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Estimation of phytoplankton carbon content in Jatigede Reservoir, Sumedang, West Java

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Abstract*. Jatigede Reservoir is stagnant inland water formed from the damming of the Cimanuk river. Jatigede Reservoir, like any other reservoir, is horizontally divided into three areas, namely riverine, transition, and lacustrine. The different characteristics of each zone also impact the composition and community of phytoplankton, trophic status, and carbon content. This study aims to calculate the carbon content of phytoplankton in the waters of the Jatigede Reservoir in each zone with the composition and community of phytoplankton at a certain trophic status. The research stations were selected using purposive sampling with station selection based on the site in the reservoir, namely riverine, transition, and lacustrine. Analysis of trophic status and carbon content was used to determine the condition and presence of carbon in the Jatiged Reservoir. The trophic position of the Jatigede Reservoir based on the Nygaard Index and TSI (Tropic State Index) is categorized into the eutrophic level. Species from the Cyanophyceae class tend to have high abundances, but the higher carbon content is in the Dinophyceae class. Riverin, transitional, and lacustrine zoning have the same trophic status but have different compositions and phytoplankton communities. Based on the study results, the carbon content of phytoplankton was relatively high in the riverine and lacustrine zones and low in the transition zone.*

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INTRODUCTION

Jatigede Reservoir is stagnant inland water formed from the dam upstream of the Cimanuk River. Jatigede Reservoir has an area of 41,12 km^2 with an adequate water storage volume of 876,9 million m^3. Jatigede Reservoir is intended to irrigate rice fields in an irrigation system covering an area of 90.000 ha to generate electricity with an installed power of 110 MW and for domestic purposes (BBWS 2020). Straskbra and Tundisi (1999) classified reservoirs based on area size and reservoir volume into four categories. Jatigede Reservoir is in the small category with an area of 1–100 km^2.

In general, there is horizontal zoning of the reservoir and the Jatigede Reservoir. The pool is divided into three areas based on the zoning, namely riverine, transition, and lacustrine. Physical characteristics, such as area, current velocity, depth, nutrients, and trophic status, can differ in each zone (Wetzel and Likens 1991).

The other characteristics of each location also impact the composition and community of phytoplankton, as well as the condition of the trophic status of the reservoir. Phytoplankton responds to differences in water conditions and results in the formation of diversity, uniformity, and dominance of the phytoplankton community (Scheffer *et al.* 2003). Mason (1991) explains that waters with specific environmental conditions have certain phytoplankton communities.

Phytoplankton is directly related to the presence of carbon in the waters in the process of photosynthesis. The concentration of carbon in water in the form of CO_2 will be absorbed by phytoplankton in the photosynthesis process and produce $C_6H_{12}O_6$. This process makes phytoplankton play a role in absorbing and storing carbon (carbon stock) in the waters. The amount of content absorbed and held by phytoplankton is essential to know. Sobek *et al.* (2006) showed that the carbon content in phytoplankton was 369 mgC/m^2 in Frisksjo¨n lake with 1.848 km^2.

Estimate carbon content in phytoplankton based on the biovolume approach of each type of phytoplankton, combined with the abundance of that type of phytoplankton (Menden-Deuer and Lessard 2000). Information about the carbon content in the reservoir is still not widely known. Therefore, this paper presents the results of research on the estimation of carbon content using the phytoplankton biovolume approach to illustrate the role of phytoplankton in carbon flux under certain trophic status conditions.

METHOD

Location and Time

The research was conducted from February to April 2021 in Jatigede Reservoir, Sumedang, West Java. Every month, sampling was carried out at eight observation points (Figure 1). The research stations were selected using purposive sampling based on the zones in the reservoir, namely riverine, transition, and lacustrine. Water quality analysis was carried out at the Water Productivity and Environment Laboratory, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University.

