Plankton community structure as a bioindicator in Jatigede Reservoir, West Java, Indonesia

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Abstract. Plankton are organisms that can be used as an indicator of water quality. This research aims to determine the condition of the waters in the Jatigede Reservoir in terms of the saprobic coefficient value of the plankton community and its role as a bioindicator. The method used is a survey with four locations and five sampling times, carried out from August to September 2019. Plankton was sampled using a plankton net with a mesh size of 20 μm. Data analysis uses comparative descriptive methods by comparing with relevant studies. The identified plankton species during research at Jatigede Reservoir were 49 genera of phytoplankton and 17 genera of zooplankton. Diversity index ranges from 0.904–2.062 for phytoplankton and 0.711–1.534 for zooplankton. Meanwhile dominancy index ranges from 0.258–0.681 for phytoplankton and 0.248–0.472 for zooplankton. Based on research results, the level of water pollution in the Jatigede Reservoir is β-meso/oligosaprobic (mildly polluted) with an average saprobic index value of 1.20 with the major contributing groups are the Chlorococcales and Diatoms.
Key Words: bioindicator, Jatigede Reservoir, plankton, saprobic index (SI).

Introduction. Jatigede Reservoir is a reservoir located in West Java Province in Sumedang Regency. Jatigede Reservoir waters have a significant contribution for the development of fisheries activities, especially capture fisheries. Capture fisheries activities in Jatigede Reservoir are not just for tourism and conducting hobby activities, but also a business activity and source of livelihood. Fishing activities are dominated by small or traditional fishermen (Setiawan et al 2018). Based on the Local Regulation No. 2 of 2012, Article 52 states that there is a prohibition of fish farming with floating net cages in the Jatigede Reservoir area. Fishery activities are allowed on a condition that the fishermen do not damage the water quality, for example fishing activities are allowed in the Jatigede Reservoir. Therefore, the existence of the capture fisheries sector in the Jatigede Reservoir is important for the support of the surrounding communities.

The capture fisheries sector in the reservoir is strongly dependent on the sustainability of the reservoir ecosystem. A good water quality condition is particularly important to support the aquatic organisms in an ecosystem (Hamuna 2018). Fish are the main commodity in capture fisheries activities, and they require good water condition to support their populations. Therefore, to conserve the fish resources and to protect the capture fisheries, the monitoring of the water quality on the Jatigede Reservoir is essential.

Bioindicator organisms in the water can be used as a tool to determine the degree of water pollution, beside other methods such as physical or chemical indicators (Utomo et al 2013). Bioindicators are organisms which can be used to detect, identify, and qualify environmental pollution (Conti & Cecchetti 2000). Phytoplankton can be used as an indicator of water quality. Phytoplankton suits the role as an indicator of water quality because of its short life cycle and amazingly fast response to environmental changes (Nugroho 2006).

The aim of this study is to reveal Jatigede Reservoirs water quality status and pollution level. One method to measure water quality status using phytoplankton as an indicator is to reveal the value of the saprobic coefficient. The use of the saprobic index is useful when compared to other indices, such as the diversity index and biotic index, in evaluating the condition of biological water quality (Wardhana 2006). This index divides the level of water pollution into: oligosaprobic, α-mesosaprobic, β-mesosaprobic, and polysaprobic. Saprobic coefficient is measured by looking at the type of plankton contained in the water, because each type of plankton is a constituent of a particular group of saprobicity, which will affect the value of the saprobic coefficient (Basmi 2000).

Material and Method

Description of the sampling sites. Research was carried out in the Jatigede Reservoir, Sumedang Regency, West Java. A survey method conducted on four locations and within five sampling times, was carried out from July to September 2019. The determination of data collection stations was based on consideration of water input, anthropogenic activities, and biochemical oxygen demand (BOD_5) values to describe the differences in the characteristics of each station. The stations locations are depicted in Figure 1.

