Mapping of trophic states based on nutrients concentration and phytoplankton abundance in Jatibarang Reservoir

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Abstract. Jatibarang Reservoir is one of the Indonesian Reservoirs, which used for human activities such as tourism and agriculture. These activities will provide input of organic matter and nutrients into the water. These materials will impact water quality and eutrophication process. Eutrophication is the water enrichment by nutrients, especially nitrogen and phosphorus which can promote the growth of phytoplankton. Some indicators of eutrophication are increasing nutrients, trophic states, and change of phytoplankton composition. The relationship between water quality and phytoplankton community can be used as an indicator of trophic states in Jatibarang Reservoir. The aim of this study was to analyze the effect of nutrients concentration and phytoplankton abundance to the trophic states and mapping trophic states based on nutrients concentration and phytoplankton in Jatibarang Reservoir. This study was conducted in June and July 2017 at 9 stations around Jatibarang Reservoir. The results showed that average concentration of nitrate, phosphate, and chlorophyll-a in Jatibarang Reservoir was 0.69 mg/L, 0.27 mg/L, and 1.66 mg/m^3, respectively. The phytoplankton abundance ranged 16-62,200 cells/L, consists of 21 genera of four classes, i.e. *Chlorophyceae, Cyanophyceae, Bacillariophyceae*, and *Dinophyceae*. *Cyanophyceae* was a dominant phytoplankton group based on the composition of abundance (>80%). High nutrient concentrations and phytoplankton dominated by *Anabaena* (*Cyanophyceae*) which indicated that the waters in Jatibarang Reservoir were eutrophic.

Keywords: Jatibarang Reservoir, nutrients, phytoplankton, trophic states, eutrophic

1. Introduction

Jatibarang Reservoir is a reservoir located in Gunungpati District, Semarang City. Jatibarang Reservoir has a water volume capacity of 20,400,000 m^3. Jatibarang Reservoir catchment area is 54 km^2 and maximum water level ± 155.30 m. Jatibarang Reservoir has an area of about 46.56 ha which functions as flood control in Semarang City, power plant, tourism area, fishing activities and irrigation. Jatibarang Reservoir that is used to various activities needs to be reviewed the water quality as a method to manage resources in the reservoir.

One common problem that often occurs in the reservoir is eutrophication. Eutrophication is a worldwide problem that occurs in both freshwater and marine ecosystems. Eutrophication is an increasing process of trophic states from oligotrophic, mesotrophic to eutrophic. Some of the eutrophication caused by domestic waste pollution [1] and watershed management issues [2]. Some of the eutrophication effects are causing changes in water quality, such as decreased dissolved oxygen and water transparency, organic matter enhancement, and phytoplankton blooms.

This study is important because the trophic state is one of the basic determination of pollution load capacity. The pollution load capacity is a consideration for the determination of spatial planning of reservoir catchment area and allowance activity that can affect the water quality. The trophic state can also use as a basis for water management for the reservoir to function properly. Water management is essential because water is an important natural resource for life and useful for maintaining ecological balance.

The aim of this study was to analyze the effect of nutrients concentration and phytoplankton abundance to the trophic states and mapping trophic states based on nutrients concentration and phytoplankton in Jatibarang Reservoir.

2. Materials and methods

2.1. Materials

Materials and tools used during the study were materials and tools for water sampling, water quality analysis, and phytoplankton identification in the laboratory. The tools used for water sampling are Boat, Van Dorn water sampler, GPS, Secchi disk, plankton net and sample bottles. The tools and materials used for phytoplankton identification were microscopes and phytoplankton identification books.

2.2. Sampling methods

This study was conducted two times during the period from June to July 2017 consisted of water and phytoplankton sampling around Jatibarang Reservoir. The sampling sites were 9 stations located in the waters around Jatibarang Reservoir (Fig. 1). The stations were chosen based on different waters and land use conditions around Jatibarang Reservoir.