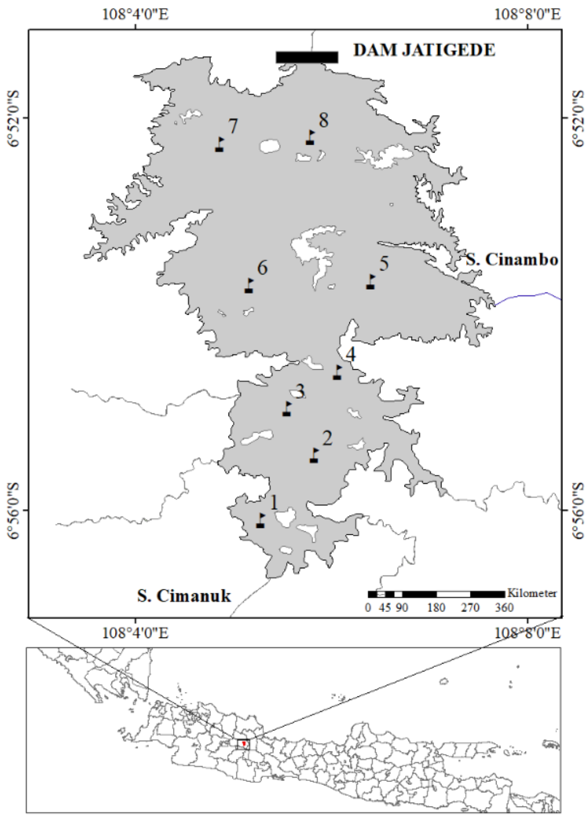

Figure 1 Location map of Jatigede Reservoir, Sumedang, West Java

Data collection

The data used in this study include primary data and secondary data. Preliminary data were obtained from laboratory measurements and analysis results, while secondary data was obtained from the management of the Jatigede Reservoir (BBWS Cimanuk-Cisagarung). Parameters measured directly in the field (in situ) are temperature, brightness, pH, and dissolved oxygen (DO). Parameters analyzed in the laboratory include chlorophyll, total phosphate, and phytoplankton. Secondary data includes reservoir morphometry and hydrology data.

Measurement of reservoir flow using a flowmeter, dissolved oxygen and temperature using a DO-meter, and pH with a pH-meter directly at each observation station. The brightness of the waters is calculated from the results of the Secchi depth measurement. Analysis of alkalinity parameters, nutrients (ammonia, nitrate, nitrite, orthophosphate), and water samples were taken using a Van Dorn Water Sampler in the surface layer of the water. After that, the water was put into a 500 ml sample bottle and given a preservative. Then the samples were analyzed in the laboratory using the APHA method (2012).

Phytoplankton sampling was carried out using the vertical towing method using a plankton net at a depth of Secchi. When then preserved, the phytoplankton samples were in 1% Lugol solution for analysis in the laboratory. To determine the filtered volume, the formula for the volume of the cylinder is:

$$\text{Filtered Volume} = 3{,}14 \times r^2 \times t$$

explanation: r = net plankton radius; t = Secchi disc depth

The abundance of phytoplankton was obtained using the strip method using 10 x 10 phytoplankton which was carried out using the Sedgewick Rafter Counting cell (SRC) tool at the service of 10 x 10. Phytoplankton identification is made by referring to the exploration book. The abundance of phytoplankton is expressed in cells/L, calculated by the APHA (2012) formula.

$$\text{No./mL} = \frac{C \times 1.000\ \text{mm}^3}{L \times D \times W \times S}$$

C : Number of organisms counted (cell)
L : Chamber Length (50 mm)
D : Chamber Depth (1 mm)
W : Chamber Width (20 mm)
S : Count the number of strips (15 strips)

Analysis

Determination of Seasons and Water Zones

The determination of the season is based on rainfall data from the BMKG Kertajati Meteorological Station. The start of the rainy season is determined based on the amount of rainfall in one basis (10 days) that exceeds 50 mm and is followed by the next two bases. Based on Wetzel and Likens (1991), the reservoir waters are divided into three parts: riverine, transitional, and lacustrine. The division of the three parts is based on the physical, chemical, and biological characteristics, namely area, depth, current, nutrient, and fertility level. However, in this study, grouping at eight stations used water quality parameters.

Status Trophic

The trophic status of the Jatigede Reservoir is determined based on the waters' physical, chemical, and biological parameters. The level of trophic status can be known through the value of the Trophic State Index

(TSI), with the parameters measured, namely Secchi disc depth, total phosphorus, and chlorophyll-a (TSI-Chl-a) (Carlson 1977). Based on the average TSI results in the equation obtained, the level of trophic status is grouped according to Carlson (1977) into four, namely oligotrophic (<40), mesotrophic (40–50), eutrophic (50–70), hypereutrophic (>70).