Station 1. Located in the Jatigede Reservoir inlet in Sukamenak Village, Darmaraja District (6°55'58.8"S, 108°05'20.3"E). This station was chosen because this location receives the dominant water input from the Cimanuk River and BOD_5 values show that this station grouped into the heavily polluted category.
Station 2. Located in the middle of Jatigede Reservoir in Leuwihideung Village, Darmaraja District (6°54'40.1"S, 108°05'46.4"E). This station is subject to anthropogenic activities waste, as well as fish farming activities. Floating net cages were found in this area and based on BOD_5 values this station was grouped as medium polluted.
Station 3. Located in the middle of Jatigede Reservoir near Jemah Village, Jatigede District (6°53'06.8"S, 108°06'11.3"E). This station receives other water inputs such as the Cinambo River, Cibayawak River, Cihonje River, Cicacaban River and Cimuja River. Based on the BOD_5 values, this area classified in the medium polluted category.
Station 4. Located at the Jatigede Reservoir outlet in Cijeungjing Village, Jatigede District (6°51'32.6"S, 108°05'49.0"E). This station is an outlet of the Jatigede Reservoir and is affected by all water inputs of any activities in the Jatigede Reservoir. Based on the BOD_5 value this station classified as a heavily polluted area.

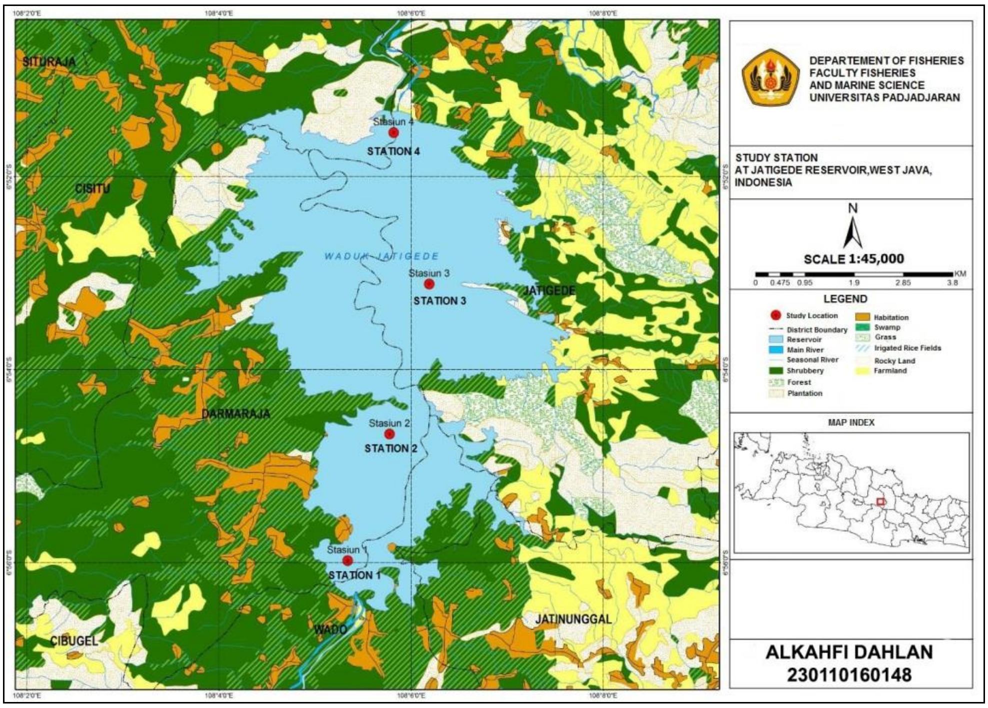

Figure 1. The location of study station at Jatigede Reservoir, West Java, Indonesia.

Sampling and measurement. Sampling was done every seven days for five times at each station. Sampling was carried out at three different depths including surface layer, half depth of compensation and depth of compensation. Plankton sampling was done using a plankton net with a mesh size of 20 μm. The filtered plankton sample was then put into a sample bottle, 1% lugol solution was added and the analysis was conducted in the laboratory. Plankton was identified up to genus level. The analysis of the water physical-chemical parameters was done for nine parameters, namely transparency, temperature, current speed, pH, carbon dioxide (CO_2), biochemical oxygen demand (BOD_5), dissolved oxygen (DO), nitrate and phosphate concentrations.