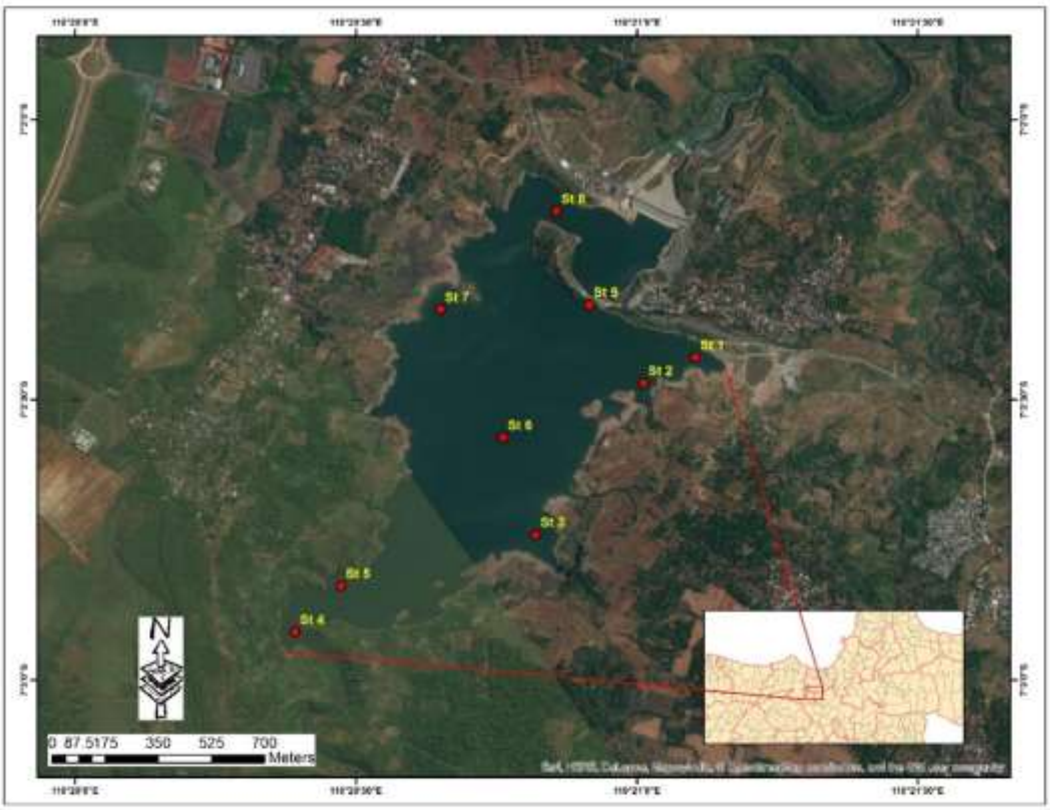

Figure 1. The sampling location at Jatibarang Reservoir

Samples were collected at a depth about 1 m below the surface at each location. Samples were carried out using Van Dorn water sampler at depth of 1 m from surface. Water and phytoplankton sample then inserted into the bottle. Water samples preserved with cooling in the cool box. Phytoplankton preserved immediately with 1% of acidified Lugol iodine solution for counting under a microscope in the laboratory.

2.3. Analytical methods

The water quality in Jatibarang Reservoir, including the water temperature, pH, dissolved oxygen, were measured in situ with Water Quality Checker. Transparency was measured with a Secchi disk. A sample of approximately 1.5 L of water was taken from each site to measure the chlorophyll-a and nutrient concentrations. Quantitative samples of the phytoplankton were collected each sampling site and preserved immediately with 1% of acidified Lugol iodine solution for counting under a microscope in the laboratory.

Nitrate and phosphate were analyzed with spectrophotometry method according to the standard method. In the filtered water samples, nitrate and phosphate with the ascorbic acid method. A spectrophotometer was used to conduct the measurements automatically. The phytoplankton samples were counted directly in counting chamber using a compound microscope at an objective magnification 10x. Phytoplankton species were identified according to plankton identification books [3][4].

2.4. Data analysis

Data analysis used in this study were phytoplankton community structure analysis and trophic states. The phytoplankton community structure analysis was determined using the diversity index, similarity, and dominance index according to Krebs [5]. The trophic state's analysis was determined based on the Nygaard index [6].

3. Result and Discussion

3.1. Variations of the environmental factors

The physical and chemical conditions in Jatibarang Reservoir are shown in Fig. 2. Fig. 2 shows the time course of water temperature, pH, transparency, and dissolved oxygen concentration, respectively. The physical-chemical conditions of the waters varied considerably during the study. The results showed that the water temperature varied from 27.60 to 29.05 ^{o}C with the highest value 29.05 ^{o}C in Station 3. The pH value of water varied from 7.14 to 8.03 with average 7.53. Water transparency varied from 0.44 to 0.77 m with average 0.62 m.