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

$$\text{TSI-TP}= 10\ \left(6 - \frac{\ln \frac{48}{\text{TP}}}{\ln 2}\right)$$

$$\text{TSI-SD}= 10\ \left(6- \frac{2{,}04\text{-}0{,}68 \ln \textit{Chl-a}}{\ln 2}\right)$$

$$\text{TSI} = \frac{\text{TSI-SD} + \text{TSI TP} + \text{TSI } \textit{Chl-a}}{3}$$

Trophic status can also be calculated based on biological parameters using the Nygaard index (Nygaard 1949 in Rawson 1956). The Nygaard index calculation (In) is based on the ratio between the number of Myxophyceae, Chlorococcalles, Centric Diatom, Euglenophyta species with the number of Desmidiaceae species, with the category for Nygaard index, In <1: oligotrophic, 1 In 2,5: mesotrophic (mild eutrophic) and >2,5: eutrophic.

Estimated Carbon Content in Phytoplankton

Phytoplankton generally has geometric shapes such as spheres, cylinders, and cones. The geometric shape of this phytoplankton is used to calculate the volume according to its geometric volume formula (Sun and Lıu 2003; Hillebrand *et al.* 1999). Volume measurements with 30 individuals of each species or taxon (more for high-abundance individuals).

The estimation of carbon content to estimate the carbon stock in phytoplankton in the waters through the cell biovolume approach is calculated using two regression equations. According to Menden-Deuer and Lessard (2000), the procedure is divided into two equations. The first equation is for non-diatoms [1], and the second equation is for diatoms [2[. Cc = carbon content per cell (µgC) and Vc = biovolume per cell (µm3).

$$C_c = 0.216\ \ V_c^{\ 0.939}$$

$$C_c = 0.288\ V_c^{\ 0.881}$$

The carbon biomass content (C) contained in phytoplankton can also be estimated by multiplying the abundance value (n) of phytoplankton with the Cc value, according to Menden-Deuer and Lessard (2000). This is done for all types of a taxon (N) with the following formula.

$$C= \sum_{i}^{N} n \times Cc$$

RESULT AND DISCUSSION

Determination of Seasons and Water Zones

Rainfall in June 2020–September 2021 is the dry season, while October 2020–April 2021 is the rainy season. The research was carried out from February–April 2021, which describes conditions during the rainy season. Based on Wetzel and Likens (1991), the reservoir waters are divided into three parts, namely: riverine, transitional, and lacustrine. The division of the three parts is based on the physical, chemical, and biological characteristics, namely area, depth, current, nutrient, and trophic level. However, in this study, grouping at eight stations used water quality parameters. The story of similarity between stations with a similarity value of 70% formed 3 major groups, first: stations 1 and 2; second: stations 3, 4, 5; and third: stations 6, 7, and 8. So that the zoning of the Jatigede Reservoir at stations 1 and 2 are riverine areas; stations 3, 4, and 5 are transition areas; while 6, 7, and 8 are lacustrine areas.

Phytoplankton Community

Reservoirs can be a place to accumulate nutrients from catchment areas around water bodies (Szalinska 2010). The addition of these nutrients will increase primary productivity and phytoplankton biomass (Sara *et al.* 2011). Based on the research, the composition of phytoplankton species in Jatigede Reservoir is 32 genera from the classes Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae, and Euglenaphyceae (Figure 2).

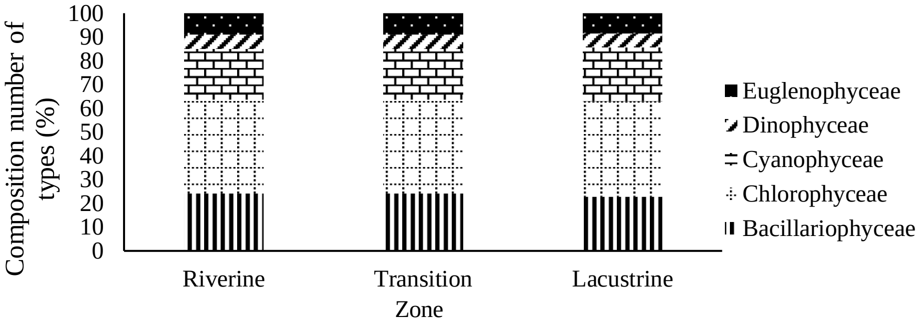

Figure 2 Composition of the number of types of phytoplankton in Jatigede Reservoir

The highest abundance was Cyanophyceae, and the lowest Euglenaphyceae in all water zones (Figure 2). Each type of phytoplankton has a different abundance in each zone. Bacillariophyceae were highest in riverine and lowest in lacustrine, Chlorophyceae were highest in lacustrine and lowest in riverine, Cyanophyceae, Dinophyceae were highest in riverine and lowest in transition, and Euglenaphyceae were highest in lacustrine and lowest in transition. Overall, we found the highest total abundance in the riverine area and the lowest in the transition area.