Data analysis. The research data was analyzed using the comparative descriptive method. Phytoplankton abundance is the number of phytoplankton individuals per unit of volume. Plankton abundance quantitatively is based on abundance expressed in individuals/liters. Phytoplankton diversity was determined using the Shannon diversity index (H'), while the Simpson dominance index (D) was used to determine species dominance. Whereas Dresscher and Mark's saprobic index was used to determine the saprobic coefficient. The discussion was explained by linking indicator species with the physical and chemical conditions of the water, to estimate the condition of a body of water and compared with similar research and water quality standards set by the Indonesian government regulation number 82 of 2001 concerning to Management of Water Quality and Water Pollution Control. Government classifies water as follows: class I, potable water, that could be used as drinking water; class II, water that could be used for water recreation infrastructure/facilities and aquaculture; class III, water that could be used for aquaculture; class IV, water that could be used to irrigate crops.

Results and Discussion

Physicochemical parameters. The measurement results of physical and chemical parameters are presented in Table 1, which displays information about water parameters at different depths (S=surface; 0.5 C=half compensation depth; C=compensation depth; R=range; A=average). The results of the research show that the average temperature of the Jatigede Reservoir waters ranges between 26.58-27.48^{o}C. Temperature conditions are relatively stable, because the temperature change was still below the tolerance limit for water temperature fluctuations according to Government Regulation No. 82 of 2001. In general, the temperature in the Jatigede Reservoir during observation decreased with the increase of depth. This was caused by the lack of intensity from the sun going through the water column. The high light intensity will have a direct effect on the water temperature. High light intensity will produce heat, which will further increase the temperature of water (Zahidah 2017).

The average value of water transparency of the Jatigede Reservoir during the research ranged from 19.5-116.5 cm. The waters transparency range of 30-50 cm are considered being optimal for supporting phytoplankton (Boyd 1990). The highest average transparency was found at Station 4, with a value of 93.10 ± 18.49 cm. Water transparency is inversely proportional to turbidity. Turbidity leads to cloudiness or decreased transparency of water (Omar & Matjafri 2009).

The results showed that the current speed in the Jatigede Reservoir ranged from 0.04 to 0.43 m/s with an average of 0.16 m/s. The current in the Jatigede Reservoir was categorized as slow (0.10-0.25 m s^{-1}) (Welch & Lindell 1980). There was a decreasing tendency in the flow velocity at station 1 to station 2 due to the reduction in the current speed of the Cimanuk River, when the river reaches the reservoir. However, there was an increase in current speed after entering station 3. It is probably caused by the situation of the station, being located on the middle of the reservoir, and thus is frequently exposed to strong winds. Currents on the water surface are commonly influenced by wind (Bayhaqi et al 2017).

The results of the pH in situ measurements of the Jatigede Reservoir water ranged from 6.5-9.3, with an average pH value ranging from 7.69-8.40, at each different depth. Based on Government Regulation No. 82 of 2001, the range of pH values must range between 6-9, for class II and class III. Therefore, in general the waters of Jatigede Reservoir were classified within the specified quality standard range for good quality. In general, the pH value decreases with the increase of depth. The decrease in pH at the bottom is due to increased microbial activity to decompose organic matter, which lead to the concentration of dissolved oxygen decreases and carbon dioxide increases. Increased carbon dioxide makes the water more acidic (pH decreases) (Araoye 2009).

The concentration of carbon dioxide in the waters of the Jatigede Reservoir during research ranged from 4.190 to 12.571 mg/L with an average value of 5.308 mg/L. The highest average carbon dioxide concentrations are at station 1 and the lowest concentrations are at stations of 2 and 4. It is probably related to the presence of phytoplankton which consumes carbon dioxide for photosynthesis. The high concentration of carbon dioxide was linearly proportional to the low abundance of phytoplankton, as well as the low concentration of carbon dioxide at stations 2 and 4 is linearly proportional to the high abundance of phytoplankton at those stations. The autotrophic component requires carbon dioxide being converted into monosaccharides in the process of photosynthesis which reduces the amount of carbon dioxide (Izzati 2008).