Dissolved oxygen (DO) varied from 6.92 to 7.94 mg/L with average 7.51 mg/L. The highest DO concentration reaching 7.94 mg/L in Station 2 and 7.85 mg/L in Station 9 and the lowest concentration (6.92 mg/L) was recorded in Station 3 when the highest temperature value occurred. A high DO concentration in water may cause by sampling time of day during when the oxygen produced by photosynthesis is higher than that consumed by respiration [7].

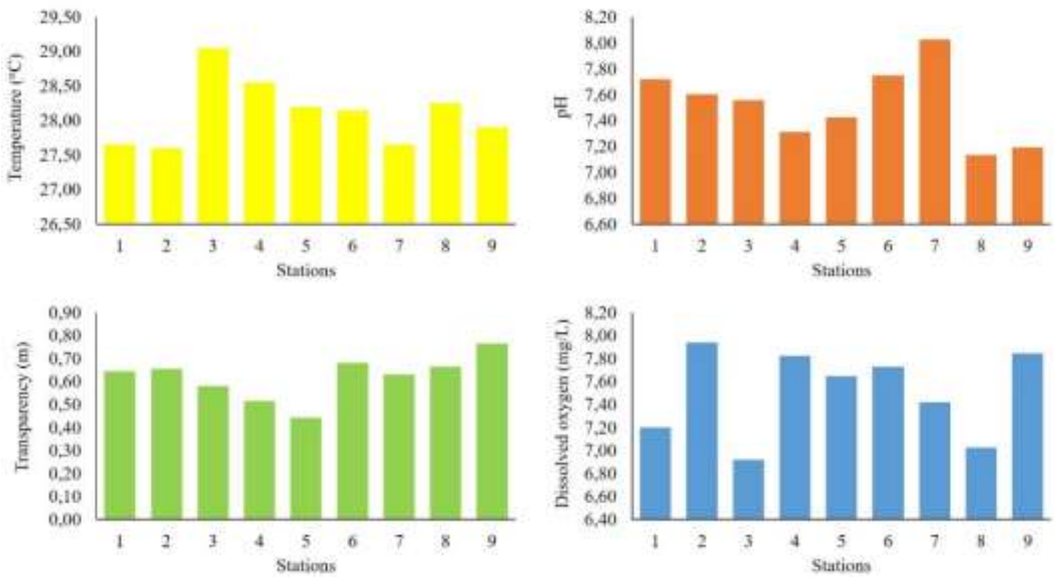

Figure 2. The physical and chemical conditions in Jatibarang Reservoir

Chlorophyll-a concentrations ranged between 1.29-2.22 mg/m^3 with an average of 1.66 mg/m^3. Nitrate concentrations ranged from 0.56 to 0.82 mg/L with an average of 0.69 mg/L. Nitrate concentration> 0.2 mg/L indicates that the waters around Jatibarang Reservoir belong to the eutrophic waters [8]. Nitrate is the main form of nitrogen in the water, stable and very soluble in water. Nitrate concentrations between 1-2 mg/L indicate the presence of fertilizer pollution from agricultural activities [9].