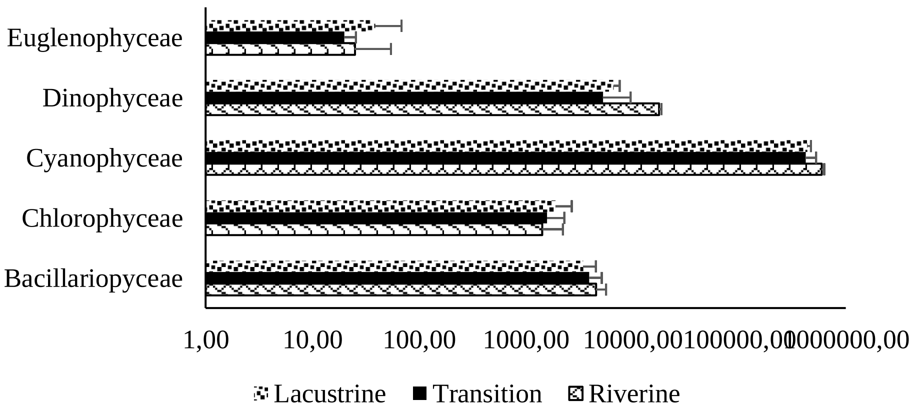

Figure 3 Phytoplankton abundance in Jatigede Reservoir

Trophic Status

Management of reservoir waters must be adjusted to the trophic status of the waters in each water. Eutrophication is a problem that is often faced in reservoir aquatic ecosystems. Reservoir water quality conditions are classified based on eutrophication caused by an increase in nutrient levels in the water (Wiryanto *et al.* 2012). Eutrophication is caused by the entry of excess nutrients (Tusseau-Vuillemin 2001). This makes the reservoir waters vulnerable to increased trophic status (eutrophication).

Table 1 Trophic status of Jatigede Reservoir

Index	**Location**			**Trophic status**
	Riverine	**Transition**	**Lacustrine**	
TSI	66,00	62,20	61,97	Eutrophic
Nygard	5,83	5,56	5,31	Eutrophic

The Nygaard index and TSI used to estimate trophic status have different parameters used, so each has advantages and disadvantages. Based on the values of the two indices, the Jatigede Reservoir is categorized as a eutrophic trophic status (Table 1). TSI index values in each zone ranged from 61,97–66,0, the highest in the riverine area, to the lowest in the lacustrine site. The Nygaard index value also illustrates that the highest value is found in the riverine zone, and the lowest is in the lacustrine area. Nygaard Index values range from 5,31–5,83. The two indexes describe the condition of the Jatigede Reservoir in a eutrophic status.

Estimated carbon content in phytoplankton

The absorption of carbon by phytoplankton during photosynthesis causes carbon transfer from the water (hydrosphere) into the phytoplankton body. The carbon is stored in the phytoplankton body as phytoplankton biomass. When the phytoplankton cells die, they will contain organic particulates, which will, in the process, settle in the aquatic sediments used by bacteria in the decomposition process (Wetzel and Likens 1991).