The BOD_5 concentration of Jatigede Reservoir during sampling time ranged between 3.24–24.32 mg/L. In general, the BOD_5 concentration in the Jatigede Reservoir exceeds the quality standards stipulated in Government Regulation No. 82 of 2001 where the maximum threshold concentration of BOD5 is 3 mg/L for class II and 5 mg/L for class III. The high value of BOD_5 is due to the high input of organic material originated from the anthropogenic activities and that are carried by the Cimanuk River as the main water source of the Jatigede Reservoir. In addition, decaying submerged trees also contributed to the high value of BOD_5 in the Jatigede Reservoir.

The concentration of dissolved oxygen in Jatigede Reservoir during sampling time ranged from 4.8 to 8.2 mg/L. The dissolved oxygen concentration of the Jatigede Reservoir was categorized in good condition according to Government Regulation No. 82 of 2001, where the minimum threshold for dissolved oxygen concentration is 4 mg/L for class II and 3 mg/L for class III. Oxygen concentration on the surface in general has the highest value due to direct contact with air. The source of dissolved oxygen in the waters comes from the diffusion of oxygen from the air and the process of photosynthesis (Nybakken 1998). The oxygen concentration generally decreases with the increase of depth. The concentration of dissolved oxygen decreases along with its depth, this is because getting deeper into the water decreases the amount of sunlight, and the phytoplankton photosynthesis process cannot be sustained (Hardiyanto et al 2012).

Nitrate concentration in Jatigede Reservoir during sampling time ranged from 0.116 to 0.370 mg/L. Based on Government Regulation No. 82 of 2001 the threshold value of nitrates in waters for class II is 10 mg/L and for class III is 20 mg/L, indicating nitrate concentrations in the Jatigede Reservoir far below the specified threshold. The optimal nitrate concentration for phytoplankton growth is in the range of 3.9-15.5 mg/L (Mackentum 1969). This shows the concentration of nitrate in the Jatigede Reservoir is less suitable for supporting the life of phytoplankton. The highest concentration was found at station 1 and the lowest at station 4. Station 1 is located on the reservoir inlet, which makes this station the area that receives the organic material transported by the Cimanuk River, which is the main source of pollutants entering the reservoir. Nitrate concentrations will increase if the location is closer to the point of waste disposal (Hasan et al 2013).

Phosphate concentrations in the Jatigede Reservoir ranged from 0.104 to 0.267 mg/L. Based on Government Regulation No. 82 of 2001 the threshold value of nitrates in waters for class II is 0.2 mg/L and class III is 1 mg/L, indicating phosphate concentrations in the Jatigede Reservoir are still in the good category. Phosphate is one of the factors that influence the growth of plankton in water (Andriani et al 2018). The optimum phosphate concentrations for phytoplankton growth are in the range of 0.27-5.51 mg/L (Mackentum 1969). This shows the concentration of phosphate in the Jatigede Reservoir was slightly less than the optimum concentration needed by phytoplankton growth. The highest phosphate concentration was obtained at station 1 and the lowest at station 4. Station 1 is located on the reservoir inlet, making this station the first to receive input of organic material carried by the Cimanuk River flow. The main source of phosphate originated from decomposition of soil weathering or decomposition of plants and the remains of dead organisms. It also depends on the surrounding conditions, including exposure to various industrial wastes containing organic compounds (Patty et al 2015).