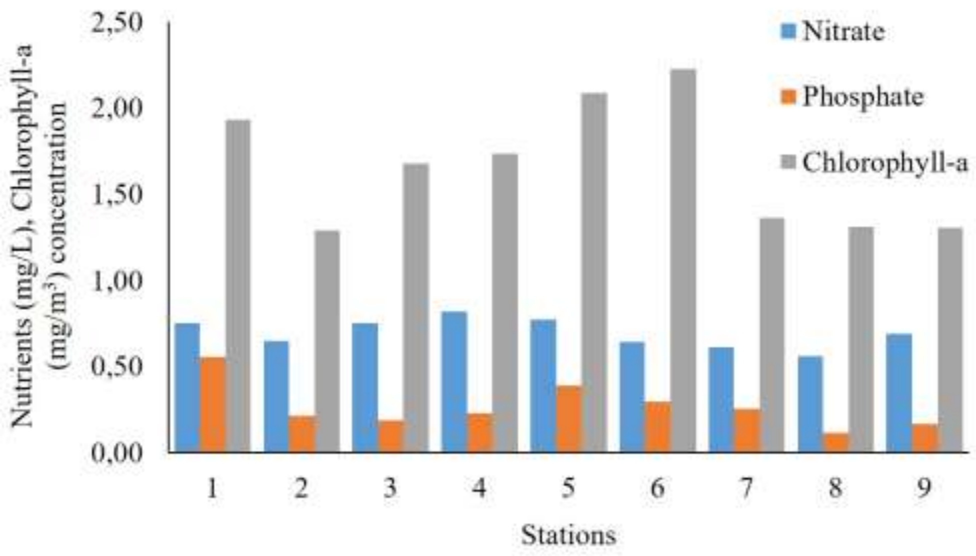

Figure 3. Nutrients and chlorophyll-a concentrations

Phosphate concentrations ranged between 0.11-0.56 mg/L with an average of 0.27 mg/L. Phosphate concentration in the waters around Jatibarang Reservoir showed a high or eutrophic condition (>0.20 mg/L) [10]. Agricultural land is one source of nutrients that enter the waters. One such agricultural activity as fertilizer will contribute to the increase of nutrient concentration in the waters and can lead to eutrophication of the waters. The use of fertilizers in agricultural activities around the lake can increase the concentration of nitrogen (ammonia and nitrate) in the waters [11].

3.2. Variations of the phytoplankton community

A total of 21 phytoplankton genera were identified. Among these genera, 2 genera in *Cyanophyceae*, 6 genera in *Chlorophyceae*, 11 genera in *Bacillariophyceae*, and 2 genera in *Dinophyceae*, respectively, were determined from the reservoir samples. The phytoplankton abundance varied between 16-62,200 cells/L. *Cyanophyceae* was greatest in 9 stations. As a phylum with the maximal genera, *Cyanophyceae* algae were determined in all samples. The composition of phytoplankton abundance is presented in Fig. 4.

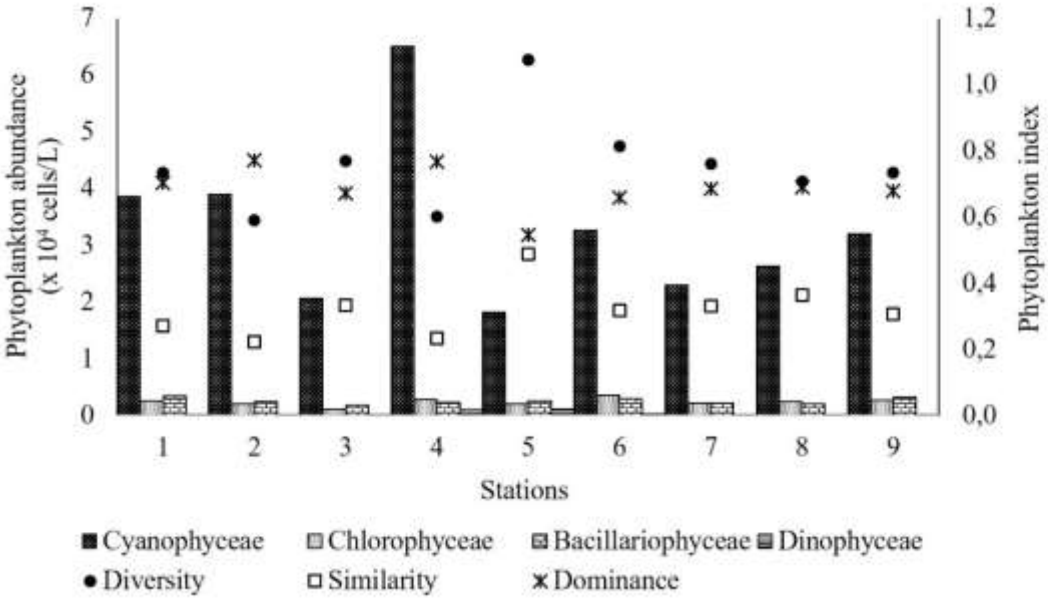

Figure 4. Composition of phytoplankton abundance in Jatibarang Reservoir

Cyanophyceae was absolutely the dominant genera of the community in Jatibarang Reservoir despite having a small number of species. *Cyanophyceae* represented ±85% of the total phytoplankton abundance, *Chlorophyceae* and *Bacillariophyceae* represented ±7%, and *Dinophyceae* represented ±1% of the total phytoplankton abundance. Cyanophyceae dominance was caused by the influence of eutrophic water conditions with high concentrations of nutrients.