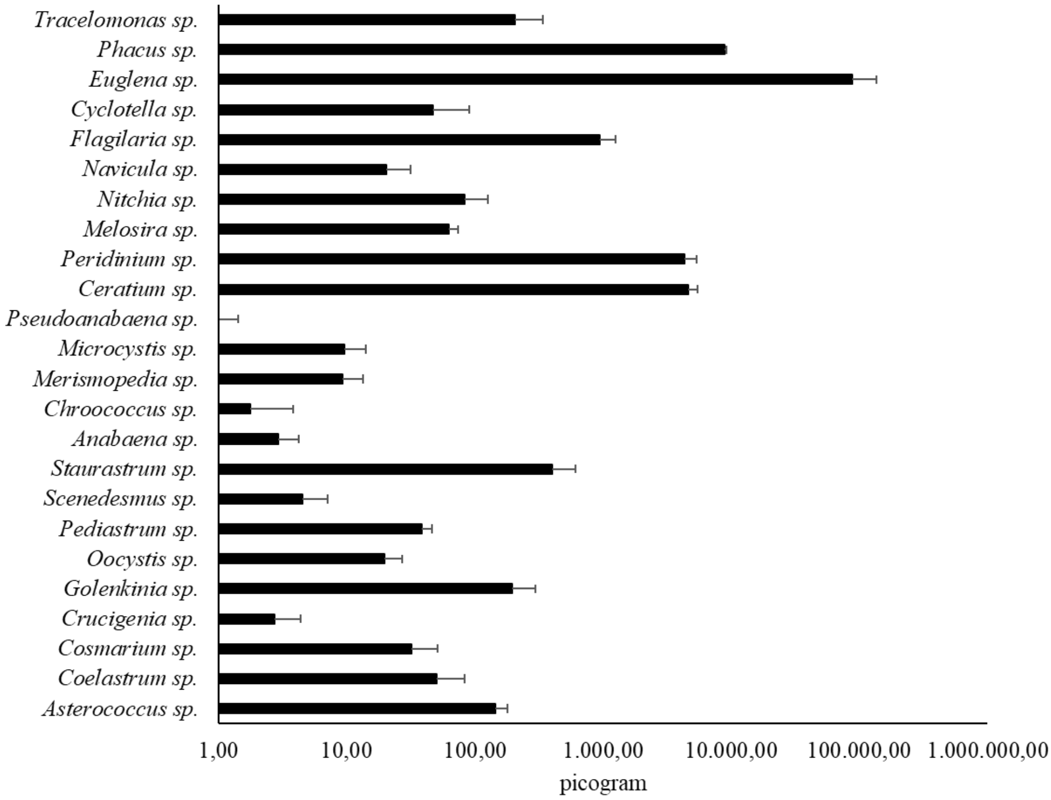

Figure 4 Carbon content in each genus of phytoplankton in Jatigede Reservoir

Based on the research results, 24 phytoplankton genera with the highest non-diatom carbon content, namely *Euglena sp*., and the lowest was in the genus *Pseudoanabaena sp.,* while the tallest diatom species were in the genus *Flagillaria sp.* and the lowest is *Navicula sp.* (Figure 4). High carbon content is more influenced by volume and abundance in each reservoir zone. Class Bacillariophyceae, Chlorophyceae, and Cyanophyceae have a high abundance size but a small volume, while the Dinophyceae and Euglenaphyceae have a larger volume size. Based on the results, the carbon content in each class also shows different values. Class Dinophyceae has the highest carbon content, and class Chlorophyceae has the lowest of the other types (Figure 5).

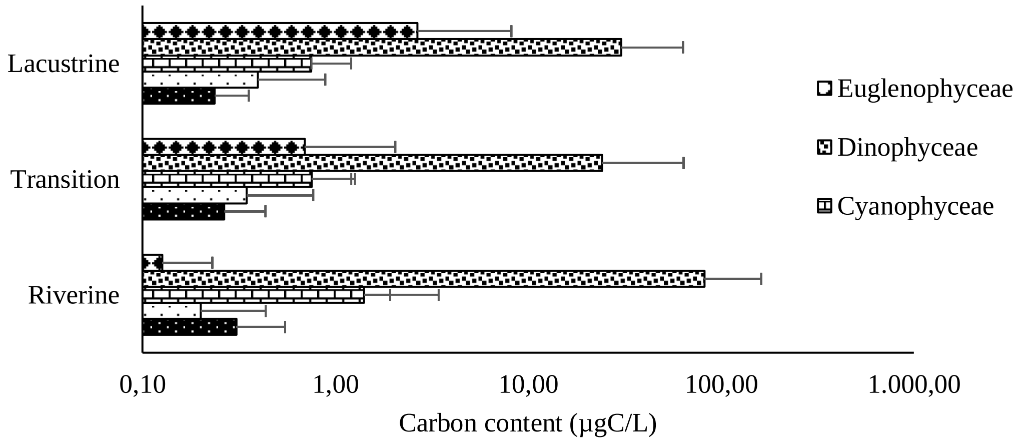

Figure 5 Carbon content in each class of phytoplankton in Jatigede Reservoir

Overall, apart from the different types of phytoplankton, the nutrient composition in each watering zone causes differences in the carbon content in the waters of the Jatigede Reservoir. Based on the analysis results on each type of phytoplankton in each location of the Jatigede Reservoir, the highest carbon content was in the riverine zone, and the lowest was in the transition zone (Table 2). The carbon content is higher in the riverine area because the types of phytoplankton from the Dinophyceae and Euglenaphyceae classes are higher than in the transition zone.