Table 1

Physicochemical parameters of water at sampling station

Parameters	*Depth*		*Station*			
			1	*2*	*3*	*4*
Trancparency (cm)		R	19.5-38,5	25-79	63-116.5	72-113
		A	27.6±7,8	54.7±21.22	88.7±19.15	93.1±18.49
Temperature (°C)	S	R	26.9-28.3	27-28.1	26.4-28.9	26.4-28.4
		A	27.48±0,54	27.46±0.5	27.02±1.06	27.26±0.73
	0,5 C	R	26.7-28	26.7-27.8	26.4-27.5	26.4-28
		A	27.38±0.53	27.32±0.45	27.02±0.53	27.04±0.59
	C	R	26.4-27.8	26.4-27.6	26.2-27.1	26.3-27.6
		A	26.96±0.59	27.06±0.51	26.58±0.36	26.72±0.6
Current speed (m/s)		R	0.14-0.16	0.05-0.25	0.06-0.43	0.04-0.20
		A	0.152±0.008	0.136±0.092	0.216±0.148	0.142±0.069
pH	S	R	7.04-8.77	7.94-8.74	7.88-8.57	7.79-8.46
		A	7.96±0.64	8.26±0.3	8.194±0.25	8.30±0.29
	0,5 C	R	7.57-8.7	7.73-8.65	7.9-9.38	7.81-8.76
		A	8.15±0.44	8.03±0.38	8.40±0.59	8.40±0.36
	C	R	7.04-8.62	6.5-8.67	8.18-8.44	7.78-8.51
		A	7.84±0.58	7.69±0.78	8.30±0.11	8.17±0.28
CO_2	S	R	4.19-12.57	4.19-4.19	4.19-8.38	4.19-4.19
		A	9.22±3,5	4.19±0	5.03±1.87	4.19±0
	0,5 C	R	4.19-12.57	4.19-4.19	4.19-4.19	4.19-4.19
		A	7.54±3.5	4.19±0	4.19±0	4.19±0
	C	R	4.19-12.57	4.19-4.19	4.19-8.38	4.19-4.19
		A	7.54±3.5	4.19±0	5.03±1.87	4.19±0
BOD_5 (mg/L)		R	4.86-21.08	6.48-24.32	6.48-17.84	3.24-17.84
		A	12.65±6.00	12±7.12	12.32±4.95	11.03±6.00
DO (mg/L)	S	R	6.2-7.9	5.4-8	5.8-7.9	6.1-7.3
		A	6.94±0.8	6.78±1.1	7.12±0.8	6.54±0.5
	0,5 C	R	6.5-7.9	4.8-7.9	6.2-7.5	6.5-7.7
		A	7±0.6	6.38±1.2	6.76±0.5	7±0.5
	C	R	6-7.9	5.5-8.2	6-7.9	6.1-8
		A	7±0.8	6.46±1	6.84±0.8	7±0.8
Nitrate (mg/L)	S	R	0.209-0.279	0.16-0.314	0.133-0.222	0.121-0.2
		A	0.238±0.028	0.232±0.066	0.187±0.034	0.168±0.037
	0,5 C	R	0.148-0.357	0.126-0.286	0.116-0.259	0.13-0.237
		A	0.244±0.082	0.222±0.061	0.199±0.051	0.188±0.046
	C	R	0.15-0.37	0.162-0.321	0.159-0.251	0.152-0.221
		A	0.256±0,103	0.236±0.064	0.191±0.036	0.183±0.029
Phosphate (mg/L)	S	R	0.128-0.211	0.114-0.169	0.127-0.182	0.115-0.183
		A	0.161±0.031	0.148±0.02	0.156±0.023	0.148±0.027
	0,5 C	R	0.146-0.215	0.104-0.214	0.123-0.17	0.131-0.16
		A	0.174±0.026	0.152±0.04	0.139±0.019	0.141±0.012
	C	R	0.14-0.267	0.134-0.183	0.113-0.219	0.111-0.193

Phytoplankton abundance. Plankton obtained in this research were identified to the genus level. Phytoplankton found in Jatigede Reservoir during the research consisted of 5 phyla with 49 genera. The five phytoplankton phyla were Cyanophyta (7 genera), Chlorophyta (28 genera), Chrysophyta (9 genera), Pyrrophyta (2 genera), and Euglenophyta (3 genera). The composition of phytoplankton abundance in Jatigede Reservoir was dominated by Chrysophyta phylum with a value of 60% (Figure 2) with the most found genera being *Nitzschia*. These results were like previous studies in 2017 which stated that the Bacillariophyceae class, especially the genus *Nitzchia*, was the phytoplankton that was the most abundant in Jatigede Reservoir (Djunaidah et al 2017). The high composition of the abundance of the chrysophyta phylum, especially the genus *Nitzschia*, was found to more frequently because this type of phytoplankton was able to adapt to the environment. The Bacillariophyceae class, including the genus *Nitzschia*, was the most tolerant type of diatom and therefore can multiply rapidly and utilize nutrients properly (Nurfadilah et al 2012). However, *Nitzschia* sp. is one species that has a high tolerance of polluted waters environment (Fitriyah et al 2016).