Cyanophyceae was common in waters with high phosphate concentrations [12]. The presence of *Cyanophyceae* was influenced by phosphate concentrations where high *Cyanophyceae* abundance was present in waters with high phosphate concentrations [13][14]. These findings suggest that Jatibarang Reservoir has become entirely eutrophic waters.

Anabaena dominated the phytoplankton community. *Anabaena* was found at all sites with a total abundance of 285,800 cells/L. *Anabaena* is one of phytoplankton genera that became the founder of eutrophic waters. Some of the most phytoplankton abundant in eutrophic waters are *Anabaena*, *Microcystis*, *Chroococcus*, and filamentous species such as *Aphanizomenon* [14][15][16]. *Anabaena* and *Microcystis* are the toxic phytoplankton and causes of problems associated with hypoxia and changes in the structure of biological communities [17][18].

Dominant phytoplankton in this study was same with another study in Lake Toba. The same of condition dominant phytoplankton can cause by same in water quality conditions, especially the nutrients concentrations. In this study, nutrient concentrations, especially nitrate and phosphate, have high concentrations same within Lake Toba [19]. The others genera of phytoplankton were *Synedra* and *Staurastrum* with a total abundance of 20,097 cells/L and 15,615 cells/L, respectively. The others genera, i.e. *Cymbella, Rhizosolenia,* and *Pleurosigma*, had low abundance in all sites.

The presence of phytoplankton is influenced by several factors, such as nutrient concentration, light conditions, temperature, pH, and predation by zooplankton and planktivorous fish [14][20]. The development of phytoplankton community in every water is dynamic. A type of phytoplankton may be more dominant than other types at relatively short intervals. The dominant phytoplankton type at any given time can be a rare species at a later time and may be replaced by another more dominant species[3].

The diversity index during this study of 0.59-1.07 indicates that low phytoplankton diversity and phytoplankton communities are unstable. The value of the diversity index is similar to that of Lake Sentani of 0.8-2.3 [21]. The similarity and dominance index during this study varied from 0.22 to 0.49 and 0.54 to 0.77, respectively. The similarity index indicating that the phytoplankton composition type was low to evenly distributed and showed the dominance of certain phytoplankton genera.

Some stations with low diversity indexes show a higher index of dominance than the similarity index (Fig. 4). Both the index of diversity and similarity in this study were low. The low of the diversity index and similarity indicates that there has been a decrease in water quality. The low index value of phytoplankton diversity can be caused by poor water quality conditions, so only tolerant types of phytoplankton can live in those waters[22].

3.3. Trophic states

The trophic states of water were determined using the Nygaard index[6]. The Nygaard index calculation was based on the composition of the number of phytoplankton species found during the study. The Nygaard index results in this study varied from 3 to 9 indicating that the trophic states around Jatibarang Reservoir were eutrophic waters (Fig. 5).

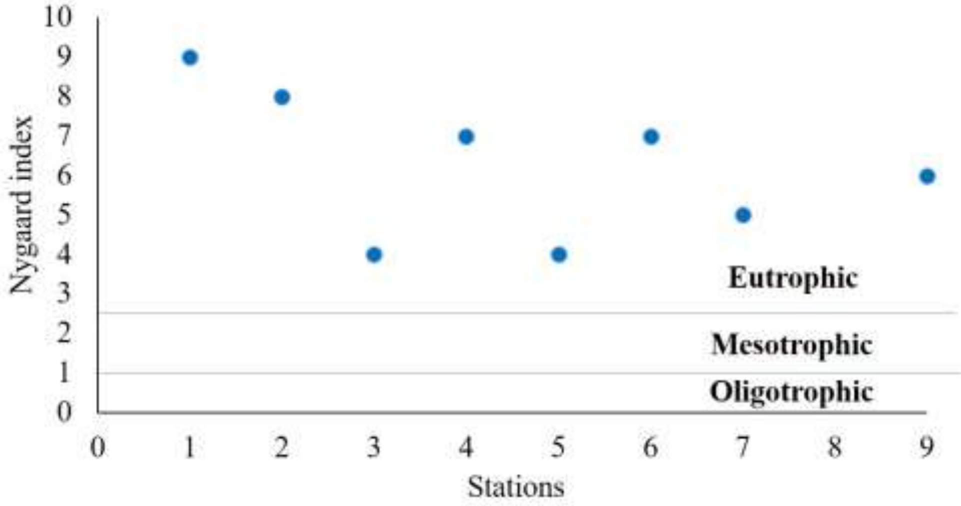

Figure 5 Trophic states in Jatibarang Reservoir

Based on the Nygaard index, nitrate and phosphate concentrations, trophic states in the waters Jatibarang Reservoir has shown eutrophic levels (Fig. 6). These results indicate that Jatibarang Reservoir has eutrophication. Eutrophication is a natural process that can occur in a wide variety of waters (especially lakes and reservoirs) and can rise very rapidly with human activities [23].

