation with environmental factors (1-Aulacoseirales, 2-Bacillariales, 3-Chlamydomonadales, 4-Chlorellales, 5-Chroococcales, 6-Cryptomonadales, 7- Desmidiales, 8-Euglenida, 9-Fragilariales, 10-Gonyaulacales, 11-Melosirales, 12-Naviculales, 13-Nostocales, 14-Oscillatoriales, 15-Peridiniales, 16-Sphaeropleales, 17-Spirulinales, 18-Stephanodiscales, 19-Synechococcales, 20-Xanthophyceae, 21-Zygnematales).

Table 3

Correlations of phytoplankton and water quality

Order	*Environmental parameters*
Chroococcales, Cryptomonadales, Desmidiales, Naviculales, Nostocales, Sphaeropleales, Spirulinales, Xanthophyceae	pH, nitrate, ammonia
Aulacoseirales, Melosirales, Stephanodiscales	Phosphate, depth, transparency
Chlorellales, Peridiniales, Synechococcales	CO_2, DO, temperature
Bacillariales, Chlamydomonadales, Euglenida, Fragilariales, Gonyaulacales, Oscillatoriales, Zygnematales	No correlation with specific parameters

Conclusions. The highest abundance of phytoplankton is 2,073,617 cell L^{-1} dominated by the phylum Pyrrophyta. The diversity index ranges from 0.46 to 0.79, indicating a low diversity, and the dominance index ranges from 0.21 to 0.54, indicating a low dominance or no dominant genus in the waters of Jatigede Reservoir. Nitrate, pH and ammonia are the parameters that influence at the highest degree the existence of most of the phytoplankton orders found in the Jatigede Reservoir.

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