The highest average of phytoplankton abundance was found at station 2 with a value of 15069 ind/L (Figure 3). This is presumably due to the location of station 2, being a transition zone between the riverine and lacustrine zones. This station is located not far from the inlet, so it still receives a lot of organic material input, but in contrast to station 1 (inlet), station 2 has a lower current speed, so that the organic material carried over from the previous station stays longer at this station and it can be utilized better by plankton, which then affects the abundance of plankton itself. The current speed was decreasing at station 2 and is the lowest current speed compared to other stations (Table 1). Current flow patterns play a role in determining the distribution characteristics of nutrients and phytoplankton (Barus 2004). In addition, Station 2 was a place for cultivation activities using floating net cages and this suggested that there was an input of organic matter pollution, in the form of leftover food and fish metabolic waste. Pollution with organic matter derived from floating net cages can stimulate the growth of phytoplankton (Herawati et al 2017). While the lowest mean phytoplankton abundance was found at station 1, with a value of 6978 ind/L (Figure 3). This is thought to be related to the low transparency of water at station 1 (Table 1). As an autotrophic organism, the presence of light in water is a limiting factor for phytoplankton life (Putra et al 2012).

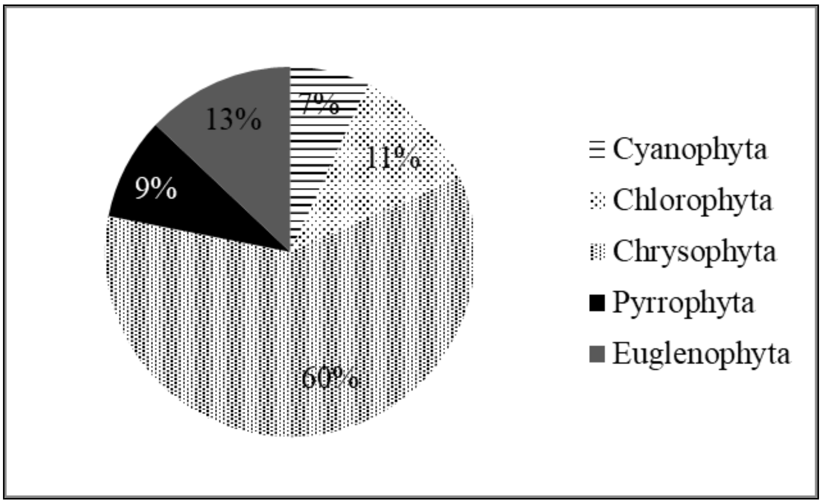

Figure 2. The abundance percentage of Jatigede Reservoir phytoplankton based on phylum.

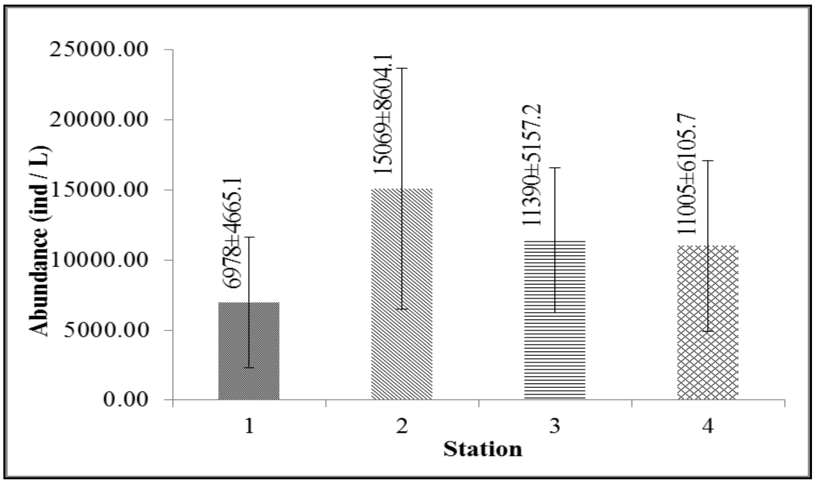

Figure 3. The abundance of Jatigede Reservoir phytoplankton.