Table 1 Abundance and carbon content of each zoning in Jatigede Reservoir

Parameter	**Riverine**	**Transition**	**Lacustrine**
Abundance(cell/L)	123,232 ± 262,337	86,798 ± 373,009	89,586 ± 188,042
Carbon content (µgC/L)	84,03 ± 36,42	26,29 ± 10,59	34,52 ± 13,19

Discussion

Eutrophication is caused by excess nutrients, especially in agricultural waste and household waste (Tusseau-Vuillemin 2001). This case makes the reservoir waters vulnerable to increased fertility (eutrophication). Based on Nygaard and TSI index analysis, the waters of Jatigede Reservoir are classified as eutrophic waters. This eutrophic condition is a potential for the Jatigede Reservoir in a situation prone to eutrophication. Research by Pratiwi *et al.* (2013) mentions that several things affect the trophic status: aquaculture activities, recreation, agriculture, and domestic waste. Another study on several reservoirs in Southern Poland showed that reservoir water quality was influenced by river water quality (Jagus and Rzetala 2011).

Inputs from rivers result in changes in water quality conditions in the reservoir. Changes in water quality due to damming will affect the ecological processes in the formed pool (Xiaoyan *et al.* 2010), such as the presence of nutrients. The addition of these nutrients will increase primary productivity and phytoplankton biomass (Sara *et al.* 2011). Fitriadi's research (2021) in Jatigede Reservoir during the dry season, phytoplankton in Jatigede Reservoir consisted of classes *Bacillariophyceae, Chlorophyceae, Cyanophyceae,* *Dinophyceae*, and *Euglenophyceae*. These results are the same as those of this study conducted during the rainy season showing the same results.

There are qualitative differences between phytoplankton communities in oligotrophic and eutrophic. For example, numerical declines are observed in species found in the mesotrophic—lake layer with decreased nitrogen saturation in the lake. In addition, there are differences between the environmental conditions favored by the Diatom, Dinoflagellate, or *Cosmarium sp.* species, Pandorina, and Gemellicystis. However, they can be found in lakes with similar nutrient levels (Reynolds *et al.* 2000). In this study, the f trophic status rate of Jatigede Reservoir in all zones was eutrophic, dominated by *Anabaena sp., Pseudoanabaena sp., Ceratium sp*., and *Peridinium sp*.

The same trophic status in Jatigede Reservoir does not mean that the carbon content value is not significantly different in each zone. The carbon content in phytoplankton is more influenced by the presence of phytoplankton types, abundance, and biovolume of each type. Based on Jakobsen *et al.* (2015), in marine waters, more extensive cell size and high abundance content make the diatom species have a higher range than other types. Research in the Jatigede reservoir with eutrophic water conditions emerged non-diatom species, namely *Euglena sp.*, with the highest biovolume but low abundance, and *Pseudoanabaena sp*., the lowest biovolume but high abundance, while for the diatom species the highest. Therefore, the carbon content in freshwaters is influenced by non-diatom species than in marine waters, which are more influenced by diatom species.

The composition of different phytoplankton will affect the presence of carbon in the waters. According to Engel (2020), phytoplankton biomass in waters is an organic carbon stock. Research by Sobek *et al.* (2006) on lake Frisksjo¨n. with an area of 1.848 km^2 lake has carbon based on the presence of phytoplankton of 369 mgC/m2. Based on Jakobsen *et al.* (2015), in estuarine and marine waters dominated by Bacillariopyceae species, the estimated carbon content is 293 ± 125 gC/L. This value is still higher than the research in Jatigede Reservoir, which was 26,29–84,03 gC/L.

Based on the person correlation value, the relationship between carbon content is strongly correlated (0,90–1) with Cyanophyceae and Dinophyceae, with p-values being 0,040 and 0,020, respectively. p-value) 0,720. The correlation value indicates that the trophic status in water has a not close relationship and has a negative value. This can be seen in the results of this study at the same trophic status having different carbon content values.

The development of water management must be adjusted to the trophic status of the waters in each reservoir area. Eutrophication is a problem that occurs in freshwater ecosystems. Reservoir water quality conditions are classified based on eutrophication caused by increased nutrient levels in the water (Wiryanto *et al.* 2012). This increase in nutrients increases the carbon content of phytoplankton. This study shows that in the riverine area, the carbon content of phytoplankton is higher than that of transition and lacustrine.

CONCLUSION

The trophic status in all zones in the Jatigede Reservoir is categorized as eutrophic. Still, it has a different phytoplankton composition, with carbon content in phytoplankton which tends to be high in the riverine zone compared to the transition zone and lacustrine.

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