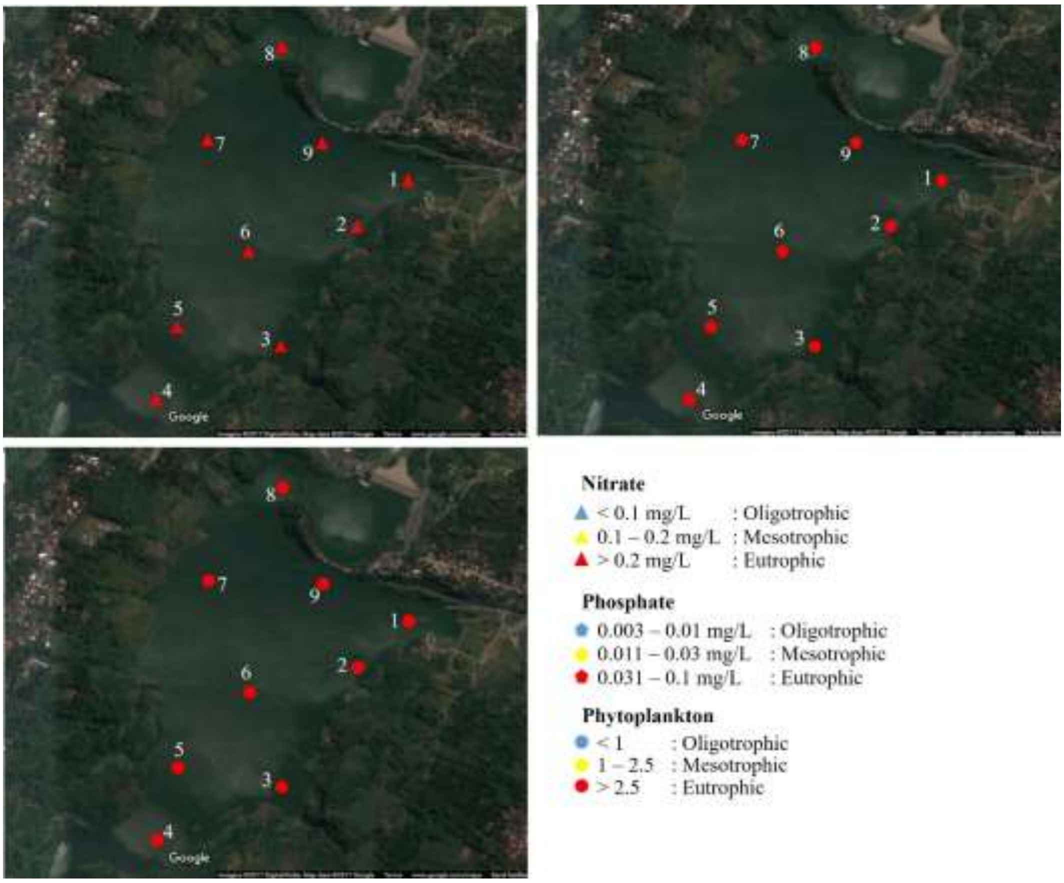

Figure 6 Trophic states distributions in Reservoir Jatibarang

The eutrophic condition is a description of the human activities impact on waters [24]. Some of the things that can affect nutrient concentration in waters are nutrient input from water catchment and lake sediment [25], fertilizer from agricultural, phosphate from detergent, soil erosion, industrial waste [26], and nutrient cycles [27].

4. Conclusion

Jatibarang Reservoir has a high nitrate and phosphate concentrations. Phytoplankton community was dominated by *Cyanophyceae*, especially *Anabaena*. High nutrient concentrations and phytoplankton dominated by *Anabaena* (*Cyanophyceae*) which indicated that the waters in Jatibarang Reservoir were eutrophic.

5. Acknowledgement

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