Plankton community structure. The Shannon diversity index (H') and the Simpson dominance index (D) can illustrate more about community structure than the abundance information (Asadi et al 2018). The results of the phytoplankton diversity index calculation ranged from 0.904 to 2.062 (Figure 4) with the highest average value at station 1 of 1.939 and the lowest at station 4 of 1.073 indicating moderate diversity. When compared with previous studies, similar results were obtained, that mention the Jatigede Reservoir has a moderate level of diversity (1.28-1.67) (Djunaidah et al 2017). This shows that the phytoplankton community in the Jatigede Reservoir was in a state of stability or low diversity, with no dominant species. The diversity index value is caused by the physical factors of water as well as the availability of nutrients and the use of different nutrients and their ability to adapt to the existing environmental conditions (Sirait et al 2018).

Phytoplankton dominance index ranged from 0.258 to 0.681 (Figure 5) with the highest average value at station 4 of 0.618, which shows moderate dominance and the lowest at station 1 of 0.287, which shows low dominance. These results were not much different from previous studies which mentioned the dominance index of phytoplankton in the Jatigede Reservoir each ranged from 0.262 to 0.521 (Djunaidah et al 2017). These results indicate that the level of dominance in the Jatigede Reservoir was low, which show the absence of competition in the utilization of resources and balanced environmental conditions.

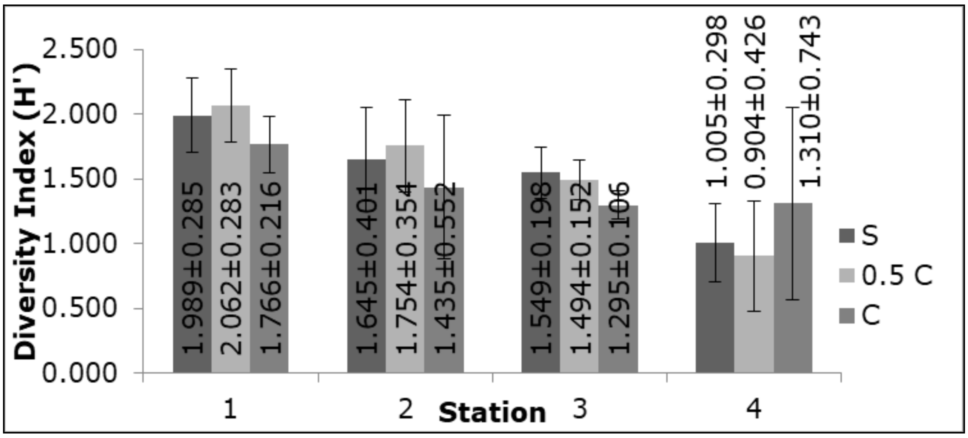

Figure 4. Diversity index of phytoplankton in Jatigede Reservoir.
(S=surface; 0.5 C=half compensation depth; C=compensation depth)

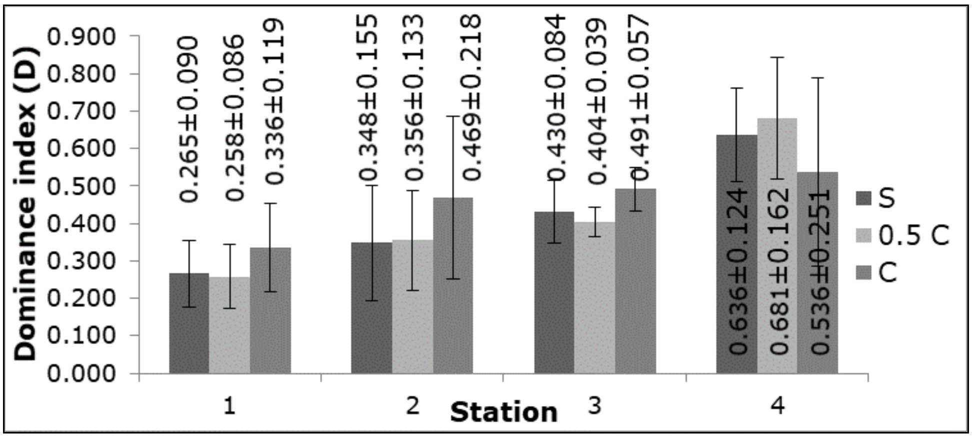

Figure 5. Dominance index of phytoplankton in Jatigede Reservoir.

Saprobic index. Saprobic index shows the degree of pollution that occurs in waters, using indicators of the composition of organisms in the water. The results of plankton identification in the Jatigede Reservoir during the study found 60 indicator plankton genera consisting of 11 genera of the polysaprobic group, 10 genera of the α-mesosaprobic group, 27 genera of the β-mesosaprobic group, and 12 genera of the oligosaprobic group (Table 2).

Based on the pollution level criteria and the results of the calculation of the saprobic index, the Jatigede Reservoir was in a mildly polluted condition (Table 3). Jatigede Reservoir saprobic index ranges from 1.14 to 1.26 with an average of 1.20, which shows a level of light pollution with organic and inorganic pollutants and is classified in the β-meso/oligosaprobic phase. This value was obtained because of the abundance of plankton making up the β-mesosaprobic group, namely plankton belonging to Chlorococcales and Diatoms (class Bacillariophyceae). The type that contributes greatly to this group was the genus *Nitzschia*. The presence of Bacillariophyceae (diatoms), such as *Nitzschia*, is an indicator species in mild to moderate polluted waters. Nitzschia has a wide range of tolerances for organic matter pollution and can act as an indicator of moderate to severe polluted waters (Aprisanti et al 2013).

Table 2

The data of phytoplankton as bioindicator in Jatigede Reservoir (saprobicity level)

No.	*Saprobicity level*	*Phyla*	*The Number of Genus*	*The Number of Total Individuals*
1	Polisaprobic	Ciliophora, Aschelminthes (class Rotatoria)	0	0
2	α– Mesosaprobic	Cyanophyta (class Cyanophyceae), Euglenophyta	10	26,351
3	β– Mesosaprobic	Chlorophyta (order Chlorococcales), Chrysophyta(class Bacillariophyceae/Diatoms)	27	89,788
4	Oligosaprobic	Pyrrophyta, Chrysophyta (Chrysophyceae), Chlorophyta (order Conjugales)	12	15,809

Table 3

Plankton identification data indicator in Jatigede Reservoir (saprobicity index)

Station	*Saprobic Index*	*Saprobic Phase*	*Pollution Level*
1	1.25	β-meso/oligosaprobic	Light
2	1.14	β-meso/oligosaprobic	Light
3	1.17	β-meso/oligosaprobic	Light
4	1.26	β-meso/oligosaprobic	Light

The lowest saprobic index value with a value of 1.14 is obtained at station 2. This is caused by the accumulation of organic matter pollution due to the long-range time of water retention. In any case, this condition is affected by the low current velocity in this station (Table 1). In addition, the existence of farming activities using floating net cages at this station also contributed to the value of saprobicity. The existence of floating net cages is supposed to be a source of reservoir waters pollution. The source of pollutants comes from food waste, and fish metabolic waste. Waste from this aquaculture activity will enter the reservoir water, which will then affect the water saprobicity (Astuti 2018). The level of saprobicity was influenced by the proximity of water bodies to human settlements, the presence of sedimentation, and the load of organic and inorganic pollutants (Fachrul et al 2005).

The highest saprobic index value was obtained at station 4 with a value of 1.26. This indicated mild pollution, which was also strengthened by the lower value of BOD_5 at station 4, compared to other stations (Table 1). The low saprobic index value of a water is characterized by a high BOD_5 value (Prasetyaningsih 2019).

Conclusion. The saprobic index ranges from 1.14 to 1.26 with an average of 1.20 and belongs to the β-meso/oligosaprobic phase, with the major contributing species being the Chlorococcales and Diatoms group, which describes mild pollution. The highest pollution level was at station 2, with an average saprobic index of 1.14 and the lowest pollution level was at station 4, with an average saprobic index of 1.26. The phytoplankton identified in the Jatigede Reservoir consisted of 49 genera with an abundance of 11,110 ind/L. Variation index was 0.904–2.062 and dominance index was 0.258–0.681.

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